A vision for Scotland's **electricity and gas** networks

DETAIL
2019 - 2030

Scottish Government
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CHAPTER **1: SUPPORTING OUR ENERGY SYSTEM**

SUPPORTING OUR ENERGY SYSTEM

Our Vision: By 2030… Scotland's energy system will have changed dramatically in order to deliver Scotland's Energy Strategy targets for renewable energy and energy productivity. We will be close to delivering the targets we have set for 2032 for energy efficiency, low carbon heat and transport. Our electricity and gas networks will be fundamental to this progress across Scotland and there will be new ways of designing, operating and regulating them to ensure that they are used efficiently.

The policy context

Scotland's Energy Strategy sets out a vision for the energy system in Scotland until 2050 – targeting a sustainable and low carbon energy system that works for all consumers.

Our electricity and gas networks form the backbone of Scotland's energy system. They provide us all, from individual households to energy intensive industries, with an essential service – the means to receive the reliable and affordable energy which is a prerequisite for any modern society and economy.

The Energy Strategy is built on three principles. These are designed to ensure that the energy system in Scotland supports our ambitions to decarbonise our economy while delivering economic growth and ensuring that everyone is able to benefit:

- **a whole system view**
- **an inclusive transition**
- **smarter local energy models.**

These principles will guide energy policy in Scotland over the coming years, shaping our decisions across the whole energy system – in areas such as heat and energy efficiency provision, and decarbonising transport.

The "whole system" principle is reflected in our target to meet 50% of energy demand across heat, transport and electricity from renewable sources in 2030. It will allow us to respond flexibly to new evidence about the best ways to decarbonise the energy system.

The energy transition must also be inclusive – all parts of society should be able to benefit. The options we identify must make sense no matter what pathways to decarbonisation might emerge as the best. Improving the efficiency of our building stock is one example of these "low regret" actions, and is something that we have made a national priority.

We also need to identify the quite distinct challenges in different areas of the country, and the different ways of solving them. For instance, developing the electricity networks in remote areas and connecting our island groups will need different thinking and approaches to the coordination of electricity and gas in densely populated urban areas.

Finally, the Scottish Government has been supporting community and local energy for over a decade and will continue to do so. Balancing supply and demand locally can ensure that networks are used efficiently, and can provide important benefits for everyone in a community. Our targets to ensure that there are 1 GW of community owned renewables by 2020, and 2 GW by 2030 reflect our desire to support smarter local energy systems.

However, the way the gas and electricity networks are regulated and funded today means that it is difficult for communities to benefit from the value that they can provide to the wider system. This is a barrier that we want to see removed, providing opportunities for innovation and local benefit to emerge across the country.

Living up to these principles will depend upon several significant changes to the ways in which electricity and gas networks are planned, operated and regulated. This is a challenge facing the UK as a whole, and indeed all modern economies.

Many of the policy levers in these areas are reserved – meaning that our historical and close collaboration with the UK Government and Ofgem, the independent regulator, on future options and changes will remain vitally important. Our aim is for Scotland to continue to play a pivotal role in supporting, influencing and enabling decarbonisation across the UK.

But our distinct circumstances, geography and priorities mean that there will be uniquely Scottish solutions and approaches, with these likely to vary across Scotland. This means that our networks will need an approach which is flexible and able to recognise and adapt to those variations.

Above everything, the interests and needs of all consumers must be at the heart of any possible developments and changes. Our networks must embody and enable a system that consumers want, and which allows them to engage and make informed choices about when and how much energy they use.

Table 1 highlights the principles and priorities that we laid out in the Energy Strategy in 2017, and summarised the importance of the gas and electricity networks in supporting each.

Table 1: Gas and Electricity networks' role in delivering the Principles and Priorities of the Scottish Energy Strategy.

PRINCIPLES	**A whole system view**	Electricity and gas networks should support an efficient and effective process of decarbonisation across the whole energy system and should support broad societal and economic ambitions. Long term investments must take account of local and regional aspirations for the whole energy system – including transport, heat, energy efficiency and support to the local economy.
	An inclusive energy transition	Access to affordable and reliable energy underpins our society and economy. The networks are instrumental in providing that access. Decarbonisation will create new opportunities, and new relationships between consumers and networks.
	A smarter local energy model *Innovative local energy systems*	The networks already support GB-wide national markets for energy. We want to see the structures and regulations develop to support innovative local energy models, and to help those models develop and reward communities for managing their energy in ways that support efficient networks and reduce costs.
	Consumer engagement and protection	Consumers must be at the heart of decisions made about networks; we need to find new and effective ways to bring consumers and their representatives into what are challenging and technical conversations. This has to extend to those who have perhaps been traditionally considered unable or unwilling to think about or benefit from the changes that are going to take place.
	Energy efficiency	The networks have an important role to play in delivering Scotland's energy efficiency ambitions. They have long term relationships with consumers, and continue to serve the same properties throughout their lives. Energy efficiency can also lead to direct savings to network companies where reduced demand reduces the need to increase capacity.
PRIORITIES	*System security and flexibility*	Our electricity and gas networks link together a diverse range of energy sources, and this will continue to be one of the most important roles that they play – especially as we move still further towards a decentralised energy system, and the greater demand for sources of flexibility that we expect that to create.
	Renewable and low carbon solutions	Electricity networks, especially at the distribution level, will need to continue to connect renewable generation, with regulation and investment decisions designed to enable this. We will also need changes to enable the gas networks to transport more low carbon alternatives. These changes will be vital to decarbonising heat and transport in particular.
	Oil and gas industry strengths	We will need the gas networks to continue to support the most appropriate use of our remaining gas resources during the coming decades. The oil and gas sector's innovation and engineering expertise can help us understand how the existing network infrastructure can support decarbonisation – for example, its role in transporting hydrogen and carbon.

Supporting wider Scottish Government policies

The Scottish Climate Change Plan, published in February 2018, influences policies across government. The need to decarbonise, and our ambition to do so in a way that supports the whole of Scotland that shaped our Energy Strategy, shapes this networks vision.

Our Climate Change Bill, introduced to the Scottish Parliament in May 2018, proposes a 90% reduction in all greenhouse gas emissions by 2050. This will mean achieving net-zero emissions of carbon dioxide by the same date. In other words, Scotland will be carbon-neutral.

The Bill also requires that the earliest credible date for a net-zero target for all greenhouse gases is kept under review. As soon as a target date can be credibly and responsibly put in legislation, that will be done.

We expect the network companies to continue to take the effects of the Scottish Government policy into account and to reflect our wider ambitions for Scotland in their forecasts and plans; likewise, we will continue to work with them and with other stakeholders to ensure that we take network availability and issues into account when developing and delivering our policies.

The regulatory system also needs to be sufficiently flexible to accommodate regional and local energy ambitions. This will enable local authorities and regional development agencies across Scotland and the rest of Britain to develop energy systems appropriate to their needs.

The boundaries between different parts of the energy system will continue to blur over the next decade as the regulated networks deliver an ever larger fraction of the energy we consume. The development of electric and hydrogen based vehicles, for example, will increase the need for network policy to interact with transport policy. The growth of new heat networks and the regulatory framework that we expect to see develop will also offer new opportunities for coordinating the delivery of low carbon heat.

There are some vital areas of the Scottish Government policy which need to be carefully considered by network companies and the regulator over the next decade:

- **Energy Efficient Scotland.** We published our Route Map in May 2018. It aims to ensure that, by 2040, our buildings are warmer, more energy efficient, and use less carbon. It will also be essential to meeting our fuel poverty targets. Energy efficiency measures can reduce the peak demand on our electricity and gas networks, and the number of network upgrades and investments that might otherwise be needed – factors that the network companies and Ofgem should consider as they discuss the price controls for these networks.
- **Local Heat & Energy Efficiency Strategies (LHEES).** We will give Scotland's local authorities a leading role in developing energy efficiency and heat decarbonisation strategies – tailored to the resources, geography and demography of each area of Scotland. Local authorities will need to engage strategically with electricity and gas network companies as they develop these LHEES – taking existing network capacity into account, and how best to use this to support decarbonisation of the whole energy system. The network companies should treat LHEES as a material consideration within their business plans – with Ofgem recognising them as such. We also expect local authorities to identify areas suitable for district heating, and to consider the opportunities that gas and electricity networks provide for generating heat. They should also ensure that the implications which district heating will have on the enduring demand for gas and electricity networks are reflected in those networks' forward planning.

- **Ultra Low Emission Vehicles (ULEVs).** Meeting our commitment to phase out the need for petrol and diesel cars and vans by 2032 will need electricity distribution and transmission networks capable of supplying low carbon electricity for electric vehicles. We will work closely with the electricity network companies to explore the balance between new investment, smart technology and innovations in charging and pricing. We will also help develop evidence which shows how best to use the gas network to deliver low carbon energy (such as hydrogen) for buses, ferries and trains.
- **Energy Consumer Vision and Action Plan.** This plan, being developed over the coming year, will largely focus on domestic retail consumers. It will set out the steps that Scottish Government, working with partners, will take to ensure the benefits of the low carbon energy transition are universal and socially inclusive, regardless of individual circumstance. We are committed to working with partners to engage and empower people as far as possible, and to protect those who are unable to engage.
- **Innovation.** Support for innovation remains a vital part of accelerating decarbonisation. We announced our intention in 2017 to spend £60 million supporting innovative, low carbon energy infrastructure solutions across Scotland – including battery storage, sustainable heating systems and low emissions transport. Our goal remains to help develop relevant technologies which can support the operation and decarbonisation of Scotland's network infrastructure.
- **National Planning Framework (NPF):** Through the third NPF (2014), we have laid out how we expect our economic strategy to be delivered across Scotland and how infrastructure development can support its delivery. NPF 3 highlights the need for enhanced electricity transmission and distribution networks to support the development of Scotland as a 'low carbon place'. It also highlights the potential to develop Carbon Capture and Storage across the East Coast, and the need to ensure that gas networks are developed to support this.

THE **GAS AND ELECTRICITY** NETWORKS TODAY

There are
71,000 miles
OF ELECTRICITY CABLE in Scotland

There are
98,000
ELECTRICITY TRANSFORMERS
in Scotland

There are
17,000 miles
OF GAS PIPELINE
in Scotland

NATURAL GAS
has an estimated
CARBON INTENSITY
of 184 g CO_2 per kWh

There are
15 low carbon gas producers
connected to the gas network in Scotland with a **CAPABILITY OF 183 GW** and the potential to **INJECT UP TO 1,600 GWh** of **LOW CARBON GAS** per year.

Approximately
£1.0 Billion
is spent on **RUNNING AND INVESTING** in the electricity networks and
£200 million
on the gas networks **EACH YEAR** in Scotland.

There is 13.5 GW of generation connected to the electricity networks in Scotland **OF WHICH 10.3 GW ARE RENEWABLE.** In 2017 this generated **25,200 GWh.**

GAS SYSTEM OPERATOR

The gas system operator is responsible for ensuring that the British gas system is balanced across each day, and that the system is secure and can continue operating in the event of a fault in any part of the system. **National Grid** is the Gas System Operator for the whole of Britain.

GAS NATIONAL TRANSMISSION NETWORK (NTS)

The high pressure gas network that transfers gas across Britain from pipelines, LNG terminals, and storage facilities. This includes gas injected from the North Sea at St Fergus in north east Scotland. **National Grid** are the Transmission Owners for the NTS.

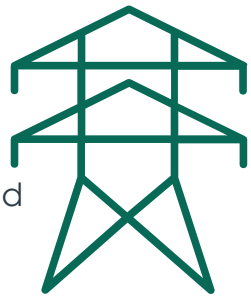
GAS DISTRIBUTION NETWORKS

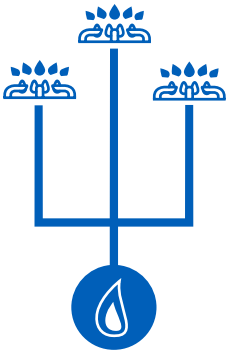
The lower pressure gas pipes that bring gas to our homes and the majority of our business are owned by Gas Distribution Network (GDN) owners. In Scotland there is one GDN: **SGN.** There are 7 GDN areas covering England and Wales.

ELECTRICITY GENERATED IN SCOTLAND in 2016 had an estimated carbon intensity of 54 g CO_2 per kWh

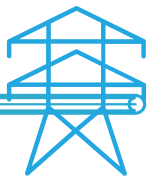
Gas and electricity network charges represent 25% of the average domestic customers **ENERGY BILL** equivalent to **£284 PER YEAR.**

The **ELECTRICITY NETWORKS** deliver 31,000 GWh per year to consumers, and meet a peak demand of approximately **5.5 GW**





The gas networks delivered 58,000 GWh in 2017 to consumers and are able to meet a Scottish peak demand of approximately **22 GW**



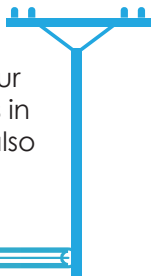
ELECTRICITY SYSTEM OPERATOR

The Electricity System Operator (ESO) is responsible for the day-to-day security of the electricity System across Britain. It adjusts which power stations are operating, and ensures there is sufficient back up in the right parts of Britain to cover important contingencies. The ESO is also responsible for recommending which major network investment projects should go ahead. **National Grid ESO** carries out this role across the whole of GB; a role which is being legally separated from its role as the transmission owner in England and Wales.

ELECTRICITY TRANSMISSION NETWORK

The high voltage networks – 132,000 volts and above in Scotland – that act as the bulk transporter of electricity across the country. They are owned by Transmission Owners (TO's). **SSE Networks** in the north of Scotland and **SP Energy Networks** in the south of Scotland. **National Grid TO** are the owner of the transmission grid in England and Wales.

ELECTRICITY DISTRIBUTION NETWORKS



The low voltage networks that bring electricity to our houses and the majority of our businesses. They are owned by a Distribution Network Owner (DNO) – **SSE Networks** in the North of Scotland and **SP Energy Networks** in the South of Scotland. There are also 12 DNO regions covering England and Wales.

BOX 1: ULTRA LOW EMISSION VEHICLES (ULEVS)

Our 2017 Programme for Government committed us to phasing out the need for new petrol and diesel cars and vans in Scotland by 2032. This creates opportunities to power cars and vans using electricity and hydrogen produced by renewable energy technologies, such as wind and solar generation. Our work to harness such opportunities is focused on delivering the following outcomes:

- Scotland is at the forefront of growth in international and regional markets for ultra-low emission vehicles.
- Growth of the market for ultra-low emission vehicles is supported by a fair distribution of investment costs, benefiting the full cross-section of consumers.
- Scotland's business community and workforce benefit from the widest possible range of economic opportunities that new markets and technologies create.

Electric Vehicles

Growth in **electric vehicles (EVs)** poses challenges for planning and operating our electricity networks, but also opportunities. Managed charging of EVs will be critical to efficient and timely investment in electricity networks. The ability to coordinate EV charging within the networks' limits, in order to maintain security and reliability, will help ensure that network costs remain affordable.

Responding to these challenges will require a coordinated approach between policy makers and network companies – as well as enough generation to meet the higher demand. The 2018 UK Automated and Electric Vehicle Act allows for new charging infrastructure to be capable of managed charging, which can support efficient and reliable networks.

Our 'ChargePlace Scotland' initiative, comprising over 800 publicly available charge points, is coordinating investment in charging infrastructure (destination, journey and hub) across Scotland. The Scottish Government has taken a deliberate decision to invest in this infrastructure ahead of need, to help build market confidence.

But much more investment will be needed over the next decade. **The Scottish Government will work closely with commercial and public sector partners to make sure that this investment – in both the electricity networks and the charging infrastructure connected to them – is based on a well-developed and informed understanding of the likely growth in uptake of EVs**. We are setting up an **EV Forum**, which will bring vehicle manufacturers, charge point providers, network companies and customer representatives together. We will use this Forum to remain focused on the implications for networks of our commitment to decarbonise transport.

We will also continue to champion the interests of vulnerable consumers and those in fuel poverty, and ensure that their needs are considered and protected when decisions are made on how to pay the additional network costs that EV charging will create.

Hydrogen Vehicles

We are also supporting ways to meet low carbon transport using the gas network. **Hydrogen** could potentially power many of our larger vehicles – buses, lorries and ferries. Trials have shown positive results; for example, the extensive trial of hydrogen powered buses in Aberdeen shows the potential benefits of low carbon and reduced air pollution from public transport. As we improve our understanding of gas networks' role in delivering hydrogen, we will need to consider their role in delivering low carbon energy for transport.

BOX 2: NETWORKS AND LOCAL ENERGY

The vibrant local energy economy described in our Energy Strategy will mean people in different areas and communities having the opportunity to take control of their own energy needs and low carbon goals.

The electricity and gas networks will have a big part to play in this process – linking community and local renewable generators or local low carbon gas projects to participating consumers, for instance, and in ways that make the best and most efficient use of the energy and infrastructure.

Our networks vision includes an ambition to coordinate local supply and demand for low carbon electricity and gas, supporting efficient network use. Examples exist today on electricity networks where new renewable generators can't get connected. Local priorities, perspectives and approaches can help resolve these problems, with similar benefits likely to arise in future from small scale production of low carbon gas.

Today's regulatory and policy environment has been developed over decades in conjunction with national energy markets, and it can present substantial barriers to local energy. For example, small generators connected to the lower voltage tiers of the distribution network are assumed to be completely independent of local demand. There is little opportunity for local and community projects to benefit from balancing the energy they produce against local demand even where this would save costs. This can drive the wrong outcome such as local energy schemes considering 'private wires' between generator and consumers, even when the existing public distribution networks have sufficient capacity. We believe that local energy opportunities and ambitions must be a key consideration when deciding how to develop the networks, and the regulations under which they operate.

We made a smarter model for local energy a principle of our Energy Strategy because we understand that this can bring a diverse range of benefits, both financial and non-financial, to communities across Scotland. We need to be able to use the gas and electricity networks in ways that encourage these models to develop.

Some changes are already happening – for example, in the way that electricity networks are planning to reward flexibility on a local basis. We are also starting to see small scale low carbon gas producers connecting to the gas networks and opening up the potential for local gas production and supply. However, we think there are opportunities to make local energy a greater priority.

Realising our local energy goals will need regulations and policies which encourage and reward projects which use the networks efficiently – including through changes and improvements in how customers access the networks and are charged for using them. We believe that local energy projects should be rewarded where they reduce investment costs or help keep open a wider range of future options.

CHAPTER 2:
DEVELOPING THE NETWORK INFRASTRUCTURE

DEVELOPING THE NETWORK INFRASTRUCTURE

ELECTRICITY NETWORKS

Our Vision: by 2030… there will have been the necessary substantial investment in new capacity for our electricity networks, including transmission links to our island groups and new undersea cables linking to the rest of Britain between Scotland, England and Wales. There will be a strategic focus on security of supply and resilience when designing these networks and the systems that they connect to. New distribution network investment will be balanced against the use of smart grid systems which have created opportunities for flexibility and thriving local markets for both the generation and use of electricity and flexibility.

GAS NETWORKS

Our Vision: by 2030… gas networks remain a vital and flexible component of Scotland's national infrastructure, delivering affordable energy for heating our homes and businesses. The energy resource carried by the networks will be lower carbon than it is today. The policy, regulatory and technical developments will have been put in place to allow natural and low carbon gas to be blended in the networks, including a contribution from hydrogen. We will also understand clearly the feasibility and costs of repurposing the gas networks to carry 100% hydrogen, and will have made strategic decisions about the long term role of the networks and the wider decarbonisation of heat.

We expect the electricity and gas network companies to rise to the challenges of decarbonisation during the coming decade – focusing on how they can deliver low carbon energy to consumers, whilst helping us maintain affordable and secure supplies. Reliable and low carbon energy is an essential service, which gas and electricity networks have an obvious and central role in delivering. This essential service needs to be at the heart of how we plan those networks. We need to ensure that all parts of Scotland, from our major cities to our remote island groups, are connected in the best and most efficient way.

By 2030 electricity networks will be smarter, flexible and more efficient, while our gas network will have evolved to deliver lower carbon gas through the existing pipes – based on a new and detailed understanding of its role in decarbonising the energy system.

Investment decisions must take full account of Scottish Government and local authority policies and priorities. This will encompass our Energy Efficient Scotland Route Map and goals, as well as our policies to promote ULEV growth. Our local authorities will need the support and cooperation of the network companies as they develop their LHEES, with those companies using their knowledge of these strategies to adapt and improve their own investment plans and decisions.

Electricity and gas networks will continue to transport energy round the country safely, and with extremely high levels of reliability – for instance, we expect to see electricity and gas transmission networks maintain or improve today's reliabilities of more than 99.99%.

This will be a substantial challenge. The high levels of reliability we see today derive from decades of experience of working with systems based on supplying gas and electricity from large, centralised power stations and gas terminals. Our networks have also developed appropriate levels of redundancy and back up, based on their knowledge and experience of how often faults happen, and what is needed to ensure that those faults do not affect consumers.

The changes expected over the coming decade and beyond will fundamentally alter how these networks will operate – challenging and reversing many of the existing assumptions used in their design and operation. This means we will have to work hard at understanding how to ensure that the new systems remain at least as reliable as the old ones.

Scotland's energy networks are already beginning to incorporate new and innovative market platforms for matching local supply and demand, as well as pioneering active network management approaches, and the introduction of decentralised, low carbon gas producers. We expect this progress to continue, and our network companies to play a huge part in bringing consumers with them on this journey.

We want to see markets and approaches develop in ways which inform, encourage and reward those consumers who can adapt their energy use and behaviour in ways that make the best use of our networks. This will include incentives for matching local supply and demand – tackling network constraints, providing business models and creating opportunities for local and community energy projects.

We appreciate that there are still uncertainties in play. For example, many of the decarbonising technologies and approaches which we are likely to rely upon aren't yet technically or commercially mature.

Our Energy Strategy included two illustrative pathways for the energy system in 2050, consistent with our current climate change targets: hydrogen, and electrification. These are designed to help us understand the different infrastructure and behaviours that might be needed, depending on progress and decisions over the coming years.

The electrification pathway features technologies that are close to mature today, such as heat pumps and electric vehicles. However, it would depend on continuing and significant investment in new electricity infrastructure to replace gas supplies as demand for heat shifts to electricity; and, whilst the technologies themselves are mature, appropriately coordinating them remains a major challenge which is likely to require significant innovation.

By contrast, the hydrogen pathway comprises technologies that are yet to be proven on a large scale, such as Carbon Capture and Storage (CCS), and the development of large scale hydrogen gas networks. However, this pathway would retain the greater flexibility that gas networks provide – compared to electricity.

The most likely outcome may well be a mixture of these pathways – for example, greater electrification in some areas, and a hydrogen and low carbon gas future in others. New and disruptive technologies and innovations could also emerge, providing alternative and faster routes to a decarbonised future. We need to assess and understand the various available options between now and 2030, and to decide and prepare for the major changes and investment which will be needed.

These are technical challenges, with often technical solutions. We need to understand how they might affect our access to energy and our relationship with networks. Table 1 summarises the key technical challenges that we will face, and the rest of this section explores these issues in more detail.

KEY TECHNICAL CHALLENGES

ELECTRICITY

- The ability to continue connecting new renewable generation capacity to the electricity networks in Scotland throughout the 2020s and using those networks efficiently to deliver renewable electricity to consumers across Scotland and beyond.
- Integrating electric vehicles and heat pumps into existing electricity distribution networks designed on increasingly outdated assumptions.
- Ensuring the physical limits of networks are protected as new and smarter ways emerge for consumers, generators and energy storage to engage and national as well as local markets.
- Maintaining a secure and stable electricity system, including greatly reduced capacity from large, dispatchable and synchronous generation and increasing contribution from intermittent renewables and interconnection.

GAS

- Valuing the flexibility that Scotland's gas networks provide to the wider energy system through their significant energy storage capabilities.
- Finding ways to safely and incrementally decarbonise the gas that flows through the networks during the 2020s by blending low carbon gases such as biomethane, and low carbon hydrogen.
- Clearly identifying the options for using the gas networks to link with new, low carbon technologies including Steam Methane Reforming to produce Hydrogen, Carbon Capture Utilisation and Storage, and power-to-gas.
- Using these options to understanding the feasibility and costs of converting parts of the gas networks to deliver 100% hydrogen in the future, and the role those networks should play in a fully decarbonised energy system, alongside the potential for use of hydrogen in transport decarbonisation.

ELECTRICITY

Transmission network

Our electricity system is changing radically. Scotland's last coal power stations at Cockenzie and Longannet have closed in recent years, while renewable generating capacity exceeded 10 GW in 2018 – leading to a huge reduction in the carbon intensity of our electricity supply. The shift to renewables means that supplies within Scotland have become more variable, increasing the importance of the transmission network linking us with England and Wales.

Two major projects are in the process of increasing the capacity of the Scottish transmission network. The Western HVDC[1] Link, which connects Hunterston to Deeside in North Wales via an undersea cable, will add around 2,200 MW of new capacity to the transmission network – allowing more electricity generation in Scotland to connect and meet demand across Britain.

The Caithness-Moray HVDC link is a 1,200 MW undersea connection between Spittal in northern Caithness and Blackhillock in Morayshire, which was commissioned in January 2019. This link increases the capacity available to transport renewable electricity generated in northern Scotland, including Orkney and Shetland, into the wider transmission network.

But we will need more investment in new transmission infrastructure to connect the levels of renewable generation we want by 2030. We expect this to include new links between Scotland and England, as well as within Scotland – including those needed to connect the huge marine renewables potential around our coasts, and wind generation on the Western Isles, Shetland and Orkney. This will require regulatory and investment decision processes capable of identifying, agreeing and delivering these in a timely way.

Some proposals are in the early stages of development, including two additional undersea cables on the east coast linking Scotland with northern England. These links need to be designed to support the networks' resilience, as well as allowing energy to flow where it needs to.

Recommendations to take forward these projects, as well as others that reinforce the main integrated part of the transmission system in Britain, are taken by National Grid Electricity System Operator through the annual Network Options Assessment (NOA) processed. This identifies the benefits of each upgrade across four Future Energy Scenarios[2]. National Grid works closely with the Transmission Owners to identify the costs and benefits of a range of options for upgrading the network.

The NOA process in 2018 recommended investment in electricity transmission networks in Scotland of between £0.94 Billion - £1.45 Billion[3] across 6 to 10 projects over the range of the Future Energy Scenarios. In 2019 the NOA assessment specifically identified the need for two reinforcements of at least 2 GW each.

Proposals for transmission links to each of the island groups have now been submitted under Ofgem's Strategic Wider Works process. Delivering these requires Ofgem to approve a 'needs case' from the Transmission Owner which lays out the costs and benefits that the link will bring, both to the islands and across the British system. We believe that these links, and the huge renewable energy potential that they can help connect, will benefit the local economies of the islands, as well as further decarbonising electricity supplies for everyone in Britain.

We will also need strong interconnections to our European neighbours – ensuring that Scottish renewable generation has access to as wide a market as possible and helping to meet demand and supporting network operation when required. We welcome the proposals to link Norway to Scotland via Peterhead and Shetland, and remain open to the possibility of further links to the all-Ireland electricity system and other European neighbours.

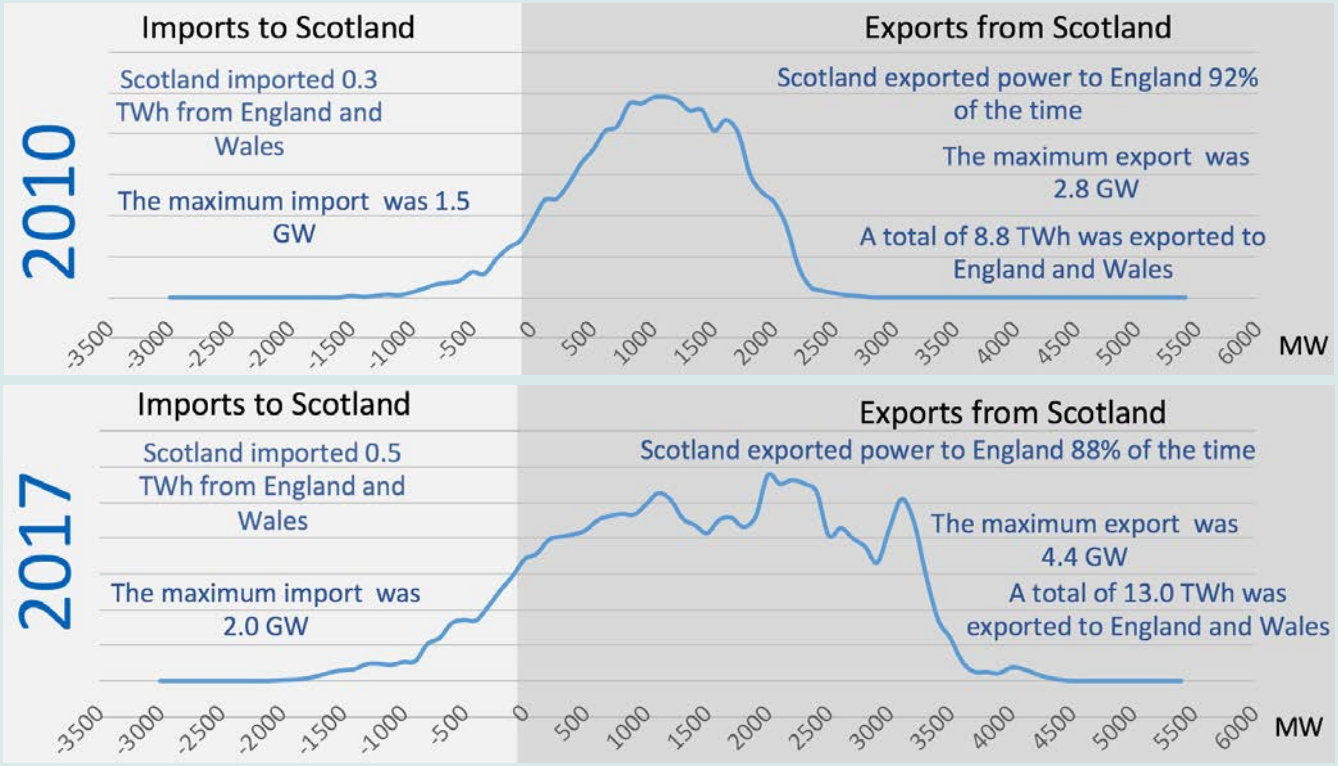
1 High Voltage Direct Current
2 http://fes.nationalgrid.com/fes-document/
3 A number of these projects are designed to facilitate increased power transfer between Scotland and England. The costs above reflect project costs related to the Scottish TOs and assumes currently that cross border HVDC project costs are split 50:50 between Scotland and England. The Network Option Assessment only considers major network investment, it does not include connections works or non-load related investment. Costs are for investments recommended against the FES 2017. Investment recommendations are reviewed annually by NGESO.

BOX 3: THE CHANGING ELECTRICITY TRANSMISSION NETWORK

The way that electrical energy flows over the transmission network has changed significantly over the past decade, with increases in the quantity of energy flowing both in and out of Scotland. In 2017, we exported nearly 50% more energy to England and Wales than in 2010, with upgrades of the transmission network increasing the peak-flow that the transmission network can accommodate from around 3 GW to 4.4 GW. The Western Link is expected to increase this to 5.7 GW in the near future.

We also import more electricity from England and Wales following the closure of Scotland's coal stations. We imported to Scotland for 12% of the time in 2017 compared with 8% in 2010. Currently the ability of the network to securely import electricity into Scotland is estimated at 2.65 GW and is expected to rise to 3.9 GW on completion of the Western Link.

Figure 1: sharing power – the flow of electricity between Scotland and England in 2010 and 2017



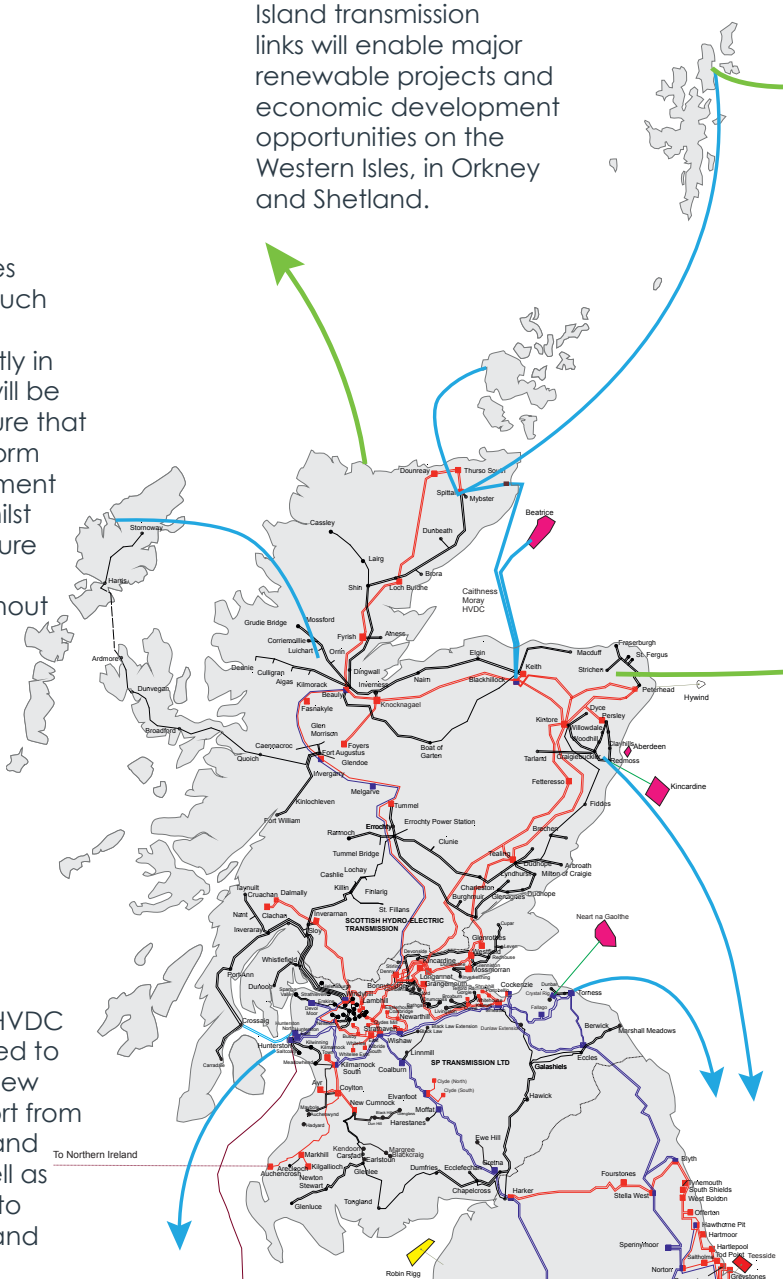
The capacity of the electricity transmission network to move power around the country represents one dimension of its role in delivering a secure electricity system. There is a wide range of other factors which need to be considered. **The design and operation of the transmission system has a major bearing on the ability of the electricity system as a whole to respond to faults, to maintain safe voltages, to be resilient to storms, and to recover quickly from a major black-out**. The changing nature of the electricity system in Scotland means that these operability and resilience issues must be at the heart of discussions about upgrading the network.

Figure 2: New transmission links will be needed to ensure that Scotland is able to make the most of opportunities for renewable generation and to ensure security and reliability of electricity supply in Scotland. This will include new links with our Island Groups, with E&W and with our European Neighbours.

Island transmission links will enable major renewable projects and economic development opportunities on the Western Isles, in Orkney and Shetland.

Interconnectors to Norway and possibly to other neighbouring countries will provide additional markets for Scottish wind generation whilst supporting a secure supply and increased resilience

Network upgrades within Scotland, such as the Caithness-Moray link currently in commissioning, will be important to ensure that we can benefit form continued investment in renewables whilst ensuring that secure supplies exist are delivered throughout urban and rural Scotland.



The Western link HVDC project is expected to provide 2.2 GW new capacity to export from Scotland to England and Wales, as well as increased ability to import from England and Wales

New links on the east coast will be important in delivering energy from offshore wind in the North Sea as well as onshore development. Plans for these projects are already well developed, focusing on new subsea links to north East England. Ensuring they are completed during the 2020s will be important to delivering on our renewable targets.

Operating and securing the system

Network design and operation is about more than just capacity; networks also have an important role in linking the wider electricity system. The difference between wind turbines and fossil fuel power stations is much deeper than just the fuel used. New sources of energy are connected using very different technical principles. This means we will need to redesign many of the systems we've traditionally relied upon to ensure the safety, security and reliability. Box 4 provides more detail.

National Grid ESO, the GB electricity transmission system operator, will continue to need ancillary services to operate and ensure stability and resilience across the system as well as back up generation – response and reserve services. This will mean continuing the current trend and efforts to open up these markets and to source the relevant services from new and increasingly small-scale parties. These mechanisms need to be designed to take account of the physics, the engineering and the economics of the new providers.

Conventional transmission connected generators will also continue to have a role. For example, new pumped storage hydro capacity can provide valuable network services. However, the large capital investment involved in these projects mean that developers need to have confidence that there will be sufficient revenues available for the ancillary and system services they provide over years or decades. The way these services are procured needs to consider the long term investments required to bring forward new pumped storage projects.

BOX 4: KEEPING THE ELECTRICITY SYSTEM OPERATING

There are several ways in which new sources of electricity such as wind farms, solar panels and HVDC interconnectors differ from the large fossil fuel power stations which are coming offline. Each of these differences has implications for how we design and operate the electricity networks and the whole electricity system.

New generators are often **smaller**; this means that a larger number needs to be coordinated to deliver the same level of services that used to be provided by one or two large generators. The majority of these smaller generators are **distribution connected**, meaning that we need to change the way we plan and operate the distribution networks as well as reviewing the interface between distribution and transmission. This is important to to ensure that we can use those generators, as well as other resources connected to the distribution network, to support the wider system.

Renewable generators are **intermittent**. This means that we need to find ways to make sure that the system can still operate, and meet demand, when the wind doesn't blow or the sun doesn't shine. Their output is also **uncertain,** meaning that we need back up that is flexible and able to respond quickly to changing conditions.

Finally, wind and solar generation, like HVDC interconnectors, are **not synchronised** to the system frequency. This creates new challenges for operating the system in a stable way.

As well as delivering energy, power stations have traditionally provided a range of services to keep the system balanced and the networks operating. We need to plan carefully to ensure that the resources connected to our networks can do the following:

- **Manage network voltage:** keeping voltage within statutory ranges ensures that the system is safe, and that equipment connected to the network is not damaged. Renewable generators, such as wind farms, have the capability to support voltage, even when it isn't windy; we need to make effective use of this capability, as well as other options such as new network equipment and greater use of distributed connected generators, consumers and storage.
- **Keep the frequency stable:** large fossil and nuclear generators are synchronised into the frequency of the system. They provide 'inertia' which helps keep the system balanced in the first few seconds after a major fault. Networks have always played an important role in linking sources of inertia across the country. Wind turbines, solar panels and HVDC interconnectors are not synchronised and we need to find new ways of either replacing the lost inertia, or keeping the system stable through new techniques. New sources of backup power, such as battery storage, can respond to changes in frequency within a second or less, and there is potential to develop ways to use wind, solar and interconnectors to rebalance the system quickly after a fault.

BOX 4: KEEPING THE ELECTRICITY SYSTEM OPERATING CONTINUED

- **Detect network faults:** fewer large synchronised generators and greater quantities of generation connected to the distribution network mean that the response to 'short circuits' and other network faults is different. In some cases, 'fault level' limits mean that new distributed generators cannot be connected without new investment. Keeping the system safe will remain the number one priority for network companies and the ESO. However, doing so in a cost-effective way may mean thinking again about the design of some of these systems.
- **Resilience and black start:** we have never suffered a full-scale black out across the whole British electricity system, and there have been relatively few major power interruptions in recent decades. However, if a black out should happen, we must be able to restart and repower the system quickly and safely. Large thermal power stations spread across the British electricity system have traditionally been at the heart of plans to 'black start' the system. When new large power stations are developed, decisions over where they are located should take account of the locational benefit they can provide – for example, their ability to support faster restoration following a black out. We will also have to do things differently in the future; this means that we must develop ways to use distributed generators, renewables and interconnectors. Ofgem's announcement in 2018 of £10.3 million for National Grid and SP Energy Networks to investigate the use of distributed generation to support a black start is a positive step.

Some of the services that National Grid use need to be provided at the right location on the network. For example, managing the voltage on the transmission network in Scotland depends on appropriate voltage support from providers within Scotland. But getting power stations to locate in Scotland is difficult due to the current combination of location specific network charges, but limited location specific revenue streams. We think that the **locational** value that new power stations, demand-response projects battery storage projects and others can provide across a range of services, needs to be taken much more into account.

We believe that the planned review of the Capacity Market mechanism must consider the locational value of capacity. This would help ensure that we have the right quantities and kinds of capacity in the right places across Scotland and Great Britain – making our networks and systems more reliable, resilient and secure.

Distribution networks

Electricity distribution network planning and operation will also be very different in 2030. We are in the early stages of a shift from Distribution Network Operators (DNOs) to Distribution System Operators – the 'DSO transition' (see Box 5). This will mean that distribution network customers – including household consumers, micro-generators, storage providers – will be able to use their flexibility to generate income. Data from smart meters, and the ability for 'real-time monitoring' of the distribution network itself, will be used to keep the network safe and secure.

BOX 5: THE DSO TRANSITION

A process is already underway which will fundamentally change the way in which electricity distribution networks are planned and operated. Constraints on these networks – areas where there isn't enough available capacity – mean that new customers (consumers, generators and increasingly energy storage providers) often can't connect without paying large costs for new capacity that may end up rarely being used. One solution is the development of Distribution System Operators (DSO) allowing substantially more flexibility over how distribution networks, and the systems they connect, are planned and operated.

DSOs will take a much more active role than DNOs do at present; they will have much greater awareness and visibility of the small generators and demand customers across these networks, and be able to enter into contracts for particular supply and demand services.

DSOs will be able to match local supply and demand, enabling much more flexible behaviour across the distribution network. This will allow the networks to connect new customers, identify when demand and generation could risk overloading the network, and take steps to influence behaviour.

This could lead to new and local markets in flexibility – where consumers can offer to reduce their demand, or generators and energy storage operators increase or reduce their generation, to keep the network safe. This already happens on a national scale. Innovative aggregator companies such as Edinburgh based Flexitricity are leading development in this field, helping businesses to get value from providing flexibility to the System Operator. In future, aggregators will also play an important part in delivering flexibility to support the local networks.

The Scottish Government believes that the following principles should guide the design of the DSO role over the coming years:

- **Safety:** This must remain the number one priority, with clear and well defined responsibility for maintaining safety.
- **Security:** Greater flexibility shouldn't come at the expense of security of supply; as above, there should be a single party responsible and accountable for dispatching the system, and making sure that demand is met at all times.
- **Efficiency:** The DSO transition should help make our distribution networks more efficient in future. The networks will need structures which can adjust to changing circumstances, and provide different solutions in different areas.
- **Openness:** Everyone should be able to provide services to DSOs, using transparent and fair processes. Those who aren't familiar with providing network services, such as community groups and local authorities, should have access to the help and advice that will allow them to do so.
- **Risk sharing:** Today's world involves taking long term investment decisions in the context of a fast changing energy system. The DSO transition allows us to review our understanding of risks, and who should carry them – creating the flexibility to keep options open when possible and appropriate, but with timely investment decisions still being taken when needed.

BOX 5: THE DSO TRANSITION CONTINUED

- **Adaptable:** Technological disruptions and advancements are creating new opportunities and challenges. The development of DSOs over the coming decade will need to happen in a way which enables systems to anticipate and react to emerging solutions, innovations and evidence in areas including the best ways to decarbonise heat, and how to respond to changing and growing demand from electric vehicles.

GAS

The gas networks will be an important part of the energy system in Scotland in 2030 and beyond, continuing to bring energy to the majority of the properties in Scotland. Gas currently provides low cost, reliable energy for heat, and represents the cheapest large-scale way to provide heat for the majority of homes, businesses and industrial processes. It is also a source of valuable flexibility across Scotland's energy system – an aspect that energy policy and system planning needs to keep clearly in mind.

Our vision for the gas networks requires the following:

- identifying and recognising the value that the gas network provides to the broader energy system, including the flexibility it provides;
- partial and increasing decarbonisation of the gas in the network between now and the end of the 2020s through the introduction of low carbon gases such as biomethane and hydrogen; and
- developing the evidence about the technical feasibility and cost effectiveness of converting the gas networks to supply 100% hydrogen.

The gas networks today

Gas remains the largest provider of heat in Scotland – connecting around 83% of domestic customers in 2016, delivering around 33% of total energy including 66% of all domestic energy. Gas also acts as a fuel and feedstock for industry, with some of the largest users of gas in the UK located in Scotland, contributing to a robust economy with opportunities to include a wider global market.

Current data[4] shows that domestic consumers pay around 3.6 pence per kWh for gas in Scotland; this compares with 14 to 16 pence per kWh for electricity on a standard tariff, with off peak electricity available at between 8 and 10 pence per kWh.

Figure 3: Gas injected into the National Transmission Network (NTS) at St. Fergus meets a substantial fraction of total British demand for gas. This graph shows the total energy injected at St. Fergus each day in 2017 and where that energy was used.

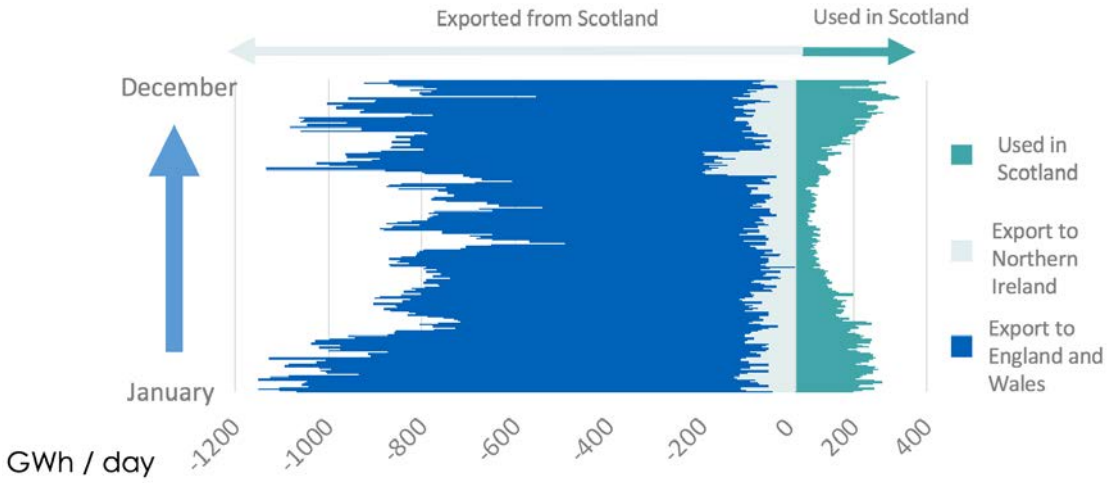


Figure 4: Gas pipes across Britain act as a substantial energy store, known as linepack, and this is used every day to provide flexibly. This graph shows the NTS linepack capacity used each day to help balance supply and demand.

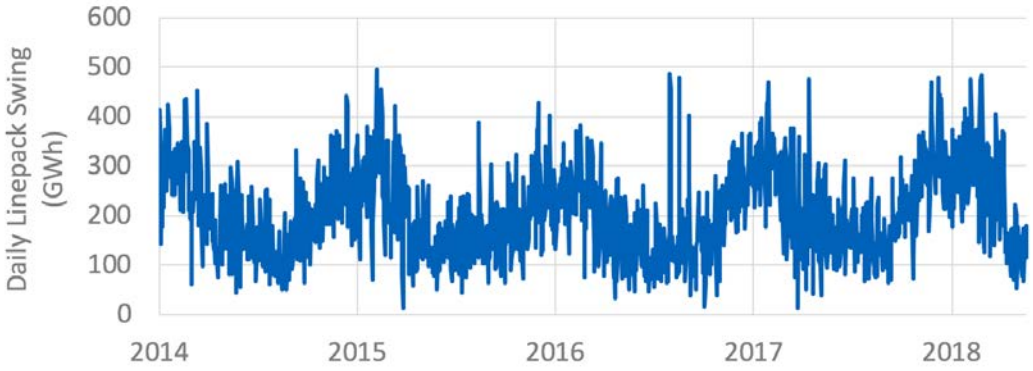
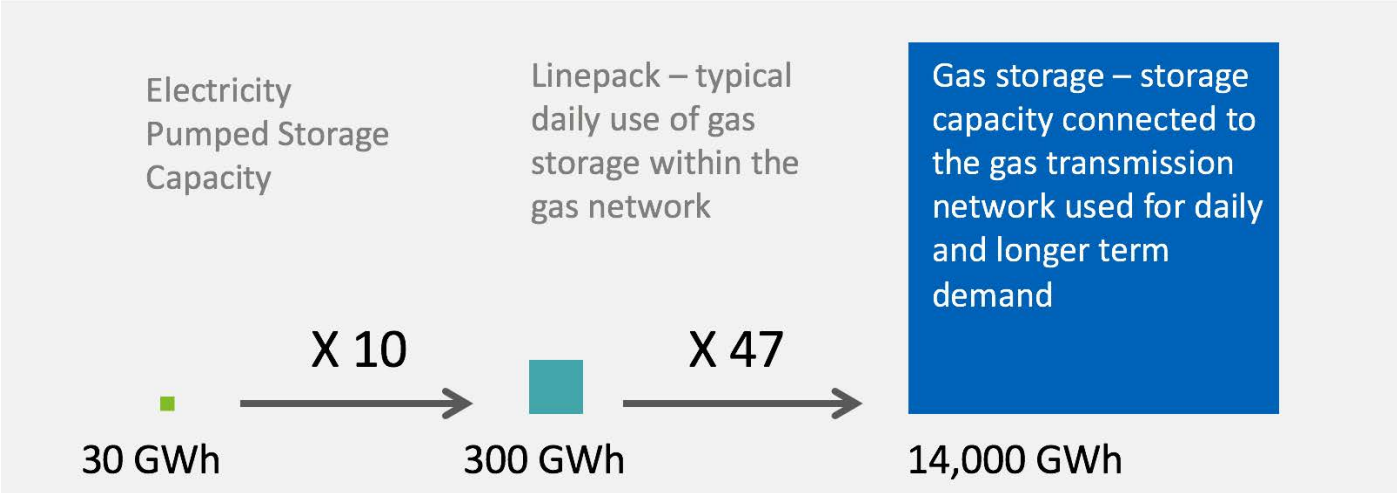


Figure 5: Energy storage is important across the energy system. Pumped Storage is central to the operability of the electricity networks but is relatively small in capacity terms; linepack helps us meet within day variations in energy demand, and dedicated gas storage sites provide bulk storage capacity which can be used to provide monthly or seasonal flexibly.



Gas containing 329 TWh of energy, with an estimated wholesale market value of £5 billion, was injected into the National Transmission network at St. Fergus during 2017. Around 18% of this was used to meet Scottish demand, with the rest exported (11% to Ireland and 71% to England). Around 40% of GB-wide demand for gas in 2017 came via St. Fergus and through Scotland.

Over and above the energy that it supplies, the gas network also provides us with important flexibility and energy storage. The gas network stores energy within its pipes and provides important daily flexibility through 'linepack'. Supplies of gas are pumped into the network overnight, increasing the pressure, and this energy is stored until demand picks up during the early morning. As more gas is drawn out over the course of the day, the pressure falls. Linepack means that the GB gas network provides flexibility through daily storage, exceeding 300 GWh during some days in winter.

In addition to the energy stored within the network itself, there are 14,000 GWh of distinct energy storage facilities connected to the GB gas network.

The gas network is therefore able to provide daily and inter-seasonal energy storage well beyond the capability of the electricity system. Pumped Storage Hydro plays a critical role in supporting the operation of the electricity network, providing important ancillary services and reserves. However, its role is quite different to that which the gas network's bulk storage can provide.

Although the gas network delivers low cost and flexible energy, the energy that it delivers today comes from a fossil fuel. Burning natural gas releases 182 g CO_2 per kWh, compared with just 54 g CO_2 per kWh for electricity generated in Scotland in 2016. We need urgently to decarbonise the gas that flows through the gas network, and to explore whether it will be feasible and cost effective to re-use the gas network in future to deliver fully decarbonised energy.

The gas networks during the 2020s

The UK Committee on Climate Change recommended in 2016 that work begin now on decarbonising heat, in order to deliver change over the coming decade[5]. The Scottish Government's Climate Change Plan, published in February 2018, acknowledges this need, and sets out ambitious and challenging trajectories for decarbonising our heat supply. The Plan recognises that decisions on future decarbonisation of the gas network are a reserved matter.

The UK Government needs to fulfil its commitment to take a decision on the approach to decarbonising heat as early as possible in the next Parliament. This will give network operators, investors and governments sufficient time to plan for any transition of the gas network, and to understand the implications for levels of demand.

We have committed to review our approach to low carbon heat – and in particular support through the Energy Efficient Scotland programme – in a future Climate Change Plan, once this aspect of UK Government policy has been clarified.

5 https://www.theccc.org.uk/wp-content/uploads/2016/10/Next-steps-for-UK-heat-policy-Committee-on-Climate-Change-October-2016.pdf

We know that the gas network can deliver flexible energy at an affordable cost; our aim should be to decarbonise that energy as far as possible between now and the end of the next decade, without sacrificing those qualities.

There is significant potential to produce and blend low carbon gases with supplies of existing natural gas, partially decarbonising the gas that is delivered to consumers. Opportunities include the use of biomethane and low carbon hydrogen. The networks themselves, and the regulations which govern them, need to be in a position to deliver this. More specifically, we need to update our Gas Quality Standards, and the way in which customers are billed for the gas that comes through the networks.

Current Gas Quality Standards were designed around natural gas from the North Sea, which didn't envisage the need to inject transport hydrogen or low carbon gases into the network. Limits on the makeup of the gas that can flow through the network are set out in the Gas Safety (Management) Regulations (GS(M) R) 1996. For example, the existing standards limit the percentage of hydrogen allowed in the gas network to 0.1% by volume, well below what is allowed in other European countries.

There is growing evidence that these standards can be widened, and low carbon gas transported through the distribution and transmission networks – significantly reducing the carbon intensity of gas over the next decade, without compromising safety.

Work is progressing at a UK level through the Institution of Gas Engineers and Managers, and at EU level through work to ensure an integrated market for suppliers across the EU. We welcome this focus, and expect to see more examples of networks working together with equipment manufacturers to verify the safety of new gas mixes and how they can work with new and existing equipment.

We also need to update the legislation that sets out the methodology for the way customers are billed for the energy that they receive. The energy content of natural gas is calculated using nationally averaged values over large geographical areas or zones. This does not allow for the variations in the energy content that we will see as locally produced low carbon gas becomes more prevalent. Low carbon gas, including blends of natural gas and hydrogen, tends to have lower energy content, and this needs to be reflected in the energy that consumers use and are charged for.

With focused work in this area, we may be able to see hydrogen blended into the network at penetrations of between 2% and 20% by volume, and fossil fuel gas mixed with low carbon gas like biomethane. This has the potential to provide a substantial carbon saving through the 2020s.

The gas network companies across Britain have recently launched a project to develop a full pathway for decarbonisation of the gas network. This will provide the next step in a coordinated approach to understanding the opportunities and barriers across both transmission and distribution, and how these vary across the country.

As well as pushing incremental decarbonisation, companies will continue to invest in the network, both to maintain the service it provides and to connect new customers. Network companies are currently considering business plans for the next price control period (2021-2026). The case for investment, reinforcement and potential expansion of network infrastructure will be influenced by several factors. These will include an assessment of the potential for access to gas to affect fuel poverty, as well as a comparison with alternative options for providing low carbon heat.

Investment decisions for general network development are made by the gas network company, operating within a framework created by Ofgem, while specific extensions or 'infill' projects are a matter for the gas network company and new connecting customers. There are currently 36 live infill projects underway in Scotland which have the potential to connect 4,719 new properties to the gas mains, with around 1,700 supported by the Fuel Poor Network Extension Scheme.

Investment decisions will also need to consider broader policy developments for decarbonising heat in Scotland. The Scottish Government is committed to exploring and supporting a range of options to decarbonise heat during the short term – with a focus on measures which will prove to be effective and good value for money, no matter which pathway to full decarbonisation emerges as the best.

Regardless of the technologies, fuels, or pathways which emerge, increasing the efficiency of buildings and reducing the demand for energy remains a priority – this is a key element of our Energy Efficient Scotland Programme. This Programme includes commitments to reduce heat demand in domestic buildings by 15% by 2032, and by 20% in non-domestic buildings, eliminating a key driver of fuel poverty. Projects which deliver low carbon gas and substitute existing gas demand are likely to be an efficient way of decarbonising.

Preparing the evidence for a long term future

Beyond the partial decarbonisation of gas we expect during the 2020s, the CCC suggests that even large scale partial decarbonisation of heat is unlikely to be sufficient to meet our 2050 targets[6].

We need to see strategic decisions made during the next decade on how to fully decarbonise heat, and – as part of that – the long term future of gas networks. This means exploring whether the valuable flexibility and energy storage capabilities that the gas networks provide today can be harnessed in a near zero carbon energy system.

The hydrogen future laid out in our Energy Strategy as one potential pathway to near full decarbonisation of energy by 2050 would see the gas network converting to transport 100% hydrogen. This would mean supporting a wholesale change across the wider energy system to develop the technologies capable of producing large quantities of low carbon hydrogen, including electrolysis and Steam Methane Reforming combined with Carbon Capture Use and Storage.

The technical feasibility and costs to consumers of a hydrogen future are deeply uncertain. Reducing this uncertainty needs to be a priority for everyone involved in the sector, with a need for the gas networks, government and the regulator to play an important role over the coming decade.

The Scottish Government plans to build on our recent support for hydrogen. We are working to publish an interactive mapping tool which charts current hydrogen activity in Scotland and plots specific hydrogen opportunities and hydrogen production potential on a region by region basis.

We will also continue to work with our stakeholders to advance a bold range of hydrogen energy and transport initiatives, with accompanying clear analysis and policy statements on the role of hydrogen in Scotland's economy. We will capitalise on Scotland's unique strengths, skills and capabilities to maximise the role and contribution of hydrogen to Scotland's economy and energy future. More detail on these aspects will be included within our Annual Energy Statement published later this year.

6 https://www.theccc.org.uk/wp-content/uploads/2016/10/Next-steps-for-UK-heat-policy-Committee-on-Climate-Change-October-2016.pdf

There is a lot of work already underway, particularly focused on the ability to repurpose the existing gas distribution networks. In 2017, Ofgem funded the H21 project[7] to assess the suitability of converting the gas distribution networks to transport 100% hydrogen. This project also highlighted the need to stimulate the growth of hydrogen hubs, where Steam Methane Reforming and CCUS capabilities, or the use of large scale renewable generation combined with hydrolysis, are developed to supply the hydrogen.

The focus in Scotland is on demonstration. SGN is planning to roll out a 100% hydrogen trial network in Scotland in the early 2020s to demonstrate the technical feasibility of distributing hydrogen and to show that it can be done safely and securely[8].

The ACORN project based at St. Fergus is aiming to deliver a demonstrator which will produce hydrogen form Steam Methane Reforming in combination with a Carbon Capture plant. The captured CO_2 will be transported using existing redundant pipes to North Sea gas fields for storage. The Scottish Government provided funding for feasibility studies into this project, which is an example of how we will continue to support the development of a hydrogen economy.

Reusing the gas networks for 100% hydrogen will mean ensuring that the pipes, pumps and pressure conversion stations can safely transport hydrogen. The gas distribution networks are increasingly constructed from plastic pipes which are suitable for carrying hydrogen, meaning that much of the distribution infrastructure is likely to be relatively easy to convert from natural gas to hydrogen.

The gas transmission system is different, however. An important piece of evidence – and one that we expect National Grid to develop, as owner and operator of the National Transmission Network – will be the role that the gas transmission network can play in a 100% hydrogen future, and the feasibility and costs of repurposing the network to achieve this.

There are a number of roles that transmission infrastructure can play. These include the continued transportation of natural gas – for or example, to Steam Methane Reforming facilities. We will also need networks to transport the gases associated with CCS to locations suitable for storage or use.

The alternative pathway described in our Energy Strategy – an electric future – could lead to the decommissioning of parts of the gas network. The gas network companies, in conjunction with Ofgem, are best placed to understand the costs of doing so, and they should lead work in this area.

The gas network companies will play a big part in gathering the evidence to inform strategic decisions about the best way to decarbonise heat in the long term and it is important that this remains a central focus of their work over the coming years.

The Scottish and UK governments are working closely together, and collaborating with industry, to ensure that we are in a position to make informed decisions during the 2020s.

7 http://www.smarternetworks.org/project/ngngn03
8 https://www.sgn.co.uk/Hydrogen-100/

BOX 6: CONVERTING THE GAS NETWORK TO HYDROGEN

Gas networks have the potential to deliver low carbon hydrogen. In the near term, hydrogen could be blended with natural gas to reduce its carbon intensity. In the longer term, it may be feasible and cost effective to use the gas networks to deliver 100% hydrogen to some or all connected areas.

Blending Hydrogen

Hydrogen can be blended with natural gas and with other low carbon gases. International projects such as the Thüga power-to-gas electrolysers in Frankfurt, Germany show that this is possible today. In Germany, up to 10% of the gas volume can be hydrogen, which – if produced by zero carbon means – can reduce the carbon content of the energy delivered by 3%.

The Hydeploy project at Keele University is planning to trial and demonstrate the safety of up-to a 20% hydrogen mix, decarbonising the delivered energy by around 8%. A 20% hydrogen mix across Scotland, supplied from low carbon sources, could provide decarbonised heat equivalent to the demand of around 280,000 homes. One source of energy for this could be renewable generation, requiring the equivalent of around a quarter of Scotland's renewable generation output in 2016.

Blending hydrogen into the gas mains is likely to be viable at concentrations where existing consumers' equipment can safely burn the blended gas. Trials such as the one at Keel can help establish the percentage of hydrogen that can be used safely.

100% Hydrogen

Converting the gas networks to deliver 100% hydrogen is a much greater challenge. This will require a long term and coordinated programme covering gas transmission and distribution, the production of low carbon hydrogen, and the replacement or adjustment of existing consumer and industrial equipment.

Scotland can lead in this area. SGN is planning to demonstrate a 100% hydrogen gas network in Scotland in the next few years, converting part of the gas distribution network to trial delivering hydrogen. The area around St. Fergus also offers a unique combination of resources which make it suitable for trialling the broad range of technologies needed, including large scale production of hydrogen from natural gas, CCS through existing but redundant pipelines in the north sea, and access to transmission and distribution network assets.

Evidence of the gas networks' suitability to support a hydrogen system will be critical to the strategic government decisions over the widespread decarbonisation of heat, and which we need to see well before 2030.

BOX 6: CONVERTING THE GAS NETWORK TO HYDROGEN CONTINUED

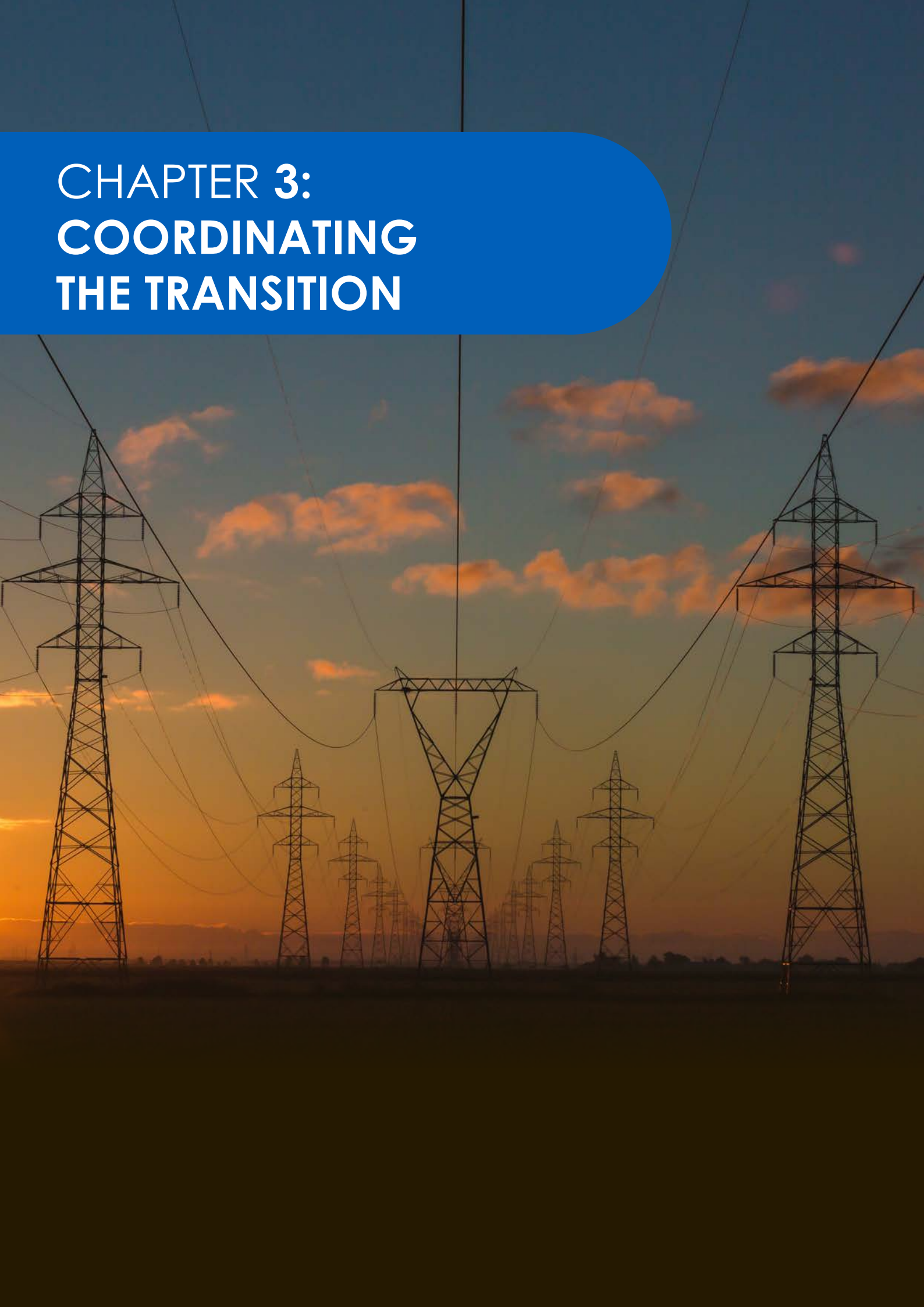
Producing Hydrogen

We will ultimately need the hydrogen that the networks carry to be produced in a low carbon way. Nearly half of the hydrogen in the world today is produced by **Steam Methane Reforming (SMR)**, a chemical process which converts natural gas into hydrogen, while emitting CO_2. This can only be 'low carbon' if combined with Carbon Capture Utilisation and Storage (CCUS); developing the SMR process in combination with CCUS will be central to a long term high-hydrogen future.

Alternatively, hydrogen can be produced via **electrolysis** from renewably-generated electricity. For example, the Surf and Turf project on Orkney links a 500 kW electrolyser to a community owned 900 kW wind turbine.

Scotland's offshore wind capabilities also offer a potential opportunity to harness renewable energy for the production of hydrogen.

Electrolysis also provides an opportunity to link the gas and electricity networks in a more coordinated way. Electrolysers could be fitted at locations where the network is constrained, and where the extra electrical demand they create helps reduce the need to curtail wind power. This could also support efficient cross-network decarbonisation, if the same locations were suitable for injecting hydrogen into the gas network.



CHAPTER 3: COORDINATING THE TRANSITION

COORDINATING THE TRANSITION

By 2030… network regulation and governance will be more flexible and agile, based on deeper relationships with consumers. Scottish policies and priorities, as well as those of local authorities, will be taken fully into account ensuring that networks help deliver regional and local aspirations for energy. A coordinated, 'whole system' approach to infrastructure planning will exist, with strong and effective discussion between the electricity and gas network companies and everyone in the wider energy system. The way networks are funded ensures that the essential service they provide – access to affordable, reliable, and low carbon energy – is available to all citizens and businesses in an efficient and cost effective way.

Overview

The electricity and gas networks are natural monopolies that play a vital role in providing access to energy for people and businesses. Ensuring that they deliver the service that we want, to everyone, in a cost effective way, means that strong regulation and agile governance are important.

Although the technical characteristics of gas and electricity networks are very different, their shared economics, capital intensive and long term natures mean that key aspects of our vision apply equally to both – these include:

- The ways in which they are **regulated and governed**.
- The ways in which they are **planned**, especially the need for a whole system perspective.
- The ways in which they are **funded**.

Gas and electricity network policy and regulation are reserved to the UK Government. However, there are some important overlaps between UK and Scottish Government responsibilities on broader energy issues, and where decisions about gas and electricity networks can have an important influence. A good example is the provision of heat; the development of district heating during the coming decade will create new questions concerning the traditional split between the regulated and non-regulated parts of the energy system – with the Scottish Government having proposed and consulted upon regulation of district heating in Scotland.

We expect these overlaps to grow throughout the coming decade. The growth of electric vehicles is already forging new connections between transport policy and the electricity system – meaning that the network companies and regulator need to bear these aspects closely in mind when making decisions about the future of Scotland's networks. We will continue to work constructively with the UK Government on these matters – sharing information and making sure that Scotland's voice and interests are properly represented.

While Scotland has its own distinct targets, needs and priorities in this and other areas, the same issues and questions exist across the UK. We think that a collaborative and practical relationship between the Scottish and UK Governments will help ensure that the governance and regulatory structures can be made sufficiently flexible to accommodate differing priorities across Britain.

Scottish energy policy teams will meet with UK Government colleagues during 2019 to discuss the issues set out in this document, and how our joint ambitions can contribute towards UK wide decarbonisation and industrial strategy. This will

be in addition to continuing meetings between Scottish and UK Government ministers, which cover a range of energy policy matters.

The Scottish Government similarly values its close and constructive relationship with Ofgem. We remain keen to find ways in which to improve this – to find better means of discussing and sharing views on our energy policy, and the regulator's ability to take these views into account in a manner consistent with its independent status.

We will discuss and agree with Ofgem a programme of regular meetings between senior officials focused on the energy networks in Scotland, as well as arranging an annual discussion between the Scottish Government energy minister and Ofgem's board.

We believe that electricity and gas networks enable the provision of an essential service – namely, access to affordable, reliable and low carbon energy for everyone in society. We expect this principle to inform decisions by government at all levels, and to be reflected throughout the regulatory and governance system.

Regulation and governance

The extent and pace of innovation and change is asking much more of our systems for regulation and governance. The structural changes which we need to drive through our gas and electricity systems demand practices which can adapt, adjust and respond accordingly – with the regulator playing its part in enabling networks that meet the needs and priorities of society.

Ofgem acts as the independent energy regulator, answerable to the UK Parliament and UK Government. Part of its remit is to act as a strong financial regulator to the monopoly network sector and to ensure that network companies deliver a safe and reliable service. In doing so, it oversees the broader governance structures – the licences and codes that define the rules under which the sector operates.

An important part of regulation is the way in which Ofgem agrees the level of spending that network companies are allowed to recover from network customers. These price control settlements are made for periods of several years and aim to ensure that network spending is efficient and focused, whilst giving the network companies the level of financial stability they need to invest in long term assets.

The current process is called RIIO: Revenue = Incentives + Innovation + Outputs. RIIO has a focus on regulating total expenditure across capital and operational activities – Totex – and allowing network companies to choose how they deliver the levels of service defined in their licences and the degree to which they go beyond these baseline standards. RIIO provides a range of incentives which reward networks for delivering high quality service, and penalises them where it is poor. RIIO also contains separate funding streams for innovation.

The first round of RIIO price controls began in 2013, when Ofgem agreed eight year settlements with gas transmission, gas distribution and electricity transmission; these run until 2021. The first electricity distribution price controls were agreed two years later, running from 2015 to 2023.

Gas network and electricity transmission companies are now preparing business plans for the RIIO-2 period to begin in 2021. The length of the RIIO-2 settlements has been reduced to five years, reflecting the high degree of uncertainty in the energy system and the challenges of forecasting further into the future. The second RIIO period for electricity distribution will be 2023 - 2028.

Price controls are complex negotiations. Final settlements must ensure a good deal for customers, whilst providing the stability needed for capital intensive investments where payback periods are measured in decades. They also need to account for uncertainty over the future development of the energy system. This uncertainty needs to be dealt with openly, identifying low regret options and considering the pros and cons of particular investments in different future scenarios.

This means considering carefully how risk is managed. Where spending might be approved to enable the development of the broader energy system – for example, the roll out of EVs – it runs the risk of the system developing along a different pathway, or taking place more slowly than forecast. This doesn't mean that investment should not be made, but it highlights the importance of quantifying the risk, identifying who carries it, and how it is managed.

The current price control agreements must clearly identify areas where any anticipatory spending may be required, and look carefully at options to mitigate the risk. Mechanisms should be introduced to support and enable investment where that is critical for the decarbonisation of the energy system and the wider economy.

We are following the RIIO discussions and development closely, and aim to ensure that the process and outcomes properly reflect the Scottish Government's energy priorities. That means striking the right balance between investing in the network at the right time and in the right places while supporting Ofgem in its efforts to curb excessive returns and deliver a fairer and better deal for consumers.

Governance mechanisms will also need to respond more quickly and more flexibly, with clear pathways for new and innovative businesses to inform how network codes and regulations develop. Increasing stability, transparency and open governance across the energy sector, sufficient to meet the demands of a fast changing world, will be challenging.

Ofgem is trialling open governance across some codes under which the network industry operates, while in other areas it is moving towards 'principles based regulation'. We believe these are positive developments; they signify that Ofgem understands the careful thought that must be given to the most appropriate mix of regulatory styles for the future of networks, based on the changes that are both underway and expected.

The growing interdependencies between different parts of the energy system are creating new areas in which the Scottish Government, UK Government and Ofgem need to interact. We believe that this will need new, strong and well-defined relationships between reserved and devolved government, and the regulator. Our desire to see smarter local energy provision, and our vision for local authorities to take a greater role in energy policy making, means that this collaboration needs to extend to local government.

Consumers

Big data and smart technologies give consumers new opportunities to provide services to the networks. **It can also fundamentally change the relationship between consumers and networks, with new rights and obligations on both sides;** consumers will become active participants in how network companies deliver their obligations for security and reliability of supply.

The growing focus on using flexibility from customers to support networks is important, particularly in the electricity sector. The 'DSO transition' (See box 5) shows that the industry is moving quickly towards a new model based on new relationships with their customers. But we need to avoid easy assumptions, and carefully consider what is feasible, desirable and affordable. We also need to remember that some consumers may not be able to adjust their consumption patterns, whilst others may find it difficult to engage in an increasingly complex market. It is imperative that these groups are not left behind.

Consumers and their representatives need to have access to the tools, expertise and knowledge that can help ensure that these rights and relationships are fully considered, and appropriate protections put in place where necessary. They will need to engage in technically complex areas, and come to informed views across a range of knowledge areas. **We will also look at ways to support consumers and their representatives, communities, businesses and local authorities to engage in conversations about the future of our energy networks in the most effective way.**

There have been positive developments in this area. Ofgem has initiated an 'Enhanced Stakeholder Engagement' process to ensure that network companies engage meaningfully with all users of their networks, including representatives of the end users. **We will support the efforts of Ofgem and the network companies to capture meaningful input from consumers as well as other users of the electricity and gas networks, and apply that learning to develop fair and effective business plans.**

Ofgem's primary duty is to protect the interests of existing and future energy consumers. It is able to choose how it interprets and fulfils this duty, a level of flexibility which can be valuable during periods of such great change and uncertainty; what matters is that the relevant principles are clearly set out, and their impact on decisions and approaches well understood.

Ofgem's decisions must balance the interests of different groups of energy consumers – for example, domestic and industrial consumers, plus those who range from relative affluence through to the fuel poor. But Ofgem also needs to consider, and to trade-off between, the short term interests of today's consumers and the interests of consumers in decades to come.

For instance, Ofgem's approach to weighing the interests of consumers in 2020, 2030 and 2050 will affect decisions about investment in network assets with lifetimes reaching into the second half of this century. Clarifying how Ofgem balances these considerations will help deliver the decarbonised networks and energy system to which we aspire.

Whole System Planning

Our Energy Strategy argues that whole system planning is a concept whose time has come. Parts of the energy system which have traditionally operated in isolation are beginning to intersect; for instance, energy for transport looks ever more likely to be delivered through our electricity or gas networks. That means new approaches and more dynamic, inclusive planning will be needed over the coming years.

The successful introduction of hydrogen into the gas network is an example of technology that could lead to new links between the gas and electricity networks through electrolysis. Another is the potential for hybrid heat pumps, which combine a heat pump with a gas boiler. A trial in Wales is looking at ways to optimise these in ways that make best use of both networks[9].

We want to see, and to support, more formal coordination between electricity and gas network companies as they develop their business plans. But whole system planning goes well beyond just the gas and electricity network themselves, and even beyond the traditional concept of the energy system – it should take account of our broader social and economic objectives. We want a prosperous, inclusive and successful Scotland; our energy networks can play a part in realising this ambition.

The principles for planning infrastructure across the country are laid out in our Scottish Planning Policy and National Planning Framework. The NPF 3 highlights the long term developments that we anticipate across Scotland, and the values which should be captured in their design.

9 There is a trial project taking place in Wales just now involving the local electricity and gas distribution networks, and which looks at the operation and effects of hybrid heat pumps (https://www.westernpower.co.uk/projects/freedom)

NPF 3 highlights the need to develop the electricity transmission and distribution networks to meet our low carbon goals. It also identifies five areas of coordinated action that have particular significance for the delivery of the low carbon economy, and where the infrastructure assets needed to realise the potential of those areas should be progressed in a co-ordinated manner. These include the waters around Orkney and their potential for marine energy, and the Peterhead and St. Fergus areas in terms of opportunities for CCUS.

The NPF underlines the need to balance competing uses for natural and infrastructure assets, and to ensure that development takes place in ways that respect the environments and landscapes in which it is located. For example, the NPF prioritises the need to mitigate environmental and visual impacts in ways that help ensure that infrastructure is a positive addition to places.

More broadly, the current suite of development plans prepared by Strategic and Local Planning Authorities form the legal basis for making decisions on planning applications. Proposals that accord with the development plan should be approved unless material considerations indicate otherwise.

We will expect new network infrastructure projects to make clear how they can help meet the NPF's aspirations. We would also like network companies and the regulator to work closely with us as we continue to develop our planning policy. We intend a review of the NPF and Scottish Planning Policy following the passage of the Planning Bill, which is currently with the Scottish Parliament.

Our aspiration for a smarter local Energy Strategy will be influenced by the role that local authorities have in planning and consenting developments within their area. The development of Local Heat and Energy Efficiently Strategies (LHEES) will take place hand-in-hand with Strategic and Local Development Plans.

We want local authorities to work with electricity and gas network companies on these matters – ensuring that their strategies take full account of local network infrastructure, and especially areas where specific developments can improve those networks. This could mean locating new demand in areas where wind energy is often constrained, and potentially preventing it from being switched off at certain times. It could also involve considering ways in which local energy resources can support resilience and reliability of supply in isolated communities.

A gap remains between the broad economic and societal planning policies led by national and local government, and detailed network planning carried out by individual companies. There are currently no institutions, either nationally or locally, responsible for looking across the whole energy system, and considering direct and indirect social and economic impacts. We think this needs to be corrected.

Scenario planning is an increasingly common component of planning and development. National Grid's Future Energy Scenarios (FES)[10] process for GB is well established. SP Energy Networks and SSE Networks have now begun to develop similar scenarios for their own electricity network businesses and areas in Scotland, and which can be fed into the GB FES.

Scenario planning has great value in helping us understand costs and benefits that particular decisions deliver depending on uncertain areas such as economic growth, technological development and changing societal attitudes as well as helping us identify investments that keep options open across different pathways. We believe it should underpin the way in which the networks are planned and investment decisions are made.

Whilst these principles are being used today and continue to broaden the set of energy sectors they consider in order to understand the impact on their specific networks, there is an opportunity to apply any lessons learned in pursuit of a truly whole energy system approach.

10 http://fes.nationalgrid.com/

We believe that there is a case for institutions to be developed and given responsibility for whole energy system scenario planning. These should be capable of developing regional and local scenarios and pathways that take the whole energy system into account, and which can inform decisions made by planners in any part of the system.

There's a strong case for building up this kind of scenario development up from work carried out at local levels. This might often be at the local authority level, for example – building on the LHEES pilots getting underway in Scotland just now.

We believe there is an opportunity for Scotland to lead the way on coordinating whole system and local focused input into network planning assumptions. We will include thinking in this area within the Scottish Energy Networks Group, which will bring together senior representatives from industry, government and consumer groups, and which we will set up in 2019.

Network Funding

Paying for electricity and gas infrastructure is complex. Getting it right will play a huge part in delivering a genuinely inclusive energy transition.

Today's charging mechanisms use the principles of cost reflectivity and cost recovery to fund the building and safe, secure operation of our networks. But these are based to a large extent on assumptions about how consumers, businesses and generators have used networks in the past.

The same technologies which we expect to create more value and flexibility for consumers could conceivably allow us to drill costs down to a level where we can measure the impact each and every customer has on the networks.

Whilst this could increase the opportunities to set network charges in a cost reflective way, it is difficult to see how this would be appropriate for getting access to affordable, reliable energy.

The Scottish Government believes that the networks' role in providing this essential service should be the guiding principle by which decisions are made on how customers are charged to access them. The principles of cost-reflectivity, cost-recovery, fairness, certainty and transparency can all suppport this; but by placing the essential service role of networks at the heart of decisions over funding will ensure that everyone in society and across the economy has affordable and reliable access and connections to our energy networks.

The social importance of affordable access to networks is already recognised in the Hydro Benefit Replacement Scheme[11]. This is implemented by the UK Government, and protects customers in the north of Scotland from having to pay in full the higher costs of electricity distribution in their area, since these costs are judged rightly to be inappropriate for what is an essential and universal service.

Ofgem points out quite legitimately that, as things stand, any significant redistribution of costs away from a cost reflective outcome – for example, to protect particular groups of vulnerable customers – is a matter for government.

We agree, and believe that striking the right balance between cost reflectivity and cost sharing needs a more transparent process through which governments can consider, agree and implement the right principles. We believe that our principle of an inclusive transition, and our belief in affordable, reliable and low carbon energy as a fundamental right, is the right value around which to plan network charging. **We intend to work with the UK Government and Ofgem to help design and influence the principles around which future network charging should be developed.**

11 https://www.gov.uk/government/consultations/hydro-benefit-replacement-scheme-and-common-tariff-obligation-three-year-review-of-statutory-schemes-consultation

CHAPTER **4: SCOTLAND LEADING THE WAY – INNOVATION AND SKILLS**

SCOTLAND LEADING THE WAY – INNOVATION AND SKILLS

Our vision: by 2030… the culture of innovation in the sector will continue to grow. For electricity networks this means a focus on coordinating and integrating new technologies, particularly electric vehicles, heat pumps and new generation. Meanwhile, for gas, it means a focus on innovation to support hydrogen and low carbon gases. With the development of new technologies, innovative approaches to bring together previously disparate parts of the energy system can ensure that we make the most of local opportunities in a 'whole system' way. Delivering the skills that a changing sector needs, including in new specialisms such as cyber security and data science, will be a key priority for us, our businesses and our education sector.

The current explosion in new business models and entrepreneurial innovation is creating new ways to interact with the energy system. Innovation from network companies will be essential if our electricity and gas infrastructure is to keep pace with these developments, and with the nature and demands of an increasingly decentralised, decarbonised and flexible energy system.

The Scottish Government understands and supports the vital role that innovation in the energy sector is playing. Our Low Carbon Infrastructure Transition Programme has, since 2015, supported over 50 low carbon projects, providing over £48 million of financial support.

We committed £60 million in 2017 to support innovative low carbon energy infrastructure solutions across Scotland, such as electricity battery storage, sustainable heating systems and electric vehicle charging. Innovation over the next decade will need to focus on integrating new technologies and business models coherently across an evolving energy system. This will mean developing new ways to manage these systems alongside networks in ways that can support the security and reliability of supply that they provide.

Ofgem is also playing a big part in supporting the many innovative ideas and approaches which communities and the network companies are generating. The regulator provided £500 million to support network innovation between 2010 and 2015, and has made innovation a key component of funding for the networks through its price controls.

But there is still more that can be done to make innovation business as usual. For instance, it is more than ten years now since Active Network Management (ANM) was pioneered across the distribution system on Orkney – the world's first smart grid. Today the number of generators connected via ANM across Britain remains small.

We would like to see greater emphasis placed on reporting how and where innovation funding has led to changes in networks' "business as usual" processes. Consumers invest in innovation through their electricity and gas bills and this innovation has to translate into delivery.

Innovation needs to prioritise the challenges that society needs solved, and to focus on today's big challenges – such as the potential role for hydrogen, and the coordination of DSO systems. This means directing innovation funding towards gathering and exploring the relevant evidence and technical issues.

We have seen examples of this, such as the Scottish Government funded ACCESS project on the Island of Mull (see box 7), and Ofgem funded initiatives such as the Scottish Power ARC project, which aimed to integrate new local demand into Active Network Management in south East Scotland.

New innovations and technologies will guide, and could transform, the integration of electric vehicles across our electricity networks. As the number of such vehicles grows we need to explore the options to allow smart chargers to help manage the flow of charge to and from cars supporting safer and more efficient networks, and reducing the need for investment in new cables and wires. This will need to go well beyond technical innovation, and involve the consumer much more directly through innovative business models and techniques to engage and reward consumers for being flexible.

We expect innovation to have an equally important role on the gas side. Projects such as the H100 project, which aims to develop a 100% hydrogen network in Scotland over the coming years, can help us understand the role of networks within that and need to work closely with innovation projects focusing on the production of green gases.

We would like to see greater emphasis on gas and electricity projects working together. This will be important, for example, in identifying the most appropriate way to link the electricity and gas networks through electrolysis of hydrogen from low carbon electricity.

This cross-network innovation will also need to extend to the development of heating networks as we develop the long term regulatory and commercial environment in which they will operate. District heating offers a further opportunity to link to either the gas or electricity networks, or both, and efficient decisions will need to consider the limitations and flexibility of all three network types.

Skills

While Scotland has a strong engineering heritage, the challenges described in this document mean that developing more skilled people across a wider range of disciplines will become ever more important. We need to understand these needs, and work collectively to ensure that our education system, colleges and universities are able to respond.

Highly trained and experienced engineers will increasingly be joined by other specialists in multi-disciplinary teams. For example, we will need to ensure that the networks industry can access and develop appropriate skills in understanding customer behaviours, big data, cyber security and communications.

We will work with Skills Development Scotland to ensure that the changing needs of the sector are reflected – building on the Skills Investment Plan for Scotland's energy sector.

We will also capitalise on our research and development institutions, including our world leading universities, and organisations such as the Offshore Renewable Energy Catapult, the Power Networks Demonstration Centre, and the National HVDC Centre. We also have a number of centres of excellence such as the Future Power Networks and Smart Grids Centre for Doctoral Training at the University of Strathclyde; this is exploring novel solutions to many of the problems discussed in the paper, and producing high quality and highly qualified individuals ready to affect change in this industry.

The Scottish Government will fund new academic research in this area – starting with a CXC fellowship looking at the future stability of the electricity system in Scotland.

BOX 7: NETWORKS INNOVATION IN SCOTLAND

ACCESS - Mull

The ACCESS project on Mull has demonstrated the ability to coordinate electrical demand, the output of a distributed, community owned renewable generator, on a "virtual" constrained electricity distribution network. The community worked together with SSEN, the local DNO, using a £2 million grant from Scottish Government to connect a new 400 kW hydro generator together with over 70 installations of smart domestic electric storage heaters. The new demand has been managed to ensure that it balances the output of the new turbine, ensuring that the combined system does not overload the network. This is a leading example of the way in which smarter local energy systems can lead to more efficient use of the distribution networks. We expect the industry to consider the learning from ACCESS, and other similar projects in Scotland as we go through the DSO transition.

Surf and Turf - Orkney

Surf and Turf has been the answer to a major challenge for high curtailment of a community wind turbine in Orkney. The 900 kW turbine was connected as part of Orkney's world leading Active Network Management Scheme. However, developments since the project's inception led to higher than-expected reduction in the output of the turbine due to limited capacity of the local distribution network. The solution has been to install a 500 kW hydrogen electrolyser, and use the renewable electricity from the wind turbine that would otherwise be constrained, together with the output of a nearby tidal turbine to produce hydrogen for the local economy. Scottish Government funding of some £1.65 million helped make this project happen. This is a prime example of whole system thinking, with constrained electricity generation now being used to provide power for berthed ships in Kirkwall Harbour. Where projects such as Surf and Turf can be replicated close to the gas network, there would be the opportunity to blend the hydrogen directly into the main gas supply.

Hydrogen 100 Project - SGN

The H100 project is a £2.8 million Ofgem funded project to design the world's first 100% hydrogen gas distribution network, demonstrating the safe, secure and reliable distribution of hydrogen. The project will conduct research into the characteristics of hydrogen to provide a full understanding of the impact of its distribution in relative terms to natural gas. This will then enable the development of a safety case and compliance framework that will ensure the reliable and safe operation of a demonstration network. The project will consider the whole hydrogen supply chain, including transportation, storage, distribution and utilisation. The project is assessing the suitability of three sites in Scotland, in Aberdeen, Levenmouth and Machrihanish with one to be selected as the most suitable location for the construction of the demonstration network. All three sites have features that are representative of the wider gas distribution system and all provide locations that are UK scalable.

Local Energy System Research - University of Strathclyde

Whilst trials and demonstrations are important, so is more fundamental research. The Local Energy Systems project is a three year activity funded by ClimateXChange and based at the University of Strathclyde. It aims to identify the opportunities for linking the supply and demand of energy on a local basis across our networks. The project has developed a database of the electricity network infrastructure around Scotland alongside local heat, transport and renewable generation models. It is now working with Scottish Government and Distribution Network Companies in order to show what could be achieved, and what might be needed to do so.

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