# Just Transition Review of the Scottish Energy Sector

Chapter 2 – O&G demand in Scotland

**Reliance Restricted**

23 September 2022

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# Contents

# Abbreviations

| Abbreviation | Description | Abbreviation | Description |
|---|---|---|---|
| ADL | Alexander Dennis Ltd | EER | Energy Efficiency Rating |
| ADS | Air Discount Schemes | EfW | Energy from waste |
| ADT | Air Departure Tax | EII | Energy intensive industry |
| APD | Air Passenger Duty | EMU | Electric Multiple Units |
| ATI | Aerospace Technology Institute | EPC | Energy Performance Certificate |
| BEIS | The Department For Business, Energy And Industrial Strategy | EPR | Extended Producer Responsibility |
| BEMU | Battery electric multiple unit | ESC | Energy Systems Catapult |
| BEV | Battery electric vehicle | ETS | Emissions Trading System |
| bn | billion | EU | European Union |
| BOP | 'Balanced Option' (under ESC's Future Demand model) | EV | Electric vehicle |
| BPF | British Plastics Federation | EY | Ernst & Young LLP |
| C&B | Coaches and buses | FCEV | Fuel Cell Electric Vehicle |
| CCC | Climate Change Committee | FES | Future Energy Scenarios |
| CCGT | Combined Cycle Gas Turbine | GDP | Gross Domestic Product |
| CCL | Climate Change levy | GGL | Green Gas Levy |
| CCS | Carbon Capture Storage | GHG | Greenhouse gas |
| CCUS | Carbon Capture Usage and Storage | GVA | Gross Value Added |
| CfD | Contract For Difference | GW | Gigawatt |
| CHFS | Clyde & Hebrides Ferry Service | GWh | Gigawatt hour |
| CHP | Combined Heat And Power | HGV | Heavy Goods Vehicle |
| CI | Compression-ignition | HIAL | Highlands and Islands Airports Limited |
| $CO_2$ | Carbon dioxide | HMRC | Her Majesty's Revenue & Customs |
| $CO_2eq/MJ$ | Carbon dioxide Equivalent Per Mega-joule | ICAO | International Civil Aviation Organization |
| CORSIA | Carbon Offsetting and Reduction Scheme for International Aviation | ICE | Internal Combustion Engine |
| CPS | Carbon Price Support | IEA | International Energy Agency |
| CXC | ClimateXChange | IMO | International Maritime Organization |
| DEFRA | Department For Environment, Food And Rural Affairs | INTOG | Innovation and Targeted Oil and Gas |
| DfT | Department for Transport | k | Thousand |

# Abbreviations (cont.)

| Abbreviation | Description | Abbreviation | Description |
|---|---|---|---|
| ktoe | Kilotonne of Oil Equivalent | RET | Road Equivalent Tariff |
| kWh | Kilowatt hour | ROW | Rest of the World |
| LCV | Light Commercial Vehicle | rUK | Rest Of The United Kingdom |
| LDES | Long-duration energy storage | SAF | Sustainable Aviation Fuel |
| LEZ | Low Emission Zone | SAP | Standard Assessment Procedure |
| LOLE | Loss Of Load Expectation | ScotNS | Scottish North Sea |
| LPG | Liquid petroleum gas | SDES | Short-duration energy storage |
| m | million | SG | The Scottish Government |
| MGO | Marine gas oil | SI | Spark-ignition |
| $MtCO_2e$ | Million Tonnes Of Carbon Dioxide Equivalent | SMP | Sectoral Marine Plan |
| MWh | Megawatt hour | SNP | Scottish National Party |
| NAEI | National Atmospheric Emissions Inventory | SNS | UK Southern North Sea |
| NIFS | Northern Isles Ferry Services | SO | System Operator |
| NOA | Network Options Assessment | SOC | 'Societal Change' (under ESC's Future Demand model) |
| NPF | National Planning Framework | SPEN | Scottish Power Energy Networks |
| NRMM | Non-Road Mobile Machinery | SSEN | Scottish and Southern Electricity Networks |
| NSTA | North Sea Transition Authority | TCO | Total Cost Of Ownership |
| NSTD | North Sea Transition Deal | TNUoS | Transmission Network Use Of System Charges |
| NTS | National Transport Strategy | TO | Transmission Owner |
| O&G | Oil and gas | TOC | 'Technology' (under ESC's Future Demand model) |
| OCGT | Open Cycle Gas Turbine | TRU | Transport Refrigeration Units |
| OEM | Original equipment manufacturer | TW | Terawatt |
| Ofgem | The Office of Gas and Electricity Markets | TWh | Terawatt hour |
| OTNR | Offshore Transmission Network Review | UK | United Kingdom |
| PHEV | Plug-in hybrid vehicle | UKG | The UK Government |
| PSO | Public service obligation | ULEV | Ultra-low emissions vehicle |
| R&D | Research and development | VED | Vehicle Excise Duty |

# 1 Main Findings: Introduction and Background

# Introduction



## Background and context

The climate emergency is one of the biggest issues facing the world at present. The need for a Just Transition programme in response requires the largest re-deployment of capital and step change in behaviours since the industrial revolution, and the Scottish Government (SG) has put this at the forefront of its policy objectives. The Scottish National Party (SNP) and Scottish Green Party's Shared Policy Programme, published on 1 September 2021, states that, in order to achieve a Just Transition, it is crucial to baseline North Sea Oil and Gas (O&G) production against the backdrop of the global climate emergency and Scotland's economic security and wellbeing – before going on to take urgent proactive steps to deliver that transition.

## Our reports

We are producing three reports to provide analysis on Just Transition issues for SG. The first report (Chapter 1) set out the current and future state of the Scottish O&G industry and how it fits into the Scottish energy system, including forecasts of production and the anticipated decline in O&G jobs and GVA that will result. This report (Chapter 2) sets out the factors that contribute to the current patterns of the consumption of that O&G (not exported to the rest of the UK (rUK) or further afield). The third report (Chapter 3) will set out the contribution of the growth of renewables and associated energy industries to jobs and GVA, to replace that lost by the decline of O&G, and the factors that will need to be taken into account in managing this aspect of the transition. The Summary Report follows Chapters 1, 2 and 3 focuses on the development of a suite of accessible outputs to support the co-design of the Energy Just Transition plan.

## Report Scope

This report sets out the factors that contribute to the current patterns of consumption of O&G. It examines the consumption of O&G rather than its production. This aims to provide an evidence base to help shape policy and interventions to reduce greenhouse gas (GHG) emissions, and enable Scotland to follow a viable net zero trajectory. This report covers the following issues:

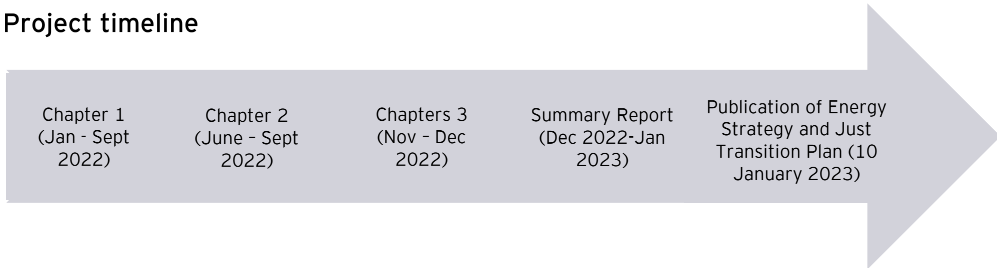
*Evidence base – where we are today and why, including historic factors*

- The current drivers of demand for consumption of O&G; and how the consumption of O&G historically became entrenched within different sectors of the economy.
- The technology that has created the shape of O&G consumption within the Scottish economy, and how we arrived at the current pattern of consumption, including cost drivers and the impacts on individuals, firms and wider society.

*Forward-looking factors – policy approaches based on this evidence base*

- How alternatives to this consumption currently stand within the different markets, looking at:
  - Their readiness and availability, as current O&G consumption is driven by the ability to carry out economic and social activity, without emitting GHG.
  - Their relative cost where they are available, and how decisions to emit or to chose a low carbon alternative are made in this context.
- The policy levers available to SG and those that exist at UK and international level, including:
  - Demand management measures, where it is desirable to try to manage demand (for instance in car travel).
  - Tax measures, changing the economic incentives on different activities.
  - The role of regulation of goods and services.
  - Subsidies and support for the implementation of new technologies.

## Project timeline



# Report Structure



## Report Structure

The report is split into two parts. The first, the **Main Findings**, sets out the overall pattern of demand for O&G in different sectors; the key themes which explain the current pattern of demand; how these themes play out in different sectors and the key drivers of demand in those sectors; and the types of policy interventions that can address each theme and how the specifics of the policies differ for each sector.

The second part, **Supplementary Analysis**, is organised by sector and sets out the detail of demand patterns and drivers, including how alternative technologies currently perform in those markets.

## Energy System Catapult scenarios

SG and the ClimateXChange (CXC) commissioned Energy Systems Catapult (ESC) to develop a set of Scotland-specific scenarios and our report incorporates the findings of this analysis to present a future view of pathways to net zero.

These scenarios demonstrate four qualitatively different routes for Scotland to meet its emissions reduction targets, allowing different choices and their potential implications to be explored. The scenarios are not fixed pathways Scotland should follow to meet GHG targets, nor do they provide specific solutions to the net zero transition. They were commissioned to inform thinking, encourage debate, and evaluate options.

These scenarios represent one possible set of outcomes based on modelling undertaken by the ESC team. Other scenarios and trajectories exist that may present an alternative view of future energy pathways.

Where applicable, we have summarised the results of these scenarios to provide the reader with a view of how they may impact future O&G consumption. For more information on the output of this analysis, please see the 2022 CXC report titled "Scottish Whole Energy System Scenarios (DRAFT)".

## Report limitations

This report provides an assessment of the key drivers of demand for fossil fuels, and the barriers to significant demand reduction, to support Scottish policy development and the new Scottish Energy Strategy. We acknowledge the reality that Scotland is a member of the United Kingdom (UK) and that the National Grid and transmission networks for gas and electricity are operated and regulated at a UK level. When considering policy levers we have considered devolution and where policy lies with the UK Government (UKG) rather than SG but, where possible, the report has been written from a Scottish perspective.

At the time of writing this report, O&G prices have been significantly impacted by the war in Ukraine and the full economic consequences of this geopolitical risk cannot be fully predicted. Although we do not expect it to alter the underlying conclusions, any period of prolonged high prices will have an impact on demand. Historical geopolitical events have impacted oil prices but other factors, such as the response from other O&G producing nations, will also need to be considered.

# 2

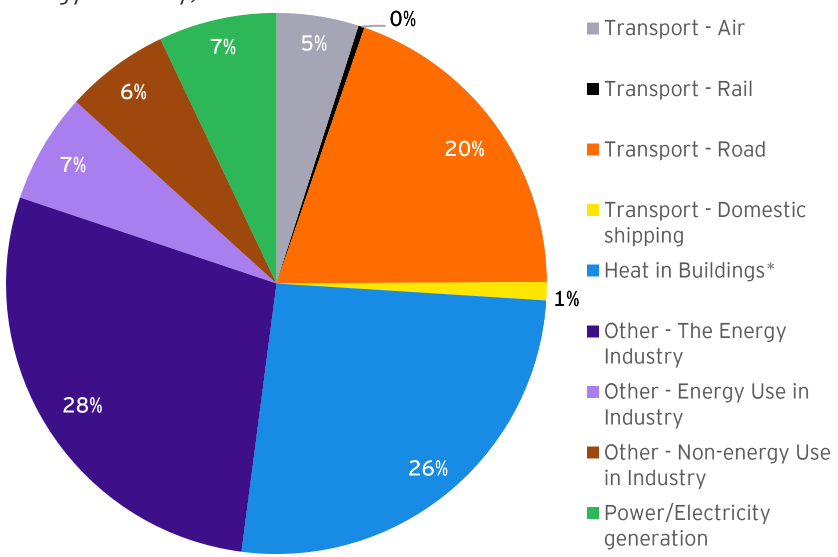
# Main Findings: Executive Summary

# The trends behind current Scottish O&G consumption



## Current Scottish O&G consumption

O&G is the principal energy source supporting economic and social activity in Scotland. As shown in the chart below, in 2019 the largest consumers of O&G in Scotland were the energy industry (28%), the transport sector (26%, of which road transport accounts for 20%), and the heat sector (26%), with the remaining 20% comprising electricity generation and other industrial sectors (not including the energy industry).




*Source: SG - Physical commodity balances of oil, gas and petroleum products Digest of UK Energy Statistics (DUKES) 2021 - GOV.UK (www.gov.uk) (commodity balances)*

Electricity generation is the only consumer sector that has made significant progress towards decarbonisation, with only 14.4% of electricity consumed in Scotland having been generated using O&G.

We have identified five key themes which explain why demand for O&G is embedded in Scotland's economy.

1. **Technology and cost** – alternatives to O&G rely on immature technologies which carry a cost premium and which are often less easy to use than O&G.
2. **Taxation, carbon pricing and levies** – carbon pricing, which will be a critical incentive for decarbonisation, has only recently been introduced in the UK and will only apply to electricity generation, energy-intensive industry and aviation. As such, carbon emissions are not reflected in the cost of O&G for many consumers. Levies on energy bills influence consumption, for example, levies on electricity bills has lead to reduced consumption of O&G in electricity generation.
3. **Infrastructure, assets and business models –** O&G infrastructure and assets' long lives (e.g. the gas gird which has been expanded for over 50 years), combined with business models which secure returns on assets for investors, make it difficult economically and commercially for O&G to be replaced by other energy sources. The rate of replacement of even shorter lived assets (such as boilers or cars) means that it will take time to reduce O&G use substantially, even when replacement technologies have become predominant in the market.
4. **Expectations of outcomes for users –** energy consumers expect low costs, greater performance, convenience and comfort which are enabled by O&G whereas green alternatives can be more expensive. For example, car travel is perceived as more comfortable and convenient than less polluting alternatives such rail, and there is anxiety around moving away from familiar O&G sources to new technologies.
5. **Wider government policy and economic growth –** governments have historically supported the consumption of O&G in pursuing economic growth, for example, supporting the expansion of air travel and road transport. Planning and other policies that have historically assumed the predominance of O&G and the car as the primary form of transport have further embedded O&G demand.

In response to these trends, a significant and fundamental change in mindset is required to further stimulate a rapid move away from fossil fuels throughout society and the economy; and there is an opportunity to redress the economic balance of the impact of new generation/consumption in a more just way across society.

# O&G consumption by sector and current status of alternatives



## O&G consumption by sector

**Transport - s**ome areas of transport are in a good place to see rapid change over the coming years as new technology takes off. For others, such as shipping and aviation, the pathway to reducing O&G use is less clear as the alternative technologies are less obvious.

- **Road –** currently the most significant consumer of all transport sectors (20% of Scottish O&G consumption), the sector having expanded with the growth of ICE vehicle availability with historical government support. The sector is in a good position to see rapid change over coming years with zero emission cars and buses now widely available at prices approaching parity with ICE vehicles. The zero emission HGV market is currently less well developed. Extensive charging infrastructure is required for consumer confidence in zero emissions vehicles.
- **Rail –** accounts for a very small proportion of Scotland's O&G consumption and an insignificant contributor to its emissions. Central to this is that 76% of all passenger journeys in Scotland are on electric lines (which represent 40% of the total Scottish network). Rail's main contribution to decarbonisation is modal shift from car travel – additional capacity will be required to deal with this and continued focus should be on further electrification of the network.
- **Domestic shipping** – accounts for only 1% of Scottish O&G consumption but 4% of Scotland's emissions, as the sector generally uses more polluting fuels. Alternatives such as electric or gas turbine vessels have not been effective or viable and vessels have long asset lives making change more difficult. Any switch to alternative fuels will require extensive infrastructure investment.
- **Aviation –** 5% of Scottish O&G consumption and 1% of emissions, due to improved energy efficiency which has been offset by rising demand. There are few alternatives for air travel and air freight. Sustainable Aviation Fuel (SAF) is the only credible short / medium term option for change, but it has not yet made a significant contribution to emissions reduction.

**Heat –** natural gas is the primary fuel for heating Scotland's buildings (which accounts for 26% of Scotland's O&G consumption), having been historically promoted to replace the more polluting burning of coal. Mature renewable heat technologies exist (such as electric heat pumps and heat networks) and have the potential to decarbonise heat, though this in part relies on progress in expanding electricity generation. There does, however, remain a lack of confidence in these technologies among consumers. Hydrogen is another potential alternative fuel – hydrogen boilers are currently in prototype phase. These alternatives are more expensive; however, as the price of gas increases, they will become more attractive if they become more widely available.

**Electricity generation –** accounts for only 7% of Scottish O&G consumption as significant progress has been made in transitioning to alternative fuels. Low carbon generation accounted for 88% of electricity in 2020 (expected to be 100% by 2035), but intermittency issues will remain. There are challenges ahead as electricity demand is expected to double by 2050, driven by the decarbonisation of other sectors, necessitating a rapid increase in renewable generation, significant investment in the electricity grid and development of support mechanisms for dispatchable low carbon power.

**Energy industry –** the Scottish O&G sector which accounts for 28% of Scottish O&G consumption in its upstream and midstream processes. Reduced O&G consumption will result from the decline in production from the Scottish O&G sector. Platform electrification could substantially decarbonise the sector, provided the electricity is generated from renewable sources.

**Other industry (energy / non-energy use) –** energy use consists of heating and electricity generation for industrial processes; non-energy use comprises production of petrochemicals. Together these account for 13% of Scotland's O&G consumption. Hydrogen and electric technologies are emerging for industrial heat but are more expensive than O&G. Renewables are more cost comparative for electricity generation so this is easier to decarbonise than heat. Scotland consumes significantly more imported petrochemical products than it produces. Plastics from renewable resources are now being developed and their market penetration is growing in certain areas, whereas in others they are still in early stages of development. Although the cost of these alternatives is higher, consumers generally seem willing to bear it.

Changing the current patterns of consumption will require a combination of policies to address the different issues. As well as all government policy having net zero as a key part of decision-making, specific policies will be required to help accelerate take-up of new technologies as they become viable and to manage the impact on those not able to afford them. These are covered in section 6 of this report.

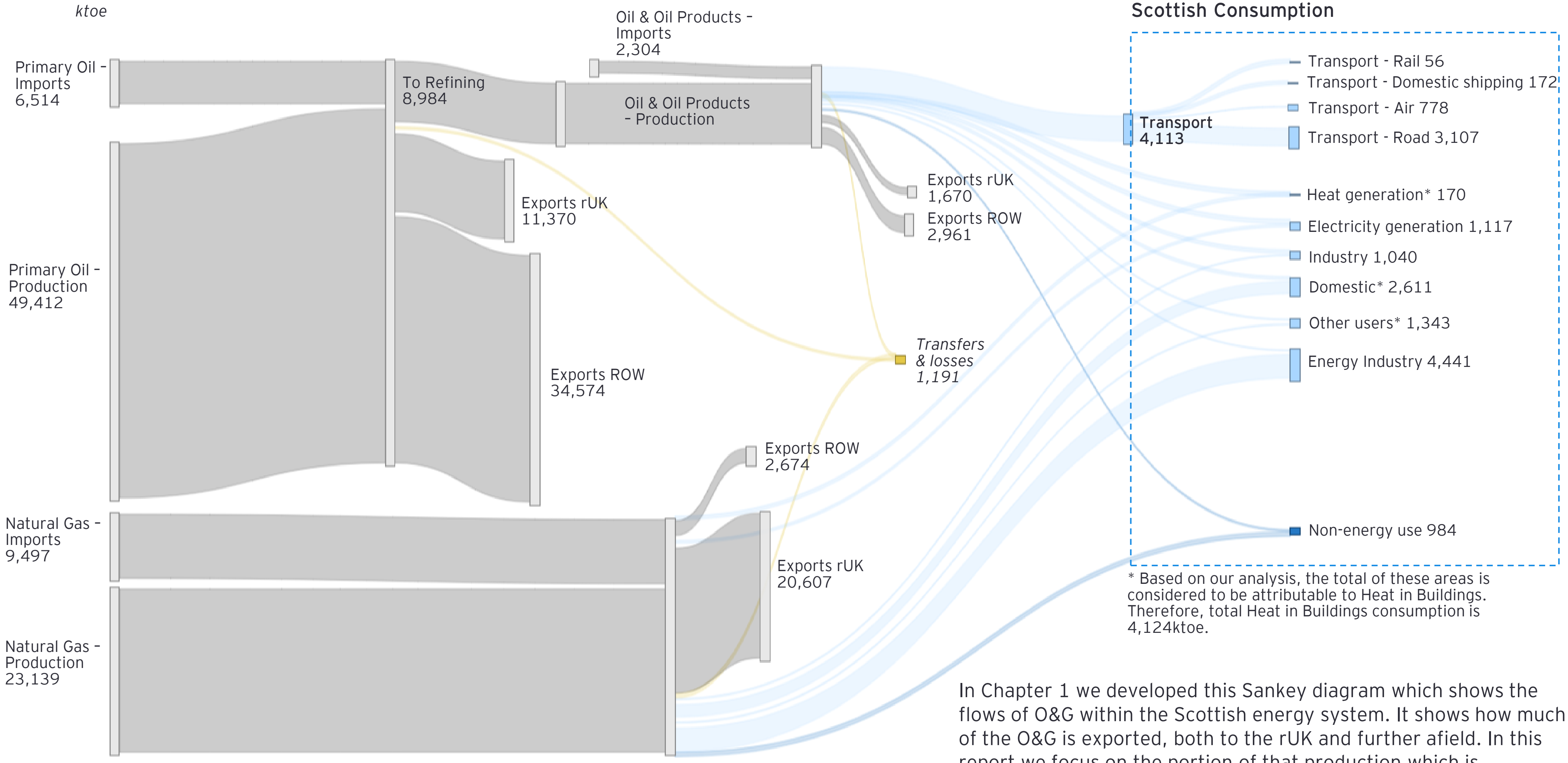
# 3 Main Findings: Current O&G Consumption

# The Scottish Energy System – Sankey Consumption Diagram

This report focusses on the areas within the below consumption box



## O&G energy system




* Based on our analysis, the total of these areas is considered to be attributable to Heat in Buildings. Therefore, total Heat in Buildings consumption is 4,124ktoe.

In Chapter 1 we developed this Sankey diagram which shows the flows of O&G within the Scottish energy system. It shows how much of the O&G is exported, both to the rUK and further afield. In this report we focus on the portion of that production which is consumed in Scotland, split between its different uses.

*Source: SG - Physical commodity balances of oil, gas and petroleum products*
*Digest of UK Energy Statistics (DUKES) 2021 - GOV.UK (www.gov.uk) (commodity balances)*

# Scotland is highly dependent on O&G to support its transport and heat sectors, but O&G demand for electricity generation is small



## Introduction

O&G has been fundamental to meeting Scottish energy demand and, in turn, driving economic growth. The significant effort needed to reform and embark on the Just Transition presents an opportunity to grow the economy around new approaches which avoid fossil fuel demand; however, it also brings the need for rapid and significant government support to enable this shift away from fossil fuels.

This report provides an analysis of the drivers of consumption of O&G, and how things have evolved to the current situation where O&G is the dominant energy source supporting economic and social activity in Scotland.

It sets out key drivers for each sector of the economy, as there are different factors that have driven demand or created barriers for alternatives in each sector.

Lastly, it summarises the policy levers available to accelerate the change from O&G to low or zero carbon energy sources.

## The key areas of Scottish O&G consumption

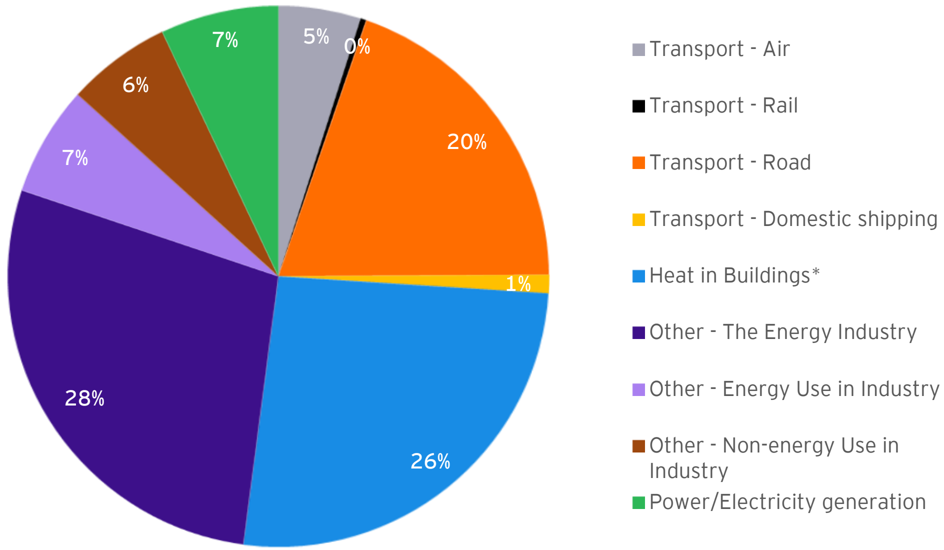
This report looks at three critical areas: electricity generation, heat, and transport. We have undertaken separate analysis of the industrial sector, but consumption in this is a combination of heat and electricity generation demand. These sectors comprise the majority of Scotland's energy needs.

The chart alongside shows the main areas of consumption in Scotland. The largest consumers of O&G are the transport sectors (specifically road), the heat sector and energy industry sector.

Our previous analysis (Chapter 1), which explored the supply of O&G in Scotland and the energy flows in Scotland, demonstrated that Scotland is a net exporter of O&G. From these energy flows, it also highlighted the scale of O&G consumption in Scotland.

In order to fit with the appropriate drivers of consumption, we have combined the Sankey diagram categories of heat generation, domestic use of O&G, and other users to be considered to be attributable to Heat in Buildings.

### Scottish Consumption of O&G, 2019




*Source: SG - Physical commodity balances of oil, gas and petroleum products Digest of UK Energy Statistics (DUKES) 2021 - GOV.UK (www.gov.uk) (commodity balances)*

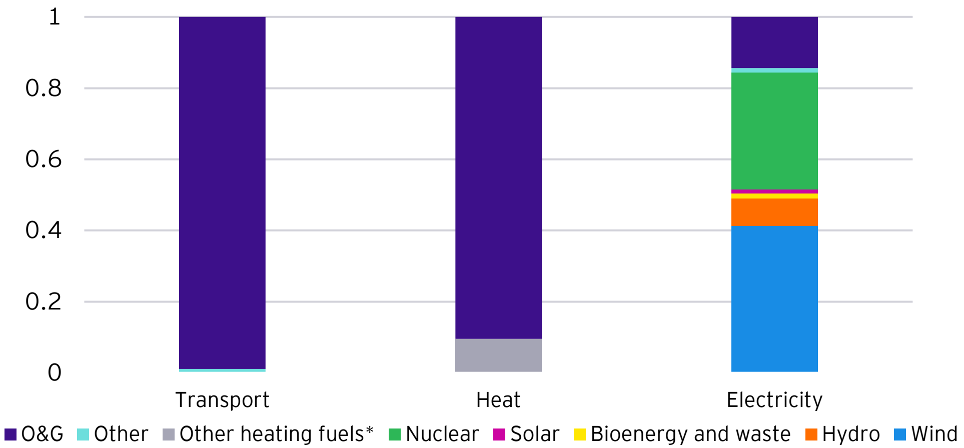
# We have identified five factors that embed O&G demand in Scotland's economy



## Energy System current state of play

Our analysis demonstrates that electricity generation is the only area to have made significant progress towards decarbonisation, with alternative sources of energy to O&G. For heat and transport, Scotland (in common with the rUK) is largely dependent on O&G for energy.

The Scottish Energy System – Three key sectors




* Other heating fuel sources include electricity, solid mineral fuels and biomass

*Source: Annual energy statement 2019 - gov.scot (www.gov.scot) Scottish Energy Statistics Hub – Proportion of electricity consumption by fuel Scottish Energy Statistics Hub – Number of ultra low emission vehicles licenced*

### *Electricity generation*

Electricity is the only area where significant change has already occurred, with substantial decarbonisation driven by new technology and government action to support and embed it. Electricity accounts for just over a fifth of Scotland's total energy consumption. In 2021, 14.4% of electricity consumed in Scotland came from O&G, 51.6% from renewables (with the majority coming from onshore wind) and 32.8% from nuclear. Scotland generates more electricity (52 TWh) than it consumes (28 TWh), with any surplus exported.

### *Transport*

Transport accounts for roughly a quarter of Scotland's total energy consumption. Given its historic dependency on O&G for fuel, the transport sector is one of the key areas of focus in the transition to a net zero Scotland and decarbonisation opportunities exist (especially for certain modes of transport, such as electric vehicles). For example, although ultra-low emissions vehicles (ULEVs) only make up 1.27% of all road vehicles licensed in Scotland, recent significant technological advancements has led to an uptake in ownership as shown by 75% growth in ULEVs between Q3 2020 and Q3 2021. However, the current dependence on O&G for fuel is prevalent across the majority of the transport sector.

### *Heat in buildings*

Heating homes and businesses accounts for roughly 26% of Scotland's total energy consumption. Approximately 90% of homes rely on natural gas for heating, with the remaining 10% relying on alternative fuel sources, e.g., electrical heating systems and oil. Conversely, the majority of Scotland's non-domestic buildings rely on electrical heating sources as opposed to natural gas; however, the factors driving this demand are unclear.

### *Energy industry*

O&G usage in the energy industry has declined in line with production levels, but to date there has been relatively little technological change in O&G usage associated with supplying power. The issues have been set out in detail in Chapter 1 and will not be repeated here.

## Demand drivers for O&G

The following pages set out five key themes we have identified that embed demand for O&G in Scotland's economy. These are:

- Technology and cost
- Taxation, carbon pricing and levies
- Infrastructure, assets and business models
- Expectations of outcomes for users
- Wider government policy and economic growth.

We then set out the critical factors for fossil fuel consumption in each sector, potential decarbonisation solutions and the development of an appropriate policy approach. This is with a view to help unwind O&G use and support societal change to new ways of achieving a Just Transition.

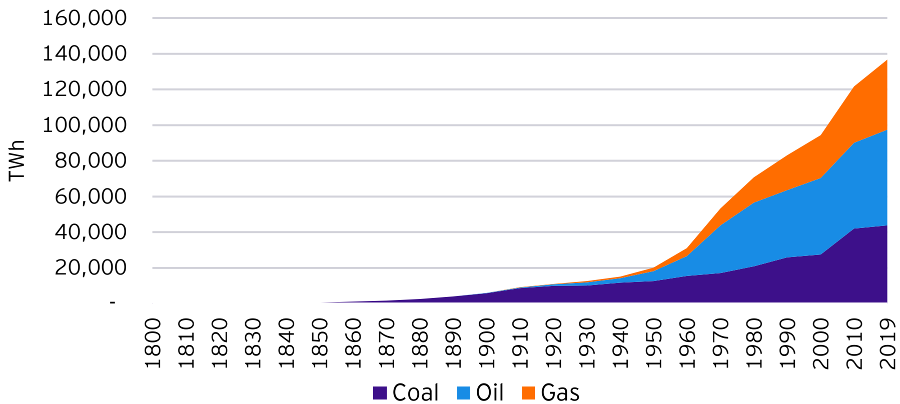
# 4 Main Findings: Key Drivers of Consumption

# Key theme 1: Technology and cost

### Initial ease of use and transformative power of fossil fuels

- The root cause of our current pattern of demand is the relative ease of use of O&G to supply the energy necessary for economic activity. Our ability to use fossil fuel sources of energy has been transformative.
- Global consumption of fossil fuels has accelerated in the second half of the twentieth century. In the period since 1980 alone, consumption has roughly doubled. Scottish demand for fossil fuels is still significant and it plays an important role in Scotland's energy mix.

**Global fossil fuel consumption**




*Source: https://ourworldindata.org/fossil-fuels*

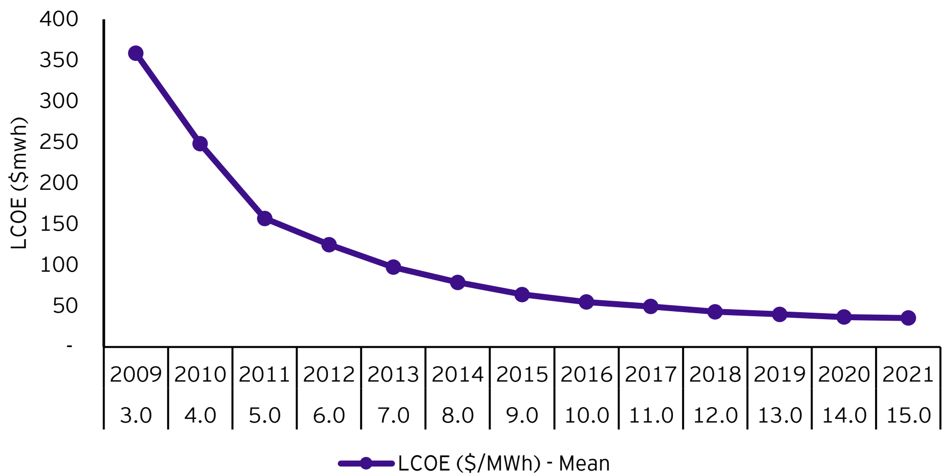
### New technologies to replace O&G are relatively recent

- In relative terms, alternatives to O&G are in their infancy. The internal combustion engine (ICE) has been a viable technology for 125 years and, whilst Battery Electric Vehicles (BEVs) technology is almost as old, BEVs have only offered similar utility and performance in the last 5-6 years. Additionally, heat pumps are recognised as an effective tool to support heat decarbonisation in our buildings, but current rollout rates are low.
- The historical adoption of fossil fuels, across many of the sectors of the economy, is an established trend caused by the lack of alternative technologies that were either as easy or as cheap to implement as the O&G solution.

### Costs to consumers

- The early stage of development of alternative technologies and lack of adoption means that, in a number of areas for consumers, costs are still high and therefore take-up is low. This can be a particular issue for certain technologies such as BEVs where, although savings can be subsequently made on operating costs, the high upfront cost is off-putting.
- Costs reduce from sustained research, investment, and use, so there are grounds for optimism where currently costs are high and therefore discouraging take-up. In electricity generation, where subsidies have been in place for more than 15 years, costs have reduced markedly. This success could be reproduced in heat and transport as technology develops,

**Unsubsidised SOLAR PV levelised cost of energy (LCOE)**




*Source: Lazard (*Lazard.com | Levelized Cost Of Energy, Levelized Cost Of Storage, and Levelized Cost Of Hydrogen

# Key theme 2: Taxation, carbon pricing and levies



## Taxation and government influence on costs of different options

### Cost and externalities

- One reason that using fossil fuels, and specifically O&G, remains competitive, especially where alternatives are increasingly available, is that the externalities of carbon use are not necessarily priced in. This means that the wider costs of emitting carbon in terms of global warming (and, for many applications, local pollution) are not reflected in the cost of using that fuel.
- Any assessment of such costs is subject to debate, and this feeds into questions around interventions such as fuel duty where government adds costs into the consumption of some fuels for certain purposes.

### Carbon taxes

- The UK taxes O&G products in different ways: at extraction (taxing energy companies as set out in Chapter 1), and through consumption via taxes that bear on consumers, such as fuel duty. There are historic reasons for this system of taxation and exceptions granted, such as red diesel.

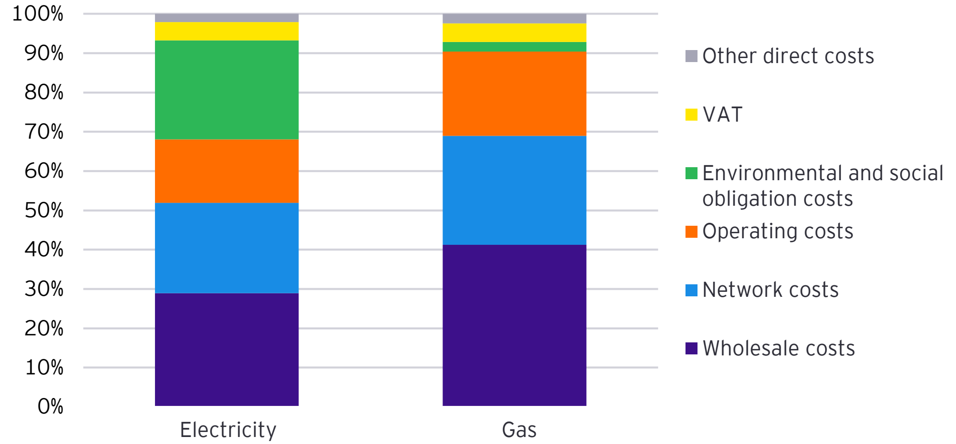
### Carbon trading and pricing

- The UK currently operates a carbon cap-and-trade scheme that aims to create a market with a carbon price signal to incentivise decarbonisation. This is an attempt to have a price for carbon which is anticipated to increase over time, pricing in the externalities associated with emissions.
- This is anticipated to be a major driver of decarbonisation as firms adapt to the increasing cost of consuming O&G without capturing the carbon.
- However, there are currently only a number of 'regulated' sectors where carbon pricing applies: energy intensive industries, the electricity generation sector and aviation. For a number of energy intensive industries (such as steel, sugar, certain types of manufacturing), firms receive free allowances if production is likely to move to jurisdictions where there is a lower carbon price. This means that the effects of the carbon price are not felt in a number of critical areas of consumption of O&G.

### Levies and the electricity generation sector

- Governments and regulators need to make choices about how the costs of the energy transition are going to be met. Historically, electricity has been more expensive than gas, partly due to the greater proportion of environmental and social obligation costs placed on electricity (23%) compared to gas (2%), as shown by the graph below. These are environmental taxes that are designed to pay for certain Government energy policies. Therefore, although electricity is a more environmentally friendly option for consumers (since electricity is already relatively decarbonised) it may be also be the most expensive.
- This means in Scotland users of low carbon fuels (e.g. electricity) are paying additional levies while those using more carbon intensive sources of energy (e.g. gas) are not.

**Breakdown of an electricity & gas bill**




*Source: Ofgem – August 2021 breakdown of an electricity and gas bill (All available charts | Ofgem)*

- While the costs of renewables have reduced, the need to increase electricity production and deal with the effects of intermittency mean that the costs of transition will need to be borne in other areas. Just Transition considerations mean that it is important to consider where, and how, these costs should be distributed in the economy.
- The shape of taxes, carbon pricing and levies helps to determine what fuels are consumed and the rate of change away from consuming O&G.

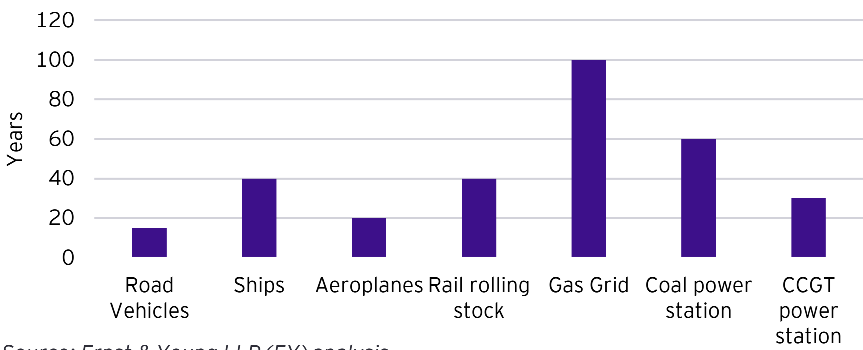
# Key theme 3: Infrastructure, assets and business models



## The effect of existing infrastructure and assets

- Fossil fuel consumption is embedded by the historic development of different types of **infrastructure and assets,** which have long lifetimes and have a significant influence over patterns of demand. There is a variance in length of asset life, but even vehicles might have long asset lives in the context of a climate emergency. For example, a diesel bus would be expected to last for 15 years in normal operation, thereby embedding O&G use.
- Other assets have longer lives. A clear example is the gas grid which has incrementally been expanded for over 50 years, and supports consumption in our homes and buildings, as well as historic economic development. Therefore the transition will require investment in very different asset classes to those historically favoured by the private and public sector.

**Illustrative asset lives**




*Source: Ernst & Young LLP (EY) analysis*

- This means that even at a relatively high market share, low carbon technologies can take an extended period of time to change patterns of consumption substantially. Scotland still uses infrastructure assets that are over 100 years old, for example some elements of Scotland's gas grid or transport network, and while there are new technologies that are lower or zero carbon, the ability to replace what is there is limited by the economic life of assets.  This embeds patterns of consumption and slows change.

## Investment returns and business models

- Assets are also embedded in the economy through certain types of business models which are sometimes difficult to change. The existence of assets usually means a stakeholder or entity is getting a return on the assets and therefore has an interest in their continued use.
- In the electricity generation and water industries, regulated utility networks have been successfully maintained through economic regulation of private firms. This applies to the electricity generation network and the gas grid in Scotland. A regulated asset value mechanism gives investors a regulated return on a notional value of the assets. This is depreciated over time at a slow rate, while being increased to account for inflation and new capital expenditure. Returns generated mean that there is no immediate end date and the system is effectively set up to be perpetual.
- Often lower carbon technology has a high capital cost but there may be savings in the operation of assets – this is true for wind energy, battery vehicles etc. This does not necessarily fit well with business models where consumers purchase assets and take depreciation risk.
- A good example is BEVs, where the upfront cost and risks in ownership mean that the model is changing. More vehicles are being leased rather than sold, both for private vehicles and for fleets. The emergence of new business models and their acceptance (for consumers and for businesses having to adapt) takes time and can slow down the rollout of rival technologies to O&G.
- However, once new business models are developed they can more rapidly promote change and reduce O&G consumption.

## New infrastructure investment required

- The energy transition will require new investment across a number of areas. Business models may require change to enable this investment, while ensuring fairness in terms of who pays. For example, the cost of solving the Scottish grid constrains (that prevent dispatch of renewable electricity) will fall on electricity customers using renewable power.

# Key theme 4: Expectations of outcomes for users



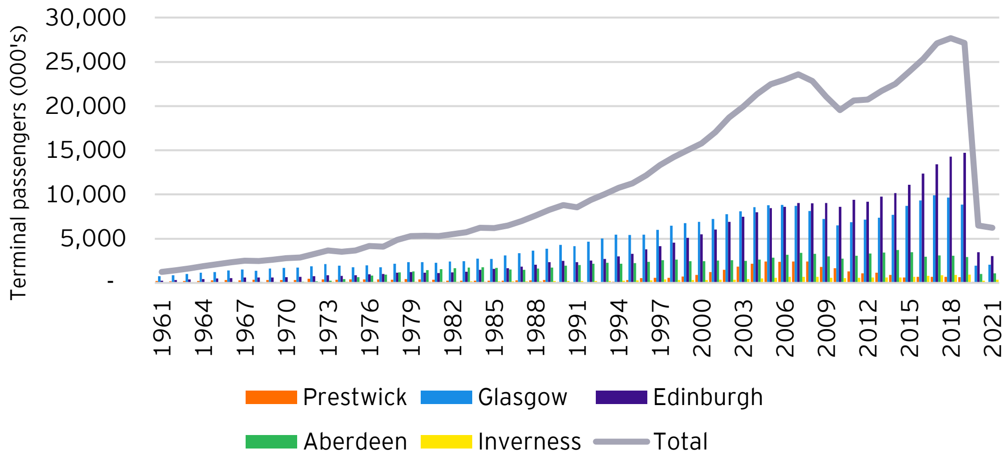
### Consumer expectations can be critical in driving change

- The development of patterns of consumption has embedded an **expectation of relatively low energy prices among consumers**, in areas such as heating of homes and certain areas within the travel sector. Although many consumers have recently signalled a willingness to change consumption patterns on environmental grounds, these high expectations still reinforce demand in different sectors – and so the transition will likely require a continuing shift in public attitude as well as provision of high quality alternatives to fossil fuels.
- For example, according to the Build Research Establishment's widely quoted model, the average room temperature in the UK today is around 18°C, compared to 12°C in 1970. Whilst an element of this increase can be explained by improved insulation measures in older homes such as double glazing, consumers' expectations of thermal comfort have also been raised by central heating at home and at work.
- The ESC models future energy scenarios (FES) which highlight different rates of increase in the average temperature of homes. The social change driven scenario (SOC) assumes 19.5°C while business-as-usual assumes 20°C; this drives different outcomes in terms of O&G consumption and therefore emissions.

### Expectations of cost and convenience can embed use of O&G

- The existence of cheap and convenient energy uses and their development over time can change the ways in which people act and consume, and develop expectations.
- A appropriate example is the cost and availability of air travel: competition and efficiencies in the sector drove down the comparative price from the 1970s onwards, meaning that consumers became used to cheap air travel to a wide variety of destinations. Customer expectations mean that it is more difficult to introduce changes that would reduce the utility available to consumers.
- Passenger numbers are beginning to rebound from the COVID-19 pandemic, with future demand expected to continue increasing.

**Terminal Passengers from the main Scottish airports 1961-2021**




*Source: Civil Aviation Authority Terminal passengers 1961 – 2021*

- O&G use has not remained static, but has been subject to efficiencies and changes that have led to new consumer expectations. At the same time consumers do not always value low carbon alternatives – such as a zero emission versus a diesel bus, because other factors (punctuality and journey time) are so much more important to them.
- It is clear that there is a lot of discussion and publicity in green alternatives for consumers, but this takes place against a backdrop of expectations created by the ease of use of O&G.

# Key theme 5: Wider government policy and economic growth



### Governments and regulators have supported O&G consumption

- Over time, O&G has become embedded across a broad spectrum of sectors in Scotland, making a significant economic contribution, albeit this has been unevenly distributed in many cases. It has been supported and encouraged by **governments and regulators**. Even where we have aimed for reform (for example, historical reform that promoted cleaner fuels such as gas rather than coal) this has supported new technologies that continue to consume O&G.
- **Economic growth** has been a consistent objective for governments, and that objective has caused them to pursue policies that have led to an increase or a continuation of O&G consumption over an extended period of time. For instance:
  - Governments have supported the expansion of air travel as an economic benefit, improving trade and connectivity. This has meant supporting airport expansion.
  - Road transport has been seen as an economic benefit in terms of moving people (and expanding labour markets) and goods (both consumer goods and goods moved between businesses). While support for road transport has fluctuated, using ICE technology has been a feature of public policy as a facilitator of an efficient economy for a large part of the 20th century and the early 21st century.

### Effects of policies aiming to modernise and reduce pollution

- Policies to reduce pollution, or even to reduce emissions, have not always created the conditions for energy transition to new technologies.
- Governments have pushed consumption toward cleaner fuels over a long period, but that has reinforced O&G consumption, particularly of gas. In heating and in the electricity generation sector, a replacement of coal with gas brought huge benefits in terms of emissions reductions, convenience and ease of use.
- Domestically the availability of natural gas was enhanced by government sponsorship of the distribution network and also the products (heating systems and cooking equipment) that used gas as fuel. In the 21st century, regulation was used to improve the efficiency of gas boilers.
- Coal remained a key part of delivering electricity for far longer and only suffered a radical reduction in its share of electricity generation production as a result of the obligations of the European Union (EU) Emissions Trading System (ETS) scheme and its UK successor.

### Planning and placemaking

- Particularly for transport, the requirements and needs of different transport types are shaped by where and how people live.
- For an extended period of time, planning was directly influenced by mobility assumptions enabled by cars, and this influenced housing policy and planning as well as road building. The longevity of the decisions made in these areas creates inertia in terms of changing lifestyles and particularly affecting the effectiveness of demand management policies.
- This is now changing, with more thought being given to integrated transport solutions in planning new development, but it is not always straightforward to ensure strong public transport links for new developments.

### Key conclusion

Scotland's current consumption of O&G is driven by the availability of technology and what costs are included in the different options available; how taxation, carbon trading and levies are structured; by the longevity of infrastructure and assets designed around particular patterns of demand for O&G; by how users and customers have developed patterns of behaviour and expectations around using these resources; and how governments have supported and embedded O&G consumption in policy.

Therefore, a significant and fundamental change in mindset is required to further stimulate a rapid move away from fossil fuels throughout society and the economy; and there is an opportunity to redress the economic balance of the impact of new generation/consumption in a more just way across society.

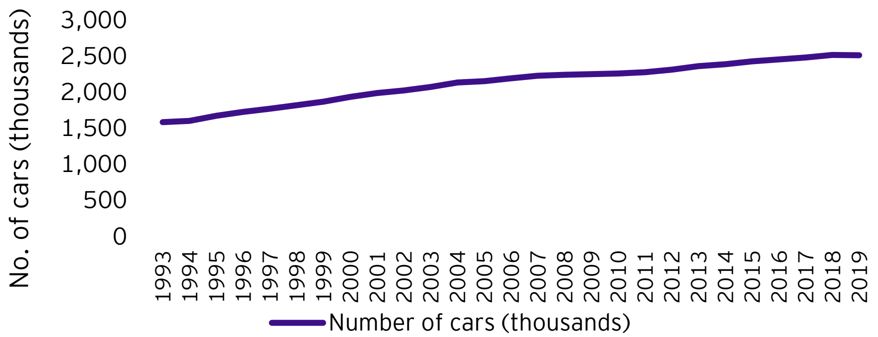
# 5 Main Findings: Sector Insight

# **Road transport:** The growth of ICEs resulted in an efficient road transport system and government & regulatory responses supported O&G demand

The following pages set out how these themes contribute to the principal drivers of demand in different sectors of the economy. Not all themes will be relevant for all sectors, and they vary considerably at different times and in different sectors.

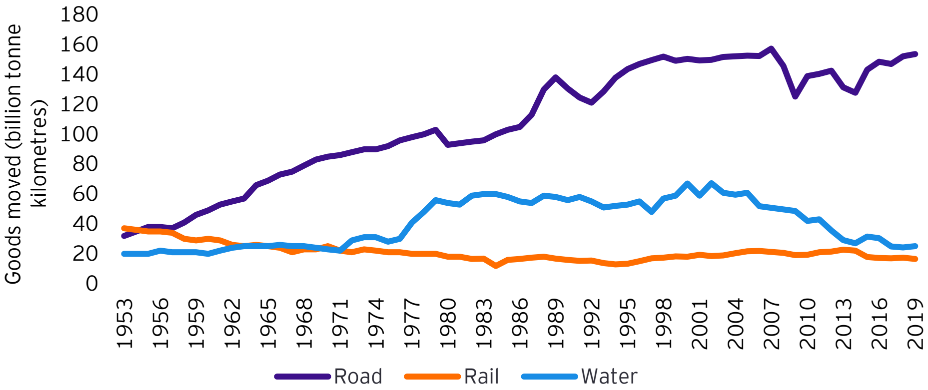
**Road transport accounts for almost 20% of Scotland's total O&G consumption and 20% of its emissions.**

### Number of cars – Scotland




*Source: Government statistics veh02-licensed cars*

### Historical UK freight transport

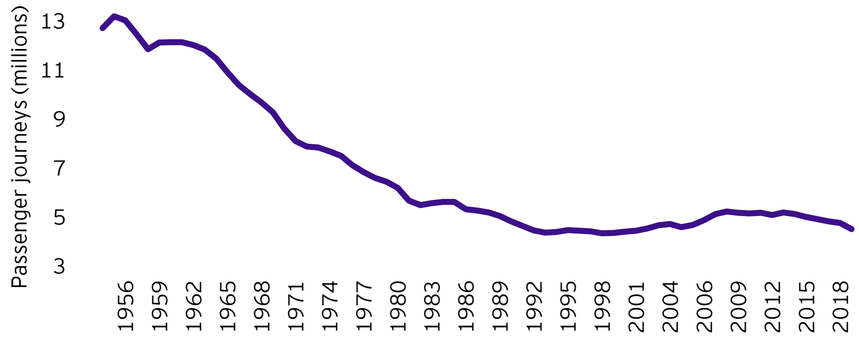



*Source: DfT statistics TSGB0401*

**Drivers of demand for fossil fuel consumption:**

- **Technology:** road transport expanded with increased availability of the ICE for personal and freight transport, and this led to the widescale availability of refining and fuelling infrastructure.
- The majority of freight (>90% at UK level) is carried by ICE Heavy Goods Vehicles (HGVs) on road, as road freight offers both cost and logistical advantages to alternate freight transport for many types of cargo.
- **Government support for the road network:** public policy for an extended part of the 20th century favoured the expansion of the road network to promote economic growth and demand for transport among individuals.
- **Trends in transport use** have historically favoured private cars and enabled independent, flexible travel for individuals and families. Whilst rail travel has been sustained in Scotland through increased use of rail for commuting, bus journeys have declined.

**UK local bus service passenger journeys**




*Source Gov.uk BUS0101*

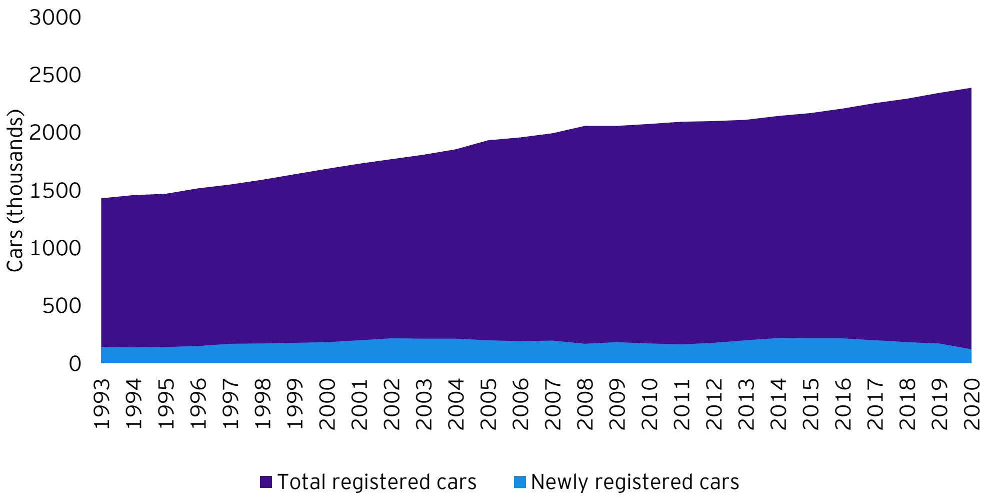
- Recently, van use has increased. A contributing factor is the rise of internet shopping, and the subsequent increased requirement for deliveries to be made. The bulk of the van fleet is diesel (having been split between diesel and petrol 20 years ago), and use of diesel for vans has increased markedly. We are now seeing the potential for fleets to transition to electric power, but this has not yet made a sufficient impact to clearly reduce diesel consumption from vans.

# **Road transport (cont.):** The growth of ICEs resulted in an efficient road transport system and government & regulatory responses supported O&G demand



- **Planning policy** also assumed households could have access to a car and built this assumption into how towns and cities were designed. For much of the 20th century, public policy supported the availability of fuel by embedding road transport into the economy and supported refining capacity.
- **Available alternatives:** Until recently, alternatives have either been unavailable or not cost effective, however, this is changing rapidly. BEV dominates the smaller vehicle market, while a combination of electric and hydrogen seems likely for larger vehicles.
  - Regulation in some jurisdictions (especially the EU) has resulted in the car industry scaling up production of zero emission technology, particularly BEVs. Many manufacturers now offer a full range of vehicles rather than one or two special models and have committed to ceasing production of ICE vehicles.
  - Many manufacturers are focussed on moving towards zero emissions models, with most manufacturers of light commercial vehicles (LCV) (such as Ford, Renault and Mercedes) offering BEV versions of their vans, though they are yet to achieve the market penetration of cars.
  - Fuel cell electric vehicles (FCEVs) have not yet penetrated the car market but may play a role in the market in the future. They offer some advantages as they do not require as large a battery.
  - The zero emission bus market is also well developed in Europe, with over 5,000 zero-emission buses.
- For HGVs, original equipment manufacturers (OEMs) are at different stages of development, with several conducting trials of new technology and a small number of models being on sale. Range and speed of charging are the key barriers being worked on here.
- **Cost of alternatives:** at current prices, the initial consumer purchase price of a BEV remains significantly higher than the equivalent ICE vehicle. The second hand market is currently very limited, but will naturally grow over time. Fuel (and maintenance) costs are currently lower for BEVs; however, annual mileage of greater than c8,000 miles is required to achieve a lower total cost of ownership (TCO).
- For buses, FCEVs have similar purchase prices to BEVs (£350k versus £357k), but both are more expensive than current diesel buses (£180k). Lower running costs mean that whole life costs are approaching parity.
- **Consumer perceptions:** The demand for electric vehicles for private transport is somewhat hampered by 'range anxiety': per SMMT, the average BEV car can travel 260 miles on a full charge. In contrast, the average sized ICE car with a 45 litre fuel tank would travel between 356 and 425 miles. The extent and reliability of the public charging network is perceived by consumers as uncertain.
- **Infrastructure & assets:** Consumer confidence requires an extensive charging infrastructure. The Climate Change Committee (CCC) has estimated that c280,000 publicly available charge points will be required across the UK by 2030, which implies a Scottish requirement of c30,000. This is clearly understood as a priority by governments and local authorities, who are increasingly funding and incentivising on-road charging.
- Change will take time even when ICE vehicles become a minority of those sold, because replacement rates are relatively low. This means that legacy assets will remain in use for a considerable period of time.

**Newly registered cars v total cars - Scotland**




*Source: Scottish transport statistics 2021*

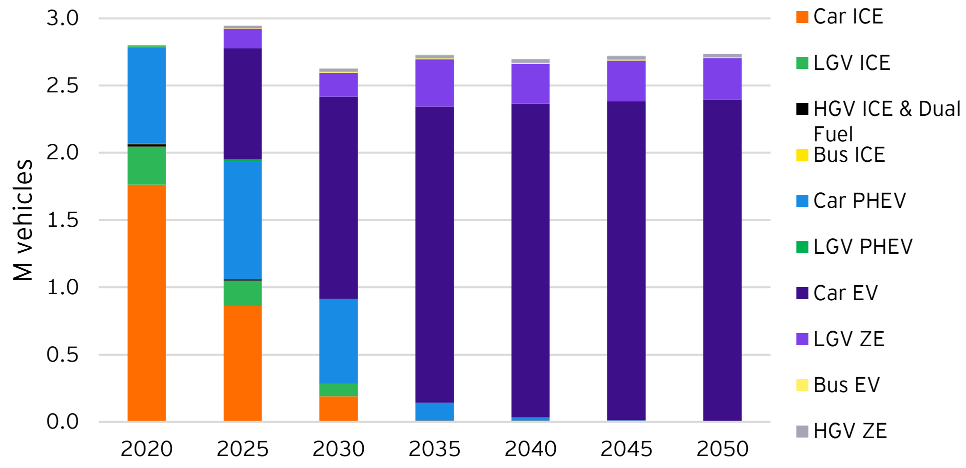
# **Road transport (cont.):** The decarbonisation of the road sector will focus on the rollout of BEVs, but demand management and reduction are also required



**Future trends and policy levers**

- Much of road transport is relatively close to being decarbonised as there are an increasing number of alternatives to ICE in the market, and they are becoming more competitive as the technology develops. There are decarbonisation challenges in areas such as charging infrastructure and grid capacity but these are in the process of being solved and decarbonisation is expected to advance year on year for road transport, albeit from a low base.
- Demand management: SG has set a target of reducing demand for car travel by 20%, but this will need to be complemented by other measures to change the shape of transport demand:
  - Place making and planning – reshaping travel requirements and reducing the need for car travel, as promoted by SG's policy to promote 20 minute neighbourhoods.
  - Ensuring the availability of public transport alternatives – including innovative schemes for individual transport such as e-bikes.
  - Low Emission Zones (LEZs) disincentivise the use of more polluting vehicles through charging and tariffs. LEZs were introduced to Scotland in 2022, in Aberdeen, Dundee, Edinburgh and Glasgow.
- For cars and vans, the shift to zero carbon technology is underway and accelerating; there are a number of policy levers available to accelerate this:
  - Taxation is currently used through fuel duty (reserved), taxation of company cars (reserved) and differential rates of vehicle tax (reserved).
  - Public procurement: public authorities (such as local authorities, blue light services, publicly owned bus services) are owners of large fleets.
  - Accelerating the rollout of the charging network will be critical in giving confidence for purchasing electric vehicles. This involves the planning system as well as JVs and other partnerships with local authorities.
- The development of technology for HGVs means a wider set of technologies that are potentially going to be significant within the market. For technologies that are not yet market ready, policy options are likely to focus more on developing and testing new technologies. Some OEMs are committed to producing BEVs and FCEV HGVs, with several conducting trials of new technology.
- The SG's ESC modelling contains a Balanced Option (BOP) scenario. This scenario assumes that road transport energy demand in 2020 was 32.2 TWh and forecasts a fall in overall demand to 14.8 TWh by 2030 and 8.1 TWh by 2050. As shown by the graph below, it is envisaged that under the BOP scenario a range of technologies will be used for road transport, and there will be a rapid reduction in the use of ICE.

**Road Transport Fleet – BOP scenario**




*Source: Energy Systems Catapult, BOP Core Charts*

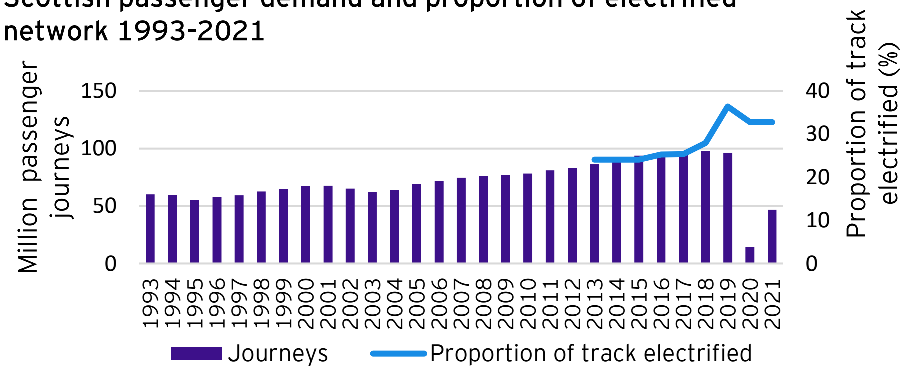
- Given the potential of assets to last a long period of time and the fact that the ban on ICE sales will not come in until 2030, achieving a net zero compliant road transport mix in the 2030s will not be straightforward. We can expect the number of BEVs to rise over the next eight years, and for zero-emission vehicles to become dominant before 2030, but that would still mean that ICE fuelled vehicles would be common on the roads for a period after that time.

# **Rail:** Diesel technology is embedded on routes beyond electrified lines, and alternatives are in their infancy



**The Scottish rail sector consumes a very small proportion of Scotland's O&G and is an insignificant contributor to total emissions.**

**Scottish passenger demand and proportion of electrified network 1993-2021**




*Source: Transport Scotland Scottish Transport statistics & Table 6320 - Infrastructure on the mainline (2022)*

### Drivers of demand for fossil fuel consumption

- **Level of electrification:** diesel provides a flexible and efficient fuel for trains outside electrified areas, which historically resulted in large parts of the UK rail system remaining unelectrified. Electrification typically costs between c£0.75m and £2m per km, which can make the economic case for investment challenging, especially on lightly used lines. Rail rolling stock has a long asset life and the required capital investment has to be factored into electrification costs.
- However, the SG's programme of electrification has led to c.40%* of Scotland's rail network now being electrified and, as these lines tend to be those with the highest passenger numbers, this translates into 76% of all passenger journeys being on electric trains.
- **Low cost of diesel:** diesel trains offered the advantage of no infrastructure spend which outweighed high operating expenditure and running costs. Increases in diesel/oil prices may undermine this cost advantage.
- **Technology readiness:** hydrogen and electric battery are the best alternatives for 'off wire' routes. Technology (range and speed) and infrastructure (refuelling and storage) are currently immature but potentially offer faster decarbonisation than electrification.
- **Infrastructure and regulation:** rolling stock has a long asset life and, while it can be 'cascaded' to different parts of the network, this creates a cost barrier to further change.
- Government investment in rail increased over the past 15 years, after an extended period when it was not prioritised by UKG. However, a lack of long-term planning around the strategic purpose and operational continuity of the railway led to short-term thinking. Correspondingly, investments only reflected the current state of the network and net zero has not been a significant factor in decision making.

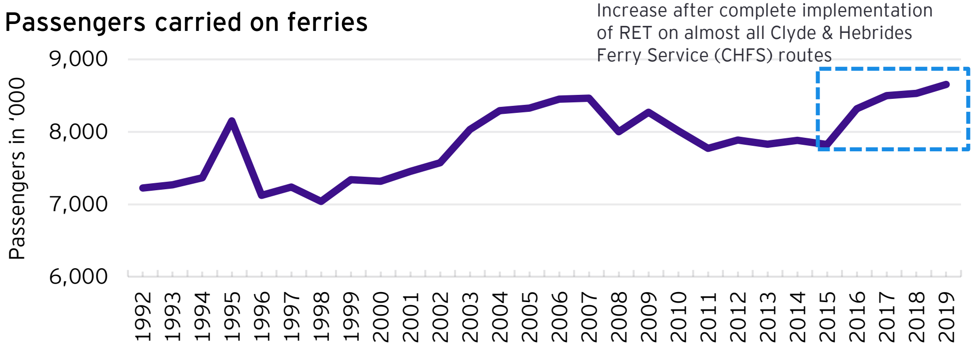
### Future trends and policy levers

- Electrification will continue and alternatives will be developed for those parts of the network where electrification is less cost effective, but progress is unlikely to be rapid.
- The main contribution to decarbonisation of rail will be modal shift from car travel rather than through changes in its energy mix. Rail travel has expanded markedly since the 1980s and this has been encouraged as an alternative to car use. Encouragement to use rail services will continue to form part of the policy mix.
- Since 2010, Scotland has delivered over 500 single track kilometres of electrification through significant schemes in the central belt and a rolling programme of electrification. Continued focus on electrification would appear to be a credible near-term option for reduced O&G consumption allied with adding capacity to deal with a prospective shift from road transport and, on some limited routes, aviation.
- SG is responsible for planning and delivering rail policy, strategy and development of Scotland's Railway, giving SG the opportunity to encourage a wider modal shift to rail. The operator ScotRail has been brought into government ownership.
- However, the SG does not have the final say on rail investment decisions, such as those relating to cross-border services, which are to be taken by Great British Railways, the UKG-owned body which will oversee rail transport in the UK from 2023.

* TS and ORR use different metrics. TS 40% has been used as per Decarbonisation Action Plan.

# **Domestic Shipping:** Demand for freight is reduced, but ferries represent a vital service with few ready alternatives to use of diesel fuel

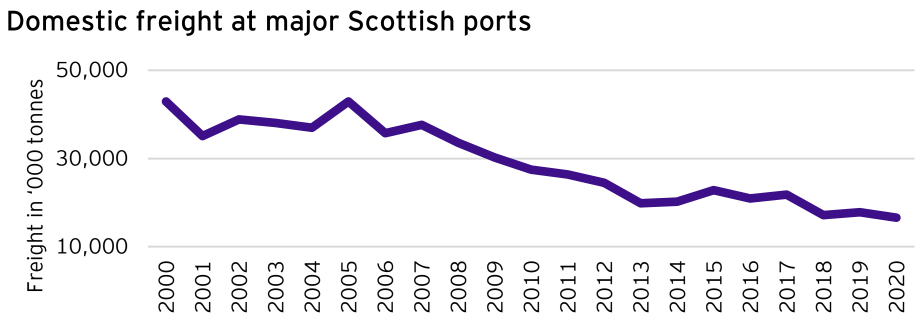
**The shipping sector represents 1% of Scotland's demand for hydrocarbons (172 ktoe in 2019) but 4% of its emissions.**




*Source: Transport Scotland - Scottish Transport Statistics No. 39, 2020*

### Drivers of demand for fossil fuel consumption

- **Technology**: marine propulsion has historically been dominated by the use of heavy fuel oil. The large marine engines use the cheaper, heavier and most polluting fuels (e.g. heavy fuel oil), which means there is scope for change.
- Vessels have long asset lives, meaning technology choices made in the past will result in fixed emissions over the longer term.
- To date, alternatives such as electric and gas turbines have not been cost effective or viable.
- **Demand**: domestic shipping freight has seen a sharp reduction of 59% between 2000 and 2019, explained by a reduction in the transport of O&G products from the North Sea. Most freight transport in Scotland is non-domestic.
- One of the main drivers of demand for ferry services is the essential requirement for those living and working on Scottish islands for transport to the mainland, which can be characterised as 'lifeline' services and vital for the economy of the islands. Shipping is also crucial to seasonal tourism, agriculture and aquaculture. Government has supported this demand through subsidies.
- **Infrastructure:** there are some opportunities in the near future as ships reach the end of their useful lives and require replacement, but as these are long-life assets, the current pattern of consumption is difficult to change quickly.
- Any innovative switch from the present situation is likely to require extensive infrastructure investment in allowing provision for different fuelling solutions.




*Source: Transport Scotland - Scottish Transport Statistics No 40, 2021*

### Future trends and policy levers

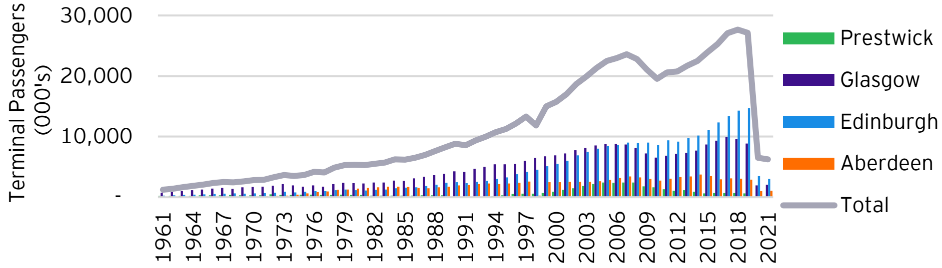
- Given the importance of services, demand management would not naturally form part of the policy landscape for ferries.
- SG financially supports ferries (and owns David MacBrayne) and so for a large portion of domestic shipping it can determine the pace of change, albeit the technical and infrastructure obstacles remain difficult to overcome.
- Scottish ferry ports are mostly publicly owned (though with different structures) and hence SG should be able to influence infrastructure development, but freight ports tend to be privately owned and will likely require commercial incentives to initiate change.
- There is a proposal to expand the UK ETS to the domestic maritime sector from 2023 onwards, taking steps towards reducing GHG emissions from ships.

# **Aviation:** The sector represents a relatively small part of Scotland's O&G use, and historical consumption aligns with demand. Alternative technologies are not readily available



Aviation overall consumed 778 ktoe of O&G in the form of kerosene, **5% of Scottish consumption and 1% of Scotland's total emissions.**

**Terminal passengers from the main Scottish airports 1961-2021**




*Source: Civil Aviation Authority Terminal passengers 1961 - 2021*

## Drivers of demand for fossil fuel consumption

- **Technology**: with few direct alternatives for air travel and air freight, the growth in consumption of O&G has been driven by the growth in air services. While engine efficiency has improved steadily, driven by airline operators' desire to reduce fuel costs, this has been outstripped by rising demand.
- Sustainable aviation fuels have not yet made a large contribution to emissions reduction.
- **Cost & demand:** over an extended period, air travel has become significantly cheaper for consumers and the number of destinations available has increased. Low cost airlines entered the aviation market in the 1990s, driving drove down prices and expanded the market for short-haul air services. Passenger numbers have increased, particularly for international travel.
- **Government support for airports & air travel:** governments have tended to see increasing aviation and connectivity by air as good for economic growth, and have supported air capacity in Scotland (for example, negotiating air access rights and financially supporting airlines).
- Most notably, governments and local authorities have supported the expansion of airports to allow for more flights and to make more destinations available to Scottish passengers.
- There has also been support for the Highlands and Islands Airports Limited and support for non-commercial services. These are seen as important 'lifeline' services but represent a small proportion of the consumption of kerosene by the aviation industry in Scotland, which is dominated by flights to other UK destinations and further afield.

## Future trends and policy levers

- Demand management could play a role in aviation emissions reduction, however, this is less credible for 'lifeline' services and other routes which are subsidised by governments to secure provision of vital services.
- While aviation fuel is not taxed due to international treaties, the Scotland Act 2016 included the power for the SG to introduce a devolved tax on air passengers from Scottish airports. SG could use its planned Air Departure Tax (ADT) to increase the cost of travel with the aim of reducing demand.
- Alternative technologies are further away from being effective, so policy options would be more about bringing forward readiness than encouraging a changeover.
- Support for research into alternative propulsion systems could also bring forward the time when these technologies can make a contribution. This will need to be integrated with UK and international efforts, with airline influence critical to the uptake of alternative technologies.
- The policy focus in relation to SAF should be ensuring that its production and use leads to a net decrease in Carbon Dioxide ($CO_2$) emissions, given that it is the only credible short-medium term option for change – hydrogen and electric aviation technology appears to be a generation away. For instance, work undertaken by ATI funding and ICAO standards will contribute to the availability of sustainable fuels.
- Since 2021, UK administered aeroplane operators have had to comply with the Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA), offsetting growth in aviation emissions.

# **Heat:** The majority of Scotland's homes are heated using gas. This trend is driven by the availability of cheap fuel, an established gas grid and support from government

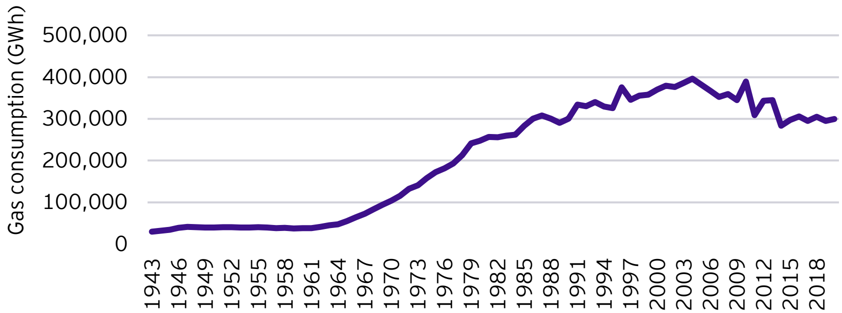


**Heating Scotland's homes and buildings accounts for 26% of O&G consumption and 20% of Scotland's GHG emissions**

Since the discovery of natural gas in the North Sea in the 1960s, UKG made a commitment to support its use for heating purposes. From the late 1970s it became the preferred heating fuel for domestic and non-domestic properties (as shown in the graph below). Today, mains gas is the primary heating fuel for 81% of Scotland's homes and this trend has remained steady based on recent available data.

As a large consumer of O&G and emitter of GHG emissions, there is a huge opportunity to decarbonise the sector and help meet Scotland's net zero objectives. Before this can take place, the factors that underpin mains gas demand in the sector must be explored.

**Historical UK domestic gas consumption**




*Source: BEIS*

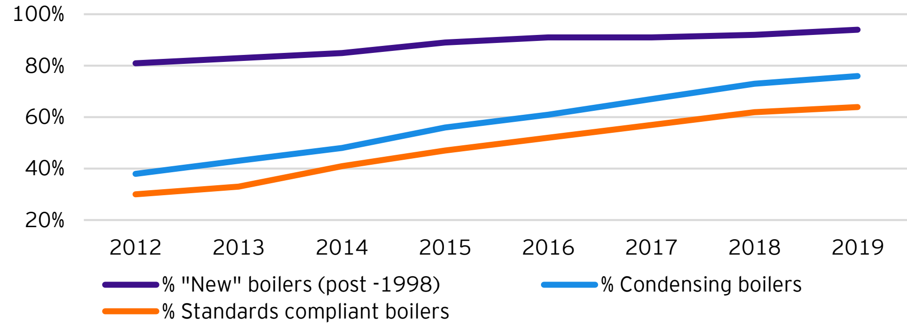
**The demand for O&G is driven by a variety of factors:**

With the discovery of O&G in the North Sea, the UK (and Scotland) had access to a cleaner and more efficient fuel supply (compared to coal or 'town gas') to heat our homes. Successive governments invested heavily in natural gas infrastructure, which consequently drove down gas prices for consumers and incentivised demand. Natural gas was viewed as an attractive substitute to coal as it was less polluting, but cleaner, low carbon alternatives are sought as we move towards net zero.

Key drivers for current demand include:

- **Regulation and government action:** Both SG and UKG have recently focussed on reducing emissions and fuel poverty. Historically, the push for gas has been largely supported by UKG as it was considered to be more environmentally friendly than coal and town gas. This has been achieved by:
  - Heavily investing in the gas network: This involved a rapid expansion of the gas grid up to the 1980s and steady expansion thereafter.
  - Providing financial support to low income households to install gas boilers. Going forward, SG plans to phase out fossil fuel heating systems and provide financial support to certain households for the adoption of low/zero carbon heating technologies.
- **Long asset lives:** Alongside the permanency of the gas grid, gas heating systems have significant asset lives (approximately 15 years) so the replacement cycle is slow. Alternative technologies have only recently become widely available, so would need to capture a high proportion of the market to make a rapid difference to consumption.
- **Consumer confidence:** Although many renewable heat technologies are mature (e.g. heat pumps and heat networks), to many individuals they are considered a 'novel' technology. Therefore individuals are uncertain as to whether their comfort needs will be met with these non-gas alternatives.

**Proportion of households using gas / oil boilers that have had improvements to their boiler**




*Source: [Scottish house condition survey: 2019 key findings - gov.scot (www.gov.scot)]*

# **Heat (cont.):** Renewable heating technologies exist, however, they can be expensive and infrastructure barriers restrict the mass decarbonisation of the sector



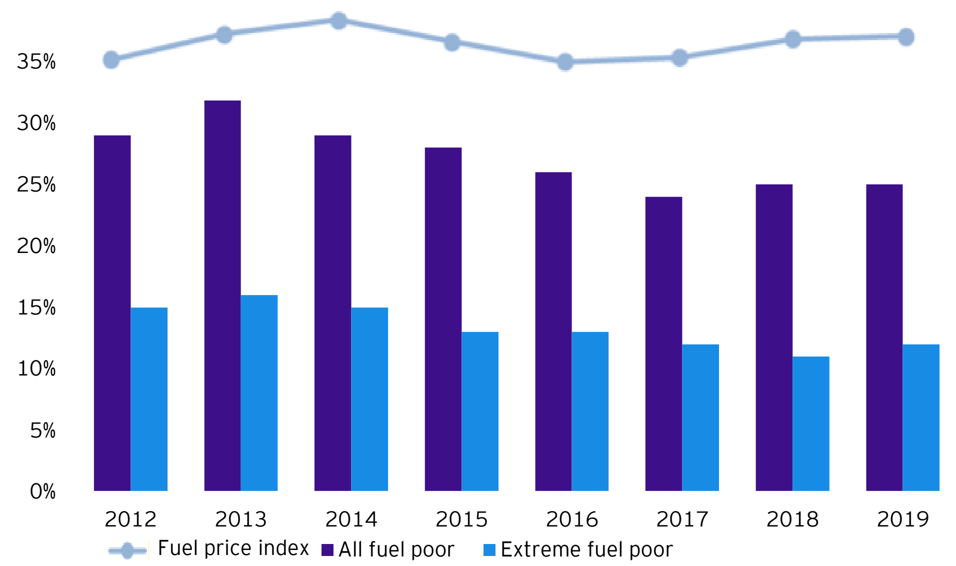
**The demand for O&G is driven by a variety of factors (cont.):**

- **Consumer expectations:** Expectations of the levels of comfort afforded by central heating have largely become embedded by consumers. Whilst for health reasons, it is recommended that UK homes are heated to 18°C in winter, research suggests that average room temperatures have increased over time beyond this level. This has driven demand and increased overall consumption.
- **Characteristics and energy performance of buildings:** Scotland's domestic landscape is complex, with a range of building types, ownerships and existing energy efficiency profiles resulting in varying O&G demands. Today more than 4 in 10 homes in Scotland have at least an EPC C rating, highlighting that there is potential for improvements in the energy performance of buildings through the introduction of retrofit measures and adopting zero / low carbon heat technologies. Going forward, regulations that govern new buildings should help reduce O&G demand.
- **Cost of natural gas:** Whilst gas prices have increased over the last 12 months, electricity is still currently more expensive than gas (historical trends demonstrate that electricity is four to five times more expensive).
- **Cost of alternatives:** Recent progress has meant that alternative heating technologies to gas and other hydrocarbons have become available. However, they are currently more expensive than traditional sources. The total lifetime cost of a heat pump to consumers (including the cost of necessary energy efficiency improvements), is estimated to be between £26,195 - £80,345[1 2], which is considerably more than a conventional gas boiler (£19,695 - £23,339). This is primarily due to the cost of additional energy efficiency measures required for a heat pump to work effectively and the relatively high costs of electricity compared to gas (even with the current volatility in the energy market).
- Whilst the anticipated costs to develop and deploy hydrogen as a primary heating source across Scotland are still unknown, it is estimated that a hydrogen boiler will cost an additional £100 to install compared to a gas boiler. Initial research shows that the total system cost per household for hydrogen (produced by electrolysis) varies between £1,410 - £1,880 per year. The costs could be lower if hydrogen produced by methane reforming and CCUS technology is used.

**Fuel poverty**

- Policy on heat will need to take into account fuel poverty, particularly if regulation were to increase the cost to consumers to heat their homes. Recent and projected increases in gas prices mean that more people will experience fuel poverty. Correctly handled, greater efficiency and technology change has the potential over the longer term to reduce fuel poverty.

**Estimates of Fuel Poverty and Extreme Fuel Poverty**




*Source: Scottish house condition survey: 2019 key findings - gov.scot (www.gov.scot)*

[1]Due to the variability and diversity of Scotland's housing stock, a range of estimated lifetime costs has been provided.
[2]Energy efficiency improvements are likely to have a positive impact on reducing energy bills beyond the life of a heat pump.

# **Heat (cont.):** Renewable heating technologies exist, however, they can be expensive and infrastructure barriers restrict the mass decarbonisation of the sector



**Future trends and policy levers**

- Improvements to the energy efficiency of buildings can help to reduce O&G demand. There has been a steady improvement in the adoption of energy efficiency measures (e.g. double glazing, floor insulation). Based on the rate of improvements in recent years, Scotland should be on track to meet SG's target (whereby all homes are equivalent to at least an Energy Performance Certificate (EPC) C rating); however, the rate / scale of improvements will need to be maintained if 2033 targets are to be achieved.
- Heat pumps are part of SG's No and Low Regrets Strategic Technologies. Whilst they are considered to be more expensive in terms of capital costs compared to standard gas boilers, it is envisaged that, as heat pumps become more widespread across Scotland, suppliers will be able to achieve economies of scale which may be passed on to the end consumer.
- Low carbon heat networks also form a key part of SG's decarbonisation of heat strategy. One of the key advantages of adopting heat networks is that they should benefit from the economies of scale in terms of heat production efficiency and the purchase of fuel, and therefore help to eradicate fuel poverty by reducing overall operating energy costs for consumers. However, the capital and running costs for households to connect to low carbon heat networks is currently uncertain, which could potentially disincentivise consumer demand.
- Another alternative, which is still being explored, is to use hydrogen. This would be achieved by modifying the current gas grid to become a hydrogen grid. Hydrogen boilers are currently in a prototype phase and estimated to be available from 2025.
- The electrification of heat will require improvements to the electricity grid to scale up the delivery of power to households. Additionally, the potential binary nature of a switch over to hydrogen requires significant co-ordination across both consumers and the supply chain and does not lend itself to an incremental approach. Further details are provided in the Power section.
- To enable Scotland's Just Transition towards the decarbonisation of heat in buildings, there needs to be a collaborative approach between SG and UKG.
- SG has a number of key policy levers specific to heat, including:
  - Climate change and pollution control;
  - Energy efficiency and building standards (including the planning system) are within SG's control and therefore new buildings can be controlled;
  - Reliefs in the tax system (e.g., rates) and subsidies for the deployment of heating systems (i.e., heat pumps and heat networks); and
  - Supply chain measures to encourage installation, e.g., regulation and also industrial strategy to support the supply chain in Scotland around renewable heating technologies.
- However, there are some important levers that remain with UKG and UK regulators, including:
  - Control of the cost and development of the gas and electricity grids and the quantum of cost that will be passed on to consumers.
  - Wider parts of the tax system such as energy taxes and control of gas / electricity pricing, operations and coverage of the UK ETS.

# **Electricity Generation:** Electricity has been extensively decarbonised, but demand will increase to hit net zero

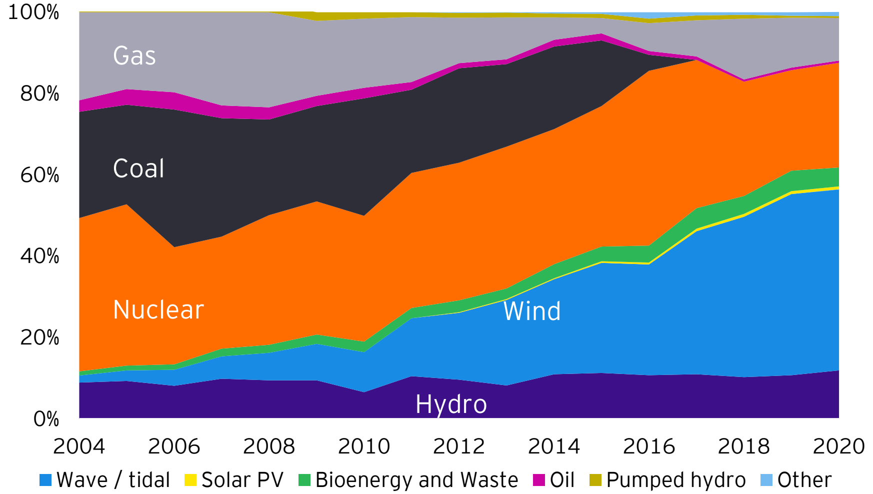


**Electricity generation accounts for 7% of Scottish consumption of O&G.**

**Drivers of demand for fossil fuel consumption in the electricity generation sector**

- Fossil fuels have historically played a major role in electricity generation in Scotland. In 2004, around 50% of generation came from fossil fuels and 38% from nuclear as a baseload fuel. However, over the following years, low carbon generation became the dominant generation technology amounting to almost 88% of generation in 2020.
- Significant progress has been made in transitioning to alternative fuels in the electricity sector than other sectors because of the availability and cost of alternatives.
- As renewables have increased their share of the generation mix, gas generation has decreased gradually over time. In 2004, gas accounted for 21% of electricity generation in Scotland compared to 10% in 2020. Combined Cycle Gas Turbine (CCGT) plant load factors have also been decreasing over time.

**Generation mix in Scotland**



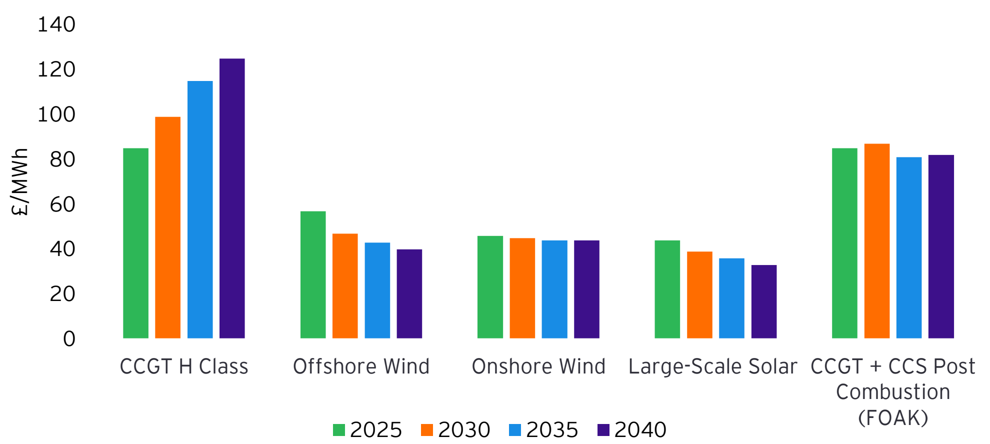

*Source: Scottish Energy Statistics Hub (shinyapps.io)*

- Importantly, in 2020, **97.4%** of Scotland's gross electricity generation consumption was from renewable and low carbon sources, with the majority of renewable electricity generation coming from wind.

**Alternatives to O&G use in electricity generation are cost-effective but intermittency problems are still being addressed**

- As the chart below shows, renewables have become cost-effective against gas generation (CCGT) due to a combination of increasing fuel and carbon costs for gas as well as falling renewable technology costs.
- The cost of managing the intermittency issues associated with renewables will be critical in determining the overall cost to consumers and the Just Transition impact of changes to electricity generation as demand increases. There is also uncertainty surrounding the cost of emerging technologies.
- One source of uncertainty will be the amount of renewables required in Scotland given the ambition to be a renewable energy hub. This will result in the overcapacity of Scottish renewable electricity generation, much of which may be exported when it is available.

**Levelised cost estimates by technology type**




*Source: Electricity Generation Costs 2020 (publishing.service.gov.uk)*

# **Electricity Generation (cont.):** Electricity has been extensively decarbonised, but demand will increase to hit net zero

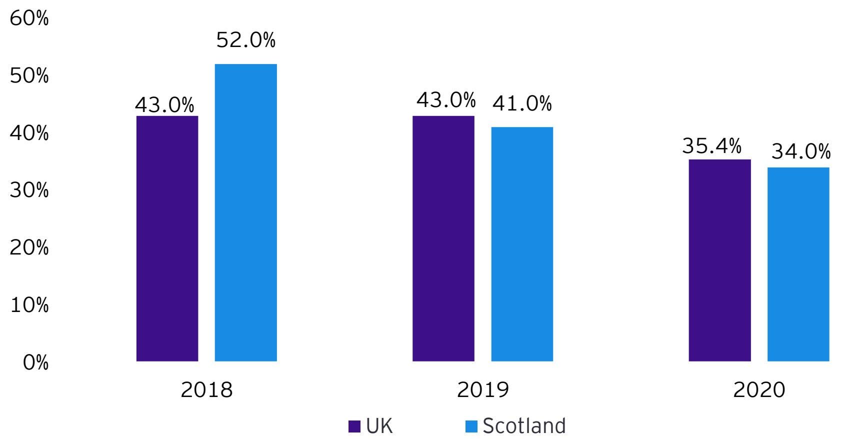


- **Dealing with intermittency and abundance of renewables:** the next stage of decarbonisation will require further commercial and technological innovation.
- Gas is likely to have an important role in the generation mix because of the intermittent nature of renewables. The UK expects to achieve 100% clean energy production by 2035, but gas generation will still have a role beyond 2035 (in combination with CCUS technology).
- Although the UK is targeting a decarbonised electricity generation system, increasing the use of renewables beyond a certain point means that there are times when there is excess generation on the system, creating commercial model challenges as the market price they can command would trend to zero.
- **Future demand for electricity generation**: Despite expectations for continued energy efficiency improvements and a reduction in demand for natural gas in energy generation, demand for electricity generation is expected to rapidly increase and to **double between now and 2050**. This will be principally driven by the expected deployment of electric heat pumps and road vehicles, as well as O&G platform electrification.
- The scale of demand increase in the National Grid ESO's FES varies between scenarios according to the speed of decarbonisation and the level of societal change in how energy is consumed. In all FES a rapid increase in renewable generation will be necessary to keep pace with electrification and to maintain and improve the low carbon nature of generation in Scotland.

**Current continued requirement for gas generation and how its role may change**

- The lack of dispatchable renewable electricity generation has meant a continued role for gas.
- The introduction of the UK Capacity Market in 2014 recognised the value of reliable capacity (principally gas) as a backup generation source, and supported the continued operation of existing plants and construction of new ones. The capacity market auctions are technology neutral, with existing generators and potentially new generation competing against a range of other technologies to obtain agreements under which they commit to making their capacity available when needed, in return for guaranteed payments.[1]
- The results of the 2021 four year ahead Capacity Auction (T-4) saw generators using gas as the primary fuel representing 65% of the capacity market, the largest share among all types.[2]
- Three new gas-fired Open Cycle Gas Turbines (OCGTs)[3] being developed by Drax were awarded 15-year contracts for 854MW of capacity. 460MW of new gas reciprocating engine capacity were successful in the auction (principally in the South of England), although this was lower than in previous auctions.
- The increasing demand for more electrification will be met with increasing renewables coming into the system. This will likely shift the role of gas as a key source of baseload generation to a key source of flexibility alongside other providers (i.e. storage, demand side response) to compensate the intermittency of renewables.

**Gas-fired plant utilisation level**




*Source: DUKES 5.10 Plant loads, demand and efficiency, CCGT*

*Sources:*[1] Scottish Energy Statistics Hub (Note: due to losses in the transmission and distribution network, and an element of generation being consumed to generate electricity, consumption plus net exports does not equal total generation.
[2] *BEIS - Electricity Generation Costs (2020)*
[3] *Drax T-4 Provisional Results*

# **Electricity Generation (cont.):** Technological and commercial solutions are being pursued for low carbon electricity sources that are non-intermittent



### Infrastructure

- Scotland will need to explore solutions to grid capacity challenges for transporting electricity generation. Increasing distributed renewables is required due to the scale of the electrification ambitions and the forecast increase in demand, especially as there are currently constraints in the system that mean renewables cannot dispatch electricity generation at certain times.
- The scale of increases in renewable technology is extremely ambitious. Scotland currently has relatively little offshore wind capacity (0.4GW) but the ScotWind auction implies an ambition of 25GW of installed capacity.
- This is going to increase the network reinforcement needs in some areas and there will be a need to reduce the impact of network constraints, to enable the maximum build-out of renewable capacity on the system and lower costs for the end consumer.
- The Network Option Assessment (2021/2022) by National Grid ESO highlighted the need for a £7bn strategic infrastructure investment in the transmission network in Scotland and the rest of the UK.

### Future trends and policy levers

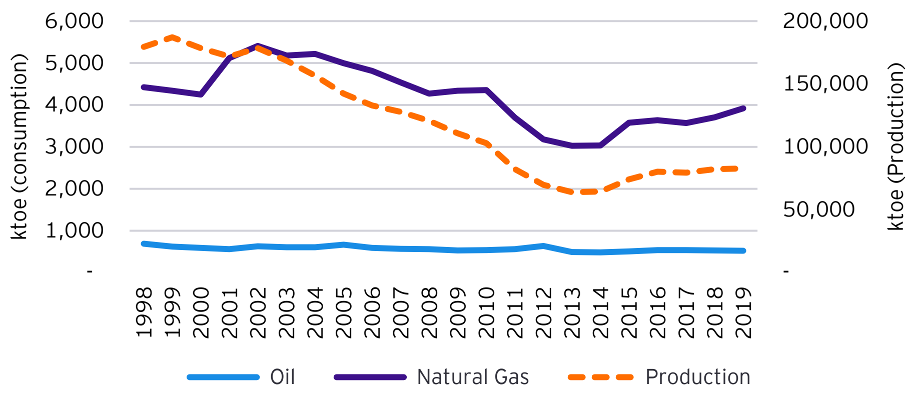
- Further progress will result in an increase in low carbon generation in Scotland, replacing nuclear on decommissioning and allowing the export of electricity generation to the rUK.
- Offshore wind will be a major contributor to this trend. This has been given further impetus by the recent ScotWind auction.
- Challenges in developing appropriate grid infrastructure will need to be overcome to help resolve current and future capacity constraints.
- Future demand for gas will be determined by the availability of low carbon dispatchable power, which is a significant technical challenge in renewables.
- From a policy perspective, the challenge for SG is that the principal policy levers sit with UKG in the incentive regime (for example, contracts for difference (CfDs) and the capacity market) that allows for the development of renewable low-carbon solutions to intermittency challenges.
- Further, UK regulators and particularly Ofgem will be important in two ways: first, the development of the grid that will allow for offshore renewable electricity generation to be installed and be effective (including connections to rUK), and secondly the grid development required for increased consumption and some distributed generation.
- However, SG controls the planning and consenting regime for offshore and onshore wind and other renewables, and also for grid connections and expansion. Measures to ease deliverability and increase will accelerate development.

# **The Energy Industry:** Primarily associated with the extraction of O&G, this is declining but still represents a high proportion of emissions



**The Energy Industry accounts for 28% of Scotland's total O&G consumption.** This is largely from the energy required to extract resources from the North Sea and to get them ashore. 'Midstream' activities such as use of energy to run refining and processing is also significant. Percentages of emissions are lower because they do not include offshore activity for Scotland.

**Energy Industry demand for hydrocarbons, 1998 to 2019**




### Drivers of demand for fossil fuel consumption

- **Availability:** Gas is readily available on platforms in the SNS given the production there. It was therefore the natural energy source to use to power the extraction of O&G. Oil is used to a much lesser extent.
- The same applies to the midstream activities onshore such as at Grangemouth.
- **Infrastructure and asset lives:** Once platforms are in place and the infrastructure there, this tends to be maintained for the life of the field rather than being replaced, given the difficulty and expense of so doing. Use of gas is therefore part of the way in which many fields operate.
- **Emissions reduction has focused on other areas:** Emissions reduction efforts have focused on venting and flaring where it is easier to make progress. The greater potency of methane as a GHG means that this is likely to be the right option, but it means that alternatives to the use of O&G are further behind.

### Cost of alternatives to fossil fuels

- Changing is costly: there is potential to electrify production, and this has been done in Norway using onshore sources of electricity generation, especially hydro. Power would need to be renewable for this to represent a significant carbon saving.
- Using offshore wind is a possibility, but this would require large-scale investment outside of the O&G industry to enable partnerships to directly power O&G extraction. It is not likely to happen for existing fields where extraction is declining, but could be a possibility for newer fields where infrastructure is being put in place.
- The Innovation and Targeted Oil and Gas (INTOG) leasing round by Crown Estate Scotland, allowed 4GW of offshore wind to be available for O&G platform electrification. However, the absence of an offshore transmission network remains a challenge.

### Future trends and policy levers

- The North Sea Transition Deal (NSTD) contains commitments to emissions reductions. However, these closely parallel the reduction in production so it may be that these targets will be met without major technological change.
- Policy levers include the ability for regulators to examine field production plans and to only allow production in certain circumstances. The Climate Compatibility Checkpoint analysis will provide further details on this.

# **Energy Use in Industry:** As with heat, the shift from coal to O&G increased efficiency and reduced emissions, resulting in a varied picture of use



**Industry accounts for 7% of Scotland's total O&G consumption.** This is a combination of heating for industrial processes (predominantly gas) and electricity generation. This area also includes combined heat and power (CHP) plants where spare heat can be used to generate electricity.

### Drivers of demand for fossil fuel consumption

- **Gas technology and gains in efficiency and cleanliness:** A range of technologies are used in industrial processes that require heat, and the period from the 1950s onwards saw a shift from solid fuels (coal) to O&G, particularly gas. This was driven by efficiency improvements through the use of gas as well as environmental improvements, such as less pollution.
- At the same time, electrification of many industries shifted some energy use to electricity generation. Some of this generation has been off-grid to fulfil requirements, and some as a by-product of heat generation in CHP plants.
- Efficiency and an abundance of relatively cheap gas has allowed costs for industry to be reduced though the use of O&G.
- **Regulation & government support**: As with space heating, government support for the expansion of the gas grid historically was critical to driving the current pattern of use, and industry has often lobbied for expansion and connection to the grid.
- **New technologies are at an early stage:** Hydrogen and electric technologies are emerging for industrial heat in a market that is still currently dominated by natural resources.
- Emerging technologies are harder to price and some of these may become competitive in due course. As with heating, replacing natural gas with hydrogen is likely to come with increased cost.
- **Infrastructure and asset lives**: Industrial replacement cycles will be slow and investment requires a return to make changes and to pay for any disruption caused. Therefore savings would need to be proven and significant before action would be taken by industrial users of O&G.

### Cost of alternatives to fossil fuels

- For electricity generation, some renewables can be cost comparative and enable change in this sector.
- Power Purchase Agreements (PPAs) can be cost competitive with grid supply and are entered into currently on commercial terms. When entered into with renewable suppliers, this is done because of the cost parity of those sources (with the grid supplied by O&G continuing to be used as a backup to intermittent renewables).

### Future trends and policy levers

- Power is relatively easier than heat to decarbonise as renewable sources are available. This can be done either via the grid, through direct PPAs with renewable generators or through a separately owned direct wire connection. Other alternatives are the same as those discussed in the heat and electricity generation sections.
- The importance of jobs and economic growth means that demand management will be focused on efficiency rather than stopping the industrial processes concerned (which would add the risk of exporting emissions).
- A similar set of policy levers are available to SG as with heating, including incentive schemes for take-up of new technology and subsidies for early technological development.
- UKG and regulators retain levers around grids and infrastructure investment. These will determine the extent to which solutions which rely on electrification will be able to be put in place.

# **Non-Energy Use in Industry:** Products derived from O&G are widely integrated into the economy and demand remains high for many applications



Non-energy use accounts for 6% of total O&G consumption, but Scotland consumes significantly more products derived from hydrocarbons than this figure suggests due to hydrocarbon-based goods being manufactured outside the country and imported.

### Drivers of demand for fossil fuel consumption

- **Demand for plastic products**: The development of plastics and other materials from O&G has had a transformative effect on the products consumed within the economy. This has meant the integration of petrochemicals with the rest of the economy and the expansion of uses to every sector and type of use.
- Production is concentrated in Scotland at Grangemouth and has been based on the availability of resources from the North Sea. More recently, demand has been satisfied using imported feedstocks such as ethane from the US.
- Emissions from non-energy use is hard to quantify, as production only accounts for approximately 35% of the total potential. Emissions are locked in the material and are released at the end of life through degradation or incineration for disposal or in Energy from Waste (EfW) plants. The emissions impact of these uses are therefore impacted by the position on recycling and reuse.
- **Regulation & government action**: The development of the domestic petrochemical industry has been seen as positive and encouraged by different governments over time.
- More recently, highlighting of single-use plastics and the longevity of plastics in the environment has led to a renewed focus on alternatives, and some action through SG's Extended Producer Responsibility (EPR) schemes and the tax system such as the plastic bag tax and the new plastic packaging tax (introduced 1 April 2022).
- **Alternatives are only available in some areas**: Plastics from renewable resources are now being developed and their market penetration is becoming significant in some areas, such as in cutlery and reusable cups. However, in many other areas bio-based replacement plastics are still in early stages of development and replacement plastics that need to be more durable, malleable and impact resistant than those used in cutlery are more difficult to develop and rollout.
- Further sustainability issues will potentially arise as this market develops and there will be competition for space from other needs such as food production. Where there are alternatives, these tend to be more expensive at present. In a number of areas this financial cost has proven acceptable to consumers and businesses, e.g., the incremental costs of reducing the use of single-use plastics.

### Future trends and policy levers

- Demand for plastics is embedded in the economy through a huge range of uses and this is difficult to change quickly. While there has been publicity on the issue of plastic pollution for a number of years, the utility of plastics means that change is difficult.
- Tax is a key policy lever and the plastic packaging tax is a UKG measure; the current devolved tax powers do not fit with measures regarding the use of plastics that differ from the UK position.
- SG has levers around support for technological development and the development of a Scottish supply chain for new technologies.
- Other forms of regulation aimed at specific uses of plastics, such as legislation introduced by SG in 2021, could help to promote alternatives.

# 6 Main Findings: Policy Levers

# Drivers of demand and policy levers



**What are the implications of the drivers of demand for policy?**

There are a large number of policies across different sectors of the economy that will be required to move towards net zero and to support an energy transition.

Section 6 sets out which types of polices are required to address the key themes that drive the consumption of O&G. The section then details the current policy interventions by sector, noting where they are devolved to SG or held by UKG.

| Key theme | Types of policy levers |
|---|---|
| **Technology and cost** | ▶ While progress in low carbon technology is global, governments can promote progress in different areas of technology by subsidising research at different points in the value chain – from basic scientific research to applications closer to market.<br>▶ This type of intervention can also help to secure the supply chain for new technologies in Scotland. This will be explored in more detail in Chapter 3. Such examples might include:<br>    ▶ Funding for early stage research into new technologies such as wave or tidal energy.<br>    ▶ Funding for firms investing in manufacturing or other facilities.<br>▶ Targeted subsidies for renewables or other technologies can create markets and improve demand. These can work at a high level (such as CfDs for renewables) or in more targeted areas such as the subsidies to incentivise purchase of zero carbon vehicles. Such interventions can bridge funding gaps to create a viable business case.<br>▶ Direct regulation can target technologies and drive change – such as the proposed ban on the sale of new ICE vehicles from 2030 onwards. |
| **Taxation, carbon pricing and levies** | ▶ Increasing the cost of O&G technologies through taxation can change the balance between these technologies and others. O&G are already extensively taxed, but there are areas where this has not changed in recent years – for example, UKG has held or reduced the level of fuel duty over the past decade.<br>▶ The UK ETS is a 'cap and trade' scheme, which on an annual basis sets a cap on the total amount of relevant greenhouse gases that can be emitted by sectors covered by the scheme. In the scheme, within the cap, participants receive free allowances and/or buy emission allowances at auction or on the secondary market which they can trade with other participants as needed. Each year, installation operators and aircraft operators covered by the scheme must surrender allowances to cover their reportable emissions. The cap is reduced over time, which limits the total amount of carbon that can be emitted. This is intended to make a significant contribution to how the UK meets its legally binding carbon reduction commitments.<br>▶ Currently the cost of changing electricity generation technology and of building grid infrastructure falls on a certain set of customers. How regulators and governments choose to spread the burden of paying for new grid infrastructure can change how quickly and fairly this can be rolled out. |

# Drivers of demand and policy levers



| Key theme | Types of policy levers |
|---|---|
| Infrastructure, assets and business models | ▸ Governments often either own assets such as the road and rail networks (and therefore the level of technological readiness for low carbon technologies that they have), or can control how they will evolve over time.<br>▸ Governments can also play a role in the evolution of new business models – potentially through funding not available in commercial markets.<br>▸ While regulators have duties to consumers and to companies, governments set the strategic direction and framework within which they work. Where certain outcomes – such as grid capacity – are important for decarbonisation, government can influence spending. |
| Consumer expectations | ▸ Awareness of the costs of using O&G can be an effective part of policy, but action in specific areas is also required to accelerate change away from O&G.<br>▸ Policy can also target consumers' reluctance to change technology and the inertia that can affect different markets. In combination with subsidies, demonstrating that new technologies are effective for consumers can improve demand. Demonstrator projects and pilot schemes are an important part of improving the demand for new technologies and normalising their use.<br>▸ Direct programmes to educate consumers and show how new technologies can be employed and work well for them can be effective – for instance, Business Energy Scotland helps publicise energy and heat options.<br>▸ Measures to make active travel choices, such as walking and cycling, safer and more attractive options can change the structure of choices made by consumers in transport markets. |
| Actions of government and regulators | ▸ Current patterns of usage have been driven by governments pursuing economic growth and other policy goals.<br>▸ One critical policy action is to ensure that the consequences of emitting GHG are considered alongside the merits of economic growth when looking at choice, investment decisions and policies. This can lead to difficult trade-offs but can be used to inform a wide range of policy making. Greater awareness and clear targets now mean that in contrast to the past, these trade-offs are more likely to be actively considered in making decisions.<br>▸ Planning policy can be changed and used in two ways: first, to influence the efficiency of new buildings and how they use energy and what sources of energy they use; secondly, to influence population locations - where people live is a key factor in the shape of transport demand and how people use transport networks. |

# **Demand management:** can play a role in reducing O&G use in a variety of different ways



### Demand Management

- Demand management will need to play a role in reducing O&G usage. The potential for demand management varies across different sectors and the ways in which this can be done will differ.
- The Intergovernmental on Panel Climate Change (IPCC) sixth Assessment Report (AR6) concluded that demand management should be an integral part of the mix of policies to reduce fossil fuel use. In its 2022 report, the Climate Change Committee (CCC) identified the risks of the UK Government's reliance on technological progress to achieve net zero.
- Some ways of managing demand more precisely involve use of technology, and some of these methods are dealt with below.

| Sector | Issues for demand management |
|---|---|
| Road | ► SG has an objective of reducing private car use as part of achieving net zero. As well as changing the mode of transport (in other words, for the same journey using public or mass transit instead of a car) demand can be reduced by promoting non-car lifestyles and changing the need to travel.<br>► Placemaking and planning policies will be critical to reduce travel demand and car use, enabling fewer or shorter journeys and also increased active travel and use of mass transit modes such as bus.<br>► Fuel duties, workplace parking levies, company car tax rates and low emission zones can all be used to manage demand by changing the cost of journeys. |
| Rail | ► Rail is a low emission mode that should be seen as an alternative to private transport – demand should not be managed but rather encouraged. |
| Domestic Shipping | ► Domestic freight has been in decline but the shipping represented by ferries to Scottish islands represents 'lifeline services' and so demand management would not be appropriate. |
| Aviation | ► Aviation has seen unprecedented growth in recent years<br>► Given the lack of direct alternatives available, the only way to reduce aviation emissions would be to reduce demand for flights.<br>► While this may not be desirable for 'lifeline' services, travel within the UK could be encouraged on other modes through pricing (via tax policy) and through encouragement and promotion of those services.<br>► Air travel outside the UK is also responsible for use of oil and restricting demand would reduce usage. The trade-off is that the economic and social benefits of such travel would be lost. |

# **Demand management:** can play a role in reducing O&G use in a variety of different ways



| Sector | Issues for demand management |
|---|---|
| Heat | ▸ Energy efficiency standards, for existing and new homes, will impact the overall demand for heat and hence the energy required to supply that, irrespective of the source (e.g. natural gas or electricity).<br>▸ The regulation of minimum energy efficiency ratings (EERs) for both domestic and non-domestic properties can reduce heat demand. By 2033 homes must reach a rating at least equivalent to an EPC band C.<br>▸ The development of planning policy to enable and encourage energy efficiency and low and zero emissions heating can reduce demand in the longer term as the shape of the housing and building stock changes.<br>▸ The consumer preference for levels of heat also drives demand and expectation have been increased in recent years given the effectiveness of central heating and the pricing of gas. O&G consumption could be reduced by encouraging consumers to not increase or reduce the temperature at which they maintain their homes. |
| Electicity generation | ▸ The efficiency of devices that use electricity has for a number of years been a focus in reducing demand. There has been success in reducing demand for electricity through measures such as the ban on incandescent light bulbs and ratings of appliances.<br>▸ This will continue but will be offset by increasing demand from electrifying energy consumption from fossil fuels to enable decarbonisation. However, this does not mean that effort should stop in driving efficiency. |
| Energy industry | ▸ Demand will be dependent on the level of extraction of O&G which is expected to decline. |
| Industry | ▸ Industry requires energy but the efficiency of processes can help to reduce demand – this is an established area of endeavour, but should not be ignored in decarbonising industrial processes. |
| Non-energy uses of O&G | ▸ Demand for plastics and other products could be reduced through promotion of alternatives but in particular reduction in ‘single-use’ products. |

# Innovative and technology based solutions: can facilitate change



## Innovation

- This report has focused on the explanation for the current use of O&G in Scotland. Part of this explanation relates to the readiness and cost of replacement technologies today, but it has not examined the changes that might come to demand from innovative technology.
- There is the potential to accelerate switchover to low carbon technology and to manage demand in ways that will reduce consumption of O&G through the use of newer technologies. This can help deliver benefits to consumers and hence have a stronger behavioural impact as well as simple technology switching.
- A focus on technological solutions can increase risks that progress on decarbonisation is postponed while waiting for new technologies to break through, so looking at these solutions is not a substitute for trying to promote more proximate technologies (such as BEVs).

## Policy implications

- For policymakers the dilemmas of emerging technologies are significant: future technologies are not certain and it is often not clear which ones should be supported. The 'do no harm' principle and the need to avoid picking winners results in interventions being different for more mature technologies.
- Early stage support for new technologies, trials and pilot projects can be significant in supporting new technology and demonstrating effectiveness. However, there are also times when risks need to be taken in order to accelerate change.
- New technologies can also require changes in behaviour to be effective and can themselves enable such changes, and there can be a complex set of consequences from the introduction of new technology that cannot always be foreseen.

## Examples

- The table below sets out some examples and issues by sector, along with some issues:

| Sector | Potential technologies |
|---|---|
| Road | ▸ Pricing technologies: while road pricing is often controversial, new technology can be more granular in terms of geography and split by time to enable demand to be managed.<br>▸ Batteries in BEVs when plugged in can form parts of smart grids and help to manage electricity demand and reduce the need to dispatchable power.<br>▸ 'Mobility as a service' offerings can make public transport more attractive by bringing together information and ticketing across modes to create more seamless journeys and improve confidence in the system, and the value for money offered. This can encourage mode shift. |
| Rail | ▸ Digital rail technology can improve safety and also allow trains to run closer together, which can help in reducing crowding and make rail more attractive. |
| Domestic Shipping | ▸ While zero carbon technologies are further away, newer propulsion technologies are available that can reduce emissions, albeit at increased cost. |

# Innovative and technology based solutions: can facilitate change



| Sector | Potential technologies |
|---|---|
| Aviation | ▸ There are few technologies in this sector that will make a significant difference to emissions. |
| Heat | ▸ Smart systems in homes and other buildings can help to manage demand – through timing of heating more precisely and heating specific areas which are in use.<br>▸ Heating systems can also take advantage of more precise timing in terms of electricity pricing where demand can be matched to availability through pricing in 'micro' increments (allowing more power to be used when it is available). |
| Electicity generation | ▸ 'Smart grids' will increasingly be necessary to balance electrical power and enable a greater degree of localised renewable generation without destabilising supply. This can enable more diverse sources of power and also begin to incorporate different types of storage.<br>▸ Smart cities technologies across a number of areas of consumption have the potential to reduce and manage demand for electric power, including lighting and heating. These will involve data driven solutions and the use of data to improve services as well as reduce demand.<br>▸ Smart meters: in homes these (especially if linked to differential pricing) can help to manage and spread demand as customers respond to price signals to change the timing of their demand – so energy intensive activities such as washing can be changed in time.<br>▸ While most renewable technologies are known, if not fully mature, electricity / power storage technologies are at an earlier stage but will become important as the electricity generation market adapts to increased renewables. |
| Industry | ▸ Smart and data driven technology has the potential to improve efficiency in industrial processes and this has already been apparent in progress made in efficiency. |
| Non-energy uses of O&G | ▸ There are increasing alternatives to O&G derived materials and the nature and uses of these are extremely diverse.<br>▸ New materials and materials derived from organic sources will help reduce the need for O&G consumption. |

# Policy levers - Road Transport



## Key actions of SG and UKG to achieve the decarbonisation of road transport

| Policy Lever | Examples | Primary Responsibility |
|---|---|---|
| Vehicle excise duty (VED) | ▶ The tax raised on individual vehicles which varies by the carbon intensity of its emissions. | UKG |
| Fuel duties | ▶ Tax raised on various types of fuels, most importantly petrol and diesel. | UKG |
| Company car tax rates | ▶ Tax paid on company cars. Differential rates are paid for different levels of carbon emissions. | UKG |
| Bus Service Operator Grant | ▶ Subsidy paid to bus operators. In England and Wales, this remains linked to litres of fuel used, in Scotland it is paid per km, with differential rates for BEV versus ICE. | SG |
| Public procurement of vehicles | ▶ Vehicles procured by public authorities such as police, local authority, fire, ambulance. Can, where practical, be focused on BEV or other low carbon technologies. | SG |
| Subsidy powers | ▶ Providing subsidy to encourage infrastructure development e.g. charging networks or hydrogen infrastructure. | SG |
| Technology regulation | ▶ Banning certain technologies or regulating standards (e.g. emissions standards). UKG has announced a ban on petrol and diesel vehicles from 2030. | UKG |
| Low emission zones | ▶ Local authorities in Scotland have the power to impose low emission zones, charging for certain types of vehicles (e.g. no Euro VI vehicles) in certain areas.<br>▶ Congestion charge in London if you drive within the Congestion Charge Zone during certain times on certain days. | SG / UKG |

# Policy levers - Road Transport (cont.)



## Key actions of SG and UKG to achieve the decarbonisation of road transport (cont.)

Measures to make public transport a more attractive option will help to reduce demand for road transport. Among others, these might include:

| Policy Lever | Examples | Primary Responsibility |
|---|---|---|
| Concessionary travel | ► Providing concessionary travel to people who are under 22, over 60, or disabled, aiming to make travel accessible and affordable. | SG |
| Active travel choices | ► Funding available to organisations responsible for delivering walking and cycling infrastructure. | SG |
| Modernisation of equipment and infrastructure | ► Providing smart technology travel with new digital ticketing and payment options. | SG |
| Investing in Scotland's railway | ► Ensuring railway meets future demand, having invested £9bn since 2007. | SG |
| Investing in bus services | ► Modernising bus services and supporting them where they are not commercially viable can create a more coherent public transport system that encourages modal shift. | SG |
| Workplace Parking Levy (WPL) | ► Levy paid for parking spaces provided to employees at work places. | SG |

# Policy levers - Rail Transport



**Key actions of SG and UKG to achieve the decarbonisation of rail transport**

| Policy Lever | Examples | Primary Responsibility |
|---|---|---|
| Control of ScotRail | ► The franchise that covers Scotland: SG now owns ScotRail and runs the franchise directly.<br>► It therefore controls rolling stock procurement (though these are under long term contracts) and could choose to develop solutions in areas such as hydrogen or battery electric rolling stock. It is also the franchising authority, setting out what the franchise should deliver. | SG |
| Control of fares | ► SG takes the revenue risk on the ScotRail franchise and so is also in control of fares and fare structures. | SG |
| Control of Great British Railways | ► Network Rail is owned by UKG. SG will have input into the price control process for setting infrastructure upgrades and has operational control of maintenance, but does not ultimately have complete control of the railway in Scotland. | UKG |
| Planning Powers | ► Electrification and other changes, for example hydrogen infrastructure, may require planning changes and also interaction with utilities to be delivered. | SG |
| Fuel Excise Duty | ► Train Operating Companies (TOCs) pay fuel duty, but at lower rates than road fuel. | UKG |
| Subsidy for technology | ► Development / trialling of alternative technology for rail travel such as hydrogen trains. | SG / UKG |

# Policy levers – Domestic Shipping Transport



## Key actions of SG and UKG to achieve the decarbonisation of domestic shipping transport

| Policy Lever | Examples | Primary Responsibility |
|---|---|---|
| Tendering of services | ▸ Many of the ferry services in Scotland are subsidised by SG in the form of either directly provided or tendered services. Tendering would allow SG to specify ships used, as long as the infrastructure was provided. | SG |
| Direct ownership | ▸ SG owns Caledonian Maritime Assets Ltd and therefore can control the ships they procure. | SG |
| Port ownership / infrastructure | ▸ There are a variety of port ownership structures in Scotland – many of the key ports are trust ports / local authority owned ports. SG will have strong influence over facilities and over infrastructure requirements for new fuels. | SG |
| Fuel Excise Duty | ▸ Ferry operators pay fuel duty, but at lower rates than road fuel (fuel used for non-private marine voyages can obtain full rebate from HMRC). | UKG |
| Subsidy for technology | ▸ For instance, development / trialling of alternative technology for maritime drive trains. | SG / UKG |
| Reduce emissions | ▸ UKG has proposed to expand the UK ETS to the domestic maritime sector from 2023 onwards, taking steps towards reducing GHG emissions from ships. | UKG |

# Policy levers – Aviation Transport



**Key actions of SG and UKG to achieve the decarbonisation of aviation transport**

| Policy Lever | Examples | Primary Responsibility |
|---|---|---|
| Control of Airports | ▸ SG owns Highlands and Islands Airports Limited (HIAL) and ministerially owns Glasgow Prestwick Airport. It therefore controls asset procurement and could choose to develop solutions in areas such as hydrogen or battery electric for Island connectivity flights. However, Scotland's other main airports (Aberdeen, Edinburgh and Glasgow) are privately owned. As such limited control over capital and infrastructure spend exists. | SG |
| Planning powers | ▸ Hydrogen infrastructure (for example, storage and refuelling) may require planning changes to be delivered to airports. | SG |
| Control of ADT and APD | ▸ ADT is SG's planned replacement for APD. | SG / UKG |
| Subsidy for technology | ▸ Development / trialling of alternative technology for aviation travel such as battery electric, SAF development or hydrogen. | SG / UKG |
| Fuel Excise Duty | ▸ Airlines currently pay no fuel duty on aviation fuel. | International Civil Aviation Organisation |
| Fuel Blend | ▸ UKG has committed to aviation fuel consisting of SAF blend of 10% and 75% by 2030 and 2050 respectively. | UKG |
| Reduce emissions | ▸ UK administered aeroplane operators to comply with the Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA), offsetting growth in aviation emissions. | UKG |

# Policy levers - The Heat Sector



**Key actions of SG and UKG to achieve the decarbonisation of the heat sector**

| Policy Lever | Examples | Primary Responsibility |
|---|---|---|
| Regulation of gas and electricity networks (including the potential use of hydrogen) | ▶ Explore the potential use of hydrogen in the existing gas grid as a future heating fuel source.<br>▶ Increase the connection capacity to meet future demand on the electricity grid from the increased use of heat pumps and non-gas fuelled heat networks. | UKG / UK regulators |
| Regulation of energy prices (including the enforcement of taxes) | ▶ Explore mechanisms to restructure or rebalance the environmental and social levies that are added to electricity bills. | UKG / UK regulators |
| Regulation of heat networks | ▶ Introduction of the Heat Networks (Scotland) Act 2021 providing regulation for heat networks, intended to be implemented by 2024. However, the 2021 Act does not provide consumer protection powers as these remain reserved to the UKG. | SG / UKG |
| Regulation of energy efficiency and building standards (including the planning system) | ▶ The regulation of minimum energy efficiency ratings (EERs) for both domestic and non-domestic properties. By 2033 homes must reach a rating at least equivalent to an EPC band C.<br>▶ The development of planning policy to enable and encourage energy efficiency and low and zero emissions heating. | SG |
| Subsidies / tax reliefs to encourage investment in energy efficiency improvements and conversion to zero emissions heat technologies | ▶ Funding programmes to assist with the capital cost and running costs for both the public and private sectors (detailed overleaf).<br>▶ Introduction of the Non-Domestic Rates (District Heating Relief and Renewable Energy Generation Relief) (Scotland) Amendment Regulations 2021 providing a 90% relief from non-domestic rates until 31 March 2024 for new networks run from renewable sources. This goes beyond the existing 50% relief that is currently in place for heat networks. These regulations also provide for the 50% relief to continue until 2032.<br>▶ Introduction of tax relief measures towards the capital cost for the investment in low / zero carbon technologies. | SG / UKG |
| Deployment of zero / low emissions heat technologies (i.e. heat pumps and heat networks) | ▶ Phasing out of gas boilers and fossil fuel heating systems in on-gas areas by 2030 and in off-gas areas by 2025.<br>▶ From 2024, all buildings requiring a building warrant will need to use a zero emissions heat technology. | SG |

# Policy levers – The Heat Sector (cont.)



**Key actions of SG and UKG to achieve the decarbonisation of the heat sector (cont.)**

| Policy Lever | Examples | Primary Responsibility |
|---|---|---|
| Strengthening and identifying supply chain and skills needed to deliver energy efficiency and zero emissions heat | ▸ Work with the private sector to grow skills and supply chains to meet raising demand, which specifically focuses on the deployment of energy efficiency and zero emissions heat the Scottish supply chain. | SG |
| Raise public awareness of zero emissions heat technologies and energy efficiency measures, to reduce overall energy demand | ▸ Provision of advice programmes including Home Energy Scotland and Business Energy Scotland to inform the public.<br>▸ Establishment of a National Public Energy Agency to provide advice to consumers. | SG |

# Policy levers - Electricity Generation



**Key actions of SG and UKG to achieve the decarbonisation of the electricity generation**

| Policy Lever | Examples | Primary Responsibility |
|---|---|---|
| Subsidy support for renewable electricity generation | ► UKG has supported new generation assets through contracts for difference (CfD) mechanisms and these have proved successful and value for money in increasing low carbon power.<br>► This policy carries risk and will need to be adapted to deal with increasing potential for there to be zero-pricing for renewable energy when there is too much being generated for grid capacity, or in future years, for demand. | UKG |
| Other support for renewable generation | ► Supporting ScotWind process.<br>► Supply chain measures to ensure more content is produced in Scotland.<br>► Use of planning and other powers to support renewable generation where necessary. | SG |
| Support for dispatchable power / renewable dispatchable electricity generation | ► Mechanisms such as the capacity market to support dispatchable electricity generation required as renewables increase their proportion of overall generation.<br>► New support mechanisms may be required for low carbon dispatchable power and to encourage battery storage etc. | UKG |
| Support for the hydrogen industry / CCUS | ► The hydrogen industry will potentially support dispatchable renewable power, as well as a host of other decarbonising measures. This will require a support mechanism on both the supply side and potentially the demand side.<br>► CCUS can support low carbon hydrogen, as well as reducing emissions from gas-powered dispatchable generation that acts as a backup to renewables. | UKG |
| Grid improvement | ► Scottish renewables are held back by grid capacity and this means that renewable electricity generation is wasted and carbon emitted.<br>► If Scotland is to export more wind energy to the rUK and become a regional energy hub, sufficient grid capacity will be required to allow this to happen. | UKG / UK regulators |

# Policy levers - Industry



**Key actions of SG and UKG to achieve the decarbonisation of Industry**

| Policy Lever | Examples | Primary Responsibility |
|---|---|---|
| Regulation of gas and electricity networks (including the potential blending of hydrogen) | ► The potential use of blended hydrogen in the existing gas grid as a future heating fuel source.<br>► Increase the connection capacity to meet future demand on the electricity grid from the increased use of heat pumps and non-gas fuelled heat networks.<br>► Introduce regulatory framework for heat networks to ensure consumer protection and quality standards. | UKG / UK regulators |
| Regulation of energy prices | ► Mechanisms to restructure or rebalance the environmental and social levies that are added to electricity bills. | UKG / UK regulators |
| The regulation of heat networks | ► Introduction of the Heat Networks (Scotland) Act 2021 providing regulation for heat networks, intended to be implemented by 2024. However, the 2021 Act does not provide consumer protection powers as these remain reserved to UKG. | SG / UKG |
| Energy efficiency and building standards (including, the planning system) | ► The regulation of minimum EERs for both domestic and non-domestic properties. By 2033 homes must reach a rating at least equivalent to an EPC band C.<br>► The development of planning policy to enable and encourage energy efficiency and low and zero emissions heating.<br>► Through its planning framework, SG will look for opportunities to strengthen planning policy to enable and encourage energy efficiency and low and zero emissions heating. | SG |
| Subsidies / tax reliefs to encourage investment in energy efficiency improvements and conversion to zero emissions heat technologies | ► Funding programmes to assist with the capital cost and running costs for both the public and private sectors.<br>► Introduction of the Non-Domestic Rates (Scotland) Amendment Regulations 2021 providing a 90% relief from non-domestic rates until 31 March 2024 for new networks run from renewable sources. This goes beyond the existing 50% relief that is in place for heat networks. These regulations also provide for the 50% relief to continue until 2032.<br>► Introduction of tax relief measures towards the capital cost for the investment in low / zero carbon technologies. | SG / UKG |
| Raise public awareness of zero emissions heat technologies and energy efficiency measures, to reduce overall energy demand. | ► SG has a number of existing advice programmes Energy Efficient Business Support Service.<br>► Establishment of a National Public Energy Agency to provide expert advice. | SG |

# Policy levers - Industry



**Key actions of SG and UKG to achieve the decarbonisation of Industry (cont.)**

| Policy Lever | Examples | Primary Responsibility |
|---|---|---|
| Support and funding in industry | ▶ The IETF in the UK has assigned £315 million to aid businesses transitioning from high energy use to a low carbon future and decrease bills via increased efficiency. SG is engaged with UKG on the design of the fund for Scottish interests.<br>▶ UKG's Industrial Heat Recovery Support Programme (IHRSP) has £18 million assigned for match funding feasibility studies or capital projects.<br>▶ Engaging with UKG to support the placement of Scottish industrial operators to access Industrial Strategy Challenge Fund programmes in the areas of Decarbonising Industrial Clusters (£170m). | UKG / SG |
| Industrial decarbonisation as an economic investment opportunity | ▶ SG wants to support activity that incentivises investment in existing sectors, building on existing strengths. SG wants to secure investment in new manufacturing sectors attracted by a low carbon energy supply, new fuels such as hydrogen, the high skilled labour force, and the locational advantages that clustering and access to carbon capture utilisation and storage (CCUS) infrastructure can offer. | SG |

# Policy levers – Non-Energy Use in Industry



**Key actions of SG and UKG to achieve decarbonisation of non-energy use in Industry**

| Policy Lever | Examples | Primary Responsibility |
|---|---|---|
| Regulation addressing full lifecycle of petrochemical products | ▶ Continue with move away from single use plastics towards reusable plastics, e.g., plastic packaging tax.<br>▶ Mandatory recycled content requirements for all plastic products and packaging.<br>▶ Short-term support to kickstart the plastic reprocessing market to reduce exports of waste and keep plastics within UK circular economy.<br>▶ A fund to stabilise the market for companies investing in recycling plastic domestically. | SG / UKG |
| Regulation and subsidies around EfW plants | ▶ CCUS or similar carbon capture as part of EfW process. | UKG |
| Investment/subsidies in bio-alternatives | ▶ Research investment, subsidies for manufacturers. | SG / UKG |

# 7 Supplementary Analysis: Transport - Overview

# Transport – Introduction



## Introduction

This section will explore the key issues and drivers of fossil fuel consumption in the Transport sector. Transport includes the following subsectors: Cars, Buses, Rail, Vans, HGVs, Agriculture, Aviation, Rail and Domestic Shipping. Each subsector contributes differently towards transport emissions. For the purposes of this report all forms of road transportation have been grouped together in one section (with multiple sub-sections), leaving rail, aviation and shipping to be explored separately.

## Overview of O&G usage in the transport sector

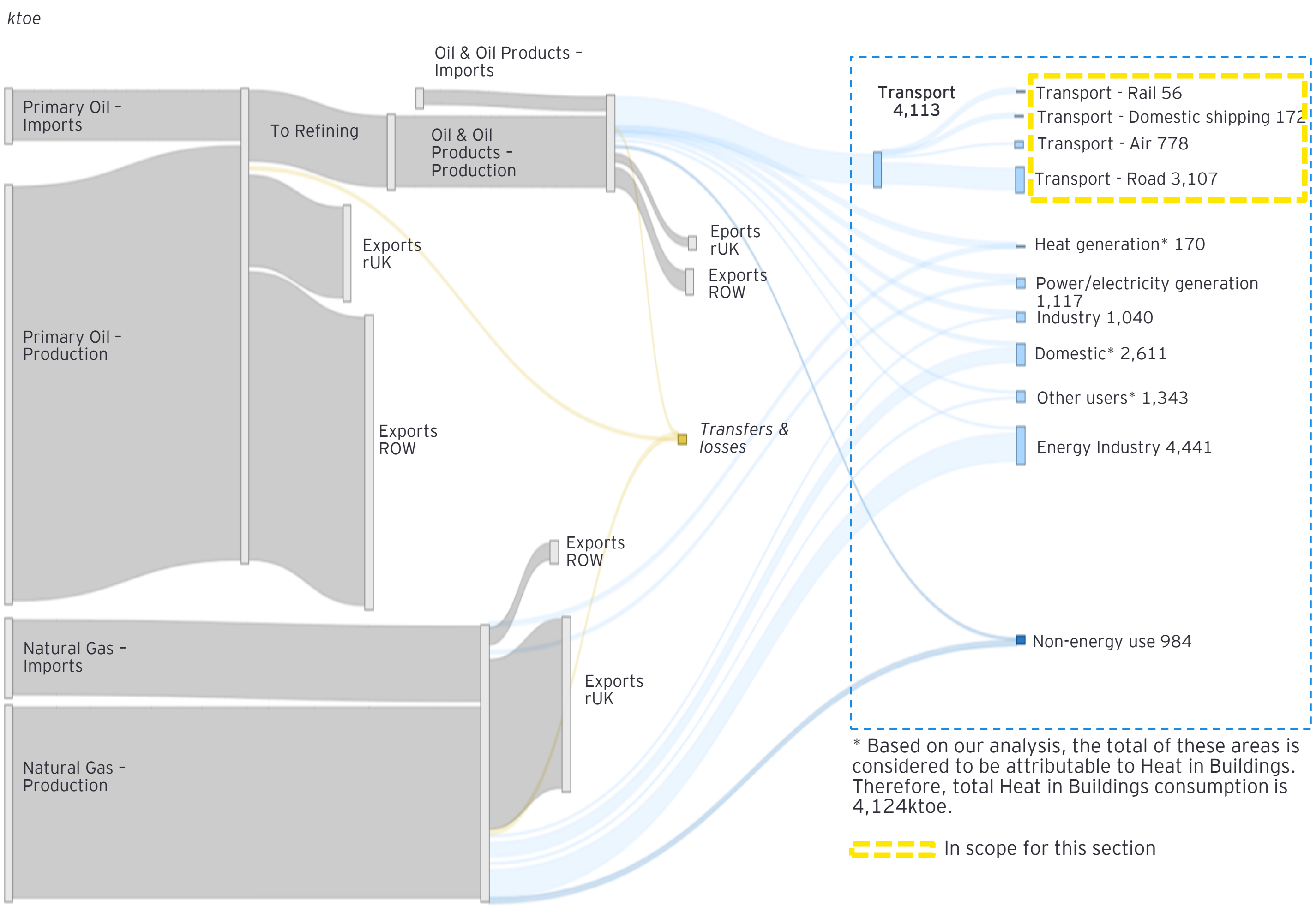
The Sankey diagram of Scotland's O&G production and consumption that we produced as part of our review of the Scottish O&G sector (Chapter 1) illustrates that the transport sector accounts for roughly a quarter of Scotland's total O&G consumption.

For over a century, the principal fuel source for the most heavily used forms of transport has been derived from hydrocarbons, whether in the form of petrol, diesel, kerosene or marine gas oil (MGO).

Demand for transport is created by the nature of Scotland's physical geography, its economy and its society. Where people live, work, learn and access goods and services are all key to the need to travel and have been shaped by decades of development and decisions, many of which were made in the context of plentiful oil use and without fully understanding its consequences for the environment.

As the Scottish economy has developed, demand for transport and the O&G to fuel it has grown as people and goods are moved at a greater volume and over longer distances.

## Scottish energy consumption overview




*Source: SG - [Physical commodity balances of oil, gas and petroleum products](#) [Digest of UK Energy Statistics (DUKES) 2021 - GOV.UK (www.gov.uk)](#) (commodity balances)*

# Transport – Introduction



## Transport growth over time – long term trends

The growth of Scotland's population and economy has been reflected in an increase in all the areas of transport considered in this report, with the exception of bus.

| | 2013-14 | 2018-19 | Variance |
|---|---|---|---|
| Car traffic (m/Veh km) | 33,811 | 36,413 | 7.7% |
| ScotRail Passengers (millions) | 86.3 | 97.8 | 13.3% |
| Bus Passengers (millions) | 421 | 380 | -9.8% |
| Air Passengers (millions) | 23.3 | 29.4 | 26.2% |
| Ferry Passengers (millions) | 9.7 | 10.3 | 6.2% |

*Source: Scottish Transport Statistics 2019 Edition, Transport Scotland*

The findings of the 2019 Scottish Household Survey indicated that most journeys were for the purpose of shopping (24%), commuting (23%), or visiting friends or relatives (10%). There has been little change in the proportion of journeys made for each purpose since 2012.

68% of people usually travelled to work by car or van, either as a driver (63%) or passenger (5%). 10% of people usually took the bus and 5% travelled by rail. 12% people usually walked to work in 2019, while 3% usually cycled.

The number of motor vehicles registered in Scotland (3.0 million) is at an all-time high – 12% higher than in 2008 – and the distance driven by motor vehicles on roads increased by 8% between 2014 – 2019 to reach 48.7 billion vehicle kilometres in 2019. There has been a steady increase in new vehicle registrations for cars, and especially light goods vehicles (vans) – the latter reflecting a growth in trades use and, in particular in recent years, the growth of home deliveries for internet shopping (which has accelerated in 2020-21 due to pandemic).

The area of transport that has shown the most dramatic increase in this timeframe is aviation – the low cost flight model and an increasing range of destinations available to Scottish passengers has seen air passenger demand grow dramatically.

## Transport and the Just Transition

A Just Transition offers an opportunity to build a low-carbon transport system that actively promotes equality, allowing people convenient access to services. High quality, affordable transport can enable people to access jobs, education and recreational opportunities. All of this would help build well-being and contribute to raising household income and lifting people out of poverty.

Scotland's National Transport Strategy (NTS) is designed to address this. It sets out a Vision for Scotland's transport system, that will help create great places – a sustainable, inclusive, safe and accessible transport system, helping deliver a healthier, fairer and more prosperous Scotland for communities, businesses and visitors. It is designed around four key principles – reduces inequalities, takes climate action, helps deliver inclusive economic growth and improves our health and wellbeing.

Access to transport has a direct impact on an individual's opportunities and their quality of life – it provides access to education, employment, healthcare and leisure activities.

It will be essential to ensure that people and communities are not left behind as we make the vital transition to net zero. Those who are less well off, or who live in more deprived areas, rely more on public transport, whilst people who live in rural or remote areas have little alternative to a private car. One size will not fit all and care will therefore be required. Therefore, when implementing solutions like smart innovations and modifications in transport, we must be aware that they may not all be universally accessible and therefore take care to avoid exacerbating existing inequalities.

Many measures that will reduce O&G use will have a positive effect on inclusion, ranging from addressing the health problems caused by air pollution to the way the current transport system can reinforce problems of social exclusion.

Social inclusion is a fundamental element of Just Transition. When we consider that 29% of Scottish households do not have access to a car and 24% of men, and 36% of women did not have a full driving licence in 2018, with licence ownership tending to increase with household income, it is clear that the priority that has been given to car users for many decades has excluded a significant proportion of the population – and the Just Transition is an opportunity to reverse this historic trend.

# Transport - Introduction



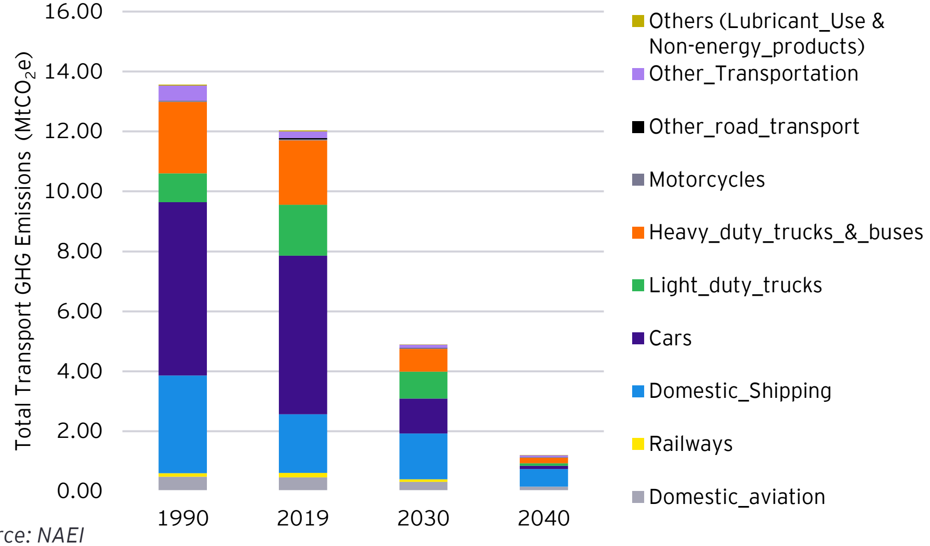
## Overview of emissions in the transport sector

Transport is Scotland's single biggest emitting sector, generating 30.6% of emissions in 2018. The current structure of Scotland's economy, both in urban and rural areas, means there are unique challenges to reaching net zero emissions in the sector. People will always need to move around and meet their daily needs, and significant changes across most forms of transport will be necessary to achieve net zero.

Analysis conducted for Transport Scotland highlights the scale of the challenge, but also the opportunity, faced by the country in order to achieve the target to reduce emissions to net zero by 2045, via interim targets of reducing emissions by 75% between 1990 and 2030 and 90% by 2040. To help reach the overall 2030 emissions reduction target of 75%, transport emissions are targeted to reduce by 56%.

The Element Energy Decarbonising the Scottish Transport Sector study found that emissions from domestic transport had fallen by 2-3% since 1990, with improvements in vehicle efficiency having been offset by increasing demand.

**Total Transport emissions**




*Source: NAEI*

Bus and coach emissions have fallen as engine technology has improved, and those from rail are comparatively small in the overall picture. The relatively small emissions from these highlight the opportunity offered by modal shift to public transport, where existing spare capacity could be filled with limited associated increased fuel use.

The analysis showed that the largest proportion of emissions comes from road transport. Despite the significant improvements in engine efficiency over the past three decades, emissions generated by cars has not changed significantly in that time due to the increase in car use, although the recent increase in the demand for zero and low emission vehicles is starting to change that. A similar story applies for HGVs, while emissions from vans in particular have increased significantly, reflecting their increasing use in transport fleets, use by trades and, most recently, significant growth in the home delivery market.

Emissions from domestic shipping are a significant proportion of total transport, and relate to freight as well as ferry services. Much of that freight shipping represents the movement of fossil fuels, so demand is closely linked to the O&G industry. The Element Energy study found that emissions have shown a reduction over time, which is consistent with the reduction in domestic freight demand.

The area of transport that has shown the most dramatic increase in this timeframe is that of international aviation – emissions relating to this increased by over 40% as the low cost flight model developed and the range of destinations available to Scottish passengers grew dramatically.

## Scope of this report – domestic transport

The scope of this report focuses on Scottish domestic transport, i.e. journeys that start and finish within Scotland, given SG can exercise significant policy influence over these. International aviation and shipping are international commercial markets, and even where SG had the appropriate devolved powers to take strong action, unliteral action could just lead to a shift in the associated trade to other regions.

Our focus is also on Scotland's consumption of hydrocarbons; so the embedded emissions inherent in the manufacture of an imported vehicle are not considered in our assessment.

# Transport – Introduction



### Key decarbonisation challenges facing the sector

The two key levers to deliver a decarbonised transport sector are the introduction of zero-emission vehicles and changes in transport behaviour. Across the sector, these present a range of consistent challenges to plans for decarbonisation:

- **Readiness of technology** – The technologies necessary for zero-emission vehicles are developing very quickly. Some likely solutions, such as in aviation and shipping, are however, still some years from widescale realisation. In those areas where the technology is commercially available, such as Electric Vehicle (EV) cars, some buyers perceive risk associated with being an early adopter: high capital costs and the need to adapt to the needs of the technology, though this is quickly reducing.
- **Availability of infrastructure** – As with all new technologies, investment is required, over time, to build out the necessary supporting infrastructure for zero emission vehicles, whether that is EV charging stations, the strengthening of the National Grid required to carry the charging load for the numbers of EVs required, or the production, storage and distribution facilities necessary for green hydrogen's use as a fuel at a commercial level.
- **User behaviour** – Analysis consistently indicates that changes in the way people travel will be needed – in particular, major modal shift to more efficient transport modes, such as buses, rail and active travel modes, as well as a significant reduction in transport demand.
- **The need for a Just Transition** – SG has set out the clear need for a Just Transition, meaning that the move to a greener Scotland should be fair for all the people in Scotland. It should ensure equal access to zero-emission vehicles and deliver decarbonisation in all areas fairly so that no sector or users are unfairly burdened by the associated cost.

### Pathways to decreased hydrocarbon use

Change is already happening. Increased awareness of the climate emergency has led government, local authorities, companies and individuals to take steps to address the issue. Decarbonisation is built into government and corporate strategies, including many that would bring wider benefits such as improved quality of life, reduced noise and air pollution, increased physical activity, reduced inequality, and strengthened communities. Tackling O&G dependency will go hand-in-hand with substantial improvements across society, for government, businesses and individuals, with benefits to health, wellbeing and the economy.

SG has set out its NTS over the next two decades, making climate action a core priority. It acknowledges that, whilst technological advances to bring low or no emission green vehicles into use in Scotland will be important, managing transport demand and embedding behaviour change will also be vital. The demand for less sustainable transport modes must be reduced, while promoting and facilitating active travel and modal shift to more sustainable modes.

Aligned to this, SG has outlined a variety of measures which promote a place-based agenda and support localism, such as the 20 minute neighbourhood concept. Among the benefits of this approach is to increase proximity of where people live, work, learn and access goods and services, reducing distances travelled and the need to travel unsustainably. The National Planning Framework (NPF) aims to accelerate emissions reduction, including by directing future development to the right locations reducing transport demand.

The Covid-19 pandemic and associated lockdown showed that demand reduction is possible in many commuting flows through working from home and flexible working.

Certain modes – HGVs, shipping, aviation – require particular investment and focus, given that the technological solutions to manage emissions are in earlier stages of development. Considerable further innovation is required to bring them to market, and the scale of Scotland's transport emissions mean that these changes need to happen for Scotland to reach the target of net zero emissions by 2045.

### Next Steps

On the following two pages, we look ahead to approaches to reduce the consumption and impact of land transport using ESC modelling. As we described in the introduction, SG and the CXC commissioned ESC to develop a set of Scotland-specific whole energy system scenarios. These scenarios demonstrate four qualitatively different routes for Scotland to meet its emissions reduction targets, allowing different choices and potential implications to be explored. The outlook for the transport sector are summarised overleaf.

# Transport Consumption - Results of the Catapult modelling



## Future consumption - ESC model

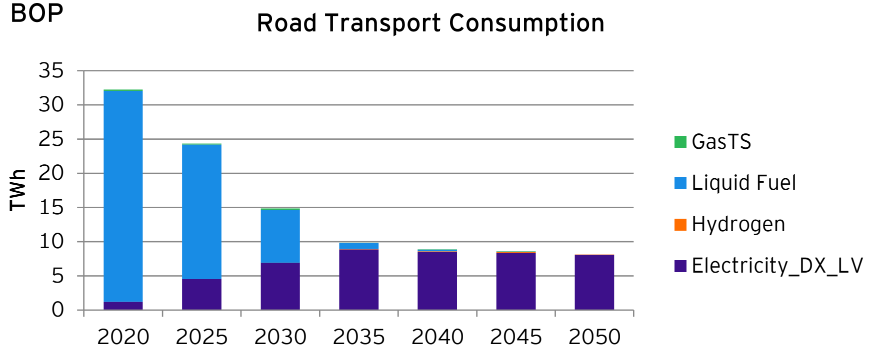
As set out on the previous page, an ESC model has been built to include future demand scenarios specifically for the transport sector. The ESC model forecasts:

- Aviation is a difficult area to decarbonise and there are few suitable technology options for maritime decarbonisation before 2045, the catapult model focuses on the decarbonisation of land transport through electrification.
- The ESC model assumes that 2020 road transport demand is between 31.0 TWh (Societal Change (SOC) scenario) and 32.2 TWh (BOP). Across all the scenarios, the transition to more efficient EVs from ICEs is projected to cause a significantly reduced total energy demand, with the forecast differing under each of the three scenarios, largely as a result of the extent to which societal changes cause reduced car use:
  - The BOP scenario forecasts a fall in overall energy demand to 14.8 TWh by 2030 and 8.1 TWh by 2050.
  - The Technology (TEC) scenario forecasts a similar fall, to 14.9 TWh in 2030 and 9.1 TWh in 2050.
  - The SOC scenario forecasts demand falls faster, to 12.3 TWh in 2030 and 7.7 TWh in 2050.
- The ESC model forecasts that in each scenario road transport will largely be decarbonised as ICE vehicles are replaced by EVs, driven by the ban on new sales of ICE cars and vans in 2030 and 2035 respectively.
  - For example, in the BOP scenario liquid fuel demand falls to 7.8 TWh in 2030, falling to 0.2 TWh in 2040 and 0.0 TWh by 2050.
  - The TEC scenario has liquid fuel demand down to 6.5 TWh in 2030, falling to 0.4 TWh in 2040 and 0.0 TWh by 2045.
  - In the SOC scenario, liquid fuel demand for road transport falls faster, to 4.8 TWh in 2030 and 0.0 TWh achieved by 2035.

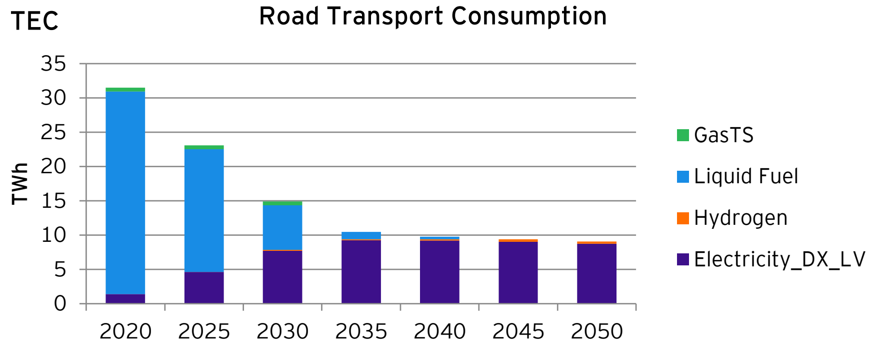
**Key conclusion**

The Catapult model shows significant reduction in energy demand for road transport, driven by the ban on new sales of ICE cars and vans and the greater efficiency of EVs compared to ICEs.

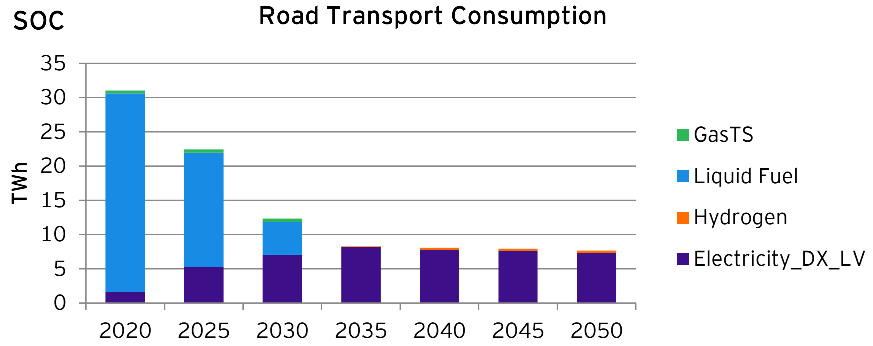
BOP




TEC




SOC




*Source: ESC, BOP, TEC, SOC Core Charts*

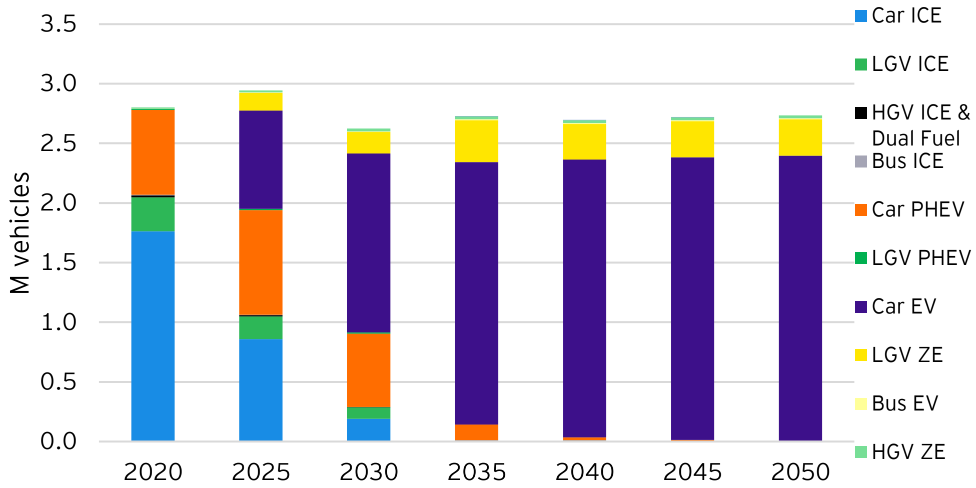
# Transport – Technology; Catapult modelling



## Technology mix

- The reductions in O&G consumption and emissions in the Catapult model are driven by the assumption that road transport will be decarbonised largely through electrification. Technological advances in relation to EV battery range (and, importantly, public perception about battery range) are expected to lead to an increasing demand, while the ban of new sales of ICE cars and vans in 2030 and 2035 respectively will cause ICEs to be removed from use.
- After the 2030 sales ban, it is assumed that, whilst all new cars will be EVs, ICEs will remain in use for some time. Plug-in hybrid vehicles (PHEVs) will also continue in use, although a ban on new PHEV sales is assumed from 2035.
- Further reduction in demand for ICE (and EV) use is assumed in the BOP and SOC scenarios also assume some behavioural change on the part of the public. For example, SOC assumes a 20% fall in miles travelled by car by 2030 relative to 2019 (pre-COVID) demand. Along with the 2030 ICE ban, this means that car travel is entirely decarbonised by 2035.
- In terms of other road traffic, the Catapult model assumes that new buses will be zero emission from 2025. For HGVs, the model assumes that by 2035 the majority of HGVs will be full electric, but with some using hydrogen in a fuel cell to extend the range of the battery. Agricultural vehicles and other heavy-duty vehicles are also expected to be electrified.
- The Catapult modelling regards Shipping and Aviation as slower to decarbonise. It assumes that there are few suitable technology options for maritime decarbonisation before 2045, when shipping is able to reduce emissions substantially using hydrogen, in the form of either stored hydrogen or ammonia.
- Within the aviation modelling the only available decarbonisation option is to replace old, inefficient aircraft with more fuel efficient ones, and in the SOC scenario, the Scottish people's heightened engagement with the climate agenda sees demand for air travel decline.
- The Catapult assumptions broadly align with the findings of Chapter 2, with road transport representing the area where the combination of scale and technological readiness means action can be most immediately effective. It also shows the benefits of demand management/modal shift to decarbonise public transport and active travel in providing headroom in the energy system.

**Road Transport Fleet - BOP scenario**




*Source: ESC, BOP Core Charts*

### Conclusion from the modelling

- The Catapult modelling indicates that the decarbonisation of road transport, in particular through the large-scale adoption of battery EVs, is key to delivering Scotland's net zero targets. The lower energy demands assumed in the SOC scenario also highlight the benefits demand management and modal shift can deliver by making targets achievable with lower amounts of engineered $CO_2$ removal. With relatively low reliance on hydrogen use, it also suggests that decarbonising transport is not hydrogen-dependent.
- It highlights the need for a concerted effort to encourage people to buy EVs (by alleviating concerns about battery life and range, providing evidence about lifetime of second-hand EVs and ensuring necessary infrastructure exists and is easy to find) and preventing a rush to purchase ICEs before the ban by 2030.
- The impact of demand management and modal shift shows the benefit of promoting improved public transport, active travel infrastructure and options, and other alternatives delivered by technology (e.g. hybrid working, e-bikes, etc).

8

# Supplementary Analysis: Transport - Road Transport

# Road Transport - Introduction



## Road transport and demand for fossil fuels

Road transport in 2019 accounted for c77% of total domestic transport emissions in Scotland, and 20% of Scotland's total emissions due to road transport's almost complete reliance on O&G, dominated as it is by vehicles with ICE using petrol and diesel as fuel.

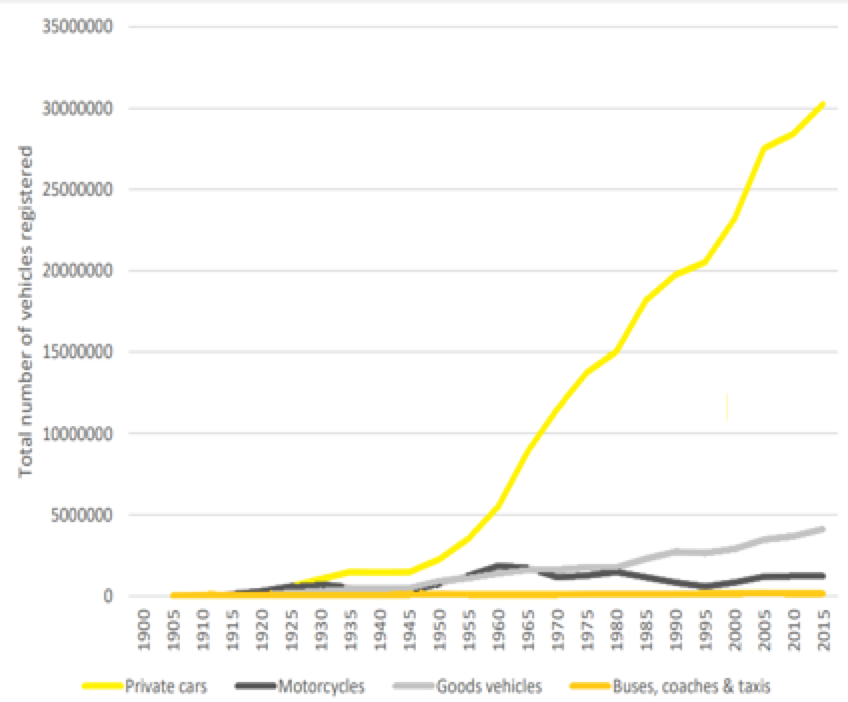
### ICE's advantage

ICE vehicles currently represent by far the largest share of road transportation, although this was not always the case. As mechanically driven vehicles were invented to replace horse power in the early 20th century, BEVs and steam powered vehicles were developed alongside ICE vehicles. However, the ICE's superior range, convenience, efficiency and relative affordability overcame its challengers and it became the standard technology.

As demand grew, a network of supporting infrastructure, from filling stations and refining facilities to car manufacturers, was developed by the private sector. In the post-WW2 years, demand started to grow dramatically as economic growth brought cars within more people's reach and stimulated the motoring industry.

Successive governments added to a transport network that focused on road transport, developing a motorway and truck road network that facilitated fast and convenient travel for motorists and commerce – by 1970 HGVs accounted for c80% of freight tonnage carried by road, as the convenience of door-to-door transport grew. HGV use was also stimulated by international trade, as trade with and access to continental Europe grew with roll-on/roll-off ferries and the interchangeability of shipping containers with HGVs developed. ICE HGVs now offer logistical and cost advantages, and are embedded in all aspects of the economy. Over time ICE vehicles have continued to become more affordable, through both the relative reduction in price at which a vehicle can be purchased and the availability of vehicle financing. The relative cost allowed unprecedented access to private transport and private vehicle ownership increased dramatically. It has continued to show an upwards trend - car ownership in Scotland specifically increased by c1m cars from 1993 to 2019.

### Motor vehicles registered in UK by type, 1905-2015




*Source: UKG for science – the history of transport systems in the UK*

**Key conclusion**

Alternate technologies to ICE, such as BEVs and steam power, have always been available, but the convenience, efficiency and range offered by the ICE made it the preferred technology. Transport planning focused on the road network, cementing the position of ICE and O&G as the most prominent power source of transport.

# Road Transport - Introduction



## Planning for roads

In the years post-WW2, public policy increasingly favoured the expansion and improvement of the road network, building on the economic growth and demand for transport among individuals. From the 1960s until 1997, UK transport planning operated under a 'predict and provide' model, which forecast increasing road transport demand and sought to provide for that. This model favoured the private car, as roads were built to link new areas to old, and the preferred solution for congestion was adding more road space. Planning policy assumed households could have access to a car, and built this assumption into how towns and cities were designed. The 1997 'New deal for transport' white paper signalled that 'predict and provide' was unsustainable, and was to be abandoned, but by then, road use was designed into many people's everyday lives.

## Disinvestment in alternatives

As the advantages of the road network and the private car increased, alternatives became increasingly unattractive.

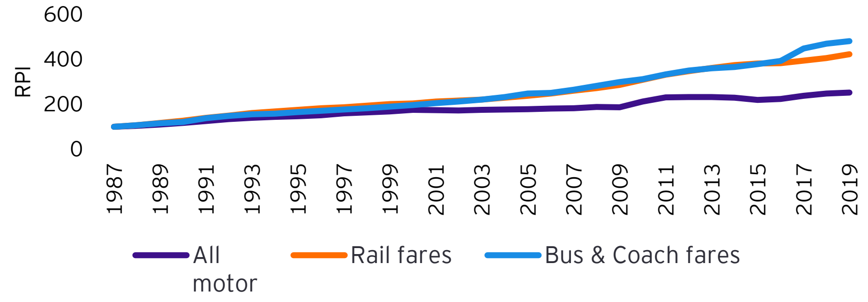
A long period of managed decline in the railways, most prominently following the Beeching report, reduced their attractiveness. Bus patronage fell as the relative cost of driving reduced, and people preferred the comfort and convenience of their own vehicle. This led to reduced service levels that in turn reduced utility and further reduced bus patronage. Bus travel also suffered from sharing road space with cars, as increasing car use increased congestion, making buses slower and less reliable. The attractiveness of active travel such as walking and, in particular, cycling was also adversely affected by increased car numbers and their impact on road safety.

The cost of public transport has increased relatively to the cost of private road transport. Bus and coach fares and rail fares has increased at a quicker rate than of private road transport costs, further reducing the appeal of public transport.

**Key conclusion**

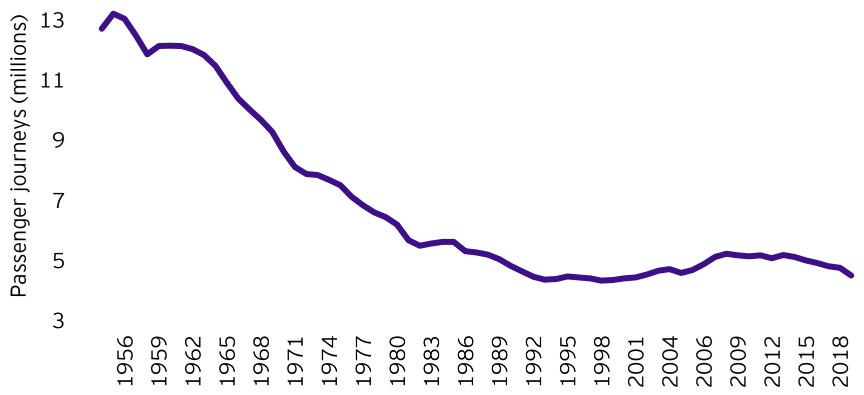
For an extended period of the 20th century, Government transport policy favoured road transport. As it becomes the embedded norm, it is increasingly the most convenient mode of transport, and with the increased use of ICEs came a growing reliance on O&G.

**Relative costs of transport - transport components of RPI**




*Source: DFT = TSGB1308*

**UK local bus service passenger journeys**




*Source: Gov.uk BUS0101*

# Cars - Drivers of demand

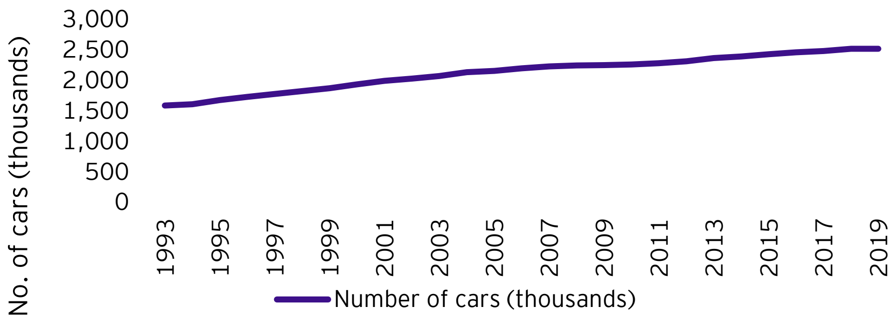


### Drivers of demand for cars

Car vehicle miles have increased steadily from 1994 to 2019, and the number of cars registered in Scotland has increased from 1.6m to over 2.5m. Despite the growth in the number of cars, the petrol and diesel fuel used in 2019 (1.85m tonnes) is similar to the total used in 1994 (1.84m tonnes) and the average use per car over the period has fallen by 41.5%. This growth in car demand reflects a number of advantages, both actual and perceived. Cars offer:

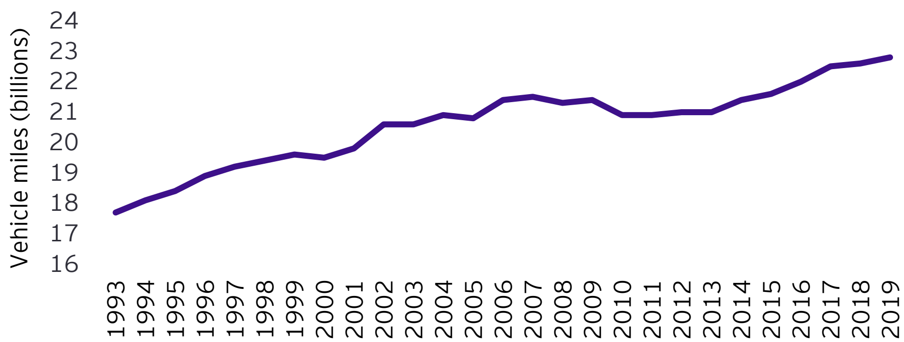
- **Convenience**: Cars makes travel more flexible and convenient as journeys are not tied to public transport scheduling, which is often seen as infrequent, inflexible and expensive. As commuting has grown and people now live further away from their places of work, driving has become the easiest and most comfortable means of transport for many. Indeed, for many people it is the only practical means of transport.
- **Comfort and safety**: Vehicles have increased in size. The AA reviewed the car sizes of six car models, the Mini One, Fiat 500, Toyota Corolla, VW Golf, Ford Fiesta and the Porsche 911 comparing the size of the initial models of each to those offered to customers in 2018. The AA found that there was an average car area increase of c35%. Larger cars have become more popular, partly as they are perceived to be safer.
- **Relatively low cost per journey:** In whole life cost, taking into account capital costs and overheads, cars tend to be more expensive than public transport use; however, the cost of motoring relative to public transport has been falling and cars are now more affordable than they have been at any time since the late 1950s. The incremental cost of a single journey is substantially lower by car - the growth in size of cars has been offset by an increase in ICE engine efficiency.
- **Readily available financing:** A sophisticated car financing market has made the capital cost of motoring affordable across a range of income levels.
- **Societal and cultural factors:** The car has become a status symbol for many, with the type, age or cost of a car indicating the social and financial position of the owner. They also provide a comfortable, private space in which to travel. However, there appears to have been a decline in young adults driving cars in recent years, with motivations for this shift including the rise of ride-sharing apps (e.g. Uber), increased awareness of climate change, and the impact of Covid.
- **Necessity:** Notably, vehicle ownership per head is higher in rural areas. Orkney and Shetland for example had 945 and 922 vehicles per 1,000 people aged 17+ respectively in 2019, and 84% of adults living in 'Rural remote' areas held a full driving licence in comparison to 63% of adults living in large urban areas.

**Number of cars - Scotland**




*Source: Government statistics veh02-licensed cars*

**Car vehicle miles - Scotland**




*Source: DfT statistics*

# Cars – Hydrocarbon usage and emissions



## Hydrocarbon usage

Cars have a high reliance on hydrocarbon fuels, predominantly petrol and diesel.

Diesel and petrol use is similar for cars in Scotland, with c0.933m tonnes of diesel being consumed in 2019. c0.918m tonnes of petrol was used by Scottish cars in the same year. Other hydrocarbon fuel usage, such as liquid petroleum gas (LPG), is not significant relative to petrol and diesel.

The only significant change in car fuel usage over the last 30 years is that petrol use has declined while diesel use has increased, following UKG's changes to diesel VED rates in 2001. As both are hydrocarbon fuels, this has not led to wholesale changes within vehicle infrastructure or technology, and both are widely available. Notably, BEVs have recently been penetrating the market at pace, and it is likely that in the near future there will be a reduction in usage of petrol and diesel fuel due to the increase in electric usage. As part of the UKG's delivery plan to transition to zero emission cars and vans by 2035, the sale of new diesel and petrol cars is to be banned by 2030, further contributing to the reduction in petrol and diesel fuel usage as UKG encourages a transition to ZEVs.

## Emissions

Cars accounted for c5.28Mt$CO_2$ of all transport emissions in Scotland in 2019. Cars are the biggest emitter on the road, reflecting their high number and usage. They represent nearly 44% of Scottish transport sector emissions, and 11.5% of total Scottish emissions.

Both diesel and petrol perform similarly in emission terms – data from the EEA showed 2019 $CO_2$ emissions from diesel cars (127g $CO_2$/km) to be similar to that of petrol cars (127.6g $CO_2$/km). Car users switching from an ICE fuelled by either fuel to a ULEV would therefore offer significant carbon reduction.

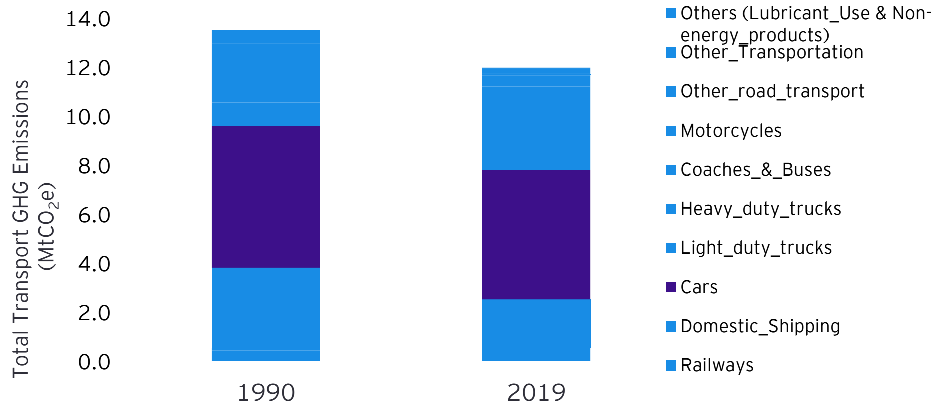
## Efficiency and other factors

As set out above, the emissions from cars has remained constant between 1990 and 2018. There have been major improvements in efficiency since 1990 (including the deployment of hybrid technology and more recently PHEVs), which has allowed emissions to remain constant while mileage has increased.

However, the efficiency gains have been offset by the development of larger, more powerful, and heavier cars, and by consumers choosing to buy these vehicles. The average 2019 emissions set out above (c127g $CO_2$/km) are higher than the available fleet: there have been vehicles available below 100g $CO_2$/km for some time and versions of larger vehicles that emit well below 127g $CO_2$/km. This has meant that no reduction in hydrocarbon usage has been achieved.

The International Energy Agency (IEA) estimates that between 2010 and 2019, 40% of efficiency gains in Europe have been offset by larger and more powerful vehicles (IEA Tracking Report: *Fuel consumption of cars and vans*, 2021).

### Cars as part of total domestic transport emissions




Source: *National Atmospheric Emissions Inventory (NAEI) UK data*

**Key conclusion**

Users view cars as convenient, comfortable and safe, and for many it is the only practical means of transport. The public transport alternative, where it exists, may take longer and cost more in incremental terms. As a result, cars dominate the transport landscape, accounting for 44% of transport sector emissions. A future increase in electric usage will contribute to a reduction in transport sector emissions.

# Cars – Readiness of alternatives



## Readiness of alternatives

Zero emission technology for cars is better developed than in any of the other road transportation sub-sectors. Several hybrid technologies are available that utilise both hydrocarbons and electric battery technology, but in recent years the car industry has scaled up production of zero emission technology, such as BEV and FCEV, with these vehicles commercially available to consumers.

The market has largely settled on BEVs as the future of zero emission car technology; however, in the longer term, FCEVs may become more important depending both on Scotland's progress in becoming a leading hydrogen supplying nation and the potential limitations in battery manufacture. In addition to UKG committing to end the sale of ICE cars by 2030, several car manufacturers have confirmed dates from which they will only produce BEV cars, while others plan to increase their production. For example:

- Volvo is aiming to phase out new petrol and diesel cars by 2025, then spending the next five years phasing out hybrids to become 100% BEVs by 2030.
- BMW plans to have delivered over 2m BEV cars by 2025, and by 2030 plans for half of all its car sales to be BEVs.
- Ford is investing $22bn through 2025 to deliver BEVs.
- Jaguar Land Rover and Bentley both plan to only produce BEV cars by 2030.

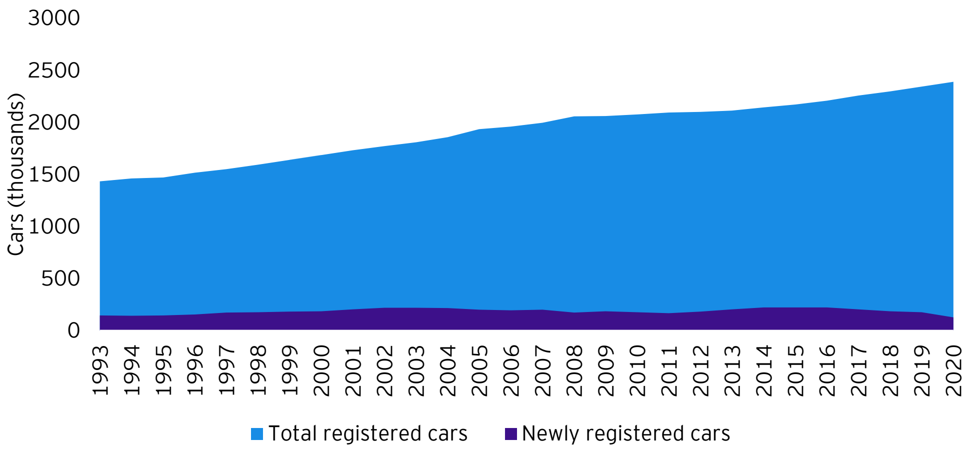
Zero emission cars are already in operation in Scotland and in 2021, per UKG vehicle statistics, there were 22,555 registered BEVs. The number of registered BEV cars in Scotland has been increasing from 2012, conveying the increased appetite of consumers for BEV technology and its increasing affordability and availability.

However, the number of registered BEVs in Scotland remains insignificant to both the number of cars registered (over 2.5m) and newly registered (c180k) in Scotland. The composition of Scotland's car fleet will gradually change with the purchase of new vehicles reflecting the gradual growth in sales forecasted in DfT's 'Transitioning to zero emission cars and vans: 2035 delivery plan' and the removal of ICE vehicles through the typical scrapping process.

**Key conclusion**

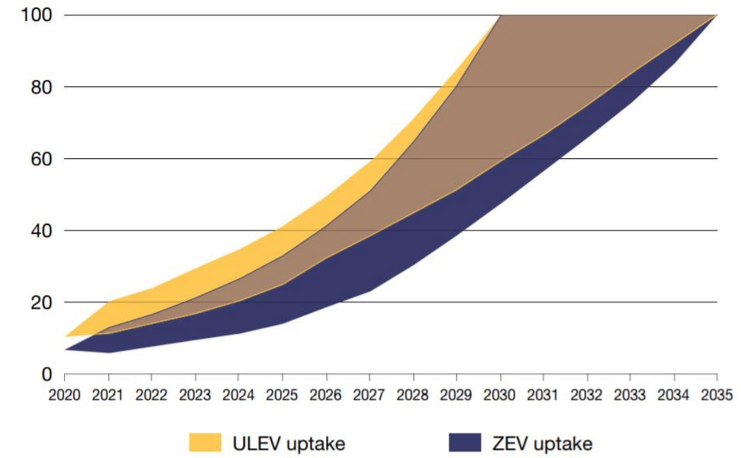
BEV technology for cars is commercially available and will come to dominate the car market in the medium term. However, it will take time for the diesel and petrol cars that currently dominate Scotland's fleet to fall out of use.

### Newly registered cars v total cars - Scotland




*Source: Scottish transport statistics & 2021*

### Percentage of new car sales accounted for by ULEV and ZEVs




*Source: DfT's Transitioning to zero emission cars and vans: 2035 delivery plan*

# Cars - Financial barriers



## Barriers to take up of new technology

The transition from O&G to BEVs presents many opportunities for Scotland, including the upskilling of existing O&G workers to strengthen Scotland's position within renewable supply chains, including BEV battery manufacture. However, despite the readiness of the technology, there are still both financial and non-financial barriers to the take up of zero emission technology. After decades of ICE vehicle use, this shift presents a significant change which will need to overcome considerable inertia.

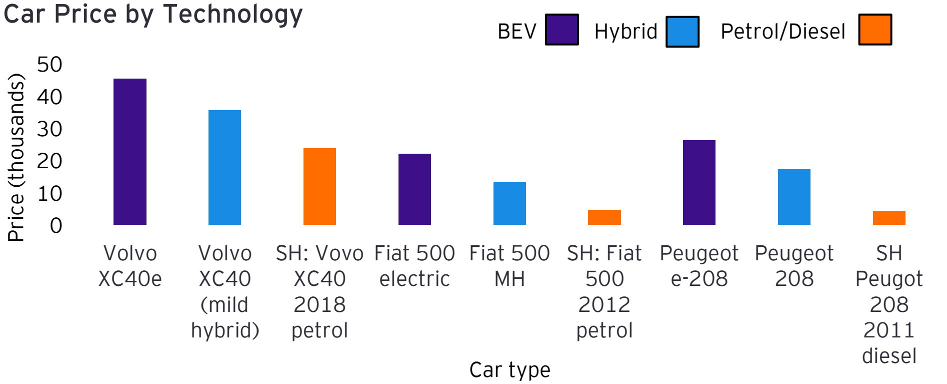
## Financial barriers

The purchase price of BEVs has decreased over time, however, in addition to the capital cost of the vehicle, running costs and the costs of infrastructure are also important to consider.

### Vehicle price

At current prices, the initial purchase price of a BEV is significantly higher for the consumer than the equivalent ICE vehicle. We sampled the prices of three different car manufacturers who sell BEVs and mild hybrid ICE versions of the same car models. In each example, the BEV was more expensive than the equivalent mild hybrid ICE model and the second hand equivalent was considerably cheaper.

**Car Price by Technology**




*Source: Arnold Clark*

The sunk costs of buying a new car and the reduction in its value as a second hand vehicle acts as a brake on mode shift as it can cause consumers to retain their vehicle in order to "get their money's worth".

Further, as BEVs are still relatively new, the second-hand market is limited and as such there is no lower price point of entry. Used cars reduced the price significantly, with savings of £12k, £9k, and £13k when compared to the ICE models respectively. This may restrict take up of BEVs for many consumers who prefer not to pay the premium associated with a new car.

### Running costs

BEVs are currently cheaper to fuel than ICE vehicles. When comparing the Fiat 500 petrol to the BEV fiat 500 over 100 miles, assuming a cost of 29p per kilowatt hour
(kWh), and £1.60 per litre of petrol, the BEV Fiat makes a saving of 7p per mile. Assuming an average annual travel distance of 10,000 miles, the BEV would save £700 per year in fuel costs. However, we note the volatility of energy prices, which make it difficult for the consumer to forecast future running costs with certainty.

Research undertaken by the Energy Saving Trust on behalf of Transport Scotland conveys a TCO comparison between diesel and electric vehicles. The TCO includes efficiency of the vehicle, depreciation, repair and maintenance costs and less significant factors such as tax for vehicles owned over an eight year lifetime. The research states that at lower mileages, the TCO is higher for BEV cars than ICE cars, however, at an annual mileage of c8,000 (the average mileage per car in 2019 was c8,900 miles) a BEV car would break even with the equivalent ICE car and at greater mileage than c8,000 the BEV car would have a lower TCO.

**Key conclusion**

BEV cars have lower running costs than ICE cars, but the high purchase price puts them out of reach of many households. The TCO of BEV cars is lower than ICE cars at annual mileages greater than c8,000 miles, this is less than the average mileage per car in 2019.

# Cars – Financial barriers



### Road and Fuel tax

Fuel duty on hydrocarbon fuels generated c£28bn for UKG in 2019, and for petrol and diesel, fuel duty was charged at 57.95p per litre. Electricity currently has no fuel duty rate, further pure electric vehicles attract a zero first year VED rate. Significant savings can be made by the consumer in road and fuel tax when driving a BEV.

### Other cost considerations – battery replacement

The batteries used in BEVs have a finite life. Manufacturers tend to provide, on average, a five to eight year warranty on electric car batteries; whilst EDF Energy predicts that an electric car battery should last between ten and twenty years. However, when they do need replacing, batteries will represent a significant outlay for the car owner. Buyacar estimate that a replacement Nissan Leaf battery costs upwards of £5,000.

Despite the advances in battery pack technology, and the ability to utilise economies of scale, the rising raw material prices and supply chain constraints may prevent a reduction in battery prices in the medium term. Scotland can transition the existing O&G workforce towards opportunities relating to battery manufacture.

Transport Scotland statistics for 2020 showed the average age of cars in Scotland to be 7.6 years, with many cars much older than that. As a result, buyers in the second-hand market would need to consider this additional cost, which may restrict BEV take up for lower income consumers.

**Key conclusion**
The second-hand BEV market is currently limited, and continuing uncertainty around battery life and replacement costs may act as a further brake on the second-hand BEV market.

# Cars - Non-financial barriers



## Non-Financial Barriers

### Refuelling and Associated Infrastructure

In the AA's October 2020 survey, 49% of respondents said they would consider buying an electric car when they next changed car. Of those who said they would not consider buying an electric car, the opinion that charging takes too long was cited by 70% of respondents and 52% were concerned about the national grid being unable to cope. Research suggests that volatile and high hydrocarbon fuel prices are drivers that influence consumer appetite for BEVs. ICE vehicle sales are allegedly four to six times more sensitive towards fuel prices than that of BEVs, suggesting that as fuel prices increase, BEVs become more appealing.

A rapid charger (50kW) can take up to 60 minutes to charge a car to 80% capacity. Further, it takes 35 minutes to add up to 100 miles of range. A stark contrast to the minutes that it takes to refuel an ICE car. The behavioural change required of users changing from ICE to BEVs adds to the inertia that may slow take up.

### Range Anxiety

Despite improvement in vehicle range, this is another common concern cited by drivers in relation to BEV technology. BEV cars' range on a full charge is lower than that of equivalent ICE vehicles with a full tank. The average BEV car per SMMT can travel 260 miles on full charge. In contrast, EY analysis finds that the average sized ICE car with a 45 litre fuel tank would travel between 356 and 425 miles, depending on whether it was a petrol or diesel car. It is likely that the range of BEVs will increase as BEV technology improves.

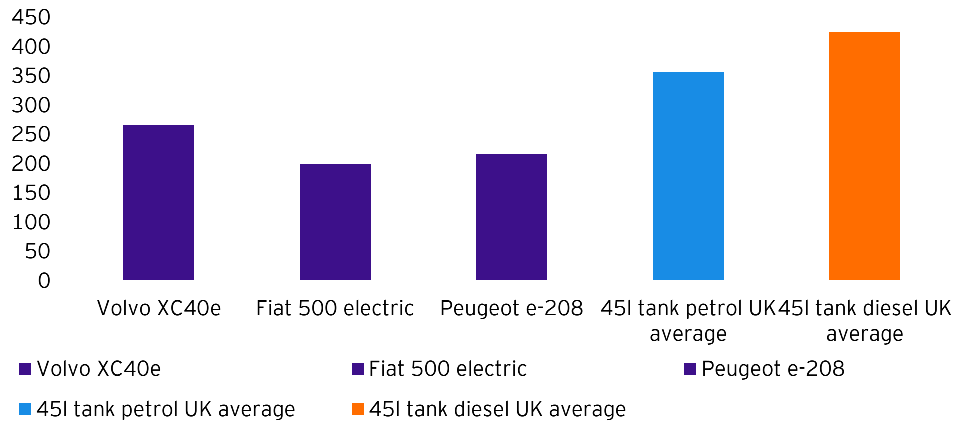
There are a range of factors that can reduce the attractiveness of BEVs for potential purchasers, who worry about the extent of route planning and organisation required for longer journeys. For example, concerns about the availability of a charging point on a long journey (with far fewer places available to recharge than petrol stations), the reliability of those chargers and the length of time to charge the vehicle all play a role. Per Transport Scotland, was 6.8km, and therefore, these concerns, although valid, likely do not apply to the journeys drivers take most frequently.

### Vehicle availability

Transport & Environment's 'Electric Surge' report estimates that c2.5 million BEV cars will be produced in Europe by 2025, meeting only 13% of European BEV car demand. To put this production in context, in 2019 in Europe, per ACEA's 'vehicles in use report' there were c243m registered cars.

In 2019 there were 2.52m cars registered in Scotland. There will be challenges in ensuring there are enough BEVs available to the Scottish market to fulfil the transition to net zero at pace.

### Car Range by fuel type




*Source: Arnold Clark*

**Key conclusion**

Refuelling of BEVs currently requires users to carry out significantly more forward planning than for ICEs and when combined with the lower range of BEVs relative to ICEs, this reinforces the inertia of drivers staying with the cars types they are comfortable with. Confidence in BEVs and recharging can be expected to grow as they become more common, but there is a risk that BEV manufacturing will not meet demand.

# Cars – Availability of infrastructure



### Availability of infrastructure

In addition to the costs relating to vehicle price and battery replacement, significant infrastructure costs need to be incurred to rollout zero emissions technology.

### Charge point cost

The infrastructure required to support charging BEVs is different to that of ICE vehicles. Charging a BEV takes time and as such charge points need to be installed that will allow a BEV to park and charge for a period of time. Charge points can offer different speeds of charging, with 'rapid charge points' offering the quickest charge times.

Charge points can be installed at home and for public use. A sizeable amount of Scotland's housing stock in cities comprises in multi-occupancy buildings, such as tenements, which do not have sole access to the ground level in front of their home meaning they will be unable to rely on off-road, private charging facilities. This places greater emphasis on the need for public facilities.

ChargePlace Scotland, Scotland's national EV charging network owned by SG, have already installed c2.5k publicly available charge points in Scotland. The CCC has estimated that c280k publicly available charge points will be required across the UK by 2030, which implies a Scottish total of c30k. Assuming 4,000 publicly available charge points are required annually at an average cost of £15k-£20k then the required annual investment would be c£60m-£80m.

The capital cost of each charge point varies depending on the speed at which they charge, c£5k for slow charging up to c£40k for rapid charging. This suggests a total cost not including the cost of servicing of c£687.5m for public electric vehicle charging in Scotland by 2030.

### Barriers to private investment

As at Sept 2021, around 1,000 of ChargePlace Scotland's charging points were tariff free. Whilst this has been successful in encouraging initial BEV take-up, it acts as a disincentive for private sector investment in publicly available charge points in Scotland, as the private sector is crowded out and unable to compete.

The commercial case for many charge points will remain marginal in the short term, and this provides further barrier to private investment. Without further private investment, there is a concern that the growth of the charging network in Scotland is restricted as higher than necessary levels of public spend would be incurred to set up the charging network. Transport Scotland has identified that if the current provision of public charge points and free electricity is maintained this would be at significant public cost. To incentivise businesses, charities and public sector organisations to install chargers on their commercial premises, UKG is providing up to 75% toward the upfront costs of the purchase and installation of EV charge points through the Workplace Charging Scheme.

### Grid infrastructure

We note that the substantial additional electrical load required by charging Scotland's growing BEV fleet will necessitate upgrades to the electrical grid, and that grid infrastructure will need to keep up with demand for charging. This is addressed in our analysis of Power, in Section 13.

### Key conclusion

Substantial investment is required to ensure that Scotland has enough charging points to meet the expected user demand. Public concerns about charging, and range anxiety associated with BEVs, suggest that the rollout of the charging network should be accelerated to provide confidence but, until BEV use grows, the commercial case for many charge points will remain marginal in the short term.

# Cars – Demand reduction



## Demand reduction

In addition to the reduction of O&G use and emissions, from the change in technology from ICE to BEV, considerable opportunities exist to reduce car kilometres through modal shift to public and  travel and via demand reduction.

The Element Energy Decarbonising the Scottish Transport Sector study estimated that behavioural changes offer a carbon reduction of c1.2Mt$CO_2$ from annual car emissions in Scotland. Examples of positive changes include:

- Making use of sustainable online options, such as working from home and virtual meetings, to reduce the need to travel;
- Choosing local destinations to reduce the distance travelled;
- Modal shift to low emission modes such as walking, cycling or public transport where possible; and
- Combining a trip or sharing a journey to increase vehicle occupancy rates and reduce the number of individual car trips that you take.

SG has the stated intention of reducing total car travel (kilometres) by 20% by 2030 by promoting each of the behaviours above. It is also facilitating these changes through a number of interventions, such as the rollout of the 20-minute neighbourhood concept, which is intended, where appropriate and possible, to ensure that housing and services are close enough together to make trips more suitable for active travel.

NPF aims to accelerate emissions reduction, including by directing future development to the right locations reducing transport demand, while bus prioritisation measures, support for segregated cycling facilities, rollout of 20mph zones and place making measures such as pedestrianisation all help to encourage modal shift.

The reduction of car travel is important as it would reduce both emissions and congestion while encouraging more active miles which will ultimately benefit the commuter. Realising this proposed reduction will be challenging, as there is not a ‘one size fits all’ approach that would work nationally. In some rural areas, walking, cycling, or using public transport may not be a reasonable alternative from relying on cars. Further, there could be less opportunity to car share. Targeting urban and more densely populated areas may provide better and quicker results.

A shift away from cars has always been a challenge, with many barriers to change stemming from decades of measure that encouraged a reliance on and a long term habit of driving. The scale of that challenge is illustrated by Transport Scotland’s 2018 Transport Model for Scotland’s forecasts that the baseline demand for car travel will increase by 12% by 2030 and 27% by 2045 relative to 2019, due to population and economic growth.

However, many examples of successful car reduction strategies exist. The Belgian city of Ghent reduced motor vehicle trips from 55% to 27% through restricting car movement within the city, whilst studies in Germany have found that 41% of all e-bike trips and 62% of e-bike commuter trips were previously made by car.

The Covid-19 pandemic forced mass behavioural change and demonstrated possibilities. Government legislated lockdowns during the pandemic resulted in the closure of offices, restaurants and shops (including car showrooms), and demonstrated the efficacy and efficiency for some of practices like working from home has become much more popular. Less than 60% of the adult workforce worked at their workplace from May 2020 to April 2021, and many businesses found no deterioration of productivity as a result. Several large employers have promised to continue a ‘flexible working’ approach, which will reduce commuter car miles.

The lockdown also gave people, particularly those in urban areas, experience of reduced car use in their neighbourhoods, and a less car-dependent lifestyle, making the benefits of reduced car use tangible rather than theoretical.

**Key conclusion**

The quickest and cheapest way to reduce emissions from cars is to use them less. To achieve its emission targets, SG needs to deliver a significant reduction in car use, and has set itself the challenging target of a 20% reduction by 2030. This will require significant changes to the way our communities and neighbourhoods are designed and how we work, but the pandemic has shown that behavioural change is possible and that such changes can generate substantial benefits to physical and mental health.

# Vans – Drivers of demand



## Drivers of demand for vans

Vans or LCVs are a growing part of road transport demand. As at 2019, UKG transport statistics recorded a total of c307k vans registered in Scotland. The 2019 figure was 2% higher than in 2018 and 15% higher than in 2009. Total van mileage increased from 1993 to 2019 by over two billion vehicle miles.

DfT's 'Final Van Statistics April 2019-March 2020' found that the most common primary usage of licensed vans was for 'carrying equipment, tools and materials' (54%), followed by 'delivery/ collection of goods' (16%) and 'private/domestic non-business use' (16%).

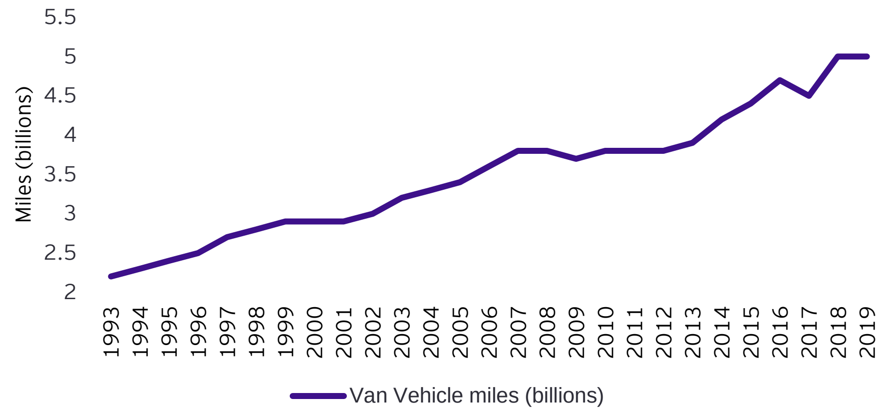
Additionally, vans offer:

- A greater capacity to move goods and tools than cars due to the amount of storage space available;
- The opportunity to carry heavier loads than would be possible with cars;
- A viable alternative to using HGVs for smaller scale deliveries;
- Versatility, as they can be used for short urban trips as well as longer trips. As the back does not bleed into the drivers cabin, a range of goods or tools could be transported without inconveniencing the driver; and
- Ambulances have been considered under 'vans', and provide lifesaving and emergency transport for those who require hospital treatment.

It is likely that van usage is developing in frequency, with the Covid-19 pandemic being a trigger for increased numbers of local deliveries being made, often by vans. More people are working from home and are increasingly choosing to shop online instead of in store, leading to an increase of local deliveries made by van.

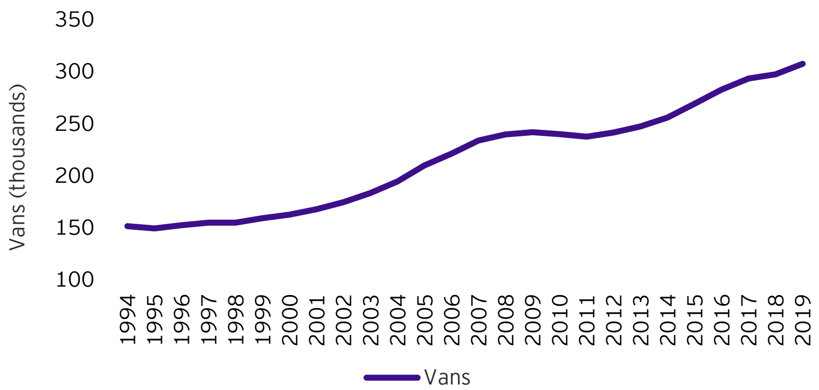
The Society of Motor Manufacturers and Traders recently reported that the UK's new LCV market grew by more than a fifth (21.4%) in 2021, citing strong underlying demand from key sectors – notably construction and home delivery fleets – as the reason for the growth.

### Van Vehicle miles (billions)




*Source: DfT statistics*

### Number of vans (thousands)




*Source: UKG VH0404*

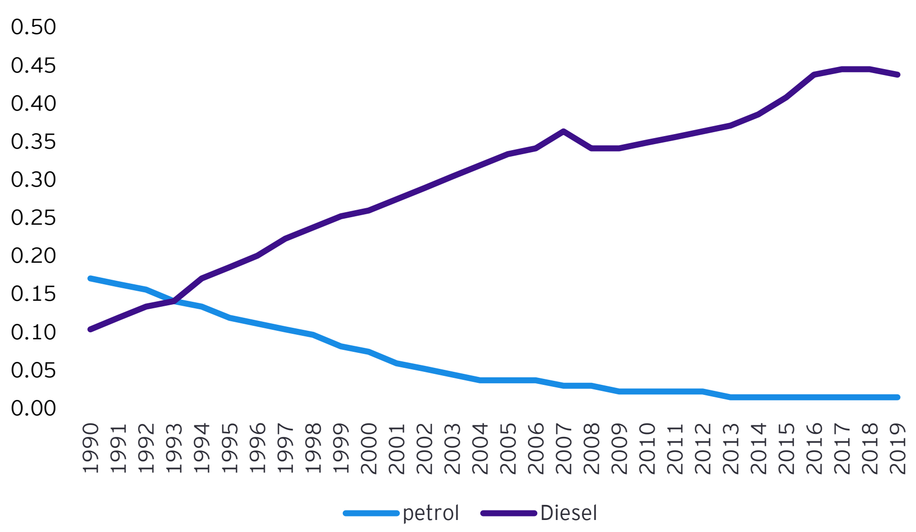
# Vans - Hydrocarbon usage and emissions



### Hydrocarbon usage

The Scottish van transport subsector has a high reliance on hydrocarbon fuels. This reliance is predominantly on diesel and petrol.

Diesel is the most used fuel, with c0.584 million tonnes being used in Scotland in 2019. There were c0.017 million tonnes of petrol used by vans in the same year. As with cars, the significant change in usage from 1990 to 2019 has been the shift from petrol to diesel use.

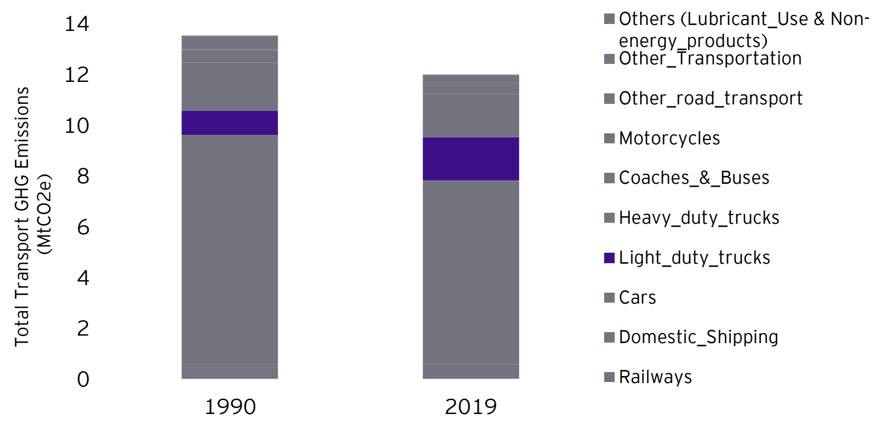



*Source: DfT statistics*

### Emissions

Emissions from vans totalled c1.71Mt$CO_2$ in 2019, representing a significant growth of 78% from the equivalent figure of c0.96Mt$CO_2$ in 1990. Vans represent 14.2% of Scottish domestic transport emissions, and 3.7% of total Scottish emissions.

**Vans as part of total domestic transport emissions**




*Source: NAEI UK data*

**Key conclusion**

Vans are a growing element of road transport, and expected to grow further as delivery patterns develop to reflect the increasing move to online shopping and the ongoing strength of this market.

# Vans – Readiness of alternatives



## Readiness of alternatives and their cost

Both BEV and FCEV vans are commercially available, albeit not at the same scale as in the car market.

The market was slower to pick up van production than it was for cars, meaning that vehicle availability is more limited; however, as many car manufacturers also make vans, synergies exists which can be used to develop zero emission vans.

FCEV or BEV vans offer different advantages to users, and many manufacturers are developing both; however, the FCEVs are often referenced as "supplementing the electric offering", which suggests that the OEM view the BEV as the core range. This reflects the current cost profile and availability of fuelling:

- FCEVs and their associated fuel are more expensive than the BEV equivalents. For example, the FCEV Vauxhall Vivaro is expected to cost around £60k, the BEV Vauxhall Vivaro costs around £35k new. Per Energy Saving Trusts TCO comparison, the breakeven mileage for small vans is 8,000 miles, with larger vans breaking even around 12,000 to 14,000 miles (the average mileage per van in Scotland in 2019 was c16,000 miles). Additionally, hydrogen fuel costs are around four times that of electricity when completing a 100km trip. However, FCEV vans currently have greater range than BEV vans (although battery technology and therefore range is improving).
- BEV charging infrastructure that is already in place for cars can also be used for BEV vans, giving them access to c2,500 charge points in Scotland. However, there are only three filling stations that offer hydrogen currently in Scotland.
- Given synergies in OEMs, and their favouring of BEV cars, BEV vans will be in greater supply. As they will be more readily available they can be expected to remain the cheaper technology.

## Barriers to take up new technology

The barriers to the take up of zero emission technology in vans are largely similar to those that were discussed in relation to cars.

The key non-financial barriers being:

- **Financial:** the price of the vehicles, the cost of battery replacement and lack of depth in the second hand zero emission van market.
- **Range anxiety:** Range anxiety could be more prominent in vans as there are more likely to be commercial implications if goods or services are delayed due to time lost to refuelling/recharging. In particular, delivery vehicles are often planned to be on the road for extended periods throughout the day, so time lost to charging can introduce costly inefficiencies.
- **Vehicle availability:** Production of zero emission vans is less well developed than production of cars in Europe, so it is likely that demand will be greater than supply in the short to medium term. The market was slower to pick up production than it was for cars, meaning that vehicle availability is more limited; however, as many car manufacturers also make cars, synergies exists which can be used to develop zero emission vans.

## Demand reduction

Transport Scotland's Transport Model for Scotland (TMfS:18) forecasts that the demand for goods vehicles will increase by 20% between now and 2030, and then by 50% from today to 2045, reflecting the strong growth in the sector.

Demand reduction may be possible through efficiency improvements on the collection and delivery of goods which may reduce mileage and emissions. The logistics sector is highly competitive and it will be in its own commercial interest to seek changes that deliver efficiencies. Efficiency improvements on delivery and collection of goods has been considered further within our discussion of HGVs below.

Opportunities may also centre around developing logistics hubs or urban consolidation centres, where deliveries are transported to an area's UCC and their delivery within the area coordinated for greatest efficiency. The 'last mile' of deliveries could be undertaken by electric vans or cargo bikes.

**Key conclusion**

The technology for zero emission vans is ready and the vehicles are commercially available from many manufacturers, although the market is currently lagging behind that of cars. The barriers to take up are similar to cars, such as issues around range and charging. Improvements to range is expected as technology develops further.

# HGVs - Drivers of demand



## Drivers of demand for HGVs

HGVs are defined as heavy goods motor vehicles with a minimum allowed mass of over 3.5 tonnes. In Scotland they are predominantly used to carry freight, both within the country and externally for export.

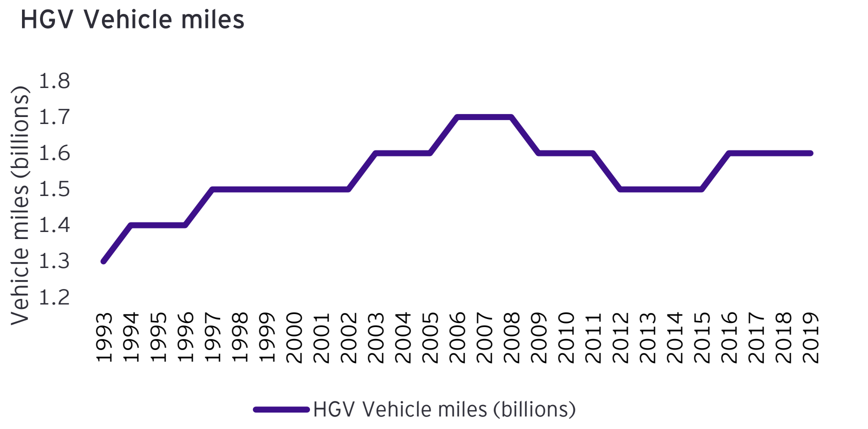
HGVs play a vital role in Scotland's economy. Due to their size, HGVs are able to move large quantities of goods in shorter periods of time. They are a more convenient method of delivery for many purposes than potential alternatives like rail freight, being able to deliver door to door. The HGV industry in Scotland is however, very fragmented, of the 5,592 HGV license holders in Scotland, around 90% have ten vehicles or less registered on their licence.

Many freight movements by HGV are short to medium distance: most freight journeys are 100km or less in length, and 45% of all tonnes lifted by road in Scotland travelled less than 50km. Even when goods are moved by other modes, such as rail freight or shipping, the final miles from rail head or port to destination will be covered by HGV.

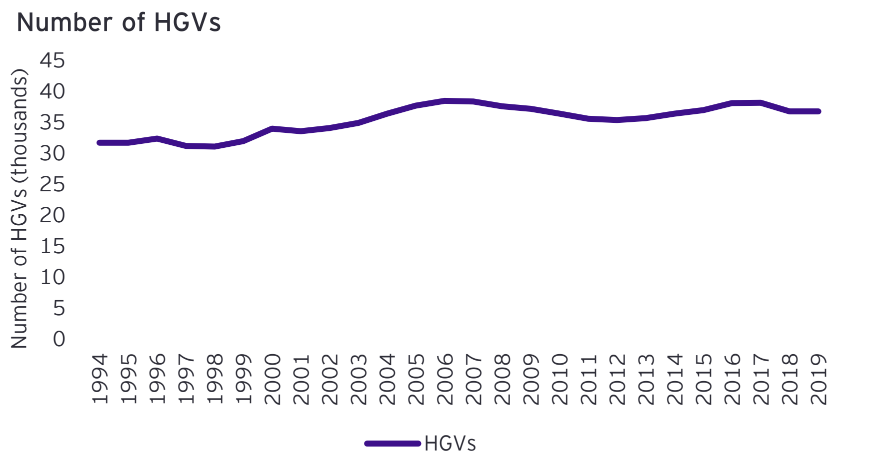
Between 1993 and 2019 the mileage covered by HGVs increased by 23%, albeit not by as significant an amount as both car and van mileage.

The Scottish Transport statistics no.39 details the usage and demand of HGVs in Scotland in 2019:

- 97.8 million tonnes of goods were transported internally within Scotland, covering a total of 8.4 billion tonne-kilometres.
- 19.1 million tonnes of goods from Scotland were delivered to elsewhere in the UK.
- 20.7 million tonnes of goods were brought into Scotland from elsewhere in the UK.
- 14.1 billion tonne-kilometres of freight originating in Scotland was transported to all destinations.




*Source: DfT statistics*




*Source: UKG VH0504*

# HGVs – Hydrocarbon usage and emissions



## Hydrocarbon usage

In the current Scottish HGV sector there is a high reliance on hydrocarbon fuel. The principal fuel used is diesel, with c0.599m tonnes of diesel being consumed by HGVs in 2019.

There is a growing interest in biofuels. Biomethane is proving to be the most cost effective and lowest carbon alternative HGV biofuel to diesel, which can reduce well to wheel emissions by an average of 85% when compared to diesel.

HGV fuel use has been largely unchanged from 1990 to 2019, with diesel use in 2019 only 0.02m tonnes less than was in 1990 (0.47m to 0.45m), and an average annual diesel use throughout this period of 0.45m tonnes. In 2019. HGVs were responsible for 56% of the diesel use across all road transport. Given the high diesel usage, and the appetite of haulage operators to explore technologies that will reduce emissions and fuel costs, SG have established a Zero Emission Truck Taskforce which will aid the transition towards zero emission trucks.

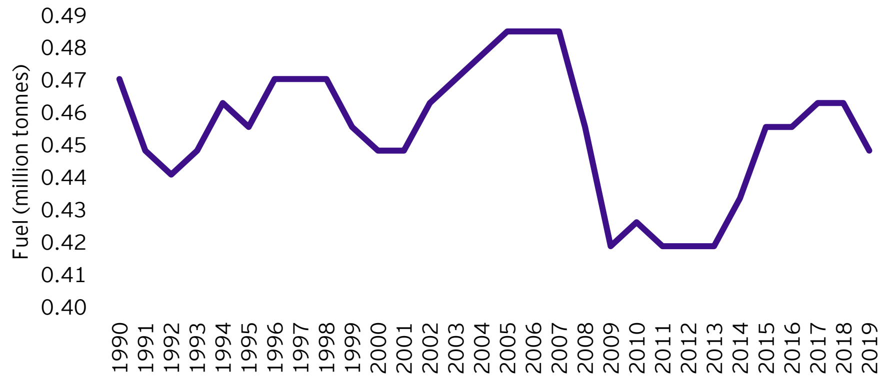
## Emissions

HGVs accounted for total emissions of 1.7 $MtCO_2$ in 2019, c14% of the total Scottish domestic transport sector and c3.7% of total Scottish emissions.

**Key conclusion**

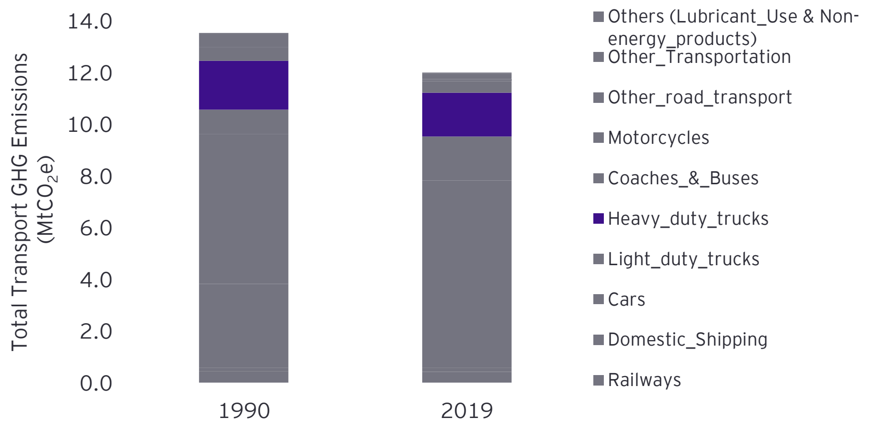
HGVs play a vital role in the Scottish economy, providing flexible door to door logistics services over short-, medium- and long-distances. Demand and fuel use has remained relatively consistent over the past three decades. The HGV industry is, however, fragmented, with c.90% of HGV licence holders owning ten or fewer vehicles, which could cause a slow take up of new technologies.

**Diesel use Scotland in HGVs**




*Source: DfT statistics*

**HGVs as part of total domestic transport emissions**




*Source: NAEI UK data*

# HGVs – Readiness of alternatives



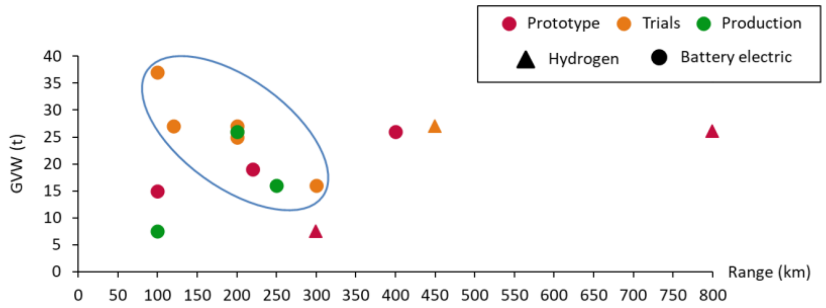
### Technological readiness of alternatives

The two leading renewable alternative drive systems for HGVs are BEVs and FCEVs.

The technology is less developed in HGVs in comparison to cars as the technology has to overcome a number of significant challenges before it becomes a viable alternative. These include vehicle size, weight and the longer daily mileages and the shorter stop periods favoured by the logistics industry – the latter meaning that the long dwell times required for battery charging present an issue.

The figure below shows that the European OEMs that are developing alternative technology for HGVs are at different stages with several conducting trials of new technology but only a few producing models for sale.

### HGV OEM stages by gross vehicle weight




*Source: Element Energy – 'Analysis to provide costs, efficiencies and roll-out trajectories for zero emission HGVs, buses and coaches*

### BEVs

BEV HGVs are now commercially available from some manufacturers, and HGV manufacturers like Scania, Volvo, DAF, Renault Trucks and MAN are committed to producing electric versions of their vehicles. Live examples of BEV HGVs are in use in the UK: earlier in 2022, Amazon introduced five 27-tonne DAF's CF Electric, which will operate from the company's fulfilment centres in Tilbury and Milton Keynes. The CF Electric can cover 155 miles on a single charge. Limitations associated with range mean that the BEV HGVs currently available are unsuitable for many logistic companies' business model, which require flexibility and distance.

Further development of BEV technology to extend range and accelerate charging will be required before the majority of HGVs users are confident of replacing their current ICE-based fleet. This developed technology could be in use as early as 2024, as Mercedes-Benz intend to begin customer testing of their eActros longhall BEV which will have a range of 500km and will facilitate appropriate charge times. However, the current technology, even with its lesser range, could service urban delivery and refuse collection. For example, in Scotland BEV refuse collection vehicles are already in use.

### FCEVs

FCEV HGVs are also commercially available. For example, Hyundai developed its H2 XCient Fuel Cell truck according to European regulations. It has an operational range of around 248 miles, and has been deployed in Switzerland through a joint venture with green energy and logistics partners. The project's demand driven approach proved to be very successful as c1,600 hydrogen HGVs are to be delivered between 2020 and 2025.

FCEV HGVs currently offer a better range and quicker refuelling than BEV HGVs, which would be better suited to the current HGV logistics operating model; however, they would also need significant investment and, to be truly emission-free, production and widespread of green hydrogen at scale.

Neither FCEV or BEV technology is manufactured in Scotland or can be sourced locally currently, however, there are new OEMs working on prototype FCEV trucks so this could lead to local production. It is however, unlikely that there will be a large number of either HGV in the Scottish market before the mid 2030s.

Ultimately, the future of HGV technology will be a commercial decision as companies will seek the technology that facilitates the most efficient way for them to meet their operating requirements.

**Key conclusion**

Whilst the technology for zero emission HGVs exists, issues of range and fuelling relative to current technology mean that it is not yet an ideal fit for business as usual operations.

# HGVs – Financial and non-financial barriers



## Financial Barriers

### Vehicle Price

Forecast costs for BEV HGVs indicate that they will be considerably more expensive than ICE HGVs, and it is likely that FCEV HGVs will be more expensive again, with no indication whether this price gap will reduce over time.

For example, the Nikola Motors class 8 rigg FCEV is expected to retail at c£308k, whilst Tesla has indicated that its Semi BEV will cost in the region of c£148k. The cost of a comparable diesel HGV is c£99k. The up front cost will be a significant challenge for many businesses, and coupled with increased running costs could make operation unviable without SG assistance.

### Running costs

Per Element Energy's 'Analysis to provide costs, efficiencies and roll-out trajectories for zero emissions HGVs, buses and coaches' report, the TCO of a diesel artic HGV (£453k) is less than that of a FCEV (£608k) or a BEV (£559k) equivalent. BEVs are expected to save c£89k in fuel over the first six years; however, the cost of hydrogen is estimated at c£17k greater than that of diesel. Per the Energy Saving Trust's TCO comparison, the breakeven mileage of HGVs is c20,000 miles (the average HGV 2019 mileage in Scotland was c43,000 miles).

## Non Financial Barriers

### Range

The relatively limited range of current BEV HGVs is a barrier to many HGV users. Many HGVs have to cover hundreds of miles in a day, and diesel HGVs can travel 600 miles or more without needing to refuel. However, current BEV models such as the Renault DZ.E (186 mile range), Mercedes eActoros (125 mile range) and the Nikola TRE (300 mile range) are more limited.

FCEVs generally offer greater range: as noted above, the Hyundai Hydrogen Xcient fuel cell HGVs that will be delivered to Switzerland can travel 248 miles before they need to refuel.

### Availability of infrastructure

Zero emission HGV fleets will require significant investment in charging infrastructure. For BEVs, to service rapid charging of large batteries used by larger vehicles, HGV-specific charging facilities will be required.

Some uses, such as urban servicing, may allow for a single depot or hub model, where smaller trucks can take on board sufficient overnight charge to carryout a day's work around a single location. However, heavy-duty intercity HGV transport may require a combination of en-route and depot charging. For FCEVs, a network of hydrogen fuel depots or stations would be necessary. There are currently only three hydrogen fuel stations in Scotland, for hydrogen to become a widespread fuel for HGVs then the roll out of further fuel stations will be necessary.

This will require considerable investment in infrastructure - Ricardo Energy & Environment's 'Zero emission HGV infrastructure requirements' report for the CCC estimates a cumulative capital cost in the UK of £7.7bn in 2060 for hydrogen and £11.4bn for BEV HGVs.

### Vehicle lifespan

HGVs have a fairly long lifespan, generally 10-15 years, and companies that have invested in them will seek the best return on that investment.

The significant cost and lifespan of that investment also means that many companies are likely to delay moving to BEVs or FCEVs until they are confident in the technology's ability to work efficiently and at reasonable cost.

However, commercial incentives to change do exist. Pressure from customers, such as supermarkets and distillers, seeking a net zero supply chain is increasing. This will make operators actively consider the attributes of the new technology and also wary of buying new non-net zero vehicles, the usefulness and potential resale value of which will suffer if the market continues to move to net zero. Further, per the ICCT's 'Total cost of ownership for tractor-trailers in Europe: Battery electric versus diesel' report, BEV HGVs can achieve TCO parity with diesel equivalent HGVs within the next five years without any policy support.

**Key conclusion**

The range limitations of current zero emission HGVs relatively to current ICEs makes them less attractive to current operators, and it is likely that significant advances in the technology will be required before it is embraced by the freight industry at scale. At the same time, substantial investment is required to ensure that the industry has enough charging points in Scotland to meet the expected demand. The possibility of two different technologies coming through for HGVs makes decision making and progress more challenging in this sector.

# HGVs – Demand reduction



## Demand reduction

Demand reduction can offer a reasonable saving in hydrocarbon use prior to the take up of zero emissions technology. The following are examples of demand reduction, through changes in behaviours and modal shift:

### Road to Rail

A single freight train can replace 76 trucks, reducing emissions per tonne km by an estimated 76%-90%. In addition to the reduction in $CO_2$, rail freight is less intrusive than road freight to towns and villages as it is generally segregated from residential areas and has less visual and noise pollution.

### Backhauling

'Backhauling' or removing all empty HGV kilometres is estimated to reduce emissions by up to 30%. Backhauling would involve the delivery of goods on return trips instead of returning empty. For backhauling to be effective, customers' time constraints would need to be loosened so that there was more time for cargo matching between delivery and pick up.

### Effective operating

When laden, HGVs often only carry c40-60% of their maximum rated payload, which is inefficient. Operating HGVs at maximum laden weight could reduce emissions by as much as 37-69% depending on HGV size. Improvements in internal logistics operations and collaboration with other firms could help to maximise payloads. These efficiencies would also benefit renewable technology, as, per The Advanced Propulsion Centres 'Fuel Cell Roadmap 2020' narrative report, both BEV and FCEV fuel cells are heavier, and take up more space than ICE engines so space may need to be used more efficiently.

### UCCs

The use of UCCs, where deliveries are grouped by geographic region and are then delivered to that area's UCC, could reduce related emissions by up to 30% when the 'last mile' of deliveries is undertaken by zero emission vehicles like electric vans or cargo bikes. An example of a UCC system in operation in Scotland is that of Royal Mail. UCCs also bring other benefits, such as reduced visual and noise pollution as HGVs are not travelling through towns and villages, reduced congestion, pollution and distribution costs. Each UCC design would need to be specific the location that it serves, and as such roll out would likely need to be considered at a council level rather than nationally.

### Key conclusion

Demand reduction measures offer opportunities to accelerate emissions reductions ahead of BEVs and FCEVs becoming widely available and used. They do, however, require considerable coordination between commercial companies and may only be attractive to larger players in the industry.

# C&B – Drivers of demand



## Drivers of demand

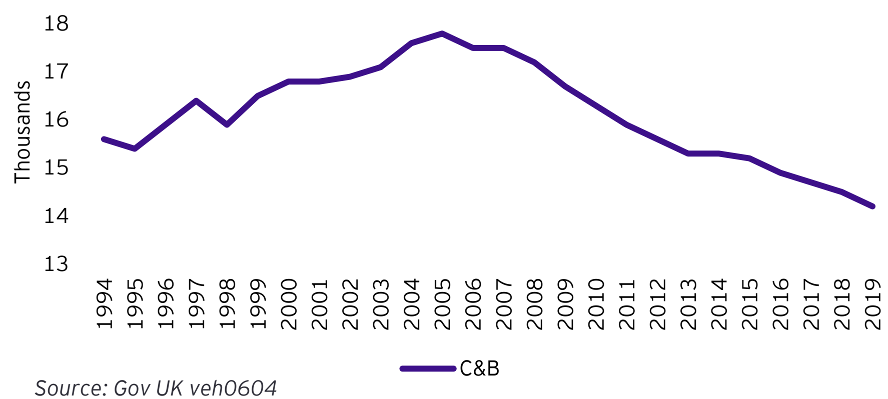
Buses and coaches provide an important public transport service, offering affordable transport efficiently, both in terms of road space and emissions.

However, bus patronage has fallen as the relative cost of motoring has reduced – passenger numbers and vehicle kilometres have decreased by 12% and 3% respectively over the past five years. Vehicle miles have, however, remained at a similar level which suggests buses are still fulfilling their routes despite low passenger numbers.

Per the Scottish Transport statistics no.39, for 2019:

- 366 million journeys were made by bus, with c40% of these being made under the national concessionary scheme.
- The average bus journey length was 12km.
- Bus use was higher in urban areas than in rural areas.

### Number of Coaches & Buses




*Source: Gov UK veh0604*

# C&B - Hydrocarbon usage and emissions



### Hydrocarbon Usage

Ultra low emission technology is becoming more established in this sector, with zero-emissions buses in use in many Scottish cities. There is, however, still a high reliance on hydrocarbon fuels.

The reliance is predominantly on diesel, with c0.149m tonnes of diesel being used in Scotland in 2019. Diesel use has fallen from 1990 to 2019 by c0.06 million tonnes and in 2019 was as low as use had been. Some of the reduction in diesel use could be assigned to more efficient ICEs and the take up of ULEV technology, but the principal cause is the lower number of buses in use (25% less than in 2009).

### Emissions

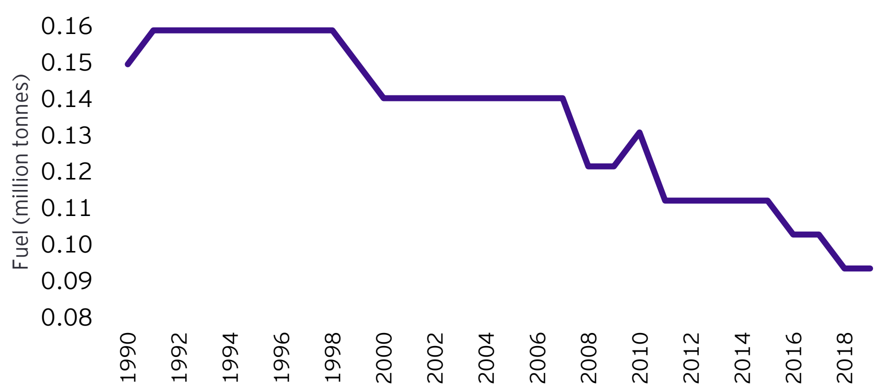
As with the other subsectors of road transport, barriers to zero-emission C&B are cost, infrastructure and the supply and availability of vehicles. Similarly to HGVs, zero-emission C&B also face the challenge of meeting longer range demands and the delay in phasing out some ICE vehicles due their longer lives.

C&B were responsible for emissions of c0.45Mt$CO_2$ in 2019, per Element Energy's Decarbonising the Scottish Transport Sector report. This represents c3.6% of Scottish domestic transport emissions, and c0.9% of all Scottish emissions.

**Key conclusion**

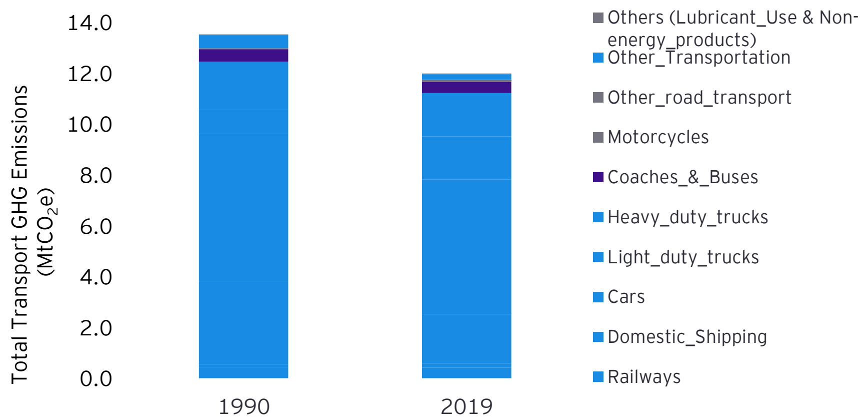
Buses and coaches provide an important public transport service, offering affordable transport efficiently, in terms of road space and emissions relative to the car. As a result, demand growth for buses and coaches should lead to reduced emissions and congestion in overall transport system terms. However, demand for buses has fallen, leading to reduced hydrogen usage and increased net transport emissions, as the relative cost of motoring has decreased.

**Coach & Bus Diesel use 1990-2019**




*Source: DfT statistics*

**Coach and Bus as part of total domestic transport emissions**




*Source: NAEI UK data*

# C&B – Readiness of alternatives



### Technological readiness

The zero emission bus market is relatively well developed in Europe, with over 5,000 zero-emission buses in operation. Scotland can be included within this market, as SG has invested or earmarked more than £40m for ground breaking hydrogen projects over the past five years. Hydrogen buses have been deployed in Aberdeen and Dundee and over 600 zero emission electric buses are now in use in Scotland.

Unlike in the other subsectors of road transport, SG does have some influence over supply chain as OEM Alexander Dennis Ltd (ADL), who are based in Scotland, have been involved in the supply of electric buses to the Scottish market to date, and can produce hydrogen buses. SG provided ADL with a £10m Research and Development (R&D) grant to manufacture ultra low emission coaches and Buses (C&Bs) and ADL have the opportunity to become a centre of excellence. The hydrogen buses in use currently in Scotland were provided Van Hool, a Belgian company. It should be possible for zero emission C&B supply to meet demand in Scotland as the market is small and in addition to ADL, there are 30 other OEMs in Europe offering zero emission bus models.

Similarly to HGVs, there is still discussion around which technology will become the new normal for C&B and action to date has not been coordinated with other nations. Currently, there are significantly more battery powered C&Bs operating in Europe (c8,500 at the end of 2021) than hydrogen powered buses (c260 at the end of 2021); however, this does not mean that hydrogen buses are not in demand. There were 5,648 hydrogen buses deployed globally at the end of 2021, 5,290 of which were located in China.

In terms of hydrogen supply, SG issued a hydrogen policy statement in 2020 which reiterated Scotland's ambition to be a leading hydrogen nation in the production of reliable, competitive sustainable hydrogen. As part of this ambition, SG plans to undertake work to develop a programme of activity to support supply chain development, growth and transition in order to establish a stable and sustained hydrogen economy in Scotland. Scotland has several advantages in relation to hydrogen production:

- The potential offshore and onshore wind resource
- The extensive port and pipeline infrastructure that can be repurposed for hydrogen export to the rUK and Europe.
- There is considerable hydrocarbon supply chain overlap, notably from the O&G, offshore wind and subsea engineering sectors. This overlap will aid transition, giving Scotland the opportunity to grow operations in hydrogen effectively. This growth should allow Scotland to successfully establish a sustained hydrogen economy, both creating employment and increasing the Scottish supply chain.
- The Scottish Offshore wind to green hydrogen opportunity assessment identified over 100 companies that are either already involved in green hydrogen production or are interested in becoming involved. The assessment also identified Scotland's competition/ other hydrogen supply as likely being the green hydrogen produced from solar energy in Southern Europe and North Africa

Further development is still required for SG to meet its ambition, most notably there are gaps in the supply chain in relation to design, manufacture and maintenance of hydrogen production, storage and transportation systems. However, it is clear that Scotland is in a relatively strong position to influence the growth of the hydrogen industry.

**Key conclusion**

BEV and FCEV technology for C&Bs is commercially available and in use in Scotland, with both BEV and FCEV buses currently in operation. Further, FCEV C&Bs could utilise Scotland's advantages in relation to hydrogen production as Scotland becomes a leading hydrogen producing nation.

# C&B – Financial and non-financial barriers



## Barriers to take up of new technology

C&Bs provide a vital service in Scotland, providing affordable transport to a large number of people across the country. Services need to be reliable, available and continue to be cost efficient for passengers despite the increased TCO of renewable C&Bs to encourage the modal shift from car to bus. The main barriers to the introduction of cleaner technology are the cost, refuelling infrastructure, the weight of BEV/FCEV technology and the supply of vehicles.

### Financial

#### Vehicle price

The price of both BEV and FCEV buses are currently higher than the price of an equivalent diesel bus, and the initial capital cost is the barrier to take up. A single decker FCEV bus costs c£350k, a comparable single decker BEV bus costs c£357k, and a single decker diesel bus costs c£180k. It is worth noting however, that per EYs 'Low Carbon investment – Scottish bus Electrification commercial and economic content' analysis, despite the higher initial price, the TCO of a zero emissions vehicle is expected to be lower over the vehicles lifetime. For example, due largely to lower operating costs, a BEV bus has a greater net cash flow per vehicle mile by £2.69 than a diesel equivalent (£21.61 versus £19.22).

#### Maintenance costs

EY analysis finds a slightly lower annual maintenance cost for BEV buses in comparison to diesel. Assuming that maintenance costs include labour, parts and upkeep, there is a saving of c£2.5k per year for BEV buses. Battery maintenance costs for BEVs reduce these savings. Most EV batteries are designed to operate for at least c160 miles per charge over a period of seven years. Batteries in operation beyond this period will require a maintenance programme. Assuming replacement of fuel cells during the buses useful life, and that buses continue to operate for 15 years, we estimate this cost to be £25k per year for years 9 to 11.

#### Weight

Larger batteries would allow for further range, however, these would be constrained by the vehicle's weight allowance. Every kWh of energy carried on a BEV or FCEV vehicle adds c6kg or 0.6kg of weight respectively; comparatively, diesel adds only 0.1kg. In addition to extra weight, both technologies take up more volume at 5 litres and 1.7 litres respectively per kWh, where diesel again takes up only 0.1 litres. This increase in weight and size would incur more tax as a result of the HGV levy tax, potentially deterring transition.

### Non financial

#### Refuelling

Bus refuelling is generally performed at the depot and, as such, if BEV buses are unable to complete their current routes on a full charge then scheduling may need to be disrupted to facilitate buses traveling back to the dept to recharge unless infrastructure such as 'flash charging' stations, or pantograph technology currently being trialled in Germany is rolled out. Further, charging will take longer than filling the tank with diesel and this too will have implications on scheduling.

#### Range

In line with the conclusions drawn from the other subsectors, FCEVs have greater range than BEVs. For example, the Hyundai FCEV city bus has a range of c745 kilometres, whereas ADLs Enviro200EV has a range of only c242km on a full charge, which is significantly less. Despite having greater range than the Environ200EV, the Hyundai FCEV city bus still falls short of range of a diesel alternative which has an average range of c1,100km.

#### Other

The life of second hand vehicles in small local fleets can extend as far as 20-25 years, this being after use by their first owner of 10-15 years. This suggests that without intervention, new ICE buses purchased in 2023 may still be in operation at 2063, some 23 years after the 2040 zero emission target.

**Key conclusion**

The vehicle price and maintenance costs are significantly higher in both FCEV and BEV technologies in comparison to ICE; however, lower operating costs convey a longer term benefit. Additionally, appropriate infrastructure will need to be installed to address concerns around range and refuelling to ensure that there is no disruption to scheduled service.

# C&B – Availability of infrastructure



### Infrastructure cost

Buses have different infrastructure needs to other heavy duty vehicle segments such as HGVs or coaches. Buses are typically depot based, with operators' fuelling or battery recharging facilities located there. As a result, zero emission buses require investment in different refuelling/charging infrastructure, with the majority of refuelling / charging likely to take place in the depot. Coaches would find more efficiencies in hydrogen than battery electric, as they tend to be heavier vehicles, and would be driving for longer distances at higher speeds. Hydrogen refuelling takes significantly less time than charging electric batteries, but requires the movement of busses through a central fuelling point; whereas BEV busses can be parked up for charging, but do need infrastructure to be in place for each bus to have a charging point, with often expensive retrofit costs in a depot.

Mid route charging through 'flash charging', which uses a high powered charger (<500kW) for a couple of minutes at bus stops or charging for the short periods of time at the end of bus routes may be a viable solution for BEVs.

For FCEVs, in addition to depot refuelling, hydrogen refilling stations will be required. There are currently only three hydrogen refilling stations in Scotland.

Transport Scotland estimated, within its 'bus financing information and ideas pack', that for each BEV double decker bus there would be a corresponding infrastructure cost of c£34.9k. The cost of the corresponding infrastructure in relation to a double decker FCEV would be c£96k. This included a grid connection cost, per BEV of £25k and depot retrofit costs of £1k per BEV, and £35k per FCEV.

Assuming the current European split between FCEVs and BEVs (3% to 97%), and that all c14k C&B required the spend on the corresponding infrastructure at double decker bus costs, then this would suggest the upper end infrastructure costs of around £514.2m.

### Key conclusion

Significant infrastructure cost will be required to continue the roll out of FCEV and BEV C&Bs, and infrastructure cost will vary depending on the split of BEVs and FCEVs that are in operation in Scotland.

# C&B – Demand promotion and policy levers



### Demand promotion and policy levers

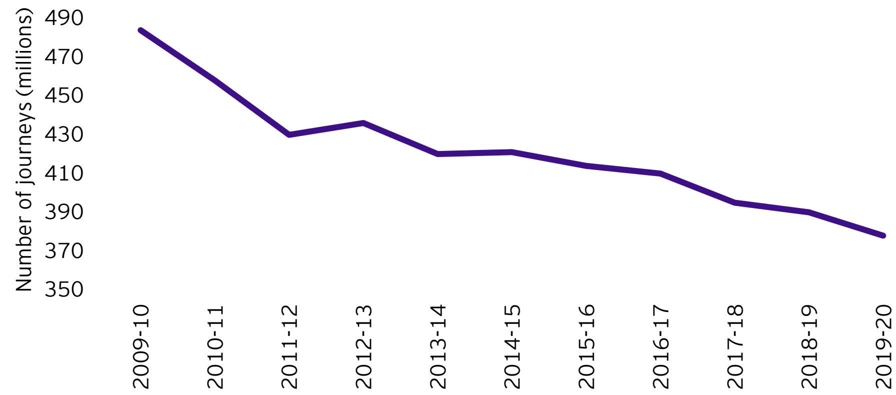
Although an increase in demand for buses would increase emissions from the bus sector (based on current ICE fleet), its overall impact could be expected to reduce the emissions from road transport sector as whole by reducing equivalent car journeys. Element Energy estimated that this would have an impact of +0.4Mt$CO_2$ on the bus subsector, but the impact of emissions due to all behaviour changes in cars is estimated to reduce car emissions by c1.2Mt$CO_2$, a net saving of 0.8Mt$CO_2$.

Increasing bus demand will require the reversal of recent trends, which has seen a fall in bus passenger numbers, associated with rising car use, congestion, changings in shopping patterns and concerns around reliability. However, increasing bus usage would bring considerable benefits, many of which are linked to wider SG policy goals:

- A single bus can take up to 75 private cars off the roads, which would have a significant impact on both O&G use and emissions. The $CO_2$e figure per passenger kilometre in Scotland is around 150g per passenger by bus, the average for a diesel or petrol car is 171g or 192g respectively.
- Bus usage also tends to be more active than car use, due to the likeliness of a walk to and from a bus stop. Walking to and from bus stops and interchanges often leads to bus users meeting the 30 minute daily minimum threshold of activity recommended by the chief medical officer.
- In the UK each year c40k deaths are attributed to exposure to outdoor air pollution. There is less city centre congestion and better air quality when there is more bus and less car use.
- Increased bus use can enhance placemaking. Currently 30%-60% of surface space in towns and cities is devoted to private transport. Public space is scarce, and better utilising the surface space currently devoted to private transport would reduce visual pollution and could enable more urban greenery.
- Increased bus and less car use would make for more efficient travel, as roads will be quieter meaning less time stuck in traffic on journeys.

The SG continues to support and promote bus use through a number of initiatives, including supporting services with the Network Support Grant, infrastructure through the Bus Partnership Fund, a £500m fund investing in bus priority infrastructure to reduce the negative impacts of congestion on bus services, and zero emission vehicles through the Scottish Zero Emission Bus challenge fund. Further support could be provided by the Scottish National Investment bank, through soft loans to support businesses with the initial capital outlay on new zero emission buses.

**Passenger journeys on local bus service**




*Source: Scottish transport statistics no.39*

**Key conclusion**

Growing bus demand will have a positive impact through increased active miles, public space and reductions in air pollution and congestion, in addition to reduced overall transport emissions. However, increasing bus use presents a challenge as it will require the reversal of a long trend of decline.

# Transport – Non-Road Mobile Machinery



### Demand drivers

Non-Road Mobile Machinery (NRMM) covers a wide variety of machinery across various industries, including some agricultural machinery, transportation refrigeration units (TRU) and construction plant. As these sectors are primarily driven with demand from population, an increase in population will directly increase a demand for NRMM.

The most common engine types used in NRMM vehicles are:

- Compression-ignition (CI), with diesel as fuel which is more often used for construction equipment, agriculture machinery and industry machinery.
- Spark-ignition (SI) engines, which are mainly fuelled by petrol and are used in garden equipment, recreational vehicles and crafts.

### Hydrocarbon Usage

The primary hydrocarbon used in NRMM is diesel, however, a range of emission reducing technologies and biofuels could be utilised as stepping stones prior to the uptake of zero emission technology. Fuels such as biodiesel, hydrotreated vegetable oil, bio-propane and biomethane have all proven to emit significantly less $CO_2$ than diesel. On average, emissions from renewable fuels save 84% in comparison to a hydrocarbon equivalent. In 2021, renewable fuels accounted for c5.1% of total road and non road mobile machinery fuel for the year.

### Emissions

The total emissions from the NRMM subsector are not as significant as the other subsectors, at c0.22Mt$CO_2$. This represents c1.8% of Scottish transport emissions, and c0.5% of total Scottish emissions. There is no specific date in relation to the phase out of hydrocarbon NRMMs bar the 2045 zero emission target, however, LEZs have already been implemented in London. NRMM, particularly in the construction sector, is a significant contributor to air pollution and this was one of the drivers behind the implementation of LEZs.

### Technological readiness of alternatives

At present, there are 2 predominant technologies available for emission reduction, which are:

- In-cylinder approaches, where the engine system is refined through fuel injection, air handling systems and exhaust gas recirculation systems.
- Exhaust aftertreatment devices, which include particulate filters, selective catalytic reduction systems and diesel oxidation catalysts.

In-cylinder approaches and exhaust aftertreatment help in the reduction of emissions on existing machinery but do not completely curb emissions. Also, the cost implication for these techniques is dependent on multiple parameters which include power consumption, the fuel used, and the stage of compliance as per the regulation. It can vary from as low as £50 up to £10,000 in the form of fixed or incremental costs.

### Alternate fuel

There are multiple alternatives for diesel which are available in the market for application, however, they are not applicable to all NRMMs.

Many NRMMs are now becoming battery operated. Similar to the operation of electric cars, these machines utilise power from in-built batteries. Depending on the power output the size of the batteries vary accordingly. These have no emissions and are silent in operation. However, the major drawback comes in the form of higher initial cost, slow charging, limited space for batteries and limited applicability for high powered machinery.

As previously stated, bio-fuels can be used in combination with diesel to reduce emissions. Although, methanol can be used as a substitute, the demand for retrofitting engines has been very low resulting in low application. As the biofuels are not produced commercially, the cost has remained high compared to diesel. In addition, not all bio-fuels are compatible to the existing NRMM engines, further reducing applicability.

# Transport – Non-Road Mobile Machinery



### Barriers to take up of new technology

- Due to the wide power requirements by NRMM, applying a general technology or emission regulation is difficult, and this poses a significant challenge in terms of wider application of any alternate technology.
- Further challenge comes from the cost of reinvesting in ULEV NRMM, especially in the agricultural sector where many farmers do not have money to invest in new vehicles or equipment.
- As the emissions from NRMM are small in comparison to other road transport subsectors, there is probability that NRMMs will not be considered a priority for decarbonising.
- NRMM which operate below 19kW, such as transport refrigeration units (TRU), operate below the cut-off limit set for NRMM regulation.

### Demand reduction

NRMM are regulated under the 'Non-Road Mobile Machinery Regulations 2018' act which has been effective in reducing emissions, however, SG plan to reduce demand further by implementing policy measures that will:

- Utilise the Scottish Environmental Protection Agency's sector plan approach to achieve a reduction in emissions.
- Engage with industry to produce guidance on requirements for gaseous and particulate emissions.
- Develop an emission impact and evidence base on TRU emissions.

**Key conclusion**

There are alternate fuels and technologies available for this sub-sector of transport, however, as it is a smaller emitter transition in this sub-sector may not be prioritised. Further, there is no one size fits all approach, as NRMM offers a significant variety in both types of machinery and application.

# Road Transport – Conclusion



## The Road transport sector accounts for almost 20% of Scotland's total O&G consumption and 19.9% of its emissions

- The majority of road vehicles in Scotland are fuelled by either diesel or petrol. This has been the case for decades, with the only significant change in the fuel mix being a shift from petrol to diesel following UKG's changes to diesel VED rates in 2001.
- Whilst the efficiency of ICE technology has improved over the past three decades, increasing demand across most areas of road transport has outstripped the resulting savings, leading to an overall rise in total emissions.
- To meet SG's net zero emissions targets, the majority of Scotland's petrol and diesel cars will need to be phased out of use, replaced by BEVs, and many car journeys replaced through modal shift to public and active travel and overall journey demand reduction. A move to zero emission light goods vehicles, buses and coaches will also be needed, with zero emission HGVs joining the mix as the technology advances to the point that it is commercially viable.

## Cars are the biggest emitter on the road and the biggest consumer of O&G

- The below table summarises the O&G usages and domestic transport emissions for road vehicles considered in this report, highlighting cars as the biggest emitter.

| Vehicle Type | O&G Usage[1] | Emissions[2] | Emissions %[2] |
|---|---|---|---|
| Cars | C0.93m tonnes (diesel)<br>c0.92m tonnes (petrol) | c5.28Mt$CO_2$ | 44.0% |
| Vans | c0.58m tonnes (diesel)<br>c0.02m tonnes (petrol) | c1.71Mt$CO_2$ | 14.2% |
| HGVs | c0.59m tonnes (diesel) | c1.70Mt$CO_2$ | 14% |
| Coach and Bus | c0.15m tonnes (diesel) | c0.45Mt$CO_2$ | 3.6% |

## Road demand has shown a consistent upwards trend for decades

- The Scottish and UK transport system has largely been designed around roads. For many, the car is the most flexible and convenient form of transport, offering comfort and perceived safety. Over decades, the cost of motoring has fallen while the relative cost of public transport has increased, meaning that the incremental cost of a car journey is often cheaper than alternatives. The domination of road space by motor vehicles has also made active travel less attractive.
- Much of Scotland's freight is moved by the road network in HGVs, which are able to move large quantities of goods in shorter periods of time and offer a convenient and flexible method of delivery.

## Alternative technologies for most road transport are commercially available

- Zero emission technology for cars is better developed than in any of the other road transportation sub sectors. Hybrid technologies have been available for some time that utilise both hydrocarbons and electric battery technology, and in recent years the car industry has scaled up production of zero emission technology, in particular BEVs. These vehicles are commercially available to consumers, with a growing pipeline of models offered by carmakers. Similar technology is expected to dominate the low emission van market, with some FCEVs also possible, but the rollout of BEV vans is lagging behind that for cars somewhat.
- The zero emission bus market is also relatively well developed in Europe, with over 5,000 zero-emission buses in operation. Hydrogen buses are in use in Aberdeen, and electric buses have been deployed in Glasgow, Edinburgh and Inverness.
- HGV's larger size and weight, longer daily mileages and shorter stop periods means that low emission technology is more challenging and not as well advanced. OEMs are at different stages of development with several conducting trials of new technology but only a few offering models for sale. Range and speed of charging are the key barriers here.
- Modal shift and demand reduction is also a key strategy to reducing O&G use and emissions from road transport. SG has a **target of reducing car kilometres travelled in Scotland by 20% by 2030.** It plans to address this through measures which promote a place-based agenda and support localism, such as the 20 minute neighbourhood concept, which will increase proximity of where people live, work, learn and access goods and services, reducing distances travelled and the need to travel unsustainably.

[1]*TS Statistics (2021)*
[2]*NAEI UK data (2019)*

# Road Transport – Conclusion



## Alternative road vehicles cost more in capital terms, but tend to have lower operating costs

- At current prices, the initial purchase price of a BEV is significantly higher for the consumer than the equivalent ICE vehicle, and the second hand market is currently very limited. However, for those who can afford them, BEVs are cheaper to run and fuel than ICE vehicles.
- For buses, FCEVs have similar purchase prices to BEVs (£350k versus £357k), but both are more expensive than current diesel buses (£180k). Despite purchase prices being greater, operating costs are lower over the vehicle's lifetime.
- Forecast costs for BEV HGVs indicate that they will be more expensive than ICE HGVs, and it is likely that FCEV HGVs will be more expensive again. The Tesla Semi BEV HGV has an expected cost of c£148k, the Nikola Motors class 8 rigg (FCEV) is expected to retail at c£308k, while a comparable diesel HGV costs c£99k.
- Energy Saving Trusts TCO model suggests that if current annual mileages for cars, vans and HGVs remain constant, BEV vehicles will provide, on average, a better than break even return to owners over an eight year life time.

## There is considerable inertia among consumers

- After decades of ICE vehicle use, the shift to BEV technology presents a significant change and needs to overcome considerable inertia among consumers. Key non-financial barriers include:
  1. **Refuelling:** In the AA's October 2020 survey, only 49% of respondents said they would consider buying an electric car when they next changed car. Of those who said they would not consider it, charging taking too long was cited by 70% of respondents.
  2. **Range anxiety:** BEV car range on a full charge is lower than that of equivalent ICE vehicles with a full tank. The average BEV car can travel 193 miles on full charge. In contrast, EY analysis finds that the average sized ICE car with a 45 litre fuel tank would travel between 356 and 425 miles. Uncertainty over availability of charging points and recharging time creates concerns about the extent of route planning and organisation required for longer journeys.
  3. **Vehicle availability:** As demand for BEVs grows, there may be insufficient vehicles available to meet demand. Transport & Environment's 'Electric Surge' report estimates that c2.5 million BEV cars will be produced in Europe by 2025, meeting only 13% of European BEV car demand.
  4. **Availability of infrastructure:** ChargePlace Scotland, a SG-owned national charging network, has installed c2,500 public charge points in Scotland, but many more will be required if users are to be confident of switching to BEVs. The CCC estimates that c280,000 publicly available charge points will be required across the UK by 2030, which implies a Scottish requirement of c30,000. The private sector has been slow to invest in charging facilities in Scotland, anecdotally suggesting that they unable to compete with ChargePlace Scotland. The commercial case for many charge points will remain marginal in the short term.

## What is the policy landscape and levers?

- The global car manufacturers have largely settled on BEV as the future of car technology, and the market is moving towards this. Several carmakers have confirmed dates from which they will only produce BEV cars, and demand among consumers is growing. As such, the principal policy levers focus on facilitating this growth and helping people to make the change.
- A key point in this must be encouraging the private sector in the Scottish charging network, so private investment can be leveraged to grow the network at pace.
- To meet Scotland's targets, there is also a need to reduce overall transport demand. SG has outlined a variety of measures which promote a place-based agenda and support localism, such as the 20 minute neighbourhood concept, reducing distances travelled and the need to travel unsustainably. NPF aims to accelerate emissions reduction, including by directing future development to the right locations reducing transport demand.

# 9 Supplementary Analysis: Transport - Rail

# Introduction



### Drivers of fossil fuel demand

From the 1930s rail companies began to introduce diesel engines as these had lower operating and maintenance costs, and greater range between fuelling. Unlike electrification, the replacement of steam with diesel did not require significant changes to infrastructure (whereas electrification requires major work to bridges and tunnels in addition to the overhead line equipment), therefore, in comparison significantly lower initial capital costs were incurred.

Other European countries opted for electrification of their railways, as relatively short trackage and high traffic volumes made electrification more cost effective. Consequently, the European average for electrified rail is around 56%.

### O&G consumption and emissions in the rail sector

Neither passenger nor freight rail are significant users of O&G with the sector only using 56ktoe of O&G (<0.5% of total Scottish consumption). Although diesel engines are still used, large elements of the network have already been electrified. For example, in 2019/20 electrified services consumed 255GWh generated by the national grid. However, although consumption is small, opportunities remain to contribute to the reduction of O&G demand in Scotland and ensure rail represents a strategic component of a decarbonised transport sector.

In 2019, the Scottish rail sector represented only 0.3% of Scotland's overall emission levels due to the levels of electrification that has already taken place on the network. Our analysis demonstrates that:

- Other than coach travel, rail was the most emissions efficient means of transport in 2019 (excluding active travel).
- As noted in the Rail Services and Decarbonisation Action Plan, rail represented 1.2% of current Scottish transport emissions (primarily passenger rail (1%) and the freight the remainder). Whilst emissions fell by 7.8% between 2017 and 2018, rail emissions are currently 27% above the 1990 base level.
- Transport Scotland forecasts that emissions will continue to reduce due to electrification, with new electric trains being more energy efficient and electrification encouraging wider modal shift to rail.
- Pre Covid-19 passenger activity had rail emissions of 36.6g$CO_2$e per passenger kilometre. The decline in usage through the pandemic meant emissions per passenger kilometre grew to 146g$CO_2$e per ORR 2020-21 emissions data.
- Freight train emissions are 25.3g$CO_2$e per tonne kilometre which is only c25% of the emissions per tonne km of road freight.

### Inherent challenges to reducing O&G

The Rail Services Decarbonisation Action Plan states that approximately 40% of Scotland's railway is electrified. As electrified lines are in areas that experience a high volume of passengers, this translates into 76% of passenger journeys being operated by electric train. The main freight routes are also all electrified, resulting in 45% of rail freight journeys being electrified.

Rail suffers from an inherent inflexibility of assets in use due to the long lives of capital-intensive rail assets. Unlike private transport, rail assets have life cycles greater than 20 years therefore technology upgrades can be much more infrequent. Delivering major upgrades on an active network also represents a major barrier to improvement, as closure is extremely disruptive to commuters, freight traffic and the economy. To avoid this disruption, upgrade work is often carried out without closing the line, significantly adding to the time and cost of the enhancement work.

SG and UKG have stated an ambition to reduce and remove the use of diesel over the next two decades. UKG is planning to remove all diesel-only trains from the network by 2040, while Transport Scotland's Rail Services Decarbonisation Action Plan sets out SG's intention that all diesel trains will be removed from the Scottish network by 2035.

This builds on the existing electrification programme in Scotland which has enabled its railway to move away from diesel trains through continued electrification of all major routes to encourage more low emission transport usage. There are continued plans to electrify the remaining major routes, however, some lines are not commercially viable to electrify and as a result these will likely require alternative fuel technologies to replace the existing diesel trains.

**Key conclusion**

Rail has a history of being reliant on fossil fuels. However, the electrification programme has delivered significant increases in electric trains and reduced O&G use, and SG has targeted a diesel-free railway by 2035.

Rail O&G usage represents <0.5% of Scotland's O&G consumption. c40% of the Scottish rail network is currently electrified, with the majority (76%) of all passenger journeys on electrified lines. As a result, opportunities to decarbonise the sector will be focussed on the non-electrified elements of the network.

# Demand drivers



## The factors impacting rail demand

The rail sector is strategically important to Scotland's transport network and historically it is well used, with demand for both passenger and freight use. Our analysis of historical passenger and freight demand indicates:

- Based on data from ScotRail average passenger usage of 96.5 million per year between 2015 and 2020. This primarily relates to commuter traffic;
- Post national lockdowns, journey numbers rebounded as demonstrated by 2021-22 ORR data showing combined passenger journeys of 46.69 million. Figures may exhibit a lag in returning to pre-pandemic heights due to hybrid working;
- Demand patterns have also changed due to hybrid working which may present new opportunities to improve performance and service offerings, for example less focus on peak hours, requiring fewer trains; and
- The composition of demand for distance travelled shows journeys taking place in the Glasgow area represented the highest proportion of shorter distance journeys (up to 20km). For journeys occupying 20-100km, journeys taking place relating to Edinburgh were the most prevalent, and in the greater than 100km range, Aberdeen related journeys were most common. Transport Scotland 2019 Social Survey figures showed the majority of employees not working from home were travelling to large or other urban areas.

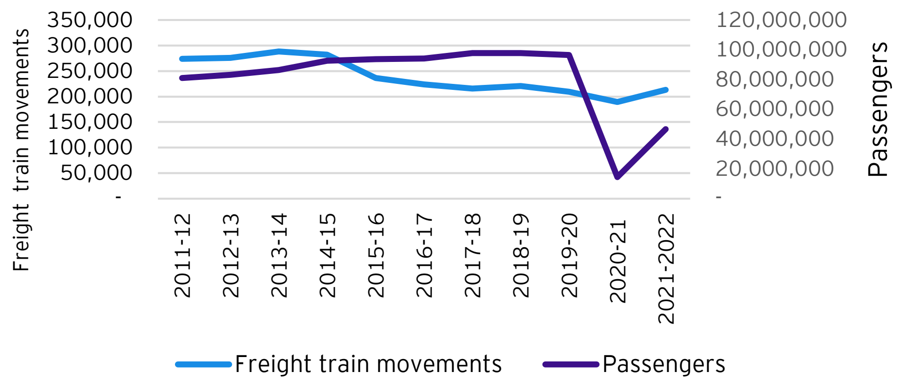
Whilst the number of passenger journeys declined heavily in the pandemic, freight rail was not as significantly affected. For example, overall UK freight train movements have continued to decrease from a peak of 288k in 2013-14, following the reduced demand for coal, to 2019-20 levels of 209k (based on April to March figures). The impact of the pandemic was negligible as 2020-21 only exhibited a decrease to 189k which has rebounded to 213k for 2022.

The declining UK freight movement trend can partly be attributed to the addition of next day deliveries by retailers, which has led to increased HGV and van transport reducing traffic on the freight corridors.

### Key conclusion

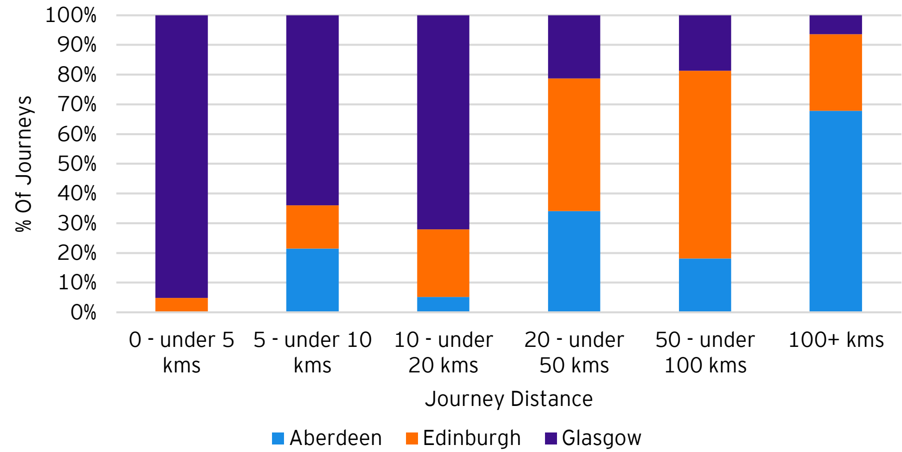
Passenger rail demand showed a steadily upward trend until the Covid-19 pandemic. Conversely, rail freight has shown a continued decline in demand. Although rail is a small consumer of O&G, as it represents an strategic transport network that can support the decarbonisation of the whole transport sector by moving road transport to the rail network.

### ScotRail Passenger & UK Rail Freight Activity 2011-2022




*Source: ORR Table 1223: Passenger journeys by operator, Great Britain, April 2011 to December 2021 + ORR Freight rail usage and performance table 1330 – freight trains run October - December 21 (March 2022)*

### Demand For Distance Travelled To Key Cities




*Source: Transport Scotland - Scottish Transport Statistics No 40 – 2021 (Chapter 7 Rail Data)*

# Demand drivers



**Rail demand and how to encourage modal shift to rail**

*Passenger services*

Unlike many other modes of transport, increased demand for rail can help reduce Scotland's overall O&G use and emissions, because in passenger terms it is efficient (e.g. a train can transport more passengers compared to a car / bus).

Network constraints and ultimate capacity mean that rail is not, and likely cannot, be the solution for everyone, but rail is extremely effective for point-to-point mass transit, for example, commuting to cities.

One catalyst for demand is continued investment in the rail infrastructure. Transport Scotland's Decarbonisation Plan outlines a number of factors that make electrified rail more attractive to users, including:

- Newly electrified passenger railway lines often show what is known as a 'sparks effect' where, if a line is electrified, patronage increased. Newly electrified lines use modern rolling stock.
- Electric rolling stock is also smoother, quieter, cleaner and faster than its diesel equivalent.
- Additionally, electrification often stimulates wider infrastructure interventions and timetable changes which can be attractive for users, for example, at Bathgate the passenger numbers increased 87% four years post-electrification.

However, as noted on the previous page, the Covid-19 pandemic and associated lockdowns caused a dramatic reduction in rail passenger demand. A significant proportion of rail commuters are office workers who were able to work from home during the pandemic and whose employers have moved, post-pandemic, to a hybrid working model. Demand patterns have changed, which may present some new opportunities to improve performance and offering, for example, placing less focus on peak hours, requiring fewer trains to be running at these times.

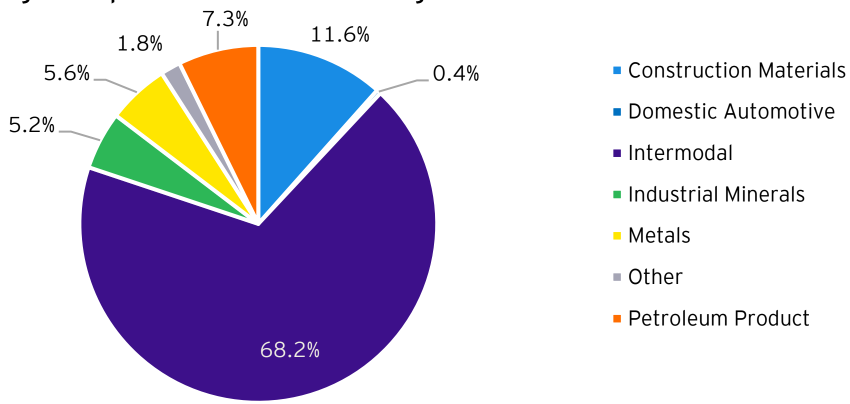
*Freight services*

The National Infrastructure Commission states that rail emits only about a quarter of the $CO_2$ of road freight per tonne kilometre. As such, modal shift of HGV traffic to rail has the potential to reduce Scotland's road emissions.

Demand drivers of freight journeys are not solely controlled by the rail industry, rather they are part of a wider distribution network, requiring cross-mode coordination. For example, maritime freight may arrive in Scottish ports, to then be distributed overland using rail freight, while supermarkets are increasingly moving grocery goods by rail to distribution centres, where they are transferred to HGVs for onward transport by road. The use of intermodal containers allows freight to be easily moved between ship, rail and road.

Demand for rail freight is commercially driven. Factors mainly driving demand are cost, flexibility and convenience, but environmental concerns are increasingly a factor in the industry. Tesco has promoted its use of "Tesco trains" by removing 76 HGVs worth of goods off the road, with zero exhaust emissions, citing "clear advantages for our business, our customers and the planet".

**Percentage Composition Of Scottish Freight Moved**




*Source: ORR - Table 1310: Freight moved by commodity, Great Britain, April 1982 to December 2021 (2022)*

# Readiness of alternatives

### Rail replacement technologies – electric trains

An electrified network is the core current replacement technology for diesel trains in Scotland. In its Rail Services Decarbonisation Action Plan, Transport Scotland sets out how it intends to remove all diesel trains from the Scottish network by 2035. The plan notes that a rolling programme of electrification is essential to achieve journey time savings, lower operating costs and reduce emissions on more busy, high speed or heavy haul routes.

Electrification is the preferential technology due to its low emissions, quiet operating capabilities and faster travel than its diesel counterparts. Electric trains are cheaper than the diesel counterpart and from an operational perspective, maintenance is reduced due to improved reliability compared to diesel models. Lease rates for electric trains (leasing being the standard rolling stock financing structure given the maturity of the off-balance sheet leasing market) are lower than diesel trains given the greater longevity of electric traction in the UK market.

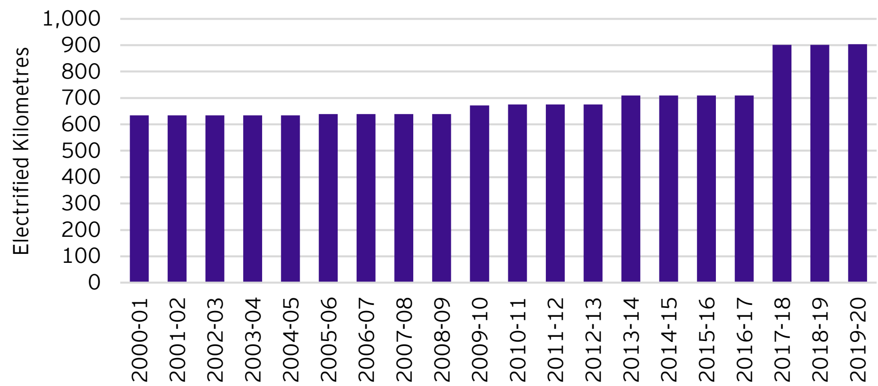
Electrification involves high capital costs. However, with the Great Western and Edinburgh-Glasgow electrification schemes completed, TransPennine electrification ongoing, and the soon-to-be-started East Midlands electrification project, there is growing capability to deliver electrification in the most efficient way possible, applying learning from these schemes to the topography and distribution network of Scotland. Leasing more new-build, highly efficient electric trains alongside investment in further electrification projects is a clearly evidenced and sustainable approach which can be deployed in the short and medium term.

The high capital costs referred to above make the electrification of some long and lightly used sections of railway, such as the Far North line, economically unviable. As such, decarbonisation will require the use of additional technologies alongside electrification. These include:

- Battery-powered trains; and
- Hydrogen fuel cell trains.

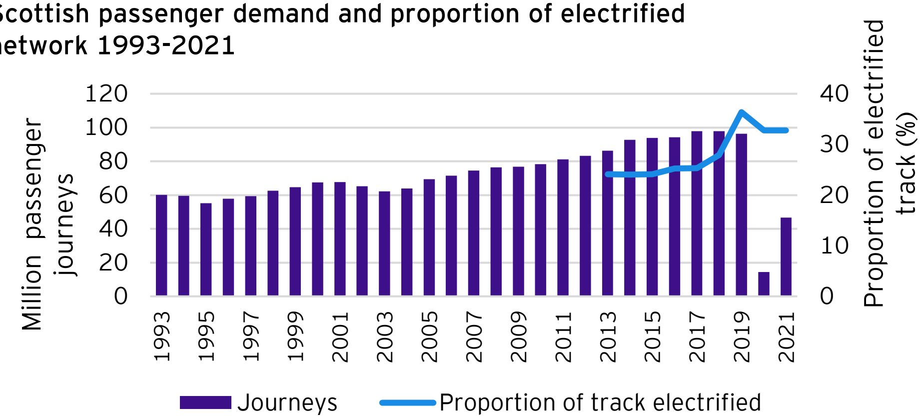
Additionally, electric-diesel hybrid trains are an alternative option currently in use in other parts of the UK. However, as they will not conform to the SG's goal of removing diesel-powered trains from the network by 2035, they have not been considered further.

**Total electrified kilometres in the Scottish rail network from 2000-2020**




*Source: Transport Scotland – Scottish Transport statistics 2021 No 40*

**Scottish passenger demand and proportion of electrified network 1993-2021**




*Source: Transport Scotland Scottish Transport Statistics & Table 6320 - Infrastructure on the mainline (2022)*

# Readiness of alternatives



**Rail replacement technologies (cont.)**

### 1. Battery electric trains

This technology uses on-board batteries to power the train's electric motors, reducing the need for continuous overhead line electrification. Battery electric trains were first run in the 1950s and have been commercially operated In Japan for the last 20 years. Benefits and drawbacks of this technology include:

*Benefits*

- No use of traditional fossil fuels;
- High levels of energy efficiency (almost 70%) as 1.4kW of power for 1kW of drive;
- Battery electric trains can fast charge in 2 minutes, but this delivers a reduced range of 25 miles. Such technology could be used for frequent-stop short hops 'off wire' on non-electrified routes;
- Existing technologies can help charge the onboard batteries, for example, through regenerative breaking or through contact charging from existing electrification infrastructure; and
- There would likely be an attractive lease financing market for these long-life sustainable assets which can rely on today's power generation capability and network, freeing up capital budget for investment in other improvements.

*Drawbacks*

- The size and weight considerations for rail transport, particularly freight, require much larger batteries with longer charging requirements.
- Range and speed restrictions may limit the operational effectiveness of the trains. For example, the Rail Industry Decarbonisation Taskforce (Final Report to the Minister for Rail 2019) noted that current battery-operated trains have a range of 60 miles, with top speeds of 60mph.

### 2. Hydrogen trains

Hydrogen trains use hydrogen fuel cell technology to drive the train. This is relatively new technology, however, it has been put in use: two Alstom hydrogen trains are currently in use in Germany, whilst PorterBrook recently converted a 30-year old train to a hydrogen demonstrator to run on the Cathcart to Glasgow Central route during COP26. Benefits and drawbacks of this technology include:

*Benefits*

- Reduced emissions compared to diesel alternative.
- Hydrogen-powered trains can travel "off wire".

*Drawbacks*

- Currently the technology exhibits only 30% energy efficiency at 3.4kW of power to generate 1kW of drive. Comparatively, electrified rail achieves over 80% efficiency (1.2kW for 1kw of drive).
- The infancy of the technology makes capital cost far greater than cheaper existing equivalents.
- Operating costs are currently high, but can be expected to decrease as hydrogen production increases.
- Hydrogen storage requires up to eight times more space than that of diesel, which may lead to reduced passenger accommodation space.

# Readiness of alternatives



### Rail sector replacement technologies (cont.)

In the Rail Decarbonisation Action Plan, Transport Scotland sets out its plan to continually electrify the remaining rail network to reduce its emissions. This will focus on the electrification of routes from the central belt to Aberdeen and Inverness.

For those routes that cannot be electrified by 2035 or later, the Plan recommends alternative technology, with hydrogen or battery trains used for Glasgow to Mallaig routes, Aberdeen to Inverness or routes north of Inverness.

In this way it will use hydrogen and electric battery technology as 'off wire' technologies that can refuel/recharge at stations en route.

The map shows Transport Scotland's plans for the decarbonisation of the Scottish rail network. This assumes significantly increased electrification compared with today, in particular north of the central belt. Authority to fund and deliver electrification, and introduce new electric rolling stock, sits with SG and so is an immediately available, credible option to reduce diesel consumption.

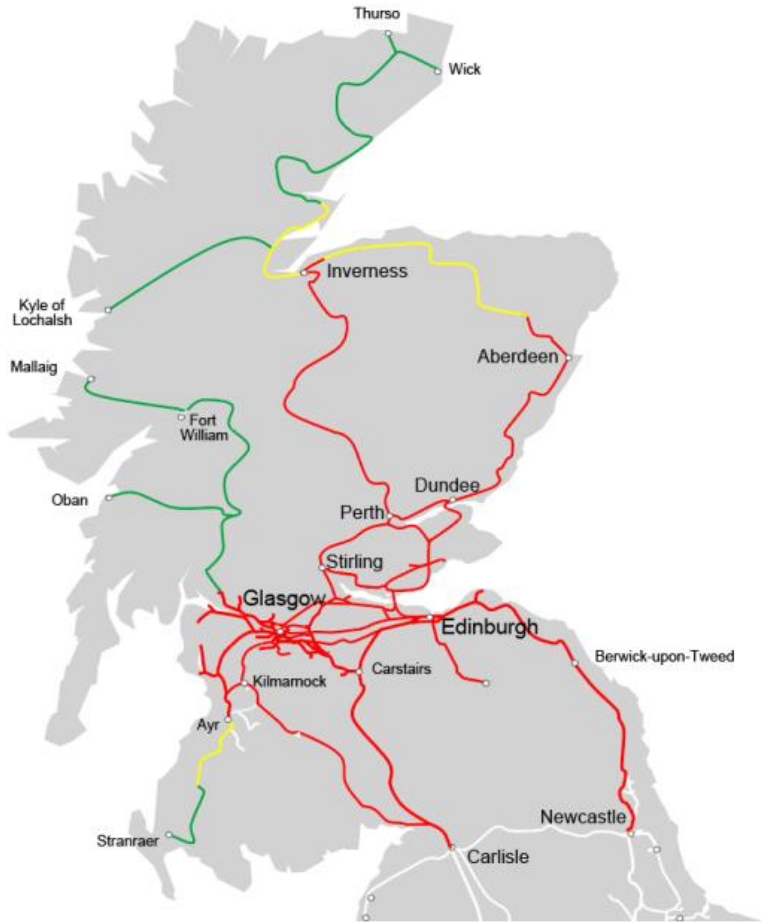
### Key

- **Red line:** Electrified network envisaged by 2035.
- **Yellow line:** Temporary alternative traction (this could be partial electrification and/or the use of alternative technology, hydrogen or battery, prior to electrification).
- **Green Line:** Permanent alternative traction (hydrogen or battery electric trains).

### Key conclusion

Hydrogen and electric battery are the best alternatives for 'off wire' routes that cannot be electrified. However, technology (range and speed) and infrastructure (refuelling and storage) barriers need to be overcome first to allow implementation.

### Map of decarbonised rail network in Scotland, 2035




*Source: Rail Services Decarbonisation Action plan (Pathway to 2035) – Transport Scotland (July 2020)*

# Financial barriers



**What are the costs of the alternatives?**

**Electrification**

*Capital Expenditure* – Electrification requires expenditure on both the rail infrastructure and new rolling stock.

Costs vary with specific circumstances of the track being addressed, but the Railway Industry Association estimates that it costs around £0.75m to £1.5m to electrify 1km of railway line in the UK. With the Rail Decarbonisation Plan indicating on average 130km of single track kilometres per year to 2035, that would suggest £97.5m to £195m per year or a total of £3.4bn at today's prices.

In terms of rolling stock, Abellio purchased 70 modern class 385 rolling stock units at a cost of £475m in 2015 to service the newly electrified central belt lines.

*Operating Costs* – From an energy perspective, Transport Scotland detailed that ScotRail had used 255GWh of electricity for all electrified services. Based on Network Rail's energy tariff (9.991p per kWh[1]), this would imply energy costs of c£25.5m.

**Hydrogen**

*Capital Expenditure* – With hydrogen trains in operation in Continental Europe but not widely used, capital costs for these models are considerably higher at £11.05m[2]. Whilst these costs can be expected to decrease with further development in technology, the current cost is more than double that of the class 385 trains used on the electrified track.

*Operating Costs* – The CCC estimates that hydrogen production will likely cost 7.3p per kWh in an estimated range of 4.8p-8.0p/kWh. Whilst this is comparable to electricity costs, wider infrastructure investment is required to allow for hydrogen trains, for example refuelling, storage and transportation networks. Additionally, due to the nature of hydrogen propulsion technology, maintenance costs are also expected to be lower than with diesel trains.

**Battery Electric**

*Capital Expenditure* – Similar to hydrogen trains, battery electric technology is not widely utilised. Battery Electric trains are likely to use the similar drivetrains as electric trains, but need to carry a large battery, which will add to the capital cost. Transport Scotland estimates battery electric trains cost up to a third more than existing rolling stock models. For example, a battery train would cost c£7m based on a class 385 model.

*Operating Expenditure* – ScotRail has been reported[3] to use electric multiple units (EMUs), battery electric multiple units (BEMUs) on the railway network with anticipated rapid technology developments in battery technology units in the next 5-10 years.

ScotRail estimates operating costs for EMU and BEMU units to be £1.32 and £1.62 per mile respectively. Similarly, battery electric trains are expected to have lower maintenance costs than existing diesel trains.

*Cost conclusions*

The ongoing electrification programme will require consistent capital investment over the next 12 years to deliver a diesel-free network by 2035. However, Transport Scotland's commitment around the programme is positive as it ensures that the industry in Scotland retains expertise and capabilities to service the constant flow of projects.

Hydrogen or battery electric technology would only replace current diesel trains on routes that will not be electrified as aligned to the expected 2035 route network diagram. As such, the capital outlay and infrastructure would only be required on certain routes, rather than the full rail network. While battery electric and hydrogen trains offer competitive operating costs, there will be significant upfront capital costs when replacing the existing rolling stock.

Additionally, large investment will be needed for hydrogen refuelling infrastructure and storage. The fleet plan in support of the Decarbonisation Action Plan makes use of the life expiry of current diesel fleets to ensure that it is economically optimal to replace them with electric/battery electric fleets. Existing diesel trains can be relocated to routes pending electrification (or leased to other operators if not required in Scotland).

*[1] Prices taken from Network Rail EC4T charter tariff letter.*

*[2] Capital cost based off Germany's RMV €360m Euro Contract with hydrogen train supplier Alstom for 27 hydrogen trains ( €1/£0.85).Note the contract also included supply of hydrogen and maintenance provision costs.*

*[3] https://www.railengineer.co.uk/decarbonising-scotlands-railway/*

# Non-financial barriers



## Considerations and risks in selecting new technologies

### Non-financial barriers

Although the route to a decarbonised rail sector is well understood and the replacement technologies are identified, Scotland still faces challenges in decarbonising the sector further:

- **Adoption of technology on existing infrastructure** – Whilst there are a considerable number of electrified rail routes in Scotland, no hydrogen trains are in operation on non-electrified routes yet. Consequently, infrastructure investment is needed to accommodate hydrogen trains, for example, hydrogen fuelling stations.
- **Supply of technology** – The lead time for trains is considerable (years) and as such, production timescales and requirements need considering when planning a large-scale shift to new propulsion methods.
- **Commercial and strategic analysis** – The Rail Service Decarbonisation Plan notes that detailed cost analysis by route has yet to be performed. Analysis will need to be undertaken to establish the likely impact on the cost of running alternative traction on the network and to understand what it means for the overall cost and revenue position for rail.
- **Relative immaturity of battery traction technology** – Compared with overhead line electrification, the multiple ongoing experiments with battery electric technology show that similar issues remain as with battery electric road vehicles, and the future speed of technological improvement in this area is insufficiently clear to bank on battery trains entirely replacing diesel without the need for any further line electrification.

*Conclusions*

Whilst the technology alternatives are not fully ready to be implemented, changes in the short to medium term (to 2035) needs to be a priority to continue decarbonisation of the rail sector.

Transport Scotland's Rail Decarbonisation Action Plan detailed the challenges faced in further decarbonising Scotland's rail network and likely timescales. The plan noted:

- The most feasible way to achieve further decarbonisation of the rail network will be the continued electrification on planned routes (central belt to Inverness/Aberdeen) with an aim of 130STK per annum.
- Additionally, less busy rural routes present a prime opportunity for the early introduction of battery or hydrogen-based technology on fleet expiry dates. Rural routes will place less strain on the technology compared peak commuter routes and will help limit disruption.

### Infrastructure considerations for further electrification and other replacement technology

The rail sector is strongly positioned to decarbonise further through continued electrification, and in the Rail Service Decarbonisation Plan, Transport Scotland has set out its vision for how this will be achieved.

This commitment and identification of a programme of works will provide industry suppliers with confidence in a pipeline to maintain the necessary expertise and capabilities to deliver this work in Scotland.

For areas of the rail network that cannot be fully electrified, infrastructure improvements are crucial to the successful implementation of the alternative technologies. For example, hydrogen production and hydrogen storage facilities are required for the successful adaptation of the hydrogen fuel cell technology or partial electrification of non-electrified lines so contact charging can be used for electric battery trains. For example, projects like Whitlee's hydrogen storage and Aberdeen City Council's hydrogen refuelling station will be paramount in managing hydrogen supply levels.

# Rail - Conclusion



**The Scottish rail sector consumes a very small proportion of Scotland's O&G and is an insignificant contributor to total emissions**

- The sector represents 1% of Scottish transport O&G consumption (<0.5% of the total Scottish consumption) and 1.2% of its transport emissions. Over 40% of Scotland's railways are already electrified and 76% of all passenger journeys are on electric trains.

**Passenger rail demand grew steadily until the Covid-19 pandemic**

- The rail sector is an important component of Scotland's transport system. Historic ScotRail usage demonstrates average passengers of 96.5m per year from 2015, with a consistent upwards trend until 2020.
- Delivering a modal shift from high emitting road sectors to rail will support the decarbonisation of the Scottish transport sector.

**The future of the decarbonised rail sector will focus on the continued electrification of the Scottish rail network**

- Plans are in place to continue investment in electrified rail lines, however, the full electrification of the Scottish rail network is neither practical nor cost-effective.
- For those routes that cannot be electrified, alternative technology is recommended.
- Hydrogen and electric battery are the best alternatives for 'off wire' routes that cannot be electrified. However, technology (range and speed) and infrastructure (refuelling and storage) barriers need to be overcome first to allow implementation.

**The costs of additional replacement technology has not been quantified**

- While electric battery and hydrogen trains offer competitive operating costs, significant upfront capital costs will be required to replace the existing rolling stock – this would likely be lease financed, as is normal practice in the rail industry. Additionally, large investment will be needed for hydrogen refuelling infrastructure and storage, or electric charge infrastructure for battery trains.
- However, hydrogen and battery trains will not replace all the existing rolling stock. Existing diesel trains can be relocated to routes pending electrification (or leased to other operators if not required in Scotland) and hydrogen or battery technology would likely only replace current diesel trains on routes that will not be earmarked for electrification. As such, the capital outlay and infrastructure would only be required at certain routes not the full rail network.

**Continued electrification is the best means of decarbonisation. Non-financial barriers need to be navigated prior to alternative traction technology replacing diesel rolling stock**

**SG has a number of policy levers, including being responsible for planning and delivering rail policy, strategy and development of Scotland's railway, to support the continued electrification of the network**

# 10 Supplementary Analysis: Transport - Domestic Shipping

# Maritime Transport Overview



## Maritime Transport Overview

Maritime transport is essential for connecting people and transporting goods across Scotland. It not only acts as major support for trade but also plays a vital role in sustaining its geographically dispersed communities and remote locations.

The sector can broadly be divided into international and domestic shipping, where international shipping includes water-based transportation bound for, or coming from non-Scotland origin or destinations, whereas all water transport activities originating in and destined for Scotland are part of domestic shipping. This section focuses on domestic shipping, as SG policies can govern activities associated with domestic transport.

The components of domestic shipping include the freight movement and all ferry services. Vessels handle freight largely through sea routes with fuel being the major commodity transported. Scotland's ports are the modal change point for freight enabling further distribution through rail or road and vice versa.

Ferries provide vehicle and passenger services to the mainland and islands through 66 scheduled routes. The routes that are vital for Scotland's island communities have been determined as lifelines and are subsidised by SG. These are operated under Clyde & Hebrides Ferry Services (CHFS) and Northern Isles Ferry Services (NIFS) contracts. Other ferry services are either operated by local councils or by commercial operators.

## Key statistics domestic shipping (2019)

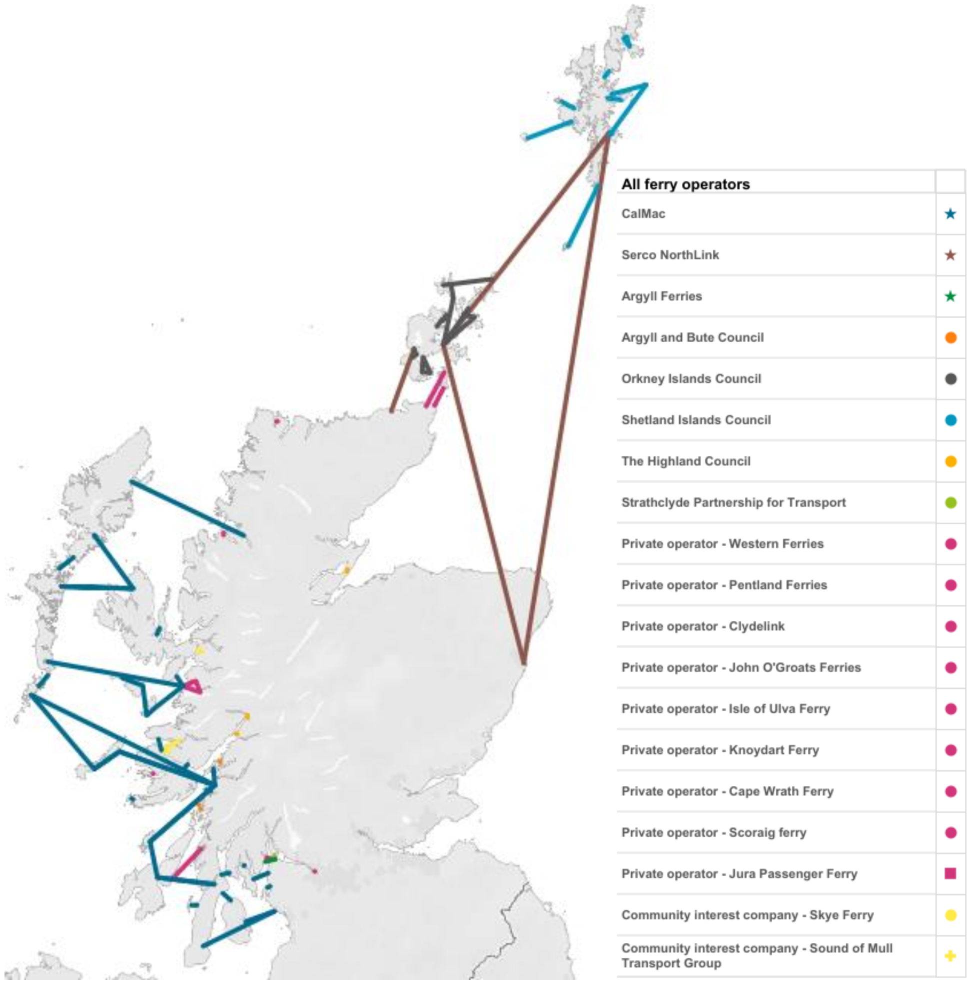
- Domestic Freight: 17.8m ton
- Passenger Transported: 8.7m
- Vehicles Transported: 3.1m

## Hydrocarbon usage

The domestic shipping sector has seen a reduction over the years due to a decline in domestic freight. Diesel is the most commonly used fuel for domestic shipping in Scotland. At present, there are 3 hybrid ferries operating in Scotland's ferry fleet using diesel and electric batteries.

*Footnote: Data is from Scottish Transport Statistics and is as per the statistics obtained from Ferry operators for all ferry services. Data for Pentland ferries is not included due to unavailability. Some ferry services have data only for main routes. Freight data is for major ports only.*

## Ferry routes in Scotland




*Source: Audit Scotland, [Transport Scotland's ferry services | Audit Scotland (audit-scotland.gov.uk)]*

# Domestic shipping primary activities



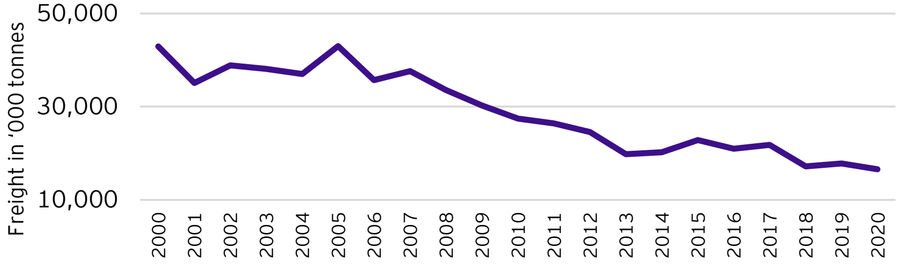
## Domestic shipping activity

The sector's reliance on oil is also impacted by freight and passenger demand:

- Domestic freight transported through shipping has declined by 59% from 2000 to 2019. However, there was an increase of 3.6% from 17.2 million tonnes in 2018 to 17.8 million tonnes in 2019. A major proportion of the freight moved is fossil fuels from the O&G industry. In 2019, liquid bulk accounted for 6 million tonnes of total freight (34%), followed by roll-on/roll-off traffic representing 5.9 million tonnes (33%) and dry bulk representing 4.1 million tonnes (23%). A decline in O&G production is expected to reflect a reduction in freight movement as per historical trends. However, Scotland's ambition to develop the hydrogen economy and become an exporter of hydrogen by 2035, could lead to the transport of hydrogen via shipping. Primarily transported by sea, this acts as a major driver of demand for domestic freight via new low-carbon methods, offsetting the reduction in fossil fuel freight.
- Passenger and vehicle traffic on the ferry network has seen an increase since 2015. In 2019, 8.7 million passengers and 3.1 million vehicles were carried within Scotland, an increase of 1.5% and 2.5% from 2018, for passengers and vehicles respectively.
- The introduction of the Road Equivalent Tariff (RET) in 2008 made ferry use more affordable by linking fares to a rate per mile, in line with the SG's commitment to providing one single overarching fares policy across Scotland's entire ferry network. It led to an estimated average fare reduction of 34% for passengers and 40% for car traffic on the CHFS network, making ferry transport more affordable.
- A steady growth in passenger movement is expected due to ferry development plans focusing on increasing the level of service through better connectivity, resulting in frequent sailings between ports.
- COVID-19 impact – Domestic waterborne freight passing through all ports decreased by 7% in 2020 to 16.5 million tonnes. Dry bulk witnessed the largest decline in terms of quantity, reducing 1.2 million tonnes from 4.1 million tonnes in 2019, to 2.9 million tonnes in 2020. Ferry traffic was also hit by lockdown restrictions, with a significant decline of 53% in passenger numbers and a 44% decline in the vehicles carried.

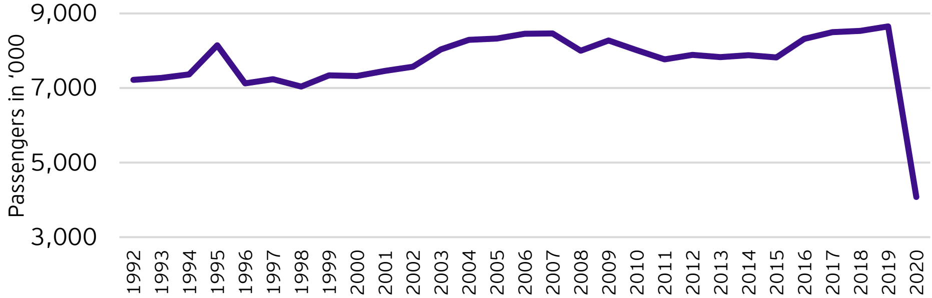
1. *Data is from Scottish Transport Statistics obtained from Ferry operators for all ferry services.*
2. *Freight data is for major ports only (as per STS)*

### Domestic freight at major Scottish ports



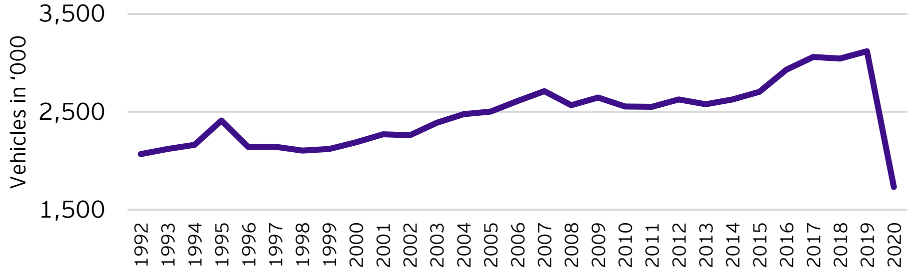

*Source: Transport Scotland - Scottish Transport Statistics No 40, 2021*

### Passengers carried on ferries




*Source: Transport Scotland - Scottish Transport Statistics No 40, 2021*

### Vehicles carried on ferries




*Source: Transport Scotland - Scottish Transport Statistics No 40, 2021*

# Domestic shipping emissions



### Emissions and the percentage of Scotland's emissions

In 2019, Scotland domestic shipping contributed to 16.28% (1.96 Mt$CO_2$e) of transport sector GHG emissions. This includes the emissions from associated services such as marine engines on ships, and tug boats. The 2019 emissions have reduced by 41% as compared to 1990 emissions.

The decrease can be attributed to a range of factors, including optimising the number of trips, and upgrades to the vessel or fleet such as hybrid propulsion systems, and use of drag reducing paints. However, a decline in domestic freight carried is a major factor in reducing total emissions. The emissions and domestic freight transported followed a similar trend and reduced significantly between 2000 to 2014. However, from 2015, emissions have shown a gradual increase.

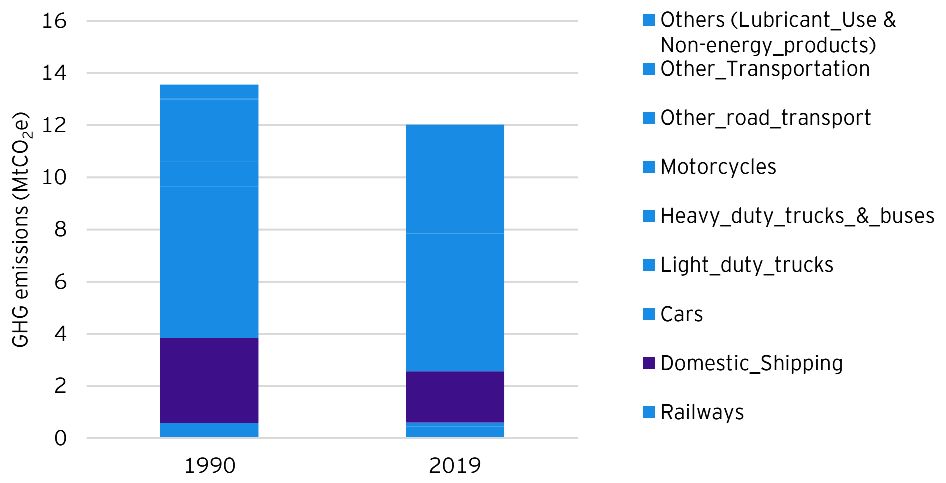
Whilst recent trends suggest passenger numbers will marginally increase in the coming years, the emissions from passenger services can be expected to remain at similar levels, even if there are no, or minor, changes in the propulsion technology. However, an increase in number of vehicles carried may result in increased levels of emissions if this required additional vessel sailings.

The average useful lifespan of a vessel is generally considered to be around 30 years and, at present, the average age of vessels used for ferry services in Scotland is 22-23 years. The vessel replacement programme provides an opportunity to plan for the addition of more efficient technology to the fleet, reducing emissions as part of long term strategy.

**Key conclusion**

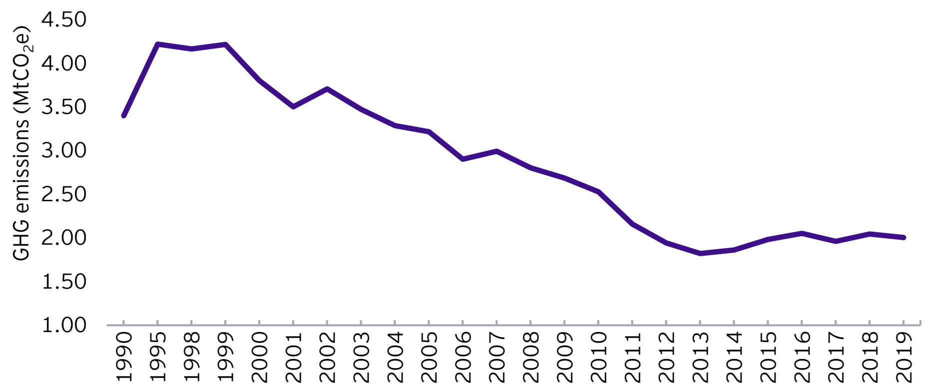
The International Maritime Organization (IMO) adopted short-term measures for international shipping industry, which aimed at cutting the carbon intensity of all ships by at least 40% by 2030 compared to a 2008 baseline. If the same is to be applied to domestic shipping a further reduction from current levels is required for Scotland's domestic shipping by 2030.

### Transport emissions – Domestic shipping




*Source: NAEI GHG emissions by sector*

### Scotland's domestic shipping GHG emissions




*Source: NAEI GHG emissions by sector*

# Drivers of demand



### Drivers of demand in the fossil fuel consumption

Shipping is an integral part of the transport system in Scotland. With technological advancements, sea transport became more important for the expansion of trade and connectivity in the 19$^{th}$ century, but with the advent of rail systems in Scotland saw shipping activity reduce.

In 1990, Caledonian MacBrayne became wholly owned by the Secretary of State for Scotland (and subsequently, the SG). Ferry routes were subsidised as private operators were not able to generate enough operable profits at lower fares. At present, the SG has CHFS and NIFS as subsidised contracts to cater to the demand on major routes.

The ferry sector continues to be an accessible mode of transport for the island communities, which rely heavily on the domestic shipping for connectivity and trade. The demand for ferry services can eb expected to increase with the government's measures targeted towards improving frequency and quality of services to boost business and tourism for the islands.

Several factors have impacted a dependence on fossil fuels in the sector, including a reliance on oil based fuels, a lack of technological advancement over the years, and, to some extent, the reliance on lifeline ferry services.

### Technology

Marine propulsion has historically been dominated by fossil fuels. This was primarily due to oil having greater energy density compared to previous coal powered steam engines. During the mid 1900s marine gas oil (MGO) gained popularity as a shipping fuel due to the increasing demand of cheaper fuels. From the 1960s to 1980s the major transition took place with the roll-on/roll-off vessels being integrated in the fleet. This brought major upgrades to the fuel technology and the infrastructural changes required to support the change. Scotland made noteworthy upgrades to vessels in 2011 when it placed orders for 3 hybrid vessels to be added to the fleet. These vessels are estimated to reduce up to 38% of emissions during their life span.

### Deterrents for change

The reliance on fossil fuels has also been impacted by the following:

- Lack of global policy levers towards a sustainable fuel for marine vessels;
- Higher investment cost for the fuel changes, e.g. upgrades of vessels and propulsion systems;
- Development of support infrastructure, e.g. infrastructure on ports; and
- Higher cost of fuel compared to MGO or other fossil fuels used for shipping.

In Scotland, the cost of acquiring and operating new vessels is another barrier to transforming the sector's reliance on oil. This is particularly true of the Scottish Ferry sector, where the public sector is bearing these costs. If these costs are going to be passed down to customers, the affordability for travelling reduces, negatively impacting island communities which is contrary to policy intent.

The current subsidy system has increased the utilisation of ferry services but has also resulted in financial deficits for SG. As the social and environmental benefits outweigh the financial losses in the long run, the benefits of subsidies cannot be undermined. It is not only essential for the movement of goods and services, but is an integral part for sustenance.

With high dependency of islands on ferries and a gradual increase in the use of these services, the demand for fossil fuels are also expected to rise. As the change in technologies would put pressure on the travel expenditure of the residents, SG will need to find a balance between providing subsidies and making upgrades to the fleet to achieve long term sustainable operations.

This shows how vital government investment is to unlocking opportunities to reduce consumption in the ferries sector.

# Drivers of demand



### Contribution of RET to demand

Launched in 2008, RET was implemented on almost all of the CHFS network in 2015, and is a distance based tariff structure applicable for passengers and cars (including small commercial vehicles upto a length of 6m in length). Over the period the initiative has contributed to an increase in the number of cars carried across various ferry routes. The annual net cost of RET was £25 million in 2018, with two-thirds of the cost relating to cars. It has induced c20% increase in car travel by ferry on the CHFS network. The subsidy has more than doubled since the 2015 rollout. The estimated cost of RET is calculated based on the following parameters:

- Loss of revenue due to subsidy; and
- Revenue due to added influx caused by RET.

The initiative resulted in a total spending of £120 million from 2008 to 2018. Apart form the financial expenditure, the following observations were highlighted in the assessment conducted by Transport Scotland among island residents:

- Flexibility of travel is restricted; and
- Pressure on island infrastructure or communities due to increased transfers.

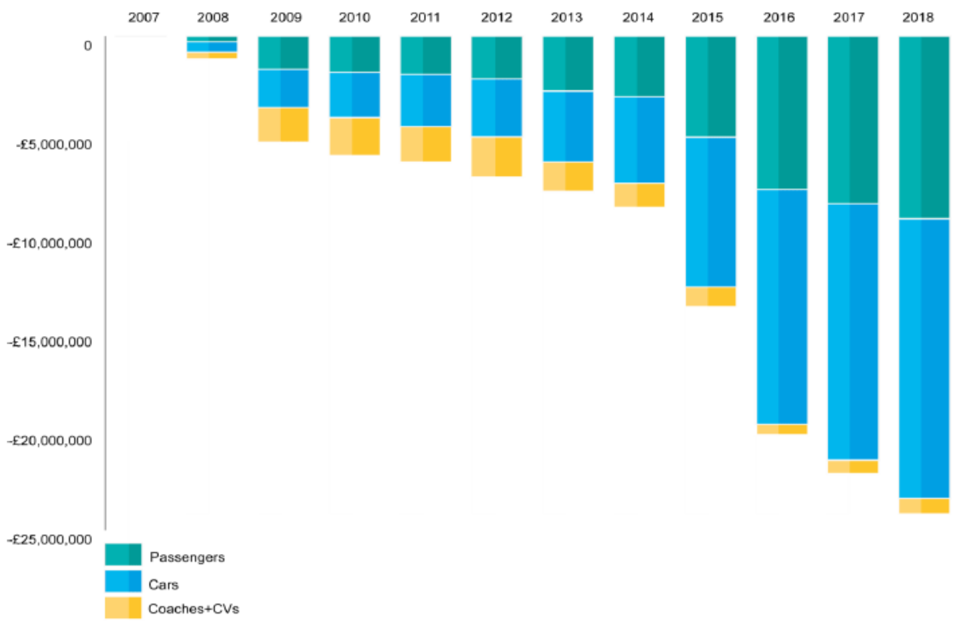
In order to address the above issues, the following measures were identified:

- Demand management needs to be further explored to understand flexibility in travel. Additionally, developing a variable fleet size can also address the concern of flexibility; and
- Implementing measures to reduce visitor numbers or car-based visitor numbers; or investing in tourism infrastructure.

**Key conclusion**

Since its introduction in 2008, RET has had a material impact on the demand for ferry services. Hence, with increasing service levels, RET can be expected as an important driver of demand in the future with improved services provided and vehicle purchase capacity increases.

### Annual net cost of RET




*Source: Transport Scotland website*

# Technology alternatives



## Technological readiness of alternatives

At present, the most common fuels used for shipping in Scotland are bunker fuel (or MGO) and white diesel.

The shipping industry is testing new technologies as pilot-runs for propulsion systems which have lower emissions as compared to the conventional fuels, but these technologies are still in their infancy. The major technologies available at present or in pilot phase aiming towards reducing emissions are discussed below.

### All-electric (battery operated) ferries

The concept of electric ferries is based on powering the complete vessel through electricity stored in batteries. It is gaining momentum in countries which have short-sea ferries, inland navigation vessels and small boats. Electricity generated from renewables provide a clean and emission-free fuel for the ferries, enabling reduction of almost 100% emissions. Electric ferries are also efficient in reducing the noise pollution at sea due to their almost silent operations.

A live example is provided by Denmark, where an all-electric ferry is estimated to have saved 2,000 tonnes of $CO_2$ emissions per year compared to the traditional vessels. The ferry cost c40% more to construct than a diesel ferry but generates 75% savings on fuel costs. A break even point of 4 to 5 years is expected by the operators of the vessel. Other countries such as Norway and the USA, have also taken similar initiatives but are currently at trial or pilot stages.

Electric ferries may face some hurdles in implementation due to the following reasons:

- Low range at present does not make it a feasible option for longer routes;
- Charging infrastructure requires major upgrade to ports, resulting in higher initial capital expenditure
- The need for a large battery takes up hold space, which reduces carrying capacity and makes retrofitting into existing ferries difficult; and
- Other challenges to overcome currently include slow charging, large storage areas and high electricity demand for higher power ships or ferries.

### Biofuels

Biofuels are produced from substances such as vegetable oil, and organic waste, and can be blended with several existing commercial marine engines. They provide lower emissions and emit less pollutants but appear to be best suited to being a transitional fuel to reduce emissions, rather than a net zero solution.

### Hydrogen ferries

Hydrogen could be used either as a combustion fuel or as a fuel cell. Fuel cells provide a clean energy supply source and their use is being explored, as it may be more cost efficient. The use of hydrogen as a combustion fuel requires additional filters to be attached to reduce the release of nitrous dioxide.

To maximise the benefits, the development of a green hydrogen industry at large scale will be required to allow the shipping industry to embrace it as a zero-emission fuel, because at present, hydrogen extraction can often require burning fossil fuels which increases the indirect emissions. With more advances in hydrogen extraction and production, the cost of hydrogen is expected to reduce making it a favourable fuel for powering vehicles in the longer term. Additionally, the energy density of hydrogen is three times lower than bunker oil, leading to large storage requirements.

### Ammonia-hydrogen ferries

Ammonia is an alternative means of storing hydrogen, which is made by combining hydrogen with nitrogen from the air. It is easy to store, and handle compared to hydrogen as it has a higher density and does not require extreme temperatures for storage. It can be converted to hydrogen onboard a ship, allowing it to be carried and stored as ammonia on the ship before being used in a hydrogen fuel cell.

Issues to overcome with ammonia lie primarily with the high level of investment needed to produce the fuel at present. The production cost of green hydrogen is already high (but likely to fall), and green ammonia production requires green hydrogen coupled with an additional step of transforming it again to be used in a fuel cell, raising the already higher fuel cell cost. It is also toxic for humans and aquatic life, meaning additional steps and costs are required to secure safety and sustainability.

**Key conclusion**

As the alternatives are at an experimental stage, it is challenging to draw conclusions on the cost of replacement technology. Whilst all-electric battery ferries are in development and may be appropriate for shorter Scottish crossings, considerable further development is required before the technology to power longer sailings is available.

# Technology alternatives



### *HySeas III*

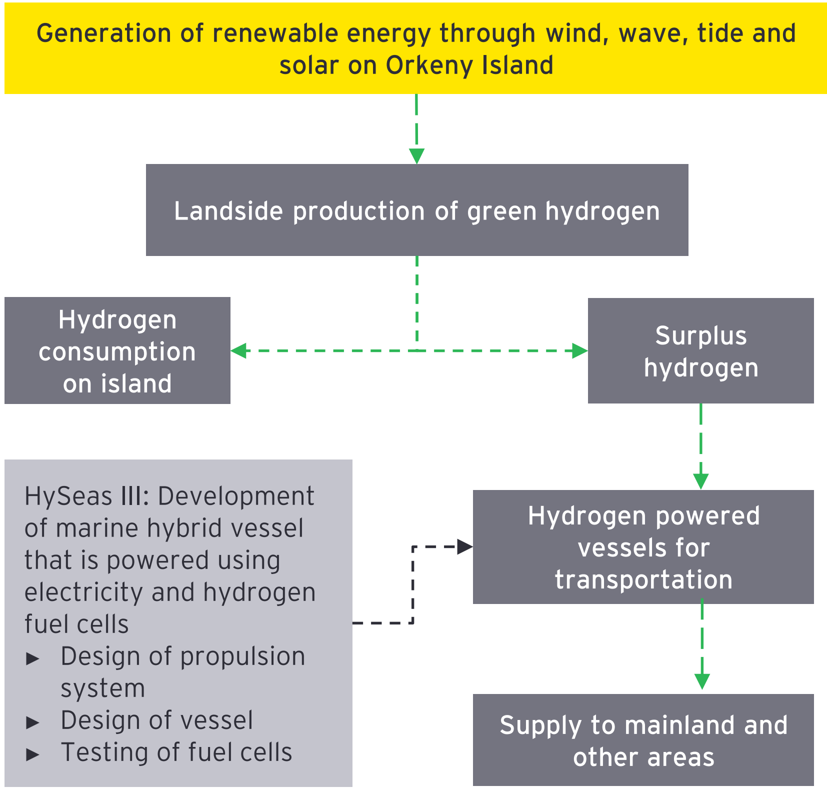
Hyseas III is a consortium comprising an experienced team of commercial and public sector organisations working towards the development of a marine vessel with a hybrid electric drive system, along with the associated hydrogen storage and bunkering arrangements. The project is planned for the Orkney Islands where there is surplus energy generation through tidal and wind energy, but, due to a lack of connectivity to mainland, the energy cannot be utilised. This energy is to be used for the production of hydrogen and the excess will be used to power ships and ferries. HySeas has received funding from the EU's Horizon 2020 research and innovation programme.

Currently it is in the final stage where development, construction, testing and validation of a full sized drive train on land will be conducted. Upon successful run, it will then be integrated into a ferry.

Major partners in the consortium include:

- Vessel design and development: Caledonian Maritime Assets Limited (Scotland);
- Fuel cell power systems: Ballard Power Systems Europe A/S (Hobro, Denmark);
- Vessel Systems Integrator: Kongsberg Maritime AS (Kongsberg, Norway);
- Fuelling Infrastructure: McPhy Energy SA (France);
- Vessel and ports owner/operator: Orkney Island Council (Orkney Islands);
- Lifecycle and socio-economic analysis: DLR Institute of Networked Energy Systems (Oldenburg, Germany);
- Dissemination and Communications: Interferry (Sweden), Arcsilea Ltd (London, UK);
- The team is coordinated by the University of St Andrews (St Andrews, Scotland); and
- After the completion, the expected route for the vessel is Kirkwall to Shapinsay, in the Orkney Islands.

**Proposed utilisation concept for hydrogen under HySeas**




*Source: Welcome to HySeasIII (hyseas3.eu)*

# Non-financial barriers



## Non-financial barriers

The immediately available alterative technologies lie in the form of hybrid ferry vessels or all-electric vessels for shorter routes. While hybrid vessels are not the most efficient, they can be integrated in existing vessels with marginal modification to existing infrastructure and lower costs.

Due to high purchase investment and long life-spans of vessels, early replacement is not usually a viable option, rather, retrofitting or upgrade are preferred. However, in the case of transitioning to an alternate technology or fuel, retrofitting also does not offer a prospective solution. This is primarily due to significant alterations to the propulsion system that require a significant amount of time to complete. Another challenge presented is in the form of storage, as almost all other fuels require more storage than diesel.

Subsequently, with refined and economically viable options highly likely to be available in the future, the sector can witness a gradual change through strategically phasing out redundant technologies. Early investment in future proofing long-life assets could potentially accelerate that gradual change.

There are four major challenges that lie ahead for the decarbonisation of the domestic shipping sector:

1. Lack of readily available replacement technology to be implemented across all vessels. Whilst there is some international movement towards electricity-powered vessels, their application is currently limited to smaller vessels as increased carrying capacity requires an increase in storage and increased electricity consumption. For other fuel options such as hydrogen or ammonia, further development and growth of a supporting hydrogen industry is required.
2. Supporting infrastructure facilities in ports will be required, including potentially remodelling several ports. The challenge faced in operating electric vessels is the availability of fast charging points on ports and harbours. For example, Bastø Electric, an electric ferry in Norway, operates in hybrid mode as only one of its destination ports is equipped with fast charging. For electric charging, harbours need to be upgraded with a complete grid overlay. The electricity demand for operation at such a scale would necessitate a sub-station for smooth operation. The accompanying challenge with implementation of new technologies is the storage and handling of the alternate fuels. All fuels which are being considered as prospective options pose a challenge either in the form of storage or in the form of handling, or both. As noted above, hydrogen or ammonia would require nearly three times more storage compared to bunker oil. Finding additional areas for development for these facilities will pose a challenge as ports and harbours might be placed in restricting terrain or limited land availability for development.
3. With the lack of readily alternate technology, the future road map cannot be ascertained with concrete time estimates and financial costs, meaning there is uncertainty to overcome. Also, with the advent of mass applicable sustainable alternatives, the demand and supply dynamics initially would be high, primarily due to the stringent timelines set by nations for emission reductions. This could lead to delayed timelines or higher than expected investments due to global demand for the technology.
4. Ferries and other vessels have a high capital value and a long asset life and so emissions can be baked in through procurement decisions.

Therefore, early planning and careful consideration of the future opportunities will be required to ensure the best chance of harnessing technological improvements in these areas.

**Key conclusion**

A change in fueling technology will require significant investment to upgrade port infrastructure and the vessels over a short period of time.

# Policy levers



## Policy Levers

SG has taken various measures to address the decarbonisation of the transport sector but with respect to shipping, the future roadmap is not clearly defined due to a lack of available alternatives. Although a huge amount of freight is handled in Scotland, much of this is international trade, limiting the influence of national policies.

As more international decarbonisation policies are framed, SG is also developing short term and long-term strategies for domestic shipping (primarily ferries). In 2020, SG's NTS included several objectives which offer the opportunity to reduce the oil use and emissions of the ferries sector:

- To minimise connectivity and cost disadvantages for island communities, support the development of a long-term investment programme for new ferries and development at ports;
- Highlight the importance of decarbonising the shipping sector, and exploring alternatives to zero/low emission ferry transport;
- Small Vessels Replacement Programme for CHFS network to explore alternative fuel options for a low emission vessel design; and
- Importance of international policy approach to reduce the emissions in shipping through UKG and International Maritime Organisation.

Transport Scotland's Strategic Transport Projects Review 2 also identifies elements of domestic shipping that could help reduce emissions through managerial and technological aspects.

- Ferry vessel renewal and replacement, and progressive decarbonisation: Strategic Transport Projects Review 2 recommends decarbonising the ferry services across various contracts through renewal and replacement of vessels which includes progressive decarbonisation by 2045.
- Integrated journeys at ferry terminals: Due to limited choices or connections, public transport use is discouraged. This can be addressed by improving access and creating a better traveller experience at ferry terminal and interchange facilities. Aligning bus, rail and ferry schedules can also encourage the use of public transport, in turn decreasing the dependency on use of cars.

## Policy Levers – wider developments

Lack of availability, and cost, of the limited alternative technologies have been a roadblock for decarbonising the shipping sector. However, governments are seeking ways to reduce the emissions, and the UK has set a pathway towards net zero for shipping by 2050. The Sixth CCC report makes the following policy recommendations:

- Formally include International Shipping emissions within UK climate targets when setting the Sixth Carbon Budget;
- Continue working with the IMO on global shipping policies, research funding, tighter efficiency targets, and strengthening the IMO 2050 global target;
- Build on the Clean Maritime Plan to set a net zero 2050 goal for UK shipping and develop incentives for zero-carbon ammonia and hydrogen supply chains;
- Commit to the UK's first clean maritime cluster(s) operating at commercial scale (supplying at least 2 TWh/year of zero-carbon fuels) by 2030 at the latest, with zero-carbon fuels expanding to 33% of UK shipping fuel use by 2035;
- Provide support for ports' investment in shore power and electric recharging infrastructure;
- Continue innovation and demonstration support for zero-carbon fuel technologies and their use in shipping, and ship efficiency measures; and
- Monitor non-$CO_2$ effects of shipping and consider how best to tackle them alongside UK climate targets.

The IMO has introduced mandatory measures to reduce GHG emissions from international shipping. It also envisaged a strategy to reduce the GHG emissions by achieving a target of 40% reduction by 2030 and 70% reduction by 2050 as compared to 2008 emissions. The IMO proposed that, for new vessels, an Energy Efficiency Design Index is implemented to reduce carbon intensity of vessels. It further lays down efficiency requirements for the container ships to take a steps towards decarbonisation.

### Key conclusion

Due to the low level of technology readiness, the policy measures should focus on a short term overhaul of new vessels and upgrades to recently procured vessels between 2035 and 2045.

# Domestic Shipping – Conclusions



**Domestic shipping has a high contribution to GHG emissions as compared to the demand for hydrocarbons.**

- The shipping sector represents **1.09% of Scottish demand for hydrocarbons** (172ktoe in 2019), but **4.27% of Scotland's emissions**. This disparity is due to the nature of the fuels used in vessels, as these tend to be heavier and more polluting diesels (often called marine diesel or bunker fuel for the heavier grades).

**Demand has increased for ferry traffic over the last 20 years, but has declined for domestic freight.**

- Domestic freight has seen a sharp reduction of 59% between 2000 and 2019, which is explained by a reduction in the transport of O&G products from the North Sea. Most freight transport in Scotland is non-domestic.
- The driver of demand for ferry services is the essential requirement for those living and working on Scottish islands for transport to the mainland, which can be characterised as 'lifeline' services.
- Ferries have seen an increase in demand over the last 20 years; steadily for passengers and more rapidly for vehicles. The introduction of RET on almost all CHFS routes by 2015 has led to a **20% increase in vehicle traffic on ferries since 2015**.

**Some zero carbon technologies are approaching readiness but their large scale deployment is not currently possible**

- There are few available solutions to decarbonise domestic shipping. There have been incremental improvements to efficiency for newer vessels which can reduce emissions.
- For shorter routes, electric technology solutions might prove to be a feasible solution. In port charging and some technology is also being trialled.
- For longer routes, the alternatives are hydrogen fuel cell technology or alternatively low carbon fuels, such as ammonia, which could support fuel cells for longer routes.
- There are few opportunities to affect demand given the essential nature of services.

**Alternatives have not been quantified, but are likely to be more expensive.**

**Non-financial barriers include the capital and investment costs of changing technology.**

- Apart from the lack of available technology, both vessels and ports are capital intensive assets with long lives, and so the timing and co-ordination is challenging as is the level of investment required.

**SG has a number of policy levers, such as the specification of the subsidised ferry contracts, including the vessels to be used.**

- SG financially supports ferries and so for a large portion of domestic shipping can determine the pace of change, albeit the technical and infrastructure obstacles remain difficult to overcome.

# 11 Supplementary Analysis: Transport - Aviation

# Introduction



### Drivers for fossil fuel demand

The demand for the Scottish aviation sector arose in the mid-1900s. The first civil flight from the Scotland's mainland to Kirkwall was in the early 1930s, however, it wasn't until the 1950s that Scotland witnessed the large scale development of its aviation sector and subsequent demand for O&G in the sector.

As a by-product of World War II, the UK became the world's largest producer of aircraft and through technology improvements, passenger aviation majorly emerged in the 1950s.

In Scotland, airports have operated since the 1930s however, expansion followed in the 1960s and 1970s to cater for the increased passenger demand. For example, Prestwick Airport and Edinburgh Airport opened a new terminal building in 1964 and 1977 respectively, whilst Glasgow Airport consumed Renfrew Airport's commercial operations in 1966.

Highlands and Islands Airports Limited (HIAL) was founded by the Civil Aviation Authority in 1986 with ownership subsequently transferred to the Scottish Office in 1995. The majority of HIAL O&G consumption stems from the provision of island connectivity services.

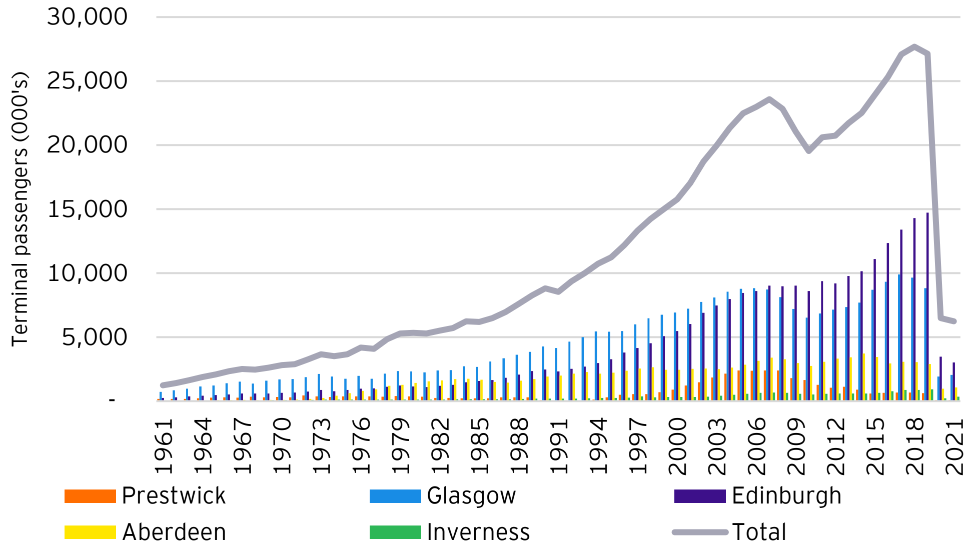
### Deregulation – The catalyst sparking furthered O&G demand

Aviation was predominantly nationalised until deregulation in the 1990s which facilitated the introduction of budget airlines. The emergence of budget airlines resulted in increased international connectivity and improved accessibility to aviation through widespread affordability.

Consequently, aviation demand experienced significant growth from the 1990s with an accompanying increase in international airports served. The increased growth was facilitated by the steep reduction in average ticket prices from the 1960s to the present day as shown by terminal passengers from main Scottish Airports.

Total terminal passengers from the main airports details the extent of the growth with 1.25 million in 1961, 12.18 million in 1996 and a peak 27.68 million in 2018 (as detailed in the graph opposite). The decline in 2020 and 2021 is due to Covid travel restrictions.

**Terminal Passengers from the main Scottish airports 1961-2021**




*Source: Civil Aviation Authority Terminal passengers 1961 – 2021*

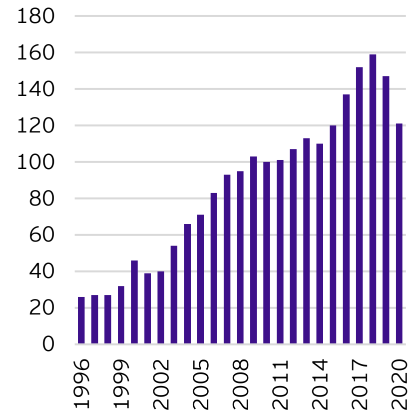
# Introduction



This international growth is underpinned by the number of international airports served from Scotland's main airports. For example, in 1996 26 international airports were served versus a peak of 159 in 2018.

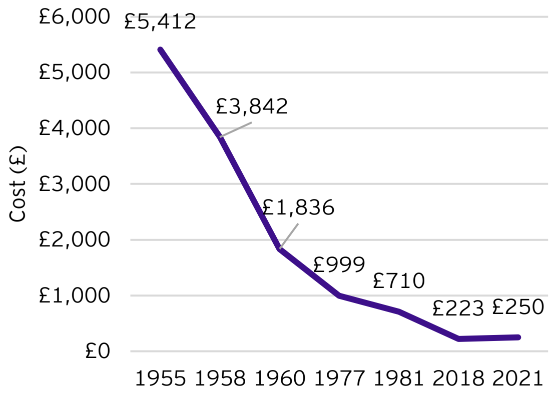
Growth in international connectivity has also been due to the decline in international fares. The cost decline arose from increased budget airline presence and market competition through the availability of competitive pricing information. For example, considering transatlantic connectivity, adjusted for inflation, tickets were more than 24x as expensive in 1955 than 2021.

**Foreign Airports Served from Scotland 's main airports**




*Source: Transport Scotland – Scottish Transport Statistics No 40 2021*

**London–New York Airfare Cost 1955-2021**




Note: Prices adjusted for inflation and based on a one way ticket

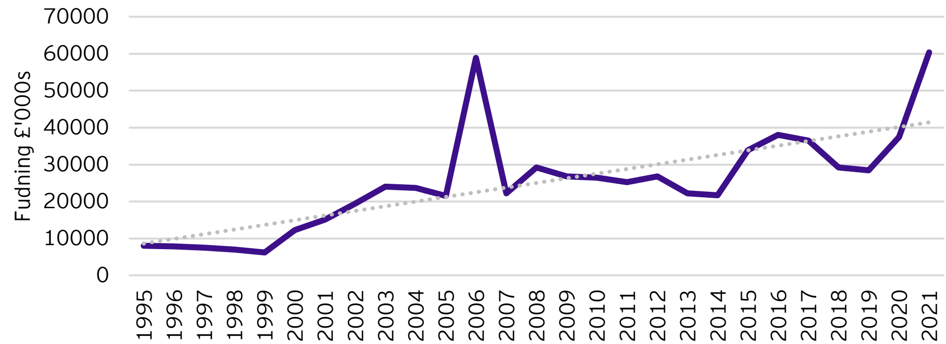
*Source: The Telegraph 'How far have fares really fallen since the golden age of flying?' 2021*

### Government support for aviation demand

Connectivity of intra-Scotland services has been enabled through SG's subsidies. HIAL received direct capital subsidy for infrastructure costs whilst Logan Air (the main airline provider for the islands) received support for non commercially viable routes (for example, Glasgow to Campbeltown, Tiree and Barra).

The graph opposite shows revenue and capital support from 1995 to 2021. The increase in spend shows continual support for maintenance of services. The 2006 spike due to the buyout of the Inverness Airport Terminal Building PFI contract.

**HIAL – Total Government Subsidies from 1995-2021**




*Source: Companies House*

### Demand Management

It may not be desirable to actively manage demand for air travel in some areas – where they represent lifeline services, for example. However, in areas where SG has influence, strategic thought could be applied to manage airport expansions or other less dramatic areas such as restricting night flights could help manage future demand.

### Economic and social benefit

Transport Scotland's Aviation Strategy Discussion Document highlights the economic importance of Scotland's aviation sector providing a £400m Gross Value Added (GVA) contribution. SG's intra-Scotland subsidies and support of HIAL are key to maintaining air connectivity that help positively contribute towards GVA.

**Key conclusion**

Aviation demand has continuously grown due to decreasing ticket prices and increased international connectivity. Continued investment in maintenance and connectivity subsidies for intra-Scotland services has been justified through the economic and social benefits they provide.

# Hydrocarbon usage



### Demand - Hydrocarbon usage and information about its origins

Scotland's aviation sector represents for 778 ktoe, or <5% of total Scottish O&G consumption (19% of Scottish transport consumption). This stems from the kerosene used to fuel aircraft.

- International flights and flights to the rUK are the largest proportion of Scotland's overall aviation hydrocarbon usage. However, the focus of our analysis is on intra-Scotland services as SG has greater influence over these types of services versus international and rUK flights.
- Demand has increased because of the reduced cost of international travel and air travel within the UK, including the growth of Budget Airlines and a wider range of potential destinations available at relatively low cost. It is projected that aviation usage will continue to grow.

### Intra-Scotland services

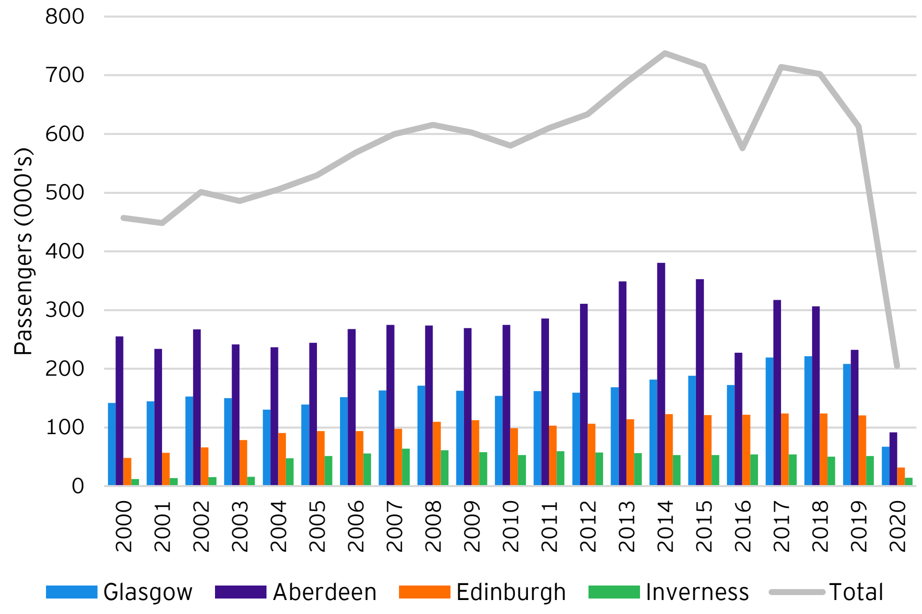
- Intra-Scotland services predominantly connects Scotland's main cities (Aberdeen, Edinburgh, Glasgow and Inverness) and its islands.
- Some services constitute 'lifeline' services (those that are not commercially viable without government support) that provide isolated communities with air links to main centres.
- Historic trends show overall aviation passenger usage rose from 456k in 2000 to a peak of 701k in 2018. The fall in demand in 2020 relates to the travel restrictions imposed as a result of the Covid-19 pandemic.
- Going forward, demand is expected to exhibit marginal continued growth. The DfT predicts overall Scottish passenger growth on domestic flights to display a 14% increase in aviation passengers by 2030 (from 2022) and 41% by 2045.

**Key conclusion**

Overall aviation O&G usage is <5% of Scotland's total O&G consumption and <19% of transport consumption.

The demand for intra-Scotland services stems from flights to Scottish islands and rural locations as part of lifeline services. Therefore demand reductions are unlikely, and a drive for fuel efficiency and a shift to hydrogen technology appears optimal.

**Intra-Scotland Passengers To/From Scottish Airports Only**




*Source: Transport Scotland - Scottish Transport Statistics No 40 2021*

# Emissions



### Demand - Emissions and the percentage of Scotland's emissions

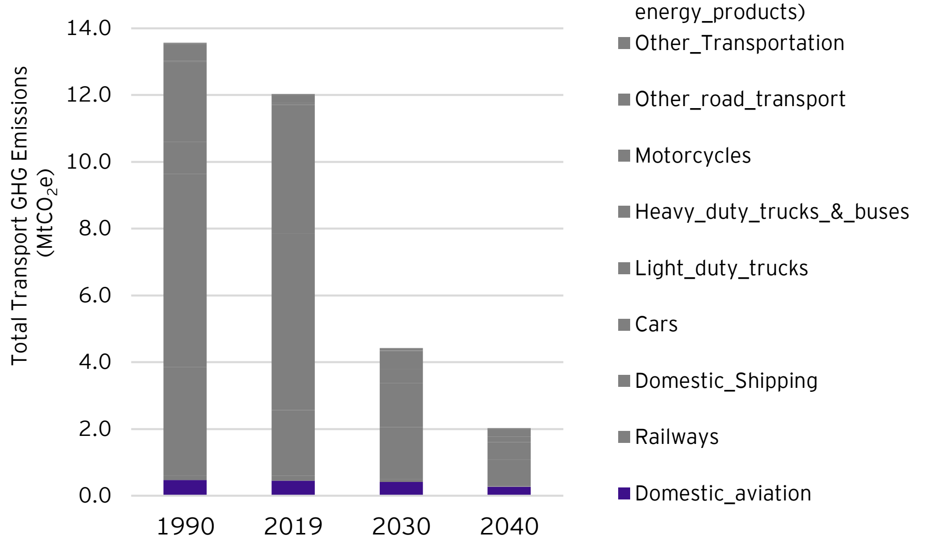
Domestic services to rUK only account for 3.8% of the Scottish transport sector's domestic emissions in 2019 (<1% of Scotland's total emissions). As shown in the NAEI emissions chart, whilst aviation accounts for less domestic emissions than cars, HGVs and shipping there is still scope for further decarbonisation through alternative technology being used.

Due to the lag in technology and policy compared to other transport sectors, it will be challenging to entirely decarbonise aviation.

The International Air Transport Association states that aircraft technology only makes small efficiency improvements each generation and since aviation demand is expected to grow, emissions will still be present. The reduction of emissions depends on large scale technology break-throughs that can be readily implemented by all airlines/aircraft suppliers.

It should be again acknowledged that international and flights to the rUK are the largest emissions sources for Scottish and UK aviation. For example, 96% of the UK's aviation emissions are from international travel. Only a small proportion of Scottish aviation's emissions relates to intra-Scotland services.

**Transport Emissions – Domestic Aviation**




*Source: NAEI GHG emissions by sector + EY analysis*

**Key conclusion**

Emissions associated with intra-Scotland services are very low compared to international aviation and other modes of transport. However, further decarbonisation of domestic and international aviation will likely be realised through technology improvements due to the barrier of limited government influence.

# Readiness of alternatives



## Availability of alternative technologies

Current aviation technology relies on kerosene as a means of propulsion as it is the cheapest aviation fuel. However, to decarbonise the sector alternative technologies need to replace fossil fuel methods, such examples include:

- Hydrogen
- Electric
- Sustainable Aviation Fuel (SAF).

The development of hydrogen and electric aircraft is still in the design concept and prototype phase, whereas SAF is a more feasible replacement technology at present.

ATI's (Aerospace Technology Institute) FlyZero 2022 report states "significant technical, safety and operational challenges remain which must be characterised and solved before a hydrogen powered aircraft could achieve certification and enter commercial service". As such, our analysis primarily focuses on SAF whilst also outlining the benefits and drawbacks of hydrogen and electric.

1. **Hydrogen**

Hydrogen technology is proposed in two forms:

1. As a fuel - Modifications can be made to existing jet engines that enable hydrogen combustion to occur. Hydrogen would be stored in the wings or fuselage.
2. As a fuel cell – Using the electrolysis of hydrogen to drive electric motors similar to a propellor plane. Hydrogen again would be stored in the wings or fuselage.

*Benefits*

The benefits of using hydrogen are as follows:

- Technology safer than traditional kerosene combustion
- No CO² emissions produced
- Greatly reduced engine noise pollution
- Compatible with existing engine designs.

*Drawbacks*

The drawbacks of using hydrogen are as follows:

- Technology readiness level at present – Hydrogen requires much larger space for the same output as kerosene and current aircraft are not at a feasible design stage. As such commercially ready hydrogen alternatives are not currently in operation.
- Operating cost – The production of hydrogen is more expensive than kerosene at present. With airlines operating as businesses and placing a heavy focus on profitability, the adoption of hydrogen would not occur unless wider market forces made it commercially feasible.
- Capital costs – The technology is currently too theoretical to be able to determine fleet replacement costs. However, the initial aircraft models are likely to be more expensive than current technology. Costs will eventually decline and flatten overtime.
- Production and infrastructure – The infrastructure does not exist to readily implement hydrogen technology. For example, there are no airport scale hydrogen refuelling or storage facilities that are equivalent to existing kerosene and fossil fuel infrastructure.

*Conclusion*

Whilst hydrogen technology is the preferable choice, it is unlikely to be commercially ready before the mid 2030s based on current aircraft designs. As such, no cost data is available to provide further analysis

# Readiness of alternatives



## What are the replacement technologies? (cont.)

### 2. Electric

Another alternative is the use of electric battery aircraft. These use similar electric motor technology to other EVs with the battery driving the propellor(s) on the aircraft.

The technology shares similar benefits and drawbacks to hydrogen due to it being in the prototype phase.

*Benefits:*

The benefits of using electric battery aircraft are as follows:

- The technology is feasible and in the testing phase. For example Ampaire trialled a six seater Cessna for the flight from Orkney to Wick (60km) using a combustion/electric hybrid.
- This hybrid provides an hour of pure electric flight from a 90 minute rapid charge. Whilst this is hybrid technology, it may offer a shorter term solution for short haul flights in Scotland.
- Following further technological developments in battery technology, small aircraft can become fully electric and have an enhanced range.

*Drawbacks*

The drawbacks of using electric battery aircraft are as follows:

- As the technology is in the prototype phase, the capital costs are higher than existing services technology which, without further subsidy, would only further strain lifeline services if implemented at present.
- Current technology carry capacity is still small and short term (2030s) is likely only to be 20 seats maximum.

*Electric Feasibility*

As noted above, hybrid electric planes are currently in their testing phase and HIAL has been awarded £3.7m of funding from UK Research and Innovation through the Industrial Strategy Challenge Fund. The funding supports zero emission projects at its Kirkwall airport to provide a test environment for alternative technology.

With further technological breakthroughs and investment, electric aircraft could further decarbonise intra-Scotland aviation.

*Conclusion*

Electric battery aircrafts present a potential short to medium term solution for Scottish Island flights, however, the technology is still in the prototype phase with range limitations and high capital costs.

### 3. SAF

SAF is another alternative and is a synthetic fuel created from feedstocks, residues or other production by-products. It can also be created from power to liquid processes using the conversion of renewable energy to produce liquid fuels. The synthetic fuel would work in a similar manner to existing jet fuel (kerosene).

SAF can be produced locally from existing production cycles utilising already emitted carbon. For example Ardnamurchan Distillery, Woodlands Renewables and Celtic Renewables' new biorefinery can produce 1 million litres of SAF per year using some of the by-products from the distillery.

SAF can be produced from:

- Distillery by-products – Utilisation of hydrolysis and fermentation processes on pot ale to produce a carbohydrate fraction to generate commodity chemicals or biofuel.
- Municipal Solid Waste and food processing by-products.
- Agricultural biomass.
- Forestry biomass (residues).
- Marine Biomass: Scotland has one of the longest coast lines in Europe as such both macro (seaweed) and microalgae have been recognised as having potential to be used as a feedstock for biorefining. Potential uses of algae include the production of pharmaceuticals, nutraceuticals, in sewage and wastewater treatment and synthetic fuels.
- Power to liquid processes: Renewable energy is the key energy source with water and $CO_2$ being the main resources. Renewable energy powers electrolysers to produce green hydrogen. $CO^2$ captured from carbon capture schemes is then converted to carbon feedstock which are then synthesised with green hydrogen to generate liquid hydrocarbons. Liquid hydrocarbons can then produce a synthetic sustainable equivalent to kerosene.

These sources are all readily available in Scotland. SAF production facilities would require investment and development to harness the production potential.

# Readiness of alternatives



**What are the replacement technologies? (cont.)**

*Benefits*

The benefits of using SAF are as follows:

- Existing engine technology can be modified to use SAF therefore no revolutionary designs are needed.
- It can be readily implemented. For example Ryanair and United Airlines have recently announced that certain percentages of their flights will use SAF (in varying blends) for their flights to reduce emissions. Most recently UKG announced the first 100% SAF transatlantic flight is expected to occur in 2023.
- The UK SAF mandate consultation (2021) states emissions are reduced by over 70% using low carbon feedstocks combined with jet fuel over the lifecycle of the fuel. Whilst emissions are still present it is a strong decarbonisation movement.

*Drawbacks*

The drawbacks of using SAF are as follows:

- SAF costs more than kerosene. Production of SAF is not yet ready to yield economies of scale making the alternative between 2.5 – 8x more expensive. With airlines running as commercial businesses they will not utilise it if it is not financially viable.
- Local production is not at a viable scale to allow implementation. As with biofuels for road transport, real $CO_2$ savings are highly dependent on the mode of production and certification of sustainability.
- By-products from potential SAF production processes have existing uses in their respective production cycles (for example by-products in the brewing process). Therefore, additional SAF would be created purely for SAF purposes rather than from by-products.
- SAF still emits carbon emissions and is not a zero emission technology unlike hydrogen or electric aircraft designs.

*Feasibility*

Element Energy's study of the aviation sector notes that Scottish aviation would need to adopt a 50% blend of SAF by 2030 to meet emissions targets. However, with limited control of airlines' fuel purchasing policies, implementing alternatives to jet fuel will be challenging unless commercially feasible. For example, both the UK and EU have proposed SAF mandates surrounding emissions schemes. The proposals introduce an obligation on jet fuel suppliers to blend an increased share of SAFs into fuel provided at major airports in the EU.

Additional headwinds faced by SAF are its low production volumes that result in high premiums over kerosene. However, with continued investment and incentives SAF production will increase. UKG announced £180m of funding toward SAF production which can be further backed by Breakthrough Energy Catalyst £400m of funding. This demonstrates SG can encourage innovation in the aviation sector through further investments in production.

*Conclusion*

- At present SAF is the most feasible short-medium term emissions reduction solution for the Scottish aviation sector. Once economies of scale are achieved or wider macro economic forces enable SAF to be commercial viable for airlines, it could become widely used.
- However, to continue decarbonisation, reliance is placed on current technology making efficiencies breakthroughs.

**Key conclusion**

Hydrogen and electric technology will not be commercially ready before 2035 at the earliest, meaning a near-term solution is required if aviation is to reform its O&G consumption materially – which will likely involve SAF.

Electric hybrids could provide a Scottish Island short haul Scottish solution before wider commercial implementation. SAF is the best alternative for decarbonisation, however, is currently too costly and scarcely produced to make it financially feasible for airlines, without significant subsidies.

# Financial barriers



### Cost of Alternatives

There is limited cost analysis available for alternative technologies. The following cost conclusions are made for the three alternative technologies:

*Hydrogen*

Hydrogen is still in the development stage and not commercially available or produced.

Additionally, capital expenditure on infrastructure investment is required to allow for transport, storage and refuelling of hydrogen at airports.

With regards to operating expenses, when hydrogen aircraft are feasible, hydrogen production is expected to be similarly priced to kerosene due to readily available supply.

*Electric*

Similarly, the technology for electric battery aircraft is not commercially in use and is in the prototype phase. Therefore, competitive market prices are not available.

As such capital costs comparisons are not meaningful. Additionally, the cost of charging infrastructure at airports would need to be included (this is not currently in place at airports).

With regards to operating expenses, the cost of charging will be dependent on the cost of electricity from the grid supply.

*SAF*

SAF is more expensive than kerosene at 2.5 – 8x the cost making SAF not commercially feasible for airlines.

However, SAF may help alleviate some costs from existing ETS schemes due its lower emissions. Potential SAF mandates should encourage the most sustainable SAF uptake otherwise airlines may face further obligations.

Until SAF is mass produced the cost will likely remain higher than kerosene without wider market intervention or subsidies. However, with the £180m in funding announced by UKG in May 2022, the aim is to accelerate SAF infrastructure to make SAF commercially feasible.

*Cost Expectations*

Capital costs for hydrogen and electric technology will be excessively overinflated due to the technology still being in the prototype phase.

Transport Scotland's Zero Emission Energy for Transport Report notes that 2035 is the expected implementation for alternative technologies. Once available and implemented, the capital cost of hydrogen and electric aircraft would be expected to decline and flatten out similar to the introduction of any other new technology.

Similarly, SAF cost will decline and flatten like any other form of fuel when widely produced and adopted by the aviation industry.

**Key conclusion**

SAF is possible to implement and would be more affordable when mass produced. However, airlines operate in highly competitive markets. Whilst some passengers may willingly pay to support emission reduction, airlines must be commercially incentivised to use SAF.

Given the global nature of aviation, SG cannot readily control the price of SAF to incentivise airline uptake.

As such, decarbonisation will only occur when passenger demand or international agreements (or wider macroeconomic factors) pressurise airlines to adopt SAF

# Non-financial barriers



**The choices and risks in selecting new technologies and non-financial barriers**

Below are other non financial barriers being implemented in Scotland.

*Technology availability*

Aviation technology is not advanced enough to allow short term uptake of the alternative technology. ATI FlyZero 2022 Technology Roadmap states hydrogen aircraft are expected to reach market in mid-2030s with narrow body aircraft (180 seaters) entering by mid 2040s. However, the report also caveats it is uncertain when or how a hydrogen fleet will come to market.

Similarly, ATI's Electric propulsion roadmap shows earliest competitor development of electric motor aircraft from the 2030s.

*Fleet purchasing and Infrastructure strategy*

Similar to rail, aviation assets have long service lives (15+ years) and with recent generations of aircraft entering fleets in 2020, new technology will not make widescale penetration until 2035. The mid 2030s, being the time envisaged for introduction of new technology, infrastructure investment must be considered.

As such, SG's funding of HIAL infrastructure investment should be aligned with new fleet introduction to ensure the efficient use of resources. Failure to consider alternative technology introduction could result in inefficient and obsolete infrastructure spending.

*Key players influence*

Scotland's private airports (Aberdeen, Edinburgh and Glasgow) and HIAL airports are ran as commercial businesses with cost focussed airlines using them. If technology is not commercially beneficial to the airlines or airports, it is likely these will not be implemented.

HIAL being government-owned could influence technology and infrastructure uptake, however, as these airports have airlines operating subsidised intra-Scotland services it will be challenging to justify additional spending on infrastructure when cheaper alternative intra-Scotland transport exists.

*SAF production and supply*

Whilst the ICAO estimate Scotland's current SAF production capability is only 1m litres, Petroineos, Scotland's largest producer of aviation fuel, have the expertise and facilities to produce SAF. Their production of jet fuel serves Edinburgh, Glasgow and Aberdeen airports. Therefore, if SAF were produced, existing supply chain relations are in place and can be readily leveraged.

The UK SAF mandate's ambition is to make the UK a world leader in both the production and use of SAF. As such, Scotland will be well positioned with the production capabilities and expertise required (with facilities such as Petroineos at Grangemouth).

Other production sources are possible as many of the by-product materials in SAF can be used in existing process cycles (for example by-products from brewing processes can often be re-used in the production cycle). However, these businesses are unlikely to produce and sell SAF at the opportunity cost of using the by-products in their own production cycles without adequate incentive.

**Key conclusion**

Unlike other transport sectors with readily available alternatives, for example EVs or hydrogen fuel cell trains, aviation technology lags behind on implementation readiness.

Additionally, the sector is highly competitive, driven by private sector norms (despite some public service obligation (PSO) subsidies and requirements), and behaviour of airlines is hugely influential. As such, to implement alternative technologies (even if technologically viable) these would need to be commercially attractive to airlines. Consequently, aviation relies on the sector demonstrating a behavioural shift to new technology when available and requires macroeconomic trends to influence the future outlook of the sector.

# Demand management



**Demand management**

To understand the drivers of demand management, the influence of the key players in the Scottish aviation sector should be considered.

*Key Players*

Airlines drive demand from airports. Where airlines provide supply for serviced routes, demand will follow.

Airport ownership in the Scottish aviation sector is split between public and private ownership. Accordingly, SG has very limited influence over the airlines operating from the three largest privately owned airports (Aberdeen, Edinburgh and Glasgow).

HIAL airports are government owned with Air Discount Schemes (ADS) and subsidies in place for airlines servicing intra-Scotland. However, the ADS for airlines and subsidies provided to HIAL represent the limited control that SG has over airline and airport operations.

*Demand drivers*

However, the services supplied by LoganAir at HIAL operated airports are predominantly commercial (other than PSO routes) to and from Scottish highlands and remote islands. Demand for these services fluctuates in the same manner as other services but largely stems from passengers seeking quicker transport options.

Subsequently, passengers using intra-Scotland aviation services are not likely to migrate to the slower ferry option from the Island communities without incentive.

Regarding air freight, the Highlands and Islands Transport Partnership state the main cargoes are mail, newspapers and smaller higher value items that are on a more time sensitive journey, for example seafood.

*Modal Shift outlook*

Air freight carries an insignificant proportion of Scottish freight compared to road (0.05%). However, air freight often needs to be transported by air due to time sensitivity otherwise alternate transport could be used, for example shipping. Goods like mail, newspapers and small high value goods use air freight. Shipping could not move the perishable goods as quickly as air freight and the Islands do not have rail infrastructure to the mainland.

Similarly, intra-Scotland passenger travel often replaces other transport methods as air services are much quicker.

*Actions*

SG could introduce a modal shift grant similar to the UK MSSR grant to encourage non-time sensitive aviation freight to shift to more emission friendly modes of transport (rail or maritime shipping).

*Barriers*

It is not viable for parties transporting smaller and time sensitive goods to switch to slower means of transport. Therefore, intra-Scotland services are preferential to ferries.

# Aviation - Conclusions



### O&G consumption and emissions are not significant

- Aviation overall consumed **778 ktoe** O&G in the form of kerosene, **5%** of overall Scottish consumption (equating to <1% of Scotland's total emissions).

### Overall demand has been driven by the cost of flying reducing and the expansion in the number of destinations served

- Demand for air travel has increased steadily over the last 30 years and this trend continued until the Covid-19 pandemic.
- The driver of demand for purely intra-Scotland flights is travel to and from Scottish Islands from mainland airports. These Island services are driven by the need for access to the mainland, many of these are lifeline services.

### Alternative aircraft design technologies are not yet ready for the market and those for longer flights are further away from being available

- Hydrogen technology (either direct combustion or in a fuel cell) is the most promising technology for longer flights, but is unlikely to be available before the mid 2030s.
- For shorter flights with smaller numbers of passengers, battery electric or hybrid technology might be appropriate technology, and is closer to being available.
- SAFs can be part of the solution for longer flights, and these are closer to being commercially available, but concerns remain about their impact and ensuring that the $CO_2$ balance is positive.

### Alternatives cannot be quantified, but will be more expensive in the short term

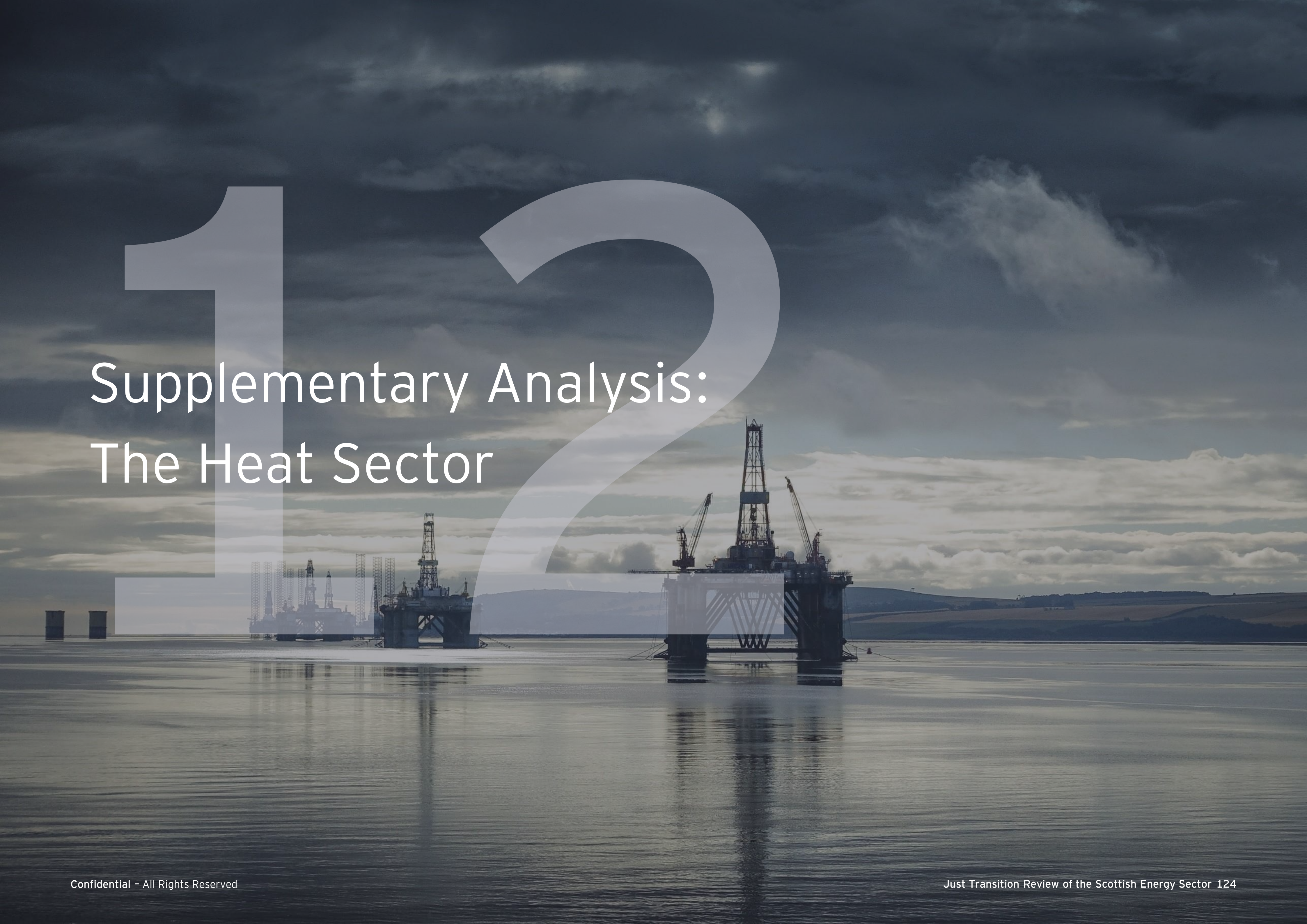
- SAFs are likely to be between 2.5 and 8 times the cost of oil-derived fuel for aircraft.

### Non-cost barriers to take up are technology and system change

- Technology change will be challenging and there will be a number of competing technologies available. Standardisation and infrastructure changes will be difficult to plan and anticipate.
- As an international industry, Scotland will have little control over the development of this nascent technology.

### SG has a number of policy levers, including its support for island services and the revised passenger tax arrangements

- The focus will be on technology development in the near future, rather than deployment.
- Airline influence will be critical in the long term for uptake of alternative technologies.



12

# Supplementary Analysis: The Heat Sector

# Introduction - Heat in buildings



## Introduction

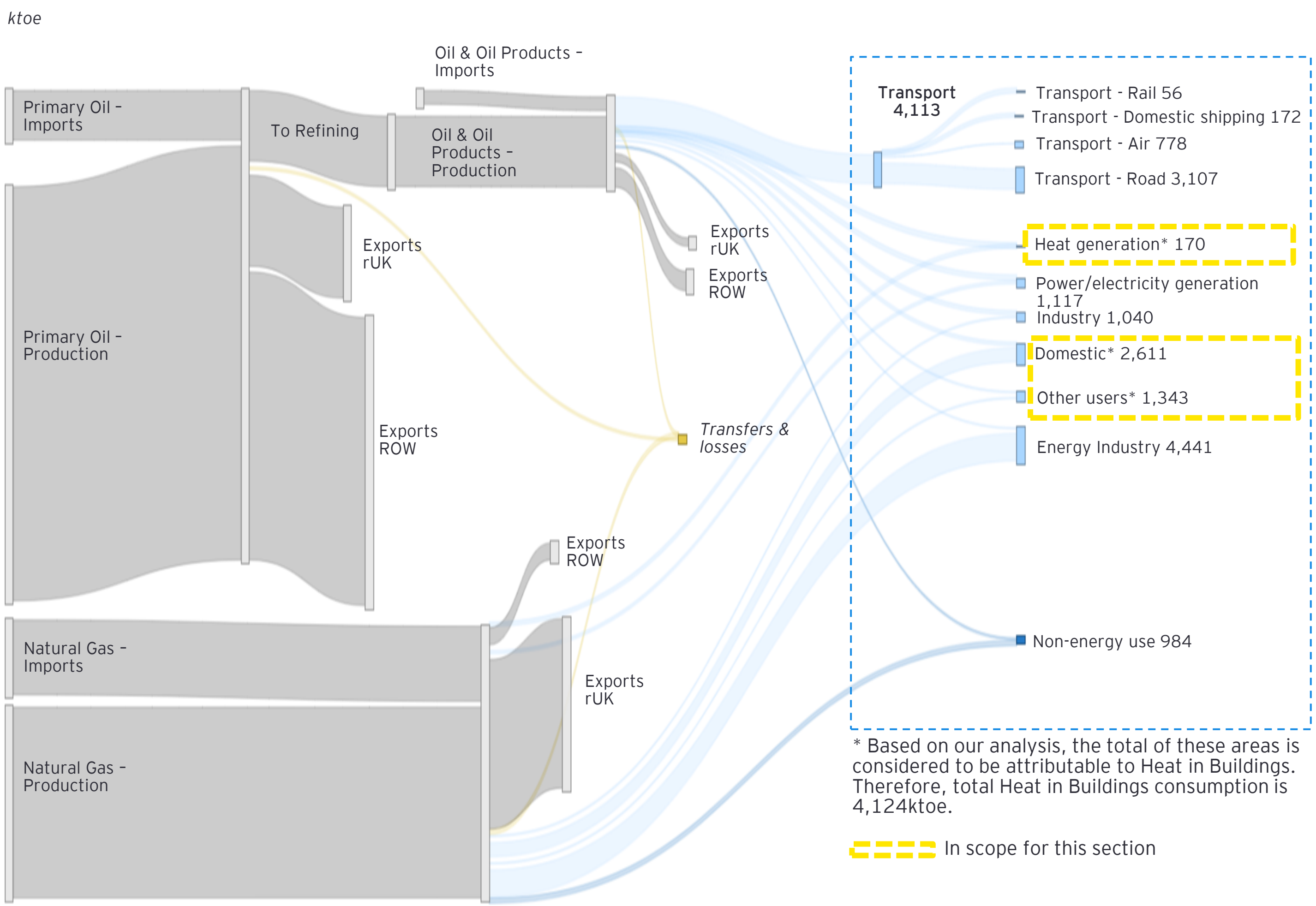
Like the transport sector, demand for O&G in heating plays a critical role in meeting Scotland's heat needs with approximately 81% of Scotland's domestic properties relying on mains gas as their primary heating source and 170,000 homes using high emission fuels (e.g. heating oil, LPG etc). As a result, heating homes and buildings contributes roughly 20% to Scotland's total GHG emissions.

A key priority identified in SG's Heat in Buildings Strategy is that by 2045, all homes and buildings in Scotland are cleaner, greener and easy to heat, with Scotland's homes no longer contributing to climate change as part of the wider Just Transition to net zero.

These ambitious targets will require emissions from homes and non-domestic buildings to fall by 68% by 2030 compared to 2020 levels. This means that the vast majority of the 170,000 off-gas homes that currently use high emissions fossil fuels, and at least 1 million homes that currently use mains gas, must convert to zero emissions heating. Similarly, by 2030 the equivalent of 50,000 of Scotland's non-domestic buildings will need to adopt zero emissions heating.

To ensure a Just Transition, Scotland's heat decarbonisation targets must also consider SG's fuel poverty objectives. Such targets require that in 2040 no more than 5% of households are in fuel poverty, no more than 1% are in extreme fuel poverty and the fuel poverty gap is no more than £250 (in 2015 prices).

### Scottish Energy consumption overview




* Based on our analysis, the total of these areas is considered to be attributable to Heat in Buildings. Therefore, total Heat in Buildings consumption is 4,124ktoe.

*Source: SG - Physical commodity balances of oil, gas and petroleum products*
*Digest of UK Energy Statistics (DUKES) 2021 - GOV.UK (www.gov.uk) (commodity balances)*

# Key factors impacting O&G demand - Introduction



### An introduction to Scotland's heat sector

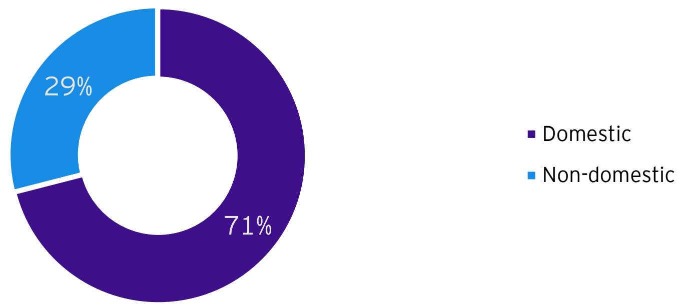
Heating Scotland's domestic and non-domestic properties (in terms of space and water heating) accounts for approximately 26% of its total O&G consumption[1]. There are approximately 2.5 million domestic properties in Scotland, which account for the majority (71%) of Scotland's total O&G consumption for space and water heating. The remaining 29% is energy used to heat Scotland's 220,000 non-domestic properties, see chart opposite.

The demand for heat varies across Scotland. The Scotland Heat Map estimates annual heat demand for all domestic and non-domestic properties in Scotland, split between the different local authority areas. Given regions with high levels of heat demand cover a range of both rural (particularly Highland) and urban areas (Edinburgh, Glasgow City), low carbon heating solutions should be versatile.

### Key conclusion

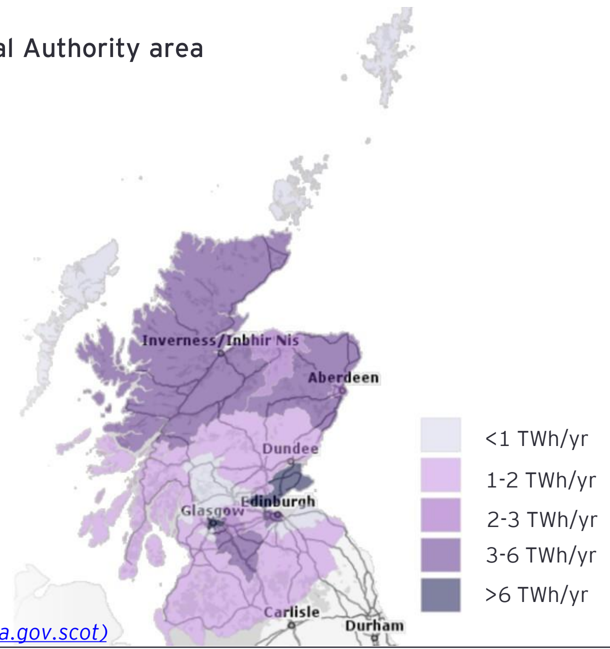
Heating Scotland's homes and buildings accounts for 26% of its total O&G consumption. It is a significant consumer of gas, both in the domestic and non domestic setting and heat demand varies significantly across the country.

### Heat energy O&G consumption, 2019




*Sources:*
*EY analysis*
*SG - Physical commodity balances of oil, gas and petroleum products*
*Digest of UK Energy Statistics (DUKES) 2021 - GOV.UK (www.gov.uk) (commodity balances)*

### Demand for heat by Local Authority area




*Source: Scotland Heat Map (data.gov.scot)*

[1]*EY analysis of the following:*
*SG- Physical commodity balances of oil, gas and petroleum products*
*Digest of UK Energy Statistics (DUKES) 2021 - GOV.UK (www.gov.uk) (commodity balances)*

# The Heat sector - GHG emissions



### Heat as a contributor to Scotland's GHG emissions

Scotland's homes and buildings contribute roughly 20% to its total GHG emissions[1] and accounts for approximately 26% of its total O&G consumption.

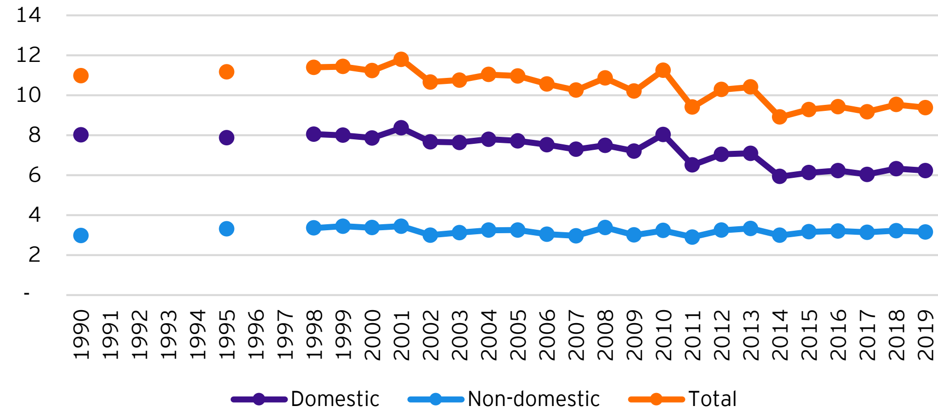
The key source of GHG emissions in buildings is the use of O&G for heating purposes. Domestic buildings in particular are key contributors to Scotland's overall GHG emissions (13%), however in recent years there has been a gradual decline in the volume of GHG emissions attributed to both heat in domestic and non-domestic buildings, resulting in a 23% and 2% reduction between 1990 and 2020 respectively. The reduction in emissions during this period is primarily a result of a switch from less efficient solid and liquid fuels to natural gas for heating and also improvements to energy efficiency.

Over the last ten years the total rate of decline has been 17% which is considerably less than the 68% reduction required over the ten-year period from 2020 to 2030. If SG's emissions targets are to be met, there needs to be further improvements to energy efficiency measures and an accelerated deployment of zero carbon emissions heat technologies.

**Key conclusion**

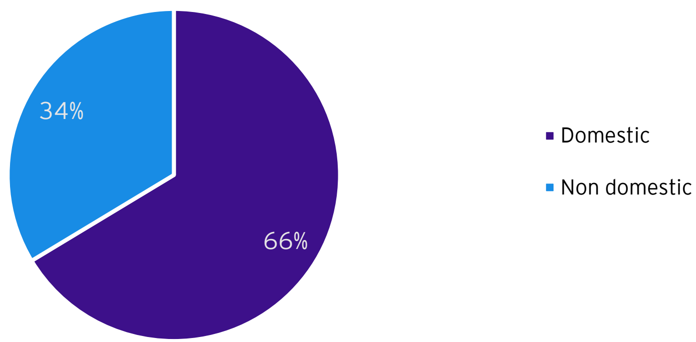
There has been a gradual decline in GHG emissions in the last 30 years, however, the rate of decline will need to be significantly accelerated if 2030 emissions targets are to be met. Further energy efficiency improvements and a rapid deployment of zero carbon emissions heat technologies are required.

**Scottish GHG emissions from buildings ($MtCO_2e$), 1990-2019**




*Source: Scottish Greenhouse Gas Emissions 2019 (www.gov.scot)*

**Total GHG emissions attributable to buildings split between domestic and non-domestic sectors, 2019**




*Source: Scottish Greenhouse Gas Emissions 2019 (www.gov.scot)*

[1] *Scottish Greenhouse Gas Emissions 2019 (www.gov.scot)*

# Key factors impacting O&G demand - Overview



## Drivers of O&G demand

In recent years, the use of mains gas as a primary heating fuel source has remained consistent, with approximately 81% of Scotland's domestic properties relying on gas as their primary heating source. Households require energy for a variety of reasons, however, space heating systems are the primary energy users.

Scotland's reliance of gas as a primary heating system has been built up over the decades, with factors such as gas availability, infrastructure and policy choices helping to cement this position.

A high proportion of houses in Scotland have access to natural gas, with only 17% in off-gas areas[1]. For those not on the gas grid, other sources of heat, such as direct electricity or oil heating are generally used.

There are several factors that impact the amount of O&G used to heat our buildings. This includes amongst others:

1. The availability of natural gas
2. Technological shift to gas central heating
3. The low cost of gas versus electricity
4. The type of building and its energy efficiency performance
5. Existing heating systems and their efficiency

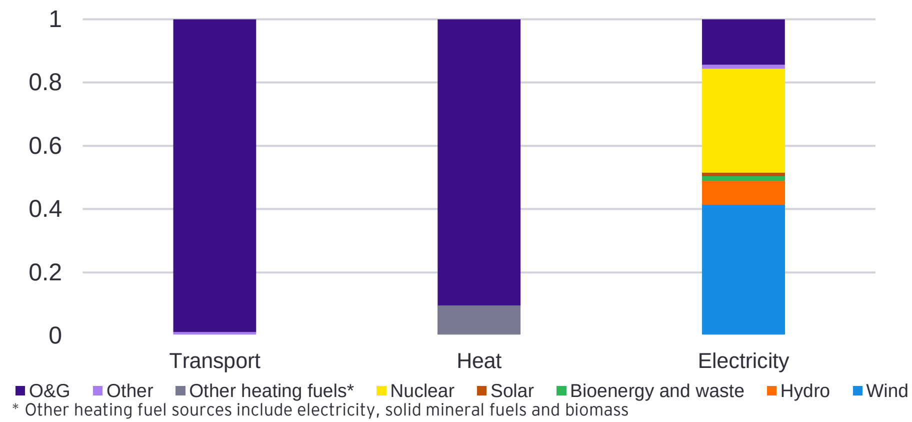
These drivers are important, not only to understand the factors impacting the O&G sector, but to also identify potential barriers that may impact the rollout of replacement technologies. These items are explored in more detail overleaf.

**Key conclusion**

The majority of homes in Scotland use gas to heat their homes. This is a stable and consistent trend that has not changed in recent years, but the reasons for this are mixed.

[1]Scottish house condition survey: 2019 key findings - gov.scot (www.gov.scot)

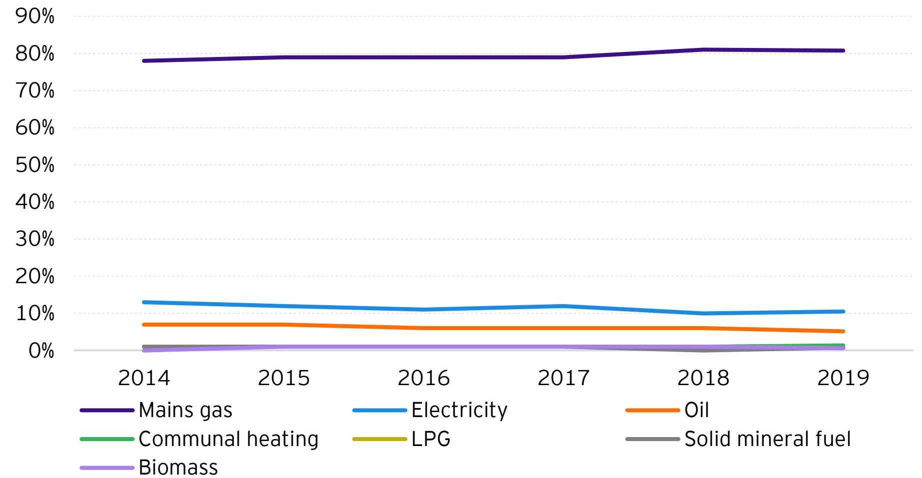
### The Scottish Energy System




* Other heating fuel sources include electricity, solid mineral fuels and biomass

*Source: Annual energy statement 2019 - gov.scot (www.gov.scot)*
*Scottish Energy Statistics Hub – Proportion of electricity consumption by fuel*
*Scottish Energy Statistics Hub – Number of ultra low emission vehicles licenced*

### Primary heating fuel as % of households




*Source: Scottish House Condition Survey - gov.scot (www.gov.scot)*

# Key factors impacting O&G demand - Domestic

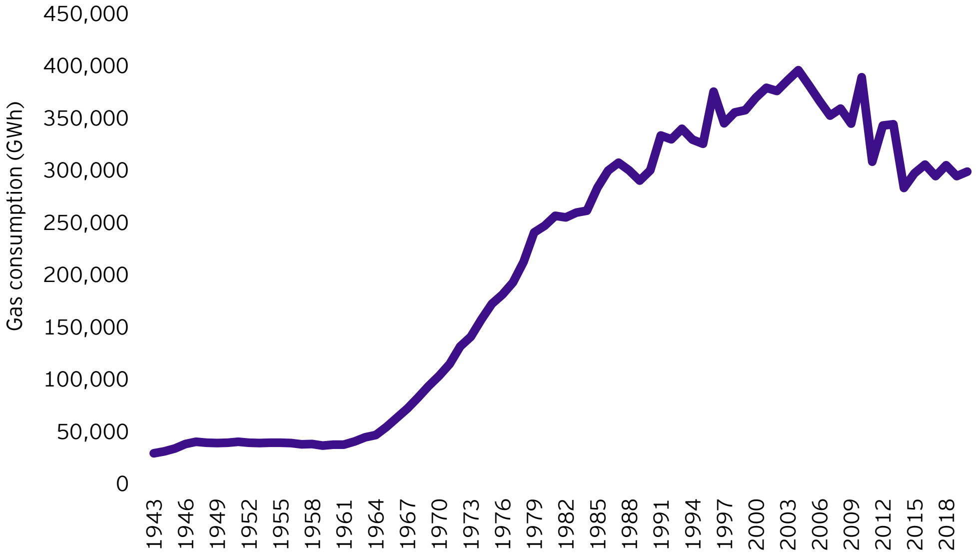


1. **Availability of natural gas to the UK**

Natural gas was first discovered in the North Sea in the 1960s, after which UKG took a national policy decision to convert the UK heat supply from coal to natural gas over the next ten years, in order to bring a sense of self-sufficiency for the country and it was considered a relatively more environmentally clean fuel than coal.

The conversion programme was a major shift in terms of supply and distribution techniques, given that around that time on an energy supply basis, natural gas contributed only 5.4% of the UK's primary energy consumption[1]. Over the years that followed, there were significant developments to the UK's National Transmission System (from around 500km in the late 1960s to 5,000km in the 1980s) to improve its accessibility for homes. By the late 1970s, natural gas became the preferred heating source for both domestic and non-domestic properties.

**Historical UK domestic gas consumption (natural gas and coal derived gas)**




*Source: Historical gas data: gas production and consumption and fuel input - GOV.UK (www.gov.uk)*

[1] *Department of Energy & Climate Change - Energy Consumption in the UK (2015)*

# Key factors impacting O&G demand - Domestic



## 1. Availability of natural gas to the UK (cont.)

Today the UK's National Transmission System is roughly 7,000km[1] and provides approximately 83% of Scotland's homes with access to natural gas[2], leaving the remaining 17% of households in Scotland relying upon on alternative sources of heating*. Islands such as the Shetlands and Orkney are entirely off the gas grid and 86% of the Western Isles are off-grid[3]. Overall, almost two-thirds of homes in rural areas of Scotland do not have access to the gas grid[2].

Whilst there are currently no rules / regulations requiring existing homes to be connected to the gas grid, due to its availability and the affordability of natural gas as a heating fuel (in comparison to electricity or oil) this has been the preferred method of heating.

**Key conclusion**

Since the exploration of natural gas in the North Sea, the UK's gas grid has developed rapidly with over 83% of Scotland's homes having access to natural gas.

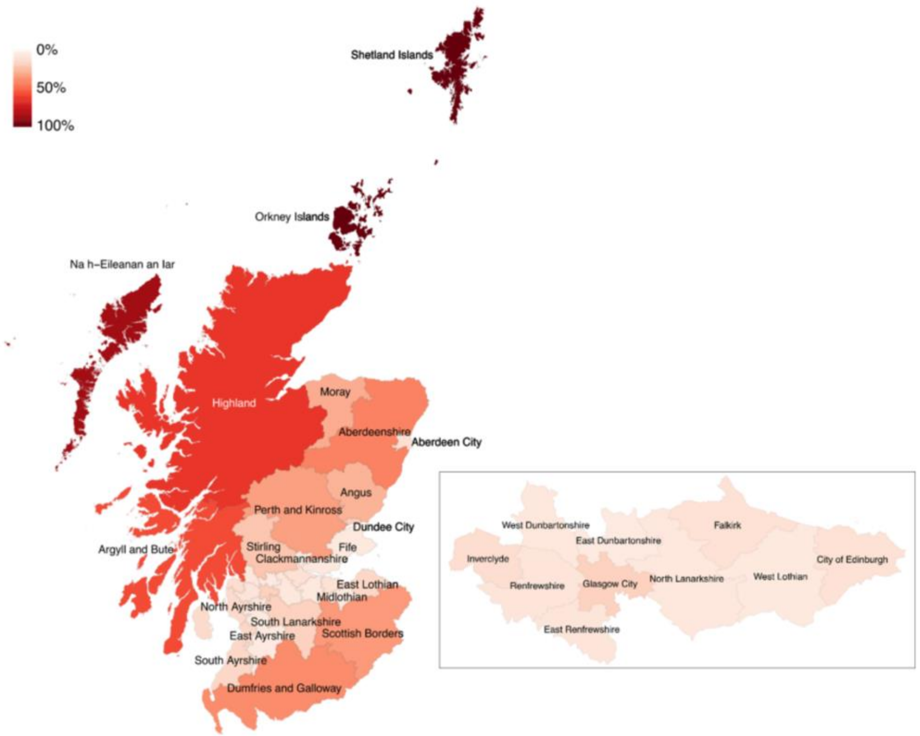
## 2. Technological shift to central heating

Central heating has been available for hundreds of years, however, it is only in the last forty years that it has become widespread and affordable in the UK. Research suggests only 31% of homes in the UK had central heating in 1970 and by 2006 this rose to 91%[4].

Evidence shows that average indoor temperatures have increased by approximately 5-6°C since the 1970s[3] to around 17-21°C in the early 2000s[5]. Whilst an element of this increase can be explained by improved insulation measures in older homes, consumers' expectations of thermal comfort have also been raised by central heating[4].

This technological shift plays an important role in understanding consumer expectations about comfortable heating levels and the levers that can be adopted to encourage householders to reduce their gas demand.

### Proportion of households not on the gas grid by local authority




Source: *BEIS: Sub-national estimates of households not connected to the gas network*

**Key conclusion**

Technological shifts in central heating have changed the way in which we heat our buildings. Generally as a result of central heating, people have become more accustomed to warmer homes which has increased demand for gas.

[1] *About us | National Grid Gas*
[2] *Scottish House Condition Survey: 2019 Key Findings (www.gov.scot)*
[3] *Scottish Energy Statistics Hub*
[4] *Utley JI, Shorrock LD: Domestic energy fact file 2008. Building Research Establishment; 2008*
[5] *Historic Variations in Winter Indoor Domestic Temperatures and Potential Implications for Body Weight Gain (sagepub.com)*

* Whilst 83% of Scotland's homes have access to the gas grid, only 81% of homes use gas as their primary heating fuel source.

# Key factors impacting O&G demand - Domestic



### 3. Gas versus electricity prices

The historical disparity between the cost of electricity and gas has been a major driver for gas consumption in our homes and buildings.

Although recent gas prices have been volatile,[1] gas prices remain substantially cheaper than electricity, as well as other forms of fuels used in the heat sector.

| Fuel | Average Price (pence/kWh) |
|---|---|
| Gas | 7.4 |
| Oil | 11.8 |
| LPG | 15.5 |
| Electricity (off peak economy 7) | 16.7 |
| Electricity (on peak economy 7) | 34.1 |
| Electricity (Standard) | 28.3 |

*Source: Energy Saving Trust April 2022*

As shown in the chart alongside, energy bills for domestic energy customers include a number of elements, namely: the wholesale energy cost, the cost of transporting the energy via networks, social and environmental policy costs suppliers' own costs and margin and VAT. Wholesale costs make up the biggest part of a typical energy bill. The second largest component of energy bills is network costs. These are the costs recovered from suppliers to cover the maintenance of the distribution and transmission networks. VAT on domestic energy bills in the UK is currently charged at 5%, both for electricity and gas.

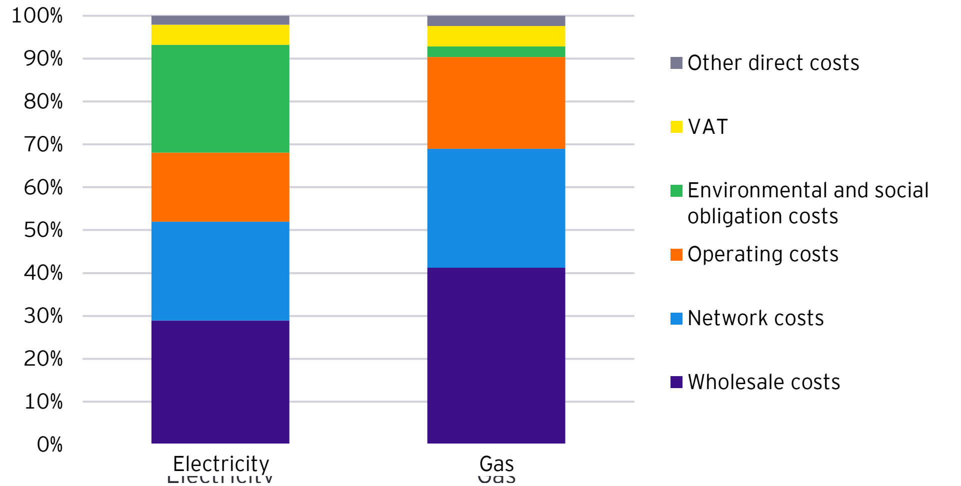
One reason why electricity has historically been more expensive to gas relates to environmental and social obligation costs. These are environmental taxes that are designed to pay for government energy policies, like the energy efficiency improvements or to encourage the adoption of new renewable technology.

Analysis from Ofgem shows that this accounts for 23% of an electricity bill and 2% of a gas bill. Although the power to control energy prices does not sit with SG, UKG is currently seeking evidence to explore this issue.

As a result, although electricity is a more environmentally friendly option for consumers (since electricity is already largely decarbonised), it may be a more expensive option for consumers, unless heat demand is reduced or a high heating system efficiency is achieved (e.g., via a heat pump).

SG does not have the levers to control energy prices. UKG is exploring the potential to moving these levies from electricity to gas, as a means of closing this gap. Alternatively, these costs could be dropped, but this will result in a decrease in funding for low carbon and energy efficiency measures. Other measures may include introducing a carbon tax on gas or moving obligation costs to general taxation.

**Breakdown of an electricity & gas bill**




*Source: Ofgem - breakdown of an electricity and gas bill (All available charts | Ofgem)*

**Key conclusion**

The comparatively cheap price of gas is a significant driver for the continued use of O&G in the heat sector.

[1] *System Average Price (SAP) of gas - Office for National Statistics (ons.gov.uk)*

# Key factors impacting O&G demand - Domestic



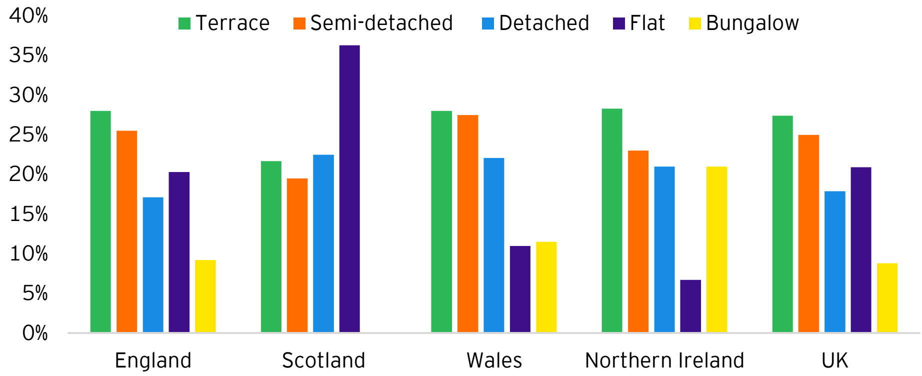
## 4. The characteristics and energy efficiency performance of our buildings

The characteristics and energy performance of our buildings has a direct impact on the demand for O&G and the emissions generated from our homes. Scotland's landscape is complex, with a range of building types, ownerships and existing energy efficiency profiles:

- **Dwelling type** – Scotland has a diverse range of dwelling types, each with its own set of energy characteristics and energy demands. For example as shown in the chart opposite, Scotland has a relatively high proportion of flats (36%) compared to the rUK. Flats generally have a smaller heat loss area than houses and should therefore benefit from greater energy efficiency performance[1]. However, research suggests that many of Scotland's flats are likely to face practical barriers when it comes to the installation of certain renewable heat technologies (such as heat pumps)[1]. Additionally, Scotland also has a high proportion of traditional buildings, with 19% built prior to 1919[2]. Older properties generally have poorer insulation and are therefore less energy efficient[2]. Adopting a one-size-fits-all approach to energy demand reduction and the adoption of a replacement technologies is unlikely to be suitable for all types and ages of buildings.
- **Energy efficiency –** The energy efficiency of a dwelling depends on its physical characteristics, such as age of construction, dwelling type and insulation of the building fabric. Over the last 10 years Scotland's homes have become generally more energy efficient, however, Scotland's energy efficiency landscape varies significantly[2]. This is explored further in the 'Energy Efficiency Measures' section.
- **Property ownership –** The majority of homes in Scotland are occupied by their owners (62%). On average, properties occupied by their owners show the lowest level of fuel poverty rates (between 12%-21%) compared to the social sector (37%) and the privately rented sector (36%)[2]. Therefore, the social and privately rented sectors may require support to bear the potential increased running costs associated with converting to zero emissions heat technologies compared to owner occupied properties. SG has introduced various schemes to provide financial assistance with the costs associated with zero emissions heat technologies, particularly for those households in fuel poverty.

[1] *Suitability of Ground and Air Source Heat Pumps (nesta.org.uk)*
[2] *Scottish house condition survey: 2019 key findings - gov.scot (www.gov.scot)*

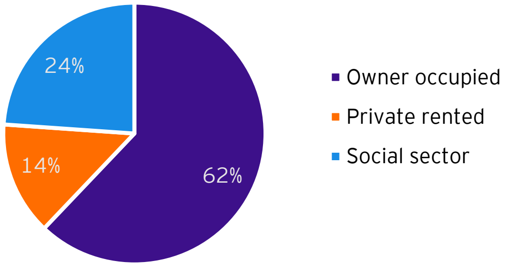
### Dwelling types by UK nations, 2017




Note: Bungalows are included in terrace, semi-detached and detached house types for Scotland

*Source: The-Housing-Stock-of-the-United-Kingdom_Report_BRE-Trust.pdf (bregroup.com)*

### Proportion of dwellings by Tenure




*Source: Scottish Household Survey Annual Report 2019*

**Key conclusion**

The characteristics of homes, their energy efficiency performance and the ownership of properties has a significant impact on O&G demand. Given the different types of buildings in Scotland, there are varying demands.

# Key factors impacting O&G demand - Domestic



## 5. The current heating system and its efficiency

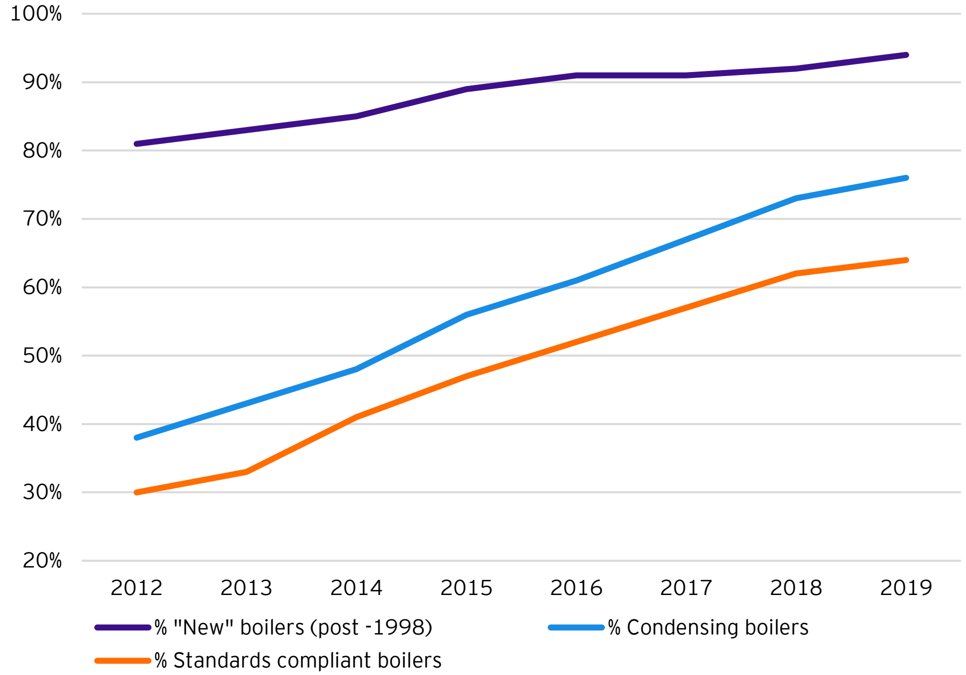
The type of heating system used by homes has an impact on O&G demand. Heating Scotland's homes primarily relies on natural gas. Going forward, since many of the low / zero emissions heat technologies proposed by SG rely on electricity, there should be less natural gas consumed directly from heating people's buildings.

In recent years, UKG has introduced regulations requiring gas and oil boilers to be more energy efficient (e.g. condensing boilers) so that consumers use less energy to achieve the same level of thermal comfort. Since consumers should benefit from reduced energy bills, there has been an increase in the demand for these new boilers with over 94% and 76% of Scottish households using a post-1998 boiler and condensing boiler in 2019, respectively.

However, research suggests that in practice a significant number of energy efficient boilers are substantially over-sized for the properties in which they are installed and this is believed to be endemic in the UK housing stock[1]. Over-sized boilers are at risk of excessive energy dumps of heat, resulting in lower energy efficiency performance.

Overall, this complex landscape highlights a number of factors that impact O&G demand and therefore must be considered when designing solutions to decarbonising Scotland's heat sector.

**Proportion of households using gas / oil boilers that have had improvements to their boiler**




*Source: Scottish house condition survey: 2019 key findings - gov.scot (www.gov.scot)*

**Key conclusion**

The majority of homes rely on gas boilers for their heating. Whilst there have been regulations introduced by the Government to increase the minimum energy efficiency standards of boilers (and therefore reduce O&G demand), in practice their performance may not reduce O&G demand as expected due to potential over-sizing issues.

[1] *Effect of boiler oversizing: University College London by George Bennett and Cliff Elwell (2020)*

# Key factors impacting O&G demand – Non-domestic



### Key drivers of O&G demand in our non-domestic buildings

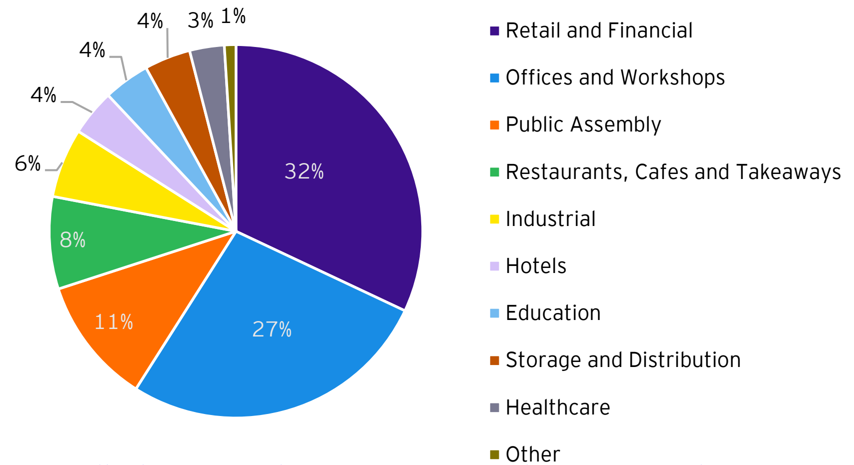
Scotland's non-domestic properties are made up of a wide range of buildings; the type and amount of energy used will vary depending on the size of the building, the building's use and its energy demands (for example, a school will use its energy differently to a hotel). Given that energy will be used in many different ways, this adds a layer of complexity to the decarbonisation of heat in the non-domestic sector and it is likely that there is no one-size-fits-all solution.

Evidence has shown that over half of non-domestic premises use renewable sources such as electricity and biomass as their primary heating fuel and only 42% use mains gas (as shown in the diagram opposite). The drivers for using gas for space and water heating purposes are likely to be similar to those discussed on the previous pages, however, due to the limited publicly available information it is unclear i) why a greater proportion of the non-domestic market use low-carbon heating technologies compared to the domestic sector; and ii) how this demand varies across the different types of non-domestic buildings.

**Key conclusion**

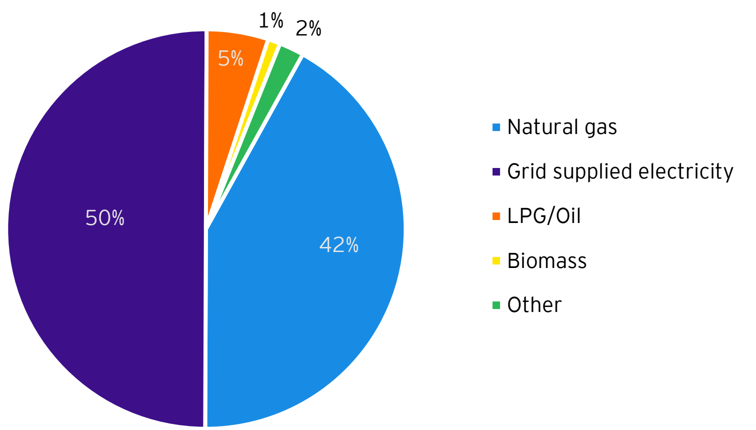
The majority of non-domestic properties adopt low carbon fuel sources for space and water heating purposes, however, the reasons driving this demand are unclear due to the limited publicly available information. There needs to be greater clarity on the drivers for O&G demand in the non-domestic market.

**Share of number of non-domestic properties**




*Source: Scotland's Non-Domestic Energy Efficiency Baseline (www.gov.scot)*

**Proportion of non-domestic premises by main heating fuel**




*Source: Scotland's Non-Domestic Energy Efficiency Baseline (www.gov.scot)*

# Key factors impacting O&G demand – Fuel poverty



### The role fuel poverty plays in the decarbonisation of heat

Before exploring the potential options to decarbonise Scotland's heating sector, a fundamental principle of Scotland's Just Transition plans must be considered. This focusses on the principle that a Just Transition should not have an adverse impact on those in, or at risk of, fuel poverty.

SG has set ambitious targets of requiring no more than 5% of households being fuel poor, no more than 1% in extreme fuel poverty and the fuel poverty gap is no more than £250 (in 2015 prices) in 2040.

The number of households in fuel poverty and extreme fuel poverty has decreased between 2012 and 2019. However, in 2019 an estimated 25% (613,000 households) of all households were in fuel poverty and around 12% (311,000 households) were living in extreme fuel poverty.

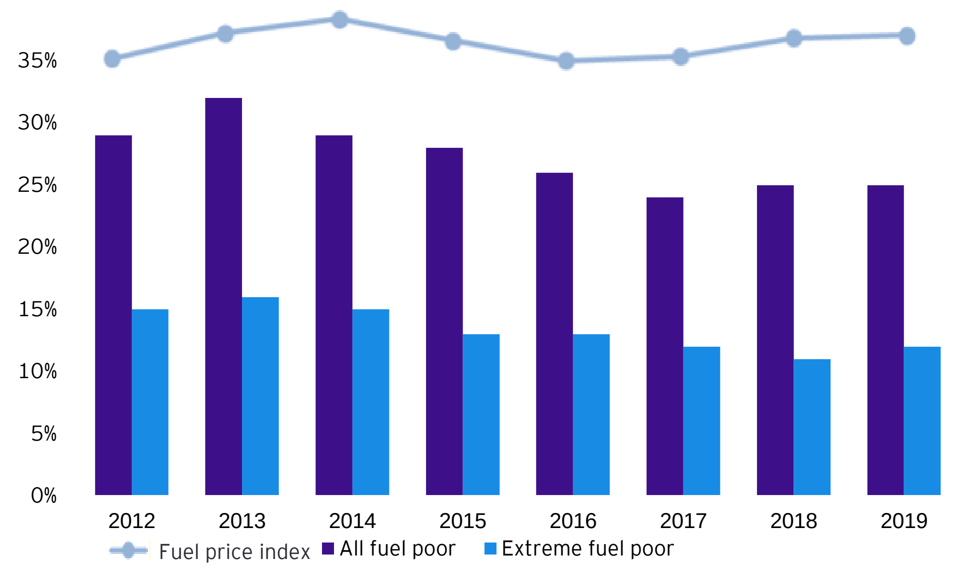
Fuel poverty is impacted by a number of factors, including levels of household income, the price and volume of fuel required for heating, and the energy efficiency of the dwelling.

Between 2012 and 2013 the rate of fuel poverty increased in line with the rise in average fuel price index. The overall rate of fuel poverty decreased between 2014 and 2017 due to an overall decrease in the average fuel price index (with the exception of 2014), improvements in energy efficiency and increases in the median incomes of households. There was a slight increase in 2018 and 2019 as a result of rising fuel prices partially offset by the increase in median incomes and marginal improvements in energy efficiency.

Whilst household income is not the only factor leading to fuel poverty, it is strongly associated. Nearly all individuals in Scotland that are in the bottom net income bracket of earning less than £200 per week, and over half of those earning £200-£300 per week, are considered to be fuel poor.

The energy price of fuels used by consumers also plays a key role with respect to the levels of fuel poverty. In general, the levels of fuel poverty are highest for those households using electricity (43%) and other fuels (e.g. solid mineral fuels) (31%), as their primary heat fuel source compared to those using gas (22%), and oil (28%). This is primarily due to the increase in the prices of these fuel types.

### Estimates of Fuel Poverty and Extreme Fuel Poverty




Source: *Scottish house condition survey: 2019 key findings - gov.scot (www.gov.scot)*

| Definitions | |
|---|---|
| **Fuel poverty** | A household is considered to be in 'fuel poverty' if:<br>• In order to maintain a satisfactory heating regime, total necessary fuel costs for the home are more than 10% of the household's adjusted net income; and<br>• After deducting those fuel costs, benefits received for a care need or disability and childcare costs, the household's remaining adjusted net income is insufficient to maintain an acceptable standard of living. |
| **Extreme fuel poverty** | Follows the same definition as above except that a household would have to spend more than 20% of its adjusted net income (after housing costs) on total fuel costs to maintain a satisfactory heating regime. |

# Key factors impacting O&G demand - Fuel poverty



## The role fuel poverty plays in the decarbonisation of heat (cont.)

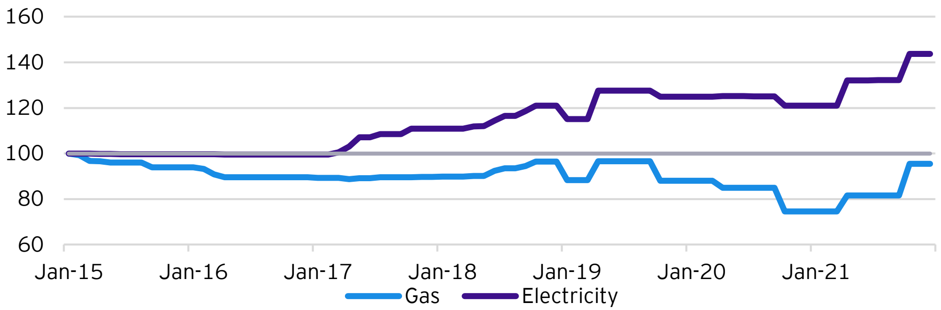
To illustrate the correlation, fuel poverty is generally greatest in those areas across Scotland that do not have access to the gas grid, such as the Islands and Highland, where households are forced to use less affordable energy sources such as electricity.

The graph below demonstrates how the price of electricity has significantly increased compared to 2015 levels, unlike gas which shows a marginal decrease. This historical price trend further emphasises the vulnerability of those properties which do not have access to the gas grid.

SG's low / no regret heat technologies rely on electricity (to varying extents) which has been less affordable than gas as shown in the graph below, however, recent volatility in the energy market clouds this position. Scotland must confront the challenge as to how such costs should be distributed and the capacity of households to the pay the share allocated to them.

### Energy Price Index

Index prices, January 2015 =100

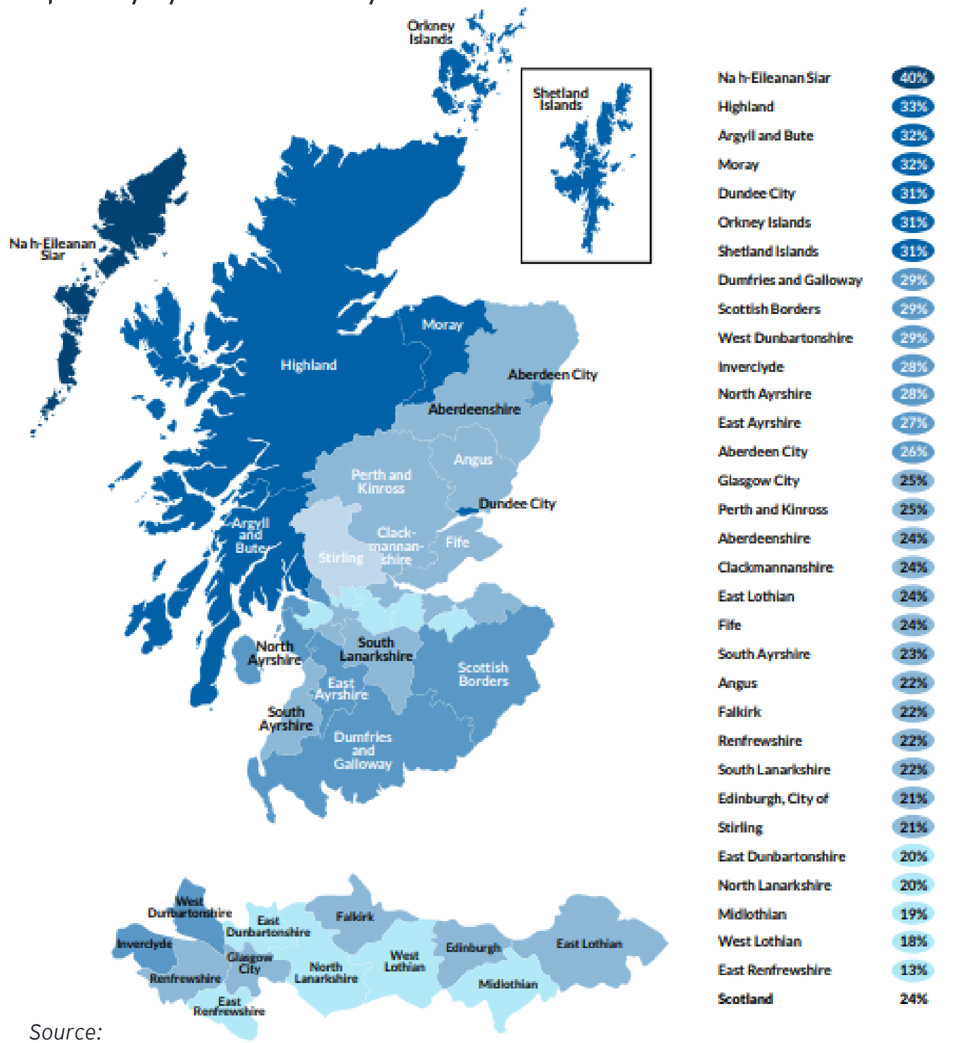



Source: *Energy prices and their effect on households - Office for National Statistics (ons.gov.uk)*

### Key conclusion

Fuel poverty plays a key role in SG's Just Transition plan, however, it is strongly linked to energy prices. Therefore, consideration will be required as to how the cost of potentially less affordable renewable heat technologies are distributed and the capacity of households to pay the share allocated to them.

### Fuel poverty by Local Authority




*Source:*
*Map produced by Energy Action Scotland (Fuel poverty map).*
*Underlying sources include Scottish house condition survey: 2019 key findings - gov.scot (www.gov.scot) and Local Authority Analysis published December 2020*

# Future demand scenarios - Results of 'Catapult' Modelling



## Future consumption – ESC model

Before exploring the potential replacement technologies, we look forward to understand the potential future consumption patterns for the heat sector. As we described in the introduction, SG and the CXC commissioned ESC to develop a set of Scotland-specific whole energy system scenarios. These scenarios demonstrate four qualitatively different routes for Scotland to meet its emissions reduction targets, allowing different choices and potential implications to be explored.

The ESC model includes future demand scenarios specifically for the residential heat sector. The forecast residential heat demand differs under each of the three scenarios (but each scenario assumes 2020 residential heat demand is 42TWh):

- The BOP scenario forecasts a slight decline in production, with demand falling to between 38.5 TWh in 2030 and 39.3 TWh in 2050.
- The TEC scenario forecasts demand will remain relatively constant, falling to 40TWh in 2030 before increasing to 42.4TWh in 2050.
- The SOC scenario forecasts demand will fall to 37TWh in 2025 and remain constant at this level until 2050.

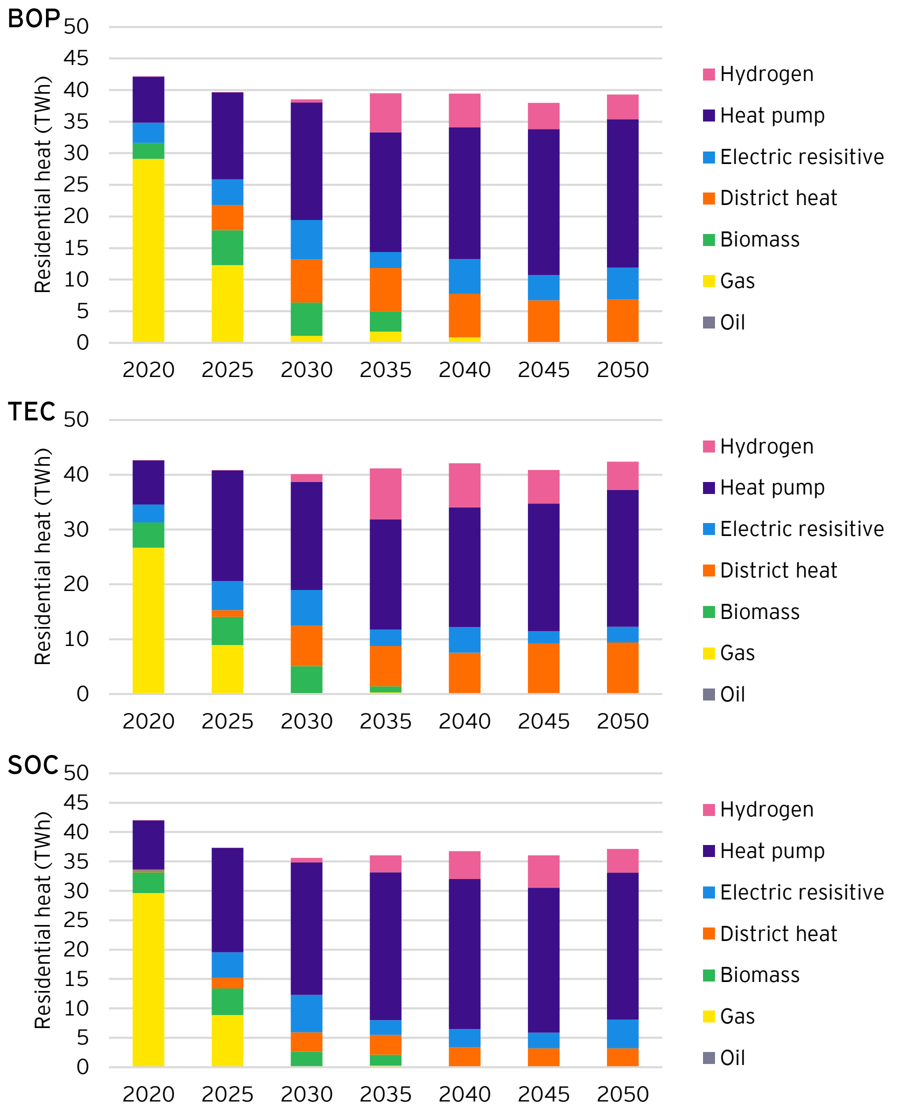
In each scenario the Catapult model forecasts residential heat will largely be decarbonised by 2030. For example, gas only represents c3% of residential heat in the BOP scenario. This is driven by the assumption that there will be a ban on new gas boilers from 2030 in Scottish homes.

The SOC scenario is the only scenario where there is a material reduction in heat demand, as people have adopted lower energy lifestyles. In the BOP scenario, a small percentage (<5%) of gas is still in the mix post 2030.

The decarbonised energy system involves a range of technologies, described overleaf.

**Key conclusion**

The ESC model shows significant reduction in natural gas by 2030, driven by the assumption that gas boilers are no longer used to heat homes.




*Source: ESC modelling*

# Future demand scenarios



## Future technology mix

The ESC model forecasts:

- The move away from natural gas results in an increase in the use of heat pumps, district heating and hydrogen. This new technology mix, and the move away from O&G, is prevalent between 2030 and 2050.
- Heat pumps provide approximately 50% of residential heat from 2030 and 60% by 2040 (BOP scenario).
- The model assumes that biomass plays a role in until the 2035s (representing 8% of heat production in the 2035 for the BOP scenario). At this point, the model predicts that CCUS will result in biomass being diverted to electricity and hydrogen production.
- District heating will also play a role in the energy mix. These may operate either on a small communal scale utilising a communal heat pump, or on a larger, potentially urban scale utilising heat from secondary source such as EfW plants or electricity generation sites. In the BOP and TEC scenarios, district heating represents c18% of the energy mix from 2030s. In the SOC scenario, this is c9%.
- The Catapult model predicts that hydrogen for heat represents c15% from 2035 and c10% from 2045. Hydrogen is more prevalent in the TEC scenario and represents 23% of the energy mix from 2035 and 15% from 2045. These increases align with the increase in CCUS commercialisation.
- It should be noted that the Catapult model does not provide insight about the use of energy efficiency measures and how these are used to reduce energy demand.

# Replacement technologies - Introduction



**The replacement technologies and focus areas to decarbonise Scotland's heat**

In order for Scotland to meet its heat decarbonisation targets, it is necessary that at least 1 million homes switch to zero emissions heating systems by 2030. SG estimates that the total capital cost of converting building stock to zero emissions by 2045 is in excess of £33 billion (of which £27 billion relates to the domestic sector and the remaining £6 billion for the non-domestic market). It is worth noting that this is based on a high electrification pathway.

To support the rollout of these ambitious plans, SG has proposed a range of replacement technologies. These include:

- The deployment of heat pumps
- The creation of low and zero emission heat networks
- The role of hydrogen in the home, gas grid and industry
- The continued focus on energy efficiency measures
- Other secondary heat decarbonisation measures such as biomass boilers, solar and the role of thermal storage.

In their Heat in Buildings Strategy SG focuses on the deployment of 'no and low regrets technologies' where the technology is readily available today and the cost uncertainty is low such as energy efficiency improvements, installation of heat pumps and heat networks.

Longer term, more complex technologies, such as the use of hydrogen in the existing gas network, are being explored and developed. The potential benefits and challenges for the adoption of such technologies are explored further in this section.

| Replacement technology | Overview |
|---|---|
| **Heat pumps** | ▸ An established technology that captures heat from the environment (air, water or ground) and uses electricity to produce heat.<br>▸ Works effectively and efficiently in homes that have a high energy efficiency performance.<br>▸ Potentially greater installation / running costs than gas boilers. |
| **Heat networks** | ▸ An established technology that takes heat from a central source and delivers it to a number of buildings.<br>▸ Should benefit from the economies of scale in terms of heat production efficiency and the purchase of fuel, and therefore help to eradicate fuel poverty by reducing overall energy costs. |
| **Hydrogen** | ▸ Several potential uses including hydrogen boilers, blending hydrogen with natural gas in the gas grid, or for bespoke industrial uses.<br>▸ The technology is in development, but needs to be further developed and trialled to determine whether it's a viable option.<br>▸ Uncertainty over costs to develop and installation/running costs. |
| **Energy efficiency measures** | ▸ The level of insulation in buildings (both in existing and in new-builds) needs to be improved to reduce overall energy demand.<br>▸ Energy efficiency measures improve the performance of many zero emissions heat technologies. |
| **Other** | ▸ **Biomass:** Generates heat through burning organic matter. Affordable but anticipated to play a limited role, due to the potential competing uses in the future with other sectors and associated carbon emissions.<br>▸ **Solar:** Converts sunlight into heat. Anticipated to be used as a secondary fuel source in conjunction with a primary fuel source.<br>▸ **Hybrid systems:** Combination of two or more heating technologies, often a heat pump and a gas boiler. Anticipated to play a limited role due to associated emissions.<br>▸ **Storage technologies:** Systems that store electricity at cheaper tariffs to enable lower running costs. Anticipated to be used as a secondary fuel source in conjunction with a primary fuel source.<br>▸ **Geothermal technologies**: Use of geothermal energy for heating. Less well developed and therefore anticipated to play a limited role. |

# Replacement technologies - Heat pumps



## 1. Overview – Heat Pumps

Heat pumps are strategically important technology to deliver low carbon heat in buildings and form a central role in SG's Heat in Building Strategy. SG states that installations need to reach at least 124,000 between 2021 and 2026, with 200,000 systems installed per annum in the late-2020s[1].

A heat pump captures heat from the environment and uses electricity to deliver this to a building. Heat pumps can extract heat from the air, ground or from water. Under normal operating conditions, the pumps do not emit emissions and are a more efficient means of heating compared to traditional systems, like a gas boiler. Heat pumps are a mature technology used in several European countries including countries that have a colder climate than Scotland. Research from the CXC found that there is no evidence to suggest that heat pumps, if installed correctly, could not operate effectively in Scotland based on its climate[1].

Heat pumps are not restricted to specific geographical areas of Scotland and can be effectively rolled out. Whilst heat pumps are described as a 'low-regrets' option due to the technology being readily available, they remain unfamiliar to the majority of Scotland. Recent surveys by SG suggest that although 51% of respondees had heard of heat pumps, only 6% are currently very likely to consider installing one[2].

### Risks and issues

Like all replacement technologies, consumers must consider the following factors before selecting the technology:

- **The interface with energy efficiency measures** – Although heat pumps can operate effectively in a large number of buildings at current energy efficiency levels, in order for a heat pump to work effectively a building needs to be well-insulated; this could be costly for homes that currently have poor thermal performance, both in terms of operational costs and any costs to improve the retrofit of the building's fabric. Introducing insulation measures to properties could be costly, disruptive and impractical (particularly where planning consent is required).
- **Housing stock suitability –** Even with improved energy efficiency measures, heat pumps may not be suitable for a proportion of Scotland's housing stock. This is particularly the case for older properties which typically have poor insulation and also for those properties with limited space, for example, the tenement flat which makes up 24% of Scotland's housing stock. Based on Home Energy Dynamics' analysis, it was concluded that installing a heat pump into a pre-1914 flat / tenement without retrofit measures would leave the house below acceptable comfort levels for more than 22% of the time during the coldest months and would require external wall insulation at a minimum[3].
- **Physical space –** Physical challenges of installing a heat pump, including lack of space in certain properties and disruptive noise, particularly in built-up areas and terraced dwellings.
- **Required upgrades** – In certain instances, radiator and internal pipework upgrades are required to allow compatibility with heat pumps. This adds significantly to total installation costs and the inconvenience involved is one of the key deterrents to consumers in installing a heat pump system[4].
- **Consumer confidence** – There is a lack of consumer confidence around heat pump technology and concerns that their comfort needs will not be met. Additionally, heat pumps generally take a longer time to provide heat which means that households will need to predict their heating requirements more accurately and / or use more sophisticated controls at an additional cost.
- **Supply chain** – There is a strong global supply chain manufacturing heat pumps. Scotland also contributes to this supply chain, with the Mitsubishi site producing 300,000 units annually[4].The global manufacturing capacity should not be a constraint, however, there are potentially UK downstream supply chain issues, whereby there are a limited number of qualified heat pump installers in the UK.
- **Infrastructure –** If deployed at scale, there will be a significant increase in electricity demand. There will need to be upgrades made to the electricity network to provide additional capacity (see 'Non-financial barriers – Infrastructure' section for further details).

[1]*Heat In Buildings Strategy: Achieving Net Zero Emissions in Scotland's Buildings (www.gov.scot)*
[2]*Heat pump use in Scotland: an evidence review (climatexchange.org.uk)*
[3]*Suitability of Ground and Air Source Heat Pumps (nesta.org.uk)*
[4]*Scottish Government Heat Pump Sector Deal Expert Advisory Group: final report*

# Replacement technologies - Heat pumps



## Cost comparison

The costs of heat pumps can vary both from a capital and operating cost perspective.

*Capital costs*

The capital cost of a heat pump can be significantly greater than the cost of a traditional gas boiler, both for an air source or ground source heat pump. Capital costs also vary depending on the heating capacity and specification requirements.

Analysis by UKG, highlighted in the table opposite, shows the potential range of costs for different heat pump options. The inclusion of additional energy efficiency modifications and heating system upgrades (such as modifications to radiator sizes) significantly increases the total cost of a new heat pump.

The capital cost of new technologies should decrease over time, with future capital costs reducing as heat pumps become established.

*Operating costs*

The running costs for heat systems depend on a variety of factors including:

- The heat demand, how well insulated, and how large the building is;
- The efficiency of the pump; and
- The price of electricity and the electricity tariff.

Heat pumps are an efficient way of using electricity to produce heat. Although one kWh of electricity is more expensive than one kWh of gas, the higher efficiency of the heat pump means that the amount of energy needed to produce the same level of heat is less.

Historically electricity prices have been on average 4 to 5 times greater than gas, although recently volatile electricity and gas prices cloud this position. As a result, the operating costs of gas heating may be cheaper than a heat pump, unless the efficiency of the heat pump (also known as its coefficient of performance) remains high.

A heat pump may result in potentially lower running costs, however, poor heat pump design and installation can lead to a reduction in efficiency. Operating costs will also be impacted by the specific consumer electricity tariff as well as user behaviour and the temperature the home is heated to. As a result, forecasting future operating costs of a heat pump is complex. We might expect heat pump efficiency, installation quality and overall price to reduce as technology becomes embedded and supply increases.

Additionally, to support the rollout of heat pumps, energy bills must remain affordable and the relatively low cost of gas (even with the current volatility in the energy market and the predicted increase in gas prices) may present a financial barrier to the mass rollout of heat pumps. The impact of electricity levies and VAT are also factors that impact the operating costs.

| Installation cost comparison of gas boilers versus heat pumps | Installation cost range |
|---|---|
| Cost of gas boiler in a new home[1] | £2,250 - £6,228 |
| Cost of installed air source heat pump[1] | £8,750 - £14,900 |
| The costs of retrofitting an insulation and glazing package into an existing home[2] | Nil - £48,000[3] |

[1] *Delta Energy & Environment, 'The Cost of installing heating measures in domestic properties' (July 2018)*
[2] *Heat pump retrofit in London | The Carbon Trust*
[3] *The nil lower range reflects the fact that not all properties require energy efficiency upgrades. The upper range of £48,000 is based on a small sample size with deep retrofit costs.*

# Replacement technologies - Heat pumps



## Cost comparison (cont.)

*Total costs to operate*

Our analysis, utilising data from Nesta / ESC summarises the capital and operating costs for an air source heat pump versus a conventional gas boiler under several different scenarios (see table opposite), assuming a typical 15 year lifespan:

- Scenario A – Cost of using an air source heat pump for the average household, assuming the same level of heat demand as the gas boiler scenario below.
- Scenario B – Cost of using an air source heat pump assuming heat demand is halved. This provides a transparent alternative scenario to show the impact of a significant reduction in the fuels costs. This scenario does change any other assumptions, including property size, capital costs or if the heat pump is the most efficient zero emission option.
- Scenario C – Cost of using a gas boiler for the average household.

The analysis shows that, due to the upfront cost of the heat pumps versus gas boilers, the lifetime costs of those options substantially exceed those of the gas boilers. The capital costs also increase when the additional energy efficiency measures are factored in.

To highlight the variability of the potential operating costs of a heat pump, we included a second heat pump scenario (Scenario B) where the heat pump operating costs are significantly lower than the £1,063 under Scenario A. This is to represent a property with smaller heat demand. In this example, the total cost of a heat pump still exceeds the total cost of a gas boiler.

Whilst heat pumps are more expensive in terms of unit capital costs compared to standard gas boilers, it is envisaged that as heat pumps become more widespread across Scotland, suppliers will be able to achieve economies of scale which may be passed on to the end-consumer. Nevertheless, the critical consideration for future uptake will be the cost of electricity and the impact on future operating costs and in some situations, it is expected that installation of a low carbon heating system, such as a heat pump, may be more expensive than a gas boiler.

This has a significant implication for Scotland's Just Transition, described

**Key conclusion**

The total cost to operate a heat pump is expected to exceed conventional gas boilers, the primary heating system in Scotland. Costs are dominated by capital costs rather than operating costs, meaning measures are needed to reduce capital costs for end users.

| Illustrative total cost to operate scenarios | Heat Pump - scenario A | Heat Pump - scenario B | Gas boiler - Scenario C |
|---|---|---|---|
| **Capital costs** | | | |
| Heat pump and installation costs | £8,750 - £14,900 | £8,750 - £14,900 | £2,250 - £6,228[1] |
| Additional costs of energy efficiency measures[5] | £0 - £48,000 | £0 - £48,000 | N/A |
| **Operating costs** | | | |
| Fuel costs (electricity or gas) | £1,063 (based on an average weekly costs of £20.45[2] | £531 (based on an average weekly costs of £10.22[2] | £729 (based on an average weekly cost of £14.01[2] |
| Service and maintenance costs | £100 - £250 p.a.[3] | £100 - £250 p.a.[3] | £100[4] |
| **Typical asset useful life** | 15 years | 15 years | 15 years |
| **Total gross cost over 15 years** | £26,195 - £80,345 | £18,215 - £72,365 | £19,695 - £23,339 |

*Source: EY analysis. See footnotes for more assumptions and sources of data.*

*[1] These inputs are based on the analysis undertaken by Nesta/ESC and do not reflect the current volatility in the gas market.*

*[2] Illustrative analysis based on the inputs from Comparison of Heat Pump and Gas Boiler Cost Estimates" Catapult Energy Systems. Our analysis assumes an illustrative heat demand of 18,600 kWh, price of electricity at 20p/kWh and a coefficient of performance of 3.5. For scenario B, the heat demand is halved. For the gas prices, a unit cost of 3.5p/kWh and a coefficient of performance of 0.9 was used.*

*[3] How to Heat Scotland's Homes: Nesta/Catapult Energy Systems*

*[4] Technical Feasibility of Low Carbon Heating in Domestic Buildings : Scottish Government*

*[5] Some buildings may not require significant energy efficiency upgrades and if this is the case, the likely costs will fall towards the lower end of this range.*

# Replacement technologies - Heat pumps



## Conclusion

As Scotland transitions to net zero, heat pumps will play a central role as a decarbonised heating solution. The emissions benefits of heat pumps are clear and SG's Heat in Building Strategy places heat pumps, along with heat networks, at the heart of the decarbonisation agenda, both in an on and off-gas grid context.

Whilst electricity is generally more expensive than the price of gas, the higher efficiency of the heat pump means that the amount of energy needed to produce the same level of heat is less. In off-gas grid properties, where oil, solid fuel or direct electric heating are used, heat pumps can offer a competitive alternative, assuming the heat pump has been correctly specified and installed. However, there are several significant implications that must be considered before these goals can be realised:

- **The pace of the rollout** – SG states that to meet its emissions targets, rapid scaled up zero emission heat systems are required, which means a combination of heat pumps and heat networks. This is expected to peak at over 200,000 new systems per annum in the late 2020s. This is compared to the current rate of installing renewable heating systems of 3,000 per year. This ambitious target exceeds the rollout forecasts proposed by the CCC and demonstrates the scale of the challenge. To achieve this, the number of heat pumps being installed must double every year.
- **Impact on a Just Transition and fuel poverty** - It is important not to disincentivise householders from switching to heat pumps. The current imbalance between electricity and gas prices creates a barrier to rolling out low carbon heating systems, and without action to rectify this imbalance, this may result in higher heating costs. This has significant implications for a Just Transition as it may exacerbate fuel poverty in Scotland.
- **Physical space –** Depending on the type of heat pump, it may not be a suitable technology for all buildings, particularly those that have little outside space or are in close proximity to neighbouring properties, due to their relatively large size and noise considerations.
- **The role of consumer behaviour –** Further work is required to raise general consumer awareness about heat pumps and how they operate.
- **The role of installers and the supply chain** – For many properties, the operational and cost effectiveness of a heat pump will rely on the correct specification, installation and efficiency of the unit. As a result, there will be a requirement for appropriate market regulation to ensure the supply chain meets these high standards. This theme is explored further later in this section under 'Non-financial barriers – Supply chain'.
- **A need for a combined energy efficiency and heat pump rollout** – For all zero emissions technology to be effective, including heat pumps, a 'fabric first' approach is required to ensure energy efficiency measures are installed in tandem with the heat pumps. This not only reduces the amount of heat required, but it will also reduce the demands on the electricity grid and make future operating costs more reasonable.
- **Infrastructure –** If deployed at scale, there will be a significant increase in electricity demand. Therefore, there will need to be electricity network upgrades to provide the additional capacity. This is applicable for all replacement technologies and is described in more detail later in this section under 'Non-financial barriers – Infrastructure'.

### Key conclusion

Heat pumps will be a core replacement heat technology and are viewed as a "low regret" option by SG. However, several barriers still exist regarding the scale of the rollout and costs of the heat pump before SG's ambitions are met.

# Replacement technologies - Heat networks



## 2. Overview – Heat networks

Whilst heat networks are an established technology available today, there are currently only an estimated 34,000 homes in Scotland that are connected to heat networks[1], and these have historically been powered using natural gas. According to the Energy Saving Trust, the uptake in other European countries has been far greater than the UK, for example 65% of heat in Denmark's homes comes from district heating, with Copenhagen almost entirely served by heat networks[2]. Going forward, SG aims to develop networks powered using low or zero emissions sources such as surplus or waste heat or heat pumps as part of its no and low-regrets strategic technologies.

Heat networks are a heat supply technology which can be powered from a wide range of low carbon sources such as recovered heat from industrial processes and renewable technologies such as heat pumps, biomass and solar thermal. They take heat from a central source and deliver it to a number of buildings and work most efficiently connected to anchor loads (typically large non-domestic buildings) that require a significant, reliable and long term heat demand. However, Denmark has implemented a number of small scale heat networks in rural areas, indicating that there should also be scope for using heat networks in smaller communities that are clustered together e.g. rural towns and villages.

SG requires the combined supply of thermal energy by heat networks to reach 2.6 TWh of output by 2027 and 6 TWh of output by 2030 (3% and 8% respectively of current heat supply). Targets for 2035 are anticipated to be set in early 2023.

These targets are broadly equivalent to 120,000 and 400,000 gas-using homes being connected to heat networks by 2027 and 2030 respectively, however, actual numbers are likely to be lower. To accelerate the growth of heat networks in Scotland, SG state that it will implement the Heat Networks (Scotland) Act 2021 putting in place a functioning regulatory regime by early 2024.[3]

SG states that any new heat networks and extensions of existing heat networks will need to be powered using low and zero emissions sources of heat, and although many of the existing 1,080 heat networks[3] will continue to use fossil fuels as their main sources of heat, these will need to be decarbonised by 2040-2045. Generally, the decarbonisation of heat networks (by switching their heat source) should cause minimal disruption to the end-consumer.

Whilst the cost of operating a heat network depends on the fuel source, it is anticipated that heat networks should benefit from the economies of scale in terms of heat production efficiency and the purchase of fuel, and therefore help to eradicate fuel poverty by reducing overall operating energy costs for consumers. The Competition and Markets Authority report that up to 90% of current heat network customers enjoy similar, or lower, bills than those with standard gas boilers[4]. This is further evidenced through surveys performed by BEIS which found that on average, heat networks customers paid around £100 less per year compared with those using a standard gas boiler[5], however, this is based on traditional gas powered heat networks rather than low carbon equivalents. There is limited information publicly available on the cost comparison for the capital and operating costs for households using low carbon heat networks.

### Risks and issues

- **Capital costs –** The cost to develop a new heat network, including the decarbonisation of existing heat networks is a significant barrier to companies, particularly where there is currently little market demand. According to its Heat Networks Delivery plan, in order to encourage investment SG will provide £400 million to support the development of large-scale heat infrastructure, such as heat networks. SG's £300 million Heat Network Fund launched earlier this year is part of this new suite of delivery schemes.
- **Natural monopolies –** Heat networks have a number of features of natural monopolies whereby they require a relatively large initial capital investment and recoup that initial outlay over a long period of time. This raises barriers to entry for other competitors and could lead to abuse of monopoly power. It should be noted that heat network regulation is currently being developed to ensure consumer protection in Scotland.
- **Limited flexibility –** Once heat networks are connected to homes there is limited ability for consumers to switch.

[1] *Heat In Buildings Strategy: Achieving Net Zero Emissions in Scotland's Buildings (www.gov.scot)*
[2] *What is district heating? A low carbon solution for the UK's homes - Energy Saving Trust*
[3] *Heat Networks Delivery Plan (www.gov.scot)*
[4] *Competition and Markets Authority (2018), Heat Networks Market Study: Final Report*
[5] *Heat Networks Consumer Survey: consumer experiences on heat networks and other heating systems - GOV.UK (www.gov.uk)*

# Replacement technologies - Heat networks



## Risks and issues (cont.)

- **Supply chain –** There are currently skill gaps in Scotland's supply chain for the design, installation and ongoing maintenance / operation of heat networks.[1]
- **Suitability with dispersed rural areas –** Heat networks are generally suitable for urban areas which are densely populated and in certain cases, rural areas where there is still sufficient energy demand (e.g. small village communities). Heat networks may not be suitable for dispersed rural communities.

## Conclusion

Heat networks are one of SG's low and zero regret technologies and although they are an established technology, only a small minority of homes in Scotland are currently connected to heat networks and, historically, these have been powered by gas. This is in comparison to many other Northern European countries, where the use of heat networks has become increasingly popular. Going forward, SG aims to develop networks powered using low or zero emissions sources such as surplus or waste heat or heat pumps as part of its no and low-regrets strategic technologies.

One of the key advantages of adopting heat networks is that they will benefit from the economies of scale in terms of heat production efficiency and the purchase of fuel, and therefore help to eradicate fuel poverty by reducing overall operating energy costs for consumers.

However, the capital and running costs for households to connect to low carbon heat networks is currently uncertain which could potentially disincentivise consumer demand. Further, the capital cost required for their development and the cost to decarbonise existing heat networks will require significant investment from companies. SG offers a range of funding programmes to support the development of low carbon heat networks, however, there will still need to be a significant investment from the private sector which could be challenging to attract, particularly given the current limited market demand.

### Key conclusion

Low carbon heat networks are a key heat solution, particularly where it is not feasible to change the fabric of a building to the insulation levels suitable to use an individual heat pump. However, there are number of challenges involved with their development, including the significant investment required from the private sector.

[1] *Scottish Government's Heat Networks Delivery Plan*

# Replacement technologies - Hydrogen



## 3. Hydrogen - Overview

Hydrogen is rapidly emerging as a potential low carbon and sustainable solution for decarbonising many parts of Scotland's economy including the heat sector. There are two key solutions:

- 100% hydrogen domestic heating solution – this includes the introduction of specific hydrogen boilers, heaters and cooking appliances.
- Hydrogen blended with natural gas – heating buildings with blended hydrogen and natural gas, using the existing gas network, boilers and other appliances. Research currently indicates that a volume blend of 20% hydrogen (80% natural gas) is the limit that can be safely used in existing infrastructure and appliances.

The rollout of hydrogen as a low carbon heat fuel source has not yet been established, either domestically or by international markets, however, Scotland and the UK as a whole are ahead of the curve compared to many other countries in terms of research and testing. SG's draft Hydrogen Action Plan describes the actions that will be taken over the next five years to support the development of a hydrogen economy in Scotland, detailed in Appendix A.

### Cost comparison

*Capital costs and operating costs*

The anticipated costs to develop and deploy hydrogen as a primary heat source across Scotland are still unknown due to its early stages of development, however, the CCC estimate that a future hydrogen boiler will cost an incremental c£100 more in capital costs compared to a natural gas boiler[1].

The running costs of hydrogen will depend on the chosen production technology and the costs of repurposing the current gas network. In this regard, Element Energy[2] state that capital expenditure associated with gas network repurposing, transmission and storage costs could be in excess of £33bn. Initial research[3] shows that the total system cost per household for hydrogen (produced by electrolysis) varies between £1,410 - £1,880 per year. The costs could be lower if hydrogen produced by methane reforming and CCUS technology is used.

### Risks and issues

Like all replacement technologies, hydrogen will only be considered with reference to the following risks and issues:

- **Limited impact –** Blending hydrogen with natural gas will only delivery small levels of emissions savings on its own. A 20% hydrogen blend has the potential to reduce carbon emissions from natural gas by up to 8%.[4]
- **Infrastructure and appliance upgrades –** Any large scale rollout of 100% hydrogen for heat will require upgrades to existing infrastructure and applications. For example, existing natural gas boilers and appliances designed specifically for hydrogen will need to be introduced. Additionally, even for a blended hydrogen solution, some distribution infrastructure may require upgrades, e.g. replacement of traditional metal pipes with polyethylene pipes. Some of this activity is already underway through the Iron Mains Risk Replacement Programme.
- **Safety and public perception –** Potential public safety concerns will need to be overcome before the large scale rollout of hydrogen can take place.
- **Limited hydrogen supply –** To produce sufficient hydrogen to achieve a 20% volume blend of natural gas by 2030, the UK will have to more than double its hydrogen production plans[5]. Additionally, hydrogen is initially expected to be adopted to decarbonise hard-to-abate sectors such as heavy industry, electricity generation and storage and heavy transport. As such, hydrogen as a solution for the heat sector will only be unlocked with a scale up of the hydrogen economy and the expansion of supply.
- **Green hydrogen supply –** Most hydrogen produced today is fossil fuel based, therefore if hydrogen is to be used to decarbonise the energy sector the ideal hydrogen type is 'green' hydrogen which uses renewable/low-carbon electricity in its production. However, 'blue' hydrogen, where the GHG emitted from creating hydrogen are captured and stored is likely to be the primary production method until 2050 due it being much cheaper than green hydrogen. The residual emissions associated of this method must be considered.
- **Natural gas regulation –** The demonstration of greater blends of hydrogen are limited due to the restrictions under existing UK gas regulations. SG has urged UKG and the UK regulator to expedite changes to regulations to facilitate greater levels of gas blending.

[1] The Climate Change Committee - The Sixth Carbon Budget: Fuel Supply
[2] Technical Feasibility of Low Carbon Heating in Domestic Buildings : Report for Scottish Government's Directorate for Energy & Climate Change (www.gov.scot)
[3] Delivering net-zero carbon heat: Technoeconomic and whole-system comparisons of domestic electricity- and hydrogen-driven technologies in the UK - ScienceDirect
[4] Heat in Buildings Strategy - achieving net zero emissions in Scotland's buildings - gov.scot
[5] EY's Review of Future Homes Standard" report dated June 2021

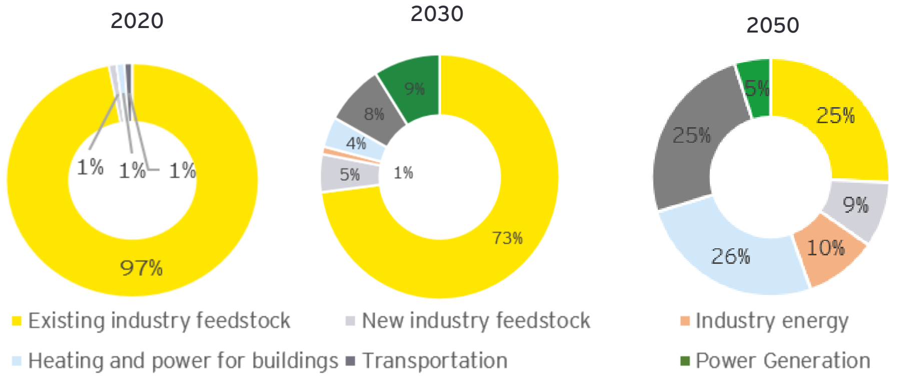
# Replacement technologies - Hydrogen



### Conclusion

Hydrogen as a heating solution is unlikely to play an immediate role in Scotland's heat decarbonisation strategy, however from 2030 onwards it is likely to have a significant role globally. Analysis conducted by EY indicates that by 2030 global demand for hydrogen for heating and powering buildings is going to be less than 5% of total demand, and 26% in 2050.

### Future hydrogen demand by sector




*Source: EY analysis*

Hydrogen offers a number of benefits that may result in it being adopted for specific targeted purposes:

- When coupled with CCUS, large scale production of hydrogen can be achieved with low carbon emissions and when produced using biomass, potentially negative emissions. CCUS is the process of capturing and storing carbon dioxide before it is released into the atmosphere and is an area that is being explored in greater detail.
- For specific geographical locations, converting 100% of the gas grid may make sense if there is a local hydrogen supply or strong industrial demand results in economies of scale for other users.
- Hydrogen provides a potential solution to creating a base energy load, where it helps with variable output from renewables whose availability is not always well matched with demand.
- Consumers may be more willing to convert to hydrogen as opposed to other zero carbon heat technologies as it could potentially deliver a similar user experience to using gas boiler and a hydrogen-ready boiler may be able to be installed and used prior to conversion to a low-carbon hydrogen supply, reducing disruption to consumers.

Therefore, whilst hydrogen is more expensive to produce in comparison to high carbon fuels, Scotland with its abundant natural resources (including onshore and offshore wind, tides and water), existing skills in the O&G industry and supply chain is uniquely placed to provide large scale production of renewable hydrogen to power Scotland. This may not be realised immediately, but future hydrogen demand may have a role to play from the 2030s onwards. The role of policy, particularly the role of the UKG on the regulation and deployment of hydrogen is explored later in this section under 'Policy Environment'.

**Key conclusion**

Before 2030, hydrogen for domestic heating is unlikely to form a core replacement technology in Scotland. Its future role as a central heat decarbonising technology is still being explored, however it will primarily be targeted at hard to abate sectors or specific industrial purposes.

# Energy efficiency measures – Domestic



## 4. Overview – Energy efficiency measures

As part of SG's 'fabric first' approach there is a focus on improving the energy efficiency of homes in Scotland. The aim is that by 2030 the majority of domestic buildings should achieve a good level of energy efficiency (where technically / legally feasible and cost effective), which for homes is at least equivalent to an EPC band C, with all homes in Scotland meeting at least this standard by 2033. According to its Heat in Buildings Strategy, SG plans to reform its EPC metrics to ensure alignment with its net zero objectives (and remove anomalies within the current metrics) before using it as the standard by which properties will be measured.

Energy efficiency measures are critical for the deployment of many zero emissions heat technologies (including heat pumps) and are essential for reducing overall energy demand and subsequently reducing energy costs and fuel poverty. The Energy Saving Trust estimates that roughly one-third of all heat lost in an uninsulated home escapes through the walls, whilst 25% of heat is lost through the roof[1], therefore energy efficiency measures such as improvements to loft insulation, cavity wall insulation and double glazing are considered a priority.

### Domestic properties

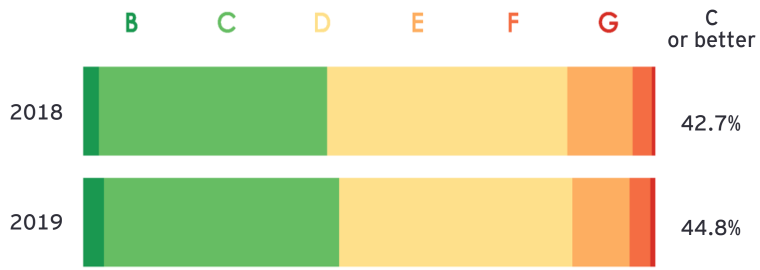
Energy efficiency levels in Scotland's dwellings are monitored using the Standard Assessment Procedure (SAP) and expressed as an EER. These ratings are banded from A to G where A is a highly energy efficient dwelling and G represents low energy efficiency.

The energy efficiency of a dwelling depends on its physical characteristics, such as age of construction, dwelling type, insulation of the building fabric and the heating and hot water systems in use.

Over the last 10 years Scotland's homes have become generally more energy efficient. Since 2010, the share of the most energy efficient dwellings (rated at least EPC C) has increased by 27 percentage points[2] and in 2019, more than 4 in 10 homes in Scotland were rated at least an EPC band C. Social housing is among the most energy efficient, likely due to improvements mandated under the Scottish Housing Quality Standard and Energy Efficiency Standard for Social Housing which introduced minimum energy efficiency levels for that sector.

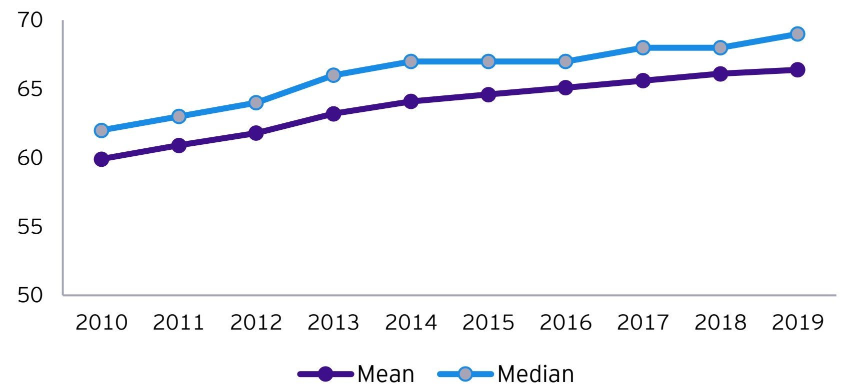
The share of dwellings in the lowest energy efficiency bands (F and G) is particularly high for pre-1919 dwellings (13%), non-gas heated properties (between 18% and 24%), detached properties (10%) and in the private rented sector (10%). Across Scotland as a whole, 4% of properties were in bands F or G in 2019[3]

**Distribution of Scottish housing stock by EPC band (based on SAP 2012 RdSAP v9.93)**




*Source: [Scottish Energy Statistics Hub]*

**Average EER, SAP 2009**




*Source: [Scottish House Condition Survey: 2019 key findings - gov.scot]*

[1] Measures to help reduce home heat loss - Energy Saving Trust
[2] Scottish house condition survey: 2019 key findings - gov.scot (www.gov.scot)
[3] Scottish house condition survey: 2019 key findings - gov.scot (www.gov.scot)

# Energy efficiency measures - Domestic



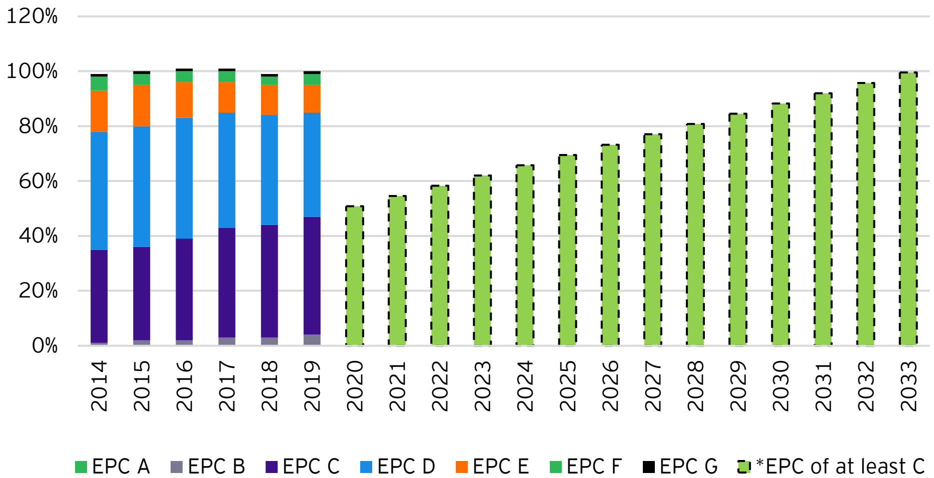
## Domestic properties (cont.)

Proximity to the gas grid is correlated with a home's EER, whereby those that are near the grid have a slightly higher energy efficiency. Since housing stock in rural areas are more likely to be older, detached and not gas heated (due to less likely being within the coverage of the gas grid), energy efficiency of properties in rural areas are lower than those in urban areas.

Between 2014 and 2019, the proportion of homes scoring an EPC of at least C has increased by 6.1% on average per annum (as shown in the graph below).

If SG's energy efficiency target of all homes scoring at least an EPC band C by 2033 is to be achieved, the rate of increase would need to be approximately 5.2% per annum between 2019 and 2033. Therefore assuming the rate of energy efficiency improvements is maintained, SG's targets should be met.

**EPC ratings of Scottish Housing, SAP 2012 (RdSAP v9.92)**




*Required growth rate for homes between 2020 - 2033 to achieve target of 100% homes having an at least an EPC band C.

*Source [Scottish House Condition Survey: 2019 Key Findings (www.gov.scot)](#) and modelled EY analysis for 2020 - 2033*

To help achieve its targets, SG has set out a timeline in its Heat in Buildings Strategy for the proposed introduction of legislative measures across the various types of properties. These are summarised as follows:

- **Private Rented Housing: It** is anticipated that regulations will be introduced in 2025 requiring private rented sector properties to reach an EPC C, where technically feasible and cost effective, at a change of tenancy, with a backstop of 2028 for all remaining existing properties.
- **Owner occupied private housing:** Whilst regulations have not yet been introduced (anticipated from 2023-25 onwards), it is envisaged that energy efficiency standards will be at least equivalent to an EPC C by 2033.
- **Social housing:** The Scottish Housing Regulator reports that 89% of social housing has met the Energy Efficiency Standard for Social Housing 2020 milestone and landlords are working towards all households being at least EPC B or be as energy efficient as practically possible by the end of 2032.
- **Mixed-tenure and mixed-use buildings:** For these buildings energy efficiency standards may need to apply to the whole building rather than just an individual unit (e.g. flats, ground floor commercial properties). The regulatory approach for these types of properties is unclear and anticipated to be introduced from 2023-25 onwards.
- **New buildings:** Regulations are being developed which will require all new buildings from 2024, for which a building warrant is applied for, to use zero emissions heating and to feature high levels of fabric energy efficiency.

**Key conclusion**

Improving the energy efficiency performance of homes plays a pivotal role in the deployment of zero emissions technologies, the reduction of energy demand, and thus energy costs (and fuel poverty). The energy efficiency performance of properties has improved in recent years and assuming the rate of increase is maintained, Scotland is on track to meet SG's 2033 targets.

# Energy efficiency measures – Non-domestic



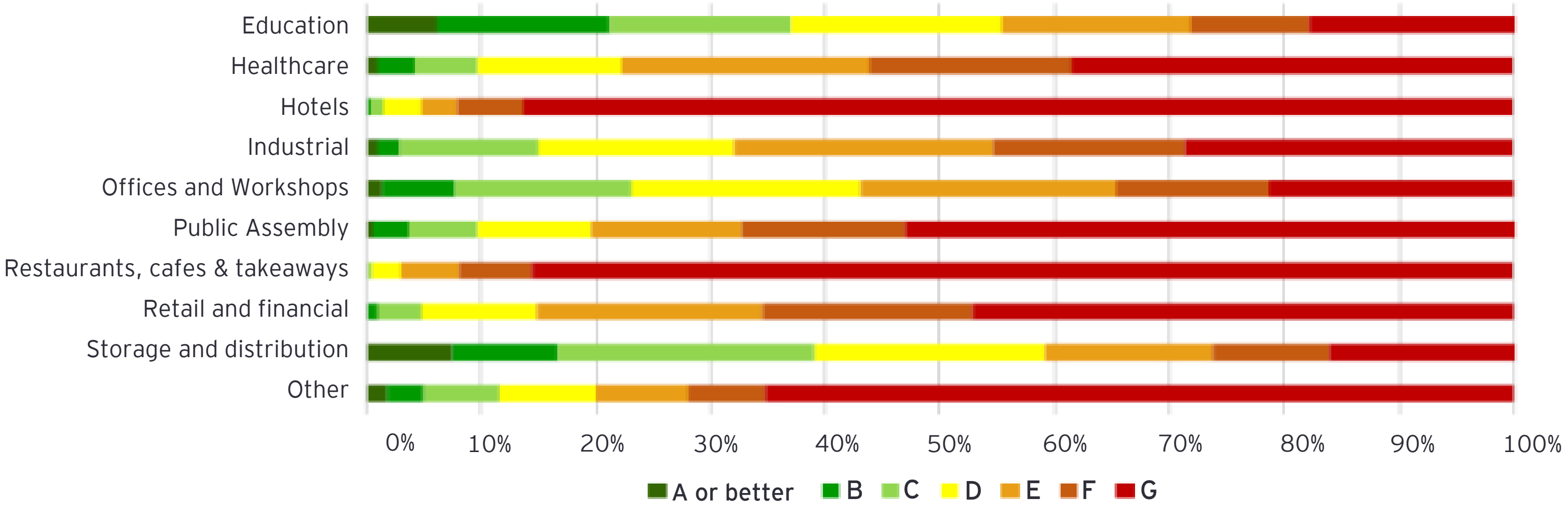
## Non-domestic properties

Scotland's 220,000 non-domestic buildings are hugely diverse and, according to the SG's Heat in Buildings Strategy, almost three in four of all non-domestic premises have a current EPC of E or worse, with only 5% scoring at least an EPC B. However, it should be noted that Scottish non-domestic EPCs are derived on a different basis to domestic EPCs (and English non-domestic EPCs) as they present the calculated GHG emissions for a building on a scale of A to G and are therefore not comparable. These figures only highlight that a significant number of Scotland's non-domestic buildings are heavy users of energy, they do not signal fabric energy efficiency performance.

For example, the graph below shows the EPC band ratings between the varying non-domestic building types. It shows that 86% of hotels and 85% of restaurants, cafes and takeaways are classed as a band G. This is likely to reflect that these specific buildings are being used throughout the day and being heated to comparatively high temperatures. This is compared to storage and distribution and education premises where only 16% and 18%, respectively, lie in band G. This is perhaps due to the fact schools are often newly built, are not being operated all day, at the weekends or during holidays and similarly in the case of warehouses, they are generally less energy intensive and heated to lower temperatures[1].

[1] Current EPC banding - Scotland's non-domestic energy efficiency baseline: report - gov.scot (www.gov.scot)

**Non-domestic building types by current EPC band**




*Source:* Current EPC banding - Scotland's non-domestic energy efficiency baseline: report - gov.scot (www.gov.scot)

# Energy efficiency measures – Non-domestic



## Non-domestic properties (cont.)

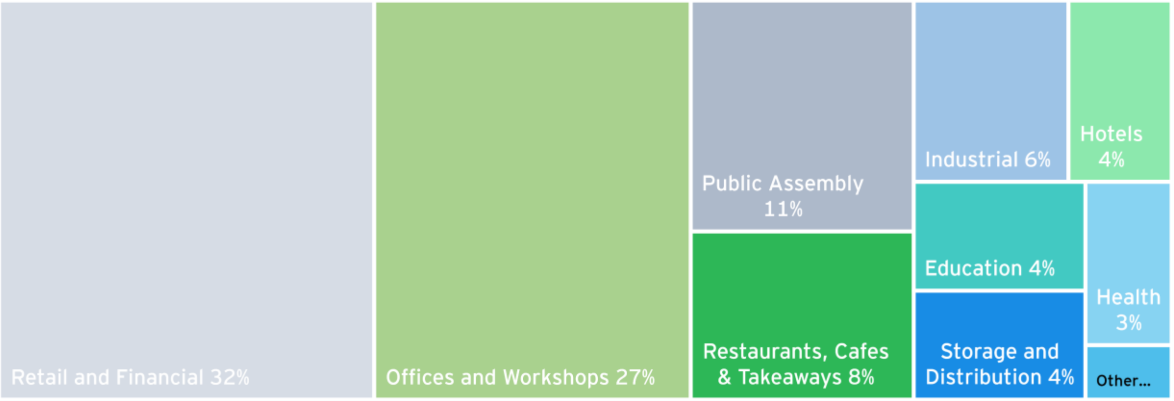
Further, the size of non-domestic buildings varies considerably, as shown in the graphs opposite. Retail and finance premises are smallest on average, as they account for 32% of the total non-domestic properties, however, they account for only 18% of the share of non-domestic internal area (i.e. there is larger proportion of them, however, due to their size, they account for a much smaller share of total internal area). On average, educational premises are the largest, as they represent over 9% of the total internal area of all non-domestic premises but make up just less than 4% of the premises.

Overall, due to the diversity of non-domestic building uses and varying energy demands e.g. small corner shops compared to large schools and warehouses, the regulatory approach for energy efficiency targets / measures is still under consultation and is anticipated to be introduced in 2025, however, it is envisaged that by 2045, the energy efficiency levels of all non-domestic buildings will be improved.

### Key conclusion

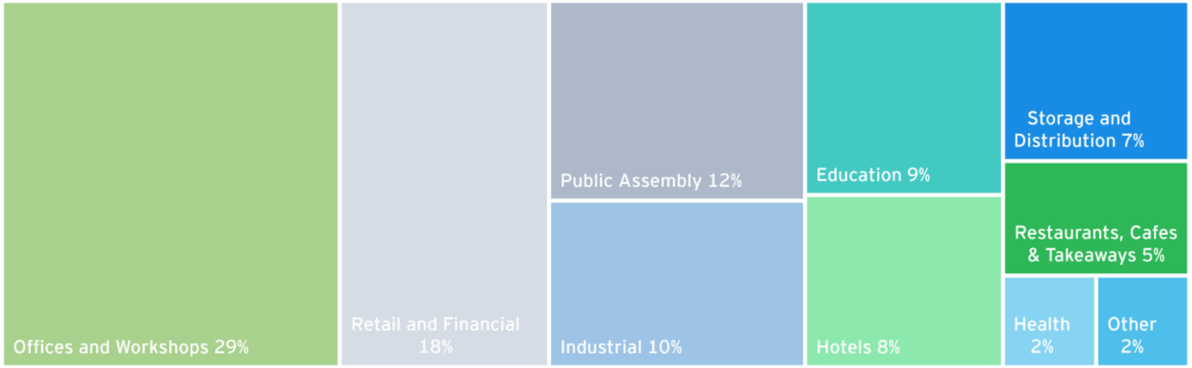
Due to the diverse nature of non-domestic buildings, there is less known about their current energy performance, compared with the domestic sector. The energy efficiency performance of non-domestic buildings needs to be urgently reviewed and monitored if targets are to be met.

### Number of non-domestic properties




Source: *Current EPC banding - Scotland's non-domestic energy efficiency baseline: report - gov.scot (www.gov.scot)*

### Share of non-domestic internal area




Source: *Current EPC banding - Scotland's non-domestic energy efficiency baseline: report - gov.scot (www.gov.scot)*

# Energy efficiency measures - Conclusion



## Conclusion

Improvements to energy efficiency performance play a pivotal role in the decarbonisation of heat in buildings. SG's 'fabric first' approach places an emphasis on undertaking energy efficiency measures first as they are essential for the deployment of many zero emissions heat technologies (including heat pumps) and are critical for reducing overall energy demand and subsequently reducing energy costs and fuel poverty.

The aim is that by 2030 the majority of domestic buildings in Scotland should achieve a good level of energy efficiency (where technically / legally feasible and cost effective), which for homes is at least equivalent to an EPC band C, with all homes in Scotland meeting at least this standard by 2033.

In recent years, the energy efficiency performance of domestic buildings has been improving and today there are more than 4 in 10 homes which achieve at least an EPC band C. Assuming that the rate of energy efficiency performance improvements seen in recent years is maintained going forward, SG's 2033 targets should be met.

Due to the diverse nature of non-domestic buildings, there is less known about their current energy performance, compared with the domestic sector. Therefore, the energy efficiency regulatory landscape for non-domestic properties is uncertain, however, there is anticipated to be clarity by 2025 and it is envisaged that by 2045, the energy efficiency levels of all non-domestic buildings will be improved.

Whilst SG has set up a number of funding programmes to assist both the domestic and non-domestic sector with the cost of installing energy efficiency measures, it is likely that there will still need to be significant investment from the private sector. The extent to which the private sector will need to fund such improvements is uncertain.

### Key conclusion

Energy efficiency measures play a pivotal role in reducing energy demand, fuel poverty and the deployment of zero emissions heat technologies. Overall the energy efficiency performance of buildings has been improving and the domestic market should be on track to meet SG's 2033 targets.

More information on Scotland's non-domestic building stock is required to assess the energy efficiency performance of these properties.

# Replacement technologies - Other



## 5. Overview – Other replacement technologies

*Biomass*

In line with the UK's CCC, it is envisaged that bioenergy in heating, such as biomass and bio-heating oil are expected to have a limited role in Scotland being able to achieve its net zero emissions targets. SG's Heat in Buildings Strategy envisages that bioenergy sources will be used in home heating if they are displacing fossil fuels in off-gas grid areas where electric heating or heat pumps are unsuitable, however, further detail on the future sustainable use of bioenergy resources within Scotland will be published in the Bioenergy Action Plan.

Biomass boilers generate heat through burning organic matter, such as wood in the form of logs, pellets or wood chips, thus producing hot water or steam. Although they are sourced from fallen trees and then burnt, they are considered more environmentally friendly compared to burning gas, as plants can generally be replaced quickly (and therefore arguably considered a carbon-neutral fuel).

Whilst a biomass boiler is generally cheaper to run than a gas boiler[1], this technology is viewed as the least acceptable option, primarily due to its potential competing uses in the future with other sectors where low carbon alternatives are limited. Further disadvantages include its associated carbon emissions, fuel storage and maintenance requirements.

*Solar*

Solar works by converting sunlight into heat for hot water or air. It is an efficient energy source, especially in warmer months, however, it tends to need to be operated in conjunction with another heating system as the levels of heat produced are not sufficient enough to meet the heat comfort needs of consumers. SG views that the use of solar technologies (thermal and photovoltaic systems) could be used alongside primary zero emissions heat sources, such as heat pumps.

*Hybrid systems*

Hybrid systems combine two or more heating technologies, often a heat pump with a boiler. These systems may be preferable for existing homes where insulation levels cannot be brought up to a standard that allows zero emissions technologies, if used on their own, to work efficiently. However, due to the uncertainty over the scale and distribution of these potential advantages and their associated carbon emissions (given there is still a natural gas element), they are envisaged to play a smaller role in the decarbonisation of heat.

*Storage technologies*

SG is evaluating a number of building storage technologies (including electric batteries, heat batteries and thermal storage) which could potentially reduce energy costs when installed with zero emissions heat technologies.

These systems enable the decoupling of heat production and heat use by taking advantage of fluctuations in electricity prices throughout the day by storing heat during the cheapest electricity tariff period then releasing it gradually throughout the day. They should allow consumers to benefit from off-peak tariffs, resulting in lower running costs.

It is considered that thermal storage could be used not only for individual buildings, but also for heat networks to optimise their operations and potentially reduce running costs.

*Geothermal technologies*

Geothermal technologies use the heat energy from the Earth's surface for heating applications. It is anticipated that this type of technology will play a limited role in the decarbonisation of heat due to it currently being less well developed.

**Key conclusion**

A number of replacement technologies e.g. hybrid heat pumps and solar panels could be used in conjunction with another primary heating system. This is particularly the case where insulation levels cannot be improved up to a standard that allows a primary fuel source to run effectively on its own. Additionally, the use of storage heat technologies and their potential to reduce energy bills is being explored.

[1] *Biomass Boilers: Prices and Running Costs | Boiler Guide*

# Non-financial barriers - Regulation and planning



## Non-financial barriers - Introduction

Although the additional financial burden associated with the deployment of zero emissions heating technologies and energy efficiency measures is a key barrier limiting the large scale adoption of heat decarbonisation measures, there are also other non-financial barriers. These include:

- **Regulation and planning:** Implementing retrofit solutions for existing buildings can improve energy efficiency performance and the roll-out of zero / low carbon emissions heating. Given Scotland has a significant proportion of listed and traditional buildings, the planning system will play a key role in determining the extent to which retrofit solutions can be made.
- **Supply chain:** Although Scotland has an extensive supply chain from its experience in the O&G sector which may be transferrable, there are potentially skill gaps in skills that are specific to implementing zero emissions heat technologies.
- **Infrastructure:** SG's low / no regret technologies (e.g. heat pumps and low / zero emissions heat networks) rely on electricity. To meet demand, there will need to be significant upgrades and increased capacity to the electricity network and low carbon heat networks. Separately, the role hydrogen plays in the existing gas grid is still uncertain.

## Regulation and planning

The planning system plays an important role in supporting Scotland's climate change targets, not only for the development of new buildings, but also for the retrofit of existing housing stock.

Scotland has a significant proportion of traditional buildings, with around a fifth of homes built prior to 1919. There are approximately 47,000 listed buildings and roughly 10% of total homes are either listed or located in a conservation area.

Given that a number of zero emission heat technologies require improvements to the fabric of a building to enhance its energy efficiency performance, the existing planning policy will need to be developed to enable and encourage the adoption of these measures.

Recently the planning system has adapted to encourage low carbon heat solutions. In the future, it is envisaged that this will evolve, and policies will be introduced that support significant reductions in emissions. This will include retrofit solutions, energy efficiency measures, the development of new and existing heat networks and the deployment of other forms of decarbonised heating.

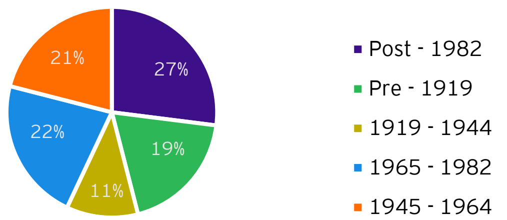
The planning system covers a wide range of development, however, minor developments that involve small alterations to be carried out are often granted Permitted Development Rights. This allows small alterations to be carried out without the need to apply for planning permission. Planning Development Rights are already granted to some extent, for a range of technologies including biomass heating systems and ground / water / air source heat pumps.

For non-domestic properties, Permitted Development Rights are in place and generally permit the installation of a range of low / zero carbon emissions heating technologies, including solar panels, and ground and water source heat pumps.

SG envisages that the Permitted Development Rights will be expanded to include the development of low and zero emissions heat networks (both existing and new) and micro-renewable technologies.

There are certain circumstances where the size and scale of installation means that planning permission may still be required, such as within designated places such as conservation areas, World Heritages Sites or where limitations attached to the Permitted Development Rights cannot be met. In the case of listed buildings, any external and internal works which affect the historic fabric, will require planning permission. SG states that it will work with stakeholders, including Historic Environment Scotland, to develop approaches and solutions to transition Scotland's historic buildings to low / zero carbon emissions heating whilst preserving the buildings characteristics.

**Breakdown of Scotland's building stock by age**




*Source: Scottish House Condition Survey: 2019 key findings - gov.scot*

**Key conclusion**

Scotland has a significant number of traditional buildings. The planning system plays an important role in determining the extent to which retrofit solutions can be made.

# Non-financial barriers - Supply chain



## Supply chain

To support its heat decarbonisation targets, Scotland requires a reliable supply chain to support future growth. Scotland has a strong foundation on which to build, with the heat and energy efficiency sectors in Scotland currently generating an annual turnover of £2 billion and supporting around 12,500 full-time equivalent jobs servicing today's demand. However, the supply chain must be scaled up to support the rollout of decarbonised heating systems.

It is estimated that an additional 16,400 jobs will be supported across the economy in 2030 as a result of the deployment of zero emissions heat technologies[1]. However, the transition will present challenges for traditional, fossil-fuel based jobs particularly in the gas industry and also ensuring sufficient capacity in the supply chain for renewable energy technologies.

The construction sector and its supply chains have been significantly impacted by both COVID-19 and Brexit, with industry bodies highlighting a shortage of skilled workers to meet existing levels of demand, before taking into account increased demand from transitioning to net zero. This, together with material shortages and inflationary price increases across the construction sector, means there needs to be significant investment in the heat in buildings supply chain.

*Heat pumps*

Scotland has an established upstream heat pump supply chain with manufacturers such as Mitsubishi, Star Renewable and Sunamp having a presence in Scotland. However, the downstream heat pump supply chain will need to ramp up rapidly to support SG's target of at least 124,000 heat pump installations between 2021-2026 and 200,000 per annum in the late-2020s. There will need to be sufficient capacity in the manufacturing and installation of heat pumps to deliver the large scale roll-out.

Whilst there are a number of heat pump manufacturers in Scotland, the majority of heat pumps currently used in the UK are produced in Asia[2]. Overall there is considered to be ample global manufacturing capacity to ensure these targets are met; it is the downstream supply chain which may present more significant challenges.

The downstream supply chain of heat pump installers in Scotland is currently limited and fragmented (90% of installers are Small-Medium Sized Enterprises) resulting in only 3,000-4,000 installations per year. It is viewed that the number of installers is only likely to increase when there is significant demand for heat pumps, in this regard SG needs to provide confidence to the supply chain to allow it to commit and invest in rapid expansion[3].

*Heat networks*

Around 60 companies in Scotland are active in the heat networks sector, however, this services only 1.5% of total heat supply[4]. SG's Heat Networks Delivery Plan sets out the actions SG are taking to drive the growth of heat networks in Scotland. In order to meet SG's target of heat networks providing 2.6TWh of output by 2027 and 6TWh by 2030, the supply chain capacity will need to double by 2027 and be roughly five-times greater by 2030[5].

Research suggest that that there are skills gaps in Scotland's heat network supply chain, including in their design, installation, and ongoing operation and maintenance[6].

*Hydrogen*

Due to Scotland's considerable experience within the O&G sectors and offshore wind skills, it should be well-positioned to capitalise on the opportunities that the hydrogen economy presents. Many of the supply chain elements required for the hydrogen economy exist in Scotland's O&G industry today and should be transferrable, in particular engineering and management skills. However, there are potentially skill gaps in terms of the manufacturing supply chain for hydrogen-specific key plant elements, such as electrolysers.

**Key conclusion**

Scotland's existing supply chain is a strong foundation on which to build, however, there will need to be substantial growth in Scotland's supply chain to meet future demand, including the development of new skills that are specific to zero carbon technologies.

[1] *The Economic Impact to 2030 of Decarbonising Heating in Scotland (www.gov.scot)*
[2] *Heat pump manufacturing supply chain research project report (publishing.service.gov.uk)*
[3] *Heat Pump Sector Deal - Final Report (www.gov.scot)*
[4] *Unpublished statistics from BEIS heat metering and billing collection.*
[5] *Heat Networks Delivery Plan (www.gov.scot)*
[6] *Heat network skills in Scotland (energysavingtrust.org.uk)*

# Non-financial barriers - Infrastructure



## Infrastructure

Transitioning to zero emissions heat technologies will transform the way in which homes and businesses use our existing energy networks (both gas and electricity) and will influence future investment decisions such as energy network upgrades, heat networks and increasing electricity generation capacity.

*Electricity network*

SG envisages that by 2030 a much larger proportion of heat demand will be electrified compared to today, using either individual heat pumps within buildings or larger heat pumps providing heat to heat networks[1]. As noted in the Power section, the increased demand on the existing electricity system will require significant network upgrades and additional electricity generation capacity.

Significant investment will be required to make the necessary upgrades and increases to the grid capacity, however, there is still a great deal of uncertainty on the scale of investment required and how this will be financed, who will contribute, and what the impact may be on consumer bills.

*Gas network*

Subject to the availability of technology, hydrogen could play a role in heating Scotland's homes in the long term. It would require a change in the way in which we currently use our existing gas network by replacing natural gas in the gas network with hydrogen. The extent to which hydrogen can be blended with natural gas in the existing gas distribution network, coupled with how heating appliances in homes and buildings can be 'hydrogen-ready', is still uncertain and is being explored and tested across the UK as a whole.

If the existing gas network cannot be entirely (or partially) repurposed using alternative decarbonised fuels, then given that overall demand for natural gas will fall in the coming years, there may be stranded parts of the gas network which may need to be decommissioned for safety reasons, resulting in potentially additional costs to consumers and network operators.

Overall, the future role that our existing gas network plays in, amongst other things, heating our homes and buildings is still very much uncertain. UKG has committed to making the decision of the future of the gas network by 2026.

[1] *Heat in Buildings Strategy - achieving net zero emissions in Scotland's buildings - gov.scot*

# Non-financial barriers - Infrastructure



## Infrastructure (cont.)

*Heat networks*

Whilst heat networks are not a new heat technology, their use across Scotland is limited, with only 1.5% of heat in Scotland attributable to them[1]. Going forward, low / zero emissions heat networks are considered a key strategic technology for reducing emissions from heating homes and buildings in Scotland as they can be adapted to use other fuel sources, including renewable sources such as heat pumps. SG anticipates that 3% and 8% of current heat supply in 2027 and 2030 respectively will be sourced via heat networks, therefore there will need to be significant investment to meet increasing demand.

Whilst SG has committed to a number of funding programmes to support the development of heat networks such as its £300 million Heat Networks Fund and its District Heating Loan Fund, public investment alone will not be enough to develop at the scale needed to contribute to Scotland's climate change targets.

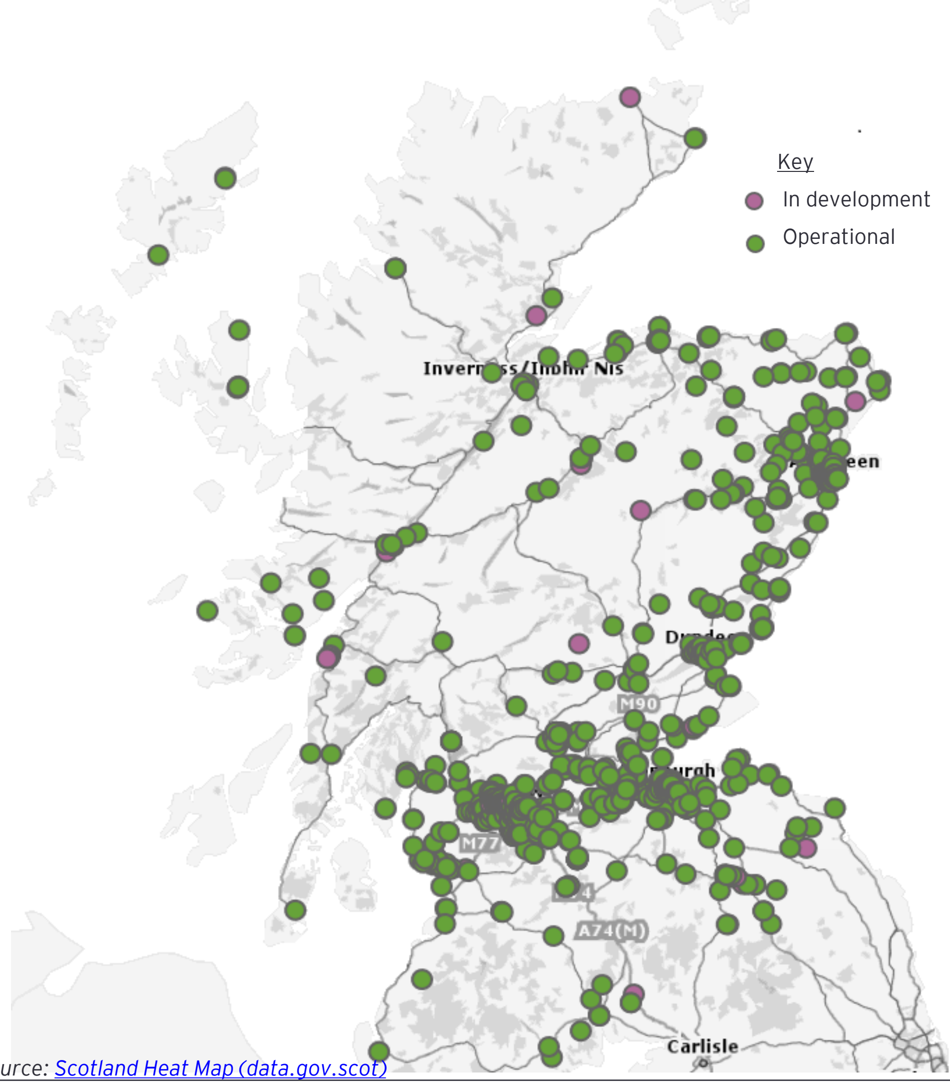
To attract new investment into the sector and provide some certainty to heat network operators of the available consumer base, the Heat Networks (Scotland) Act 2021 plans to introduce heat network zoning and permits by 2024. A heat network zone permit will provide an operator with exclusive access to a consumer base within a zone which will help with securing sufficient heat demand to use economies of scale[2].

### Key conclusion

Moving to zero / low emissions heat technologies will involve significant levels of investment in Scotland's current infrastructure. To meet demand, there will need to be significant upgrades and increased capacity to the electricity network and low carbon heat networks.

The future of the gas grid, including its capability of being replaced with hydrogen needs to be determined.

**Current district / communal heat networks across Scotland**




Source: [Scotland Heat Map (data.gov.scot)]

[1]Unpublished statistics from BEIS heat metering and billing collection
[2][Heat networks delivery plan - gov.scot (www.gov.scot)]

# Demand management



## Demand management

SG's Heat in Buildings Strategy places a focus on reducing demand for energy by making homes easier to heat and preparing them for zero carbon heating technologies, as explained earlier in this section. These will involve significant changes, however, in the meantime, there are a number of measures that consumers can use with their current heating system to make it more energy efficient in the near-term.

*Smart heating controls*

Smart heating controls prevent people's homes getting warmer unnecessarily. This technology allows you to turn the heating on or off and use thermostats to control the level of heat remotely. The system learns your habits and adjust times to minimise energy use. However, the extent to which heat demand is reduced is dependent on the consumer's lifestyle and how heating is currently controlled.

*Zone controls*

Zone control allows households to heat different rooms at different times of the day, this helps to reduce energy demand by avoiding heating rooms that are not being used.

*Programmable thermostatic radiator valves*

For those existing homes that do not have a zone control system already, an alternative is to install thermostatic radiator valves, which are temperature controls for individual radiators but include a timing control as well. These allow each radiator to come on at different times.

*Energy efficient boilers*

Modern gas boilers are generally more energy efficient than older boilers, primarily due to the fact they are 'condensing'. They work by recovering more heat from the exhaust flue gas and using it to heat the central heating water. The proportion of households using energy efficient boilers in recent years has been increasing, which is partly due to a regulatory push to increase minimum energy efficiency standards of boilers but also due to increasing demand from consumers as they should benefit from lower energy bills.

*Smart meters*

A smart meter is a modern type of gas and electricity meter, they are being rolled out across Scotland and the UK as a whole. Smart meters are installed in people's homes and show how much energy is being used in monetary terms. Given these meters provide an energy bill in near real time, it may encourage consumers to reduce their energy consumption[2].

*Changing consumer behaviour*

The Energy Saving Trust recommends that homes are heated between 18°C to 21°C during winter[1]. It is estimated that if households were to drop the temperature in their homes by one degree this could reduce energy bills by 10%[3], however, homes should still be heated to level that is considered comfortable for the household. The issue is that over time as households have become more reliant to central heating, their heat requirements have become greater (i.e. consumers have become more accustomed to warmer temperatures).

*Energy efficiency measures*

As noted earlier in this section, it is estimated that roughly one-third of all heat lost in an uninsulated home escapes through the walls, whilst 25% of heat is lost through the roof[4], therefore energy efficiency measures such as improvements to loft insulation, cavity wall insulation and double glazing are considered key in reducing energy consumption.

**Key conclusion**

Part of SG's key focus is to reduce demand for energy by making homes easier to heat. There are a number of measures that consumers can take with their current heating system to make it more energy efficient.

[1] *How to control your central heating system - Energy Saving Trust*
[2] *Smart meters: all you need to know - Energy Saving Trust*
[3] *Most Brits concerned about energy efficiency - Energy Saving Trust*
[4] *Measures to help reduce home heat loss - Energy Saving Trust*

# Policy environment – Overview



## Overview

Whilst SG has implemented a number of measures to encourage improvements to energy efficiency performance and converting to zero emissions heat technologies, there will need to be a collaboration between UKG and SG to achieve their respective emissions targets.

SG has made ambitious commitments in some areas of its heat decarbonisation path which require going ahead of the UK-wide path, such as an uplift in standards for new build homes from 2024 (versus 2025 for rUK) and phasing out fossil fuel boilers from 2025 onwards (versus 2026 for rUK). Transforming Scotland's building stock and developing zero / low carbon heat technologies will require new policy and updated regulation across a breadth of areas. Some powers that are needed, such as heat policy (including heat networks), climate change, energy efficiency and building standards are currently devolved to SG, while regulation of energy markets, decisions regarding energy prices, electricity and gas networks (including the potential use of hydrogen in the existing gas grid) and consumer protection remain reserved to UKG.

There needs to be a collaborative approach where the UKG makes decisions that facilitate Scotland's decarbonisation of heat roadmap (detailed overleaf). SG can introduce measures to decarbonise heat in buildings, however, this may not be reduced to zero in a fair and just way through its devolved powers alone. As a result of Scotland's more ambitious targets, the roll-out of many low / zero carbon heat solutions may need to start in Scotland before moving south of the border. This may require SG to complement UK-wide funding schemes with its own funding.

## Policy levers

SG and UKG can use a variety of policy levers to achieve the decarbonisation of heat, see 'Main Findings: Policy Levers – The Heat Sector' section. Such measures include i) regulatory measures, ii) government programmes carried out via financial support (including loans / grants), advice and delivery schemes; and iii) tax incentives. These are explored in further detail in this section opposite.

*Regulatory measures*

As part of its Heat in Buildings Strategy, SG has used its devolved powers to propose regulation to encourage improvements to energy efficiency measures and the conversion of zero / low emissions heat technologies.

Such regulatory measures include the introduction of minimum energy efficiency standards for domestic properties and whilst not yet clarified, standards for non-domestic buildings. Countries like Germany have introduced energy efficiency schemes / initiatives e.g. Energy Efficiency Ordinance (EnEV) and Green Mortgages. The EnEV has had a positive impact on both reducing heat demand and the deployment of zero emissions technologies by regulating the maximum level of primary energy consumption of all buildings which use energy for heating and cooling. Energy efficiency measures and / or heat pumps have typically been installed to ensure that maximum values for primary energy demand are not exceeded [2]. Similarly Green Mortgages in Germany grant an interest discount for buildings whose final energy consumption is less than a certain kWh per square meter, thus encouraging the adoption of energy efficiency improvements.

Subject to technological developments, SG has committed to phasing out the installation of new or replacement fossil fuel heating systems in off-gas properties by 2025 and in on-gas areas from 2030, with all buildings needing to meet this standard by no later than 2045. For newly constructed homes, all building warrant applications made from 2024 will require zero direct emissions heating. A similar 'phasing-out' approach has been successfully deployed by other European countries, such as Sweden and Denmark where fossil fuels play a relatively minor role in heating buildings [1].

[1] *A Review of Heat Decarbonisation Policies in Europe (climatexchange.org.uk)*
[2] *International Comparisons of Heating, Cooling and Heat Decarbonisation Policies, Vivid Economics 2017*

# Policy environment – Overview



## Policy levers (cont.)

*Regulatory measures (cont.)*

Governments in other countries such as Norway, have taken a step further by introducing a mandatory ban on the use of fossil fuels in heating. This is a hard end point rather than the point after which replacement systems must not use fossil fuels. Whilst Norway is relatively well-progressed in its decarbonisation of heat journey, fossil fuels have only ever provided a small portion of its overall supply [1]. Given Scotland's current high dependency on fossil fuels for heating with over 90% of homes using either gas or oil as their heating source, a staggered approach (as suggested) may be more appropriate.

Some key decisions of the regulatory landscape are reserved to UKG, such as energy prices. Electricity has historically been more expensive than gas (even with the current volatility in the energy market), which has disincentivised people in adopting it as a fuel source for heating. In the Heat in Building Strategy, SG has already made calls for UKG to take action to rebalance energy prices, to ensure the running costs of zero emission systems are comparable to fossil fuel incumbents.

[1] *A Review of Heat Decarbonisation Policies in Europe (climatexchange.org.uk)*

# Policy environment – Key actions to achieve the decarbonisation of heat



## Roadmap to achieve the decarbonisation of heat in Scotland's homes and buildings

2021 2022 2023 2024 2025 2026 2027 2028 2029 2030 2035 2040 2045

### Developing the Whole System

- Coordination to ensure that heat networks do not crowd out the hydrogen network and vice versa
- Implementation of New Build Heat Standard
- Network upgrades (transmission and generation) start to support the increase in heat pump installations required to decarbonise homes and buildings
- More challenging energy improvement targets for non-domestic buildings
- Current planning rules may hinder installation of heat pumps
- 2.6TWh output from heat networks
- Phasing out the installation of new/replacement fossil fuel boilers in off-gas areas
- 1 million domestic and the equivalent of 50,000 non-domestic buildings have decarbonised heat
- Most homes are at least an EPC band C, with all homes achieving this by 2033
- GHG emissions from buildings are 68% lower than 2020 levels
- 6TWh output from heat networks
- Domestic and non-domestic heat demand reduced by 15% and 20% respectively (compared to 2015)
- Phasing out the installation of new/replacement gas boilers in on-gas areas
- Heat networks are decarbonised
- Energy efficiency improvements to all non-domestic buildings
- Heat networks supply 8% of Scotland's heat

### Developing Understanding

- Heat Networks Delivery Plan
- Heat in Buildings Supply Chain Delivery Plan
- Identification of homes characteristics suitable for heat pump installation for prioritisation
- UKG makes a strategic decision on the role of hydrogen in the gas grid

### Developing Demonstration

- H100 on site construction planned for 2022
- H100 in Fife becomes operational, testing suitability of hydrogen replacing gas boilers
- Hydrogen – ready boilers should be available for use
- 5GW of renewable and low-carbon hydrogen production
- 25GW of renewable and low-carbon hydrogen production

### Developing Infrastructure

- Homes identified for energy efficiency upgrades
- Home modifications commence
- Training/reskilling for heat pump installations commences
- Homes suitable for heat pump installation identified
- Increasingly rapid deployment of heat pumps
- Locations suitable for Heat Networks identified
- Construction of new heat networks commences
- Engagement with planning/ consenting process
- Fuel switching of legacy heat networks commences

Note: Many of the above dates are a range rather than occurring in a specific year

Key: Heat in Buildings; Heat networks

# Policy environment – Government Programmes

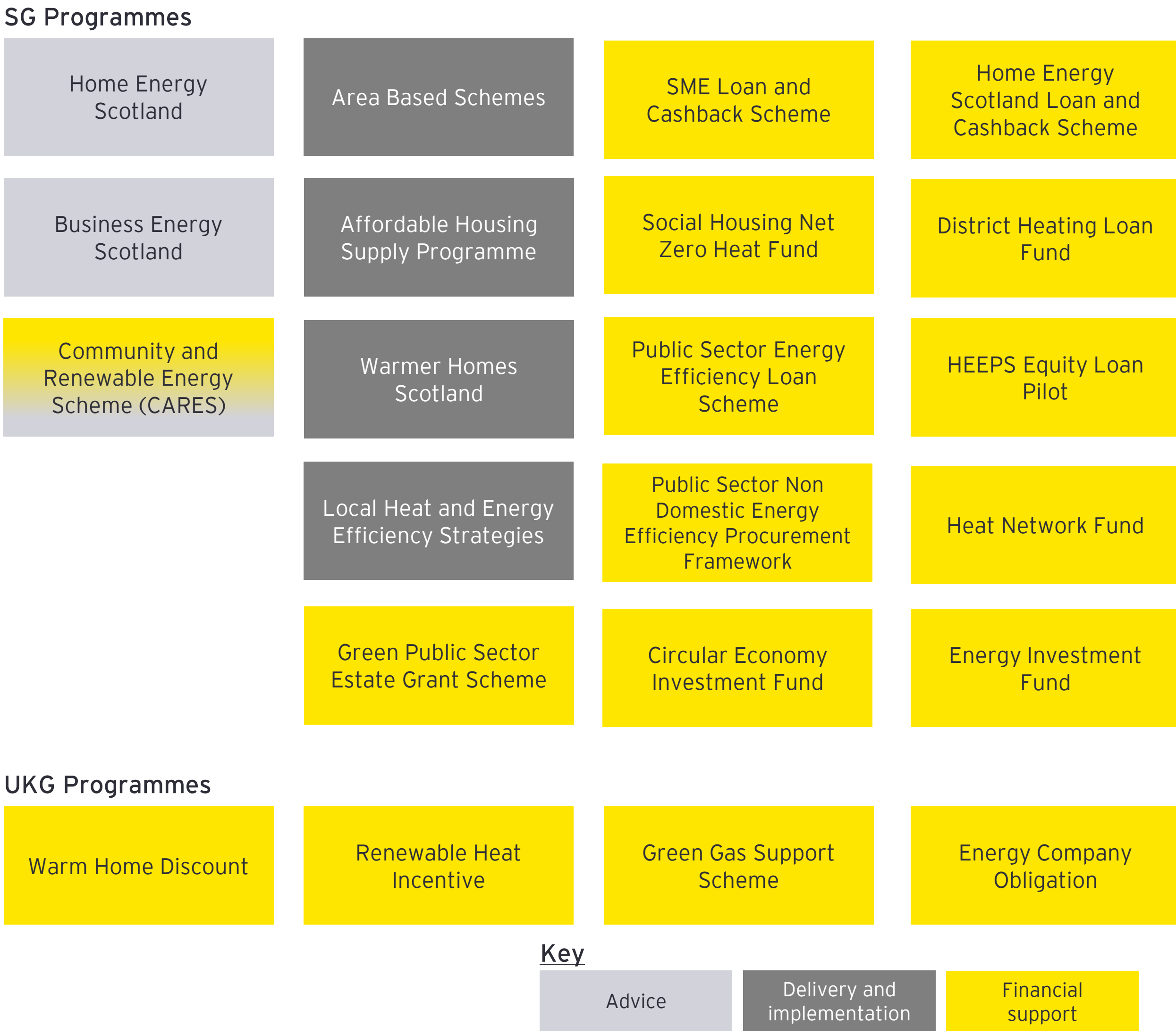


*Government Programmes*

There are a range of UK-wide and Scotland-specific programmes that have been introduced to encourage the investment in energy efficiency measures and decarbonisation of heat in buildings. These are carried out via financial support (including loans / grants), advice and delivery schemes, as depicted in the chart opposite. For further detail regarding what each programme provides, please refer to Appendix B. Historically, these have generally been required to make low / zero emission heat technologies commercially viable to consumers.

Due to the disparate, varied nature, and potential overlaps of its existing schemes, SG plans to establish a National Public Energy Agency to consolidate advice and provide information to consumers / business on how to heat and use energy in homes and buildings. It is intended that the Agency will consult extensively with stakeholders and citizens as regulations and delivery programmes are developed, to help people make informed choices on the options available.

On an international level, the use of grants / subsidies are a common and effective approach applied by many countries that are already relatively decarbonised, including in New Zealand, where in the last ten years the share of heat pumps in residential buildings has increased significantly as a result of subsidies. Other examples include Norway's subsidies and financial incentives for heat pumps, district heating and energy efficiency measures, and Sweden's subsidies encouraging the use of biomass and heat pumps[1].




[1] *Comparisons of Heating, Cooling and Heat Decarbonisation Policies, Vivid Economics, 2017*

# Policy environment – Tax incentives



*Tax incentives*

To encourage private investment in low / zero carbon technologies, additional government support has been provided by way of tax reliefs:

1. **Investment in heat networks:** The Non-Domestic Rates (District Heating Relief and Renewable Energy Generation Relief) (Scotland) Amendment Regulations 2021 introduces a 90% relief from non-domestic rates until 31 March 2024 for new networks run from renewable sources. This goes beyond the existing 50% relief that is in place for heat networks. These regulations also provide for the 50% relief to continue until 2032.
2. **VAT reduction**: It was announced in the Government's Spring Budget 2022 that the VAT rate for the installation of certain energy saving materials and technologies will be reduced to 0% from 1 April 2022 until 31 March 2027.

Tax credits have been adopted by many overseas countries in the decarbonisation of heat including in France and the US although not as widespread as grants / subsidies[1].

UKG has introduced measures to encourage businesses to operate in a more environmentally friendly manner by way of environmental taxes, such as the Climate Change Levy (CCL) and the Green Gas Levy (GGL):

1. **CCL:** The CCL is aimed at encouraging companies in the industrial, commercial, agricultural and public services sectors to be more energy efficient in how they operate and to reduce their overall emissions. CCL is charged on certain commodities used for heating such as natural gas, electricity (if not generated from renewable sources), petroleum, and coal (measured in terms of energy used). However, it does not currently apply for commodities supplied to domestic consumers, including for domestic heating purposes. Therefore its impact on the decarbonisation of heat is currently limited.
2. **GGL:** The GGL places financial obligations on licensed gas suppliers by way of making levy payments in quarterly instalments. Proceeds are used to fund the Green Gas Support Scheme (GGSS), a scheme which provides quarterly payments to participates based on the amount of eligible biomethane the participant injects into the gas grid.

Whilst not currently on UKG's policy agenda, carbon taxes have proven to be efficient and act as key drivers in steering the public away from using fossil fuels for heating in many countries (e.g. France, Finland and Sweden).

Carbon taxes work by introducing a fee to businesses and households on the emissions they use and are considered by many economists to be among the most effective way of driving reductions in carbon emissions. They are aimed at ensuring the competitiveness of the price of renewables compared to other fossil fuels such as gas, which could potentially be useful for Scotland and for the UK given the relatively low price of gas compared to electricity.

Generally, the UK imposes relatively low taxes on the domestic market's energy use (particularly for gas but also electricity) in comparison to many other European countries (e.g. the Netherlands, Germany, Denmark, Finland)[2]. If the UKG introduced carbon taxes to discourage using gas, it is likely that this will compromise SG's fuel poverty objectives as many existing households currently using gas will face increased energy bills.

[1] *Comparisons of Heating, Cooling and Heat Decarbonisation Policies, Vivid Economics, 2017*
[2] *A Review of Heat Decarbonisation Policies in Europe (climatexchange.org.uk)*

# Policy environment – Tax incentives



*Tax incentives (cont.)*

An alternative to traditional tax incentives is to explore expanding the scope of the UK ETS scheme to include the heat in buildings sector. The UK ETS came into force from 1 January 2021 (replacing the UK's participation in the EU ETS) to act as a cap-and-trade system by capping the total level of GHG emissions and creating a carbon market. Participants in the scheme are required to obtain and surrender allowances to cover their annual GHG emissions. To meet zero emissions targets, each year the overall cap is lowered which means the cost of emissions allowances increases.

The aim of UK ETS is to incentivise reductions to GHG emissions while balancing this ambition with maintaining the competitiveness of the market. Whilst the UK ETS is currently only applicable to energy intensive industries, electricity generation and aviation, its expansion to include heat in buildings (i.e. a price on fossil fuels) could play a key role in the decarbonisation of heat in buildings.

However, if the UK ETS was to expand to the heat sector it is recommended that the scheme is developed as part of a wider package of complementary policies that address heat-specific challenges, including fuel poverty and distributional impacts[1]. If compensatory policies were not introduced this could significantly impact low income households in particular, since they are less able to invest in low carbon alternatives, in response to higher prices of fossil fuels.

**Key conclusion**

There are a variety of policy levers that could be deployed by UKG and SG to help to achieve the decarbonisation of heat, including regulatory measures, government programmes that provide advice and financial assistance and tax incentives (including exploring the expansion of UK ETS).

[1] *The future of UK carbon policy: how could the UK Emissions Trading Scheme evolve to help achieve net-zero?' by Grantham Research Institute on Climate Change and the Environment and Catapult Energy Systems, April 2022*

# Policy environment – The need for private investment



**The need for private investment**

It is estimated that the total capital investment in buildings alone will need to be in excess of £33 billion in order for Scotland to meet its net zero targets (based on a high-electrification pathway). Of this amount, it is estimated that £27 billon is required to install zero emissions heating systems and energy efficiency measures in domestic properties, and the remainder £6 billion for the non-domestic market.

SG has committed to funding of at least £1.8 billion over the current parliament, targeting those that are most vulnerable, to assist with making the necessary transition. However, clearly there will also need to be significant investment from the private sector to bridge the financial gap.

Similarly, SG has proposed certain policies and regulations that will require investment from end-consumers (both individuals and businesses). Such policies and regulations include, but are not limited to, an uplift in energy efficiency measures for existing and new housing stock and requirements to adopt low / zero emissions (potentially less affordable) heat technologies. Whilst there may be government funding available to certain businesses and individuals through UKG's and SG's delivery programmes to alleviate the financial burden of implementing these changes, there will still need to be investment to some extent from the private sector, in terms of funding both the upfront and ongoing running costs. The extent to which the private sector will need to fund zero emissions heat technologies and improvements to energy efficiency performances is unclear.

Given that both SG and UKG plan to phase out the installation of new and replacement gas boilers, and potentially use the UK's existing gas network to deploy hydrogen heat technology in the future, there is a question as to who pays for the additional cost this brings when it comes to new homes. Given that gas boilers are effectively being prohibited in new homes by 2024, house builders are unlikely to want to incur the costs of a gas network connection from 2024. However, if new homes do not have a connection to the gas grid, this prevents homes easily accessing hydrogen in the future. Additionally, the heating infrastructure in a house previously fitted with a heat pump system would have to be replaced and connection to the gas grid would need to be made.

Overall, greater clarity is required from SG with regards to the funding and practical arrangements for the deployment of zero emissions heat technologies in new homes.

**Key conclusion**

It is estimated that the total capital investment required to decarbonise heat in Scotland's buildings will be in excess of £33 billion.

Whilst there are a range of SG and UKG funding schemes, there will need to be significant investment from the private sector. There needs to be greater clarify on the extent to which consumers and businesses are required to fund for the deployment of zero emission technologies and energy efficiency upgrades.

# The Heat Sector - Conclusion



**Heating Scotland's homes and buildings accounts for 26% of O&G consumption and 20% of Scotland's GHG emissions**

- The majority of Scottish homes rely on gas heating as this is one of the most affordable heating solutions. This is a stable and consistent trend that has not changed in recent years.
- The challenge of meeting SG's net zero emissions targets, is equivalent to the 170,000 off-gas homes that currently use high emissions fossil fuels, and at least 1 million homes that currently use mains gas, converting to zero / low carbon heating.
- GHG emissions from heat have declined in the last 30 years, however the rate will need to be accelerated if 2030 emissions targets are to be met. Further energy efficiency improvements and rapid deployment of zero carbon emissions heat technologies could be tools to accelerate these improvements.

**O&G consumption in our homes has been driven by the historical technological shift to natural gas, its relatively low cost and greater regulation and government action to support its use**

- **The availability and technological shift to natural gas:** Fossil fuel use in Scotland is dominated by natural gas. Domestic and commercial premises have been heated by gas-fired boilers from the 1960s, and the ubiquitous nature of this technology and central heating systems has resulted in a steady increase in the consumption of gas.
- **The cost of natural gas:** Whilst gas prices have increased markedly over the last 12 months, electricity is historically four to five times more expensive than gas.
- **Regulation and government action:** Both SG and UKG have recently focussed on reducing emissions and fuel poverty. Historically, the push for gas has been largely supported by UKG as it was considered to be more environmentally friendly than coal and town gas. This has been achieved by:
  - Heavily investing in the gas network: This involved a rapid expansion of the gas grid up to the 1980s and steady expansion thereafter.
  - Providing financial support to low income households to install gas boilers. Going forward, SG plans to phase out fossil fuel heating systems and provide financial support to certain households for the adoption of low/zero carbon heating technologies.

**To meet Scotland's ambitious decarbonisation targets, a portfolio approach is needed to rapidly scale up the rollout of a decarbonised heating system**

- Meeting Scotland's decarbonisation targets would require the equivalent of at least 1 million homes switching to zero emissions heat by 2030. There are multiple opportunities in these areas to switch away from O&G:

1. **Heat pumps –** Heat pumps will be a core replacement technology. However, several barriers still exist regarding the scale of the rollout, and costs of the heat pump, before SG's ambitions are met. The total cost to operate a heat pump is expected to exceed conventional gas boilers, the primary heating system in Scotland. This has significant implications for a Just Transition.
2. **Heat networks** – For urban or densely populated areas, low or zero carbon heat networks may be more efficient than standalone heating systems. However, the cost comparison between low carbon heat network customers and non-users is not yet known. At present, a relatively small number of heat networks are currently available and those that have been developed are primarily gas powered which will need to be decarbonised.
3. **Hydrogen** – The ability to blend hydrogen with natural gas (or as a replacement) in the gas grid is uncertain. In the short to medium term, hydrogen is unlikely to form a core replacement heating technology in Scotland. Rather it will be targeted initially, at hard to abate sectors or specific industrial purposes. Its role as a central heat decarbonising technology is still being explored.
4. **Energy efficiency measures –** Improving the energy efficiency performance of homes plays a pivotal role in the deployment of zero emissions technologies, reduces energy demand and thus energy costs (and fuel poverty). The energy efficiency performance of properties have improved over the years but the rate / scale of improvements will need to be maintained if 2033 targets are to be achieved.

# The Heat Sector - Conclusion



**The capital and running costs of the replacement technology presents challenges for consumers and has implications for Scotland's Just Transition**

- The large scale electrification of Scotland's homes will involve, not only high upfront capital costs, but also additional running costs that may exceed the lower cost gas alternatives. If this is not resolved, consumers may face higher fuel bills, exacerbating the problem that fuel poverty plays.

1. **Heat pumps** - The total lifetime cost of a heat pump (including the cost of necessary energy efficiency improvements), is between **£26,195 - £80,345.** This is considerably more than a conventional gas boiler (£19,695 - £23,339). This is due to costs of additional energy efficiency measures required for a heat pump to work effectively and the high costs of electricity compared to gas (even with the current volatility in the energy market). Whilst heat pumps are more expensive in terms of unit capital costs compared to standard gas boilers, it is envisaged that as heat pumps become more widespread across Scotland, suppliers will be able to achieve economies of scale which may be passed on to the end-consumer.
2. **Heat networks** – Heat networks users are expected to benefit from higher heat production efficiency and lower running costs. Whilst there is limited information publicly available on the capital and ongoing costs for households using low carbon heat networks as the majority of existing heat networks available today use natural gas, studies show that energy bills of consumers using gas powered heat networks compared to a standard gas boiler are **£100 cheaper per annum.** One of the key issues is the cost of developing heat networks, they require **significant investment.**
3. **Hydrogen** – The majority of natural gas boilers available today are safe to use with a blend of 20% hydrogen with natural gas. However, if the blend of hydrogen increases or even replaces gas in the gas grid, consumers will need to install hydrogen-ready boilers. Hydrogen-ready boilers are not likely to be available until 2025, but the CCC estimates that the **capital cost will be £100 more expensive** compared to a natural gas boiler. Additionally, studies show that the total system costs per household using hydrogen (produced by electrolysis) varies **between £1,410 - £1,880 per year.**
4. **Energy efficiency measures** – The estimated costs to households to suitably insulate their property will be up to **£48,000 t**o ensure the effective use of heat pumps. However, the costs vary dramatically per property and may not be required for all property types.

**Non-financial barriers such as infrastructure, regulation and planning and the supply chain also play a significant role in the rollout of the new technology**

- Although the additional financial burden associated with the deployment of zero emissions heating technologies and energy efficiency measures is a barrier limiting the large scale adoption of heat decarbonisation measures, there are also other non-financial barriers. These include:
  1. **Infrastructure:** To support the electrification of the heating systems there will need to be significant upgrades and increased capacity to the electricity network and low carbon heat networks. Separately, the role hydrogen plays in the existing gas grid is still uncertain.
  2. **Regulation and planning:** Implementing retrofit solutions for existing buildings can improve energy efficiency performance and the roll-out of zero / low carbon emissions heating. Scotland's planning system needs to be developed to ensure such improvements can be made in the vast number of its traditional / listed buildings.
  3. **Supply chain:** Scotland has an extensive supply chain from its experience in the O&G sector which may be transferrable, however, there are potentially gaps in skills that are specific to zero emissions heat technologies.
- Other non-financial barriers also exist, not only impacting the update of replacement technology, but also consumers' ability to drive down heat demand. This relates to consumer behaviour around how we heat our homes and attitudes to energy efficiency measures.

# The Heat Sector - Conclusion



**Consumers can take a number of actions in their home today using their current heating system**

- The adoption of zero emissions heat technologies will involve significant changes, however, in the meantime, there are number of measures that consumers can take to reduce their energy consumption, this includes changes to their behaviour (e.g. reducing temperature in homes) and using their current heating system more efficiently (e.g. zone controls, smart meters, smart heating controls and energy efficient boilers).

**There needs to be greater collaboration between both the UKG and SG and the private sector if SG's heat targets are to be met**

- A collaborative approach from the UKG and SG is optimal to achieve their respective decarbonisation of heat in buildings objectives. Policies such as heat decarbonisation, building standards and energy efficiency measures are devolved to SG, however, some of the key measures such as the future of the gas network and energy markets regulation are currently reserved to UKG:

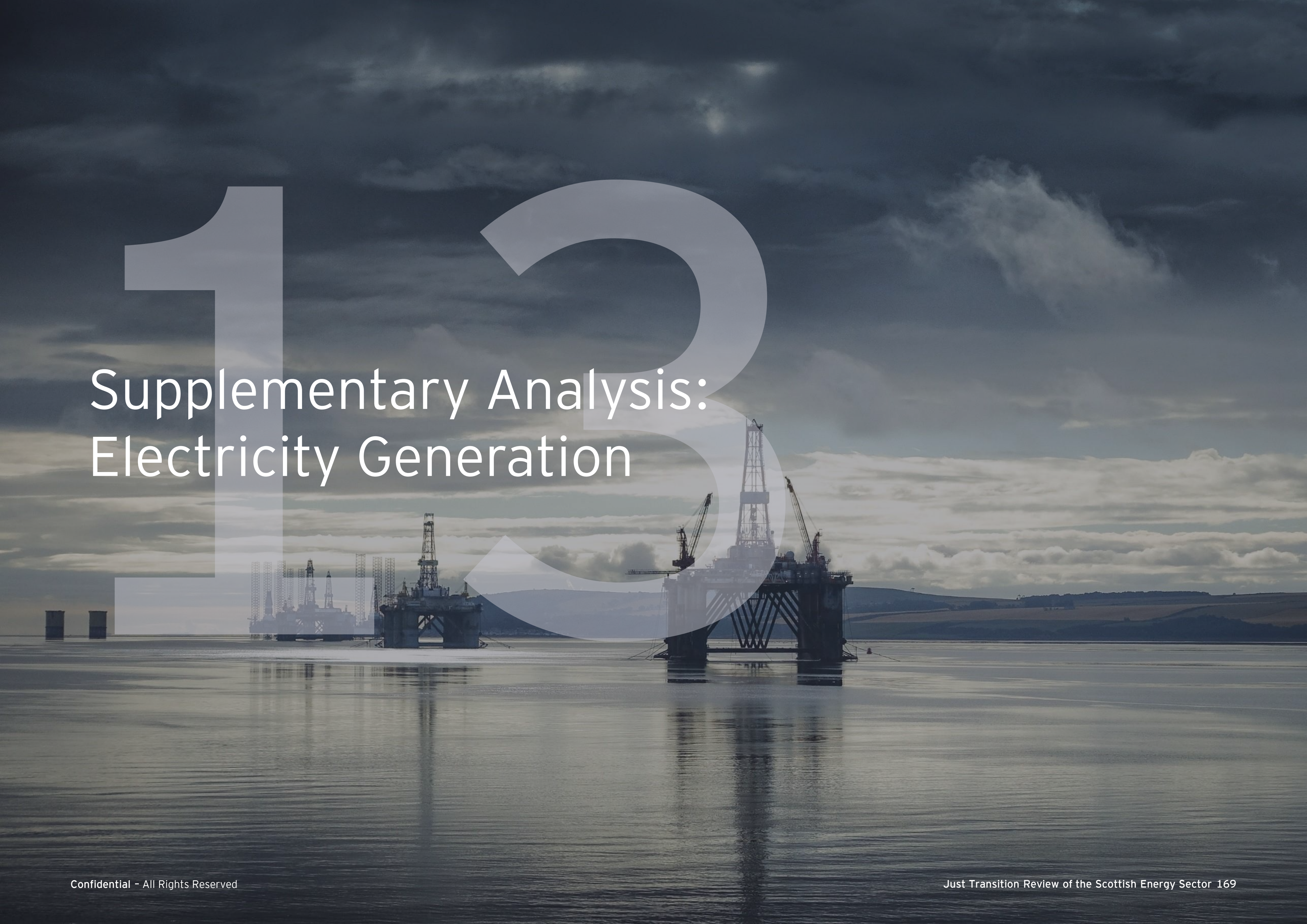
  *UKG*

  - Regulation of gas and electricity networks (including the potential use of hydrogen);
  - Regulation of energy prices (including taxation); and
  - Consumer protection.

  *SG*

  - Regulation of heat networks;
  - Energy efficiency and building standards (including, the planning system);
  - Deployment of zero / low emissions heat technologies (i.e. heat pumps and heat networks);
  - Supply chain; and
  - Subsidies / tax reliefs.

- It is estimated that the total capital investment to decarbonise heat in buildings will need to be in excess of £33 billion. Whilst there are a range of Scottish and UK-wide Government funding schemes, there will also need to be significant investment from the private sector to meet SG's targets. In this regard, it is unclear the extent to which consumers and businesses will need to self fund the deployment of zero emission technologies and energy efficiency upgrades.



# 13

# Supplementary Analysis: Electricity Generation

# There are significant regional differences in the distribution of generation technologies across the UK



Scotland accounts for 16.7% of the UK's electricity supply, compared to 72.6% in England, 7.5% in Wales and 3.2% in Northern Ireland.[1]

At the start of the 2010s, Scotland was the largest producer of wind-powered electricity generation of the four UK countries, providing 48% of the UK's total wind generation. In 2013, England overtook Scotland to become the primary supplier of wind-generated electricity in the UK.[2]

The four maps below show the dispersion of four key generation types across the UK[3]. Note that the Hunterston B nuclear plant in Scotland is now closed, despite the map showing otherwise.


Gas


Nuclear


Solar

Wind

[1] BEIS (2021). Electricity generation and supply in Scotland, Wales, Northern Ireland and England, 2016 to 2020
[2] HM Government (2019). Wind powered electricity in the UK.
[3] Carbon Brief - How the UK generates its electricity.
*Note that the maps are dated to 2015.*

# Electricity generation has historically been dominated by fossil fuels



Fossil fuels have historically played a major role in electricity generation in Scotland. In 2004, around 50% of generation came from fossil fuels. Over the years, low carbon generation (including nuclear) has become the dominant generation technology in Scotland, accounting for almost 88% of generation in 2020.

Coal historically dominated electricity generation as it was cheap, reliable and easily sourced. In the 1980s the capacity of operational coal plants was 2,304MW compared to 300MW coming from renewables[1].

The UK's coal fleet has since almost entirely closed down as a result of higher extraction costs, discovery of gas in the North Sea, as well as the imposition of carbon pricing and EU restrictions on coal to tackle emissions.

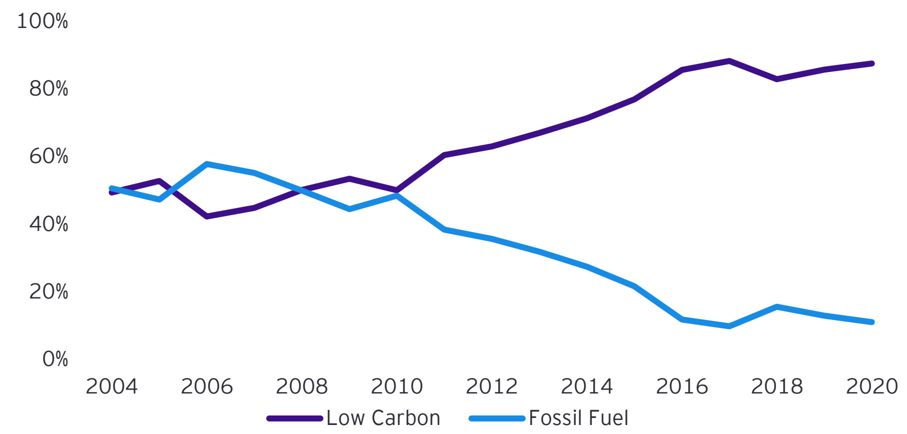
The UKG is currently discussing with coal-fired generators whether it is possible to temporarily extend the life of remaining UK coal plants in light of gas market shortages following Russia's invasion of Ukraine.

The adjacent figures provide an overview of how the electricity generation mix has evolved in Scotland since 2004.

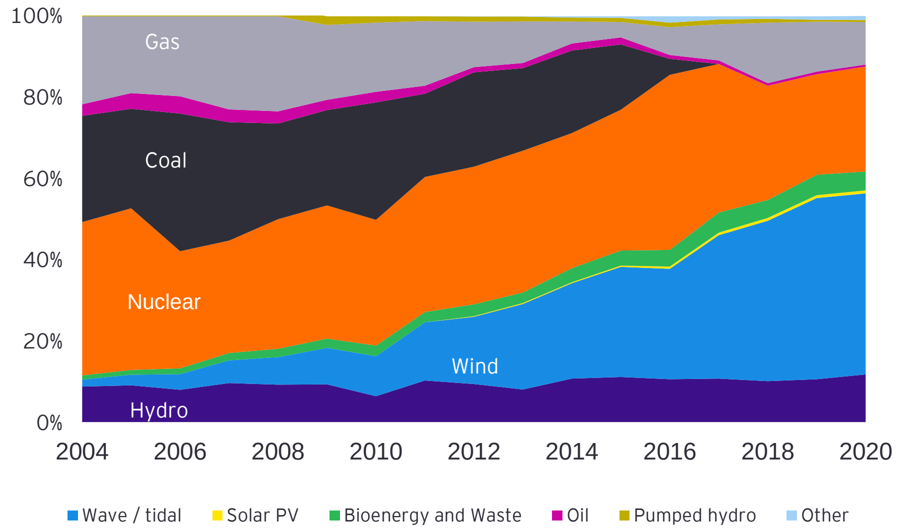
**Key conclusion**

While fossil fuels have historically dominated generation, renewables and low carbon generation are currently the major source of electricity supply.

**Share of Scottish electricity generation by technology[2]**




**Electricity generation mix in Scotland[3]**




Sources: [1] Fraser Economic Commentary – The electricity generation mix in Scotland
[2,3] Scottish Energy Statistics Hub - Electricity Generation

# Scotland is a net exporter or renewable generation and a net importer of non-intermittent generation



While Scotland has seen significant increases in its proportion of generation coming from renewable sources, this has partly been facilitated by the availability of non-intermittent generation from the rUK (including gas-fired and nuclear generation).

Scotland has relied on nuclear power more than any other nation of the UK in 2020, with 26% of generation coming from nuclear compared to 14.7% in England and Wales as shown in the adjacent figure.

In January 2022, the Hunterston B nuclear station in Scotland retired after 46 years of service. The last remaining operational nuclear station in Scotland is the 1.2GW Torness Station which is expected to be retired in 2028. SG is against the build of any new nuclear stations in Scotland.[1]

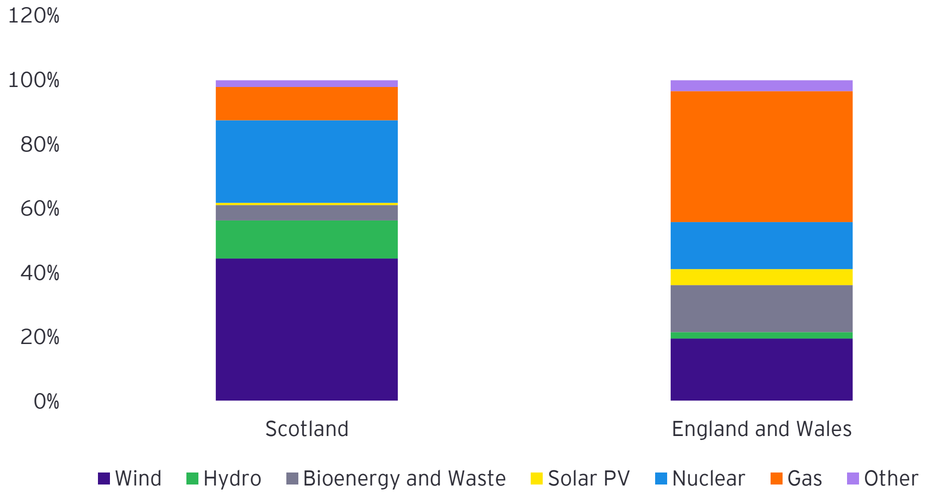
The last remaining major operational gas plant in Scotland is the 1,180MW flexible gas-fired Peterhead Power in Aberdeenshire. The long-term shutdown at Hunterston B station has led to more unabated generation at the gas-fired Peterhead station.[2] The contribution of gas to the generation mix is further discussed on the next page.

Going forward, CCUS makes continued emissions possible in Scotland, enabling the presence of flexible generation and reliable capacity.

SSE Thermal is currently exploring redevelopment opportunities for a decarbonised power station at Peterhead, using CCUS or hydrogen solutions, to ensure the site can continue to provide essential flexible generation.[3] This would be connected to the proposed Scottish CCUS Cluster from 2030. As part of Scotland's Net Zero Infrastructure project, plans are being developed for the construction of a new 900MW CCS equipped power station at Peterhead, capable of producing large volumes of predictable net zero 'base-load' power.[4]

Additionally, some industrial sites still use gas-fired plants for their own supply of electricity. Grangemouth CHP is a 145MW power plant with 257MW of heat generation capacity and provides electricity and steam to INEOS' petrochemical operations.[5] Excess electricity is sold to the grid.

**Share of electricity generation by fuel type (Scotland and England and Wales, 2020)** [6]




**Key conclusion**

As Scotland's remaining nuclear and gas-fired generators reach retirement, Scotland may become more reliant on power imports from the rUK at times of low-wind output.

*Sources: [1] SG- Nuclear Energy*
*[2] SSE Thermal - Peterhead Power Station*
*[3] NECCUS - Scotland's net zero infrastructure (SNZI) project*
*[4] BBC - Power sector problems see greenhouse gas target missed*
*[5] INEOS - INEOS acquires Grangemouth power plant from Fortum*
*[6] Scottish Energy Statistics Hub - Propotion of electricity by fuel type*

# The contribution of gas to the generation mix has decreased over time, but gas turbines still provide reliable capacity in light of renewable intermittency issues

As renewables have increased their share of the generation mix, gas generation decreased gradually over time. In 2004, gas accounted for 21% of electricity generation in Scotland compared to 10% in 2020.

This long-term downward trend does vary year to year in response to other market drivers, for instance with the share of gas from electricity generation increasing in 2015 due to the shutdown of coal plants.

CCGT plant load factors have also been decreasing over time indicating a reduced reliance on gas across the UK. However, gas is still seen as having a role to play in the generation mix, providing reliable generation capacity at times of low wind and solar energy.

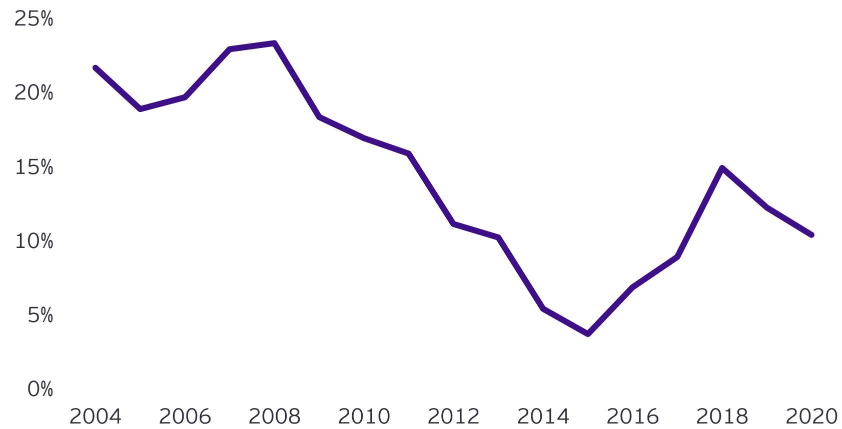
The majority of the UK's nuclear fleet is expected to retire by the end of the decade, along with the closure of coal-fired generation by 2024, and many gas-fired plants are also coming to the end of their operational lives.

According to the Energy White Paper, by 2050 low carbon capacity such as hydrogen-fired generation and CCS-enabled generation are expected to meet peak demand, alongside flexible technologies such as long duration storage.[1]

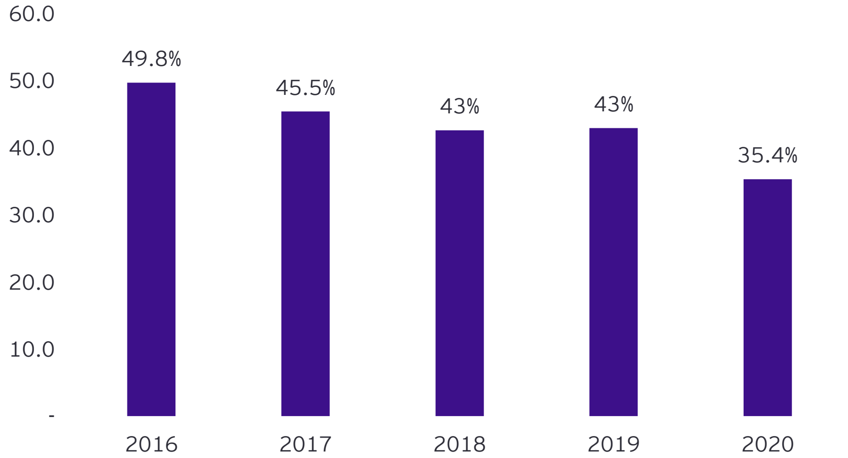
However, these technologies won't be deployed at scale before the 2030s. Until then, much of the demand for new build capacity is therefore likely to be met by more carbon intensive forms of generation such as unabated gas-fired generation.[2]

BEIS expects that the power system will continue to require carbon intensive capacity (such as unabated gas generation) for operability and adequacy purposes, although not indefinitely.[3]

Share of gas from electricity generation (Scotland)[4]




CCGT plant load factors in % (UK)[5]




*Sources: [1] HM Government-Energy White Paper*
*[2,3] BEIS – Capacity Market: Improving delivery assurance and early action to align with net zero*
*Scottish Energy Statistics Hub - Electricity Generation*
*[4] Scottish Energy Statistics Hub – Propotion of electricity by fuel type*
*[5] Digest of UK Energy Statistics (DUKES) 2021 - GOV.UK (www.gov.uk)*

# The UK Capacity Market recognises the value of reliable capacity such as gas



The introduction of the UK Capacity Market in 2014 recognised the value of reliable capacity (principally gas) as a backup generation source, and supported the continued operation of existing plants and construction of new.

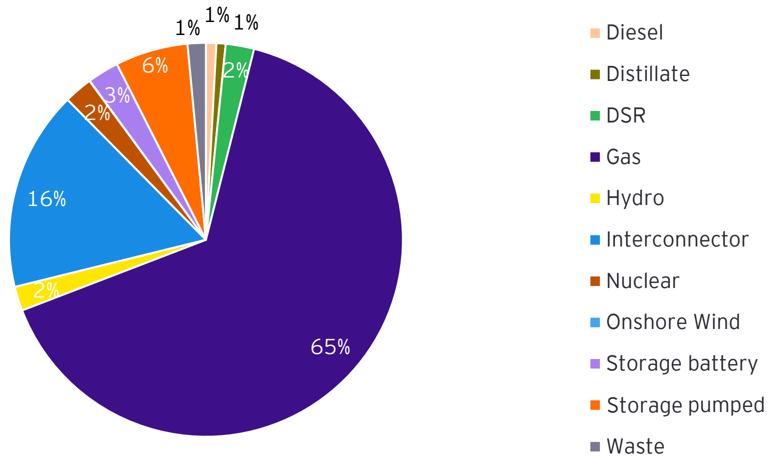
The capacity market auction are technology neutral, with existing generators and potentially new generation competing against a range of other technologies to obtain agreements under which they commit to making their capacity available when needed, in return for guaranteed payments.[1]

The results of the 2021 four year ahead Capacity Auction (T-4) for the UK saw generators using gas as the primary fuel representing 65% of the capacity market, the largest share among all types. Interconnector received the second highest share (16.4%) followed by Storage Pumped (5.9%) and Storage Batteries (2.58%).[2]

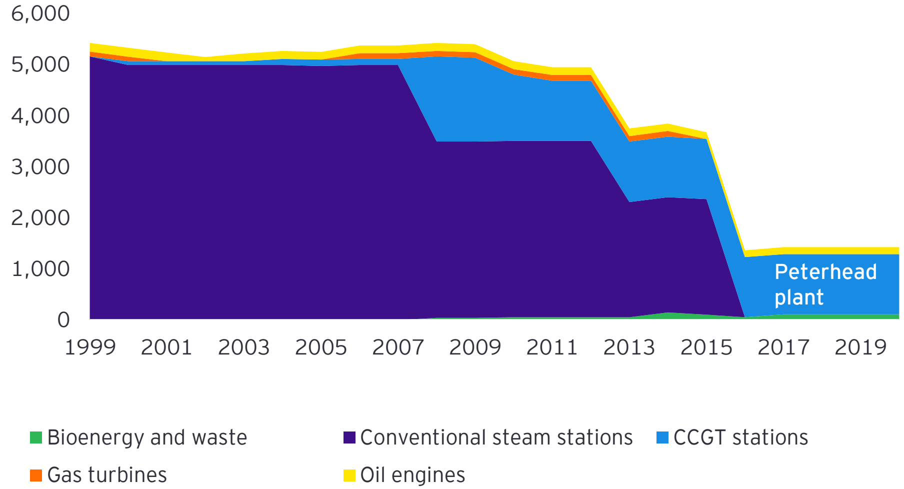
Three new gas fired OCGTs being developed by Drax were awarded 15-year contracts for 854MW of capacity in the UK. New gas reciprocating engine capacity was quite a bit lower than in previous auctions, at 460MW.

The Peterhead gas plant in Scotland (1,083MW) secured contracts for the 12 months from 1 October 2025 to 30 September 2026. The total capacity of thermal station in Scotland was 1,431MW in 2020 which is mostly provided by Peterhead plant.

**Breakdown of Capacity Auction (T-4) by technology type[3]**




**Total capacity of thermal stations in Scotland (in MW)[4]**




Sources: [1] BEIS – Capacity Market: Improving delivery assurance and early action to align with net zero
[2,3] National Grid ESO – Final Auction Report. 2021 Four year ahead Capacity Auction (T-4).
[4] Digest of UK Energy Statistics (DUKES) 2021 - GOV.UK (www.gov.uk)

# Carbon prices curb fossil fuel use and are expected to increase over time



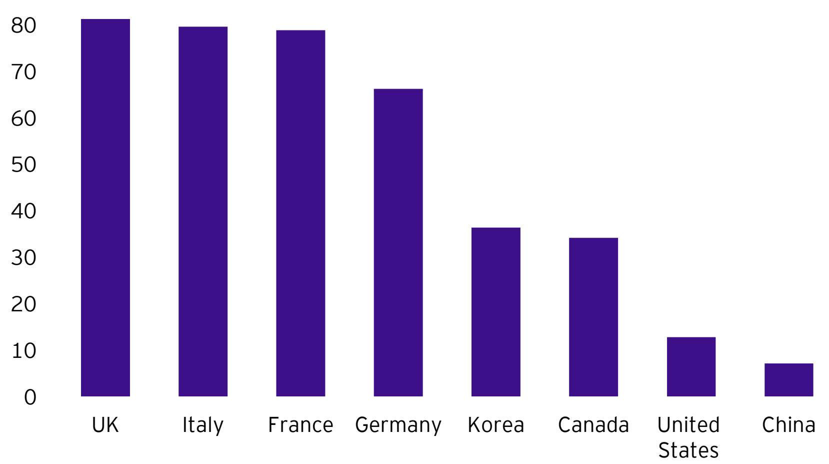
Carbon pricing is enacted by governments through the establishment of a carbon tax or an ETS scheme. In the UK, different pricing mechanisms are used including ETS and the carbon price support (CPS). The UK has a high effective carbon price when compared to other G20 countries as shown in the figure below.

Carbon pricing increases the unit cost of generation for carbon-intensive technologies. Coal and gas technologies have to pay carbon and fuel costs by purchasing allowances for each tonne of $CO_2$ emissions. When demand is low and renewables are operating, the marginal unit providing power has a lower marginal cost, pushing less efficient gas and coal producers out of merit. As demand increases or renewable output decreases, more expensive power stations need to be used.

In 2013, the EU ETS imposed a Carbon Price Support (CPS) to stabilise price signals to investors in low carbon technologies, CPS is applied to fuel for electricity generation only.

A UK ETS replaced the UK's participation in the EU ETS in January 2021, with trading launched in May 2021.[1] The UK ETS applies to energy intensive industries, the electricity generation sector and aviation.[2] It has a similar scope to the EU scheme, covering energy intensive industries, the electricity generation sector, aviation, hospitals and some small emitters within the UK, between the UK and Gibraltar and between the UK and the EEA.[3] The cap has been set 5% below the notional level that the UK would have had if it had stayed in the EU ETS[4]. In other words, the UK now has 5% less carbon allowances to auction out for emissions compared to the amount it had as part of the EU ETS.

**Effective carbon prices in selected G20 countries (£/$tCO_2$)[5]**




Note: The effective carbon rate is the sum of tradeable emission permit prices, carbon taxes and fuel excise taxes, all of which result in a price on carbon emissions. Prices have been converted using EUR/GBP exchange rate of 0.849.

*Sources:* [1] *BEIS- Participating in the UK ETS*
[2,3,4] *UK and EU - Greenhouse Gas Emissions Trading*
[5] *OECD (2021). Carbon Pricing in Times of COVID-19: What Has Changed in G20 Economies?*

# In 2020, 88% of electricity generation came from low carbon sources in Scotland



The decarbonisation of electricity generation is a crucial step towards fulfilling the wider net zero agenda in the UK. To fulfil this target, the electricity sector must continue to increase the proportion of energy consumption and generation originating from low carbon and renewable fuel sources.

By analysing the drivers of fossil fuel demand, SG will be better informed to develop policies which incentivise sustainable energy generation and energy usage, and discourages fossil fuel production / consumption.

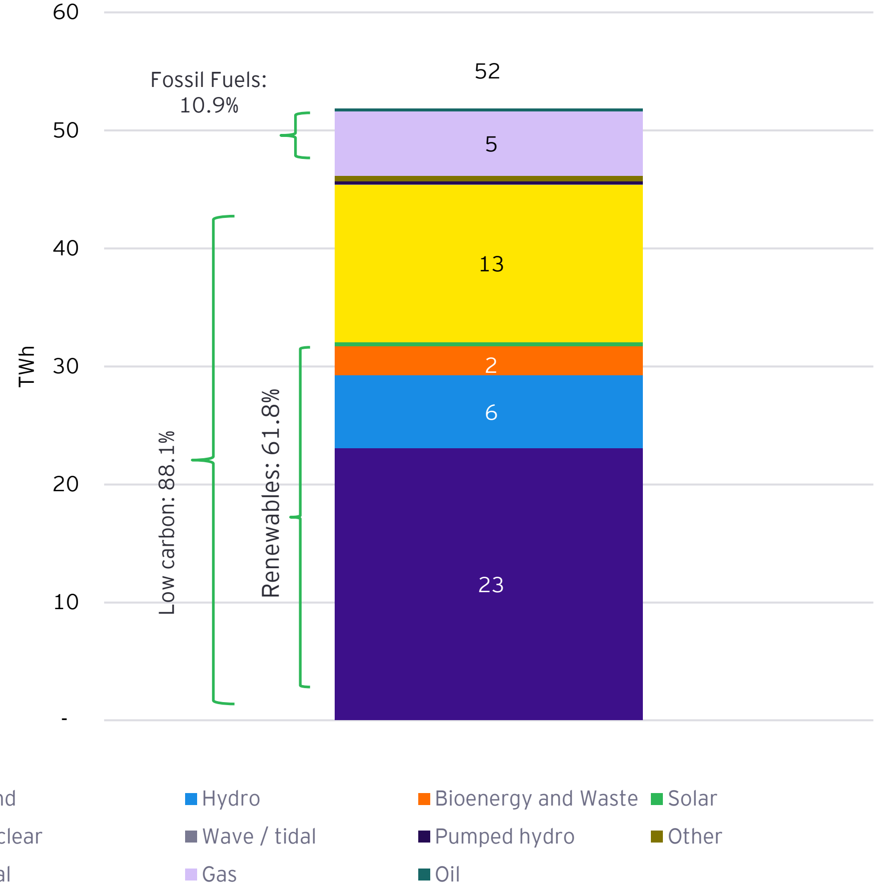
The adjacent figure shows that 88% of the 52 TWh of electricity generated in Scotland comes from low carbon sources (including nuclear), with 62% specifically from renewable energy sources, and only 11% coming from fossil fuels.

Scotland's high portion of wind-powered generation (45% of total generation) has made it a net exporter of electricity, and its export levels have steadily increased over time. In future we expect to see further significant power flows associated with new offshore wind.

In 2020, Scotland generated 51.9 TWh of electricity and exported 20.4TWh, which has an estimated wholesale value of £763m (net exports in 2020 totalled 19.3TWh)[2].

SG does not intend to build new nuclear power plants with existing technologies; UKG has confirmed that it has "no plans to impose nuclear reactors in Scotland" in the future without the support of SG.

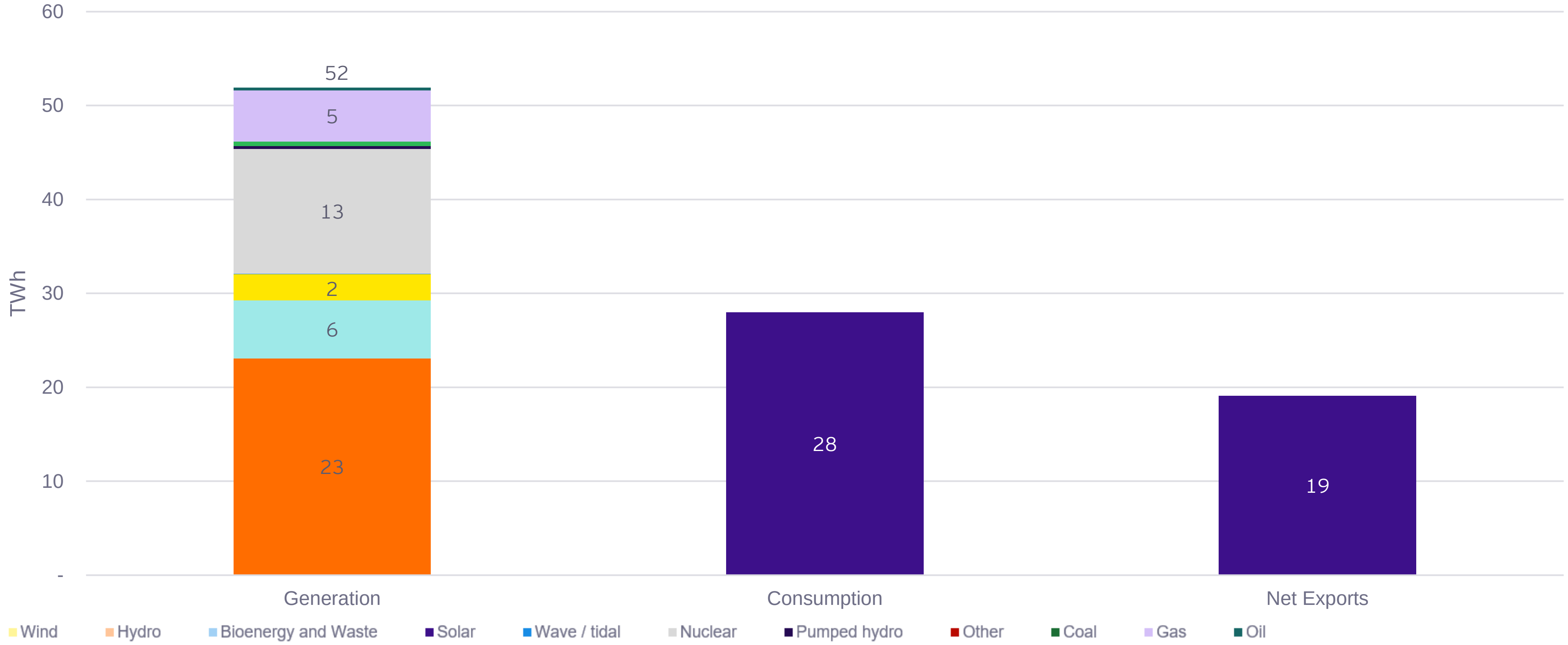
**Electricity generation by technology type in Scotland (2020)[1]**




Sources:
[1]Scottish Energy Statistics Hub - Electricity Generation
[2]Scottish Gov Energy Stats Hub - Annual Electricity Imports & Exports

# 53% of the energy generated in Scotland was consumed within Scotland in 2020

**Electricity generation, consumption and net exports in Scotland (2020)**




*Source: Scottish Energy Statistics Hub*

Scotland is a net exporter of electricity to the rUK, with 20TWh of exports and 1 TWh of imports in 2020.

Note: Due to losses in the transmission and distribution network, and an element of generation being consumed to generate electricity, consumption plus net exports does not equal total generation.

**Key conclusion**

Almost 90% of Scotland's electricity generation in 2020 came from low carbon sources. Total consumption in the same year was just over half of total generation, indicating that Scotland is a major net exporter of electricity. The level of Scotland's net exports has increased steadily over time.

# Scotland's electricity generation is almost four times less carbon-intensive than that of England and Wales



SG's Climate Change Plan update sets out the government's ambitions to achieve net zero by 2045, and highlights the importance of grid decarbonisation and the continuing growth of renewable electricity generation[1].

Achieving net zero will be driven by multiple policy actions, crucially the decarbonisation of the public sector, business and industry through collaboration with local and national governments.

The SG has also committed to delivering a fair transition for all members of society, known as Just Transition. The Just Transition plan sets the SG's long-term vision for Just Transition and provides details in the National Just Transition Planning Framework.[2]

The SG has also committed to a green recovery from the COVID-19 pandemic, and has emphasised the important statutory role of the CCC in providing independent expert advice. The CCC produce annual reports on Scotland's progress in reducing emissions, the feasibility of targets, and the impacts of climate programmes.

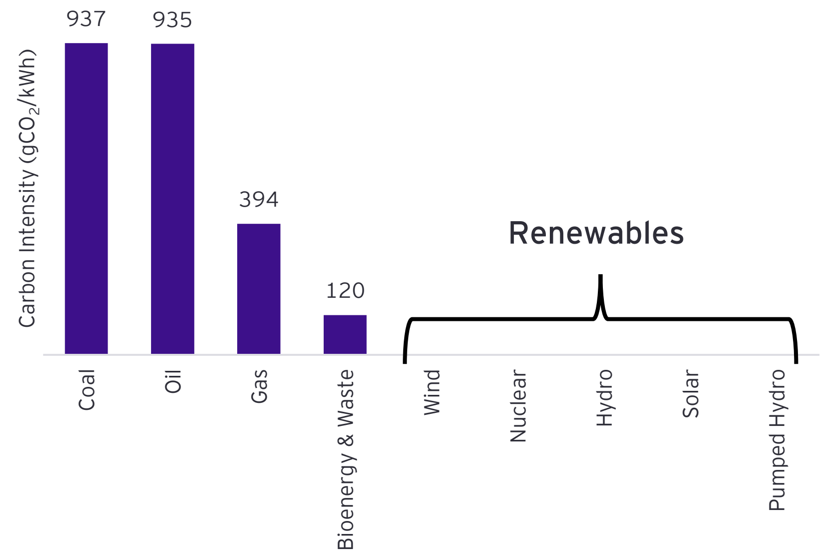
Carbon intensity data from National Grid electricity system operator (ESO) quantifies the unit impact of emissions for each fuel type.[3] The figure on the right shows that coal, oil, gas and bioenergy & waste are the four largest contributors to carbon emissions.

Renewable and low carbon technologies do not emit carbon in their generation, hence have a carbon intensity of zero. We have calculated a weighted average of carbon emissions for Scotland and compared it to that for England and Wales.

As shown in the adjacent table, Scotland's carbon intensity of 54.35 $gCO_2$/kWh is significantly less than the 206.44 $gCO_2$/kWh for England and Wales. This difference is primarily due down to Scotland's higher adoption of renewable and low carbon sources whilst minimising its use of fossil fuels.

The carbon intensity figures include $CO_2$ emissions from all large metered power stations, interconnector imports, transmission and distribution losses, and accounts for national electricity demand, and both regional embedded wind and solar generation.[4]

**Carbon intensity per fuel type[5]**




**Weighted average carbon intensity in energy generation**

| | Scotland | England & Wales |
|---|---|---|
| Weighted Average ($gCO_2$/kWh) | 54.35 | 206.44 |

**Key conclusion**

Due to Scotland's rapid uptake of renewable technologies, electricity generation is almost four times less carbon incentive than in England and Wales.

*Source: [1] Scottish Government - Climate Change*
*[2] Scottish Government - Just Transition*
*[3,5] Carbon Intensity*
*[4] NG ESO – Carbon Intensity Forecast Methodology*

# Future electricity demand is expected to increase as other sectors of the economy are electrified



Electricity will be increasingly important in delivering net zero, potentially meeting half of energy demand as its use in heat and transport increases.

The FES, developed by the National Grid ESO, represent four different pathways to decarbonise the UK energy system and become net zero by 2050, these include:[1]

- **Leading the way:** The UK reaches its net zero target in 2047 through a combination of high consumer engagement and investment in technology. In this scenario, the UK reaches net zero in 2047 and goes on to reduce emissions by 103% by 2050 (compared to 1990 levels).
- **Consumer transformation:** The 2050 net zero target is met with measures that have a greater impact on consumers and is driven by greater levels of consumer engagement.
- **System transformation:** Domestic consumers will experience less disruption than in consumer transformation as more key changes in the energy system happen on the supply side, away from the consumer.
- **Steady progression:** Decarbonisation is slowest in this scenario, emissions reduced by 73% from 1990, but the UK would miss its 2050 net zero target.

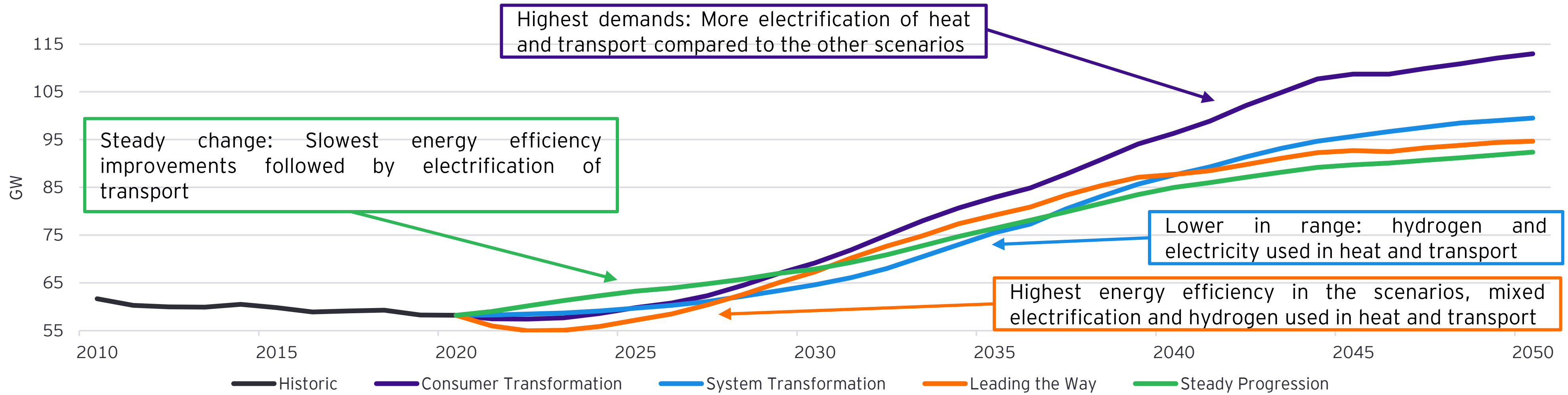
Electricity demand across Great Britain has gradually declined, falling from a peak of 64GW in 2005 to 58GW in 2020, however, peak demand is expected to increase in all four FES between now and 2050, as the electrification of other sectors of the economy continues, particularly heat and transport.

The level and pace of electrification of other sectors of the economy will depend in part on the mix of replacement heat technologies deployed (e.g. electric heat pumps versus hydrogen boilers) and whether hydrogen is principally produced as blue (i.e. through transformation of methane) or green (i.e. through electrolysis).

**Key conclusion**

National Grid ESO's FES describes the 4 possible pathways to net zero by 2050. The UK has made significant progress in reducing its carbon emissions over the last couple of decades.

**Electricity peak demand forecasts (Great Britain)**




*Source: Future Energy Scenarios (2021) Note that the scenarios are updated regularly by NG ESO.*

# Electrification is principally driven by expected deployment of electric vehicles and heat pumps



The UK economy is expected to become increasingly reliant on electricity for its energy needs, as it transitions away from the use of fossil fuels in the generation of heat, and for use in vehicles. Therefore the demand for electricity will increase across each of the four FES in Great Britain.

The variance in the demand for electricity fluctuates between scenarios depending on the speed of decarbonisation and the level of societal change in how we consume energy. We have considered some of the factors which will constrain the impact on electricity demand between now and 2050 below.

### Residential

Residential demand for electricity will increase, partially offset by technology improvement and the energy efficiency gains. There is also scope for accelerated uptake of energy efficient measures if supportive government policy measures are put in place.

### Transport

In 2020, demand from road transport for energy was almost entirely met through oil/petroleum sources. However, in the three net zero FES, demand in 2050 is assumed to be entirely met by electricity and hydrogen.

The Scottish Zero Emission Bus challenge fund has offered awards of £62 million to nine bus operators and local authorities for 276 zero-emissions buses and associated charging infrastructure.

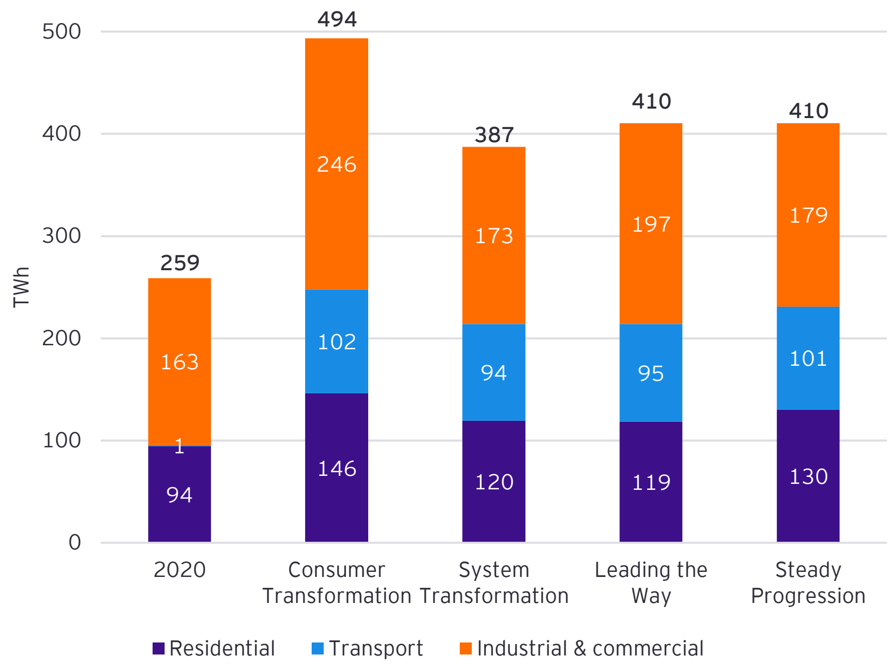
UKG's Ten Point Plan has brought forward the ban on petrol and diesel cars and van sales to 2030, and all cars on the road will be required to be ultra-low emission vehicles by 2050 – this alone will lead to a reduction of at least 60% in energy demand for road transport compared to 2020.[1]

### Industrial and commercial

The majority of emissions in the commercial sector come from heating and lighting. Emissions and energy consumption will therefore primarily be limited by investment in efficient lighting and sources of low carbon heating. The industrial sector accounted for 13% of emissions in the UK in 2020 and 11% of emission in Scotland in 2018, with significant transformation in energy consumption needed to hit net zero targets.

The Ten Point Plan includes commitments to develop industrial clusters and CCUS 'SuperPlaces'[2], whilst the Industrial Decarbonisation Strategy outlines the path to reducing emissions by at least 90% of 2018 levels by 2050[3].

**Annual electricity demand in 2050 in Great Britain[1]**




**Key conclusion**

In the UK, all four FES pathways predict a significant increase in electricity demand compared to 2020 levels, largely driven by mass deployment of EVs and heat pumps. The scenario with the largest electricity demand (Consumer Transformation) will be driven by relatively higher levels of residential as well as industrial & commercial electricity demand.

Sources: [1] Future Energy Scenarios (2021)
[2] The Ten Point Plan for a Green Industrial Revolution
[3] Industrial decarbonisation strategy - GOV.UK (www.gov.uk)

# Peak demand for electricity in Scotland is set to increase by over 50% by 2050

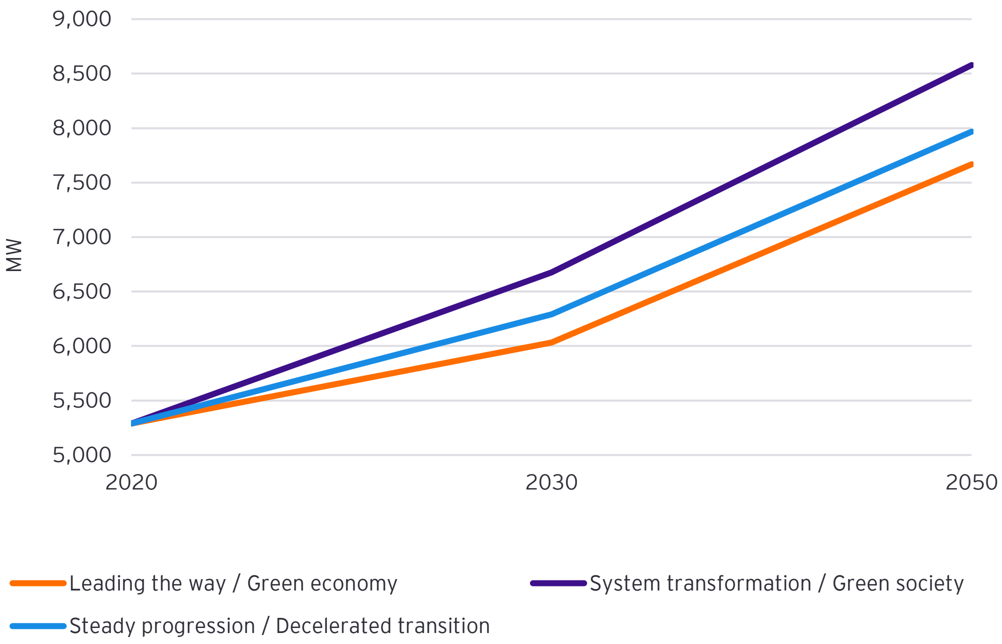


Peak electricity demand in Scotland is expected to increase by between 45-62% between 2020 and 2050.

The forecasts set out below are a combination of those set out within the SP Energy Networks FES report, which follow the four FES used by National Grid ESO (*leading the way, system transformation, consumer transformation and steady progression*), and the forecasts set out in the Scottish and Southern Electricity Networks (SSEN) FES report, which defines three different future energy scenarios (*green economy, green society and decelerated transition*).

These scenarios have been aligned to provide an estimate of the approximate peak energy demand for Scotland between 2020 and 2050.

**Peak electricity demand in Scotland[1]**



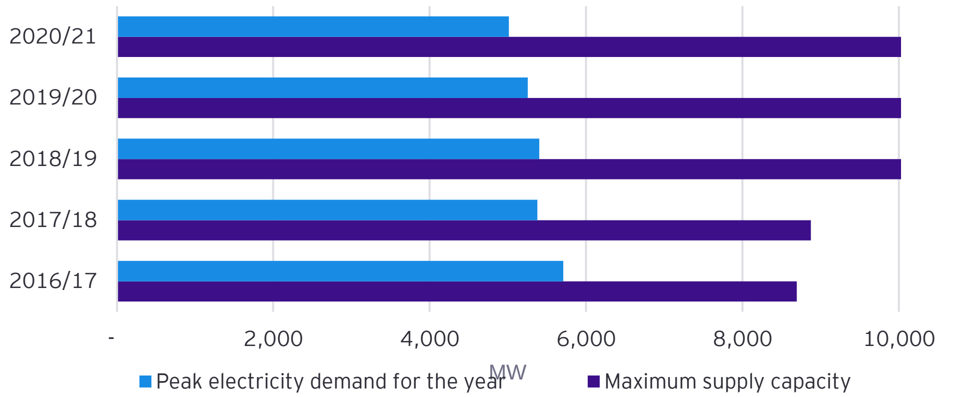

Security of supply is measured via the Loss Of Load expectation (LOLE), which reflects the average number of hours in a year when the electricity market will not be able to meet the demand for electricity. At this point, electricity system operators must step in to balance the system.

The National Grid forecast LOLE for this winter was less than 0.1 hours per year, which is well within the Reliability Standard of 3 hours set by UKG.[2]

Scotland's electricity system is secure, with the maximum supply capacity exceeding the peak electricity demand archived in the winter. Scotland's peak demand for electricity in in 2020/21 was 5.0GW, less than the maximum supply capacity of 10.0GW. This supply capacity was split between 5.5GW of non-intermittent generation in Scotland, and 4.5GW of import capability (This import capability refers to what could still be safely imported following major faults on the electricity system).

However, the expected shutdown of nuclear capacity by 2028 means that the maximum non-intermittent capacity would be reduced by around 2.4GW, indicating the need for other sources of reliable capacity such as gas.

**Installed supply capacity and peak electricity demand in Scotland (exc. Intermittent renewables)[3]**




*Sources: [1]EY Analysis based on peak demand projections from SP Energy Networks FES and SSEN FES*
*[2]National Grid Winter Outlook 2021/22*
*[3]Scottish Energy Statistics Hub*

# Orkney, Shetland and the Western Isles have the potential to provide 50% of UK's total energy needs



Scotland plays a significant role in the generation of renewable energy across the UK. In 2020, **97.4%** of Scotland's gross electricity consumption was from renewable sources, with the majority of renewable electricity generation coming from wind; the abundance of Scotland's natural resources will support the continued growth of renewable energy generation[1].

The Orkney, Shetland and Western Isles potentially have a pivotal role in helping SG meet net zero targets, and supporting the UK's total energy needs.

The islands are geographically perfectly placed, with Orkney and the Shetlands positioned at the intersection of the North Sea and the North Atlantic. This means that strong tides and winds run through the islands, giving the opportunity to harvest energy.

Orkney is also positioned at the most northern point on the National Grid, meaning that energy generated on the islands already flows back to the grid. However, this is subject to grid constraints i.e. existing capacity may be insufficient for larger scale projects to be connected to the mainland.

In the Scottish Affairs Committee meeting in June 2021 on renewable energy in Scotland, Dr Gareth Davies told the Committee that the Orkney, Shetland and Western Isles could provide 50% of the UK's total energy[3] need through harnessing a range of renewable energy initiatives, focussing on wave, wind, tidal, thermal and floating solar[4].

Over 100% of the Orkney islands' electricity needs are generated from local renewable energy sources, and one in ten islanders generate their own power[5].

The Islands Growth Deal which will be worth £335 million over the ten-year programme, was signed by UKG and SG in 2021. This deal aims to put the islands at the forefront of the transition to becoming net zero and support energy transition for all three island groups by creating sustainable "green" jobs within the islands. [6] The deal outlines eighteen project proposals spread across the islands. Some of the plans which could receive UKG investment include:

- The Shell-volution – a new and innovative means of enabling expansion in the low carbon and sustainable mussel farming sector in Shetland, and more widely in Scotland.
- The Orkney Community Vertical Farm – focused on agricultural innovation and creating an islands' vertical farm.
- Islands Centre for Net Zero – supporting the energy transition for all three island groups and creating sustainable "green" jobs within the islands for 300 people.
- The Outer Hebrides Energy Hub – establishing the initial infrastructure necessary to support the production of Green Hydrogen from renewable energy (onshore and offshore wind) [6].

**Key conclusion**

Due to the productivity of wind, waves and tide, the Orkney, Shetland and Western Isles can play a pivotal role in supporting the UK's total energy needs. However, enabling this will require the reinforcement and expansion of the transmission grid so that renewable energy generated in Scotland can connect to the grid and benefit the rUK.

*Sources:*
[1] *Scottish Government, Renewable and low carbon energy*
[2] *Energy Statistics for Scotland Q4 2020 Figures*
[3] *Scottish Affairs Committee (June 2021)*
[4] *October 2021 I Transformational Projects – the Orkney story so far by Dr. Gareth Davies (pmi.org.uk)*
[5] *Renewables | Orkney.com*
[6] *Islands Growth Deal worth £335 million signed - GOV.UK (www.gov.uk)*

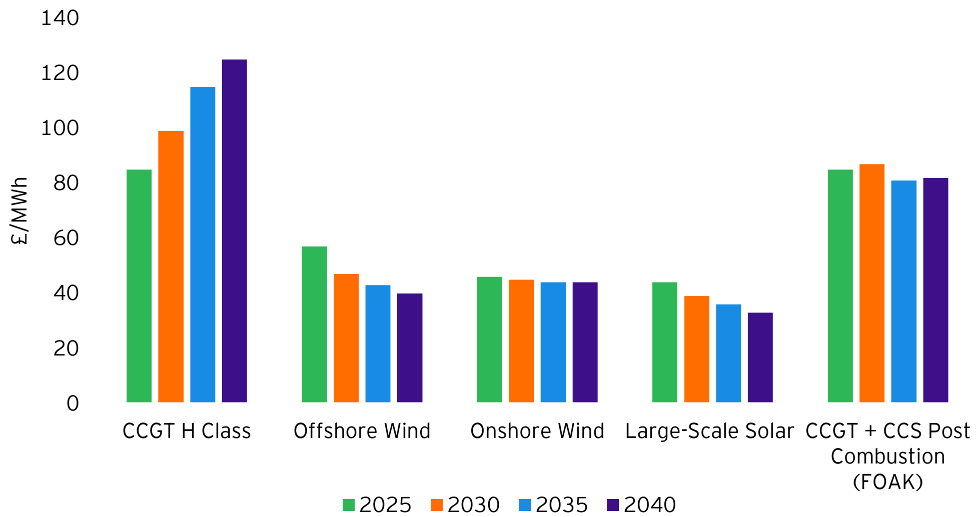
# The cost of renewable energy technology is expected to decline



Wind and solar energy are often intermittent sources of renewable electricity generation because, unlike coal and gas generation, they cannot immediately increase their output to meet demand surges, despite having a theoretically large generation potential. Batteries also suffer from intermittency due to capacity constraints, hence a flexible transmission network is vital for optimising electricity generation across the UK.

Levelised costs are a measure of the average cost per MWh generated over the expected lifespan of a plant.[1] Levelised costs are commonly used as they provide a straightforward way of consistently comparing the costs of different generating technologies with different characteristics, however, the simplicity of this approach means that costs will not include wider factors, such as delivery timing and location.

### Levelised cost estimates by technology type




*Note: Price estimates are in 2018 real values*

*Source: [1] BEIS - Electricity Generation Costs (2020)*

*[2] CFD AR4 auction*

The cost of onshore wind and offshore wind (both fixed-bottom and floating offshore), as well as the cost of solar, is expected to decline in the future, as can be seen in the figure on the left hand diagram. In contrast, the cost of CCGT H Class (combined-cycle gas turbines with 60% efficiency) will steadily rise over the next two decades (due to higher carbon costs), with CCGT and CCS post combustion prices remaining relatively stable.

In the 2022 CfD AR4 auction, offshore wind constituted 70% of the total secured capacity including two Scottish offshore wind farms (Inch Cape – 1080MW, Moray – 294MW) [2]. Offshore wind cleared at a strike price of £37.35/MWh (real 2012), reflecting the cost reduction of offshore wind compared to previous CfD rounds. Floating offshore wind cleared at a price of £87.30/MWh (real 2012) reflecting its higher costs relative to fixed-bottom wind.

This widening of cost differentials between the technologies will increase the affordability of renewables and support greater switching away from non-renewable energy. However, there are also costs associated with intermittency, such as higher costs of electricity grid reinforcement as well as of balancing the energy system at times of low wind and solar generation. There are also non-cost barriers to the deployment of renewable technologies, such as around the lead times for achieving relevant planning and environmental consents, and in achieving grid connections to shore.

The cost competitiveness of emerging technologies (such as floating wind or marine energy) will partly depend on the size of R&D funding. This will impact the speed which technological development is made and speed which the technology can be installed.

**Key conclusion**

The costs of renewable technologies are expected to continue decreasing over the next two decades in comparison to other technologies such as CCGT. This suggests that the uptake rate of renewables to replace non-renewables should increase as new technologies become mainstream.

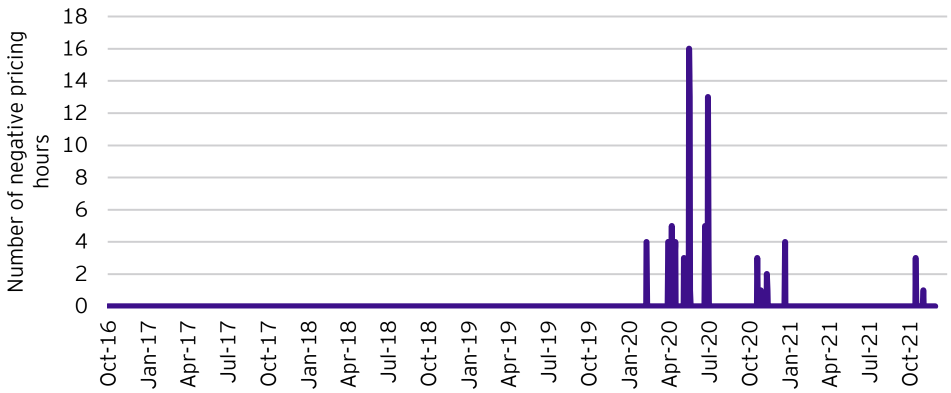
# The growing penetration of renewables is affecting price volatility and the frequency of prices below zero



In wholesale electricity markets, electricity is traded between producers and consumers 'over the counter' or via an exchange. Trading can occur on the day of delivery, as little as one hour in advance of delivery. Closer to delivery, in the balancing market, the ESO buys and sells energy to balance the system.

Negative prices occur when high and inflexible generation is meet with much lower demand for electricity. Negative prices can occur in any of these markets but are more likely to happen in the Day-Ahead and Balancing Markets. Negative prices occur most frequently during overnight hours in winter in the UK, as inflexibility is high due to higher amounts of wind generation colliding with low electricity demand.

**Negative pricing hours in EPEX Spot Day-Ahead market[1]**




Negative pricing periods have been gradually increasing, with a spike occurring during the Covid -19 lockdown where demand reduced substantially. Without the presence of increased electricity system flexibility, growing renewable generation and constrained networks, could increase the frequency of negative pricing even

**Implications for renewable investment**

Growing price volatility and frequency of negative prices create increased risks to the investability of intermittent renewables. As renewable penetration increases, there is greater potential for price cannibalisation, with renewable projects achieving a lower "capture rate" (i.e. a lower average power price than a baseload power plant would achieve.

The CfD mechanism largely mitigates price volatility risk by providing a fixed price at day-ahead stage. Since CfD Allocation Round 4 developers do not receive a CfD payment in the event of negative prices. However, this has seemingly not impacted negatively on the investability of renewables, given the continued reductions achieved in offshore wind strike prices in AR4.

Cannibalisation risk can also be partially mitigated through greater deployment of flexible energy technologies that smooth out intraday price volatility. Flexible resources such as energy storage systems, hydro reservoirs and interconnectors, have the opportunity to secure profitable periods ahead of time in forwards markets, and respond – buying back the previously contracted generation volumes at much lower prices.

Similarly, smart meters or EVs can respond to negative price signals by increasing their consumption, as often they can be set to charge when the grid is cheapest, therefore taking advantage of the negative pricing. Businesses in the commercial and industrial segment and households can access the opportunity created by negative pricing through Time of Use Tariffs e.g. the Agile Tariff offered by Octopus Energy [2].

Green hydrogen production presents a further technology for mitigating price volatility – with excess low carbon power used to create hydrogen through electrolysis, which can then be used in heat, electricity generation, and transport. However, electrolysers currently have a significant capital cost and require significant technological advancements to provide a solution to renewable intermittency.

**Key conclusion**

The increasing penetration of renewable energy has increased the frequency of negative pricing in the Day-Ahead market. This will be partly be mitigated by deploying a greater amount of flexible technologies that reduce intraday price fluctuations.

*Sources: [1]EPEX Spot via Bloomberg*
*[2] Agile Tariff offered by Octopus Energy*

# The intermittent nature of weather-dependent renewable technologies means that electricity from these sources will not be continuously available, especially wind



One of the most common concerns associated with renewable energy technologies is that energy production can be intermittent, particularly when considering weather-dependent renewables such as wind power or solar power.

2020 was a record year in the UK for renewable energy generation, with 43.1% of the UK's total electricity generation being delivered by renewables. However, in 2021, renewables accounted for 39.3% of the UK's total generation. This decline of 9.5% was primarily driven by less favourable weather conditions in 2021 compared to 2020 – in particular, there was a 14% decrease in wind generation as wind speeds were below average in every month except February in 2021.[1]

Onshore wind output had the largest drop with a reduction of 20% in 2021 (27 TWh estimated) as compared to 2020 (34 TWh)[2]. This has had a significant effect on the volumes of wind energy constrained off the system, with a corresponding reduction in the total cost to consumers.[3]

Wind power is the UK's largest green energy source, with onshore and offshore wind generating a combined 26.1% of the UK's total electricity generation in 2021.[1]

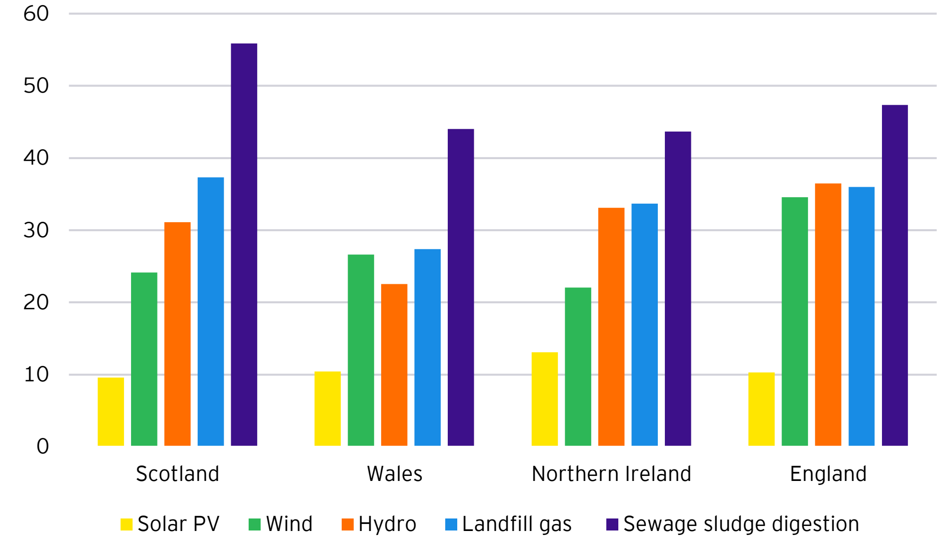
The supply of electricity on the national grid must be equal to the electricity demand at all times, and relying on energy generated by an intermittent and variable resource such as wind necessitates having an alternative capacity that is flexible and reliable able to generate when needed.

Having a wider range of renewable technologies (e.g. including marine energy) can reduce the volatility of renewable output at a portfolio level and partially offset the requirements for increasing available capacity.

The demand for flexible technologies such as storage (e.g. through batteries) and interconnectors is expected to rise with increasing intermittency in the UK energy system. On the following page, a number of other options that can help manage intermittency (such as electricity storage capacity) are considered.

The figure opposite provides an overview of renewable energy load factors across Scotland and the rUK. Load factors measure the ratio of actual electricity generated to the amount that could potentially be generated if the installed capacity were operating continuously throughout the year.

**Renewable energy load factors by region in %, 2021[4]**




*Sources: [1]Energy Trends March 2022 (publishing.service.gov.uk)*
*[2,3] REF- Constraint Payments to Wind Power in 2020 and 2021*
*[3,4] BEIS - Renewable Energy Statistics*

# Electricity storage capacity helps reduce the problem of intermittency



Electricity storage is an important source of flexibility in the grid. Being able to efficiently store energy that has been generated rather than waste it, means that the amount of energy that is created can be maximised – this is important for intermittent renewable energy sources such as wind and solar.

One way to help balance fluctuations in electricity supply and demand is to store electricity during periods of relatively high production and low demand, then release it back to the electric power grid during periods of lower production or higher demand, rather than generating additional energy.

Energy can be stored in a variety of ways, including:

- **Pumped hydroelectric:** electricity is used to pump water up to a reservoir. When water is released from the reservoir, it flows down through a turbine to generate electricity.
- **Batteries:** similar to common rechargeable batteries, very large batteries can store electricity until it is needed. These systems can use lithium ion, lead acid, lithium iron or other battery technologies.
- **Thermal energy storage:** electricity can be used to produce thermal energy, which can be stored until it is needed. For example, electrolysis of water can be used to produce hydrogen that can be stored and later used to generate energy during periods of peak consumption.

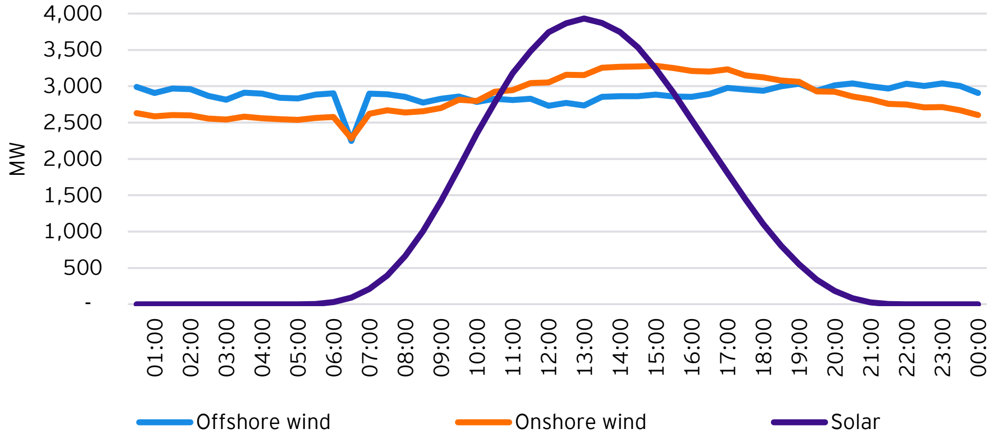
As a high-level classification, energy storages can be short-duration (SDES) lasting seconds to several hours (e.g. lithium-ion batteries) or long-duration (LDES) lasting days, weeks and months (e.g. hydrogen). LDES can respond to daily and seasonal supply demand variations and have relatively low marginal cost for storing electricity for longer durations. On the other hand, being a relatively nascent technology, LDES has relatively high investment costs and long lead times, which necessitates more policy support from the government to de-risk the market for investors and adaptation of market design (e.g. enabling the Capacity Market to capture the full potential of LDES). There are a significant number of different storage technologies. In 2018, BEIS compared different types of storages with a detailed assessment of each technology[1].

*Sources: [1]HM Government - Storage cost and technical assumptions for electricity storage technologies*
*[2]Scottish Energy Statistics Hub*

The figure below shows the average amount of energy generated by solar, onshore wind and offshore wind each hour in the UK. The energy generated by solar power is predictable, with energy generation peaking in the middle of the day. Offshore wind fluctuates between 2,200 MW and 3,050 MW with greatest generation at the end of the day. Onshore wind fluctuates between 2,200 MW and 3,300 MW, with the most energy generated between midday and 6pm. These peaks and troughs of energy generation highlight the importance of storage capacity to help alleviate the problem of intermittency.

Deployment of energy storage in the UK is growing substantially in recent years (by 70% in 2021 compared to 2020). Last year, BEIS issued a call for evidence regarding how to enable LDES with a review of market barriers and how they can be addressed.

**Average energy generation per hour by technology type (2021)[2]**




**Key conclusion**

The intermittent nature of renewables can affect the resilience of the Scottish electricity generation market. Energy storage technologies such as batteries and demand-side responses are required to lessen the risks of intermittency.

# Transmission constraints and charges are critical barriers to the deployment of renewables for increased demand



Constraint management is required when the electricity transmission system is unable to transmit power to the location of demand, due to congestion at one or more parts of the transmission network. Constraints are driven by technical limits on the network: broadly thermal, voltage, and fault-level. Constraint management may also be needed for distribution networks.

Distribution Network Operators, Transmission Owners (TOs) and the System Operator (SO) plan and build the networks taking account of these physical limits, various technical standards, and the capacity already reserved for other parties through existing connection agreements.

Some level of network constraint is healthy and part of the normal reinforcement cycle - a network that always has spare capacity is likely to be oversized and underutilised, meaning consumers would pay more than needed.

However, constraints can have negative impacts, both directly on parties looking to connect, and more broadly on the costs of the electricity system overall and the cost to consumers. Specifically focussing on the transmission system, there is a clear and direct cost for consumers of managing congestion through the SO's system balancing actions, including constraint payments to generators which is when the SO compensates generators to reduce their output to maintain system stability.

A large proportion of these congestion areas and constraint costs are associated with Scottish boundaries (SSE-SP and SCOTEX) and often requires high amounts of renewable generation in Scotland to be turned down. The map opposite highlights the outturn system costs across UK borders, whilst the table shows constraint costs associated with Scotland are more than 7 times higher than those associated with England and Wales.

Over the next 10 years, Scotland is going to be experiencing a rapid growth in renewable generation capacity, mainly wind. This is going to increase the network reinforcement needs in some areas and there will be a need to reduce the impact of network constraints, to enable to maximum build out of renewable capacity on the system and lower costs for the end consumer.

The ESO are aiming to achieve this through their Network Options Assessment (NOA) Constraint Management Pathfinder[2].

Sources: [1]ESO system constraint costs
[2]ESO NOA Pathfinders

Map of UK system constraints[1]


Total UK constraint costs for FY 21/22[1]

| Constraint areas | Constraint cost (£m) FY21/22 |
|---|---|
| Scotland | 844 |
| England & Wales | 117 |

**Key conclusion**

The rapid expansion of renewable generation capacity (mainly wind) will require network reinforcement. Given that Scotland already has high network constraint costs compared to England and Wale, reinforcement investments are needed.

# The level of transmission charges is a challenge for investment in renewable energy generation in Scotland



In the UK, the transmission network is operated by 3 separate transmission operators (TOs) – SSEN Transmission in the north of Scotland, Scottish Power Energy Networks (SPEN) in the south of Scotland, and the National Grid Electricity Transmission in England and Wales. This implies a natural monopoly in each area, hence the network is subject to strict Ofgem regulation.

Although the TO owns the infrastructure, it is the ESO who use the transmission network to ensure power is available at all times. The TO charge the ESO for use of its network, and the ESO charges its own customers (transmission network users including consumers and generators) by applying its Transmission Network Use Of System Charges (TNUoS) methodology. The total charged by the TO to the ESO reflects the value the ESO charges transmission network users.

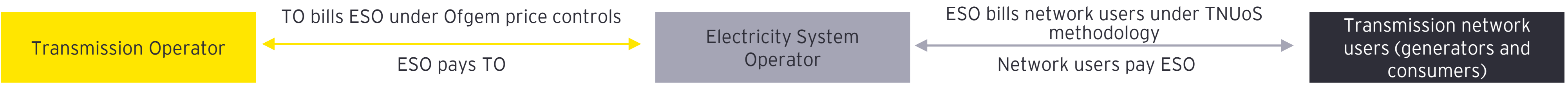
One of Ofgem's responsibilities is to set price controls setting the maximum amount that the three TOs are allowed to charge each year for use of their networks. In 2020/21, £2.4bn was recovered by the TOs.[1] The regulation of transmission charges by Ofgem provides the market with regulatory certainty and removes some of the short-term volatility of charges.

Despite the charge controls in its 2021 Transmission Charges paper, SSEN found that "the year-on-year volatility of charges and the difficulties in being able to accurately forecast charges" was one of the biggest challenges for existing and future generation developers in the north of Scotland[1].

This lack of cost clarity and certainty could increase the cost of renewable energy generation or discourage investment in renewable energy developments.

SSEN's analysis found TO allowed revenues which were regulated by Ofgem remain stable and highly predictable, although TNUoS charges in the region were volatile and unpredictable, and these higher charges discouraged future investment in electricity generation in remote areas [1].

**Payment flows of transmission charges**[1]




The ESO publish a five-year view of future TNUoS tariffs annually. The table below shows the forecast TNUoS charges (£/kW) and the disparity between charges in Scotland compared to England and Wales –with average charges in England and Wales being negative (i.e. generators receive a payment stream for alleviating network congestion) and significantly positive in Scotland.

**Average wider generation tariffs (£/kW) in Scotland compared to England and Wales**[2]

| | 2023/24 | 2024/25 | 2025/26 | 2026/27 | 2027/28 | 2028/29 |
|---|---|---|---|---|---|---|
| Scotland | 19.9 | 20.7 | 21.4 | 22.9 | 24.3 | 29.9 |
| England & Wales | -0.1 | -0.6 | -1.9 | -2.0 | -3.1 | -3.9 |

The TNUoS revenue collected by the ESO is split between generation and demand charges, where demand side recovers majority of the costs (e.g. generation share on average being one-third of the demand in the ESO's Five Year View of TNUoS for 2023/24 to 2027/28[3])

Regional price variation is a barrier to investing in renewable technologies that help UKG and SG deliver on net zero ambitions. Given the variation in TNUOS charges, generators applying to CfD auctions in Scotland will be at a disadvantage and are less competitive than generators in England and Wales.

Incentivising investment in generation close to demand may save costs in developing the network, but it limits the opportunity for effective deployment of renewable generation. If investments are only financially viable in a few specific locations, generators are not incentivised to locate in areas offering other requirements (i.e. strong winds, high levels of sunlight etc.) which could lead to more efficient electricity generation.

*Sources: [1]SSEN: Transmission Charges Paper (Feb 2021)*
*[2]National Grid: 5YV of TNUoS Tariffs for 2023/24 to 2027/28*
*[3]Five-Year View of TNUoS Tariffs for 2023/24 to 2027/28*

# The Offshore Transmission Network Review seeks to minimise network infrastructure requirement for growing offshore wind, reducing the issue of intermittency



## Introduction

UKG has set a target to increase offshore wind capacity to 50GW by 2030 (five-fold the 10GW capacity in 2022) as outlined in the Energy Security Strategy.

Currently, offshore wind farms are connected to the UK's electricity grid by way of constructing individual routes of connection from offshore infrastructure to onshore infrastructure which is known as a 'point-to-point' connection. The current point-to-point, uncoordinated approach to offshore wind was designed when offshore wind was an emerging sector. As the scale of offshore development increases on the pathway to net zero, there are ongoing challenges on limiting damage to valuable ecosystems, biodiversity, and the natural beauty of the UK coastlines.

Offshore wind farms and their associated infrastructure have long lead times (it can take around ten years for an offshore wind farm to move from seabed lease to operation).

There are a number of potential unintended consequences that could result from making policy and regulatory changes where developments have such long lead times. Developments could be delayed or require substantial change; both of these could increase cost and risk.[1]

## Offshore Transmission Network Review Overview

The Offshore Transmission Network Review (OTNR) was launched in July 2020 by the Energy Minister, in support of achieving the UKG's 50GW target. The OTNR was established in order to address the barriers in increasing the offshore wind capacity and the integration into the grid aiming to deliver a more coordinated approach in offshore development.

The ONTR is also considering an 'Enduring Regime' that takes a more strategic approach to windfarm development and considers the offshore transmission system to deliver a more coordinated approach and reduce the cumulative impacts of transmission.

*Source: [1] Offshore Transmission Network Review: Multi-Purpose Interconnectors: government response, [2] OTNR Ofgem Consultation, [2] Scotland's New Floating Wind Projects – What We Know So Far | Offshore Wind, [4] scotwind-briefing-may-2022, [5] Crown Estate Scotland announces partnership to improve coordination of Offshore Wind infrastructure*

To achieve the objectives of the ONTR, there are four workstreams[2]:

| Workstream | Description |
|---|---|
| Early Opportunities | Identify and facilitate opportunities for increased coordination in the near term. |
| Pathway to 2030 | Drive coordination of offshore projects progressing through current Scotwind and Crown Estate Leasing Round 4, connecting before 2030. |
| Enduring Regime | Develop a new post-2030 framework that drives coordination from the earliest stages of an offshore project. Changes must be driven across multiple government departments e.g. planning. |
| Multi-purpose Interconnectors (MPIs) | Make changes to facilitate early opportunity MPIs; Develop an enduring MPI regime for 2030 onwards. |

### Spotlight: Scotwind

Scotwind is the first round of Offshore Wind Leasing in Scottish waters for a decade. As of April 2022, there are 17 Scotwind projects with seabed option arrangements totalling almost 25GW in capacity.[3] These agreements are for up to ten years and Crown Estate Scotland will offer a full seabed lease (enabling projects to be built and operated) once developers have secured the necessary consents, licences and finance[4]

In October 2021, Crown Estate Scotland, The Crown Estate and National Grid Electricity System Operator committed to collaborate to support the development of a more coordinated approach to delivery of transmission infrastructure for offshore wind projects as key partners of the OTNR.[5]

# O&G platform electrification is a major potential source of power demand but requires new offshore transmission networks



The O&G sector is significant to the economies of UK and Scotland. The sector contributes £8.8bn in GVA to Scotland's economy, representing 5% of the country's total Gross Domestic Product (GDP).[1]

SG has set a new ambition to increase offshore wind capacity to 11GW of energy installed by 2030.[2] This assumes that the share of Scotland's contribution to the UK's offshore wind capacity would grow from 9% today to 27.5% in 2030.

In October 2020, SG published the Sectoral Marine Plan (SMP) for Offshore Wind Energy. The SMP allows for offshore wind targeted projects to progress with the specific focus of seeking to electrify O&G infrastructure.[3]

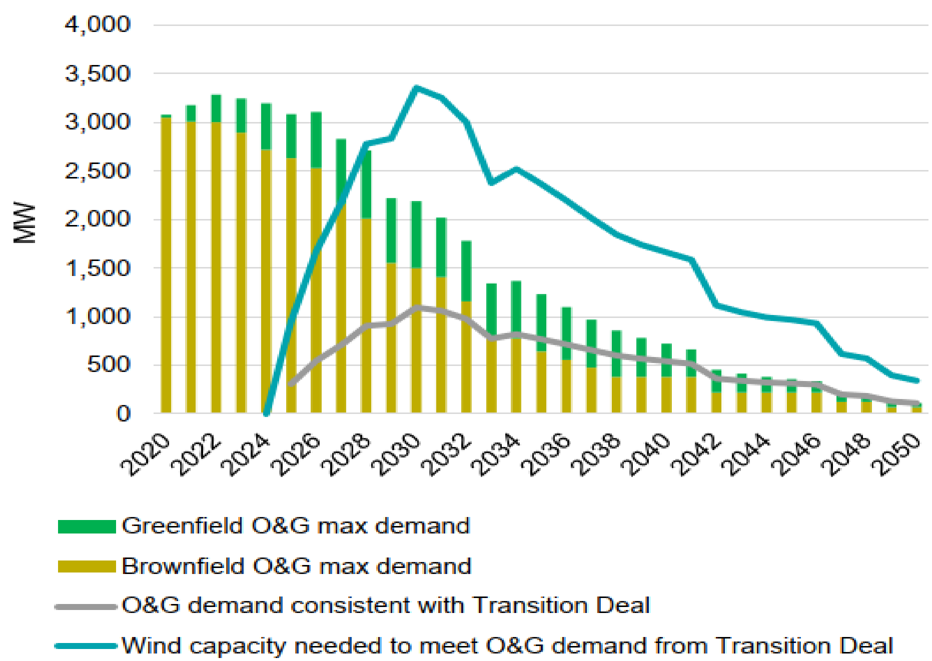
In March 2021 UKG, SG and the O&G industry agreed to the NSTD. The deal involves the O&G sector committing to achieving a 60Mt reduction in GHG emissions, including 15Mt through the progressive decarbonisation of UK Continental Shelf production over the period to 2030.[4]

EY's analysis for the North Sea Transition Authority's (NSTA) Energy Integration Project suggested that O&G platform requirements for electricity are around 3GW in 2022, rising to 3.5GW by 2023 before declining from the late 2020s. The O&G sector deal commitment to reach a reduction in emissions from production of 50% by 2030 implies an average 900MW of annual electricity generation demand for a 10-year period from 2027.

Offshore wind sits at the heart of O&G electrification with windfarms being a key enabler for platform decarbonisation. This has been a cornerstone in Crown Estate Scotand approach to seabed leasing. In February 2022, CES announced the SMP Innovation and Targeted Oil and Gas (INTOG) leasing round with 4GW being made available for platform electrification.[5]

Platforms can connect to a nearby wind asset which would allow the platform to draw on renewable power when available, while also providing an alternative demand source for offshore wind situated behind a transmission constraint and at risk of having export interrupted.

**O&G platform electricity demand by year[6]**




**Key conclusion**

The NSTD involves commitments by UKG, SG and industry to reduce greenhouse emissions by 60Mt in the O&G sector – more than all of Scotland's emissions, which are around 40Mt. Achieving this ambition involves significant commercial and regulatory challenges including the development of an offshore transmission grid.

*Sources: [1] Scottish Government - Oil and gas*
*[2] Scottish Government - Increased offshore wind ambition by 2030*
*[3,5] Marine Scotland (2022). 'Sectoral Marine Plan for Offshore Wind for Innovation and Targeted Oil and Gas Decarbonisation (INTOG)'*
*[4] HM Government - North Sea Transition Deal*
*[6] EY analysis*

# Electricity Generation – Conclusions and policy levers



### Demand

- The opportunity for scaling up renewable generation is dependent on the electrification of other sectors, particularly heat and transport. A further major opportunity for expanding power demand is through O&G platform electrification, as set out in the next section of this report.
- Promoting energy efficiency measures, especially in heating of buildings is also critical to ensure a Just Transition, including helping address fuel poverty.
- The electrification of heating and transport will increase the requirements of stand-by capacity, and given that the supply-side is dominated by renewables (which offer low system flexibility), there is a need for Demand Side Response (DSR) measures at the industrial, commercial and domestic levels.

### Solutions to intermittency

- A growing commercial barrier to renewable deployment is the risk from price cannibalisation due to the lower wholesale prices as a result of high intermittent generation.
- Technologies to mitigate renewable intermittency (e.g. green hydrogen, batteries, demand response) can reduce the degree of price cannibalisation for renewables.
- Scotland's natural resources create the optionality for large-scale pumped hydro storage projects which offer the additionality of long-term storage. The ESO's 'Leading the Way' scenario assumes a further 10GW of storage capacity will be needed by 2030, reaching some 40GW by 2050 (currently only 4GW is available in the UK).
- Developing business models and market mechanisms that provide developers certainty over revenues can open the door for such investments (e.g. storage capacity purchase agreements).

### Connecting the network

- Barriers to renewables growth are around the capacity constraints and charges for exporting power to England & Wales through the transmission network. In addition, there is a need for an offshore transmission network to facilitate offshore wind expansion as well as O&G platform electrification.

### Policy levers – SG

- SG currently has limited ability to influence the incentives in place for renewables, with these principally coming from UKG. SG sets some incentives through the design of offshore wind leasing rounds and R&D incentives. Scottish supply chain requirements is also another policy lever (for instance favouring onshore wind and prohibiting new nuclear).
- Some of the Supply Chain Development Statement requirements can be relaxed to enable Scottish projects to become more competitive against projects located in the rUK. Revisiting supply chain requirements offers a trade-off between achieving energy security and the Just Transition goals.
- Use of these levers to promote renewable technologies involves considering trade-offs with wider energy objectives, for instance maximising revenue from offshore wind leasing rounds, planning objections to infrastructure and objectives for Scottish content in new capacity deployed.

### Policy levers – Government and wider developments

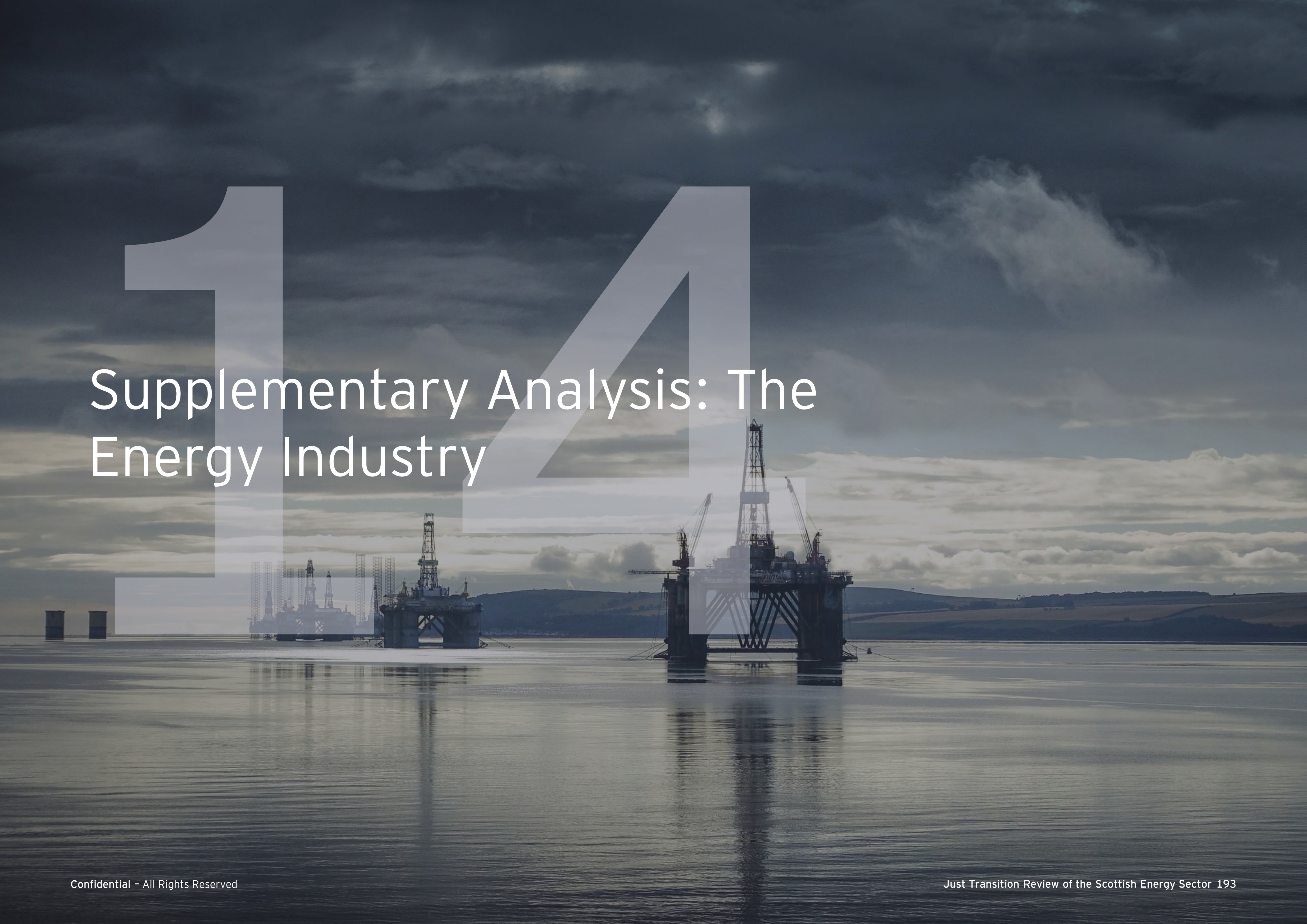
- Incentives for renewable generation principally come from UKG through the CfD mechanism and other national support measures. For mature renewables, these principally involve a fixed price guarantee rather than an expected subsidy.
- Delivering the scale of renewables deployment envisaged in UKG's targets may require continued regular CfD auctions, allowing mature technologies such as wind and solar to participate, setting sufficient funding and volumes to procure for the auctions and funding floating wind as the technology comes down in cost.

# Electricity Generation – Conclusions and policy levers



### Key areas for focus

- SG has a limited number of policy levers that it can use to accelerate the deployment of low carbon generation, these are:
  - Minimising barriers with the planning and consenting regime.
  - Requiring Scottish supply chain plans for offshore wind projects seeking to obtain seabed leases.
- Key areas where Scotland could look to influence UKG to promote low carbon generation include:
  - Maintaining annual CfD auctions, including for onshore wind, to provide a highly investable means of attracting investment in renewables.
  - Ensuring adequate budget to support deployment of floating offshore wind at scale such that the technology can mature with costs converging to those of fixed-bottom floating wind.
  - Platform electrification: Supporting the electrification of offshore O&G platforms by addressing regulatory barriers (for instance application of retail levies on O&G seeking to import power from shore).
  - Network planning: Promoting the development of an offshore transmission network to support least-cost development of offshore wind at scale and to minimise challenges around number of connections needed to shore.
- While Scotland has significant natural resources for wind and wave generation, these technologies remain far from being cost effective against more mature renewables. Further innovation funding can help promote cost reductions, although deployment at scale will likely require separate provision of funding by UKG through the CfD framework.



# 14

# Supplementary Analysis: The Energy Industry

# Introduction



## Introduction

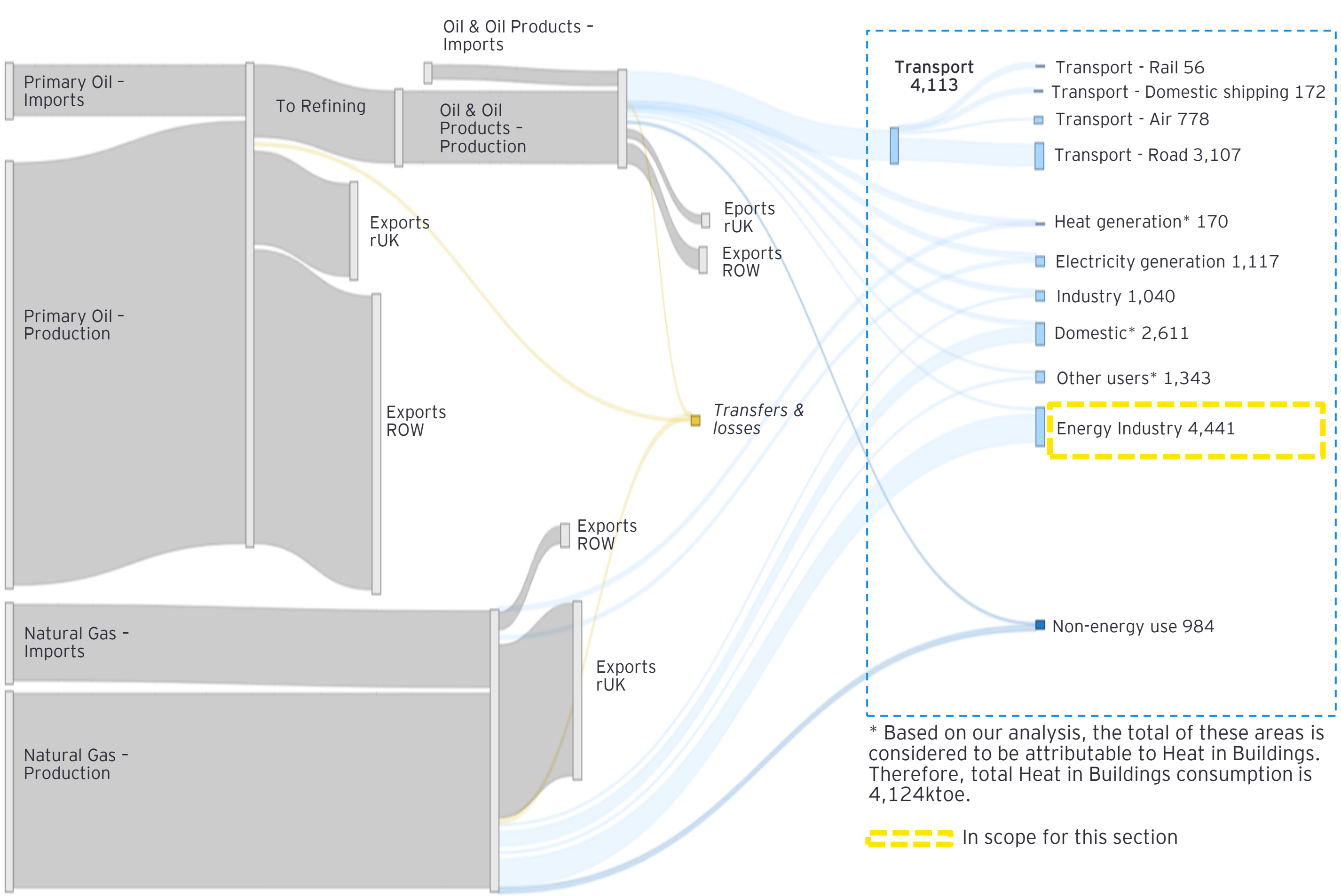
Sections 7-13 have highlighted the main consumers of O&G – transport, heat and electricity generation. These three sectors are the key focus of this report, however, **a significant portion of Scottish demand, 4,441ktoe or c28% of total Scottish consumption of O&G actually comes from the energy industry itself.**

The vast majority, 88%, of this energy industry consumption figure is natural gas consumed by upstream O&G producers, who use gas in the extraction process. As the upstream process needs to use natural gas in the course of producing O&G products, the NSTA often report "net natural gas" figures in their production data. Net natural gas production refers to gross production less producers' own use, i.e., the portion consumed by the extraction process and therefore not available for sale to end users.

Energy Industry use also includes use of both oil and natural gas in the downstream process at refineries and petrochemical plants, such as the Grangemouth and Mossmoran facilities discussed in Chapter 1. Oil refining and NGL production are inherently energy-intensive activities, and can actually consume more energy in the endeavour to produce "cleaner" end products (Concawe, 2012).

Despite this, the volume of consumption by the downstream sector is insignificant in Scotland given the scale of production at Grangemouth compared to the scale of upstream Scottish North Sea (ScotNS) production.

**Scottish Energy consumption overview**




* Based on our analysis, the total of these areas is considered to be attributable to Heat in Buildings. Therefore, total Heat in Buildings consumption is 4,124ktoe.

In scope for this section

*Source: SG - Physical commodity balances of oil, gas and petroleum products Digest of UK Energy Statistics (DUKES) 2021 - GOV.UK (www.gov.uk) (commodity balances)*

# Hydrocarbon usage and demand drivers

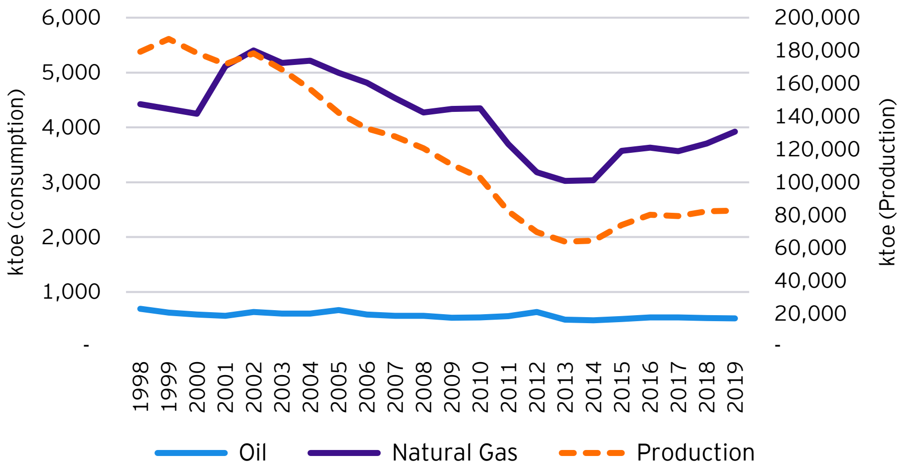


**Hydrocarbon usage in the Energy Industry primarily relates to the upstream extraction process and will naturally decline in line with declining ScotNS production.**

The chemical and control processes in upstream O&G extraction are very complex, and as a result are extremely energy intensive, more so than normal manufacturing processes. A significant volume of gas is used to generate heat for the extraction process, as well as for pressure maintenance required throughout the process. ScotNS gas production figures are often reported as "net natural gas", i.e. less the amount consumed in the process that is not available to end users.

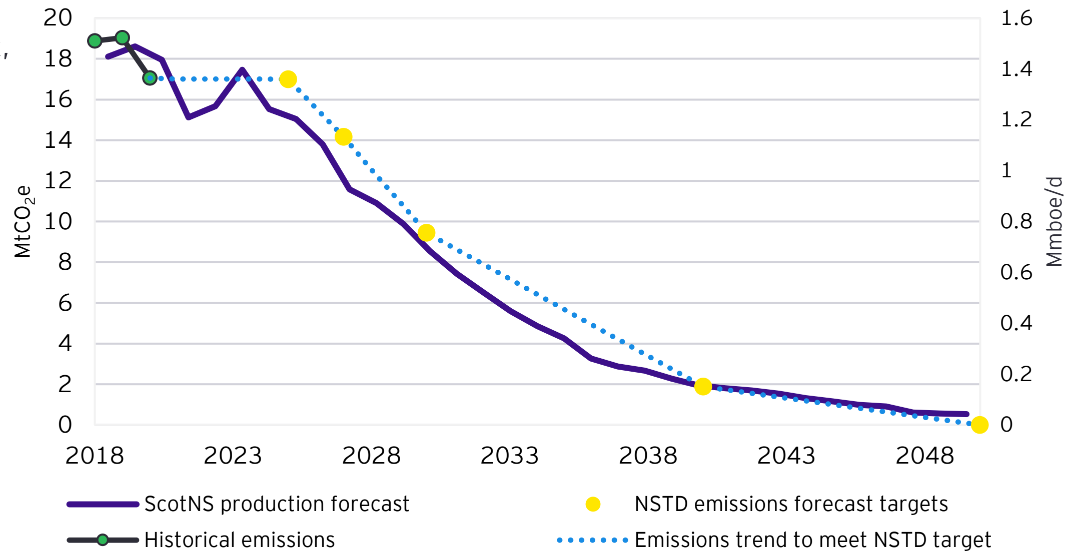
The energy industry undoubtedly benefits from the ease of using its own output (i.e. O&G) to fuel its own processes. There are more sustainable, eco-alternatives available to the energy industry as the rest of manufacturing industry. Energy industry demand for gas will naturally decline in line with production. The graph below shows the similar trajectories between total ScotNS production and energy industry consumption of natural gas.

**Energy Industry demand for hydrocarbons, 1998 to 2019**




*Source: SG Commodity Balances, Exports and Imports of Oil, Gas and Petroleum 2019*

**ScotNS emissions and production forecast (medium case)**




*Source: EY analysis, NAEI, NSTA*

# GHG emissions



We are not able to clearly highlight the GHG emissions from the Scottish Energy industry because, as discussed in Chapter 1, offshore North Sea O&G emissions are not allocated to Scotland. Emissions of GHGs from offshore O&G exploration and production are classified within the UK GHG Inventory as "Unallocated" emissions and not attributed to any of the devolved administrations.

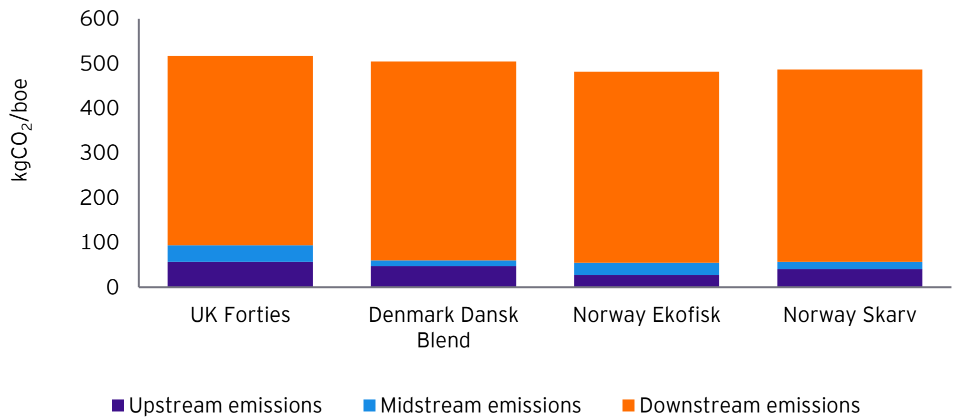
Emissions relating to onshore activity were 9.4% of Scotland's total emissions in 2019, but this is not an accurate reflection of the sector's total contribution to GHG emissions.

The carbon emissions associated with the O&G extracted from the ScotNS are not limited to the upstream and midstream activities (also known as scope one and two emissions). To help illustrate this point, analysis from the Carnegie Endowment as shown in the graph opposite highlights that over 80% of the carbon emissions from various oil fields in the North Sea per barrel of oil are associated with downstream activities and end use (scope three emissions).

A much smaller proportion of the carbon emissions are associated with the upstream (including production) activities. Data from the NAEI also shows that UK O&G emissions and emissions related to O&G refining are significantly lower than the emissions associated with electricity and heat production. Nevertheless, these upstream carbon emissions do represent a significant source of carbon emissions.

The type of product being produced also has an impact on the emissions intensity of the energy industry, for example a 2019 article by McKinsey & Co explains that assets producing oil with an API of 20 or less, and higher reservoir complexity, can be on average three-times more intensive than those with an API gravity of 50 or more.

**Illustrative total emissions per barrel of oil**




*Source: Carnegie Endowment*

Note: Scotland's GHG emissions data uses a different definition of "energy industry" to data set underpinning our Sankey diagram. Per the emissions data, mining activity and public heat are also included under "energy industry". To ensure the emissions discussed here are relevant to the hydrocarbon usage in question, we have stripped out any non-O&G sector emissions from the data set.

# Replacement technologies



**The easiest way to reduce emissions from the Energy Industry would likely be to reduce demand from other sectors for O&G products, as reducing production would naturally reduce the Energy Industry's consumption and associated emissions.**

Other than reducing wider demand for O&G, some of the other key technologies available to reduce Energy Industry consumption are as follows:

*Upstream*

- Optimising operations, both in terms of energy efficiency and in terms of asset integrity (by reducing fugitive emissions from leaks).
- Sustainable electricity generation options such as grid-based electrification and renewable power sources.
- Electrification of equipment such as using electric steam-production systems instead of gas boilers in separation units.
- CCUS, including reinjection and enhanced oil recovery.
- Reduction of both routine and unplanned venting and flaring (by improving processing reliability, infrastructure or by capturing methane).
- Rebalancing portfolios by focusing development and investment of less complex and therefore less energy intensive reservoirs.

*Downstream*

Many of the same options exist for downstream operations, such as exploring sustainable electricity generation options, improving operations efficiency and asset integrity, and the electrification of equipment, however, some additional technologies to reduce emissions also exist for the downstream sector:

- Use of green (or blue) hydrogen for electrolysis. This is not speculative technology as companies like Shell have already begun to develop hydrogen based electrolysis plants in mainland Europe.
- Using electric coils for high-temperature cracking, instead of gas. This technology is still in its infancy hence not being widely adopted.
- Use of greener bio-based feedstocks or recycled-plastic materials instead of conventional fossil fuel feedstocks. This could reduce not only scope one but also scope three emissions.

Many of the above technologies are already in use in both the upstream and downstream sector at Grangemouth and Mossmorran.

# The Energy Industry - Conclusion

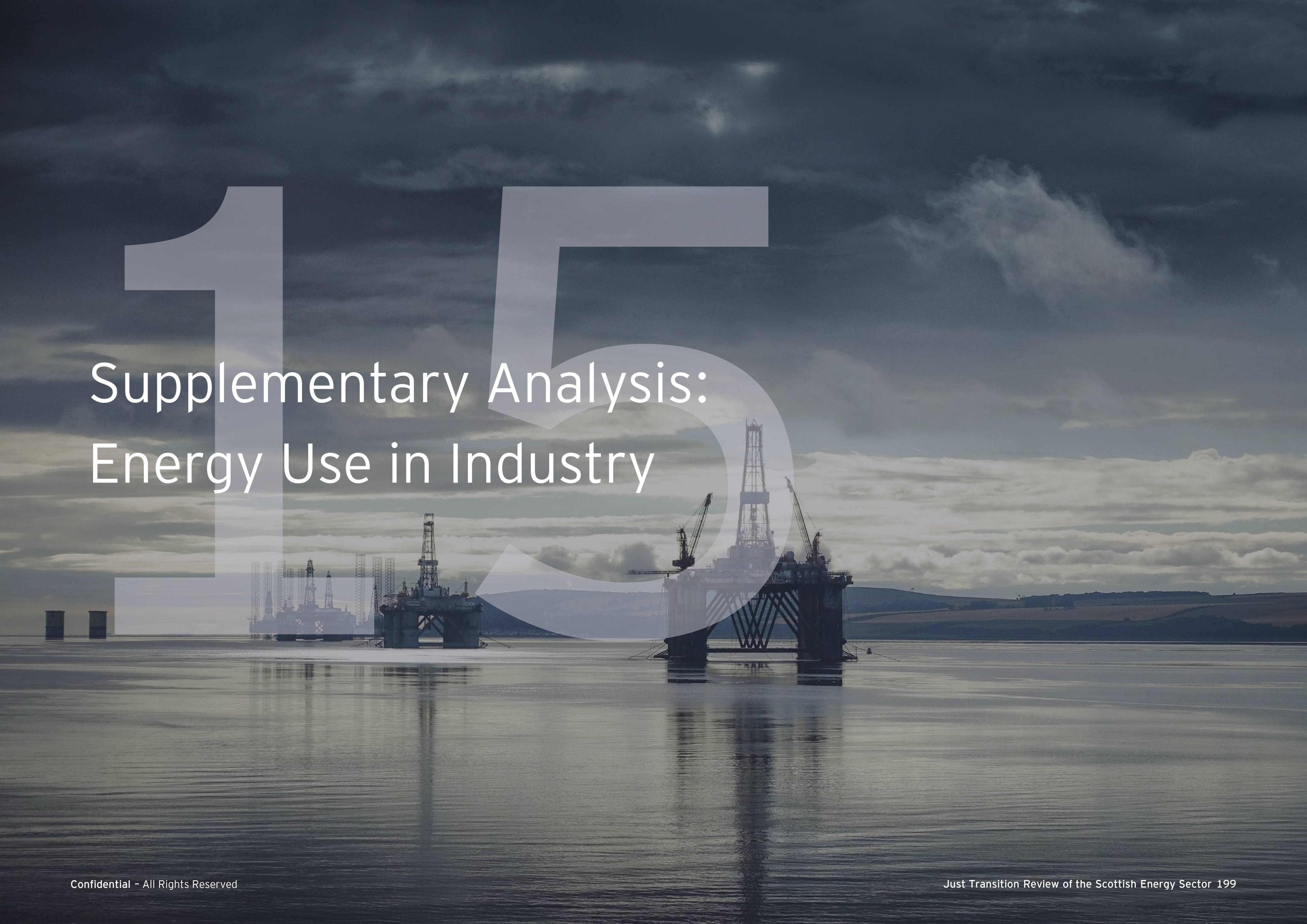


**Hydrocarbon usage in the Energy Industry primarily relates to the upstream extraction process and will naturally decline in line with declining ScotNS production.**

- Hydrocarbon usage in the O&G industry is mostly accounted for by the energy required for O&G extraction, and to a lesser extent the energy required in processing.
- These have historically come from using gas a fuel for these processes, supplying electricity offshore and heat for onshore processes.
- This usage is strongly correlated with production, although different platforms and fields have different requirements and levels of efficiency.
- The NSTD aims to make an absolute reduction in emissions from O&G production of 10% by 2025, 25% by 2027 and 50% by 2030 (against a baseline of emissions in 2018). The absolute reduction means that the targets are not linked to the level of production in the North Sea. Our analysis shows that the natural decline in the ScotNS will be the most significant factor in meeting the goals set out in the NSTD. Emissions from new fields or new developments will slow this decline, unless further abatement activity was to take place. The NSTD assumes that emissions from new developments or future discoveries will need to be kept within the overall industry emissions reduction targets.

**Some of the ways to reduce consumption outside of declining production rely on high levels of investment, such as electrification of platforms**

- These measures that could make a radical difference to emissions – such as using wind energy in the SNS in order to be able to reduce emissions – have large price tags and require co-ordination of different activities.
- It is therefore not certain that they will come forward in the near future.



# 15 Supplementary Analysis: Energy Use in Industry

# Introduction



## Introduction

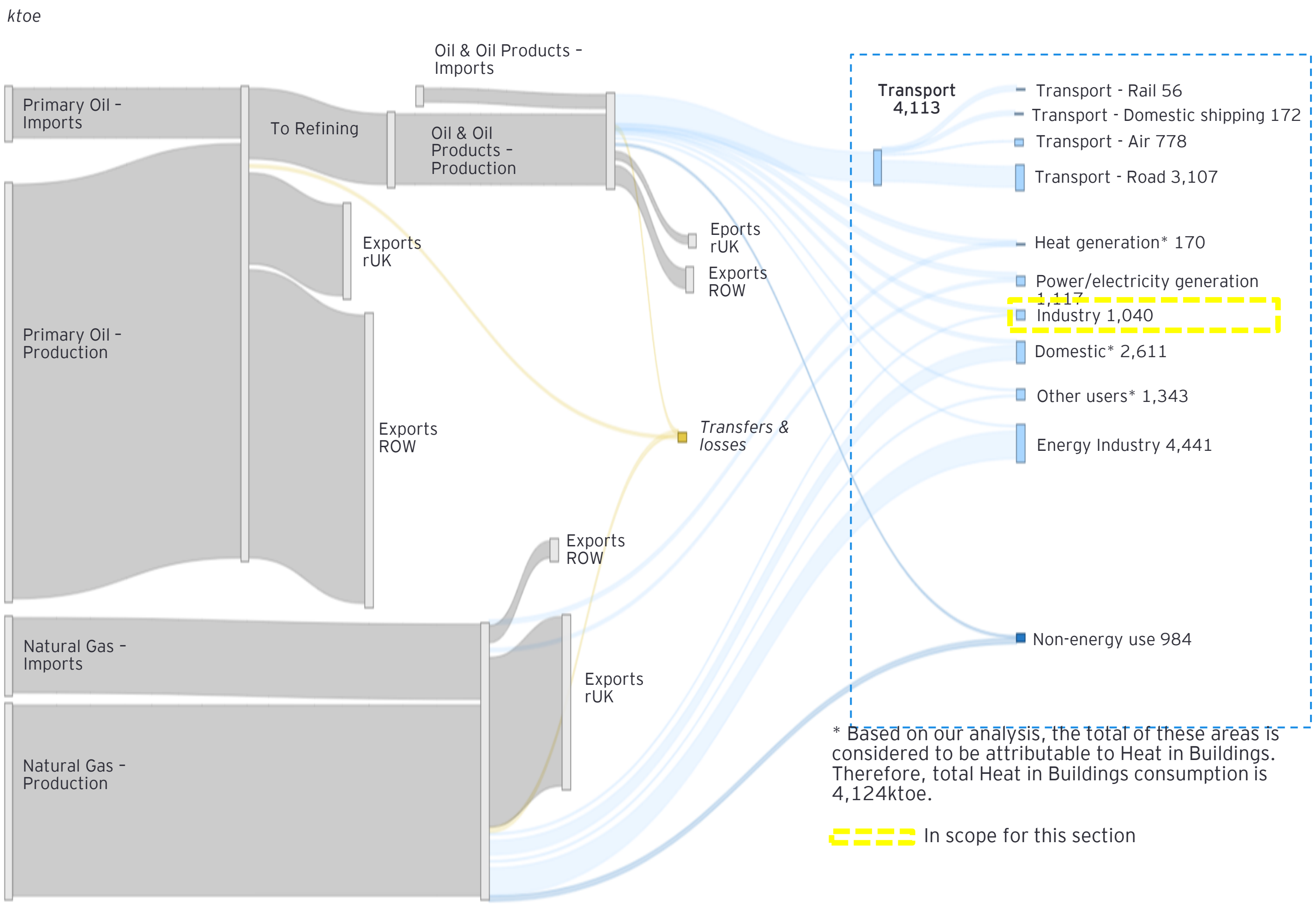
The rest of the manufacturing industry is also a significant consumer of O&G in Scotland, **with 1,039ktoe, or 7% of Scotland's total demand in 2019, related to industry consumption.** This industry figure refers to the use of O&G as an energy source in a wide range of manufacturing processes for goods such as:

- Iron & steel
- Non-ferrous metals
- Mineral products
- Chemicals & petrochemicals
- Mechanical & electrical engineering
- Vehicle production
- Food and beverages
- Textiles and leather
- Paper and printing
- Construction.

Industrial use of O&G includes heat and electricity generation for industrial buildings, as well as heating used in many industrial processes such as smelting, boiling, sterilising, washing, as well as fuel for coke ovens and blast furnaces.

The exact split of consumption in terms of heat for industrial buildings versus heating industrial processes is not clear based on the underlying BEIS data.

**Scottish Energy consumption overview**




* Based on our analysis, the total of these areas is considered to be attributable to Heat in Buildings. Therefore, total Heat in Buildings consumption is 4,124ktoe.

In scope for this section

*Source: SG - Physical commodity balances of oil, gas and petroleum products*
*Digest of UK Energy Statistics (DUKES) 2021 - GOV.UK (www.gov.uk) (commodity balances)*

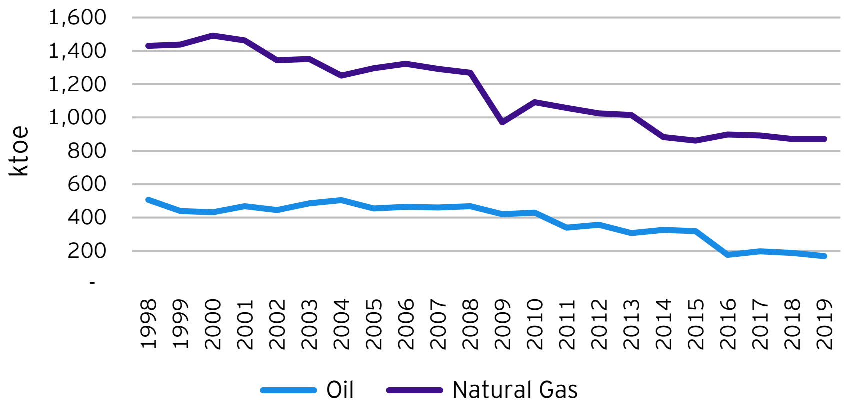
# Use of hydrocarbons & main demand drivers



**The manufacturing industry consumes hydrocarbons in many ways, including heat for industrial buildings, heat for industrial processes, electricity generation and some use of oil products to fuel large machinery.**

The exact mix of hydrocarbons in industry is unclear based on the data available. We know that 83% of industrial demand for hydrocarbons relates to natural gas combustion, and therefore most likely relates to heating – both heating industrial buildings, and heat used for industrial processes (e.g. furnaces, smelting etc). There is also a small portion of oil products used by industry which could include e.g. industrial heating or machine oil.

**Industry demand for hydrocarbons, 1998 to 2019**




*Source: SG Commodity Balances, Exports and Imports of Oil, Gas and Petroleum 2019*

**Demand for hydrocarbons is intrinsically linked to the fate of individual industries.**

Industry demand for hydrocarbons has declined over the last 20 years. This is partly due to general deindustrialisation, which has hit the UK harder than most other countries. It is also because many manufacturers are already making a conscious effort to create greener practices with sustainability and corporate social responsibility in mind. The link between industrial demand for hydrocarbons and wider industry activity is clear from the dip in demand during the 2007-09 financial crisis.

The key drivers for the manufacturing industry's reliance on hydrocarbons today include:

1. Availability of fossil fuels – since its discovery in the 1960's, natural gas has been considered a relatively environmentally clean fuel compared to its predecessor coal. As a result, natural gas, which was available in great quantities from the ScotNS, quickly became the preferred fuel choice for heating industrial buildings and industrial processes. Industrial process heating includes both indirect (e.g. making steam) and direct (e.g. furnaces);
2. Availability of alternative technologies, some of which are still in their infancy. These are explored in more detail later in this section; and
3. Relative price of fossil fuels – which continue to be cheaper than emerging technologies which tend to rely on electrification (for both heat and electricity generation). Although electricity is historically more expensive, it is recognised that many replacement technologies, such as heat pumps, are more efficient and therefore overall costs are more comparable and competitive.

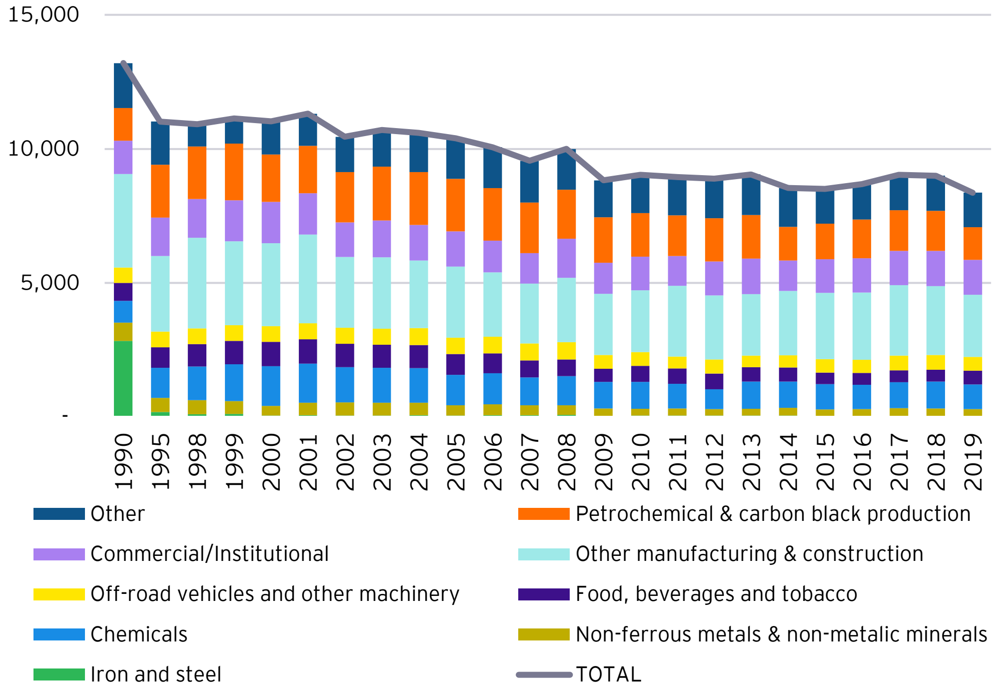
# GHG emissions



## Industry emissions were 18.2% of Scotland's total emissions in 2019

Industry emissions are spread across a wide variety of subsectors (e.g. cement, iron and steel, chemicals) but ultimately all stem from the same sources - fuel combustion (for high and low-grade heat, drying/separation, space heating and on-site electricity generation), process emissions (which arise from a range of chemical reactions e.g. from the calcination of limestone for cement) or off-road mobile machinery.

## Scottish GHG from Industrial Processes, 1990 to 2019




*Source: Scottish Greenhouse Gas statistics: 1990-2019 - gov.scot (www.gov.scot)*

# Replacement technologies



**The Scottish manufacturing industry is very diverse and as such decarbonisation will only be achieved through a combination of different replacement technologies and measures.**

*Heat - Industrial Buildings*

In terms of heating, the following opportunities for technology improvements would likely help meet Scotland's decarbonisation targets:

- Introduction of Industrial heat pumps – However, several barriers still exist regarding the scale of the rollout, issues with retrofit and relative costs of heat pumps versus traditional gas boilers.
- Heat networks – Low / zero carbon heat networks are considered to be more efficient for both domestic properties and industry, than standalone heating systems. These can help to reduce energy costs, however, the cost comparisons are not clear. This is further complicated by the need for mass infrastructure rollout.
- Hydrogen – The ability to blend hydrogen with natural gas (or as a replacement) in the gas grid is uncertain but is considered a key technology for the decarbonisation of industry. This includes both green and blue hydrogen (including CCUS).
- Energy efficiency measures - Improving the energy efficiency performance of factories and industrial buildings plays a pivotal role in the deployment of zero emissions technologies, reducing energy demand and therefore the related energy costs as well as emissions.

*Heat - Industrial Processes*

- Energy efficiency measures such as heat recovery & reuse, as well as improved asset integrity to prevent fugitive emissions.
- Fuel switching from gas to electrification of equipment (e.g. heat pumps instead of traditional gas boilers, use of electricity to facilitate smelting, cleaning, distilling etc).
- Hydrogen and CCUS – as above.

*Power*

The generation mix in Scotland for electricity generation is already mostly decarbonised, with renewables (principally wind) having largely replaced the role of coal and gas in the mix. Principal replacement technologies include onshore and offshore wind, combined-cycle gas turbines and large scale solar.

As the sector continues to decarbonise, further investment in flexible low-carbon technologies, including battery storage, green hydrogen, CCUS and interconnectors, would likely assist accelerate improvements and benefits.

One of the biggest challenges will be making industrial sites retrofit-ready to adopt new low carbon heat and electricity generation technology.

# Energy Use in Industry - Conclusion



**Scottish industry accounts for 7% of O&G consumption but 18% of GHG emissions**

- Some of the emissions come from the industrial processes themselves rather than the consumption of O&G, hence the disparity between these figures.
- Hydrocarbon usage in Industry is mainly natural gas for heating, but also includes some electricity generation and some use of oil products in large machinery.
- Demand for hydrocarbons is intrinsically linked to the fate of individual industries. SG do not want to reduce industrial activity, just make it greener.

**Industry has moved away from coal but this has meant use of other hydrocarbons has become embedded**

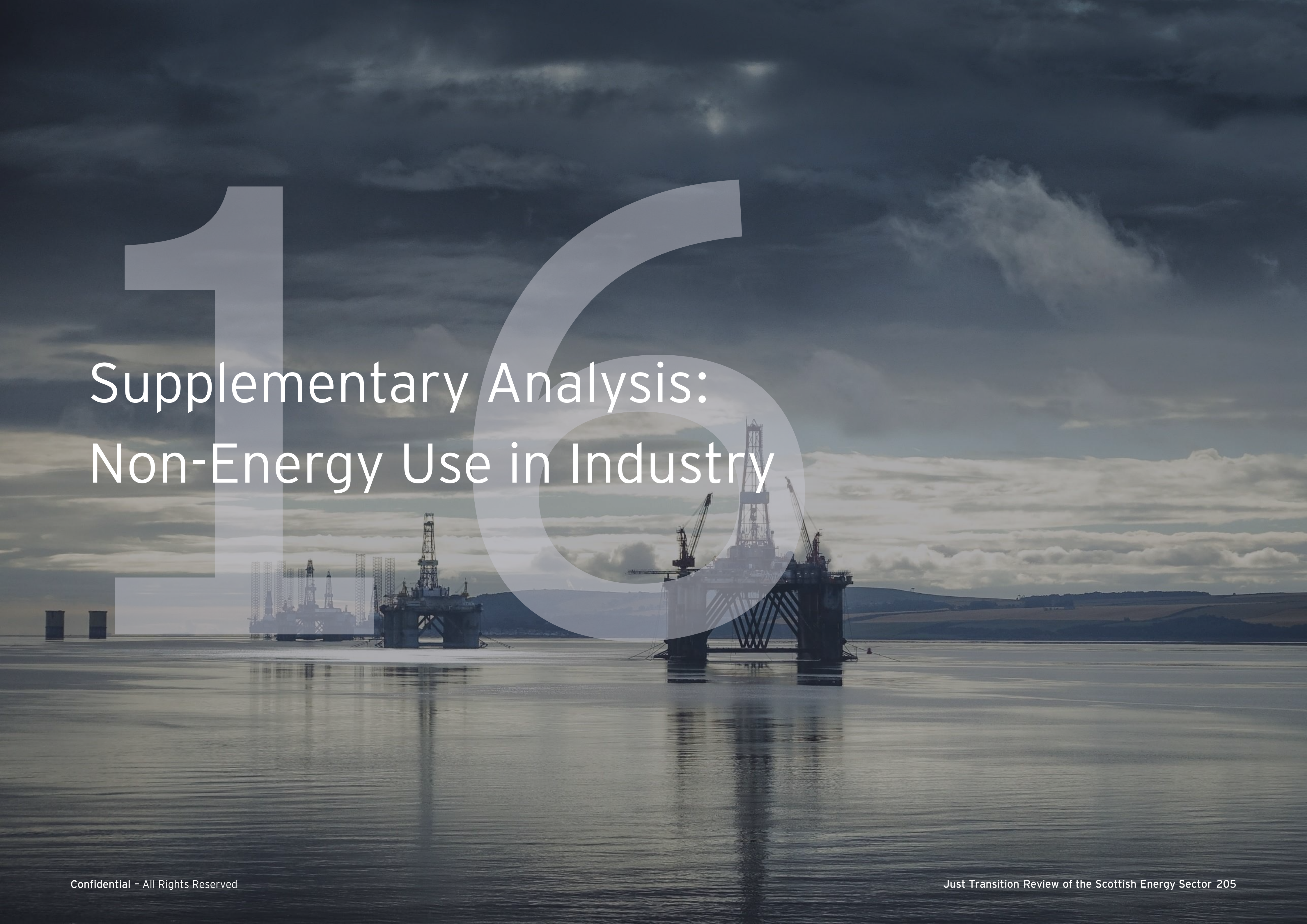
- Availability of gas has meant it is an easily available source for industry to use, and replacement equipment has a long asset life.
- Changing processes and plant power sources is expensive and requires a strong business case to be taken forward.

**Replacement technology for Industry & the Energy Industry utilises the same technology changes as for heat and electricity generation**

- For heat – industrial heat pumps, heat networks, hydrogen and better efficiency measures. These are at an early stage and will require time to come to maturity to become natural choices.
- For electricity generation – progress has already been made in onshore and offshore wind, CCGTs and large scale solar. Further low carbon technologies to be explored include battery storage, green hydrogen, CCUS and interconnectors.
- Firms will be able to use these forms of energy directly or to contract with firms offering lower carbon generation either close to the industrial site or even further.

**One of the biggest challenges will be making industrial sites retrofit-ready to adopt new low carbon heat and electricity generation technology**

- High levels of heating required for some industrial processes are more difficult to decarbonise.
- For these applications, CCUS might be appropriate, as well as those industrial processes that emit carbon.



# 16

# Supplementary Analysis: Non-Energy Use in Industry

# Introduction



## Introduction

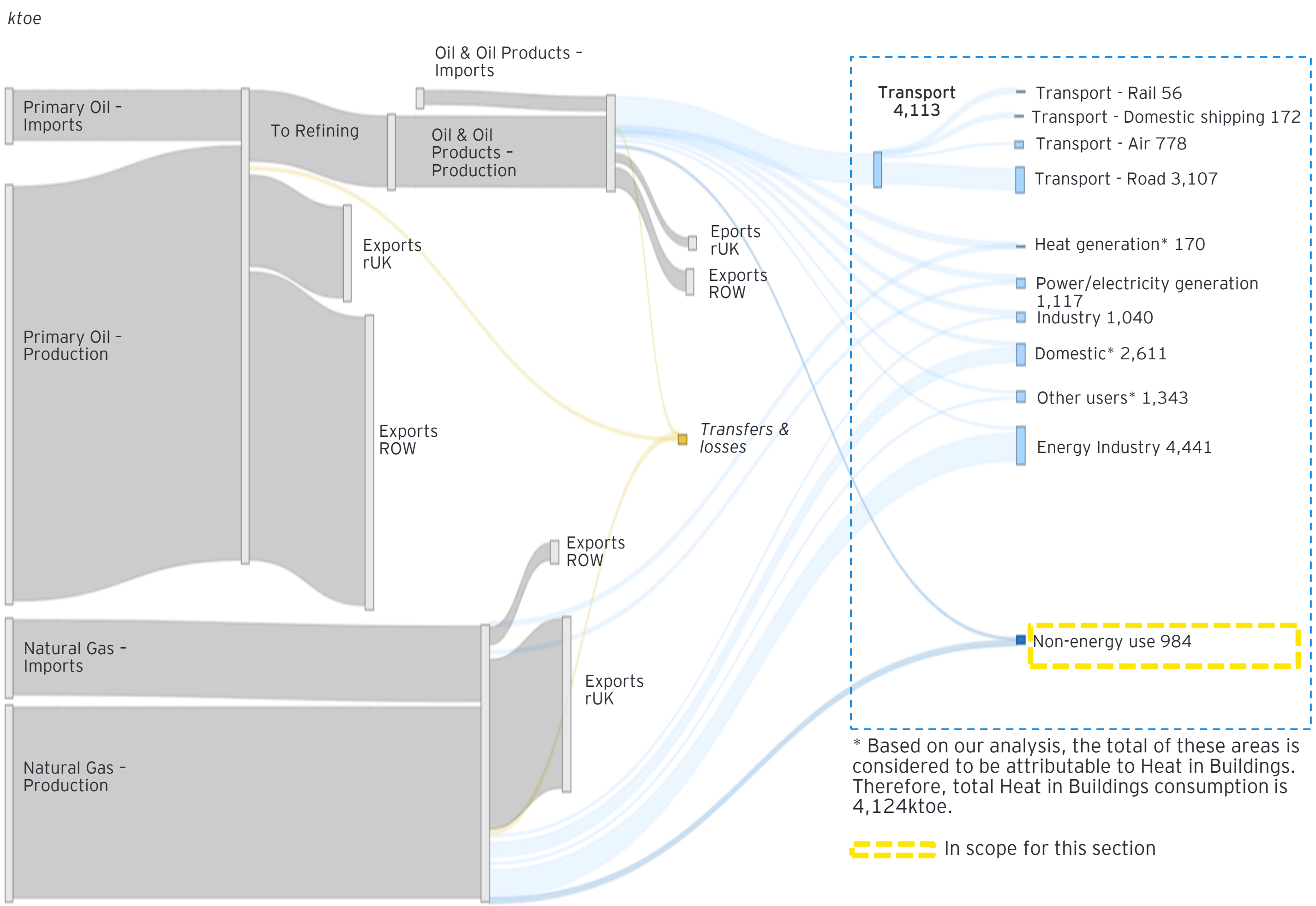
The previous sections have highlighted the primary use of O&G – as a source of energy to fuel various key sectors. However, there other ways we consume O&G in our daily lives which are not energy related and often overlooked. The connection between the petrochemical industry and everyday commodities is less obvious due to the multiple transformations undergone by hydrocarbons before being used in end products.

In Chapter 1 we highlighted that the petrochemical industry in Scotland is actually growing as Grangemouth and Mossmorran facilities continue to invest in and expand the petrochemical side of operations.

These petrochemical plants produce commonly used plastic 'building blocks' such as polyethylene and polypropylene, which are used widely in manufacturing to make anything from sandwich bags and clothing fibres, to pipes and car bonnets. Hydrocarbons are also used to produce many beauty and household goods as well as medical products. More examples are detailed in the International Association of Oil & Gas Producers 2022 report, and the page overleaf.

**Non-energy use accounts for c6% of total Scottish consumption of O&G, the majority of which is feedstock for petrochemical processing plants.**

### Scottish Energy consumption overview




* Based on our analysis, the total of these areas is considered to be attributable to Heat in Buildings. Therefore, total Heat in Buildings consumption is 4,124ktoe.

In scope for this section

*Source: SG - Physical commodity balances of oil, gas and petroleum products*
*Digest of UK Energy Statistics (DUKES) 2021 - GOV.UK (www.gov.uk) (commodity balances)*

# Hydrocarbons are used as a feedstock in the production of many everyday products



**Non-energy use of hydrocarbons mainly relates to petrochemical processes to create plastics, but also as feedstocks for many other everyday commodities**

The majority of non-energy use is feedstock for petrochemical processing of plastics, as summarised in the flowchart on the next page. According to the British Plastics Federation (BPF), 4-6% of total global demand for oil relates to the production of plastic.

Non-energy use of O&G also includes the manufacture of the following commonly used products:

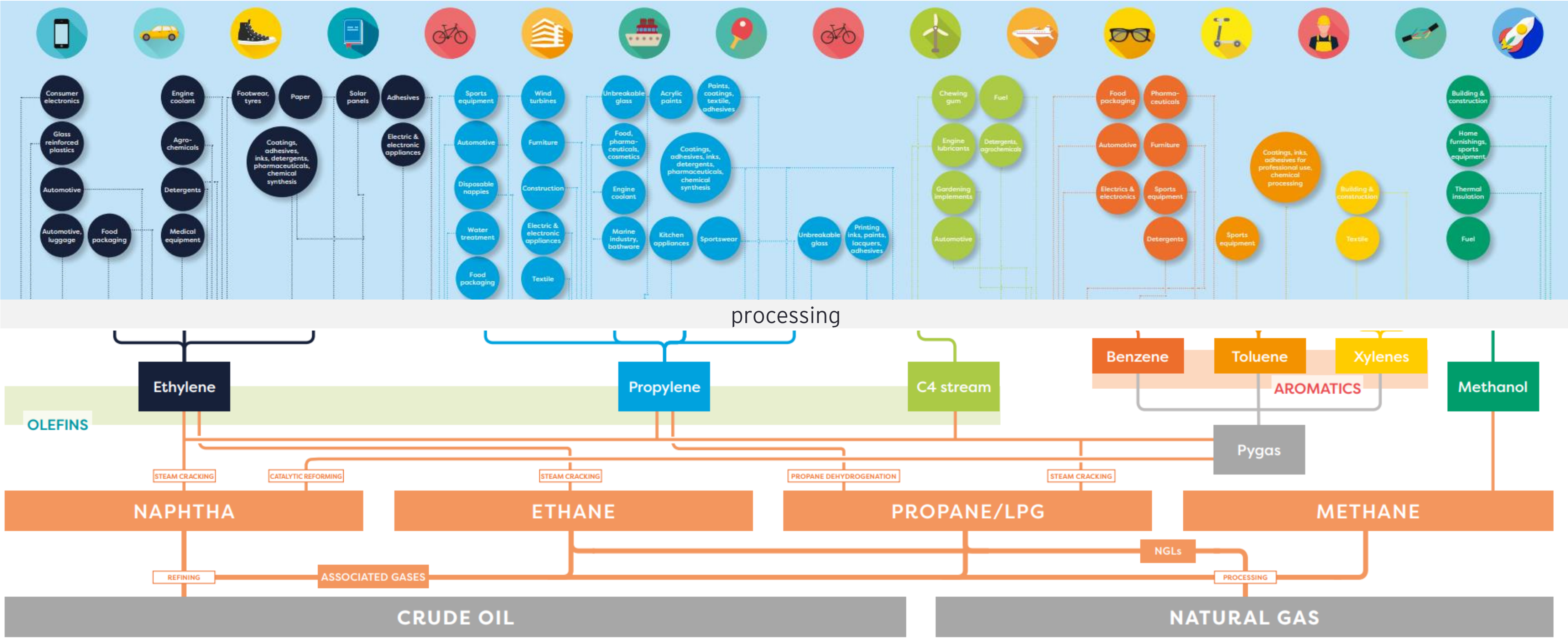
- White spirit and specific boiling point (SBP)/industrial spirits used as paint or commercial solvent, rubber solvents and perfume.
- Lubricating oils (and grease) sold either alone or blended with fixed oils, metallic soaps and other organic and/or inorganic bodies.
- Bitumen, used mainly for road making and building construction materials.
- Petroleum wax (including paraffin wax) used for candle manufacture, polishes, food containers and wrappings.
- Petroleum cokes, used to make electrodes.
- Miscellaneous products including aromatic extracts, defoaming solvents and others.

As well as the use of O&G products to make many every day goods, the manufacturing industry also consumes O&G to fuel production, e.g. large machinery. As this has been covered by the previous Industry section, this section will solely look at the feedstock function of O&G in the petrochemical process, primarily focusing on the production of plastics.

# Hydrocarbons are used as a feedstock in the production of many everyday products



The majority of non-energy use is feedstock for petrochemical processing of plastics, as summarised in the flowchart below:




Source: *[Petrochemistry in Europe]*

# Demand for plastic products has been relatively steady until recent years



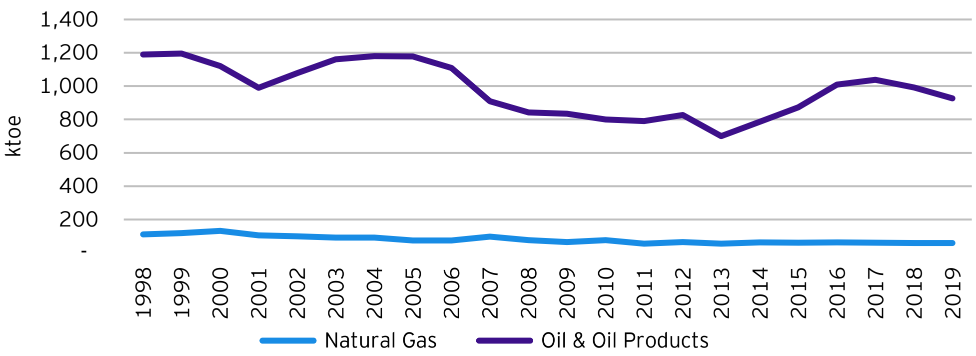
The UK plastics industry is a global leader in its field. It is an important part of the Scottish economy, with the largest UK producer of plastic situated in Scotland.

Figures provided by the BPF show that the plastics industry is the largest employer in UK manufacturing, directly employing roughly 182k people and another 500k indirectly. It has annual turnover of £27bn, with 5,200 companies defined as "manufacturers" of plastic, who process 3.3bn tonnes of plastic a year. As well as producing plastic domestically, the UK is also a net importer of plastic products, importing £13bn of plastic products and exporting £8.4bn each year (BPF, 2017). The scale of these imports is not captured in the "non-energy use" figure in the Sankey diagram.

As discussed on the previous page, the plastic industry has a long, complex, and quite unique, supply chain as it permeates into many other UK manufacturing sectors who depend on plastic products for their own operations.

Non-energy use of hydrocarbons has varied with economic conditions and commodity prices, but remains close to the level that it was 20 years ago. However, recent initiatives to switch from single-use plastics to eco-friendly alternatives such as reusable plastics (e.g. bags for life), recycled plastics (commonly used in packaging) or bioplastics (such as disposable, biodegradable utensils and straws) suggest that the everyday consumer is not against using greener alternatives to conventional plastics, as long as the function is not compromised and relative cost not too high.

**Non-energy use of hydrocarbons, 1998-2019**




*Source: SG Commodity Balances, Exports and Imports of Oil, Gas and Petroleum 2019*

Demand for plastics is intrinsically linked to large industry activity and while some areas, e.g. single use plastics, have already seen reduction in demand through regulation and voluntary consumer behaviour change, other areas are more difficult to replace because industry needs alternatives with the same functionality, e.g. weight, strength and malleability, as the plastics they currently use. There is an opportunity to reshape what our plastic consumption looks like, not only the role of hydrocarbons in the plastic production process, but also the current lifecycle of plastic products as well as demand.

A report by the Green Alliance in 2018 stated that the UK currently does not have an adequate system to capture, reuse and recycle plastic materials, and exports two thirds of its plastic waste to be recycled overseas. The design of a circular economy could recycle more plastic, supply three-quarters of UK domestic demand, and still meet industry demand for raw materials. For example, a circular economy could recycle an additional 2 million tonnes of plastic in the UK.

# Key factors driving O&G demand in Industry



**"The material of a thousand uses".**

In 1907 Leo Baekeland invented Bakelite, the first fully synthetic plastic, in his quest to create a synthetic insulator to meet the needs of the rapidly electrifying US. Bakelite was indeed a good insulator, but Baekeland discovered it was also durable, heat resistant, and could be moulded into almost any shape. It was well suited for mechanical mass production and marketed as "the material of a thousand uses".

Baekeland's discovery encouraged chemical companies to invest in the R&D of new polymers.

**The petrochemical industry saw huge expansion during WW2 as industrial expansion and resilience was needed to supply the resources to fight.**

The main use of oil was of course to produce petrol to fuel trucks, tanks, and airplanes, but the refining process also had useful byproducts that were used as petrochemical feedstocks for other production processes.

The production of synthetic materials was specifically prioritised during the war in an attempt to preserve scarce natural resources and traditional materials such as wood, glass, steel and paper. Nylon was invented in 1935 as a synthetic silk and was used in parachutes, ropes, body armour, helmet liners, and more. Plastic was used as an alternative to glass in aircraft and military vehicle windows. Petrochemical products were also used to make explosives, manufacturing synthetic rubbers for tires, lubricants for firepower and machinery. A 1942 Harper's Magazine article stated that "plastics have been turned to new uses and the adaptability of plastics demonstrated all over again"

The endless possibilities presented by synthetic plastics meant that the surge in production continued after the War ended, and plastics quickly saturated the market, completely changing the way that we manufactured and consumed goods.

**Bio-based plastics have actually been around longer than synthetic plastics, but uses were limited compared to oil-based plastics, which were also much cheaper and easier to mass-produce.**

Ancient MesoAmerican cultures were known to have used natural latex to make rubber balls and bands, sandals and to waterproof their clothing. More recent bio-based plastic inventions in the 1800s included Parkesine and Galalith, which were both used for small objects such as buttons and pens, but were limited in use due to the fact they could not be moulded and were not particularly durable.

Since these early discoveries, bio-based plastics were repeatedly overshadowed by developments in the application of synthetic plastics & the abundance of cheap oil supply. For example, Henry Ford used to use bioplastics made from soy beans for some car parts until after WW2 when cheap oil supply meant that synthetic plastics were the preferred choice. W.R. Grace, an American chemicals company, applied for several patents in the 1950s to see if short-chain and medium-chain polymers polyhydroxyalkanoate and polyhydroxybutyrate could be produced from microbes and bacteria on a commercial scale, but lost interest because of cheap oil.

Research into bio-based plastics and bio-alternatives to other petrochemical products has been revisited over time, normally as a result of spikes in global oil prices, but has not been properly prioritised until more recent years when people have started to recognise the significant environmental impact that our petrochemical consumption has.

# GHG emissions story is more complex



**There are additional emissions considerations re. plastic usage – not as simple as looking at emissions from the production process.**

According to a 2021 study by the Kleinman Center for Energy Policy, only 35% of potential total emissions from petrochemicals are released during the production process. Petrochemicals Europe, the industry voice of the European Chemical Industry Council claim that the European chemicals industry has a strong record of cutting its GHG emissions relating to production and has successfully decoupled its GHG emissions from production growth – reducing GHG emission by nearly 60% while increasing production by 84% between 1990 and 2017.

The majority of the potential emissions are actually trapped within the plastic products and become an issue when the plastics and other petrochemical products are disposed of. At the end of their life, plastics can either be recycled, sent to landfill, or incinerated. The obvious preference from an environmental perspective is to recycle, however, the Department for Environment, Food and Rural Affairs (DEFRA) reported that only 44.2% of plastic waste in the UK was recycled in 2021. There are ongoing debates about the pros and cons of landfill versus incineration of plastic waste. Plastics are very stable and do not break down in landfill meaning there is no release of harmful GHGs into the atmosphere unlike with burying other household waste. However, this option contributes massively to the global waste crisis and is not sustainable in the long term.

The main argument for incineration is that the burning of plastics generates a lot of heat which can be harnessed by EfW plants and used to heat domestic homes and business. According to the Environmental Services Association (ESA), it is "better to recover energy than sending it to landfill", and SG has plans to build nine new incinerators over the next five years. However, there are health concerns surrounding the burning of plastics and other household waste, and the emissions impact is significant. Burning waste to produce electricity can produce more than ten times the amount of carbon emissions than average Scottish grid electricity generation.

**Plastics can actually help to reduce emissions as well as enable other sectors to decarbonise.**

Although the disposal of plastic products has negative and widely discussed carbon implications, plastic products can actually enable some energy savings and reduce carbon emissions during their life-cycle.

For example, insulation materials help to reduce the emissions from heat in buildings, and plastic packaging materials can help to reduce food losses and waste. Petrochemicals Europe argue that the petrochemical industry actually enables other industries to reduce their own carbon footprint because products derived from petrochemicals are key for other industries to innovate their own low-carbon technologies. Examples include plastics being used in the manufacture of windmills and wind turbines, solar panels and electric car parts.

The role that the petrochemical industry, specifically plastic production, plays in total emissions is a complicated one and it is very difficult to quantify the net carbon impact after the manufacturing process.

**Key conclusion**

There are more complex emissions implications of the plastic industry than just those released during manufacturing.

The majority of the potential emissions from plastics are trapped within the product and become an issue when burned at the end of its lifecycle.

On the plus side, plastics versatile functionality can be used to reduce emissions and enable other sectors to decarbonise.

# Replacement technology



## Replacement technology is still in its infancy

Plastic can either be 'synthetic' or 'bio-based'. Synthetic plastics are derived from crude oil, natural gas or coal, while bio-based plastics come from renewable products such as carbohydrates, starch, vegetable fats and oils, bacteria and other biological substances.

The vast majority of plastic in use today is synthetic because of the ease of manufacturing methods involved in the processing of crude oil. However, growing demand for green alternatives is driving a need for newer plastics made from renewable resources.

For example, a study published in the journal Science in August 2020 showcased the discovery of a previously unknown way that bacteria can produce the chemical ethylene as a by-product of metabolising sulphur. Some manufacturers have made more progress in introducing bioplastics than others – for example Vegware plant-base cutlery, or compostable waste bags. However, this is due to the end use, and the introduction of bioplastics is a more challenging task for manufacturers who require more durable plastics.

Replacement technology is also more developed for some other non-energy uses of hydrocarbons, for example paraffin wax can be replaced with beeswax and soy wax, and recent studies have explored the use of lignin, one of the most abundant natural polymers present in plant materials, as a potential bio-alternative to the bitumen currently used in asphalt and other construction materials. That being said, lignin is only a "partial" replacement for bitumen used as the binder in asphalt, and is commonly used in combination with bitumen rather than as a full substitute.

A report by Scottish Enterprise in 2021 highlights the potential of bio-based production through the growth of sugar beet, as extracted sugar can be used in the production of ethanol as a substitute for petroleum-based chemicals in a range of products.

**While plastics from renewable resources are now being developed, their current market penetration is not high. This is because replacement technology for bio-based plastics which match the performance of many currently used plastics is still in early stages of development.**

**Currently, petrochemical feedstocks are a by-product of existing O&G operations & the introduction of bio-alternatives could require additional processing. The full lifecycle of bio-alternatives needs to be considered to ensure emissions are actually reduced.**

**The production of bio-alternatives can have additional emissions implications that must be taken into account.**

Bio-based plastics are generally considered to be more eco-friendly than traditional plastics, however, a replacement technology does not always result in a reduction in emissions.

A 2010 study from the University of Pittsburgh found that bio-based plastics are not a greener alternative when the materials' full life cycles were taken into consideration. The study compared seven traditional plastics, four bioplastics and one made from both fossil fuel and renewable sources. The researchers determined that bioplastics production resulted in greater amounts of pollutants due to the fertilizers and pesticides used in growing the crops, and the chemical processing needed to turn organic material into plastic.

There are similar challenges with bio-alternatives for other non-plastic products. For example, due to its complicated structure the production of lignin requires it to be heated to temperatures of c125° C to make it viscous, while bitumen is a by-product of pre-existing crude oil processes. It could be argued that the use of lignin as a green alternative to bitumen is only viable if the additional processing is fuelled by green power, and if the more complex production process does not in itself have adverse effect on environment in terms of carbon emissions.

There are concerns with the use of soy as a green-alternative, both in food products and as a replacement for paraffin wax. Without proper safeguards, various aspects of soy production generate GHGs that contribute to climate change. Tropical countries like Brazil, Argentina and Paraguay face emissions from deforestation and area conversion. The Brazilian Government previously estimated that carbon emissions associated with the soy industry were equivalent to more than half the total emissions from the UK in 2009.

# Non-energy use in Industry - Conclusions



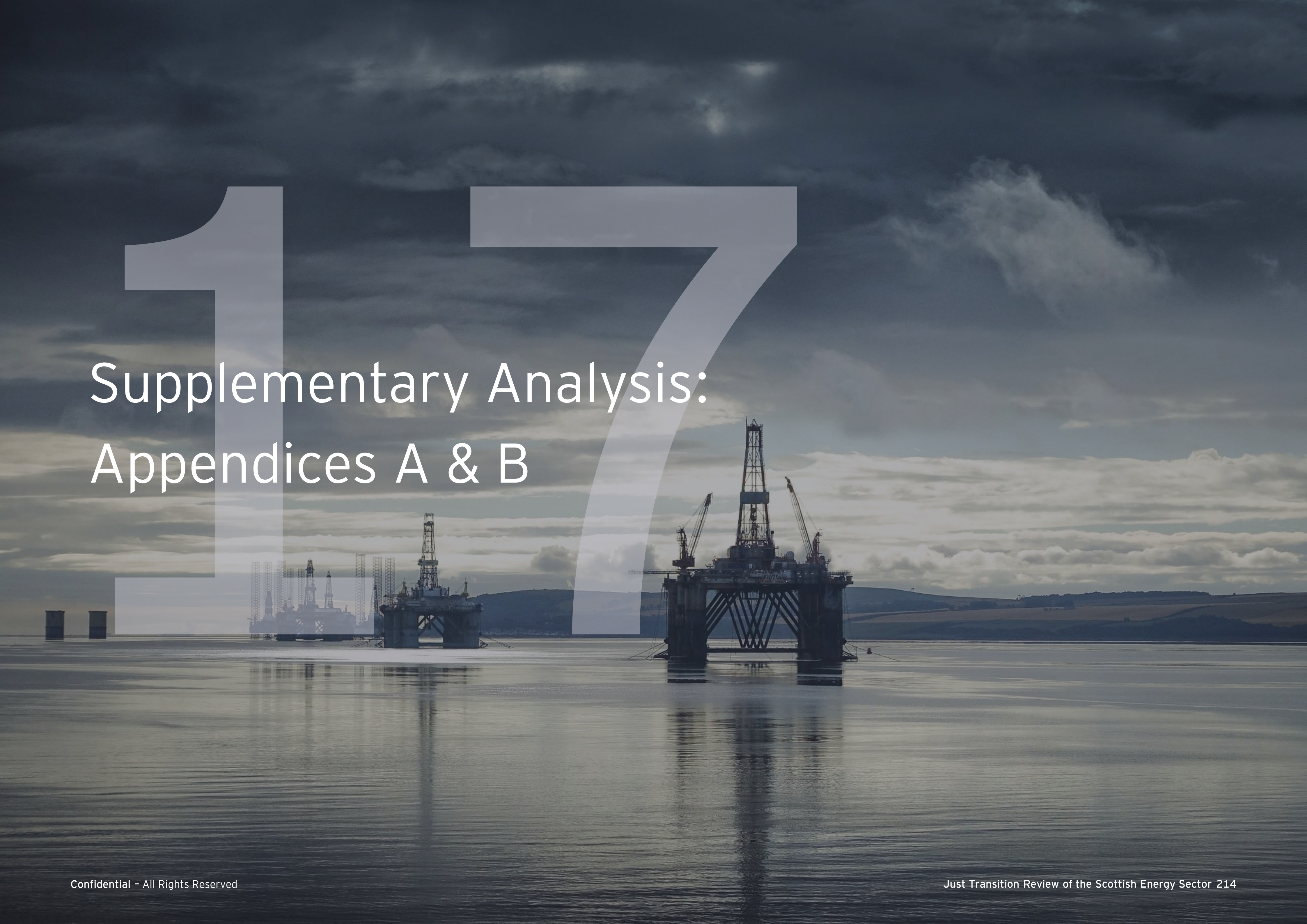
**Non-energy use accounts for 6% of total O&G consumption, but we consume significantly more products derived from hydrocarbons than this figure suggests, as final products are imported from elsewhere. The plastics industry alone imports roughly £13bn of product per year**

**Non-energy use of hydrocarbons mainly relates to petrochemical processes to create plastics, but also as feedstocks for many other everyday commodities such as wax, lubricants and white spirits**

- It is hard to quantify the emissions impact of non-energy use because there are more complex emissions implications of the plastic industry than just those released during manufacturing.
- The majority of the potential emissions from plastics are trapped within the product and become an issue when burned at the end of its lifecycle.
- According to DEFRA, We only recycle c44% of our plastic waste, with the rest being sent to landfill or incineration.
- Incineration of plastic has significant negative emissions impact, but can be used to harness heat in EfW plants.
- On the plus side, plastic's versatile functionality can be used to reduce emissions and enable other sectors to decarbonise.

**While plastics from renewable resources are now being developed, their current market penetration is not high. This is because replacement technology for bio-based plastics which actually match the performance of many currently used plastics is still in early stages of development. (e.g. weight, durability and malleability)**

**Currently, petrochemical feedstocks are a by-product of existing O&G operations & the introduction of bio-alternatives could require additional processing. The full lifecycle of bio-alternatives needs to be considered to ensure emissions are actually reduced**



# 17 Supplementary Analysis: Appendices A & B

# Appendix A: Heat-specific objectives from SG's Hydrogen Action Plan



The table below sets out the SG's key heat-specific objectives and actions from its draft Hydrogen Action Plan.

| What | How | Timeframe |
|---|---|---|
| **SG will continue to work with SGN and National Grid Gas Transmission to provide evidence on the role gas decarbonisation can play in meeting its targets, and a timeline for resolving uncertainties.** | SG has invested £6.9 million in the H100 Fife project and will continue to support the development of evidence on the potential role of hydrogen in decarbonising heat including the potential expansion phases of the H100 Fife project. | 2021 - 26 |
| | SG will support initial action by SGN on their pathway to converting large segments of their network to 100% hydrogen, wherever those actions are commensurate with keeping options open and limiting consumer costs. | 2021- 26 |
| | SG will undertake a strategic review working with stakeholders, including network companies, local authority and delivery partners, to identify regions and areas most likely to have access to hydrogen in the future, and considered high-potential areas for the use of hydrogen for heat in Scotland. | 2021-22 |
| | SG will work with the Gas Network Operators and UKG to explore opportunities for increasing the blend of up to 20% hydrogen in the existing gas network. | Ongoing |
| | SG will identify ways to support projects which seek to demonstrate renewable hydrogen production and blending in the gas network. | Ongoing |
| **SG will continue to press UKG to take urgent action to facilitate decarbonisation of heat in buildings, in line with its Heat in Buildings Strategy.** | Alongside other action in reserved areas to support delivery of its Heat in Buildings Strategy, SG will urge UKG to expedite progress on amending regulations and legislation to support hydrogen blending, accelerate decisions on the role of 100% hydrogen in the gas grid, and to enable its ambition to maximise volumes of renewable hydrogen in its energy system as quickly as possible. | Ongoing |
| | SG will continue to press UKG to progress the consultation on enabling and requiring hydrogen-ready boilers. | Ongoing |

*Source: [Draft Hydrogen Action Plan (www.gov.scot)]*

# Appendix B: SG and UKG Heat Programmes



## SG Programmes (page 1 of 4)

| Name of programme | Aims | Type of support | Target Audience | Scope |
|---|---|---|---|---|
| **Business Energy Scotland** | Provides support to Scottish SMEs on implementing energy efficiency and heat decarbonisation measures, through energy assessments, highlighting key actions and how to access support further advice and financing. | Advice | Private sector – non-domestic | Energy efficiency and heat decarbonisation measures |
| **Home Energy Scotland** | Provision of Energy Efficiency and Heat Decarbonisation advice and support schemes to the domestic market.<br>The current scheme is Home Energy Scotland, which facilitates range of programmes and initiatives across heat in buildings and beyond (i.e. Fuel Poverty) | Advice | Domestic | Energy efficiency and heat decarbonisation measures |
| **Warmer Homes Scotland** | Makes homes of households living in or at risk of fuel poverty warmer and more affordable to heat by providing energy efficiency and heating measures (including low and zero carbon heating) through a full end-to-end service, including assessment, installation, inspection and follow-up. | Delivery and implementation | Domestic | Energy efficiency and heat decarbonisation measures |
| **Affordable Housing Supply Programme** | Installs zero emissions heating systems in homes delivered through the SG's Affordable Housing Supply Programme.<br>Contributes to the delivery of the procurement, design, and evaluation elements of the Edinburgh Home Demonstrator project (which aims to build approximately 1,000 affordable homes to net zero standards in the Edinburgh City Region). | Delivery and implementation | Registered Social Landlords, Local Authorities, not-for-profits, and private developers | Heat decarbonisation measures |
| **Area Based Schemes** | Provides energy efficiency measures to private households in or at risk of fuel poverty that help to reduce energy usage and costs. | Delivery and implementation | Domestic | Energy efficiency measures |

# Appendix B: SG and UKG Heat Programmes



## SG Programmes (page 2 of 4)

| Name of programme | Aims | Type of support | Target Audience | Scope |
|---|---|---|---|---|
| **Home Energy Scotland Loan and Cashback Scheme** | Helps homeowners make energy and money saving improvements to their home. Interest free loans are funded by SG, the schemes are provided through Home Energy Scotland and managed by the Energy Saving Trust. Funding is available to owner occupiers and eligible registered private sector landlords in Scotland. Cashback scheme aims to overcome upfront cost of measures. | Financial support | Domestic | Energy efficiency measures |
| **Green Public Sector Estate Grant Scheme** | Provides pre-capital support (building surveys, options appraisals, feasibility, business cases) and capital support for installation of energy efficiency and low carbon heat retrofit measures in buildings owned and operated by the public sector.<br>The scheme is targeted at public bodies with no borrowing powers, such as Central Government and associated agencies, NHS, Police, Fire and Rescue, Prisons and Colleges.<br>SG has committed to invest at least £200million into this scheme. | Financial support | Public sector | Energy efficiency and heat decarbonisation measures |
| **Public Sector Non Domestic Energy Efficiency Procurement Frameworks and Project Support Unit** | The programme has two National Procurement Framework Agreements for the provision of Non Domestic Energy Efficiency (NDEE) capital installation for projects under £1m capital and projects over £1m capital for the Scottish public sector. There are a number of pre-approved suppliers for retrofit of public sector and third sector buildings with energy efficiency assets using Energy Performance Contracts to guarantee carbon and costs savings. | Financial support | Public sector | Energy efficiency measures |
| **SME Loan and Cashback Scheme** | Provides interest-free loans from £1,000 to £100,000 to small and medium sized Scotland based enterprises for the installation of energy efficiency measures and renewable energy technologies. SMEs can also receive a cashback grant of up to £20,000 for the installation of renewable and energy efficiency measures. | Financial support | Private sector and not-for-profit | Energy efficiency and heat decarbonisation measures |
| **District Heating Loan Fund** | Provides loans aimed at promoting communal heating solutions including heat networks across Scotland. It will provide competitive fixed rate loans to projects employing net zero emission heat technologies that demonstrate a carbon emissions reduction | Financial support | Public, private sector and not-for-profit | District heating - heat decarbonisation measures |

# Appendix B: SG and UKG Heat Programmes



## SG Programmes (page 3 of 4)

| Name of programme | Aims | Type of support | Target Audience | Scope |
|---|---|---|---|---|
| **Social Housing Net Zero Heat Fund** | Provides total investment of £200 million to support existing social housing landlords across Scotland to deploy low carbon heat and contribute towards heat decarbonisation and fuel poverty objectives, improving Scotland's overall energy efficiency. | Financial support | Registered Social Landlords | Heat decarbonisation, energy efficiency measures and fuel poverty |
| **Heat Network Fund** | Provides total investment of £300 million to support the development and rollout of large-scale zero emissions heat networks. | Financial support | Public, private sector and not-for-profit | Heat decarbonisation measures |
| **HEEPS Equity Loan Pilot** | A pilot programme that helps homeowners and private landlords make energy improvements and repairs to their properties. Able to borrow up to £40k against the value of the property (no more than 50% of market value). There are no ongoing repayments - homeowners only pay back what they have borrowed when they sell the property or when the last applicant dies. | Financial Support | Domestic | Energy efficiency measures |
| **Community and Renewable Energy Scheme (CARES)** | Offers grant funding, advice and support to community groups that want to decarbonise their community buildings by installing low carbon or renewable technologies, such as heat pumps or solar panels. | Financial support and advice | Public, private sector and not-for-profit | Heat decarbonisation measures |
| **Local Heat and Energy Efficiency Strategies (LHEES)** | Aims to establish local authority area-wide plans and priorities for systematically improving the energy efficiency of buildings and decarbonising heat. LHEES sets out long-term approaches to reducing emissions from buildings and tackling fuel poverty by identifying a solution tailored to the local area, as well as identifying zones suitable for the development of heat networks | Delivery and implementation | Public, private sector and not-for-profit | Energy efficiency and heat decarbonisation measures |

# Appendix B: SG and UKG Heat Programmes



## SG Programmes (page 4 of 4)

| Name of programme | Aims | Type of support | Target Audience | Scope |
|---|---|---|---|---|
| **Circular Economy Investment Fund** | Invests £18 million as grant funding to small and medium sized enterprises who are helping to create a more circular economy.<br>Aims at supporting innovative projects that have the ability to deliver carbon savings, leverage investment and create jobs. | Financial support | Private sector – non-domestic | Heat decarbonisation measures |
| **Energy Investment Fund** | Provides flexible investment and debt funding for energy projects in Scotland that will facilitate, catalyse and accelerate Scotland's transition to a low carbon economy, focused on increasing community ownership of energy projects in Scotland (including community stakes in commercial developments) and accelerating the development of commercial low carbon energy projects in Scotland.<br>In 2019-20 a total of £20m was made available for both community energy projects and commercial energy projects. | Financial support | Public, private sector and not-for-profit | Heat decarbonisation measures |

# Appendix B: SG and UKG Heat Programmes



## UKG Programmes (page 1 of 1)

| Name of programme | Aims | Type of support | Target Audience | Scope |
|---|---|---|---|---|
| **Energy Company Obligation** | Under ECO, certain energy suppliers fund the installation of energy efficiency measures in low income and vulnerable households. This UKG scheme helps tackle fuel poverty whilst reducing overall energy demand. | Financial support | Domestic | Energy efficiency, fuel poverty |
| **Green Gas Support Scheme (GGSS)** | A UKG environmental scheme that provides financial incentives for plants producing biomethane via anaerobic digestion which is injected into the gas grid. The GGL, a tax on licensed gas suppliers funds the GGSS. | Financial support | Private and public sector | Heat decarbonisation measures |
| **Renewable Heat Incentive (RHI)** | A UKG scheme which provided funding for the upfront capital costs for certain low carbon technologies, including but not limited to biomass boilers, solar water heating and certain heat pumps. This scheme helped both the domestic and non-domestic market and closed to new applicants on 31 March 2022. | Financial support | Domestic and non-domestic | Heat decarbonisation measures |
| **Warm Home Discount** | One-off payment to help eligible customers with the cost of energy during winter. The scheme aims to help vulnerable and low-income households with their energy bills. | Financial support | Domestic | Fuel poverty |

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# Appendix C - Transmittal letter

**Reliance Restricted**

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## Just Transition Review of Scottish Energy Sector – Chapter 2

23 September 2022

Dear Sir/Madam

In accordance with our engagement letter dated 22 October 2021, we have prepared our report in relation to the Scottish Government's Just Transition review of the energy sector. This report relates to Chapter 2, an assessment of the key drivers of fossil fuel demand in Scotland.

### Purpose of our report and restrictions on its use

This report was prepared on your instructions solely for the purpose of the Scottish Government and should not be relied upon for any other purpose. Because others may seek to use it for different purposes, this report should not be quoted, referred to or shown to any other parties except as permitted under the Engagement Letter. Additionally, we have agreed that you may publish the whole of this report as a single document without amendment or redaction as a portable document format (pdf) file on the world wide web.

In carrying out our work and preparing our report, we have worked on the instructions of the Scottish Government. Our report may not have considered issues relevant to any third parties. Any use such third parties may choose to make of our report is entirely at their own risk and we shall have no responsibility whatsoever in relation to any such use.

### Scope of our work

Our work in connection with this assignment is of a different nature to that of an audit. Our report to you is based on inquiries of, and discussions with, the Scottish Government and Transport Scotland. We have not sought to verify the accuracy of the data or the information and explanations provided by the Scottish Government and Transport Scotland.

This report provides an assessment of the key drivers of demand for fossil fuels and the barriers to and opportunities for significant demand reduction, and the direct and indirect impacts / effects of such demand reduction. Any subsequent policy decisions will be informed by the full package of analysis completed from all of the phases of the project and not just the conclusions of this report.

If you would like to clarify any aspect of this review or discuss other related matters then please do not hesitate to contact us.

Yours faithfully

Ernst and Young LLP