Scottish Government
Riaghaltas na h-Alba

An Official Statistics publication for Scotland

AGRICULTURE, ENVIRONMENT AND MARINE

Revision Notice:

The legislated target value for 2021 was originally specified as a 51.1 per cent reduction in this release. This value was revised from a 51.1 per cent reduction to a 51.2 per cent reduction in October 2024. One derived value is revised in this release; the cumulative value of missed targets in Annex A (Section 33/2/e) has been revised from 4.6 MtCO2e to 4.7 MtCO2e.

Scottish Greenhouse Gas Statistics 2021

There are two measures of greenhouse gases presented in this release:

Source Emissions

A net measure of the actual emissions and removals of greenhouse gases in Scotland. Includes international aviation and shipping.

This measure can be used for UK and international comparisons.

- **41.6 MtCO2e in 2021**
- **Down 49.2% from 1990**
- **Up 2.4% from 2020**

Emissions For Reporting Against Targets

The Committee for Climate Change (CCC) recommended a new method of reporting emissions for the purposes of monitoring performance against targets for the June 2020, and future, publications. This is known as the GHG Account and the calculation is detailed in section C.

Laid before the Scottish Parliament by the Scottish Ministers under section 33 of the Climate Change (Scotland) Act 2009, June 2023. [SG/2023/123.]

- **Down 49.9% from baseline period**

On this adjusted basis, the GHG account reduced by 49.9 per cent between the baseline period and 2021. The Climate Change (Emissions Reduction Targets) (Scotland) Act 2019 specifies a target reduction of 51.2[1] per cent reduction over the same period.

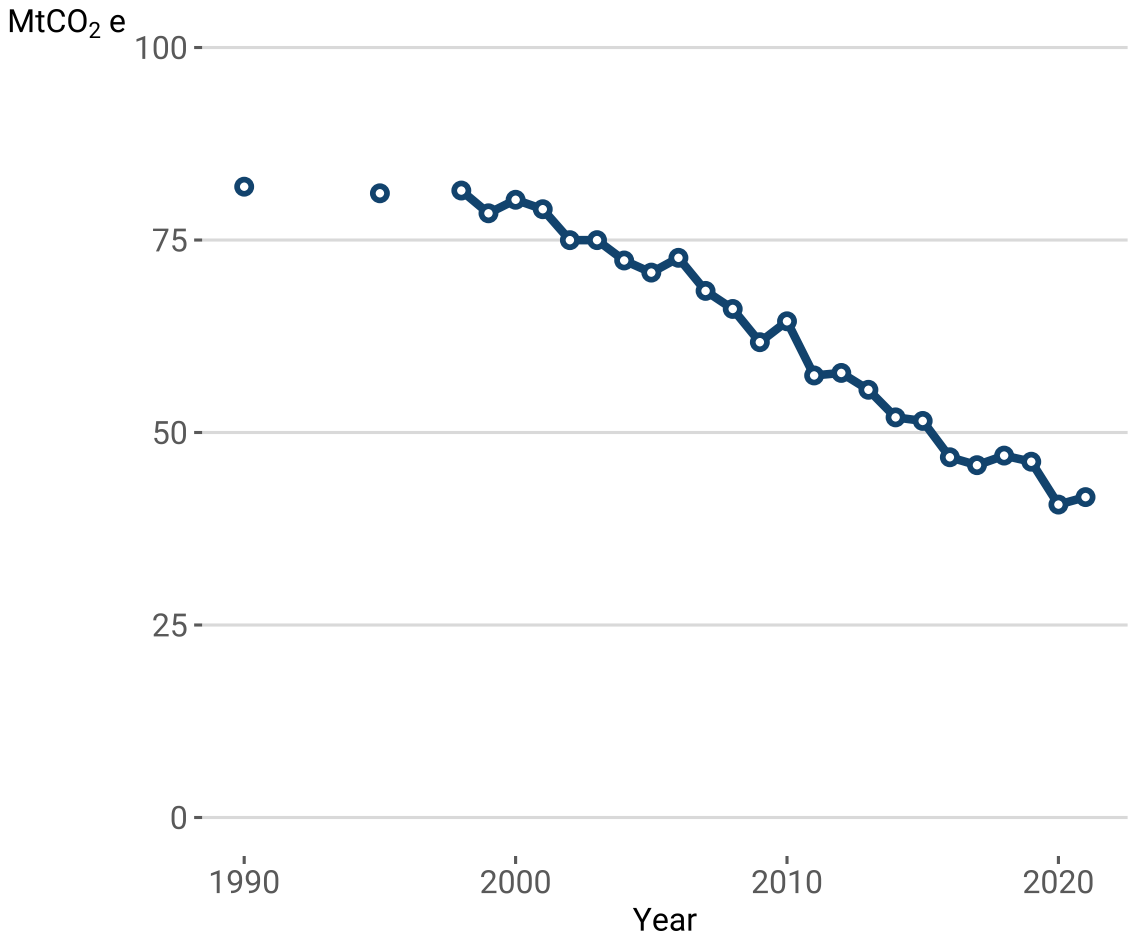
Therefore the interim target for 2021 has not been met.
Figures have been revised since last year's release to incorporate methodological improvements and new data

$MtCO_2e$ refers to million tonnes of carbon dioxide equivalent. This is a consistent measure of assessing the contribution of greenhouse gases to global warming.

The Baseline Period uses 1990 for carbon dioxide, methane and nitrous oxide and 1995 for hydrofluorocarbons, perfluorocarbons, sulphur hexafluoride and nitrogen trifluoride.

[1] The legislated target value was revised from 51.1% to 52.2% in October 2024.

Chart 1: Scottish Greenhouse Gas Emissions, 1990 to 2021.



In 2021, Scottish source emissions of the basket of seven greenhouse gases were estimated to be 41.6 million tonnes carbon dioxide equivalent ($MtCO_2e$). This is 2.4 per cent higher than the 2020 figure of 40.6 $MtCO_2e$; a 1.0 $MtCO_2e$ increase. The main contributors to this increase between 2020 and 2021 were increased emissions in Domestic Transport (+1.1 $MtCO_2e$) following the impact of the COVID lockdown in 2020, and residential (+0.4 $MtCO_2e$) sectors. Emissions reductions were seen in Energy (-0.5 $MtCO_2e$), Business (-0.2 $MtCO_2e$) and International Aviation and Shipping (-0.1 $MtCO_2e$) sectors. All remaining sectors showed relatively modest increases in the latest year.

Between 1990 and 2021, there was a 49.2 per cent reduction in estimated emissions, a 40.3 $MtCO_2e$ decrease. The most significant contributors to this overall reduction were:

- Reduction in Energy Supply emissions (such as power stations) (-16.8 $MtCO_2e$; 77.6 per cent reduction)
- 'Land Use, Land Use Change And Forestry' (LULUCF) reducing its net emissions over the period, reducing by 5.7 $MtCO_2e$ since 1990.
- Reduction in Waste Management emissions (such as Landfill) (-5.0 $MtCO_2e$; a 76.2 per cent reduction)
- Reduction in Business emissions (-4.2 $MtCO_2e$; a 35.3 per cent reduction)

- Reduction in Domestic transport emissions (-2.6 $MtCO_2e$; a 19.3 per cent reduction).

All other sectors have demonstrated a reduction in emissions since 1990.

More details can be found in Section B.

Revisions To Greenhouse Gas Emissions Statistics

Note that as part of this release all of the figures have been revised since the previous publication, to incorporate methodological improvements and new data. Comparing these 2021 figures with the 2020 figures published a year ago will therefore give a different year-on-year percentage change; one which is incorrect and should not be used. The correct percentage changes are given in this publication and associated tables. Details of these revisions can be found later in this statistical release in Section D.

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Section A. Introduction to Greenhouse Gases

Purpose of this Publication

The "Scottish Greenhouse Gas Emissions 2021" Official Statistics publication contains the results of the Scottish Greenhouse Gas Inventory for 1990-2021. The Scottish Greenhouse Gas Inventory is the key data source for understanding the origins and magnitudes of the emissions. The inventory is compiled in line with international guidance from the Intergovernmental Panel on Climate Change (IPCC). Data are reported by source sector (such as energy supply) and by greenhouse gas (such as carbon dioxide). The inventory is also used to report data against targets as required under the Climate Change (Scotland) Act 2009.

Using the Statistics. Which measure to use and when?

The official statistics publication "Scottish Greenhouse Gas Emissions 2021" includes data on two categorisations of greenhouse gas emissions.

- **Estimated net source emissions.** These are sometimes referred to as "territorial" emissions, as they are produced within a country's territory or economic sphere. Section B contains results using this categorisation.
- **GHG account.** These are net source emissions which have been adjusted to remove the effect of successive revisions to the data over time. Section C contains results using this approach.

The publication does not contain information on consumption-based emission estimates. This refers to greenhouse gas emissions which are associated with the spending of Scottish residents on goods and services, wherever in the world these emissions arise together with emissions directly generated by Scottish households, through private heating and motoring. This information was most recently published in March 2023 for the years 1998 to 2019 as part of the Official Statistics publication: "Scotland's Carbon Footprint 1998-2019". Section E contains information on what territorial emissions are excluded from the greenhouse gas inventory.

The table below shows how to use the different categorisations of statistics on greenhouse gas emissions.

	Estimated Source Emissions (Section B)	GHG Account (Section C)
Used for reporting progress against Scotland's Climate Change Targets [1]	No	Yes
Can be compared with EU countries [2]	Yes	No
Can be compared with UK [3]	Yes	No
Includes International Aviation and Shipping	Yes	Yes
Includes North Sea Oil & Gas	No	No
Data on individual greenhouse gases	Yes	No
Data on sectoral emissions	Yes	No
Base Year	**1990**	**Baseline Period (Variable)**

[1] Further information on Scotland's Climate Change Targets can be found in Section C.
[2] Following the inclusion of drainage and rewetting of organic soils into the Scottish inventory, EU comparisons including land use are technically invalid.
[3] Direct comparisons between Scotland and the UK can be made by adding up the results for the four Devolved Administrations separately. The UK figure in this case would exclude offshore emissions.

Which greenhouse gases are reported on and how do they contribute to global warming?

The basket of greenhouse gases consists of carbon dioxide, methane, nitrous oxide, and the four F-gases (hydrofluorocarbons- HFCs, perfluorocarbons – PFCs, sulphur hexafluoride- SF_6 and nitrogen trifluoride- NF_3). These gases are weighted by Global Warming Potential (GWP), so that total greenhouse gas emissions can be reported on a consistent basis. The GWP for each gas is defined as its warming influence relative to that of carbon dioxide over a 100 year period. Greenhouse gas emissions are then presented in *carbon dioxide equivalent* (CO_2e) units. In the case of some of the F-gases, the global warming potential is listed as being within a range of values, due to the gases existing as a variety of isotopes with differing GWPs.

Table 1. List of Greenhouse Gases and their contribution to Scotland's net greenhouse gas emissions, 2021

Name of Greenhouse Gas		Global Warming Potential (GWP) (Conversion factor to carbon dioxide equivalent)	Contribution to Scotland's Net Greenhouse Gas Emissions, 2021 (in $MtCO_2e$)	Percentage of Scotland's Net Greenhouse Gas Emissions, 2021 (in $MtCO_2e$)
Carbon dioxide	CO_2	1	27.5	66.0%
Methane	CH_4	28	10.2	24.5%
Nitrous oxide	N_2O	265	3.0	7.2%
F-gases [2], of which….			0.9	2.2%
• Hydrofluorocarbons	HFC	4 – 12,400	0.8	2.0%
• Perfluorocarbons	PFC	6,630 – 11,100	0.1	0.1%
• Sulphur hexafluoride	SF_6	23,500	0.0	0.1%
• Nitrogen trifluoride	NF_3	16,100	0.0	0.0%
Total Net Greenhouse Gases			41.6	100.0%

The Global Warming Potentials (GWPs) are based on international reporting standards, as set by the Intergovernmental Panel on Climate Change (IPCC)[2].

Section B contains further data on the individual greenhouse gases. Section D contains a more detailed discussion of the causes and impacts of revisions between the 1990-2020 and 1990-2021 inventories.

Reporting of the Baseline Period and 1990

In this publication, a single 1990 Base Year is used for all estimated source emissions (Section B). This year is referred to as "1990" in charts, tables and text.

A different baseline is used for the reporting progress against Scotland's Climate Change Targets, using the GHG account. This is referred to as "Baseline Period" when referring to changes over time in the charts, tables and text.

The Baseline Period for reporting against Climate Change Targets is:

[2] Fifth Assessment Report — IPCC

- 1990 for carbon dioxide carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O)
- 1995 for Fluorinated gases (F gases)[3]: hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), sulphur hexafluoride (SF_6), nitrogen trifluoride (NF_3)

The difference between these definitions of baseline year tend to be small as F gases are a minority contribution to the total emissions in terms of carbon dioxide equivalent.

Within this publication, data are estimated for the Baseline Period; and the years 1990, 1995 and 1998 to 2021.

What are net emissions and carbon sinks?

The emissions reported are the combination of emissions minus removals from the atmosphere by *carbon sinks*. Carbon sinks are present in the 'Land Use, Land Use Change and Forestry' (LULUCF) category, they are mostly associated with the effects of grasslands and forestry to sequester carbon, as well as the carbon stored in wood products. These are known as "removals" as they offset emissions.

Categories

This publication provides the latest estimates of Scotland's greenhouse gas emissions by source from 1990-2021. It uses the 'National Communication' categories, which are the same categories used for the UK report. For the purposes of reporting, greenhouse gas emissions are allocated into categories as follows:

Energy Supply - Emissions from fuel combustion for electricity and other energy production sources, and fugitive emissions from fuels (such as from mining or onshore oil and gas extraction activities). North Sea oil & gas emissions are not allocated to Scotland[4].

Business – Emissions from fuel combustion and product use in industrial and commercial sectors, and F gas emissions from refrigeration and air conditioning in all sectors. Includes industrial off-road machinery

Industrial Processes - Emissions resulting from industrial processes, except for those associated with fuel combustion which are included in the Business sector.

Transport (excluding International Aviation and Shipping) - Emissions from domestic aviation, road transport, railways, domestic navigation, fishing and aircraft support vehicles.

[3] The Kyoto Protocol allows Parties flexibility to choose either 1990 or 1995 as the base year for the industrial gases. Using a 1995 base year is in line with the approach adopted by the UK Government and many EU Member States.

[4] Emissions of GHGs from offshore oil and gas exploration and production are classified within the Greenhouse Gas Inventory as "Unallocated" emissions and not attributed to any of the devolved administrations.

International Aviation and Shipping – This category is called “Exports” in some inventories. Includes emissions from international aviation and shipping.

Public - Emissions from combustion of fuel in public sector buildings.

Residential - Emissions from fuel combustion for heating/cooling and garden machinery and fluorinated gases released from aerosols/metered dose inhalers.

Agriculture - Emissions from livestock, agricultural soils (excluding carbon stock changes which are included in the LULUCF sector), stationary combustion sources and off-road machinery.

Waste Management - Emissions from waste disposed of to landfill sites, waste incineration, and the treatment of waste water.

Land Use, Land Use Change And Forestry (LULUCF) – Emissions/removals of CO_2 from changes in the carbon stock in forestland, cropland, grassland, wetlands, settlements and harvested wood products, and of other greenhouse gases from drainage (excl. croplands and intensive grasslands) and rewetting of soils, nitrogen mineralisation associated with loss and gain of soil organic matter, and fires. Because the impact of biomass harvest on carbon stocks in ecosystems is included in this sector, any emissions of CO_2 from burning biomass (regardless of the country of origin) are excluded from other sectors to avoid double counting them.

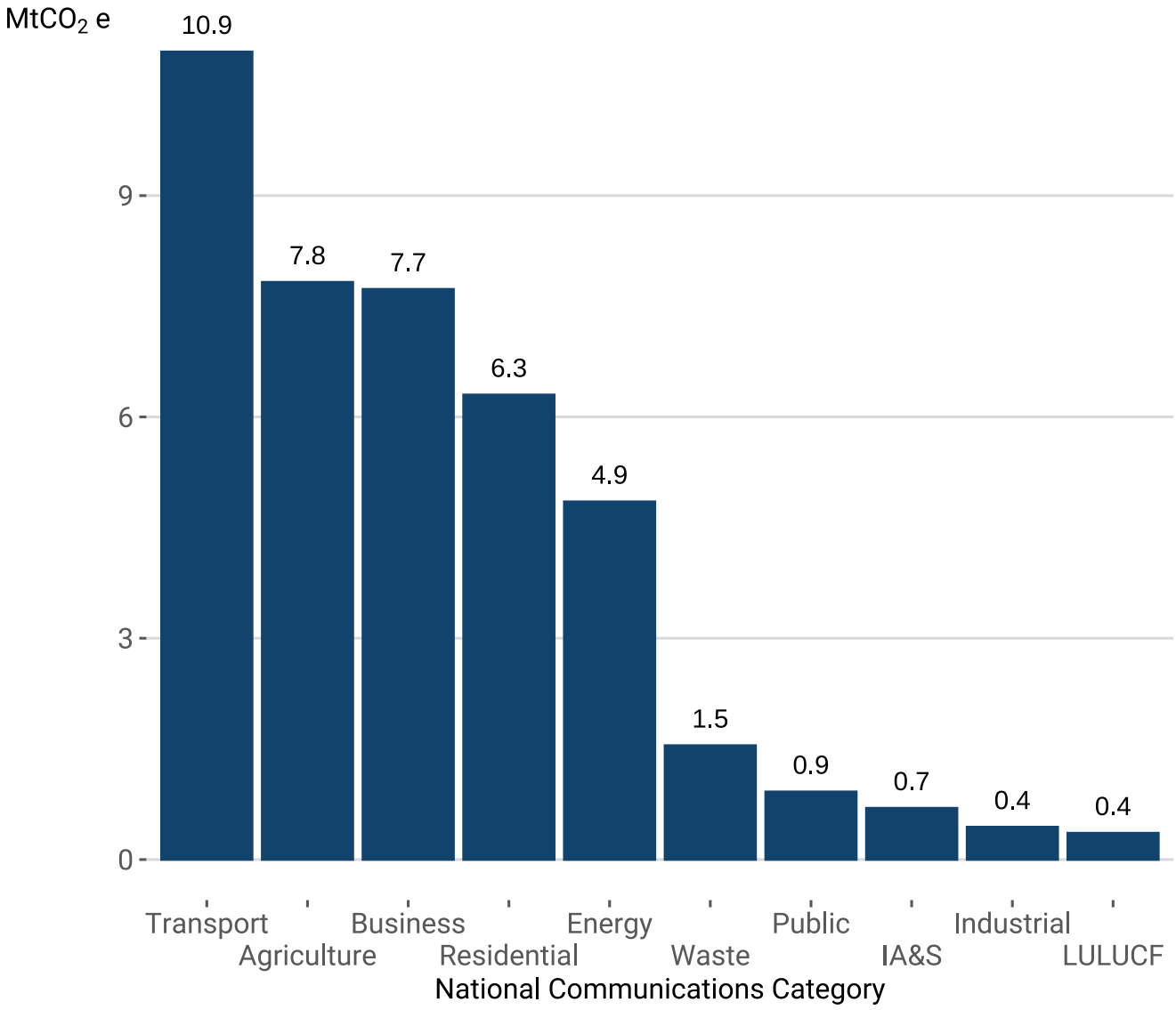
When emissions are reported by source, emissions are attributed to the sector that emits them directly. These high-level sectors are made up of a number of more detailed sectors, which follow the definitions set out by the Intergovernmental Panel on Climate Change (IPCC), and which are used in international reporting tables which are submitted to the United Nations Framework Convention on Climate Change (UNFCCC) every year. Section E contains a more detailed mapping of what is included in each source. It also contains information on which greenhouse gas emissions are excluded from the greenhouse gas inventory and why they are excluded.

Section B. Results – Net Sources of Scottish Greenhouse Gas Emissions

2021 results

Chart 2 presents the net sources and sinks of Scottish Greenhouse Gas Emissions in 2021, grouped by National Communication category.

Chart 2. Scottish Greenhouse Gas Emissions by National Communication category, 2021.



Main points

- In 2021, Domestic transport (excluding International Aviation and Shipping) (10.9 $MtCO_2e$) was the largest source of net emissions, followed by Agriculture (7.8 $MtCO_2e$), Business (7.7 $MtCO_2e$), Residential (6.3 $MtCO_2e$) and Energy Supply (4.9 $MtCO_2e$).

Table 2. Scottish Greenhouse Gas Emissions by Gas and by National Communications Category, 2021. Values in $MtCO_2e$

NC category	Carbon Dioxide	Methane	Nitrous Oxide	Fluorinated gases	Total
Agriculture	1.2	4.6	2.0		7.8
Business	6.8	0.0	0.1	0.8	7.7
Energy Supply	4.4	0.4	0.0		4.9
Industrial processes	0.4	0.0	0.0	0.0	0.4
International Aviation & Shipping	0.7	0.0	0.0		0.7
Land use, land use change and forestry	-4.0	3.7	0.7		0.4
Public	0.9	0.0	0.0		0.9
Residential	6.1	0.1	0.0	0.1	6.3
Transport	10.8	0.0	0.1		10.9
Waste Management	0.0	1.4	0.1		1.5
Total net emissions	**27.5**	**10.2**	**3.0**	**0.9**	**41.6**

Main points

Carbon dioxide was the main greenhouse gas emitted or removed in most sectors, with the exceptions of the Agriculture and Waste Management sectors.

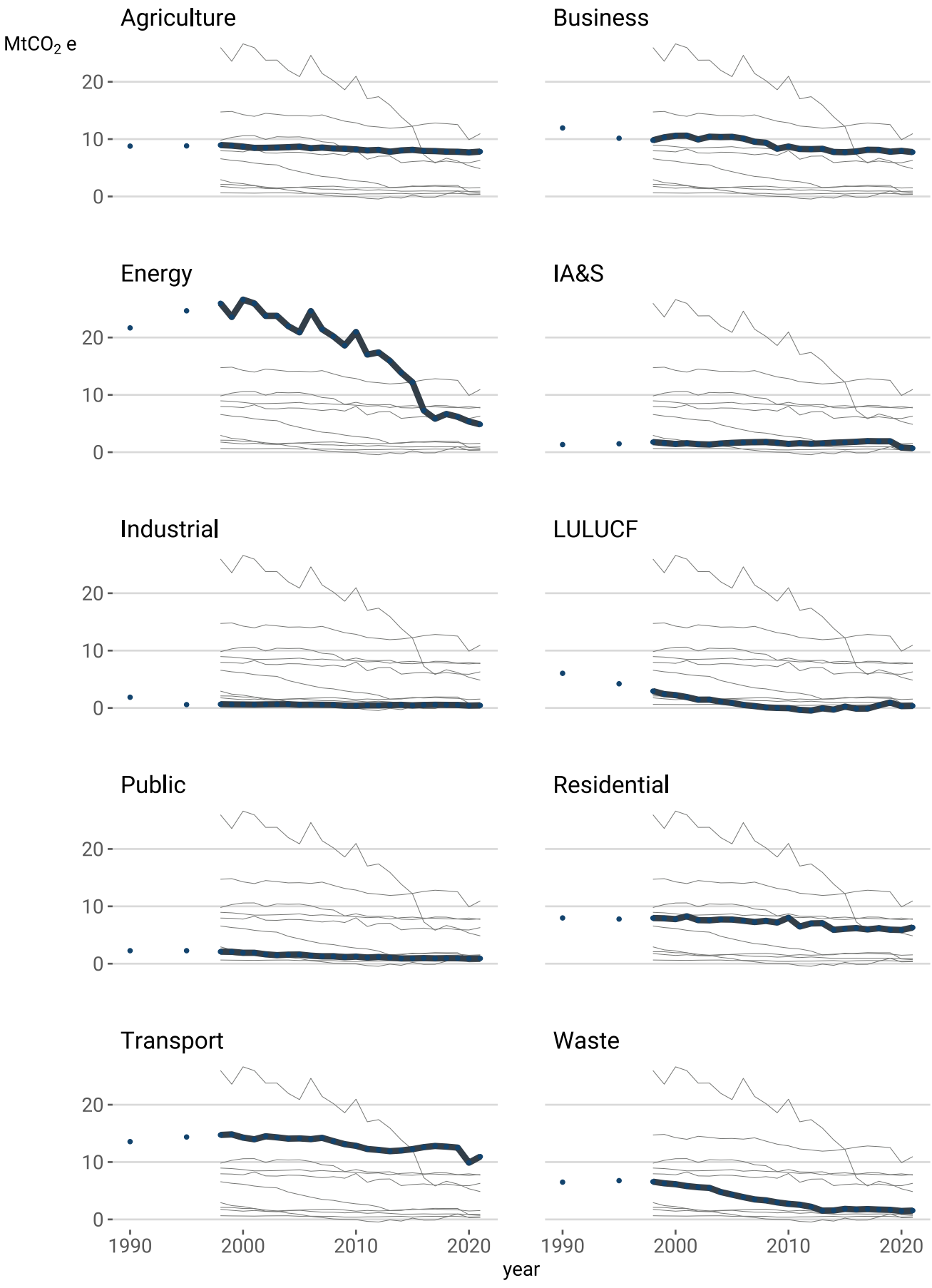
- Methane was the main net gas emitted in the Agriculture (4.6 $MtCO_2e$), followed by nitrous oxide (2.0 $MtCO_2e$) and carbon dioxide (1.2 $MtCO_2e$).
- Almost all emissions in the Waste Management sector were emitted in the form of methane (1.2 $MtCO_2e$).

Where F gases are emitted, they have been in relatively small amounts via the Business and Residential sectors.

Key Trends By national communications category.

Chart 3 presents the main sources of Scottish Greenhouse Gas Emissions from 1990 to 2021, broken down by National Communication categories.

Chart 3: Greenhouse Gas Emissions in Scotland, by National Communications category 1990 to 2021.



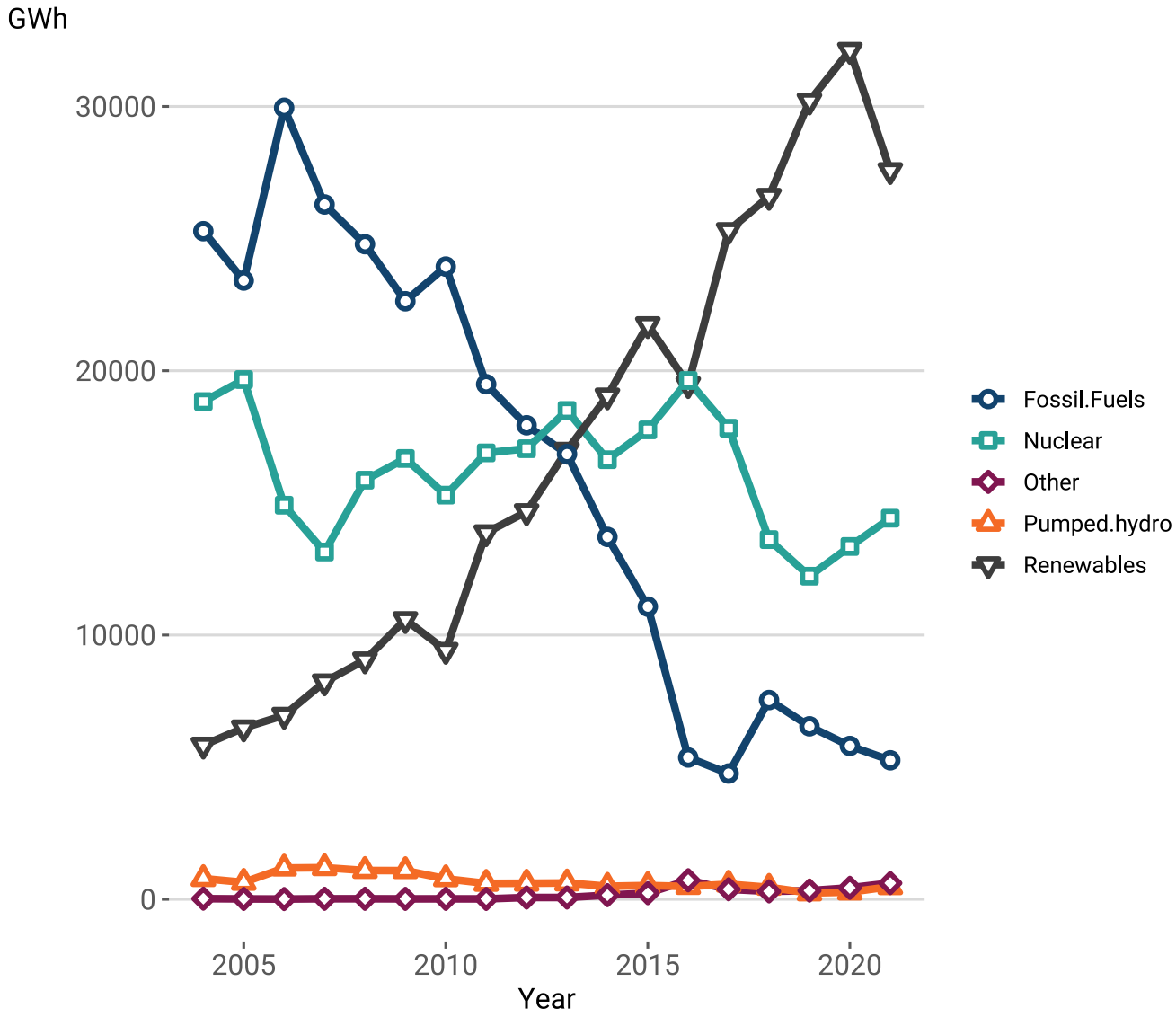
Main Points

All sectors exhibit a general downwards trend between 1990 and 2021:

- Energy Supply emissions have seen the largest decrease in GHG emissions (-16.8 $MtCO_2e$, a reduction of 77.6 per cent) followed by net LULUCF emissions (-5.7 $MtCO_2e$, a reduction of 94.1 per cent), Waste Management (-5.0 $MtCO_2e$, a reduction of 76.2 per cent), and Business (-4.2 $MtCO_2e$, a reduction of 35.3 per cent).

Chart 4 shows how the generation of Scotland's electricity has changed over time. Emissions from the electricity supply sector (such as power stations) are associated with these changes.

Chart 4. Generation of Electricity by Fuel, Scotland, 2004 to 2021. GWh of Electricity Generated by Year



Data obtained from Scottish Energy Statistics Hub[5]

[5] Scottish Energy Statistics Hub (shinyapps.io)

Main Points

Overall, the gigawatt-hours of electricity generated in Scotland decreased by 7.0 per cent between 2020 and 2021. Renewables were the single largest source of electricity generated in Scotland in 2021 at 57.0 per cent, followed by nuclear generation at 29.8 per cent with fossil fuel generation making up only 10.9 per cent of total electricity generation.

Long term (1990 to 2021) and short term (2020 to 2021) trends by category

Chart 5 shows how emissions have changed between 1990 and 2021 in all source categories. Chart 6 shows how emissions have changed between 2020 and 2021.

Chart 5. Change in net emissions by National Communication category between 1990 and 2021

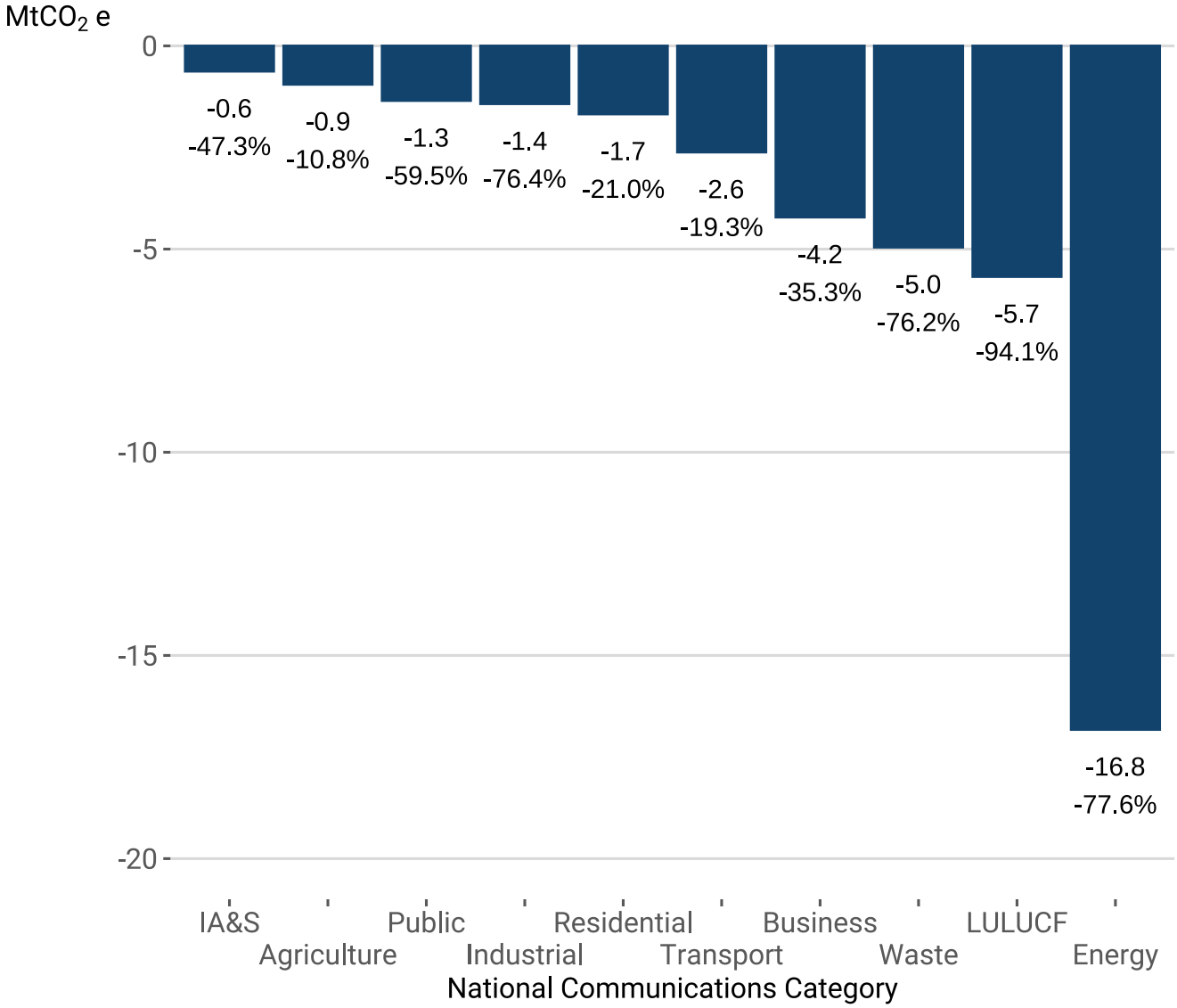
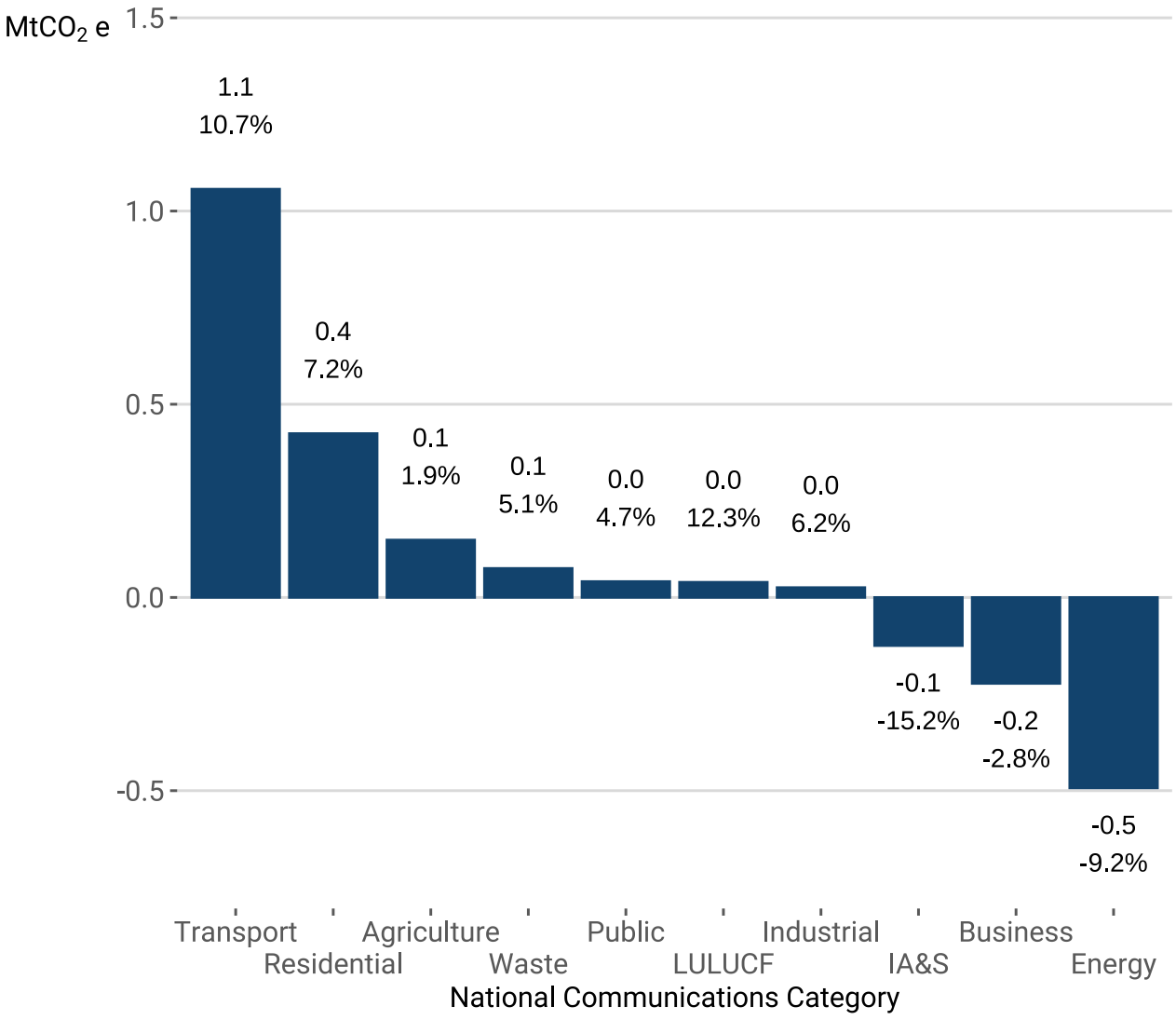


Chart 6. Change in net emissions by National Communications category between 2020 and 2021.



Total Emissions

Overall, there has been a 40.3 $MtCO_2e$ (49.2 per cent) decrease in net emissions between 1990 and 2021. Total emissions have increased by 1.0 $MtCO_2e$ (2.4 per cent) between 2020 and 2021.

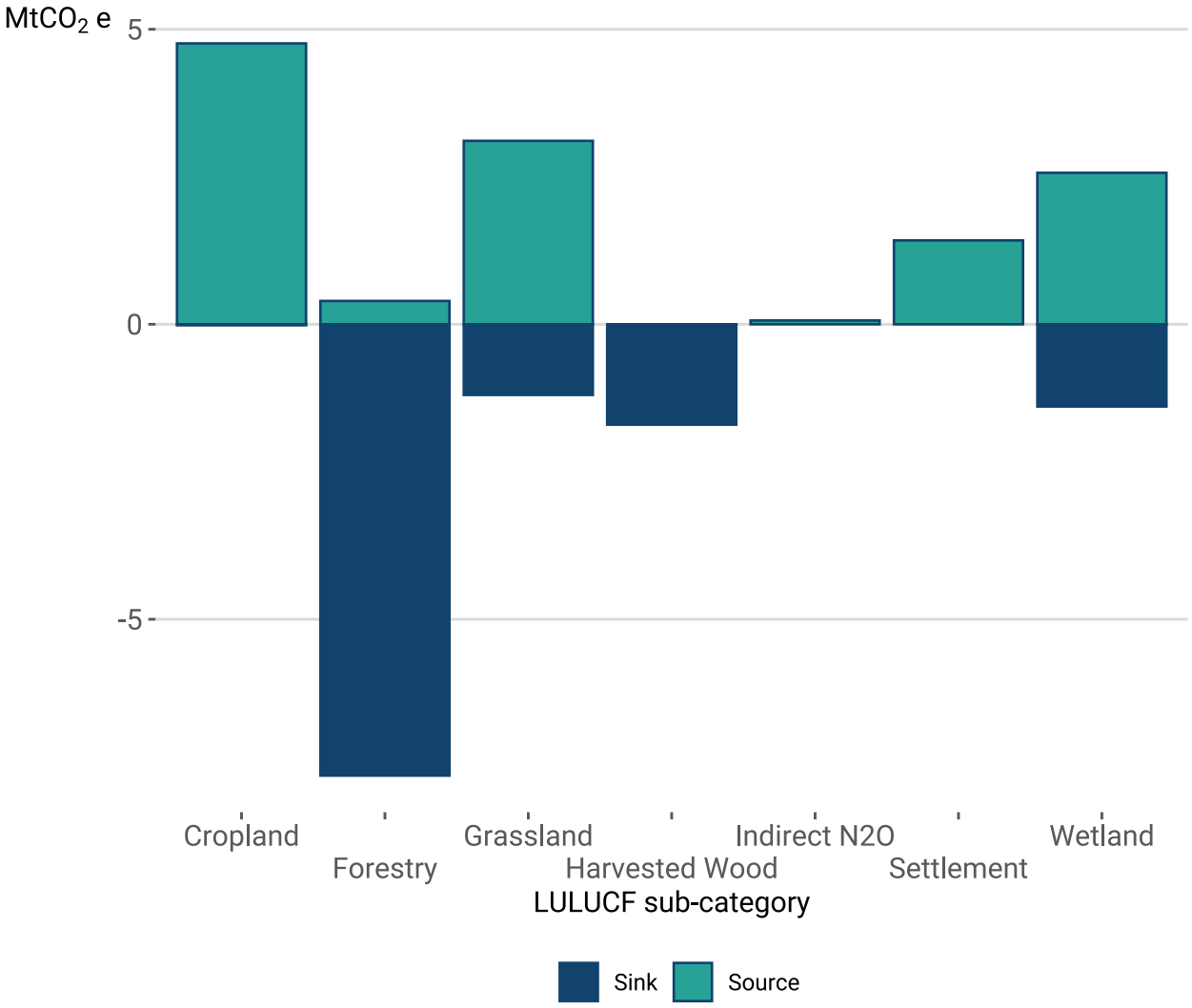
Land Use, Land Use Change And Forestry (LULUCF)

LULUCF is a net source of GHG emissions in Scotland in 2021, emitting 0.4 $MtCO_2e$ of net emissions. In 1990 net emissions were 6.0 $MtCO_2e$. In the periods 2011-2014, and 2016-2017, LULUCF exhibited net removals of greenhouse gases in Scotland.

Chart 7 below shows, for each sub-sector of the land use sector in 2021, that the net total includes some significant emissions sources, and equally significant 'sinks' which remove carbon dioxide from the atmosphere. Forestry and the related

'harvested wood products' categories are net sinks of GHG emissions in 2021, removing a net amount of GHG emissions of 7.3 $MtCO_2e$ and 1.7 $MtCO_2e$ respectively. All other land use types are net sources of greenhouse gas emissions, with croplands, grassland, settlements and wetland showing substantial net emissions to the atmosphere.

Chart 7. Sources and sinks of GHG emissions in Land Use, Land Use Change and Forestry, Scotland, 2021



Domestic Transport

Domestic Transport has consistently been a large part of Scotland's emissions. This sector showed dramatic reduction in emissions associated with the COVID-19 lockdown in 2020 (-2.6 $MtCO_2e$) but have rebounded in the latest year by 1.1 $MtCO_2e$.

Energy Supply

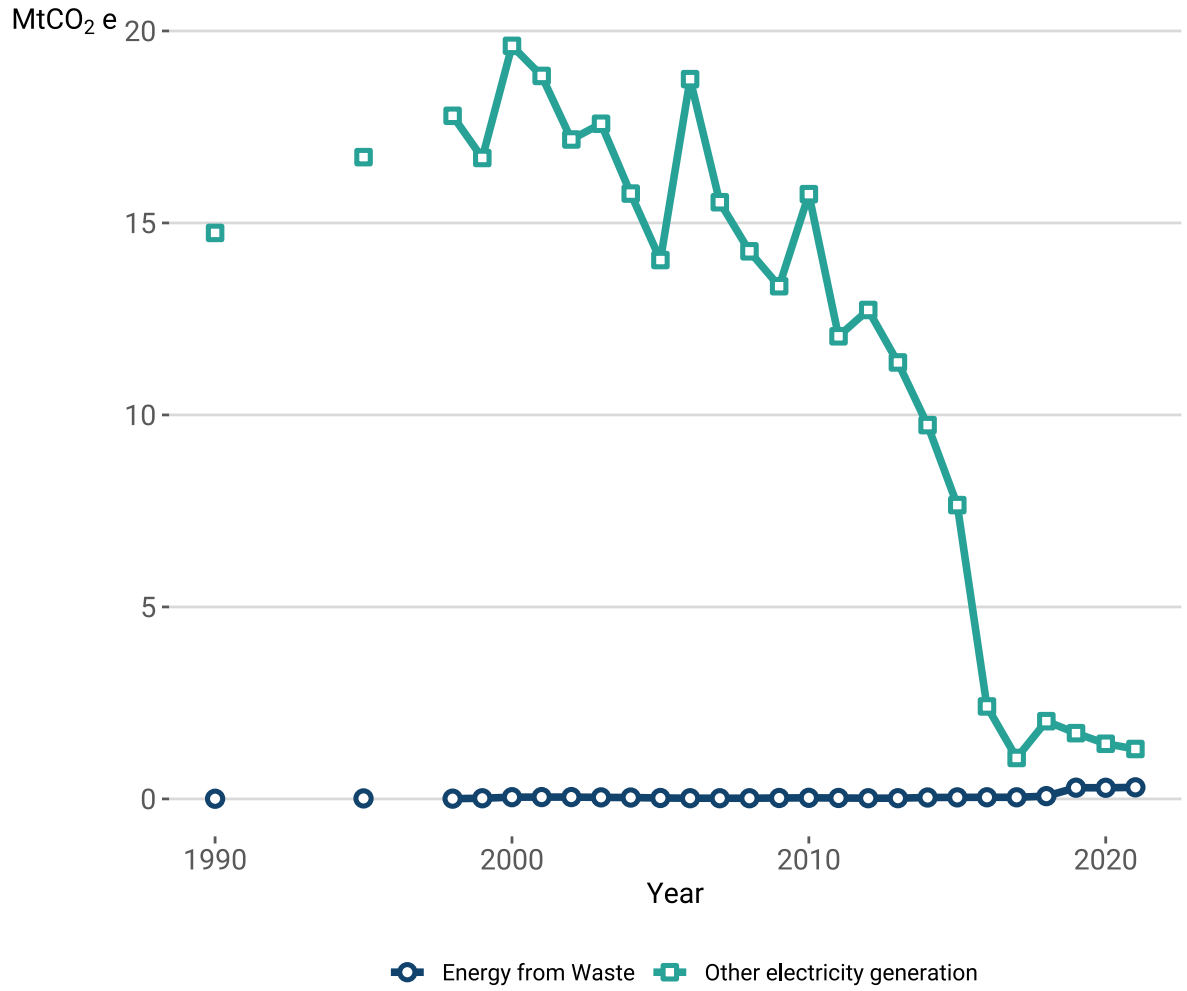
Energy Supply was historically the biggest contribution to emissions, but has seen large changes over the period covered by these statistics, reducing from 21.7

$MtCO_2e$ in 1990 to 4.9 $MtCO_2e$ in 2021 (77.6 per cent reduction). Overall emissions reductions in this sector are mainly due to reductions in emissions from power stations and the complete cessation of coal use for electricity generation in Scotland.

Between 2020 and 2021 Energy Supply emissions decreased by 0.5 $MtCO_2e$ (9.2 per cent decrease). This decrease was driven by an decrease in CO_2 emissions from power stations. Chart 4 above shows the decrease in fossil fuel use for power generation in 2021.

Chart 8 below shows, for the first time, the contribution of energy from waste (EfW) emissions to total emissions from electricity generation in Scotland. EfW emissions have historically been very low and only reached a notable level from 2019 when these emissions equalled 0.3 $MtCO_2e$. Emissions have stayed at this level since, but we expect future increases in these emissions as more plants, currently under construction, begin operation. In 2021, EfW plants contributed 19 per cent of total emissions from electricity generation.

Chart 8. Electricity generation emissions by fuel source, Scotland, 1990-2021.



Business

This sector has seen a 4.2 $MtCO_2e$ (35.3 per cent) fall in emissions between 1990 and 2021. As shown in Chart 3, much of this decrease occurred between 1990 and 1995 – linked to a decline in emissions from manufacturing and the iron and steel industry over this time period. There was a further smaller reduction between 2008 and 2009 (-1.0 $MtCO_2e$), coinciding with the recession. Between 2020 and 2021 there was a reduction of 0.2 $MtCO_2e$ in total emissions from business.

Agriculture

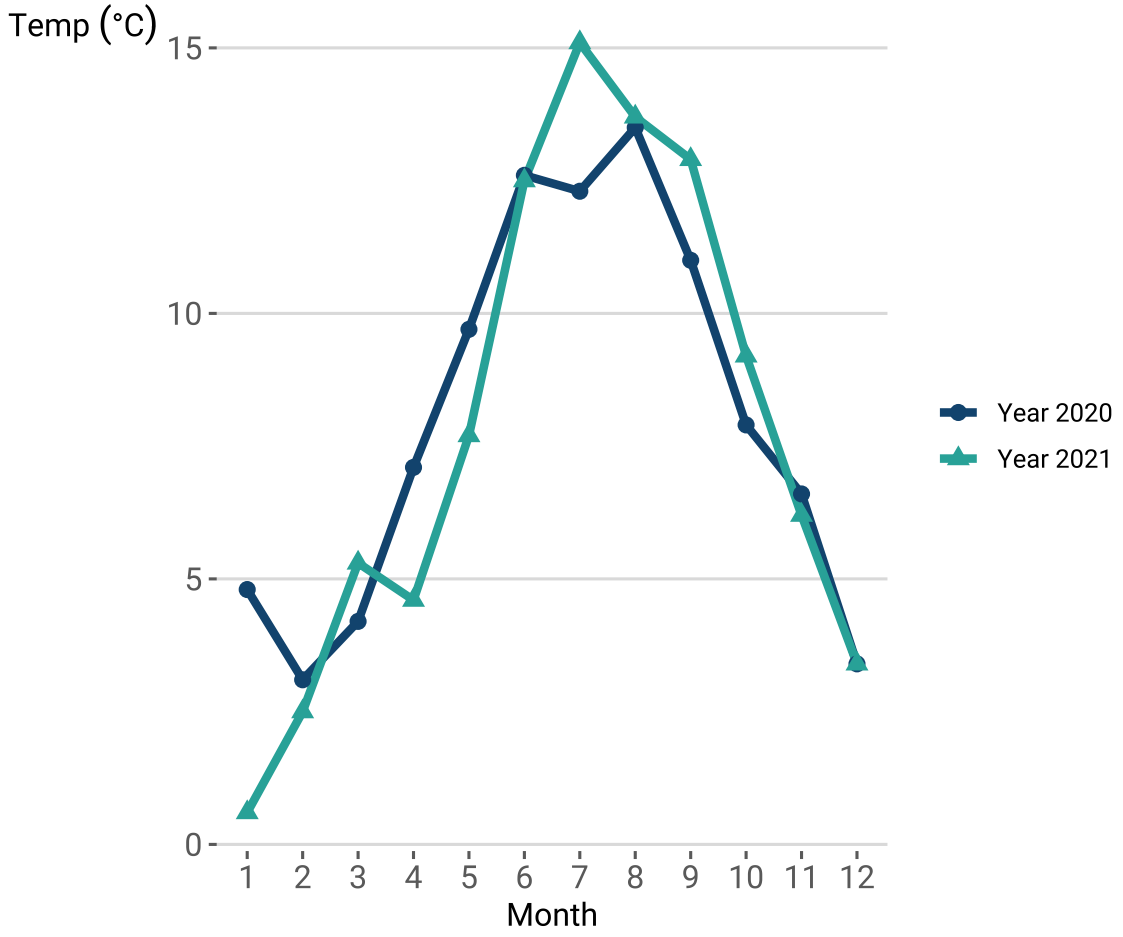
This sector has seen a 0.9 $MtCO_2e$ (10.8 per cent) fall in emissions between 1990 and 2021. Between 2020 and 2021 there was a increase of 0.1 $MtCO_2e$ (1.9 per cent).

Residential

The residential sector is dominated by direct fuel combustion for home heating in households. There has been a reduction of 21.0 per cent between 1990 and 2021. This long-term decrease is mainly due to a switch from less efficient solid and liquid fuels to natural gas for heating, and improvements in energy efficiency.

Residential emissions increased between 2020 and 2021 from 5.9 $MtCO_2e$ to 6.3 $MtCO_2e$ (+7.2 per cent). This change in emissions was caused by relatively colder temperatures in January, February and April 2021, resulting in more fuel being used for domestic heating (Chart 9).

Chart 9. Mean air temperature by month, Scotland. 2020 and 2021.



Data obtained from Met Office[6]

International Aviation and shipping (IA&S)

International aviation was affected dramatically during the early part of the COVID-19 restrictions with International shipping affected to a lesser degree. Between 1990 and 2021, international aviation and shipping decreased by 0.6 $MtCO_2e$ (47.3 per cent). Between 2020 and 2021 international aviation and shipping emissions decreased by a further 0.1 $MtCO_2e$ (15.2 per cent decrease).

Waste Management

Waste management emissions are dominated by methane emissions. Emissions from Waste Management have been relatively static over recent years, with a value of 1.5 $MtCO_2e$ for 2021, with no significant change from 2020. However, between 1990 and 2021 emissions reduced by 5.0 $MtCO_2e$ (76.2 per cent). This decrease is largely due to the progressive introduction of methane capture and oxidation systems within landfill management.

Public

The main source of emissions from this sector is the use of natural gas for heating public buildings. There was a 1.3 $MtCO_2e$ (59.5 per cent) fall in emissions from

[6] Source Met Office: Met Office data download

public sector buildings between 1990 and 2021. Emissions over the last few years have been relatively flat, with a value of 0.9-1.0 $MtCO_2e$ between 2014 and 2021.

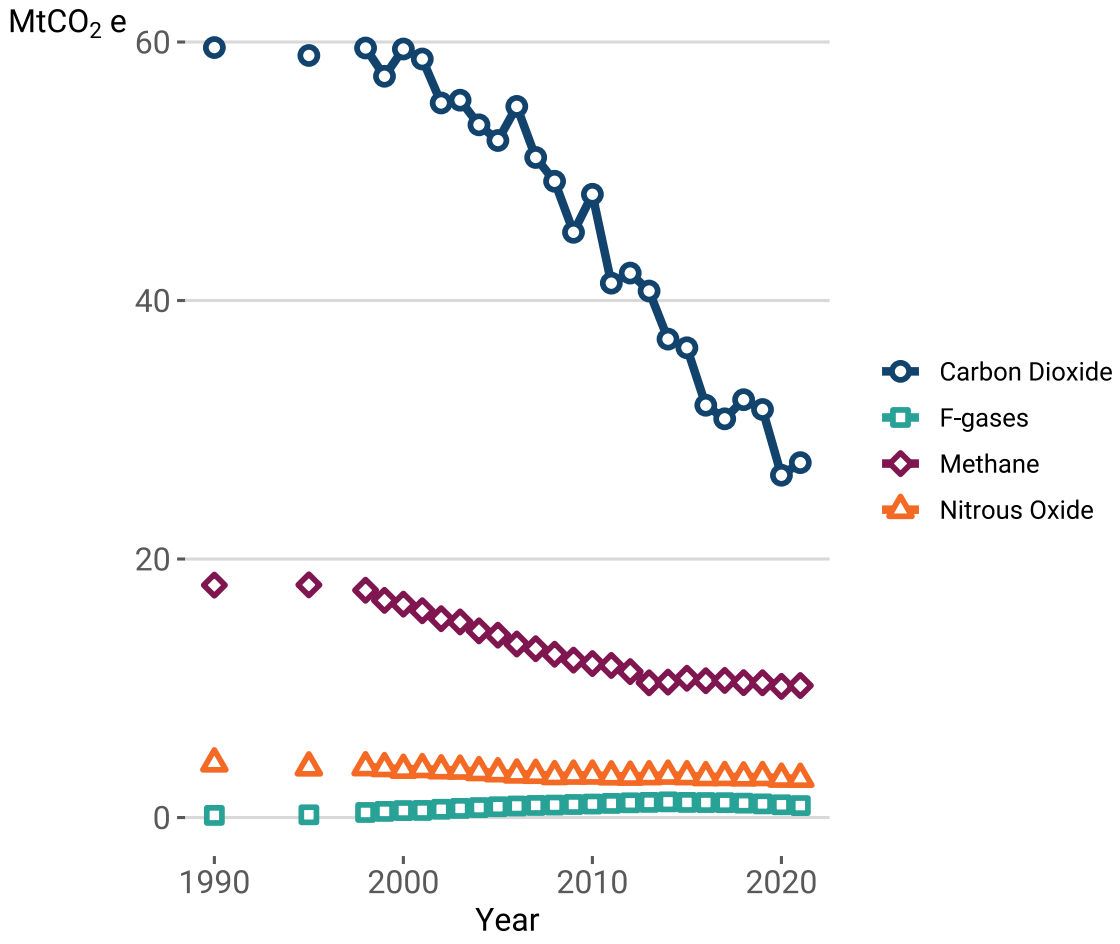
Industrial Processes

This sector has seen a 1.4 $MtCO_2e$ (76.4 per cent) decrease from 1990 to 2021. Values have been relatively stable in recent years, with 2021 having a value of 0.4 $MtCO_2e$. Most of the decrease in the sector happened between 1990 and 1995, and was associated with decreased emissions in the Nitric acid production industry and from a process known as sintering – a process associated with the iron and steel industry.

Emissions by type of gas

Chart 10 shows the trends in emissions, broken down by gas from 1990 to 2021.

Chart 10. Scottish Greenhouse Gas Emissions, by Gas, 1990-2021.



Main Points

- Carbon dioxide is by far the largest contributor to Scottish greenhouse gas emissions in all years (66.0 per cent of all emissions in 2021) and is the most

volatile series of all gases – largely driven by changes in energy supply emissions and to a lesser extent, emissions from the residential and business categories.

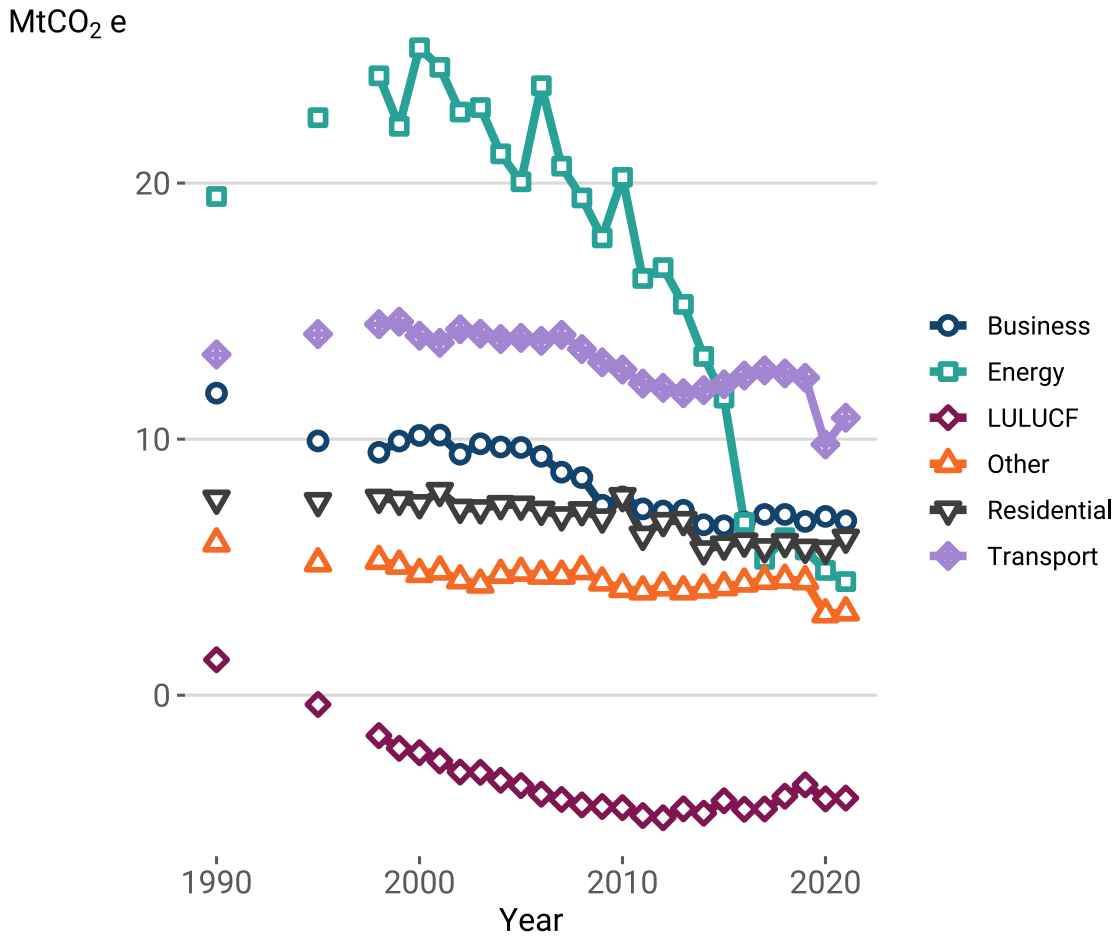
- Methane is the second most common greenhouse gas in 2021 (24.5 per cent of all net emissions) followed by nitrous oxide (7.2 per cent) and F-gases making up the remainder (2.2 per cent).

- Carbon dioxide has seen the largest reduction from 1990 to 2021 (32.1 $MtCO_2e$ reduction). There have also been reductions in both methane (7.8 $MtCO_2e$ reduction) and nitrous oxide (1.2 $MtCO_2e$ reduction). Emissions from fluorinated gases showed a large increase from 1990 to 2013 but have been declining since 2016. Although they still remain small in absolute terms, driven by the introduction of hydrofluourocarbons (HFCs) from 1995 onwards. These HFCs replace chlorofluorocarbons (CFCs) which were banned by the Montreal Protocol due to their impact on the ozone layer.

Charts 11 to 14 present results on individual gases broken down by main sectors over time. Chart 11 shows how carbon dioxide emissions have changed from 1990 to 2021.

Carbon Dioxide (CO_2)

Chart 11. Carbon Dioxide (CO_2) Emissions by National Communications Category, 1990 to 2021.



Main Points

- Chart 11 shows that Energy Supply is a key source of carbon dioxide emissions in all years between 1990 and 2015, after which the change in fuels used in electricity generation substantially reduces CO_2 emissions from this source. Change in energy supply emissions is the main driver of changes in total carbon dioxide emissions. Emissions from this category have been volatile, with the highest emissions occurring between 1995 and 2003, and a spike in 2006, related to a greater use of coal in that year.

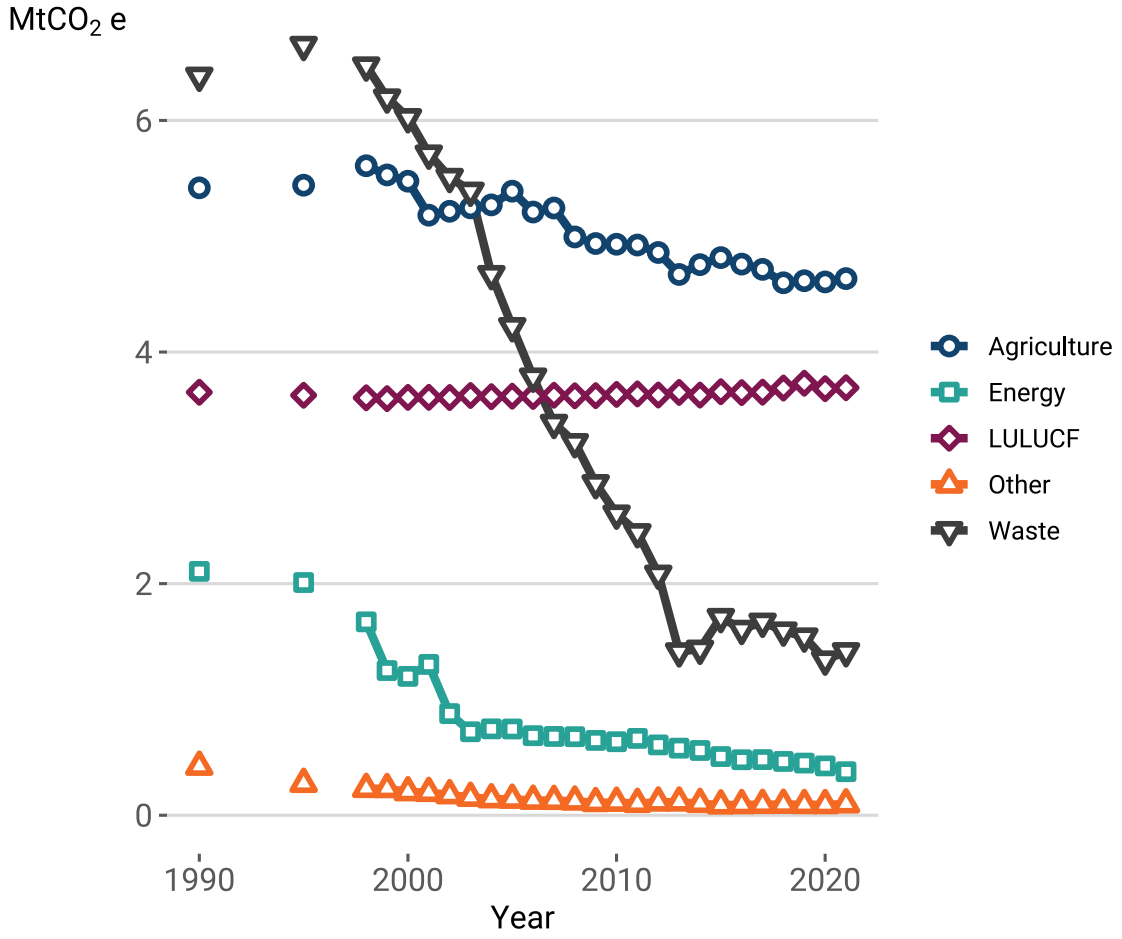
- Transport (excluding international) is the next most common source of carbon dioxide emissions across the entire time-series. In 2015 Transport became the highest source of emissions for the first time in the time series.

- Despite revisions to total greenhouse gases for the LULUCF sector, it has become a much greater net CO2 sink for Scotland over the period. In 1990 it emitted 1.4 $MtCO_2$ of net CO2 emissions. From 1995, this sector became a net-CO2 sink, reaching a maximum in 2012 when it acted to sequestrate 4.8 $MtCO_2$. Since that time, this net CO2 sink has been generally reducing to its current (2021) level where it reached net CO2 emissions of -4.0 $MtCO_2$ These

trends reflect forestry planting activities in the early 1990s reaching maturity and gradually reducing its potential to remove CO2.

Methane (CH_4)

Chart 12. Methane (CH_4) Emissions by National Communications Category 1990 to 2021.



Main Points

- Methane emissions from Waste Management have fallen by 5.0 $MtCO_2e$ between 1990 and 2021 (a 77.9 per cent reduction). This is largely due to the progressive introduction of methane capture and oxidation systems within landfill management.

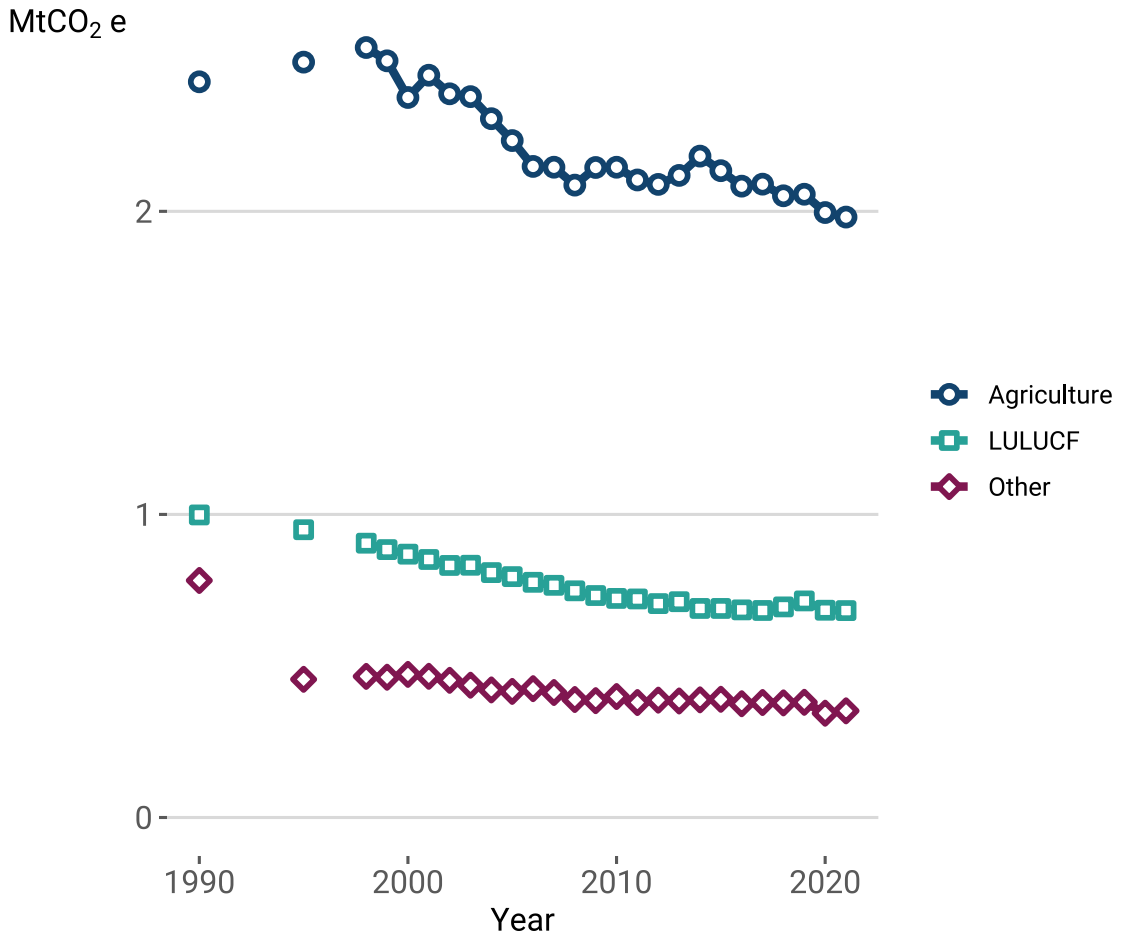
- In the Energy Supply sector, methane emissions have fallen by 1.7 $MtCO_2e$ between 1990 and 2021 (a 82.1 per cent reduction), partly due to reductions in emissions from sources such as coal mining.

- Methane emissions in the Agriculture sector have fallen by 0.8 $MtCO_2e$ between 1990 and 2021 (an 14.5 per cent reduction). This is mainly due to a decrease in livestock numbers (particularly cattle and sheep).

- Land Use emissions of methane have risen very slightly over the entire time-series.

Nitrous Oxide (N_2O)

Chart 13. Nitrous Oxide (N_2O) Emissions by National Communications Category, 1990 to 2021.



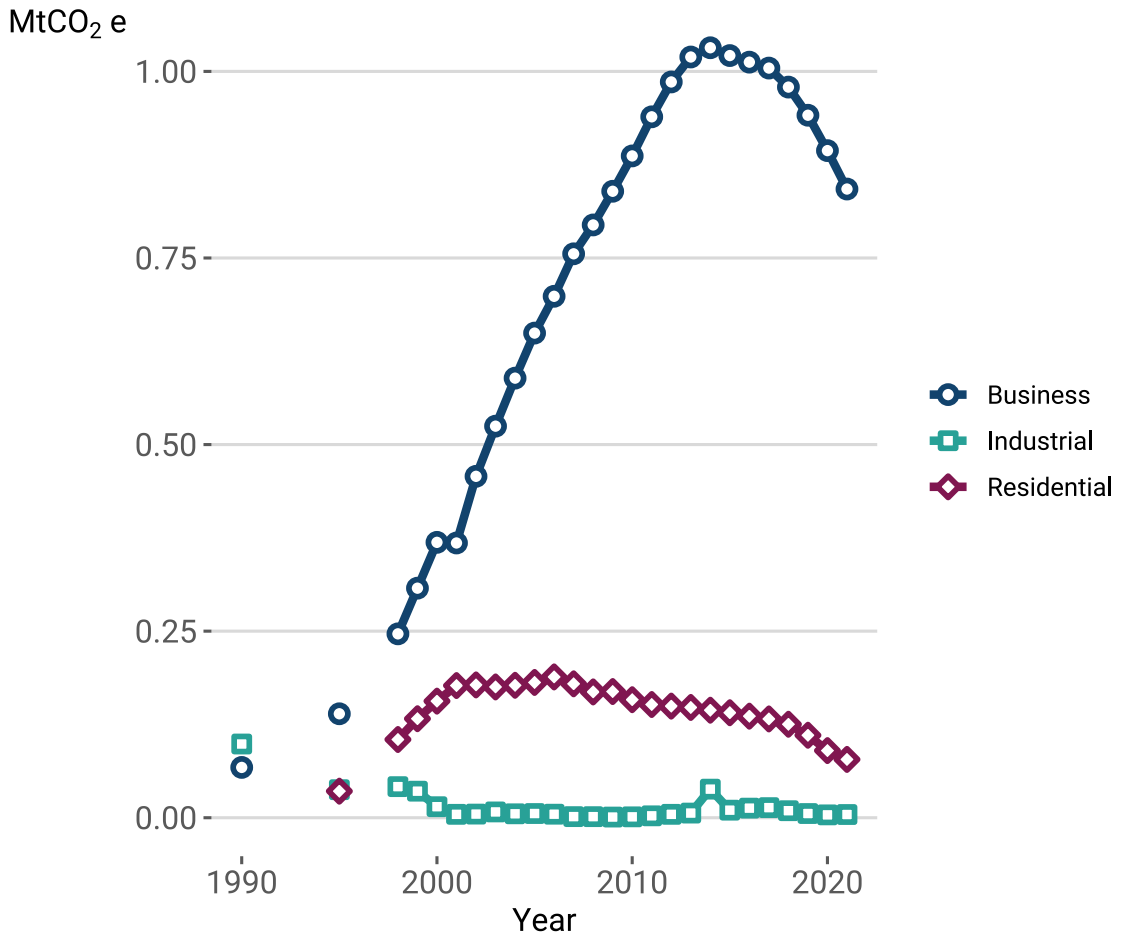
Main Points

- Agriculture is by far the main contributor to emissions of nitrous oxide. These are largely produced by agricultural practices on soils, and to a lesser extent by animal manures. Emissions of nitrous oxide in this sector have fallen by 0.4 $MtCO_2e$ between 1990 and 2021 – an 18.4 per cent reduction.

- 'Land Use, Land Use Change And Forestry' fell by 0.3 $MtCO_2e$ (31.6 per cent reduction) between 1990 and 2021.

Fluorinated gases (F-gases)

Chart 14. F-gas Emissions by National Communications Category, 1990 to 2021



Main Points

- F gases are the most potent greenhouse gases with high global warming potentials but they are emitted in very small quantities. As a result, they contribute less to global warming than the other greenhouse gases in Scotland. (For targets these gases use 1995 as a baseline year rather than 1990)

- There is a sharp increase in HFC gases of 0.9 $MtCO_2e$ between 1990 and 2014 (from 0.2 $MtCO_2e$ in 1995 to 1.2 $MtCO_2e$ in 2014), but have since decreased every year from that peak. This change is almost entirely in the Business sector. This increase is because F gases were introduced to replace chlorofluorocarbons (CFCs), which were used in appliances such as industrial air conditioning units. CFCs were banned under the Montreal Protocol, as they were contributing to the depletion of the ozone layer.

- F gas emissions in the residential sector result from the use of aerosols and asthma inhalers, and represent around 0.1 $MtCO_2e$ in 2021.

Table 3. Greenhouse Gas Emissions in Scotland by National Communications Category: 1990 to 2021. Values in $MtCO_2e$

	1990	2020	2021	1990 - 2021		2020-2021	
				Change	% change	Change	% change
Agriculture	8.8	7.7	7.8	-0.9	-10.8%	0.1	1.9%
Business	11.9	8.0	7.7	-4.2	-35.3%	-0.2	-2.8%
Energy Supply	21.7	5.3	4.9	-16.8	-77.6%	-0.5	-9.2%
Industrial processes	1.9	0.4	0.4	-1.4	-76.4%	0.0	6.2%
International Aviation & Shipping	1.3	0.8	0.7	-0.6	-47.3%	-0.1	-15.2%
Land use, land use change and forestry	6.0	0.3	0.4	-5.7	-94.1%	0.0	12.3%
Public	2.3	0.9	0.9	-1.3	-59.5%	0.0	4.7%
Residential	8.0	5.9	6.3	-1.7	-21.0%	0.4	7.2%
Transport	13.6	9.9	10.9	-2.6	-19.3%	1.1	10.7%
Waste Management	6.5	1.5	1.5	-5.0	-76.2%	0.1	5.1%
Net Emissions	**81.9**	**40.6**	**41.6**	**-40.3**	**-49.2%**	**1.0**	**2.4%**

(some early years omitted to fit table on page, full table available in the accompanying excel tables file)

Table 4. Scottish Greenhouse Gases, by gas, 1990 to 2021. Values in $MtCO_2e$

Pollutant	1990	2020	2021	1990 - 2021		2020-2021	
				Change	% change	Change	% change
CO2	59.6	26.5	27.5	-32.1	-53.9%	1.0	3.7%
CH4	18.0	10.1	10.2	-7.8	-43.2%	0.1	0.6%
N2O	4.2	3.0	3.0	-1.2	-28.3%	0.0	-0.3%
F-gases	0.2	1.0	0.9	0.8	456.5%	-0.1	-6.4%
HFC	0.0	0.9	0.8	0.8	27086.8 %	-0.1	-6.6%
NF3	0.0	0.0	0.0	0.0	339.0%	0.0	0.0%
PFC	0.1	0.1	0.1	-0.1	-57.8%	0.0	-4.9%
SF6	0.0	0.0	0.0	0.0	2.6%	0.0	-3.7%
Net emissions	81.9	40.6	41.6	-40.3	-49.2%	1.0	2.4%

(some early years omitted to fit table on page, full table available in the accompanying excel tables file)

Table 5. Detailed breakdown of transport emissions (domestic and international) 2019 to 2021: Values in $MtCO_2e$.

Transport mode	2019	2020	2021
Cars	5.7	4.2	4.7
Light_duty_trucks	1.7	1.5	1.8
Heavy_duty_trucks_and_buses	2.2	1.9	2.2
Railways	0.2	0.1	0.1
Domestic_aviation	0.4	0.2	0.2
Aviation_Bunkers	1.5	0.5	0.4
Domestic Shipping & Fishing	2.0	1.8	1.7
International shipping	0.4	0.3	0.3
Other	0.3	0.2	0.2
Total emissions	**14.4**	**10.7**	**11.6**

(some early years omitted to fit table on page, full table available in the accompanying excel tables file)

Table 6. Breakdown of Land Use, Land Use Change and Forestry (LULUCF) Emissions. Values in $MtCO_2e$.

LULUCF category	1990	2020	2021
Cropland	6.3	4.8	4.7
Sink	0.0	0.0	0.0
Source	6.3	4.8	4.8
Forestry	-5.2	-7.4	-7.3
Sink	-5.6	-7.8	-7.6
Source	0.4	0.4	0.4
Grassland	3.0	1.9	1.9
Sink	-1.8	-1.2	-1.2
Source	4.9	3.1	3.1
Harvested Wood Products	-0.7	-1.6	-1.7
Sink	-0.7	-1.6	-1.7
Indirect N2O emissions	0.1	0.1	0.1
Source	0.1	0.1	0.1
Settlement	1.5	1.4	1.4
Source	1.5	1.4	1.4
Wetland	1.0	1.2	1.2
Sink	-1.4	-1.4	-1.4
Source	2.4	2.6	2.6
Net LULUCF Emissions	**6.0**	**0.3**	**0.4**

(some early years omitted to fit table on page, full table available in the accompanying excel tables file)

Table 7. Electricity generation emissions. Values in $MtCO_2e$.

Generation type	1990	2019	2020	2021
Energy from waste (EfW)	0.0	0.3	0.3	0.3
Other electricity generation	14.7	1.7	1.4	1.3
Total emissions	**14.7**	**2.0**	**1.7**	**1.6**

(some early years omitted to fit table on page, full table available in the accompanying excel tables file)

Section C. Scotland's GHG Account for assessing progress against statutory targets

Introduction

A full reporting of the figures, required by the statutory requirements of Climate Change (Scotland) Act 2009, is available in Annex A which accompanies this publication.

In December 2017 the Climate Change Committee (CCC) provided advice on the future measurement and accounting of emissions against Scotland's climate change targets[7].

The CCC used the term "GHG Account" to refer to their recommended manner of accounting for emissions, which is intended to better separate the impacts on targets of scientific and methodological improvements to the GHG inventory, from those of 'on-the-ground' policy actions. The Climate Change (Emissions Reduction Targets) (Scotland) Act 2019 requires that Scottish Ministers follow the CCC's most recent advice on the method to be used for reporting on target outcomes, which currently means the GHG Account method set out here.

At the heart of this method is the freezing of inventory methods (the scientific methods used for the measurement and estimation of emissions levels) between the time that target levels are set (or reviewed through independent advice from the CCC) and the time when target outcomes come to be reported. To ensure that the inventory methods used for the purpose of reporting target outcomes do not become too far separated from the best science and evidence, the base inventory will be re-aligned to the most up to date inventory methods at least every 5 years.

The base inventory has been updated in this release and now uses the 1990-2020 data, published in June 2022.

[7] Letter from Lord Deben to Roseanna Cunningham MSP advising on Scottish climate target framework - Climate Change Committee (theccc.org.uk)

2021 GHG Account Calculation

In accordance with advice from the Climate Change Committee, the calendar year 2020 (for which emissions data was first published in June 2022) has been selected as the base inventory for reporting progress to the 2021 interim target.

Table 8: Calculation of the Scottish GHG Account for 2021

Year	Baseline Period (1)	2020	2021
Inventory data			
A. Base Inventory source emissions data (June 2022 data (1990-2020)) (3)	83.0	40.6	N/A
B. June 2023 source emissions data (1990-2021 inventory)	82.0	40.6	41.6
Revisions between inventories (2)			
between A and B	-1.0	0.1	0.1
GHG Account (latest inventory, less combined revision) (4, 5)	**83.0**		**41.5**
GHG Account figures, expressed as a percentage reduction from the baseline period (5).	**0.0%**		**-49.9%**

1. The Baseline period uses a 1995 base-year for F-Gas emissions, and 1990 for all other greenhouse gases.
2. Where data do not exist for a particular year, revisions are carried over from the previous complete year
3. Values for the base inventory use updated global warming potentials as shown in chart D4 in the June 2022 publication. In line with international carbon reporting practice, the GWPs used in the 2023 inventory are consistent with the IPCC 5th Assessment Report (AR5 without climate feedback effects. This change has resulted in methane moving from a GWP multiplier of 25 to 28, and nitrous oxide reducing from 298 to 265. Other changes to individual isotopes of fluorinated gases have also been made.
4. Totals may not exactly equal the sum of components due to rounding.
5. The GHG Account for 2020 is shown in Scottish Greenhouse Gas Statistics 2020 published in June 2022

Under the Climate Change (Emissions Reduction Targets) (Scotland) Act 2019, targets are set for the years from 2018 onwards. A full list of these target levels is available on the Scottish Government website, with the 2021 interim target being a 51.2[8] per cent reduction from baseline levels.

[8] The legislated target value was revised from 51.1% to 52.2% in October 2024.

Table 8 shows a 49.9 per cent reduction from baseline levels in 2021. As a result, **the statutory emissions reduction target for 2021 has not been met**.

Section D. Revisions to the Inventory and Methodology

This section examines key revisions in estimated source emissions between the latest inventory (1990-2021) and the previous inventory (1990-2020). It also provides a summary of the cumulative impact of revisions since the 1990-2008 inventory. In October 2015, the Scottish Government published a paper Scottish Greenhouse Gas Emissions 2013. Key Revisions Since 2008, which provides a breakdown of the key revisions to the data within the Scottish Greenhouse Gas Emissions Official Statistics publication over successive years from the 1990-2008 inventory to the 1990-2013 inventory. This section of the publication is intended to build on this revisions paper.

Compilation of the Greenhouse Gas Inventory

The greenhouse gas inventory covers a wide variety of anthropogenic sources of greenhouse gas emissions. There is therefore a wide variety of emissions sources which require different approaches to their estimation. There are a large number of data sources used in its compilation, obtained from Government statistics, regulatory agencies, trade associations, individual companies, surveys and censuses. The methods used to compile the greenhouse gas inventory are consistent with international guidance on national inventory reporting from the Intergovernmental Panel on Climate Change.

Most emission estimates are compiled by combining activity data (such as fuel use) with a suitable emission factor (such as amount of CO_2 emitted per unit of fuel used). Estimates of emissions from the industrial sector are often compiled based on plant-specific emissions data. Emissions from some sectors are based on more complicated models - such as the model used to estimate emissions from landfill, and the model used to estimate the carbon dynamics in soils when trees are planted. Much of the data on net emissions from 'agriculture' and 'land use, land use change and forestry emissions' are based on modelled data for Scotland, which are consistent with, but not constrained to, the UK totals and thus are known as "bottom up" estimates.

Many of the remaining emissions sources within the inventory have been collated on a "top down" approach where estimates of emissions have been apportioned to Scotland using proportions of energy use in the Department of Business, Energy and Industrial Strategy (BEIS) Publication "Digest of UK Energy Statistics (DUKES)". This approach is prompted by data availability on emissions being more limited at the sub-UK level.

Impact of Revisions

Revisions between the 1990-2020 and 1990-2021 inventories

Charts 15 to 17 illustrate the impacts of revisions between the 1990-2020 and 1990-2021 inventories. This is followed by a discussion of the reasons for the key revisions.

Chart 15. Scottish Greenhouse Gas Emissions. Comparison of the net greenhouse gas emissions for the 1990-2020 and 1990-2021 Inventories.

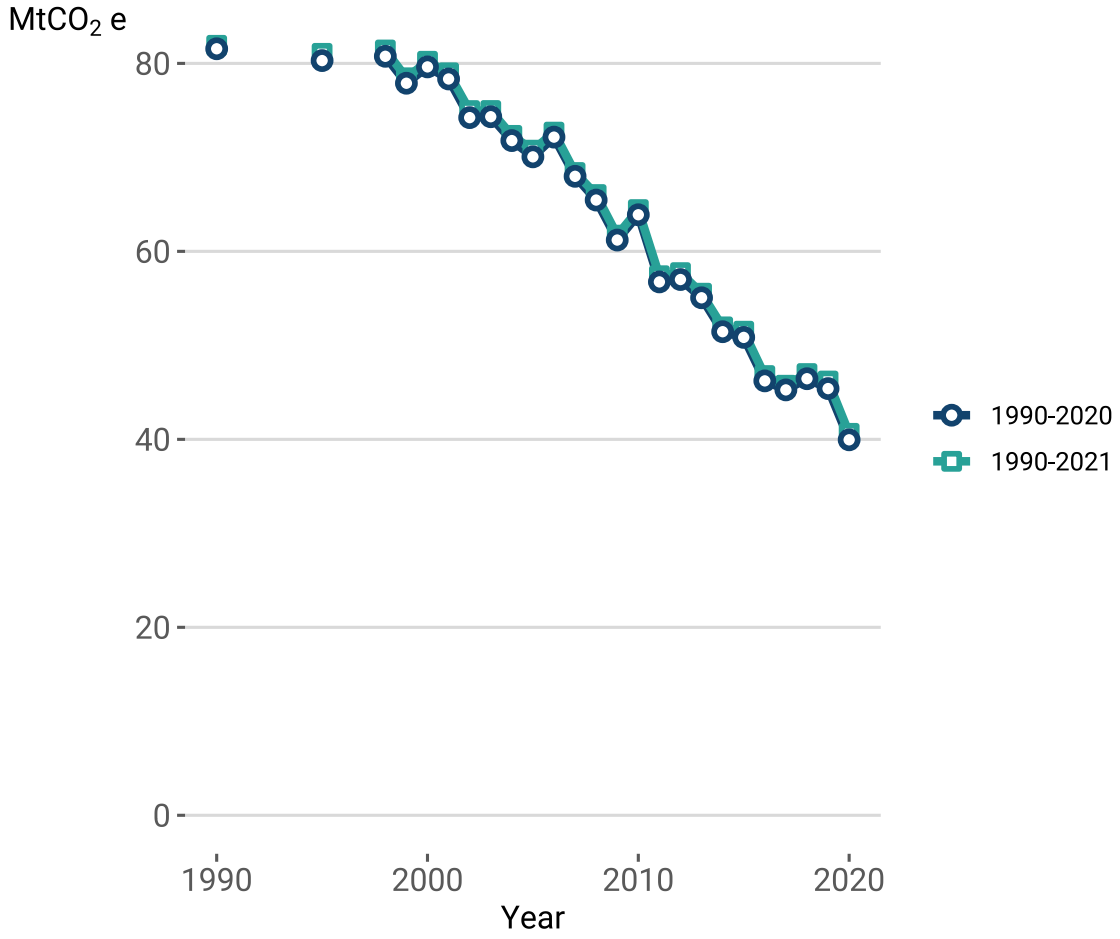


Chart 16 shows revisions to the baseline period, between the two most recent inventories.

Chart 16. Revisions to emissions in the Baseline Period, from the 1990-2020 inventory to the 1990-2021 inventory, by national communications category.

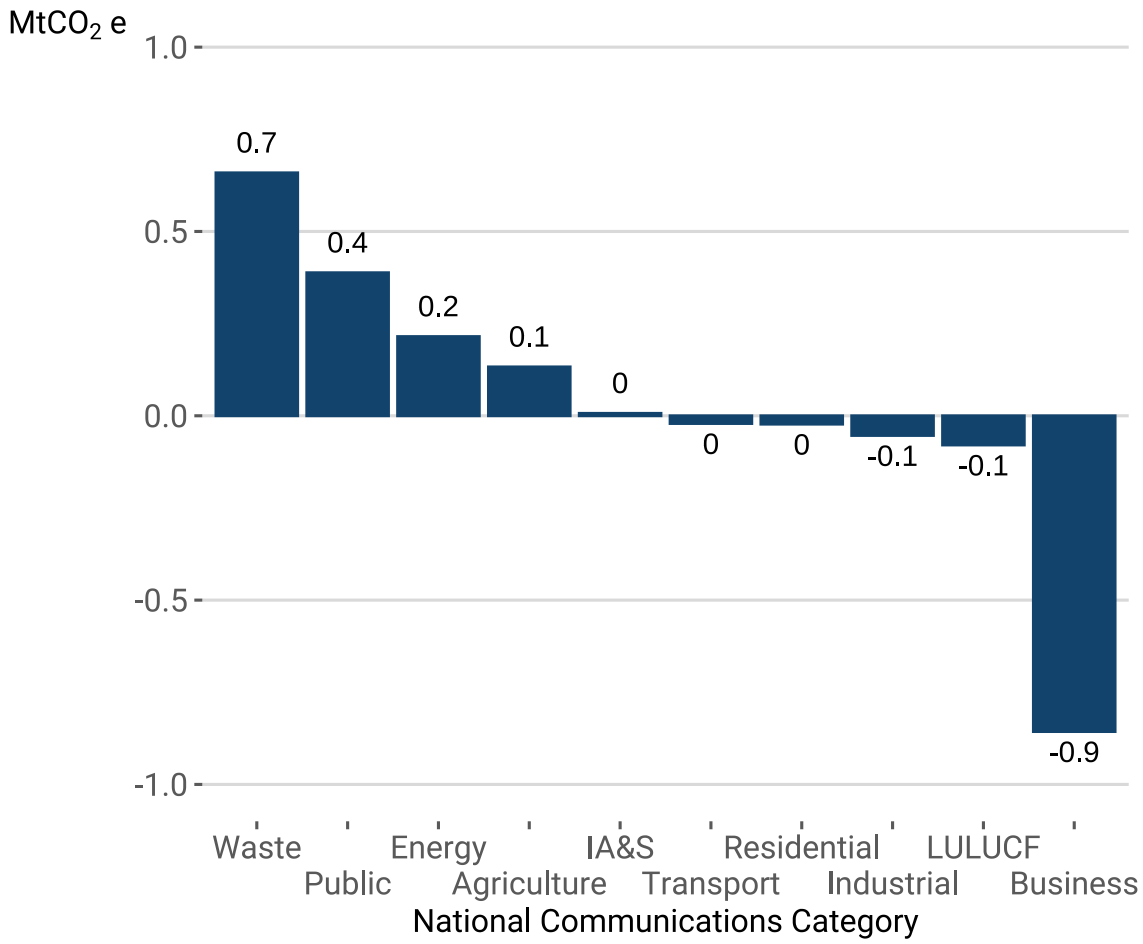
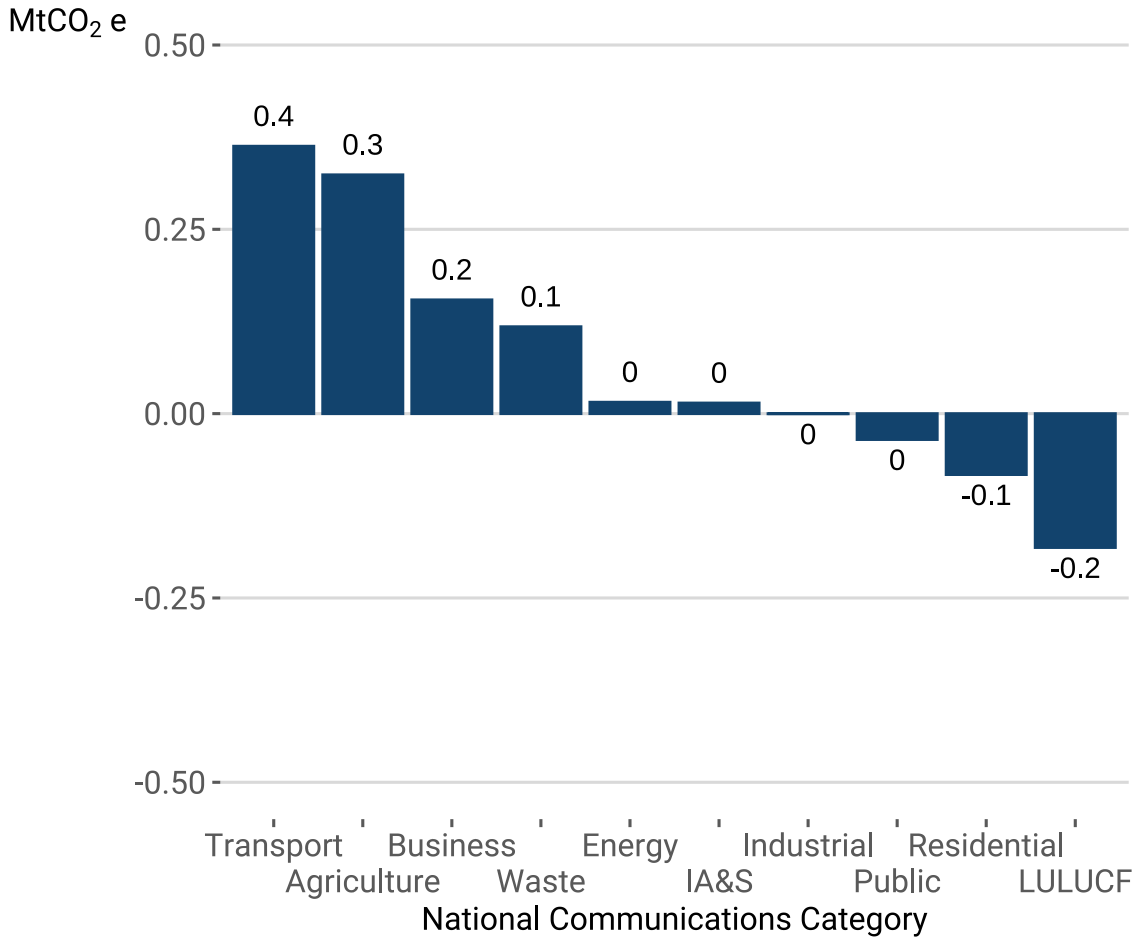


Chart 17 shows revisions to the data for the year 2020, between the two most recent inventories.

Chart 17. Revisions to emissions in 2020, from the 1990-2020 inventory to the 1990-2021 inventory, by national communications category.



Details of Main Revisions and Interpretation of Revisions to the Inventory

Revisions to emission inventory estimates reflect the continuous development of scientific understanding of emissive processes, and the improvement to underlying data and methods to generate accurate emission estimates; few revisions to the Greenhouse Gas Inventories arise as a result of 'errors' in the popular sense of the word. The compilation of the inventory is governed by a rigorous quality assurance process and is subject to a great deal of third party scrutiny, such as annual reviews by the UNFCCC of the UK inventory.

The latest published Scotland greenhouse gas inventory (currently 1990-2021) represents the best available data at the time and these supersede any previous data, which should be disregarded.

A complete list of the revisions between the previous and latest inventories can be found in the National Atmospheric Emissions Inventory report Greenhouse Gas

Inventories for England, Scotland, Wales and Northern Ireland: 1990 - 2021. Details of the most notable revisions are listed below:

Revised global warming potentials

Emissions are reported for the seven direct greenhouse gases, and these are listed in Table 1 alongside their Global Warming Potential (GWP). Depending on their molecular weights, radiative properties, and residence times in the atmosphere, each GHG has a different capacity to impact global warming. The GWP is an attempt to encapsulate these parameters and provide a consistent measure of the relative effects of the emissions of the relevant GHGs, through the units CO2 equivalent (CO2e). As gases have varying residence times in the atmosphere, the respective GWPs differ over different time-horizons are considered; GWPs of gases with shorter residence times than CO2 would increase if a shorter time-horizon is considered.

All figures are now reported using the Fifth Assessment Report (IPCC, 2014). The combined impact of this change has been a slight increase in emissions estimates.

LULUCF

Recalculations due to implementation of updated activity data used in LULUCF soils and non-biomass models.

Agriculture

There has been an increase in emissions from the agriculture sector across much of the time-series, with reasons for these recalculations including;

- Updated farm yard manure storage proportions for Scotland and proportion of cattle stored on slurry systems updated. Revisions to slaughter weight timeseries from 2018 and milk yield data in recent years which impacts the timeseries from 2011 due to interpolation. Revision to the methodology used to estimate fertiliser application rates. Revision to land use areas and crop yield.
- Integration of a new non-road mobile machinery model that causes major revisions to estimated emissions from agricultural machinery.

Energy supply

Recalculations are primarily due to revisions to DUKES data in later years and change in activity data for petroleum refining.

Business

There were large revisions to the UK inventory due to new bottom-up estimates of off-road machinery fuel use by machinery type, resulting in the reallocation of residual fuel use in other sectors.

Integration of new mapping grids for the use of fuels at industrial sites, particularly for gas oil, coal, fuel oil and natural gas use impacts emissions across the time-series.

Emissions for later years of the time-series were affected by recalculations in the DUKES activity data.

Transport

There were recalculations due to a revised DfT minor road data for 2000-2019 and a revision to the total gas use in road transport for later years.

Residential
Large recalculations in 2019 and 2020 due to revisions to the DUKES activity data.
Domestic combustion of natural gas was revised for 2019 and 2020 due to updates to the Carbon Emission Factors in the Local Distribution Zone (LDZ) data.
Minor recalculations throughout the time series due to revisions to the calorific values in the domestic combustion model.

Waste Management
Revisions to the UK total for municipal wastewater which is the scaled across all DAs as there has been no change to the methodology used to split emissions between DAs.

A decrease due to the removal of methane emissions associated with disposal to land, landfill, or incineration, to prevent double counting.

A decrease due to the revision to the approach of uplifting of wastewater to sea to be region-specific, and uplift to reach only 90% of the 'stable' level of sludge generation per capita.

Interpretation of uncertainties in the inventory

All estimates, by definition, are subject to a degree of statistical 'error' but in this context it relates to the uncertainty inherent in any process or calculation that uses sampling, estimation or modelling.

Estimates of greenhouse gases are compiled by a consortium of contractors. The source emissions are based upon a range of data sources, ranging from model based estimates to point source emission data. As a result, the estimates are subject to a degree of uncertainty. Full analyses of these uncertainties are provided on the National Atmospheric Emissions Inventory website[9].

The Scottish Government previously commissioned research to overhaul and update the uncertainties model used for the Scottish greenhouse gas inventory. A detailed study was carried out in parallel with the compilation with the 1990-2014 Scottish greenhouse gas inventory to review and improve the uncertainty calculations. A link to this project and to the full report can be found in the Scottish Greenhouse Gas Inventory Uncertainties Project.

[9] Report: UK Greenhouse Gas Inventory, 1990 to 2021: Annual Report for submission under the Framework Convention on Climate Change - NAEI, UK (beis.gov.uk)

Section E. Exclusions, Glossary and Acknowledgements

Why are some greenhouse gas emissions not considered in this statistics release?

The methods used to compile the Scottish Greenhouse Gas Inventory are consistent with international reporting and are therefore comparable to the greenhouse gas emission estimates reported by all other EU Member States and other Annex 1 parties[10] to the UNFCCC. All countries estimate and submit their greenhouse gas inventory estimates to be consistent with methods set out in international guidance for national inventory methods from the Intergovernmental Panel on Climate Change (IPCC), known as the IPCC (2006) guidelines. The IPCC (2006) guidelines state that national inventories should report on all anthropogenic (human) emissions and removals of greenhouse gas emissions, as a result of human activities within a country's territorial sphere.

However, there are some emissions and removals of carbon dioxide that occur as a result of short-cycle biogenic processes. This biocarbon has only recently been abstracted from the atmosphere before it is then re-released as carbon dioxide. In accordance with the IPCC (2006) guidelines, these emissions and sinks are therefore excluded from the greenhouse gas inventory, as they could lead to double counting. If countries do choose to estimate these biocarbon emissions, they are reported *outside of the national inventory total*, as a memo item to that country's submission to the UNFCCC. This means that some sources and sinks of greenhouse gases are not included in the Scottish and UK inventory totals.

Examples of reasons for why some sources and sinks of greenhouse gases are not included in the greenhouse gas inventory

1. Due to short-cycle biocarbon (carbon only been recently abstracted from the atmosphere)

- **Carbon dioxide (CO_2) emissions from biomass combustion.** For example, this includes CO_2 emissions from biomass power stations
- **Process emissions in food and drink production**. These include CO_2 emissions from brewing, fermenting and malting and in the production of food.
- **CO_2 emissions from biodegradable waste to landfill**. Emissions are not estimated where they arise from biogenic sources of waste such as food. Fossil-derived organic matter (such as plastic) is assumed to be non-biodegradable and there are no emissions associated with its decomposition.

[10] Annex 1 countries are required to submit information on their national greenhouse gas inventories annually to the UNFCCC.

However, methane (CH_4) emissions from biodegradable waste sent to landfill are considered in these greenhouse gas statistics as they are formed by the anaerobic (oxygen-free) decay of organic matter in solid waste disposal sites.

2. Where there has been no anthropogenic influence

- **Natural accumulation and storage of carbon in peatland.** For emissions or removals of peatland to be considered for IPCC reporting, they require humans to alter the peatland – either through wetland drainage, rewetting, peatland extraction or through another land use change. The UK and Scotland has elected to include the IPCC (2006) Wetlands Supplement as part of their inventory reporting from the 1990-2019 vintage of the inventory: http://www.ipcc-nggip.iges.or.jp/home/wetlands.html

3. Beyond the territorial definitions as prescribed by the IPCC (2006) reporting requirements

- **"Blue carbon".** Blue carbon refers to the carbon captured by the world's oceans and coastal ecosystems. The carbon captured by living organisms in oceans is stored in the form of biomass and sediments from mangroves, salt marshes and seagrasses. However, it should be noted that research in underway to being to develop estimates of the environmental changes resulting from changes to coastal wetlands environments.

Glossary

Adjusted emissions
See GHG Account

Afforestation
The act or process of establishing a forest on land that has not been forested in recent history.

Baseline Period
Emissions reduction is based on a Baseline Period. For the greenhouse gases CO2, CH4 and N2O, 1990 was specified as the baseline. 1995 is the baseline for emissions of the F-gases.

Carbon dioxide (CO_2)
Carbon dioxide is one of the main gases responsible for climate change. It is mostly emitted through the oxidation of carbon in fossil fuels, e.g. burning coal.

Carbon sink
A carbon sink is a natural or artificial reservoir that accumulates and stores CO2 for an indefinite period.

Climate change
Climate change is a long-term change in the earth's climate. This can be accelerated by human activity, e.g. by releasing CO2 into the atmosphere.

Deforestation
The removal of forest stands by cutting and burning to provide land for agricultural purposes, residential or industrial building sites, roads, etc., or the harvesting of trees for building materials or fuel.

Fluorinated gases (F-gases)
F-gases are the generic name given to HFCs, PFCs, SF6 and NF3. These have been used as replacements for CFCs, which are ozone depleting substances that have been banned under the Montreal Protocol. They have very high global warming potentials.

Greenhouse effect
The greenhouse effect is the process by which heat from the sun is trapped within the Earth's atmosphere by greenhouse gases. This process is also known as radiative forcing.

GHG Account
The Climate Change Committee (CCC) recommended a new method of adjusting emissions for the purposes of reporting against targets in this, and future, publications. This adjustment acts to remove the impact of revisions to the historical time-series. This is known as the GHG Account and the calculation in detailed in section C.

Greenhouse gas
A greenhouse gas is a gas which absorbs infrared radiation emitted from the surface of the Earth, helping to retain a portion of that energy in the atmosphere as heat.

Global warming potential (GWP)
GWP is a measure of how much a greenhouse gas is estimated to contribute to global warming. It is a relative scale which compares the potency of each gas to CO2.

Hydrofluorocarbons (HFCs)
HFCs are produced commercially as a substitute for chlorofluorocarbons (CFCs) and hydrochlorofluorocarbons (HCFCs). HFCs are largely used in refrigeration and insulating foam. Their Global Warming Potentials range from 4 to 12,400 times that of CO2, depending on the gas type.

Inventory
The inventory contains greenhouse gas emissions estimates for Scotland and the UK. The Inventory is a disaggregation of the UK Inventory, which is based on five major sectors: energy, industrial processes, agriculture, land-use, land-use change and forestry, and waste.

IPCC
The Intergovernmental Panel on Climate Change (IPCC) assesses the scientific, technical and socio-economic information relevant for the understanding of the risk of human-induced climate change. They provide advice to the UNFCCC on the scientific evidence and developments which are used to inform National Inventories.

LULUCF
Estimates of emissions and removals from land use, land use change and forestry (LULUCF) depend critically on assumptions made on the rate of loss or gain of carbon in Scotland's carbon rich soils. In Scotland, LULUCF activities, taken as a whole, acts as a sink, absorbing more greenhouse gas emissions than it releases.

Methane (CH_4)
Methane is a greenhouse gas that is around 28 times more potent in the atmosphere than CO2 over a 100-year time horizon. Main sources include agriculture and landfill.

National Communication (NC) Sectors
The UK NC sectors are agreed groupings of the more detailed sectors reported to the United Nations Framework Convention on Climate Change by the UK. This report uses NC sectors.

Nitrogen trifluoride (NF_3)
Nitrogen trifluoride is a greenhouse gas that is around 16,100 times more potent in the atmosphere than CO2 over a 100-year time horizon. The main source of nitrogen trifluoride is in the making of semiconductors.

Nitrous oxide (N_2O)
Nitrous oxide is a greenhouse gas that is around 265 times more potent in the atmosphere than CO2 over a 100-year time horizon. The main source is agricultural soil.

Other Petroleum Gas (OPG)
This consists mainly of ethane plus some other hydrocarbons, excluding butane and propane.

Perfluorocarbons (PFCs)
PFCs are a by-product of aluminium smelting. They are also the replacement for CFCs in manufacturing semiconductors. The Global Warming Potentials of PFCs ranges from 6,630 – 11,100 times that of CO_2 over a 100-year time horizon.

Radiative forcing
An externally imposed perturbation in the radiative energy budget of the Earth's atmosphere. Such a perturbation can be brought about by changes in the concentrations of radiatively active species (e.g. greenhouse gases), changes in the solar irradiance incident upon the planet, or other changes that affect the radiative energy absorbed by the surface (e.g. changes in surface reflection properties).

Sequestration
The process by which carbon sinks remove carbon dioxide (CO_2) from the atmosphere.

Source (UNFCCC definition)
Any process or activity which releases a greenhouse gas or a precursor greenhouse gas to the atmosphere.

Sulphur hexafluoride (SF_6)
It is largely used in heavy industry to insulate high-voltage equipment and to assist in the manufacturing of cable-cooling systems. Its global warming potential is 23,500 times that of CO_2 over a 100-year time horizon.

UNFCCC
In 1992, the UNFCCC was adopted as the basis for a global response to climate change. The ultimate objective of the Convention is to stabilise greenhouse gas concentrations in the atmosphere at a level that will prevent dangerous human interference with the climate system.

Acknowledgements

We would like to thank our contractors, Ricardo, in consortium with Aether, Rothamsted Research and the Centre for Ecology & Hydrology for their invaluable support in compiling and improving the Scottish greenhouse gas inventory every year. Links to the Devolved Administrations inventories for each year can be found here: Devolved Administrations - Greenhouse Gas Reports - NAEI, UK (beis.gov.uk)

Annex A: Information required for reporting under sections 33 and 34 of the Climate Change (Scotland) Act 2009.

Introduction

The following sections summarise, using data from the main sections of this statistics bulletin and other sources, the information required under the requirements of sections 33 and 34 of the Climate Change (Scotland) Act 2009. For ease, the information is interspersed with the wording of the requirements themselves.

Under section 33

Subsection 2 requires the report must state—

(a) the emissions reduction target for the target year

The emissions reduction target for 2021 is a 51.2% reduction from the baseline.

(b) whether the emissions reduction target for the target year has been met

The target has not been met.

(c) the percentage by which the net Scottish emissions account for the target year is lower than the baseline,

For the purpose of assessing progress to the 2021 target (on the basis of the 1990-2021 inventory), the net Scottish emissions account was 49.9% lower in 2021 than the baseline.

(d) the amount by which the net Scottish emissions account for the target year is lower or higher than the emissions reduction target for that year

The net Scottish emissions account for 2021 was 1.0 million tonnes of carbon dioxide equivalent ($MtCO_2e$) higher than the target for that year.

(e) the cumulative amount by which the net Scottish emissions accounts are lower or higher than the corresponding emissions reduction targets, calculated by adding each amount by which an account is lower or higher than the corresponding target for each year in the period beginning with 2018 and ending with the target year.

The cumulative amount by which the net Scottish emissions accounts over the period from 2018 to the current target year (2021) was 4.7 $MtCO_2e$ higher than the targets for those years.

Subsection 3 requires the report must specify the methods used to determine each figure and amount in subsection 2 in accordance with the most up-to-date advice provided by the relevant body (the UK Climate Change Committee) on the methods to be used for that purpose:

The figure in subsection 2(c) above has been derived using an identical calculation to that recommended by the Climate Change Committee (CCC) in their advice on the future measurement and accounting of emissions against Scotland's climate change targets[11]. This calculation is shown below, using the 1990-2020 inventory as the reference inventory, and adjusting for cumulative revisions subsequently introduced in the 1990-2021 inventory:

Year	**Baseline Period (1)**	**2020**	**2021**
Inventory data			
A. Base Inventory source emissions data (June 2022 data (1990-2020)) **(3)**	83.0	40.6	N/A
B. June 2023 source emissions data (1990-2021 inventory)	82.0	40.6	41.6
Revisions between inventories (2)			
between A and B	-1.0	0.1	0.1
GHG Account (latest inventory, less combined revision) (4, 5)	**83.0**		**41.5**
GHG Account figures, expressed as a percentage reduction from the baseline period (5).	**0.0%**		**-49.9%**

1. The Baseline period uses a 1995 base-year for F-Gas emissions, and 1990 for all other greenhouse gases.
2. Where data do not exist for a particular year, revisions are carried over from the previous complete year (see shaded cells)
3. Values for the base inventory use updated global warming potentials as shown in chart D4 in the June 2022 publication. In line with international carbon reporting practice, the GWPs used in the 2023 inventory are consistent with the IPCC 5th Assessment Report (AR5 without climate feedback effects. This change has resulted in methane moving from a GWP multiplier of 25 to 28, and nitrous oxide

[11] Letter from Lord Deben to Roseanna Cunningham MSP advising on Scottish climate target framework - Climate Change Committee (theccc.org.uk)

reducing from 298 to 265. Other changes to individual isotopes of fluorinated gases have also been made.
4. Totals may not exactly equal the sum of components due to rounding.
5. The GHG Account for 2020 is shown in Scottish Greenhouse Gas Statistics 2020 published in June 2022

Under section 34

All of the information under this section is reported on the basis of the most up to date available greenhouse gas inventory methods, i.e. the 1990 – 2021 inventory.

Subsection 1 requires the report must state — (a) in relation to net Scottish emissions of greenhouse gases—

(i) the baseline,

The Baseline period uses a 1995 base-year for F-Gas emissions, and 1990 for all other greenhouse gases. In the 1990-2021 inventory the baseline amount of emissions was 82.0 $MtCO_2e$.

(ii) the aggregate amount of net Scottish emissions of greenhouse gases for the year covered by the report,

On the basis of the 1990-2021 inventory, net Scottish emissions in 2021 were 41.6 $MtCO_2e$.

(iii) the percentage by which the aggregate amount of net Scottish emissions of greenhouse gases for the year covered by the report is lower than the baseline,

On the basis of the 1990-2021 inventory, net Scottish emissions in 2021 were 49.2 % lower than the baseline.

(iv) the percentage by which the aggregate amount of net Scottish emissions of greenhouse gases for the year covered by the report is lower or higher than the equivalent amount for the immediately preceding year, and

On the basis of the 1990-2021 inventory, net Scottish emissions in 2021 were 2.4 % higher than in 2020.

(v) the methods used to determine the aggregate amount of net Scottish emissions of greenhouse gases, together with details of any changes to those methods,

The aggregate amount of net Scottish emissions set out above has been determined from regional disaggregation of the UK Greenhouse

Gas Inventory. Full details of the methodology used in the UK Inventory, together with further breakdowns, are provided in the National Inventory Report[12] submitted annually by the UK Government to the United Nations Framework Convention on Climate Change (UNFCCC).

This latest release now reports data using global warming potential that are consistent with the IPCC's 5th Assessment Report, without climate feedback. Other reasons for revisions to previously published data include:

- Agriculture: Incorporation of revised farm slurry data, slaughter weight and fertiliser application data. Revisions to land use areas and crop yield. New mobile machinery model now incorporated.
- Energy Supply: Revised fuel use data.
- Business: Incorporation of new estimates of off road machinery, improved data on consumption of fuels.
- Transport: revised DfT minor road data for 2000-2019 and a revision to the total gas use in road transport for later years.
- Residential: Revised fuel use data. Domestic combustion of natural gas was revised for 2019 and 2020 due to updates to the Carbon Emission Factors in the Local Distribution Zone (LDZ) data.
- Waste Management: Revisions to the UK total for municipal wastewater emissions. Removal of methane emissions associated with disposal to land, landfill, or incineration, to prevent double counting. Incorporation of region-specific wastewater to sea data.

(b) in relation to the net Scottish emissions account—

(i) its amount for the year covered by the report,

In 2021, the net Scottish emissions account was 41.6 $MtCO_2e$.

(ii) the percentage by which the account for the year covered by the report is lower than the baseline,

On the basis of the 1990-2021 inventory, the net Scottish emissions account in 2021 was 49.2 % lower than the baseline.

(iii) the percentage by which the account for the year covered by the report is lower or higher than the equivalent account for the immediately preceding year.

On the basis of the 1990-2021 inventory, the net Scottish emissions account in 2021 was 2.4 % higher than in 2020.

(iv) the percentage of any reduction in the account for the year covered by the report, relative to the equivalent account for the

[12] National Inventory Report

immediately preceding year, which is accounted for by reductions in net Scottish emissions of greenhouse gases,

All (100%) of the reduction in the net Scottish emissions account between 2020 and 2021 was accounted for by changes in net Scottish emissions of greenhouse gases.

(c) the total amount of carbon units that were—

(i) credited to or debited from the net Scottish emissions account for the year covered by the report,

No carbon units were credited or debited to the net Scottish emissions account for 2021.

(ii) purchased by the Scottish Ministers in the year covered by the report, and

No carbon units were purchased by Scottish Ministers in 2021.

(iii) held by the Scottish Ministers immediately after the end of the year covered by the report and which remained available to offset greenhouse gas emissions for other target years,

No carbon units were held by Scottish Ministers immediately after the end of 2021.

(d) for each target year preceding the year covered by the report—

(i) the aggregate amount of net Scottish emissions of greenhouse gases.

Year	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**
Net GHG emissions ($MtCO_2e$)	64.4	57.4	57.7	55.5	52.0	51.5
Year	**2016**	**2017**	**2018**	**2019**	**2020**	
Net GHG emissions ($MtCO_2e$)	46.8	45.8	47.0	46.2	40.6	

(ii) the amount of the net Scottish emissions account *

Year	2010	2011	2012	2013	2014	2015
Net Scottish Emissions Account ($MtCO_2e$)	64.4*	61.6*	61.8*	54.1*	48.8*	50.6*
Year	**2016**	**2017**	**2018**	**2019**	**2020**	
Net Scottish Emissions Account ($MtCO_2e$)	51.4*	53.3*	47.0	46.2	40.6	

* The figures set out here for the net Scottish emissions account for the years 2010 to 2017 are consistent with the approach used in previous statutory annual target reports and are on the basis of Scottish emissions adjusted for the operation of the EU Emissions Trading System (EU ETS). The Climate Change (Emissions Reduction Targets) (Scotland) Act 2019 has subsequently altered the emissions accounting basis for assessing progress to targets from 2018 onwards, to remove that adjustment. As such, these earlier figures are not directly comparable to those in other columns of the table or other sections of the report.

(e) the fair and safe Scottish emissions budget, and the aggregate amount of net Scottish emissions of greenhouse gases for the period from 2010 to the end of the year covered by the report.

The fair and safe Scottish emissions budget for emissions over the period 2010 to 2050[13] is 1,028 $MtCO_2e$. The total amount of net Scottish emissions of greenhouse gases over the period from 2010 to 2021 is 606.6 $MtCO_2e$.

Subsection 3 requires that, if the methods used to determine net Scottish emissions of greenhouse gases change and that change is such as to require adjustment of an amount for an earlier target year, the report must —

(3)

(a) specify the adjustment required and state the adjusted amount, and (b) explain why the adjustment is required.

[13] The level of fair and safe Scottish emissions budget is determined directly from the advice of the UK Committee on Climate Change. The Committee's most recent advice on this matter was provided in December 2022: Scottish Emission Targets & Progress in reducing emissions in Scotland – 2022 Report to Parliament - Climate Change Committee (theccc.org.uk)

This latest release now reports data using global warming potential that are consistent with the IPCC's 5th Assessment Report, without climate feedback. Other reasons for revisions to previously published data include:

- Agriculture: Incorporation of revised farm slurry data, slaughter weight and fertiliser application data. Revisions to land use areas and crop yield. New mobile machinery model now incorporated.
- Energy Supply: Revised fuel use data.
- Business: Incorporation of new estimates of off road machinery, improved data on consumption of fuels.
- Transport: revised DfT minor road data for 2000-2019 and a revision to the total gas use in road transport for later years.
- Residential: Revised fuel use data. Domestic combustion of natural gas was revised for 2019 and 2020 due to updates to the Carbon Emission Factors in the Local Distribution Zone (LDZ) data.
- Waste Management: Revisions to the UK total for municipal wastewater emissions. Removal of methane emissions associated with disposal to land, landfill, or incineration, to prevent double counting. Incorporation of region-specific wastewater to sea data.

The combined impact of these revisions has resulted in the previously published value for emissions in 2020 being increased from 40.0 MtCO2e, to their current value of 40.6 MtCO2e.

Annex B: Scottish greenhouse gas emissions using categories presented in Scotland's climate change plan.

The Scottish Government's Climate Change Plan was published in February 2018 presenting a strategy to reduce emissions over the period to 2032. The modelling activity supporting this plan used a modified version of the sectoral categories used in the Scottish Greenhouse Gas Emissions publication. The following table presents the latest Scottish emissions data using these alternative categories.

Annex B: Table 1. Scottish GHG emissions using Climate Change Plan emissions categories, All values shown in $MtCO_2e$.

	Base-Year	2020	2021	Baseyear - 2021		2020-2021	
				Change	% change	Change	% change
Agriculture	8.8	7.7	7.8	-0.9	-10.8%	0.1	1.9%
Electricity Generation	14.7	1.7	1.6	-13.1	-89.1%	-0.1	-7.2%
Industry	19.5	10.2	9.6	-9.9	-50.7%	-0.6	-6.0%
LULUCF	6.0	0.3	0.4	-5.7	-94.1%	0.0	12.3%
Buildings	11.6	8.5	9.0	-2.5	-21.8%	0.5	6.1%
Transport	14.9	10.7	11.6	-3.2	-21.8%	0.9	8.7%
Waste Management	6.5	1.5	1.5	-5.0	-76.2%	0.1	5.1%
Total net emissions	**82.0**	**40.6**	**41.6**	**-40.4**	**-49.2%**	**1.0**	**2.4%**

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How to access background or source data
Background data are available from National Atmospheric Emissions Inventory website and from a separate Excel workbook accompanying this publication

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