Climate Change Committee

The Sixth Carbon Budget

F-gases

This document contains a summary of content for the F-gases sector from the CCC's Sixth Carbon Budget Advice, Methodology and Policy reports.

Introduction

The Committee is advising that the UK set its Sixth Carbon Budget (i.e. the legal limit for UK net emissions of greenhouse gases over the years 2033-37) to require a reduction in UK emissions of 78% by 2035 relative to 1990, a 63% reduction from 2019. This will be a world-leading commitment, placing the UK decisively on the path to Net Zero by 2050 at the latest, with a trajectory that is consistent with the Paris Agreement.

Our advice on the Sixth Carbon Budget, including emissions pathways, details on our analytical approach, and policy recommendations for the F-gases sector is presented across three CCC reports, an accompanying dataset, and supporting evidence.

- **An Advice report**: *The Sixth Carbon Budget – The UK's path to Net Zero*, setting out our recommendations on the Sixth Carbon Budget (2033-37) and the UK's Nationally Determined Contribution (NDC) under the Paris Agreement. This report also presents the overall emissions pathways for the UK and the Devolved Administrations and for each sector of emissions, as well as analysis of the costs, benefits and wider impacts of our recommended pathway, and considerations relating to climate science and international progress towards the Paris Agreement. Section 11 of Chapter 3 contains an overview of the emissions pathways for the F-gases sector.
- **A Methodology Report:** *The Sixth Carbon Budget – Methodology Report*, setting out the approach and assumptions used to inform our advice. Chapter 11 of this report contains a detailed overview of how we conducted our analysis for the F-gases sector.
- **A Policy Report:** *Policies for the Sixth Carbon Budget and Net zero*, setting out the changes to policy that could drive the changes necessary particularly over the 2020s. Chapter 11 of this report contains our policy recommendations for the F-gases sector.
- **A dataset** for the Sixth Carbon Budget scenarios, which sets out more details and data on the pathways than can be included in this report.
- **Supporting evidence** including our public Call for Evidence, 10 new research projects, three expert advisory groups, and deep dives into the roles of local authorities and businesses.

All outputs are published on our website (www.theccc.org.uk).

For ease, the relevant sections from the three reports for each sector (covering pathways, method and policy advice) are collated into self-standing documents for each sector. A full dataset including key charts is also available alongside this document. This is the self-standing document for the F-gases sector. It is set out in three sections:

1) The approach to the Sixth Carbon Budget analysis for the F-gases sector
2) Emissions pathways for the F-gases sector
3) Policy recommendations for the F-gases sector

Chapter 1

The approach to the Sixth Carbon Budget analysis for the F-gases sector

The following sections are taken directly from Chapter 11 of the CCC's Methodology Report for the Sixth Carbon Budget.[1]

Introduction

This chapter sets out how we developed scenarios for F-gas emissions to inform the Committee's advice on the UK's Sixth Carbon Budget. It builds on evidence used in 2019 for our *Net Zero* advice on cost-effective abatement measures that go beyond existing EU regulations.

Fluorinated gases (F-gases) are released in very small volumes relative to other greenhouse gases (GHGs), but can have a global warming potential (GWP) up to 26,000 times greater than carbon dioxide. They are used across many sectors of the UK economy as refrigerants, aerosols, solvents, insulating gases, or blowing agents for foams, and they can also be emitted as fugitive emissions from other manufacturing processes. Due to their highly damaging impact on the climate, F-gases should be restricted to the very limited uses where there are no viable alternatives.

The key messages from this chapter are:

- **Background**. F-gas emissions accounted for 3% of UK greenhouse gas emissions in 2018 and were 9% below 1990 levels. Emissions in 2018 were 37% below the year of highest emissions in 1997, as abatement technologies at halocarbon production plants have cut F-gas leakage by over 99%. The largest source of emissions is now the refrigeration, air-conditioning and heat pump (RACHP) sector, where emissions are released due to refrigerant leakage from appliances during use and when they are disposed.
- **Baseline emissions**. There already exists a strong international framework for reducing F-gas emissions, through the Kigali Amendment to the UN Montreal Protocol. The UK was previously subject to the 2014 EU F-gas Regulation and 2006 Mobile Air Conditioning (MAC) Directive and is transitioning to equivalent standards. Our baseline assumes that the UK maintains a regulatory framework at least as strong as the EU F-Gas Regulation that can deliver an 80% reduction of F-gas emissions in 2050 compared to the 1995 baseline.
- **Deeper emissions reduction pathways.**
  - Our scenarios explore action to further reduce emissions in the RACHP sector, as well as a transition to medical inhalers that have a lower global warming impact. In our Widespread Innovation scenario, we explore more speculative abatement measures in more niche F-gases subsectors such as the use of foams.
  - These scenarios may require stronger regulation (for example in the RACHP sector), technical shifts to lower-GWP aerosols and behavioural changes amongst end-users (e.g. between clinicians and patients). These measures can deliver an additional 1-2 $MtCO_2e$ abatement by 2050 compared to the 1995 baseline.
- **Costs and benefits.** Actions to reduce F-gas emissions are expected to be broadly cost-neutral. Many of the technologies required exist already and are cheaper than high-GWP alternatives.
- **Delivery**. The UK Government has already taken a crucial step towards reductions in F-gas emissions, by adopting standards at least as stretching as the EU F-gas Regulation. Beyond this, there will be a need to increase

training, certification and monitoring of non-compliance in the RACHP sector, introduce alternatives to Metered Dose Inhalers (MDIs), and consider regulatory approaches to deliver further reductions in the RACHP sector.

We set out our analysis in three sections:

1. Sector emissions
2. Options to reduce emissions
3. Approach to analysis for Sixth Carbon Budget pathway

1. F-gas emissions

This section outlines the recent trends in F-gas emissions and their sources. For more detail, see our 2020 Progress Report to Parliament.[2]

a) Breakdown of current emissions

F-gas emission levels were 15 $MtCO_2e$ in 2018, accounting for 3% of total UK GHG emissions (Figure M11.1). Emissions were 14% below 1990 levels and 37% below the peak in 1997.

F-gases are released in small volumes. However, they are very effective at trapping heat and can remain in the atmosphere for many centuries after their release. As a result, they have a high climate impact per molecule, which is reflected in the high Global Warming Potentials (GWP) used in international emissions accounting.

The climate impacts of all greenhouse gases are compared to CO_2, which has a GWP defined as 1. Future methodology changes to the GWPs* of different F-gases will tend to increase estimates of their warming potential, meaning that compared to the current UK greenhouse gas inventory, estimated total F-gas emissions will be revised upwards by around 1-2 $MtCO_2e$ per year.

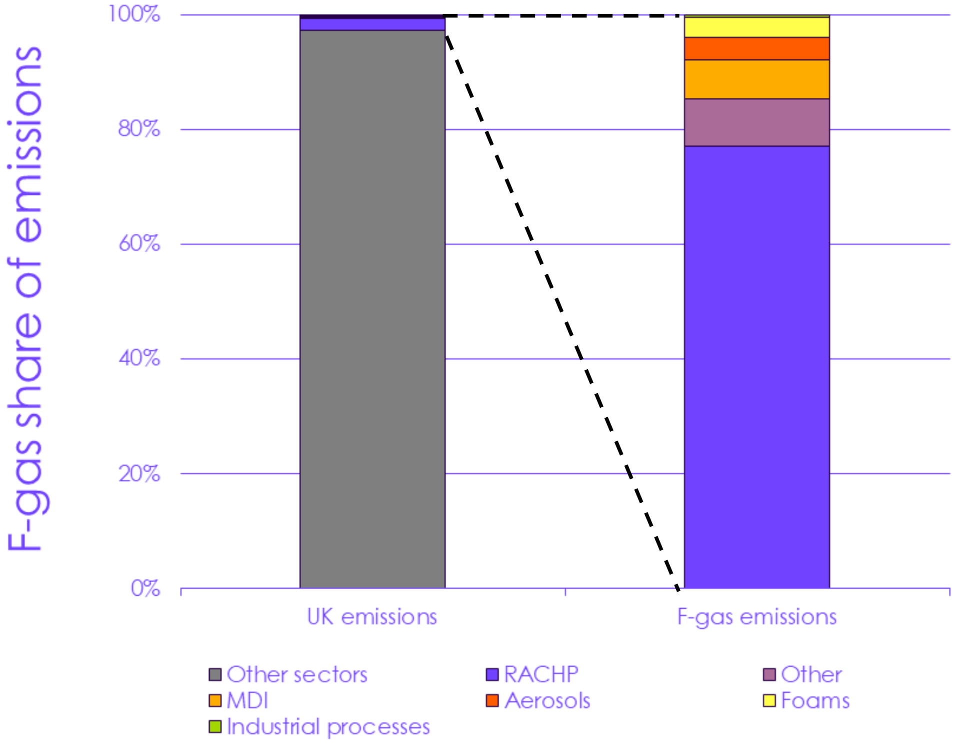
The four F-gases included in the UK emissions inventory are hydrofluorocarbons (HFCs), sulphur hexafluoride (SF_6), perfluorocarbons (PFCs), and nitrogen trifluoride (NF_3):

- **HFCs** (94% of total F-gas emissions in 2018) are used in refrigeration, air-conditioning appliances, aerosols and foams, metered-dose inhalers and fire equipment. They are emitted during the manufacture, lifetime and disposal of these products and can stay in the atmosphere for up to 270 years (although some have shorter lifetimes). HFCs have GWPs ranging from approximately 100 to around 15,000.
- **SF_6** (4%) is mainly used in insulation for electricity networks, magnesium casting and military applications. It stays in the atmosphere for around 3,000 years. SF_6 has a GWP of 26,087.
- **PFC** emissions (2%) result mainly from the manufacture of electronics and as a by-product of aluminium and halocarbon production. Their lifetime in the atmosphere ranges from 2,600 to 50,000 years. PFCs have GWPs of approximately 7,000 to approximately 19,000.
- **NF_3** emissions are currently very low (less than 0.001 $MtCO_2e$) and result from semi-conductor manufacturing. These emissions do not count towards the UK Net Zero target or carbon budgets. NF_3 stays in the atmosphere for around 700 years and has a GWP of 17,885.

The largest source of emissions in 2018 was leakage from refrigeration and air-conditioning systems (77%). These systems have mainly used HFCs since ozone-depleting chlorofluorocarbons (CFCs) were phased out. Other F-gas emissions came from technical aerosols (4%), metered-dose inhalers (7%), and foams (3%).

* Using AR5 Global Warming Potential values with carbon-cycle feedbacks. See Box 2.1 of the Sixth Carbon Budget Report

Figure M11.1. Breakdown of F-gases sector emissions (2018)



Source: BEIS (2020) *Provisional UK greenhouse gas emissions national statistics 2019*. RACHP: Refrigeration, Air-Conditioning and Heat Pumps. MDI: Metered Dose Inhalers.

b) Trends and drivers

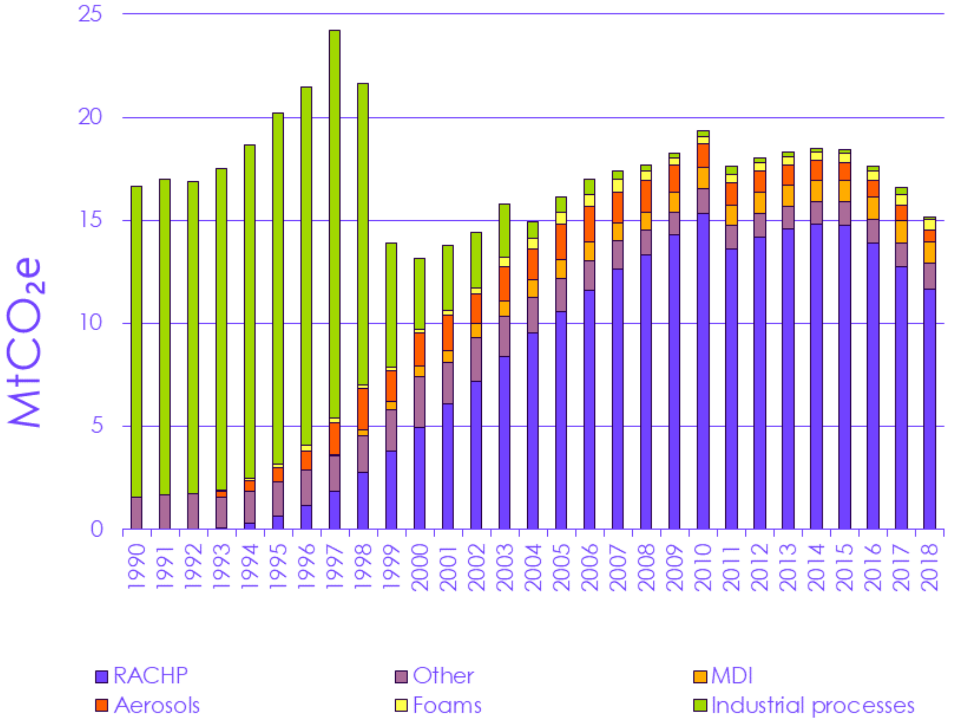
Total F-gas emissions peaked in 1997, reaching 24 $MtCO_2e$, around 80% of which was due to HFC and other halocarbon production (Figure M11.2). Between 1997 and 2000, F-gas emissions dropped significantly as a result of mitigation measures to reduce leakage in the industrial production of halocarbons. From 2001 to 2015, F-gas emissions rose slowly, mainly due increasing demand for the refrigerants used in air-conditioning and refrigeration. F-gas emissions fell by around 18% from 2015 to 2018 due to the introduction of new EU regulations.

The UK has signed up to a strong international legal framework for reducing F-gas emissions the Kigali Amendment to the UN Montreal Protocol, and was previously subject to the F-Gas Regulation (EU) 517/2014 and the Mobile Air Conditioning (MAC) Directive.

Legislation has been the key driver of a transition to low-GWP alternatives in recent years:

- The Kigali Amendment to the UN Montreal Protocol sets out pathways for developed and developing countries for controlling the production and consumption of HFCs. Under the amendment HFCs in developed countries will be reduced through incremental targets up to a cut of 86% by 2036. These plans are less stringent than the EU F-Gas Regulation up to 2034, after which the Kigali Amendment targets are more ambitious. This may not remain the case, as the EU plans to consider in 2022 an extension of the ambition of the F-Gas Regulation beyond 2030. The UK ratified the Kigali Amendment in November 2017 and the amendment took effect in January 2019.
- The 2014 EU F-Gas Regulation came into force in the UK in January 2015, and equivalent measures will be enforced into UK law in at the end of the transition period of leaving the EU. It introduced a number of new measures and strengthened the 2006 EU F-Gas Regulation:
  - The regulation sets a cap on the amount of HFCs that producers and importers are allowed to place on the market. The cap will be cut every three years until reaching a 79% cut by 2030 from 2015 levels.
  - Some uses of HFCs are exempt from the regulation, including medical use, military equipment and manufacturing of semiconductors. Emissions from SF_6 and PFCs are not included in the cap.
  - The regulation bans the use of F-gases in many new types of equipment where less harmful alternatives are widely available, such as fridges in homes or supermarkets, air-conditioning and foams and aerosols.
  - The regulation strengthens existing obligations in terms of mandatory 'management measures' including regular leak checks and repair, gas recovery at end-of-life, record keeping, training and certification of technicians and product labelling.
- The 2006 MAC Directive focuses on emissions from air-conditioning in new cars and vans. From 2017, all new cars and vans are required to use substances with a GWP less than 150.
- Emissions of PFCs from aluminium production are priced under the EU Emissions Trading System.

Figure M11.2. Breakdown of F-gases sector emissions (1990-2018)



Source: BEIS (2020) *Provisional UK greenhouse gas emissions national statistics 2019*. RACHP: Refrigeration, Air-Conditioning, Heat Pumps. MDI: Metered Dose Inhalers.
Notes: Emissions data is shown adjusted to AR5 Global Warming Potentials with carbon-cycle feedback and therefore does not match the total published UK Greenhouse Gas inventory.

2. Options to reduce emissions

Many applications that use F-gases can reduce their emissions, or be switched to lower-warming alternatives, with few costs and barriers. In 1990, manufacture of halocarbons was the largest source of F-gases emissions in the UK. Emissions fell substantially between 1997 and 2001, as a result of fitting abatement technologies at production sites. There is now little potential to further reduce emissions from this source.

However, there remain other source of F-gases and these will be more challenging to abate, typically due to long product lifetimes or a lack of viable alternative technologies to replace F-gases:

- **Refrigeration, air-conditioning and heat pump (RACHP) emissions where no low-GWP alternatives currently exist (approximately 5% of total 2018 emissions).** The EU F-Gas Regulation is already driving a shift from very high-GWP gases to lower-GWP options such as HFC-32, which is expected to be the dominant HFC refrigerant in 2040. There is, however, little current progress towards an even lower-GWP alternative. For small systems, hydrocarbon refrigerants such as propane are a good option, but high flammability limits the proportion of the market that can safely use hydrocarbon refrigerants. It is unlikely that more than 25% of the small sized air-conditioning market and 50% of the residential heat pump market could use hydrocarbons.[3]
- **Lifetime and disposal emissions from foams (approximately 2%).** It is extremely challenging to recover F-gas blowing agents from foams, typically used in building insulation, because of the difficulties in separating the foam from the associated building material.
- **Emissions from current gas-insulated high-voltage switchgear (GIS) (approximately 1%).** The long lifetime (up to 40 years) of high voltage switchgear equipment used in the electricity system, and the lack of mature non-SF_6 alternatives means that accelerating the replacement of existing GIS equipment would be difficult and very expensive. New equipment is more efficient and minimises leakage.
- **Other sources of F-gas emissions (approximately 5%).** Emissions from other small sources, including aluminium fugitives, semiconductors, solvents, military use, and laboratory use are difficult to reduce, reflecting a lack of alternatives. It is possible that there may be some scope to reduce emissions from halocarbon production and magnesium casting.
- **High uptake of low-carbon alternatives to Metered Dose Inhalers (MDIs) (approximately 8%).** Low-carbon alternatives to MDIs are abundant (e.g. Dry Powder Inhalers DPIs). Shifting to these alternatives will require behaviour change from practitioners and patients.

Despite these challenges, there is potential for further abatement that goes beyond the UK's existing regulation and international agreements.

a) Behaviour change measures

Metered dose inhalers (MDIs) use F-gases (HFA-134a and HFA-227ea) as propellants, and account for around 1 $MtCO_2e$ of annual emissions in the UK. There are two solutions to reducing emissions from MDIs:

- Viable alternatives to MDIs already exist in the form of dry-powder inhalers (DPIs), which do not use a propellant and therefore have zero F-gas emissions. Around 25% of all inhalers prescribed in the UK are currently DPIs, which is a much lower share than many European countries. In Denmark, more than 80% of all inhalers prescribed are DPIs. Increasing the uptake of DPIs in the UK has significant potential to reduce F-gas emissions, but will require changes to both patient and doctor behaviour.

- MDIs could switch to using a propellant with a lower warming potential. This new technology would have to be adopted by the National Health Service, but would require virtually no behaviour changes for patients. There is active research towards a low-GWP metered dose inhaler using the propellant HFA-152a, which could be in use by the end of 2025 and cut emissions from inhalers by around 90%.[4]

b) Technical measures

A range of low-GWP F-gases, or alternative technologies that do not cause climate change, are already available on the market, and new innovation will likely bring more forward (Box M11.1).

The deployment of lower-GWP or ultra-low-GWP alternatives to current F-gases in the refrigeration, air conditioning and heat pump (RACHP) sector has the potential to reduce emissions further than the existing baseline.

It is important to recognise that the RACHP market is highly complex, with many different market sectors and sub-sectors. This leads to the need for a range of different refrigerants that are designed to suit specific applications. Key variables that have informed our assessment of the potential for the RACHP sector to go further include:

- **System size**. RACHP systems vary in cooling capacity from under 1 kW (e.g. domestic refrigerators) to >10,000 kW for large industrial systems.

- **Temperature level**. Most refrigeration applications are either in the range 0°C to 5°C (e.g. for chilled food) or -15°C to -40°C (e.g. for frozen food). However, some refrigeration is required at much lower temperatures, between -60°C and -270°C. Air-conditioning typically provides cooling at temperatures in the range 10°C to 20°C. Heat pumps deliver heat at between 40°C and 120°C. This significant range of different temperatures requires various refrigerants to be available, with a range of thermodynamic properties that can be selected to suit the temperature level of the application.

- **Location / accessibility.** Some RACHP systems are located in areas with public occupancy e.g. shops, hotels, private residences. In such locations, safety issues might restrict the choice of available refrigerants or the size of refrigerant charge. For some RACHP applications, the equipment is located in a restricted area, with only trained personnel allowed access e.g. in factories or special machinery rooms. In these circumstances, a wider range of refrigerant options can be considered.

- **New equipment and retrofits.** Most refrigerant selections are made for new equipment, where the designer may have several options available. However, under an HFC phase-down it may also be appropriate to retrofit an existing plant with a lower-GWP refrigerant. In these circumstances there are many more design constraints and fewer refrigerants will be suitable.

Some areas of abatement measures highlighted in our Net Zero report were identified as technically feasible, but were not costed and market-ready solutions do not yet exist. These opportunities lie in military radar systems (AWACS), halocarbon and magnesium production, foams, semiconductors, and solvents. Abating emissions from these subsectors will require alternative low-GWP technologies to be designed and implemented. As these solutions are more less certain, they are included only in the Widespread Innovation and Tailwinds scenarios.

Box M11.1
New evidence on reducing F-gas emissions

The European commission has been a major driver of research into the prospect of using lower-GWP F-gases. Since our Net Zero report, they have published two further reports into the prospect of low-GWP refrigerants for new split air conditioning systems, and one into alternatives to F-gases used in switchgear and related equipment.

The major findings of these reports are that:

- There is growing potential for ultra-low-GWP alternatives to F-gases to be used in a greater range of cooling systems. Increasing knowledge, practices and know-how in how to manufacture, install, use and manage flammable refrigerants will allow even greater uptake, alongside countries revisiting their restrictions around F-gases alternatives.[5]
- There is an increasing pipeline of low-GWP F-gases that have the potential to reduce the average GWP of gases used in single split systems to less than 150.[2]
- There are commercially available alternatives to SF_6 for many applications in electric switchgear and related equipment. These alternatives are marginally more expensive but have "almost identical" technical characteristics. Within the next two to five years, commercially viable alternatives to higher voltage systems using SF_6 could be available.[6] The deployment of SF_6-free equipment will be easier to do at the installation or replacement of a system rather than retrofitting systems mid-life.

3. Approach to analysis for the Sixth Carbon Budget advice

This section details how the options for abatement outlined in Section 2 are utilised in our different scenarios.

a) Analytical methodology

Our baseline assumes that the UK remains in an equivalent regulatory environment to that of the EU. Our projections of F-gas emissions under this regulatory framework indicate this will deliver significant abatement across several sectors:

- **Refrigeration, air conditioning and heat pumps (RACHP)** emissions fall by 75%, from 12 MCO_2e in 2018 to around 3 $MtCO_2e$ in 2030, allowing for a substantial increase in the number of heat pumps in the UK (Box M11.2).
- **Technical aerosols** emissions fall by 94% between 2017 and 2022 to less than 0.05 $MtCO_2e$ following the ban of high-GWP F-gases.
- **Fire Protection Systems (FPS)** emissions to fall by around two-thirds by 2030 and to zero emissions by 2038.
- **Manufacture of new foams** emissions fall to zero in 2023, following a ban on the use of high-GWP F-gases as blowing agents in 2022.
- **Gas Insulated Switchgear (GIS)** emissions from GIS in electricity networks are expected to fall slowly (35% from 2017 to 2030), as older SF_6 equipment is replaced with modern equipment with much smaller SF_6 charges and lower levels of leakage.

This baseline regulation results in F-gas emissions reaching 3.4 $MtCO_2e$ by 2050, a reduction of 85% on 1990 levels and 84% on 2018. The scenarios in this report show that an additional 1-2 $MtCO_2e$ can be achieved on top of these baseline reductions.

Box M11.2

Methodology for F-gas emissions associated with refrigerant leakage in heat pumps

Emissions in each scenario are influenced by the total number of heat pumps assumed to be deployed in that scenario in buildings (see Chapter 2 of this report).

Net GHG benefits of heat pumps. The greenhouse gas benefits of switching from fossil fuel heating to heat pumps far outweigh the potential increase in HFC emissions from refrigerant leakage:

- Analysis for the Government in 2014 showed that for every additional 1 tCO_2e of additional HFC emissions from refrigerant leakage in heat pumps, there are 161 tCO_2e of CO_2 savings due to avoided emissions from gas boilers and efficiency improvements.
- This analysis assumed a power sector that was decarbonised to be consistent with the UK's old 80% target for 2050, at 32 gCO_2/kWh_e. In our Balanced Net Zero pathway, the UK would reach that level of electricity carbon intensity before 2035 (see Chapter 5), and the net greenhouse gas savings of heat pumps with a Net Zero power sector in 2050 will therefore be even greater.

In all our scenarios, millions of heat pumps are deployed by 2050. This will cause F-gas emissions to rise, but this increase will be orders of magnitude lower than the carbon savings.

If these heat pumps use lower-GWP F-gases or alternatives (as explored in our scenarios), this rise can be even smaller, and the net benefit even greater.

Market-ready solutions. The existing UK F-gas regulation applies to heat pumps, meaning that producers for the UK (and EU) market are mandated to shift to lower-GWP gases.

This regulation is already driving a shift from high-GWP gases to lower-GWP options such as HFC-32, which is expected to be the dominant HFC refrigerant in our analysis during the Sixth Carbon Budget period.

Switching to low-GWP technology may also lead to efficiency improvements in heat pumps. However, as our analysis of the residential buildings sector already includes efficiency improvements for heat pumps (Chapter 2), we do not include any additional carbon savings in this chapter, to avoid 'double counting' efficiency improvements.

Potential for further abatement. There is little current progress towards an even lower-GWP alternative to HFC-32. For small systems, hydrocarbon refrigerants such as propane are a good option, but high flammability limits the proportion of the market that can safely use hydrocarbon refrigerants. It is unlikely that more 50% of the residential heat pump market could use hydrocarbons.

There is little likelihood of an ultra-low-GWP refrigerant with similar properties to HFC-32 becoming available, so the industry would need to look for a 'not-in-kind' design. One possibility would be to use the type of air-conditioning technology adopted in car air-conditioning – based on HFO-1234yf. This has a GWP of just four, which could reduce F-gas emissions further by around 1 $MtCO_2e$. This more speculative technological solution is not included in our Balanced Net Zero Pathway.

Alternative technological solutions are being developed and our analysis should not be interpreted as a recommendation on which particular low-GWP or ultra-low-GWP solution for heat pumps is most suitable.

Source: Eunomia Research for DECC (2014) *Impacts of leakage from refrigerants in heat pumps*; Ricardo and Gluckman Consulting (2018) *Assessment of the potential to reduce UK F-gas emissions beyond the ambition of the F-gas Regulation and Kigali Amendment*.

b) Emissions in the Balanced Net Zero Pathway and exploratory scenarios

Due to the strong regulatory environment in the UK, our scenarios all show similar emissions reductions over time compared to current levels.

We use exploratory scenarios to explore different pathways to 2050:

- **Abatement beyond the baseline in all scenarios.** This results in 2050 emissions being 2.5 $MtCO_2e$ in 2050. All scenarios include:
  - **Lower leakage rates of refrigerants** due to improved equipment design, technical training and more controls on end-of-life disposal.
  - **Lower-GWP alternatives in small retail condensing units, small industrial sites and in marine industries**, replacing R-448A and R-449A units.
  - **Retrofits to lower-GWP alternatives** for large industrial R-404A refrigeration systems and R-134A air conditioning units in cars.
  - **Metered dose inhaler (MDI) improvements and substitutes.** Existing beclomethasone dipropionate and compound drug MDI inhalers are replaced with dry powder inhalers. Salbutamol MDIs are reformulated to use lower-GWP aerosols from the mid-2020s.
- **Balanced Net Zero Pathway.** Our Balanced Pathway results in 2050 emissions of 2.5 $MtCO_2e$. The pathway includes the measures in the Widespread Engagement scenario, but has slightly higher emissions overall due to further heat pump rollout in the buildings sector.
- **Headwinds scenario.** Our headwinds scenario contains the measures included in all scenarios (see bullets above) and nothing else. This achieves emissions on 2.5 $MtCO_2e$ by 2050.
- **Widespread Engagement scenario.** This scenario assumes that increased willingness to change behaviour results in increased uptake of dry powder inhalers (DPIs), specifically the replacement of salbutamol MDIs with DPIs. The emissions difference between a low-GWP MDI and a zero-emission DPI is extremely marginal, so this behavioural change makes little difference to emissions compared to the Balanced Net Zero Pathway, reaching 2.5 $MtCO_2e$ in 2050.
- **Widespread Innovation scenario.** Our Widespread Innovation and Tailwinds scenarios go further than the other scenarios, modelling HFC-32 replaced by a lower-GWP alternative. There is preliminary research being done into the technical capacity for hydrocarbons to replace HFC-32. Measures from our 2019 Net Zero report described as technically feasible but un-costed are included in this scenario. They are assumed to cost the UK-wide carbon price in the year of abatement (Chapter 1). Including these additional measures results in 2050 emissions of 1.6 $MtCO_2e$.
- **Tailwinds scenario.** This scenario includes all measures from the widespread engagement and innovation scenarios, resulting in 2050 emissions of 1.4 $MtCO_2e$.

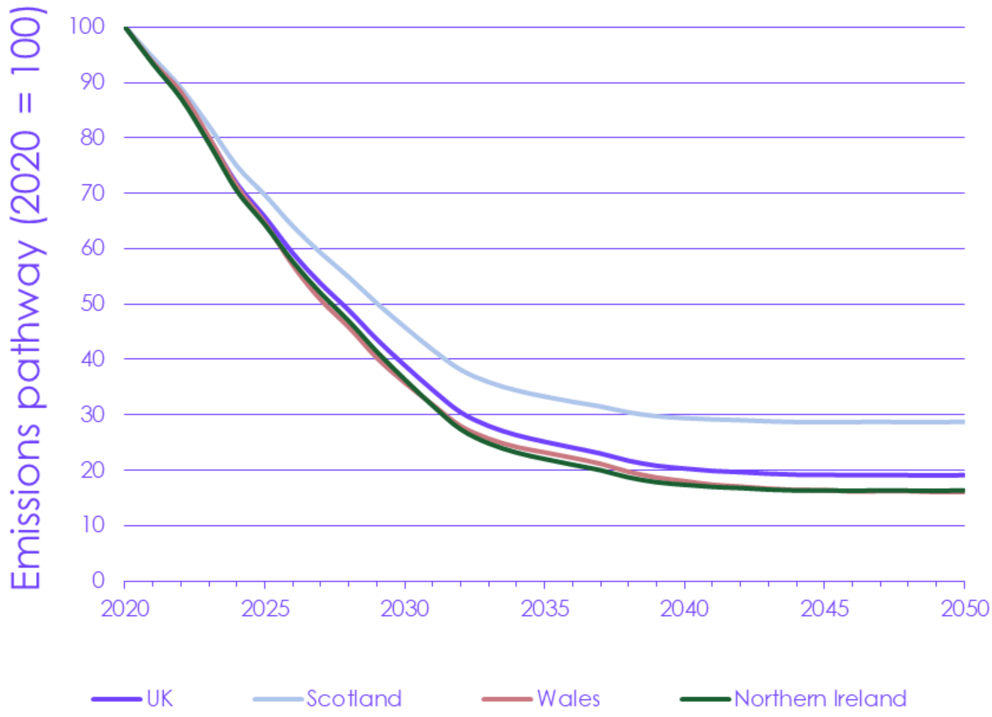
c) Deriving scenarios for emissions in Scotland, Wales and Northern Ireland

To determine the pathways for Scotland, Wales and Northern Ireland, we apply the same measures from the UK to current emissions sources of F-gases. Different existing shares of F-gases sources results in different speeds and depths of decarbonisation for the different parts of the UK:

- F-gases emissions from aluminium production and semiconductor production are higher in Scotland than the rest of the UK.
- There are no emissions from magnesium production in Scotland and Northern Ireland.

Due to the different shares of existing emissions, Northern Ireland and Wales can reduce emissions marginally faster and deeper than Scotland, which more closely mirrors the path that the UK takes (Figure M11.3).

Figure M11.3. Comparison of the Balanced Net Zero Pathway for the UK, Scotland, Wales and Northern Ireland



Source: CCC Sixth Carbon Budget Analysis

d) Approach to uncertainty and potential impacts of COVID-19 on sector emissions over time

Given the strong regulatory framework to drive down baseline emissions, the principal risk of not reducing F-gas is that policy is not maintained or enforced. This can be minimised through:

- **Maintaining a regulatory framework at least as strong as EU F-Gas Regulation.** Legislation has been passed that enables the UK to set a quota system that is independent from the EU quota. Defra has committed to maintaining the same percentage reductions as the EU F-Gas Regulation. The UK should match any strengthening of the EU system in the near future.

- **Minimising non-compliance, especially in the RACHP sector.** The Environment Audit Committee has reported evidence of suspected non-compliance, especially as EU F-Gas Regulation increase demand for lower-GWP refrigerants, and a lack of resources for the Environment Agency to carry out adequate inspections.

- **Increasing training and certification for F-gas users.** The current regulatory framework does not require retrospective training for workers trained under previous regulations and allows untrained members of the public to top-up their own car air-conditioning units with high-GWP refrigerants. The Government should consult with industry and bring forward proposals to ensure that all those who handle refrigerants have up-to-date training.

A further risk to the pathway is public knowledge of the warming impacts of metered dose inhalers (MDIs) and acceptance of dry powdered inhalers (DPIs):

- **Lack of awareness.** Previous analysis for the Committee has found a lack of awareness of the high global warming impact of metered dose inhalers (MDIs). The UK prescribes fewer DPIs than most other EU countries, despite evidence that DPIs can be more effective in clinical use for a large proportion of patients. This lack of knowledge is a behavioural barrier to a transition away from high-GWP MDIs. The Environmental Audit Committee corroborated this finding, reporting that low take-up of DPIs in the UK is, in part, due to low awareness of DPIs as an alternative among patients and GPs.[7]

- **Behavioural barriers** may also exist as patients and medical practitioners are reluctant to switch to new devices.

- **Promoting the use of DPIs** is likely to require engagement across organisations such as the Royal College of GPs, the British Thoracic Society and the National Institute for Health and Care Excellence (NICE) and the NHS Sustainable Development Unit. Clinicians and patients must be informed of the equivalent (or better) performance of DPIs and low-GWP MDIs as well as the environmental benefits.

- **Low-GWP MDIs** are another option that are currently in development and would require less behaviour change from patients while still cutting emissions by around 90%.

The COVID-19 pandemic does not present a material risk to the F-gases emission pathway.

Endnotes

[1] CCC(2020) *The Sixth Carbon Budget – Methodology Report*. Available at: www.theccc.org.uk

[2] CCC (2020) *2020 Progress Report to Parliament*

[3] Ricardo and Gluckman Consulting (2018) *Assessment of the potential to reduce UK F-gas emissions beyond the ambition of the F-gas Regulation and Kigali Amendment.*

[4] European Pharmaceutical Review (2020) *Environmentally friendly pressurised Metered Dose Inhaler to be developed*.

[5] European Commission (2020) *The availability of refrigerants for new split air conditioning systems that can replace fluorinated greenhouse gases or result in lower climate impact*

[6] European commission (2020) *Assessing the availability of alternatives to fluorinated greenhouse gases in switchgear and related equipment, including medium-voltage secondary switchgear*

[7] House of Commons Environmental Audit Committee (2018) *UK Progress on reducing F-gas emissions.*

Chapter 2

Emissions pathways for the F-gases sector

The following sections are taken directly from section 10 of chapter 3 in the CCC's Advice Report for the Sixth Carbon Budget.[1]

Fluorinated gases (F-gas) are man-made gases that can stay in the atmosphere for centuries. Their emissions account for around 3% of total UK GHG emissions. Major emissions sources are refrigerants, aerosols, solvents, insulating gases, or blowing agents for foams and medical equipment. They can also arise as fugitive emissions from other manufacturing processes. Most of the emissions reduction to 2050 will be driven via EU F-Gas Regulation, with further abatement possible through a more aggressive shift to lower Global Warming Potential (GWP) F-gases, behavioural shifts to Dry Powder Inhalers (DPI) and reduced leakage.

The evidence base on how to decarbonise F-gases builds on our 2019 *Net Zero* report, and in particular a 2019 report commissioned by the CCC from Ricardo-Gluckman consulting on decarbonising the F-gases sector.

This section is split into three sub-sections:

a) The balanced scenario for F-gases
b) Alternative routes to delivering abatement in the mid-2030s
c) Impacts of the scenarios: costs, benefits and co-impacts on society

a) The balanced scenario for F-gases

The majority of F-gases emissions come from HFCs used in refrigeration and air-conditioning.

F-gas emission levels were 15 $MtCO_2e$ in 2018, accounting for 3% of total UK GHG emissions (Figure A3.12.a). Emissions were 14% below 1990 levels and 40% below the peak in 1997.

Approximately 95% of F-gas emissions come from (HFCs) which are emitted from production, use and manufacture of refrigeration, air-conditioning equipment, aerosols, foams, metered-dose inhalers and fire equipment. SF_6, other perfluorinated compounds (PFCs), and NF_3 comprise the remaining percentage and are released in various industrial processes. F-gases have a particularly high global warming potential (GWP):[*]

- **HFCs** have GWPs ranging from approximately 100 to over 10,000
- **SF_6** has a GWP of 23,500
- **NF_3** has a GWP of 16,100
- **Other PFCs** (excluding SF_6 and NF_3) have a GWPs of approximately 7,000 to approximately 17,000

There is strong existing regulation for the F-gases sector.

Our pathways start from a baseline assumption that the UK adopts comparable legislation to the current EU F-Gas Regulation. The regulation sets an EU-wide cap on the amount of HFCs that producers and importers are allowed to place on the EU market. The cap will be cut every three years until reaching a 79% cut by 2030 from 2015 levels. The Government signed this regulation into UK law in March 2019, meaning that Brexit should not impact this baseline assumption.

[*] Given in AR5

Reducing emissions further requires a range of behavioural and technical measures, predominantly:

Further abatement in the F-gases sector is possible through replacement of current F-gases with lower GWP alternative, more widespread moves to dry powder inhalers and reduced leakage from heat pumps and refrigerators.

- **Further replacement of current F-gases with lower GWP F-gases.** The deployment of lower GWP alternatives to current F-gases in heat pump systems and refrigerators has the potential to reduce emissions from the sector further. Specifically, the deployment of low GWP alternatives to 448a and 449a F-gases and accelerated transition away from R-404A systems, retrofitting of R-134a car air-conditioning systems.* A host of low GWP F-gases or F-gases alternatives are already available on the market, and innovation will likely bring more forward.
- **More widespread move to dry power inhalers (DPIs).** Metered dose inhalers (MDIs) are a significant source of F-gases emissions. Our Balanced Pathway assumes widespread move from MDIs to DPIs for drugs such as salbutamol.
- **Reduced leakage from heat pump and refrigerators** through improved equipment design and technical skill.

As discussed in the methodology report, our Balanced Pathway involves a widespread rollout of heat pumps. Heat pumps are currently a source of F-gases emissions, and without implementing the measures above, F-gases emissions would increase significantly. For this reason, decarbonising heat pumps is critical in our Balanced Pathway.

b) Alternative routes to delivering abatement in the mid-2030s

Further abatement is possible if lower GWP F-gas alternatives can be developed and deployed, and there is greater uptake of DPI inhalers.

All F-gases scenarios aim to reduce emissions as far as possible by 2050, resulting in a range of residual emissions of 1.5-2.5 $MtCO_2e$/year, and emissions of 2.5-4.0 $MtCO_2e$/year over the Sixth Carbon Budget period (Figure A3.12.a). Across the scenarios we vary the assumptions relating to behavioural change and technological innovation:

- **Headwinds.** Decreased leakage from heat pumps and refrigerants, greater rollout of low GWP alternatives to F-gases, retrofitting of some car air-conditioning systems and partial replacement of MDI inhalers with DPI inhalers (beclomethasone dipropionate and compound drug inhalers).
- **Widespread engagement.** All the measures from headwinds are included, alongside greater willingness to shift to DPI inhalers (specifically the reformulation of salbutamol MDIs to DPIs).
- **Widespread innovation.** All the measures from Headwinds are included. Further shift away from HFCs for which low-carbon alternatives are currently at an earlier stage of deployment. Measures outlined as technically feasible but not costed in our *Net Zero* report are included in this scenario.
- **Tailwinds.** Tailwinds includes the measures from headwinds, widespread engagement and widespread innovation.

c) Impacts of the scenarios: costs, benefits and co-impacts on society

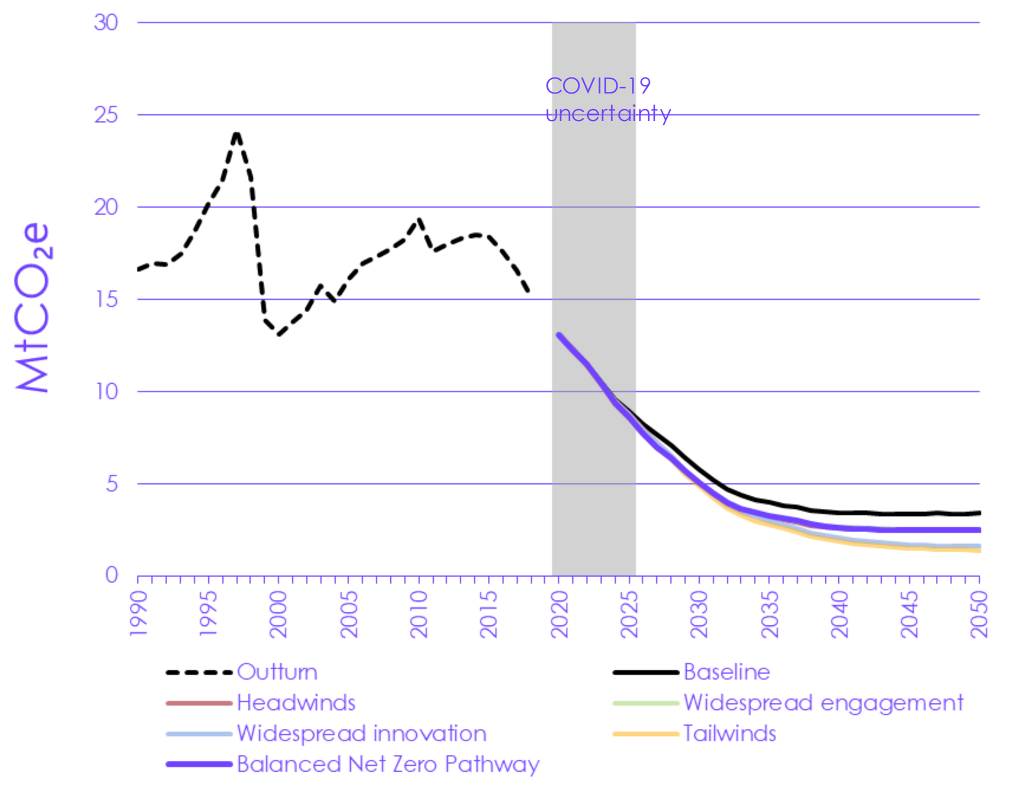
Abating emissions from F-gases should be cost saving by 2050.

Our estimates suggest that reducing emissions from the UK's F-gases sector is achievable as part of a cost-effective scenario towards the Sixth Carbon Budget. In the Balanced pathway we estimate costs of around £7 million per year in 2035, and savings of around £1 million per year by 2050.

* 448a and 449a F-gases are high GWP F-gases used as refrigerants. R-134a is a high GWP F-gas use in car air-conditioning systems that was banned from being used in new cars from January 2017.

The majority of the 2035 costs are due to upfront investment in refrigeration and heating systems that have greater efficiency and lower GWP F-gases that are also often cheaper. By 2050, the efficiency savings more than offset this additional capital investment.

Figure A3.10. Emissions pathways for the F-gases sector



Source: BEIS (2020) Provisional UK greenhouse gas emissions national statistics 2019; CCC analysis.
Notes: Headwinds and widespread engagement scenarios are obscured by Balanced Net Zero Pathway curve. Full data can be found in the exhibits CCC's databook.

Endnote

[1] CCC (2020) *The Sixth Carbon Budget – Methodology Report*. Available at: www.theccc.org.uk

Chapter 3

Policy recommendations for the F-gases sector

The following sections are taken directly from Chapter 11 of the CCC's Policy Report for the Sixth Carbon Budget.[1]

Existing policy

The UK has signed up to a strong international legal framework for reducing F-gas emissions the Kigali Amendment to the UN Montreal Protocol, and was previously subject to the F-Gas Regulation (EU) 517/2014 and the Mobile Air Conditioning (MAC) Directive. This existing regulatory framework is expected to drive the significant majority of reduction of F-gases required for Net Zero.

Legislation has been the key driver of a transition to lower-GWP alternatives in recent years:

- The Kigali Amendment to the UN Montreal Protocol sets out pathways for developed and developing countries for controlling the production and consumption of HFCs. Under the amendment HFCs in developed countries will be reduced through incremental targets up to a cut of 86% by 2036. These plans are less stringent than the EU F-Gas Regulation up to 2034, after which the Kigali Amendment targets are currently more ambitious. This may not remain the case as the EU plans to consider an extension of the ambition of the F-Gas Regulation beyond 2030 in 2022. The UK ratified the Kigali Amendment in November 2017 and the amendment took effect in January 2019.

- The 2014 EU F-Gas Regulation came into force in the UK in January 2015, and equivalent measures will be enforced into UK law in at the end of the transition period of leaving the EU. It introduced a number of new measures and strengthened the 2006 EU F-Gas Regulation:

  - The regulation sets a cap on the amount of HFCs that producers and importers are allowed to place on the market. The cap will be cut every three years until reaching a 79% cut by 2030 from 2015 levels.

  - Some uses of HFCs are exempt from the regulation, including medical use, military equipment and manufacturing of semiconductors. Emissions from SF_6 and PFCs are not included in the cap.

  - The regulation bans the use of F-gases in many new types of equipment where less harmful alternatives are widely available, such as fridges in homes or supermarkets, air-conditioning and foams and aerosols.

  - The regulation strengthens existing obligations in terms of mandatory 'management measures' including regular leak checks and repair, gas recovery at end-of-life, record keeping, training and certification of technicians and product labelling.

- The 2006 MAC Directive focuses on emissions from air-conditioning in new cars and vans. From 2017, all new cars and vans are required to use substances with a GWP less than 150.

- Emissions of PFCs from aluminium production are priced under the EU Emissions Trading System.

Policy recommendations

In our 2020 Progress Report to Parliament, we reported that the Government was yet to publish a plan to restrict the use of F-gases to the very limited uses where there is no viable alternative – going beyond the requirements of the Kigali Amendment and existing F-gas regulations. The Government should bring forward such a plan as part of its Net Zero strategy.

Priority areas for policy development are to:

- **Ensure that any increase in ambition in EU F-gases regulation is matched or exceed by the UK.** Legislation has been passed that enables the UK to set a quota system that is independent from – but equivalent to – the EU quota. The EU is currently looking into strengthening its F-gas regulation and should this occur, the UK should ensure that equivalent or more rigorous standards are maintained.
- **Minimise non-compliance, especially in the RACHP sector.** The Environment Audit Committee has reported evidence of suspected non-compliance, especially as EU F-Gas Regulation increase demand for lower-GWP refrigerants, and a lack of resources for the Environment Agency to carry out adequate inspections. The Government should ensure that the Environment Agency is sufficiently resourced to allow it to ensure compliance.
- **Increase training and certification for F-gas users.** The current regulatory framework does not require retrospective training for workers trained under previous regulations and allows untrained members of the public to top-up their own car air-conditioning units with high-GWP refrigerants. The Government should consult with industry and bring forward proposals to ensure that all those who handle refrigerants have up-to-date training.
- **Encourage the use of more sustainable inhalers in the NHS.** Practitioners and patients must be educated about the global warming effects of medical inhalers and the importance of proper disposal. Dry powdered inhalers (DPIs) – used commonly in other countries – can be more clinically effective and have zero greenhouse gas emissions. Lower-GWP alternatives to existing metered dose inhalers are currently being developed, and should be adopted from the mid-2020s in cases where DPIs are not suitable.

Table P10.1
Summary of policy recommendations for F-gases sector

	Recommendation	Department	Date
F-gases	**Publish a plan to restrict the use of F-gases to the very limited uses where there are currently no viable alternatives** beyond the limits of the Kigali amendment.	DEFRA and devolved agencies	Overdue
	Ensure that any increase in ambition in EU F-gases regulation is matched or exceeded by the UK.	DEFRA and devolved agencies	Ongoing
	Minimise non-compliance, especially in the RACHP sector by ensuring that the Environment Agency and equivalent devolved bodies are sufficiently funded.	DEFRA and devolved agencies	2021
	Increase training and certification for F-gas users.	DEFRA and devolved agencies	2021
	Encourage the use of more sustainable inhalers in the NHS.	DHSC, NHS England, NHS Scotland, NHS Wales, HSCNI	Before mid-2020s
	Support research into lower-GWP refrigerants for heat pumps	UKRI	2020s

Endnotes

[1] CCC (2020) *Policies for the Sixth Carbon Budget and Net Zero*. Available at: www.theccc.org.uk

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