De Minimis Assessment

Title:	Proposed reform of the phasedown of hydrofluorocarbons (HFCs)
Type of measure:	Proposed policy reform
Department or agency:	Department for Environment, Food and Rural Affairs
IA number:	
RPC reference number:	…
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Date:	02/09/2025

1. Summary of proposal

In Great Britain, fluorinated greenhouse gases (F gases) are regulated through assimilated legislation including the Regulation on Fluorinated Greenhouse Gases (the F gas Regulation)[1]. The main objective of the F gas Regulation is to reduce F gas emissions.

This De Minimis Assessment accompanies the Government consultation for a proposed reform to the F gas Regulation.

The aims of the proposed reform are to ensure the Regulation continues to deliver greenhouse gas emissions savings. Secondly, that industry continues to transition away from using F gases, especially those with high global-warming potential (GWP), in line with domestic and international commitments.

[1] As part of the process of leaving the EU, EU F gas legislation, including Regulation (EU) No 517/2014 of the European Parliament and of the Council, was assimilated into UK law with technical amendments made to ensure the legislation functions properly as UK domestic law.

F gases are used in a variety of setting and sectors, the sources of their emissions can be seen in Figure 1. These are from: refrigeration, air-conditioning and heat pumps (RACHP); metered dose inhalers (MDIs) and aerosols; electrical switchgear (GIS); closed-cell insulation foams; fire protection systems (FPS); and other specialist applications, such as semi-conductor manufacturing, solvents and tracer gases. F gas emissions occur through leakage during the manufacture, operation and disposal of products, contributing to climate change.[2]

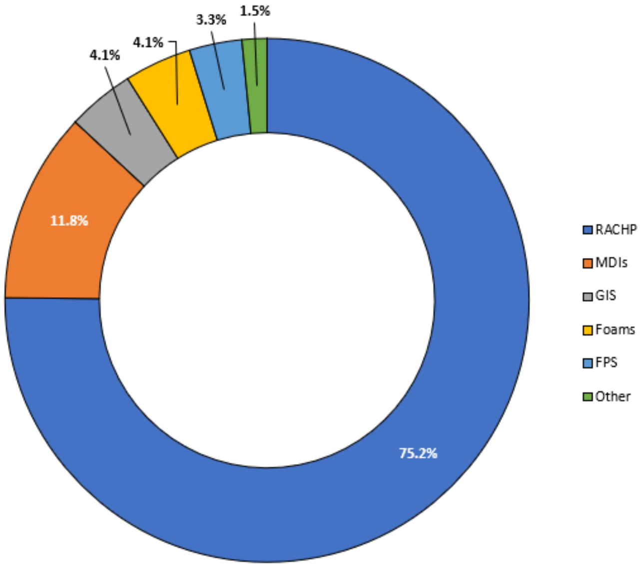

Figure 1: Sources of F-gas emissions (taken from the GHG National Inventory

In 2023, F gases accounted for around 2% of UK greenhouse gas emissions and fell into four groups[3]:

- Hydrofluorocarbons (HFCs), which form 94% of UK F gas emissions;
- Sulphur hexafluoride (SF6), 4%;
- Perfluorocarbons (PFCs), 2%; and
- Nitrogen trifluoride (NF3), negligible quantities.

F gases, alongside carbon dioxide (CO2), methane and nitrous oxide, are the seven direct greenhouse gases under the Kyoto Protocol and are monitored and reported on under the UK Greenhouse Gas Inventory.[4] When considering the relative impact of F gases in comparison to other greenhouse gases, carbon dioxide equivalent (CO2e) is used as a measure of how much a gas contributes to global warming, relative to CO2. The GWP measures how much a greenhouse gas contributes to atmospheric warming over a specific time, typically 100 years, compared to carbon dioxide which has a GWP of 1 for reference. HFCs are potent greenhouse gases with very high GWPs, for instance R32 and R134a, two HFCs used in small heat pumps, have GWPs of 675 and 1430 respectively. This means they are hundreds to thousands of times more effective at trapping heat than carbon dioxide. Thus, it demonstrates the importance of controlling these substances seeing as they disproportionately contribute to atmospheric warming. The specific GWP for different F gases can be seen in Annex 1 to this Assessment.

The F gas Regulation includes prohibitions on certain uses of F gases and sets requirements for leak checks, leakage repairs and recovery of used gas. In addition, the F gas Regulation sets training and certification requirements for technicians doing specified forms of work regarding certain types of equipment containing F-gases.

This De Minimis Assessment focuses on one main policy lever, with various sub options:

[2] F gas regulation in Great Britain (publishing.service.gov.uk)

[3] Final UK greenhouse gas emissions statistics: 1990 to 2023 - GOV.UK

[4] What is the Kyoto Protocol? | UNFCCC

- **Option A: Phasedown –** This lever explores options which would impact the quantity of HFCs, a type of F gas, that can be placed on the market for the first time. HFCs are the only type of F gas in scope of the existing F gas Regulation's phasedown provisions and were responsible for 94% of total F gas emissions in 2023. Phasedown options include matching the EU's revised phasedown and introducing a new bespoke GB schedule (adapted to fit our sectors).

The proposed option is a reformed HFC phasedown that would reduce HFCs placed on the market for the first time by 98.6% by the final step down in 2048 (from a 2015-2019 baseline). By comparison, the existing phasedown will reduce the amount of HFCs placed on the market for the first time by 79% with the last step-down set for 2030. The proposed new phasedown has been modelled using GB inputs, catering for domestic demand around heat pumps for example.

A reformed HFC phasedown would promote industry innovation and support a transition away from potent HFCs by creating a market for more-climate friendly alternatives. The proposed stricter phasedown would help us to continue to meet our legally binding international climate obligations under the Montreal Protocol on Substances that Deplete the Ozone Layer (the Montreal Protocol)[5], with the UK required to reduce HFC production and consumption by 85% by 2036 in accordance with the Kigali Amendment to the Protocol. The proposal would also offer additional emissions savings to contribute to the Government's objective of reaching Net Zero by 2050.

2. Strategic case for proposed reform

2.1 Problem under consideration

Fluorinated gases (F gases) are a family of manufactured gases used in a range of industrial, commercial and domestic applications. F gases were largely introduced as replacements to chlorofluorocarbons (CFCs) and wider ozone-depleting substances (ODS), following the requirement to phase out ODS under the Montreal Protocol. While F gases are not ozone-depleting, they are powerful greenhouse gases. They can have a Global Warming Potential (GWP) that can be many thousand times higher than CO2, indicating their potency at trapping heat and exacerbating global warming.

The UK and devolved governments are committed to bringing greenhouse gas emissions to net zero. HFCs have a role to play in ensuring that Net Zero objectives are met across the UK and further ambition on HFCs is needed to support this. Reducing the availability of HFCs limits the amount of F gas related emissions entering the atmosphere through leakages or venting. This mitigates the effect of climate change by exposing the atmosphere to less of these powerful, heat-trapping F gases.

The F gas Regulation includes a range of measures (Articles 3 to 9) aimed at preventing emissions during the installation, operation, and end-of-life of equipment containing F gases. These provisions have requirements on containment, leak testing and recovery, including:

- A prohibition on intentional release of F gases into the atmosphere (Article 3)

[5] https://ozone.unep.org/treaties/montreal-protocol

- Regular leak checks on certain equipment containing F gases, and the installation of leak detection systems where applicable (Articles 4 and 5)
- Mandatory record keeping of leak checks and related actions (Article 6)
- An obligation on producers to take all necessary precautions to prevent emissions of F gases during production, transport, and storage (Article 7)
- Mandatory recovery of F gases from equipment at end-of-life. For certain equipment this is to the extent recovery is technically feasible and does not entail disproportionate costs (Article 8)

The F gas Regulation also sets out an HFC phasedown: measures which cap and progressively reduce the overall maximum quantity of HFCs placed on the market in Great Britain for the first time, from production and imports. Key provisions are in Article 15 and Annex 5 of the F gas Regulation. Annex 5 of the Regulation sets out the current phasedown schedule and additional steps to establish the maximum quantity of HFCs that can be placed on the market. The phasedown schedule sets steps that, by 2030, reach a 79% reduction of HFCs placed on the market compared to the baseline. The baseline is determined as the annual average of the total quantity of HFCs placed on the market during the baseline period, which is 2015-2019. The phasedown initially applied only to bulk gas but from 1 January 2017, RACHP equipment charged with HFCs could not be placed on the market unless the HFCs in that equipment were accounted for within the quota system (as set out in Article 14(1)). As a result, quota authorisations are required for placing pre-charged equipment on the market, and equipment importers must receive sufficient quota authorisations, from a quota holder, to cover the HFCs contained within the pre-charged equipment.

The F gas Regulation has provisions on reviewing the effects of the Regulation (by the end of 2022). Defra led a joint review, on behalf of UK, Scottish and Welsh governments, to assess the impact of the F gas Regulation and published an assessment report in December 2022 (the 2022 Assessment Report).[6]

In 2024, the EU repealed previous EU F gas legislation and passed new legislation. The 2024 EU F gas Regulation includes (in its Annex 7) a revised HFC phasedown from 2025 that ends in a complete phaseout by 2050.[7]

2.2 Evidence supporting problem statement

Since commencement of the F gas Regulation, further international action has been taken to address the use of F gases, specifically HFCs. The UK is a Party to the Montreal Protocol and ratified the Kigali Amendment to the Protocol in 2017. The Kigali Amendment sets out phasedown schedules and associated baseline years for the production and consumption of HFCs for Parties which have ratified it. Under this Amendment, the UK is required to reduce HFC production and consumption by 85% by 2036. The F gas Regulation forms a core part of the UK's implementation of its obligations pursuant to the Kigali Amendment and the phasedown under the Regulation (which runs to 2030) has led the UK to be currently well ahead of the Kigali Amendment schedule.[8] While the UK is ahead of schedule, the F gas Regulation's 79% phasedown target would not fully

[6] Assessment of the F gas Regulation in Great Britain - GOV.UK (www.gov.uk)

[7] Regulation - EU - 2024/573 - EN - EUR-Lex

[8] Note that the percentage cuts under the F gas Regulation and the Kigali Amendment are based on different ways of measuring the phasedown.

implement Kigali Amendment provisions to reduce to production and consumption by 85%. Reform of the phasedown is therefore needed to address this.

The current Regulation has been a success as demonstrated by Figure 2 below. The phasedown has been the most effective component responsible for almost all emission reductions. The flexibility of the phasedown is thought to be the key characteristic of the Regulation that is promoting and driving innovation. Despite its success, the Regulation can be strengthened, revised or amended, and there are two key points driving intervention. First, considering UK's climate targets and observed progression of innovation in the sector there is scope for further emissions reduction than currently planned for. The reduction in F gas emissions, resulting from the HFC phasedown, plays a key role in Net Zero objectives being met across the UK. Second, is that further action will be needed to extend the current HFC phasedown in the F gas legislation so that it will, in future, fully implement the end part of the phasedown under the Kigali Amendment. While the 2022 Assessment Report suggested that achieving the Kigali Amendment end target might be deliverable without intervention, this conclusion was borderline. Furthermore, assumptions on non-RACHP uses of HFCs have since been updated, meaning confidence in achieving the target without policy intervention is low.

The 2022 Assessment Report provides a demand forecast based on currently available and likely to be available technologies through to 2050. Modelling suggests there may be space for further cost-effective abatement above already established targets. This is consistent with qualitative findings garnered through discussions with stakeholders and adds weight behind the need to reform the regulations.

Quota utilisation figures provided by the Environment Agency would suggest the quota reduction under the phasedown is yet to have an impact on the market in, reflected in the sustained low quota price. The consumption of HFCs have fallen such that the quota phasedowns are yet to create a binding constraint. Greater availability of alternatives has enabled users of HFCs to transition away, a product of the innovation driven by the quota phasedown. However, the low price of quota reduces incentives for continued innovation, and this may fail to push industry towards developing or adopting better alternatives where available. Not reforming the phasedown would represent a lost opportunity to capitalise on maximising industry innovation. In the EU, some Member States implemented deposit and recovery schemes to create a better alignment between price and emissions, but the UK did not implement any such measures.[9]

2.3 Rationale for government intervention (what gaps or harm would occur if government does not intervene)

The rationale for the reforms to the legislation is to pursue the policy objectives listed below in Section 3 of this assessment. We aim to continue providing monetised societal benefits that far outweigh the costs to industry as specified in the 2022 Assessment Report.[10] This is to extend the current HFC phasedown in F gas legislation so that it would fully implement the end part of the phasedown under the Kigali Amendment to the Montreal Protocol, and to support Net Zero commitments across the UK. The effect of the current Regulation on emissions can be seen over time, as shown above in Figure 2 (for all sectors) and in Figure 3 (just for the RACHP sector). These figures show that while F gas use trends downwards

[9] End-of-life treatment of Hydrofluoroolefins (HFOs)

[10] Assessment of the F gas Regulation in Great Britain - GOV.UK

with the current Regulation, the reduction starts to slow in the 2020s and plateaux from 2030 onwards. In the absence of any phasedown reform, F gas use emissions will be around 4.1 million tonnes of carbon dioxide equivalent (MtCO2e) by 2050, as per the 2022 Assessment Report[11], which condemns our climate to many more years of dangerous F gases and doesn't capitalise on potential contributions towards the Government's Net Zero target. As the UK battles towards the 2050 Net Zero target, F gas can contribute more emission savings. In Figure 2, the residual F Gas emissions flat-line and even rise a little between 2036-2050 because the final phasedown step in the current Regulation occurs in 2030. There is the opportunity here to continue the industry transition towards lower-GWP alternatives and provide carbon budget contributions on the pathway to Net Zero in 2050. Making no amendments to the current F gas regulatory regime would cause the F gas pathway to fall short on carbon budgets 5 and 6 contributions. Regulatory reform could rectify this, and in doing so deliver more carbon savings to meet future carbon budgets.

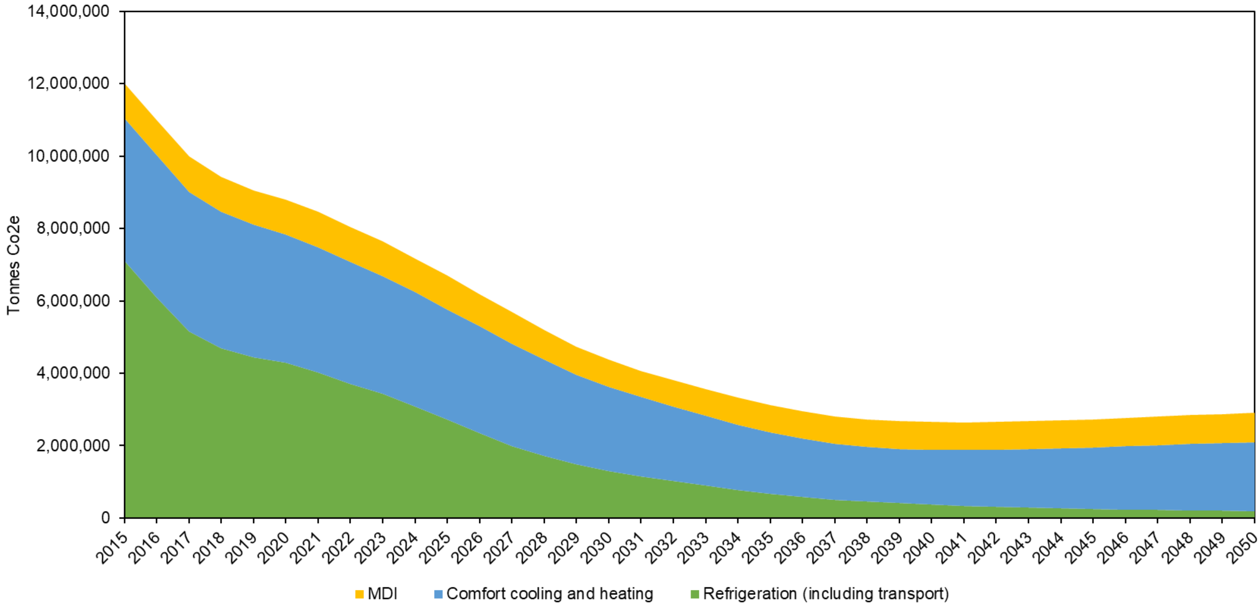

Figure 2: Total Projected F-Gas Emissions by Sector to 2050 under current Regulation (2022 Assessment Report)

11 F gas regulation in Great Britain (publishing.service.gov.uk)

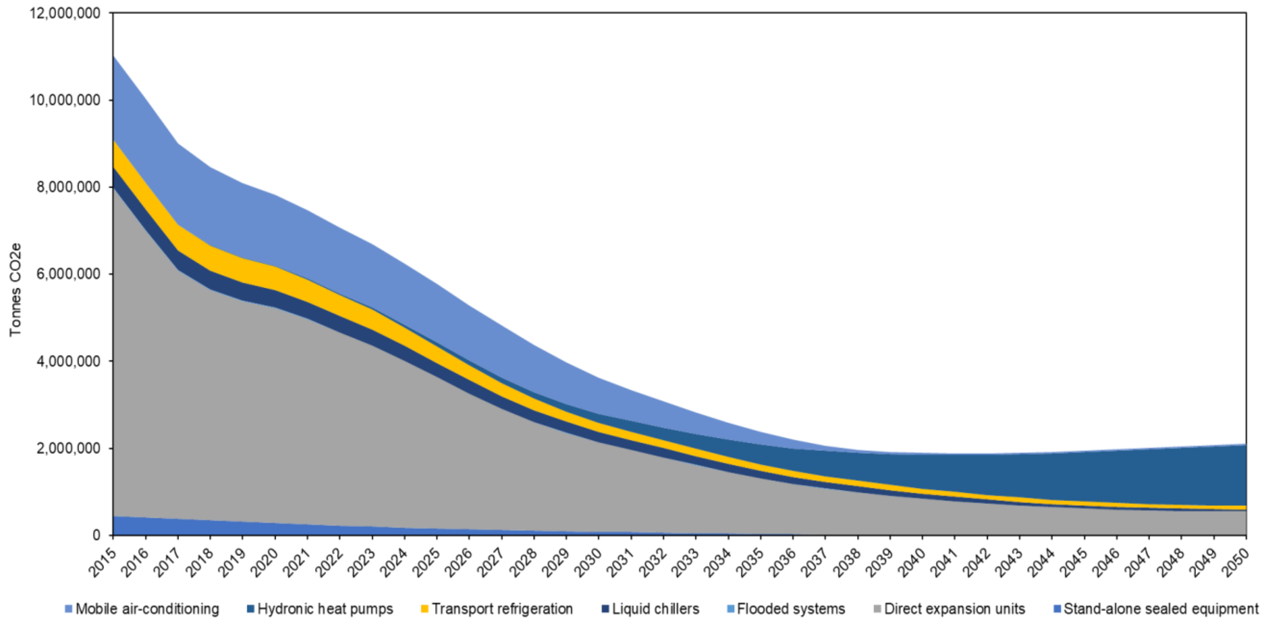

Figure 1: Total Projected RACHP F-Gas Emissions by Sub-Sector (2022 Assessment Report)

2.4 Post-implementation review of the existing Regulation

The F gas Regulation has provisions on reviewing the effects of the Regulation (by the end of 2022). Defra led a joint review, on behalf of UK, Scottish and Welsh governments, to assess the impact of the F gas Regulation and published the 2022 Assessment Report. It concluded that the current Regulation has been effective with regards to its original objectives, and the component parts of the legislation are all necessary and interact well together. It was found that the phasedown has been the most effective component of the Regulation and is responsible for almost all emissions reduction, and the bulk of the costs[12]. Thus, the overall approach of the Regulation is not put into question. In Great Britain, F gas emissions have reduced by 20.7 – 23.0 MtCO2e average annualised between the years 2015-2024.[13] In the 2022 Assessment Report, monetised gross benefits were measured at £1.9 – 8.5 billion through valuation of carbon savings and total costs at approximately £118 million accounting for marginal abatement costs.[14] The gulf between legacy benefits and costs indicates that the Regulation is good value for money, when comparing the low cost to the private sector and the large societal benefits. This success is mainly the result of the HFC phasedown, by curbing low value uses and helping to drive the transition from high global warming potential (GWP) HFCs to lower GWP alternatives. In addition, the presence of the Regulation has acted as a nudge to move towards lower-GWP alternatives with it signalling government climate intentions. The market incentives created by price increases in HFCs are seemingly yet to take hold under the current phasedown, but it's hoped restricted supply under a tighter phasedown would see market price having a bigger impact.

Defra has developed an internal business critical model since leaving the EU to help support its Regulation decision making. As part of the development of the De Minimis Assessment,

[12] The only emissions reductions not attributable to the HFC phasedown are those from regulation of non-HFCs (such as SF6) which are too small to review.

[13] Emissions lag consumption meaning that emissions reductions due to the Regulation differ from emissions reductions that occurred during the period the Regulation is in force. UK F gases emissions have declined by 2.3 MtCO2e per year from 2015 to 2023, as shown by the final UK greenhouse gas emissions national statistics: 1990 to 2023.

[14] Figures are based on a 1.5% discount rate. Using a 3.5% discount rate gross benefits of £1.8-8.1 billion. Total costs fall to £107 million.

Defra worked with industry stakeholders in the summer of 2023 through a primary research survey which focused on gathering information about the cost of using different types of equipment (with focus on initial fixed costs and variable running costs). Our assumptions and data inputs associated with this assessment can be seen in the technical spreadsheet published alongside this De Minimis Assessment and Consultation. This research survey helped build on several of our key data gaps. We are now hoping to clarify further on the conclusions and the remaining gaps. These will continue to be used to refine and confirm assumptions and the inputs for the final stage De Minimis Assessment in conjunction with stakeholder views gathered through the consultation on the proposal to reform the HFC phasedown.

3. SMART objectives for intervention

3.1 Policy objectives and intended outcomes

The conclusions of the 2022 Assessment Report formed the basis for policy development to consider options for change.

Three broad objectives were agreed to underpin this work:

1. Delivery of UK domestic commitments for Net Zero by 2050, as informed by the Carbon Budget Delivery Plans. Crucially, quota restrictions must be achievable for industry with adequate transition time taken allocated. Measuring F gas emissions and consumption through time to assess the effectiveness of the reformed phasedown and give confidence for quantifying impact.
2. Continued implementation of our international obligations under the Montreal Protocol. Confirmation of compliance comes through reporting data and the Environment Agency are responsible for issuing the preset allocation of quota.
3. Supporting wider UK, Scottish and Welsh governments' aims and objectives by implementing a system that is flexible to allow for sufficient gas for beneficial uses. Not obstructing the infrastructure and options of other sectors needed to deliver Net Zero, for example sufficient provision to HFCs to not impede the demand for heat pumps integral to the Department for Energy Security and Net Zero's (DESNZ's) forthcoming Warm Homes Plan. Close stakeholder engagement ensured due consideration was given to all potential consequences, present and future.

3.2 Future critical success factors

The three policy objectives, under the umbrella of Strategic fit, combine with Achievability, Affordability and Deliverability to give a total of six core critical success factors considered during the options appraisal. See Annexes 2-6 for the six critical success factors in use.

- Critical Success Factor One: **Strategic fit with policy objectives x3**, including domestic commitments, international obligations and wider government objectives;
- Critical Success Factor Two: **Achievability**, looking at whether the option is feasible; has it been delivered before; industry capacity to meet regulation change; technology availability;
- Critical Success Factor Three: **Affordability**, looking at cost to central government and industry / users; and

- Critical Success Factor Four: **Deliverability**, looking at who is going to deliver this. Includes:
    a. Minimising administrative burdens (for government, regulatory bodies and industry)
    b. Impact on delivery timeframes
    c. System and Policy coherence

3.3 How objectives align with HMG objectives (e.g. growth)

We consider that amending the phasedown would help deliver the broad objective of supporting the ambitious Net Zero commitments across the UK and would contribute to timely delivery of further emission savings. This includes supporting the delivery Net Zero commitments by 2045 for Scotland and 2050 for the UK. As the proposed amended phasedown would lead to a near phaseout of HFCs, it would also demonstrate the UK's global leadership in tackling climate change. The UK establishing itself as a global climate leader would ensure that it continues to attract investment into green technologies and provides opportunities for domestic businesses in the clean technologies market.

Industry is already aware that reform will be needed to fully implement the end part of the HFC phasedown under the Montreal Protocol and has begun to invest in innovative low GWP technologies.

We anticipate that the proposed reform would further accelerate investment into the skills that are required to work with F gas alternatives and support the UK's transition to a green economy. (Note that the 2022 Assessment Report identified that stakeholders considered that the F gas Regulation should include training on such alternatives.) In the context of the global phasedown of HFC consumption, we expect that further reducing F gas consumption would help promote early mover opportunities for UK industry, particularly in the heat pump sector. Leveraging ambitious decarbonisation goals to increase investment into domestic manufacturing and supply chains could lead to export opportunities in the global heat pump markets.

An effectively managed phasedown is integral to ensuring the DESNZ led heat pump rollout is not impeded from lack of F gas supply. Allowing sufficient F gas for beneficial uses while encouraging those that can transition to indeed transition. This would be achieved through innovation encouraged by market development and a growing demand for low-GWP alternatives, which counteracts the restricted availability to HFCs quota. Higher quota price, thought to arise when demand outstrips supply, would incentivise innovation and streamline the commercialisation of new low-GWP alternatives. This would reinforce the market for switching to and developing future technologies.

4. Description of proposed intervention options and explanation of the logical change process whereby this achieves SMART objectives

For this reform we are only proposing amendments to the existing phasedown for placing HFCs on the market for the first time.

The proposed reform would achieve the best balance of meeting the UK's climate commitments whilst mitigating the impact on domestic Net Zero delivery, by supporting the heat pump rollout through the avoidance of big phasedown step shocks. It would also mean going beyond our international phasedown obligations under the Montreal Protocol in order to support price incentives in the market and ensure business are incentivised to invest in developing technologies. Excessive quota allocation drives down the price of HFCs with damaging high GWPs. This reduces demand for alternatives and disrupts that market, which hinders innovation because businesses are reluctant to invest in developing technologies without certainty there will be a market.

Compared to the current phasedown the high ambition option (the proposed reform) would see HFC put on the market for the first time reduced by 46.1 million tCO2e from 2027 to 2050 (see Figure 4). Over the appraisal period (2027 – 2036) this figure is around 17.6 million tCO2e compared to the current phasedown.

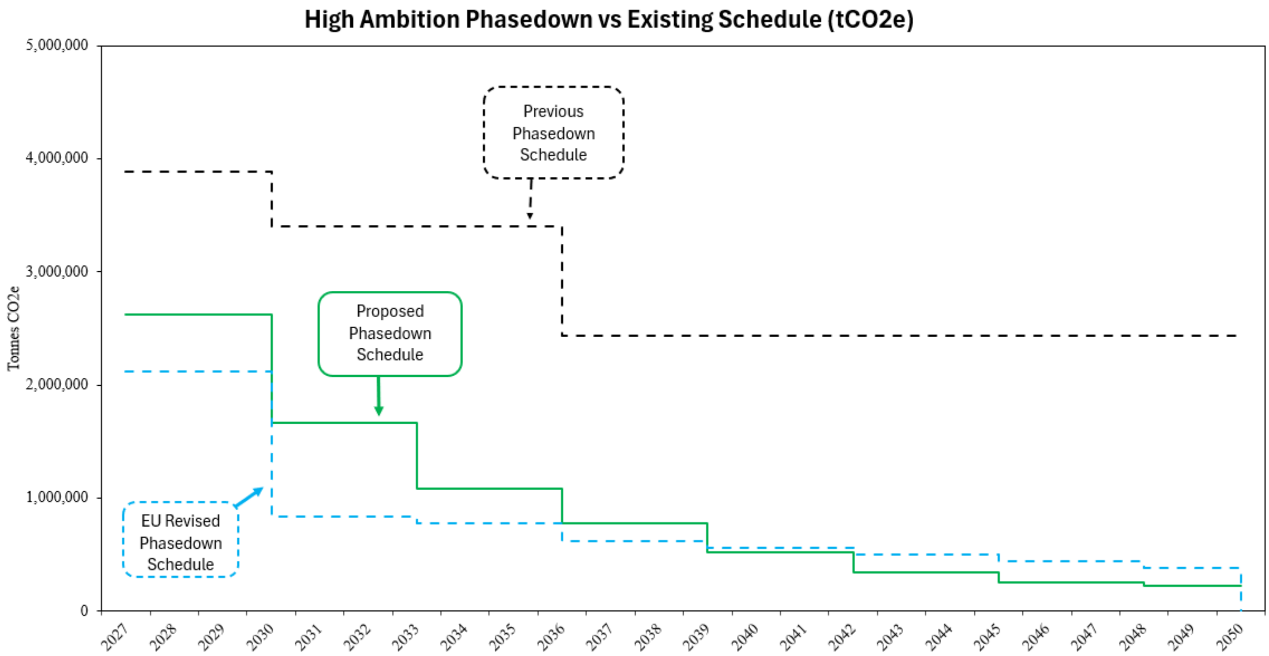

Figure 4: Proposed HFC phasedown

The default 10 years appraisal period was deemed appropriate because the abatement costs for adapting to the Regulation are front loaded. By far the biggest phasedown steps would occur in the early years, which would prove to be the most challenging period for transitioning businesses. By 2036, the proposed reform would see the HFC phasedown reduced to 4.8%

of the 2015-2019 baseline. This tiny percentage is not sufficient to sustain a market, and any incumbent looking to succeed would have transitioned to HFC alternatives by then. After the 10 years, there will be so little interest in the HFC market given that the transition to HFC alternatives would've occurred, what is left of the quota peters out to ensure there is no long-term profit in trading HFCs.

The proposed reform is tailored to GB markets, taken from modelling that uses GB-specific inputs. This would give more flexibility in the earlier phasedown steps, compared to the EU's revised phasedown, providing the time industry needs to adjust (see Figure 4). It's designed to not suffocate the heat pump rollout, a key component to decarbonising domestic heating, and more generally account for differences between the markets in GB and in EU.[15]

Environmental targets are met internationally and domestically. The Kigali Amendment stipulates an 85% reduction in HFC consumption by 2036. The proposed reform would achieve a 95.2% reduction by the same year (see Table 1). In pursuit of Net Zero by 2050, the proposed reform would lead to further tapering down of HFC emissions, continuing the theme of falling emissions since the HFC phasedown was first introduced in 2014.

Table 1: Existing vs Proposed HFC phasedown

Years	Existing HFC phasedown – F gas Regulation (tCO2e)	Existing phasedown percentages (2015-2019 baseline)	Proposed HFC phasedown (tCO2e)	Proposed phasedown percentages (2015-2019 baseline)
2027-2029	3,888,710	24%	2,625,306	16.2%
2030-2032	3,402,621	21%	1,666,518	10.3%
2033-2035	3,402,621	21%	1,081,946	6.7%
2036-2038	3,402,621	21%	780,063	4.8%
2039-2041	3,402,621	21%	520,338	3.2%
2042-2044	3,402,621	21%	342,708	2.1%
2045-2047	3,402,621	21%	252,827	1.6%
2048-2050	3,402,621	21%	219,981	1.4%

Following on from the success of the existing regulation, which the 2022 Assessment Report found to be mainly down to the HFC phasedown, this proposal is an extension of existing regulation focused solely on the phasedown ambition. Stakeholder engagement, the EU

[15] 2022 Assessment Report more info on page 79 of differences.

phasedown revision and quota under-utilisation have led us to believe a more ambitious phasedown is possible. As stated in the 2022 Assessment Report, the mechanism for success was curbing low value uses and helping to drive the transition from high global warming potential (GWP) HFCs to lower GWP alternatives. In the future, it is thought market incentives developed by increasing HFCs prices would help drive the transition to lower GWP alternatives.

5. Summary of long-list and alternatives

5.1 Options assessment

F gases are controlled through the F gas Regulation. The purpose of this consultation is to set out a proposal to reform the Regulation to deliver ambitious emissions savings to achieve our Net Zero targets and to fully implement the end part of the HFC phasedown under the Montreal Protocol. Stakeholder engagement, with regulators, other government departments and external stakeholders, has been key in developing the proposal. This engagement will remain ongoing with the consultation to finalise the policy detail and technical implementation.

Option Descriptions and Assessment Summary

The assessment criteria for marking against the Critical Success Factors (outlined in Section Three) can be seen in Table 2. Green ticks in the summary tables show where sub-options hit a Critical Success Factor (CSF), orange dashes imply a neutral score or not enough information to assess the criteria, while red crosses mark when a critical success factor has not been hit.

Table 2: De Minimis Assessment Criteria Thresholds

Options Assessment Outcome	Strategic Fit	Achievability	Affordability	Deliverability
✓	Two of the three criteria would need to be met: • Option outcome will deliver / contribute to emissions approaching or nearing 0 by 2050. • Kigali Amendment targets are met. • Option does not prohibit or slow down other government objectives.	The transition needed from industry is in a realistic zone to be achievable for leading to our desired outcomes (i.e. technology transition is already happening or developed, industry investment is planned, new reporting requirements are realistic etc).	Option will have no departmental cost associated with it or will be deliverable within current departmental spending plans and workforce.	Detailed policy (where relevant) under option can be designed and implemented to be in law by 2027.
–	Critical success factor might not be relevant to option or there might not be enough information to assess the criteria.			
✕	If option does not deliver emissions reductions which be nearing or approaching 0 by 2050 and / or does not lead to meeting Kigali Amendment targets.	Option might require unrealistic transition by industry (i.e. too short of a transition window, technology advancement is developed etc). Assessment incorporates stakeholder feedback to date.	Option will need significantly more or new funding to be implemented.	Any significant barriers which meant option was undeliverable or unable to be implemented in 2027 (i.e. new IT infrastructure, change in role / scope of regulating body etc)

For each respective option the Business as Usual (BAU) sub option has always been shortlisted to provide a baseline for comparison, against which interventions can be better assessed. For each respective option the non-regulatory sub option, should it be presented, has always been shortlisted to provide an alternative proposal to intervention. This helps frame the purpose of the De Minimis Assessment by challenging whether that intervention is necessary. Except for BAU and non-regulatory sub options, only those sub options with no failed critical success factors are shortlisted.

5.2 Options considered

Amendments to the phasedown represent the only lever to reach the shortlist after the longlist assessment. While some options would meet the achievability and affordability CSFs, a strong emphasis and weight is given to deliverability of the option by 2027 due to strategic fit to ensure any interventions align effectively with government objectives. Option not taken forward now may be re-considered in due course.

Option A: Phasedown

This lever explores options which would impact the quantity of HFC allowed to be placed on the market. Phasedown options include comparing the EU's revised phasedown schedule against a new bespoke GB path to fit our sectors.

Table 3: Phasedown Options Longlist Description Summary (Option A)

Option		Description
Core	Sub Option	
Option A Phasedown	Status Quo / BAU (A1)	No change to existing Regulation. Scope of the phasedown remains the same – HFCs, bulk gas and pre-charged equipment, with exempted uses. Phasedown schedule remains the same, with each step lasting three years.
	EU's Revised Phasedown (A2)	Matching the revised EU phasedown schedule from 2027. Removal of the exemption from quota for gas used in MDIs, with a phasedown freeze for MDIs until 2027 but no requirement for quota authorisations. Includes a provision to enable the amendment of the quota allocation where necessary to prevent market disruptions.
	Bespoke GB Phasedown Scenarios, Low Ambition (A3, I)	Option considers relatively little change in the current mix of technologies used in the Great Britain market. Industry should be able to meet this phasedown without concerns for heat pump deployment.
	Bespoke GB Phasedown Scenarios, Medium Ambition (A3, II)	Option assumes industry relies on existing technologies but increases deployment of lower GWP alternatives that are already commercially available. 7 MtCO2e of additional quota compared to higher ambition (A3, III) over the ten-year appraisal period, which may be important for critical uses/sectors (e.g. heat pump deployment and ensuring supply for MDIs).
	Bespoke GB Phasedown Scenarios, High Ambition (A3, III)	Option considers industry adoption of technologies that have either not been developed or have not yet reached the market, but that are likely to be technically feasible in the future. We assume there is the ability to address matters such as safety, capital cost, energy efficiency and timeframes for deployment. Most like the EU's Revised Phasedown (A2) but tailored to the GB market. Less extreme initial step downs to give industry time to adapt and to not inhibit ambitious heat pump rollout plans.
	Bespoke GB Phasedown Scenarios, Most Challenging (A3, IV)	Option considers a phasedown under extreme modelling assumptions: low annual leakage and maximum recovery rates for example. Over-tightening risks unintended consequences for the wider infrastructure needed to deliver Net Zero. This is more restrictive than the EU's Revised Phasedown (A2).

Bespoke GB Phasedown Scenarios, Bulk Gas Only Phasedown (A3, V)	Phasedown in this option only applicable to bulk gas, no requirement for quota authorisations. Change to come into effect from 2027/2030, to allow time for companies to use existing quota authorisations. Existing quota authorisations could act as a buffer to allow for a steeper phasedown prior to this change coming into effect. This option is more aligned with international commitments to control consumption of bulk gas.
European Parliament and Council Additional Quotas for Heat Pumps (A4)	Similar to the EU's Revised Phasedown (A2) but including an equivalent measure to the European Parliament amendment to require the assessment of the impact of the quota phasedown on the heat pump market and allow a limited amount of additional quota for HFCs for use in heat pumps until 2029.
Additional Quota for Critical Uses, Allocated the Following Year (A5, I)	Option considers how additional quota could be calculated and allocated in the subsequent year to alleviate any pressures flagged by critical uses/sectors in the current year. Would help mitigate any disruption on the heat pump roll out or MDI supply as a result of an ambitions phasedown.
Additional Quota for Critical Uses, Allocated in Year (A5, II)	Option considers how additional quota reserve could be used, being made available within year to alleviate any pressures in critical uses/sectors, such as MDIs and heat pumps. Setting out criteria for what is a critical use/sector and what is considered as a sufficient pressure to warrant additional quota.
Phasedown Extended to Core F gases (HFCs, PFCs and SF6) (A6)	Phasedown extended to cover F gases listed in Annex I of the current F gas Regulation[16].
Phasedown Extended to All F gases (A7)	Phasedown extended to cover all F gases – including HFCs, PFCs, SF6, HFOs and volatile anaesthetics.
Non-regulatory (A8)	Option will rely on voluntary industry action and incentives set by OGDs (e.g. DESNZ incentives to promote heat pump roll out). The EU have set out an ambitious revised HFC phasedown, with industry already moving to natural refrigerants in response to this and the phasedown more generally.

Each of the sub-options for the phasedown is covered in more detail in Annex 2. A summary of the longlist assessment marking each sub-option against the critical success factor is found in Table 4 below.

Table 4: Phasedown (Option A) Shortlisting Outcome

Option		Strategic Fit	Achievability	Affordability	Deliverability	Short Listed Option?
Core	Sub Option					
Option A Phasedown	Status Quo / BAU (A1)	✗	✓	✓	✓	Yes
	EU's Revised Phasedown (A2)	✓	–	✓	✓	Yes
	Bespoke GB Phasedown Scenarios, Medium Ambition (A3, II)	✓	✓	✓	✓	Yes
	Bespoke GB Phasedown Scenarios, High Ambition (A3, III)	✓	–	✓	✓	Yes
	Bespoke GB Phasedown Scenarios, Most Challenging (A3, IV)	✓	–	✓	✓	Yes
	Non-regulatory (A8)	✗	✓	✓	✓	Yes

16 https://www.gov.uk/guidance/fluorinated-gases-F gases

5.3 Small and Micro Businesses Assessment (SaMBA) and medium-sized businesses scope

The only exemption under the F gas Regulation arranged for businesses is for producers or importers placing less than 100 tCO2e of HFCs on the market annually. Starting to exempt more businesses would reduce the scope of HFCs covered by the phasedown, which would sabotage maximal efforts to reduce F gas emissions.

As the reformed phasedown would not come as a surprise to businesses in the sector, disproportionate effects on smaller businesses are not expected. This is because the EU, where we rely on much of the equipment and products for our refrigeration systems, have already implemented a revision phasedown in early 2024 so the momentum in the market is already swinging away from HFCs.

Given the niche use in the UK economy which HFCs cover we do not have full understanding on the composition of sub-sectors. Information on business demography is an evidence gap. We will be asking for feedback during the consultation to better understand business size and potential scale of impacts.

6. Description of shortlisted policy options carried forward

6.1 Shortlist appraisal

For this reform we are only proposing amendments to the existing phasedown for placing HFCs on the market. We have discarded options related to expanding the phasedown scope, reporting or allocation process of the quota, due to falling short of meeting policy objectives or being undeliverable in time for 2027.

From our initial thirteen sub-options, we have narrowed the list to six shortlisted sub-options. This includes adjusting the phasedown (Option A) component of the F gas Regulation, maintaining the status quo and exploring a non-regulatory approach.

- **Quota Phasedown (Option A)** – Status quo; Medium ambition GB Phasedown; High ambition GB Phasedown; EU's Revised Phasedown, Most challenging GB Phasedown, and non-regulatory approach.

Cost and Benefits Methodology and Assumptions

The core cost methodology is estimated through a bespoke HFC trajectory model developed internally in Defra. Detailed methodology is outlined in the Technical Annex, along with provisional outputs and assumptions used. We are seeking feedback on the modelling approach, scenarios and assumptions used during this consultation. Where we have limited and mixed data, we will directly seek industry feedback to improve our calculations and estimations.

The cost-benefit analysis follows the precedence of the methodology used in the 2023 Emissions Trading Scheme Impact Assessment and the Impact Assessment that accompanied the 2014 consultation on implementing the 2014 EU F gas Regulation.[17] [18]

[17] Developing the UK ETS: impact assessment

[18] Annex B in the Consultation document on Draft FGas Regulations.pdf

The cost and benefits models four components:

- F gas Consumption Demand Forecast (more information in the Technical Annex)
- Phasedown Schedule Estimate Based on Demand
- F gas Related GHG Emissions (Benefits)
- Marginal Abatement Cost (Cost)

Benefits are estimated from the change in consumption emissions as a best estimate, rather than territorial reported emissions. The caveat is that under a territorial reported emissions pathway the actualised emission savings will be spread out over a longer period. They can diverge greatly from the consumption-based pathway due to the nature of F gas emissions. F gas emissions occur at different times over an equipment’s lifetime, such as first fill, servicing leakages and end-of-life. The staggered nature of these emissions makes the modelling of exact emission savings difficult but is something we are looking to refine after the consultation. The extent to which benefits outweigh costs demonstrates that this would not impact our understanding of the economic case for a HFC phasedown, nor our recommended proposal.

A cost-benefit assessment has been carried out for each of the four short-listed do-something options for the Quota Phasedown at this stage.

Status Quo / Business As Usual (Option A1)

The first sub option considered in the shortlist is do nothing. This provides a baseline scenario, essential for assessing the policy’s impact and changes in business behaviour under the phasedown proposal.

By doing nothing, we distort incentives for businesses who then experience inertia in the face of transition and are reluctant to invest in the alternatives market. It is an advantage of the structure of the Regulation that it encourages innovation not marketed at the time of its drafting, which can lower the cost of abatement. However, this also makes it difficult to provide price certainty which may hamper investment in the long run. The Regulation operates through price incentives in the market. Declining prices reduce the incentive to undertake efficient abatement. Price data and industry engagement indicate that the price of high GWP gases, such as HFC-134a, have fallen to the extent that they are cheaper than HFO blends. This reduces the incentive to use HFO blends where technology is available, but also to invest in developing technologies without certainty that there will be a market.

UK manufacturers are awaiting and preparing for a more ambitious phasedown akin to the more aggressive EU phasedown implemented in January 2024. Stakeholders have informed us they are currently in limbo with future business planning and the uncertainty is impacting their profitability. Industry stakeholders highlighted that, by doing nothing, the UK risks becoming a dumping ground for old equipment banned in the EU. New product bans in the EU could lead to manufacturers exploiting an available GB market and discarding recently banned stock to offset profit loss. If we can eliminate the excess quota, through a more ambitious phasedown then this risk is mitigated.

Heat pumps remain critical in the Government’s strategy to decarbonise domestic heating and achieve Net Zero targets. The installations of heat pumps will ramp up in the coming years. Doing nothing to the existing phasedown would not impede any deployment targets, however it would increase the number of heat pumps containing HFCs which would increase the potential leakage of highly potent F gases. Doing nothing would hold back the alternative refrigerant market from developing and introduce confusion as to the direction the nascent heat pump market should be heading.

In the UK, the use of air conditioners has increased from 3% in 2011 to 20% in 2022[19]. The demand for indoor temperature regulation is expected to continue increasing, in response to summer warming trends and heatwaves. The ability of the RACHP industry to meet the observed surge in demand for domestic cooling has not been affected by the HFC phasedown. This demonstrates that alternative refrigerants to HFCs are already commercially available and being deployed, examples include ammonia, carbon dioxide, hydrocarbons and hydrofluoroolefins (HFOs). The EU has noted cost-effective abatement in air conditioning (AC) and the prevalence of AC in Southern Europe is resulting in lower average abatement costs in the quest to phase out HFCs[20].

Importantly, it is demand for HFCs that is decreasing, the demand for RACHP equipment will increase as UK temperatures continue to rise and 2050 nears. Our understanding is that manufacturers of HFCs also deal with other gases. This ability to pivot with diversified income streams should limit profit loss. Energy efficiency, affordability concerns and new training requirements are to be addressed as key components of the HFC transition. Future profits depend on the extent to which increased business costs are passed onto consumers or absorbed by profit margins. When an alternative refrigerant is widely available for a given equipment type, the expectation is there would be a ‘tipping point’ effect in which manufacturers commit to the transition when it is commercially viable to do so.

Given the quota under-utilisation recorded in 2021-2023, it is indicative that the effectiveness of the existing Regulation has plateaued. The supply of quota is currently greater than the demand which is reflected in the low market prices for HFCs. In the case of doing nothing, the bank of quota authorisations and quota delegations would continue to grow and roll over in perpetuity year-on-year which ensures the potential for persistence use of HFCs in the affected industries long into the future. The mechanism of quota authorisations and quota delegations builds some flexibility into the system, meaning businesses who plan can build some cushion for themselves when facing years of quota reductions.

Without action, potent HFCs released into the atmosphere through equipment leakages or end-of-life venting would continue to have a disproportionately large effect on atmospheric warming based on volumes emitted. HFCs are assessed to have very large global warming potentials, meaning they are hundreds to thousands of times more effective at trapping heat than carbon dioxide. Getting the release of such potent F gases under control would be an effective way of ameliorating the impacts of climate change. For a more comprehensive list of GWPs for different F gases, see Annex 1.

Medium ambition GB phasedown (Option A3, II)

The second sub option considered in the shortlist is a medium ambition GB specific phasedown. The phasedown calculation is based on the expected demand from the market under this medium ambition scenario, which can be seen in Figure 5. The methodology for the demand calculation can be seen in Annex 7 and sector specific assumptions are in the accommodating technical spreadsheet.

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[19] A nation unprepared: Extreme heat and the need for adaptation in the United Kingdom

[20] F gas regulation in Great Britain p79

The modelled demand curve represents demanded emissions and reflects the phasedown that could be possible assuming certain inputs and timely industry transition. The quota is designed to provide supply through time for the equipment that relies on high-GWP F gases until such a time when transition to lower-GWP becomes viable. In this scenario we have applied assumptions to equipment lifespan, leakage and recovery rates for instance, to better reflect the ability of industry to handle the transition in line with our current understanding.

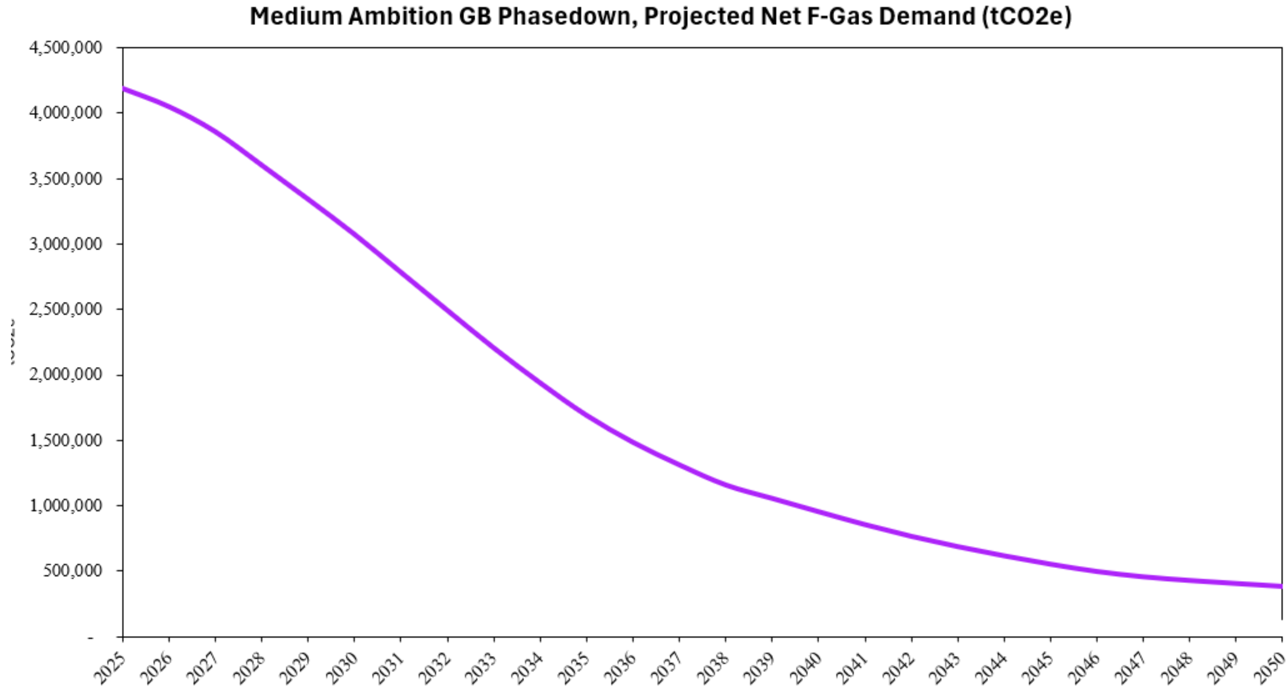

Figure 5: Demand Forecast under Medium Ambition Scenario

The phasedown calculation is based on a 3-year average window starting in 2027 of set quota accounting for what the market can respond to at a proportionate cost under certain assumptions. For instance, the demand forecast is estimated to be around 3.86, 3.61 and 3.34 $MtCO_2e$ for 2027, 2028 and 2029 respectively, so the quota limit for this period (2027-2029) is based on an average of this demand. This calculation is then repeated every 3-year period until 2050 (note this is not a rolling average), this 3-year window is referred to as 'phasedown steps'.

The calculated phasedown for this option can be compared to the current Regulation phasedown schedule, as seen in Figure 6. One of the key changes is the additional phasedown steps which would be introduced after 2036, where this was previously held constant until 2050. This option poses the most comfortable transition for industry. Industry relies on existing technologies but increases deployment of lower GWP alternatives that are already commercially available.

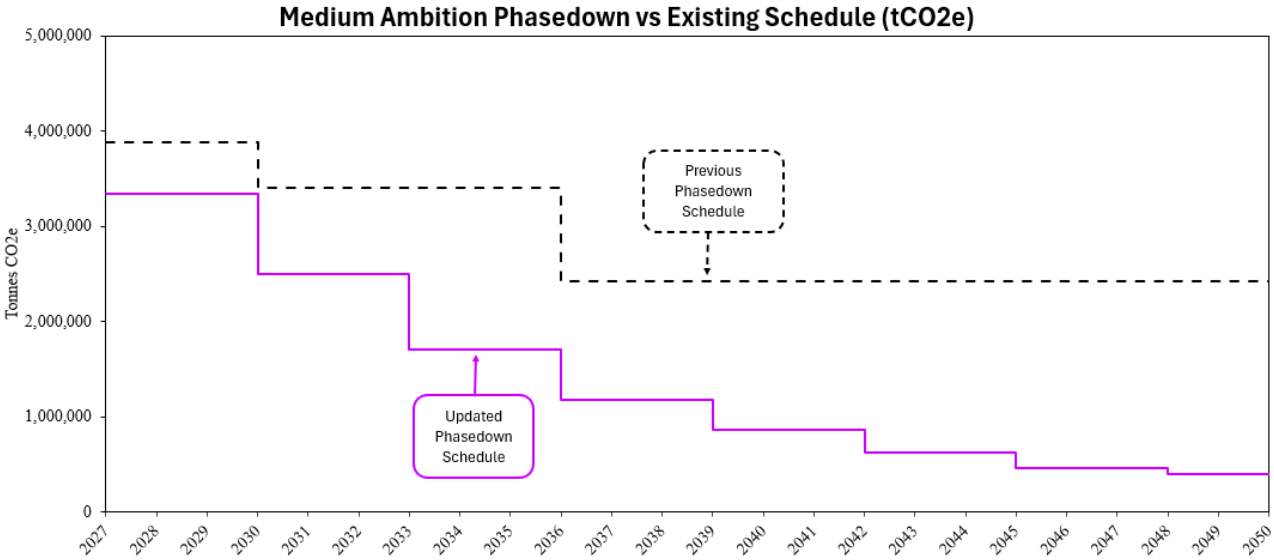

Figure 6: Medium Ambition Phasedown

Compared to the current phasedown the medium ambition options sees a reduction of quota allowed and put on the market by 35.4 million tCO2e from 2027 to 2050 (see Figure 5). This is calculated by aggregating the difference between the two-phasedown schedules on a per year basis. Over the appraisal period (2027 – 2036) the total quota reduction is around 10.7 million tCO2e compared to the current phasedown.

Cost is calculated by using the estimated price of quota to determine the marginal cost of abatement. We then assume a linear demand curve to calculate average abatement cost in each year and multiply by total abatement in that year. For more information on how the range for cost per tonne of abated emissions was calculated see Annex 3. Profit loss for businesses is thought to be minimal and has not been included. The market is switching from HFCs to low-GWP alternatives, so expected demand for products previously containing HFCs will persist or more than likely increase once alternatives are established and commercialised. Demand is not disappearing; it is instead shifting with the times to a more climate-friendly alternative where quota affected businesses are able to pivot towards.

Costs are estimated based on the additional emissions the new phasedown schedule would require industry to abate per year compared to the current regulation. The amount of additional abatement required (per tCO2e) is then multiplied by our cost estimates of £4.10 (lower bound), £7.40 (higher bound) and £5.75 (best, average between the range) for this transition per tCO2e. The caveat is that this is a simplification using the best data available, we intend to use the consultation to inform our position and consider better the dynamic nature of pricing, especially as the depleted quota increasingly influences market prices.

The total cost associated with this phasedown option is estimated to be around £48m (present value) over the appraisal period, with a range of £34m – £61m, using a discount rate of 3.5%.

This reduction has an associated carbon saving value (benefits). Similar to cost, this is based on the additional amount of emissions the new phasedown schedule would prevent per year compared to the current regulation. The value of this benefit is calculated by multiplying the amount of emissions prevented (tCO2e) to a carbon market price. The Department for Energy Security and Net Zero (DESNZ) publish projected carbon price figures under different scenarios[21] to use in analysis and modelling which we incorporated into our assessment.

For our best, lower and upper bound benefits estimates we use three different projected carbon price scenarios. For our best estimate on carbon savings, we use the 'market carbon values' scenario from DESNZ. For the lower bound estimate, we use 'Low Sensitivity' scenario and for the upper bound estimate, we use the 'High Sensitivity' scenario. These can be found in Table 13 for the prices used during the appraisal period.

Table 13: Carbon Price Scenarios Used in Cost Benefit Analysis[22]

	Market Carbon Value	Low Sensitivity Scenario	High Sensitivity Scenario
2027	£75	£66	£104
2028	£88	£62	£110
2029	£80	£53	£105
2030	£78	£50	£107
2031	£85	£54	£114
2032	£91	£60	£118
2033	£97	£63	£123
2034	£100	£65	£125
2035	£109	£72	£134
2036	£115	£77	£140

Total benefits from carbon savings are estimated to be around £786m (present value) over the appraisal period, with a range of £525m – £1,002m. A summary of the lower, higher, and best estimated for the total costs and benefits for this option can be seen in Table 14. Social benefits vastly outweighing costs indicates that this option offers strong Value for Money.

Table 14: Medium Ambition Phasedown (Option A3,II) Costs and Benefits Summary

Prevent Value (2027-2036)	Total Costs	Total Benefits	Net Present Value
Low	£34m	£525m	£491m
High	£61m	£1,002m	£941m
Best Estimate	***£48m***	***£786m***	***£738m***

[21] Traded carbon values used for modelling purposes, 2024 - GOV.UK

[22] Traded carbon values used for modelling purposes, 2024 DESNZ

High ambition GB phasedown (Option A3, III)

The third sub option considered in the shortlist is the proposed reform, a high ambition GB specific phasedown. The same methodology as in the option above was also used here. The phasedown calculation is again based on the expected demand from the market in this scenario and option, which can be seen in Figure 7. This option maximises carbon savings while allowing time for industry transition. Devised using more ambitious modelling assumptions grounded in the expectations of market participants and stakeholder appetite.

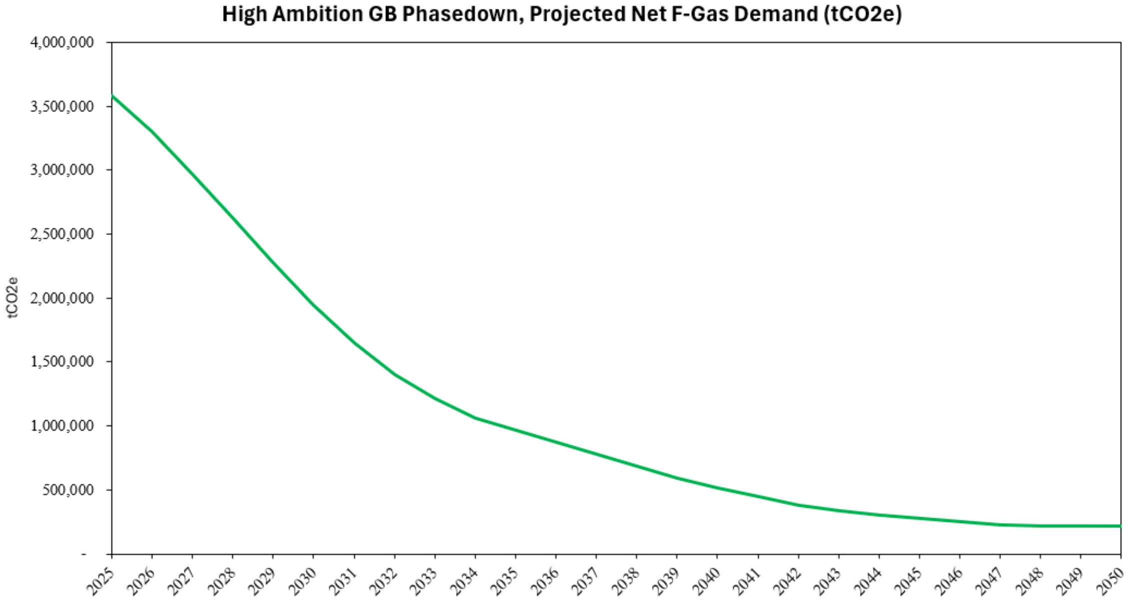

Figure 7: High Ambition Forecasted Demand

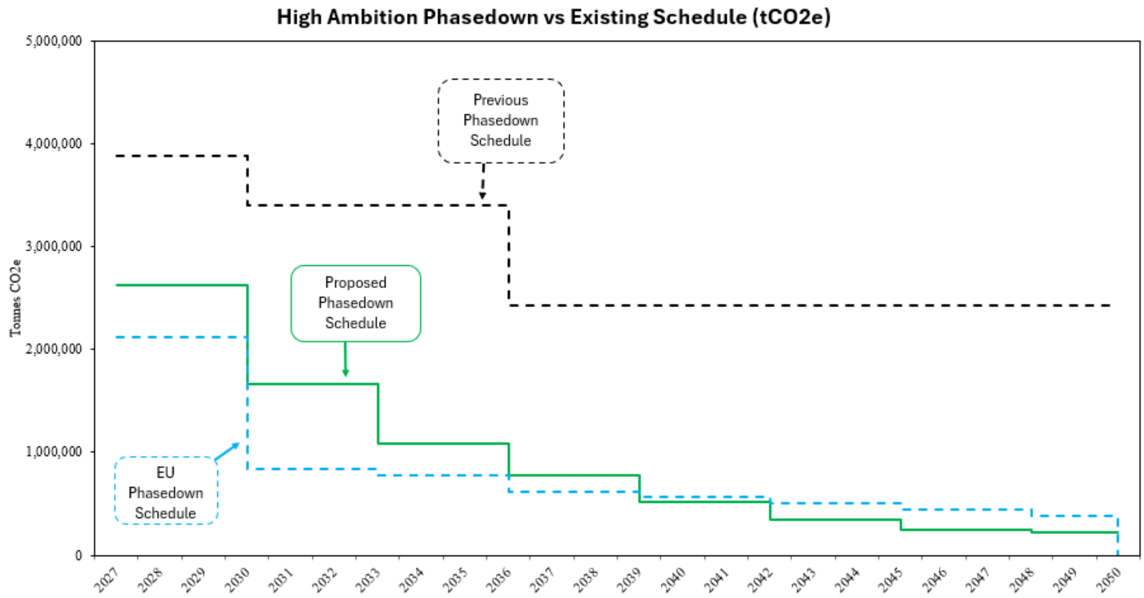

Figure 8: High Ambition Quota Phasedown

Option considers industry adoption of technologies that have either not been developed or have not yet reached the market, but that are likely to be technically feasible in the future. We assume there is the ability to address matters such as safety, capital cost, energy efficiency and timeframes for deployment.

Compared to the current phasedown the high ambition option would see the amount of HFCs put on the market for the first time reduced by 46.1 million tCO2e from 2027 to 2050 (see Figure 8). Over the appraisal period (2027 – 2036) this figure is around 17.6 million tCO2e compared to current the phasedown. The total cost associated with this phasedown option is estimated to be around £80m (present value) over the appraisal period, with a range of £57m – £103m.

This reduction has an associated carbon saving value, which we use DESNZ's carbon price figures[23] from 2027 – 2050 to estimate the total benefits over the phasedown schedule length. Total benefits from carbon savings are estimated to be around £1,286m (present value) over the appraisal period, with a range of £865m – £1,650m.

A summary of the lower, higher, and best estimated for the total costs and benefits for this option can be seen in Table 15. Social benefits vastly outweighing costs indicates that this option offers strong Value for Money

Table 15: High Ambition Phasedown (Option A3, III) Costs and Benefits Summary

Prevent Value (2027-2036)	Total Costs	Total Benefits	Net Present Value
Low	£61m	£865m	£804m
High	£110m	£1,650m	£1,540m
Best Estimate	***£83m***	***£1,286m***	***£1,203m***

GB matching the revised EU phasedown (Option A2)

The same methodology as in the option above was also used here. The fourth sub option considered in the shortlist is matching the revised EU phasedown.

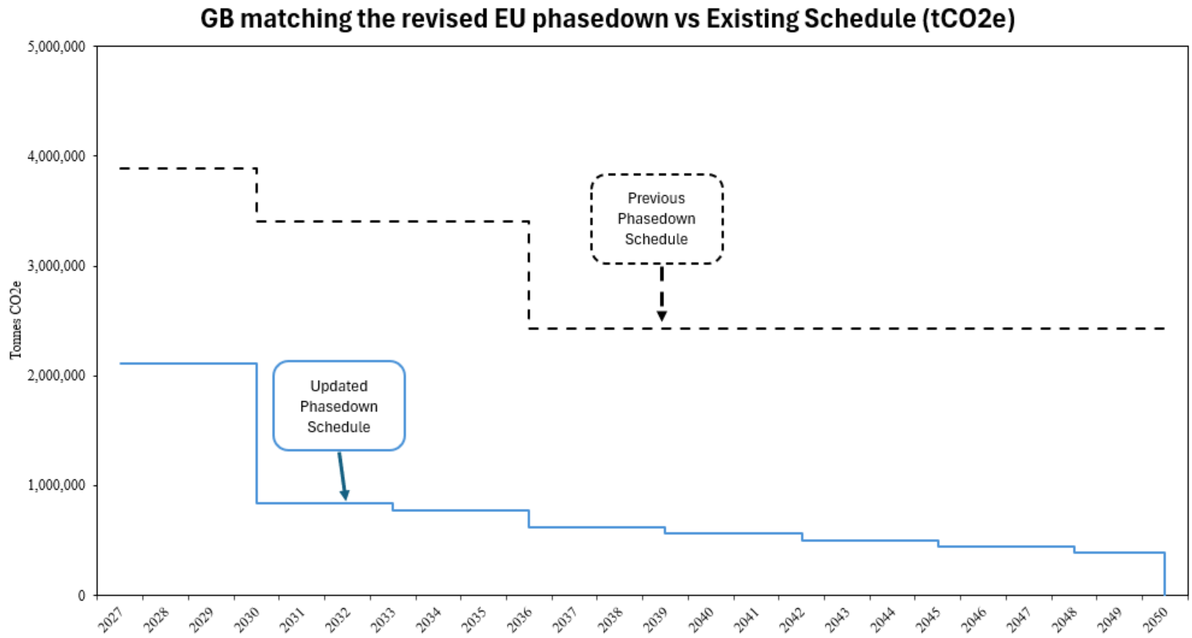

Figure 9: EU's revised phasedown

Compared to the current phasedown the matching the EU phasedown option sees HFCs put on the market for the first time reduced by 50.2 million tCO2e from 2027 to 2050 (see Figure

[23] Traded carbon values used for modelling purposes, 2024 - GOV.UK

9). Over the appraisal period (2027 – 2036) this figure is around 22.7 million tCO2e compared to current the phasedown. The total cost associated with this phasedown option is estimated to be around £104m (present value) over the appraisal period, with a range of £74m – £134m.

This reduction has an associated carbon saving value, which we use DESNZ's carbon price figures[24] from 2027 – 2050 to estimate the total benefits over the phasedown schedule length. Total benefits from carbon savings are estimated to be around £1,649m (present value) over the appraisal period, with a range of £1,112m – £2,126m. Due to how costs and benefits are calculated there is a trend that as options get more ambitious environmentally (i.e., more carbon emission savings), the greater the Net Present Value. Deciding upon the preferred option requires nuance and it not simply the case of opting for the most ambitious. This is because the deliverability of more climate ambitious phasedowns becomes uncertain. Problems arise if suddenly the burden on industry to transition is too extreme leading to unintended consequences.

There are notable differences between the GB and EU HFC markets[25] that make matching the revised EU phasedown option sub-optimal. For example, the EU uses more air conditioning, whereas GB uses (and plans to continue using) proportionally more heat pumps. Feedback from stakeholders has demonstrated concern about safety and energy efficiency in using alternatives in particular circumstances should the GB market face a rushed transition that does not account for domestic nuances. Less punishing early phasedown steps, while forgoing theoretic emission savings, allows GB industry time to transition.

A summary of the lower, higher, and best estimated for the total costs and benefits for this option can be seen in Table 16.

Table 16: EU's Revised Phasedown (Option A2) Costs and Benefits Summary

Prevent Value (2027-2036)	Total Costs	Total Benefits	Net Present Value
Low	£74	£1,112m	£1,038m
High	£134m	£2,126m	£1,993m
Best Estimate	***£104m***	***£1,649m***	***£1,545m***

Most challenging GB phasedown (Option A3, IV)

The same methodology as in the option above was also used here. The fifth and final sub option considered in the shortlist is the most challenging GB specific phasedown. The phasedown calculation again is based on the expected demand from the market in this most extreme scenario.

[24] Traded carbon values used for modelling purposes, 2024 - GOV.UK

[25] F gas regulation in Great Britain see page 79

Compared to the current phasedown the most challenging option sees a reduction of HFCs put on the market for the first time reduced by 55.8 million tCO2e from 2027 to 2050 (see Figure 10). Over the appraisal period (2027 – 2036) this figure is around 24.9 million tCO2e compared to current the phasedown. The total cost associated with this phasedown option is estimated to be around £119m (present value) over the appraisal period, with a range of £88m – £158m.

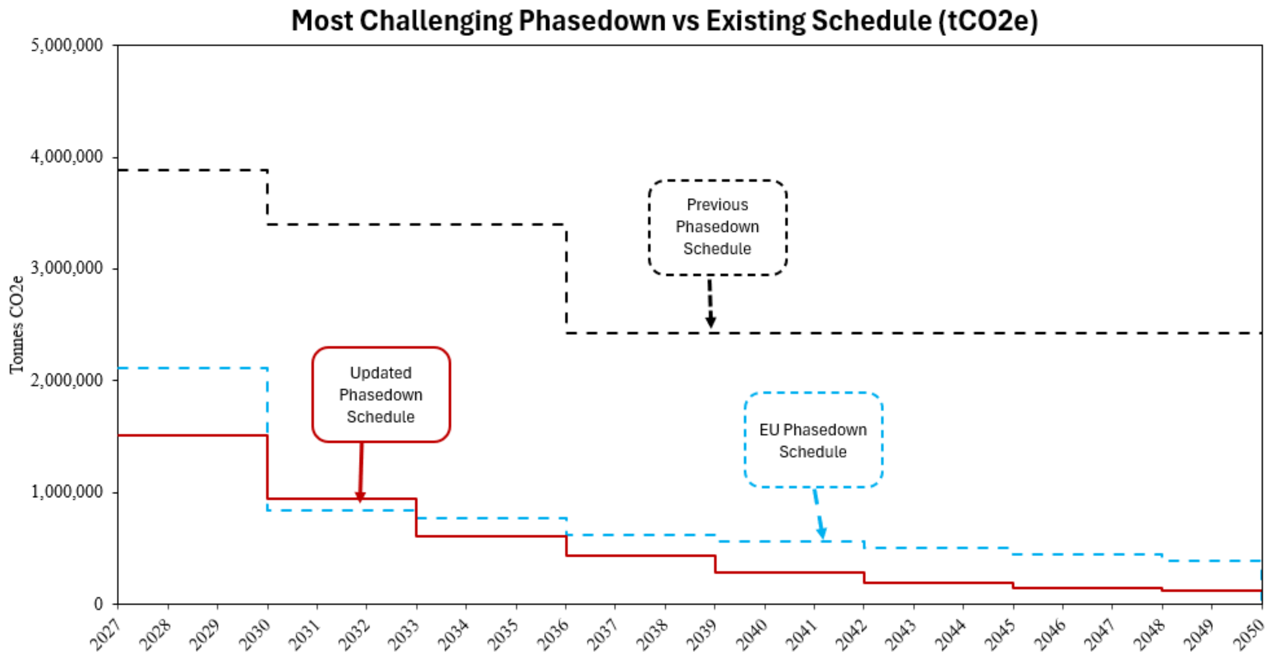

Figure 10: Most Challenging Phasedown

This reduction has an associated carbon saving value, which we use DESNZ's carbon price figures[26] from 2027 – 2050 to estimate the total benefits over the phasedown schedule length. Total benefits from carbon savings are estimated to be around £1,812m (present value) over the appraisal period, with a range of £1,231m – £2,335m.

A summary of the lower, higher, and best estimated for the total costs and benefits for this option can be seen in Table 17.

Table 17: Most Challenging GB Phasedown (Option A3, IV) Costs and Benefits Summary

Prevent Value (2027-2036)	Total Costs	Total Benefits	Net Present Value
Low	£88	£1,231m	£1,144m
High	£158m	£2,335m	£2,178m
Best Estimate	***£119m***	***£1,812m***	***£1,693m***

This poses the most challenging scenario for industry. Additional product bans and prohibition timetables would be needed to achieve this phasedown, beyond that of those due to be implemented in the EU. Even though Net Present Value is the greatest under this option, the fundamental question around achievability makes this a sub-optimal choice. Over-tightening could have considerable unknown negative impacts. It is important that regulations do not

[26] Traded carbon values used for modelling purposes, 2024 - GOV.UK

make gas unavailable for critical uses or impede other strategic goals, such as the heat pump roll out in DESNZ's forthcoming Warm Homes Plan.

6.2 Small and Micro Businesses Assessment (SaMBA)

The only exemption arranged for businesses is for producers or importers placing less than 100 tCO_2e of HFCs on the market annually. Starting to exempt more businesses would reduce the scope of HFCs covered by the phasedown, which would sabotage maximal efforts to reduce F gas emissions.

Given the niche use in the UK economy which F gases cover we do not have full understanding on the composition of sub-sectors. Information on business demography is an evidence gap. We will be asking for feedback during the consultation to better understand business size and potential scale of impacts.

Additional expected burden to small and micro businesses is likely to be small due to both the GB and EU phasedown. As such these businesses will and have invested in preparing for this transition, this is supported anecdotally by stakeholders. Given the proposal is focused on only adjusting the phasedown, there would be no new cost or burden put on these small and micro businesses.

Furthermore, with other policy options, such as recovery and the quota allocation approach, not being considered further at this stage, again these reduce the need for additional or new administrative or reporting burdens being introduced for these businesses.

New entrants have an 11% share of the F gas quota ringfenced annually. This is not expected to have any significant exclusionary effect on businesses or competition issues, because fundamentally HFCs are a dwindling, unsustainable market to operate in. On 1st April 2025, the Environment Agency introduced a new charging scheme for those using the F gas service[27]. The revenue covers the costs of providing the service and helps ensure the new entrants quota goes as is intended.

6.3 Medium Businesses Assessment

It is hard to comment on the impact on medium businesses (between 50-249 employees) due to the evidence gap around business demography for F gas businesses. We will be asking for feedback during the consultation to better understand business size and potential scale of impacts.

[27] The Environment Agency (fluorinated greenhouse gases and ozone-depleting substances) charging scheme 2025 - GOV.UK

7. Regulatory scorecard for preferred option

Part A: Overall and stakeholder impacts

(1) Overall impacts on total welfare		**Directional rating**
Description of overall expected impact	The reformed phasedown would be expected to drive industry into transitioning away from high-GWP HFCs to low-GWP alternatives. The reduction in powerful F gases escaping and persisting in the atmosphere would help slow the global warming effect, that leads to climatic tipping points and multitude of other social problems. The phasedown needs to be carefully managed to ensure adequate supply for critical uses and wider Net Zero delivery infrastructure is maintained. Quota on the market would in theory go to the application/use experiencing the greatest transition costs. The price increase in HFCs would help encourage a move to natural alternatives that already exist or would be developed. At this moment, we do not have enough data and information to properly cost each individual part of the Regulation burden.	**Positive** **Based on all impacts (incl. non-monetised)**
Monetised impacts	NPSV = £1,203m (sensitivity analysis £804m-£1,540m)	**Positive** **Based on likely £NPSV**
Non-monetised impacts	Adhering to international climate obligations under the Kigali Amendment to the Montreal Protocol. Reinforcing the reputation of the UK as a global climate leader, and continuation of the clean energy investment that attracts. Meeting domestic environmental targets on track to delivering Net Zero by 2050.	**Positive**
Any significant or adverse distributional impacts?	No. The proposal furthers existing Regulation and as such there are no anticipated adverse distributional impacts on businesses. We are seeking industry feedback through the consultation to help expand our understanding on SMBs and household impacts specifically.	**Uncertain**

(2) Expected impacts on businesses		
Description of overall business impact	From stakeholder interactions we are under the impression that in the time between the 2024 EU phasedown revision and now, stakeholders are expecting a GB phasedown revision and have been adjusting to EU markets to boost preparedness.	**Uncertain**

	Assurance to allow for future planning is another ask from industry which is achieved by committing to a revised phasedown. Business may be faced with changes in costs relating to: • Technological adjustments resulting in changes in investment costs and operating expenditures (e.g. energy use, maintenance costs) for users of mainly new equipment that are shifting to (more) climate-friendly alternatives. • Higher HFC prices ("HFC price premium") resulting in higher HFC equipment prices and maintenance costs for users that continue to rely on equipment using HFCs. HFC price premium would benefit the sellers of HFCs, who receive the quota free of charge mainly based on historic grandfathering.	
Monetised impacts	Business NPV = £83m across the appraisal period (2027-2036). With a range of £61m - £110m from sensitivity analysis. **EANDCB = £9.6m. Consisting of estimated cost of abatement to businesses proxied by the historic quota price. Businesses would need to adapt in order to transition away from HFCs, but we are not expecting major profit loss from demand drop-off.** Pass through to households has not been deducted from these figures. The cost incidence of the increase costs to business operations will become more established through the consultation.	**Negative** **Based on likely business £NPV**
Non-monetised impacts	Most of the cost comes from the use of more expensive (lower GWP) alternatives. No ongoing cost from higher manufacturing costs or reduced energy efficiency. The easy transitions occur first, sometimes alternatives to cheaper cleaner gas are possible. As the quota squeezes use, it would get increasingly more difficult for businesses to switch. I.e., there would be a good reason why they are slow to transition away from F gas. The risk is high abatement costs for difficult-to-transition sectors, that push the cost to businesses towards the upper end of the range. Average annual costs that arise from changing to climate-friendly equipment, either new investment into alternative equipment or operating alternative equipment, e.g. the technological adjustment costs. At sector level we expect there to be large differences but are seeking feedback to standard the scale. We expect that the targeted refrigeration and air conditioning (RAC) users would see benefits because higher investment costs are in general counterbalanced by lower operating cost (e.g. better energy efficiency). While rising HFC prices are an additional cost to end-users this is passed on as additional revenue to quota holders.	**Uncertain**

Any significant or adverse distributional impacts?	Uncertain. We are seeking industry feedback through the consultation to help expand our understanding on SaMBA impacts and possible regional impacts. The F gas Regulation is applied to almost all businesses. The only exemptions, covered in the primary legislation, include producers or importers placing less than 100 tCO2e of HFCs on the market annually. This is nothing new or expected to change from the existing Regulation.	**Uncertain**

(3) Expected impacts on households		
Description of overall household impact	Following the European Commission's 2022 impact Assessment Report[28], our current understanding is that private consumers are not expected to bear any significant costs. Households are only the end-user in a few sub-sectors. It is thought energy efficiency savings would balance out increase equipment costs for users of small AC units like heat pumps. Tightening the phasedown is expected to lead to price hikes in HFCs quota as it becomes scarcer. The extent to which these increased business costs are passed through to households through higher market prices will be tested at consultation. Unclear at this stage whether the pass through can be considered direct and therefore included in the EANDCH and subtracted from the EANDCB	**Uncertain**
Monetised impacts	Our current understanding is that monetised household impacts would not be significant. We are seeking industry feedback through the consultation to gather evidence and check this understanding.	**Uncertain** **Based on likely household £NPV**
Non-monetised impacts	To be filled in after the consultation.	**Uncertain**
Any significant or adverse distributional impacts?	None anticipated, the consultation will help alert us to any.	**Uncertain**

Part B: Impacts on wider government priorities

Category	Description of impact	Directional rating

[28] European Commission Impact Assessment Report, 2022

Business environment: Does the measure impact on the ease of doing business in the UK?	The proposed revised phasedown would more closely align F gas regulation between GB and the EU. This provides more certainty for the business environment in terms of future planning, given that HFC markets across GB and the EU strongly interact. The tighter quota would provide financial incentive to innovate and development new low-GWP solutions. This would guide demand away from HFCs towards the open-market of low-GWP alternatives. An established challenge of developing HFC alternatives is balancing the requirements of the gas/blend to operate effectively and efficiently with the properties of the gas/blend (flammability, toxicity, etc).	**Supports**
International Considerations: Does the measure support international trade and investment?	GB may be presented with great exporting opportunities in the future should frontier technological break throughs in replacing HFCs be marketed globally. Increased climate ambition is a decision made to meet domestic targets, international targets and with respect to increased European ambition through their 2024 Revised Regulation.	**Supports**
Natural capital and Decarbonisation: Does the measure support commitments to improve the environment and decarbonise?	The proposed phasedown is expected to provide significant carbon emission savings equivalence. Compared to the current phasedown the preferred high ambition option (the proposed reform) would see a reduction of quota allowed and put on the market reduced by **46.1 million tCO2e from 2027 to 2050**. Over the appraisal period (2027 – 2036) this figure is around 17.6 million tCO2e compared to current the phasedown. Further prevention of use and therefore release of potent, high-GWP HFCs would limit their dangerous contribution to global warming. This would directly help slow the degradation of the UK's sources of natural capital. Heat pumps are key for decarbonising domestic heating, allocating sufficient HFC quota to ensure a manageable transition for industry and government roll out intentions is one of the key objectives for the proposal.	**Supports**

8. Monitoring and evaluation of preferred option

There is currently no Post-Implementation Review (PIR) requirement in place for the GB F gas Regulation. Under the existing Regulation structure, there is no requirement to produce a monitoring and evaluation report on a regular or formal basis. The F gas Regulation has provisions on reviewing the effects of the Regulation (by the end of 2022). The 2022 Assessment Report was a retrospective examination of the Regulation, its impacts, and outcomes. It would provide a suggested structure and process should the time come for another formal review.

The effects of the Regulation in reducing the quantities of HFCs placed on the market are continuously monitored and will continue to be. Data and evidence is frequently gathered from relevant stakeholders to assess the effectiveness of the F gas Regulation. This varied approach enables engagement with a range of stakeholders and sectors. The feedback received has been invaluable in supporting the development of the policy to date, continued development in thinking for future policy proposals and understanding the overall impact.

Three sector-specific groups were established covering the main F gas sectors and priority areas for the review and evaluation to inform the 2022 Assessment Report. These sectors were – refrigeration, air-conditioning and heat pumps (RACHP), metered dose inhalers (MDIs) and power (for example, electric power transmission and distribution grids). RACHP and MDIs both use HFCs, while the power sector relies on SF6.

The aim of these groups was to gather evidence and feedback on the implementation of the Regulation and, where appropriate and applicable, support the development of options for future legislation. Previous sector group meetings considered specific issues relating to those sectors, both in the current regulations and for policy proposals.

Alongside the stakeholder engagement, specific sector level analysis was carried out as part of this process to evaluate the impact of the Regulation on these key areas. Depending on the specific sector this analysis covered areas like; understanding their transition away from equipment reliant on F gases (i.e. composition of equipment used), total emissions from F gas from the sector (direct and indirectly), total abatement from the sector to date and resulting from the regulation change, gas recovered and re-used, updating projected demand and tracking of quota price. Analysis of the above metrics allowed for holistic evaluation of the updated Regulations, insight as to its effectiveness in limiting HFC quota and bringing down F gas emissions.

Enforcement of the GB F gas Regulation is the responsibility of the Environment Agency in England, Scottish Environment Protection Agency in Scotland and Natural Resources Wales in Wales. The Environment Agency also run the HFC quota system for the whole of Great Britain. (Northern Ireland remains subject to EU F gas legislation.) Businesses placing HFCs on the market must acquire quota from the Environment Agency and have reporting requirements on usage. There is data on quota utilisation and the quantity of F gas banked in authorisations and delegations. These could assist in evaluating the impact of any new policy should it be implemented and the extent to which businesses adapt to that new policy.

If it became apparent that, following implementation of the proposed reform, there were significant inaccuracies in our modelling assumptions that were leading to unintended consequences, a review could be undertaken. For example, scenarios where technological developments towards providing HFC alternatives were much quicker or slower than anticipated, therefore enhancing or hindering the transition, or consequential changes to the political landscape.

Given the proposed reform would focus only on amending the HFC phasedown, there would be no updating or changing of the monitoring and evaluation approach. Proposed policy changes being suggested in this De Minimis Assessment would be incorporated into next evaluation process.

We would track the progression to key domestic and international targets. As part of this we would also review if impacts to demand had the intended consequences as would be modelled in the Final Impact Assessment.

9. Minimising administrative and compliance costs for preferred option

The process of reporting quota usage and authorisations to the Environment Agency is established under the F gas Regulation and there would be no change to this process. The proposed reform would not change the reporting requirements and therefore we are anticipating there would be no changes to business as usual or administrative burdens for participants. Very small familiarisation costs would be expected with participants having to engage and get up to speed with the new phasedown schedule. Plus, engagement in business planning in response to clarity on future quota limits may be anticipated. It is our understanding that participants are approximately planning off the new EU phasedown, given that a GB phasedown amendment is widely anticipated.

The Government have a new initiative to cut admin burdens to business by 25%. The Environment Agency is the regulator and is constantly looking at streamlining and improving processes. The latest example is the introduction of digital automation to reduce their administrative burdens. Every reporting year sees further streamlining and improving of reporting templates and guidance. Importantly, the administrative burden consists of distributing and tracking HFC quota, which over time should disappear as the phasedown nears zero. Further streamlining is dependent on legislative freedom and future access to IT systems.

10. How might the regulatory provision impact on businesses and traders moving goods, and providing services, between Northern Ireland and Great Britain (or a part of it), and Great Britain (or a part of it) and Northern Ireland?

Pursuant to the Windsor Framework, EU legislation and systems for F gases and ODS apply in Northern Ireland. We do not anticipate that the proposed reform will have any significant impact on the movement of goods between GB and Northern Ireland or impose significant new burdens on business in Northern Ireland because the proposal is to adjust the existing system rather than establish a completely new system.

As is currently the case, an importer in Northern Ireland will still be able to import equipment pre-charged with HFC gas from GB, provided the importer holds sufficient EU quota authorisations and the movement complies with the EU legislation. Equally, they will still be able to import bulk HFC gas if they hold sufficient EU quota. Similarly, as is currently the case, movements from Northern Ireland to GB will continue to need to meet the GB rules on quota and quota authorisations in assimilated F gas legislation. Guidance on the rules for such movements is available on gov.uk.

Declaration

Department: Environment, Food and Rural Affairs.

Contact details for enquiries:

Parsa.Mohammadpour@defra.gov.uk

Director responsible: Nigel Miller

I have read the De Minimis Assessment and I am satisfied that, given the available evidence, it represents a reasonable view of the likely costs, benefits and impact of the leading options.

Signed: N.J. Miller

Date: 02/09/2025

Summary: Analysis and evidence

For Options Assessment, it is not a requirement to complete all the below, but please complete as much as you can where possible.

Price base year: 2025

PV base year: 2025

This table may be reformatted provided the side-by-side comparison of options is retained	**1. Business as usual** **(baseline)**	**2. Do-minimum Option** Medium ambition option.	**3. Preferred way forward** High ambition option.	**4. More ambitious Option** EU's Revised Phasedown	**5. Most ambitious Option** Most challenging option.
Net present social value (with brief description, including ranges, of individual costs and benefits)	No added quantified costs or benefits.	NPV: £738m Carbon saving benefits vastly outweigh the abatement cost for businesses. Benefits: £786m Costs: £48m	NPV: £1,206m Carbon saving benefits vastly outweigh the abatement cost for businesses. Benefits: £1,286m Costs: £83m	NPV: £1,545m Carbon saving benefits vastly outweigh the abatement cost for businesses. Benefits: £1,649m Costs: £104m	NPV: £1,693m Carbon saving benefits vastly outweigh the abatement cost for businesses. Benefits: £1,812m Costs: £119m
Public sector financial costs (with brief description, including ranges)	No cost for doing nothing.	The proposal of extending existing Regulation would come at no cost to the public sector.	The proposal of extending existing Regulation would come at no cost to the public sector.	The proposal of extending existing Regulation would come at no cost to the public sector.	The proposal of extending existing Regulation would come at no cost to the public sector.
Significant un-quantified benefits and costs (description, with scale where possible)	Defaulting on our legally binding international climate obligations (Kigali Amendment to the Montreal Protocol	Continuing to meet international objectives and targets under Montreal Protocol. Meeting domestic	Continuing to meet international objectives and targets under Montreal Protocol. Meeting domestic	Hidden costs to industry transitioning. Continuing to meet international objectives and	Hidden costs to industry transitioning. Continuing to meet international objectives and

	missing the end part of the 85% target by 2036)	carbon budgets as we progress towards Net Zero by 2050.	carbon budgets as we progress towards Net Zero by 2050.	targets under Montreal Protocol. Meeting domestic carbon budgets as we progress towards Net Zero by 2050.	targets under Montreal Protocol. Meeting domestic carbon budgets as we progress towards Net Zero by 2050.
Key risks (and risk costs, and optimism bias, where relevant)	N/A	For amassed carbon emission savings this provides a conservative estimate because the annual quota puts a hard stop on any more HFCs going to market. If demand is lower than expected the quota could be under-utilised leading to more savings. The key risk lies in abatement costs to businesses proving greater than expected leading to a more difficult transition than anticipated. In the consultation we will clarify the	For amassed carbon emission savings this provides a conservative estimate because the annual quota puts a hard stop on any more HFCs going to market. If demand is lower than expected the quota could be under-utilised leading to more savings. The key risk lies in abatement costs to businesses proving greater than expected leading to a more difficult transition than anticipated. In the consultation we will clarify the	For amassed carbon emission savings this provides a conservative estimate because the annual quota puts a hard stop on any more HFCs going to market. If demand is lower than expected the quota could be under-utilised leading to more savings. The key risk lies in abatement costs to businesses proving greater than expected leading to a more difficult transition than anticipated. In the consultation we will clarify the	For amassed carbon emission savings this provides a conservative estimate because the annual quota puts a hard stop on any more HFCs going to market. If demand is lower than expected the quota could be under-utilised leading to more savings. The key risk lies in abatement costs to businesses proving greater than expected leading to a more difficult transition than anticipated. In the consultation we will clarify the

		expectations of industry.	expectations of industry.	expectations of industry.	expectations of industry.
Results of sensitivity analysis	N/A	Accounting for sensitivity in the market carbon price the following ranges were calculated. NPV £491m - £941m Benefits £525m - £1,002m Costs £34m - £61m	Accounting for sensitivity in the market carbon price the following ranges were calculated. NPV £804m - £1,540m Benefits £865m - £1,650m Costs £61m - £110m	Accounting for sensitivity in the market carbon price the following ranges were calculated. NPV £1,038m - £1,993m Benefits £1,112m - £2,126m Costs £74m - £134m	Accounting for sensitivity in the market carbon price the following ranges were calculated. NPV £1,144m - £2,178m Benefits £1,231m - £2,335m Costs £88m - £158m

Annex 1: F gases and GWPs

Annex I of the F gas Regulation – fluorinated greenhouse gases (as defined in the F gas Regulation) and GWP values (based on AR4 values).[1]

Industrial designation	Chemical name (Common name)	Chemical formula	GWP
Hydrofluorocarbons (HFCs)			
HFC-23	trifluoromethane (fluoroform)	CHF_3	14 800
HFC-32	difluoromethane	CH_2F_2	675
HFC-41	fluoromethane (methyl fluoride)	CH_3F	92
HFC-125	pentafluoroethane	CHF_2CF_3	3 500
HFC-134	1,1,2,2-tetrafluoroethane	CHF_2CHF_2	1 100
HFC-134a	1,1,1,2-tetrafluoroethane	CH_2FCF_3	1 430
HFC-143	1,1,2-trifluoroethane	CH_2FCHF_2	353
HFC-143a	1,1,1-trifluoroethane	CH_3CF_3	4 470
HFC-152	1,2-difluoroethane	CH_2FCH_2F	53

[1] AR4 means based on the Fourth Assessment Report adopted by the Intergovernmental Panel on Climate Change.

HFC-152a	1,1-difluoroethane	CH_3CHF_2	124
HFC-161	fluoroethane (ethyl fluoride)	CH_3CH_2F	12
HFC-227ea	1,1,1,2,3,3,3-heptafluoropropane	CF_3CHFCF_3	3 220
HFC-236cb	1,1,1,2,2,3-hexafluoropropane	$CH_2FCF_2CF_3$	1 340
HFC-236ea	1,1,1,2,3,3-hexafluoropropane	CHF_2CHFCF_3	1 370
HFC-236fa	1,1,1,3,3,3-hexafluoropropane	$CF_3CH_2CF_3$	9 810
HFC-245ca	1,1,2,2,3-pentafluoropropane	$CH_2FCF_2CHF_2$	693
HFC-245fa	1,1,1,3,3-pentafluoropropane	$CHF_2CH_2CF_3$	1 030
HFC-365 mfc	1,1,1,3,3-pentafluorobutane	$CF_3CH_2CF_2CH_3$	794
HFC-43-10 mee	1,1,1,2,2,3,4,5,5,5-decafluoropentane	$CF_3CHFCHFCF_2CF_3$	1 640
Perfluorocarbons (PFCs)			
PFC-14	tetrafluoromethane (perfluoromethane, carbon tetrafluoride)	CF_4	7 390
PFC-116	hexafluoroethane (perfluoroethane)	C_2F_6	12 200
PFC-218	octafluoropropane (perfluoropropane)	C_3F_8	8 830
PFC-3-1-10	decafluorobutane	C_4F_{10}	8 860

(R-31-10)	(perfluorobutane)		
PFC-4-1-12 (R-41-12)	dodecafluoropentane (perfluoropentane)	C_5F_{12}	9 160
PFC-5-1-14 (R-51-14)	tetradecafluorohexane (perfluorohexane)	C_6F_{14}	9 300
PFC-c-318	octafluorocyclobutane (perfluorocyclobutane)	$c\text{-}C_4F_8$	10 300
Other perfluorinated compounds			
	sulphur hexafluoride	SF_6	22 800

Annex 2: Phasedown (Option A) Assessment

Option A Long-List Assessment

	Status Quo / BAU (Option A1)	EU's Revised Phasedown (Option A2)	GB Phasedown (I) Low ambition (Option A3)	GB Phasedown (II) Medium ambition (Option A3)	GB Phasedown (III) High ambition (Option A3)	GB Phasedown (IV) Most challenging (Option A3)	GB Phasedown (V) Bulk gas only (Option A3)
Delivery on UK Domestic Net Zero Commitments (CSF1)	No added emissions savings	Ambitious emissions savings through phasedown.	Emissions savings through phasedown, but not as ambitious.	Emissions savings through phasedown, but not as ambitious.	Ambitious emissions savings through phasedown.	Most ambitious for emissions savings through phasedown, under extreme assumptions.	No further emissions savings from phasing down F gases in equipment.
Continued Compliance with International Obligations (CSF1)	No added emissions savings to support international obligations	Would far exceed Kigali Amendment targets	Would exceed Kigali Amendment targets				Assume it would exceed Kigali Amendment targets
Supporting Wider Government Objectives and Aims (CSF1)	No MDI controls & sufficient quota to enable flexibility for critical uses	Concerns in early years that phasedown too severe for needed flexibility in industry.	Less ambitious phasedown should allow for continued flexibility for critical uses. Need to be mindful of MDIs, depending on the transition.		Highly ambitious phasedown could prevent necessary flexibility for critical uses.		No authorisations, flexibility for bulk gas uses depending on phasedown.
Achievability (CSF2)	N/A	Concern with early phasedown steps, depends on available and marketed technology in the UK.	Industry already transitioning in a number of sectors where alternatives are available	Concerns around availability and accessibility of alternatives in some sectors (MDIs, split a/c) depending on timing and severity of the phasedown.			Less regulation on equipment and retain bulk gas requirement.
Affordability (CSF3)	N/A		Low impact on industry, existing alternatives in number of sectors. Extension of existing requirement for regulators.	Extension of existing requirement for regulators. Dependant on the severity of the phasedown steps, there could be significant cost impacts on NHS and heat pump roll out.			Regulators adjust system to only control bulk gas. No need for new tech, reduced equipment price.
Deliverability (CSF4)	N/A		Less support for NZ, but easy change for industry and regulators.	More support for emissions savings but could impact delivery of other NZ commitments (heat pumps). Change to existing system for regulators. Industry – cost/supply impacts.			Regulators adjust systems, industry consider existing authorisations.

Option A Long-List Assessment Continued

	Extra heat pump quota (Option A4)	Critical use (i) quota in next year (Option A5)	Critical use (ii) quota in year (Option A5)	All Annex I F gas (Option A6)	All F gases (Option A7)	Non regulatory (Option A8)
Delivery on UK Domestic Net Zero Commitments (CSF1)	Ensures heat pump deployment & safeguard MDIs, while maintaining emissions savings target			Expected potential positive emissions saving impact but not enough data to assess	Expected potential positive emissions saving impact but not enough data to assess	No guarantee on emissions savings.
Continued Compliance with International Obligations (CSF1)	Assume it would exceed Kigali Amendment target.			Kigali Amendment only requires action on HFCs.		No guarantee.
Supporting Wider Government Objectives and Aims (CSF1)	Flexibility for heat pumps, but quota in following year of new phasedown might not be most efficient solution.		Flexibility for critical uses.	No added flexibility. Possible pressure on phasedown.		No added regulatory flexibility or restrictions.
Achievability (CSF2)	Place an administrative burden on industry and regulators. Not an existing requirement for industry. Assume similar quota allocation for regulator, but new requirement for data collection for industry.			New requirement for non-HFC F gas users, but there is existing guidance and support. Adjustments to existing phasedown to account for additional gases.		N/A
Affordability (CSF3)	Additional requirement for regulator. Need for additional resource to assess data and calculate additional allocation. Waiting until there is a supply shortage would negatively impact industry and end-users. Quota allocation may not be fast enough to reduce this impact.			Additional companies for regulators to process. New requirement for non-HFC F gas users, and sectors would be exposed to quota prices.		N/A
Deliverability (CSF4)	Help support delivery of Net Zero commitments. Additional burden for industry and regulators.			Additional burden for industry and regulators. Regulators extend phasedown to other gases/uses. New requirement for some industry.		N/A

Option A Long-List to Short-List Summary

Option	Long-List Assessment Conclusion
Option A1 – Status Quo / BAU	Option proposed for short listing
Option A2 – EU's Revised Phasedown	Option proposed for short listing
Option A3 – UK Phasedown (ii) Medium ambition	Option proposed for short listing
Option A3 – UK Phasedown (iii) High ambition	Option proposed for short listing
Option A3 – UK Phasedown (iv) Most challenging	Option proposed for short listing
Option A8 – Non regulatory	Option proposed for short listing

Option proposed for short listing:

BAU / Status Quo (A1) – No change to the current GB HFC phasedown. However, businesses operating across both the EU and GB would still be required to meet the amended EU HFC phasedown for their activities in the EU market. In addition, from our work on the 2022 Assessment Report, it would appear that industry does not require so much quota, as shown by the decline in the price of quota and the bank of quota authorisations.

EU's Revised Phasedown (A2) – This scenario would involve matching the revised EU HFC phasedown. It would ensure consistency on climate ambition between GB and Europe and could be beneficial for trade to have market synchronicity.

GB Phasedown, medium ambition / commercially available scenario (A3, II) – This scenario assumes that industry relies on existing technologies but increases deployment of lower GWP alternatives that are already commercially available. This would provide additional quota, which may be beneficial for critical uses/sectors.

GB Phasedown, high ambition / challenging available scenario (A3, III) – This scenario assumes that industry adopts technologies that have either not been developed or have not yet reached the market, but that are likely to be technically feasible soon. This option is more similar in ambition to the EU, at least from the mid-2030s. It would deliver additional ambition compared to others, in support of Net Zero and promoting the uptake of low GWP or non-F gas alternatives, which would have long term beneficial impacts on emissions. Implications and impacts on critical uses cases would need to be considered, ensuring no adverse impacts.

GB Phasedown, most challenging / extreme scenario (A3, IV) – The most extreme output our model can provide. This scenario assumes industry can manage an accelerated transition and that recovery/leakage/equipment factors are as favourable as possible. It would be an extremely difficult transition for industry and would require precarious juggling of competing government priorities. It assumes, for instance, low annual leakage rates, low equipment lifespan, high rate of gas recovery and low charge sizes within equipment. It maximises F gas emission savings.

Non-regulatory (A8) – Rely on voluntary industry action and incentives set by Other Government Departments to phase down HFCs and other F gases. The EU have implemented an ambitious phasedown and supporting measures, and businesses who also operate in the EU market will continue to respond to this. We have already seen the increasing uptake and transition to natural refrigerants.

Annex 3: Modelling and Technical Assumptions

Equipment New Items and Stock

To estimate the amount of equipment stock which use F gases we take a twostep process. The first step is to estimate the current and past levels of equipment stock. The second step is to project forwards, to estimate the future levels of stock. The new model follows IPCC tier 2a guidelines[30] for stock and emissions calculations, with the addition of a retirement function to gradually retire items over time. This gradual retirement smooths the annual stock compared to the EU methodology[31] and matches the previous HFCOutlook model[32] used XWH to estimate F gas emissions. New items are assumed to all enter service on the 1st of July each year, with all retirements also on the 1st July. This is a simplification of the HFCOutlook model[33] which counts stock from the first of July such that 50% on new items enter the stock in the same year and 50% enter the stock in the following year.

Equipment stock is calculated from new and retired items:

$$Stock_t = Stock_{t-1} + New_t - Retired_t.$$

$Retired_t$ for all t using the matrix equation $\overrightarrow{Retired} = \boldsymbol{R}\,\overrightarrow{New}$ with $\boldsymbol{R} = R_{ij}$ a matrix formulated with elements $\frac{3}{2L}$ for $j + \frac{2L}{3} \le i < j + \frac{4L}{3}$ and zero for all other elements. Note: $\frac{2L}{3}$ and $\frac{4L}{3}$ are rounded to the nearest whole number if L is not a multiple of three. $\overrightarrow{Stock}$ is then the cumulative sum of $\overrightarrow{New}$ minus the cumulative sum of $\overrightarrow{Retired}$. Using a retirement function for new items an equivalent expression is:

$$Stock_t = \sum_{i=t-\frac{4L}{3}}^{t} rf_i \times New_i$$

With L the average equipment lifetime and the retirement function

$$rf_i = \begin{cases} rf_i = 1\ for\ t - \dfrac{2L}{3} \le i \le t \\ rf_i = \dfrac{3}{2L}\left(i - t + \dfrac{4L}{3}\right) for\ t - \dfrac{4L}{3} \le i < t - \dfrac{2L}{3} \\ rf_i = 0\ for\ i < t - \dfrac{4L}{3}\ and\ i > t \end{cases}$$

This is useful to form the matrix equation $\overrightarrow{Stock} = \boldsymbol{rf}\,\overrightarrow{New}$ with the replacement $t \rightarrow j$ to form $\boldsymbol{rf} = rf_{ij}$. The inverse can be taken to calculate new items from a stock forecast $\overrightarrow{New} = \boldsymbol{rf^{-1}}\,\overrightarrow{Stock}$. This allows stock modelling based upon GDP, population, housing stock data… etc. The above equation requires the start year to be the first year of stock, or before the

30 IPCC Updates Methodology for Greenhouse Gas Inventories — IPCC

31 F gases_impact_assessment_en.pdf (europa.eu)

32 HFC-Outlook-Description-and-Specification.pdf (gluckmanconsulting.com)

33 HFC-Outlook-Description-and-Specification.pdf (gluckmanconsulting.com)

stock begins, and for the matrix $\boldsymbol{rf}$ to be truncated to i equal to the final year of new items to form an invertible square matrix.

New_t is split into two categories:

$$New_t = New_t^{pre-charged} + New_t^{site-filled}$$

$New_t^{pre-charged}$ are equipment items filled with gas during manufacturing. $New_t^{site-filled}$ are equipment first filled at the installation site.

The model does not include an economic calculation or drives of demand for new stock. As such, future changes to the price and availability of gas do not therefore affect total equipment growth. There is also no substitution between equipment types that could be used to perform a similar function. From testing, both of these factors would cause the model to overestimate equipment demand in some policy scenarios.

Gas Type

To estimate the type of gas used in equipment in the future (beyond 2023) we use the MAC curve outputs to implement the transition from current commercially available equipment to equipment preferable after increased regulation on F gases (in a given option or scenario) are implemented.

The transition between equipment types is approximated using a four-parameter logistic function:

$$GasTransition(Year, a, b, c, d) = d + \frac{a - d}{(1 + e^{-b(Year-c)})}$$

With d the pre-regulation proportion of a gas used in equipment, a the post-regulation proportion of a gas used in equipment, $b = 12/(P_f - P_i)$ and $c = (P_i + P_f)/2$ with P_i the start year of the phasedown/transition to a new equipment gas type and P_f the assumed final year of the phasedown/transition when all new equipment will be approximately the same as the optimal choice in the MAC curve.

Demand for F gas

Demand D_t is split into gas demand for new items either manufactured in the UK or filled on site during installation, and gas demand for refilling leakage. If manufactured in the UK, gas quota is required for initial filling. If the equipment is imported an alternate import quota mechanism is employed. Retrofill of existing stock with a lower GWP gas is currently excluded from the analysis.

$$D_t^{new} = c \times (New_t^{site-filled} + \ell^{UK-manufactured} New_t^{pre-charged})$$

$$D_t^{refill} = E_t^{lifetime} = \ell_t^{lifetime} \times c \times Stock_t$$

For demand D_t^{new}, for example, if all $New_t^{pre-charged}$ are manufactured outside of the UK, $\ell^{UK-manufactured} = 0$. Three scenarios for UK manufacture are assumed, $\ell^{UK-manufactured} = 0\%, 10\%$, and 20%. This assumption may be an underestimate if heat pump manufacturing increases in the UK or other factors increase UK manufacturing. In this case, additional quota will be required by manufacturers.

Mobile air conditioning containing HFCs was manufactured in the UK for domestic use and export but should not contribute to future demand due to the switch to HFO refrigerants in mobile air conditioning post 2016. Historic estimates of HFC demand for mobile air conditioning are therefore an underestimate.

The latter demand D_t^{refill} assumes leakage from items is refilled annually. This may overestimate demand towards the end of equipment life if items are not refilled for several years before retirement.

The total quota demand Q_t may be reduced if recycled gas is reintroduced into equipment:

$$Q_t = D_t - Recycled_t = D_t^{new} + D_t^{refill} - Recycled_t$$

Assuming all recycled gas is reintroduced into equipment in the same year as recovery. $Recycled_t$ makes up a percentage of recovered gas with the rest of the recovered gas destroyed.

$$Recycled_t = \ell_t^{recycled} \times \ell_t^{recovery} \times \ell_t^{remaining} \times c \times Retired_t$$

$$Destroyed_t = \ell_t^{destroyed} \times \ell_t^{recovery} \times \ell_t^{remaining} \times c \times Retired_t$$

With $\ell_t^{recycled}$the percentage of gas recycled, $\ell_t^{destroyed}$ the percentage of gas destroyed and $\ell_t^{recycled} + \ell_t^{destroyed} = 1$.

Further work will be carried out to test the assumptions on recycled and destroyed gas against the Environment Agency reported data. Further updates to Environment Agency data should help to provide more accurate estimates the proportion of gas destroyed and recycled.

Emissions

Emissions estimated attached to the demand or use of F gases are split into three parts:

$$E_t = E_t^{initial} + E_t^{lifetime} + E_t^{retirement}.$$

Emissions during initial fill, during the equipment's lifetime due to leakage and catastrophic failure, and emissions at equipment retirement for each equipment type in kg are;

$$E_t^{initial} = \ell_t^{initial} \times c \times New_t,$$

$$E_t^{lifetime} = \ell_t^{lifetime} \times c \times Stock_t,$$

$$E_t^{retirement} = \ell_t^{retirement} \times \ell_t^{remaining} \times c \times Retired_t.$$

$\ell_t^{initial}$, $\ell_t^{lifetime}$, and $\ell_t^{retirement}$are inherently time dependent annual leakage rates of the equipment type and c the equipment charge size in kg. However, for this model we utilise a fixed leakage rate for $\ell_t^{lifetime}$ based upon German leakage data gathered between 2013 and 2022.[34] This data is voluntary and was gathered post EU regulation restricting HFC use.

[34] https://www.vdkf.de/download/vdkf-information-juli-august-2023/#

Therefore, the leakage rates used will not accurately reflect the higher historic leakage rates pre regulation, and the emissions estimates are inaccurate pre-2013. $\ell_t^{initial}$ and $\ell_t^{retirement}$ are based upon HFCOutlook assumptions from 2030.[35] All leakage rate assumptions have a $\pm 20\%$ uncertainty estimate applied for low and high leakage scenarios. Charge size uncertainty is also assumed to be $\pm 20\%$

$Remaining$ is an assumed the percentage of charge left in the equipment at retirement. $\ell_t^{initial}$ is the percentage of equipment charge lost during on site filling of equipment, $\ell_t^{lifetime}$ is the percentage of equipment charge lost due to equipment leakage and catastrophic failure, and $\ell_t^{retirement}$ is the percentage of equipment charge vented to the atmosphere when the equipment is decommissioned. $\ell_t^{retirement} = 1 - \ell_t^{recovery}$ with $\ell_t^{recovery}$ the percentage of equipment charge recovered for recycling or destruction.

However, the recovery rate is a fixed exogenous variable. Different abatement scenarios use the same recovery assumptions whereas recovery would likely vary in response to changes in the demand for gas. It is hard to predict the impact of this simplification: reducing available quota would increase the price of quota which would increase incentives for recovery but may reduce demand for higher GWP gases which are phased out.

Additional sources of emissions not currently considered are; emissions from gas storage containers, and emissions due to retro-fill of equipment. It is assumed that it will be unlikely that consumers will retro-fill their equipment due to the large quantities of available gas for service recovered from retiring equipment.

Modelling Approach and Demand Forecast

An overview of the modelling approach can be seen in the flow diagram below, which has three compartments. The model has superseded Defra's previously used HFC Outlook Model developed by Gluckman Consulting.[36] Broadly the new and previous models take a similar methodology approach, but where possible input data, assumptions and scenarios will be UK tailored and specific, which was not previously feasible.

[35] HFC-Outlook-Description-and-Specification.pdf (gluckmanconsulting.com)
[36] HFC-Outlook-Description-and-Specification.pdf (gluckmanconsulting.com)

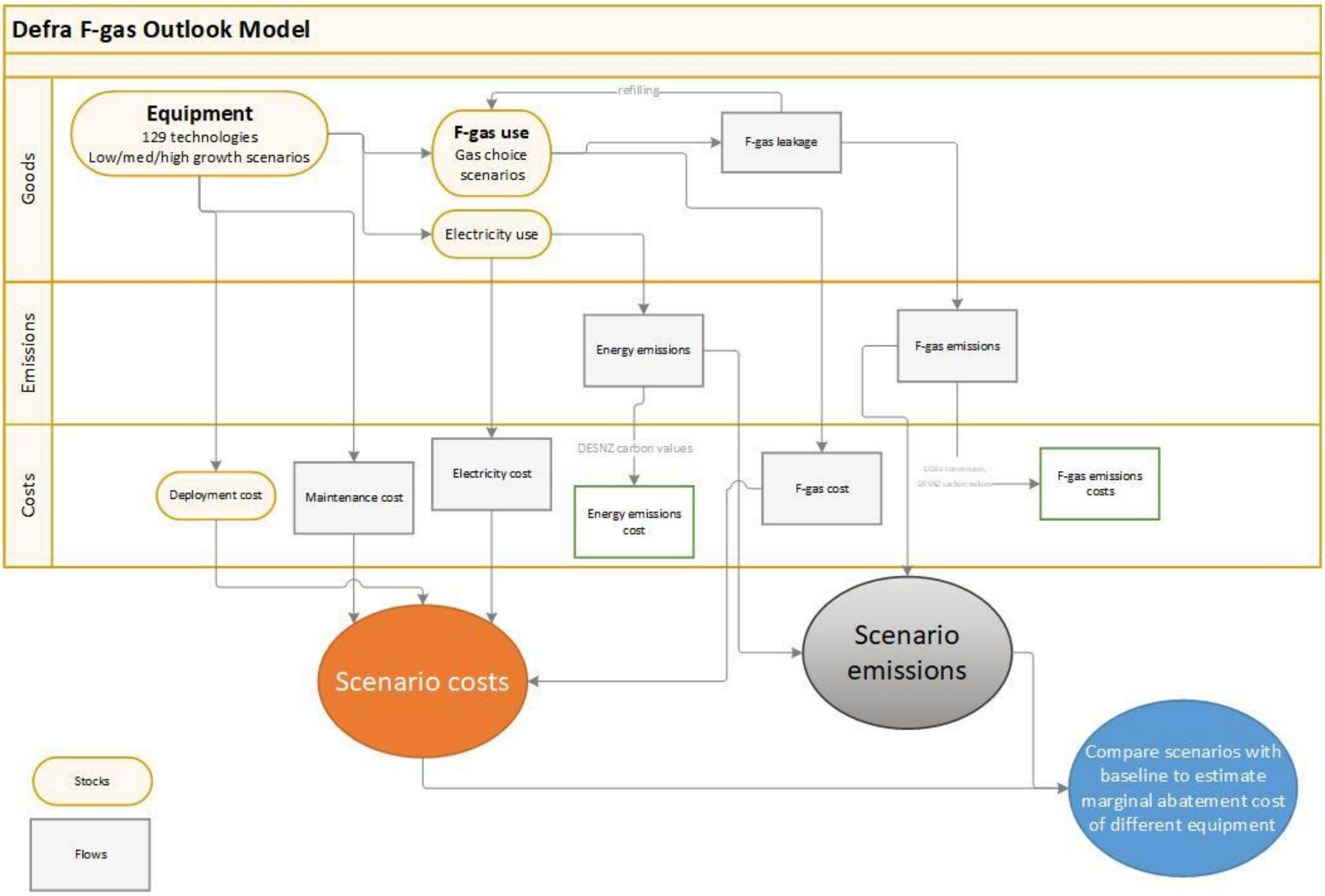

Figure X: Overview of Defra F-Gas Model

Initial projections from our model on F gas emissions derived from demand forecasts can be seen in Figure 11 (dotted black line). The grey band indicatives the upper and lower ranges where demand could be depending on assumptions and scenarios (to be finalised in the Final Impact Assessment).

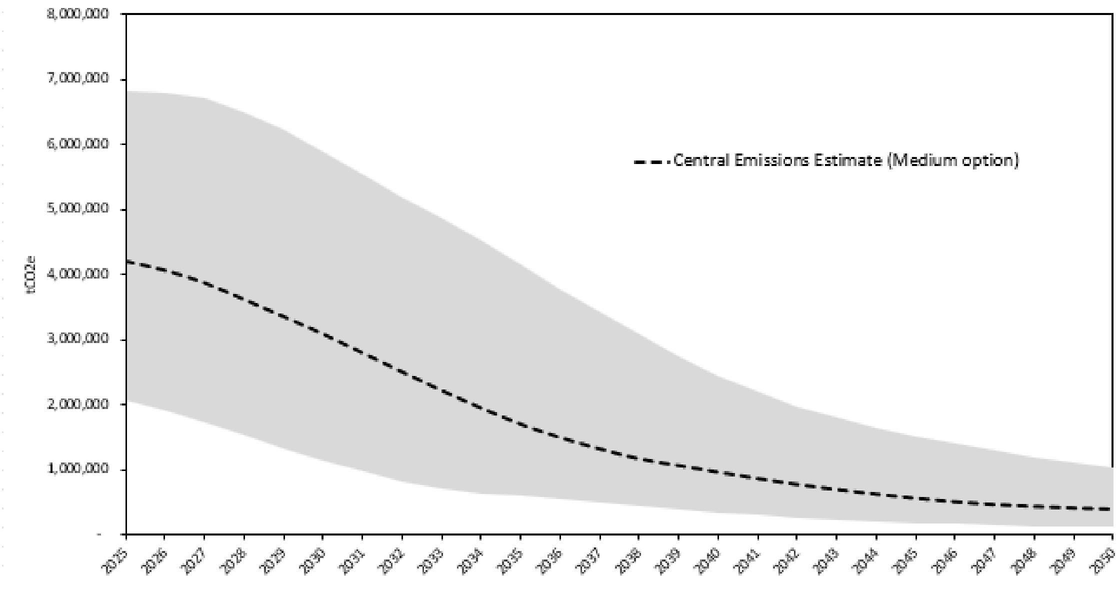

Figure 11: F-Gas Emissions Demanded (After Recovery) under different modelling assumptions

Summary of the assumption, their impacts and our confidence in the underlying data can be seen in Table 18 below. We hope through the consultation particular areas with Low RAG rating could be refined and improved.

Table 18: Assumption Summary

Assumption	Impact on Total Emissions Under High vs Low Scenario	RAG Rating Confidence in Data Assumption
Sector Growth	+/- 6%	Medium
Domestic Manufacturing	+/- Less than 1%	Medium
Equipment Lifespan	–/+ 25%	High
Leakage (of equipment)	+/- 6%	Low
Leakage at First Fill (of equipment)	+/- Less than 1%	Low
Recovered Gas	–/+ 20%	Low
Charge Size (of equipment)	+/- 20%	Low

Marginal Abatement Cost

A marginal abatement cost curve (or MACC) is core approach adopted for understanding the cost burden to businesses for the options and suggested regulation changes. In this application, abatement means reducing, a MAC resents the costs or savings expected from different opportunities, alongside the potential volume of emissions that could be reduced if implemented. MAC measure and compare the financial cost and abatement benefit of individual policy actions. They use the metric of GPB per tonne of carbon dioxide equivalent – usually represented as £/tCO2e.

Marginal abatement cost is calculated by comparing total emissions with total cost for a scenario for each sector. There may be several abatement scenarios for each sector. The marginal abatement cost curve is formed of discrete changes.

$$\text{Marginal Cost of Abatement}\left[\frac{£}{tCO^2e}\right] = \frac{Marginal\ Cost[£]}{Marginal\ Abatement[tCO^2e]} = \frac{Cost_A[£]-Cost_B[£]}{E_{t_B}[tCO^2e]-E_{t_A}[tCO^2e]}$$

Where A and B are abatement scenarios:

$$Cost = UpfrontCost + \sum_{t=1..lifetime} \frac{AnnualCost}{(1+\delta)^t}$$

Where $(1+\delta)^t$ reflects an annual discount rate of $\delta[\%]$

$$UpfrontCost = InitialCost + CostFirstFill$$

$$CostFirstFill = ChargeSize(1 + LeakageFirstFill) * GasPrice$$

$$AnnualCost_t = RefillCost_t[£] + EnergyCost_t[£]$$

Emissions assumptions, included energy emissions are also described above along with energy usage. Energy cost is calculated as:

$$EnergyCost_t = W_t[kWh] * EnergyPrice[£]$$

The MAC curve currently operates across a single end-year. The model then assumes an uptake trajectory. The model projects an adoption rate based on maximum feasible potential. At present this is fixed across all technologies, however, adoption rates will vary depending on the maturity of technologies and also on the similarity to existing equipment. Entirely new technologies will need research and development: especially if they come with new safety risks or have very different properties (such as the unusually high pressures of CO_2 systems).

For most sectors we use HFC Outlook[37] data for energy use, and maximum uptake, and Öko-Recherche data for price[38]. Maximum abatement (i.e. reduction in emissions at maximum uptake of alternative technologies) is based on expert opinion. To validate this we compared assumptions in the HFC Outlook model[39] with Öko-Recherche's assumptions[40]. For most categories this generates a minimal change in demand. For the remaining categories we used a Defra survey to gather additional data, this information can be found in accommodating spreadsheet published in with consultation. Where available we use survey data for price, efficiency, and maximum uptake for alternative technologies. Survey data also provides a guide to the possible adoption rate, but this is not currently reflected in modelling.

For prices for all other categories we rely on Öko Recherche data.[41] If there is an exact match we use the price of equipment listed in the Öko study.[42] Where equipment in the HFC Outlook model corresponds to equipment in the AnaFGas model but falls between two size categories we calculate an "elasticity" of responsiveness of changes in price to changes in capacity.

[37] HFC-Outlook-Description-and-Specification.pdf (gluckmanconsulting.com)
[38] https://www.oekorecherche.de/en/topics/F gases
[39] HFC-Outlook-Description-and-Specification.pdf (gluckmanconsulting.com)
[40] https://www.oekorecherche.de/en/topics/F gases

[41] https://www.oekorecherche.de/de/support-related-preparing-hfc-phase-down-mechanism-labelling-rules-and-guidance-documents-eu-F gas
[42] https://www.oekorecherche.de/de/support-related-preparing-hfc-phase-down-mechanism-labelling-rules-and-guidance-documents-eu-F gas

$$Responsiveness = \frac{ln[Price_A] - ln[Price_B]}{ln[Price_A] - ln[Price_B]}$$

This assumes that a given percentage change in capacity translates to a fixed percentage change in cost variables. Natural logs are used because the calculation does not vary depend on the choice of denominator. In some cases, the HFC Outlook model only has one similar category in which case we scale from a single unit.

At the moment we do not have all the necessary data and information to develop a MAC curve to understand the cost of the regulation. This is a specific area we are look for feedback from industry to help understand the cost burden before publishing of the Final Impact Assessment.

However, through our evaluation and the 2022 Assessment Report we have a good understanding that the average cost per tCO2e emissions abated from the Regulation is around £4.10 – 7.40[43] (€4.80 – 8.60) being estimated.[44] This estimate is consistent with EU estimates of €6. It is also considerably less than initial estimates of an average abatement cost of €16. A maximum marginal abatement cost is also estimated, recorded in 2017, of £23.60-28.30 (€27.40-32.90) as compared to a maximum abatement cost of €50 proposed in the impact assessment produced ahead of the 2024 EU F gas Regulation.[45]

For our purposes, we use a cost figure in our option analysis of £4.10 (lower bound), £7.40 (higher bound) and £5.75 (best, average between the range).

Heat Pumps

Heat pumps will be the main source of F gas emissions due to the planned national rollout of heat pumps as a replacement to gas boilers. The model incorporates a higher rate of heat pump deployment than that presented in the 2025 Carbon Budget and Growth Delivery Plan which reflects a sensitivity test of the F-gas emissions trajectory. For simplicity and due to lack of historic data we assume the heat pump stock begins in 2018.

Hydronic Monobloc Heat Pumps

Hydronic monoblocs should make up the majority of heat pump installations. For residences with a large enough outdoor area, far enough from other dwellings so that noise can be isolated, a monobloc heat pump should be possible. Therefore, it is assumed that medium to large terraced houses, detached houses, and bungalows in the current housing stock will be eligible for a monobloc heat pump. The majority of these may use R290 (propane) but some homes may be suited for a monobloc but not for propane. Based on survey responses we assume this is 85% but will seek additional guidance through the consultation.

Under legislation due soon, gas boilers will be banned in new builds where planning permission is granted. We assume that from 2028 all new housing builds will be able to accommodate a R290 monobloc heat pump from 2028, or alternative technology that does not require HFCs. New homes may be more prone to overheating (due to improved insulation standards) and may require cooling. However, in new builds this may be accomplished with

43 At a 3.5% discount rate.

44 F gas regulation in Great Britain (publishing.service.gov.uk)

45 Regulation - EU - 2024/573 - EN - EUR-Lex

chiller systems or forced air systems (common in some other countries) which are not included in the HFC Outlook model but we assume could use propane.

Split Hydronic Systems

In smaller homes without outside space and apartments. monobloc heat pump outdoors may not be possible. Split hydronic systems require less outside space and are currently used in 10% of installations. However, MCS data indicates that current installations are not typical of the housing stock and feature a much higher proportion of large detached homes than indicated by the English housing survey.

Unlike air conditioning systems (described below) where there is typically adequate space for flammable refrigerants to safely disperse, the internal unit for hydronic splits are typically installed in a room much smaller than the one being heated or cooled (usually where the boiler is installed). For high temperature systems CO2 may be an efficient alternative but this is not suited to low temperature systems which are typically more efficient.

Leakage rates

There is limited available data on leakage rates. Only a small number of countries use electronic logbooks; most of these are voluntary systems and with the exception of West Germany all of which are former eastern Bloc states.[46] We use our own survey data where available and German logbook data in most other cases. For mobile systems we use HFC Outlook assumptions for 2035 leakage rates.[47] Assumptions can be noted in the accommodating spreadsheet attached with the consultation.

German logbook data suggests lower leakage rates than applied by the European Commission. It is also lower than some other countries' logbook data. This is voluntary data which may be biased toward best practices but is also more granular than other sources. Stakeholders have indicated there may be differences between industries and countries due to differences in maintenance practice. We assume German data is likely to best reflect UK practices. Further, the tightening of regulations is likely to increase recovery rates (except for existing equipment using gas that is phased out).

Source of leakage rate for each sector are listed the accommodating spreadsheet attached with the consultation. For leakage at first fill and gas percentage recovered at retirement, HFC Outlook assumptions for 2030 are used.

Marginal Abatement Cost

Abatement potential is a function of cost, energy efficiency, and technical feasibility. There are a limited number of gases which may be used as refrigerants. Only 9 elements are used to build all refrigerant gases (H, C, N, O, F, S, CL, Br, and I). Moving away from Fluorine increases flammability and/or toxicity. This may limit deployment or require additional capital cost to mitigate risk. Some refrigerant choices may reduce energy efficiency or require additional cost to accomplish equal efficiency. There may also be trade-offs between energy efficiency and safety, such as with flammable refrigerants where reducing charge size may mitigate safety risk but reduces energy efficiency (by reducing the size of the heat exchanger). There is a further trade-off, not considered here, whereby unit scan be made

46 https://www.fluorocarbons.org/logbook/

47 HFC-Outlook-Description-and-Specification.pdf (gluckmanconsulting.com)

smaller without loss of energy efficiency by increasing noise. While not quantified this is a potentially important cost.

We use survey data for four categories: split and monobloc domestic heat pumps, and small/medium air-to-air systems. These, and in particular the first two, account for the bulk of gas demand in previous modelling. Air-to-air systems currently account for a small amount of demand. But at present we do not model increased demand for air conditioning or the possibility of using air-to-air in small homes. Air-to-air has better potential for using propane than split hydronics and also increases efficiency so further modelling here would be instructive. For some refrigeration categories there was inadequate survey data and we are forced to rely on mapping the HFC Outlook categories against the Öko categories[48]. Further work may be needed here, especially around industrial DX where there remains considerable uncertainty about the availability of cost effective and energy efficient alternatives to HFCs.

For heat pumps costs we have assumed that heat pumps do not replace existing equipment. Cost therefore include one-off installation costs including some home retrofit costs such as replacing radiators. This differs from other equipment which is assumed to replace a like-for-like system. Although retrofit cost would be the same regardless of gas choice, and therefore would not matter for the MAC curve which presently assumes same equipment, this would potentially allow further development of cost scenarios which allow different equipment types serving a similar function.

For large heat pumps the Öko model appears to overestimate cost. The cost per kW is higher than medium heat pumps but heat pumps can be used in parallel meaning there is normally no barrier to using multiple smaller heat pumps if this is cheaper. The anomaly is likely due to a small number of bespoke heat pumps driving an unrealistic number. To calculate costs for large and medium heat pumps we fit a logarithmic curve (selected for best fit) to listed sales price provided by a manufacturer. The manufacturer exclusively uses naturals and mostly CO2, and has higher costs than indicated in the Öko model[49] for similar-sized units. We therefore use the fitted curve re-baselined to prices in the Öko model[50] to calculate heat pump price.

Retrofit costs do not include the cost of home insulation. Firstly, because this is not affected by type heat pump installed and we anticipate that government targets are the primary driver for heat pump uptake. Secondly because insulation is economic even without the installation of a heat pump.

Although a small number of CFCs were used for a range of uses, there is currently no single gas which is considered appropriate for all uses. Differences in thermodynamic properties mean different gases are suited to different temperature. Differences in density may also restrict the use of a gas, and in particular low-density gases will tend to be suited to larger applications.

Only three non-HFCs are widely used as refrigerants gases: CO_2, NH_3, and C_3H_8 (known also as R744, R717 or ammonia, and R290 or propane respectively). H_2O has also been proposed as a refrigerant and is widely used in proposed EU scenarios but informal discussions with industry and experts suggest this technology may further development

48 https://www.oekorecherche.de/en/topics/F gases

49 https://www.oekorecherche.de/en/implementation-F gas-regulation-eu-no-5172014

50 https://www.oekorecherche.de/en/implementation-F gas-regulation-eu-no-5172014

before its technical feasibility can be well understood. Air (R729) may be suitable for very low temperature applications but these are niche and are not considered further.

Both R717 and R290 are considered thermodynamically efficient for multiple applications. R717 is generally limited to large applications. R290 is suitable for both very small applications where charge size can be limited (in particular hermetically sealed units which have small charges and low leak rates) and large applications where access can be limited to trained personnel.

R744 does not suffer from issues of toxicity or flammability but has a low critical point. Some stakeholders have expressed concern that this can make R744 unreliable during warm weather. While it is widely used for large refrigeration systems (especially in supermarkets) and large high temperature heat pumps, it’s feasibility for other applications remains unclear.

R410A, R32, R454C, R455A, and R290 all operate at similar pressures and have somewhat similar thermodynamic properties to the extent that in some cases the same system could switch between the gases. In the latter case relatively little effort may be required to shift production to a lower GWP alternative. Adopting different assumptions about deployment rate for each technology would improve the accuracy of the model.

For some applications HFOs could be suitable lower GWP alternatives. However, these are PFAS which comes with both risk of ecological harm and the potential of these substances being banned which may discourage industry from making long term investments in these alternatives. Blends of HFCs and HFOs allow some mixing of the benefits of existing HFCs while reducing GWPs.

At present there are still sub-sectors where low GWP alternatives may not be feasible. For example, some facilities require refrigerants which do not react with chemicals in their manufacturing process. Nuclear reactors and particle accelerators require refrigerants that are inert under exposure to radiation. There remains a question of how widely flammable refrigerants can be used in the transport sector.

The maximum feasible deployment of a gas depends on factors such as flammability and toxicity. A2L, or partially flammable gases, can be used in a wider range of applications than A3, or flammable, gases, but some applications cannot accommodate any flammability. If multiple possible alternatives have similar issues then they would compete for the same market share. In other words maximum feasible deployment is not additive across technologies. Assuming that each technology could reach maximum feasible deployment risks double counting.

To avoid this problem, the model uses manually generated scenarios.

Emissions

We assume that all recovered gas is either destroyed or displaces virgin gas usage. If recovered gas is used in addition to virgin gas this would cause us to underestimate emissions associated with increased quota and underestimate abatement values.

The same is true for the lifetime leakage rate as it becomes more cost effective to regularly service equipment to avoid leakage vs. high gas costs to refill equipment. The lifetime leakage rate may also improve due to improved manufacturing that reduces the likelihood of equipment failure and leakage. An improvement in leakage due to improved manufacturing is not considered in this model, unlike the HFCOutlook model[51] due to lack of verifiable data on manufacturing improvements. $Remaining$ is typically less than one due to the equipment not being serviced for several years. We assume that equipment is refilled annually and $\ell_t^{remaining} = 1 - \ell_t^{lifetime}$. This will typically overestimate the amount of gas demand and gas recovered from equipment at the end of life.

Electricity Usage and Emissions

Equipment electricity usage contributes to indirect emissions. Each equipment type has associated running hours for heating RH_h, running hours for cooling RH_c, system heating capacity C_h, system cooling capacity C_c, inverse coefficient of performance (COP) for heating $iCOP_t^h$, and inverse coefficient of performance for cooling $iCOP_t^c$. Annual electricity usage for a piece of equipment is given by the formula:

$$W_t[kWh] = RH_h[h] \times C_h[kW] \times iCOP_t^h[\%] + RH_c[h] \times C_c[kW] \times iCOP_t^h[\%].$$

Total electricity usage is found by the sum:

$$Electricity_t = \sum_{\substack{equipment \\ type}} Stock_t \times W_t$$

Where the equipment type index is suppressed. The inverse COP has an associated time dependence as it is possible for energy efficiency improvements in equipment to arise as technologies mature.

Electricity emissions are calculated by multiplying the total electricity usage $Electricity_t$ by an emission factor $EF_t^{electricity}[\frac{tCO2e}{kWh}]$. This emission factor can also change over time as renewable energy becomes a larger percentage of total electricity production. The emission factor does not vary based on time of day or year. Grid carbon factors are typically lower at night and during the summer, when there is a higher portion of renewables. For most equipment this is not important but air conditioning and heat pumps are used seasonally. Using a fixed grid carbon factor will tend to overstate the carbon intensity of air conditioning and understate the carbon intensity of heat pumps.

For vehicles we use a separate calculation based on emissions from the vehicle's engine. Over time this will converge with grid electricity as vehicles convert to electric.

Split System Air-to-Air

Split air-to-air systems heat the air directly without using water. These systems are capable of providing water heating in some configurations, and are also capable of providing air conditioning. Because air-to-air systems are deployed in the room they heat or cool, there is typically enough space for a flammable refrigerant to disperse although this is still limited to charges of 1kg.

51 HFC-Outlook-Description-and-Specification.pdf (gluckmanconsulting.com)

The latter constraint may limit the size of air-to-air systems using flammable refrigerant to around 6.5-7kw and slightly smaller for multi-split systems. Multiple systems may be a reasonable cost-effective alternative for larger homes but this needs to be further tested with stakeholders in the consultation.

Approximately 11% of homes suffer from overheating. These tend to be newer homes which have better insulation. However, heat pumps require better insulation than gas boilers. This can lead to overheating during the summer months and may require mechanical cooling.

Ground Source Heat Pumps

All the above heat pump designs are compatible with a ground source in place of an air source. These are typically more expensive and require more space, but are also quieter and offer increased energy efficiency. Large houses may be able to install an individual ground source heat pump. Additionally, blocks of flats can install large ground source heat pumps that share heating across multiple dwellings.

We do not model the differences between air and ground source heat pumps in houses because the latter are not widely used in the UK and while there are impacts on cost and efficiency, there is minimal interaction with gas choice (although charge sizes may be slightly smaller for ground source systems).

However, ground source heat pumps may offer an alternative to HFC-based systems in apartments. Water from the trench or bore hole can be pumped to an hermetically-sealed unit within the apartment. This allows a unit of sufficiently small charge size to use a flammable refrigerant. Individual units may be preferable to a centralised system by offering an improved ability to charge users for individual energy use. However, while flammable refrigerants are technically feasible stakeholders have indicated that operators of social housing are often reluctant to accept the risk.

Selecting Heat Pump Types

There is relatively little information to predict the types of heat pump used in the rollout. MCS installations and BSRIA data give a current breakdown but the former also indicates that heat pumps installations are not typical of UK housing stock. Heat pumps are more likely to be installed in larger detached homes (which have more outdoor space and may be more likely to be off-grid) which favours monoblocs.

To simplify modelling we ignore other categories such as ground source and focus exclusively on monoblocs and hydronic split systems. We therefore calculate the split in the current market based on these two categories. We assume two possible scenarios; firstly, that detached, semi-detached homes, and large terraced houses may use monobloc heat pumps; or secondly, that all residences with a private garden can use a monobloc heat pump. We further assume that all new builds after 2025 may use heat pumps. All other homes are assumed to use split hydronics systems. The data used to determine this split between monobloc and split system heat pumps is the English Housing Survey 2021-22, shown in tables below.

English Housing Survey data on dwelling types in thousands

Dwelling type	Dwellings (thousands)	Heat pump assumption
Small terraced house	2,111	Hydronic split
Medium/large terraced house	4,512	Monobloc
Semi-detached house	5,758	Monobloc
Detached house	4,167	Monobloc
Bungalow	1,796	Monobloc
Converted flat	1,018	Hydronic split
Purpose built flat, low rise	3,762	Hydronic split
Purpose built flat, high rise	616	Hydronic split

English Housing Survey data on dwellings with a private garden/plot

Garden/plot type	House or bungalow	Flat	Total	Heat pump assumption
Private plot	18,246	1,062	19,309	Monobloc
Shared plot only	66	3,089	3,155	Hydronic split
No private plot or shared plot	32	1,245	1,277	Hydronic split

This approach does not consider the possible expansion of air-to-air systems. Currently there is insufficient data to project the possible role of air-to-air systems. The model may therefore underestimate HFC usage for larger houses but may also overestimate the need for HFCs in smaller homes.

We assume a start point of $\widehat{d} = 7.2\%$ for hydronic splits based upon 2022 BSRIA sales data and specify a four-parameter logistic curve converging on 2022 housing stock data; $\hat{a} = 31.6\%$ total market share in existing homes for hydronic split systems in small terraces and flats, or $\hat{a} = 18.7\%$ if all houses without private gardens require a hydronic split system. We further assume a midpoint of the logistic function in $\hat{c} = 2038.5$ with the start of the transition in $\hat{c}_0 = 2025$, estimating the slope of the transition as $\hat{b} = 6/(\hat{c} - \hat{c}_0)$. This gives us share of total installations as:

$$PercentageSplit(Year, \hat{a}, \hat{b}, \hat{c}, \hat{d}) = \hat{d} + \frac{\hat{a} - \hat{d}}{\left(1 + e^{\hat{b}(Year - \hat{c})}\right)}$$

To estimate new installations, we assume 200k installations per year in new homes from 2025, of which all are monoblocs. We then reduce total heat pumps installations, as described above, by this amount to give total installations in existing properties. We apply the split described above to heat pump installations in existing properties to calculate new equipment of each type.

In the first scenario where small terraces and flats have split systems. The above formula estimate of new item splits leads to an overall stock of 80% monobloc to 20% split system by 2050. In the second scenario, where all houses without a private garden require a split system, the above formula estimate leads to an overall stock of 87% monobloc to 13% split system in 2050. Moving the centre point $\hat{c}$ of the transition earlier will move the proportional split of the stock in 2050 towards the English Housing Survey stock split.