Nordic Council of Ministers

Nordic Working Paper

Second report on F-gas measurements and methodologies in the Nordic Countries

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This working paper was funded by the Nordic Council of Ministers. However, the content does not necessarily reflect the Nordic Council of Ministers' views, opinions, attitudes or recommendations

NA2025:904
ISSN 2311-0562
http://dx.doi.org/10.6027/NA2025-904

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Date: February 4th, 2025
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Content

Abbreviations

CO	CO
EF	Emission factor
GIS	Gas Insulated Switchgear
GWP	Global warming potential
HFC	Hydrofluororcarbon
HFO	Hydrofluoroolefins
IPCC	Intergovernmental Panel on Climate Change
MAC	Mobile
MDI	Medical Dose
NKL	Nordic Working Group for
PFC	Perfluorocarbons
UNFCCC	United Nations Framework Convention on Climate Changes

1. Introduction

Background

This project report is a part of the NKL project *Continuation of the Nordic F-gas Inventory Group 2023* with the purpose of comparing and developing the Nordic countries' methodologies related to the use of F-gases.

Fluorinated gases (F-gases, including HFCs, PFCs, SF_6 and NF_3) are a range of potent greenhouse gases that are used in a number of different applications and products for refrigeration, foams, aerosols, and technical installations.

The project report summarizes project findings from our work and discussions conducted during the project period 2023-2024. The work includes a.o. development of a benchmark calculator of F-gas emissions, workshops on applied emission factors, workshop on projection methods, discussion of type of questions, answers and lesson learned from UNFCCC reviews and other present F-gas related issues for the Nordic framework for F-gas emission calculations. Link to previous published report from the workgroup can be found in footnote[1].

The project group comprise representatives from the following Nordic countries:

- Denmark
- Finland
- Iceland
- Norway
- Sweden

The Nordic F gas inventory workgroup consist of:

- Lene Skyrudsmoen, Statistics Norway, Norway
- Birgir Ásgeirsson, Sigríður Rós Einarsdóttir, Icelandic Environment and Energy Agency, Iceland
- Tomas Gustafsson, Malva Laurelin, IVL Swedish Environmental Research Institute, Sweden
- Tomas Sander Poulsen, Provice, Denmark
- Tommi Forsberg, Markus Niemelä, Finnish Environment Institute, Finland

The workgroup was formally established in January 2017 and have had online meetings on a regularly basis supplemented with physical meeting when possible. The meetings in this project period were organized as workshops with varying topics for discussion, i.e.:

- Benchmark and comparison of the Nordic F-gas emissions and sources
- Standardized reporting format for emission data tables
- Discussion of applied emission factors at country level with particular focus on emission factors from commercial refrigeration (CRF 2.F.1.a) and heat pumps
- Methods for projection of F-gas emissions
- Methods for data-collection sources
- Discussion of data-gaps and uncertainties related to F-gas imported in various products, e.g. heat pumps, Metered dose inhalers (MDIs), SF_6 in switch gear, and XPS insulation foam
- Trends in import and consumption of HFC's

1 https://norden.diva-portal.org/smash/record.jsf?pid=diva2%3A1691867&dswid=-3706

Furthermore, a Nordic webinar will be organised for dissemination and discussion of the results. Invitees are Nordic and EU representatives with experiences from F-gas regulation, and other interested F-gas specialists. The webinar is scheduled to be conducted February 2025.

Objective

The overall objective of the project was to further develop the work group's results from the previous project work with recommendations for method development for emission calculations of F-gases, and proposals for efforts that can reduce emissions of F-gases in the Nordics, as well as to prepare an overview of the development of F-gas emissions in The Nordic region and benchmark between countries.

The project has ensured continued coordinated method development of F-gas data collection and emission calculations in the Nordic countries.

The specific project objective was to continue the Nordic coordination work in the F-gas Inventory group with collaboration around method development for calculating F-gas emissions, competence building in relation to UNFCCC in-country reviews, as well as benchmarking and structuring of Nordic F-gas data.

In addition to be used in various equipment and applications, F-gases can be generated during industrial processes, e.g. PFC emissions from aluminium production. In this work, however, such F-gas emissions are excluded.

2. Nordic F-gas emissions

The Nordic F-gas emissions from handling, use and disposal of F-gases were in 2022 estimated to approx. 2.9 mio. tonnes of CO_2 equivalent (CO_2 eq). There is a steady decreasing trend in the F-gas emissions and from 2020 to 2022, the total Nordic emissions have decreased by approx. 390,000 tonnes of CO_2-eq, see table 1.

Table 1: The Nordic F-gas emission (HFCs, PFCs, SF_6) according to the 2024 national inventory submissions to the UNFCCC.*

Year	Emission, t	Index 2015
2015	3,994,179	100.0%
2016	3,992,514	100.0%
2017	3,759,390	94.1%
2018	3,701,169	92.7%
2019	3,453,884	86.5%
2020	3,265,747	81.8%
2021	3,014,615	75.5%
2022	2,875,862	72.0%

* NF_3 emissions are not occurring in the Nordic countries. PCF emissions from Aluminium production are not included here

Overall, the sum of emissions of the Nordic countries have reduced from 3,994,179 tonnes CO_2-eq in 2015 to 2,875,862 tonnes CO_2-eq in 2022. A reduction of 28.0% and 1,118,317 tonnes CO_2-eq.

In table 2 below there is a summary of the development in each of the Nordic countries.

Table 2: Total F-gas emissions t CO_2 eq. (HFCs, PFCs, SF_6) according to the 2024 national inventory submissions to the UNFCCC.

Total emission, 1,000 t CO_2-eq.	Denmark	Finland	Iceland	Norway	Sweden
2015	580.8	1,217.4	158.5	941.0	1,096.5
2016	600.3	1,167.3	175.1	933.8	1,116.0
2017	488.4	1,093.5	167.4	934.4	1,075.6
2018	549.0	1,040.7	186.5	904.7	1,020.3
2019	390.8	990.8	196.8	903.3	972.3
2020	363.0	927.2	201.4	847.9	926.3
2021	290.0	862.0	165.6	815.8	881.3
2022	274.2	792.9	135.4	820.4	853.0

In table 3 the total F-gas reduction from 2015-2022 is summerized. All Nordic countries have an absolute reduction from 2015-2022 in the total national F-gas emission. However, the actual difference in reductions range from 13% to 53%.

Table 3: Total F-gas emission reduction from 2015 to 2022 pr. country.

Reduction from 2015-2022	Denmark	Finland	Iceland	Norway	Sweden
In 1,000 t CO_2-eq.	306.7	424.5	23.1	120.5	243.5
In %	53%	35%	15%	13%	22%

The Danish emission has reduced substantial during the later years, in particular because of the reduction of HFC-404a emission from stock in commercial refrigeration and SF_6 emission from stock in windows.

Comparison per capita
When comparing development in the F-gas emission per capita, there is also a general decreasing trend in the total emissions for all Nordic countries.

The relative contribution of F-gas emissions per capita is illustrated in Figure 1.

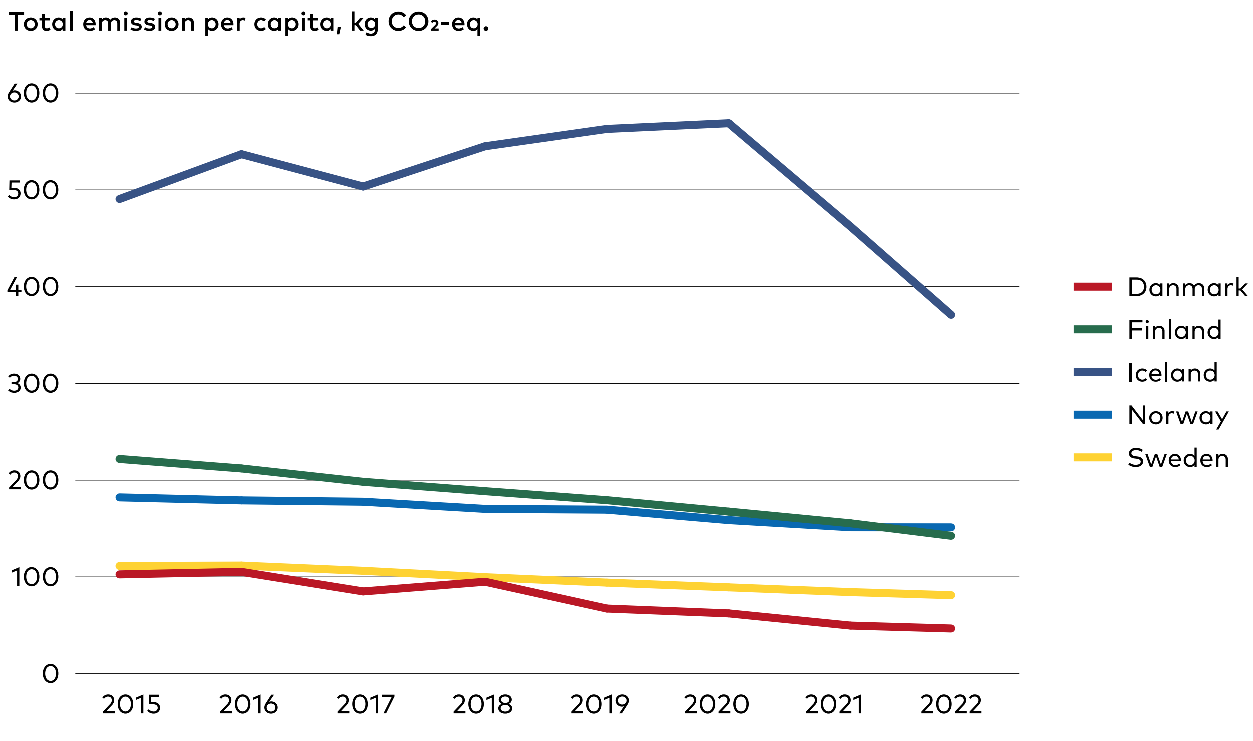

Figure 1: F-gas emission per capita, kg CO_2-eq.

At total levels, Finland and Norway are relatively equal when comparing F-gas emissions per capita and Denmark, Sweden and Iceland differ significantly. In 2022, Denmark has a per capita emission of a third of Finland/Norway and Sweden has a per capita emission of half of Finland/Norway.

The differences are not consistent across categories but can be isolated to differences in commercial refrigeration (2.F.1.a), mobile air-conditioning (2.F.1.e) and stationary air-conditioning (2.F.1.f). Below, we discuss reasons for some of these differences related to actual variations installed amounts of F-gases, equipment types and regulatory differences among the Nordic countries. However, to some extent, differences in methods for data collection and model assumptions (e.g. leakage factors, equipment lifetime) are still a cause for significant divergences in emission results.

Iceland has the highest emissions per capita, with a significant decreasing trend from 2020. The main cause is that Iceland has a relatively large fishing fleet with emissions from refrigeration systems on-board fishing vessels, which contributed to approx. 65% of emissions from the refrigeration sectors in 2016, though this has decreased to less than 37% in 2022.

Table 4: Overview of per capita F-gas emissions across emission categories in 2022. Comparison between Nordic countries.

kg CO_2-eq per capita	2.F.1.a	2.F.1.b	2.F.1.c	2.F.1.d	2.F.1.e	2.F.1.f	2.F.2-6	2.G	2.H	SUM
Denmark	17.3	0.0	0.0	1.7	8.8	14.7	2.0	2.1	0.0	**44.7**
Finland	77.4	0.0	9.6	1.5	20.8	23.6	3.1	4.1	1.7	**141.8**
Iceland	74.0	0.1	112.2	135.1	38.8	2.4	2.6	5.7	0.0	**370.9**
Norway	34.5	0.8	6.7	3.8	54.8	31.8	5.7	13.1	0.0	**151.2**
Sweden	22.9	0.0	24.4	3.0	13.6	11.0	1.4	3.7	0.0	**80.0**

For commercial refrigeration (2.F.1.a) especially Finland has high emissions per capita. Finland has had a large stock of HFC refrigerants in commercial refrigeration equipment. Direct centralized refrigeration systems with large refrigerant charges have traditionally been used in Finland in food retail stores. This is in contrast to other Nordic countries where indirect systems with smaller refrigerant charges have been used already for a long time.

In relation to industrial refrigeration (2.F.1.c), Iceland has significantly higher per capita emissions, partly because of food production including fish processing. Sweden also has a larger contribution which is explained in the Swedish industrial sector with many large industries within the primary production, e.g. car manufacturing, steel, foodstuff etc.

According to transport refrigeration (2.F.1.d) Iceland is significant higher per capita, partly because of the large installations of HFC's in the fishing vessels.

With respect to mobile air-conditioning (2.F.1.e) especially Norway differs from the other countries with a high emission per capita. Denmark's emission is relatively lower. The differences can be explained by the fact that the countries apply different calculation models, both with regards to activity data and how they add consumption for service of MAC's. In its F-gas model, Sweden applies lower annual leakage rates and lower emission factors for disposal than other Nordic countries, especially for passenger cars in the last decade.

For stationary air-conditioning (2.F.1.f), Norway has the highest emissions per capita, Finland also has relative high emissions per capita compared to the rest of the other Nordic countries. This is mostly due to long-time popularity and large amount of installed heat pumps in Finland. According to EHPA https://www.ehpa.org/market-data/, Norway and Finland have the highest amount of installed heat pumps per 1,000 households. Sweden has the third highest amount.

Iceland has a relative lower emission per capita because of a lower installed stock amount for stationary air-conditioning including heat pumps, partly due to intensive usage of geothermal energy for heating in Iceland.

The emissions of SF_6 differ also significantly between the countries.
Norway differs from the other countries with notably high emissions per capita from SF_6 in power switchgear, Denmark has the lowest SF_6 emissions per capita. While countries apply more or less the same emission factors, the differences are related to the size of stock.

On overall – beside a few exemptions - the relatively similar infrastructure and societal conditions in the Nordic countries suggest that differences are mainly caused by different methodological approached for calculating the F-gas emissions, e.g. emission factors and data collection.

It is also worth noting that, although all the Nordic countries follow the IPCC guidelines when allocating emissions in different source categories, there are some differences in the allocation of emissions. This is related e.g. to the treatment of confidential emissions in the inventory. Finland allocates most of its confidential F-gas emissions in category 2.H.3 and Norway has HFC's from MDI, aerosols, foam, fire and solvents in 2.F.6 in category 2.F.6.b. Other Nordic countries do not report any emissions in these categories.

F-gas emissions arise during different life cycle stages: when charging a new equipment at manufacturing or assembly, during lifetime (operation and service), and at end-of-life (disposal), see table 5.

Table 5: Overview of the Nordic F-gas emission contribution between countries and life cycle stages in 2022 (total)

Emissions, ton CO_2-eq	Charging of new equipment	During lifetime	Disposal	Total
Denmark	4,196	251,294	18,665	274,154
Finland	1,018	710,146	81,758	792,923
Iceland	28	117,616	19,813	137,457
Norway	468	534,907	285,070	820,445
Sweden	8,576	715,192	129,212	852,980
Sum	14,285	2,329,156	534,518	2,877,959

The Nordic F-gas emissions are primary related to the emissions from stock (81% of total), secondly to the disposal and end of life (19% of total). It illustrates that the most effective emission reduction initiatives are incentives that can accelerate reduction of installed F-gases in stock, e.g. substitution to natural refrigerants where applicable, before lifetime for the units reach end-of-life.

Table 6: Share of Nordic F-gas total emission between countries and life cycle stages in 2022 (percentages)

Share of total emissions	Charging of new equipment	During lifetime	Disposal	Sum
Denmark	0%	9%	1%	**10%**
Finland	0%	25%	3%	**28%**
Iceland	0%	4%	1%	**5%**
Norway	0%	19%	10%	**29%**
Sweden	0%	25%	4%	**30%**
Sum	**0%**	**81%**	**19%**	**100%**

Table 6 has calculated the Nordic emission contributions at life cycle stage per country. The largest life cycle stage contributions are from Sweden (25%), Finland (25%) and Norway (19%) at the operations phase. For all countries, the largest contribution is from the operation phase, along with a notable contribution from Norway (10%) in the disposal phase. The significantly higher emission contribution from disposal in Norway is rather due to access to import data and methodological assumptions than actual differences in emission profiles between the Nordic countries.

Most F-gas emissions in the Nordic countries are from refrigeration and air-conditioning (RAC) equipment. In Figure 2 below, the share of emissions from the particular RAC categories is illustrated.

Total emission, ton CO_2-eq.

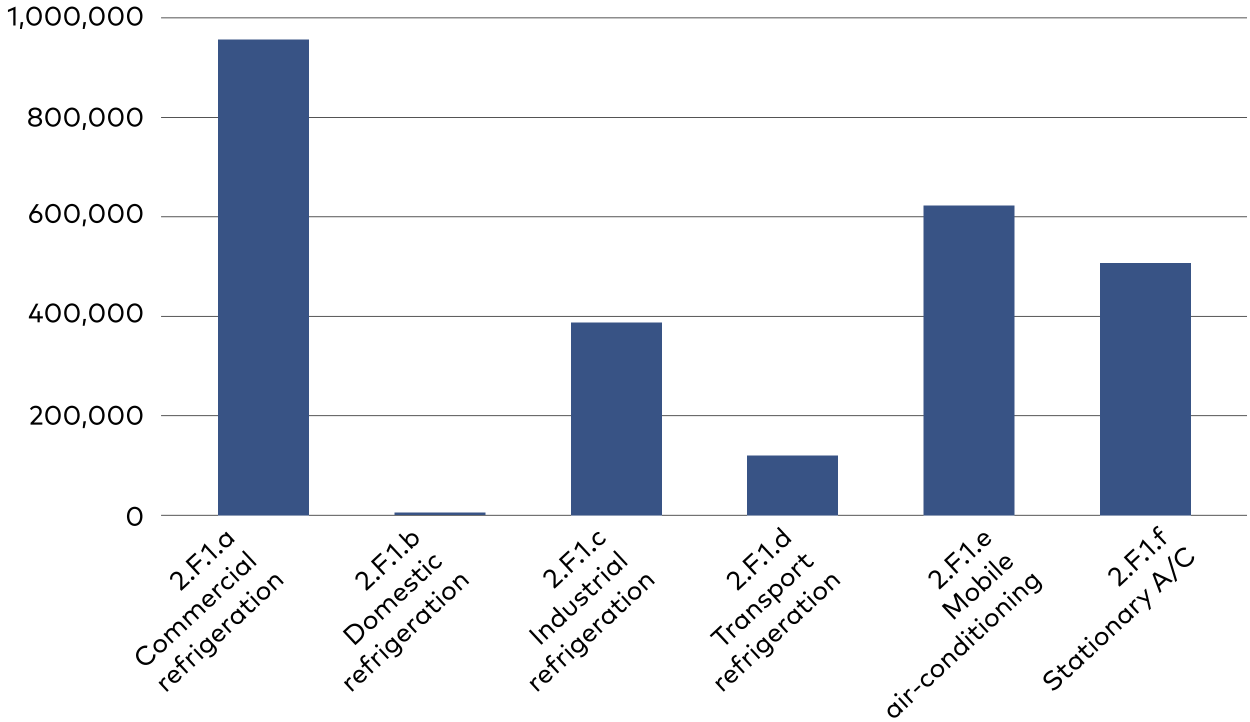

Figure 2: Share of Nordic F-gas emission between RAC-categories in 2022 (t CO_2-eq)

The largest emission category is *commercial refrigeration*, which constitutes 36.8% of total emissions in 2022. *Mobile air-conditioning* (MAC) comprises 23.9% of total emissions, *stationary air-conditioning* covers 19.5%, *Industrial refrigeration* covers 14.9%, *transport refrigeration* covers 4.6% and *domestic refrigeration* constitutes 0.2%.

Based on the overview in Figure 2, Nordic efforts for alignment has concentrated particularly on exploration of *medium and large commercial refrigeration* while these sub-categories contain the majority of emissions.

3. The Nordic HFC import in bulk and product

To assess the overall trend, data are collected for total F-gas bulk import and total pre-filled products import into the Nordic. These two elements represent the HFC consumption for manufacturing, new installations and maintenance of existing stock.

The bulk HFC import is a.o. an indicator for the condition in existing installations (leakage rates) and also the development in introduction of low GWP refrigerants as a substitute for high GWP refrigerants. Beside the registered import of HFC's, a certain amount of illegal imported HFC's may be considered to be used in the market as well.

The available data at country level differs, and due to confidential measures, the detailed level cannot be published.

Nordic HFC bulk import

Data for bulk import has been collected for all years from 2015 to 2022. In overall there is a steady decreasing trend in both total bulk import and average GWP, however the difference in reduction between the Nordic countries is significant.

Figure 3 presents an overview of the country variation in import of HFCs as bulk for 2015 and 2022. All countries have decreased their bulk imports from 2015 to 2022. The bulk import to Sweden is relative larger because of use in manufacturing. The total bulk import of HFC's in the Nordic has decreased from 2,100 tonnes in 2015 to 1,700 tonnes in 2022. A reduction of approx. 400 tonnes HFC. The reduction indicates lower leakage rates from existing HFC equipment and a substitution to equipment based on HFC-free refrigerants.

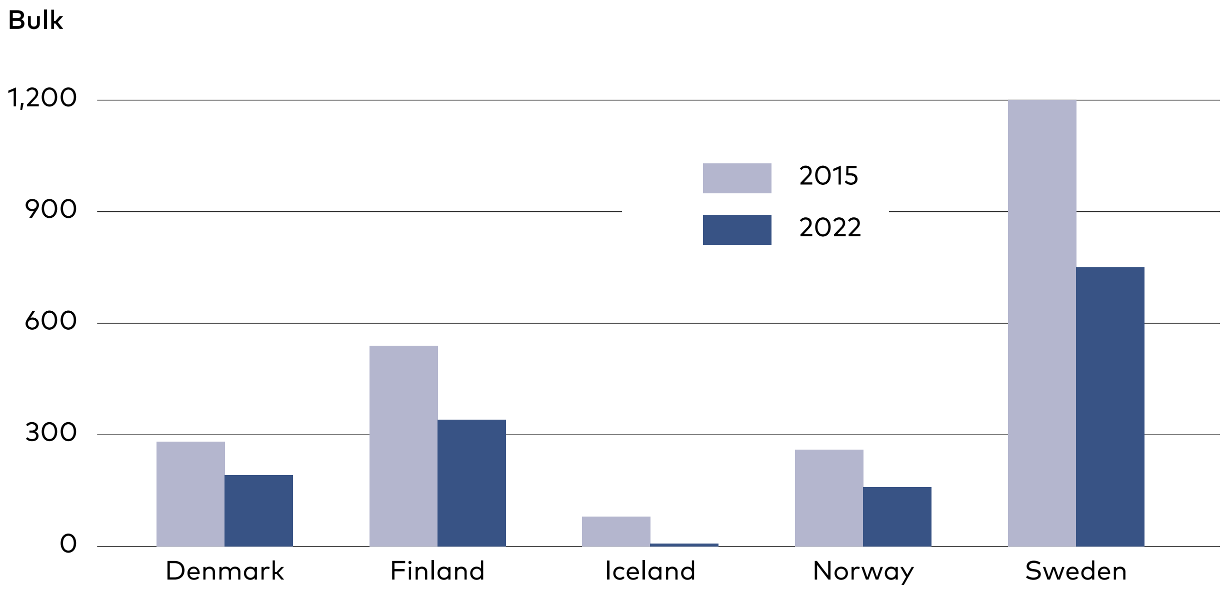

Figure 3: The Nordic HFC import in bulk, 2015 and 2022 comparison (tonnes)

In recent years 2021-2022, the total Nordic bulk import of HFCs was approx. 1,450 tonnes HFCs. The import has been decreasing in total even though there has been a slight increase in Finland and Sweden. The total use of HFCs across the Nordic countries is illustrated in Figure 4.

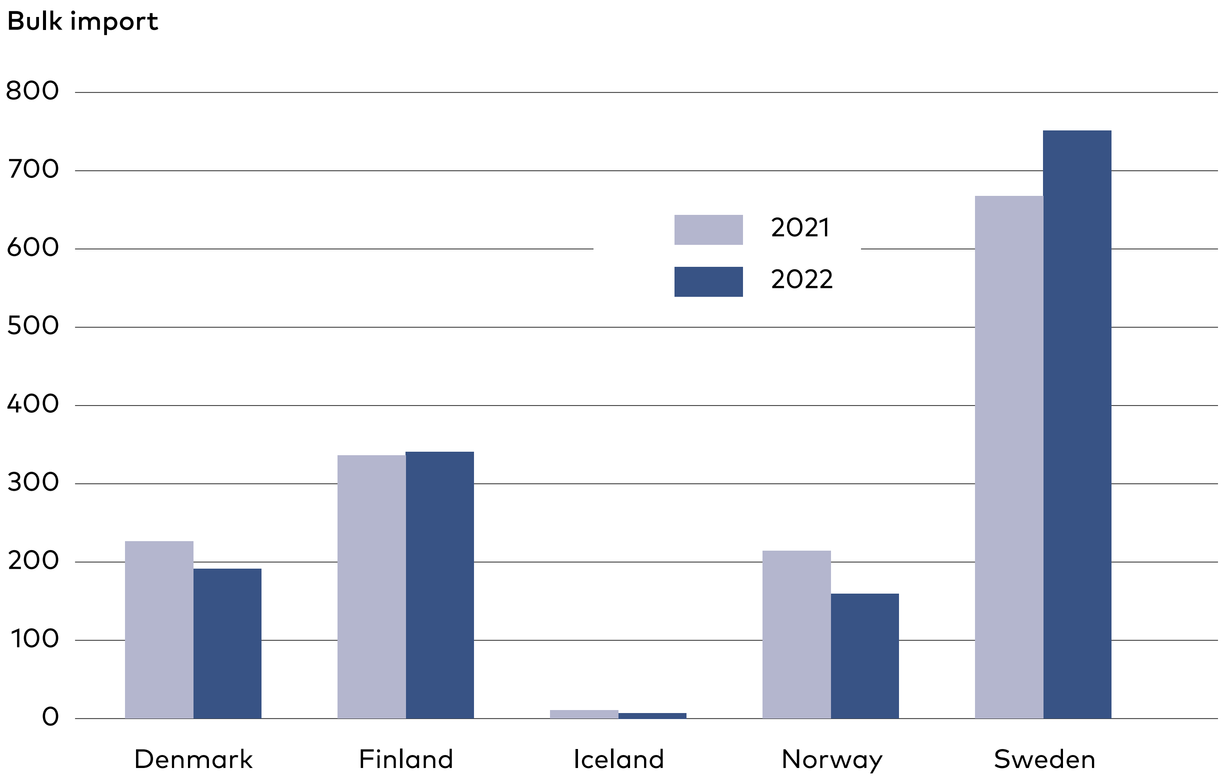

Figure 4: The Nordic HFC import in bulk, 2021-2022 (tonnes)

Figure 5 below shows the Nordic HFC consumption per capita (kg) in 2022 based on imported HFCs in bulk.

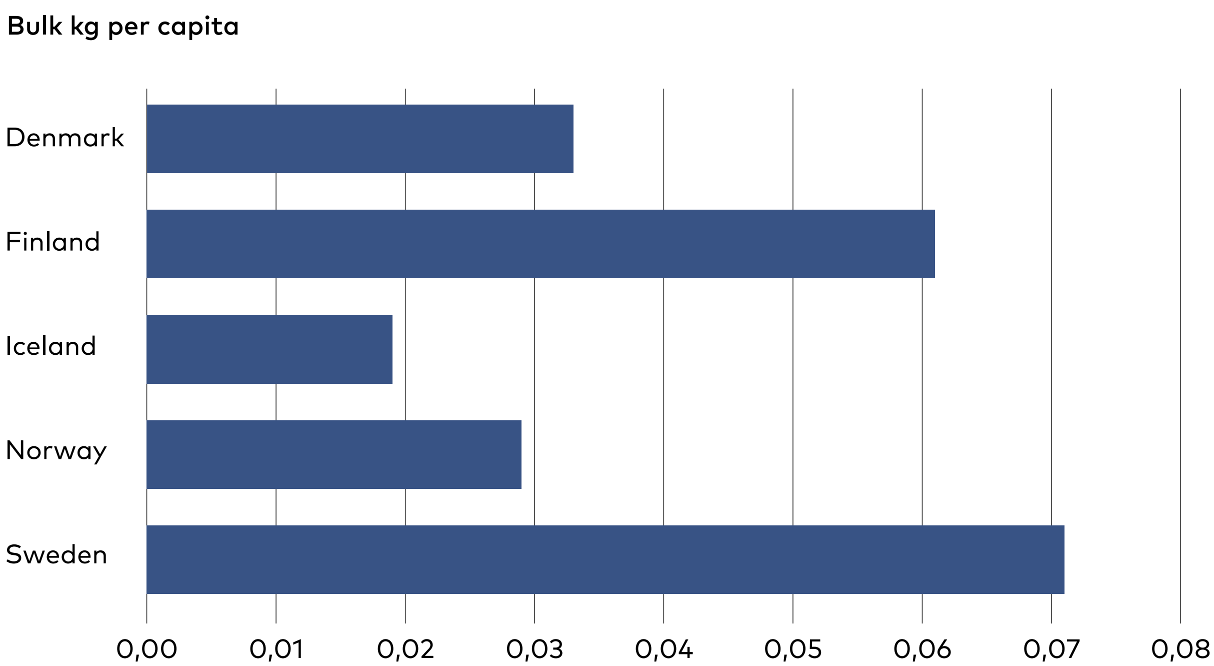

Figure 5: The Nordic HFC consumption per capita (kg, 2022)

Import of HFC's in product

The development of import of HFC's in product is summarized in the table below. The import of HFC's in products has increased significantly from 2015-2022 for Denmark, Finland and Sweden. For Norway, a decrease can be seen.

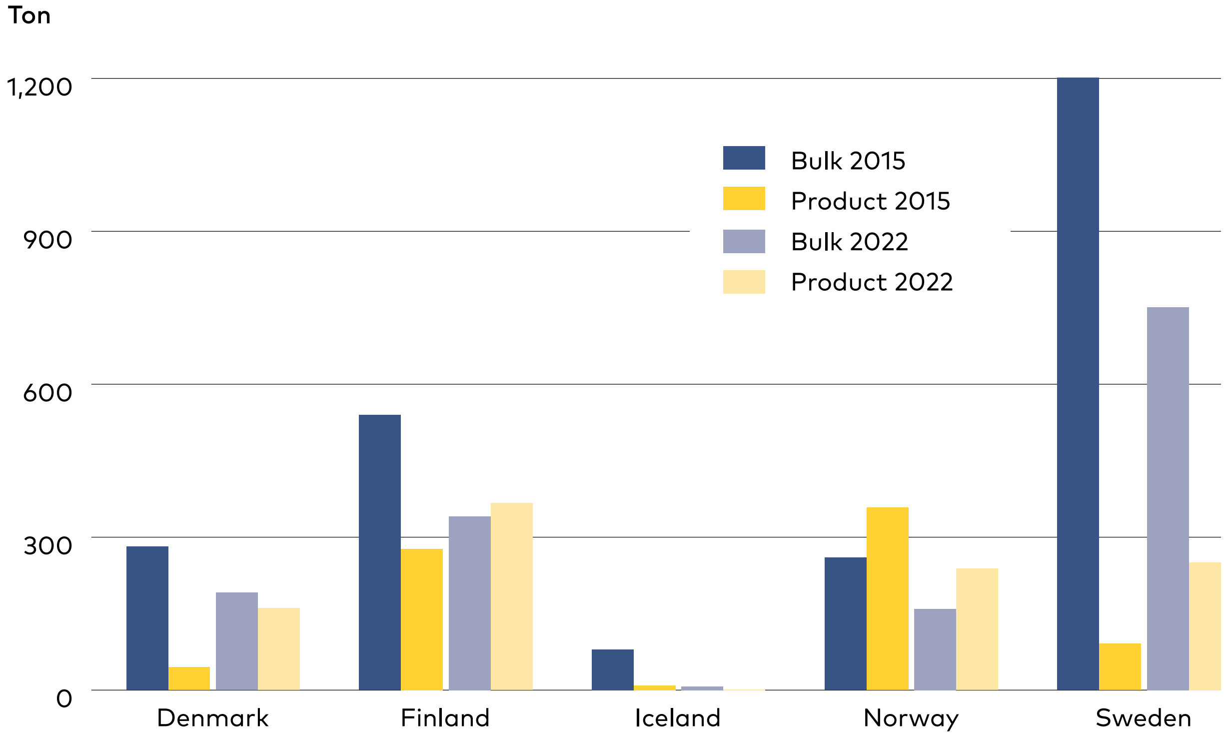

Figure 6: The Nordic import of HFC's in product (orange) and bulk (blue), ton.

The majority of imported HFC's in products are in particular related to heat pumps and A/C in vehicles.

Figure 7 below summerize the Nordic HFC import from bulk and product per capita (kg) in 2022.

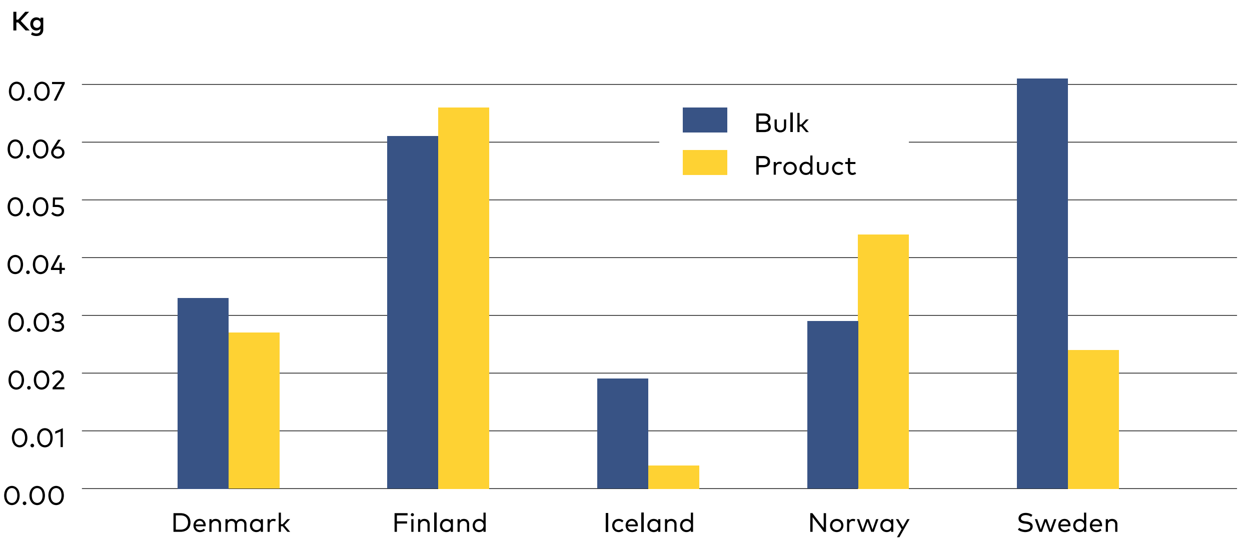

Figure 7: The Nordic import of HFC's in product (yellow) and bulk (blue), kg. per capita

There are large differences between the Nordic countries HFC import. The Finnish import of HFC's in products is more than double the import of HFC's in products from Denmark and Sweden per capita.

Regarding the Finnish and Danish 2022 figures, the import of HFC's in heat pumps was at a record high level in 2022. Thus both Denmark and Finland register a lower import of heat pumps in 2023.

GWP average for HFCs

The previous EU F-gas Regulation 517/2014 includes the provision for the phase down of the quantities of F-gases (and blends) placed on the EU market by producers and importers. By 2030, the GWP target is a reduction of 21% with 2015 as reference year.

The EU Regulation 517/2014 has been replaced by the new F-gas Regulation 573/2024 and in the new F-gas regulation, the quota system is prolonged until 2050 and will lead to a phase-out of HFCs by 2050. In the regulation 573/2024, the base year for the quota system is also 2015 and base-value for the maximum quantity is set to be 176, 700,479 tonnes CO_2-eq.

Starting from 2025-2026, the maximum amount of HFCs allowed to be placed on the EU market decreases in specific year-intervals (until zero in 2050). The phase-down steps will lead to phase-out.

In the new regulation, the maximum amount allowed to be placed on the EU market is 9,132,097 t. CO_2-eq. in the years 2030-2032. This is 5% of the base year 2015 level.

In addition to HFCs in bulk, the quota system includes also HFCs in prefilled equipment and MDIs.

This EU Regulation has not yet been incorporated into the EEA Agreement and does therefore not apply to Iceland and Norway[2].

In Iceland the phasing out of F-gases is primarily achieved through the implementation of an Icelandic F-gas regulation. The goal was the implementation of EU Regulation No 517/2014 on F-gases with import quotas to reduce gradually the amount of F-gases coming to the country until 2036. This regulation limits the total amount of the most significant F-gases which can be sold, banning the use of F-gases in many new types of equipment where less harmful alternatives are available, and preventing emissions of F-gases from existing equipment. The F-gas regulation is adapted to Icelandic conditions and the import quota differs from the values stated in the Annex V of the EU Regulation. The first regulation was adopted in December 2018 and repealed in 2019 with Icelandic Regulation 2019/1066. A stricter quota was twice adopted through amendments which took effect in January 2021 and January 2024, further accelerating the decrease in F-gas emissions in Iceland (see table below). Certain other provisions are made in the regulation which aim to further reduce F-gas emissions, such as limits on their marketing and use. Refilling big systems with F-gases which have a very high global warming potential (maximum 2,500 GWP) are banned since 1st of January 2020.

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2 The European Economic Area (EEA) Agreement brings Iceland, Liechtenstein, and Norway (EEA EFTA countries) into the EU's internal market, guaranteeing the freedom of movement for goods, services, people and capital, as well as unified related policies (competition, transport, energy, economic and monetary cooperation).

Table 7: Phasing out the bulk import of F-gases according to Icelandic Regulation No 1446/2023.

Steps	Years	Percentage compared to baseline	kt
1 step	2019-20	90%	243.9
2 step	2021-23	35%	94.9
3 step	2024-26	12%	32.5
4 step	2027-29	10%	27.1
Final/ 5 step	2030-35	8%	21.7
Final	2036	6%	16.3
Baseline			271

The tables below calculate the development of the average GWP for HFCs in bulk placed on the Nordic market.

By calculating the total potential CO_2 equivalent emission from imported HFC's in bulk and divide total GWP with the imported HFC's in tonnes, it expresses the average GWP for all imported HFC's.

For Denmark the average GWP has decreased from 2,333 pr. kg HFC in 2015 to 1,697 pr. kg HFC in 2023. A decrease of 27.3%.

Table 8: Development of average GWP for HFC's placed on the Danish market (ton)

Year	HFCs, t CO_2-eq	Consumption t	GWP	%
2023	318,999	188	1,697	73%
2022	359,545	191	1,882	81%
2021	455,034	231	1,970	85%
2020	368,205	190	1,938	83%
2019	405,055	202	2,005	86%
2018	535,267	269	1,990	85%
2017	620,689	271	2,290	98%
2016	670,894	305	2,200	94%
2015	656,914	282	2,3	100%

For Finland the average GWP has decreased from 2,138 pr. kg HFC in 2015 to 1,339 pr. kg HFC in 2022. A decrease of 37%.

Table 9: Development of average GWP for HFC's placed on the Finnish market (ton)

Year	HFCs, t CO_2-eq	Consumption t	GWP	%
2023	621,686	385	1,615	76%
2022	456,023	341	1,339	63%
2021	708,718	336	2,108	99%
2020	775,869	322	2,412	113%
2019	698,262	263	2,652	124%
2018	802,442	367	2,185	102%
2017	1,284,880	547	2,349	110%
2016	1,324,442	609	2,176	102%
2015	1,153,974	540	2,138	100%

For Iceland the average GWP has decreased from 3,518 pr. kg HFC in 2015 to 1,484 pr. kg HFC in 2023. A decrease of 58%.

Table 10: Development of average GWP for HFC's placed on the Icelandic market (ton)

Year	HFCs, t CO_2-eq	Consumption t	GWP	%
2023	8,352	6	1,484	42%
2022	11,021	7	1,552	44%
2021	15,849	10	1,524	43%
2020	54,318	21	2,552	73%
2019	236,700	69	3,416	97%
2018	376,291	106	3,540	101%
2017	257,052	76	3,402	97%
2016	99,272	29	3,419	97%
2015	280,577	80	3,518	100%

For Norway the average GWP has decreased from 2,018 pr. kg HFC in 2015 to 1,394 pr. kg HFC in 2023, corresponding to a decrease of 31%.

Table 11: Development of average GWP for HFC's placed on the Norwegian market (ton)

Year	HFCs, t CO_2-eq	Consumption t	GWP	%
2023	167,159	120	1,394	69%
2022	248,443	159	1,559	77%
2021	386,249	261	1,483	73%
2015	564,818	280	2,018	100%

The bulk import of Sweden has decreased steadily over the years 2015 to 2021. However, in 2022 there was an increase in F-gases imported to the Swedish market. Therefore, when comparing 2015 with 2022, the average GWP of Sweden has seemingly increased slightly from 1,636 pr. kg HFC in 2015 to 1,638 pr. kg HFC in 2022. The decreasing trend is however expected to resume the coming years.

Table 12: Development of average GWP for HFC's placed on the Swedish market (ton)

Year	HFCs, t CO_2-eq	Consumption t	GWP	%
2022	1,230,125	751	1,638	100%
2021	1,002,194	667	1,502	92%
2020	1,027,397	734	1,401	86%
2019	1,158,954	811	1,429	87%
2018	1,303,059	899	1,449	89%
2017	1,379,244	901	1,530	94%
2016	1,985,518	1,160	1,712	105%
2015	1,965,258	1,201	1,636	100%

In the table below the total Nordic development in GWP reduction from 2021-2022 is stipulated.

Table 13: Development of average GWP for HFC's across Nordic countries (ton)

	2021	2022	%
HFCs, t CO_2-eq, Nordic total	2,568,044	2,305,921	89%
Consumption, t, Nordic total	1,505	1,640	109%
GWP, t CO_2-eq/t, Nordic total	1,706	1,406	82%

The total Nordic average GWP was reduced with 18% from GWP 1,706 to GWP 1,406. It demonstrates that there in the recent years have been a significant introduction of low-GWP drop in refrigerants and phase out of high GWP refrigerants. in the same period, there has been an increase of 9% in bulk import of HFC's.

4. Calculator to benchmark F-gas emission

To provide an overview of the development in the Nordic F-gas emissions, and to assess and address key phases and sub-categories over a time-series, the project has developed a calculator to benchmark F-gas emissions at sub-category level and per capita.

The developed calculator includes all Nordic countries reported F-gas emission data from 2015-2022 at sub-category level in the different life-cycle stages and at total emission level.

The benchmark calculator is developed by the workgroup to assess status, trends, compare underlying data and assumptions, and pinpoint initiatives for reduction. The calculator forms the basis for further alignment in methodology, and for easier communication of the trends and results across Nordic countries.

The calculator prototype was developed and tested in 2023 and updated in 2024 with the latest 2022 (2024 submission) data.

The calculator is an Excel spreadsheet with pivot table macros and the structure of the calculator consist of a front-page dashboard where selection criteria for the benchmark can be defined and background pages with country-level data structured in accordance with the levels in the UNFCCC submission structure. The aggregation levels are:

- Total emissions, tonnes CO_2 equivalent
- Total emissions tonnes CO_2 equivalent pr. sub-category
- Total emissions, tonnes F-gases
- Total emissions tonnes F-gases pr. sub-category
- Emission per capita, kg. CO_2 equivalent
- Emission per capita, g. F-gases

The calculator frontpage is a dashboard, where selection options are defined. The dashboard selection options are based on selection of countries and years (2015-2022) to be profiled and compared. And the combinations mentioned above can be selected.

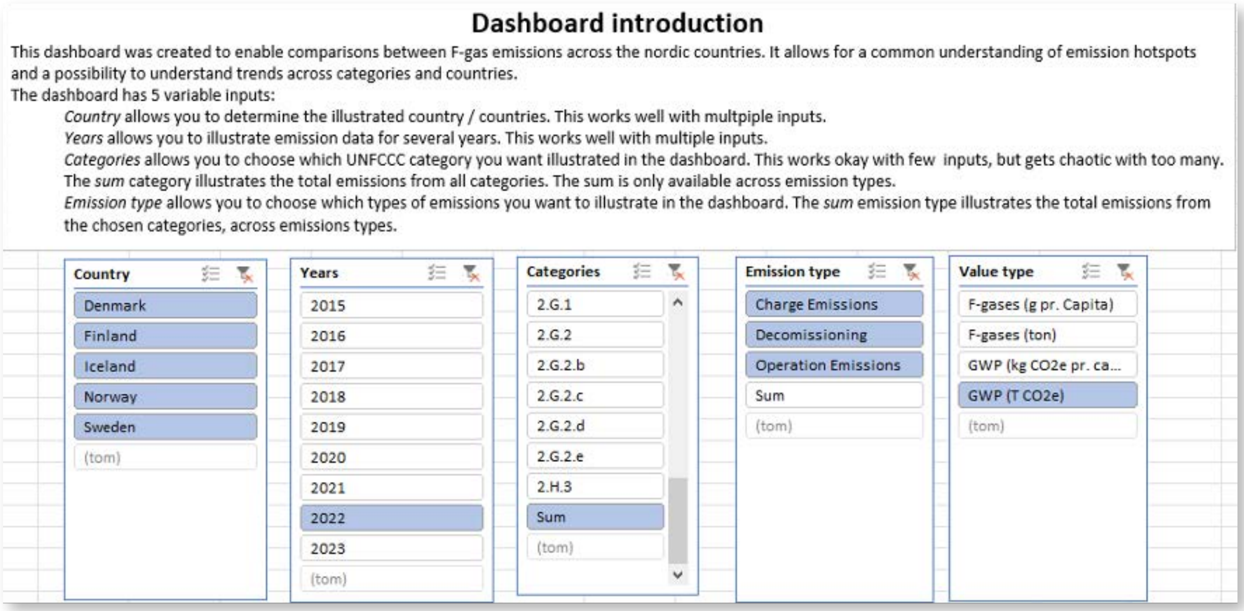

Figure 8: Calculator dashboard. There are five possible inputs in the calculator: Country, Year, Category, Emission type and value type.

The results are presented in figures as well in a pivot table for specific data-details, as illustrated in figure 4 and figure 5.

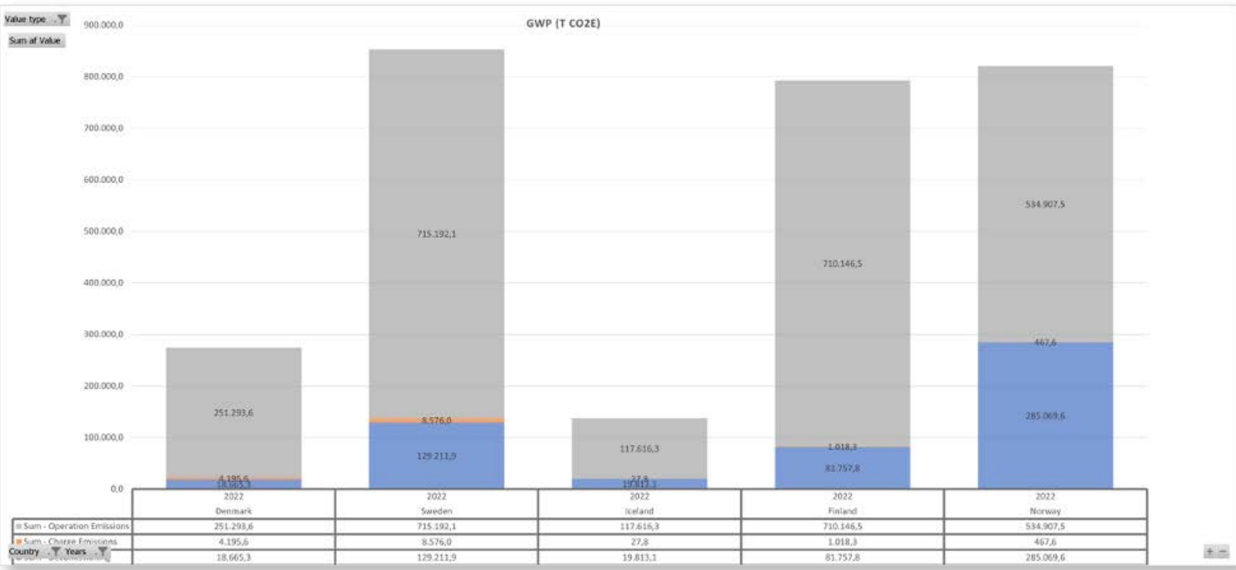

Figure 9: Graphical output of the calculator. This example illustrates the emissions across charge emissions, operations emissions and decommissioning, for all Nordic countries in 2022, in ton CO_2-eq.

Sum af Value		Categories	Emission type		
		Sum			Sum Total
Country	Years	Decomissioning	Charge Emissions	Operation Emissions	
Denmark		18.665,3	4.195,6	251.293,6	274.154,4
Sweden		129.211,9	8.576,0	715.192,1	852.980,1
Iceland		19.813,1	27,8	117.616,3	137.457,2
Finland		81.757,8	1.018,3	710.146,5	792.922,6
Norway		285.069,6	467,6	534.907,5	820.444,7
Hovedtotal		**534.517,7**	**14.285,2**	**2.329.155,9**	**2.877.958,9**

Figure 10: Numerical output of the calculator.

The calculator will be updated annually for including the newest available emission data. The process for updating is as follows:

1. When following year UNFCCC inventory data is available for publication, data can also be integrated in the calculator
2. The country coordinator structure UNFCCC data to the calculator format
3. A responsible for maintaining the calculator integrate the new country level data in the calculator
4. Calculator with updated data is checked for functionality and quality assurance test are performed
5. Updated calculator is distributed to country coordinator

The calculator is a central tool to remain maintenance of overview and development in the Nordic F-gas emissions and the calculator is the primary source to future reporting on the trends for F-gas emissions in the Nordics.

5. Allignment initiatives and new insight

During the project period several alignment initiatives have been discussed. The alignment initiatives have been divided into following themes:

- Alignment toward same Nordic emission factors and sources for data
- Alignment on projection methods

Alignment on the Nordic emission factors (EF) are a general ambition for the Nordic F-gas inventory workgroup. But in practice these decisions are complicated, because of the lack or the availability for certain data etc. for the country which decide to change approaches. The F-gas inventory workgroup has therefore an on-going information exchange on relevant intelligence for EF or data sources with the purpose of discussing the quality of EF decisions and the background data.

When comparing the different national inventory approaches for F-gas emissions, it is evident that our approaches differ significant even though all countries are following the IPCC guidelines. The approaches are different and customized according to available data sources and country structures for receiving data. The F-gas emission estimation systems have long histories in all the Nordic countries and their technical solutions have been developed independently from each other throughout the years.

The F-gas inventory workgroup has previously discussed alignment on stationary refrigeration EF and are now quite aligned. The central category for alignment initiatives now is commercial refrigeration. It is the largest source for emission-contribution and data for leakage rates is getting better. The F-gas inventory workgroup therefore continues with development and alignment on this category.

Another area for alignment is import of HFC's in product. The data sources and methods for assessing HFC's imported in product is rather different between countries, both in relation to what products that are calculated and the methods for the calculations. In particular, the workgroup has discussed the different national models for calculating import of HFC's in heat pumps because this source has increased the stock and emissions during the recent years and is now a significant source.

Alignment on projection methods has also been discussed in the project period. Based on a workshop where the country specific projection methods were presented, the group discussed how to decide assumptions for anticipated impacts when certain regulative initiatives or expected technological development are introduced.

- Denmark uses regulatory phase out dates, sector specific assumption on consumptions and accelerated reduction because of tax increase and technological innovations and steady state last year for some categories.
- Finland uses sector specific assumptions for activity data, emission factors, refrigerant shares and other relevant parameters. More simplified methodologies are also used for some minor categories. With existing measures (WEM) scenario comprise existing EU legislation and its emission reduction measures, and with additional measures (WAM) scenario comprise a group of additional national measures in some sectors that slightly accelerate the reduction of emissions.

- Norway uses linear reduction or steady state scenario in certain time-periods for consumptions of pure HFC gases.
- Iceland assumed average percentage use of import quota to estimate the total future bulk import amount based on the future quota. For the import in products, Iceland used steady state last year or average for a number of years for some categories.
- Sweden uses regulatory phase out dates and quota gradually reduced from 100% of the reference value in 2015, to 21% of the reference value in 2030. All sectors reduce the proportion of F-gases by the same amount.

New insight

New insight is generated through our coordination and workshops, e.g.

- New products containing F-gases
- Emission factors for large and medium sized commercial refrigeration equipment
- Greenhouse gas inventory review questions
- Projection methods
- Trends in F-gases in ships
- Trends in F-gases in trucks and busses

New product containing F-gases

The Norwegian tax-system provides a unique approach to determine in which products the F-gases may be applied, as all imports are declared and registered in the customs clearance systems at the corresponding commodity code. The main system is TVINN (Norwegian Customs). Thus, the tax on F-gas provides important statistical data, such as the amount of imported F-gases divided into the type of F-gas in each product and the expected area of use.

An analysis done on imports in 2022 registered in TVINN (tolltariffen.toll.no) shows that approximately 55.000 products containing HFC-gases was imported to Norway. The products were present in 197 different commodity codes, where 90% of the products (unit) were related to 23 different codes. The total amount of HFC's imported in products amounted to 146 tonnes of HFC-gas and corresponds to 160 ktonnes of CO_2-equivalents.

Table 14: The five largest product groups containing HFC registered in TVINN, based on CO_2-eq.

Commodity code		HFC, tonne gas	HFC, ktonne CO_2-eq	Share of total CO_2-eq
84151001	Air conditioning machines	58	40	25%
84186101	Refrigerators, freezers and other refrigerating	11	19	12%
30049008	Medicaments	12	15	9%
84158201	Air conditioning machines	9	10	6%
84512100	Machinery for washing	7	9	6%

From the analysis, it can be found that products within the aircooling application area, not surprisingly, dominate. According to the overview in Table 13, they account for 44% of the imported amount of HFC. Above all, heat pumps are the largest product group for imported HFC-gases in products. The heat pumps cover approx. 25% of the total product-unit import in terms of CO_2-eq. HFC-32 is, as expected, the most common F-gas in air-air heat pumps (commodity code 84151001). Surprisingly, they also contain several other HFC's than HFC-32 but only in very small amounts. The other registered HFC's are HFC-410C, HFC-134a, HFC-407C, HFC-452A, and HFC-454B. The registered import of HFC-32 was 57 tonnes in 2022 and the registered import of HFC-410A was 0,6 tonnes. The distribution of HFC-32 and HFC-410A is 99/1.

The HFC's are contained in closed systems in small air-air heat pumps units. The data can therefore be considered as an indication for the average contents of HFC's in small air-air heat pump units and an average rate of HFC-32 and HFC-410A in air-air heat pumps. The indicative average content of HFC's in the imported heat pumps are below 0,4 kg. HFC pr. unit.

The product group containing refrigerators, freezers and other refrigerating or freezing equipment and heat pumps other than air-conditioning (commodity code 84186101) is considered to comprise among other air-water heat pumps and plug-in units for comfort heating. The import of HFC's in this product group amounted to just under 12% of the total import in terms of CO_2-eq in 2022 and corresponds to approximately 11 tonnes F-gas. HFC-410A was the main imported HFC with a coverage of 6 tonnes. HFC-407C cover 2 tonnes, HFC-32 cover 1,5 tonnes and HFC-452A cover 1 tonne.

The product group – heat pumps for ventilation, dehumidification etc. in commodity code 84158201 had a total import of HFC's of approximately 9 tonnes F-gas in 2022 and HFC-32 was the main imported HFC with a coverage of 5,5 tonnes and HFC-410C covered 3 tonnes.

The medical dose inhalers constitute for 9% of the total import in 2022 in terms of CO_2-eq, corresponding to 15,000 tonnes CO_2-eq. Only HFC-134a is registered.

The analysis also identified a relatively high import of HFC's in condensed tumble dryers (commodity code 84512100). In 2022 the total import of HFC-134a in condensed tumble dryers was 7 tonnes F-gas. With a total of 9,500 tonnes CO_2-equivalents, this product group constitute for 6% of total import in products.

The statistics on imported F-gases in products in Norway indicate relatively higher rates than in the other Nordic countries. The experiences gained by Norway could be beneficial for other Nordic countries in terms of reaching more harmonized methodological assumptions.

Emission factors for large and medium sized commercial refrigeration equipment

The current status of refrigerants used in large and medium sized commercial refrigeration systems has been changing significantly in the recent years. The high-GWP HFC refrigerants have been replaced by natural refrigerants as CO_2, propane/butane og HFO in all the Nordic countries mostly as a result of the measures introduced in the EU F-gas regulation to phase-down the use of HFC in the EU. R-404A has traditionally been the most widely used refrigerant but is now replaced mostly with systems using CO_2. In addition to direct replacement of R-404A systems with CO_2, R-404A in some installations have also been temporarily replaced with the so-called drop-in refrigerants (e.g. R-448A and R-449A) that are blends of HFC and HFO gases and have a lower GWP compared to R-404A. The purpose of using these medium-term alternatives is mostly to reach the end of the service life of the equipment with the drop-in refrigerant and then eventually replace the whole system with a new system that uses natural refrigerants.

When estimating HFC and PFC emissions from large and medium sized commercial refrigeration equipment, all the Nordic countries currently use the default emission factor 10% for the operation emissions from the IPCC 2006 Guidelines. In the IPCC 2006 Guidelines, the default emission factors for the operation emissions are given as a range of 10% to 35%, where the lower end of the emission factor range is intended to indicate the status within developed countries, while the upper end of the range is intended to indicate the status within developing countries. Large and medium sized commercial refrigeration equipment comprise mostly centralized refrigeration systems in different types of food retail stores and professional kitchens.

During the recent years there has been discussion whether the 10% operation emission factor might overestimate HFC and PFC emissions from large and medium sized commercial refrigeration equipment and whether the present emission factor should be closer to e.g. 5%. To investigate this, new data was compiled in the project on the current state of leakage rates in different Nordic countries. The major food retail chains in Denmark, Sweden and Finland were contacted and it turned out that the retailers have detailed data on the leakage rates or at least data that can be used to estimate leakage rates.

In Denmark, a specific survey was conducted that covered all the major local supermarket chains (Coop, Salling Group, Rema and Dagfora with total market share of 85-95%). According to the Danish chains, phasing out of HFCs in the refrigeration systems has been a strategic priority and the amount of HFC installations has reduced substantially in the latest years. In 2023, around 20% of the supermarkets used HFCs in their refrigeration systems. The Danish data revealed that there can be differences in the leakage rates in systems using different refrigerants. When comparing systems with R-134a and R-404A, the systems using R-404A generally have larger leakage rates. Based on a smaller quantitative dataset for approximately 50 units from one retailer, the average leakage rate varies between 15-19% for HFC 404A units and 2-10% for HFC 134a units. More quantitative data from unit-installations are needed to calculate statistical evident average EF, but this data-set do not indicates that operation emission factor of medium and large commercial refrigeration equipment should be below 10% and closer to 5%.

According to one of the larger Swedish retailers, 44% of the food chain stores have converted to natural refrigerants in Sweden. Other major retailers are also converting the HFC installations to use natural refrigerants, but detailed figures were not available. The average annual HFC leakage rate from medium and large commercial refrigeration systems was estimated at 5.9-6.8% and is based on data from about 1,000 installations and from the years 2018-2022. This indicates that using an annual leakage rate of 10% may be too high for Sweden. However, the data for Swedish retailers does not cover all stores, and, as of yet, no method for estimating a weighted national average has been established. This is an area for further development in the future.

In Finland, the medium and large HFC installations in different types of food stores have been converted to natural refrigerants at an accelerating pace during the recent years. The old centralized systems using R-404A have been mostly replaced by CO_2. Some systems especially in smaller supermarkets have also been replaced by the so-called water-loop systems that use propane as a refrigerant. According to a specific Finnish survey, the share of CO_2 and propane as a refrigerant in medium and large refrigeration systems in food stores was 53% at the end of 2023. The survey covered all the Finnish food retail chains. The two largest Finnish retailers, Kesko and S Group, have a total market share of over 90% in Finland. They also follow the leakage rates in their medium and large refrigeration systems. Based on the data received from the Finnish retailers in this project, the current annual leakage rate of HFC refrigerants from medium and large systems is below 10%. The range is from around 4% to close to 10%. This represents the best practice. Generally, based on the Finnish data, R-404A has the lowest leakage rate and the leakage rate of other refrigerants is more towards the upper end of the range. The 10% leakage rate represents CO_2, and it is generally higher compared to HFC refrigerants. According to the Finnish retailers, when systems using HFC refrigerants are under maintenance (refilling to replace leakage), all the leakages can usually be recovered and captured. Today, the service work is performed very precisely. Therefore, also the annual leakage rates of HFCs are also relatively low. It is not yet possible to recover or capture CO_2 during maintenance because the pressure is so high. Also, if there is a leak, CO_2 is discharged faster than, e.g. R-404A. This is the main reason why CO_2 has a higher leakage rate compared to HFCs.

F-gases in trucks and busses

Because of the EU F-Gas Regulation (EU 517/2014) quota requirements, a manufacturer can choose to produce a smaller quantity of product containing high-GWP refrigerants, or a larger quantity of products containing low-GWP refrigerants, as long as the total environmental impact remains within the allocated quota.

Thus, the use of high GWP HFCs as refrigerants in the Swedish automotive industry are gradually being phased out. Examples of alternative refrigerants include HFOs (unsaturated hydrofluorocarbons) and CO_2.

F-gases have been used in the automotive industry for cooling processes, and in vehicles, for many years. A large proportion of F-gases is used in mobile air-conditioning systems to regulate cabin temperatures. Since 2006, the EU's Mobile Air Conditioning (MAC) Directive has limited the use of F-gases in passenger cars and light vehicles, requiring refrigerants not to exceed a GWP of 150. For heavier vehicles, the F-Gas Regulation (EU 517/2014) has been in effect since 2015.

In the past, HFCs were predominantly used in mobile air-conditioning systems for machinery and heavy vehicles. Following the introduction of the F-Gas Regulation, vehicle manufacturers have had to seek alternative refrigerants to ensure long-term availability. The alternatives often include HFOs or natural refrigerants like CO_2.

The vehicle manufacturing industry in Sweden made efforts to identify alternatives to high-GWP refrigerants with uncertain future availability. Consequently, in recent years, R134a has been replaced with R1234yf in passenger car A/Cs. In trucks, this transition is largely complete. However, F-gases with higher GWP are still used in the battery packs for hybrid and electric vehicles.

In contact with two of the major vehicle manufacturers in the Nordic countries, information was provided that for electric buses, plans are in place to transition from R134a to CO_2, while electric buses intended for warmer climates are likely to retain R134a. The refrigerant consumption for buses is higher than for trucks as cooling is required in both cabin and passenger areas. For heavy-duty machinery, no definitive decisions have yet been made regarding refrigerants, but options under consideration and tests include natural refrigerants such as propane (R290) or CO_2 (R744). Due to the operational requirements of heavy-duty machinery compared to other vehicles, R1234yf is not a suitable option.

Moreover, the vehicle industry is closely following the discussions on the possible changes in the PFAS regulation, as proposals include a ban of some of the low-GWP substitute HFCs and HFOs refrigerant blends.

Greenhouse gas inventory reviews

Greenhouse gas inventory reporting to the Paris Agreement started in 2024. All the Parties to the Paris Agreement reported their first Biennial Transparency Reports (BTRs) in accordance with the Paris Agreement by 31 December 2024. The BTRs include also the annual greenhouse gas inventory submission. Starting in 2025, all the first BTRs submitted in 2024 will be reviewed as an in-country review that is organized by the UNFCCC secretariat.

A brief workshop related to the review process was organized between the Nordic countries in September 2024. In the workshop, experiences from the previous UNFCCC and EU reviews were discussed in detail. The workshop provided valuable experience in preparing for the upcoming in-country reviews.

6. Emission factors

The following tables provide an overview of the Nordic country emission factors used at the different subcategories. The figures categorise the emissions at the different life-cycle stages (charge, operating, and disposal).

The various emission factors used for calculating the F-gas emissions were compared and evaluated for all categories and applications where F-gases are used (CRF sub-categories according to the 2006 IPCC guidelines).

Key findings from the overall assessment of the Nordic F-gas emission calculation:

- The data sources and methods for collecting data on import of F-gases in bulk and in products vary between countries.
- The Nordic countries follow the IPCC methods and apply factors mostly within the IPCC default ranges.
- Generally, there are only few country-specific emission factors available.
- Countries have applied different values from the IPCC default ranges, which results in artificial differences in F-gas stocks and emissions.
- Some actual differences in types of equipment and practices can be observed.

Commercial refrigeration (2.F.1.a)

This category includes both medium and large refrigeration and stand-alone applications. Stand-alone commercial applications are defined as "*smaller hermetically sealed plug-in appliances commonly used in retail food stores and also in pubs, restaurants, and other, hospitality and catering outlets such as hotels, hospitals, and schools*".

All countries have applied the same emission factor for medium and large sized equipment for operation. Finland has the highest operation emissions because of a large stock. The cause of Finland's comparatively higher level of stocks is a large share of direct centralized refrigeration systems using HFCs, which are still in use. The refrigerant charge level is considerably higher in the direct systems compared to the indirect HFC systems more commonly used because of strengthened regulation in the other Nordic countries. Norway has high emissions from disposal.

The Benchmark per capita emphasizes large differences between the countries, particularly in relation to operating emissions as well as disposal emissions.

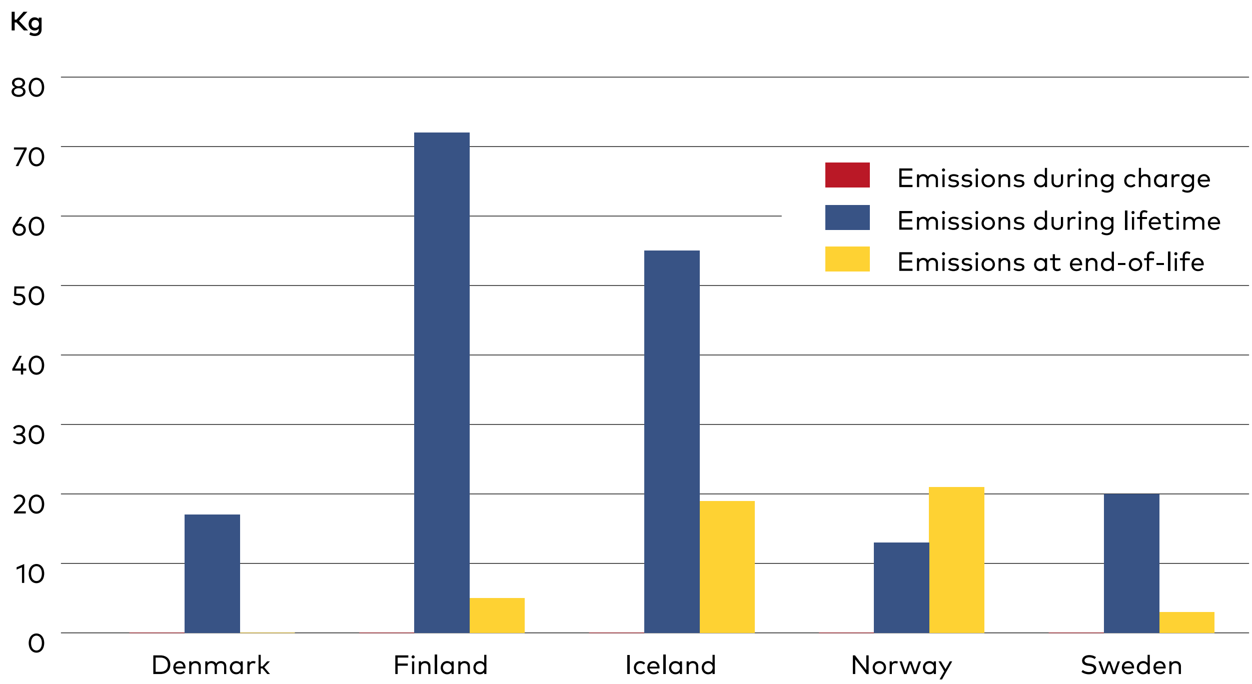

Figure 11: Benchmark of emissions, commercial refrigeration (2.F.1.a), kg CO_2 per capita in 2022.

Finland uses higher emission factors from the 1996 IPCC guidelines when estimating emissions for the 1990s. In addition, the recovery efficiency increases during 2010s/2020s. These were reduced to the level of the 2006 IPCC guidelines during the 2000s. Recovery efficiency for Denmark, Finland and Sweden is above levels set out by the IPCC guidelines, while Norway and Iceland use the maximum level of 70%.

Table 15: Emission factors for medium and large commercial refrigeration (2.F.1.a)

	Lifetimes (years)	Initial Emission (%)	Operation Emission (%)	Recovery Efficiency (%)	Initial Charge Remaining
IPCC 2006 Guidelines	$7 \leq d \leq 15$	$0.5 \leq k \leq 3$	$10 \leq x \leq 35$	$0 < \eta_{rec,d} < 70$	$50 < p < 100$
Denmark	15	1.5	10	88.5	
Finland	12	5/0.5	17/10	70/90/95	90
Iceland	8	2	10	70	
Norway	12	2/0.5	10/4	70	100
Sweden	7	0.5	10	95	90

Iceland do not report emissions separately for stand-alone commercial applications.

Table 16: Emission factors for stand-alone commercial applications (2.F.1.a)

	Lifetimes (years)	Initial Emission (%)	Operation Emission (%)	Recovery Efficiency (%)	Initial Charge Remaining
IPCC 2006 Guidelines	10 ≤ d ≤ 15	0.5 ≤ k ≤ 3	1 ≤ x ≤ 15	0 < ηrec,d < 70	0 < p < 80
Denmark	15	2	1	100	85
Finland	10	5/0.5	17/1	70/90/95	80
Iceland	-	-	-	-	
Norway	10	NO	3.5	NA*	65
Sweden	10	0.5	1	95	90

*The recovery efficiency varies with the amounts destroyed each year.

Key findings on *stand-alone commercial refrigeration*:

- All countries have used more or less the same emission factors.
- Denmark has pr. 2023 introduced emission factors for stand-alone commercial equipment for the full time-seria. Until 2022, it was a subcategory in stand-alone household applications.
- Finland has direct HFC systems with larger charge compared to the indirect HFC systems which are wider used in e.g. Denmark because of regulation.
- Norway has high emissions from disposal.
- Sweden, Denmark and Norway have a relatively equal estimated stock per capita.

Domestic refrigeration (2.F.1.b)

Domestic refrigeration is a minor source of F-gas emissions in the Nordic countries.

The category includes household stand-alone refrigerators, freezers and coolers and combinations of the two.

Denmark estimates zero emissions from disposal, because the disposal procedures are efficient and Denmark exports large amounts of waste household appliances to Germany for recycling and disposal.

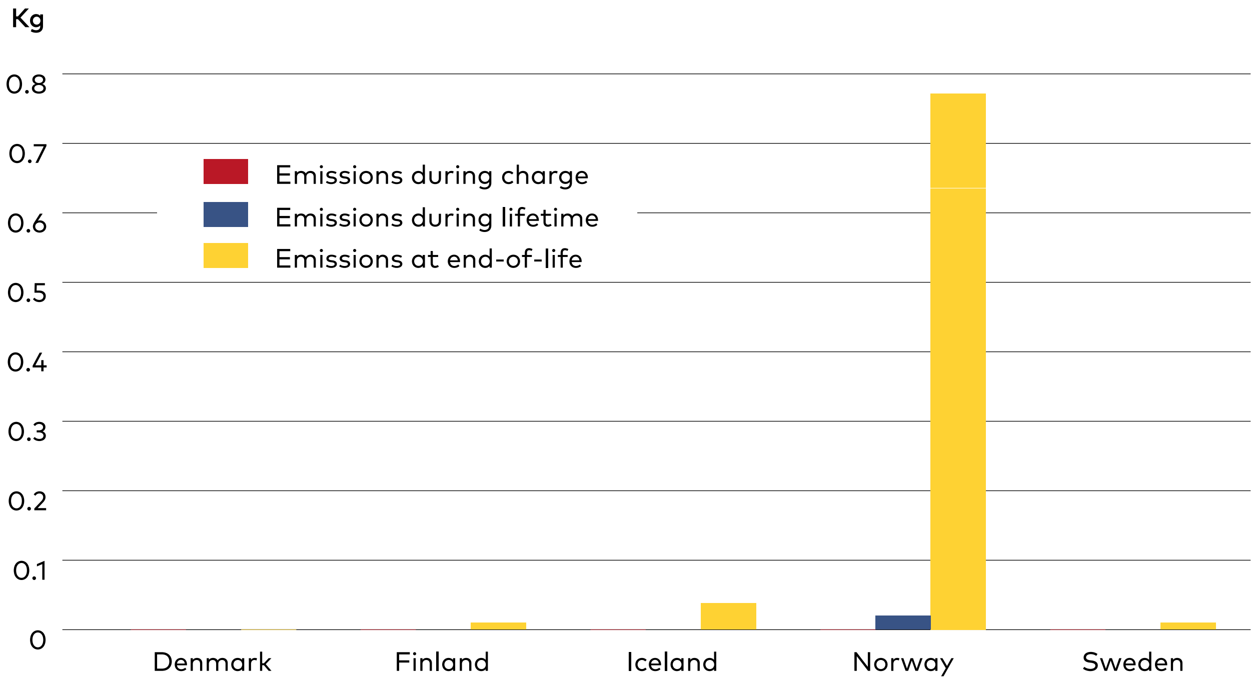

Figure 12: Benchmark of emissions, Stand-alone household appliances (2.F.1.b), kg CO_2–eq. per capita in 2022

Sweden uses a long average lifetime for the applications, but it is still within the IPCC guideline.

In Denmark and Sweden, there are manufacturers of domestic refrigerators, but emission factors are not adjusted to the IPCC 2006 guideline as for the case of Finland.

The recovery efficiency for Denmark, Finland and Sweden is higher than the IPCC guideline (max. 70%).

Norway does not calculate any recovery from domestic refrigeration. However, the calculation uses specific figures from the facilities that empty the units of gas before export to correct the emissions from disposal.

Denmark and Norway register both HFC 134a (used for fridges) and HFC 404a (used for freezers). Finland, Iceland and Sweden register HFC 134a only.

The most commonly used refrigerant in this application area is the non-HFC gas isobutane (R-600A), which was introduced on the market in the 1990s at the same time as HFCs. Under the EU F-gas regulation (517/2014), use of refrigerants with GWPs of 150 or higher in new household refrigerators and freezers is prohibited as of 2015.

Table 17: Emission factors for Domestic refrigeration (2.F.1.b)

	Lifetimes (years)	Initial Emission (%)	Operation Emission (%)	Recovery Efficiency (%)	Initial Charge Remaining
IPCC 2006 Guidelines	$12 \leq d \leq 20$	$0.2 \leq k \leq 1$	$0.1 \leq x \leq 0.5$	$0 < \eta_{rec,d} < 70$	$0 < p < 80$
Denmark	15	2	1	100	85
Finland	12	2.7/0.6*	1/0.3**	70/90	80
Iceland	12	NO	0.3	70	
Norway	15	NO	0.5	NA*	92.5
Sweden	20	2	1	95	90

* The recovery efficiency varies with the amounts destroyed each year.

** Higher emission factor for 1990s and lower for later years (da1ta sources: 1996 IPCC guideline and 2006 IPCC guideline)

Industrial Refrigeration (2.F.1.c)

With regard to industrial refrigeration, the Nordic countries use different methodological approaches. Denmark does not explicitly report industrial refrigeration, but includes these applications in medium and large *commercial refrigeration*. This demonstrates the diversity of this application area: From major food and beverage industries and cold storage to specialised smaller capacity equipment, e.g. specialised environmental simulation chambers or laboratory equipment. The category can also be applied to large-scale customised on-site build systems and factory build equipment from series production. Natural refrigerants, mainly ammonia, have been widely used in this sector in larger scale systems.

The industrial emissions of Iceland consist mainly of the food industry such as fish processing, meat processing (slaughter houses), and vegetable production. Emissions from the fishing ships falls mainly in the category of *transport refrigeration* (2.F.1.d).

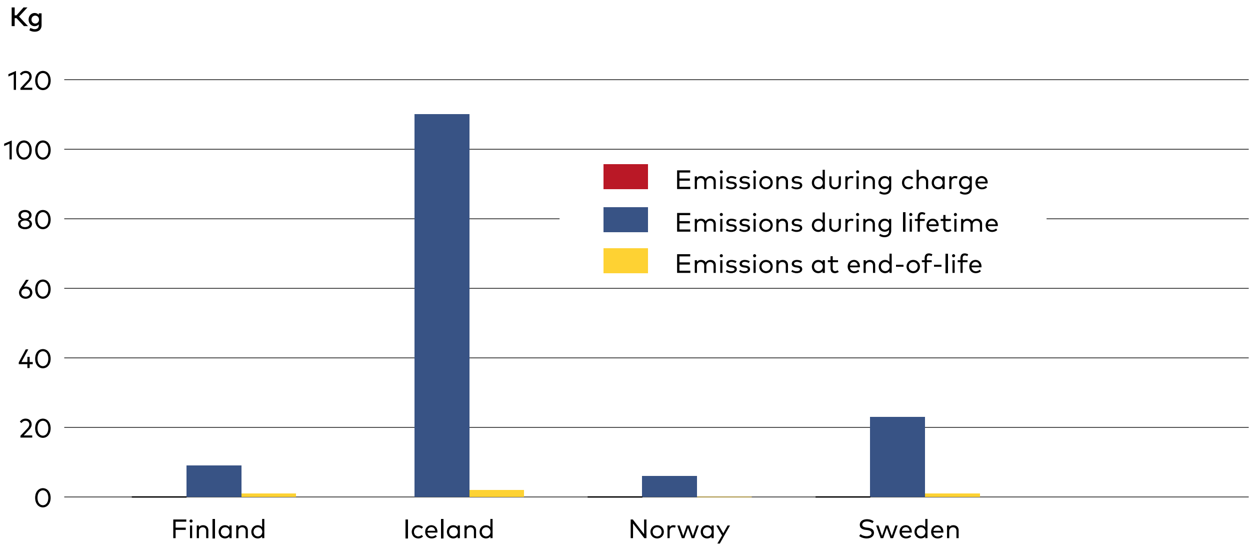

Figure 13: Benchmark of emissions, Industrial refrigeration (2.F.1.c), kg CO_2-eq. per capita in 2022.

Finland uses old and new emission factors from the 1996 IPCC guideline and 2006 IPCC guideline. The new emission factors are introduced from 2000-2005 and onwards. In addition, the recovery efficiency increases during 2010s.

The recovery efficiency for Sweden is above the level of the IPCC guideline while Iceland and Norway use the maximum level of 90% as recovery rate.

Table 18: Emission factors for Industrial Refrigeration (2.F.1.c)

	Lifetimes (years)	Initial Emission (%)	Operation Emission (%)	Recovery Efficiency (%)	Initial Charge Remaining
IPCC 2006 Guidelines	$15 \leq d \leq 30$	$0.5 \leq k \leq 3$	$7 \leq x \leq 25$	$0 < \eta_{rec,d} < 90$	$50 < p < 100$
Denmark	15	1.5	10	88.5	
Finland	15*/20**	2/1	17/10*, 17/9**	80/90	90
Iceland	15	2	10	90	
Norway	17	2	10	90	100
Sweden	15	0.5	7	95	90

* Industrial refrigeration

** Ice rinks

Key findings on *industrial refrigeration*:

- All countries have used more or less the same emission factors.
- There are large emissions per capita in Iceland due to food production including fish processing.
- For Denmark, industrial refrigeration is included in *commercial refrigeration*.
- Natural refrigerants, mainly ammonia, have been widely used in this sector in larger scale systems.

Transport Refrigeration (2.F.1.d)

Transport refrigeration consists mainly of refrigerated trucks and trailers or containers, which can be transported by road, sea or rail. When comparing the per capita operation emission from *transport refrigeration*, the levels between Denmark, Finland, Sweden and Norway are relatively similar. Iceland differs because of their large fishing fleet, which constitute much of the stock.

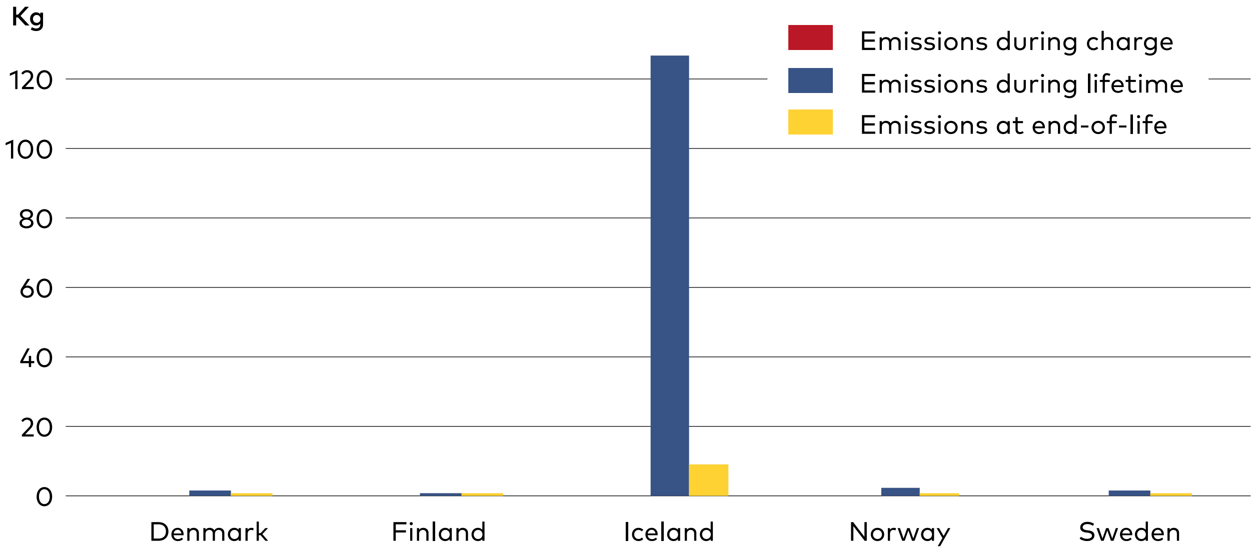

Figure 14: Benchmark of emissions, Industrial refrigeration (2.F.1.d), kg CO_2 eq. per capita in 2022.

Sweden uses a high emission factor for initial emissions and above IPCC guidelines. The recovery efficiency for Denmark and Sweden are above IPCC guidelines (max. 70%), while Iceland, Finland and Norway have 70% as recovery rate.

This sub-category contributes the most to the Icelandic F-gas emissions. The Icelandic fishing fleet replaced the refrigeration system to ammonia-based systems, but due to the spatial requirements of these systems, a number of ships retrofitted their systems to the use of HFCs. The initial emission is calculated as a linear decrease from 50% emission in 1993 to 20% in 2012 and onwards.

Table 19: Emission factors for transport refrigeration (2.F.1.d)

	Lifetimes (years)	Initial Emission (%)	Operation Emission (%)	Recovery Efficiency (%)	Initial Charge Remaining
IPCC 2006 Guidelines	$6 \leq d \leq 9$	$0.2 \leq k \leq 1$	$15 \leq x \leq 50$	$0 < \eta_{rec,d} < 70$	$0 < p < 50$
Denmark	7	0.5	17	88.5	
Finland	6	5/0.6/0.3**	17/15***	50/70	50
Iceland (reefers)	NE	NO	15/10**	NE	
Iceland (fishing Vessels)	15	2	20*	70	
Norway	9	1	20	70	100
Sweden	10	4.5	7-30	85	90

* Linear decrease from 50% in 1993 to 20% in 2012; 20% since 2012
** 15% until 2015 and 10% since 2016.
*** Higher emission factor for 1990s and lower for later years (data sources: 1996 IPCC guideline and 2006 IPCC guideline)

Mobile air-conditioning (2.F.1.e)

Finland and Sweden are on same emission levels during end-of-life, but differ during operations. Norway is significantly higher in the operation phase because of larger estimated stock. Norway receives import/export data from customs. The Danish operation emission from MAC is approximately half of the Norwegian. The Danish estimates are based on data from sold refrigerant for MAC service and do not include calculation of stock. Regarding emissions from disposal, Denmark estimates zero emissions because of efficient disposal procedures.

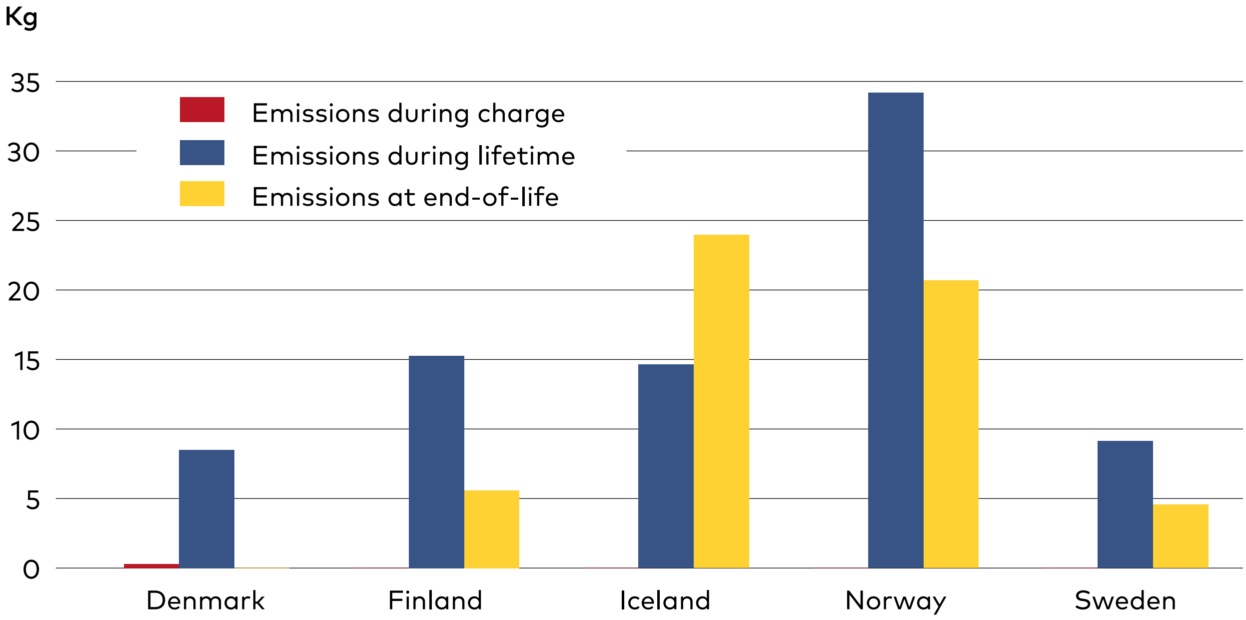

Figure 15: Benchmark of emissions, mobile air-conditioning (2.F.1.e), kg CO_2–eq. per capita in 2022

Finland and Sweden calculate the stock in a similar way. The basis is the data of first registrations, which is considered very precise data. In addition, they use estimates for the share of vehicles with AC and refrigerant fills per vehicle and what refrigerants are used. Norway calculates the stock with the help of import data from the customs.

The Swedish emission factors are related to following vehicles: Passenger car, Light duty, Heavy duty, Bus, Tractor, Other non-road vehicles and Working machinery. Finland includes the following vehicle types: Road vehicles (passenger cars, vans, trucks and busses), non-road vehicles (tractors and motorised working machines) and Rail vehicles (trains, trams and metro).

The Danish calculation of MAC changed to a Tier 2 top-down approach from 2011 and onwards. Sales data from importers/suppliers of MAC refrigerants = sold gas to MAC = use for refilling = emission the particular year. There are no car manufacturers in Denmark, and consumption is therefore used for service only.

Sweden uses a high charge and operation emission factor for non-road and tractors (5% and 30%).

Iceland does not apply F-gas recovery, while Sweden has an effective and large F-gas recovery.

Iceland calculates a disposal emission from an assumption of 100% remaining charge at disposal time.

Sweden and Finland voluntarily include the new alternative refrigerant HFO-1234yf in the calculation. The EU MAC Directive (2006/40/EC) prohibits the use of F-gases with GWP larger than 150 in all new passenger cars and light duty vehicles manufactured in 2017 or later. HFO-1234yf has replaced HFC-134A, which was formerly used in new passenger cars and vans registered in the EU. In addition, CO_2 is used in a very small scale in some specific passenger car models. HFO-1234yf may be prohibited depending on the PFAS prohobition decision (EU).

Table 20: Emission Factors for mobile air-conditioning (2.F.1.e)

	Lifetimes (years)	Initial Emission (%)	Operation Emission (%)	Recovery Efficiency (%)	Initial Charge Remaining
IPCC 2006 Guidelines	$9 \leq d \leq 16$	$0.2 \leq k \leq 0.5$	$10 \leq x \leq 20$	$0 < \eta_{rec,d} < 50$	$0 < p < 50$
Denmark	NE	4.5 (until 2011)	30 (until 2011)	NE	NE
Finland	9/12/20	5/0.2*	30/20/10*	50	50
Iceland	14	NO	10/7**	0	100
Norway	12	NO	10	50	100
Sweden					
Cars	11	1/0.5	15/5	85	90
Light	11	1/ 0.5	15 /5	85	90
Heavy	6	1 /0.5	15 /5	85	90
Bus	12	1 /0.5	10	85	90
Tractor	7	5	30	85	90
A-tractor	11	1/0.5	15/5	85	90
Non road	8 /20	5	30	85	90

* Higher emission factor for 1990s and lower for later years (data sources: 1996 IPCC guideline and 2006 IPCC guideline)

** 10% from 1990 and 7% from 2008.

Key findings on *mobile air-conditioning* (MAC):

- There are relatively large differences in emissions per capita between the Nordic countries and the difference cannot be explained with differences in the vehicle fleet.
- The highest emissions per capita are in Norway and the lowest in Denmark.
- Danish emission statistics are based on data on sales to service stations.
- Norway, Iceland and Finland use the same emission factor (10%) for lifetime emissions.
- Sweden uses emission factors lower than IPCC values for passenger cars (5%).

Stationary air-conditioning (2.F.1.f)

The category *stationary air-conditioning* includes different types of heat pumps and other stationary equipment from large water coolers to small room air conditioners used for air conditioning in buildings.

The benchmark per capita emphasizes large differences between the countries. Especially in relation to operating emissions and disposal emissions.

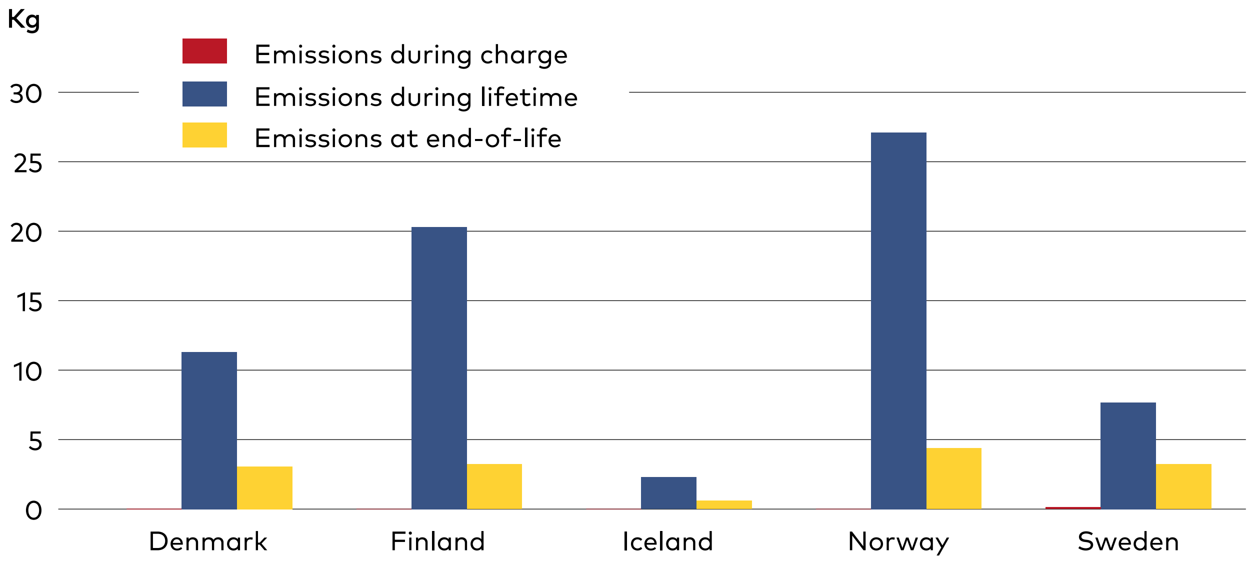

Figure 16: Benchmark of emissions, stationary air-conditioning (2.F.1.f), kg CO_2 per capita in 2022

All countries include heat pumps in the category of *stationary air-conditioning*. However, heat pumps are not commonly used in Iceland due to the sufficient availability of geothermal heat for space heating.

Finland and Denmark used a high operation emission factor until 2000 (Finland) and 2010 (Denmark).

The operation emission factor between the Nordic countries varies between 1% to 4%, where Sweden had the lowest emission factor and Norway had the highest emission factor.

Denmark and Sweden use higher factor for recovery efficiency than the IPCC guidelines. Norway calculates remaining charge to be 100%. Finland uses lower recovery efficiency (80%) for heat pumps (except large heat pumps) compared to other equipment (90/95%) in this category.

Table 21: Emission factors for Stationary air-conditioning (2.F.1.f)

	Lifetimes (years)	Initial Emission (%)	Operation Emission (%)	Recovery Efficiency (%)	Initial Charge Remaining
IPCC 2006 Guidelines	10 ≤ d ≤ 20	0.2 ≤ k ≤ 1	1 ≤ x ≤ 10	0 < ηrec,d < 80	0 < p < 80
Denmark	15	1.5 /0.5	10/3	100	NE
Finland	10-20	5 /0.2*	17/10/3.5*	80/90/95	80
Iceland	12	1	3	80	
Norway	18	0.2	4	80	100
Sweden (heat pumps)	20 - 15	1	1	95	90
Sweden (other)	10	0.2	1	95	90

* Higher emission factor for 1990s and lower for later years (data sources: 1996 IPCC guideline and 2006 IPCC guideline)

Key findings on *stationary refrigeration*:

- Large differences in emission factors for annual emissions during lifetime (all in line with IPCC guidelines).

Summary of emission per capita

The analysis illustrates that Denmark has the lowest emissions from RAC pr. capita and whereas Finland's emission are 3 times higher. A core reason for this is its large stock of HFCs in direct centralized commercial refrigeration systems in use, compared to Norway, Sweden and Denmark. Emissions from Iceland are high, partly due to the fishing industry, and therefore comparison on per capita-data is less relevant.

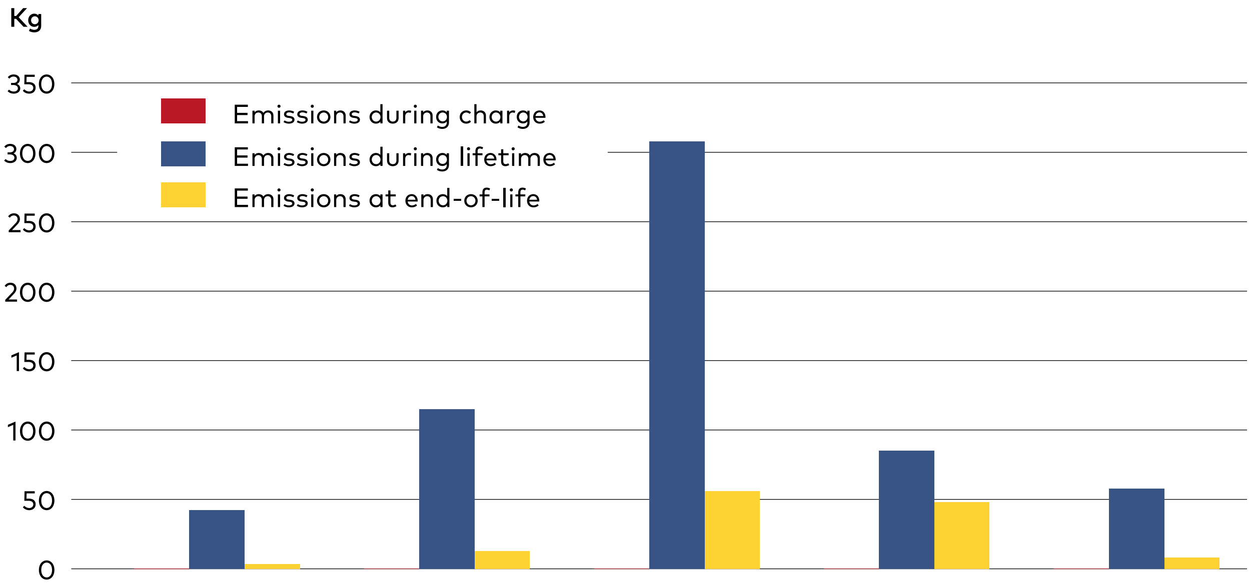

Figure 17: Benchmark of emissions, sum of RAC categories, kg CO_2 per capita in 2022

The main issues are:

- Use of different emission factors within the main categories and large variations in stock per capita. For example, the emission factors range from 1% to 4% in operation emission from stationary A/C (2.F.1.f) among the countries. Norway uses the highest emission factor[3], and for *medium and large commercial refrigeration*, Finland has a substantially large stock per capita.
- Use of different emission factors for recovery of emissions at end-of-life.
- Different data sources for identifying imported/exported products containing F-gases, especially MAC, heat pumps and coolers. Norway receives data directly from customs because taxes are imposed on F-gases in bulk as well as in products. New product areas and reports on exact volumes are therefore assumed to be accurate. For the other Nordic countries, the methods are based on statistic sources, extrapolations and data collection from the market.
- Special conditions in terms of industrial and commercial activities in a particular country. For example, Iceland has a large fishing fleet, which affects its per capita data.
- Identification of the country-specific sectoral details in the equipment stock, that are independent of the methodological choices applied in emission estimation. For example, there is still a large share of direct commercial HFC refrigeration systems in use in Finland.

3 At detailed level, when comparing refrigerant charge levels etc. it has to be kept in mind, that the countries may not have similar devices/applications in all sectors. For example, Finland has more direct centralised refrigeration systems in use with larger refrigerant charge and also leakage rate.

7. Conclusion and recommendation

The overall conclusions from the project are the following:

- Significant decrease in F-gas emissions and average GWP of HFCs placed on the market in the Nordic countries. Depending on the country, the emission reduction is between 13% and 53% for the period 2015-2022.
- The transition towards low GWP refrigerants (e.g. CO2 and HFOs) is apparent. From 2021 to 2022, the average GWP per ton imported HFC decreased from GWP 1,706 to GWP 1,406, a reduction of 18%. In total the HFCs, ton CO2-eq, Nordic total has decreased from 2,568,044 in 2021 to 2,305,921 in 2022, a reduction of 9% and 262,123 ton CO2-eq. It is expected a solid further decrease during the next years.
- There is progress in methodological development in the different Nordic inventories. A number of specific improvements have been introduced in recent years (see section "implemented and planned improvements" below).
- The Nordic F-gas inventories are getting more complex due to regulatory initiatives which accelerate phase out and substitution of units before anticipated End-of-Life, import of HFC's in various products which are difficult and time consuming to collect data for, and due to the introduction of a number of low GWP blends and alternative refrigerants, such as propane/butan or HFO's.
- There is still a lack of alignment on central EF and assumptions, especially in relation to how we estimate emissions from disposal. For example, Norway account for 10% of the overall of the Nordic HFC emissions, whereas Denmark assumes very low or no emissions occurring during end-of-life stage for several sub-categories.
- The information available on the imported HFCs in products vary between the Nordic countries. Apart from Norway and Finland, product import data is usually based on unit import and assumptions for used gases and their charges and not direct data of amounts of F-gases in products. Finland conducts annual surveys where direct data on F-gases imported in products are available (these are supplemented with data based on unit imports e.g. for MACs). Norway's precise toll statistics on imported F-gas amounts in products together with Finland's data could be a solid base for further analysis of data for other Nordic countries.
- There is a good understanding of the main national characteristics explaining some of the differences in emissions, e.g. HFC stock in Finnish large and medium commercial equipment, differences in heat pump usage and the amount of fishing vessels in Iceland. Sweden has a relatively large import in bulk which is partly due to, for example, domestic manufacturing of vehicles and heat pumps.
- The benchmark-calculator is a useful and effective tool to compare the Nordic countries emissions in totals and per sub-category level in relation to pr. capita and specific emission figures. Thus, it would be a benefit also to include stock data as well to determine the relation between emissions, emission factors and trends.

Recommendations for future coordination

- In most cases, the Nordic countries apply emission factors within the default ranges set out in the 2006 IPCC guidelines. Therefore, it is relevant to apply more similar emission factors for charge and operation for RAC categories, especially 2.F.1.a (*commercial refrigeration*) and 2.F.1.f (*stationary air-conditioning*)

- Mainstream emission factors for disposal emissions for all RAC categories as much as possible, including the assessment of background information to define current state of F-gas recovery from RACs

- Further evaluate information on import in products and improve the Nordic analysis to make the import data collection more complete.

- Continue to share and discuss UNFCCC review questions

- Annual update of the Nordic benchmark calculator for sharing of F-gas emission status

- Share new intelligence, e.g. country specific reports of relevance

- Further assessment and explanations of the large differencies between the Nordic countries SF_6 stock and import of SF_6 in switchgear

Implemented or planned improvements as a result of the project work

Denmark

- The 2023 F-gas inventory has included a number of revision and improvements.
- New sub-category for stand-alone commercial refrigeration
- Emission factor for SF_6 charge changed from 5% to 0,25%
- Projection prolonged to 2050
- EU F-gas directive phase out dates consequently introduced in projection model for all categories

Further A national strengthening of the F-gas Regulation was introduced in November 2024. The Regulation comprises an increase in taxes on F-gases imported as bulk or products to DK market. The taxes will be increased to 750 DKK pr. ton CO_2-eq from 1. January 2027.

Finland

The following major recalculations were made to the Finnish F-gas emission inventory in the 2023 and 2024 submissions to the EU and UNFCCC:

- Recalculation of SF_6 bank (and therefore emissions) in category 2.G.1 for 2013 onwards due to inclusion of previously missing data. The SF_6 bank was underestimated prior to the recalculation.
- The revision of equipment lifetime for air-to-air heat pumps from 10 years to 15 years in category 2.F.1.f. and the following recalculation of the HFC emissions for the whole time series. The same revision of the equipment lifetime was also made to Finland's energy statistics by Statistics Finland.

In addition to the major recalculations, new refrigerants that have entered the market have been added annually to the category 2.F.1 calculation model. The F-gas projections were also prolonged to 2055 during 2024.

During 2025 there will be an assessment of the possible update of the operation emission factor in category 2.F.1.a (medium and large commercial refrigeration equipment).

Iceland
In recent years some improvements have been done in the Icelandic inventory regarding the F-gases. Most of the changes were discussed at some extent in this Nordic platform.

- Revised lifetime for systems in fishing ships.
- Investigation about end of life emissions from ships, MAC and industry that did not lead to any changes.
- Revised EF for MAC in passenger cars (leakage) and the ratio of cars that have R134a over the timeline.
- Projections prolonged to 2055.
- Impact of policy about taxation and quota of F-gases quantified.

Plans
- Add F-gases imported in heat pumps to the inventory. Method probably based on cooperation with Norway through this platform.

Norway
There have been several updates to the Norwegian F-gas-calculations in the past few years, focusing primarily on the refrigeration sector. The last main update was made in the 2023 submission, when Norway implemented new emission factors for end-of-life emissions.

Norway performed these updates due to feedback from both the previous EU revision and actors within the industry:
- Previous imports of HFC-134 and HFC-143 were changed to HFC-134a and HFC-143a as it is suspected that the imports were misinterpreted.
- The lifetime and leakage rates in the Fire extinguishing sector were updated due to having received new information from the industry. New extinguishing systems are now being equipped with other gases, and there is a particular focus on removing the use of HFC-227ea. As a part of the update the lifetime of the systems is expanded from 15 to 30 years, and the leakage rate is reduced from 5 to 2 percent.

There are no concrete plans for the HFC calculation in the coming period, but Norway will continue to focus heavily on the calculations related to cooling, as well as increasing quality and reducing uncertainty. When it comes to SF_6, Norway has introduced tax on import of the gas from 2023. This may give new information and will be followed closely in the future.

Sweden
The new implementations in the Swedish F-gas model during submission 2025 consist of the following:

- 2.F.1.d – Introduction of a lower GWP refrigerant into model calculations, R452A, as a consequence of new market intel. The introduction of R452A occurs from 2018 onwards. This has a minor decreasing effect on emissions.
- 2.F.1.e – Introduction of a lower GWP refrigerant into model calculations, R1234yf, as a consequence of new activity data. Introduction of R1234yf occurs from 2021 onwards, and leads to a decrease in emissions by 8, and 14 percent, for 2021 and 2022 respectively. This is, however, only applied to vehicles manufactured in Sweden.
- 2.F.1.f – Introduction of a lower GWP refrigerant into model calculations, R290, as a consequence of new market intel. The introduction of R290 occurs from 2021 onwards and leads to a small decrease in emissions.

National F-gas register
With regard discussions on National F-gas register

- DK is looking into it. DEPA have started planning such a register.
- SE is looking into it. IVL and S EPA are discussing and trying to find some funding.
- IS is following but has no plans of implementation.
- NO has no plans to implement a new register as the tax systems give control of use.
- FI is following but has no plans of implementation.

If this subject is going to increase, we should consider coordination of concepts etc.

Appendix

Methods for datacollection

All Nordic countries collect consumption data of F-gases from suppliers and main consumers. However, the systems and methods for data collection vary considerably.

Generally, two models are used:

1. Data collection from relevant importers and users supplemented with data from customs. In Norway, the regulatory framework requires all stakeholders importing or exporting F-gases in bulk or products to report the exact quantities to customs. Customs are therefore able to provide detailed data of F-gas quantities to the entity calculating the emissions.
2. Data collection from manufacturers, importers, main users and product statistic. This approach is applied in Denmark, Finland, Iceland and Sweden.

Table A1: Bulk data

	Denmark	Finland	Iceland	Norway	Sweden
Data from importers	x	x	x		
Data from custom				x	
Data from agencies				x	x
Use of questionnaire	x	x			

The table illustrates the fundamental differences in used bulk data sources. Some countries use statistics, and other countries use different sorts of questionnaires.

All Nordic countries have good and precise bulk data in terms of quantities of particular imported F-gases, whilst none of the Nordic countries have manufacturing of F-gases. Therefore, the input base for emission calculations from bulk seems to be accurate. However, there could be uncertainties in relation to import/export of F-gas bulk between Iceland and parts of the large ships in the Norwegian fishing fleet, because of incentives for buying refrigerant without taxes directly from harbours. Cross-bordering issues have not been a part of the study.

A challenge for data collection is to include and cover imported products containing F-gases. Because F-gases are used in various applications for various purposes, with changing charges and introduction of alternative substances, it can be difficult to ensure that data collection is up-to-date on the latest market trends. In this regard, the Norwegian legal framework with a tax on F-gases is a robust data source to ensure continuous, reliable data for existing and new applications containing F-gases.

Even though Denmark has a tax on F-gases, it is not possible for the tax entity to provide data on products containing F-gases or quantities.

Table A2: Data for import of products containing F-gases

	Denmark	Finland	Iceland	Norway	Sweden
Data from importers/ users	GIS (Gas Insulated Switchgear)	GIS Refriger-ants in product (MAC, heat-pumps etc.) Aerosols	GIS		Heat-pumps Fire protection
Data from custom				MAC in cars MDI AC units Commercial and domestic applications Heat-pumps Fire protection Insulation foam	
Data from Agencies	Heat-pumps		MAC, Domes-tic ap-pliance, MDI	GIS	MDI
Data from statistic	MDI, (Cars)	Vehicles, Various RAC sector data			Cars, Light and heavy duty vehicles

The table illustrates differences when comparing data sources for import and export of products with F-gases. The survey indicates differences in which product there are included in the national inventories.

List of identified products with HFC’s

It would be relevant to continue the work and provide a detailed overview of products identified to contain F-gases and methods for data collection.

The following list contains examples of products potentially containing HFCs or PFC:

- Dehumidifiers
- Heat pumps
- Tumble dryers
- Special refrigerators/freezers (laboratory etc.)
- Water coolers
- Carbonate stream automates
- Milk coolers in large coffee machines
- Mobile air-conditioning
- A/C in busses and trains
- Ice machines
- Large ice water machines
- Stop leak to air-conditioning spray box which combines sealer and refrigerant
- Wine coolers
- Centrifuge to hospitals and laboratory
- Special low temperature freezers for hospital and laboratory use
- Medical Dose Inhalers
- Open refrigerators for buffets, salad bars etc.
- Aerosols with cooling/freezing spray
- Aerosols with compressed air, e.g. “Dust Off”
- ”Pet corrector” aerosol spray
- Foam spray
- Blowing/foaming agents (gases for blowing, e.g. Solkane 365)
- Fire extinguishers for boats
- Laser coolers
- Applications for medical laser and freeze treatment