Nordic Council of Ministers

Nordic Working Paper

Nordic cooperation on F-gas emission inventories

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Nordic cooperation on F-gas emission inventories

Project report

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Introduction

Background

Fluorinated gases (F-gases, including HFCs, PFCs, SF6 and NF3) are a range of potent greenhouse gases that are used in a number of different applications and products for refrigeration, air-conditioning, foams, aerosols, and technical installations.

This report presents results from the project *Continuation of the Nordic F-gas Inventory Group,* granted by the Nordic Council of Ministers' Working Group for Climate and Air (NKL). The project is a continuation of the Nordic F-Gas Inventory Group's work with developing and coordinating knowledge and methods for calculating F-gas emissions in the Nordic towards a more uniform Nordic approach. The project period was 2019-2022.

In continuation of the group's work, this project focuses on the following themes:

- The general development in the Nordic F-gas emissions, applied methodologies and data sources
- Continue development of methodologies for End-of-Life emissions and benchmark of the Nordic F-gas emissions
- Establish overview of regulation and control of unintended emissions from A/C and Heat pumps at building demolition and renovation
- Continue the ongoing analysis of Nordic bulk import, illegal import of F-gases, and methods for forecasting emission calculations
- The development of HFOs as substitute for HFCs

The project comprises the following Nordic countries:

- Denmark
- Finland
- Iceland
- Norway
- Sweden

The actual Nordic F-gas Inventory workgroup participants (2022) are:

- Lene Skyrudsmoen, Berit Storbråten, Statistics Norway, Norway
- Birgir Urbancic Ásgeirsson, Sigridur Røs Einarsdottir, Umhverfisstofnun, Iceland
- Helena Danielsson, Tomas Gustafsson, IVL Swedish Environmental Research Institute, Sweden
- Tomas Sander Poulsen, Provice, Denmark
- Tommi Forsberg, Finnish Environment Institute, Finland

The Nordic F-gas Inventory workgroup was established in January 2017 and has held regular meetings with varying topics for discussion. The topics for discussion within this project have been e.g.:

- Assessment of the methodologies and emission factors used for the calculation of emissions from end-of-life
- Methods for projection of F-gas emission to 2040 forecast
- National methods and reference data for calculating stock emissions
- The revised IPCC refinements
- Experience from revised calculation of SF6 emission in Norway
- Emission calculation and emission factors from RAC's in vessels
- Trends and development for HFO's in the Nordic countries
- Data sources for emission calculation of F-gasses from MDI
- Development for bulk import of HFC's in the Nordic countries

A Nordic workshop for dissemination and discussion of the results and Nordic representatives is organized and held in august 2022 with participants with experiences from F-gas regulation, the refrigeration and air-conditioning (RAC) industry, and other interested F-gas specialists

Objective

The project is a continuation of the Nordic F-gas Inventory Group's work to develop and coordinate science and methods for calculating F-gas emissions in the Nordic region and to continue the work for a more uniform Nordic approach to calculating F-gas emissions. Our previous results and method development have led to various reassessments and improvements of data and emission factors.

The overall objective with the project is to provide an overview of differences and similarities within the Nordic countries in relation to F-gases. To a certain extent, the Nordic countries infrastructure and legislation for disposal of refrigeration and air-conditioning equipment and installations are similar. The analysis shall enable harmonization of data collection, emission factors and choice of methods.

1. Overview and benchmark of the Nordic F-gas emission

The total Nordic F-gas emissions from handling, use and disposal of F-gases were in 2020 estimated to approx. 3.44 M. tonnes of CO_2 eqv. Compared to 2019, the total Nordic CO_2 eq. emission has reduced with 0.23 M. tonnes CO_2 eqv. During the period 2015-2020, the total Nordic emissions deriving from the use of F-gases have decreased by approx. 0.8 M. tonnes of CO_2 eqv., according to the latest national inventory data submitted to the UNFCCC. The emission reduction is believed to mainly stem from the introduction of more modern equipment and the substitution of HFCs with less greenhouse gas potent refrigerants (e.g. CO_2, NH_3 and HFOs).

In overall the various national recalculations in the period from establishment of the Nordic F-gas Inventory workgroup have led to a total estimated decrease of the Nordic F-gas emission inventories of approx. 2.27 M. tonnes of CO_2 eqv. (emission calculations during the last 5 submissions). The decrease is especially because of changes in modelling End-of-Life emissions. The decrease is the consequence of aggregated and recalculated emissions for the full timeseries.

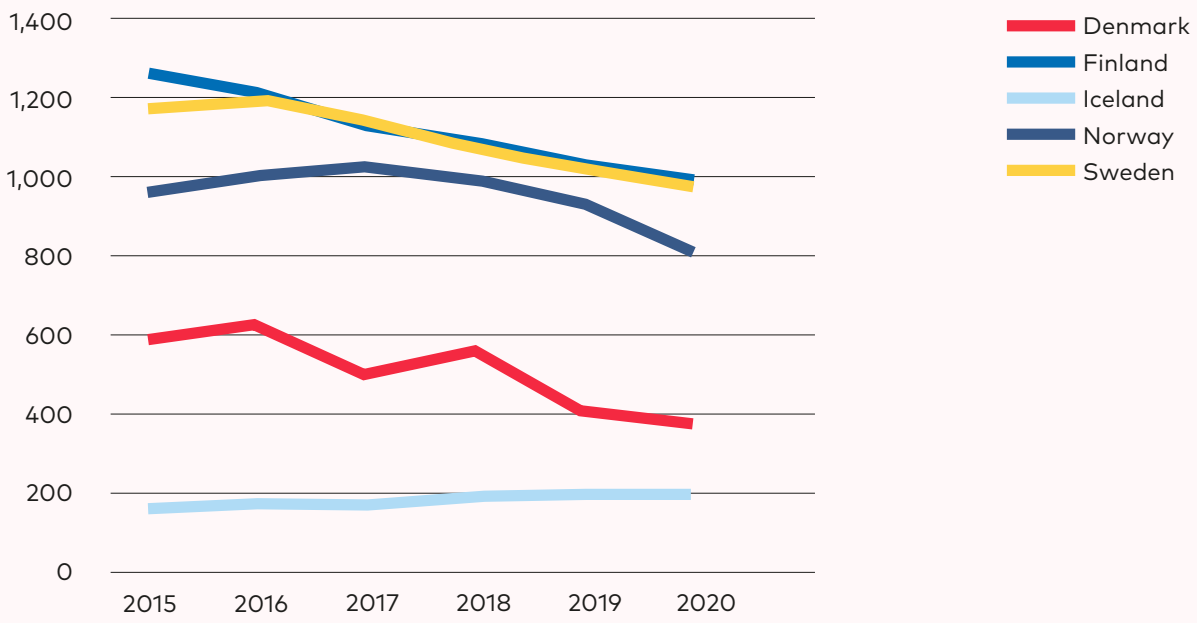
Overall, the sum of emissions of the Nordic countries have reduced significantly from 2015 to 2020. The latest total F-gas emission data according to the 2022 submission to the UNFCCC with updated methods and emission factors, are summarized in the table below.

Total emission, 1 000 t CO_2 eqv.	Denmark	Finland	Iceland	Norway	Sweden	Total
2015	594	1 262	165	964	1 175	4 160
2016	631	1 212	183	1 006	1 196	4 227
2017	503	1 137	176	1 029	1 146	3 990
2018	566	1 087	195	997	1 071	3 916
2019	408	1 031	205	934	1 022	3 601
2020	380	997	201	810	978	3 365

Table 1: The development in Nordic F-gas emission (HFCs, PFCs, SF61) 2015-2020
[1] NF3 emissions are not occurring in the Nordic countries.

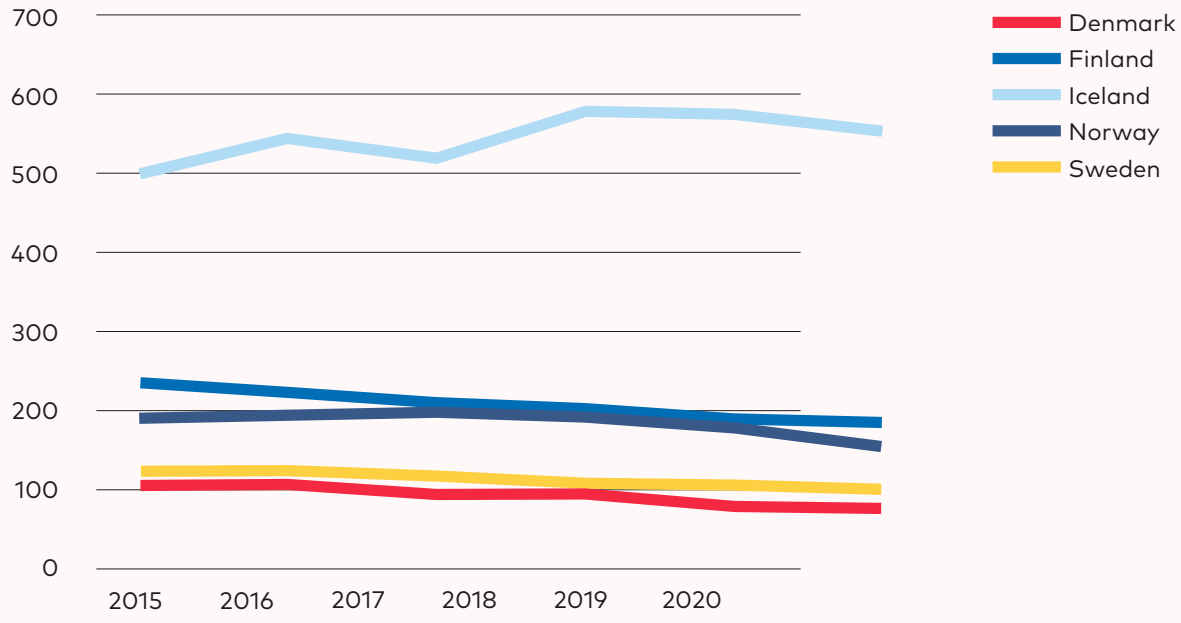
The figure 1 below illustrate the total F-gas emissions per country from 2015 to 2020. Denmark, Finland, Norway and Sweden all have a decrease in the total F-gas emission. Iceland has a small increase, which are discussed further in the following.

Figure 1: Trend in total F-gas emission per country 2015-2020, 1 000 t CO_2 eqv.



The F-gas emissions per capita in the respective countries are illustrated in Figure 2.

Figure 2: F-gas emission pr. capita, kg CO_2 eqv.



Iceland has the highest emission per capita. Iceland has a relatively large fishing fleet with emissions from refrigeration systems on-board fishing vessels. Furthermore, Iceland is a small society with approx. 365 000 inhabitants (2020). This is considered as the main reason for the higher pr. capita emission. Finland has higher per capita emissions compared to Denmark and Sweden. A reason for this may be the relatively large stock of HFC refrigerants in direct centralized commercial refrigeration systems with large refrigerant charges that are still in use in Finland. Indirect systems using HFC refrigerants and smaller refrigerant charges have been used e.g. in Denmark due to national regulation.

At total levels, Sweden/Denmark and Finland/Norway are relatively equal when comparing F-gas emissions per capita. Consequently, the Swedish/Danish emissions per capita are less than half of per capita emissions compared to Finland/Norway. The Nordic countries have relatively similar infrastructure and societal conditions. However, some special industrial conditions affect the emission level (Iceland, Finland). Otherwise, the differences are mainly caused by different methodological approaches and assumptions made for calculating the F-gas emissions, e.g. emission factors, stock in equipment and data collection.

Emissions divided into life-cycle stages

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). Table 2 shows emissions per life cycle 2017-2020 by Nordic countries. In total, emissions decreased by about 600 k tonnes CO_2 eq. 2017-2020.

F-gas emission	Charging of new equipment	During lifetime	Disposal	Total
DK 2017	12	389	102	503
DK 2019	8	303	97	408
DK 2020	6	288	86	380
FI 2017	4	1 007	126	1 137
FI 2019	1	911	120	1 031
FI 2020	1	881	115	997
IS 2017	2	158	16	176
IS 2019	2	176	27	205
IS 2020	0	165	36	201
NO 2017	2	648	435	1 085
NO 2019	2	557	443	1 002
NO 2020	2	532	349	884
SE 2017	33	978	135	1 146
SE 2019	19	887	117	1 022
SE 2020	14	855	109	978
SUM 2017	51	3 144	794	3 990
SUM 2019	31	2 786	783	3 601
SUM 2020	22	2 668	676	3 365

Table 2: The Nordic F-gas emissions divided in life-cycle stages

Norway had the largest total decrease from 2017 to 2020 of approx. 202 000 tonnes CO_2 eqv. Sweden had a decrease of 168 000 tonnes CO_2 eqv., Finland had a decrease of 140 000 tonnes CO_2 eqv., and Denmark had a decrease of 122 000 tonnes CO_2 eqv. Only Iceland has an increase from 2017 to 2020 of approx. 25 000 tonnes CO_2 eqv.

Table 3 below identifies the Nordic emission relative contributions at life cycle stages per country. For 2020 the largest life cycle stage contributions are from Finland (26.2%) and Sweden (25.4%) and Norway (14.2%) at the operation phase.

Share of total emissions	Charging of new equipment	During lifetime	Disposal	Total
DK 2017	0.3	9.8	2.5	12.6
DK 2019	0.2	8.4	2.7	11.3
DK 2020	0.2	8.6	2.6	11.3
FI 2017	0.1	25.2	3.2	28.5
FI 2019	0.0	25.3	3.3	28.6
FI 2020	0.0	26.2	3.4	29.6
IS 2017	0.1	4.0	0.4	4.4
IS 2019	0.1	4.9	0.8	5.7
IS 2020	0.0	4.9	1.1	6.0
NO 2017	0.0	15.4	10.4	25.8
NO 2019	0.0	14.2	11.8	25.9
NO 2020	0.0	14.2	9.8	24.1
SE 2017	0.8	24.5	3.4	28.7
SE 2019	0.5	24.6	3.2	28.4
SE 2020	0.4	25.4	3.2	29.0
SUM 2017	1.3	78.8	19.9	100.0
SUM 2019	0.9	77.4	21.8	100.0
SUM 2020	0.6	79.3	20.1	100.0

Table 3: Overview of the Nordic F-gas emission contribution between countries and lifecycle stages (percentages)

The average Nordic F-gas contribution from each life cycle stage 2020 is 0.6% from charge, 79.3% from stock/operation and 20.1% from End-of-Life. From *2017* to 2020 there is a decrease of F-gas emissions at charge and End-of-Life stages from all Nordic countries.

Following should be noted:

- Contribution from *charge* has decreased in the period due to introduction of low GWP refrigerants and fewer bulk refrigerants installed.

- The charge emission from Sweden is also significantly higher than for the other Nordic countries, especially compared to Finland, Iceland and Norway where the charge emission is near zero. This is partly due to significant emissions from the Swedish vehicle manufacturing.

- Contribution from operation is relatively high due to old commercial refrigeration systems with R404A.

- The emissions at disposal from Norway are higher than for other Nordic countries due to different methodology regarding the determination of the amounts recovered.

The majority of F-gas emissions in the Nordic countries stem from refrigeration and air-conditioning (RAC) equipment.

2. Nordic methods for F-gas calculation at end-of-life

Background

This chapter summarizes the current understanding of the end-of-life situation in the F-gas emission inventories of the Nordic countries. Information is collected through a conducted survey circulated to the members of the Nordic F-gas Inventory group. The purpose is to establish a basis for introducing more accurate emission factors for estimating emissions from end-of-life within each sub-category.

All Nordic countries use the Tier 2a emission factor approach of the 2006 IPCC Guidelines to estimate F-gas emissions from different refrigeration and air-conditioning applications (CRF categories 2.F.1.a-f). According to the methodology, the emissions are estimated separately for the different life cycle stages of the equipment: charge of new equipment, lifetime (operation and servicing) and end-of-life (disposal of equipment). The amounts of refrigerants released from equipment at end-of-life depends on the amount of refrigerant left at the time of disposal (residual charge), and the portion recovered (recovery efficiency). The final emission factor for end-of-life emissions can be calculated with these two parameters. Residual charge of refrigerant in equipment being disposed of is expressed in percentage of full charge. Recovery efficiency is also expressed as percentage.

The CRF tables used for the reporting of greenhouse gas emission data for the UNFCCC and EU include reporting of "Recovery" under the emissions data in some of the F-gas categories. The Nordic countries follow the EU default approach when reporting the "Recovery" in the CRF tables. According to the default approach, "Recovery = amount of gas in products at decommissioning minus emissions of gas from disposal". This default approach originates from the capacity building workshop organized in 2016 under the review process of the Effort Sharing Decision (ESD).

There is no clear picture of the "End-of-life" situation for many products and installations containing F-gases, and emission calculations rely therefore often on default values provided for residual charge and recovery efficiency in the 2006 IPCC Guidelines or general assumption.

Method

The first step for the survey was to conduct an overview at national level, e.g. of the current status for recovery of refrigerants from systems at disposal and end-of-life emissions at sub-category level. The second step was to disseminate the survey results and eventually propose revised emission factors for estimation of F-gas emission from end-of-life for each relevant sub-category.

The survey comprises the following CRF sub-categories:

2.F.1.a Commercial refrigeration: Stand-alone Commercial Applications
Commercial refrigeration: Medium & Large Commercial Refrigeration
2.F.1.b Domestic refrigeration
2.F.1.c Industrial Refrigeration including Food Processing and Cold Storage
2.F.1.d Transport Refrigeration
2.F.1.e Mobile A/C
2.F.1.f Residential and Commercial stationary A/C, including Heat Pumps

The categories 2F2 Foam blowing, 2G1 Electrical equipment and 2F3 Fire extinguishers were not included since their effect on the total F-gas emissions is minor compared to refrigeration and air-conditioning equipment.

The survey was structured to provide information on:

- legal basis
- handling/treatment of refrigerants at end-of-life
- if available – quantitative data useful for calculating or estimating, e.g. amount of disposed gases/units or similar
- stakeholder contact relevant for interview or just for drawing up the overall picture for handling and disposal process

According to Article 8 of the EU F-gas regulation, the recovery of F-gases from the following equipment must be carried out by natural persons that hold the relevant certificates provided for by Article 10 of the regulation: the cooling circuits of stationary refrigeration, stationary air-conditioning and stationary heat pump equipment; the cooling circuits of refrigeration units of refrigerated trucks and trailers; stationary equipment that contains fluorinated greenhouse gas-based solvents; stationary fire protection equipment and stationary electrical switchgear.

2.F.1.a – Stand-alone Commercial Applications
These units are disposed of from supermarkets, restaurants and similar, apparently as "waste from business" and as a particular unit, with the F-gas included. The refrigerants containing F-gases used in these applications can be R-134A, or R-404A but also others are applied in such units. Usually this kind of waste collection/treatment is organized (and paid) directly between the company and the waste collector. It is assumed that the waste collector is legally bound to treat the units according to a certain procedure including controlled separate emptying of F-gas filling and disposal of the gas to a controlled facility.

The recovery efficiency rates applied in the emission inventories in the Nordic countries varies from 70-100%. EoL factors vary between 30-0%.

2.F.1.a – Medium and Large Commercial Applications
This category seems quite clear when it comes to recovery of refrigerants from systems at disposal. The owners are supermarkets and similar sectors with need for refrigeration etc. eg. restaurants. According to legislation, these units should be maintained by certified RAC companies on a regular basis. At end-of-life, these companies should also assure correct emptying of the filling. The waste collection is organized between RAC owner and RAC service company. The disposal is organized by the RC service company.

The recovery efficiency varies from 70 to 95% and the EoL factors vary between 30-5%.

2.F.1.b – Domestic refrigeration
These units are primarily collected from private households or delivered by private households to collecting points as a unit, with the F-gas included. The most commonly used F-gas refrigerant has been R-134A. Use of refrigerants with GWPs of 150 or higher in new household refrigerators and freezers is prohibited as of 2015 in the F-gas regulation. Usually this kind of waste collection/treatment is organized through the public service waste collecting. It is assumed that the waste collectors are only few operators operating with national contracts for e.g. WEEE waste and the operators are legally binded to treat the units after a certain procedure including controlled separate emptying of F-gas filling and disposal of the gas to controlled facility for destruction. In some cases, units can be exported for treatment in other countries.

The recovery efficiency varies from 70-100% and the EoL factors vary between 30-0%.

2.F.1.c Industrial Refrigeration including Food Processing and Cold Storage
The recovery efficiency varies from 80-95% and the EoL factors vary between 20-5%. Norway use reported figures for destroyed amounts as recovery, corresponding to a recovery efficiency between 22 and 32% in the period 2017-2019.

DK: Industrial refrigeration disposal emission is considered similar to medium and commercial refrigeration, see above.

2.F.1.d Transport refrigeration
F-gases in transport refrigeration are probably maintained by certified RAC companies. And this service can be specialised to few companies, e.g. for trucks, ships (trains). The F-gas should be emptied from RAC and disposed of as chemical gas or reused/recycled.

The recovery efficiency varies from 50-88,5% and the EoL factors vary between 50-11,5%. Norway use reported figures for destroyed amounts as recovery, corresponding to a recovery efficiency between 29 and 36% in the period 2017-2019.

2.F.1.e Mobile air-conditioning (MAC)
F-gases from MAC should be refilled by auto-repair shops only. Traditionally R-134A has been used in MACs. However, it has already been replaced by HFO-refrigerant R-1234yf in new passenger cars and small light duty vehicles as a consequence of the EU MAC directive (2006/40/EC). Other vehicles still mostly use R-134A. It is assumed that auto repair shops are certified/trained and legally binded to treat the units after a certain procedure including controlled separate emptying of F-gas filling and disposal of the gas to controlled facilities.

The recovery efficiency varies from 50-85% and the EoL factors vary between 50-15%.

2.F.1.f Residential and Commercial stationary A/C, including Heat Pumps
The RAC's are disposed from many kinds of companies, apparently as "waste from business". Heat pumps can be disposed from both private households and companies as a particular unit, with the F-gas included. Heat pumps are classified as WEEE waste. This sub category is rather unclear when it comes to EoL, because the owners of RAC's, e.g. office building not necessarily are aware of the F-gas problem, and it might be overlooked at demolition or renovation projects, if no certified RAC company are requested to maintain service and closing of the unit. There are examples/stories about demolition workers, that simply cut the pipes while the F-gas filling emit. The same situation can occur at private homes, if a "do-it-your-self" person wants to remove the heat pump and does not call a RAC company (and pay them) to remove the unit. It is interesting to find out, if you have a legislation that assures correct disposal for private households.

The waste collectors are legally required to treat the units after a certain procedure including controlled separate emptying of F-gas filling and disposal of the gas to controlled facilities.

The recovery efficiency varies from 75-100%.

F-gas data for volume collected/year or waste management statistic

Denmark
The volumes of f-gases are not registered.

Units of collected refrigerators and freezers are registered through the WEEE collection scheme but does not contain information on F-gas contents. Stakeholders handling WEEE does not document and register amounts of F-gases emptied from applications.

Finland
Finland reports WEEE data annually to the European Commission. This data contains also data on refrigeration and cooling equipment. However, any figures for refrigeration and cooling equipment are not identifiable from the data. The same also applies to the national waste statistics.

Iceland
The Icelandic Recycling fund repays a fee (356 ISK for recycling and 626 ISK for destruction, 2020) of F-gases. Companies can send the information about how much F-gases are exported to destruction to the Recycling fund, which is paying them back, regardless of the type of F-gases.

The Recycling fund had received following amounts of F-gases for further export/disposal during the past years[1].

	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
t	2,3	2,4	0,7	0,7	1,3	0,5	1,5	0,8	3	4,4	3,2	3,5	2,5

Table 4: F-gases received for disposal by Iceland Recycling Fund

Norway
It is assumed that financial incentives increase the returns of F-gas for destruction in Norway. With high taxes on import, Norway has introduced a system for refund of tax if the F-gases are delivered for destruction. As the tax rate depends on the type of gas (high gwp leads to high tax), the gas is analysed before destruction to ensure correct refund and documentation. These amounts are the base for the calculations of recovery in Norway.

The table below contains the destroyed amounts of different F-gases during the period 2015-2020.

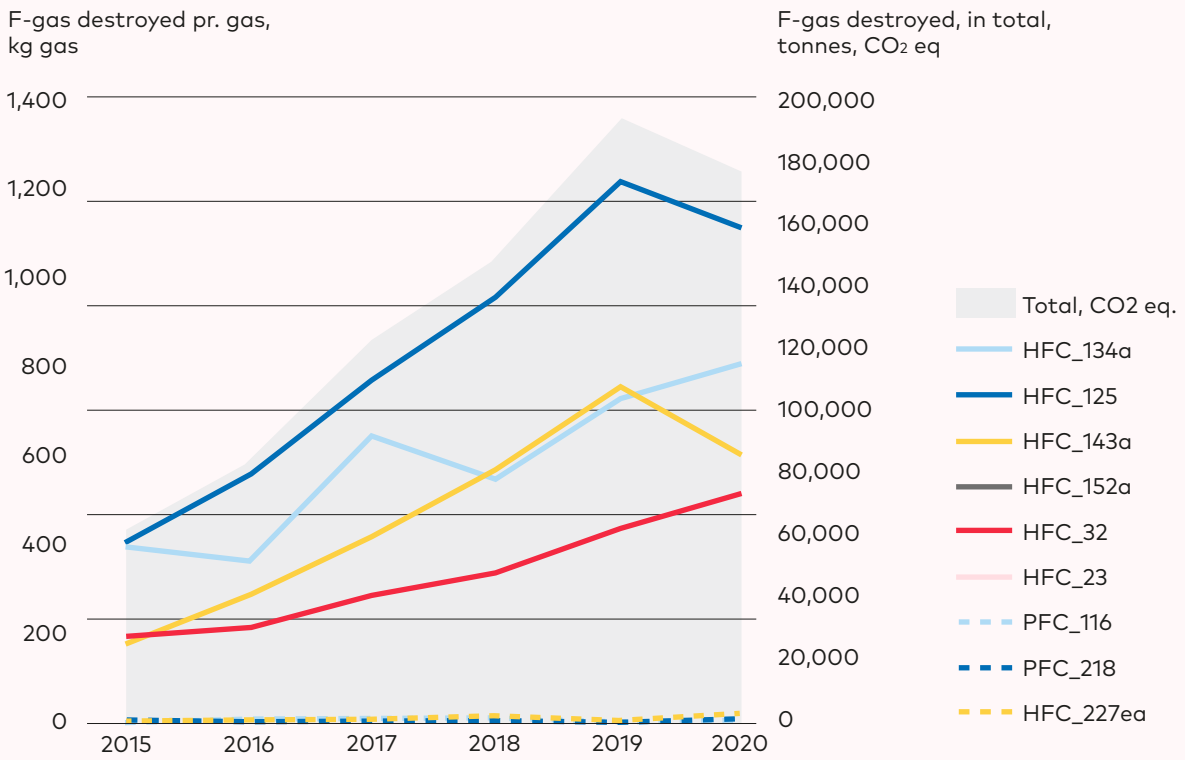
1 E-mail from Íris Gunnarsdóttir iris@irf.is from 20/12/2019 and updated with 2019 and 2020 figures by Birgir Asgairsson, Umhverfis.

	2015	2016	2017	2018	2019	2020
HFC-134a	8.4	7.8	13.8	11.7	15.6	17.2
HFC-125	8.7	11.9	16.4	20.4	25.9	23.7
HFC-143a	3.8	6.2	9.0	12.2	16.1	12.8
HFC-152a	0.1	0.1	0.0	0.0	0.0	0.0
HFC-32	4.1	4.6	6.2	7.2	9.3	11.0
HFC-23	0.0	0.0	0.0	0.0	0.0	0.1
HFC-116	0.0	0.0	0.0	0.0	0.0	0.0
HFC-218	0.0	0.0	0.0	0.0	0.1	0.0
HFC-227ea	0.0	0.0	0.0	0.3	0.0	0.4

Table 5: Destructed amounts, tonnes gas, Norway

The figure below illustrates development in the Norwegian refund and destruction of F-gases.

Figure 3: Development in amounts of F-gas destructed in Norway, 2015-2020. Amounts per kg gas and total in tonnes CO_2 eqv.



Sweden
Sweden reports WEEE data to the European Commission. Reported data cannot be used to estimate the quantities imported / exported as recovered HFCs, HCFCs and CFCs are reported together. No national data on imported / exported amounts of recovered HFC is available.

Procedures for handling and destruction of f-gases (gas)

Denmark
Kølebranchens Miljøordning – KMO. The refrigeration industry's environmental scheme (KMO) handles the authorization of companies and persons who must work with refrigerants,

Category 1 approval requires working with fillings over 2.5 kg. (4 years of professional training as a cooling technician)

Category 2 approval is required for fillings under 2.5 kg. (14 days course), i.a. authorization for decommissioning and emptying.

KMO member list of approved companies with authorization can be found on KMO's website (www.kmo.dk).

When performing installation, servicing, maintenance, repair or decommissioning of plant or equipment, leakage control or recycling of fluorinated greenhouse gases, you must have approval from KMO. Importers of F-gases may only sell HFC refrigerants to certified companies.

KMO is financed by importers / wholesalers through a smaller charge on the sale of HFC refrigerant. If the gas can be reused, DKK 10 is refunded and if the gas is to be destroyed, DKK 5 is refunded. The wholesalers provide pressure bottles service companies can use for bottling.

KMO approves the provision of authorization courses. Courses are held at private and technical schools.

Finland
All the requirements for handling of F-gases at end-of-life come from the EU regulation on F-gases. F-gases are removed and collected from the equipment when they are decommissioned (either on-site or at the end-of-life treatment facilities).

Iceland
Gases are collected by service companies from units including fishing ships (Transport refrigeration) and commercial and industrial units (Commercial and Industrial refrigeration) without distinguishing different blends/species and hand them over to a specialized company such as Terra Efnaeyding in dealing with waste/hazardous waste.

There is no facility in Iceland wich provides cleaning and remarketing of F-gases.

All collected F-gases are exported to third countries, mainly Denmark (H.J.Hansen).

The gases are extracted by service companies from appliances but also collected in bulk under the form of containers; that is single appliances are brought collected from privates or over the local waste collection system and also third parties, such as companies dealing specifically with F-gases bring their collected F-gases to this company.

The quantity sent to Denmark since 2013 are summarized in the table below.

Year	Quantity (kg)
2013	0
2014-march	251
2014-november	504
2015	0
2016	261
2017	1 353
2018	941
2019	0
2020	0

Table 6: F-gases from refrigerants exported to destruction

The Icelandic Recycling fund repays a fee

Norway
The EU F-gas regulation (517/2014) is implemented in Norway and F-gases in equipment are removed and collected at end of life. All handling of collected F-gas in Norway is administered and coordinated by the association Stiftelsen Returgass (SRG).

Sweden
Sweden follows the EU regulation (517/2014) and the Swedish F-gas regulation (2016:1128). F-gases in equipment are removed and collected at end-of-life.

Procedures for handling and destruction of insulation foam

Denmark
No certain procedures or requirements for destruction of insulation foam with f-gases.

Finland
The treatment facilities that receive equipment containing insulation foams process the foams as part of the treatment process. The equipment bodies containing the foam are crushed and the resulting fraction containing the foam is recovered.

Norway
No data available.

Sweden
The treatment facilities that receive equipment containing insulation foam process the material and the F-gases are collected.

Available data for collected F-gas for destruction

Denmark
No data available.

Finland
The total annual amounts of destructed refrigerants is available from the only destruction facility operating in Finland. In addition, data on amounts of refrigerants delivered for destruction is collected annually in the GHG-inventory from the RAC service companies.

Norway
Norway has good information on the F-gas collected for destruction. When the collected gas is sent to the destruction facility all gas is analysed, and composition and amount of each component in the gas is quantified.
This info leads to a total amount sent for destruction each year. There is no information on source/ where the gas has been used before it is sent for destruction. To distribute the gas between the different sources there is a calculation based on a number of assumptions.

Sweden
Sweden has no data on amounts of F-gases collected and destructed. The emission model assumes that all gas is destroyed.

Identified national stakeholders with treatment facilities

Denmark
Fortum Waste Solutions - https://www.fortum.dk/ receives f-gases for destruction

H.J. Hansen - https://hjhansen.dk/ receives refrigerators and freezers for waste treatment. Foam is sent to external part for shredding. F-gases are sent to Fortum Waste Solutions

Finland
Two facilities in Finland have environmental permits for handling of refrigerant wastes, Fortum Waste Solutions (in Riihimäki) for destruction and Eco Scandic (in Helsinki) for recovery & reclamation. In addition to these, there are several treatment facilities in Finland and some of them have crushing plants. End-of-life refrigerant equipment is processed in these facilities. Refrigerants recovered from the processed equipment are sent to destruction or reclamation.

Iceland
Terra Efnaeyðing is the only company in Iceland handling disposal of HFC´s. Efnarás/Hringrás and Íslenska gámafelagið collect equipment containing F-gases.

Norway
Stiftelsen Returgass / Isovator AS

Sweden
There are several treatment facilities that receive equipment containing F-gases at end-of-life, e.g. Fortum Waste Solution. The F-gases in the equipment are removed and collected.

F-gas waste export

Denmark
Parts of waste refrigerators and freezers are sent to Germany for treatment/recycling. Whether treatment is contracted in DK or abroad depends on specific tenders between municipalities responsible for household waste and treatment facilities.

Finland
As a general rule, a permit is required for trans frontier shipments of waste. The supervision and control of international waste shipments is based on Basel Convention on the control of trans frontier movements of hazardous wastes, on the OECD Decision on the control of trans frontier movements of waste destined for recovery operations and on EU Waste Shipment Regulation. Finland reports annually on the trans frontier shipments of waste to the Basel convention. The reporting data includes exports and imports of refrigerating devices. However, the data does not include any specification of more detailed equipment types. Some stand-alone commercial equipment may be included in the data. In addition, refrigerants may or may not have been recovered from the equipment prior to shipment. It is not possible to take this data into account in the F-gas emission estimation due to lack of details in the data.

Refrigerants recovered from equipment at disposal are not exported from Finland.

Iceland
Iceland export F-gases to DK for destruction (see previous sections)

Norway
There is some waste exported from Norway to Sweden for destruction. These represent only small amounts of F-gas, but they are still registered by the Norwegian Environment Agency.

This data is not yet accounted for in the inventory causing a slight over-estimation. Norway is planning to include this data in the future estimations of emissions.

Sweden
Sweden reports WEEE data to the European Commission. Reported data cannot be used to estimate the quantities imported / exported as recovered HFCs, HCFCs and CFCs are reported together. No national data on imported / exported amounts of recovered HFC is available.

Requirements to register F-gas data from Transport refrigeration and MAC

Denmark
No specific national requirements to register data for recovered amounts from transport refrigeration or mobile air-conditioning equipment.

Finland
No specific national requirements to register data for recovered amounts from transport refrigeration or mobile air-conditioning equipment.

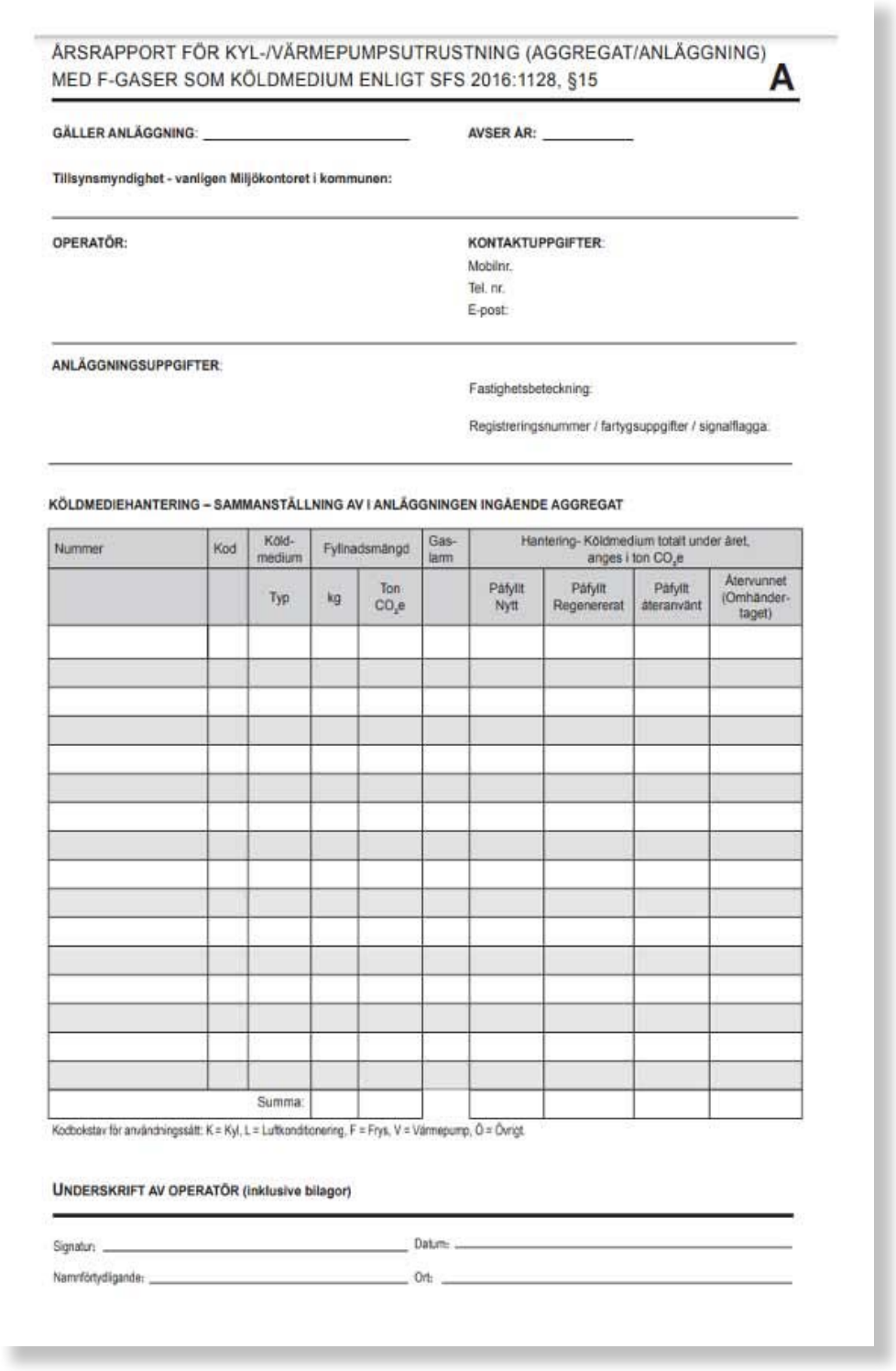
Norway
There is no specific national information on the transport sector. However, it is assumed that there is some reuse of gas from MAC, as well as destruction of recovered amounts by SRG.

Sweden
The operator shall submit a report to the supervisory authority if during any part of a calendar year there are at least 14 tonnes of CO_2 eq. in a stationary facility, in a facility on a ship or in a mobile equipment that is subject to leakage control in accordance with section 11 or in Article 3.3. second paragraph and 4.1-4.3 (refrigeration units of refrigerated trucks and trailers is specified in Article 4.2) of the EU regulation on f-gases.

The report shall include:

a. the quantity and type of fluorinated greenhouse gases installed;
b. the quantities of fluorinated greenhouse gases added during installation, maintenance or servicing or due to leakage;
c. whether the quantities of installed fluorinated greenhouse gases have been recycled or reclaimed, including the name and address of the recycling or reclamation facility and, where applicable, the certificate number;
d. the quantity of fluorinated greenhouse gases recovered;
e. the identity of the undertaking which installed, serviced, maintained and where applicable repaired or decommissioned the equipment, including, where applicable, the number of its certificate;
f. the dates and results of the checks carried out under Article 4(1) to (3);
g. if the equipment was decommissioned, the measures taken to recover and dispose of the fluorinated greenhouse gases.

Below you can see the format for reporting in Sweden:



ÅRSRAPPORT FÖR KYL-/VÄRMEPUMPSUTRUSTNING (AGGREGAT/ANLÄGGNING) MED F-GASER SOM KÖLDMEDIUM ENLIGT SFS 2016:1128, §15 **A**

GÄLLER ANLÄGGNING: _____ **AVSER ÅR:** _____

Tillsynsmyndighet - vanligen Miljökontoret i kommunen:

OPERATÖR:

KONTAKTUPPGIFTER:
Mobilnr.
Tel. nr.
E-post:

ANLÄGGNINGSUPPGIFTER:

Fastighetsbeteckning:

Registreringsnummer / fartygsuppgifter / signalflagga:

KÖLDMEDIEHANTERING – SAMMANSTÄLLNING AV I ANLÄGGNINGEN INGÅENDE AGGREGAT

Nummer	Kod	Köld-medium	Fylinadsmängd		Gas-larm	Hantering- Köldmedium totalt under året, anges i ton CO_2e			
		Typ	kg	Ton CO_2e		Påfyllt Nytt	Påfyllt Regenererat	Påfyllt återanvänt	Återvunnet (Omhänder-taget)
		Summa:							

Kodbokstav för användningssätt: K = Kyl, L = Luftkonditionering, F = Frys, V = Värmepump, Ö = Övrigt

UNDERSKRIFT AV OPERATÖR (inklusive bilagor)

Signatur: _____ Datum: _____

Namnförtydligande: _____ Ort: _____

Legislation references for decommissioning at EoL

Denmark
No requirements beside the general F-gas framework, however procedures are stipulated in the EU F-gas legislation, which Denmark has implemented. But it should be noted that requirement for documentation of contents and disposal of F-gases at closing is not stipulated in Danish legislation.

Iceland
No requirements beside the general F-gas framework

Norway
No requirements beside the general F-gas framework

Finland
No requirements beside the general F-gas framework

Sweden
There are requirements beside the general F-gas framework. The Swedish regulation (SFS 2016:1128) is sharper than the EU 517/2014 because the Swedish regulation also includes mobile equipment in the requirements for certificates and leakage control.

Certification of auto repair shops to handle F-gases

Denmark
KMO certificate and authorization is required for all personnel handling f-gases. Auto repair shops need also KMO certificate to be able to purchase F-gases from DK importers

Finland
Companies and persons working in the field of refrigeration or AC handling F-gases must have appropriate approval and qualification granted by Finnish Safety and Chemical Agency Tukes.

Iceland
Certification required

Norway
Certification required

Sweden
Certification required

Available data for disposal of F-gases from MAC

Denmark
No data available.

Norway
There is no detailed information on the amounts sent to destruction each year available. However, it is established contact with the industry association and gathered data has led to a reliable quantification of recovery (reuse and destruction) at end-of-life.

Finland
No specific collected F-gas data is available for disposal of MACs. End-of-life vehicle data is available and also annually reported to the European Commission. However, this data does not contain any information of F-gases or MACs. In the emission calculation model, the amounts of F-gases in road vehicle MACs at disposal are estimated with the help of average lifetime. Activity data for the disposal emissions is the annual new registration from the year n-average lifetime. Emission factors are default values from the 2006 IPCC GL, 50% for initial charge remaining and 50% for recovery efficiency.

Sweden
No data available.

Legislation references for refilling and decommissioning A/C at EoL

Denmark
Heat pumps from private household are not necessarily handled by certified personal at EoL. Potential for emission. The DK recovery rate is 100% due to general legislative requirements. However, it might not include the fact, that heat pumps – which constitute a larger part of the category's stock – not always are recovered 100%.

Stationary A/C in office buildings above 2,5 kg are maintained by certified personnel. But there is a "black box" regarding EoL, while service companies not always close down the systems. Owners are not inspected on this topic and requirements for documentation is not stipulated en the DK legislation even through it is stated in the F-gas regulation (that system owners have to document the close down of a system in a logbook).

Regulation could be clearer on requirements for owner documentation of system close down and track of refrigerants.

DK has no estimate for accidental leakages, e.g. at demolition, but suppose it happen to a certain extend.

Norway
All service and disassembling of air conditions are to be carried out by certified personnel, both in households and other buildings. In the Norwegian calculation model there is no difference between domestic heat pumps and other stationary AC. As previously described, Statistics Norway receives figures on the total amount of HFC/PFC delivered for destruction each year. Hence, the recovery rate is calculated from this information.

Finland
According to the EU F-gas Regulation, all service and recovery of F-gases at end-of-life must be carried out by certified personnel.

The building sectors awareness to handle F-gases at demolition/renovation

Denmark

They have internal instruction and plans and screening of demolition work. Thus, they do not always receive relevant information from building owners with regard to installations, and accidental leakages can occur, e.g. in renovation projects, with many unknown pipes.

Installation of units with F-gases not included in building permits. No registration of A/C in building registers, e.g. at municipalities.

Finland

No specific study has been conducted on the awareness. Nevertheless, companies and persons working in the field of refrigeration or AC handling F-gases must have appropriate approval and qualification granted by Finnish Safety and Chemical Agency Tukes.

F-gases and their recovery are generally not mentioned separately in the building permits. In general, regarding ecological considerations in buildings in the Land Use and Building Decree, permit applications and notifications concerning the construction or demolition of a building or part of a building shall include an account of the amount and type of construction waste and how it will be sorted, unless the amount of waste is minor. Applications and notifications shall report separately any construction and demolition waste that is harmful to health or the environment, and how it will be disposed of. Municipalities are the building supervision authorities in Finland.

F-gases are not registered in building registers in Finland. The Finnish Building and Apartment Registry (RHR) contains information on air-conditioning in buildings. But no information on refrigerants is registered. The number of air-conditioning units is not registered, only the information whether AC is installed or not. In addition, the data is not comprehensive and a lot of data gaps exist.

Norway

No investigations have been carried out into whether the F-gas regulations are followed in the event of demolition or major renovation of buildings. Any activity that does not comply with the regulations is assumed to be small, and any breaches that lead to emissions of F-gas are not taken into account in the calculations.

Iceland

No studies or data available.

Sweden

No studies or data available. It is unknown to what extend the F-gas regulations are followed in the event of demolition or renovation of buildings.

Summary and conclusions

	DK	FI	IS	NO	SE
Authorization and certification scheme required to handle F-gases (all categories)	X	X	X	X	X
Refund for F-gases delivered for disposal	X		X	X	
Disposal of F-gases free of charge (or income)			X	X	X
Data for F-gases received for destruction		X	X	X	
Recovery of F-gases in insulation foam		X			X
Export of F-gases for destruction	X		X	X	X

Table 7: Overview of Nordic approached according to EoL

- F-gases in the Nordic are collected by authorised and certified personnel/companies
- F-gases are destructed at controlled facility
- EU F-gas regulation require certification for operators handling F-gases in MAC
- No available data for handling of F-gases at decommissioning of air-air heat pumps in private sector
- No Nordic countries include registration of A/C in building registers (and building permits)

3. Emission factors for the recovered amounts of refrigerants at end-of-life/disposal

End-of-Life emissions

The Nordic countries are quite similar in their approach to waste management and handling. Organized collection and access to incineration, special treatment, and recycling facilities are a common part of the infrastructure, except for Iceland where parts of the waste are disposed at landfills.

In addition, the Nordic countries have quite similar regulation of F-gases. Denmark, Finland and Sweden have implemented the F-gas regulation in national legislation, and Norway and Iceland have applied similar regulation requiring collecting, handling and disposal of F-gases by certified persons and companies.

However, from a methodological point of view, there are differences in the applied emission estimation parameters (recovery efficiencies and residual charges) and activity data sources between the Nordic countries. The differences do not correspond to the fact that the waste management frameworks are rather similar.

Approach

For Denmark, Finland, Sweden and Iceland, the estimation of end-of-life emissions is based on expected quantities (refrigerants initially charged to the systems) and not on monitored data for collected F-gases. In case of Norway, the recovery rate is based on registered data of F-gases collected for destruction, refund taxes and assure further recycling or disposal.

The Nordic countries apply in some cases relatively high recovery efficiencies in the emission estimation, and for Denmark and Sweden, the applied recovery efficiencies actually exceed the default range provided in the IPCC 2006 Guidelines for some of the main sub-categories.

A Norwegian study indicates that the recovery rate for stationary A/C applications in reality is rather low. The study stipulates that there are large differences between amounts put into the market and amounts received for controlled destruction at end of life[2]. Even though stakeholders receive a high refund per kg F-gas (600 – 1,700 DKK per kg), only 16% of the installed amounts of F-gasses in A/C installations are received for destruction.

Thus, it is likely that a larger amount is recycled/recovered that the amounts registered. The study also included a survey which concludes that approx. 50% of the interviewed Norwegian service companies recycle refrigerants. It indicates that the total amount installed is much larger than estimated.

The study also concludes that approx. 50% of all heat pumps delivered for disposal as WEEE waste, were emptied of F-gases. In theory, these charges could all have been emitted.

New emission factors for end-of-life emissions

The project has explored the emission factors for end-of-life emission estimation at category level per country to assess and compare similarities and differences.

2 (Utredning av flourholdige gasser i Næringsbyg, marts 2018)

An overview of Nordic status for the actual applied emission factors is provided in the following tables. The tables describe the recovery efficiencies and residual charges (initial charge remaining) applied in the estimation of end-of-life emissions per category with each country's remark to implemented revisions of emission factors or considerations regarding future revisions.

The main considerations in relation to EoL emission factors among the Nordic countries are summarized in the table below.

CRF Category	Revision considerations
2.F.1.a: Stand-alone Commercial applications	NO: EF update is considered. Await answers from the waste industry for final decision
2.F.1.a: Medium and Large Commercial refrigeration	NO: Initial charge remaining changed to 80% in 2021-submission after receiving information from the industry. Recovery from EoL is estimated from figures on the destroyed amount. Consider increasing the recovery by including reuse in addition to the amounts destroyed. DK: Await more documentation, but minimum 90% as stated in BREFs
2.F.1.b: Domestic refrigeration	NO: Changes in the EF will be considered. More data will be collected to support an update. FI: Recovery efficiency updated in submission 2022 (70% in 2005 and 90% in 2015).
2.F.1.c: Industrial Refrigeration	NO: Initial charge remaining and lifetime has been updated in the 2021 submission after receiving information from the industry. Recovery from EoL is estimated from figures on the destroyed amount. Consider increasing the recovery by including reuse in addition to the amounts destroyed. DK: Await more documentation, but minimum 90% as stated in BREFs FI: Recovery efficiency updated in submission 2022 (80% in 2009 and 90% in 2015)

Continues ...

CRF Category	Revision considerations
2.F.1.d: Transport Refrigeration	NO: Changes are considered. More data needs to be collected. Consider increasing the recovery by including reuse in addition to the amounts destroyed. DK: Await more documentation, but minimum be 90% as stated in BREFs IS: Since 2020, 70% recovery are applied and not planning to change due to absence of better data. EF was changed from 75% to 70% to be within the IPCC Guidelines range and in absence of references which could confirm 75%. lifetime of appliance). FI: Recovery efficiency updated in submission 2022 (50% in 1998 and 70% in 2015).
2.F.1.e: Mobile A/C	SE: Possibly revise to submission 2022. Might be too high at the moment. NO: Initial charge remaining and recovery efficiency were updated in the 2021 submission after receiving information from the branch organization DK: Has no stock estimates as reference for recovery emission because of selected calculation method
2.F.1.f: Residential and commercial A/C including heat pumps	SE: Maybe change for air-to-air heat pumps. NO: Lifetime increased to 18 years in the 2021 submission. Recovery from EoL is estimated from figures on destructed amounts. Consider increasing the recovery by including reuse in addition to the amounts destroyed. DK: Await more documentation, but minimum 90% as stated in BREFs FI: Recovery efficiency updated for other stationary AC equipment in submission 2022. (80% in 2005, 90% in 2015 and 95% in 2020). Recovery efficiency for large heat pumps is also 95% but they haven't been decommissioned by 2020 (the latest reporting year in submission 2022). Recovery efficiency for all other heat pumps is 80% for the whole time series.

Table 8: Overview of emission factor consideration related to EoL

	Charge (kg)	Lifetimes (years)	Recovery Efficiency	Initial Charge Remaining	New recovery Efficiency	Comment
IPCC 2006 Guidelines	0.2 ≤ M ≤ 6	10 ≤ d ≤ 15	0 < ηrec,d < 70	0 < p < 80		
Sweden	NE	10	95	90		No plan to change
Norway	NE	10	0	65	70-90	EF update is considered. Await answers from the waste industry for final decision.
Denmark	NE	15	100			No plans for change
Finland	0.4	10	70	80	95	Recovery efficiency updated in submission 2022 (70% in 2004, 90% in 2015 and 95% in 2020).
Iceland	NE	8	70			EF changed from 80 to 70 in 2020 submission

Table 9: Commercial refrigeration – stand-alone Commercial applications 2.F.1.a

	Charge (kg)	Lifetimes (years)	Recovery Efficiency	Initial Charge Remaining	New recovery Efficiency	Comment
IPCC 2006 Guidelines	50 ≤ M ≤ 2 000	7 ≤ d ≤ 15	0 < ηrec,d < 70	50 < p < 100		
Sweden	NE	7	95	90	-	No plans for change
Norway	NE	15	based on known amounts of destroyed F-gas.	80	70-90	Initial charge remaining changed to 80% in 2021-submission after receiving information from the industry. Recovery from EoL is estimated from figures on the destroyed amount. Consider increasing the recovery by including reuse in addition to the amounts destroyed.
Denmark	10-600	15	88,5		90-100	Await more documentation, but minimum 90% as stated in BREFs
Finland	7-1 000	12	70	90	95	Recovery efficiency updatet in submission 2022 (70% in 2004, 90% in 2015 and 95% in 2020).
Iceland	NE	8	70			Since 2020 submission, 70% recovery EF has been applied. and there are no plans to change that due to absence of better data. It was changed from 80% to 70% to be within the IPCC Guidelines range and in absence of references which could confirm 80%

Table 10: Medium and Large Commercial refrigeration – 2.F.1.a

	Charge (kg)	Lifetimes (years)	Recovery Efficiency	Initial Charge Remaining	New recovery Efficiency	Comment
IPCC 2006 Guidelines	0.05 ≤ M ≤ 0.5	12 ≤ d ≤ 20	0 < ηrec,d < 70	0 < p < 80		
Sweden	0,1	20	95	90	-	No plans for change
Norway	NE	15	0	92,5		Changes in the EF will be considered. More data will be collected to support an update.
Denmark	0,065 - 0,164	15	100	85	-	No plans for change
Iceland	0,25	12	70			No plans for change
Finland	0,1	12	70	80	90	Recovery efficiency updated in submission 2022 (70% in 2005 and 90% in 2015).

Table 11: Domestic refrigeration – 2.F.1.b

	Charge (kg)	Lifetimes (years)	Recovery Efficiency	Initial Charge Remaining	New recovery Efficiency	Comment
IPCC 2006 Guidelines	10 ≤ M ≤ 10000	15 ≤ d ≤ 30	0 < ηrec,d < 90	50 < p < 100		
Sweden	NE	15	95	90	-	No plans for change
Norway	NE	17	varies, based on known amounts of destroyed F-gas.	80		Initial charge remaining and lifetime has been updated in the 2021 submission after receiving information from the industry. Recovery from EoL is estimated from figures on the destroyed amount. Consider increasing the recovery by including reuse in addition to the amounts destroyed.
Denmark	NE	15	88,5		90-100	Await more documentation, but minimum 90% as stated in BREFs
Iceland	NE	15	85			
Finland	NE	15, 20	80	90	90	Recovery efficiency updated in submission 2022 (80% in 2009 and 90% in 2015)

Table 12: Industrial Refrigeration – 2.F.1.c

	Charge (kg)	Lifetimes (years)	Recovery Efficiency	Initial Charge Remaining	New recovery Efficiency	Comment
IPCC 2006 Guidelines	3 ≤ M ≤ 8	6 ≤ d ≤ 9	0 < ηrec,d < 70	0 < p < 50		
Sweden	6-10	10	85	90	-	No plan to change
Norway	NE	9	based on known amounts of destroyed F-gas.	100	70	Changes are considered. More data needs to be collected. Consider increasing the recovery by including reuse in addition to the amounts destroyed.
Denmark	6-8	7	88,5		90-100	Await more documentation, but minimum be 90% as stated in BREFs
Iceland (fishing vessels)	NE	7	70			Since 2020, 70% recovery are applied and not planning to change due to absence of better data. EF was changed from 75% to 70% to be within the IPCC Guidelines range and in absence of references which could confirm 75%. lifetime of appliance).
Iceland (reefers)	5	NE	NE			No plans for change
Finland	NE	6	50	50	70	Recovery efficiency updated in submission 2022 (50% in 1998 and 70% in 2015).

Table 13: Transport Refrigeration – 2.F.1.d

	Charge (kg)	Lifetimes (years)	Recovery Efficiency	Initial Charge Remaining	New recovery Efficiency	Comment
IPCC 2006 Guidelines	0.5 ≤ M ≤ 1.5	9 ≤ d ≤ 16	0 < ηrec,d < 50	0 < p < 50		
Sweden	0.8 - 0.7 0.8 - 0.7 1.2 7 1 1.5	11 11 6 12 7 8 - 20	85 85 85 85 85 85	90 90 90 90 90 90	?	Possibly revise to submission 2022. Might be too high at the moment.
Norway	NE	12	50	60		Initial charge remaining and recovery efficiency were updated in the 2021 submission after receiving information from the branch organization
Denmark	0,75	NE	NE	NE		Has no stock estimates as reference for recovery emission because of selected calculation method
Iceland	0.8 passenger cars, 1.2 trucks, 10 coaches	14	0			No plans to change, we called the only car scraper company and they do not collect any F-gases when scraping the cars.
Finland	0,63-19,4	9, 12, 20	50	50	-	No plans for any changes.

Table 14: Mobile A/C – 2.F.1.e

	Charge (kg)	Lifetimes (years)	Recovery Efficiency	Initial Charge Remaining	New recovery Efficiency	Comment
IPCC 2006 Guidelines	0.5 ≤ M ≤ 100	10 ≤ d ≤ 20	0 < ηrec,d < 80	0 < p < 80		
Sweden, heat pumps	5-1	20 - 15	95	90	?	Maybe change for air-to-air heat pumps
Sweden	NE	10	95	90		
Norway	NE	18	varies, based on known amounts of destroyed F-gas.	80	70-90	Lifetime was increased to 18 years in the 2021 submission. Recovery from EoL is estimated from figures on destructed amounts. Consider increasing the recovery by including reuse in addition to the amounts destroyed.
Denmark A/C	NE	15	88,5	NE	90-100	Await more documentation, but minimum 90% as stated in BREFs
Denmark Heatpumps			80			No plans for change
Iceland	NE	12	75			No plans for change
Finland	0,23; 1; 2; NE	10, 12, 15, 20	80	80	95	Recovery efficiency updated for other stationary AC equipment in submission 2022. (80% in 2005, 90% in 2015 and 95% in 2020). Recovery efficiency for large heat pumps is also 95% but they haven't been decommissioned by 2020 (the latest reporting year in submission 2022). Recovery efficiency for all other heat pumps is 80% for the whole time series.

Table 15: Residential and commercial A/C including heat pumps – 2.F.1.f

	Use	Initial Charge Remaining	Recovery Efficiency	Lifetimes (years)	New recovery Efficience	Comment
IPCC 2006 Guidelines						
Sweden	GIS	98	98	35		No plan for change
Sweden	Distribution system	98	98	35		No plan for change
Norway	GIS	NO	90	50		No plan for change
Norway	Switch gear	NO	90	50		No plan for change
Denmark	GIS + switch gear	5	100	50		No plans for change
Iceland						At current knowledge no SF6 appliance has reached the end-of-life. The first installations of CB are from 1981 and 1989 and they are still in operation
Finland	GIS, circuit breakers	0,25				Emission factor for disposal emissions is 1,5%. No plans or change.

Table 16: Electrical equipment – 2.G.1

4. End-of-life emission estimation data

In general, the legislation with regard to handling and disposal of HFC-refrigerants (authorization and environmental permits) should assure that only professional personnel work with HFC's.

Regarding MAC systems. scrap companies are regulated with environmental permits and are obliged to treat and dispose of waste as stipulated in the permits. F-gases in mobile air-conditioning is waste for recycling or destruction.

Based on the received information of legal requirements, waste treatment and procedures established in the Nordic countries, it seems to be a high standard for handling and disposal of MAC refrigerants among scrap companies. ISO certification is a common state of art standard and companies have certified personnel to handle the F-gases from mobile air-conditioning. The procedure is to dispose F-gases to destruction facilities. It has not been possible to verify or cross check amounts of F-gases received by destruction facilities.

The effect of implementing updated end-of-life emission factors

All Nordic countries have made a simulation of the impact on calculated F-gas emissions, if/when new emission factors for EoL are changed. The simulation was conducted in the project during 2020. Countries have updated some end-of-life emission factors in the 2021 and 2022 submissions. More details of these updates are described in chapters 3 and in the national inventory reports of the submissions. Link to the most recent submission can be found here: https://unfccc.int/ghg-inventories-annex-i-parties/2022

The following changes has been simulated:

- Denmark has based the simulation on changing the recovery EF from 88,5% to 100% for 2.F.1.a (and b) and 2.F.1.f – stationary air condition. Air-air heat pumps remain unchanged (80% recovery at EoL)

- Finland has based the simulation on changing the recovery EF from 70% to 90% for 2.F.1.a and 2.F.1.b and changed recovery EF from 80% to 90% for 2.F.1.f

- Norway has based the simulation on changing the recovery EF for 2.F.1.a from 8-53% depending on particular year of recovery to 90% and the recovery EF for 2.F.1.f from 5-41% depending on particular year of recovery to 90%. The recovery is an average allocated to all categories based on amounts collected for destruction.

- Sweden has based the simulation on changing the EoL EF for 2.F.1.f – air-air heat pumps from 95% recovery efficiency to 80% recovery efficiency

- Iceland has no change

The total impact on Nordic emissions of F-gases in 2019 and for the full time series are:

All Nordic		
	Actual	New EoL EF
2019, CO_2 eqv. t (2018 for FI)		-246 693
1990-2019 CO_2 eqv. t		-3 184.802

Table 17: Impact from updated Nordic EoL emission factors

The impact by generally increasing the recovery efficiency in the models are substantial. For year 2019, it means a reduction of 246 993 tons CO_2 eqv. If the changes are to be introduced in the full time series 1990-2019, the impact is approx. 3.2 M. t CO_2 eqv.

Especially Finland and Norway have high impact and significant reduction of F-gas emission, if models and EF for recovery efficiency are increased. The Danish impact is more moderate and the Swedish impact leads to increased emission.

The following tables provide an overview of consequences at country level, if considered new emissions factors are applied. The consequences are calculated for the recent year and for the full adjusted historical time series.

Iceland does not consider preliminary changes of EoL emission factors, and they are not included in a separate country table.

Denmark		
	Actual	New EoL EF
2019, CO_2 eqv. t	333 138	299 723
Change in CO_2 eqv. 2019		-33 416
1990-2019 CO_2 eqv. t	13 646 792	12 870 670
CO_2 eqv. total		-776 122
Index, total	100	94

Table 18: Impact from updated DK EoL emission factors

Finland		
	Actual	New EoL EF
2018, CO_2 eqv. t	1 149 018	1 035 268
Change in CO_2 eqv. 2018		-113 750
1990-2018 CO_2 eqv. t	22 897 090	21 843 572
CO_2 eqv. total		-1 053 518
Index, total	100	95

Table 19: Impact from updated FI EoL emission factors

Norway		
	Actual	90%
2019, CO_2 eqv. t	348 275	242 952
Change in CO_2 eqv. 2019	0	-105 323
1990-2019 CO_2 eqv. t	5 074 935	3 706 522
CO_2 eqv. total	0	-1 368 413
Index, total	100	73

Table 20: Impact from updated NO EoL emission factors

Sweden		
	Actual	New EoL EF
2019, CO_2 eqv. t	115 888	121 683
Change in CO_2 eqv. 2019		5 795
1990-2019 CO_2 eqv. t	1 298 825	1 312 077
CO_2 eqv. total		13 252
Index, total	100	101

Table 21: Impact from updated SE EoL emission factors

In sum, the largest differences in emission factors between the countries are:

- Different emission factors for 2.F.1.a, b, d, and e, where especially FI use a relatively lower recovery rate because of different recovery assumptions

5. Unintentional release of F-gases from air conditioning and heat pump systems

The EU regulation 517/2014 states that, operators of air conditioning and heat pump systems shall take precautions to prevent the unintentional release ('leakage') of F-gases, and take all measures which are technically and economically feasible to minimise leakage. In addition, systems that contain f-gases of more than 5 tonnes of CO_2 eqv. must be checked for leaks regularly.

In contrast to refrigeration systems in industry and retail, the decommissioning of heat pump and A/C systems occurs to a larger extent in connection with building and construction tasks that include renovation or demolition. It is likely that authorized service companies are not always summoned, especially for smaller heat pump systems in residential houses, despite the fact that the service personnel are the only entities who have authorization to empty refrigerants from installations.

For air conditioning systems in buildings, it is assessed that the problem is limited. Most air conditioners are subject to periodic inspection and maintenance rules and will be associated with an authorized refrigeration technician. Therefore, it is to be expected that the vast majority of installation owners are also aware that refrigerants may only be handled by authorized refrigeration technicians and will therefore be involved if installation is to be dismantled. It is therefore only considered to be in situations where the client has not ensured to shut down systems via authorized refrigeration techniques, accidents in connection with renovation where air conditioning is still in operation, or if you deliberately avoid the rules that a spill will occur. In the project, we have not been able to provide a data basis for the extent of such situations, but have received feedback that the situations may occur. We believe that the emission factors used in the Nordic emission inventories to a large extent reflect these circumstances.

Interviews have been conducted in Denmark with demolition companies. The interviews were random interviews and therefore not representative. From the interviews, it was explained that it is a standard of the initial procedure for a demolition task that the client provides documentation for installations, including piping, etc. And for air conditioning systems, an authorized service company is called if the system is not documented emptied of refrigerant.

From similar interviews with authorized service companies, it is expressed that it is rare that authorized service company are called for supporting decommissioning of A/C units in connection with demolition. The interviewed also indicate that decommissioning of A/C units sometimes happens without involving f-gas authorized personnel.

There may be situations where a building owner has not emptied the A/C unit and has not communicated it to the demolition company. It can e.g be in situations, where the building owner is not aware of the existence of A/C units and required rules related to the owner of a A/C unit.

It is therefore likely that the problem of unintentional emissions from air condition and heat pump systems during renovation and demolition exists in all the Nordic countries, mainly related to decommissioning of heat pumps in residential houses, but to what extent, it has not been possible to quantify further in this project.

For heat pumps, it is relatively recent that units are reaching end-of-life and disposed of as waste. The problem will therefore be increasing unless more preventive measures are taken.

Summarizing, there are a number of possibilities for unintentional emissions of F-gases when dismantling air conditioners and heat pumps, including:

- Installations with F-gases, especially small heat pumps, can be dismantled by unauthorized personnel / craftsmen, where pipes are cut over etc.
- Demolition tasks that do not involve a refrigeration technician. It is the client's responsibility to know the current rules for handling refrigerants in installations. Therefore, there may also be a lack of personnel who are authorized to empty facilities.
- Municipalities are not well aware of setting requirements for the correct dismantling of air conditioners and heat pumps in connection with demolition permits.
- There is a lack of control over whether fillings in heat pumps or air conditioners are secured in connection with demolition.
- There is no legal control with decomissioning of A/C units.
- There is a lack of knowledge and guidance from demolition workers, builders and municipalities.

Air-air heat pump sale in the Nordic

The project has investigated the amount of air-air heat pumps installed in Nordic private households. The objective was to quantify the development trend and simulate the consequences in terms of potential F-gas emissions from unintended emission at demolition or EoL.

The project has assessed the statistical data available and prepared a Nordic survey of the municipal practice and control measures for correct disposal of air-air heat pumps from private households.

There are available statistical data for the annual sale of air-air heat pumps for all Nordic countries (except for Iceland). Finland and Sweden have statistics starting at least from 1990. Denmark has statistical data from 2008, and Norway has data starting from 2013. Air-air heat pumps have been sold in DK and NO before 2008 and 2013, it is just not registered on specific technology level (small air-air heat pumps). With regard Iceland, the assessment had applied a Nordic average pr. capita as representative for the annual unit sale in Iceland, introduced from 2008 and forward. The uncertainty of the assessment is not considered low.

The development of annual sale of air-air heat pumps is illustrated in the figure below. It is significant that the annual sale had increased substantially from 2014 and forward with a total sold amount increasing from 164 000 units to 287 000 units in 2020.

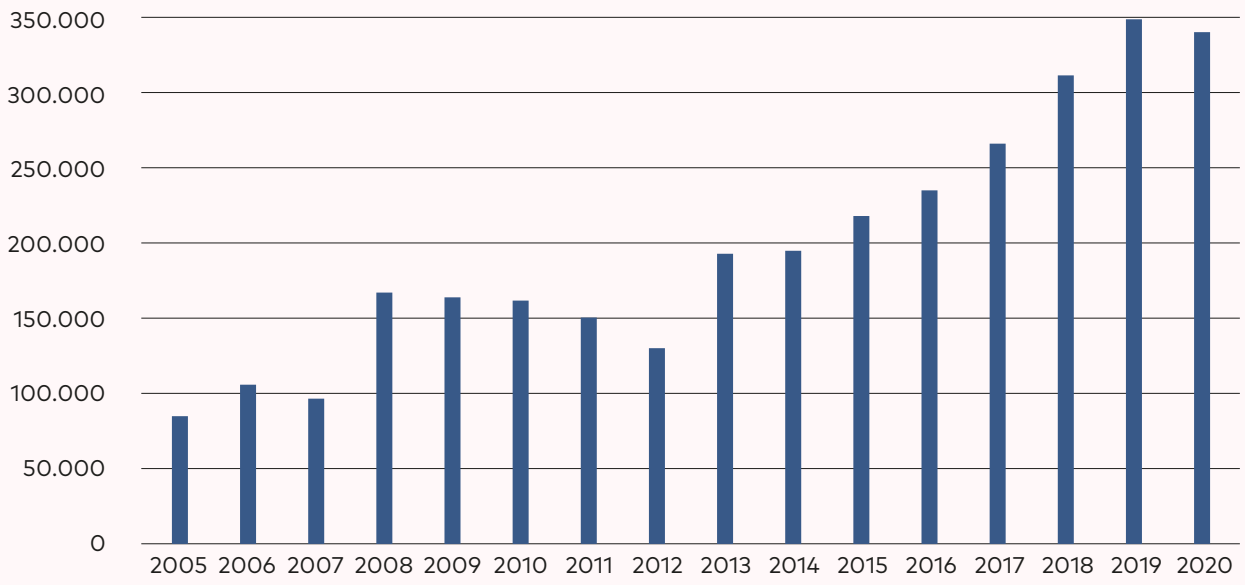


Figure 4: The development of Nordic annual sale and installation of air-air heat pump, 2000-2020 (unit sold)

The total number of sold units in the Nordic is 2.8 M. units. Considering a 15-year lifetime the total amount of units in operation year 2020 is 2.76 M. units.

GWP installed in air-air heat pumps

There are three F-gas refrigerants applied in air-air heat pumps. It is R-407C, R410A and R-32. The first applications in the mid-1990s were containing R-407C. R-410A was introduced to the market shortly after that and became the most widely used refrigerant. R-32 is the new low GWP refrigerant which has mostly substituted R-410A in new equipment in the most recent years.

The average filling pr. unit is roughly estimated as 1,5 kg. pr. unit. By calculating the sold number of units with average filling, the total amount of filling in Nordic air-air heat pumps are approx. 4 015 tonnes – 1 350 tonnes R-407c, 2 234 tonnes R-410A, and 431 tonnes R-32.

The total GWP installed in air-air heat pumps are estimated to approx. 6.15 M. tonnes CO_2 eqv. It is a significant amount. In the following table, there are conducted a scenario analysis to illustrate emission impact with different levels of accidental discharge of heat pumps where f-gases emit.

The scenarios are calculated with following assumptions:

- 80% remaining f-gas filling as accidental discharge
- 90% remaining f-gas filling as accidental discharge

The table below illustrate the potential accidental emission from air-air heat pumps based on GWP total in sold heat pumps in 2019 and 2020. The reason for substantially lower total GWP in 2020 is the assumption of all sold heat pumps from 2020 is with low GWP refrigerant R-32. From 2016-2019, the total GWP were increasing from 513.118 to 762 528 tonnes CO_2 eqv.
The potential emission is estimated for 8 scenarios. Two scenarios each with 5%, 10%, 20% and 30% accidental discharge.

	Total GWP	80% EoL, 5% A	90% EoL, 5% A	80% EoL, 10% A	90% EoL, 10% A	80% EoL, 20% A	90% EoL, 20% A	80% EoL, 30% A	90% EoL, 30% A
2019	762 528	30 501	34 314	61 002	68 627	122 004	137 255	183 007	205 882
2020	249	9 993	11 242	19 986	22 484	39 972	44 969	59 958	67 453

Table 22: Scenarios for the 2019 and 2020 potential F-gas emissions from accidental discharge emission (AD) of air-air heat pumps, tonnes CO_2 eqv.

The potential emission for the 2019 generation of heat pumps in the Nordic vary from 30 501 to 205 882 tonnes CO_2 eqv. depending on scenario. The potential emission for the 2020 generation of heat pumps in the Nordic vary from 9 993 to 67 453 tonnes CO_2 eqv. depending on scenario. It can be concluded that especially the scenario for accidental discharge impacts on emissions. The remaining filling has less impact. It can also be concluded that a scenario with 20% or more accidental discharge of heat pumps will contribute signeficant to the Nordic emission of f-gasses and can be prevented through control and information.

There is no reporting that determines the volume of unintended emission from air-air heat pumps. Thus, interviews with service and maintenance companies confirm that air-air heat pumps are not always removed and dismantled by authorized personnel.

The following table summarize the amount of heat pumps sold pr. capita in the Nordic countries. Iceland is not included because of lack of data.

	Finland	Sweden	D	Norway	Average pr. capita, Nordic
2005	174	259			108
2006	139	207			87
2007	117	296			103
2008	82	138			55
2009	95	173	315		146
2010	103	148	519		192
2011	100	192	376		167
2012	123	246	270		160
2013	121	235	379	97	208
2014	105	241	352	108	201
2015	123	188	250	94	164
2016	121	159	273	84	159
2017	117	148	169	77	128
2018	93	138	155	61	112
2019	70	148	123	57	99
2020	67	148	122	64	100

Table 23: Development in air-air heat pumps pr. capita (inhabitant pr. unit)

The number of installed air-air heat pumps in Sweden in the last decade or so seems to be considerably lower than comparable countries like Finland and Norway. The data from Sweden is estimates provided by the Swedish Refrigeration & Heat Pump Association. Data from Finland and Norway and Denmark is exact statistical data from units sold.

Municipal measures

In addition to assessment of statistical data, the objective was to collect quantitative information from selected municipalities in all the Nordic countries. This ambition were adjusted while we did not succeed with receiving appropriate answers to the survey from other countries than Denmark. However, a similar but not identical survey to the construction supervision and environmental protection authorities of the municipalities was conducted in Finland. The survey was part of another project related to F-gases in Finland. The survey covered similar questions compared to the Danish survey.

While evaluating the issue, the main problem for the F-gas inventory group was to identify responsible contact persons within selected municipalities to answer the survey questions. The target group to answer the questions was considered the person or persons preparing the demolition permits.

It is therefore concluded that a successful survey is supposed to require cooperation with, and distribution of the survey from the national municipal associations in the Nordic, as it was organized in Denmark.

Danish questionnaire

A questionnaire was developed to contribute to the analysis with clarifying the municipal practice for screening refrigerants and requirements for documentation for correct handling of refrigerants when preparing demolition permits.

1. Is the municipality aware of the rules for shutting down air conditioning and refrigeration systems (may only be carried out by persons with authorization)?

2. Does the municipality have examples of demolition permits with conditions for the disposal of F-gas refrigerants installed in air conditioners, heat pumps or refrigeration systems?

3. If the municipality uses a checklist for screening a building, are F-gas refrigerants explicitly included as a theme in the municipality's screening when applying for demolition / renovation?

4. Does the municipality request documentation from the client that F-gas refrigerant has been drained by air conditioning, cooling systems and large heat pumps during demolition?

5. Does the municipality request documentation from the client that F-gas refrigerant has been drained or sealed by authorized personnel before disposal as WEEE when demolishing small heat pumps?

6. Does the municipality have examples of how demolition workers handle F-gas fillings during demolition tasks?

7. In your opinion, is there a need for more focus on handling and correct disposal of F-gases during demolition tasks? Yes / no if yes which (comment field)

8. Do you have any proposals or recommendations for initiatives that can reduce unintentional emissions of F-gases during demolition?

How demolition permits are organized

9. Which professional administration receives applications?

10. Which digital system is used to process applications?

11. Which professional administration issues demolition permits?

12. Coordinates between professional administrations in connection with. demolition permits?

Finnish questionnaire

The survey conducted in Finland included the following questions:

1. Are you aware of the legal requirements related to the decommissioning of refrigeration and air-conditioning equipment and handling of refrigerants in this connection?

2. Are refrigerants taken into account in the permit applications and notifications concerning the demolition of a building or part of a building? If yes, in what way? If no, are they considered somewhere else?

3. Are you aware how the demolition companies take care of the recovery of refrigerants during demolition of buildings? If yes, how is the recovery taken care of?

4. Have you observed any practical barriers for the recovery of refrigerants from refrigeration or air-conditioning equipment during demolition of buildings? If yes, what kind of barriers?

5. When the municipality is the client of the demolition work, do you check that the recovery of refrigerants is performed by personnel with appropriate approval and qualification granted by Finnish Safety and Chemical Agency Tukes? If yes, how do you check that?

6. Are you aware that the handling of refrigerants during demolition of buildings would be performed by personnel without appropriate approval and qualification granted by Finnish Safety and Chemical Agency Tukes? If yes, in what kind of situations?

7. Are you aware that intentional releases of refrigerants from refrigeration and air-conditioning equipment would occur during demolition of buildings? If yes, in what kind of situations has this happened?

8. Do you hope for more information and instructions related to refrigerants and F-gases in demolition of buildings? If yes, what kind of information and to whom should the information be targeted to?

Survey result

The questionnaire form in DK was sent to the technical directors, with a request to delegate to the relevant employees. A total of 61 out of 98 municipalities have answered the questions.

As many as 85% of the municipalities do not request documentation for correct handling and disposal of refrigeration systems, including heat pumps. Thus, in the majority of the municipalities, it is not part of the municipality's routine to check for compliance with the handling and disposal of refrigerants.

The current set of rules in connection with the enforcement of rules to prevent F-gas emissions from installations does not contain legal basis for municipalities to control compliance in connection with the dismantling of refrigeration systems. It is also reflected in the questionnaire response, that the majority of municipalities do not focus on correct handling and recycling or disposal when dismantling installations with F-gases.

Currently there is no overview of the building stock of HFC air conditioning in any of the Nordic countries. Such an overview could provide a solid database that can be used to target campaigns, information efforts or control. Existing building registers could be a platform for such information.

The response rate in the survey sent to the construction supervision and environmental protection authorities of the municipalities of Finland was 30%. When asked about the familiarity of legal requirements related to F gases, many responded that they know the requirements related to the disposal of refrigeration and air-conditioning equipment and handling of refrigerants in the general level and many were aware of the requirement related to the certification of the personnel handling refrigerants. 56% of the respondents didn't know the legal requirements.

When asked whether the refrigerants contained in the refrigeration and air-conditioning equipment are somehow considered in the demolition permits or reports, 26% responded that they are considered and 67% that they are not. The respondents commented that when the refrigerants are considered, it can mean e.g. that a list of all the equipment and heating and cooling systems in the building may be requested and also a report how they are handled. In some cases, information may be provided on the correct handling and recovery of refrigerants prior to the demolition. Many respondents referred to the analysis of harmful substances and assessment of demolition waste but added that refrigerants are not mentioned in these documents. In general, instructions are given to find out all the necessary requirements and to sort out and handle the waste appropriately. Some respondents stated that the clients of the demolition work or authorities may not have any knowledge of where the refrigerants are used (e.g. in heat pumps). In larger demolition sites, the demolition plan or report is often more precise.

Most of the respondents didn't know how the demolition companies take care of the recovery of refrigerants from buildings being demolished. No practical barriers for the recovery of refrigerants were identified, but some responded also that they don't know the practical situation.

90% of the respondents answered that they are not aware that there would exist any handling of refrigerants in building demolition by personnel without the correct certifi-cates or that there would occur any intentional releases of refrigerants during demoli-tion. Some individual respondents had also observed these cases.

When asked whether the municipality as a client of the demolition work checks the correct certificates of the contractors, 40% responded yes and an equal amount responded no. Many responded that they themselves are not involved in procurement of demolition work and therefore are not able to answer the question. Many also responded that the municipality checks or requires the correct certificates.

80% of the respondents hoped for more information and instructions related to refrigerants and F-gases. The following were suggested as target groups:

- construction and demolition companies
- companies carrying out pre-demolition audits
- procurement and real estate organisations in municipalities
- technical services and construction supervision
- environmental protection authorities in municipalities.

Recommendations

It is recommended that national authorities in the Nordic initiate procedures, which assure registration of A/C installations in the building registers. The registration should include both A/C systems and heat pumps.

A precondition for control measures in connection with demolition and renovation of air conditioning system and heat pumps is that it is notified whether there is air conditioning system or heat pumps with F-gases in the building that is to be renovated or demolished.

In principle, there should be a check of whether a heat pump, an air conditioning system or a cooling system is involved in a demolition or renovation case. If so, a documentation must be attached in the form of a receipt from a service company, who is the only one who, according to current regulations, is authorized to handle refrigerants.

Legal framework for municipalities

With the current legal framework in the Nordic it is only indirect that municipalities are able to prevent unintentional emissions of F-gases or carry out inspections. This is also reflected in the Danish questionnaire response, where the majority of the municipalities state that they do not focus on correctly emptying and recycling or disposal when dismantling installations with F-gases.

The regulatory framework for environmental permitting and inspection only covers companies that are subject to environmental permitting (usually large industries), and the broad target group of building owners with air conditioning systems will not be subject to environmental inspection.

However, the municipal authorities may issue demolition permits of buildings to be renovated or demolished. In such situations, the municipality will be able to screen for F-gases and require documentation for preventive measures.

In the EU regulation on authorization and condition for periodic inspection of A/C system, there is no lower limit for which filling sizes require authorization to handle, but a distinction is made between requirements for different filling sizes. There is a risk for owners of A/C systems with unit fillings below 2.5 kg. does not have periodic inspections performed by an authorized service company. Lack of awareness can result in owners of a building to be demolished not call an authorized service company when dismantling the A/C unit.

EU requirements for registering data at shutdown
The F-gas regulation sets requirements for registration of data, e.g. that owners of installations with HFC's must register and specify preventive measures in connection with decommissioning of the installation. However, requirements for registration do not appear in some, or perhaps any of the national legislation in the Nordic. Legally, the owner of an installation is responsible for the proper decommissioning of plants without unintentional emissions of HFCs. However, due to the fact that there are no requirements stipulated in national legislation, it is likely that these rules will be overlooked. A log with data on shutdown will i.a. be a useful documentation basis for authorities.

Based on the Danish and Finnish questionnaire survey's answers, it is indicated that there is also a need to prepare guidance for the municipalities in connection with demolition permits, which ensure that refrigerants in heat pumps and air conditioners are screened, and the correct instructions are given in relation to waste management, and that the necessary documentation is presented. The possibility of adding HFCs as priority substances and materials in screening should be explored.

Information for owners of heat pumps
Private households are not sufficiently aware that the refrigerants are potent greenhouse gases. The current information for owners (buyers) of heat pumps that fillings must not be discharged is provided by the refrigeration service installer or can be found in the product data sheet. Do-it-yourselfers therefore do not necessarily have information on how to properly disassemble the installation again if the heat pump needs to be removed due to relocation or disposal. It should be investigated whether effective communication can be given to private individuals, e.g. with product labels or otherwise.

Waste plan for renovation and demolition
Following the Norwegian model, requirements may be considered for the building owner to prepare a waste plan that describes the planned handling of construction waste with different types of waste, including refrigeration systems and refrigerant. The plan describes requirements for handling building components, installations and the like that may constitute hazardous waste, including refrigeration systems / refrigerants. For all major measures, a separate effort must be made for environmental protection. The waste plan can be attached to the application for a demolition permit. The description can be a tool to ensure the attention to the building owners responsibility as well as requirements for disassembly and disposal of refrigerants.

Lack of inspection
The Occupational Health Authority in DK is the immediate authority to inspect air conditioners, but the authority is not necessarily aware of whether there is an air conditioner in buildings they visit. In the F-gas regulation art. 6 it is required that operators of facilities record certain

information specified in art. 6 pieces. 2, and this information shall be made available to the competent authorities.

As the situation is today, one can have an air conditioner without it being known to an authority. There is no central registration of the installation or the possibility of systematic control that an owner of the air-conditioning system ensures that the plant is operated correctly, and whether there is documentation in the form of journaling of data on filling and possibly decommissioning in accordance with the EU F-gas regulation.

Guidance on closure requirements
There are specific requirements and conditions for shutting down air conditioners, but there is a lack of knowledge among building owners about these rules. It is therefore proposed that more guidance and information be given to building owners and the like to help the actors to be aware of the rules.

6. Illegal Trade of HFC's

None of the Nordic countries are currently including illegal import/trading of HFC's in their F-gas calculation models. In theory it influences the F-gas inventories by underestimation of the F-gas emission. Primarily according to RAC where the illegal refrigerants are applied. Basically, the total Nordic stock from RAC may be larger than calculated.

Knowledge to the subject is there for important to establish and maintain good quality in the calculation of F-gas emissions. The following sections describe findings that are important to consider if assumptions regarding illegal trade should be included in the calculations.

Illegal import and trade of HFCs is a noticed problem in the Nordic countries. The illegal import is motivated by access to cheap refrigerants sold to customers with a higher profit. The typical customers have almost no possibility to control the origins of the HFCs supplied, and most customers do not focus on the issue at all. The illegal import of HFC refrigerants to Denmark and Norway has even higher profit potential because no tax has been paid for the refrigerant. The taxes range up to 80 € pr. kg in DK[3] and 200 € pr. kg in NO[4]. In Norway, the tax is refunded when delivering the HFCs for destruction.

There is no data available for the proportions of illegal import of HFCs in the Nordic countries, but the RAC sector itself claims that the problem is considerable.

The EU F-gas regulation is undermined by a black market for illegal F-gas trade. The impacts affect the climate reduction goals, but also cause national tax revenue losses. According to an analysis conducted for the EU Fluorocarbon Technical Committee, the illegal trade of HFC's to EU can be substantial[5]. By assessing trade flow of HFC's from various trade statistics, discrepancies between statistical sources are identified. Especially when comparing reported data for the Chinese export of HFC's leaving China to the EU (China Export data) and the registered import of HFC's in the EU (Eurostat). Further the import from China to neighbouring border countries to the EU had increased with 41% from 2017 to 2018, where the F-gas quota regulations were implemented. In total the discrepancies between Eurostat and China Export Data to EU is 19 M. tonnes CO_2 eqv, and the increase of HFC's exported from China to neighbouring EU countries is 15 M. tonnes CO_2 eqv. The total potential of illegal trade to the EU may be up to 34 M. tonnes CO_2 eqv which is one third of the total legal import to EU.

How can non-compliance be inspected?
In practice is it difficult to verify or control compliance. There exist no such registers with that information. Therefore the origin of the supplied HFCs should be documented: Who is the importer? and when was it imported?

It should be noted that HFCs in general have increased in price, since the HFCs have been affected by quota trading (from the EU F-gas regulation). Especially in 2018, the quota-trading effects have been visible in terms of price increase for high GWP HFC

3 CFC afgiftsloven, Skatteministeriet. https://www.skm.dk/skattetal/satser/satser-og-beloebsgraenser/cfc-afgiftsloven

4 https://www.skatteetaten.no/en/business-and-organisation/vat-and-duties/excise-duties/about-the-excise-duties/hfc-and-pfc/

5 Oxera, Nicole Rosenbaum, webinar June 2020. www.stopilligalcooling.eu

refrigerants. And combined with HFC tax charges in some Nordic countries (Denmark and Norway), both investment costs and life cycle costs increased considerably for owners of HFC based installations. A refilling with 30 kg high GWP HFCs will e.g. in Danish terms cost approx. 3,000 €. In other words, the service cost for larger HFC units will continually increase and reach non-competitive levels, while it is fair to expect an accelerated trend for phasing out RAC's based on HFC's. This will positively affect the total installed amount of HFC's in equipment. Thus, illegal trade is assumed to continue and even increase further if the control measures are not strengthened. The benefits for illegal traders are escalating as the price for legally registered and imported HFC's goes up.

In general, with regard to illegal trade, three themes are mentioned by the authorities:

- Illegal trade
- Lack of authorization to sell
- Incorrect packaging

The F-gas regulation is very complex and the capacity to inspect and enforce the complex legislation face lack of resources. The police in general may need more knowledge and information about the F-gas legislation.

Border control and seizures have increased in some of the Nordic countries. Custom officers in Denmark and Sweden are e.g. looking for disposable containers (it is illegally to import bottles or spray cans that are not reusable). Confiscated spray cans are typically R134a for MAC. The shipping document can clarify whether it is a disposal or reuse container.

Custom control has improved with installing scanners at custom borders. The scanners screen goods or trucks and are able to identify pressure vessels.

Denmark, Norway, Sweden, Finland have made information campaigns in the branch organizations about illegal trade, e.g. MAC spray or bulk HFC.

The Nordic competent authorities of the F-gas regulation receive reports on suspicious sales on websites, Facebook or other digital platforms. And it is the experience that e-commerce can remove illegal products immediately without being able to be prosecuted.

With the new EU legislation, "Mystery shopping", the authorities now receive a strong tool to enforce online sale actors. Before the legislation on Mystery shopping the problem was that authorities could not initiate contact via Facebook etc. because it was incriminating. Furthermore, it was difficult to find the traders due to missing addresses. The mystery shopping legislation is from the Market Surveillance Regulation which is implemented in the Nordic EU member states. The new opportunity with Mystery shopping is that an authority can pretend to be another. The legislation entered into force January 2021.

There is ongoing cross-bordering cooperation within the EU on illegal trade with Nordic coordination and coordination at EU level. The Nordic countries conducted a cross-bordering workshop in January 2021 and a similar one was organized by the EU in January 2020.

Customs control

The customs have scanners at airport hubs and in post distribution hubs. They scan all packages for compressed air. Therefore, there is considered to be reasonable control of illegal import sent with packages into the Nordic countries.

Regarding bulk import, there can be problems with imported items using the wrong item code (for another non F-gas pressure gas) Then it may be difficult to detect/control. However, customs can easily find data on the item codes and track actors.

Quota fraud

It has become known that there are some traders who cheat with the quotas. According to the legislation, quotas are allocated to the specific importers (to ensure a restriction on supply). Example: company X has permission to import 35 000 tonnes CO_2 eqv. import. However, the company imports 45 000 tonnes CO_2 eqv. and claims that they re-export 10 000 tonnes CO_2 eqv. But the claimed re-exported bulk is never sent out of the EU again. Search robots can now follow the product and document it never leaves the EU. But the track is very difficult to follow because papers on goods and the physical HFC bulk not necessarily are checked together.

Illegal import via vans

Pressure bottles are legal to import. All companies are allowed to import 10 000 tonnes CO_2 eqv./year. But it is difficult for customs to control how many times a van with pressure bottles crosses a border during a year. This type of illegal import might be the essential distribution of illegal F-gases. Typically, the illegal bulk imports are brought into the EU from east Europe or Turkey, and as soon as it is inside the EU, there is only random road control and digital tracing to stop the distribution. The largest successful confiscation happened in 2020 where the Romanian customs and OLAF (EU office for fraud) confiscated more than 76 tonnes of bulk HFC's in a single action.

Summarizing

The Nordic countries have no data or estimated amounts of illegal trade of HFC's. Thus, the attention and coordination among authorities had strengthened the last years. Sweden has established a task force on illegal trade and Denmark has improved the cooperation and coordination between custom control and DEPA.

The branch organisations in the Nordic countries are aware of the problems and have initiated information campaigns to their members regarding how users/buyers can assure that the HFC's are not illegal. As an example, the Danish Branch organisation *Dansk køl & varme* reports fraud with regenerated R-404A which are sold in the market, nevertheless the legal importers report it is sold out. Furthermore, the registered HFC bulk import the recent years are reduced significantly, e.g. the registered bulk import of HFC's 2019 decreased by more than 66% compared to 2018. It is a dramatic reduction which does not correspond with the service companies' expectation and observations of the general development and phase out of HFC based units in the market.

Methodological impacts

According to the Nordic F-gas inventories, illegal trade affects the possibilities to predict and calculate the "real" amounts of installed amounts of F-gases in the stock. Basically, it is logical to assume the total stock is larger than the stock determined from registered import of F-gases as bulk and in product.

While there is no data on the volume of illegal imported F-gases, it is only possible to acknowledge, there is an uncertainty which will impact with increases of the total F-gas emission inventory, if the amount of illegal F-gas import were included.

The F-gas inventory group has investigated experiences from other countries and Austria has developed a method to include the effect on emissions of illegal F-gas import into their inventory. Representatives from Austria were invited to present and discuss the method with the group at a Team meeting held in Q4/2021.

The Austrian method acknowledges the fact that custom and border control detect illegal bulk import of F-gases to be applied in refrigeration systems. There is no knowledge of how the gases may be distributed to stock, whether certain systems, e.g. stationary refrigeration systems, contain more illegal F-gases than other applications. There for Austria has decided not to distinguish between applications, but assume the same distribution and weighting as for the legal F-gases. And the total bulk F-gas import is amended with a 10% flat rate for all HCF substances.

None of the Nordic countries consider to include such approach yet in the national inventories, but it is notified the last years, that the legal bulk import in some Nordic countries is higher than the predicted import/consumption for regular maintenance in some categories, e.g. 2.F.1.a, stationary commercial refrigeration. It indicates weakness in the model based on a mass-balance and can be explained with the fact that the real stock is larger and underestimated because illegal F-gases is not included.

7. HFOs in the Nordic countries

In recent years HFOs have been introduced to the Nordic market as a low GWP alternative, either as pure HFO or in blends with HFCs.

HFOs (Hydrofluoroolefins) are composed of hydrogen, fluorine and carbon and are applied as refrigerants or blowing agents. Unlike traditional HFCs, which are saturated, HFOs are unsaturated olefines (or alkenes).

HFOs are categorized as having zero ODP[6] and low GWP. Many refrigerants in the HFO class are inherently stable chemically and inert, non-flammable or mildly flammable. Many HFOs have suitable freezing and boiling points to be useful for refrigeration at common temperatures. They are also applied as blowing agents, i.e. in aerosols or production of insulation foams, food industry, construction materials, and others. According to the UNFCCC reporting guidelines, HFOs are categorised as additional greenhouse gases for which a GWP exists but have not yet been adopted by the COP (Conference of the Parties). Emissions of HFOs are reported separately from the national total emissions.

Although HFOs have a very low GWP value (GWP 1-7), the other mentioned environmental risks are considered important. For most RAC product categories, it is possible to substitute high GWP refrigerants with low(er) GWP refrigerants consisting of blends combining HFC's and HFO's. For some categories HFO are being introduced fully as a substitute for HFC, e.g:

- HFO 1234yf. The HFO 1234yf is an alternative to R134a with low GWP with a similar pressure, but with a slightly less volumetric efficiency and cooling capacity. The GWP value for HFO 1234yf is 4 and much lower than HFC 134a (1,430) and this is one of the reasons why it has been chosen by the majority of the automotive industry as a replacement for HFC 134a in Europe for air conditioning in cars. HFO 1234yf is also an important ingredient in the most applied low GWP HFC blends, e.g. the blend HFC 449 where 25% is HFO 1234yf.

- HFO 1234ze. The HFO 1234ze is a low GWP alternative to HFC 134a with a similar pressure, but with a smaller volumetric efficiency and cooling capacity. The production cost of this refrigerant, which was originally developed for blowing foam plastic, is lower than HFO 1234yf. Along with the high molecular weight, this is among the reasons why, at HFO 1234ze is being considered for replacing HFC 134a in centrifugal chillers for large air conditioners. The GWP value for HFO 1234ze is 7.

The main HFO product in the Nordic market are:

- HFO 1234yf substitute HFC-134a in MAC
- HFO 1234ze substitute HFC-134a in aerosols
- The HFC blend HFC 449A contain 25% HFO 1234yf and are used for low GWP refrigerant in commercial refrigeration and air-condition
- The HFC blend HFC 452A contain 30% HFO 1234ze and is used for low GWP refrigerant in commercial refrigeration, transport refrigeration and air-condition

In cases where the choice of refrigerant stands between low GWP HFCs or HFOs there are some constraints to be mentioned. The pure HFOs have a low GWP. And when mixed, also with

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some conventional HFCs, this can also be considered as 'drop-ins' (can be directly substituted without modification of equipment). There is no need to significantly modify the technology design when refilled with certain HFC/HFO blends. Many HFO/HFC blend refrigerants have significantly smaller GWPs compared to the traditional HFC refrigerants, but the GWPs are still several hundreds in magnitude. HFO/HFC blend can be considered as a temporary or medium-term alternatives in the transition away from HFCs. In addition, studies on HFO show negative environmental impacts.

For example, it is known that the decomposition of HFO in the atmosphere leads to formation of tri-fluoroacetic acid (TFA). TFA is a strong acid, which is toxic to some organisms and is highly persistent with no known degradation mechanism. Whilst only 10-20 % of commonly used HFCs (e.g. HFC-134a) are transformed to TFA in the environment, 100 % of the HFO-1234yf transforms to TFA. Additionally, the combustion of HFO (e.g. in case of fire) can lead to the formation of hydrogen fluoride (HF) and carbonyl fluoride. HF is highly toxic and corrosive and can cause severe burns or blindness and lead to death when inhaled[7].

There is an ongoing discussion in the RAC sector and among regulatory authorities about the benefits or disadvantages of HFOs where the benefits are the low GWP values of HFOs while the disadvantages are their environmental and occupational health risk.

In a few years, several of the RAC product categories which use HFCs or HFOs today are assumed to be available with natural refrigerants.

7 Text edited from The Blaue Angel for Stationary Room Air conditioners – market analysis, technical development and regulatory framework for criteria development. Background Report. Project 3714 95 3060, Texte 22/2018. German Environment Agency, 2018.

Nordic use of HFOs

In the Nordic countries, the use of HFOs has slowly been introduced to the market. The registration of imported HFOs is not adequately registered at national levels. It means that specific registered data of the HFO import and use is only partly available. In addition, import and consumption data can be covered by confidentiality. The table below comprises the Nordic countries registration of HFOs.

	Data registration	Included in inventory	2018	2019	20	Category
Denmark	From importers	Yes	13,2	50,8	66,7	2.F.1.a 2.F.1.d 2.F.1.e 2.F.4
Finland	From importers, service and installation companies	Yes	104,8	152,0	195,2	2.F.1.a 2.F.1.c 2.F.1.d 2.F.1.e 2.F.1.f 2.F.4
Iceland	No	No	-	-	-	-
Norway	Only for HFOs in blend with HFCs (no tax on HFOs)	No	-	0,5	N/A	2.F.1.a
Sweden	Only estimated modelled use for MAC	Yes	145,4	314,5	*	2.F.1.e

Table 24: The Nordic Countries registration of HFOs

** Data on imported HFOs in Sweden 2020 are only available to the emission inventory team after the due date for data preparation. Same values for 2020 as for 2019 is thus assumed; 2020 data will be updated during 2022.*

The countries which estimate the HFO emission have all registered an increase during the recent years.

The earliest identified registration of HFO import is 2012 (HFO 1234ze and HFO 1234yf). The registration of HFO/HFC blends relates to several different refrigerants, e.g. HFC 449A (25% HFO 1234yf) and HFC 452A (30% HFO 1234ze).

The trend in the use of HFOs is significantly increasing in those Nordic countries that measure the import. In the case of Denmark, the registered import of pure HFOs has doubled from 2018 to 2019. In 2018 the import was approx. 10 tonnes, in 2020 it was 30 tonnes and in FI it was approx. 50% increase. From 2019 to 2020 the increase in DK and Fi were approx. 25%.

In the recent years we generally have identified e.g. substitution of HFC 134a in aerosols with HFO 1234ze and strong increase of HFO 1234yf use in service/refilling of MAC.

There are no calculations on emissions of HFO's in Norway even through HFO's are increasing, and to some extend replacing the existing HFC's. The reason why Norway do not make calculations for the HFO's is that the data is collected from information on the tax paid on import. As the HFO's are exempt from tax, Norway currently lacks data to fully understand the extent of use and emissions.

8. Conclusion and recommendation

The overall objective with the project was to provide an overview and new insight in the Nordic F-gas inventories, similarities and differences with the perspective to enable harmonization of data collection, emission factors and choice of methods.

Nordic F-gas emissions
The total Nordic F-gas emissions from handling, use and disposal of F-gases were in 2020 estimated to approx. 3.44 M. tonnes of CO_2 eqv. Compared to 2019, the total Nordic CO_2 eq. emission has reduced with 0.23 M. tonnes CO_2 eqv. During the period 2015-2020, the total Nordic emissions deriving from the use of F-gases have decreased by approx. 0.8 M. tonnes of CO_2 eqv. The emission reduction is believed to mainly stem from the introduction of more modern equipment and the substitution of HFCs with less greenhouse gas potent refrigerants (e.g. CO_2, NH_3 and HFOs).

End-of-Life F-gas emissions
The estimated reduction potential by improving EoL emission factors throughout the Nordic countries' methods are approx. -246.000 tonnes of CO_2 equivalents (2019)

A survey of EoL emissions has been conducted. It can be concluded that all countries require collection and handling of F-gases from authorized and certified persons/entities. With regard refund, DK, NO and IS have refunds for F-gases delivered for disposal, FI and SE have no refund schemes. It is not evident whether the refund assure a higher amount delivered to disposal. Information received indicates that service companies prioritise to reuse collected refrigerants and mainly polluted refrigerants are send to disposal. The disposal of refrigerants is free of charge in IS, NO and SE, but not in DK and FI. DK and SE have no data for destruction of F-gases. It is registered in FI, NO and IS. Only FI has recovery of F-gases in insulation foam.

The project found large differences between collected recovered HFC in the waste sector and the anticipated recovery rates in Norway and Iceland, which are the only two countries with such data. This might be the situation in Denmark, Finland and Sweden as well

Further, there is no available data for handling of F-gases at decommissioning of air-air heat pumps in private sector and no countries include registration of A/C in building registers (and building permits).

Unintentional emission from stationary A/C and Heat Pumps
Summarizing, there are a number of possibilities for unintentional emissions of F-gases when dismantling air conditioners and heat pumps, including:

- Installations with F-gases, especially small heat pumps, can be dismantled by unauthorized personnel / craftsmen, where pipes are cut over etc.
- Demolition tasks that do not involve a refrigeration technician. It is the client's responsibility to know the current rules for handling refrigerants in installations. Therefore, there may also be a lack of personnel who are authorized to empty facilities.
- Municipalities are not well aware of setting requirements for the correct dismantling of air conditioners and heat pumps in connection with demolition permits.
- There is a lack of control over whether fillings in heat pumps or air conditioners are secured in connection with demolition.

- There is no legal control with decomissioning of A/C units.
- There is a lack of knowledge and guidance from demolition workers, builders and municipalities.

The potential emission for the 2019 generation of heat pumps in the Nordic vary from 30 501 to 205 882 tonnes CO_2 eqv. depending on scenario. The potential emission for the 2020 generation of heat pumps in the Nordic vary from 9 993 to 67 453 tonnes CO_2 eqv. depending on scenario. A scenario with 20% or more accidental discharge of heat pumps will contribute significant to the Nordic emission of F-gasses and can be prevented through control and information.

Municipal survey
Surveys from DK and FI exploit following observations:

– Most municipalities do not request documentation for correct handling and disposal of refrigeration systems, including heat pumps.

– In the majority of the municipalities, it is not part of the municipality's routine to check for compliance with the handling and disposal of refrigerants.

– Currently there is no overview of the building stock of HFC air conditioning in any of the Nordic countries. Such overview could provide a solid database that can be used to target campaigns, information efforts or control. Existing building registers could be a platform for such information.

Illegal Trade of HFC's
None of the Nordic countries are currently including illegal import/trading of HFC's in their F-gas calculation models. In theory it influences the F-gas inventories by underestimation of the F-gas emission. Primarily according to RAC where the illegal refrigerants are applied. Basically, the total Nordic stock from RAC may be larger than calculated.

According to the Nordic F-gas inventories, illegal trade affects the possibilities to predict and calculate the "real" amounts of installed amounts of F-gases in the stock. Basically, it is logical to assume the total stock is larger than the stock determined from registered import of F-gases as bulk and in product.

HFOs
The trend in the use of HFOs is significantly increasing in those Nordic countries that measure the import. In the case of Denmark, the registered import of pure HFOs has doubled from 2018 to 2019. In 2018 the import was approx. 10 tonnes, in 2020 it was 30 tonnes and in FI it was approx. 50% increase. From 2019 to 2020 the increase in DK and Fi were approx. 25%. There is no HFO data at bulk level for the other countries yet.

Other project conclusions

- Exchange of key figures for HFC contents in MDI's has improved the emission calculation for MDI's in several countries

- It is very difficult to obtain quantitative data for illegal trade. The problem is acknowledged and has increased since HFC quotes were strengthened in 2018

- The harmonisation of methodologies in the Nordic countries is initiated and will continue in the next submissions

- Revisions and some recalculations are already implemented for submission in 2021 and 2022

- The Nordic F-gas Inventory workgroup has studied the new IPCC 2019 refinement to assess whether the Nordic countries are in compliance with the updated recommendations. The work was organized as a self-study of the IPCC refinement material, combined with a workshop with presentations and discussion of the new contents in the refinement recommendations.

Recommendations

– In most cases, the Nordic countries apply emission factors from the default ranges set out in the 2006 IPCC guidelines. However, in some cases, the applied factors differ largely between country and category. 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)*.

– Continue and expand regulation and enforcement of illegal import of HFC's. The shadow import of HFC's may have high impact on the quality and uncertainty for the F-gas emission calculations of actual emissions, while the stocks might be underestimated significantly.

– It is recommended that national authorities in the Nordic initiate procedures, which assure registration of A/C installations in the building registers. The registration should include both A/C systems and heat pumps. A precondition for control measures in connection with demolition and renovation of air conditioning system and heat pumps is that it is notified whether there is air conditioning system or heat pumps with F-gases in the building that is to be renovated or demolished. In principle, there should be a check of whether a heat pump, an air conditioning system or a cooling system is involved in a demolition or renovation case. If so, a documentation must be attached in the form of a receipt from a service company, who is the only one who, according to current regulations, is authorized to handle refrigerants.

– According to inventory forecast, it could be useful to clarify trends in bulk sale on a Nordic level – which refrigerants are increasing, which are declining, how accelerated are introduction of the low GWP refrigerants.

Implemented or planned improvements as result of the project work

Denmark
Assessment of potential revising SF6 emission factors to the Norwegian emission factors based on a detailed study of the Norwegian sector (planned)
DK split ift. AC systems and commercial (implemented)

The 2021 submission has included a number of revision and improvements as a result of the project work:

– Revision and update of MDI emission calculation including HFC content data per product reported from manufactures and available from the Swedish Läkemedelsverket. The update has been made from 2015 and onwards
– Change of emission factors for operation from 2.F.1.f from 10% to 3% from 2010

– Introduction of new refrigerants (HFC-449A and HFC-452A) to categories 2.F.1.a and 2.F.1.f from 2015

The applied Initial charge EF for stationary A/C may be revised and reduced.

Finland
The 2022 submission included the following recalculations that resulted from the project work:

– In categories 2.F.1.a/b/c/d/f, F-gas emissions from end-of-life were recalculated for 2011 to 2019 due to update of recovery efficiencies applied in the emission estimation. Details of the updated recovery efficiencies are described in chapter 3.
– Emissions of HFC-227ea from metered dose inhalers in category 2.F.4 were included in the inventory. The companies importing these products were identified with the help of the data from the Swedish Läkemedelsverket and available in this project.

Norway
There have been several improvements in the 2021 submission with updates of the EFs. When it comes to the recovery efficiency Norway has detailed information on the amounts destructed. The knowledge on reuse of F-gas is somewhat deficient, but efforts to improve this will be maintained with the intention to implement this in the emission calculation. There is also missing some information on the waste handling in some categories. This needs further investigation.

Iceland
Since the inventory 2020 Iceland is using 70% recovery and will await changes until better data is available. It was changed from 80% to 70% to be within the IPCC Guidelines range and in absence of references which could confirm 80%. Initial charge remaining is calculated according to the formula of the IPCC Excel sheet "M. in retired equipment" and corresponds to the initial charge of the year in which the appliance was first used (= current year minus lifetime of appliance).

Sweden
Sweden may consider introducing a new emission factor for air-to-air heat pumps at end of life in submission 2022. Following has been introduced in the 2021 submission:

– Change of the recovery efficiency factor for air-to-air heat pumps from 95% to 80%

Appendix 1:
GWP values for F-gases

F-gases, their chemical formulas and Global Warming Potential (GWP) values used for reporting to the UN Climate Convention and the Kyoto Protocol. GWP values are from IPCC new revised GWP values Assessment Report 4 (AR4)

Substance / Blend	Chemical formula	GWP value
HFC-23	CHF3	14 800
HFC-32	CH2FH2	675
HFC-41	CH3F	92
HFC-125	C2HF5	3 500
HFC-134	C2H2F4	1 100
HFC-134a	CF3CFH2	1 430
HFC-143	CHF2CH2F	353
HFC-143a	CF3CH3	4 470
HFC-152	CH2FCH2F	53
HFC-152a	CF2HCH3	124
HFC-161	CH3CH2F	12
HFC-227ea	C3HF7	3 220
HFC-236cb	CH2FCF2CF3	1 340
HFC.236ea	CHF2CHFCF3	1 370
HFC-365mfc	CH3CF2CH2CF3	794
HFC-245ca	C3H3F5	693
HFC-245fa	CHF2CH2CF3	1 030
HFC-404A(1)	Blend	3 922
HFC-401A(2)	Blend	18
HFC-402A(3)	Blend	2 100
HFC-407C(4)	Blend	1 774
HFC-408A(5)	Blend	1 030
HFC-409A(6)	Blend	0
HFC-410A(7)	Blend	2 088
HFC-449A(7)	Blend	1409
HFC-452A(7)	Blend	1397
HFC-507(8)	Blend	3 985
Sulphurhexafluoride	SF6	22 800
PFC-14	CF4	7 390
PFC-116	C2F6	12 200
PFC-218	C3F8	8 830
PFC-3-1-10	C4F10	8 860
PFC-318	c-C4F8	10 300
PFC-4-1-12	C5F12	9 160
PFC-5-1-14	C6-F14	9 300
PFC-9-1-18b	C10F18	7 500
Perfluorocyclopropanec		17 340
Nitrogen Trifluoride	NF3	17 200

(1) Mixture consisting of 52 % HFC-143a, 44 % HFC-125 and 4 % HFC-134a.
(2) Mixture consisting of 53 % HCFC-22, 13 % HFC-152a and 34 % HCFC-124.
(3) Mixture consisting of 38 % HCFC-22, 60 % HFC-125 and 2 % propane.
(4) Mixture consisting of 25 % HFC-125, 52 % HFC-134a, and 23 % HFC-32.
(5) Mixture consisting of 46 % HFC-143a and 7 % HFC-125.
(6) A HCFC mixture consisting of HCFCs, where the GWP is 0, since the mixture does not contain greenhouse gases. The real GWP value is 1,440.
(7) Mixture consisting of 50 % HFC-32 and 50 % HFC-125
(8) Mixture consisting of 50 % HFC-125, 50 % HFC-143a.

Appendix 2:
Updated overview of legislative requirement to removal of refrigerant

Denmark

There are four key legislative orders in relation to End-of-life and disposal of F-gas refrigerants.

The EU F-gas Directive
Article 3 stipulates that intentional emission of F-gases is prohibited when the emission is not technically necessary, and operators of plant or equipment must take the necessary measures to prevent accidental release.

Article 6 stipulates that operators (plant owners) have a duty to keep records, and must maintain and archive data for 5 years regarding filling, bottling, leakage and recycling. In the case of decommissioning, data must be recorded on the specific measures with regard to recovery and disposal, including who carried out recovery and disposal.

The F-gas regulation requires plant owners to avoid emissions of F-gases in all respects, including shutdowns. Furthermore, plant owners are imposed a number of journaling obligations, which are only partially fulfilled with the Danish operating journal that must be kept, according to "kølebekendtgørelsen".

The F-gas executive order
Executive Order on the Regulation of some Industrial Greenhouse Gases (Bek. No. 1326 of 19/11/2018), states a ban on the use of new and recycled HFCs, except for those exempted from the ban. Servicing of refrigeration systems, air conditioning systems, heat pumps and dehumidifiers is an area of application, which is exempt from the ban.

Kølebekendtgørelsen
The Refrigeration Executive Order (Executive Order on the use of pressure equipment (Decree no. 100 of 31/01/2007 with associated amendments) regulates conditions for installation, operation and control and dismantling of refrigeration systems with refrigerant fillings over 2.5 kg. Units must only be operated if it meets the requirements that apply to its construction, equipment, safety, etc. according to the working environment legislation.

The obligations for compliance with the executive order has to be assured by owners of the installation, users, service suppliers and others. according to the rules of the Working Environment Act.

Inspection and maintenance etc. of refrigeration systems must be carried out by a person who has received the necessary instruction and practice in inspection and maintenance, etc. of the type of unit/system.

For systems with a filling larger than 2.5 kg of refrigerant, the annual inspection must be carried out by a certified person from an approved refrigeration service company. It is also a requirement that it must be a certified company that handles closure. Systems with fillings less than 2.5 kg. is covered by the rules of EU Regulation 2015/2067 on authorization.

Private households (heat pumps) are not covered by this legislation because they are not included in regulations for occupational health and safety.

The Electric Scrap Order and the WEEE Directive
The WEEE Directive (EU / 2012/2019) has been implemented in Denmark by amending the Environmental Protection Act and the so-called Electricity Scrap Order with subsequent amendments Bek. No. 148 of 08/02/2018. The purpose of the regulation is to ensure that the collection and recycling of materials in electronics and electronic products when they have become waste.

The purpose of the WEEE Directive EU / 2012/2019 is to ensure the collection and recycling of materials in electronics and electronic products when they have become waste.

All variants of heat pumps powered by electricity are in principle covered by the WEEE directive. Heat pumps are classified in the WEEE Directive as category 1 - equipment with temperature exchange.

Stationary air conditioners, which contain F-gases, are complex products consisting of metals, cables, electronics, plastics and F-gases. When such systems are disposed of, the various parts are separated and sorted and only the electronic components will be disposed of as electronic waste.

Equipment that is defined as household equipment is produced for use in private households and the municipality is responsible for the collection from the citizens, e.g. via recycling sites and via bulky waste schemes. After this, it is the task of the manufacturers and importers to collect these electronics from the municipality and ensure further environmental treatment.

Finland

Legislation related to recovery and end-of-life treatment of F-gases and equipment containing F-gases comes from the EU regulation.

The key legislative acts are EU F-gas Regulation (517/2014) and WEEE Directive (2012/19/EU).

According to the criminal code of Finland (chapter 48), it is an environmental offence to intentionally or through gross negligence to emit F-gases into the environment.

In the waste legislation, the general obligation to comply with order of priority is set in the section 8 of the waste act. In the case of F-gas refrigerants, the general obligation to comply with order of priority means that the refrigerants need to be sorted and recovered. If this is not technically possible or economically profitable, they must be destructed. The Finnish waste legislation follows the EU waste legislation.

Iceland

There are three key legislative orders in relation to End-of-life and disposal of F-gas refrigerants.

- Lög um úrvinnslugjald - 2002 nr. 162 20. Desember: Law about the Icelandic Recycling fund (https://www.urvinnslusjodur.is/english)

- 1061/2018: Reglugerð um raf- og rafeindatækjaúrgang: adoption of 2012/19/EU „DIRECTIVE 2012/19/EU OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 4 July 2012 on waste electrical and electronic equipment (WEEE)"

- 1066/2019 Reglugerð um flúoraðar gróðurhúsalofttegundir: adoption of REGULATION (EU) No 517/2014 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 16 April 2014 on fluorinated greenhouse gases and repealing Regulation (EC) No 842/2006 and the former regulations 834/2010 and 1279/2018

Norway

There are following key legislative orders in relation to End-of-life and disposal of F-gas refrigerants.

Import, use and removal of f-gases are regulated through the F-gas regulation, product regulations and the f-gas regulation build upon:

EU regulation (EC) nr. 842/2006 (from 6th of May 2010) The most important consequences of the regulation are the requirements set for leakage control and proper handling of refrigerants in plants that contain HFCs, PFCs and SF6 gas. Requirements are also introduced for certification of personnel and companies involved in the gases, as well as import restrictions for certain types of products and equipment.

The EU Regulation EU 517/2014 was implemented in the product regulation from December 2018. The regulation stipulates the requirements for certification of technical personnel who perform service and maintenance on refrigeration systems.

The certification requirement has also been extended to transport refrigeration including the requirement for leakage testing

Commission Implementing Regulation (EU) 2015/2067 of 17 November 2015 establishing, pursuant to Regulation (EU) No 517/2014 of the European Parliament and of the Council, minimum requirements and the conditions for mutual recognition for the certification of natural persons as regards stationary refrigeration, air conditioning and heat pump equipment, and refrigeration units of refrigerated trucks and trailers, containing fluorinated greenhouse gases and for the certification of companies as regards stationary refrigeration, air conditioning and heat pump equipment, containing fluorinated greenhouse gases

Financial incentives (taxes and refund) have been introduced to ensure increased returns.

Sweden

There are following key legislative orders in relation to End-of-life and disposal of F-gas refrigerants.

Sweden follows the EU regulation (517/2014) and the Swedish F-gas regulation (2016:1128).

Also, the WEEE (Directive on Waste Electrical and Electronic Equipment) directive is of importance.

The Swedish legislation states that those who supply gas must take back delivered gas free of charge.

Starting as early as in the 1980s Sweden has had strict regulation regarding F-gases through legislation, (SNFS 1988:3, later amended by SNFS 1992:16). The Swedish Refrigeration Code of Best Practice (Svensk Kylnorm) includes directives concerning annual supervision of refrigeration and heat pump equipment, which includes leakage control, but also requirements for preventive measures. In addition, starting in the late 1980s, companies operating with installations, service, maintenance or execution of the mandatory supervision, have professional permits from the Swedish Environmental Protection Agency, later transferred to requirements for accreditation with SWEDAC (Sweden's national accreditation body).