MODULE 1

Inventory

NAMAs in the refrigeration, air conditioning and foam sectors. A technical handbook.

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Executive Summary

The aim of national inventories is the quantification of greenhouse gas (GHG) emissions. All Parties to the UN Framework Convention on Climate Change (UNFCCC) must submit national reports to the UNFCCC secretariat. However, the contents and timetables given differ between Annex I (developed countries)[1] and Non-Annex I countries (developing countries). National inventories give a comprehensive overview of current emission patterns. This is the first step towards understanding the relevance of the different sectors with regard to contributing to climate change. Appropriate mitigation actions can be identified based on detailed inventories. Thus, a detailed emission inventory is the first step for any political action to reduce emissions. GHG for the national reporting to the UNFCCC are regulated under the Kyoto Protocol. They include fluorinated gases, the so-called F-gases: hydrofluorocarbons (HFC), perfluorocarbons (PFC) and sulphur hexafluoride (SF_6).

HFCs are predominantly used in the refrigeration, air conditioning and foam blowing (RAC&F) sectors. Energy consumption for the production and use of RAC&F products is not reported separately. These emissions are reported at the point of energy generation i.e. coal power plants producing electricity. This module therefore focuses on the direct emissions from refrigerants and foam blowing agents. Despite the growing importance of F-gases in many countries, relevant emission data is often not available, in particular in Non-Annex I countries. For the purpose of conducting inventories and quantifying emissions, the Intergovernmental Panel on Climate Change (IPCC) has published two versions of the *Guidelines for National Greenhouse Gas Inventories* (IPCC 1997, 2006). The first version (1996) is approved for national reporting to the UNFCCC. The second version includes substantial updates. At the Conference of the Parties to the UNFCCC (COP) in Durban in 2011, it was decided to encourage Annex I countries to follow the 2006 methodology as of the beginning of October 2012 (decision 15/CP.17). Obligatory reporting according to the 2006-methodology is expected by 2015, at least for Annex I countries.

The methodologies described by the IPCC follow a tiered approach, where Tier 1 denotes the most aggregated, top-down approach using mainly national chemical sales data and generic emission factors as default values. The Tier 2 approach goes into more detail to calculate the emissions. In the RAC sector, this approach often relies on quantifying the stock of appliances which use F-gases, i.e. mainly HFCs, to estimate the demand and emissions.

It is advisable to engage local consultant agencies specialised in the sector to support the compilation of a national F-gas inventory. Being familiar with the specific culture and language, local agencies can facilitate the process of gathering detailed technical information which will often involve face-to-face discussions with local industry and experts. The first step towards a national F-gas inventory should be an extensive literature research, reviewing existing data and collecting available statistics related to F-gases. Based on this aggregated data, the most important subsectors can be defined in terms of demand and emissions of F-gases. The subsectors are referred to as "source categories" in the IPCC literature.

The second important step is to identify key stakeholders, particularly the market leaders, and key actors in the different sectors. These include the manufacturing industry or producers, importers, exporters, trading associations, servicing enterprises and reclaim or destruction industry. The National Ozone Units (NOU) also plays an important role, as F-gases are used as substitutes for ozone depleting substances (ODS). Market and production data in the RAC&F sectors are an important source for establishing national F-gas inventories. Additionally, workshops and personal interviews with key stakeholders complement the data collection efforts for the inventories.

Finally, the detailed data from the inventories may be used to feed vintage bottom-up stock models where the time-related phase-out of old stock and the phase-in of new stock, i.e. new sales, are considered. Vintage bottom-up stock models are powerful tools for the simulation of the future emissions and the demand for fluorinated substances. These kinds of simulations support policy makers when choosing appropriate mitigation actions.

1 UNFCCC refers to Annex-I-Countries for industrialised countries

1. Introduction

The aim of national inventories is the quantification of GHG emissions; inventories are structured by sectors. Parties to the UNFCCC must submit national reports to the UNFCCC secretariat. However, the contents and given timetables differ between Annex I and Non-Annex I countries. Among the top six GHG with high global warming potential (GWP) are the so-called F-gases: HFC, PFC and SF_6. GHG covered by the Montreal Protocol on Substances that Deplete the Ozone Layer are not reported to the UNFCCC. A comprehensive overview about current emission patterns is the first step to understanding the relevance of the different sectors and how their emissions contribute to climate change. Based on this detailed knowledge, appropriate reduction measures such as the so-called Nationally Appropriate Mitigation Actions (NAMAs) can be identified. Thus, a detailed emission inventory is the first step for any political action.

Political decisions to reduce emissions are often supported by mathematical models that project future emissions and reduction potentials. In the refrigeration, air conditioning and foam blowing, vintage bottom-up stock models (cf. annex 1 to this module) provide a powerful tool to simulate future emissions and demand of fluorinated substances. A business-as-usual scenario serves as a reference scenario to estimate the future potential for emission reductions. In different scenarios, mitigation measures can be illustrated by the models for each sector to demonstrate the reduction potential in a quantitative manner. Vintage bottom-up models rely on data from national inventories but also include other parameters such as growth rates and emission factors. Thus, the national inventories are not only important to estimate the current relevance of the different sectors, but represent a fundamental source for simulation models. The models in turn play a decisive role in the NAMA debate, as they can demonstrate the potential of emission reductions and thus contribute to sound decision making. Furthermore these models set up a framework to design a monitoring, reporting and verification (MRV) system in the RAC&F sector (cf. module 7).

The objectives of this chapter are
- to describe the current data availability with regard to HFCs as the most relevant F-gases,
- to introduce different approaches in order to conduct national inventories,
- to present a practicable inventory method to tackle the RAC&F sectors,
- to introduce a practical step-by-step guide on how to build up a national inventory in the RAC&F sectors.

The practical guidance will help local consultant agencies to conduct national F-gas inventories, the fundamental basis for any NAMA in the RAC&F sector. It also highlights what kind of data are needed to feed a vintage bottom-up stock model, which is separately described in annex 1 to this module.

BOX 1
Terminology in the refrigeration, air conditioning and foam sectors

The handbook refers to sectors (e.g. air conditioning), subsectors (e.g. stationary air conditioning) and systems (e.g. ducted split unit) for RAC, and to applications and sub-applications for foams. The term system is synonymously used for appliance, equipment and unit. It is a functional unit in the different subsectors. Depending on the nature of the subsector, a unit can be as simple as a domestic refrigerator or a complete commercial refrigeration system consisting of compressors, condenser, pipe work, display cabinets etc. (cf. module 3). For the foam sector, a unit is a defined volume or a tonne of foam with a respective content of blowing agent.

Data availability in Non-Annex I countries

HFCs are the most important chemicals among the F-gases in terms of quantity used and emissions. They are mainly used in the RAC&F sectors, thus, national F-gas inventories must particularly focus on HFCs in these sectors. However, a look at the ten recently submitted National Communications of Non-Annex I countries[2] shows that in most countries there are hardly any data on HFCs available. The reports from Azerbaijan, Lebanon and Malaysia[3] state that emissions of halogenated substances only play a minor role in overall GHG emissions while other countries do not even mention F-gases in their National Communications at all.

The situation for the reported data of chlorofluorocarbons (CFC) and hydrochlorofluorocarbons (HCFC) is much better, because the Montreal Protocol established a mandatory reporting of their consumption. The data are reported in aggregated form and in ozone depleting potential (ODP) tonnes. However, it is still difficult to attribute these aggregated data to specific sectors and subsectors. In contrast to CFC and HCFC, HFC production and consumption is usually not regulated in Non-Annex I countries and monitoring systems are often lacking. The expertise of CFC and HCFC monitoring is typically based within the National Ozone Unit, while HFC-related issues are in the responsibility of a climate unit, which may be affiliated to a different ministry. Thus, relevant knowledge gathered during the CFC and HCFC-reporting might not or not fully be applied for HFC reporting.

2. Methodology for the establishment of a national F-gas inventory

2.1 Available methodologies

The Intergovernmental Panel on Climate Change has published two versions of the IPCC Guidelines for National Greenhouse Gas Inventories (IPCC 1997, 2006). These guidelines contain instructions for calculating emissions in the refrigeration and air conditioning sectors. The first version (1997) is approved for the national reporting to the UNFCCC. This was complemented by the *IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories* published in 2000 (IPCC 2000). The second version, published in 2006, contains substantial updates. At the COP in Durban in 2011 it was decided to encourage Annex I countries to follow the 2006 methodology with the beginning of October 2012 (decision 15/CP.17)[4]. An obligatory reporting according to the 2006-methodology is expected by 2015, at least for Annex I countries.

2.2 The IPCC Tier 1 and Tier 2 approach

The methodologies described by the IPCC follow a tiered approach, where Tier 1 denotes the most aggregated, top-down approach using mainly national chemical sales data and generic emission factors as default values. The Tier 2 approach goes into more detail to calculate the emissions. Here, either chemical sales data can be used for the different RAC&F subsectors (top-down) or data on the equipment and appliance numbers containing fluorinated substances are gathered (bottom-up). In the latter case, both market data and production data have to be captured, as well as the stock, i.e. the appliances in use.

The approval of the 2006 version will likely occur within the next few years. For this reason, major differences between the two methodologies are explained and summarised in Table 1.

2 http://unfccc.int/national_reports/non-annex_i_natcom/items/2979.php
3 Second National Communications, 2011, for all three countries
4 http://unfccc.int/resource/docs/2011/cop17/eng/09a02.pdf

Comparing the two versions with regard to the HFC emission reporting, one major modification is the definition of the **Tier 1 approach**. While the method from 1996 defines Tier 1 as potential emissions, the 2006 Tier 1 method calculates actual emissions based on a simple algorithm using default emission factors. Thus, the latter up-to-date formulation of Tier 1 accounts for the time lag between the consumption and emission as emissions may occur after consumption of F-gases. Potential emissions, as calculated with the 1996-method, basically mirror the consumption. According to the Montreal Protocol, consumption is defined as production plus import minus export.

The **Tier 2 approach**, on the other hand, has not changed substantially. Only the differentiation into Tier 2a and 2b was added in the 2006 version. The first method refers to an emission-factor approach and the latter to a mass-balance approach. The emission factor approach relies on stock and market/production data, i.e. number of appliances/units, and estimates emissions via emission factors. The mass-balance approach considers sales data of refrigerants but also makes use of activity data.

TABLE 1
Differences between the 1997 and 2006 version of the IPCC Guidelines for National Greenhouse Gas Inventories

Tier	1997	2006
Tier 1	Potential emissions based on annual consumption figures Potential emissions = Production + Imports – Exports – Destruction	Actual emissions calculated based on annual sales, introduction year and growth using generic assumptions to back-calculate the build-up of banks
Tier 1a	Production, Import and Export bulk of chemicals	Hybrid Tier 1a/b approach considers import and export of refrigerants contained in products
Tier 1b	Production, Import and Export bulk of chemicals and those contained in imported/exported products	
Tier 2	Actual emissions based on system-specific refrigerant charge, lifetime and emission factors	Same as 1996
Tier 2a	No distinction between Tier 2a and Tier 2b Emissions = Manufacture Emissions + Operation Emissions + End-of-Life Emissions	Emission-factor approach: Emissions = Emissions from Container handling + Manufacture Emissions + Operation Emissions + End-of-Life Emissions
Tier 2b		Mass-balance approach: Emissions = Annual Sales of New Refrigerant – Total Charge of New Equipment + Original Charge of Retiring Equipment – Amount of Intentional Destruction

Comparison of the methods

Tier 1 methods are less data and time-consuming than Tier 2 methods. The Tier 2 method works on a high level of disaggregation and provides more specific details on emission patterns. The Tier 2 approach should be preferred, as it gives a more comprehensive overview about the demand and emissions in the different sectors and subsectors in RAC&F. Depending on the resources available, the rough estimate is achieved by using Tier 1 approach. However, **it is considered as good practice to use both approaches, i.e. Tier 1 top-down and Tier 2 bottom-up approach, and to compare the results for quality control.**

Tier 3 is of minor importance for national inventories. This approach is based on actual monitoring and measurement of emissions from point sources. However, as these point sources are highly disparate, if at all available, the Tier 3 approach is hardly employed in the RAC&F sectors.

Getting started

The first step to set up a national F-gas inventory is intensive literature research. Field experts can assist in the review of existing data, reports and statistics related to F-gases (cf. chapter 3 Practical application). Based on this aggregated data, the most relevant subsectors can be identified in terms of demand and emissions of F-gases. The subsectors are defined as source categories in the IPCC (IPCC 2000), which introduces appropriate calculation methods. The most important source categories are called key source categories. These should be studied comprehensively. The investigation of key source categories is considered as sufficient for national inventories.

In contrast to the reporting requested under the UNFCCC, which includes only greenhouse gases regulated under the Kyoto Protocol, it is proposed here to include the ozone depleting substances – mainly HCFCs – into the inventory. As mentioned above, the uses of HCFCs and HFCs are strongly connected as HCFCs are increasingly being replaced by HFCs. Thus, the CFC and HCFC data are an important source to get a first estimate of the historical and current refrigerant consumption and emissions. Furthermore, CFCs and HCFCs must be considered when designing a NAMA. A business-as-usual scenario to which NAMA measures are compared must include the activities under the Montreal Protocol, i.e. the phase-out of ODS such as HCFC and CFC. These data are typically available at the National Ozone Units. All countries set up HCFC phase-out management plans (HPMP), which provide further detailed and valuable information on how and where transformations will take place in terms of replacing HCFCs by alternative substances.

If resource and time constraints exist, it is possible to directly focus on the RAC&F sectors, because these are the dominating sectors with HFC consumption of more than 80% of the total (IPCC, 2006). As this report is considered as a practical supplement to the IPCC Guidelines for National GHG Inventories, an effective methodology to derive emissions from RAC&F is introduced later in this module (cf. also annex 1 to this module). This handbook emphasises practical aspects of data collection, in particular considering the Tier 2 bottom-up approach.

Before starting with an inventory, there must be a clear understanding of sectors, subsectors and systems, including their definition, where HFCs occur. There is a trade-off between the level of information in terms of demand and emissions derived from a detailed categorisation – and thus inventory – and the associated effort: More subsectors represent a higher degree of disaggregation. However, more specific information such as emission factors, initial charge of equipment etc. is needed.

2.3 Inventory in the refrigeration and air conditioning sector

HFCs are used as refrigerants in many types of refrigeration and air-conditioning equipment. The applications need to be grouped to facilitate the calculation and reporting procedure. Each category should encompass appliance systems with similar key characteristics such as initial charge, emission factors, lifetime etc. Table 2 shows the suggested subsectors and systems for RAC (based on the UNEP RTOC reports; UNEP 2011).

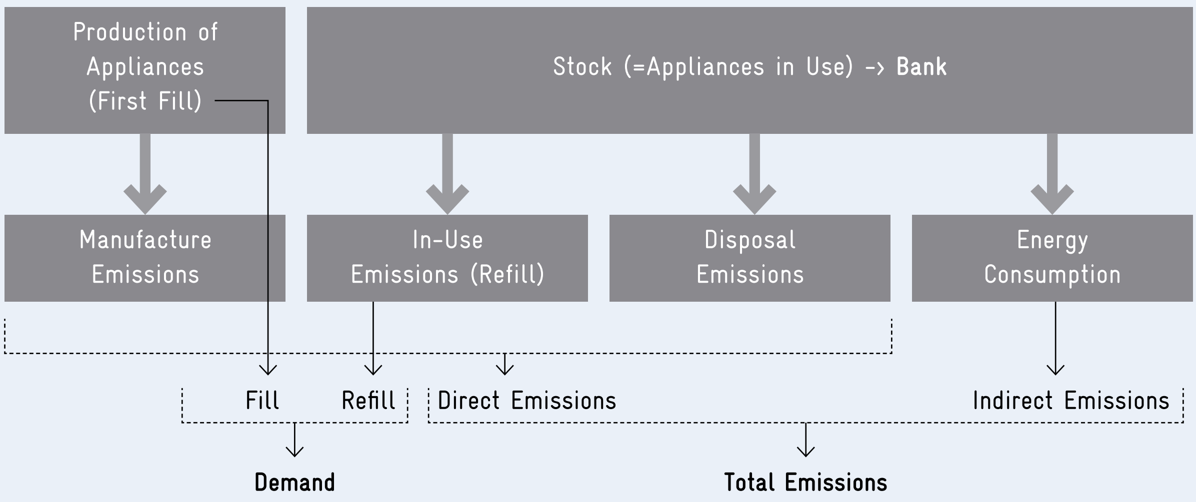
Data collection for the different systems is based on the previously introduced Tier 2a method, i.e. the emission-factor approach. This approach seeks information on the number of appliances that contain HFCs, as well as other parameters such as the amount of refrigerant per unit, life time of equipment, emission rates etc. As the systems vary significantly at the subsector level, the characterisation of this equipment can be a time-consuming task. The equipment data may be derived from appropriate statistics. In case these data are not available, field data must be collected, using subsector specific questionnaires that have to be send out to representatives of the various industry sectors (cf. sample questionnaire in annex 2). It is recommended to also collect historical data. Growth rates can be derived from these sources, which help to estimate future sales figures. However, assumptions on growth rates can also be derived from expert judgments, results of market studies or derived from the gross domestic product and/or population growth estimates.

TABLE 2
Suggested definition of subsectors and systems for refrigeration and air conditioning

Subsector	Systems
Unitary air conditioning	Self-contained air conditioners Split residential air conditioners Split commercial air conditioners Duct split residential air conditioners Commercial ducted splits Rooftop ducted Multi-splits
Chillers	Air conditioning chillers Process chillers
Mobile air conditioning	Car air conditioning Large vehicle air conditioning
Domestic refrigeration	Domestic refrigeration
Commercial refrigeration	Stand-alone equipment Condensing units Centralised systems for supermarkets
Industrial refrigeration	Stand-alone equipment Condensing units Centralised systems
Transport refrigeration	Refrigerated trucks/trailers

Figure 1 gives an overview of the data that have to be collected during the inventory compilation for the RAC sector, the different types of emissions and key terminology. In general, emissions occur during the production of new systems (manufacturing emissions) or from the stock (in-use emissions or operation emissions). Direct and indirect emissions must be strictly differentiated. Additionally, there are disposal emissions that occur during decommissioning of equipment at its end-of-life.

FIGURE 1
Schematic overview of the data that need to be collected during an inventory of RAC appliances, corresponding emissions and specific terminology



Terminology

Production: The production of equipment can be intended for sale within the country or for export. Both production figures must be considered for a national inventory, because production processes cause manufacturing emissions. Furthermore, the equipment that is produced in the country must be filled with refrigerants, thus contributing to the demand. The equipment that is sold on the domestic market will contribute to the stock and therefore to further in-use and end-of-life or disposal emissions (Figure 1).

Sales: Most available data will be sales figures, i.e. bottom-up data. For the inventory it is important to separate between imports and exports. The sales figures minus the imported fraction have been produced in the country (cf. production). In contrast to uncharged imported equipment, pre-charged imported equipment will not contribute to demand and manufacture emissions. However, all kind of equipment that is sold on the domestic market will contribute to the stock and therewith to further emissions (Figure 1). Where such market data are the primary source of activity data, cross-checks with chemical consumption data should be carried out as a quality control.

Stock: The stock is defined as the number of units in use in the different subsectors in a given year. The stock is increased by sold equipment and reduced by units that are disposed of at their end-of-life. The stock is a dominant source of emissions (Figure 1).Thus, high effort should be made for its proper estimation. The stock contributes to direct emissions with in-use and disposal emissions. However, even more important in terms of CO_2 emissions are the indirect emissions that result from the energy consumption of the appliances. These emissions can be 10 to 20 times higher than the direct emissions and should be taken into account. However, indirect emissions must be clearly separated from direct emissions. CO_2 emissions from energy consumption are quantified separately in the National Communications. Information about the number of appliances in the different subsectors, together with information on the type of refrigerant and the average charges, allow the quantification of the bank.

Bank: The bank is defined as the amount of substances, which is stored (in appliances) in the country.

Demand: F-gases can be monitored in terms of demand or emissions. The conversion from one to the other is not possible without sufficient background data. It is recommendable to calculate both demand and emissions. Demand arises from two different activities: the initial filling either at production or installation of the unit which is referred to as manufacture demand or first fill, and from service activities, when the equipment is topped-up during routine servicing or due to other kinds of leakage, which is referred to as service demand or refill. Thus, demand is defined as first fill plus refill. The demand from first filling actually corresponds to the average charge of the equipment.

Emissions: Total emissions result from direct emissions and indirect emissions. Direct emissions originate from the fluorinated substances; indirect emissions result from the energy consumption of the appliances. The quantification of direct emissions of fluorinated greenhouse gases is the primary goal of the inventory. However, indirect emissions might be additionally considered, because of their high contributions to overall emissions. As mentioned earlier direct emissions from HFCs must be reported in the National Communications of each country to the UNFCCC. For direct emissions, basically three types of emissions can be differentiated in the refrigeration and air conditioning sectors (Figure 1):

- manufacture emissions,
- emissions from banks (in-use or operating emissions), and
- disposal emissions.

Emission factors describe these emissions as percentages of the initial equipment charge. Default values are given by the IPCC (2006). However, country specific values should be used whenever possible.

Sources of direct HFC emissions

Manufacture emissions: Manufacture emissions or assembly emissions occur during domestic production of appliances when new equipment is filled for the first time. This includes emissions that occur on-site after installation or during filling of imported uncharged equipment.

In-use emissions: RAC equipment is usually topped-up regularly due to leakage. This amount is referred to as in-use emissions or operating emissions. However, these emissions also include losses due to technicians' activities during servicing. The amount reflects the service demand or refill.

Disposal emissions: Disposal emissions occur when equipment reaches its end-of-life and is decommissioned. The amount of refrigerant in the appliances at the end-of-life should be reclaimed or destroyed. Unfortunately, this is still rather an exception, in particular in developing countries. Thus, this amount of refrigerant will escape into the atmosphere, most often in the year of decommissioning.

The above mentioned categorisation of emissions is considered as suitable for inventories in most developing countries. However, more detailed categorisations are also accessible, for example in the German F-gas inventory (Schwarz, 2005).

Methodologies

The **Tier 2a approach**, which relies on the above mentioned emissions, is particularly suitable in homogeneous subsectors where the appliances have similar charge sizes, emission factors, cooling capacities etc. (e.g. domestic refrigerators). However, some subsectors such as industrial refrigeration are highly diverse and cover a variety of different applications. The units here are not always produced serially but frequently installed on site and designed with respect to specific circumstances, i.e. tailor-made to specific cooling needs. Therefore, depending on the specific situation of the industrial refrigeration subsector in a given country, a top-down approach or an indirect approach might be suitable to start with.

The **indirect approach** aims at estimating the refrigerant demand. Therefore, the amount of food that needs to be cooled, such as meat and milk, might be quantified. These data, which are also published by the Food and Agriculture Organisation (FAO) globally, support an estimation of the power that is needed for cooling this amount of food and consequently of the amount of refrigerants needed. The amount of refrigerant depends on the system (direct or indirect) and the working temperature. However, a full description of this approach is beyond the scope of this report.

In case reliable unit data cannot be acquired for each subsector, a **hybrid approach** might be also suitable: Elements of top-down and bottom-up methods are combined depending on the data availability. However, the hybrid approach requires caution in order to avoid double counting when combining both methods.

2.4 Inventory in the foam sector

The majority of the presented inventory descriptions applies to the foam sector as well. However, there are some significant differences. In this sector, we generally differentiate between open and closed foam cell types. Consequently, a basic categorisation is given by the cell type, but there are various sub-applications within each cell type. The suggested categorisation is given in Table 3.

The foams displayed in Table 3 have different emission profiles, and there is a variety of products for the sub-applications. Open-cell foams are predominantly used in mattresses, moulded products, interior equipment of cars and office furniture. Closed-cell foams are mainly used for insulation applications, in particular for house building. It is practically impossible to gather information about the number of different foam products. Therefore, we suggest to focus on the HFC supplier for the foam industry or the foam producing industry itself. Ideally, an inventory should directly focus on the amount of blowing agents (BLA) that is used in the foam industry. However, this information may not always be available or industries might not provide these kinds of data. Thus, alternatives are to gather data on produced tonnes of foam or produced volumes of foam, i.e. units. Also the length of produced panels in meters are sometimes reported which can be used for an inventory. In any case, the amount of blowing agents must then be estimated from the foam data which often needs additional information such as the density of the foam.

The main difference between open and closed-cell foam types is given by their emission profile. For the open-cell type, emissions occur during the manufacturing process and shortly thereafter, i.e. in the manufacturing country. For closed-cell foams three types of emissions are differentiated:

TABLE 3
Suggested definition of cell types and sub-applications for foams (PU=Polyurethane, XPS=Extruded polystyrene).

Cell type	Sub-application
Open cell type	PU Flexible Foam Continuous PU Flexible Foam Discontinuous PU Flexible Moulded Foam PU Integral Skin Foam
Closed cell type	PU Continuous Panel PU Continuous Flexible panel PU Discontinuous Panel PU Appliance Foam PU Continuous Block PU Discontinuous Block PU Spray Foam PU Pipe-in-Pipe PU OCF (bottle foam) PU Rigid foam all other applications XPS Extruded Polystyrene boards

- **First year loss:** These emissions occur during the manufacture of foams and/or installation,
- **Annual loss:** The emissions from closed-cell foam occur during the entire product life until decommissioning,
- **Decommissioning losses:** This part of emissions occur at the point of decommissioning or thereafter. Quantifying this emission source is generally a challenging task.

Following the IPCC (2006), emissions from closed cell foams can occur as long as 50 years after the production. However, shorter emitting periods are often observed.

Even though indirect emissions occur during the manufacturing process of foams due to energy consumption, indirect emissions are generally not considered. This is because of the minor mitigation potential.

In order to adequately capture all three types of emissions from closed-cell foams (first year, annual and decommissioning losses), it is necessary to collect current and historical annual chemical sales from the foam industry. The time series actually reaches back to the date when HFCs were introduced to the market within a certain application. In case detailed bottom-up data (units per sub-application) cannot be derived or foam applications cannot be disaggregated to the sub-application level, there is still the opportunity to estimate the emissions via the Tier 1 method. It was shown that the Gamlen model (Gamlen et al. 1986) is a robust method to estimate the emissions with limited resources (Tier 1a method). Here, the assumed product life is 20 years, the first year losses are 10 % of the original HFC charge per year and the annual losses are 4.5 % of the original HFC charge per year. These details can be used to estimate the emissions from the foam sector. A mass-balance approach is generally considered inappropriate for foams.

In the foam sector (as for the RAC sector) it is important to account for the bank, because a significant part of the emissions result from the bank of closed-cell foams and at the point of decommissioning. We also suggest to research on decommissioning practices in the respective countries. If country-specific emission factors are not available, these factors can be adopted from the Emission Factor Database (EFDB[5]).

It should be noticed, that foams are also used as insulation for domestic or commercial refrigeration. Thus, a comprehensive RAC inventory allows for an indirect estimation of the foams produced and foams in banks for these specific sub-applications. In this case again, domestic production, imports and exports must be differentiated.

5 www.ipcc-nggip.iges.or.jp/EFDB

An example for a national F-gas inventory is provided in Box 2.

BOX 2
Case study – the establishment of an F-gas inventory in Thailand

GIZ Proklima has supported Thailand with the establishment of an F-gas inventory. The detailed data collection can serve as a basis for the development of NAMA proposals and for the establishment of a measurement, reporting and verification (MRV) system.

The cooperation was part of a project funded by the German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety under its International Climate Initiative[6]. Partner organisations were the Thailand Greenhouse Gas Management Organisation (TGO), and the Department of Industrial Works (DIW). Being familiar with the landscape of the Thai RAC&F industry, a local consulting company, Bright Management Consulting Co. Ltd., was commissioned to compile the data.

Scope
Established during the course of 2012, the inventory covers the RAC&F sectors. In addition to F-gases, HCFCs, which are currently phased out in the country, were also taken into account.

Approach
A Key Categories Analysis (KCA), as described by the IPCC (2000), identified the key subsectors. This approach included level and trend analysis and resulted in nine important subsectors for the inventory.

The Guidelines for National Greenhouse Gas Inventories (IPCC 1997) were used to calculate emissions. Both a Tier 1 and a Tier 2 approach were applied.

Tier 1: Since no HFCs or HCFCs are produced within the country, refrigerant and blowing agent imports were relevant to calculate the emissions according to the Tier 1 approach. These data were taken from the Hazardous Substances Control Bureau and the Thai Customs Department.

Tier 2: The detailed bottom-up data to calculate emissions according to the Tier 2 approach were derived from:

- focus group meetings with industry representatives, site visits and personal interviews with manufacturers and servicing companies
- questionnaires that were sent to manufacturers and distributors including follow-up process
- secondary data (e.g. Thai Electrical and Electronics Institute, Department of Land Transport, Office of Industrial Economics, annual reports of supermarkets)

Quality control was an integral part of the process. The collected data were submitted to local experts for review. Additionally, in October 2012, the data were presented to a broader audience with representatives from industry and academia.

This cooperation has resulted in one of the most comprehensive F-gas inventories that have been established in developing countries.

6 http://www.international-climate-initiative.com/en/

3. Practical application

Major principles for the compilation of greenhouse gas inventories are transparency, consistency, comparability, completeness and accuracy (TCCCA).

Steps for a RAC&F inventory:

1. Conduct literature research to gather existing statistical data
2. Build on step 1 and use the data to identify the most important subsectors
3. Identify key stakeholders (e.g. with support of the National Ozone Units)
4. Fill out the Data Input Sheet (DIS-Tool)
5. Organise stakeholder workshops with representatives from the relevant subsectors to improve the data mining
6. Distribute questionnaires to RAC&F industry and to representatives from the different subsectors
7. Calculate demand, banks and emissions

Step 1: Conduct literature research to gather existing statistical data

Use the data that has already been compiled and get an overview of existing statistics in the sector. Ideally consider emission data from HFC and HCFC in the different sectors. These may be available in the National Communications of GHG *(http://unfccc.int/national_reports/non-annex_i_natcom/items/2979.php)* and at the US Environmental Protection Agency *(http://www.epa.gov/climatechange/EPAactivities/economics/nonco2projections.html)*.

If emission data are not available, try to gather the following data:
- production of HFC and HCFC gases
- import of HFC and HCFC gases
- export of HFC and HCFC gases
- demand of HFC and HCFC gases

This information provides an overview of the consumption of chemicals and allows calculating emissions, following the Tier 1 approach.

You can usually get this data from:
- customs
- National Ozone Unit (NOU)
- Ministry of Industry, Economics, Trade
- RAC&F industry associations
- suppliers and distributors
- service and maintenance organisations
- United Nations Environmental Programme (UNEP) *(http://ozone.unep.org/new_site/en/ozone_data_tools_access.php)*

This data is necessary to identify important subsectors (see step 2) which then can be analysed in more detail for the Tier 2 approach. For this detailed bottom-up approach you need the following data:
- stock of equipment, production, import and export of equipment
- domestic sales figures of equipment
- demand of blowing agents

More details on this data collection process are given in step 4, helpful sources are:
- customs
- Ministry of Industry, Economics, Trade, Transport
- RAC&F industry associations
- national statistical offices
- relevant literature, e.g. BSRIA *(www.bsria.co.uk)*, JARN *(www.ejarn.com)*

Step 2: Build on step 1 and use the data to identify the most important subsectors

- In the IPCC (2000) document this is called Level and Trend Assessment. It provides formulas for the calculation of the following: Which subsector is most important with regard to GHG emissions (level assessment)?
- Which subsectors show high emission growth (trend assessment)?

A software which is provided by the UNFCCC *(http://unfccc.int/resource/cd_roms/na1/ghg_inventories/index.htm)* calculates both level and trend assessment, when sector specific emission data are entered.

Step 3: Identify key stakeholders (e.g. with support of the National Ozone Units)

Make use of relevant contacts and networks that were established during the CFC- and HCFC-phase-out, keeping in mind that HFCs are used in the same subsectors and systems. The required information sources include the following actors, particularly the market leaders, from the private sector:
- producers (manufacturing industry), importers, exporters, distributers of bulk gases and of products and equipment containing F-gases
- trade associations
- servicing enterprises
- reclaim or destruction industry for F-gases

Step 4: Fill out the Data Input Sheet (DIS-Tool)

Gather detailed market and production data in the RAC&F sectors. The required data include aggregated data for Tier 1 and detailed bottom-up data for Tier 2. Market data, production data and technical data about the appliances are particularly important (cf. lists below “Market and production data”, “Technical data“). An electronic Data Input Sheet (DIS-Tool) is provided in Annex 1 to Module 1, which shows the kind of data that needs to be collected for the different subsectors including advice on where to get them from.

Perform cross-checks and plausibility checks of the data for quality control during and after the data collection. The Data Input Sheet can be completed by using published statistical data (from step 1 and step 3), expert interviews or by using questionnaires which are sent to important stakeholders identified in the step above. When using questionnaires, design them separately for each subsector. A sample questionnaire is provided in the annex to this module. It can be used for manufacturers and distributors of equipment in the air conditioning subsector. However, questionnaires should be adapted to the country-specific situation, e.g. regarding language and categories of systems. It is also recommended to enquire only about systems and refrigerants or blowing agents which are actually used in the country. National Ozone Units generally have a good overview about the situation.

The data from the questionnaires should be summed up (e.g. produced appliance systems) and averaged (e.g. COP), respectively. Afterwards, enter these data in the DIS-Tool; existing data gaps may be filled with data from the sources mentioned above. The completed DIS-Tool serves as the basis to conduct the bottom up (Tier 2a) emission factor approach, i.e. to calculate emissions for the entire country. The following data is necessary for this approach:

Market and production data
- domestic production data of units from the year 2000 to the present
- expected future growth rates (further support on estimating growth rates of stock data is provided through the Cooling Needs Tool provided in module 2)
- units produced for export (from the year 2000 to the present)
- units imported (from the year 2000 to the present)
- domestic sales figures of units (from the year 2000 to the present)
- refrigerant distribution of sold units for the years 2000 and 2010 (i.e. percentage of different refrigerant type units and blowing agent type units, respectively)
- stock data of units (from the year 2000 to the present)
- refrigerant distribution of stock for the years 2000 and 2010 (i.e. percentage of different refrigerant-type units and blowing-agent-type units, respectively)

Technical data
- dominant refrigerants and blowing agents used for the different applications (in case data is not available or large gaps remain, estimates by experts on shares can be used)
- average initial charge of units (and expected future trends until 2030)
- average emission factors for refrigeration and air conditioning (manufacture, in-use and disposal emission factors and expected future trends until 2030); for foam production the relevant factors are first year loss (in %), annual loss (in %) and maximum potential end-of-life loss (in %)
- average product lifetime
- average cooling capacity
- average coefficient of performance (COP)
- average cost per unit (cf. Module 4)
- average runtime hours
- country-specific emission factors for electricity and expected changes (e.g. due to the increasing importance of renewable energy)

Step 5: Organise stakeholder workshops with representatives from the relevant subsectors to improve the data mining

Workshops to improve data mining may be organised in cooperation with national authorities for environmental protection or other governmental organisations. Conduct a separate workshop for each subsector in order to ensure that the expert participants can discuss detailed sector-specific approaches. At the beginning of the workshops, inform the stakeholders about the general rationale for a national F-gas inventory and the co-benefits such as possible sectoral development strategies (cf. Module 10). Furthermore, the stakeholders need to be introduced to the approaches for data collection. Let them know that questionnaires will be sent out to them in order to gather market and production data which will contribute to the national F-gas inventory. You can also use the workshop to discuss and adopt the prepared questionnaires for the different subsectors.

Step 6: Distribute questionnaires to RAC&F industry and to representatives from the different subsectors

Ideally, complete the questionnaires during face-to-face interviews or telephone surveys. A less time consuming method is the distribution of the questionnaires without following the procedure personally, however, the response rate might be low in this case. Plan enough time and follow up on the questionnaires: inform stakeholders about confidentiality; let them know exactly about the purpose of this inventory and assure the confidential handling of the data. It is also recommended to attach an official letter from the leading ministry; ideally the recipients of these letters should be addressed personally.

In the questionnaires for the RAC industry, you should at least ask for:

- type of appliance system that is produced, imported and exported
- number of produced, imported and exported appliance systems (recorded as a time series, ideally beginning in the year 2000)
- cooling capacity
- coefficient of performance (COP)
- product lifetime
- annual leakage (in-use emission)
- expected future annual growth rate of production
- name of the refrigerant
- initial charge of the system

In the questionnaires for the foam industry, you should at least ask for:

- type of foam that is produced (e.g. integral foam and spray foam)
- tonnes of blowing agent that are used (recorded as a time series, ideally beginning in the year 2000). Alternatively you may ask for tonnes or volume of foam production (then additional information is needed about the content of blowing agent per tonne or volume of foam and the foam density)
- product lifetime
- emission factors
- expected future annual growth rate of production
- tonnes of blowing agent imported and exported via foam products
- type and amount of blowing agent that is used for blended polyol

Step 7: Calculate demand, banks and emissions

Once the DIS-Tool is completed, the collected data can be used to calculate HFC demand, banks and emissions using the formulas as provided by the IPCC (1997, 2000). Alternatively, you may enter the data into the HFC Inventory and Projection Tool to calculate HFC demand, banks and emissions. A full description of this tool is found in annex 1 to this module. The results provide an overview of the most important subsectors in terms of demand, banks and emissions. Furthermore, the projections from this tool provide an estimate on future developments. The current emission data can be used for the national reports to the UNFCCC.

If your inventory data is expected to serve as a basis to develop NAMAs, the GIZ Proklima team can assist you with the development of BAU and mitigation scenarios using the Mitigation and Cost Tool, accounting also for HCFCs and indirect emissions from energy consumption (see also Module 5).

Practical advice

- Engage specialised local consultant agencies to support the establishment of a national F-gas inventory. Being familiar with the specific culture and language, local agencies can facilitate the process of gathe-ring detailed
  technical information which will often involve face-to-face discussions with local industry and experts.
- Make use of available statistical data as far as possible; this may be more efficient and timesaving than working with questionnaires.
- The commercial and industrial refrigeration sectors are generally complex, because the systems consist of different components which are assembled on site. Particularly in these subsectors, secondary data may be useful for the inventory.
- Transport ministries are a good source to get data on mobile air conditioning and transport refrigeration.
- Stock data is often difficult to get. Sometimes information is available in reports from national statistical offices, annual reports from market leaders, transport ministries (for mobile air conditioning and transport refrigeration), websites and annual reports of supermarket chains. Alternatively, you can use the Stock Projection Tool or the HFC Inventory and Projection Tool for an estimation of the stock.

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