Prepared for European Commission, DG Environment

# Study on the potential application of Art. 3 and 4(1) of Regulation (EC) No 842/2006 on certain fluorinated greenhouse gases to air conditioning and refrigeration systems contained in different transport modes

070307/2007/483336/MAR/C4

Final report

22.12.2008


BiPRO

Beratungsgesellschaft für integrierte Problemlösungen

## Document Identification

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|---|---|
| Project Number | 070307/2007/483336/MAR/C4 |
| Project Title | Study on the potential application of Art. 3 and 4(1) of Regulation (EC) No 842/2006 on certain fluorinated greenhouse gases to air conditioning and refrigeration systems contained in different transport modes |
| Deliverable title | Final report |
| Prepared by | Elisabeth Müller (BiPRO GmbH) |
| Approved by | Reinhard Joas (BiPRO GmbH) |
| Date | 22.12.2008 |
| Release | 3 |

# Content

# 1 Executive summary

**Background**

Public awareness of the problem of climate change has increased rapidly, now placing it amongst top priorities in the national and international scene. The root cause for climate change is the increasing emission of greenhouse gases, which leads to a warming of the atmosphere.

In order to tackle global warming, the international Community adopted the UNFCCC (1992) and the Kyoto Protocol (1997). The latter entered into force on 16 February 2005.

To undertake steps to fulfil the obligations of the EU and its Member States under the Protocol, the Council and the European Parliament adopted a legal framework on F-Gases in 2006 comprising Directive 2006/40/EC which is related to F-Gas emissions from air conditioning systems in certain motor vehicles and Regulation (EC) No 842/2006 on certain fluorinated greenhouse gases. The latter came into application on 4 July 2007 and aims to contain, prevent and reduce emissions of fluorinated greenhouse gases. The regulation addresses containment of F-Gases (Art. 3), recovery of F-Gases for the purpose of recycling, reclamation or destruction (Art. 4), training and certification of personnel (Art. 5), reporting obligations for producers, importers and exporters (Art. 6), labelling of specific products and equipment containing F-Gases (Art. 7), bans and controls of certain uses of F-Gases (Art. 8) and market prohibitions of F-Gases (Art. 9).

Article 10(1) requires the Commission to publish a report on air-conditioning in modes of transport (other than motor vehicles) and on refrigeration in modes of transport, followed, if appropriate, by legislative proposals, with a view to applying the provisions of Article 3 to air-conditioning systems (other than motor vehicles), and refrigeration systems contained in modes of transport.

**Key messages:**

Based on the results of this study, the answer to the question whether the provisions of Article 3 and/or Article 4(1) of Regulation (EC) No 842/2006 on certain fluorinated greenhouse gases (F-Gases) should be applied to air conditioning systems, other than those fitted to motor vehicles referred to in Directive 70/156/EEC and refrigeration systems contained in different transport modes varies between modes, as impacts are significantly different across the various sectors.

- For systems contained in modes of road transport it is recommended that both the provisions of Article 3 and 4(1) be applied.
- For systems in rail transport modes, it is recommended that only the provisions of Article 4(1) be applied.

- For systems in maritime and inland waterway transport it is recommended that Article 3 and 4(1) be applied for all modes with the exception of motorised inland cargo vessels[1].

**Problem definition**

The current emission of F-Gases resulting from refrigeration and air conditioning in modes of transport in Europe, calculated in $CO_2$ equivalents, is approximately 3,000 kt (2007).

| Sector | Emission F-Gases [t/year] | Emission $CO_2$ eq. [kt/year] |
|---|---|---|
| Road transport | ~ 875 | ~ 2,537 |
| Rail transport | ~ 82 | ~ 113 |
| Maritime and inland waterway transport | ~ 241 | ~ 376 |
| Sum | ~ 1,198 | ~ 3,026 |

Table 1: Emission of F-Gases from refrigeration and air conditioning systems in varying transport sectors in 2007

Several factors influence future emissions. Most important is an expected growth of the number of relevant transport systems fitted with air conditioning and refrigeration systems on one hand and the substitution of old technologies by modern and improved equipment on the other hand. Against this background in 2020 the following emissions are expected under the baseline scenario that no regulatory measures are taken (option 1):

| Sector | Emission F-Gases [t/year] | Emission $CO_2$ eq. [kt/year] |
|---|---|---|
| Road transport | ~ 752 | ~ 2,213 |
| Rail transport | ~ 123 | ~ 165 |
| Maritime and inland waterway transport | ~ 937 | ~ 1,994 |
| Sum | ~ 1,812 | ~ 4,372 |

Table 2: Emission of F-Gases from refrigeration and air conditioning systems in varying transport sectors in 2020 – Option 1 (BAU)

**Objectives and Scope**

Against the background of current emissions and their forecast up to 2020, the objective of the study is to support the European Commission with a decision basis for further policy measures within the scope of Regulation (EC) No 842/2006. This means in particular:

- Assessing the impacts from the potential application of the provisions of Article 3 of Regulation (EC) No 842/2006 to air conditioning systems (other than those fitted to motor vehicles referred to in Directive 70/156/EEC) and refrigeration systems contained in modes of transport;

[1] With regard to the previous study the F-Gas charge (4.5 kg) as well as the F-Gas emissions (6%) of air conditioning systems in motorised inland cargo vessels is very low. Therefore the emission reduction which can be achieved by applying Art. 3 of the F-Gas Regulation in comparison with the costs which arise is very low.

- Assessing the impacts of the potential application of the provision of Article 4(1) of Regulation (EC) No 842/2006 to the above-mentioned systems;

- Supporting DG Environment of the European Commission in consultations with stakeholders of the relevant sectors.

The assessment covers refrigeration and air-conditioning systems (excluding those in motor vehicles) in all transport modes which were identified as follows:

- Refrigerated road transport sector (vans (<3.5 t), trucks (>3.5 t) and trailers, classification according to Directive 70/156/EEC)

- Rail sector (trains (railway vehicles), metro, trams)

- Maritime and inland waterway sector (sea-going merchant ships, ships for refrigerated cargo, inland navigation vessels and shipping vessels)

The main F-Gases used in refrigeration and air conditioning systems in those modes of transport are: R-134a, R-407C, R-404A, R-410A and R-507. A list of all relevant F-Gases is provided in the Annex.

Environmental, economic and social impacts are evaluated for all three above-mentioned sectors.

Air-conditioning systems in motor vehicles referred to in Directive 70/156/EEC are excluded by article 10 of Regulation (EC) No 842/2006 and are therefore not a subject of this assessment.

Air-conditioning systems in other motor vehicles are not included in this study as there is a high uncertainty regarding the amount and characteristics of vehicles concerned. These motor vehicles are summarised in agricultural machinery such as tractors, harvesters and choppers as well as in construction machinery such as rollers, wheel loaders and dredgers. Agricultural or forestry tractors, their trailers and interchangeable towed machinery are covered by the provisions of Directive 2003/37/EC on type-approval of agricultural or forestry tractors, their trailers and interchangeable towed machinery, together with their systems, components and separate technical units. In this Directive no requirements are defined regarding F-Gas emissions from air-conditioning systems. With regard to F-Gas emissions from agricultural and construction machinery, only very little information is available up to now for Germany or other countries. According to a German study, about 30 t of HFC-134a were emitted from air-conditioning systems installed in agricultural and construction machinery in 2002 in Germany. To further elaborate on potential impacts, a workshop with the industry concerned is recommended on a European scale. As the emissions from air-conditioning systems and the systems themselves from the agricultural and construction machinery are similar to them from motor vehicles the project team suggests to further consider them in the framework of the review of the Directive 2006/40/EC which is related to F-Gas emissions from air conditioning systems in certain motor vehicles.

**Important methodological issues**

The impact assessment compares environmental, economic and social impacts of 3 different policy options with a “no action” option. 2020 has been selected as a reference year for the assessment. At this time, full enforcement of the assessed options could be expected. Environmental and economic impacts were calculated on an annual basis. Investments that are required only once (e.g. leakage detection equipment) were distributed over their periods of life. Impacts for various concerned actors were identified and, via causal chains, indirect consequences were also considered. The overall methodology follows the Commission guidelines on impact assessments.

Data collection was a major issue because in a very short time huge amounts of (partly confidential) information had to be collected. For this reason a questionnaire was distributed to authorities in Member States and interviews with concerned stakeholders and experts have been performed. Available literature, and in particular, already existing studies contracted by the Commission Services have also been used. Remaining data gaps have been closed by best estimates.

The interim report was presented for discussion at a meeting with stakeholders (held on 17.07.2008). This revised assessment has been refined to take account of comments and additional information received at, and following, this meeting.

**Policy options**

For the impact assessment, four policy options have been evaluated:

- Option1: No further action – Business as usual (BAU): baseline scenario
- Option 2: Application of the provisions of Art. 3 (containment) of Regulation (EC) No 842/2006 to air conditioning systems (other than those fitted to motor vehicles referred to in Directive 70/156/EEC) and refrigeration systems contained in modes of transport.

  This option requires the operator of the refrigeration and air-conditioning systems to improve the containment of these systems through various requirements such as regular leakage checks by certified personnel.
- Option 3: Application of the provision of Art. 4(1) (recovery) of Regulation (EC) No 842/2006 to the above-mentioned systems

  This option requires the operator of the refrigeration and air-conditioning systems to avoid emissions during maintenance or servicing, and, at the end of life of the equipment to ensure further recycling, reclamation or destruction through the proper recovery of F-Gases by certified personnel.
- Option 4: Application of the provisions of both Art. 3 and 4(1) of Regulation (EC) No 842/2006 to the above-mentioned systems

## Analysis of impacts

### Environmental impacts

From an environmental point of view, it is estimated that options 2, 3 and 4 would provide the following emission reduction potentials:

| Sector | Emission reduction potential F-Gases [t/year] | Emission reduction potential $CO_2$ eq. [kt/year] | Emission reduction potential $CO_2$ eq. [%]* |
|---|---|---|---|
| Road sector | ~ 185 | ~ 565 | ~ 26 |
| Rail sector | ~ 10 | ~ 13 | ~ 8 |
| Maritime and inland waterway sector | ~ 359 | ~ 764 | ~ 38 |
| Sum | ~ 554 | ~ 1,342 | ~ 30 |

*compared to BAU 2020

Table 3: Reduction of F-Gas emissions in various transport sectors in 2020 - option 2

| Sector | Emission reduction potential F-Gases [t/year] | Emission reduction potential $CO_2$ eq. [kt/year] | Emission reduction potential $CO_2$ eq. [%]* |
|---|---|---|---|
| Road sector | ~ 118 | ~ 349 | ~ 16 |
| Rail sector | ~ 10 | ~ 14 | ~ 8 |
| Maritime and inland waterway sector | ~ 24 | ~ 49 | ~ 2 |
| Sum | ~ 152 | ~ 412 | ~ 9 |

*compared to BAU 2020

Table 4: Reduction of F-Gas emissions in various transport sectors in 2020 - option 3

| Sector | Emission reduction potential F-Gases [t/year] | Emission reduction potential $CO_2$ eq. [kt/year] | Emission reduction potential $CO_2$ eq. [%]* |
|---|---|---|---|
| Road sector | ~ 303 | ~ 914 | ~ 41 |
| Rail sector | ~ 20 | ~ 28 | ~ 16 |
| Maritime and inland waterway sector | ~ 383 | ~ 813 | ~ 41 |
| Sum | ~ 706 | ~ 1,754 | ~ 40 |

*compared to BAU 2020

Table 5: Reduction of F-Gas emissions in various transport sectors in 2020 - option 4

**Economic and social impacts**

Economic impacts differ, depending on the concerned actors. Additional costs as well as savings for operators were calculated. For comparisons to other data, the costs in 2020 are calculated in current prices.

**For option 2, the estimated net costs for operators compared to the baseline (option 1) are as follows:**

| Sector | Additional Costs [€m/year] | Additional Savings [€m/year] | Net additional costs [€m/year] |
|---|---|---|---|
| Road sector | ~ 115 | ~ 4.6 | ~ 111 |
| Rail sector | ~ 40 | ~ 0.2 | ~ 40 |
| Maritime and inland waterway sector | ~ 27 | ~ 9.0 | ~ 18 |
| Sum | ~ 182 | ~ 14 | ~ 168 |

Table 6: Costs and savings for operators related to option 2 (compared to option 1)

Apart from the operators, other actors are also affected by the regulatory options assessed. Certification bodies and servicing companies as well as engineering companies and manufacturers of equipment would potentially have additional revenues whereas producers and distributors of F-Gases would probably have reduced revenues. Member State administration is expected to have additional costs for e.g. awareness raising, enforcement and control.

If operators need to contract external partners, additional costs on the one hand mean additional turnover on the other. Based on the additional costs and savings given in the table above, it is assumed that certification, servicing and training activities will generate roughly 2,100 jobs in Europe while no significant loss of jobs (<30) would occur in the sectors of production and distribution of F-Gases as a consequence of option 2.

**For option 3, the estimated additional costs for operators compared to the baseline (option 1) are as follows:**

| Sector | Additional Cost [€m/year] | Additional Savings [€m/year] | Net additional cost [€m/year] |
|---|---|---|---|
| Road sector | ~ 25 | ~ 2.6 | ~ 23 |
| Rail sector | ~ 3.3 | ~ 0.3 | ~ 3.0 |
| Maritime and inland waterway sector | ~ 0.8 | ~ 0.6 | ~ 0.2 |
| Sum | ~ 29 | ~ 3.4 | ~ 26 |

Table 7: Costs and savings for operators related to option 3 (compared to option 1)

As regards option 3, other actors apart from the operators would experience indirect impacts. Certification bodies and service companies as well as recycling companies are expected to have additional incomes, whereas producers and distributors of F-Gases would probably have a reduction of income. Member State administration is expected to incur additional costs for e.g. awareness raising, enforcement and control.

If operators need to contract external partners, additional costs on the one hand mean additional turnover on the other. Based on the additional costs and savings given in the table above, it is assumed that certification, servicing and training activities will generate roughly 350 jobs in Europe while no significant loss of jobs (<10) would occur in the sectors of production and distribution of F-Gases as a consequence of option 3.

**For option 4, the estimated additional costs for operators compared to the baseline (option 1) are as follows:**

| Sector | Additional Cost [€m/year] | Additional Savings [€m/year] | Net additional cost [€m/year] |
|---|---|---|---|
| Road sector | ~ 116 | ~ 7.2 | ~ 109 |
| Rail sector | ~ 40 | ~ 0.5 | ~ 40 |
| Maritime and inland waterway sector | ~ 27 | ~ 9.5 | ~ 17 |
| Sum | ~ 183 | ~ 17 | ~ 166 |

Table 8: Costs and savings for operators related to option 4 (compared to option 1)

As regards option 4, other actors apart from the operators would experience indirect impacts. Certification bodies and service companies as well as recycling and engineering companies are expected to have additional incomes whereas producers and distributors of F-Gases would probably have a reduction of income. Member State administration is expected to incur additional costs for e.g. awareness raising, enforcement and control.

If operators need to contract external partners, additional costs on the one hand mean additional turnover on the other. Based on the additional costs and savings given in the table above, it is assumed that certification, servicing and training activities will generate roughly 2,100 jobs in Europe while no significant loss of jobs (<50) would occur in the sectors of production and distribution of F-Gases as a consequence of option 4.

In addition, benefits on a macro-economic scale resulting from the reduction of F-Gas emissions also need to be considered. Although a quantification of these effects is difficult due to huge uncertainties related to costs of climate change and consequences of emission reduction in 2020, a rough estimation would show a benefit of more than 10 million euros per year for the whole of Europe.

**Recommendation:**

The main criterion, on which recommendations are based, is the cost per tonne of $CO_2$ equivalent, which gives an opportunity to compare one measure with other potential measures to reduce greenhouse gas emissions. In addition, the full scope of pros and cons related to impacts is taken into consideration, as summarised by stakeholder´s reactions.

The assessment shows a different picture for each sector. Some Member States already include or plan to include the application of Art. 3 and Art. 4(1) to air conditioning and refrigeration systems in transport modes in their own legislation (SE, FR, DE, PL). In Austria and Denmark, the use of F-gas refrigerants is already prohibited with a few exemptions.

*In the following tables, an overview of the costs per tonne of $CO_2$ reduction for each option and sector is provided.*

Option 2

| Sector | Emission reduction potential $CO_2$ eq. [kt] | Additional net costs for operators [€m] | Cost/tonne $CO_2$ reduction [€/tonne] | Recommendation |
|---|---|---|---|---|
| Road sector | ~ 565 | ~ 111 | ~ 196 | -- |
| Rail sector | ~ 13 | ~ 39.7 | ~ 2,969 | -- |
| Maritime and inland waterway sector* | ~ 764 | ~ 18 | ~ 24 | -- |

*including all sub-sectors

Table 9: Impacts by 2020 and recommendation for option 2

In the maritime and inland waterway sector, costs per tonne vary significantly depending on the types of vessels. For motorised inland cargo vessels, the abatement costs per tonne of $CO_2$ equivalent exceed €2,500. The high costs are due to low charges (<5kg) in air conditioning systems of motorised inland cargo vessels and to very low emissions (~6%). It seems therefore that application of option 2 for this sub-sector should not be recommended.

Option 3

| Sector | Emission reduction potential $CO_2$ eq. [kt] | Additional net costs for operators [€m] | Cost/tonne $CO_2$ reduction [€/tonne] | Recommendation |
|---|---|---|---|---|
| Road sector | ~ 349 | ~ 23 | ~ 65 | -- |
| Rail sector | ~ 14 | ~ 3 | ~ 215 | Yes |
| Maritime and inland waterway sector | ~ 49 | ~ 0.2 | ~ 4 | -- |

Table 10: Impacts and recommendation for option 3

Option 4

| Sector | Emission reduction potential $CO_2$ eq. [kt] | Additional net costs for operators [€m] | Cost/tonne $CO_2$ reduction [€/tonne] | Recommendation |
|---|---|---|---|---|
| Road sector | ~ 914 | ~ 109 | ~ 119 | Yes |
| Rail sector | ~ 28 | ~ 40 | ~ 1,437 | -- |
| Maritime and inland waterway sector* | ~ 813 | ~ 18 | ~ 22 | Yes |

*including all sub-sectors

Table 11: Impacts and recommendation for option 4

Based on the available information, option 2 seems to be applicable for the road, maritime and inland waterway sector (excluding motorised inland cargo vessels). Option 3 seems to be applicable for all sectors (excluding motorised inland cargo vessels).

By applying option 4 (both options 2 and 3), the emission reduction of both options 2 and 3 could be aggregated. Costs would be lower than the sum of both options as some costs (e.g. certification, training) would only occur once.

Therefore option 4 seems to be applicable for the road, maritime and inland waterway sector (excluding motorised inland cargo vessels). For the rail sector, costs per tonne still seem to be too high for applying option 4. Therefore, the application of option 3 is recommended for this sector.

*In the following paragraphs, the reactions of stakeholders to the results presented are summarized and general recommendations are derived:*

**Road Sector**

Taking into account all impacts emerging from the discussion on the results of this study, reactions of stakeholders show that they support both option 2 and 3 for the road sector. This combination is reflected in option 4, which is therefore recommended for this sector.

With this recommendation, $CO_2$ equivalent savings of 914 kt per year can be expected for 2020 compared to business as usual.

**Rail Sector**

Against the background of reasonable cost/benefit ratios and the full spectrum of impact analysis results, option 3 has been accepted by the industry sector – for the rail transport. Option 2 would bring very high costs per tonne of $CO_2$ reduction and is therefore not recommended. This is correspondingly also valid for option 4.

With the recommendation of option 3, $CO_2$ equivalent savings of 14 kt per year can be expected for 2020 compared to business as usual.

**Maritime and inland waterway sector**

Stakeholders in the maritime sector (in particular ECSA) do not support option 4, which is the preferred option as a result of the impact analysis. The main argument is an expected high economic burden for concerned operators, combined with some doubts on technical feasibility of potential reduction.

Taking into consideration the low average costs of reducing a tonne of $CO_2$ emissions of roughly €30-€80/tonne of $CO_2$ by various measures (such as replacing fossil energy by solar energy, etc.) and the discussions within the international experts community on this issue, the point of view of ECSA is not shared in general. However, due to the differences within the maritime and inland waterway sector, some specific categories (namely inland motorised cargo vessels) need to be treated separately. Here the argumentation of ECSA seems well justified. Therefore, option 4 (which combines options 2 and 3) is recommended for the sector with an exemption for inland motorised cargo vessels.

With this recommendation $CO_2$ equivalent savings of 813 kt per year can be expected for 2020 compared to business as usual.

Additional economic burdens for ship owners due to containment measures on F-Gases in refrigeration or air-conditioning systems in EU-flagged ships might generate some interest in reflagging, although there are doubts that this will occur in practice. One option to avoid reflagging is to link F-Gas Regulations to EU ports rather than only to the EU flagged fleet. Shipping is a global business and it would therefore be highly recommendable to discuss within the IMO possible activities which would then be valid for all ships on a global level.

# 2 Problem Definition

## 2.1 Background

Public awareness of the problem of climate change has increased rapidly, now putting it amongst top priorities on the national and international scene. The root cause for climate change is the increasing emission of greenhouse gases, which leads to a warming of the atmosphere. Many environmental, economic and social issues find common ground in the form of climate change. Individual and political action on climate change can take many forms, all of which have the ultimate goal of limiting and/or reducing the concentration of greenhouse gases in the atmosphere.

To tackle global warming, the international community adopted the UNFCCC (1992) and the Kyoto Protocol (1997). The latter entered into force on 16 February 2005.

Under the Council Decision 2002/358/EC of 25 April 2002 concerning the approval of the Kyoto Protocol, the EU is bound to reduce greenhouse gas emissions by 8% compared to the base year 1990, during the first commitment period 2008-2012. Greenhouse gases that are covered by the Kyoto Protocol are the so called ‘industrial greenhouse gases’ (major greenhouse gases): carbon dioxide ($CO_2$), methane ($CH_4$), nitrous oxide ($N_2O$) and three groups of fluorinated gases (hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulphur hexafluoride ($SF_6$). The latter – fluorinated gases (F-Gases) – are potent and long living gases with a global warming potential (GWP) ranging from 97 to 22,200 (Annex I, Part 1 of Regulation (EC) No 842/2006 and 2001 IPCC GWP values). The atmospheric lifetimes vary from about 12 years up to over 3,200 years.

In order to undertake steps to fulfil the obligations of the EU and its Member States under the protocol, the Council and the European Parliament adopted a legal framework on F-Gases in 2006 comprising Directive 2006/40/EC which is related to F-Gas emissions from air conditioning systems in certain motor vehicles, and Regulation (EC) No 842/2006 on certain fluorinated greenhouse gases. The latter came into application on 4 July 2007 and aims to contain, prevent and reduce emissions of these gases. The regulation addresses containment of F-Gases (Art. 3), recovery of F-Gases for the purpose of recycling, reclamation or destruction (Art. 4), training and certification of personnel (Art. 5), reporting obligations for producers, importers and exporters (Art. 6), labelling of specific products and equipment containing F-Gases (Art. 7), bans and controls of certain uses of F-Gases (Art. 8) and market prohibitions of F-Gases (Art. 9).

Within the context of this project, the following provisions are of particular relevance:

- Obligations for operators of certain stationary equipment containing fluorinated greenhouse gases to ensure that they are checked for leakage by certified personnel within a determined time-schedule (Article 3)

- Obligations for operators of certain stationary equipment containing fluorinated greenhouse gases to establish arrangements for the proper recovery by certified personnel to ensure recycling, reclamation or destruction of F-Gases (Article 4(1)). The recovery should take place before the final disposal of the equipment and, if necessary, during its servicing and maintenance.
- Training and certification of personnel and companies involved in activities provided by this Regulation (Article 5).

Article 10(1) requires the Commission to publish a report on air-conditioning in modes of transport (other than motor vehicles) and on refrigeration in modes of transport, followed, if appropriate, by legislative proposals, with a view to applying the provisions of Article 3 to air-conditioning systems (other than motor vehicles), and refrigeration systems contained in modes of transport.

## 2.2 Objectives

Against this background, the European Commission has decided to carry out an assessment of the environmental, economic and social impacts, considering – along with the application of Art. 3 – also the application of Art. 4(1) to air conditioning systems (other than motor vehicles), and refrigeration systems contained in modes of transport.

Therefore, the main objectives of this project are to

- Assess the impacts from the potential application of the provisions of Article 3 of Regulation (EC) No 842/2006 to air conditioning systems, other than those fitted to motor vehicles, referred to in Directive 70/156/EEC and refrigeration systems contained in modes of transport;
- Assess the impacts from the potential application of the provisions of Article 4(1) of Regulation (EC) No 842/2006 to the above-mentioned systems;
- Support DG Environment in consultations with stakeholders in the relevant sectors.

## 2.3 Scope

The assessment covers relevant transport sectors which were identified as follows:

- Refrigerated road transport sector (vans (<3.5t), trucks (>3.5t) and trailers, classification according to Directive 70/156/EEC) (refrigeration systems only)
- Rail sector (railway vehicles, metro, trams)
- Maritime and inland waterway sector (sea-going merchant ships, ships for refrigerated cargo shipping vessels and inland navigation vessels)

Motor vehicles referred to in Directive 70/156/EEC are excluded by article 10 of Regulation (EC) No 842/2006 and are therefore not a subject of this assessment. The air transport sector is not covered in this report.

Environmental, economic and social impacts are evaluated for the three above-mentioned sectors.

Air-conditioning systems in other motor vehicles are not covered by Directive 70/156/EEC but could therefore potentially be covered by a possible application of Art. 3 and 4(1) of the F-Gas Regulation. For such motor vehicles, which are summarised as agricultural machinery such as tractors, harvesters and choppers, as well as construction machinery such as rollers, wheel loaders and dredgers, it was difficult to obtain information regarding the number of vehicles containing air-conditioning systems and other relevant data. Agricultural or forestry tractors, their trailers and interchangeable towed machinery are covered by the provisions of Directive 2003/37/EC on type-approval of agricultural or forestry tractors, their trailers and interchangeable towed machinery, together with their systems, components and separate technical units. In this Directive no requirements are defined regarding F-Gas emissions from air-conditioning systems. So far, regarding F-Gas emissions from agricultural- and construction machinery, only very little information is available for Germany. According to a German study, about 30 tonnes of HFC-134a were emitted from air-conditioning systems installed in agricultural and construction machinery in Germany in 2002. To further elaborate on potential impacts, a workshop with the concerned industry is recommended on a European scale. Since the emissions from air-conditioning systems - and the systems themselves - from the agricultural and construction machinery are similar to those for motor vehicles, the project team suggests further consideration for them within the framework of the review of the Directive 2006/40/EC, which is related to F-Gas emissions from air conditioning systems in certain motor vehicles.

The main F-Gases used in refrigeration and air conditioning systems in modes of transport are: R-134a, R-407C, R-404A, R-410A and R-507. A list of all relevant F-Gases is provided in the Annex.

The impact assessment shall result in a recommendation on whether it would be environmentally advantageous and economically and socially feasible to apply Art. 3 and/or Art. 4(1) of the existing regulation to air conditioning systems (other than motor vehicles), and refrigeration systems contained in modes of transport.

## 2.4 Status quo of the relevant transport sectors

### *2.4.1 Road sector*

This impact assessment covers refrigeration systems in road vehicles only, as the air-conditioning systems fitted to motor vehicles referred to in Directive 70/156/EEC (covering all road vehicles such as cars, busses, trucks and trailers) are outside the scope of Article 10(1).

*Types of transport systems*

The relevant refrigerated vehicles of the road sector can be divided according to the classification used in Directive 70/156/EEC into

- vans (category N1, trucks < 3.5 t)
- trucks ( categories N2 and N3, trucks > 3.5 t)
- trailers (category O).

*Types and design of refrigeration systems*

Refrigeration systems are mostly installed on top of the vehicle. Vans typically operate more locally and are therefore used for medium temperature deliveries. According to RPA[2] most of the refrigeration systems in vans are directly driven by the vehicles own engine. When the vehicle is not in operation, the refrigeration system can be used in many cases with external electricity, or it is not in use. To a minor extend, electrically driven units are also in use (personal communication). Refrigeration systems in trucks and trailers are mostly independent units using an independent engine, but direct driven units as well as electrically driven units are also installed.

*Types of refrigerants*

Refrigerants R-134a and R-404A are typically used for refrigeration in vans. Refrigeration systems for trucks and trailers are charged with R-404A, R-410A and R-134a. R-22, which was previously used as refrigerant in these systems, has almost completely been replaced by the above mentioned HFC refrigerants due to the restrictions of Regulation (EC) No 2037/2000. Although systems using alternative refrigerants are under development, no alternative refrigerants are currently in use in refrigeration systems in the road sector.

### *2.4.2 Rail sector*

Air-conditioned rail vehicles have been considered for this impact assessment in this sector. More and more rail vehicles are being fitted with air-conditioning systems for the improved comfort of passengers. The percentage of air-conditioned passenger rail vehicles is higher in southern Europe, but also in other parts of Europe, air-conditioning of rail vehicles exists. As the use of refrigeration systems in rail vehicles is very limited, these systems have not been considered for impact assessment in this report.

2 RPA 2005: J. Vernon, C. George, A. Footitt, M. Peacock: Analysis of the Costs and the Impact on Emissions of Regulatory Measures for Reducing Emissions of Hydrofluorocarbons, Perfluorocarbons and Sulphur Hexafluoride in Foams and Mobile Refrigeration in the Road Transport Sector, prepared for the European Commission, December 2005

*Types of transport systems*

The rail sector covers railway vehicles, trams and metros. The following categorisation for railway vehicles has been used:

- Locomotives
- Coaches
- Diesel multiple units (DMU)
- Electrical multiple units (EMU)
- Electrical multiple unit cabins
- Special cars (e.g. dining cars)

*Types of air-conditioning systems*

There are four different types of air conditioning systems fitted in rail vehicles:

- Compact under floor systems

  Where enough space is left under the rail vehicle, the air-conditioning system is normally built under the floor (railroad coaches, centre cars without propulsion). In this case the air is blown bottom up to the passenger compartment.

- Compact roof systems

  Where there is no space left under the floor due to electrical drive and power supply, the air-conditioning system is built into or onto the roof (multiple units, metro vehicles, trams). In this case the air is blown top down into the passenger compartment.

- Compact central systems

  In double-decker coaches, where there is no space at the top or under the floor, two air-conditioning systems are installed in the middle of the bus (mid-mounted), one supplying the lower floor, the other supplying the upper part of the coach with cool air.

- Split systems

  Split systems are used where there is not enough space for a compact air-conditioning system either under the floor or on top of a rail vehicle. This means that compressors and condensers are under the floor and evaporators are under the roof (coaches, cars of multiple units).

*Types of refrigerants*

R-134a and R-407C are typically used as refrigerants. The use of alternative refrigerants is still under development. First prototypes exist such as the ICE-3, where the air conditioning system works with air circulation. The amount of alternative refrigerants currently used is negligible (<3% of air-conditioning systems).

### *2.4.3 Maritime and inland waterway sector*

*Types of transport systems*

The EU-flagged fleet in the maritime and inland waterway sector can be divided into four main categories with different sub-categories. For comparison, the same distribution is used as in a previous study[3].

- Sea-going merchant ships (EU flagged)
    - Cargo ships (air conditioning/refrigeration)
    - Passenger ships (air conditioning/refrigeration)
    - Cruise ships and other ships (air conditioning/refrigeration)
- Ships for refrigerated cargo (refrigeration)
- Inland navigation vessels
    - Motorised cargo vessels (air conditioning)
    - Cabin boats (air conditioning/refrigeration)
    - Excursion boats (air conditioning)
- Fishing vessels
    - Medium-sized fishing vessels (18-36 metres) (refrigeration)
    - Large vessels with RSW tanks (36-76 metres) (refrigeration)
    - Tuna longliners (25-45 metres) (refrigeration)
    - Tuna seiners
    - Freezer trawlers
    - Factory freezer trawlers

[3] Winfried Schwarz (Öko-Recherche), Jan-Martin Rhiemeier (Ecofys): The analysis of the emissions of fluorinated greenhouse gases from refrigeration and air conditioning equipment used in the transport sector other than road transport and options for reducing these emissions – Maritime, Rail, and Aircraft sector, prepared for the European Commission, November 2007

*Types and design of air-conditioning and refrigeration systems*

Whereas air conditioning systems are mainly installed in inland navigation vessels, refrigeration systems in refrigerated cargo ships and in fishing vessels contribute the major part of greenhouse gas emissions. In sea-going merchant ships, both refrigeration systems and air conditioning systems are used for passenger comfort and to cool food cargo.

Split air-conditioning units are generally installed in sea going cargo ships and in inland motorised cargo vessels,, where the compressor and the condenser (flooded with water) are installed below deck, whereas the evaporator is placed in the air-conditioning centre on deck.

In addition to the air-conditioning system, an independent refrigeration system is normally installed in sea going cargo ships.

Water chillers are installed in passenger ships and cruise liners as well as in cabin boats and excursion boats, to chill the water in a primary refrigerant circuit. In a secondary circulation system, the chilled water provides air cooling.

Direct or indirect systems are used for refrigeration in refrigerated cargo ships.

In medium-sized fishing vessels up to 18 meters in length, which are typically only at sea for a short time, ice, produced in ice machines, is used as a cooling medium. To prevent the ice from melting, a refrigeration unit is used. Only to a small extent is ice used in longer, medium-sized fishing vessels as a cooling medium. Some larger vessels have RSW (refrigerated sea water) tanks which cool down the seawater and the fish catch, to approximately -1°C without freezing the fish.

Large vessels mainly contain freezing equipment for freezing and storage. The fish is frozen to  a minimum of -18°C.

*Types of refrigerants*

As well as R-22, mainly R-134a is currently used for air-conditioning in sea-going merchant ships. It is assumed that refrigeration systems – which mainly use R-22 – are also filled with R-134a and R-404A.

Refrigeration systems in refrigerated cargo ships are still mainly charged with R-22. In one new ship, ammonia is used as an alternative refrigerant.

R-134a and R-404A are also typically used as well as R-22 for air-conditioning in inland navigation vessels. In a few systems, R-407C and R410A are used. Refrigeration systems are charged with the same type and share of refrigerants as air-conditioning systems.

R-134a and R-404A are also typically used as well as R-22 in refrigeration systems for medium-sized fishing vessels. In almost all other vessels R404A and R507 are mainly used, which have the same quality and almost the same composition. Only in large factory trawlers are refrigeration systems typically filled with R-407C and R507. About one third of refrigeration systems with refrigerant charges of over 1,000 kg are filled with alternative refrigerants such as $CO_2$ and ammonia[3].

# 3 Methodology

## 3.1 Methodology to identify data needs

As a first step, several information categories have been identified as necessary for estimating costs and the emission reduction potential of applying further requirements to air conditioning and refrigerating systems containing F-Gases in the transport sector. These include:

- Division and classification of sub-categories of transport sector modes
- Categorisation and technical information of air conditioning and refrigeration systems used in the transport sector
- Impacts of Art. 3 of Regulation (EC) No 842/2006 on HFC emissions
- Impacts of Art. 4(1) of Regulation (EC) No 842/2006 on HFC emissions
- F-Gas refrigerant specific details (type, year, amount,…)
- Data on air conditioning and refrigeration systems (type, age, ...)
- Emission rates
- Maintenance, leakage control data
- Recovery data
- Sector-specific data (who is affected, size of business, geographical distribution …)
- Economical data (cost for certified personnel, costs for leakage detection systems ,…)
- Other categories

## 3.2 Methodology of data collection

After determination of the relevant information needs to carry out the impact assessment, relevant data had to be collected. To gather the relevant data, the following four information sources have been used (see also Figure 1):

I. Data from existing studies

II. Internet research

III. Questionnaire survey

IV. Expert interviews

The following figure illustrates the procedure for data collection:

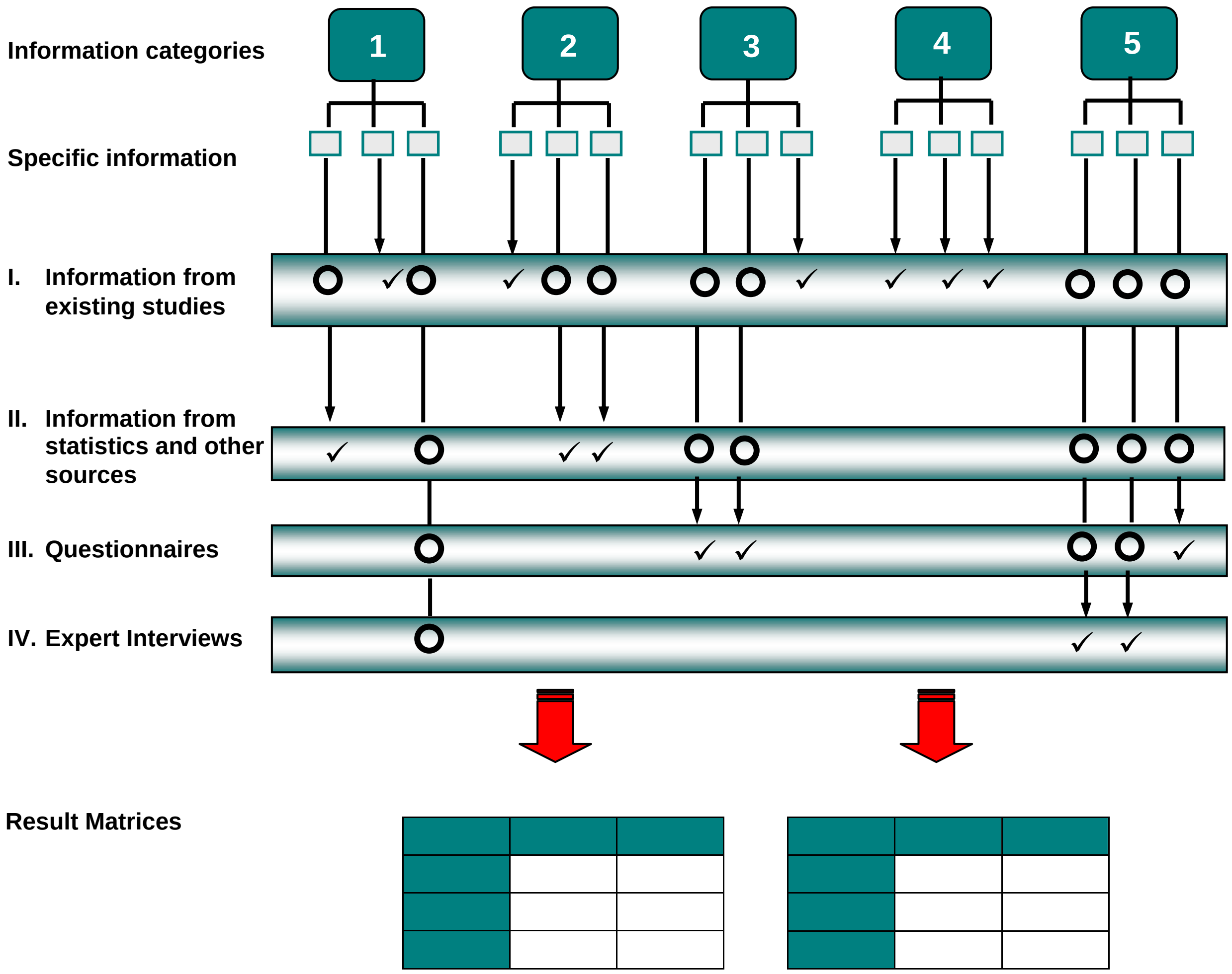


Figure 1: Methodology for data collection

As a first step, relevant data were gathered from existing studies. The following studies were used as the first basis for assessment, while the data were updated and extended to EU-27:

- J. Vernon, C. George, A. Footitt, M. Peacocka: Analysis of the Costs and the Impact on Emissions of Regulatory Measures for Reducing Emissions of Hydrofluorocarbons, Perfluorocarbons and Sulphur Hexafluoride in Foams and Mobile Refrigeration in the Road Transport Sector, prepared for the European Commission, December 2005
- Schwarz W., Rhiemeier J.: The analysis of the emissions of fluorinated greenhouse gases from refrigeration and air conditioning equipment used in the transport sector other than road transport and options for reducing these emissions – Maritime, Rail and Aircraft Sector, prepared for the European Commission, November 2007

The information provided in these studies was updated and extended to EU-27.

**Internet research**

Internet research was carried out to identify new and updated relevant data, including on-line available statistical databases, such as the COPERT for statistics on the number of road transport vehicles. Information from relevant homepages was also evaluated on project relevant data.

Furthermore, relevant stakeholders of the concerned transport sectors (road, rail, maritime) have been identified.

**Stakeholder survey**

- Relevant stakeholders in the field acting on European and national level were identified, such as transport organisations and associations acting on European and national levels, competent authorities and companies.
- With the aim of obtaining the relevant information from the identified stakeholders, two types of questionnaires were developed, one for Member State Authorities and another addressing the industry. The industry questionnaire was elaborated in three slightly modified versions for the identified stakeholders of each relevant transport sector (road, rail, maritime and inland waterway). In order to distribute the questionnaires to as many concerned stakeholders as possible, the European associations were asked to disseminate the questionnaire to national associations and companies as well.

**Expert interviews**

Missing data on future developments or data which needed to be elaborated in more detail were acquired as part of a second round of targeted personal interviews. The second round of interviews also aimed to validate data already collected.

In order to review, update and discuss existing data, a meeting with the relevant services of the European Commission and a meeting with stakeholders and other experts were both carried out.

**Data processing**

All collected data have been documented and the relevant figures have been included in spreadsheets developed to support processing of the data for impact assessment.

## 3.3 Methodology of data analysis and best estimates

As the gathered data forms the basis for calculating costs and emission reduction potential and for analysing the policy options, it was crucial to check if the data were consistent and reliable. Therefore, plausibility checks of data have been performed by presenting gathered data to several experts. Data gaps have been filled whenever necessary through short requests to experts in the field or by calculations from statistical information. Diverging results were cross checked. Where data were gathered from different sources and values were diverging, it was necessary to work with data ranges (lowest / highest value for a data category). An internal review and a quality control system have also been implemented.

Where no data were available, best estimates were used.

## 3.4 Methodology to identify and quantify impacts

For impact assessment, it was assumed that the measures stipulated in the options would be enforced in 2010. Therefore, by 2020 all requirements would be implemented in all Member States. Therefore also, the F-Gas emissions arising in 2020 by applying Art. 3 and/or 4(1) of the F-Gas Regulation (options 2-4) were compared with the emissions, which would occur in the year 2020 if no legal actions were taken (baseline scenario – option 1).

The initial point for identifying costs and emission reduction potential is the baseline scenario (BAU), describing the status in 2020 without any regulatory changes.

To estimate emissions in 2020, the following information was required for the baseline scenario:

- Increase factor of transport systems
- Increase factor of refrigerated transport systems
- Share of F-gas refrigerants in comparison with all refrigerants
- Decrease of refrigerant charge due to better technology and more modern air conditioning and refrigeration systems
- Decrease of leakage rates due to better technology and more modern air conditioning and refrigeration systems
- Share of different types of F-Gases within applications

The economic and environmental impacts of options 2-4 have been analysed with reference to the baseline scenario (option 1) in the year 2020 in the EU.

This includes a detailed analysis of impacts with a focus on costs and F-Gas emission reduction potential. The analyses for the various policy options have been carried out in accordance with the relevant Commission guidelines whenever suitable in order to provide sound information for the comparison of the options.

Indirect emissions due to energy consumption were not covered in the assessment as it was not expected that the options considered in this report would show any significant changes in indirect emissions compared to the baseline scenario. In addition, calculating the changes in energy efficiency could lead to highly complicated scenarios, as it is difficult to calculate the emission benefits from more energy efficient equipment. This depends for example on the fuel mix, which is different in most countries.

To estimate the costs associated with the application of the various policy options, the following information was needed:

- Costs per hour of certified personnel according to article 5 for leakage checks and maintenance of the air conditioning and refrigeration systems
- Costs per hour of personnel
- Average time needed for taking precautions to prevent leakage of relevant F-Gases and for repairing any detected leakage as soon as possible
- Average estimated time needed for record keeping
- Costs for installing leakage detection systems
- Costs for certification of personnel
- Costs for the use of recycling, recovery and destruction infrastructure
- Cost differences if – instead of qualified personnel –certified personnel carrying out the recovery of F-Gases

Apart from costs, also savings from reducing the quantities of virgin refrigerants were considered. Therefore, the price of F-Gas refrigerants was also of relevance.

As the operators will be directly affected by applying the options assessed, the costs, which are of particular concern to the operators, have been calculated in more detail.

Costs, which arise for example for certifying the personnel of service companies, were not considered as negative impacts. These costs of the service companies are required as investment in order to acquire additional business (contracts) to carry out leakage checks or recovery when applying Art. 3 and/or 4(1).

The costs were mainly calculated with reference to one transport system and one year. Only the costs for new F-Gases and for recovery of F-Gases were calculated per kg of gas and year. Necessary investments, for example installation of leakage detection systems, certification of personnel were distributed over their period of life or validity.

Actual prices were used for the impact assessment, for comparison with other data.

Economic and social impacts have also been evaluated for indirectly affected stakeholders who are identified as follows:

- Producers and distributors of F-Gases
- Manufacturers of refrigeration and air conditioning systems and of transport systems
- Service companies
- Certification bodies
- Reclamation and destruction companies
- RAC engineering companies
- Relevant authorities

As the costs of the application of options 2-4 mainly concern operators, economic impacts for operators (first step in causal chains) have been used for comparing costs with emission reductions. In addition, macro-economic benefits of reduced F-Gas emissions have been calculated.

Environmental benefits were assessed on the basis of an estimation of the emission reduction potential by applying the particular policy options. The leakage and the emission reduction potential were indicated in kg of F-Gases and in kt (thousand tonnes) of $CO_2$ equivalent. Only the emissions of greenhouse gases covered by the F-Gas Regulation were taken into account. Emissions of ozone-depleting refrigerants, which also have high GWP, have not been considered as they are subject to a phase-out under Regulation (EC) No 2037/2000 on ozone-depleting substances. However the use of those gases and their replacement by HFCs in both the baseline scenario and options 2-4 are considered. The F-Gas emissions and emission reduction potentials are additionally shown with unit $CO_2$ equivalents, in order to enable a general comparison of all greenhouse gas emissions.

The following information was crucial to estimate the emission reduction potential:

- Annual refrigerant loss rate
- Current recovery rates at end of life
- Data on leakage behaviour of F-Gases of air conditioning and refrigeration systems in contained in different transport modes
- Data on current emission rates related to various operations (during maintenance, during recovery, etc.)
- Information on main causes of leakage (accidents, evaporation from hoses, connections)
- Others

With data received the total net costs and the emission reduction were estimated for two cases:

- during operation (related to Art. 3)

- due to no recovery (at end of life as well as within recovery of F-Gases during maintenance and service (related to Art. 4(1))

All emissions are quantified on an annual basis.

In this context the terms used in the analysis are defined by the following:

Operation emissions (annual emissions): all emissions which occur during the operational lifetime of an air-conditioning/refrigeration system on an annual basis excluding emissions which occur during the maintenance or servicing of the system.

Maintenance and end of life emissions (annual emissions): Emissions at the end of life of a system including the emissions which occur during maintenance or servicing, calculated on an annual basis.

Recovery rate: share of F-Gases recovered from air-conditioning and refrigeration systems at end of life of the transport systems.

In a second step, the emission reduction potential was estimated for each requirement of the articles (see chapter 4).

As a result, for each requirement and option, the cost differences and emission reduction potential related to the baseline scenario were evaluated.

Assumptions and information used during the impact analyses were clearly documented and reviewed to assure robustness and transparency of the analyses and can be provided if necessary.

# 4 Options

The following regulatory options were considered for impact assessment:

- Option 1: No further action – BAU (baseline scenario)
- Option 2: Apply provisions of Art. 3 of Regulation (EC) No 842/2006 to air conditioning systems other than those fitted to motor vehicles referred to in Directive 70/156/EEC and refrigeration systems contained in modes of transport
- Option 3: Apply provisions of Art. 4(1) of Regulation (EC) No 842/2006 to the above-mentioned systems
- Option 4: Apply both the provisions of both Art. 3 and Art. 4(1) of Regulation (EC) No 842/2006 to the above-mentioned systems

The analysis assumed that the measures stipulated in the regulatory options will be enforced by 2010. A sensitivity analysis was carried out considering a delayed enforcement of the options (2013). The impacts encountered in 2020 were assessed.

In the following chapters the options will be explained in detail.

## 4.1 Option 1 – No further action – BAU (baseline scenario)

Option 1 represents the baseline scenario ("no further action"). This option describes the developments without any additional regulatory actions compared to the present situation. It is the benchmark for comparing the incremental impacts of the other options within this assessment.

## 4.2 Option 2 – Application of Art. 3 of Regulation (EC) No 842/2006

Art. 3 currently only covers stationary equipment charged with F-Gases. Option 2 considers the application of Art. 3 of Regulation (EC) No 842/2006 to air conditioning systems (other than those fitted to motor vehicles referred to in Directive 70/156/EEC) and refrigeration systems contained in modes of transport. The requirements of Art. 3 are as follows:

**Requirements of Art. 3 of the F-Gas Regulation:**

- Prevention of any leakage (concerns all charges)
- Repairing of detected leakage as soon as possible (concerns all charges)
- Leakage checks by certified personnel
  - every 12 months for charges ≥ 3 and < 30 kg (this shall not apply to equipment with hermetically sealed systems, which are labeled as such and contain less than 6 kg of fluorinated greenhouse gasses)
  - every 6 months for charges ≥ 30 and < 300 kg
  - every 3 months for charges ≥ 300 kg
- Installation of leakage detection systems for charges ≥ 300 kg (if a leakage detection system is in place, the frequency of checks for equipment containing charges ≥ 30 kg shall be halved)
- Maintenance of records (concerns charges ≥ 3 kg)

The above listed requirements are currently dedicated to the operators of stationary equipment. Within option 2, the impacts will be analysed if these requirements also have to be fulfilled by the operator of mobile equipment of the road, rail and maritime and inland waterway sector.

## 4.3 Option 3 – Application of Art. 4(1) of Regulation (EC) No 842/2006

Option 3 analyses the possible impacts of the application of Art. 4(1) of Regulation (EC) No 842/2006 to the same air conditioning systems and refrigeration systems contained in modes of transport.

The requirements of Art. 4(1), which apply to stationary equipment at present and which will be assessed in option 3 for the application to the above-mentioned systems, can be seen in the following figure:

**Requirements of Art. 4(1) of the F-Gas Regulation:**

- Recovery of F-Gases by certified personnel before final disposal for the purpose of recycling, reclamation or destruction (all charges)
- Recovery of F-Gases by certified personnel, when appropriate, during its servicing or maintenance, for the purpose of recycling, reclamation or destruction (all charges)

Art. 4 currently already covers refrigeration and air conditioning systems of mobile equipment (unless serving military operations) in the general requirement of paragraph 3. The application of the requirements of Art. 4(1) would provide a stricter framework for recovering f-gases from those systems.:

- Recovery of F-Gases has to be carried out by certified personnel (Art. 4(1)) instead of appropriately qualified personnel (Art. 4(3)). While qualification requirements at EU level are defined for air-conditioning systems of certain vehicles covered by Directive 70/156/EEC in Regulation (EC) No 307/2008, no minimum EU-wide requirements for qualification of personnel working on those systems apply. Certification would be subject to minimum EU-wide requirements.

- Recovery is mandatory (4(1)). Under the general requirement of 4(3) recovery has to be carried out to the extent that it is technically feasible and does not entail disproportionate cost (Art. 4(3))

- Article 4(1) clearly allocates responsibility for compliance to the operator in Art. 4(1)

## 4.4 Option 4 – Application of Art. 3 and 4(1) of Regulation (EC) No 842/2006

Option 4 analyses the impacts of applying the requirements of both Art. 3 and Art. 4(1) to those systems.

# 5 Analysis of impacts of options

In the following chapters the status quo, and the possible impacts of the 4 options are described for the road, rail and maritime and inland waterway sectors.

## 5.1 Starting point

### *5.1.1 Road sector*

According to the database Copert generated for the European database Tremove, about 30 million vans and trucks operated in the EU by the end of 2005. By estimating that trailers exist more or less in the same amount as trucks (RPA[2]) and that 3% of the whole fleet is refrigerated[4] the total amount of refrigerated road vehicles in the EU-27 was approximately 1 million in 2005, and with an estimated annual growth of 1.9%, nearly 1.2 million in 2007. The largest markets for refrigerated vehicles are France, Germany, Italy, Spain, and the UK.

The refrigeration systems in road transport modes contain on average the following quantities of refrigerants:

- Vans: 2.3 kg/system
- Trucks: 5 kg/system
- Trailers: 9 kg/system

The estimation of these charges takes into account the different generations of vehicles and the type of vehicle (single temperature, multi temperature)

The share of the refrigerants used for the refrigeration of road transport systems is assumed – due to expert interviews – to be as follows (information on the GWP of the relevant F-Gases is provided in the annex):

- Vans: R-134a (30%) and R-404A (70%)
- Trucks and trailers: R-404A (93%), R-410A (2%) and R-134a (5%)

In order to calculate end of life emissions for refrigeration systems of the relevant road vehicles, it must be considered that about 40% of vehicles are exported to non-EU countries for second use (best estimate). Taking into account the average lifetime of vans (~7.5 years), trucks and trailers (~10 years), it is assumed that annually about 15% of the vans remaining in Europe and 10% of the trucks and trailers reach their end of life in the EU.

4 UNEP 06, Report of the Refrigeration, Air conditioning, and Heat Pumps Technical Options Committee, 2006 Assessment, Nairobi, January 2007

The recovery rate of the F-Gases of the remaining 60% of end of life vehicles in the EU ranges very widely between nearly 0% (e.g. Romania) and over 90% (e.g. UK). The emission-percentage at end of life has two factors: on the one hand, the percentage of vehicles for which the F-Gases are recovered from the refrigeration systems and on the other hand, the amount of F-Gases which is recovered from a refrigeration system. The latter depends on the type of recovery systems and technique. An expert from Romania stated that the technique for recovery is already available but no infrastructure exists so far for taking the recovered F-Gases back for recycling, reclamation or destruction. As the space for recovery is restricted at the service stations most of the F-Gases are released into the atmosphere. As the figures received vary considerably among various European Member States, an average recovery rate of 70% of the F-Gases contained in end of life systems has been used for the calculation within this assessment. The range of 60% to 80% recovery is considered in the sensitivity analysis. It is assumed that all F-Gases which are not recovered are eventually emitted to the environment. Therefore, at end of life an average of 30% of the total F-Gas charges of end of life vehicles within the EU is used as an emission factor for further calculation. Taking into account the above described relationships, the total annual emission factor at end of life amounts to 0.027 (0.6*0.15*0.3) for vans and to 0.018 (0.6*0.1*0.3) for trucks and trailers respectively.

It is estimated that 5-10% of the charge in a refrigeration system is lost on average during maintenance or servicing due to emptying and re-filling the system with refrigerants. Servicing and maintenance takes place on average every 5-10 years. In new Member States such as Romania, the loss of F-Gases during maintenance or servicing amounts to approximately 62%. This figure is due to the fact that all F-Gas charges which are contaminated had been released into the atmosphere whereas pure F-Gases will be recovered and used again for re-filling the system. A value of 5-10% emissions has been indicated for most Member States, but in some new Member States the emissions amount to 62%. Therefore, the project team uses a best estimate of 2% annually for further calculation. As some uncertainties remain, a range between 1% and 3% annually has been analysed in the sensitivity analysis.

Based on the above information and further data as well, the average emission rates have been applied within this assessment for refrigerated road vehicles:

- Operation emissions (annual emissions, excluding emissions occurring during maintenance and end of life emissions; based on various expert statements):
    - Vans: 20%
    - Truck: 15%
    - Trailer: 13%

- Emissions at end of life and during maintenance (no recovery, annual emissions):
    - Vans: 4.7% (2.7% at end of life and 2% during maintenance)
    - trucks and trailers: 3.8% (1.8% at end of life and 2% during maintenance)

According to these figures, the following F-Gas emissions can be derived for refrigeration systems in road vehicles:

| Type of vehicle | Content [kg/ system] | Operation emission factor (annual emissions) | Operation emissions (annual emissions) [kg] | Maintenance and end of life emission factor (annual emissions) | Maintenance and end of life emissions (annual emissions) [kg] | Emissions total [kg] | Emissions total [kt $CO_2$ eq.] |
|---|---|---|---|---|---|---|---|
| Vans <3. 5 t | 2.3 | 0.20 | 358,000 | 0.047 | 84,000 | 442,000 | 1,181 |
| Trucks >3. 5 t | 5 | 0.15 | 132,000 | 0.038 | 34,000 | 166,000 | 520 |
| Trailers | 9 | 0.13 | 206,000 | 0.038 | 60,000 | 266,000 | 836 |
| **Sum** | | | **~ 697,000** | | **~178,000** | **~ 875,000** | **~ 2,537** |

Table 12: Emissions of F-Gases from road vehicles (2007)

The current emissions from road vehicles are about 2,500 kt of $CO_2$ eq. per year, where about 2,000 kt of $CO_2$ eq. per year are emitted from operational systems (annual emission) and about 520 kt of $CO_2$ eq. per year are emitted from end of life systems and systems under maintenance or servicing.

### *5.1.2 Rail sector*

According to data from Öko-Recherche / Ecofys[3], which were compared with data from UIC, and based on an estimated annual growth of 2%, about 169,000 railway vehicles existed in 2007 for EU-27. Thereof about 60,000 vehicles and an additional 20,000 EMU (electrically-driven multiple units) driver cabins were air-conditioned. From about 19,000 tram units, which were in use in 2007, about 3,000 were air-conditioned, and around 3,500 out of 22,000 metro cars provided air-conditioning in 2007. The air-conditioning systems used in the rail sector contain on average the following refrigerants:

- Railway vehicles: R-134a: 75%; R-407C: 25%
- Tram units: R-134a: 83%; R-407C: 17%
- Metro units: R-134a: 33%; R-407C: 67%

The high share of R-407C in metro units mainly results from the high share of Spanish metros (information on the GWP of the relevant F-Gases is provided in the annex).

Alternative refrigerants such as $CO_2$ play a minor role in railway vehicle air-conditioning. However, the new High-Speed train "ICE-3" is already equipped with air-cycle systems. Furthermore, some prototypes already exist and are under further development. But the energy consumption in these systems is still 20 to 30% higher than in vapour compression cycles[3]. For further calculation, the share of alternative refrigerants is negligible (<3% of air-conditioning systems).

According to experts, the current average F-Gas charge of railway driver-cabins is ~ 2.7 kg/system. For the air-conditioning systems of other railway vehicles (coaches, electrical-driven multiple units (EMU cars), diesel-driven multiple units (DMU cars), locomotives and special cars), the refrigerant charge is between 5 and 30 kg/system. In trams, the average charges of F-Gas refrigerants amount to 30 kg while in metros the typical charge was reported to be about 15 kg in 2006.

The current average annual emission rate of air-conditioning systems during operation is about 5%. Reasons for the emissions are inter alia vibrations, car pushing, loose connections and hoses. Higher emissions of 10% (for split air-conditioning systems 20%) were reported only in diesel-driven multiple units with open compressor systems in railway vehicles.

Recovery at end of life is expected to vary between 60% and nearly 100%. Information from expert interviews indicated that the emission-percentage at end of life has two factors: on the one hand, the share of vehicles for which the F-Gases are recovered from the refrigeration systems, and on the other, the amount of F-Gases which is recovered from a refrigeration system. The latter is affected by the type of recovery systems and technique. An expert from the UK railway industry expressed the view that the refrigerants from all air conditioning systems of railway vehicles, which have been scrapped so far, were recovered for further treatment[5]. Furthermore, it has to be taken into account that the number of end of life rail vehicles fitted with air-conditioning systems is so far very low and therefore the current percentage of recovered F-Gases from rail vehicles is difficult to determine. According to a representative of the Greek Competent Authorities, the provisions of Art. 3 and 4(1) have already been applied by the rail industry in Greece. For further calculation, a best estimate of 90% recovery at end of life is used.

About 40% of the vehicles are exported to non-European countries before they reach their end of life. For further calculation it is assumed that 60% of the rail vehicles reach their end of life in Europe. Considering the average lifetime of rail vehicles (railway vehicles: ~ 40 years, trams and metros: ~35 years) about 2.5% of railway vehicles and 3.3% of metros and trams reach their end of life in 2007 (upper estimate).

5 HSBC Rail UK, personal communication 2008

From the air conditioning systems fitted to those, 10% of the F-Gas charge is emitted into the environment as average in the EU. This amounts to an emission factor at end of life of 0.0015 for railway vehicles (0.6*0.025*0.1) and of 0.002 for metros and trams (0.6*0.33*0.1).

The emissions during maintenance or servicing are estimated to be about 1% annually. Therefore, the emission factor for end of life, maintenance and servicing amounts to 0.0115 for railway vehicles and to 0.012 for metros and trams (calculated on an annual basis).

According to these figures, the following F-Gas emissions can be derived for air-conditioning systems in railway vehicles:

| Type of vehicle | Content [kg/ system] | Operation emission factor (annual emissions) | Operation emissions (annual emissions) [kg] | Maintenance and end of life emission factor (annual emissions) | Maintenance and end of life emissions (annual emissions) [kg] | Emissions total [kg] | Emissions total [kt $CO_2$ eq.] |
|---|---|---|---|---|---|---|---|
| Railway vehicles | 2.7-30 | 0.05-0.1 | ~ 60,500 | 0.0115 | ~ 12,500 | ~ 73,000 | ~ 101 |
| Driver cabin | ~ 2.7 | 0.05 | 2,800 | 0.0115 | 700 | 3,500 | 4.8 |
| Vehicles except DMUs | 5-30 | 0.05 | 45,500 | 0.0115 | 10,500 | 56,000 | 77 |
| DMUs | 13 | 0.1 | 12,200 | 0.0115 | 1,400 | 13,600 | 19 |
| Tram vehicles | 30 | 0.05 | 4,400 | 0.012 | 1,000 | 5,400 | 7.3 |
| Metro vehicles | 15 | 0.05 | 2,700 | 0.012 | 600 | 3,300 | 5.0 |
| **Sum** | | | **~ 67,600** | | **~ 14,200** | **~ 81,800** | **~ 113** |

Table 13: Current emissions of F-Gases from rail vehicles

The current F-Gas emissions from rail vehicles are estimated to be about 113 kt of $CO_2$ eq. per year, where about 93 kt of $CO_2$ eq. per year are emitted from operational systems (annual emissions) and about 20 kt of $CO_2$ eq. per year are emitted from end of life systems and systems under maintenance or servicing.

### *5.1.3 Maritime and inland waterway sector*

In contrast to the road and the rail sector, maritime ships operate on the open sea and are exposed to harsh environmental conditions such as the corrosive salt-laden and wet atmosphere, vibrations, wind force, shear force, torsion etc[10,6]. These factors, combined with poor maintenance, the failure to detect leaks, the age and complexity of the equipment and

[6] ECSA position on the possible application of articles 3 & 4 of EU regulation 842/2006 on shipping, 2008

the technology employed contribute to relatively high leakage rates of refrigeration and air-conditioning systems. .

Many of the ships still have refrigeration or air-conditioning systems which contain HCFC as refrigerant. Despite the global warming potential of HCFCs, these are no longer considered for this study as they are subject to a phase-out under Regulation 2037/2000.

The relevant figures and characteristics of the four ship-categories of the maritime and inland waterway sector differ from each other. Each category will be described separately.

*Sea going merchant ships*

At the end of 2006, about 9,000 sea going merchant ships over 100 GT were in service. It is assumed that all merchant ships which have a size over 100 GT are equipped with an air conditioning system[3].

In many of the sea-going merchant ships, R-22 is still used as a refrigerant. According to Öko-Recherche / Ecofys[3] about 2,500 ships were built after 2002 and are therefore equipped with air-conditioning and refrigeration systems using mostly HFCs as a refrigerant (nearly 30%). It is assumed that the older ships are still charged with R-22 (about 70%). Systems with alternative refrigerants were not yet developed for sea-going merchant ships.

The air-conditioning and refrigeration systems used in sea-going merchant ships – built after 2002 and therefore charged with HFCs – contain on average the following refrigerants:

- Air-conditioning systems: R-134a: 100%
- Refrigeration systems: R-134a: 33%; R-404A: 67%

| Ship type | Number of ships (EU-flagged fleet) | Refrigerant charge Air-conditioning [kg] | Refrigerant charge Refrigeration [kg] |
|---|---|---|---|
| Cruise liners | 21 | 6,000 | 400 |
| Passenger ships | 365 | 500 | 20 |
| Cargo ships (including other vessels) | 2,175 | 150 | 10 |
| **All ships** | **~ 2,561** | | |

Table 14: Overview of number of sea going merchant ships including the charges used in refrigeration and air conditioning systems in EU-27 at the end of 2006

The F-Gas emissions are estimated to be about 20% of the total charge for cruise liners and passenger ships and on average about 40% for cargo ships and other vessels. In the Netherlands, annual losses of 50% were found in merchant ships by the Netherlands environmental inspectorate[4]. The leakage rates are magnified by the extreme physical conditions at sea. Inspections over the years 2002 to 2004 have indicated a leakage of 31% for strong GHG coolants[7].

*Ships for refrigerated cargo*

According to Öko-Recherche / Ecofys[3] about 160 ships for refrigerated cargo were registered in the EU under an EU flag at the end of 2006. All ships built before 2001 still use R-22 as a refrigerant, with charges between 1 and 5 tonnes (as an average, 2000 kg are estimated). Only one ship was built after 2001 using alternative refrigerants ($NH_3$). No ships for refrigerated cargo using HFCs as refrigerants are registered in the EU. No ships existed at the end of 2006 with a refrigeration system filled with F-Gases. Emissions during operation (annual loss rate) are estimated to be about 20% for older systems and 5 to 10% for newer indirect systems [4].

*Inland navigation vessels*

According to Öko-Recherche / Ecofys[3] at the end of 2006 about 11,600 inland navigation vessels were operating in EU-27, of which about 1,300 use HFCs for air conditioning and refrigeration (about 10%). The other ships are still assumed to operate with R-22 (about 90%). No alternative refrigerants were in use at the end of 2006.

The air-conditioning and refrigeration systems used in inland navigation vessels contain on average the following F-Gas refrigerants:

- Air-conditioning systems: R-134a: 67%; R-404A: 33%
- Refrigeration systems: R-134a: 67%; R-404A: 33%

| Ship type | Number of ships (EU flagged fleet) | Refrigerant charge Air-conditioning [kg] | Refrigerant charge Refrigeration [kg] |
|---|---:|---:|---:|
| Cargo vessel | 1,000 | 4.5 | -- |
| Cabin cruiser | 61 | 200 | 5 |
| Excursion boat | 255 | 100 | -- |
| **All ships** | **~ 1,311** | | |

Table 15: Overview of number of inland navigation vessels including the charges used in refrigeration and air conditioning systems in EU-27 at the end of 2006

The F-Gas emissions during operation (annual loss rate) are estimated to be about 6% of the total charge for cargo vessels and about 10% for cabin cruisers and excursion boats.

[7] VROM-Inspectie, Lekkages van ozonlaagafbrekende en broeikasgassen uit koelinstallaties in zeeschepen, 2006

*Fishing vessels*

In 2005 (EU 25) about 89,000 fishing vessels were in service, of which about 8,000 were medium or large-sized vessels. The medium or large-sized vessels are assumed to be equipped with a refrigeration unit. Öko-Recherche / Ecofys[3] estimate that about 12.5% of the ships shorter than 70m were built after 2002. Of the ships longer than 70m, about 30 were built after 2002. It is assumed that all ships built before 2002 still use R-22 as a refrigerant (about 86% of the total fleet). Some of the ships built after 2002 and with refrigerant charges over 1,000kg were already equipped with alternative refrigerants such as $CO_2$ and Ammonia (<2% of the total fleet; about one third of the ships charged with more than 1,000 kg F-Gases).

The refrigeration systems used in fishing vessels and charged with F-Gases (>12% of the total fleet) contain on average the following refrigerants:

- Medium sized fishing vessels: R-134a: 50%; R-404A: 50%
- Factory freezer trawler: R404A and R-507 (100%)
- Other fishing vessels: R-407C: 20%; R-507: 80%

Information on the GWP of the relevant F-Gases is provided in the annex.

| Ship type | Number of ships (EU flagged fleet) | Refrigerant charge Refrigeration [kg] |
|---|---|---|
| Medium sized fishing vessels | 930 | 12 - 100 |
| Large vessels with refrigerated seawater (RSW) tanks | 10 | 700 - 1,400 |
| Large vessels with freezing equipment | 65 | 150 - 10,000 |
| **All ships** | **~ 1,000** | |

Table 16: Overview of the number of fishing vessels including the charges used in refrigeration systems in EU-27 at the end of 2006

F-Gas emissions during operation (annual loss rate) are estimated to be about 40% of the total charge[3.]

*End of life emissions*

Based on discussions with stakeholders, it is expected that many of the ships are dismantled in non-European countries. There is considerable uncertainty about this share. There is a significant stronger motivation to dismantle big ships outside the EU than there is for smaller boats. The share might range from 80% outside-EU dismantling (big ships) to 10% outside-EU dismantling (smaller boats). As a reasonable approach, the project team assumes that 60% of all relevant ships will be dismantled in the EU. It is estimated that of the ships dismantled in Europe, about 80% of the refrigerants charged in air conditioning and refrigeration systems are recovered at end of life. This leads to an average emission rate of 20% concerning ships dismantled in Europe. According to expert information in some Member States, the recovery rate is already close to 100%. Taking into account the average lifetime of ships of about 30 years, it is assumed that annually about 4% of the ships remaining in Europe reach their end of life. Since ships have only been charged with HFCs since 2002, it is currently assumed that no air conditioning system or refrigeration system has reached its end of life and therefore the current end of life emissions are zero.

The F-Gas emissions during maintenance or servicing are estimated to be about 1% per year. Therefore the calculated annual emission factor amounts to 0.01.

According to the information and assumptions reported above, the following F-Gas emissions can be derived for air-conditioning systems and refrigeration systems in the maritime and inland waterway sector:

| Type | Type of system | Content [kg/ system] | Operation emission factor (annual emissions) | Operation emissions (annual emissions) [kg] | Maintenance and end of life emission factor (annual emissions) | Maintenance and end of life emissions (annual emissions) [kg] | Emissions total [kg] | Emissions total [kt $CO_2$ eq.] |
|---|---|---|---|---|---|---|---|---|
| Sea-going merchant ships | | | | 204,000 | | 6,700 | 211,000 | 290 |
| Cargo ships | AC | 150 | 0.4 | 130,500 | 0.01 | 3,300 | 134,000 | 174 |
| Cargo ships | Ref | 10 | 0.4 | 8,700 | 0.01 | 220 | 8,900 | 23 |
| Passenger ships | AC | 500 | 0.2 | 36,500 | 0.01 | 1,800 | 38,300 | 50 |
| Passenger ships | Ref | 20 | 0.2 | 1,500 | 0.01 | 75 | 1,500 | 4 |
| Cruise ships | AC | 6,000 | 0.2 | 25,200 | 0.01 | 1,300 | 26,500 | 35 |
| Cruise ships | Ref | 400 | 0.2 | 1,700 | 0.01 | 85 | 1,800 | 5 |
| Inland navigation vessels | | | | 4,100 | | 430 | 4,500 | 8.8 |
| Motorised cargo vessels | AC | 4.5 | 0.06 | 270 | 0.01 | 45 | 320 | 0.6 |
| Cabin boats | AC | 200 | 0.1 | 1,200 | 0.01 | 120 | 1,350 | 2.6 |
| Cabin boats | Ref | 5 | 0.1 | 31 | 0.01 | 3 | 34 | 0.07 |
| Excursion boats | AC | 100 | 0.1 | 2,600 | 0.01 | 260 | 2,800 | 5.5 |
| Ships for refrigerated cargo | Ref | --* | 0.2 | --* | 0.01 | --* | --* | --* |
| Fishing vessels | | | | 25,300 | | 630 | 25,900 | 78 |
| Medium seized fishing vessels | Ref | 18.8 | 0.4 | 7,000 | 0.01 | 175 | 7,100 | 16.3 |
| Large vessels with RSW | Ref | 900/1400 | 0.4 | 2,300 | 0.01 | 57 | 2,300 | 7.6 |
| Tuna longliners | Ref | 170 | 0.4 | 680 | 0.01 | 17 | 700 | 2.3 |
| Tuna seiners | Ref | 800/3000 | 0.4 | 2,600 | 0.01 | 65 | 2,700 | 8.7 |
| Freezer trawlers | Ref | 150/500 | 0.4 | 3,000 | 0.01 | 75 | 3,100 | 10.2 |
| Factory freezer trawler | Ref | 5,400 | 0.4 | 9,700 | 0.01 | 240 | 10,000 | 32.8 |
| **Sum** | | | | **~ 233,400** | | **~ 7,800** | **~ 241,400** | **~ 376** |

*no refrigeration system on an EU-flagged ship for refrigerated cargo was charged with F-Gases up to the end of end of 2006

Table 17: Current emissions of F-Gases from ships in EU-27 by the end of 2006

The current F-Gas emissions from ships are estimated to be about 376 kt of $CO_2$ eq. per year, where about 364 kt of $CO_2$ eq. per year are emitted from operational systems (annual emissions) and about 12 kt of $CO_2$ eq. per year are emitted from end of life systems and systems under maintenance or servicing.

## 5.2 Option 1

### *5.2.1 Road sector*

It is estimated that in the next twelve years without regulatory activities the following trends will be observed:

- An increase in the number of road vehicles by 25% (annually ~2%)
- The balance between second-hand vehicles and new vehicles shifts to new vehicles, thus the amount of old vehicles with higher refrigerant charges decreases significantly
- By 2020 about 15% of the refrigeration systems will contain alternative low GWP refrigerants. As an alternative, $CO_2$ will probably be used[8]. As a further alternative, the chemical industry is currently developing a low GWP synthetic refrigerant which could enter the market by about 2011. This figure is further analysed in the sensitivity analysis.
- The share of the F-gas based refrigerants for trucks will be as follows: R-404A (98%), R-410A (2%) (the use of R-134a in refrigeration systems in trucks and trailers will be discontinued)
- The average refrigerant charge will be reduced by 10% due to a decrease of older vehicles with higher refrigerant charges and due to technological developments[8]
- The emission factor during operation will be reduced by 10% for vans and by 15% for trucks and trailers resulting from a decrease of older vehicles with higher refrigerant charges and new technologies with improved leak prevention
- The F-Gas emissions at end of life will be reduced by 5% due to further improved recovery

[8] Konvekta 2008: personal comment

With these assumptions, the following emissions are expected for 2020:

| Type of vehicle | Content [kg/ system] | Operation emission factor (annual emissions) | Operation emissions (annual emissions) [kg] | Maintenance and end of life emission factor (annual emissions) | Maintenance and end of life emissions (annual emissions) [kg] | Emissions total [kg] | Emissions total [kt $CO_2$ eq.] |
|---|---|---|---|---|---|---|---|
| Vans (~3.5 t) | 2.1 | 0.18 | 308,000 | 0.047 | 80,100 | ~ 388,100 | ~ 1,037 |
| Trucks (>3.5 t) | 4.5 | 0.13 | 107,500 | 0.038 | 31,700 | ~ 139,200 | ~ 450 |
| Trailer | 8.1 | 0.11 | 167,800 | 0.038 | 57,000 | ~ 224,700 | ~ 726 |
| **Sum** | | | **~ 583,300** | | **~ 168,700** | **~ 752,000** | **~ 2,213** |

Table 18: Estimated emissions of F-Gases from road vehicles covered in this study in 2020

The HFC-emissions from refrigerated road vehicles could be reduced from ~ 2,537 kt of $CO_2$ eq. to ~ 2,213 kt of $CO_2$ eq. in 2020 when no regulatory action is taken, whereas emissions during operation decrease to 1,713 kt of $CO_2$ eq (annual emissions) and emissions at end of life and during maintenance decrease to 500 kt of $CO_2$ eq (annual emissions). The main reason for the reduction of F-Gases from the road sector is the assumption that in 2020 15% of the refrigerants are replaced by alternative refrigerants with low global warming potential and the shift from older vehicles with a higher refrigerant charge to newer vehicles with lower refrigerant charges.

### 5.2.2 *Rail sector*

It is estimated that in the next twelve years, without further regulatory actions, the following trends will be observed:

- In railway vehicles a shift from conventional coaches to DMU and EMU trains. Therefore, multiple units will increase by about 17% and the number of coaches will decrease to about 30,500 (based on Ökorecherche/Ecofys 2007[3] and expert interviews)
- In the railway sector, about 85% of passenger vehicles will be air-conditioned by 2020, about 32% of trams and about 53% of metros due to ongoing modernisation mainly in western and central Europe (based on Ökorecherche/Ecofys 2007[3] and expert interviews).
- Increase of the number of railway vehicles by 25%, increase of other rail vehicles (metro, tram) by 10%
- By 2020 about 15% of the F-Gas refrigerants will be substituted by F-Gas-free alternatives; this assumption is inter alia based on the fact that a few railway

vehicles (e.g. high-speed train "ICE-3") and a few prototypes using $CO_2$ for cooling already exist. Under Directive 2006/40/EC the use of refrigerants with a GWP higher than 150 (R-134a = 1300) in air-conditioning systems of new motor vehicles (category $M_1$ and $N_1$ according to Directive 70/156/EEC) from 2011 and in all vehicles from 2017 is prohibited. As the technique used in cars is different to the techniques used in railway vehicles, the technology will not be easily transposed, but experience is available. Development is very difficult to predict and differs considerably according to various expert opinions. A sensitivity analysis with a broader range of alternative refrigerants has been carried out for 2020.

- The refrigerant charge will be reduced by 10% due to technological developments

- The emission factor during operation will be reduced by 2.5% because of new technologies with improved leak prevention

- Emissions at end of life will be reduced by 5% due to further recovery

- Shift from R-407C to R-134a to a ratio of 15:85 as regards the railway vehicles. For trams, a ratio of 90:10 and for metros a ratio of 67:33 is expected in 2020 due to the increase of air-conditioned rail vehicles in western and central Europe, where R-134a is mainly used as refrigerant.

With these assumptions the following emissions are expected for 2020:

| Type | Content [kg/ system] | Operation emission factor (annual emissions) | Operation emissions (annual emissions) [kg] | Maintenance and end of life emission factor (annual emissions) | Maintenance and end of life emissions (annual emissions) [kg] | Emissions total [kg] | Emissions total [kt $CO_2$ eq.] |
|---|---|---|---|---|---|---|---|
| Railway vehicles | 2.5 - 27 | 0.05 - 0.1 | ~ 88,000 | ~ 0.011 | ~ 17,700 | ~ 105,700 | ~ 142 |
| Driver cabin | 2.5 | ~0.05 | 5,000 | ~ 0.011 | 1,100 | ~ 6,100 | ~ 8 |
| Vehicles except DMUs | 4.5 – 27 | ~0.05 | 64,400 | ~ 0.011 | 14,500 | ~ 78,900 | ~ 106 |
| DMUs | 12 | ~0.1 | 8,500 | ~ 0.011 | 2,100 | ~20,600 | ~ 28 |
| Trams | 27 | ~0.05 | 7,400 | ~ 0.011 | 1,700 | ~ 9,200 | ~ 12 |
| Metros | 12 | ~0.05 | 6,300 | ~ 0.011 | 1,500 | ~ 7,800 | ~ 11 |
| **Sum** | | | **~ 101,700** | | **~ 20,900** | **~ 122,700** | **~ 165** |

Table 19: Estimated emissions of F-Gases from rail vehicles in 2020

HFC-emissions from rail vehicles could be increased from about 113 kt $CO_2$ eq. to approximately 165 kt $CO_2$ eq. in 2020 when no regulatory action will be taken. F-Gas emissions during operation of the systems are estimated at 137 kt $CO_2$ eq. (annual emissions), at end of life and during maintenance as 28 kt $CO_2$ eq (annual emissions). The increase is attributed to the fact that many rail vehicles which currently operate without air-conditioning will be equipped or replaced by vehicles with air-conditioning systems and that more air-conditioning systems will be at their end of life in 2020.

### *5.2.3 Maritime and inland waterway sector*

It is estimated that in the next twelve years without regulatory activities the following trends will be observed:

- The total number of ships will not change significantly (number of new ships built and operated under an EU flag will not differ significantly from the number of old ships taken out of service). This estimation is taking into account the current economic crisis, with expected revisions of economic growth and the tendency to flag ships under non-EU nationalities. This is in line with the assumptions of the previous study[3].
- In 2020 there will be a complete phase-out of R-22 due to Art. 5 of Regulation (EC) No 2037/2000 all hydrochlorofluorocarbons (HCFCs) shall be prohibited

as of 1 January 2015. The amount of F-Gases used as a refrigerant will consequently increase.

- With regard to sea going merchant ships and inland navigation vessels, about 10% of the F-Gas refrigerants will be replaced by F-Gas free alternatives such as $CO_2$ and ammonia by 2020
- With regard to EU-flagged merchant ships equipped with F-gas based systems, there will be a shift from R-134a (100%) to R-134a (70%), R-404A (20%) and R-407C (10%). This is inter alia due to the replacement of R-22 with R-404A
- With regard to fishing vessels, about 60% of the F-Gas refrigerants will be substituted by F-Gas-free alternatives such as $CO_2$ and ammonia by 2020 due to the phase-out of R-22 and a clear trend towards these alternative refrigerants[3]
- Approximately 30% of the refrigeration systems installed in ships for refrigerated cargo will be charged with F-Gases (R-407C) by 2020. Other systems will be charged with alternative refrigerants such as $CO_2$ and ammonia due to the phase-out of HCFC-22 (about 70%)
- The refrigerant charge will be reduced by 5% due to technological developments
- The emission factor during operation will be reduced by 5% due to new technologies with improved leak prevention

Based on these assumptions the following emissions are expected for 2020:

| Type | Type of system | Content [kg/ system] | Operation emission factor (annual emissions) | Operation emissions (annual emissions) [kg] | Maintenance and end of life emission factor (annual emissions) | Maintenance and end of life emissions (annual emissions) [kg] | Emissions total [kg] | Emissions total [kt $CO_2$ eq.] |
|---|---|---|---|---|---|---|---|---|
| Sea-going merchant ships | | | | 632,800 | | 33,700 | 666,500 | 1,180 |
| Cargo ships | AC | 143 | 0.38 | 331,300 | 0.015 | 12,300 | 343,600 | 592 |
| Cargo ships | Ref | 9.5 | 0.38 | 22,100 | 0.015 | 800 | 22,900 | 59 |
| Passenger ships | AC | 475 | 0.19 | 167,600 | 0.015 | 12,400 | 180,000 | 310 |
| Passenger ships | Ref | 19 | 0.19 | 6,700 | 0.015 | 500 | 7,200 | 19 |
| Cruise ships | AC | 5,700 | 0.19 | 98,500 | 0.015 | 7,200 | 105,700 | 182 |
| Cruise ships | Ref | 380 | 0.19 | 6,600 | 0.015 | 500 | 7,100 | 18 |
| Inland navigation vessels | | | | 34,000 | | 5,200 | 39,200 | 76 |
| Motorised cargo vessels | AC | 4.3 | 0.057 | 1,800 | 0.015 | 400 | 2,200 | 4 |
| Cabin boats | AC | 190 | 0.095 | 5,300 | 0.015 | 800 | 6,100 | 12 |
| Cabin boats | Ref | 4.75 | 0.095 | 100 | 0.015 | 20 | 120 | 0.2 |
| Excursion boats | AC | 95 | 0.095 | 26,800 | 0.015 | 3,900 | 30,700 | 60 |
| Ships for refrigerated cargo | Ref | 1,900 | 0.19 | 17,100 | 0.015 | 1,300 | 18,400 | 60 |
| Fishing vessels | | | | 205,100 | | 7,600 | 212,700 | 678 |
| Medium seized fishing vessels | Ref | 17.9 | 0.38 | 20,100 | 0.015 | 700 | 20,800 | 47 |
| Large vessels with RSW | Ref | 855/1,330 | 0.38 | 10,600 | 0.015 | 400 | 11,000 | 36 |
| Tuna longliners | Ref | 162 | 0.38 | 2,000 | 0.015 | 70 | 2,070 | 7 |
| Tuna seiners | Ref | 760/2,850 | 0.38 | 21,100 | 0.015 | 800 | 21,900 | 71 |
| Freezer trawlers | Ref | 142/475 | 0.38 | 11,000 | 0.015 | 400 | 11,400 | 37 |
| Factory freezer trawler | Ref | 5,130 | 0.38 | 140,300 | 0.015 | 5,200 | 145,600 | 479 |
| **Sum** | | | | **~ 889,000** | | **~ 47,800** | **~ 936,600** | **~ 1,994** |

Table 20: Estimated emissions of F-Gases from the maritime and inland waterway sector in 2020

The HFC-emissions are estimated to increase from about 376 kt $CO_2$ eq. to approximately 1,994 kt $CO_2$ eq. in 2020 when no regulatory action will be taken. Many ships are refrigerated with R-22 (HCFCs not covered by the F-Gas Regulation) in 2007. Due to the phase-out of R-22 under Regulation (EC) No 2037/2000, it is expected that this refrigerant will be replaced mainly by F-Gases (HFCs) in most sectors and to a lesser extent by alternative refrigerants, mainly in the subsector of fishing vessels. Another reason for the increase of F-Gas emissions is the assumption that in 2007 no systems charged with F-Gases reach their end of life whereas in 2020 the systems which reach their end of life are also charged with F-Gases (due to the phase-out of R-22). Therefore it is estimated that in 2020 about 30 kt $CO_2$ eq. will be emitted at end of life.

F-Gas emissions during operation are estimated to be about 1,896 kt $CO_2$ eq. (annual emissions), and about 98 kt $CO_2$ eq (annual emissions) at end of life and during maintenance or servicing.

Sea-going merchant ships constitute about 59%, ships for refrigerated cargo: 3%, inland navigation vessels: 4% and fishing vessels: 34% of the total F-gas emissions from the maritime and inland waterway sector.

## 5.3 Option 2

### *5.3.1 Road sector*

*Environmental impacts*

It is estimated that by applying the requirements of Article 3 of the F-Gas Regulation, operation emissions could be reduced by about 20% in vans and by 45% in trucks and trailers. The requirements include better servicing or maintenance, including precautions to “prevent and repair leakage as soon as possible”, a required leakage check once a year and record keeping (the last two requirements are not relevant for vans as the F-Gas content is below 3 kg). A leakage detection system would not be obligatory in road vehicles as the F-Gas charge in the systems is below 300 kg/system.

The following table provides an overview of the estimated emission reduction factors and the derived emission reduction in 2020 by applying Article 3 of Regulation (EC) No 842/2006 to road vehicles.

| Requirement | Emission reduction factor | Emission reduction (kg F-Gas) | Emission reduction (kt $CO_2$ eq.) |
|---|---|---|---|
| Prevent and repair leakage as soon as possible | 0.15 / 0.2* | 102,900 | 298 |
| Annual leakage inspection | 0.25 | 68,800 | 222 |
| Installation of leakage detection system | 0 | 0 | 0 |
| Record keeping | 0.05 | 13,800 | 44 |
| **Sum** | | **~ 185,500** | **~ 565** |

*for vans, where leakage control is not required to be carried out, emission reduction through prevention and repair of leakage is estimated at about 20%

Table 21: Estimated emission reduction factors and resulting emission reduction in 2020 by applying Art. 3 of Regulation (EC) No 842/2006 to road vehicles

The total F-Gases emitted in 2020 are estimated to decrease by around 565 kt $CO_2$ eq. by applying Art. 3 of Regulation (EC) No 842/2006 to road vehicles. This represents a reduction of 26% of total emissions predicted in the baseline scenario for 2020 (33% reduction of the emissions during operation of the systems in 2020, thereof 29% of the emission reduction could be realised from vans, 28% from trucks and 43% from trailers).

*Economic and social impacts*

As the requirements in Art. 3 directly affect the operators, as a first step the economic impacts for operators of refrigeration systems fitted to road vehicles are determined.

Based on received questionnaires and expert information, the following costs are assumed:

- One work hour by operators' own personnel: €60.00 (ranging from €20.00-€30.00 in new Member States such as Romania, and to €70.00-€80.00 in old Member States such as Germany). These costs occur for record keeping, the prevention of leakage and the repair of any detected leakage as soon as possible.

- One annual inspection by service companies' certified personnel including costs for inspection equipment: €230.00/system. As maintenance and inspections through service contracts were already to some extent carried out in 2007 the extra costs for inspections carried out by certified personnel are expected to be about €115.00 (50% of the price for an inspection).

- Certification of one technician: €500.00/person. This figure shows the relevant dimensions, but is no longer used in the calculations

It is expected that the major share of refrigeration systems will be inspected by external service companies. Therefore, in the following calculation the cost of certification of an operator's own personnel is not accounted for, and costs for an external annual inspection are added to each system. The costs for certification of service companies' personnel are not accounted for here, as these do not arise for the operator, but are transferred to them indirectly through the inspection costs.

It is assumed that, for prevention of leakage and repairs of detected leaks, an average of half an hour is required per system and year for trucks and trailers, and one hour for vans. Based on the assumption of this time period, it is estimated that:

- approximately 1 day is needed for repair if a leakage is detected

- in approximately 10% (5% if regular leakage checks are carried out) of the systems, a leakage is detected

- a relatively short time is required if systems are checked more frequently to detect and prevent any leakage. This leads to approximately 1 hour of work time of an operator's own personnel (half an hour if regular leakage checks are carried out). For record keeping – relevant only for trucks and trailers – half an hour is assumed annually based on the information from RPA 2004[2] and on information from experts.

Further to the costs which will arise for the operators, savings are also taken into account as the costs for refrigerants would be reduced. In addition, energy consumption could be reduced with associated economic benefits. However, only savings from refrigerants will be considered in this study. The price of the refrigerants varies between €7.00 and €50.00/kg or more depending on the region and the type and amount of refrigerant. As a European average, €25.00/kg is used for further calculation. The price of the F-Gases, which is needed to calculate the savings, has a minor impact as regards the final costs of the operators (see Table 22).

The following table provides an overview on the costs and savings and the resulting estimated net costs for each requirement of Art. 3 of the F-Gas Regulation when applied to the road sector.

| Requirement | Costs [k€] | Savings [k€] | Net costs [k€] |
|---|---|---|---|
| Prevent and repair leakage as soon as possible | 60,800 | 2,600 | ~ 58,200 |
| Annual leakage inspection | 43,100 | 1,700 | ~ 41,400 |
| Installation of leakage detection system | 0 | 0 | 0 |
| Record keeping | 11,200 | 300 | ~ 10,900 |
| **Sum** | **~ 115,200** | **~ 4,600** | **~ 110,600** |

Table 22: Estimated costs for operators by applying Art. 3 of Regulation (EC) No 842/2006 to road vehicles

The estimated net costs for operators of the systems in the relevant road transport sector would amount to ~111 mio € in case the requirements of Art. 3 would be applied.

No significant impacts on the growth, further investments and competiveness of the affected companies in the EU are expected. With regard to employment, it has been stated by industry experts that negative impacts are expected concerning the additional work load for the same number of staff. In view of the existing high competition, it is expected that this statement holds true for development in many companies.

For indirectly affected actors, both negative as well as positive economic impacts are expected. Negative economic impacts are expected for producers and distributors of F-Gases, as less F-Gases are needed for the operation of refrigeration systems in the road sector. Positive impacts are expected in training companies, certification bodies and service companies, as they will have to carry out the certification, leakage checks and other activities as required in Art. 3 of Regulation (EC) No 842/2006. No impacts or slightly positive impacts are expected for manufacturers of air conditioning and refrigeration systems. Authorities of Member States have several tasks to tackle: Awareness needs to be generated, national training schemes and certification systems need to be adopted/adjusted and correspondingly the enforcement of Art. 3 of Regulation (EC) No 842/2006 needs to be ensured. This will generate additional costs, mainly for personnel.

In the following figure, an overview of the concerned actors is provided including an indication of impact that is expected (- = negative impact, + = positive impacts, +/- = no impact):

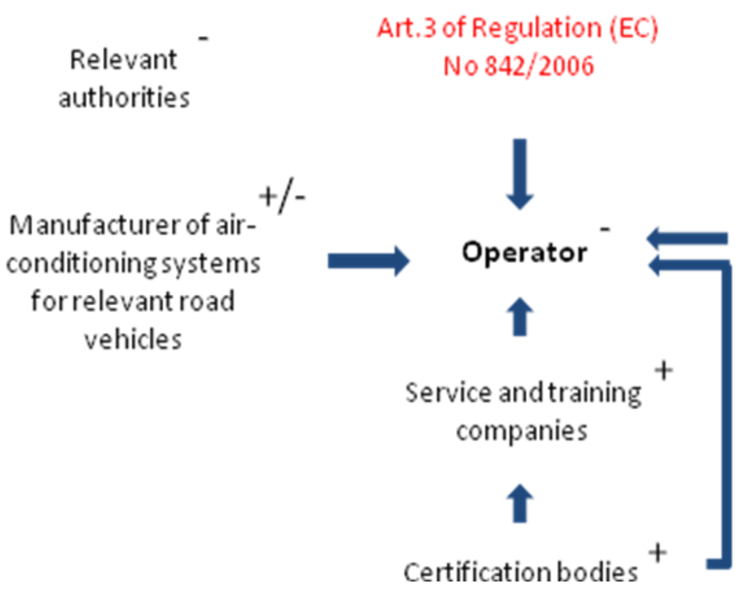


Figure 2: Relationship and type of impacts upon indirectly affected actors by applying Art. 3 of Regulation (EC) No 842/2006

Based on the relationships in the figure above, it is estimated that certification, service and training activities will generate roughly 1,400 jobs in Europe while no significant loss of jobs (<10) will occur at the producers and distributors of F-Gases as a consequence of option 2.

The following ratios have been assumed for the calculation

€80,000/year difference in turnover ≙ 1 job at service providers

€200,000/year difference in turnover ≙ 1job at equipment suppliers

€500,000/year difference in turnover ≙ 1job at F-Gas producers

### *5.3.2 Rail sector*

*Environmental impacts*

In air-conditioning systems for driver cabins of railway vehicles the refrigerant charge is typically lower than 3 kg/system. Therefore, emission reductions can only result from taking precautions to prevent leakage of F-Gases and from the requirement to “repair any detected leakage as soon as possible”.

For other air-conditioning systems where the F-Gas charge amounts to more than 3 kg, further emission reductions could be achieved through the required annual leakage checks and record keeping. Record keeping is already carried out for maintenance in some countries (e.g. UK) and therefore no greater efforts are expected in these countries.

Provisions required by Art. 3 of the F-Gas Regulation have already been introduced in the railway sector in some countries such as Greece and the UK and therefore no further emission reduction by this measure is expected for those countries.

Leakage detection systems are not relevant as the charges are below 300 kg/system.

On the other hand, it must be considered that air-conditioning systems are not hermetically sealed and that the above-mentioned measures might have at least certain effects on emission reduction.

As precise information on emission reduction potentials was limited, the share of emission reduction factors is mainly based on information of single Member States and assumptions.

The following table provides an overview of the estimated emission reduction factors and the derived emission reduction in 2020 by applying Article 3 of Regulation (EC) No 842/2006 to railway vehicles.

| Requirement | Emission reduction factor | Emission reduction [kg F-Gas] | Emission reduction [kt $CO_2$ eq.] |
|---|---|---|---|
| Prevent and repair leakage as soon as possible | 0.05/0.03* | 3,200 | 4.2 |
| Annual leakage inspection | 0.06 | 5,800 | 7.8 |
| Installation of leakage detection system | 0 | 0 | 0 |
| Record keeping | 0.01 | 1,000 | 1.3 |
| **Sum** | | **~ 9,900** | **~ 13.4** |

*for AC systems in driver cabins it is assumed that the emissions could be reduced by 5%, for other AC systems, where regular leakage control has to be carried out, the emission reduction factor is about 3%

Table 23: Estimated emission reduction factor and resulting emission reduction in 2020 by applying Art. 3 of Regulation (EC) No 842/2006 to rail vehicles

The calculated F-Gas emissions in the baseline scenario of 165 kt $CO_2$ eq. emitted in 2020 are expected to decrease by 13 kt $CO_2$ eq. by applying Art. 3 of Regulation (EC) No 842/2006 to rail vehicles. This represents a reduction of 8% of total emissions predicted in the baseline scenario for 2020 and 9% as regards operation emissions in 2020. Thereof 86% could be realised by railway vehicles, 7% by trams and 7% by metros.

*Economic and social impacts*

As the requirements in Art. 3 would directly affect the operator in the first place, the economic impacts for operators of air-conditioning systems fitted to rail vehicles have been estimated.

Based on received questionnaires and expert information, the following costs are assumed:

- One work hour by own personnel: 60€ (ranging from €20.00-€30.00 in new Member States like Romania to €70.00-€80.00 in old Member States such as Germany). These costs occur for record keeping, the prevention of leakage and the repair of any detected leakage as soon as possible.

- One annual inspection by service companies' certified personnel, including costs for inspection equipment: €400.00. As maintenance and inspections through service contracts were already to some extent carried out in 2007, the extra costs for inspections carried out by certified personnel is expected to be about €200.00 (50% of the price for an inspection).

- One certification of one technician: €500.00/person. This figure demonstrates the relevant dimensions but is no longer used in the calculations

It is expected that the major share of air-conditioning systems will be inspected by service companies. Only to a lesser extent will the operating companies have their own personnel certified. Therefore, in the following calculation, the costs for certification of a company's own personnel are neglected and costs for an external annual inspection are applied for each system. The costs for certification of service companies' personnel is not accounted for here, as these do not arise for the operator, but are transferred to them indirectly through the inspection costs.

It is assumed that for prevention of leakage and repairs of detected leaks an average of 2 hours are necessary per system and year for driver cabins and 1 hour for other railway vehicles, trams and metros. On such a basis it is estimated that a leak is detected in approximately every 20$^{th}$ vehicle (10$^{th}$ vehicle as regards driver cabins) and on average about two days are needed to repair the leak (including downtime). These two days might appear to be a long time at first glance, but the rail vehicle needs to be removed from the normal field of operation to the repair workshop. And sometimes refrigeration units need to be replaced and therefore the given time period is regarded as a good average and in line with expert information.

In this context it should be pointed out that, according to the F-Gas Regulation, all measures shall be employed to prevent any leakage and to repair any leaks as soon as possible, which are technically feasible and do not entail disproportionate cost. This does not necessarily mean "immediately" if the cost would then be disproportional with the leakage reduction achieved.

As stated by train companies, record keeping is already practiced, but in order to include all specific information required by the F-Gas Regulation, an additional time of half an hour is estimated per vehicle.

Further to the costs which will arise for the operators, savings have also been taken into account as the costs for refrigerants would be reduced. In addition, energy consumption could be reduced with associated economic benefits, however, only savings from refrigerants will be considered in this study. Prices of refrigerants vary between €7.00 and €50.00/kg and more, depending on the region and the and amount of refrigerant. As a European average €25.00 /kg is used for further calculation.

The following table provides an overview of the costs and savings and the resulting estimated net costs for each requirement of Art. 3 of the F-Gas Regulation.

| Requirement | Costs [k€] | Savings [k€] | Net costs [k€] |
|---|---|---|---|
| Prevent and repair leakage as soon as possible | 12,300 | 79 | ~ 12,200 |
| Annual leakage inspection | 24,100 | 145 | ~ 24,000 |
| Installation of leakage detection system | 0 | 0 | 0 |
| Record keeping | 3,600 | 24 | ~ 3,600 |
| **Sum** | **40,000** | **~ 248** | **~ 39,800** |

Table 24: Estimated costs for operators by applying Art. 3 of Regulation (EC) No 842/2006 to rail vehicles

If Art. 3 of the F-Gas regulation were to be applied to mobile equipment in the rail sector as well, the estimated net costs are expected to amount to ~ €40m for rail vehicle operators. As explained by train companies, it must be considered that the down time of a railway vehicle is also an important cost factor, when leakage has to be repaired as soon as possible. In the UK, a financial evaluation of the application of the F-Gas Regulation has already been carried out with the result that the costs for UK industry would be between £3.55m and £24.85m depending mainly on the interpretation of Art. 3[9].

No negative impacts are expected on the growth of the affected companies, regarding further investments and competitiveness. This conclusion is shared with several train companies. As regards employment, negative impacts are expected concerning the additional work load for the same number of staff.

Negative as well as positive economic impacts are expected for indirectly affected actors. As stated by a producer of F-Gases, no significant negative impacts are expected, as the emissions are already very low. Positive impacts are expected for training companies and certification bodies as well as service companies as they would have to carry out the measures and certification required in Art. 3 of Regulation (EC) No 842/2006. Slightly positive impacts are also expected for manufacturers of air-conditioning systems for rail vehicles. Authorities would have to ensure the enforcement of Art. 3 of Regulation (EC) No 842/2006 and this would therefore entail increased effort.

[9] Denham R.: A Financial Evaluation of the Application on EC (No) 842/2006 to the UK Rail Industry

In the following figure, an overview of concerned indirect actors is provided, including the type of impact which is expected (- = negative impact, + = positive impacts, +/- = no impact).

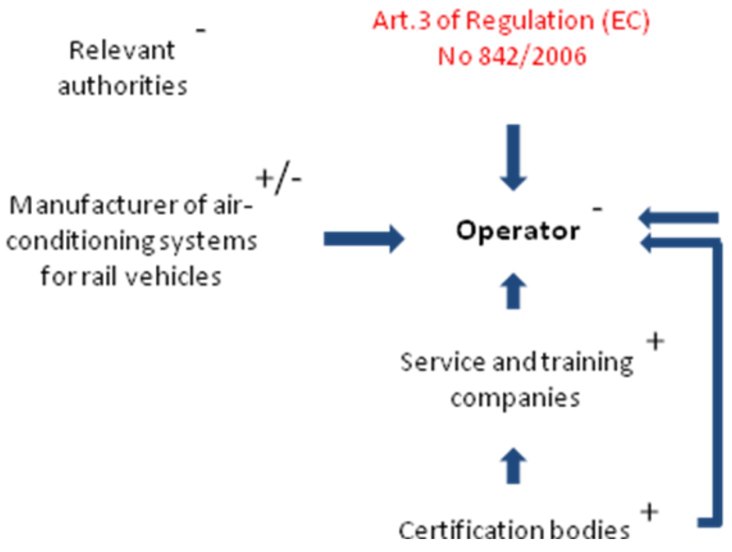


Figure 3: Relationship and type of impacts of indirectly affected actors by applying Art. 3 of Regulation (EC) No 842/2006

Based on the relationships in the figure above, it is estimated that certification, service and training activities will generate roughly 500 jobs in Europe while no significant losses of jobs are expected at the producers and distributors of F-Gases as a consequence of option 2.

The following ratios have been assumed for the calculation:

€80,000/year difference in turnover ≙ 1 job at service providers

€200,000/year difference in turnover ≙ 1job at equipment suppliers

€500,000/year difference in turnover ≙ 1job at F-Gas producers

### 5.3.3 *Maritime and inland waterway sector*

*Environmental impacts*

Charges in air conditioning and refrigeration systems installed in ships typically range from about 4.3 kg in the air-conditioning systems of inland motorised cargo vessels to about 10,000 kg in refrigeration systems of factory trawlers.

By applying Art. 3, additional emission reduction will be achieved by taking precautions to prevent any leakage and repairing it as soon as possible, by annual leakage checks through certified personnel including training and awareness-raising of the crew, by installations of leakage detection systems (mandatory where charges are >300 kg) and by record keeping.

Leakage detection systems which are already on the market are e.g. Freon detectors with 4 or more sensors or the “SIEMENS Ultramat 21P or 22P”.

According to Öko-Recherche/Ecofys 2007[3] such measures could reduce operation emissions by up to 40%.

According to the European Community Shipowners’ Association (ECSA), the F-Gas emissions from refrigeration and air-conditioning systems during operation in ships cannot be reduced by 40% just by applying Art. 3 as the high emissions mainly occur by damages in the systems due to the rough conditions at sea. Therefore, the leakages are of incidental character, sometimes up to 100% in a very short time, and, in their view, cannot be reduced by the stipulated measures. Also, detection of the leakage is complicated in ships due to various factors such as varying loads, and consequently the varying levels of refrigerant in the liquid receiver, the sea state, defrosting processes etc[Fehler! Textmarke nicht definiert.].

However, other sources state that emissions could be significantly reduced by proper maintenance and better leak detection, which is not always employed in the ship sector[4,10]. According to research carried out by the Dutch Environmental Inspection, operational measures and improved maintenance of equipment such as maintenance systems, training of crew members, installation of leak detection systems, would reduce emissions considerably[10]. One expert also stated that 40% seems to be too pessimistic regarding the emission reduction potential. This demonstrates a broad field of expert expectations that makes a fair judgement difficult. As the emission reduction potential is an average value, it has to take into account the full range of e.g. adequately and inadequately maintained ships. Therefore, the 40%, indicated by Öko-Recherche/Ecofys 2007[3] seems to be a realistic value and it has been used as an average value for further calculation.

Another way to reduce emissions could be the development of indirect systems and new technologies and installations which are more compact and robust[Fehler! Textmarke nicht definiert.,10]. Therefore, the Commission and Member States should also provide support and incentives for further research and development activities as well as for technical cooperation between all industries involved.

The following table provides an overview of the percentage of emissions which could be reduced by applying the requirements in Art. 3 of the F-Gas regulation to ships.

[10] CE Delft, Greenhouse Gas Emissions for Shipping and Implementation, Guidance for the Marine Fuel Sulphur Directive, 2006

| Charge | Prevent and repair as soon as possible | Leakage control | Installation of a detection system | Record keeping |
|---|---|---|---|---|
| > 3 kg | 15% | 23% | 0% | 2% |
| > 30 kg | 8% | 30% | 0% | 2% |
| > 300 kg | 5% | 23% | 10% | 2% |

Table 25: Estimated emission reduction factors related to the F-Gas charge of air conditioning and refrigeration systems in ships of the maritime and inland waterway sector

Based on these emission factors, the following emission reduction during operation could be achieved in 2020 by applying Article 3 of Regulation (EC) No 842/2006 to ships of the maritime and inland waterway sector:

| Requirement | Emission reduction [kg F-Gas] | | | | Emission reduction [kg F-Gas] | Emission reduction [kt $CO_2$ eq.] |
|---|---|---|---|---|---|---|
| | Sea-going merchant ships | Ships for refrigerated cargo | Inland navigation vessels | Fishing vessels | All types | All types |
| Prevent and repair leakage as soon as possible | 67,600 | 900 | 2,900 | 13,100 | 84,400 | 168 |
| Annual leakage inspection | 152,200 | 3,900 | 10,000 | 47,100 | 213,200 | 452 |
| Installation of leakage detection system | 27,300 | 1,700 | 0 | 17,800 | 46,800 | 112 |
| Record keeping | 9,300 | 300 | 700 | 4,100 | 14,500 | 32 |
| **Sum** | **~ 256,400** | **~ 6,800** | **~ 13,500** | **~ 82,100** | **~ 358,800** | **~ 764** |

Table 26: Estimated emission reduction potential in 2020 by applying Art. 3 of Regulation (EC) No 842/2006 to ships

The approximately estimated 1,994 kt $CO_2$ eq. of the baseline scenario emitted in 2020 are expected to decrease in 2020 by 764 kt $CO_2$ eq. by applying Art. 3 of Regulation (EC) No 842/2006 to ships. This represents a reduction of 38% of total emissions predicted in 2020 under the baseline scenario and more specifically a reduction of 40% of the emissions during operation of the systems (annual emissions) in 2020. Thereof 59% would be achieved by sea-going merchant ships, 3% by ships for refrigerated cargo, 4% by inland navigation vessels and 34% by fishing vessels.

According to expert information, the main problem in further reducing F-Gas emissions, from a technical point of view, even with newly built ships, is the robustness of the circuit (pipes, connections etc.) given the harsh conditions at sea. Therefore, research and development should be pursued to produce further emission reductions.

*Economic and social impacts*

As the requirements in Art. 3 would directly affect the operator in the first place, the economic impacts for operators of air-conditioning systems fitted to ships have been estimated.

Based on received questionnaires and expert information, the following costs are assumed:

- One work hour by an operator’s own personnel: €50.00
- Annual inspection costs by certified personnel of service companies including costs for inspection equipment depending on the F-Gas charge
  - < 30 kg: €200.00
  - 30-500 kg: €1,000.00
  - 500-1000 kg: €2,000.00
  - > 1000 kg: €3,000.00
- Annualised costs for a leakage detection system: ~ €700.00
- Certification of one technician: €500.00/person

It is expected that the major share of air-conditioning systems will be inspected by external service companies. This expectation is shared by several experts in the field. In the following calculation, the costs for certification of an operator’s own personnel are not accounted for and costs for an annual inspection are applied for each system. The costs for certification of personnel from service companies are not accounted for here, as these do not arise for the operator, but are transferred to them indirectly through the inspection costs.

It is assumed that for the prevention of leakage and the repairs of detected leaks as soon as possible, on average 4 hours are needed per system and year. For the purposes of record keeping (required due to Art. 3(6) of Regulation (EC) No 842/2006), one hour is estimated where one annual leakage check has to be carried out and two hours are assumed for ships with higher F-Gas charges – where two annual leakage checks are required.

For ships which have both air conditioning and refrigeration systems, the cost for prevention and repair of leakage are estimated to be double. The costs for the other requirements are estimated to be 50% higher than the costs which would arise if only one type of system had been installed.

Further to the costs which will arise for the operators, savings are also taken into account as the costs for refrigerants would be reduced. In addition, energy consumption could be reduced with associated economic benefits, however, only savings from refrigerants will be considered in this study. The price of the refrigerants varies between €7.00 and €50.00/kg and more, depending on the region and the type and amount of refrigerant. As a European average €25.00/kg is used for further calculation.

The following table provides an overview of the costs and savings and the summarized costs for each requirement of Art. 3 of the F-Gas Regulation.

| Requirement | Costs [k€] | Savings [k€] | Net costs [k€] | Costs [k€] | Savings [k€] | Net costs [k€] | Costs [k€] | Savings [k€] | Net costs [k€] | Costs [k€] | Savings [k€] | Net costs [k€] | Total costs [k€] | Total savings [k€] | Total Net costs [k€] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Sea-going merchant ships | | | | | | Inland navigation vessels | | | Fishing vessels | | | | | |
| Prevent and repair leakage as soon as possible | 3,200 | 1,700 | 1,500 | 10 | 20 | -10 | 2,100 | 70 | 2,000 | 600 | 300 | 300 | 6,000 | 2,100 | 3,900 |
| Annual leakage inspection | 11,200 | 3,800 | 7,400 | 140 | 100 | 45 | 4,900 | 200 | 4,700 | 1,300 | 1,200 | 100 | 17,500 | 5,300 | 12,200 |
| Installation of leakage detection systems | 1,400 | 700 | 700 | 30 | 40 | -10 | 0 | 0 | 0 | 100 | 400 | -300 | 1,600 | 1,200 | 400 |
| Record keeping | 1,000 | 200 | 800 | 5 | 10 | -5 | 700 | 20 | 700 | 200 | 100 | 100 | 1,900 | 400 | 1,500 |
| **Sum** | **~ 16,800** | **~ 6,400** | **~ 10,400** | 190 | 170 | 20 | **~ 7,700** | **~ 300** | **~ 7,400** | **~ 2,200** | **~ 2000** | **~ 200** | **~ 27,000** | **~ 9,000** | **~ 18,000** |

Table 27: Estimated costs for operators through application of Art. 3 of Regulation (EC) No 842/2006 to ships

The estimated total additional net costs arising for operators of the systems by applying Art. 3 to the maritime and inland waterway sector would amount to ~€18m.

During the discussion with stakeholders, one expert stated that the application of Art. 3 would have negative impacts on the growth and new investments of affected companies as the costs for fulfilling the requirements of Art. 3 would be relatively high for some companies. Furthermore, this expert stated that the application of Art. 3 would also have negative impacts on employment as no new personnel would be employed due to low margins and therefore the additional work would have to be carried out by the existing staff. Based on the figures received from various sources this seems to be only of a limited magnitude.

Negative as well as positive economic impacts are expected for indirectly affected actors. Negative impacts are expected for producers and distributors of F-Gases because less HFCs will be demanded. However, according to a distributor, this impact will be low. For manufacturers of air-conditioning systems and refrigeration systems for ships, slightly positive impacts are expected. Positive impacts are expected for training companies and certification bodies as well as service companies, because they would have to carry out the additional measures and certifications as required in Art. 3 of Regulation (EC) No 842/2006. Authorities would have to ensure the enforcement of Art. 3 of Regulation (EC) No 842/2006 and this would therefore entail increased effort.

In the following figure an overview on the concerned indirectly affected actors is provided including the type of impact which is expected (- = negative impact, + = positive impacts, +/- = no impact).

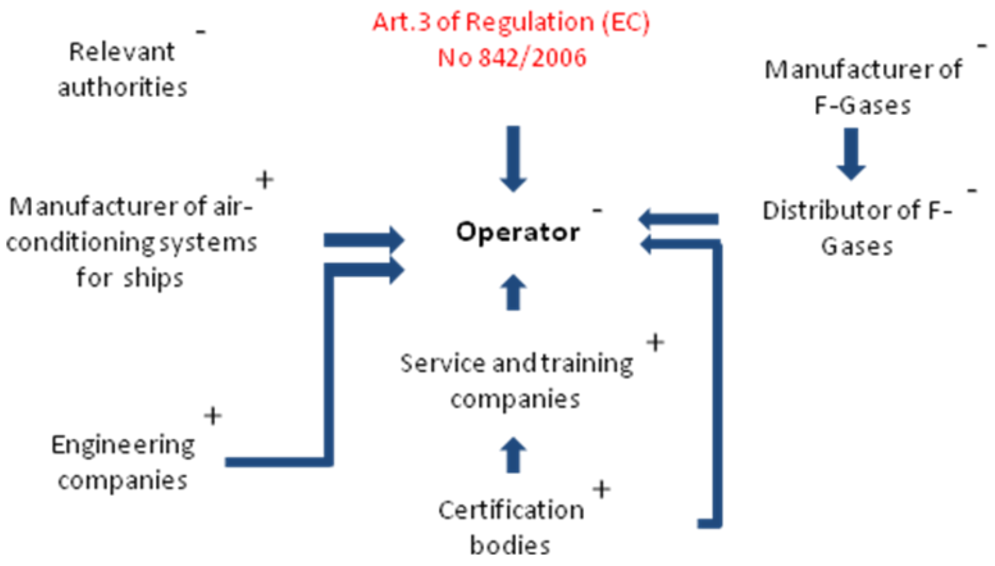


Figure 4: Relationship and type of impacts of indirect affected actors by applying Art. 3 of Regulation (EC) No 842/2006

Based on the relationships in the figure above, it is assumed that certification, service and training activities will generate roughly 200 jobs in Europe while no significant losses of jobs

(<20) are expected at the producers and distributors of F-Gases as a consequence of option 2.

The following ratios have been assumed for the calculation:

€80,000/year difference in turnover ≙ 1 job at service providers

€200,000/year difference in turnover ≙ 1job at equipment suppliers

€500,000/year difference in turnover ≙ 1job at F-Gas producers

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One potential impact seen by ECSA experts, relating to applying Art. 3 to the maritime and inland waterway sector, is the possibility of reflagging ships in the maritime sector so that the requirements could be avoided. However, there are doubts that this will show up in practise. It should be mentioned that reflagging implies several consequences of which the impacts due to measures based on Article 3 are seen as being of minor importance. An option against the ECSA concern is the possibility to link the requirements of the F-Gas Regulation also to EU ports rather than only on the EU flagged fleet.. The International Maritime Organisation (IMO) already tries to tackle the emission reduction of ships at an international level. As shipping is a global business it would therefore be highly recommendable to discuss within the IMO possible activities which would then be valid for all ships on a global level.

## 5.4 Option 3

### *5.4.1 Road sector*

*Environmental impacts*

Recovery of F-Gases at end of life and during service and maintenance – which has to be carried out by certified personnel when applying option 3 – concerns all systems, independent of the amount of F-Gases contained.

It is estimated that the recovery rate of F-Gases could be improved from over 70% to 90% on average in the EU by applying the requirements of Art. 4(1) of Regulation (EC) No 842/2006. This expectation is shared by various experts. Therefore, it is estimated that emissions at end of life could be reduced by 66%. Emissions which occur during maintenance could also be decreased by 74% (from nearly 20% to 5%).

Based on these assumptions, the following emission reduction could be derived in the year 2020 compared with the baseline emissions at end of life and during maintenance or servicing:

| Requirement | Emission reduction factor | Emission reduction (kg F-Gas) | Emission reduction (kt $CO_2$) |
|---|---|---|---|
| Recovery by certified personnel during service and maintenance | 0.74 | 57,300 | 172 |
| Recovery by certified personnel at end of life | 0.66 | 60,300 | 177 |
| **Sum** | | **~ 117,600** | **~ 349** |

Table 28: Estimated emission reduction factor and resulting emission reduction in 2020 by applying Art. 4(1) of Regulation (EC) No 842/2006 to road vehicles

The total F-Gases calculated within the baseline scenario emitted in 2020 could be reduced by around 349 kt $CO_2$ eq. by applying Art. 4(1) of Regulation (EC) No 842/2006. This represents a reduction of 16% of total emissions predicted in 2020 and more specifically of 70% as regards emissions at end of life and during maintenance or servicing in 2020 under the baseline scenario. Thereof 42% could be achieved from vans, 21% from trucks and 37% from trailers.

*Economic and social impacts*

As the requirements in Art. 4(1) would directly affect the operator in the first place, the economic impacts for operators of refrigeration systems fitted to road vehicles have been estimated.

Based on received questionnaires and expert information, the following costs are assumed:

- Costs for recovery per kg F-Gas: €20.00
- Additional costs if the recovery will be carried out be certified personnel: €20.00/system

It is expected that a major share of refrigeration systems will be inspected and recovered by external service companies. To a much lesser extent, operating companies will make arrangements for certification of their own personnel to carry out leakage checks.

Further to the costs which will arise for the operators, savings are also taken into account as smaller amounts of refrigerants will be needed. Prices of refrigerants vary between €7.00 and €50.00 or more depending on the region and the type and amount of refrigerant. As a European average €25.00 is used for further calculation. It is roughly estimated that after the recovery of F-Gases, about 75% of the refrigerants will be recycled and about 25% of the refrigerants will be destroyed[11]. Economic savings will therefore only be calculated for the 75% which can be recycled.

[11] Westfalen AG, personal comment, 2008

The following table provides an overview of the costs and savings and the resulting estimated net costs for operators for each requirement of Art. 4(1) of the F-Gas Regulation.

| Requirement | Costs [k€] | Savings [k€] | Net costs [k€] |
|---|---|---|---|
| Recovery by certified personnel | 24,000 | 1,400 | 22,600 |
| Additional recovery of F-Gases | 1,200 | 1,100 | 100 |
| **Sum** | **~ 25,200** | **~ 2,500** | **~ 22,700** |

Table 29: Estimated costs for operators by applying Art. 4(1) of Regulation (EC) No 842/2006 to road vehicles

The total estimated net costs for operators of the systems in the relevant road transport sector would amount to ~ €23m if Art. 4(1) of Regulation (EC) No 842/2006 is applied.

Negative as well as positive economic and social impacts are expected for indirectly affected actors. Negative impacts are expected for producers and distributors of F-Gases due to a lower demand of refrigerants. However, these impacts are expected to be very low. Positive impacts are expected for training companies and certification bodies as well as service companies, as they would have to carry out the training, certification and the maintenance work respectively, as required in Art. 4(1) of Regulation (EC) No 842/2006. A positive impact is expected also for the recycling and destruction companies, which are often also the distributor or producer of F-Gases, due to an increasing amount of recovered F-Gases. Authorities would have to ensure the enforcement of Art. 4(1) of Regulation (EC) No 842/2006 and this would therefore entail increased effort.

In the following figure, an overview of the indirectly affected actors concerned, is provided, including the type of impact which is expected (- = negative impact, + = positive impacts, +/- = no impact).

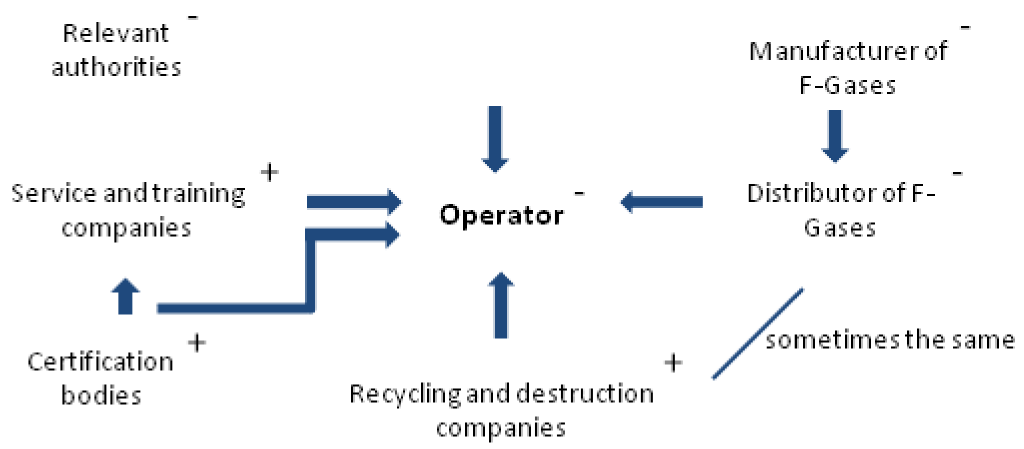


Figure 5: Relationship and type of impacts of indirectly affected actors by applying Art. 4(1) of Regulation (EC) No 842/2006 to the road sector

Based on the relationships in the figure above, it is assumed that certification, recovery, service and training activities will generate roughly 300 jobs in Europe while no significant losses of jobs (<10) are expected at the producers and distributors of F-Gases as a consequence of option 2.

The following ratios have been assumed for the calculation.

€80,000/year difference in turnover ≙ 1 job at service providers

€200,000/year difference in turnover ≙ 1job at equipment suppliers

€500,000/year difference in turnover ≙ 1job at F-Gas producers

### *5.4.2 Rail sector*

*Environmental impacts*

Recovery of F-Gases at end of life and recovery of F-Gases during service and maintenance which has to be carried out by certified personnel when applying option 3, concerns all systems independent of the amount of F-Gases contained.

According to expert information from concerned stakeholders, recovery could be improved to between 90 and nearly 100% by applying the requirements of Art. 4(1) of Regulation (EC) No 842/2006 throughout the EU. It is therefore estimated that emissions at end of life could be further reduced by approximately 50% (from 9.5 % to 5%). Emissions which occur during maintenance could also be decreased by 50% according to received expert information.

Based on these assumptions, the following reduction could be derived in the year 2020 compared to the baseline (option 1) at end of life and during maintenance or servicing:

| Requirement | Emission reduction factor | Emission reduction (kg F-Gas) | Emission reduction (kt $CO_2$) |
|---|---|---|---|
| Recovery by certified personnel | 0.5 | 9,000 | 12 |
| Additional recovery of F-Gases | 0.5 | 1,500 | 2 |
| **Sum** | | **~ 10,400** | **~ 14** |

Table 30: Estimated emission reduction factors and resulting emission reduction in 2020 by applying Art. 4(1) of Regulation (EC) No 842/2006 to rail vehicles

The estimated total F-Gases emitted in 2020 (baseline scenario) could be decreased by about 14 kt $CO_2$ eq. in 2020 by applying Art. 4(1) of Regulation (EC) No 842/2006 to rail vehicles. This represents a reduction of 8% of total emissions predicted in 2020 and more specifically of 50% as regards emissions at end of life and within recovery during maintenance or servicing in 2020 under the baseline scenario. Thereof 84% would be achieved from railway vehicles, 7% from metros and 9% from trams.

*Economic and social impacts*

As the requirements in Art. 4(1) would directly affect the operator in the first place, the economic impacts for operators of air-conditioning systems fitted to rail vehicles have been estimated.

Based on received questionnaires and expert information, the following additional costs are assumed:

- Costs for recovery per kg F-Gas refrigerant: €20.00
- Additional costs if the recovery is carried out by certified personnel: €20.00/system

Further to the costs which will arise for the operators, savings have also been taken into account because smaller amounts of refrigerants will be needed. Prices of refrigerants vary between €7.00 and €50.00 or more, depending on the region and the type and amount of refrigerant. As a European average €25.00 is used for further calculation. It is roughly estimated that after the recovery of F-Gases about 75% of the refrigerants will be recycled and about 25% of the refrigerants will be destroyed[11]. Therefore, the economic savings will only be calculated for the 75% which can be recycled.

The following table provides an overview of the costs and savings and the resulting estimated net costs for each requirement of Art. 4(1) of the F-Gas Regulation.

| Requirement | Costs [k€] | Savings [k€] | Net costs [k€] |
|---|---|---|---|
| Recovery by certified personnel | 3,300 | 225 | 3,100 |
| Additional recovery of F-Gases | 30 | 27 | 3 |
| **Sum** | **~ 3,330** | **~ 252** | **~ 3,100** |

Table 31: Estimated costs for operators by applying Art. 4(1) of Regulation (EC) No 842/2006 to rail vehicles

The total estimated net costs for the operators of air conditioning systems fitted to rail vehicles would amount to ~ €3m if Art. 4(1) of Regulation (EC) No 842/2006 is applied.

Negative as well as positive economic and social impacts are expected for indirectly affected actors. Slightly negative impacts are expected for producers and distributors of F-Gases due to a lower demand for refrigerants (statement of a distributor). Positive impacts are expected for training companies and certification bodies as well as service companies, as they would have to carry out the training, certification and the maintenance work respectively as required by Art. 4(1) of Regulation (EC) No 842/2006..A positive impact is expected for recycling and destruction companies – which are often the distributor or producer of F-Gases – due to an increasing amount of recovered F-Gases. Authorities would have to ensure the enforcement of Art. 4(1) of Regulation (EC) No 842/2006 and this would therefore entail increased efforts.

In the following figure, an overview of the indirectly affected actors concerned is provided, including the type of impact that is expected (- = negative impact, + = positive impacts, +/- = no impact).

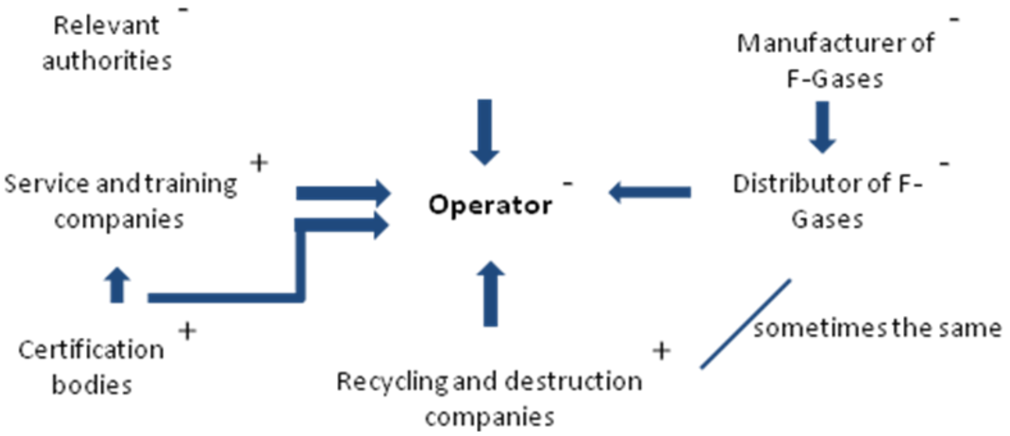


Figure 6: Relationship and type of impacts of indirectly affected actors by applying Art. 4(1) of Regulation (EC) No 842/2006 to the rail sector

Based on the relationships in the figure above, it is estimated that certification, recovery, service and training activities will generate less than 50 jobs in Europe while no significant losses of jobs (<5) are expected at the producers and distributors of F-Gases as a consequence of option 2.

The following ratios have been assumed for the calculation:

€80,000/year difference in turnover ≙ 1 job at service providers

€200,000/year difference in turnover ≙ 1job at equipment suppliers

€500,000/year difference in turnover ≙ 1job at F-Gas producers

### *5.4.3 Maritime and inland waterway sector*

*Environmental impacts*

Recovery of F-Gases at end of life and recovery of F-Gases during service and maintenance which has to be carried out by certified personnel when applying option 3, concerns all systems independent of the amount of F-Gases contained.

It is estimated that recovery could be improved to between 90 and nearly 100% due to Art. 4(1) of Regulation (EC) No 842/2006 as average in the EU. It is therefore estimated that emissions at end of life could be further reduced by 50% (from nearly 20% to 10%). Based on information from various experts, emissions which occur during maintenance can also be expected to decrease by 50%

Using these assumptions, the following annual reduction can be derived at end of life and during maintenance or servicing:

| Requirement | Emission reduction factor | Emission reduction potential [kg F-Gas] | | | | Emission reduction [kg F-Gas] | Emission reduction [kt $CO_2$ eq.] |
|---|---|---|---|---|---|---|---|
| | | Sea-going merchant ships | Ships for refrigerated cargo | Inland navigation vessels | Fishing vessels | All types | All types |
| Recovery by certified personnel | 0.5 | 11,400 | 400 | 1,800 | 2,600 | 16,200 | 33 |
| Additional recovery of F-Gases | 0.5 | 5,500 | 200 | 800 | 1,200 | 7,700 | 16 |
| **Sum** | | **~ 16,900** | **600** | **~ 2,600** | **~ 3,800** | **~ 23,900** | **~ 49** |

Table 32: Estimated emission reduction factors and resulting emission reductions in 2020 by applying Art. 4(1) of Regulation (EC) No 842/2006 to ships

The total estimated F-Gases emitted in 2020 (baseline scenario) could be decreased by about 49 kt $CO_2$ eq. in 2020 by applying Art. 4(1) of Regulation (EC) No 842/2006 to the maritime and inland waterway sector. This represents a reduction of 4% of total emissions predicted in 2020 and more specifically of 50% as regards emissions at end of life and within recovery during maintenance or servicing in 2020 under the baseline scenario. Thereof 61% would be achieved from sea-going merchant ships, 4% from ships for refrigerated cargo, 10% from inland navigation vessels and 25% from fishing vessels.

*Economic and social impacts*

As the requirements in Art. 4(1) directly affect the operator as a first step, the economic impacts for operators of air-conditioning systems fitted to relevant ships are estimated.

Based on received questionnaires and expert information, the following additional costs are assumed:

- Costs for recovery per kg: €20.00
- Additional costs if the recovery will be carried out be certified personnel: €20.00/system

Further to the costs which will arise for operators, savings have also been taken into account because smaller amounts of refrigerants will be needed. Prices of refrigerants vary between €7.00 and €50.00 or more, depending on the region and the type and amount of refrigerant. As a European average, €25.00 is used for further calculation. It is roughly estimated that after the recovery of F-Gases about 75% of the refrigerants will be recycled and about 25% of the refrigerants will be destroyed[11]. Therefore, economic savings will only be calculated for the 75% which can be recycled.

The following table provides an overview of the costs and savings and the resulting estimated net costs for each requirement of Art. 4(1) of the F-Gas Regulation.

| Requirement | Costs [k€] | Savings [k€] | Net costs [k€] | Costs [k€] | Savings [k€] | Net costs [k€] | Costs [k€] | Savings [k€] | Net costs [k€] | Costs [k€] | Savings [k€] | Net costs [k€] | Total costs [k€] | Total savings [k€] | Total net costs [k€] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Sea-going merchant ships | | | Ships for refrigerated cargo | | | Inland navigation vessels | | | Fishing vessels | | | All types | | |
| Recovery by certified personnel | 320 | 290 | 30 | 1 | 16 | -15 | 210 | 45 | 165 | 65 | 64 | 1 | 600 | 410 | 190 |
| Additional recovery of F-Gases | 110 | 100 | 10 | 4 | 4 | 0 | 20 | 15 | 5 | 25 | 23 | 2 | 160 | 150 | 10 |
| **Sum** | **~ 430** | **~ 390** | **~ 40** | **5** | **20** | **-15** | **~ 230** | **~ 60** | **~ 170** | **~ 90** | **~ 87** | **~ 3** | **~ 760** | **~ 550** | **200** |

Table 33: Estimated costs for operators by applying Art. 4(1) of Regulation (EC) No 842/2006 to relevant ships

The total estimated net costs for the operators of air conditioning systems and refrigeration systems fitted to relevant ships would amount to ~ €0.2m if Art. 4 of Regulation (EC) No 842/2006 is applied to the maritime and inland waterway sector.

Negative as well as positive economic and social impacts are expected for indirectly affected actors. low negative impacts are expected for producers and distributors of F-Gases due to a lower demand for refrigerants. positive impacts are expected for training companies and certification bodies as well as service companies, since they would have to carry out the training, certification and the maintenance work respectively as required by Art. 4(1) of Regulation (EC) No 842/2006. A positive impact is also expected for recycling and destruction companies – which are often also the distributor or producer of F-Gases – due to an increasing amount of recovered F-Gases. Authorities would have to ensure the enforcement of Art. 4(1) of Regulation (EC) No 842/2006 and this would therefore entail increased efforts.

In the following figure, an overview of the indirectly affected actors concerned, is provided, including the type of impact which is expected (- = negative impact, + = positive impacts, +/- = no impact).

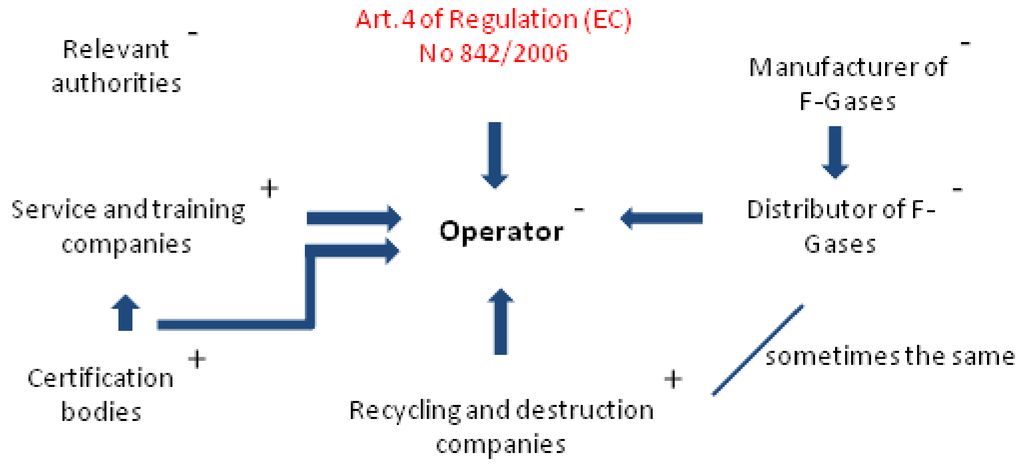


Figure 7: Relationship and type of impacts of indirectly affected actors by applying Art. 4(1) of Regulation (EC) No 842/2006 to the maritime and inland waterway sector

Based on the relationships in the figure above, it is estimated that certification, recovery, service and training activities as well as the activities of producers and distributors of F-Gases have no impact on jobs by applying option 3.

The following ratios have been assumed for the calculation:

€80,000/year difference in turnover ≙ 1 job at service providers

€200,000/year difference in turnover ≙ 1job at equipment suppliers

€500,000/year difference in turnover ≙ 1job at F-Gas producers

## 5.5 Option 4

### 5.5.1 Road sector

*Environmental impacts*

By applying both Art. 3 (option 2) and Art. 4(1) (option 3) to the road sector, it is expected that the environmental impacts from both options would be aggregated.

With this assumption the following emission reduction could be derived:

| Requirement | Emission reduction factor | Emission reduction (kg F-Gas) | Emission reduction (kt $CO_2$) |
|---|---|---|---|
| Prevent and repair leakage as soon as possible | 0.15 / 0.2* | 102,900 | 298 |
| Annual leakage inspection | 0.25 | 68,800 | 222 |
| Installation of leakage detection system | 0 | 0 | 0 |
| Record keeping | 0.05 | 13,800 | 44 |
| Recovery by certified personnel during service and maintenance | 0.74 | 57,300 | 172 |
| Recovery by certified personnel at end of life | 0.66 | 60,300 | 177 |
| **Sum** | | **~ 303,100** | **~ 914** |

Table 34: Estimated emission reduction factor and resulting emission reduction in 2020 by applying Art. 3 and Art. 4(1) of Regulation (EC) No 842/2006 to road vehicles

The total F-Gases calculated within the baseline scenario emitted in 2020 could be reduced by around 914 kt $CO_2$ eq. by applying Art. 3 and Art. 4(1) of Regulation (EC) No 842/2006 to relevant road vehicles. This represents 41% of total emissions predicted in 2020 under the baseline scenario. Thereof 34% would be achieved from vans, 25% from trucks and 41% from trailers.

*Economic and social impacts*

As the requirements in Art. 3 and 4(1) would directly affect the operator in the first place, the economic impacts for operators of refrigeration systems fitted to road vehicles have been estimated.

It is expected that by applying both Art. 3 (option 2) and Art. 4(1) (option 3), synergies would be achieved, e.g. cost of certification, thus the estimated costs of option 4 would be less than the aggregated costs of applying options 2 and 3. Therefore, it is expected that the total costs for option 4 could be decreased by the costs which will be needed in option 3 to let the recovery be carried out by certified personnel instead of qualified personnel.

Against this assumption, the following costs and savings are expected by applying both Art. 3 and Art. 4(1) to the concerned road sector:

| Requirement | Costs [k€] | Savings [k€] | Net costs [k€] |
|---|---|---|---|
| Prevent and repair leakage as soon as possible | 60,800 | 2,600 | 58,200 |
| Annual leakage inspection | 43,100 | 1,700 | 41,400 |
| Installation of leakage detection system | 0 | 0 | 0 |
| Record keeping | 11,200 | 300 | 10,900 |
| Additional recovery of F-Gases | 1,200 | 2,500* | -1,300 |
| **Sum** | **~ 116,400** | **~ 7,200** | **~ 109,200** |

*including the savings from recovery during maintenance or servicing

Table 35: Estimated costs for operators by applying Art. 3 and Art. 4 of Regulation (EC) No 842/2006 to relevant road vehicles

The total estimated net costs for operators of the systems in the relevant road transport sector would amount to ~ €109m if Art. 3 and Art. 4(1) of Regulation (EC) No 842/2006 is applied.

Negative as well as positive economic and social impacts are expected for indirectly affected actors. Negative impacts are expected for producers and distributors of F-Gases due to a lower demand of refrigerants. However, this impact is expected to be low. No impacts, or slightly positive impacts are expected for manufacturers of air conditioning and refrigeration systems. Positive impacts are expected for training companies and certification bodies as well as service companies because they would have to carry out the training, certification and the maintenance work respectively, as required by Art. 3 and Art. 4(1) of Regulation (EC) No 842/2006. A positive impact is also expected for the recycling and destruction companies – which are often also the distributors or producers of F-Gases – due to an increasing amount of recovered F-Gases. Authorities would have to ensure the enforcement of Art. 3 and Art. 4(1) of Regulation (EC) No 842/2006 and this would therefore entail increased efforts.

In the following figure, an overview of the concerned indirectly affected actors is provided, including the type of impact which is expected (- = negative impact, + = positive impacts, +/- = no impact).

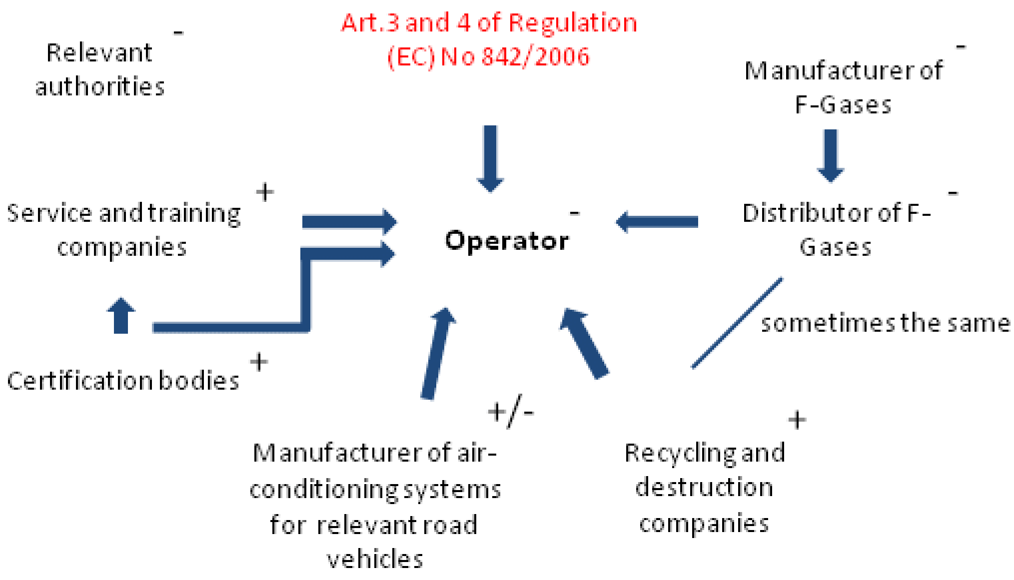


Figure 8: Relationship and type of impacts of indirectly affected actors by applying Art. 3 and Art. 4(1) of Regulation (EC) No 842/2006 to the concerned road sector

Based on the relationships in the figure above it is estimated that certification, recovery, service and training activities will generate roughly 1,400 jobs in Europe, while no significant losses of jobs (<20) are expected at the producers and distributors of F-Gases as a consequence of option 2.

The following ratios have been assumed for the calculation:

€80,000/year difference in turnover ≙ 1 job at service providers

€200,000/year difference in turnover ≙ 1job at equipment suppliers

€500,000/year difference in turnover ≙ 1job at F-Gas producers

### 5.5.2 *Rail sector*

*Environmental impacts*

By applying both Art. 3 (option 2) and Art. 4(1) (option 3) to the rail sector it is expected that the environmental impacts from both options would be aggregated.

With this assumption, the following emission reduction could be derived:

| Requirement | Emission reduction factor | Emission reduction (kg F-Gas) | Emission reduction (kt $CO_2$) |
|---|---|---|---|
| Prevent and repair leakage as soon as possible | 0.05/0.03* | 3,200 | 4.2 |
| Annual leakage inspection | 0.06 | 5,800 | 7.8 |
| Installation of leakage detection system | 0 | 0 | 0 |
| Record keeping | 0.01 | 1,000 | 1.3 |
| Recovery by certified personnel | 0.5 | 9,000 | 12 |
| Additional recovery of F-Gases | 0.5 | 1,500 | 2.0 |
| **Sum** | | **~ 20,400** | **~ 28** |

Table 36: Estimated emission reduction factor and resulting emission reduction in 2020 by applying Art. 3 and Art. 4(1) of Regulation (EC) No 842/2006 to rail vehicles

The total F-Gases emitted in 2020 (baseline scenario) are estimated to decrease by about 28 kt $CO_2$ eq. in 2020 by applying Art. 3 and Art. 4(1) of Regulation (EC) No 842/2006 to rail vehicles. This represents a reduction of 17% of total emissions predicted in 2020 under the baseline scenario. Thereof 85% would be achieved from railway vehicles, 7% from metros and 8% from trams.

*Economic and social impacts*

As the requirements in Art. 3 and 4(1) would directly affect the operator in the first place, the economic impacts for operators of refrigeration systems fitted to rail vehicles have been estimated.

It is expected that by applying both Art. 3 (option 2) and Art. 4(1) (option 3) synergies would be achieved, e.g. cost of certification, thus the cost of option 4 would be less than the aggregated cost of applying option 2 and 3. It is therefore expected that the total costs for option 4 could be decreased by the costs which will be needed in option 3 to have the recovery carried out by certified personnel instead of qualified personnel.

Against this assumption, the following costs and savings are expected by applying both Art. 3 and Art. 4(1) to the concerned rail sector:

| Requirement | Costs [k€] | Savings [k€] | Net costs [k€] |
|---|---|---|---|
| Prevent and repair leakage as soon as possible | 12,300 | 79 | ~ 12,200 |
| Annual leakage inspection | 24,100 | 145 | ~ 24,000 |
| Installation of leakage detection system | 0 | 0 | 0 |
| Record keeping | 3,600 | 24 | ~ 3,600 |
| Additional recovery of F-Gases | ~ 30 | ~ 252* | ~ -222 |
| **Sum** | **~ 40,000** | **~ 500** | **~ 39,500** |

*including the savings from recovery during maintenance or servicing

Table 37: Estimated costs for operators by applying Art. 3 and Art. 4(1) of Regulation (EC) No 842/2006 to rail vehicles

The total estimated net costs for the operators of air conditioning systems fitted to rail vehicles if Art. 3 and Art. 4(1) of Regulation (EC) No 842/2006 is applied would amount to ~ €40m.

Negative as well as positive economic and social impacts are expected for indirectly affected actors. Minor negative impacts are expected for producers and distributors of F-Gases due to the lower demand for refrigerants. No impact or slightly positive impacts are expected for manufacturers of air conditioning and refrigeration systems., Positive impacts are expected for training companies and certification bodies as well as service companies, as they would have to carry out the training, certification and the maintenance work respectively as required by Art. 3 and Art. 4(1) of Regulation (EC) No 842/2006. A positive impact is also expected for the recycling and destruction companies – which often also act as the distributor or producer of F-Gases – due to an increasing amount of recovered F-Gases. Authorities would have to ensure the enforcement of Art. 3 and Art. 4(1) of Regulation (EC) No 842/2006 and this would therefore entail increased efforts.

In the following figure an overview of the concerned indirectly affected actors is provided including the type of impact which is expected (- = negative impact, + = positive impacts, +/- = no impact).

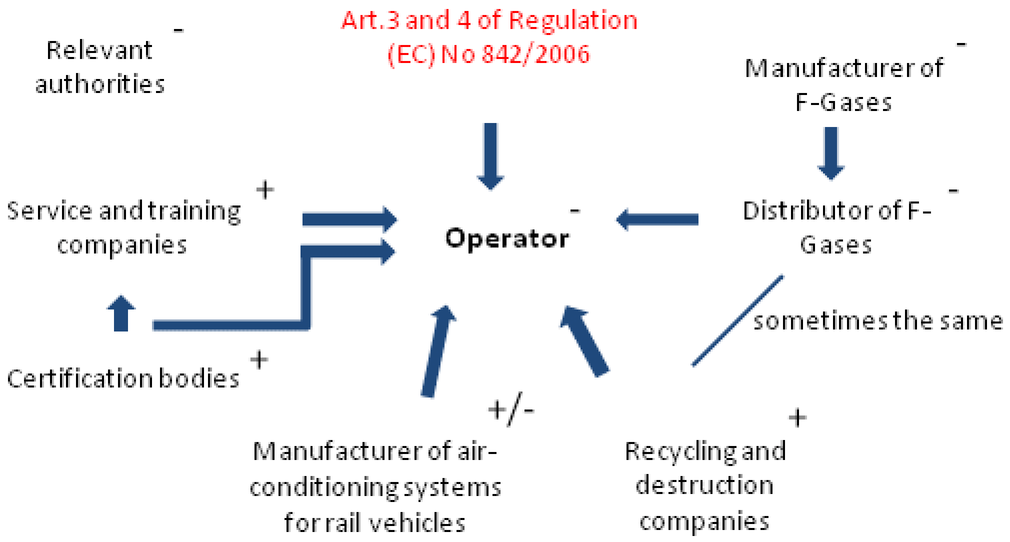


Figure 9: Relationship and type of impacts of indirectly affected actors by applying Art. 3 and Art. 4(1) of Regulation (EC) No 842/2006 to the rail sector

Based on the relationships in the figure above, it is estimated that certification, recovery, service and training activities will generate roughly 500 jobs in Europe while no significant losses of jobs (<5) are expected for the producers and distributors of F-Gases as a consequence of option 2.

The following ratios have been assumed for the calculation:

€80,000/year difference in turnover ≙ 1 job at service providers

€200,000/year difference in turnover ≙ 1job at equipment suppliers

€500,000/year difference in turnover ≙ 1job at F-Gas producers

### *5.5.3 Maritime and inland waterway sector*

*Environmental impacts*

By applying both Art. 3 (option 2) and Art. 4(1) (option 3) to the Maritime and inland waterway sector, it is expected that the environmental impacts from both options would be aggregated.

With this assumption, the following emission reduction could be derived:

| Requirement | Emission reduction [kg F-Gas] | | | | Emission reduction [kg F-Gas] | Emission reduction [kt $CO_2$ eq.] |
|---|---|---|---|---|---|---|
| | Sea-going merchant ships | Ships for refrigerated cargo | Inland navigation vessels | Fishing vessels | All types | All types |
| Prevent and repair leakage as soon as possible | 67,600 | 900 | 2,900 | 13,100 | 84,400 | 168 |
| Annual leakage inspection | 152,200 | 3,900 | 10,000 | 47,100 | 213,200 | 452 |
| Installation of leakage detection system | 27,300 | 1,700 | 0 | 17,800 | 46,800 | 112 |
| Record keeping | 9,300 | 300 | 700 | 4,100 | 14,500 | 32 |
| Recovery by certified personnel | 11,400 | 400 | 1,800 | 2,600 | 16,200 | 33 |
| Additional recovery of F-Gases | 5,500 | 200 | 800 | 1,200 | 7,700 | 16 |
| **Sum** | **~ 273,300** | **~ 7,400** | **~ 16,100** | **~ 85,900** | **~ 382,700** | **~ 813** |

Table 38: Estimated emission reduction factors and resulting emission reduction in 2020 by applying Art. 3 and Art. 4(1) of Regulation (EC) No 842/2006 to ships

The total estimated F-Gases emitted in 2020 (baseline scenario) could be reduced by about 813 kt of $CO_2$ eq. in 2020 by applying Art. 3 and Art. 4(1) of Regulation (EC) No 842/2006 to the maritime and inland waterway sector. This represents a reduction of 41% of total emissions predicted in 2020 under the baseline scenario.

*Economic and social impacts*

As the requirements in Art. 3 and 4(1) would directly affect the operator in the first place, the economic impacts for operators of refrigeration systems fitted to ships have been estimated.

It is expected that by applying both Art. 3 (option 2) and Art. 4(1) (option 3) synergies would be achieved e.g. cost of certification, thus the cost of option 4 would be less than the aggregated cost of applying option 2 and 3. It is therefore expected that the total costs for option 4 could be decreased by the costs which will be needed in option 3 to have the recovery carried out by certified personnel instead of qualified personnel.

Against this assumption, the following costs and savings are expected by applying both Art. 3 and Art. 4(1) to the concerned maritime and inland waterway sector:

| Requirement | Total costs [k€] | Total savings [k€] | Total net costs [k€] |
|---|---|---|---|
| Prevent and repair leakage as soon as possible | 6,000 | 2,100 | 3,900 |
| Annual leakage inspection | 17,500 | 5,300 | 12,200 |
| Installation of leakage detection systems | 1,600 | 1,200 | 400 |
| Record keeping | 1,900 | 400 | 1,500 |
| Additional recovery of F-Gases | 160 | 560* | -400 |
| **Sum** | **~ 27,100** | **~ 9,500** | **~ 17,600** |

*including the savings from recovery during maintenance or servicing

Table 39: Estimated costs for operators by applying Art. 3 and Art. 4(1) of Regulation (EC) No 842/2006 to relevant ships

The total estimated net costs for the operators of air conditioning systems and refrigeration systems fitted to relevant ships if Art. 3 and Art. 4(1) of Regulation (EC) No 842/2006 is applied to the maritime and inland waterway sector would amount to ~ €18m.

Negative as well as positive economic and social impacts are expected for indirectly affected actors. Negative impacts are expected for producers and distributors of F-Gases due to the lower demand for refrigerants. no impact or slightly positive impacts are expected for manufacturers of air conditioning and refrigeration systems. Positive impacts are expected for training companies and certification bodies as well as service companies, as they would have to carry out the training, certification and the maintenance work respectively as required by Art. 3 and Art. 4(1) of Regulation (EC) No 842/2006. A positive impact is also expected for the recycling and destruction companies – which are often also the distributor or producer of F-Gases – due to an increasing amount of recovered F-Gases. Authorities would have to ensure the enforcement of Art. 3 and Art. 4(1) of Regulation (EC) No 842/2006 and this would therefore entail increased efforts.

In the following figure, an overview of the concerned indirectly affected actors is provided, including the type of impact which is expected (- = negative impact, + = positive impacts, +/- = no impact).

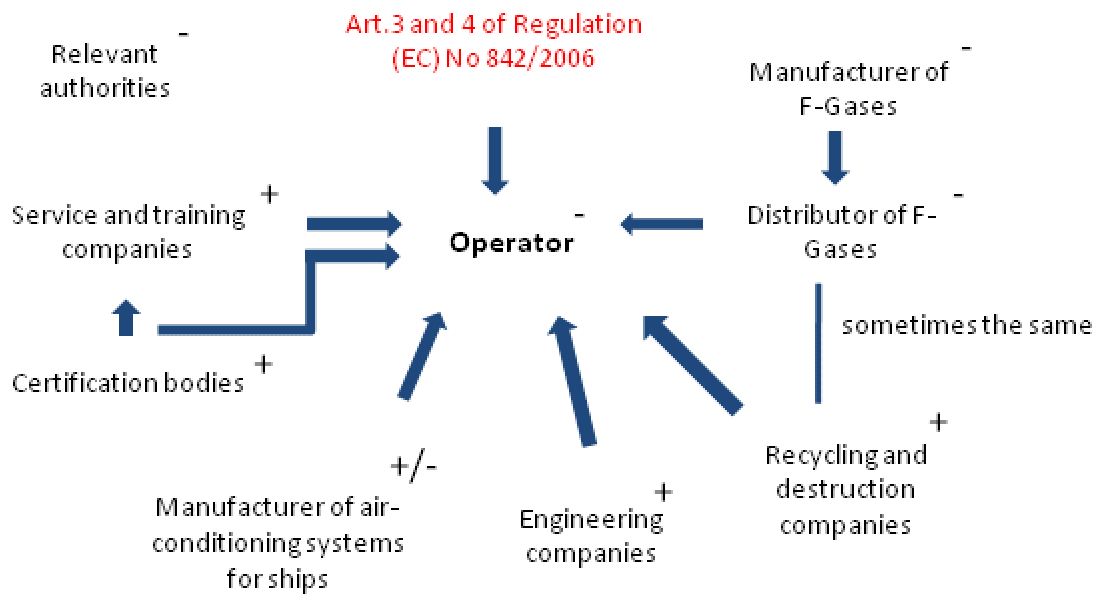


Figure 10: Relationship and type of impacts of indirectly affected actors by applying Art. 3 and Art. 4(1) of Regulation (EC) No 842/2006 to the maritime and inland waterway sector

Based on the relationships in the figure above, it is estimated that certification, recovery, service and training activities will generate roughly 200 jobs in Europe while no significant losses of jobs (<20) are expected for producers and distributors of F-Gases as a consequence of option 2.

The following ratios have been assumed for the calculation:

€80,000/year difference in turnover ≙ 1 job at service providers

€200,000/year difference in turnover ≙ 1job at equipment suppliers

€500,000/year difference in turnover ≙ 1job at F-Gas producers

## 5.6 Sensitivity analysis

### *5.6.1 Time of enforcement*

For the impact assessment, enforcement of the proposed amendments in the regulation was considered to start in 2010.

However, following analysis, the potential emission reduction for the year 2020 would not change significantly if the measures were to be enforced in 2013.

Nevertheless, enforcement by 2010 seems to be too early for some Member States. The Austrian Federal Economic Chamber stated that the foreseen enforcement in 2010 would be too early because much preparatory work needs to be done in order to implement the amended regulation. It is indicated in the questionnaires received from Member States that an enforcement of the new amendment would take about two years. It therefore seems recommendable to enforce the amendments in 2013.

In addition, the Commission could consider those options in the light of the comprehensive review of the Regulation due by 2011 on the basis of Article 10(2).

### *5.6.2 Recovery rate (in the road sector)*

The recovery rate for F-Gases of refrigeration systems in the road sector at end of life and during maintenance or servicing varies widely across EU-Member States.

The emission rates at end of life vary from 0% to nearly 100%. After an evaluation of the received data, a recovery rate of 70% seems to be a good estimation of the average for EU-27. However, uncertainty is still expressed by some stakeholders. A sensitivity analysis was therefore carried out, assuming on the one hand that the recovery rate is on average about 80% and on the other hand that approximately 60% of the F-Gases are currently recovered from the refrigeration systems for further treatment.

The emission rates during maintenance or servicing are within an interval of 0.5 and 1% annually in most Member States and increase to max 6% annually in some Member States (such as Bulgaria, Romania). After an evaluation of the received data, an annual recovery rate of 98% seems to be a good estimation of the average for EU-27. In the sensitivity analysis, an upper recovery rate of 99% during maintenance or servicing, combined with a recovery rate of 80% at end of life as well as a lower recovery rate of 97% during maintenance or servicing, combined with a recovery rate of 60% at end of life is investigated.

If the current recovery rate at end of life and during maintenance or servicing is higher, the emission reduction potential would decrease significantly and the additional net costs for operators would also decrease, but to a lower percentage. This results in higher abatement costs per tonne of $CO_2$. If the recovery rate at end of life and during maintenance or servicing is assumed to be lower, the emission reduction potential will increase significantly. The additional costs for operators will also increase, but to a lower percentage. The abatement costs would be significantly lower (see Table 40).

| Recovery rate | Emission 2007 End of life $CO_2$ eq. [kt] | Emission 2020 End of life $CO_2$ eq. [kt] | Emission reduction potential end of life $CO_2$ eq. [kt] | Additional net costs for operators [€m] | Cost/tonne $CO_2$ reduction End of life [€/tonne] | Cost/tonne $CO_2$ reduction total [€/tonne] |
|---|---|---|---|---|---|---|
| Upper boundary limit (80% / 99%) | 304 | 295 | 147 | 24 | 160 | 155 |
| Status quo (70% / 98%) | 519 | 500 | 349 | 23 | 65 | 119 |
| Lower boundary limit (60% / 97%) | 734 | 706 | 557 | 22 | 39 | 96 |

Table 40: Range of abatement costs by applying different recovery rates to refrigeration systems in the road sector (Option 4)

When considering the whole range from 60% recovery up to 80% recovery, the abatement costs per tonne of $CO_2$ eq. vary between €39.00 and €160.00/t as regards end of life emissions and between €96.00 and €155.00/t regarding total emissions.

### *5.6.3 Share of alternative refrigerants*

*Road sector*

Currently, only F-Gases are used as refrigerants in refrigeration systems in the road transport sector. Systems with alternative refrigerants with a low GWP such as $CO_2$ are still under development. It is nevertheless expected that under BAU in the next few years alternative refrigerants will enter the market. Apart from their low GWP, one of their advantages is the generally lower price in comparison with F-Gases. As regards the share of alternative refrigerants in 2020, varying estimations were expressed by stakeholders. These vary from still 0% in all vehicles up to 50% in new vehicles. An evaluation of the received data showed that a share of 15% of alternative refrigerants seems to be realistic. But there is still some uncertainty regarding the development in the near future. A sensitivity analysis has therefore been carried out assuming on the one hand that the percentage of refrigerants entering the market in 2020 is about 5% and on the other hand that the share of alternative refrigerants in refrigeration systems in the road sector amounts to about 25%. The latter will be more probable if new synthetic refrigerants with a low GPW enter the market within the next few years. According to expert interviews, such refrigerants are currently under research and development and could be available, after further testing, in the next 3-4 years.

If 5% of alternative refrigerants are in use in 2020, the emissions will rise to 2,474 kt $CO_2$ eq. and the emission reduction potential will increase to 1021 kt $CO_2$ eq. The abatement costs per tonne $CO_2$ eq. would not change because the costs for the operators will rise to the same extent as the emissions.

If the share of alternative refrigerants contained in refrigeration systems in the road sector increases to about 25%, the emissions as well as the emission reduction potential will be reduced (see Table 41).

| Percentage of alternative refrigerants in 2020 | Emissions total 2007 $CO_2$ eq. [kt] | Emissions total 2020 $CO_2$ eq. [kt] | Emission reduction potential $CO_2$ eq. [kt] | Additional net costs for operators [€m] | Cost/tonne $CO_2$ reduction [€/tonne] |
|---|---|---|---|---|---|
| Upper boundary limit 25% | 2537 | 1,953 | 806 | 96 | 119 |
| Used in assessment 15% | 2537 | 2,213 | 914 | 109 | 119 |
| Lower boundary limit 5% | 2537 | 2,474 | 1021 | 122 | 119 |

Table 41: Range of emissions and emission reduction potential by applying different percentages of alternative refrigerant in 2020 (Option 4)

The emissions in 2020 in the road sector vary between 1,953 kt $CO_2$ eq. and 2,474 kt $CO_2$ eq. resulting in an emission reduction potential between 806 and 1,021 kt $CO_2$ eq.. The abatement costs per kt $CO_2$ eq. will remain the same as in the main scenario.

*Rail sector*

At present, F-Gases are used almost exclusively as refrigerants in air-conditioning systems in railway vehicles. Some of the very first air-cycle systems have already been introduced and some prototypes have been developed for air systems operating with $CO_2$. Further increase in the number of $CO_2$-based air-conditioning systems is expected in the future. In 2020, about 15% of alternative refrigerants are estimated to be in use in the rail sector. One reason is that in air conditioning systems in the motor vehicle sector – in 2011 in all new vehicles and in 2017 in all vehicles – the use of HFC as a refrigerant with a GWP higher than 150 is prohibited according to Directive 2006/40/EC. If the technology for these air-conditioning systems is further developed, the experience could potentially also be used for the rail sector. There is still some uncertainty regarding their development in the near future. A sensitivity analysis has therefore been carried out for option 3 assuming on the one hand that the percentage of refrigerants which will enter the market in 2020 is low (10%), and on the other hand that the share of alternative refrigerants in air-conditioning systems in the rail sector amounts to 25%.

If a low percentage of alternative refrigerants is in use in 2020, the emissions will rise to 30 kt $CO_2$ eq. and the emission reduction potential will increase to 15 kt $CO_2$ eq. The abatement costs per tonne of $CO_2$ eq. would be the same because the costs for the operators will rise to the same extent as the emissions.

If the share of alternative refrigerants contained in refrigeration systems in the rail sector increases to about 20%, the emissions as well as the emission reduction potential will be reduced (see Table 41).

| Percentage of alternative refrigerants in 2020 | Emissions total 2007 $CO_2$ eq. [kt] | Emissions total 2020 $CO_2$ eq. [kt] | Emission reduction potential $CO_2$ eq. [kt] | Additional net costs for operators [€m] | Cost/tonne $CO_2$ reduction [€/tonne] |
|---|---|---|---|---|---|
| Upper boundary limit 20% | 20 | 27 | 13 | 2.9 | 215 |
| Used in assessment 15% | 20 | 28 | 14 | 3 | 215 |
| Lower boundary limit 10% | 20 | 30 | 15 | 3.2 | 215 |

Table 42: Range of emissions and emission reduction potential by applying different percentages of alternative refrigerant in 2020 (Option 3

The possible emissions in 2020 vary between 27 kt $CO_2$ eq. and 30 kt $CO_2$ eq. resulting in an emission reduction potential between 13 and 15 $CO_2$ eq. for the rail sector by applying option 3. As the emission reduction potential in total is very low in the rail sector, it does not seem to be of any major consequence whether the share of alternative refrigerants amounts to 10 or 20%.

### 5.6.4 *Reducing the limit value for leakage checks from 3 kg to 2 kg*

The majority of mobile road transport systems designed for cooling their loads are vans (<3.5t) which have refrigeration systems containing an average F-Gas charge of 2.3kg. Regular leakage checks and record keeping required under Art. 3 of the F-Gas Regulation are necessary for all equipment containing 3 or more kg of F-Gases. Therefore, all vans are *de facto* excluded from these requirements. France has already extended this limit to 2 kg in their national legislation to additionally include the main group of refrigerated road vehicles into the procedure of leakage checking and record keeping. The major part of the European refrigerated transport industry would support such an amendment to require refrigerated vans to have regular leakage checks and record keeping, and to have uniform requirements across Europe.

The impacts of reducing the limit value for leakage control and record keeping from 3 kg to 2 kg F-Gas charge are considered in this analysis. It is estimated that the emission reduction potential could be increased by about 45% (in the same range as trucks and trailers). In this case – instead of 565 kt $CO_2$ eq. – 771 kt co2 eq. could be saved annually during the operational period of road vehicles. The emission reduction potential increases from 914 kt $CO_2$ eq. to 1,120 kt $CO_2$ eq. if the end of life of the vehicles is also considered. The net costs for operators would increase €109m to €202m regarding entire emissions. The increased emission reduction potential and the increased costs would result in abatement costs of €181/kt $CO_2$ eq. respectively. These costs would be about 35% higher regarding operation emissions and 52% regarding all emissions.

| Limit value | Emission reduction potential $CO_2$ eq. [kt] | Additional net costs for operators [€m] | Cost/tonne $CO_2$ reduction [€/tonne] |
|---|---|---|---|
| 3 kg | 914 | 109 | 119 |
| 2 kg | 1120 | 202 | 181 |

Table 43: Emission reduction potential and costs/tonne by reducing the limit value for leakage checks from 3 kg to 2 kg in 2020 (Option 4)

## 5.7 Comparison of Options

Firstly, the environmental, economic and social impacts are considered separately in order to provide a comparison of options. In a second step, an overall evaluation is carried out.

The following two tables show the emissions in absolute figures in tonnes of F-Gases and kilotonnes of $CO_2$ equivalent as well as in relative figures for all options compared to the status quo.

| Sector | Status quo | Emission reduction option 1 | | Emission reduction option 2 | | Emission reduction option 3 | | Emission reduction option 4 | |
|---|---|---|---|---|---|---|---|---|---|
| | [t F-Gases] | [t F-Gases] | [%] | [t F-Gases] | [%] | [t F-Gases] | [%] | [t F-Gases] | [%] |
| **Road** | 875 | 752 | -14 | 567 | -35 | 634 | -28 | 449 | -49 |
| **Rail** | 82 | 123 | 50 | 110 | 34 | 114 | 39 | 101 | 49 |
| **Maritime and inland waterway** | 241 | 937 | 289 | 578 | 140 | 913 | 289 | 554 | 130 |
| **Sum** | **1,198** | **1,812** | | **1,255** | | **1,661** | | **1,104** | |

Table 44: Comparison of F-Gas emissions in different options

| Sector | Status quo | Emission reduction option 1 | | Emission reduction option 2 | | Emission reduction option 3 | | Emission reduction option 4 | |
|---|---|---|---|---|---|---|---|---|---|
| | [kt $CO_2$ eq.] | [kt $CO_2$ eq.] | [%] | [kt $CO_2$ eq.] | [%] | [kt $CO_2$ eq.] | [%] | [kt $CO_2$ eq.] | [%] |
| **Road** | 2,537 | 2,213 | -13 | 1,648 | -35 | 2,095 | -17 | 1,530 | -40 |
| **Rail** | 113 | 165 | 46 | 152 | 35 | 151 | 34 | 138 | 22 |
| **Maritime and inland waterway** | 376 | 1,994 | 430 | 1,230 | 227 | 1,945 | 417 | 1,181 | 214 |
| **Sum** | **3,026** | **4,372** | | **3,030** | | **4,191** | | **2,849** | |

Table 45: Comparison of $CO_2$, equivalent in different options

The tables show that, for the road sector, a reduction of emissions is expected to take place even under the baseline scenario (option 1), but the potential reduction is increased by 565 kt $CO_2$ eq. with option 2 and an additional 118 kt $CO_2$ eq. with option 3 when compared to option 1 (no action).

The picture is different for the rail and maritime and inland waterway sector. Here, an increase of emissions will take place under all options assessed. However, option 2, and to a lesser extent, option 3 could again reduce this increase.

It is difficult to generate similar tables for an economic analysis. The main reason is that there are various additional factors that influence future net costs for operators, irrespective of options 2 or 3. Energy costs are very significant and it is extremely difficult to achieve a reliable basis for 2020. Therefore, the economic analysis considers option 1 as a baseline and calculates additional costs and savings with reference to this baseline. The detailed analysis yielded the following results:

| Sector | Option 1 | Option 2 | Option 3 | Option 4 |
|---|---|---|---|---|
| | Baseline assumption for additional net costs | Relative to baseline | Relative to baseline | Relative to baseline |
| | | [€m/a] | [€m/a] | [€m/a] |
| **Road** | 0 | +111 | +23 | +109 |
| **Rail** | 0 | +40 | +3 | +40 |
| **Ship** | 0 | +18 | +0.2 | +18 |
| **Total** | 0 | +168 | +26 | +166 |

Table 46: Additional net costs of options

The table shows that additional net costs for option 3 are significantly lower than for option 2. If the additional net costs are compared to the environmental efforts, the following key figures can be derived:

Option 2

| Sector | Emission reduction potential $CO_2$ eq. [kt] | Additional net costs for operators [€m] | Cost/tonne $CO_2$ reduction [€/tonne] | Recommendation |
|---|---|---|---|---|
| **Road sector** | ~ 565 | ~ 111 | ~ 196 | -- |
| **Rail sector** | ~ 13 | ~ 39.7 | ~ 2,969 | -- |
| **Maritime and inland waterway sector*** | ~ 764 | ~ 18 | ~ 24 | -- |

*****In the maritime and inland waterway sector, the cost per tonne varies considerably depending on the type of ship. For motorised inland cargo vessels, the cost per tonne CO2 eq. is over €2,500. The reason for this is that the charges in the air-conditioning systems of motorised inland cargo vessels are very low (<5kg) and the emissions are relatively low (6%). In contrast to the very low emission reduction which can be achieved, the costs are relatively high, which results in very high abatement costs.

Table 47: Impacts and recommendation for option 2

Option 3

| Sector | Emission reduction potential $CO_2$ eq. [kt] | Additional net costs for operators [€m] | Cost/tonne $CO_2$ reduction [€/tonne] | Recommendation |
|---|---|---|---|---|
| **Road sector** | ~ 349 | ~ 23 | ~ 65 | -- |
| **Rail sector** | ~ 14 | ~ 3 | ~ 215 | Yes |
| **Maritime and inland waterway sector** | ~ 49 | ~ 0.2 | ~ 4 | -- |

Table 48: Impacts and recommendation for option 3

Option 4

| Sector | Emission reduction potential $CO_2$ eq. [kt] | Additional net costs for operators [€m] | Cost/tonne $CO_2$ reduction [€/tonne] | Recommendation |
|---|---|---|---|---|
| **Road sector** | ~ 914 | ~ 109 | ~ 119 | Yes |
| **Rail sector** | ~ 28 | ~ 40 | ~ 1,437 | -- |
| **Maritime and inland waterway sector** | ~ 813 | ~ 18 | ~ 22 | Yes |

Table 49: Impacts and recommendation for option 4

Comparison of options

| Sector | Option 2 [€/tonne] | Option 3 [€/tonne] | Option 4 [€/tonne] |
|---|---|---|---|
| **Road sector** | 196 | 65 | 119 |
| **Rail sector** | 2,969 | 215 | 1,437 |
| **Maritime and inland waterway sector** | 24 | 4 | 22 |

Table 50: Overview of impacts for options 2-4 in €/tonne

Option 3 offers lower costs per tonne of $CO_2$ reduction than option 2. In particular, the cost effectiveness of option 2 in the rail sector leads to a recommendation that this option should not be implemented for these vehicles. T Additional economic burdens for ship owners due to containment measures on F-Gases in refrigeration or air-conditioning systems in EU-flagged ships might generate some interest in reflagging, although there are doubts that this will occur in practice. One option to avoid reflagging is to link F-Gas Regulations to EU ports rather than only to the EU flagged fleet. Shipping is a global business and it would therefore be highly recommendable to discuss within the IMO possible activities which would then be valid for all ships on a global level. The combination of both options, which would achieve the most significant emission reduction, ranges between option 2 and option 3.

# 6 Conclusions and recommendations

*Road Sector*

The main criterion in deriving recommendations is the cost per tonne of $CO_2$ equivalent, which offers an opportunity to compare one measure with other potential measures to reduce greenhouse gas emissions. In addition, the full range of pros and cons related to impacts is taken into consideration. On the whole, a good indication of these various effects can be seen in stakeholders' reactions. This approach leads to the following conclusions and recommendations for the road sector:

By applying option 2 to the road sector, the additional costs per tonne of $CO_2$ equivalent seem to be comparatively high, while additional costs due to option 3 are significantly lower. Reactions of stakeholders as a result of the discussion of the results of this study show that they support both option 2 and 3 for the road sector. This combination is reflected in option 4 which is therefore recommended for this sector.

With this recommendation, $CO_2$ equivalent savings of 914 kt compared to business as usual can be expected for 2020 .

*Rail Sector*

Option 3 is recommended for the rail sector, since this measure is accepted by the industry sector against the background of reasonable cost/benefit ratios.

Option 2 would bring disproportional costs per tonne of $CO_2$ reduction and is therefore not recommended. This is also valid for option 4.

With the recommended option $CO_2$ equivalent savings of 14 kt can be expected for 2020 compared to business as usual.

*Maritime and inland waterway Sector*

Taking into consideration the low average costs of reducing a tonne of $CO_2$ emission of roughly €30-€80/t of $CO_2$ by various measures (such as replacing fossil energy by solar energy, etc.) it is recommendable to apply option 2 and 3 for the maritime and inland waterway sector (excluding inland motorised cargo vessels). Therefore, option 4 (which combines option 2 and 3) is recommended although this is not in line with the position communicated by the industry so far. Option 4 for refrigeration or air-conditioning systems in EU-flagged ships might generate some stimulation to reflagging the ships due to economic impacts for the ship owners, although there are doubts that this will show up in practice. One option to avoid the reflagging would be to link the requirements of the F-Gas Regulation to EU ports as well, rather than only to the EU-flagged fleet. Shipping is a global business and therefore it would be highly recommendable to discuss within the IMO possible activities which would then be valid for all ships on a global level.

With the recommended option $CO_2$ equivalent savings of 813 kt can be expected for 2020 compared to business as usual.

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# 7 Annex

## Questionnaire, maritime sector

**Questionnaire* on possible economic, social and environmental impacts related to the possible application of Art.3 and/or Art.4 of Regulation (EC) No 842/2006 on certain fluorinated greenhouse gases to air conditioning and refrigeration systems contained in different modes of transport**

**-maritime sector-**

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*This questionnaire was developed by BiPRO GmbH to facilitate collection of up-to-date data in the context of an in-depth study on the economic, social and environmental impacts related to the possible application of Art.3 and/or Art.4 of Regulation (EC) No 842/2006 on certain fluorinated greenhouse gases. It is not an official document from the European Commission.

**Introduction**

To undertake steps to fulfil its obligations under the Kyoto Protocol, the European Community adopted Regulation (EC) No 842/2006 on certain fluorinated greenhouse gases which entered into force on 4 July 2007 and aims at containing, preventing and reducing emissions of fluorinated greenhouse gases (F-Gases).

The Regulation addresses containment of F-Gases (Art.3), recovery for the purpose of recycling, reclamation or destruction of F-Gases (Art.4), training and certification of personnel (Art.5), reporting obligations for producers, importers and exporters (Art.6), labelling of specific products and equipment containing F-Gases (Art.7), bans and controls of certain uses of F-Gases (Art.8) and market prohibitions of F-Gases (Art.9).

The F-Gases which are covered by Regulation (EC) No 842/2006 can be divided in HFCs, PFCs and $SF_6$. For more detailed information please see Annex I, Part I of the Regulation.

Article 10(1) of the F-Gas Regulation entitles the European Commission to elaborate legislative proposals for applying the provisions of Art.3 also to air conditioning systems (other than those fitted to motor vehicles referred to in Directive 70/156/EEC) and refrigeration systems in modes of transport.

In this context the questionnaire aims at collecting up-to-date data of air conditioning systems (other than those fitted to motor vehicles referred to in Directive 70/156/EEC) and refrigeration systems in modes of transport regarding the possible application of Art.3 and additionally of Art.4 of the F-Gas Regulation.

The transport systems which are covered by this questionnaire are:

- sea going merchant ships
- ships for refrigerated cargo
- inland navigation vessels
- fishing vessels

The aim of the data collection is to carry out an impact assessment on possible economic, social and environmental impacts related to the possible application of Art.3 and/or Art.4 of Regulation (EC) No 842/2006 on certain fluorinated greenhouse gases to air conditioning systems, other than those fitted to motor vehicles referred to in Directive 70/156/EEC, and refrigeration systems contained in different modes of transport.

**How to use the questionnaire**

If your organisation covers more than one transport sector, please use a separate questionnaire for each sector.
Please use the fields marked in yellow for your answers.
When filling in the questionnaire please indicate the units you use and indicate prices in €.
Questions which are not relevant for your organisation do not need to be filled in.
Please do not hesitate to add new lines if you can provide more information.

**1) Contact details**

| | |
|---|---|
| Name of organisation | |
| Type of organisation | |
| Contact person | |
| Area of responsibility | |
| Address (including street, zip-code, city, country) | |
| Phone | |
| Fax | |
| E-mail | |
| URL | |

| | |
|---|---|
| **2) Type of transport sector** | please select |

If you have chosen the type "other", please specify the transport sector here:

**3) Potential application of containment provisions (Art.3 of Regulation (EC) No 842/2006) in modes of transport**

This section concerns the possible impacts of the possible application of Art.3 of the F-Gas Regulation to air conditioning systems, other than those fitted to motor vehicles referred to in Directive 70/156/EEC, and refrigeration systems contained in modes of transport

**Requirements of Art.3 of the F-Gas Regulation:**
- Prevention of any leakage (concerns all charges)
- Repairing of detected leakage as soon as possible (concerns all charges)
- Leakage checks by certified personnel (every 12 month for charges > 3 and < 30 kg) (this shall not apply to equipment with hermetically sealed systems, which are labelled as such and contain less than 6 kg of fluorinated greenhouse gasses)
(every 6 month for charges > 30 and < 300 kg)
(every 3 month for charges > 300 kg)
- Installation of leakage detection systems (concerns charges > 300 kg) (if a leakage detection system is in place, the frequency of checks for equipment containing charges > 30 kg shall be halved)
- Maintenance of records (concerns charges > 3 kg)

| | |
|---|---|
| How much do you estimate that a certification would annually cost per person? | |
| How much does one hour of own affected personnel of companies operating F-Gas containing equipment cost in average? | |

**To which percentage do you estimate that own personnel of companies operating F-Gas containing equipment will be certified for leakage control and maintenance? Please indicate the percentage for each group of enterprises (small enterprises, medium enterprises, large enterprises)?**

| | | | | | |
|---|---|---|---|---|---|
| small enterprises | | medium enterprises | | large enterprises | |

**Definition of enterprises**
small enterprises: headcount < 50, turnover ≤ € 10 million or balance sheet total ≤ € 10 million
medium enterprises: headcount < 250, turnover ≤ € 50 million or balance sheet total ≤ € 43 million
large enterprises: headcount > 250, turnover > € 50 million or balance sheet total > € 43 million

| | Answer | Average refrigerant charge quantity [kg] | Type of system | Provision type | Average ship type | | | Refrigeration/ air conditioning |
|---|---|---|---|---|---|---|---|---|
| | | | | | size | age | tonnage | |
| What is your estimate of leakage of F-Gases of an air conditioning/refrigeration system in mode of transport per system in % (annual refilling rate)? | | | please select | please select | | | | please select |
| | | | please select | please select | | | | please select |
| | | | please select | please select | | | | please select |
| | | | please select | please select | | | | please select |
| | | | please select | please select | | | | please select |
| Could you please indicated the main causes for the leakage? | please select | | please select | please select | | | | please select |
| | please select | | please select | please select | | | | please select |
| | please select | | please select | please select | | | | please select |
| | please select | | please select | please select | | | | please select |
| To which amount do you estimate that the emissions could be reduced per system in % due to Art. 3 of Regulation (EC) No 842/2006? | | | please select | please select | | | | please select |
| | | | please select | please select | | | | please select |
| | | | please select | please select | | | | please select |
| | | | please select | please select | | | | please select |
| How much do you estimate that the inspection for one leakage control per system would cost? | | please select | please select | please select | | | | please select |
| | | please select | please select | please select | | | | please select |
| | | please select | please select | please select | | | | please select |
| | | please select | please select | please select | | | | please select |
| How long do you estimate is the average duration of one leakage checking inspection by certified personnel per system? | | please select | please select | please select | | | | please select |
| | | please select | please select | please select | | | | please select |
| | | please select | please select | please select | | | | please select |
| | | please select | please select | please select | | | | please select |

Please use for each combination one line, if there is only one combination you only have to fill in one line, if there are more than four combinations, please add additional lines.

| | |
|---|---|
| Remarks: | |

### 4) Potential application of recovery provisions (Art.4 of Regulation (EC) No 842/2006) in modes of transport

This section concerns the possible impacts of the possible application of Art.4 of the F-Gas Regulation to air conditioning systems, other than those fitted to motor vehicles referred to in Directive 70/156/EEC, and refrigeration systems contained in modes of transport

**Requirements of Art.4 of the F-Gas Regulation:**
- Recovery by certified personnel before final disposal and, when appropriate, during ist servicing or maintenance, for the purpose of recycling, reclamation or destruction (all charges)

| What is your estimate of the costs for recovery per kg? | |
|---|---|

| | Answer | Average refrigerant charge quantity [kg] | Type of system | Refrigeration/ air conditioning |
|---|---|---|---|---|
| What is the percentage of the current recovery level of F-Gases at end of life (%)? | | | please select | please select |
| | | | please select | please select |
| | | | please select | please select |
| To which percentage do you estimate that the recovery at end of life could be increased due to Art.4 of Regulation (EC) No 842/2006? | | | please select | please select |
| | | | please select | please select |
| | | | please select | please select |
| Please give an estimation for the current emission level during recovery of F-Gases during maintenance and servicing (in %) | | please select | please select | please select |
| | | please select | please select | please select |
| | | please select | please select | please select |
| To which percentage do you estimate that the emission level during recovery during maintenance and servicing could be decreased due to Art.4 of Regulation (EC) No 842/2006 ? | | please select | please select | please select |
| | | please select | please select | please select |
| | | please select | please select | please select |
| Please give an estimation for the additional costs that would result if the recovery would be carried out by certified personnel (per system). | | please select | please select | please select |
| | | please select | please select | please select |
| | | please select | please select | please select |

Please use for each combination one line, if there is only one combination you only have to fill in one line, if there are more than three combinations, please add additional lines.

| Remarks: | |
|---|---|

### 5) Refrigerant types

Please fill in this table for refrigerants used in **air conditioning systems** in modes of transport

Please indicate for each refrigerant which is covered by your organisation the average quantities of refrigerant in the system, the types of systems in which it is contained and the share of the refrigerant in comparison to all refrigerants.
Please use for each combination a separate line!

| Name of refrigerant (F-Gas) | Average quantity of F-Gas (per system) [kg] | Type of system | Provision type | How big is the share of this refrigerant in comparison to all F-Gases used for the purpose of air conditioning [%]? | Further description of transport system (e.g. tuna seiner, freezer trawlers, etc) | Average ship type | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | size | age | tonnage |
| | | please select | | | | | | |
| | | please select | | | | | | |
| | | please select | | | | | | |
| | | please select | | | | | | |
| | | please select | | | | | | |

| Please estimate the percentage of air conditioning systems in the selected sector in your country that are filled with each of the following refrigerants: (please indicate your answer in %) | HCFC | |
|---|---|---|
| | HFC | |
| | alternative refrigerant | |

Please fill in this table for refrigerants used in **refrigeration systems** in modes of transport

Please indicate for each refrigerant which is covered by your organisation the average quantities of refrigerant in the system, the types of systems in which it is contained and the share of this refrigerant in comparison to all refrigerants.
Please use for each combination a separate line!

| Name of refrigerant (F-Gas) | Average quantity of F-Gas (per system) [kg] | Type of system | Provision type | How big is the share of this refrigerant in comparison to all F-Gases used for the purpose of refrigeration [%]? | Further description of transport system (e.g. tuna seiner, freezer trawlers, etc) | Average ship type | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | size | age | tonnage |
| | | please select | | | | | | |
| | | please select | | | | | | |
| | | please select | | | | | | |
| | | please select | | | | | | |
| | | please select | | | | | | |

| Please estimate the percentage of refrigeration systems in the selected sector in your country that are filled with each of the following refrigerants: (please indicate your answer in %) | | |
|---|---|---|
| | HCFC | |
| | HFC | |
| | alternative refrigerant | |

| Remarks: | |
|---|---|

## 6) Development of market

| | | |
|---|---|---|
| Would the application of Art.3 and/or Art.4 of Regulation (EC) No 842/2006 on mobile equipment in your opinion be an obstacle for the growth of the affected companies, new investments, etc.? If yes, please explain | Art. 3 | |
| | Art.4 | |
| Would the application of Art.3 and/or Art.4 of Regulation (EC) No 842/2006 on mobile equipment in your opinion have positive or negative impacts on employment? If yes, please explain | Art. 3 | |
| | Art.4 | |
| Would the application of Art.3 and/or Art.4 of Regulation (EC) No 842/2006 on mobile equipment in your opinion affect the competitiveness of the transport sector (in European/global context)? If yes, please explain | Art. 3 | |
| | Art.4 | |
| Which impacts do you expect related to technology development in the R&D sector due to the application of Art.3 and 4 of Regulation (EC) No 842/2006 on mobile equipment (e.g. development of recovery equipment, leakage detection systems)? | Art. 3 | |
| | Art.4 | |
| How could the application of Art.3 and/or Art.4 create new business opportunities and in which economic sectors? | Art. 3 | |
| | Art.4 | |
| Have you already conducted studies or stakeholder consultations in this field? If yes, we would be grateful if you could provide us with related documents. | | |

| How do you estimate the following trends in the selected transport sector over the next 12 years: | |
|---|---|
| Shift from F-Gases used for mobile refrigeration/air conditioning systems to alternative refrigerants: | |
| Reduction of refrigerant charge: | |
| Reduction of emissions due to better technology: | |
| Increase in transport systems: | |

| Remarks: | |
|---|---|

**7) Size and distribution of affected sectors**

**In which European Member States are organisations affected by Regulation (EC) No 842/2006 in the selected transport sector mainly represented?**

| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| AT | | BE | | CY | | CZ | | DK | | EE | | FI | | FR | | DE | | GR | | HU | | IE | | IT | | LV | | LT | | LU | | MT | | |
| PL | | PT | | SK | | SI | | ES | | SE | | NL | | UK | | BU | | RO | | | | | | | | | | | | | | | | |

**Please indicate a rough estimation of the share of affected enterprises by Regulation (EC) No 842/2006 in the selected transport sector. Please indicate the share in % and per MS (for which you have data) and, if possible, also for the EU.**

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| EU-27 | | small enterprises | | | medium enterprises | | large enterprises | |
| MS | | small enterprises | | | medium enterprises | | large enterprises | |
| MS | | small enterprises | | | medium enterprises | | large enterprises | |

**Remarks:**

**8) Data confidentiality**

| | |
|---|---|
| **Would you like the date you submitted to be treated confidentially (data will then be used in an aggregated form and not as single data in the report)?** | please select |

**9) Additional comments**

In case of any questions please contact:

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## Questionnaire, rail sector

**Questionnaire* on possible economic, social and environmental impacts related to the possible application of Art.3 and/or Art.4 of Regulation (EC) No 842/2006 on certain fluorinated greenhouse gases to air conditioning and refrigeration systems contained in different modes of transport**
**-rail sector-**

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*This questionnaire was developed by BiPRO GmbH to facilitate collection of up-to-date data in the context of an in-depth study on the economic, social and environmental impacts related to the possible application of Art.3 and/or Art.4 of Regulation (EC) No 842/2006 on certain fluorinated greenhouse gases. It is not an official document from the European Commission.

**Introduction**

To undertake steps to fulfil its obligations under the Kyoto Protocol, the European Community adopted Regulation (EC) No 842/2006 on certain fluorinated greenhouse gases which entered into force on 4 July 2007 and aims at containing, preventing and reducing emissions of fluorinated greenhouse gases (F-Gases).

The Regulation addresses containment of F-Gases (Art.3), recovery for the purpose of recycling, reclamation or destruction of F-Gases (Art.4), training and certification of personnel (Art.5), reporting obligations for producers, importers and exporters (Art.6), labelling of specific products and equipment containing F-Gases (Art.7), bans and controls of certain uses of F-Gases (Art.8) and market prohibitions of F-Gases (Art.9).

The F-Gases which are covered by Regulation (EC) No 842/2006 can be divided in HFCs, PFCs and $SF_6$. For more detailed information please see Annex I, Part I of the Regulation.

Article 10(1) of the F-Gas Regulation entitles the European Commission to elaborate legislative proposals for applying the provisions of Art.3 also to air conditioning systems, other than those fitted to motor vehicles referred to in Directive 70/156/EEC, and refrigeration systems in modes of transport.

In this context the questionnaire aims at collecting up-to-date data of air conditioning systems (other than those fitted to motor vehicles referred to in Directive 70/156/EEC) and refrigeration systems in modes of transport regarding the possible application of Art.3 and additionally of Art.4 of the F-Gas Regulation.

The transport systems which are covered by this questionnaire are:

- trains
- trams
- metros

The aim of the data collection is to carry out an impact assessment on possible economic, social and environmental impacts related to the possible application of Art.3 and/or Art.4 of Regulation (EC) No 842/2006 on certain fluorinated greenhouse gases to air conditioning systems, other than those fitted to motor vehicles referred to in Directive 70/156/EEC, and refrigeration systems contained in different modes of transport.

**How to use the questionnaire**

If your organisation covers more than one transport sector, please use a separate questionnaire for each sector.
Please use the fields marked in yellow for your answers.
When filling in the questionnaire please indicate the units you use and indicate prices in €.
Questions which are not relevant for your organisation do not need to be filled in.
Please do not hesitate to add new lines if you can provide more information.

**1) Contact details**

| | |
|---|---|
| Name of organisation | |
| Type of organisation | |
| Contact person | |
| Area of responsibility | |
| Address (including street, zip-code, city, country) | |
| Phone | |
| Fax | |
| E-mail | |
| URL | |

| | |
|---|---|
| **2) Type of transport sector** | please select |

**3) Potential application of containment provisions (Art.3 of Regulation (EC) No 842/2006) in modes of transport**

This section concerns the possible impacts of the possible application of Art.3 of the F-Gas Regulation to air conditioning systems, other than those fitted to motor vehicles referred to in Directive 70/156/EEC, and refrigeration systems contained in modes of transport

**Requirements of Art.3 of the F-Gas Regulation:**
- Prevention of any leakage (concerns all charges)
- Repairing of detected leakage as soon as possible (concerns all charges)
- Leakage checks by certified personnel (every 12 month for charges > 3 and < 30 kg) (this shall not apply to equipment with hermetically sealed systems, which are labelled as such and contain less than 6 kg of fluorinated greenhouse gasses)
  (every 6 month for charges > 30 and < 300 kg)
  (every 3 month for charges > 300 kg)
- Installation of leakage detection systems (concerns charges > 300 kg) (if a leakage detection system is in place, the frequency of checks for equipment containing charges > 30 kg shall be halved)
- Maintenance of records (concerns charges > 3 kg)

| | |
|---|---|
| How much do you estimate that a certification would annually cost per person? | |
| How much does one hour of own affected personnel of companies operating F-Gas containing equipment cost in average? | |

**To which percentage do you estimate that own personnel of companies operating F-Gas containing equipment will be certified for leakage control and maintenance? Please indicate the percentage for each group of enterprises (small enterprises, medium enterprises, large enterprises)?**

| | | | | | |
|---|---|---|---|---|---|
| small enterprises | | medium enterprises | | large enterprises | |

**Definition of enterprises**
small enterprises: headcount < 50, turnover ≤ € 10 million or balance sheet total ≤ € 10 million
medium enterprises: headcount < 250, turnover ≤ € 50 million or balance sheet total ≤ € 43 million
large enterprises: headcount > 250, turnover > € 50 million or balance sheet total > € 43 million

| | Answer | Average refrigerant charge quantity [kg] | Type of system | Refrigeration/ air conditioning |
|---|---|---|---|---|
| What is your estimate of leakage of F-Gases of an air conditioning/refrigeration system in mode of transport per system in % (annual refilling rate)? | | | please select | please select |
| | | | please select | please select |
| | | | please select | please select |
| Could you please indicated the main causes for the leakage? | | | please select | please select |
| | | | please select | please select |
| | | | please select | please select |
| To which amount do you estimate that the emissions could be reduced per system in % due to Art.3 of Regulation (EC) No 842/2006? | | | please select | please select |
| | | | please select | please select |
| | | | please select | please select |
| How much do you estimate that the costs for an inspection for one leakage control per system would cost? | | please select | please select | please select |
| | | please select | please select | please select |
| | | please select | please select | please select |
| How long do you estimate is the average duration of one leakage checking inspection by certified personnel per system? | | please select | please select | please select |
| | | please select | please select | please select |
| | | please select | please select | please select |

Please use for each combination one line, if there is only one combination you only have to fill in one line, if there are more than three combinations, please add additional lines.

| | |
|---|---|
| Remarks: | |

**4) Potential application of recovery provisions (Art.4 of Regulation (EC) No 842/2006) in modes of transport**

This section concerns the possible impacts of the possible application of Art.4 of the F-Gas Regulation to air conditioning systems, other than those fitted to motor vehicles referred to in Directive 70/156/EEC, and refrigeration systems contained in modes of transport

**Requirements of Art.4 of the F-Gas Regulation:**
- Recovery by certified personnel before final disposal and, when appropriate, during ist servicing or maintenance, for the purpose of recycling, reclamation or destruction (all charges)

| What is your estimate of the costs for recovery per kg? | |
|---|---|

| | answer | average refrigerant charge quantity [kg] | type of system | refrigeration/ air conditioning |
|---|---|---|---|---|
| What is the percentage of the current recovery level of F-Gases at end of life? | | | please select | please select |
| | | | please select | please select |
| | | | please select | please select |
| To which percentage do you estimate that the recovery at end of life could be increased due to Art.4 of Regulation (EC) No 842/2006? | | | please select | please select |
| | | | please select | please select |
| | | | please select | please select |
| Please give an estimation for the current emission level during recovery of F-Gases during maintenance and servicing (in %) | | please select | please select | please select |
| | | please select | please select | please select |
| | | please select | please select | please select |
| To which percentage do you estimate that the emission level during recovery during maintenance and servicing could be decreased due to Art.4 of Regulation (EC) No 842/2006? | | please select | please select | please select |
| | | please select | please select | please select |
| | | please select | please select | please select |
| Please give an estimation for the additional costs that would result, if the recovery would be carried out by certified personnel (per system). | | please select | please select | please select |
| | | please select | please select | please select |
| | | please select | please select | please select |

Please use for each combination one line, if there is only one combination you only have to fill in one line, if there are more than three combinations, please add additional lines.

| Remarks: | |
|---|---|

**5) Refrigerant types**

Please fill in this table for refrigerants used in **air conditioning systems** in modes of transport

**Please indicate for each refrigerant which is covered by your organisation the average quantities of refrigerant in the system, the types of systems in which it is contained and the share of the refrigerant in comparison to all refrigerants.**
**Please use for each combination a separate line!**

| Name of refrigerant (F-Gas) | Average quantity of F-Gas (per system) [kg] | Type of system | How big is the share of this refrigerant in comparison to all F-Gases used for the purpose of air conditioning [%]? | Further description of transport system (e.g. locomotive, coach, etc) |
|---|---|---|---|---|
| | | please select | | |
| | | please select | | |
| | | please select | | |
| | | please select | | |
| | | please select | | |

| Please estimate the percentage of air conditioning systems in the selected sector in your country that are filled with each of the following refrigerants: (please indicate your answer in %) | HFC | |
|---|---|---|
| | alternative refrigerant | |
| | other | |

Please fill in this table for refrigerants used in **refrigeration systems** in modes of transport

Please indicate for each refrigerant which is covered by your organisation the average quantities of refrigerant in the system, the types of systems in which it is contained and the share of this refrigerant in comparison to all refrigerants.
Please use for each combination a separate line!

| Name of refrigerant (F-Gas) | Average quantity of F-Gas (per system) [kg] | Type of system | How big is the share of this refrigerant in comparison to all F-Gases used for the purpose of refrigeration [%]? | Further description of transport system (e.g. locomotive, coach, etc) |
|---|---|---|---|---|
| | | please select | | |
| | | please select | | |
| | | please select | | |
| | | please select | | |
| | | please select | | |

| | | |
|---|---|---|
| Please estimate the percentage of refrigeration systems in the selected sector in your country that are filled with each of the following refrigerants: (please indicate your answer in %) | HFC | |
| | alternative refrigerant | |
| | other | |

| | |
|---|---|
| Remarks: | |

## 6) Development of market

| | | |
|---|---|---|
| Would the application of Art.3 and/or Art.4 of Regulation (EC) No 842/2006 on mobile equipment in your opinion be an obstacle for the growth of the affected companies, new investments, etc.? If yes, please explain | Art. 3 | |
| | Art.4 | |
| Would the application of Art.3 and/or Art.4 of Regulation (EC) No 842/2006 on mobile equipment in your opinion have positive or negative impacts on employment? If yes, please explain | Art. 3 | |
| | Art.4 | |
| Would the application of Art.3 and/or Art.4 of Regulation (EC) No 842/2006 on mobile equipment in your opinion affect the competitiveness of the transport sector (in European/global context)? If yes, please explain | Art. 3 | |
| | Art.4 | |
| Which impacts do you expect related to technology development in the R&D sector due to the application of Art.3 and 4 of Regulation (EC) No 842/2006 on mobile equipment (e.g. development of recovery equipment, leakage detection systems)? | Art. 3 | |
| | Art.4 | |
| How could the application of Art.3 and/or Art.4 create new business opportunities and in which economic sectors? | Art. 3 | |
| | Art.4 | |
| Have you already conducted studies or stakeholder consultations in this field? If yes, we would be grateful if you could provide us with related documents. | | |

| How do you estimate the following trends in the selected transport sector over the next 12 years: | |
|---|---|
| Shift from F-Gases used for mobile refrigeration/air conditioning systems to alternative refrigerants: | |
| Reduction of refrigerant charge: | |
| Reduction of emissions due to better technology: | |
| Increase in transport systems: | |

| | |
|---|---|
| Remarks: | |

**7) Size and distribution of affected sectors**

**In which European Member States are organisations affected by Regulation (EC) No 842/2006 in the selected transport sector mainly represented?**

| | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| AT | | BE | | CY | | CZ | | DK | | EE | | FI | | FR | | DE | | GR | | HU | | IE | | IT | | LV | | LT | | LU | | MT | |
| PL | | PT | | SK | | SI | | ES | | SE | | NL | | UK | | BU | | RO | | | | | | | | | | | | | | | |

**Please indicate a rough estimation of the share of affected enterprises by Regulation (EC) No 842/2006 in the selected transport sector. Please indicate the share in % and per MS (for which you have data) and, if possible, also for the EU**

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| EU-27 | | small enterprises | | medium enterprises | | large enterprises | |
| MS | | small enterprises | | medium enterprises | | large enterprises | |
| MS | | small enterprises | | medium enterprises | | large enterprises | |

| | |
|---|---|
| **Remarks:** | |

**8) Data confidentiality**

| | |
|---|---|
| **Would you like the date you submitted to be treated confidentially (data will then be used in an aggregated form and not as single data in the report)?** | please select |

**9) Additional comments**

In case of any questions please contact:

BiPRO GmbH
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Fax: +49 (89) 18979052

Please return preferable via e-mail at the latest by 12 May 2008 to: elisabeth.mueller@bipro.de

# Questionnaire, road sector

**Questionnaire* on possible economic, social and environmental impacts related to the possible application of Art.3 and/or Art.4 of Regulation (EC) No 842/2006 on certain fluorinated greenhouse gases to air conditioning and refrigeration systems contained in different modes of transport**
**-road sector-**

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*This questionnaire was developed by BiPRO GmbH to facilitate collection of up-to-date data in the context of an in-depth study on the economic, social and environmental impacts related to the possible application of Art.3 and/or Art.4 of Regulation (EC) No 842/2006 on certain fluorinated greenhouse gases. It is not an official document from the European Commission.

## Introduction

To undertake steps to fulfil its obligations under the Kyoto Protocol, the European Community adopted Regulation (EC) No 842/2006 on certain fluorinated greenhouse gases which entered into force on 4 July 2007 and aims at containing, preventing and reducing emissions of fluorinated greenhouse gases (F-Gases).

The Regulation addresses containment of F-Gases (Art.3), recovery for the purpose of recycling, reclamation or destruction of F-Gases (Art.4), training and certification of personnel (Art.5), reporting obligations for producers, importers and exporters (Art.6), labelling of specific products and equipment containing F-Gases (Art.7), bans and controls of certain uses of F-Gases (Art.8) and market prohibitions of F-Gases (Art.9).

The F-Gases which are covered by Regulation (EC) No 842/2006 can be divided in HFCs, PFCs and $SF_6$. For more detailed information please see Annex I, Part I of the Regulation.

Article 10(1) of the F-Gas Regulation entitles the European Commission to elaborate legislative proposals for applying the provisions of Art.3 also to air conditioning systems (other than those fitted to motor vehicles referred to in Directive 70/156/EEC) and refrigeration systems in modes of transport.

In this context the questionnaire aims at collecting up-to-date data of air conditioning systems (other than those fitted to motor vehicles referred to in Directive 70/156/EEC) and refrigeration systems in modes of transport regarding the possible application of Art.3 and additionally of Art.4 of the F-Gas Regulation.

The transport systems which are covered by this questionnaire are:

- refrigerated trucks
- refrigerated trailers

The aim of the data collection is to carry out an impact assessment on possible economic, social and environmental impacts related to the possible application of Art.3 and/or Art.4 of Regulation (EC) No 842/2006 on certain fluorinated greenhouse gases to air conditioning systems, other than those fitted to motor vehicles referred to in Directive 70/156/EEC, and refrigeration systems contained in different modes of transport.

## How to use the questionnaire

If your organisation covers more than one transport sector, please use a separate questionnaire for each sector.
Please use the fields marked in yellow for your answers.
When filling in the questionnaire please indicate the units you use and indicate prices in €.
Questions which are not relevant for your organisation do not need to be filled in.
Please do not hesitate to add new lines if you can provide more information.

Please note, that the transport sector addressed by this questionnaire covers only refrigerated vehicles. It does not cover air conditioning systems fitted to motor vehicles referred to in Directive 70/156/EEC.

**1) Contact details**

| | |
|---|---|
| Name of organisation | |
| Type of organisation | |
| Contact person | |
| Area of responsibility | |
| Address (including street, zip-code, city, country) | |
| Phone | |
| Fax | |
| E-mail | |
| URL | |

**2) Type of transport sector** please select

## 3) Potential application of containment provisions (Art.3 of Regulation (EC) No 842/2006) in modes of transport

This section concerns the possible impacts of the possible application of Art.3 of the F-Gas Regulation to air conditioning systems, other than those fitted to motor vehicles referred to in Directive 70/156/EEC, and refrigeration systems contained in modes of transport

**Requirements of Art.3 of the F-Gas Regulation:**
- Prevention of any leakage (concerns all charges)
- Repairing of detected leakage as soon as possible (concerns all charges)
- Leakage checks by certified personnel (every 12 month for charges > 3 and < 30 kg) (this shall not apply to equipment with hermetically sealed systems, which are labelled as such and contain less than 6 kg of fluorinated greenhouse gasses)
(every 6 month for charges > 30 and < 300 kg)
(every 3 month for charges > 300 kg)
- Installation of leakage detection systems (concerns charges > 300 kg) (if a leakage detection system is in place, the frequency of checks for equipment containing charges > 30 kg shall be halved)
- Maintenance of records (concerns charges > 3 kg)

| | |
|---|---|
| **How much do you estimate that a certification would annually cost per person?** | |
| **How much does one hour of own affected personnel of companies operating F-Gas containing equipment cost in average?** | |

**To which percentage do you estimate that own personnel of companies operating F-Gas containing equipment will be certified for leakage control and maintenance? Please indicate the percentage for each group of enterprises (small enterprises, medium enterprises, large enterprises)?**

| | | | | | |
|---|---|---|---|---|---|
| small enterprises | | medium enterprises | | large enterprises | |

**Definition of enterprises**
small enterprises: headcount < 50, turnover ≤ € 10 million or balance sheet total ≤ € 10 million
medium enterprises: headcount < 250, turnover ≤ € 50 million or balance sheet total ≤ € 43 million
large enterprises: headcount > 250, turnover > € 50 million or balance sheet total > € 43 million

| | Answer | Average refrigerant charge quantity [kg] | Type of system |
|---|---|---|---|
| **What is your estimate of leakage of F-Gases of an refrigeration system in mode of transport per system in % (annual refilling rate)?** | | | please select |
| | | | please select |
| | | | please select |
| **Could you please indicated the main causes for the leakage?** | | | please select |
| | | | please select |
| | | | please select |
| **To which amount do you estimate that the emissions could be reduced per system in % due to Art.3 of Regulation (EC) No 842/2006?** | | | please select |
| | | | please select |
| | | | please select |
| **How much do you estimate that the costs for an inspection for one leakage control per system would cost?** | | please select | please select |
| | | please select | please select |
| | | please select | please select |
| **How long do you estimate is the average duration of one leakage checking inspection by certified personnel per system?** | | please select | please select |
| | | please select | please select |
| | | please select | please select |

Please use for each combination one line, if there is only one combination you only have to fill in one line, if there are more than three combinations, please add additional lines.

| | |
|---|---|
| **Remarks:** | |

| | |
|---|---|
| **street, zip-code, city, country)** | |
| **Phone** | |
| **Fax** | |
| **E-mail** | |
| **URL** | |

| | |
|---|---|
| **2) Type of transport sector** | please select |

**6) Development of market**

| | | |
|---|---|---|
| Would the application of Art.3 and/or Art.4 of Regulation (EC) No 842/2006 on mobile equipment in your opinion be an obstacle for the growth of the affected companies, new investments, etc.? If yes, please explain | Art. 3 | |
| | Art.4 | |
| Would the application of Art.3 and/or Art.4 of Regulation (EC) No 842/2006 on mobile equipment in your opinion have positive or negative impacts on employment? If yes, please explain | Art. 3 | |
| | Art.4 | |
| Would the application of Art.3 and/or Art.4 of Regulation (EC) No 842/2006 on mobile equipment in your opinion affect the competitiveness of the transport sector (in European/global context)? If yes, please explain | Art. 3 | |
| | Art.4 | |
| Which impacts do you expect related to technology development in the R&D sector due to the application of Art.3 and 4 of Regulation (EC) No 842/2006 on mobile equipment (e.g. development of recovery equipment, leakage detection systems)? | Art. 3 | |
| | Art.4 | |
| How could the application of Art.3 and/or Art.4 create new business opportunities and in which economic sectors? | Art. 3 | |
| | Art.4 | |
| Have you already conducted studies or stakeholder consultations in this field? If yes, we would be grateful if you could provide us with related documents. | | |

| How do you estimate the following trends in the selected transport sector over the next 12 years: | |
|---|---|
| Shift from F-Gases used for mobile refrigeration/air conditioning systems to alternative refrigerants: | |
| Reduction of refrigerant charge: | |
| Reduction of emissions due to better technology: | |
| Increase in transport systems: | |

| Remarks: | |
|---|---|

**7) Size and distribution of affected sectors**

In which European Member States are organisations affected by Regulation (EC) No 842/2006 in the selected transport sector mainly represented?

| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| AT | | BE | | CY | | CZ | | DK | | EE | | FI | | FR | | DE | | GR | | HU | | IE | | IT | | LV | | LT | | LU | | MT | |
| PL | | PT | | SK | | SI | | ES | | SE | | NL | | UK | | BU | | RO | | | | | | | | | | | | | | | |

Please indicate a rough estimation of the share of affected organisations by Regulation (EC) No 842/2006 in the selected transport sector. Please indicate the share in % and per MS (for which you have data) and, if possible, also for the EU

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| EU-27 | | small enterprises | | | medium enterprises | | | large enterprises | |
| MS | | small enterprises | | | medium enterprises | | | large enterprises | |
| MS | | small enterprises | | | medium enterprises | | | large enterprises | |

| | | |
|---|---|---|
| Please estimate the percentage of refrigeration systems in the selected sector in your country that are filled with each of the following refrigerants: (please indicate your answer in %) | HFC | |
| | alternative refrigerant | |
| | other | |

| Remarks: | |
|---|---|

| | |
|---|---|
| **Remarks:** | |

**8) Data confidentiality**

| | |
|---|---|
| **Would you like the date you submitted to be treated confidentially (data will then be used in an aggregated form and not as single data in the report)?** | please select |

**9) Additional comments**

| |
|---|
| |

In case of any questions please contact:

BiPRO GmbH
Ms Elisabeth Mueller
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Phone: +49 (89) 18979050
Fax: +49 (89) 18979052

Please return preferable via e-mail at the latest by 12 May 2008 to: elisabeth.mueller@bipro.de

## Questionnaire, Member States

**Questionnaire* on possible economic, social and environmental impacts related to the possible application of Art.3 and/or Art.4 of Regulation (EC) No 842/2006 on certain fluorinated greenhouse gases to air conditioning and refrigeration systems contained in different modes of transport**

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In this context the questionnaire aims at collecting up-to-date data of air conditioning systems (other than those fitted to motor vehicles referred to in Directive 70/156/EEC) and refrigeration systems in modes of transport regarding the possible application of Art.3 and additionally of Art.4 of the F-Gas Regulation.

The transport systems which are covered by air conditioning systems (other than those fitted to motor vehicles referred to in Directive 70/156/EEC) and refrigeration systems in modes of transport are:

- in the road sector:
  - refrigerated trucks
  - refrigerated trailers
- in the rail sector:
  - trains
  - trams
  - metros
- in the maritime sector
  - sea going merchant ships
  - ships for refrigerated cargo
  - inland navigation vessels
  - fishing vessels

The aim of the data collection is to carry out an impact assessment on possible economic, social and environmental impacts related to the possible application of Art.3 and Art.4 of Regulation (EC) No 842/2006 on certain fluorinated greenhouse gases to air conditioning systems, other than those fitted to motor vehicles referred to in Directive 70/156/EEC, and refrigeration systems contained in different modes of transport.

### How to use the questionnaire

Please use the fields marked in yellow for your answers.
When filling in the questionnaire please indicate the units you use and indicate prices in €.
Please do not hesitate to add new lines if you can provide more information.
Please note, that the transport sector addressed by this questionnaire does not cover air conditioning systems fitted to motor vehicles referred to in Directive 70/156/EEC.

**1) Contact details**

| | |
|---|---|
| Name of institution | |
| Contact person | |
| Area of responsibility | |
| Address (including street, zip-code, city, country) | |
| Phone | |
| Fax | |
| E-mail | |
| URL | |

**2) Size and distribution of affected sectors**

How many direct and indirect affected enterprises do you estimate exist in your country? Please indicate a best estimate on the amount of enterprises for each sector (road, rail, maritime) and for each group of enterprises (small, medium, large)

**Road sector**

Directly affected enterprises

| | | | | | | |
|---|---|---|---|---|---|---|
| Operating companies of transport refrigeration systems (e.g. transport companies) | small enterprises | | medium enterprises | | large enterprises | |

Indirectly affected enterprises

| | | | | | | |
|---|---|---|---|---|---|---|
| Manufacturers of refrigeration systems | small enterprises | | medium enterprises | | large enterprises | |
| Manufacturer of vehicles/ vehicle bodyworks | small enterprises | | medium enterprises | | large enterprises | |
| Distributors of F-Gases | small enterprises | | medium enterprises | | large enterprises | |
| Service companies - maintenance | small enterprises | | medium enterprises | | large enterprises | |
| Service companies - training | small enterprises | | medium enterprises | | large enterprises | |
| Disposal/recovery/recycling companies | small enterprises | | medium enterprises | | large enterprises | |
| Engineering companies (e.g. manufacturer of leakage detection systems) | small enterprises | | medium enterprises | | large enterprises | |
| Total indirect affected companies | small enterprises | | medium enterprises | | large enterprises | |
| If some enterprises have more functions (e.g. one enterprise for manufacture, maintenance, recycling) please indicate that here | | | | | | |

**Rail sector**

Directly affected enterprises

| | | | | | | |
|---|---|---|---|---|---|---|
| Operating companies of transport air conditioning/refrigeration systems (e.g. train companies) | small enterprises | | medium enterprises | | large enterprises | |

Indirectly affected enterprises

| | | | | | | |
|---|---|---|---|---|---|---|
| Manufacturers of air conditioning/refrigeration systems | small enterprises | | medium enterprises | | large enterprises | |
| Manufacturer of rail vehicles | small enterprises | | medium enterprises | | large enterprises | |
| Distributors of F-Gases | small enterprises | | medium enterprises | | large enterprises | |
| Service companies - maintenance | small enterprises | | medium enterprises | | large enterprises | |
| Service companies - training | small enterprises | | medium enterprises | | large enterprises | |
| Disposal/recovery/recycling companies | small enterprises | | medium enterprises | | large enterprises | |
| Engineering companies (e.g. manufacturer of leakage detection systems) | small enterprises | | medium enterprises | | large enterprises | |
| Total indirect affected companies | small enterprises | | medium enterprises | | large enterprises | |
| If some enterprises have more functions (e.g. one enterprise for manufacture, maintenance, recycling) please indicate that here | | | | | | |

| Maritime sector | | | | | | |
|---|---|---|---|---|---|---|
| Directly affected enterprises | | | | | | |
| Operating companies of transport air conditioning/refrigeration systems (e.g. transport companies) | small enterprises | | medium enterprises | | large enterprises | |
| Indirectly affected enterprises | | | | | | |
| Manufacturers of air conditioning/refrigeration systems | small enterprises | | medium enterprises | | large enterprises | |
| Manufacturer of ships | small enterprises | | medium enterprises | | large enterprises | |
| Distributors of F-Gases | small enterprises | | medium enterprises | | large enterprises | |
| Service companies - maintenance | small enterprises | | medium enterprises | | large enterprises | |
| Service companies - training | small enterprises | | medium enterprises | | large enterprises | |
| Disposal/recovery/recycling companies | small enterprises | | medium enterprises | | large enterprises | |
| Engineering companies (e.g. manufacturer of leakage detection systems) | small enterprises | | medium enterprises | | large enterprises | |
| Total indirect affected companies | small enterprises | | medium enterprises | | large enterprises | |
| If some enterprises have more functions (e.g. one enterprise for manufacture, maintenance, recycling) please indicate that here | | | | | | |
| If some enterprises are players in more than one sector (e.g. some distributors of F-Gases are selling F-Gases for the transport, rail and maritime sector) please indicate that here. | | | | | | |

**Definition of enterprises**
small enterprises: headcount < 50, turnover ≤ € 10 million or balance sheet total ≤ € 10 million
medium enterprises: headcount < 250, turnover ≤ € 50 million or balance sheet total ≤ € 43 million
large enterprises: headcount > 250, turnover > € 50 million or balance sheet total > € 43 million

**3) Development of market**

| | | |
|---|---|---|
| Would the application of Art.3 and/or Art.4 of Regulation (EC) No 842/2006 on mobile equipment in your opinion be an obstacle for the growth of the affected companies, new investments, etc.? If yes, please explain | Art. 3 | |
| | Art.4 | |
| Would the application of Art.3 and/or Art.4 of Regulation (EC) No 842/2006 on mobile equipment in your opinion have positive or negative impacts on employment? If yes, please explain | Art. 3 | |
| | Art.4 | |
| Would the application of Art.3 and/or Art.4 of Regulation (EC) No 842/2006 on mobile equipment in your opinion affect the competitiveness of the transport sector (in European/global context)? If yes, please explain | Art. 3 | |
| | Art.4 | |
| Which impacts do you expect related to technology development in the R&D sector due to the application of Art.3 and 4 of Regulation (EC) No 842/2006 on mobile equipment (e.g. development of recovery equipment, leakage detection systems)? | Art. 3 | |
| | Art.4 | |
| How could the application of Art.3 and/or Art.4 create new business opportunities and in which economic sectors? | Art. 3 | |
| | Art.4 | |
| Have you already conducted studies or stakeholder consultations in this field? If yes, we would be grateful if you could provide us with related documents. | | |

**4) Emission reduction potential**

| | | |
|---|---|---|
| How do you estimate the emission reduction due to the possible application of Art.3 of Regulation (EC) No 842/2006 on air conditioning systems (other than those fitted to motor vehicles referred to in Directive 70/156/EEC) and refrigeration systems in modes of transport in your country for each sector? | road sector: | |
| | rail sector: | |
| | maritime sector: | |
| How do you estimate the emission reduction due to the possible application of Art.4 of Regulation (EC) No 842/2006 on air conditioning systems (other than those fitted to motor vehicles referred to in Directive 70/156/EEC) and refrigeration systems in modes of transport in your country for each sector? | road sector: | |
| | rail sector: | |
| | maritime sector: | |

**5) Implementation of legislation**

| | |
|---|---|
| Do exist stricter regulations than Art.3 and Art.4 of Regulation (EC) No 842/2006 in your country for air conditiong systems and refrigeration systems in modes of transport? If yes could we kindly ask you to specify the differences and/or to attach an annex with your legislation (in English if available)? | |
| How long do you estimate that the full implementation of Art.3 of Regulation (EC) No 842/2006 on air conditioning systems (other than those fitted to motor vehicles referred to in Directive 70/156/EEC) and refrigeration systems in modes of transport would take in your country? | |
| How long do you estimate that the full implementation of Art.4 of Regulation (EC) No 842/2006 on air conditioning systems (other than those fitted to motor vehicles referred to in Directive 70/156/EEC) and refrigeration systems in modes of transport would take in your country? | |
| How much administrative costs do you expect will arise for the implementation of Art. 3 of Regulation (EC) No 842/2006 in your country (e.g. for setting up evaluation bodies, setting up certification bodies etc.)? Please indicate a cost estimation for each type of administrative work you would have to carry out. | |
| How much administrative costs do you expect will arise for the implementation of Art. 4 of Regulation (EC) No 842/2006 in your country (e.g. for setting up evaluation bodies, setting up certification bodies etc.)? Please indicate a cost estimation for each type of administrative work you would have to carry out. | |

**6) Additional comments**

In case of any questions please contact:

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Please return preferable via e-mail at the latest by 14 April 2008 to: elisabeth.mueller@bipro.de

## List of consultees

*European Associations*

European Community Shipowners Association (ECSA)

Air Conditioning and Refrigeration European Association (AREA)

Transfrigoroute international (European Trade Association)

Community of European Railway and Infrastructure Companies (CER)

European Association for forwarding, transport, logistic and customs services (CLECAT)

International Road Transport Union (IRTU)

Union of European Railway Industries

European Partnership to Energy and the Environment (EPEE)

Institute for European Environmental Policy

Shecco

Greenpeace

*Maritime and inland waterway sector*

GEA Grenco B.V.

Maersk Ship Management B.V.

Netherlands Shipowners Association - KNVR

Fa. Überfeld

VROM Inspectorate

Wilh. Wilhelmsen ASA

Via-Donau

*Road sector*

Carrier (Manufacturer of refrigeration systems for road sector)

United Technologies

Frigoblock

Thermoking (Manufacturer of refrigeration systems for road sector)

Konvekta AG (Manufacturer of refrigeration systems for road sector)

Carrier Transicold Balkans

TT Thermoking (Poland)

TÜV SÜD

Liebherr-Transportation Systems GmbH

*Rail sector*

HSBC Rail UK

JSC Lithuanian Railways

Greek railway company

SNCF France

UK Association of Train Operating Companies (ATOC)

*F-Gas production/distribution*

Solvay Fluor

Westfalen AG

Harp international

Ineas Fluor

Honeywell

*Statistical data*

Laboratory of Applied Thermodynamics (Database Copert)

European Commission – Joint Research Centre – Institute for Prospective Technological Studies (IPTS)

Tremove model, European Commission

UNION INTERNATIONALE DES CHEMINS DE FER (UIC)

Lloyd's Register – Fairplay

*Authorities in Member States*

Polish Industrial Chemistry Research Institute

Environment Protection Agency, Germany

Federal Ministry for the Environment, Nature Conservation and Nuclear Safety, Germany

Permanent Representation of Austria in Brussels

Austrian Federal Economic Chamber

Environmental Protection Agency, Sweden

Ministère de l'Ecologie et du Développement Durable, France

Ministry of Environment and Water, Hungary

Ministry of Environment, Spain

Environmental Institute, Finland

Ministry of Environment, Lithuania

Ministry for Environment, physical Planning and Public Works, DG for the Env, Division for Air Pollution & Noise Monitoring, Department of Air Quality, Greece

## F – Gases and their GWP

| Fluorinated greenhouse gas | Chemical formula | Global warming potential (GWP) |
|---|---|---|
| Sulphur hexafluoride | $SF_6$ | 22,200 |
| *Hydrofluorocarbons (HFCs)* | | |
| HFC-23 | $CHF_3$ | 12,000 |
| HFC-32 | $CH_2F_2$ | 550 |
| HFC-41 | $CH_3F$ | 97 |
| HFC-43-10mee | $C_5H_2F_4$ | 1,500 |
| HFC-125 | $C_2HF_5$ | 3,400 |
| HFC-134 | $C_2H_2F_4$ | 1,100 |
| HFC-134a | $CH_2FCF_3$ | 1,300 |
| HFC-152a | $C_2H_4F_2$ | 120 |
| HFC-143 | $C_2H_3F_3$ | 330 |
| HFC-143a | $C_2H_3F_3$ | 4,300 |
| HFC-227ea | $C_3HF_7$ | 3,500 |
| HFC-236cb | $CH_2FCF_2CF_3$ | 1,300 |
| HFC-236ea | $CHF_2CHFCF_3$ | 1,200 |
| HFC-236fa | $C_3H_2F_6$ | 9,400 |
| HFC-245ca | $C_3H_3F_5$ | 640 |
| HFC-245fa | $CHF_2CH_2CF_3$ | 950 |
| HFC-365mfc | $CF_3CH_2CF_2CH_3$ | 890 |
| *Perfluorocarbons (PFCs)* | | |
| Perfluoromethane | $CF_4$ | 5,700 |
| Perfluoroethane | $C_2F_6$ | 11,900 |
| Perfluoropropane | $C_3F_8$ | 8,600 |
| Perfluorobutane | $C_4F_{10}$ | 8,600 |
| Perfluoropentane | $C_5F_{12}$ | 8,900 |
| Perfluorohexane | $C_6F_{14}$ | 9,000 |
| Perfluorocyclobutane | $c\text{-}C_4F_8$ | 10,000 |
| *Typical refrigerants (F-Gas preparations)* | | |
| R-407C | | 1,610 |
| R-404A | | 3,260 |
| R-410A | | 1,890 |
| R-507 | | 3,300 |

Sources:

- Regulation (EC) No 842/2006,
- Schwarz W., Rhiemeier J.: The analysis of the emissions of fluorinated greenhouse gases from refrigeration and air conditioning equipment used in the transport sector other than road transport and options for reducing these emissions – Maritime, Rail and Aircraft Sector, prepared for the European Commission, November 2007
- http://www.cfs.co.uk/sustainability2003/ecological/conversions.htm