

Category		Title
NFR:	<b>2.D.3.e</b>	<b>Degreasing</b>
SNAP:	<b>060201 060203 060204</b>	<b>Metal degreasing Electronic components manufacturing Other industrial cleaning</b>
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## 1 Overview

Degreasing is a process for cleaning products from water-insoluble substances such as grease, fats, oils, waxes, carbon deposits, fluxes and tars. In most cases the process is applied to metal products, but also plastic, fibreglass, printed circuit boards and other products are treated by the same process. Therefore, a wide range of activities is covered. The metal-working industries are the major users of solvent degreasing. Solvent degreasing is also used in industries such as printing and production of chemicals, plastics, rubber, textiles, glass, paper, and electric power. Repair stations for transportation vehicles also sometimes use solvent cleaning. Metal degreasing may be a significant source of hydrofluorocarbons (HFCs) and perfluorocarbons (PFCs) (ETC/AEM-CITEPA-RISOE, 1997).

## 2 Description of sources

### 2.1 Process description

Existing cleaning equipment for the degreasing and cleaning of metals with solvents are explained in the European Standard EN 12921-4.

Industrial metal degreasing by using organic solvents takes place in specially designed cleaning equipment. Emission limits required by the Solvents Emissions Directive 1999/13/EC can only be achieved by using hermetically-sealed cleaning equipment. This leads to a significant reduction of emissions and increased workplace safety. State-of-the-art technology is offered to address risks associated with handling, storing and disposing of solvents used in metal degreasing leading to a further reduction of emissions. For some applications, water-based cleaning systems are used.

Metal degreasing by using organic solvents takes place in either open top or closed tanks. The open-top tanks, however, have been phased out in the European Union due to the Solvents Emissions Directive 1999/13/EC. Only small facilities, using not more than 1 or 2 tonnes of solvent per year (depending on the risk profile of the solvent) are still allowed to use open top tanks. Closed tanks offer much better opportunities for recycling of solvents.

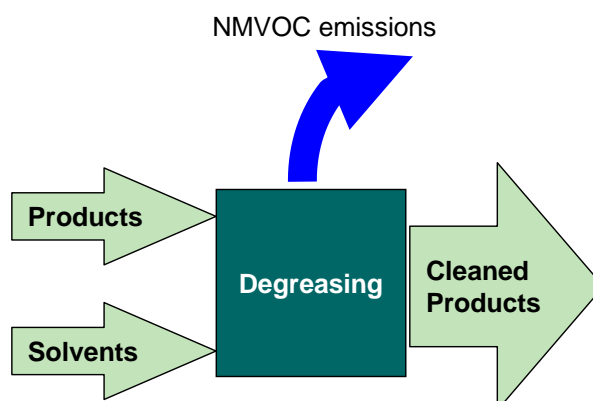


Figure 2-1 Process scheme for source category 2.D.3.e Degreasing

## 2.2 Techniques

The following technologies are used and described:

- conventional techniques:
  - cold cleaners
  - open-top vapour systems
  - conveyorised degreasers;
- modern technique:
  - sealed cleaning equipment.

### 2.2.1 *Cold cleaners*

Cold cleaners are mainly applied in maintenance and manufacturing. They are batch loaded, non-boiling solvent degreasers, providing the simplest method of metal cleaning. A distinction can be made between cleaners for maintenance, using petroleum solvents, and production cleaners using more specialised solvents. Cold cleaner operations include spraying, brushing, flushing, and immersion phases. There is a wide range of designs possible. Emissions occur by waste solvent evaporation, solvent carryout, solvent bath evaporation, spray evaporation and agitation.

### 2.2.2 *Open-top vapour systems*

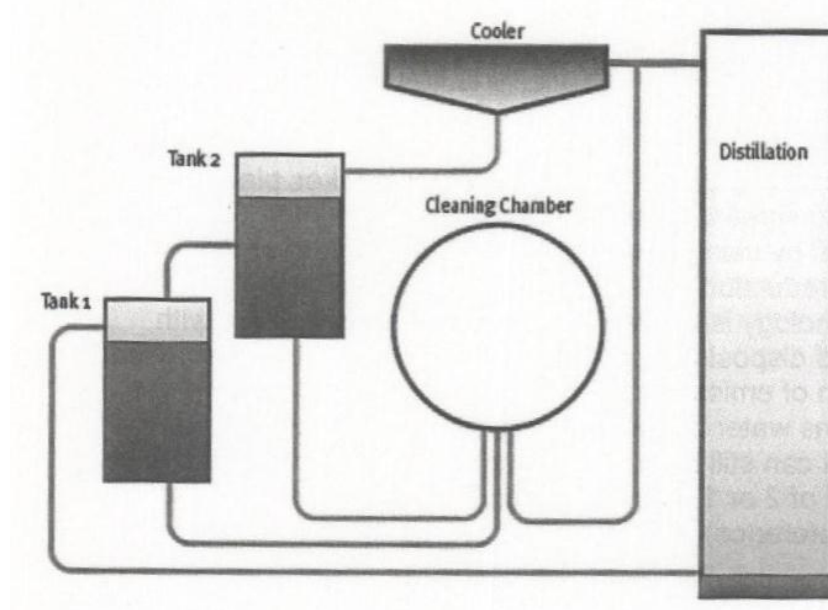
Open-top vapour degreasers have been phased out in the EU following the Solvents Emissions Directive 1999/13/EC, but may still be used outside the EU-27. These are batch loaded degreasers where the cleaning effect is achieved by condensation of hot solvent vapour on colder metal parts. Vapour degreasers only use halogenated hydrocarbons as solvents. Vapour degreasers are usually equipped with a water separator which allows the solvent to flow back into the degreaser. The use of good housekeeping can greatly affect the size of the emissions. Sources of emissions are solvent carry-out, exhaust systems, and waste solvent evaporation.

### 2.2.3 *Conveyorised degreasers*

Conveyorised degreasers may operate with either cold or vaporised solvent, but are continuously loaded and are in most cases hooded or enclosed. The large workload capacity and the fact that they are usually enclosed leads to less solvent emitted per amount product than is the case with other technologies.

### 2.2.4 *Sealed cleaning equipment*

These machines, which are designed specifically for the bulk treatment of small parts, operate a virtually closed loop with complete re-use of the solvent. A typical machine is shown in Figure 2-2 below. Such machines are usually equipped with a side entry/exit, together with protected loading/unloading zones. They are designed to wash the parts by flooding liquid solvent and then by vapour degreasing in the same cleaning chamber.



**Figure 2-2 Typical cleaning equipment machine**

The cleaning process consists of the following stages.

1. Pre-washing: flooding of the cleaning chamber with solvent from tank 1.
2. Evacuation of the cleaning chamber and transfer of the solvent back to tank 1.
3. Cleaning/degreasing: either by spray or immersion from tank 2 (clean solvent tank) into the cleaning chamber. Cleaning power may be improved by use of ultrasonic equipment (optional).
4. Evacuation of the cleaning chamber and transfer of the solvent to the distillation unit.
5. Vapour cleaning: pure solvent vapour generated by the distillation unit is sent to the cleaning chamber and condenses on the cooler parts. Any residual oil film is completely removed.
6. Vacuum drying: by applying vacuum to the cleaning chamber the evaporation of the solvent is accelerated.
7. Ventilation of the cleaning chamber to normal atmospheric conditions. The solvent concentration in the cleaning chamber is controlled and the door opens only if the concentration is below the values specified by the Solvents Emissions Directive 1999/13/EC.

As an option, the complete cleaning equipment can be operated under a vacuum. This enables distillation at lower temperatures and allows permanent control of the vapour emissions from the cleaning machine.

The vapour which is withdrawn from the cleaning chamber is condensed and returned to the clean solvent tank. In addition, the machines are typically equipped with reclaimable active carbon adsorption. The cleaning machines operate with virtually no emissions.

The contaminated solvent is passed through five strainers to remove particles. It is then distilled and returned to the clean solvent tank while the residue is removed from the machine. This process of internal solvent recovery enables a long lifetime for the solvent in the cleaning process and reduces the amount of waste sent to external waste treatment companies.

## 2.3 Emissions

The most common organic solvents for vapour cleaning are:

- methylene chloride (MC)
- tetrachloroethylene (PER)
- trichloroethylene (TRI)
- xylenes (XYL).

The use of chlorofluorocarbons (CFCs) in the past is displaced by HFCs or PFCs. The use of 1,1,1-trichloroethane (TCA) has been banned since the Montreal Protocol and replaced by trichloroethylene (TRI). Further details about the calculation of the emissions can be found in the 2006 IPCC Guidelines for National Greenhouse Gas Inventories (IPCC, 2006). The application of methylene chloride, tetrachloroethylene and trichloroethylene normally requires a closed cleaning machine.

For batch cold cleaners the primary solvents used are mineral spirits, Stoddard solvents (white spirit) and alcohols like propylene glycol.

## 2.4 Controls

### *Conventional degreasing*

In general it can be stated that good housekeeping can reduce emissions by about 20% compared to unabated emissions. Using water-based technologies wherever possible also reduces the VOC emissions. Regarding the three different types of technologies, the following measures can be taken:

- cold cleaners: waste solvent loss is the most important emission source. It can be reduced by distillation or incineration of waste solvent. Good housekeeping for this technology is also very important. Bath evaporation can be reduced by using a water layer of 5–10 cm on top of the solvent;
- open-top vapour systems: most emissions are due to diffusion and convection for which many abatement measures are available, such as reducing the opening times, applying carbon adsorption, etc.;
- conveyORIZED degreasers: as these degreasers are usually enclosed, no extra primary measures are useful.

## 3 Methods

### 3.1 Choice of method

Figure 3-1 presents the procedure to select the methods for estimating emissions from degreasing. The basic idea is:

- if detailed information is available, use it;
- if the source category is a key category, a Tier 2 or better method must be applied and detailed input data must be collected. The decision tree directs the user in such cases to the Tier 2 method, since it is expected that it is more easy to obtain the necessary input data for this approach than to collect facility level data needed for a Tier 3 estimate;
- the alternative of applying a Tier 3 method, using detailed process modelling, is not explicitly included in this decision tree. However, detailed modelling will always be done at facility level and results of such modelling could be seen as ‘facility data’ in the decision tree.

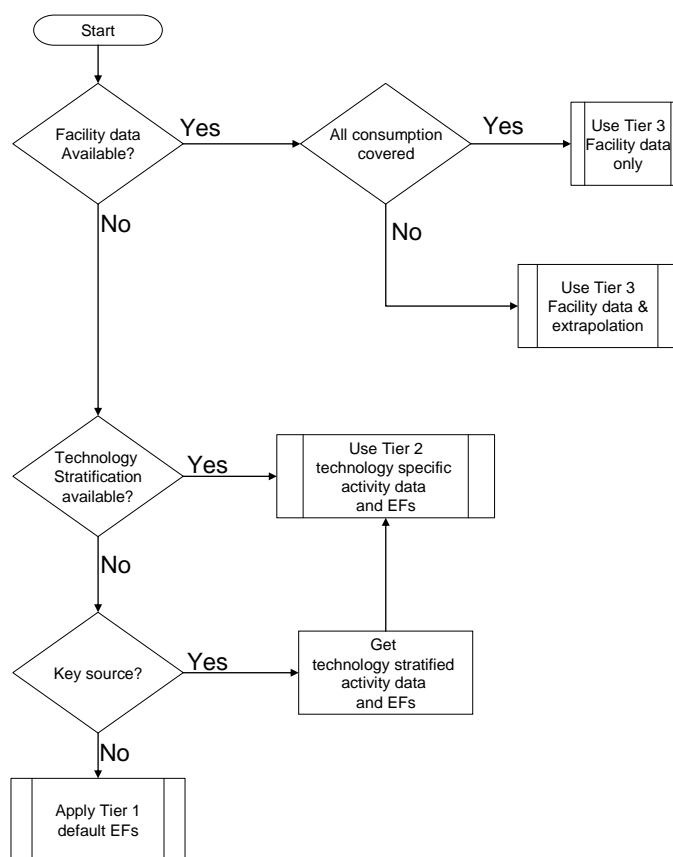


Figure 3-1 Decision tree for source category 2.D.3.e Degreasing

## 3.2 Tier 1 default approach

The Tier 1 methodology is emissions from degreasing is based on solvent sales statistics, in combination with assumptions about the distribution over the different environmental compartments (emissions to air, water, soil and conversion to waste). This method assumes that a stationary situation is reached where only the solvent losses have to be supplied. Even in situations where it is possible to use the detailed method, a comparison with sales to the sector will give a useful check on the information.

### 3.2.1 Algorithm

The Tier 1 approach uses the general equation:

$$E_{pollutant} = AR_{production} \times EF_{pollutant} \quad (1)$$

This equation is applied at the national level, using annual national total chemical production data. Information on the production of chemical compounds suitable for estimating emissions using the simpler estimation methodology (Tier 1 and 2) is widely available from UN statistical yearbooks or national statistics.

The Tier 1 emission factors assume an averaged or typical technology and abatement implementation in the country and integrate all different sub-processes in the chemical industry between feeding the raw material into the process and the final shipment from the facilities.

In cases where specific abatement options are to be taken into account, a Tier 1 method is not applicable and a Tier 2 or Tier 3 approach must be used.

### 3.2.2 Default emission factors

The Tier 1 default emission factor has been derived from an assessment of the emissions and activity data in the International Institute for Applied Systems Analysis (IIASA) Greenhouse Gas and Air Pollution Interactions and Synergies (GAINS) model (IIASA, 2008) for degreasing activities. The Tier 1 emission factor for NMVOC emissions from degreasing has been calculated by dividing the total emissions by the total activity (kg cleaning products) in all countries considered for the year 2000.

More information and documentation on the GAINS model (IIASA, 2008) is available from the website <http://gains.iiasa.ac.at/>.

**Table 3-1 Tier 1 emission factors for source category 2.D.3.e Degreasing**

Tier 1 default emission factors					
	Code	Name			
<b>NFR Source Category</b>	2.D.3.e	Degreasing			
<b>Fuel</b>	NA				
<b>Not applicable</b>	NO <sub>x</sub> , CO, SO <sub>x</sub> , NH <sub>3</sub> , TSP, PM <sub>10</sub> , Pb, Cd, Hg, As, Cr, Cu, Ni, Se, Zn, Aldrin, Chlordane,				
<b>Not estimated</b>	PM <sub>2.5</sub>				
Pollutant	Value	Unit	95% confidence interval		Reference
			Lower	Upper	
NMVOC	460	g/kg cleaning products	20	700	IIASA (2008)



### 3.2.3 Activity data

It is good practice to use statistics about solvent sales as a basis for the calculations when applying the Tier 1 method. Cleaning products to be considered are only organic solvents.

## 3.3 Tier 2 technology-specific approach

A mass balance over an individual plant taking into account the technologies applied is the best approach for situations where the information about the technology is available.

### 3.3.1 Algorithm

The Tier 2 approach is similar to the Tier 1 approach. To apply the Tier 2 approach, both the activity data and the emission factors need to be stratified according to the different processes that may occur in the country. These techniques may include:

- different products
- dust capture
- any other emission abatement technologies implemented in the country.

The following approach is used to estimate emissions from degreasing operations.

Stratify the total degreasing in the country to model the different process types occurring in the national industry into the inventory by:

- defining the degreasing operations using each of the separate process types (together called ‘technologies’ in the formulae below) separately, and
- applying technology-specific emission factors for each process type:

$$E_{\text{pollutant}} = \sum_{\text{technologies}} AR_{\text{use,technology}} \times EF_{\text{technology,pollutant}} \quad (2)$$

where:

$AR_{\text{use,technology}}$  = the use of degreasing using this specific technology,

$EF_{\text{technology,pollutant}}$  = the emission factor for this technology and this pollutant.

If no direct activity data are available, penetration of different technologies within the degreasing industry could be estimated from data on capacities, number of employees or other data that reflect the relative size of each of the different technologies.

A country where only one technology is implemented is basically a special case of the above approaches. The penetration of this technology in such a case is 100 % and the algorithm in equation (2) reduces to:

$$E_{\text{pollutant}} = AR_{\text{production}} \times EF_{\text{technology,pollutant}} \quad (3)$$

### 3.3.2 Technology-specific emission factors

The table below shows Tier 2 solvent loss emission factors for degreasing operations for an open-top degreaser (the Expert Group on Techno-economic Issues (EGTEI), 2005). When less solvent

paints are used or abatement measures are in operation, it is good practice to use reduction efficiencies as given in subsection 3.3.3 of the present chapter to calculate the emissions.

An alternative method to estimate emissions (based on the number of units in operation) is presented in the Tier 3 section of this chapter.

**Table 3-2 Tier 2 emission factors for source category 2.D.3.e Degreasing, Open-top degreaser**

Tier 2 emission factors					
	Code	Name			
NFR Source Category	2.D.3.e	Degreasing			
Fuel	NA				
SNAP (if applicable)	060201	Metal degreasing			
Technologies/Practices					
Region or regional conditions					
Abatement technologies	Open-top degreaser				
Not applicable	NOx, CO, SOx, NH3, TSP, PM10, Pb, Cd, Hg, As, Cr, Cu, Ni, Se, Zn, Aldrin, Chlordane, Chlordecone, Dieldrin, Endrin, Heptachlor, Heptabromo-biphenyl, Mirex, Toxaphene, HCH, DDT, PCB, PCDD/F, Benzo(a)pyrene, Benzo(b)fluoranthene, Benzo(k)fluoranthene, Indeno(1,2,3-cd)pyrene, Total 4 PAHs, HCB, PCP, SCCP				
Not estimated	PM2.5				
Pollutant	Value	Unit	95% confidence interval		Reference
			Lower	Upper	
NM VOC	710	g/kg cleaning products	600	900	EGTEI (2003)

Table 3-3 provides an emission factor for electronic components manufacturing (wafers).

**Table 3-3 Tier 2 emission factors for source category 2.D.3.e Degreasing, Electronic components manufacturing**

Tier 2 emission factors					
	Code	Name			
NFR Source Category	2.D.3.e	Degreasing			
Fuel	NA				
SNAP (if applicable)					
Technologies/Practices	Electronic components				
Region or regional conditions					
Abatement technologies					
Not applicable	NOx, CO, SOx, NH3, TSP, PM10, Pb, Cd, Hg, As, Cr, Cu, Ni, Se, Zn, Aldrin, Chlordane, Chlordecone, Dieldrin, Endrin, Heptachlor, Heptabromo-biphenyl, Mirex, Toxaphene, HCH, DDT, PCB, PCDD/F, Benzo(a)pyrene, Benzo(b)fluoranthene, Benzo(k)fluoranthene, Indeno(1,2,3-cd)pyrene, Total 4 PAHs, HCB, PCP, SCCP				
Not estimated	PM2.5				
Pollutant	Value	Unit	95% confidence interval		Reference
			Lower	Upper	
NM VOC	740	kg/ton wafer	400	1500	C. Trozzi (personal)

### 3.3.3 Abatement

A number of add-on technologies exist that are aimed at reducing the emissions of specific pollutants. The resulting emission can be calculated by replacing the technology-specific emission factor with an abated emission factor as given in the formula:

$$EF_{\text{technologyabated}} = (1 - \eta_{\text{abatement}}) \times EF_{\text{technologyunabated}} \quad (4)$$

The table below presents the reduction efficiencies for degreasing. The unabated emission factors are presented in Table 3-2.

Table 3-4 Abatement efficiencies ( $\eta_{\text{abatement}}$ ) for source category 2.D.3.e Degreasing

Tier 2 Abatement efficiencies					
	Code	Name			
<b>NFR Source Category</b>	2.D.3.e	Degreasing			
<b>Fuel</b>	NA	not applicable			
<b>SNAP (if applicable)</b>	060201	Metal degreasing			
Abatement technology	Pollutant	Efficiency	95% confidence interval		Reference
		Default Value	Lower	Upper	
Open-top degreaser with activated carbon filter	NMVOG	80%	70%	90%	EGTEI (2003)
Semi open-top degreaser and good housekeeping	NMVOG	25%	10%	40%	EGTEI (2003)
Semi open-top degreaser and good housekeeping with activated carbon filter	NMVOG	85%	80%	90%	EGTEI (2003)
Sealed chamber system using chlorinated solvents	NMVOG	95%	90%	100%	EGTEI (2003)
Cold cleaner	NMVOG	89%	80%	90%	EGTEI (2003)
Closed degreaser using A3 solvents or fluoro solvents (HFC and HFE)	NMVOG	96%	90%	100%	EGTEI (2003)
Closed degreaser using A3 solvents or fluoro solvents (HFC and HFE) with activated carbon filter	NMVOG	97%	90%	100%	EGTEI (2003)
Aqueous cleaning process	NMVOG	100%	100%	100%	EGTEI (2003)

### 3.3.4 Activity data

For applying the Tier 2 approach an insight into the penetration of the different technologies is necessary. As a result of the wide range of activities for which metal cleaning is used, it is very difficult to get a reliable picture of the penetration of the different techniques. Assuming a stationary situation for practical reasons, the nationwide figures can be derived from sales information. The detailed description is more applicable to situations where the applied technology is known.

For the cold cleaners used in a very wide range of different maintenance and production processes this will not be feasible in many cases. For the other processes more often used as a part of a standardised process, some information about the production derived from detailed production statistics may be available.

## 3.4 Tier 3 emission modelling and use of facility data

Tier 3 consists of a method estimating the emissions based on units in operation. Relevant emission factors are given in Table 3-5 (reference is Air Pollution Engineering Manual, 1992) and must be applied with care, since emission factors may be outdated. Emission factors have a quality rating C (see General Guidance Chapter 5, Uncertainties, for an explanation of this quality rating).

**Table 3-5 Solvent loss emission factors for degreasing operations (Air Pollution Engineering manual, 1992)**

Degreasing technique	Activity	Uncontrolled NMVOC emission factor
All (simple method) <sup>(1)</sup>	Solvent used	1 000 kg/Mg
Cold cleaner entire unit <sup>(2)</sup>	Units in operation	0.30 Mg/yr/unit
waste solvent loss	Units in operation	0.165 Mg/yr/unit
solvent carry out	Units in operation	0.075 Mg/yr/unit
bath and spray evaporation	Units in operation	0.06 Mg/yr/unit
entire unit	Surface area and duty cycle <sup>(3)</sup>	0.4 kg/hr/m <sup>2</sup>
Cold cleaner entire unit	Units in operation	9.5 Mg/yr/unit
waste solvent loss	Surface area and duty cycle <sup>(4)</sup>	0.7 kg/hr/m <sup>2</sup>
Cold cleaner entire unit	Units in operation	24 Mg/yr/unit
Cold cleaner entire unit	Units in operation	47 Mg/yr/unit

Notes:

- (1) Solvent consumption data will provide much more accurate emission estimates than any of the other factors presented.
- (2) Emissions would generally be higher for manufacturing units; lower for maintenance units.
- (3) For trichloroethane degreaser.
- (4) For trichloroethane degreaser; does not include waste solvent losses.

## 4 Data quality

### 4.1 Completeness

No specific issues.

### 4.2 Avoiding double counting with other sectors

No specific issues.

### 4.3 Verification

No specific issues.

#### 4.3.1 Best Available Technique emission factors

Information regarding emissions when using Best Available Techniques is available from the BREF documents for the Surface Treatment of Metals and the Surface Treatment using Organic Solvents.

### 4.4 Developing a consistent time series and recalculation

No specific issues.

## 4.5 Uncertainty assessment

The accuracy of the calculated emissions depends on the accuracy of the statistics used. When the sales-based methodology is used the accuracy can be estimated to be about C. The overall accuracy of the detailed method will not be much better; the local accuracy may improve to B. The inhabitant-related approach will have accuracy from D to E, dependant on the comparability of the different countries.

Explanation on these uncertainty factors is given in the General Guidance Chapter 5, Uncertainties.

### 4.5.1 Emission factor uncertainties

No specific issues.

### 4.5.2 Activity data uncertainties

No specific issues

## 4.6 Inventory quality assurance/quality control QA/QC

The weakest aspect of the methodology is the requirement for activity data on market share. This is likely to be difficult.

In addition, dry cleaning, in common with other processes using chlorinated solvents, is continually developing; solvents used will change and the efficiency of machines in use may improve rapidly. There will therefore be a need to review this chapter regularly.

## 4.7 Gridding

Metal degreasing is a process that is used in a great number of small plants. Concentrations of these plants in a certain industrial area may be considered as point sources on a regional level. This may improve the local accuracy.

## 4.8 Reporting and documentation

No specific issues

## 5 References

Air Pollution Engineering Manual (1992). Air and Waste Management Association, Anthony J. Buonicore, Wayne T. Davies, ISBN 0-442-00843-0, Van Nostrand Reinhold, New York.

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Trozzi, C. (2008). Personal communication.

## 6 Point of enquiry

Enquiries concerning this chapter should be directed to the relevant leader(s) of the Task Force on Emission Inventories and Projection's expert panel on combustion and industry. Please refer to the TFEIP website ([www.tfeip-secretariat.org/](http://www.tfeip-secretariat.org/)) for the contact details of the current expert panel leaders.