Final Background Documents
on the sector

ORGANIC CHEMICAL INDUSTRY

Prepared in the framework of EGTEI

Prepared by CITEPA, Paris

INTRODUCTION

1 General introduction and explanation

In order to estimate costs of NMVOC emission reduction in the **organic chemical industry**, it has been decided to characterize it into 4 sections and to consider an illustrative example for representing each of these sections [1].
Costs defined for each of these 4 illustrative examples are assumed to be representative of the whole chemical industry. This could be considered as an over simplified representation of this complex industry but this is the only feasible approach considering time and budget limits of this study.

The illustrative examples are as follows:
1. The **steam cracking** process with naphtha as feedstock and ethylene and propylene as products is considered as the illustrative example taken into account for representing all the production of lower olefins (ethylene, propylene, butanes and butadienes). Liquid naphthas (from crude oil refining, C6 to C10 hydrocarbons that boil in gasoline range of 50-200°C) account for 73 % of ethylene production. Other feed stocks are less significant. They are as follows: gas-oil 10%, butane (6%), ethane (5%), propane (4%) and other sources (2%). Ethylene and propylene are the unsaturated compounds produced in the largest quantities (compared to other compounds. Ethylene and propylene represent 45 % of product yields when naphtha is used as feedstock [2]) from steam crackers. The total production capacity of ethylene in the EC is 20 millions tonnes per year and accounts for some 25 % of the world supply. 9,6 Mt of propylene are also produced on steam crackers (4,9 Mt are supplied from extraction of propylene from refinery catalytic cracker off gas). Within the EC, there are 50 steam crackers and these are located on 39 sites [2].
2. The **PVC suspension process** for representing a production of chemicals with sanitary impact.
3. A process of the **downstream chemistry** for representing production of chemicals except the steam crackers, the PVC production and the speciality chemical industry. This production can be also representative of no sanitary impact unit.
4. Production of pharmaceutical active ingredients representing the **speciality chemical industry** (production in batch processes and multipurpose plants). During the meeting of 22/07/02 between CITEPA and the French Union of Chemical Industry (UIC) [1], it was decided to consider the pharmaceutical product manufacturing as the representative activity for the whole speciality organic chemistry. It is consequently assumed that costs derived for the pharmaceutical product manufacturing are representative of the whole speciality organic chemistry.

NOTE : Only **process VOC emissions** are considered in the document presented. VOC emissions from storage and handling of chemical products are not considered for the time being by EGTEI.

For these four sub sub-sectors, the activity levels are represented and documents have been prepared as follows:

1. **Steam cracking:**

Activity: production of ethylene and propylene (from steam cracking, that is to say that the extraction of propylene from refinery catalytic cracker off gas has not to be considered).
SNAP sources covered : SNAP 04 05 01 production of ethylene and SNAP 04 05 02 production of propylene (from steam crackers).
NFR 3C.
The document has been prepared on the basis of information provided by an expert group from UIC and CEFIC [3], [4].

2. **PVC suspension process:**

Activity: production of PVC by the suspension process.
Part of SNAP 040508.
NFR 3C
The document has been prepared on the basis of information provided by an expert group from Solvay, Atofina, LVM and SPMP [5].

3. Down stream units

(following the steam cracker), (all processes of the organic chemistry except steam crackers, the PVC suspension process and the speciality chemical industry).

Activity: due to the large number of sources covered, the activity level is directly defined as **VOC emissions** declared by Parties for the sources covered by this sector.

This sector is assumed to cover the following SNAP sources:

- SNAP 04 05 03/04/05 production of 1,2 dichloroethane/vinyl chloride,
- SNAP 04 05 06/07 production of polyethylene, high and low density,
- SNAP 04 05 09 to 04 05 27 from production of polypropylene to other chemical compounds except 040522 storage and handling of chemical products (According to the cases, the VOC emissions from non pharmaceutical active ingredients could be considered under this SNAP code. In that case emissions have not to be taken into account).

NFR 3C

The document has been prepared in cooperation with the French Chemical Union (UIC) and CEFIC, and expert from ADEME [3], [4].

4. Speciality chemical industry:

Production of pharmaceutical active ingredients representing the production of chemicals in batch processes and multipurpose plants.

Activity: solvent input (new + recycled solvent)

The pharmaceutical product manufacturing is covered by SNAP 06 03 06 and included in NFR 3C Chemical product manufacture and processing. The production of other types of products (non pharmaceutical products) is not well represented in the SNAP. Depending on each situation, emissions from this last activity could be encountered under SNAP codes like 060314: other chemical products manufacturing or processing as carried in the French emission inventory or code 040527 could also be used by some parties.

The document has been prepared on the basis of information provided by the SICOS : French Association of the Organic Chemistry and Biochemistry Industries [6].

This document presents results for :

1. **Steam cracking,**
2. **PVC suspension process,**
3. **Downstream units,**

The speciality organic chemistry is presented in a separate document.

2 Data from the literature

2.1 Data currently used in the RAINS model

As required by national experts, information is provided on costs data and parameters presently used in RAINS.

In its present stage of development, the RAINS model considers the sector ORG PROC for representing the whole organic chemical industry except pharmaceutical products represented by the sector PHARMA. The activity level is directly represented by the VOC emissions [7] due to the difficulty to know the levels of production of chemicals and difficulties to represent such a complex sector (several products are produced on the same process and many production levels are confidential). Storage of chemical products is considered under sector ORG_STORE.

2.1.1 Control options

Four options for emissions reduction are considered in ORG PROC:

- Reduction of fugitive emissions due to defective sealing of equipments by regular monitoring and repair program (LK_I and LK_II). Technical efficiency is estimated to range from 60 to 70% and applicability factor to 20%.
- Flaring (FLR) is estimated to reduce vent losses by about 85 to 90%. The applicability factor is determined by the amount of venting losses (20 to 40% of total emissions of the sector)
- Add-on techniques such as incineration (INC). Efficiency is estimated to 96% and applicability factor to 50%.

2.1.2 Abatement measure costs

Costs used for the some Parties are presented in table 2.1.2.1. to 2.1.2.4.

Table 2.1.2.1: Costs data used in the RAINS model [8] for ORG PROC in France

	Emission factors kg VOC/kg VOC	Applicability %	Technical efficiency %	Cost € 1990/t VOC
Activity level 1990: 19.8 kt VOC, 2010: 23.32 kt VOC; **VOC emissions scenario business as usual**: 1990: 19.8 kt VOC, 2010: 23.2 kt VOC				
No control	1.0	0	0	0
LK_I	0.88	20	60	1587
LK_II	0.86	20	70	5758
FLR	0.73	30	90	341
INC	0.52	50	96	778
LK_I + FLR	0.61	50	78	363
LK_I + INC	0.4	70	86	773
LK_I + INC + FLR	0.13	100	87	524
LK_II + FLR	0.59	50	83	467
LK_II + INC	0.38	70	89	965
LK_II + INC + FLR	0.11	100	89	595

Table 2.1.2.2: Costs data used in the RAINS model [8] for ORG PROC in Germany old Landers

	Emission factors kg VOC/kg VOC	Applicability %	Technical efficiency %	Cost € 1990/t VOC
Activity level 1990: 65 kt VOC, 2010: 130 kt VOC **VOC emissions scenario current regulation**: 1990: 50.25 kt VOC, 2010: 50.04 kt VOC				
No control	1.0	0	0	0
LK_I	0.88	20	60	1587
LK_II	0.86	20	70	5758
FLR	0.745	30	85	341
INC	0.52	50	96	778
LK_I + FLR	0.625	50	75	363
LK_I + INC	0.4	70	86	773
LK_I + INC + FLR	0.145	100	86	524
LK_II + FLR	0.605	50	79	467
LK_II + INC	0.38	70	89	965
LK_II + INC + FLR	0.125	100	88	595

Table 2.1.2.3: Costs data used in the RAINS model [8] for ORG PROC in Germany new Landers

	Emission factors kg VOC/kg VOC	Applicability %	Technical efficiency %	Cost € 1990/t VOC
Activity level 1990: 7.018 kt VOC, 2010: 14.035 kt VOC **VOC emissions scenario current regulation**: 1990: 7.018 kt VOC, 2010: 7.42 kt VOC				
No control	1.0	0	0	0
LK_I	0.88	20	60	1587
LK_II	0.86	20	70	5758
FLR	0.745	30	85	341
INC	0.52	50	96	778
LK_I + FLR	0.625	50	75	363
LK_I + INC	0.4	70	86	773
LK_I + INC + FLR	0.145	100	86	524
LK_II + FLR	0.605	50	79	467
LK_II + INC	0.38	70	89	965
LK_II + INC + FLR	0.125	100	88	595

Table 2.2.1.4: Costs data used in the RAINS models [8] for ORG PROC in Hungary

	Emission factors kg VOC/kg VOC	Applicability %	Technical efficiency %	Cost € 1990/t VOC
UK: activity level 1990: 1.289 kt VOC, 2010: 1.53 kt VOC **VOC emissions scenario business as usual**: 1990: 1.29 kt VOC, 2010: 1.53 kt VOC				
No control	1.0	0	0	0
LK_I	0.88	20	60	1587
LK_II	0.86	20	70	5758
FLR	0.745	30	85	341
INC	0.52	50	96	778
LK_I + FLR	0.625	50	75	363
LK_I + INC	0.4	70	86	773
LK_I + INC + FLR	0.145	100	86	524
LK_II + FLR	0.605	50	79	467
LK_II + INC	0.38	70	89	965
LK_II + INC + FLR	0.125	100	88	595

Data are also available for other Parties. They can be downloaded on IIASA’s web site [3]. Investments and operating costs are not more detailed in current available documents and CITEPA cannot present more explanations.

1.2 Other sources of data

The literature is quite poor concerning data on NMVOC emission reduction costs from the chemical industry. Most of data presented in this document have been obtained from industry (UIC [3] and CEFIC [4], producers of PVC [5], SICOS [6]).

3 References for the introduction

[1] MONZAIN M. (UIC) ; MONGENET F. (UIC) ; CASTRO F. (UIC): Meeting held in Paris on 21/08/02 with N. ALLEMAND and J. VINCENT from CITEPA aiming at defining the best approach for cost definition in the organic chemical sector. Minutes of the meeting.

[2] IPPCB
BREF large volume organic chemical industry
February 2003

[3] MONZAIN M. (UIC), LUYTEN P. (Atofina) and MARLIER G. (UIC): data collected in France for documenting the EGTEI work and the preparation and discussion of a project of regulation of fugitive emissions on steam crackers of the French ministry of environment.

[4] MONZAIN M. (UIC) ; DE MOULIN J.M. (CEFIC); HARSHAM K. (CEFIC) ; MARLIER G. (UIC) ; SCOLES G. (Shell chemicals) ; : Meeting held in Paris on 13/03/03 with N. ALLEMAND from CITEPA for the cost definition in steam cracking. Minutes of the meeting.

[5] Expert group from PVC manufacturers : TRIOPON S. (LVM); LIEGEOIS R. (Solvay); LOUIS H. (Atofina); BINDELLE J.P. (Solvay), DE CHAMPS F. (SPMP).

[6] SYNDICAT DE L'INDUSTRIE CHIMIQUE ORGANIQUE DE SYNTHESE ET DE LA BIOCHIMIE - INDUSTRIAL EXPERTS (RHODIA, AVENTIS, LIPHA, EXPANSIA, HOECHST MARION ROUSSEL, SANOFI, SIPSY CHIMIE FINE, ISOCHEM):

[7] KLIMONT Z. ; AMANN M. ; COFALA J. :
Estimating costs for controlling emissions of NMVOC from stationary sources in Europe
Report IR – 00- 51
IIASA – August 2000

[8] IIASA web site for NMVOC emission documents :
http://www.iiasa.ac.at/~rains/voc_review.html

Steam cracking

This section concerns the **steam cracking**.

Activity: production of ethylene and propylene (from steam cracking, that is to say that the extraction of propylene from refinery catalytic cracker off gas has not to be considered).
SNAP sources covered: SNAP 04 05 01 production of ethylene and SNAP 04 05 02 production of propylene (from steam crackers).
NFR 3C.
The document has been prepared on the basis of information provided by an expert group from UIC and CEFIC [5], [6] and the help of expert from ADEME.

1 Data from the literature

Please refer to chapter 2 of the introduction for detail.

2 Short technology description

Steam cracking units are complex installations in which suitable hydrocarbons (naphtha, gas-oil…) are heated to very high temperatures, in the presence of steam, to spilt the molecules into olefins of lower molecular weigh (unsaturated hydrocarbons: ethylene, propylene, butanes, butadienes). An excellent description of the process is given in the BREF document on large volume organic compounds [4]. The process can be divided in 3 sections :

- The pyrolysis section where the feedstock is converted into unsaturated compounds in a cracking furnace with superheated steam.
- The primary fractionation and compression section that consists of a primary fractionator, quench tower, gas compressor and gas cleaning up facilities [4].
- The product fractionation zone where fractionation towers are used to separate the desired products.

Olefin plants are part of integrated petrochemical and/or refining complex. Common utilities are provided by central facilities. It is very difficult to compare emissions from unit to unit since plant boundary definitions and degree of integration of each plant are different. All or part of the storage facilities for example can be present depending on the production structure and connexions with upstream and downstream units. Moreover, estimation of emissions is a difficult issue in this activity and methodologies used from plant to plant, country to country are not the same.

Different feed stocks produce different ethylene and propylene yields and ranges of products. When naphtha is used, ethylene and propylene represent 45 % of the product yields (other products are for example methane, propane, ethane, acetylene, butadiene, butylenes…) [4].

Figure 2.1 presents a simplified diagram of the process and associated units (storage…).
The code for characterising VOC emissions are issued from the EU VOC emission directive.
01: stack emissions
02: emissions of VOC from waste water treatment plant
04: fugitive emissions
Each source from one category is numbered (for example 04-1, fugitive emission from unloading ships and associated storages).

NOTE : In this document, only emissions from the flare, the process itself (channelled emissions and fugitive emissions) are considered. Emissions from storage are not taken into account under this document. In the scope of the EGTEI work, no working document has been developed for "storage of organic compound".

1. **VOC emissions from the flare systems:**

All steam crackers are equipped with flare gas systems to allow safe disposal of hydrocarbons or hydrogen that cannot be recovered in the process. Flaring is continuously operated and used during planned shutdowns, start-ups and unstable production periods. According to reference [4], based on an inquiry of CEFIC, hydrocarbon quantities sent to the flare range from 0,03 to 50 kg hydrocarbon per tonne ethylene. Table 2.1 presents the proportions of steam crackers emitting in different ranges of hydrocarbon per tonne of ethylene.

Table 2.1: Ranges of hydrocarbon quantities sent to the flare according to the enquiry of CEFIC [4]

kg hydrocarbon feed / t ethylene	Proportion of steam crackers with these emissions
0.03-2,2	1/3 of steam crackers
2,4-18	1/3 of steam crackers
21-50	1/3 of steam crackers

2. **Other VOC stack emissions (represented by 01 on figure 2.1):**

During normal operation, VOC emissions from the steam cracking process are recycled into the process, used as a fuel or routed to associated processes on an integrated site. Stack emissions are generally very low.

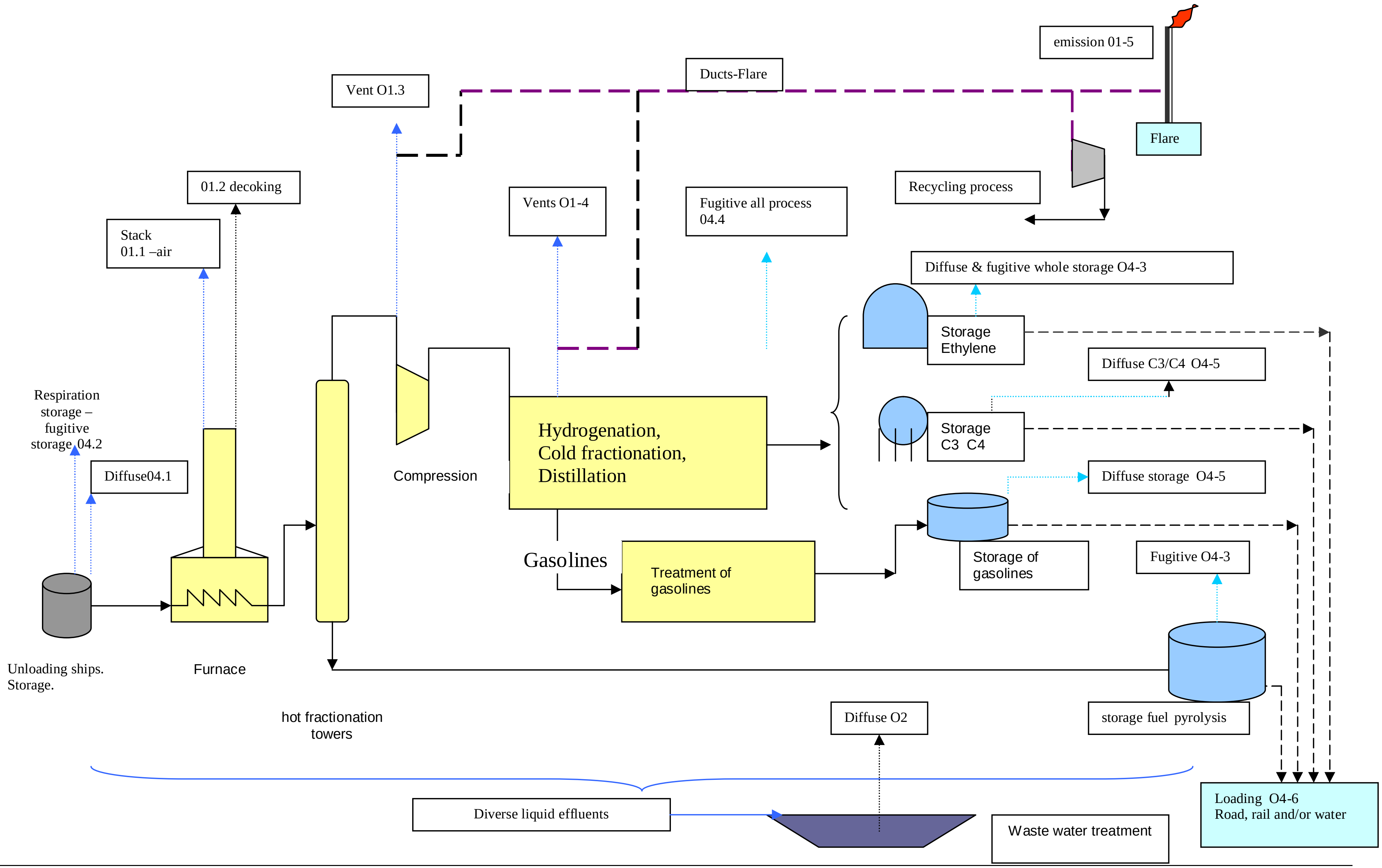
3. **Diffuse and fugitive VOC emissions (represented by 04 on figure 2.1):**

Steam crackers have a high number of components with potential leaking points of which could potentially arise fugitive emissions. Process streams are generally composed of light products (at least 20 % of substances with vapour pressure greater than 300 Pa at 20 °C) under high pressure (1500 – 3000 kPa) [4].
Fugitive emissions arise from: valve glands, pipe flanges, open ended lines, pressure relief valves, other piping components, pumps, compressors seals…

A steam cracker unit is stopped at regular intervals (periodicity may range from 4 to 5 years) for controls and maintenance.

Tightening of leaking equipment is an essential operation of a **Leak Detection And Repair programme (LDAR).** It can be achieved on line with the process in operation (**tightening operation**), but suppression of most important leaks can only be achieved during planned shutdowns with isolation and degassing of the corresponding sector. Dismantling or exchange of the pieces of equipment is required.

Figure 2.1: Steam cracking unit and its associated storage - sources of emissions



3 EU regulation

The chemical industry is concerned by Directive IPPC. No emission limits are implemented.

4 Definition of reference installations

From data collected by UIC at French level [5] and CEFIC at European level, the reference installation can be defined as a steam cracker with a capacity of 480 000 t of ethylene (the leading output of the cracker) and 270 000 t of propylene and naphtha as feedstock (the largest feedstock used).
Stack VOC emissions from the cracking process can be assumed to be recycled at a maximum level into the process or used as a fuel or routed to associated processes. Total emissions are about 50 t.
All steam crackers are equipped with elevated flare gas systems to allow efficient destruction of hydrocarbons or hydrogen that cannot be recovered in the process. The average efficiency is 99,5 % [5]. The presence of such an elevated flare is taken into account in the reference installation. Emissions are to be about 30 t (included in the 50t presented above).

The boundaries of the reference installation taken into account for estimating costs of reduction measures, exclude diffuse emissions from storage and loading/unloading operations. The grey zones on table 4.2 represent activities excluded.

On average according to UIC, this installation has about 50 000 potentially leaking points (valves, flanges, pumps, open ends…) of which 40 000 are accessible for control and repair. In the scope of this study, a simplified installation with 50 % valves and 50 % flanges is considered.

Table 4.1: Definition of the reference installation

Reference Installation Code	Description
01	Steam cracker unit with a capacity of 480 kt of ethylene + 270 kt propylene and naphtha as feed stock. Elevated flare systems with efficiency of 99.5%, VOC emission : 30 t/year. Other stack VOC emissions from the cracking process recycled into the process, used as a fuel or routed to associated processes and maintained as low as possible. Stack VOC emissions : 20 t/year. Without measure, total VOC emissions are 2500 t (other emissions come from storage and waste water treatment plant) 50 000 potentially leaking points (valves, pumps, flanges, open ends…); 40 000 accessible points : 50 % valves and 50 % flanges.

These assumptions are derived from data collected by UIC at French level [5] and CEFIC at European level. The different VOC emission sources from a steam cracker unit are described in table 4.2 for an installation without any program of emission reduction implemented [5]. It has to be outline that the measurement techniques used in Europe to estimate fugitive emissions from steam cracking units and other processes of the chemical industry are not yet well defined.
Emissions depend on the methodology used. The EPA 21 method [7] is used some times. This method begins to be used in France. There are discrepancies between emissions declared previously by industry and the emissions estimated with EPA 21 method. The EPA 21 presents several techniques for estimations. Each of these techniques gives different results **and this can have consequences on the cost effectiveness of the LDAR program.**

Fugitive emissions of the reference installation are defined with the use of correlation equations provided by US EPA for SOCMI (Synthetic Organic Chemicals Manufacturing Industry) [7]. From

measurement in ppm of VOC around a leaking point, the correlations give a quantity of VOC emitted in kg/year. EPA has established the correlation (table 5.1.3). Specific correlations defined by industry especially for steam cracking are existing. Generally the use of specific correlations gives lower emissions than the use of general SOCMI equations provided by EPA.
The CEN [8] is presently working on the redaction of a standard for the determination of leaks of VOC from process equipment. The use of EPA correlations is recommended if user defined correlations are not available.

Table 4.2: Ranges of emissions of a steam cracking unit without any program of emission reduction implemented (refer to figure 2.1 for characterising sources of VOC emissions).

Installation without any reduction technique	VOC emission t/year
Stack emissions	
Flux 01-1 – Stack	0.8
Flux 01-2 – Decoking	
Flux 01-3 – Compressors vents	10
Flux 01-4 – Vents - separation of products	10
Flux 01-5 – Flare	30(2)
Total stack emissions	**50**
Diffuse emissions	
Flux 04.1 – Storage of raw materials	100
Flux 02 – Waste water	100
Flux 04-5 – Storage of final products	100
Flux 04-6 – Loading and unloading	150
Total diffuse emissions	**450**
Fugitive emissions	
Flux 04-2 - Fugitive storage – raw material	100
Flux 04-3 - Fugitive storage - finished products	150
Flux 04-4 – Fugitive - process	2250
Total fugitive emissions	**2500**
Subtotal	**3000**

(1) Very different situations are met depending on production structure: raw materials supplied by pipe, ship, train, ... storage located in the upstream refinery or on site ... etc.
(2) Efficiency of the elevated flare is 99.5 %.

Figure 2.1 presents the simplified flowchart of the process and sources of NMVOC emissions.

5 Emission abatement techniques and costs

5.1 Definitions of primary measures

As explained in chapters 2 and 4, potential reductions only exist on NMVOC fugitive emissions but not on stack emissions that are well controlled. Fugitive emissions can be reduced through a Leak Detection And Repair programme [7].

The technique for LDAR consists in measuring the concentration of VOC in the atmosphere around the potential leak, then selecting equipments leaking over a defined threshold value and finally operating a repair on those leaking items.

A LDAR programme is established according to the following principles:
1 The definition of what constitutes a leak and fixation of corresponding thresholds,
2 The fixation of the frequency of inspections,
3 The listing and identification of components included,
4 The procedures concerning repair of leaking components depending of the leak category.

Repair procedures related to leak category considered in primary measures are indicated in table 5.1.1.

4 LDAR programmes are considered for the estimation of costs. They differ from the level of leak considered and type of maintenance carried out.

Table 5.1.1: Definition of leak and repair programme considered in primary measures 00 to 04

<table>
<tr><th></th><th>Leaks < 1000 ppm</th><th>Leaks from 1000 to 5000 ppm</th><th>Leaks from 5000 to 10000 ppm</th><th>Leaks from 10000 to 100000 ppm</th><th>Leaks > 100000 ppm</th></tr>
<tr><td>PMC 00</td><td colspan="5">No action on leaks</td></tr>
<tr><td>PMC 01</td><td>No action</td><td>No action</td><td>Tightening after detection</td><td>Tightening after detection</td><td>Tightening after detection and basic maintenance during scheduled shutdown</td></tr>
<tr><td>PMC 02</td><td>No action</td><td>Tightening after detection</td><td>Tightening after detection</td><td colspan="2">Tightening after detection and basic maintenance during scheduled shutdown</td></tr>
<tr><td>PMC 03</td><td>No action</td><td>Tightening after detection</td><td colspan="3">Tightening after detection and basic maintenance during scheduled shutdown</td></tr>
<tr><td rowspan="2">PMC 04</td><td rowspan="2">No action</td><td rowspan="2">Tightening after detection</td><td rowspan="2">Tightening after detection</td><td colspan="2">Tightening after detection and basic maintenance during scheduled shutdown for flanges</td></tr>
<tr><td colspan="2">Tightening after detection and heavy maintenance during scheduled shutdown for valves</td></tr>
</table>

Refer to the definitions here after

The following definitions have been considered:

Equipment tightening can be made with equipment **in operation** (except with remote control valves (eg tightening bolts to eliminate leaks from valves stems or flanges, installing tightening caps on open ends…).
Maintenance with dismantling equipment or exchange can only be implemented during plant shutdowns with circuits insulation and degassing. So, during plant shutdowns, two kinds of maintenance have been characterized:
Basic maintenance : maintenance on the equipment (flanges + valves) to remove some parts or to change the equipment with a new one of the same technology.
Heavy maintenance : complete change of the valves with valves of the higher grade standard, not leaking technology. Basic maintenance is maintained for the flanges.

It is considered that to **establish the LDAR program**, it is necessary to invest in a database with all potentially leaking points first measured (100 % of accessible points are considered and controlled). Then, the results of these first exhaustive measures campaign are analysed to initiate the repairing actions specific to each primary measures, including shutdown repairing. Then, each leak repaired is once again controlled to take in account the efficiency of the intervention.

For the following years, before next shutdown, the frequency of leak controls is estimated to 20 % of accessible points. Following the level of measured concentration, the leaking points (> 1 000 or 5 000 ppm depending of PMC) will be repaired by tightening on line.

At the next shutdown, the maintenance intervention (basic or heavy depending on PMC) will occur.

Table 5.1.2: Primary measure definition

Primary Measure	Description
00	No LDAR programme
01	**Establishment of the LDAR program** Inventory of all components and establishment of a database. First survey of all potential leak points of the plant (100 % of accessible points are considered and controlled), analysis of the first results of the survey. Tightening for points > 5 000 ppm Basic maintenance for 100 % points > 100 000 ppm during first shut down. **Annual control between two shutdowns** Intermediate campaign before shutdown: 20 % of accessible points are controlled each year (in five years all points are controlled). Tightening each year for 100 % controlled points > 5 000 ppm. **Next Shutdown.** Basic maintenance for 100 % measured points (during the 5 years) > 100 000 ppm.
02	**Establishment of the LDAR program** Inventory of all components and establishment of a database. First survey of all potential leak points of the plant (100 % of accessible points are considered and controlled), analysis of the first results of the survey. Tightening for points > 1000 ppm. Basic maintenance for points > 10 000 ppm during the first shut down. **Annual control between two shutdowns** Intermediate campaign before shutdown : 20 % of accessible points are controlled each year (in five years all points are controlled). Tightening each year for 100 % controlled points > 1 000 ppm. **Next Shutdown** Basic maintenance for 100 % measured points (during the 5 years) > 10 000 ppm.
03	**Establishment of the LDAR program** Inventory of all components and establishment of a database. First survey of all potential leak points of the plant (100 % of accessible points are considered and controlled), analysis of the first results of the survey. Tightening for points > 1 000 ppm . Basic maintenance for 100 % points > 5 000 ppm during the first shut down. **Annual control between two shutdowns** Intermediate campaign before shutdown : 20 % of accessible points are controlled each year (in five years all points are controlled). Tightening each year for 100 % measured points > 1 000 ppm. **Next Shutdown** Basic maintenance for 100 % measured points (during the 5 years) > 5 000 ppm.
04	**Establishment of the LDAR program** Inventory of all components and establishment of a database. First survey of all potential leak points of the plant (100 % of accessible points are considered and controlled), analysis of the first results of the survey. Tightening for points > 1 000 ppm Basic maintenance for flanges points >10 000 ppm during the first shut down. Heavy maintenance for valves points > 10 000 ppm during the first shut down. **Annual control between two shutdowns** Intermediate campaign before shutdown: 20 % of accessible points are controlled each year (in five years all points are controlled). Tightening each year for points > 1 000 ppm. **Next Shutdown** Basic maintenance for 100 % measured (during the 5 years) > 10 000 ppm. Heavy maintenance for 100 % measured (during the 5 years) > 10 000 ppm.

Correlation between ppm measurement and VOC emitted quantities :

The SOCMI correlations between screening values and emission rates are in the form [7]:

$$ER = A \cdot (SV)^B$$ with ER = emission rate in kg/h/pt and SV the screening value (ppm).

These correlations are valid between 0 and 100 000 ppm. For screening value higher than 100 000 ppm a fixed or pegged value is used always given by EPA.

The value of A and B parameters for the different equipment are as follows [7]:

Table 5.1.3: value of parameters A and B and of the pegged values according to SOCMI correlations [7]

Source	Service	A	B	Pegged value > 100000 ppm Kg/h
Valve	Gas	$1.87\ 10^{-6}$	0.873	0.110
Valve	Light liquid	$6.41\ 10^{-6}$	0.797	0.150
Pump seal	Light liquid	$1.90\ 10^{-5}$	0.824	0.620
Connector	All	$3.05\ 10^{-6}$	0.885	0.220

5.2 Secondary measures

No secondary measure is taken into account.

5.3 Emission factors, cost data and uncertainties of the different combinations

Table 5.3.1: Emission factors, investments, operating costs, abatement efficiencies and uncertainties for relevant combinations (€ 2000)

Combination Code	Emission Factor for NMVOC [kg/t ethylene + propylene]	Abatement efficiency %	Quality	CI %
01 00 00	3.40		2-3	100
01 01 00	1.87	45	2-3	100
01 02 00	1.65	51.5	2-3	100
01 03 00	1.56	54.1	2-3	100
01 04 00	1.52	55.3	2-3	100

Combination Code	Investment [€]	Fixed operating cost [€/y]	Operating costs [€/y]	Recovery of products [€/y]	Quality of cost data	CI %
01 00 00		No fixed operating cost taken into account				
01 01 00	469 860		67 970	229 450	2-3	100
01 02 00	694 240		99 580	262 430	2-3	100
01 03 00	942 140		133 380	276 090	2-3	100
01 04 00	2 181 650		286 280	282 350	2-3	100

The table 5.3.2 presents costs expressed in €/t VOC abated

Table 5.3.2 : Costs expressed in €/t VOC abated

Combination Code	Emission Factor for NMVOC kg/t [ethylene + propylene]	Annual total cost €/t VOC non emitted	Additional costs of each measure compared to the preceeding one €/ t NMVOC	Annual total cost per unit of activity €/t [ethylene + propylene]
01 00 00	3.40	0	0	
01 01 00	1.87	-90	0	-0.138
01 02 00	1.65	-59	156.5	-0.103
01 03 00	1.56	-19	752.8	-0.035
01 04 00	1.52	193	9630.4	+ 0.360

6 Data to be provided by national experts for the completion of the data basis for their country

The following tasks are required from experts:

6.1 Validation work

The national expert is invited to comment the methodology defined by the secretariat.

- Validation of the default investments provided,
- Validation of the method of derivation of operating costs,

Or

- Provide other costs for the same combination of techniques and justify them.

6.2 Provision of specific data

Tables to be filled in by national experts

- Determination of country specific data to calculate variable costs (Specific values for energy, man power… are valid for all NMVOC sectors and have to be entered in the tool only once)

Table 6.2.1: Country specific data

Parameters	Default data used for calculating costs	Country specific data
Naphtha [€/t]	200	
Wages [€/h]	25.9	

- Total activity level in accordance with units used in the document: t of ethylene + t propylene (produced by steam cracking) produced. Table 6.2.2 must be completed. Some default values for the confidence interval are given. A Party can use them if no data is available. The methodology used in Rains for estimating the future activity level will be described in the methodology. It can be used or information can be obtained from the industry.

Table 6.2.2: Activity levels on reference installations (t/y of ethylene + propylene)

RIC	2000	CI%	2005	CI%	2010	CI%	2015	CI%	2020	CI%
01										
Default values proposed for CI		10		20		50		100		100

For explanation on the confidence interval (Refer to the methodology chapter).

- Respective percentage of combinations of reduction measures in 2000 as well as if possible, the percentage of use in 2005, 2010, 2015 and 2020 due to the NMVOC directive or national regulations and applicability according to the definition used in the RAINS model.

Table 6.2.3: Application rate and applicability factor for each combination of reduction measures

Reduction measure combination for RIC 01			**Percentage of use in 2000 %**	**Percentage of use in 2005 %**	**Applicability factor 2005 %**	**Percentage of use in 2010 %**	**Applicability factor 2010 %**	**Percentage of use in 2015 %**	**Applicability factor 2015 %**	**Percentage of use in 2020 %**	**Applicability factor 2020 %**
RIC	**PMC**	**SMC**									
01	**00**	**00**									
Default value proposed for the applicability factor					100		100		100		100
01	**01**	**00**									
Default value proposed for the applicability factor					100		100		100		100
01	**02**	**00**									
Default value proposed for the applicability factor					100		100		100		100
01	**03**	**00**									
Default value proposed for the applicability factor					100		100		100		100
01	**04**	**00**									
Default value proposed for the applicability factor					100		100		100		100
Total			**100**	**100**		**100**		**100**		**100**	

The total of percentages of each combination or reduction technique must be 100 since the three combinations are assumed to represent the different situations in this activity.
The percentage of use of the different techniques depends on the Party's regulation. According to cases, combination 00 00 could be forbidden.

In the tool the absolute terms are directly entered (% for a given combination multiplied by the total activity)

7 Explanatory notes

7.1 Reference installation definition

The French Chemical Industry Federation UIC has carried out a study in order to supply the EGTEI work with data on emissions of steam cracking units. The reference installation presented in chapter 4.1 has been defined from data collected on different steam crackers in France and in Belgium [5]. The reference installation definition has also been discussed with CEFIC during the meeting of 13/03/03 held in Paris [6].

Only fugitive emissions from the production unit, channelled emissions and emissions at the flare are relevant in this context. Emissions from storages are not taken into account in this document

Elevated flares are considered to have an efficiency of 99,5 %. It can be assumed that everywhere in Europe vents are ducted to the flare with such an efficiency [5], [6].

Channelled emissions represent about 100 t NMVOC/year and cannot be easily reduced. No additional reduction of emissions option is available, when the best efficiency of vent collection towards the flare has been already implemented. It is considered that this situation is valid in Western Europe as well in Eastern Europe.

Consequently, the reference installation includes the presence of an elevated flare with an efficiency of 99,5% and vent collection for hydrocarbon recycling or hydrocarbon uses in downstream unit for limiting channelled emissions at minimum.

7.2 Definition of primary measures, derivation of emission factors

Fugitive emissions can be reduced through a Leak Detection And Repair programme (LDAR). To precise the definitions written in chapter 5.1 and to explain the cost results, it is assumed the following hypothesis :

Definition of what constitutes a leak: Table 5.1.1 presents concentration thresholds for determination of leak categories taken into account for each primary measure.
Leak classification is made from comparison between measured VOC concentration in the vicinity of leaking point and threshold values.

Inventory of equipment: A database is established. Components are classified in term of type, service and process conditions. For calculating emission factors and costs per point, only two types of equipment are taken into account for simplification reason: valves and flanges.

Non accessible leaking points: To estimate the NMVOC emission from the non accessible points, it has been considered the same average emission factor by equipment family (flanges or valves) reported to the 10 000 considered points (40 000 accessible points for 50 000 points). Obviously, no reduction impact is taken into account for these points whatever the Primary Measures chosen.

Efficiency of tightening: The efficiency of tightening is considered to be 50 % of emission reduction for leaks > 5 000 ppm (PMC 01) or > 1 000 ppm (PMC 02 – PMC 03 – PMC 04). This efficiency is only valid for the first operation when no actions has been achieved. The efficiency of the following tightening operations is lower and enables to maintain the emissions (Figure 7.2.1).

Efficiency of basic maintenance: The efficiency of basic maintenance is considered to be 80 % of emission reduction for leaks > 100 000 ppm (flanges + valves in PMC 01) or > 10 000 ppm (flanges + valves in PMC 02 – flanges in PMC 04) or > 5 000 ppm (flanges + valves in PMC 03). This efficiency is only valid for the first operation when no actions has been achieved. The efficiency of the following operations is lower and enables to maintain the emissions (Figure 7.2.1).

Efficiency of heavy maintenance: For PMC 04, the heavy intervention considered consists in replacing 100 % of valves with leak > 10 000 ppm with un-leaking valves. It has been assumed that leak higher than 100 000 ppm will appear again after that change but their number is reduced by the percentage of valve replaced.
Control is achieved on points that were detected leaking and tightening is carried out if necessary.

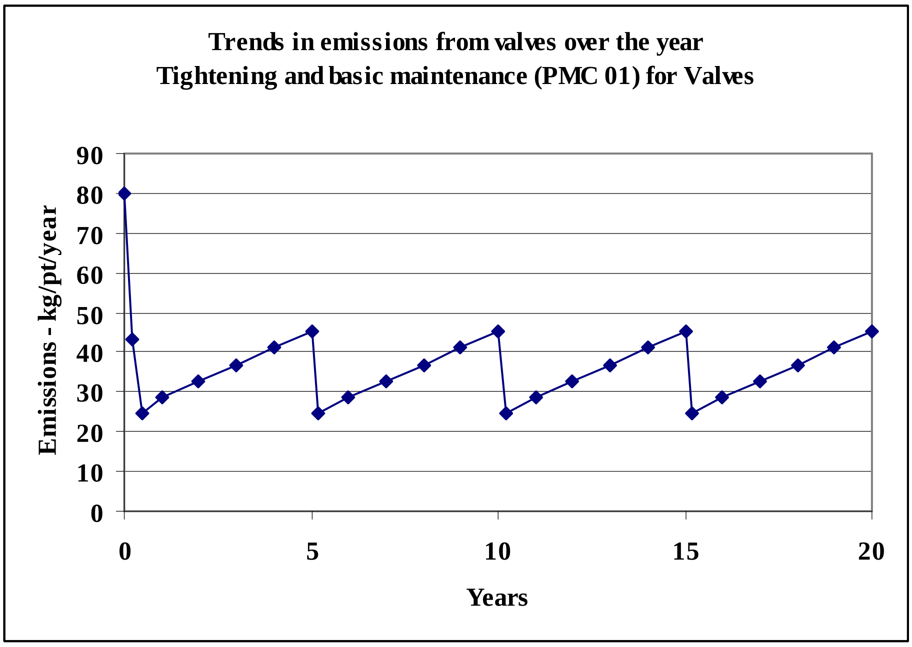
It is also assumed that the probability of emergence of new leaks is constant over time for each leak category so the average emission per point will increase linearly with time. (It is interesting to know that according to experience leaks appear in random manner). It is also assumed that if no action is taken after a maintenance campaign, the average emission value will reach the reference installation value after 10 years.
The probability of identifying medium or large leaks has been estimated on the basis of measurements made on several installations in France and Belgium [5] as well as specific emission reductions resulting from tightening or basic maintenance completed by expert judgement. The probability to meet leaks of each category is reduced after the first operation as the general standard of the installation is improved.

The efficiency of operations carried out with PMC 01, 02, 03 and 04 is presented in tables 7.2.1 to 7.2.4 for valves and in tables 7.2.5 and 7.2.8 for flanges.

References : Efficiencies are derived from the data collected by UIC [5].
UIC has provided data for the following ranges of leaks :
0-5000 ppm
5000-100 000 ppm
> 100 000 ppm

For calculation CITEPA ,in consultation with ADEME, has taken into account the following ranges :
0-1000 ppm
1000-5000ppm
5000-10 000 ppm
10 000-100 000 ppm
> 100 000 ppm

Figure 7.2.1 : Trends in emissions from accessible valves after tightening and basic maintenance from a situation where no action had been taken



It can be noticed that the first operation of tightening and basic maintenance on the leaking point (valves in steam cracking units) allows to reduce its emissions from 80 to about 25 kg/year. The operations of tightening and basic maintenance achieved after this first operation allow to maintain the emissions.

Table 7.2.1: Accessible valves - Hypothesis taken into account for estimating emissions of primary measure 01.

Ranges of leaks – ppm		**<1000**	**1000 to 5000**	**5000 to 10000**	**10000to100000**	**> 100000**
Levels of leaks		50	2500	7020	23000	pegged value
Emissions of VOC according to SOCMI equations						
Light liquid valves	kg/hr/pt	0.00014	0.00327	0.00745	0.01919	0.15
Light liquid pumps	kg/hr/pt	0.00048	0.01199	0.02806	0.07461	0.62
Average valves+pumps	kg/hr/pt	0.00031	0.00763	0.01776	0.04690	0.39
Number of hours of work	8600	h/year				
Light liquid valves	kg/year/pt	1.2	28.2	64.1	165.1	1290.0
Light liquid pumps	kg/year/pt	4.1	103.1	241.3	641.7	5332.0
Average valves + pumps	**kg/year/pt**	**2.0**	**46.9**	**108.4**	**284.2**	**2300.5**

Ranges of leaks - ppm		**<1000**	**1000 to 5000**	**5000 to 10000**	**10000to100000**	**> 100000**	**Total**
Percentage of leak according to the ranges of leaks	%	72.00%	10.00%	10.00%	6.00%	2.00%	**100%**
Average emissions	kg/year/pt	1.4	4.7	10.8	17.1	46.0	**80.0**
First operation - tightening of leak > 5000 ppm**							
Percentage of leak according to the ranges of leaks	%	81.00%	10.00%	5.00%	3.00%	1.00%	**100%**
Average emissions	kg/year/pt	1.6	4.7	5.4	8.5	23.0	**43.2**
Basic maintenance on valves with leaks > 100 000 ppm							
Percentage of leak according to the ranges of leaks	%	81.80%	10.00%	5.00%	3.00%	0.20%	**100%**
Average emissions	kg/year/pt	1.6	4.7	5.4	8.5	4.6	**24.8**
Emissions after 5 years is nothing has been done*							
Percentage of leak according to the ranges of leaks	%	76.30%	10.60%	7.50%	4.50%	1.10%	**100%**
Average emissions	kg/year/pt	1.5	5.0	8.1	12.8	25.3	**52.7**
After 5 years when tightening is operated							
Percentage of leak according to the ranges of leaks	%	80.67%	10.60%	5.00%	3.00%	0.73%	**100.%**
Average emissions	kg/year/pt	1.6	5.0	5.4	8.5	16.9	**37.4**
Average on the five year period							
Percentage of leak according to the ranges of leaks	%	80.14%	10.30%	5.63%	3.38%	0.56%	**100%**
Average emissions	kg/year/pt	1.6	4.8	6.1	9.6	12.8	**34.9**

*In 10 years, it is assumed that the proportions of leaks reach the initial level.
** the efficiency of tightening is assumed to be the same for valves with leak of 5000 to 100 000 ppm (50%).
*** See figure 7.2.2 for explanations on the average value on the period.

Table 7.2.2: Accessible valves - Hypothesis taken into account for estimating emissions of primary measure 02.

Ranges of leaks - ppm		**<1000**	**1000 to 5000**	**5000 to 10000**	**10000 to 100000**	**> 100000**
Levels of leaks		50	2500	7020	23000	pegged value
Emissions of VOC according to SOCMI equations						
Light liquid valves	kg/hr/pt	0.00014	0.00327	0.00745	0.01919	0.15
Light liquid pumps	kg/hr/pt	0.00048	0.01199	0.02806	0.07461	0.62
Average valves+pumps	kg/hr/pt	0.00031	0.00763	0.01776	0.04690	0.39
Number of hours of work	8600	h/year				
Light liquid valves	kg/year/pt	1.2	28.2	64.1	165.1	1290.0
Light liquid pumps	kg/year/pt	4.1	103.1	241.3	641.7	5332.0
Average valves+pumps	**kg/year/pt**	**2.0**	**46.9**	**108.4**	**284.2**	**2300.5**

Ranges of leaks - ppm		**<1000**	**1000 to 5000**	**5000 to 10000**	**10000 to 100000**	**> 100000**	**Total**
Percentage of leak according to the ranges of leaks	%	72.00%	10.00%	10.00%	6.00%	2.00%	**100%**
Average emissions	kg/year/pt	1.4	4.7	10.8	17.1	46.0	**80.0**
First operation - tightening of leak > 1000 ppm**							
Percentage of leak according to the ranges of leaks	%	86.00%	5.00%	5.00%	3.00%	1.00%	**100%**
Average emissions	kg/year/pt	1.7	2.3	5.4	8.5	23.0	**41.0**
Basic maintenance on valves with leaks > 10 000 ppm							
Percentage of leak according to the ranges of leaks	%	89.20%	5.00%	5.00%	0.60%	0.20%	**100%**
Average emissions	kg/year/pt	1.7	2.3	5.4	1.7	4.6	**15.8**
Emissions after 5 years is nothing has been done*							
Percentage of leak according to the ranges of leaks	%	80.60%	7.50%	7.50%	3.30%	1.10%	**100%**
Average emissions	kg/year/pt	1.6	3.5	8.1	9.4	25.3	**47.9**
After 5 years when tightening is operated							
Percentage of leak according to the ranges of leaks	%	87.07%	5.00%	5.00%	2.20%	0.73%	**100%**
Average emissions	kg/year/pt	1.7	2.3	5.4	6.3	16.9	**32.6**
Average on the five year period***							
Percentage of leak according to the ranges of leaks	%	86.52%	5.63%	5.63%	1.68%	0.56%	**100%**
Average emissions	kg/year/pt	1.7	2.6	6.1	4.8	12.8	**28.0**

* In 10 years, it is assumed that the proportions of leaks reach the initial level.
** the efficiency of tightening is assumed to be the same for valves with leak of 1000 to 100 000 ppm (50%).
*** See figure 7.2.3 for explanations on the average value on the period.

Table 7.2.3: Accessible valves - Hypothesis taken into account for estimating emissions of primary measure 03.

Ranges of leaks – ppm		**<1000**	**1000 to 5000**	**5000 to 10000**	**10000 to 100000**	**> 100000**
Levels of leaks		50	2500	7020	23000	pegged value
Emissions of VOC according to SOCMI equations						
Light liquid valves	kg/hr/pt	0.00014	0.00327	0.00745	0.01919	0.15
Light liquid pumps	kg/hr/pt	0.00048	0.01199	0.02806	0.07461	0.62
Average valves+pumps	kg/hr/pt	0.00031	0.00763	0.01776	0.04690	0.39
Number of hours of work	8600	h/year				
Light liquid valves	kg/year/pt	1.2	28.2	64.1	165.1	1290.0
Light liquid pumps	kg/year/pt	4.1	103.1	241.3	641.7	5332.0
Average valves+pumps	kg/year/pt	2.0	46.9	108.4	284.2	2300.5

Ranges of leaks – ppm		**<1000**	**1000 to 5000**	**5000 to 10000**	**10000 to 100000**	**> 100000**	**Total**
Percentage of leak according to the ranges of leaks	%	72.00%	10.00%	10.00%	6.00%	2.00%	**100%**
Average emissions	kg/year/pt	1.4	4.7	10.8	17.1	46.0	**80.00**
First operation - tightening of leak > 1000 ppm**							
Percentage of leak according to the ranges of leaks	%	86.00%	5.00%	5.00%	3.00%	1.00%	**100%**
Average emissions	kg/year/pt	1.7	2.3	5.4	8.5	23.0	**41.0**
Basic maintenance on valves with leaks > 5 000 ppm							
Percentage of leak according to the ranges of leaks	%	93.20%	5.00%	1.00%	0.60%	0.20%	**100%**
Average emissions	kg/year/pt	1.8	2.3	1.1	1.7	4.6	**11.6**
Emissions after 5 years is nothing has been done*							
Percentage of leak according to the ranges of leaks	%	82.60%	7.50%	5.50%	3.30%	1.10%	**100%**
Average emissions	kg/year/pt	1.6	3.5	6.0	9.4	25.3	**45.8**
After 5 years when tightening is operated							
Percentage of leak according to the ranges of leaks	%	88.40%	5.00%	3.67%	2.20%	0.73%	**100%**
Average emissions	kg/year/pt	1.7	2.3	4.0	6.3	16.9	**31.2**
Average on the five year period***							
Percentage of leak according to the ranges of leaks	%	89.35%	5.63%	2.79%	1.68%	0.56%	**100%**
Average emissions	kg/year/pt	1.8	2.6	3.0	4.8	12.8	**25.0**

* In 10 years, it is assumed that the proportions of leaks reach the initial level.
** the efficiency of tightening is assumed to be the same for valves with leak of 5000 to 100 000 ppm (50%).
*** See figure 7.2.4 for explanations on the average value on the period.

Table 7.2.4: Accessible valves - Hypothesis taken into account for estimating emissions of primary measure 04.

Ranges of leaks - ppm		**<1000**	**1000 to 5000**	**5000 to 10000**	**10000 to 100000**	**> 100000**
Levels of leaks		50	2500	7020	23000	
Emissions of VOC according to SOCMI equations						
Light liquid valves	kg/hr/pt	0.00014	0.00327	0.00745	0.01919	0.15
Light liquid pumps	kg/hr/pt	0.00048	0.01199	0.02806	0.07461	0.62
Average valves+pumps	kg/hr/pt	0.00031	0.00763	0.01776	0.04690	0.39
Number of hours of work	8600	h/year				
Light liquid valves	kg/year/pt	1.2	28.2	64.1	165.1	1290.0
Light liquid pumps	kg/year/pt	4.1	103.1	241.3	641.7	5332.0
Average valves+pumps	kg/year/pt	2.0	46.9	108.4	284.2	2300.5

Ranges of leaks – ppm		**<1000**	**1000 to 5000**	**5000 to 10000**	**10000 to 100000**	**> 100000**	**Total**
Percentage of leaks according to the ranges of leaks	%	72.00%	10.00%	10.00%	6.00%	2.00%	**100.00%**
Average emissions	kg/year/pt	1.4	4.7	10.8	17.1	46.0	**80.00**
First operation - tightening of leak > 1000 ppm**							
Percentage of leaks according to the ranges of leaks	%	86.00%	5.00%	5.00%	3.00%	1.00%	**100.00%**
Average emissions	kg/year/pt	1.7	2.3	5.4	8.5	23.0	**41.0**
Changes of valves with leaks > 10 000 ppm							
Percentage of leaks according to the ranges of leaks	%	90.00%	5.00%	5.00%	0.00%	0.00%	**100.00%**
Average emissions	kg/year/pt	1.8	2.3	5.4	0.0	0.0	**9.5**
Emissions after 5 years is nothing has been done*							
Percentage of leaks according to the ranges of leaks	%	81.16%	7.50%	7.50%	2.88%	0.96%	**100.00%**
Average emissions	kg/year/pt	1.6	3.5	8.1	8.2	22.1	**43.5**
After 5 years when tightening is operated							
Percentage of leaks according to the ranges of leaks	%	87.44%	5.00%	5.00%	1.92%	0.64%	**100.00%**
Average emissions	kg/year/pt	1.7	2.3	5.4	5.5	14.7	**29.7**
Average on the five year period***							
Percentage of leaks according to the ranges of leaks	%	87.15%	5.63%	5.63%	1.20%	0.40%	**100.00%**
Average emissions	kg/year/pt	1.7	2.6	6.1	3.4	9.2	**23.1**

* In 10 years, it is assumed that the proportions of leaks reach the initial level.
** the efficiency of tightening is assumed to be the same for valves with leak of 1000 to 100 000 ppm (50%).
*** See figure 7.2.5 for explanations on the average value on the period.

Table 7.2.5: Accessible flanges - Hypothesis taken into account for estimating emissions of primary measure 01.

Ranges of leaks – ppm		**<1000**	**1000 to 5000**	**5000 to 10000**	**10000 to 100000**	**> 100000**
Levels of leaks		10	2000	7500	34000	pegged value
Emissions of VOC according to SOCMI equations						
Connectors	kg/hr/pt	0.00002	0.00255	0.00820	0.03124	0.22
Number of hours of work	8600	h/year				
Connectors	kg/year/pt	0.2	21.9	70.5	268.6	1892.0

Ranges of leaks – ppm		**<1000**	**1000 to 5000**	**5000 to 10000**	**10000 to 100000**	**> 100000**	**Total**
Percentage of leak according to the ranges of leaks	%	92.00%	4.00%	2.00%	1.25%	0.75%	**100%**
Average emissions	kg/year/pt	0.2	0.9	1.4	3.4	14.2	**20.0**
First operation - tightening of leak > 5000 ppm**							
Percentage of leak according to the ranges of leaks	%	93.92%	4.08%	1.00%	0.63%	0.38%	**100%**
Average emissions	kg/year/pt	0.2	0.9	0.7	1.7	7.1	**10.6**
Basic maintenance on flanges with leaks > 100 000 ppm							
Percentage of leak according to the ranges of leaks	%	94.20%	4.10%	1.00%	0.63%	0.08%	**100%**
Average emissions	kg/year/pt	0.2	0.9	0.7	1.7	1.4	**4.9**
Emissions after 5 years is nothing has been done*							
Percentage of leak according to the ranges of leaks	%	93.10%	4.05%	1.50%	0.94%	0.41%	**100%**
Average emissions	kg/year/pt	0.2	0.9	1.1	2.5	7.8	**12.5**
After 5 years when tightening is operated							
Percentage of leak according to the ranges of leaks	%	94.00%	4.10%	1.00%	0.63%	0.28%	**100%**
Average emissions	kg/year/pt	0.2	0.9	0.7	1.7	5.2	**8.7**
Average on the five year period***							
Percentage of leak according to the ranges of leaks	%	93.88%	4.08%	1.13%	0.70%	0.21%	**100%**
Average emissions	kg/year/pt	0.2	0.9	0.8	1.9	4.0	**7.7**

* In 10 years, it is assumed that the proportions of leaks reach the initial level.
** the efficiency of tightening is assumed to be the same for flanges with leak of 5000 to 100 000 ppm (50%).
*** See figure 7.2.6 for explanations on the average value on the period.

Table 7.2.6: Accessible flanges - Hypothesis taken into account for estimating emissions of primary measure 02.

Ranges of leaks – ppm		**<1000**	**1000 to 5000**	**5000 to 10000**	**10000 to 100000**	**> 100000**
Levels of leaks		10	2000	7500	34000	pegged value
Emissions of VOC according to SOCMI equations						
Connectors	kg/hr/pt	0.00002	0.00255	0.00820	0.03124	0.22
Number of hours of work	8600	h/year				
Connectors	kg/year/pt	0.2	21.9	70.5	268.6	1892.0

Ranges of leaks – ppm		**<1000**	**1000 to 5000**	**5000 to 10000**	**10000 to 100000**	**> 100000**	**Total**
Percentage of leak according to the ranges of leaks	%	92.00%	4.00%	2.00%	1.25%	0.75%	**100%**
Average emissions	kg/year/pt	0.2	0.9	1.4	3.4	14.2	**20.0**
First operation - tightening of leak > 1000 ppm**							
Percentage of leak according to the ranges of leaks	%	96.00%	2.00%	1.00%	0.63%	0.38%	**100%**
Average emissions	kg/year/pt	0.2	0.4	0.7	1.7	7.1	**10.1**
Basic maintenance on flanges with leaks > 10 000 ppm							
Percentage of leak according to the ranges of leaks	%	96.80%	2.00%	1.00%	0.13%	0.08%	**100%**
Average emissions	kg/year/pt	0.2	0.4	0.7	0.3	1.4	**3.1**
Emissions after 5 years is nothing has been done*							
Percentage of leak according to the ranges of leaks	%	94.40%	3.00%	1.50%	0.69%	0.41%	**100%**
Average emissions	kg/year/pt	0.2	0.7	1.1	1.8	7.8	**11.6**
After 5 years when tightening is operated							
Percentage of leak according to the ranges of leaks	%	96.27%	2.00%	1.00%	0.46%	0.28%	**100%**
Average emissions	kg/year/pt	0.2	0.4	0.7	1.2	5.2	**7.8**
Average on the five year period							
Percentage of leak according to the ranges of leaks	%	96.07%	2.25%	1.13%	0.35%	0.21%	**100%**
Average emissions	kg/year/pt	0.2	0.5	0.8	0.9	4.0	**6.4**

* In 10 years, it is assumed that the proportions of leaks reach the initial level.
** the efficiency of tightening is assumed to be the same for flanges with leak of 5000 to 100 000 ppm (50%).
*** See figure 7.2.7 for explanations on the average value on the period.

Table 7.2.7: Accessible flanges - Hypothesis taken into account for estimating emissions of primary measure 03.

Ranges of leaks – ppm		**<1000**	**1000 to 5000**	**5000 to 10000**	**10000 to 100000**	**> 100000**
Levels of leaks		10	2000	7500	34000	pegged value
Emissions of VOC according to SOCMI equations						
Connectors	kg/hr/pt	0.00002	0.00255	0.00820	0.03124	0.22
Number of hours of work	8600	h/year				
Connectors	kg/year/pt	0.2	21.9	70.5	268.6	1892.0

Ranges of leaks – ppm		**<1000**	**1000 to 5000**	**5000 to 10000**	**10000 to 100000**	**> 100000**	**Total**
Percentage of leak according to the ranges of leaks	%	92.00%	4.00%	2.00%	1.25%	0.75%	**100%**
Average emissions	kg/year/pt	0.2	0.9	1.4	3.4	14.2	**20.0**
First operation - tightening of leak > 1000 ppm							
Percentage of leak according to the ranges of leaks	%	96.00%	2.00%	1.00%	0.63%	0.38%	**100%**
Average emissions	kg/year/pt	0.2	0.4	0.7	1.7	7.1	**10.1**
Basic maintenance on flanges with leaks > 5 000 ppm							
Percentage of leak according to the ranges of leaks	%	97.60%	2.00%	0.20%	0.13%	0.08%	**100%**
Average emissions	kg/year/pt	0.2	0.4	0.1	0.3	1.4	**2.5**
Emissions after 5 years is nothing has been done							
Percentage of leak according to the ranges of leaks	%	94.80%	3.00%	1.10%	0.69%	0.41%	**100%**
Average emissions	kg/year/pt	0.2	0.7	0.8	1.8	7.8	**11.3**
After 5 years when tightening is operated							
Percentage of leak according to the ranges of leaks	%	96.53%	2.00%	0.73%	0.46%	0.28%	**100%**
Average emissions	kg/year/pt	0.2	0.4	0.5	1.2	5.2	**7.6**
Average on the five year period							
Percentage of leak according to the ranges of leaks	%	96.63%	2.25%	0.56%	0.35%	0.21%	**100%**
Average emissions	kg/year/pt	0.2	0.5	0.4	0.9	4.0	**6.0**

* In 10 years, it is assumed that the proportions of leaks reach the initial level.
** the efficiency of tightening is assumed to be the same for flanges with leak of 1000 to 100 000 ppm (50%).
*** See figure 7.2.8 or explanations on the average value on the period.

Table 7.2.8: Accessible flanges - Hypothesis taken into account for estimating emissions of primary measure 04.

Ranges of leaks – ppm		**<1000**	**1000 to 5000**	**5000 to 10000**	**10000 to 100000**	**> 100000**
Levels of leaks		10	2000	7500	34000	pegged value
Emissions of VOC according to SOCMI equations						
Connectors	kg/hr/pt	0.00002	0.00255	0.00820	0.03124	0.22
Number of yours of work	8600	h/year				
Connectors	kg/year/pt	0.2	21.9	70.5	268.6	1892.0

Ranges of leaks – ppm		**<1000**	**1000 to 5000**	**5000 to 10000**	**10000 to 100000**	**> 100000**	**Total**
Percentage of leak according to the ranges of leaks	%	92.00%	4.00%	2.00%	1.25%	0.75%	**100.00%**
Average emissions	kg/year/pt	0.2	0.9	1.4	3.4	14.2	**20.0**
First operation - tightening of leak > 1000 ppm**							
Percentage of leak according to the ranges of leaks	%	96.00%	2.00%	1.00%	0.63%	0.38%	**100.00%**
Average emissions	kg/year/pt	0.2	0.4	0.7	1.7	7.1	**10.1**
Basic maintenance of flanges with leaks > 10 000 ppm							
Percentage of leak according to the ranges of leaks	%	96.80%	2.00%	1.00%	0.13%	0.08%	**100.00%**
Average emissions	kg/year/pt	0.2	0.4	0.7	0.3	1.4	**3.1**
Emissions after 5 years is nothing has been done*							
Percentage of leak according to the ranges of leaks	%	94.40%	3.00%	1.50%	0.69%	0.41%	**100.00%**
Average emissions	kg/year/pt	0.2	0.7	1.1	1.8	7.8	**11.6**
After 5 years when tightening is operated							
Percentage of leak according to the ranges of leaks	%	96.27%	2.00%	1.00%	0.46%	0.28%	**100.00%**
Average emissions	kg/year/pt	0.2	0.4	0.7	1.2	5.2	**7.8**
Average on the five year period***							
Percentage of leak according to the ranges of leaks	%	96.07%	2.25%	1.13%	0.35%	0.21%	**100.00%**
Average emissions	kg/year/pt	0.2	0.5	0.8	0.9	4.0	**6.4**

* In 10 years, it is assumed that the proportions of leaks reach the initial level.
** the efficiency of tightening is assumed to be the same for flanges with leak of 1000 to 100 000 ppm (50%).
*** See figure 7.2.9 or explanations on the average value on the period.

Figure 7.2.2: Accessible valves - Calculations of average emissions for the period of 5 years - PMC 01.

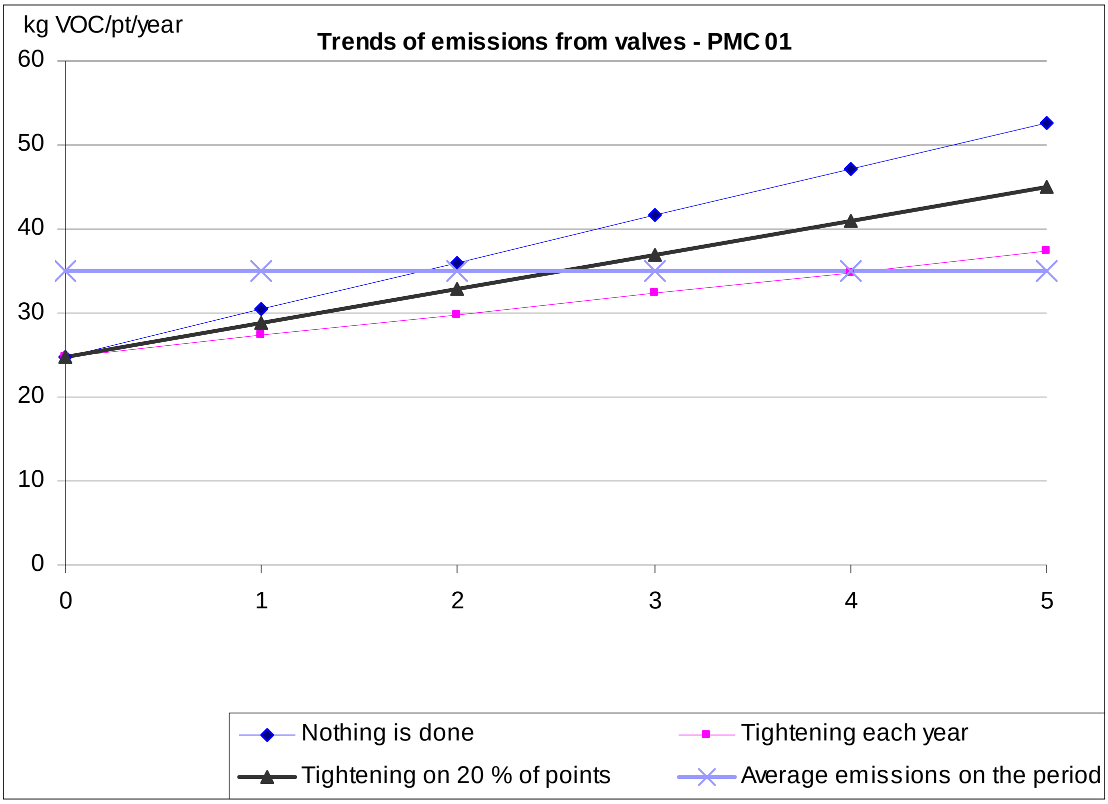


Figure 7.2.3: Accessible valves - Calculations of average emissions for the period of 5 years - PMC 02.

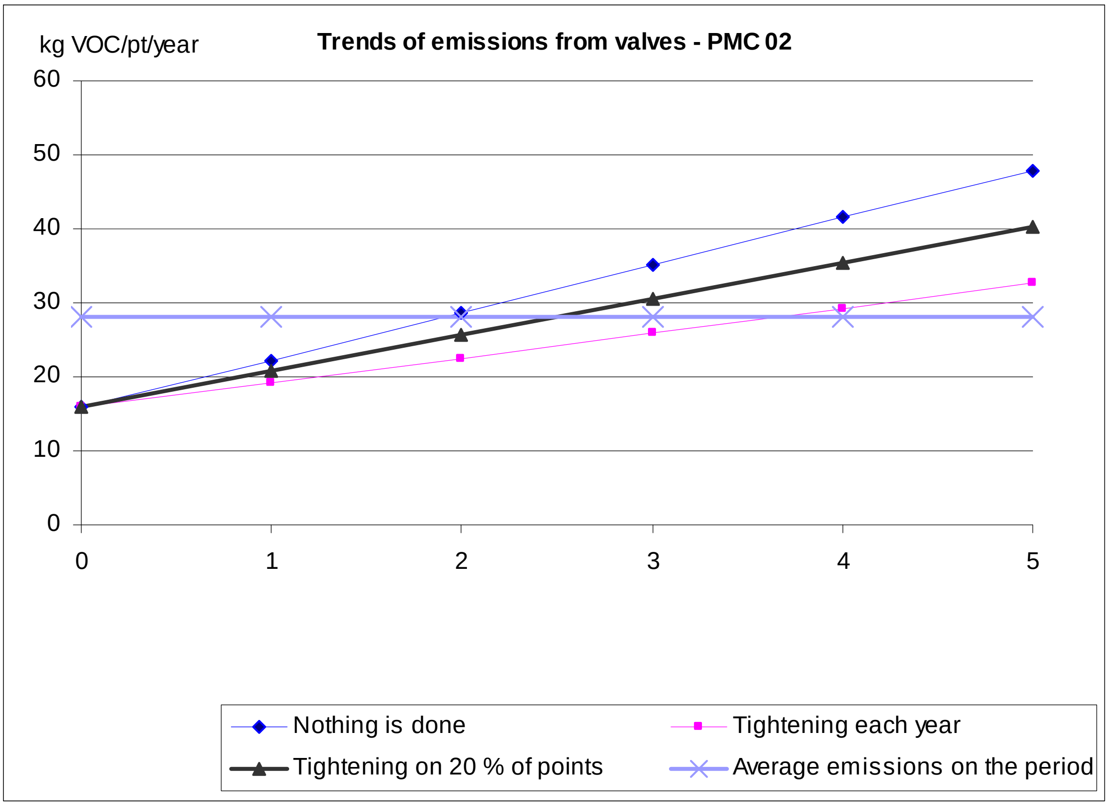


Figure 7.2.4: Accessible valves - Calculations of average emissions for the period of 5 years - PMC 03.

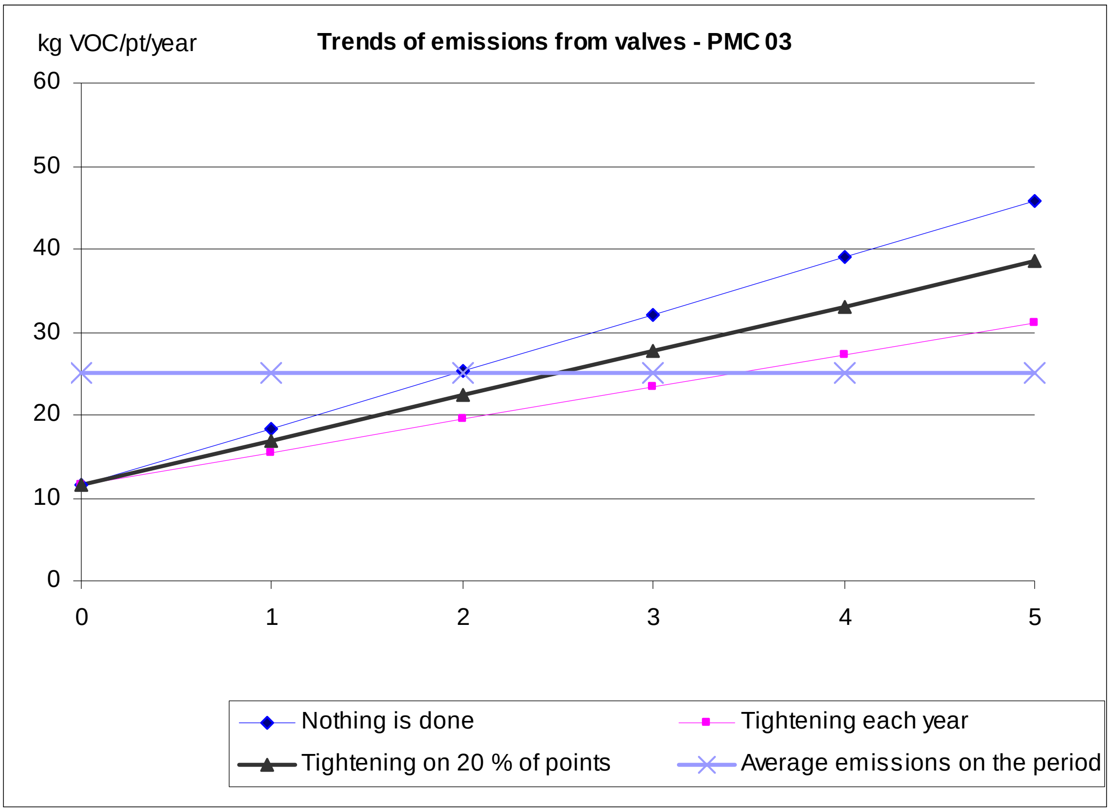


Figure 7.2.5 : Accessible valves - Calculations of average emissions for the period of 5 years – PMC 04.

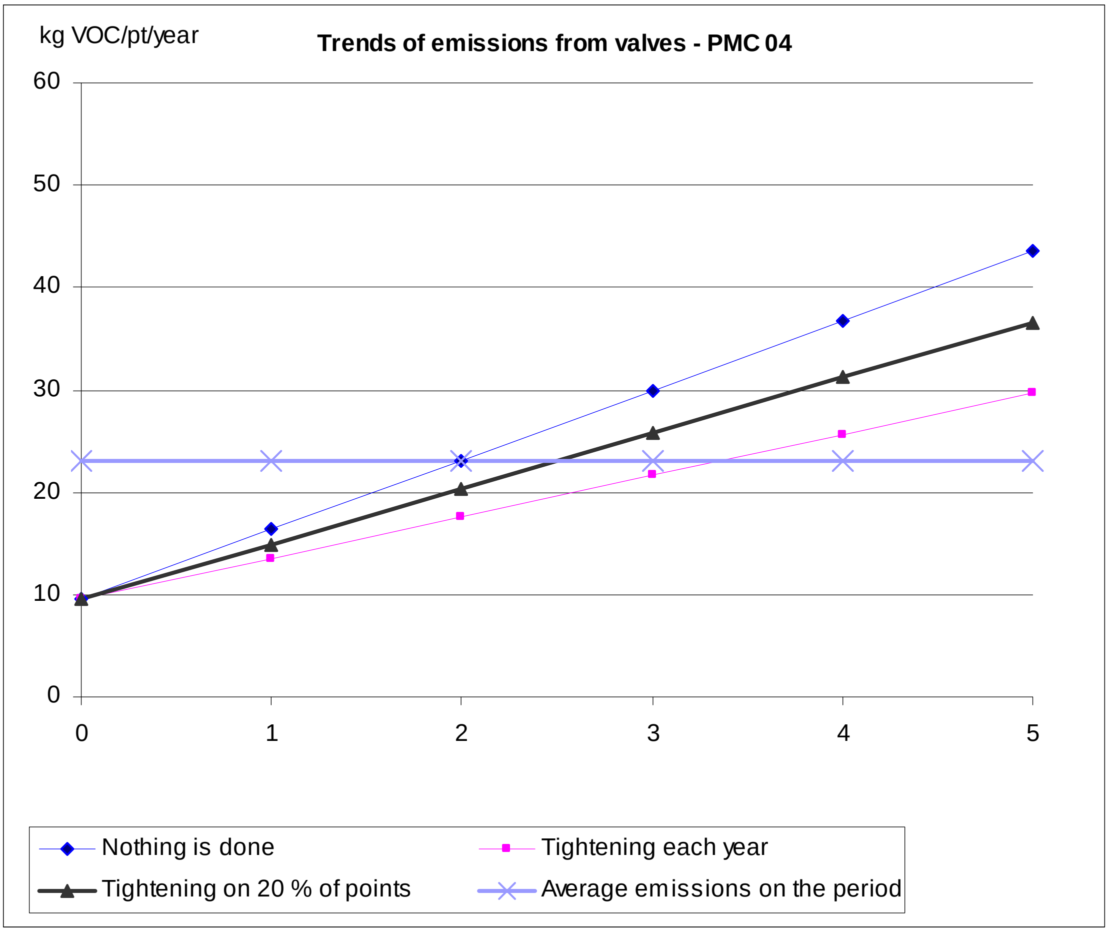


Figure 7.2.6: Accessible flanges - Calculations of average emissions for the period of 5 years - PMC 01.

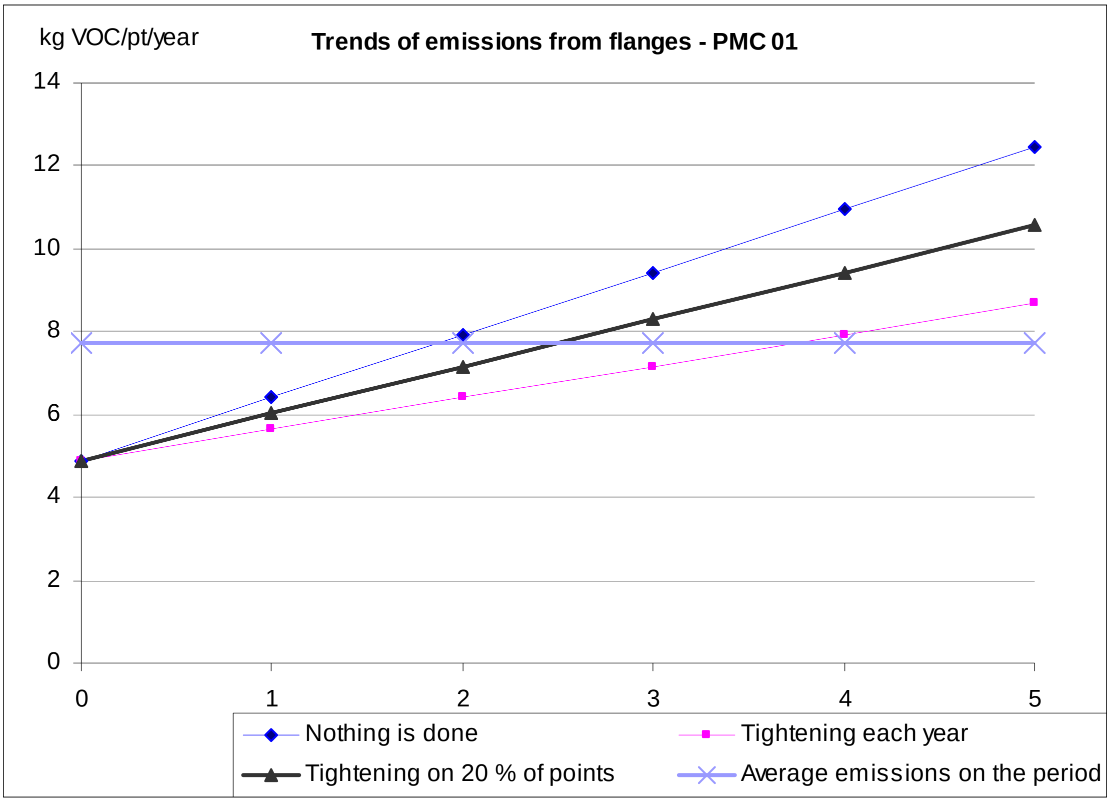


Figure 7.2.7: Accessible flanges - Calculations of average emissions for the period of 5 years - PMC 02.

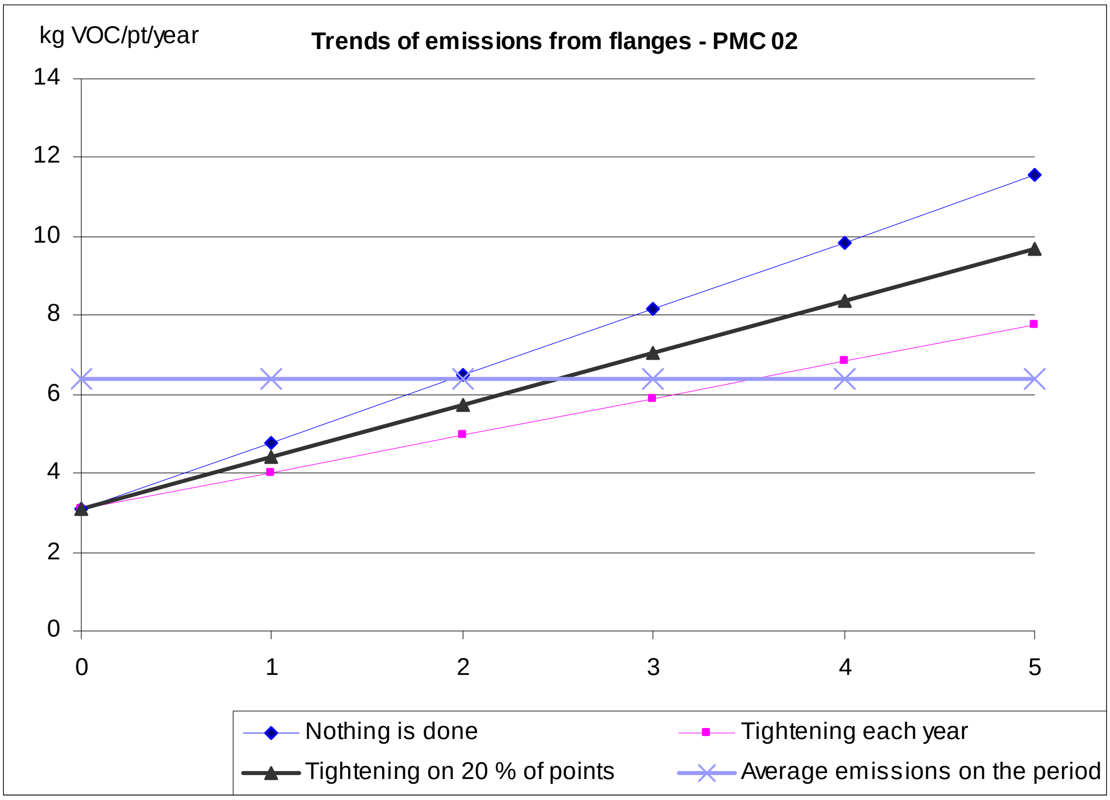


Figure 7.2.8: Accessible flanges - Calculations of average emissions for the period of 5 years - PMC 03.

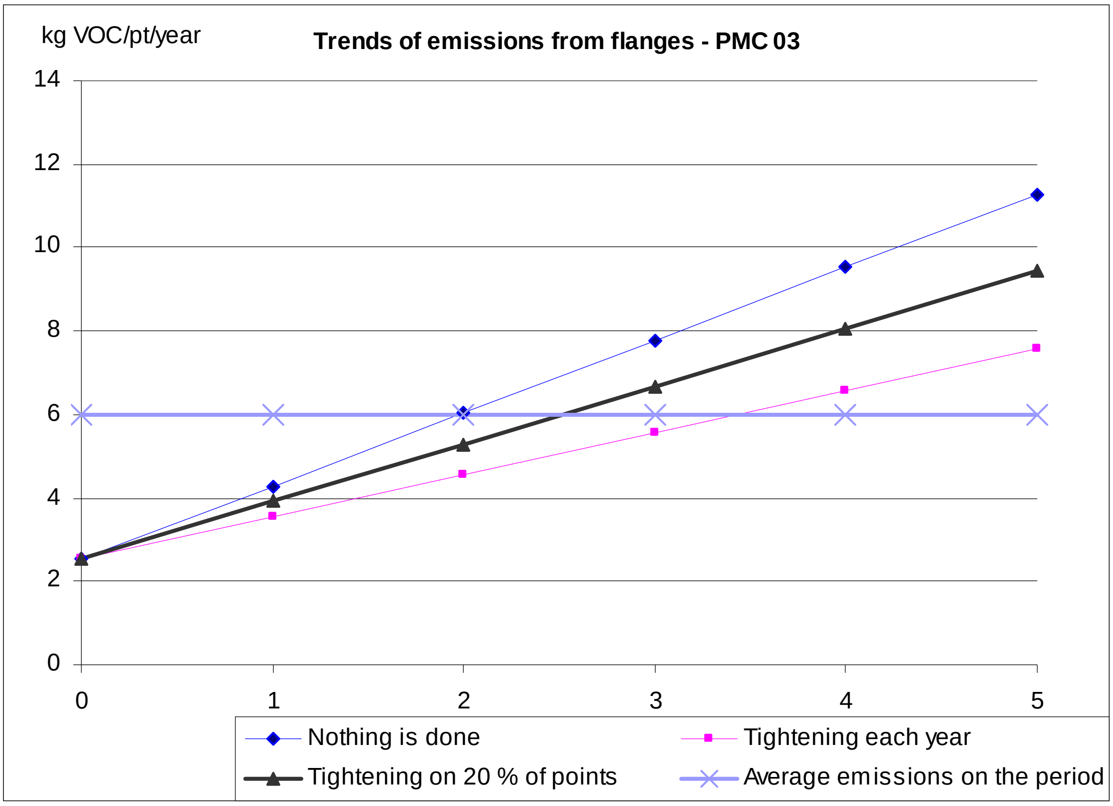
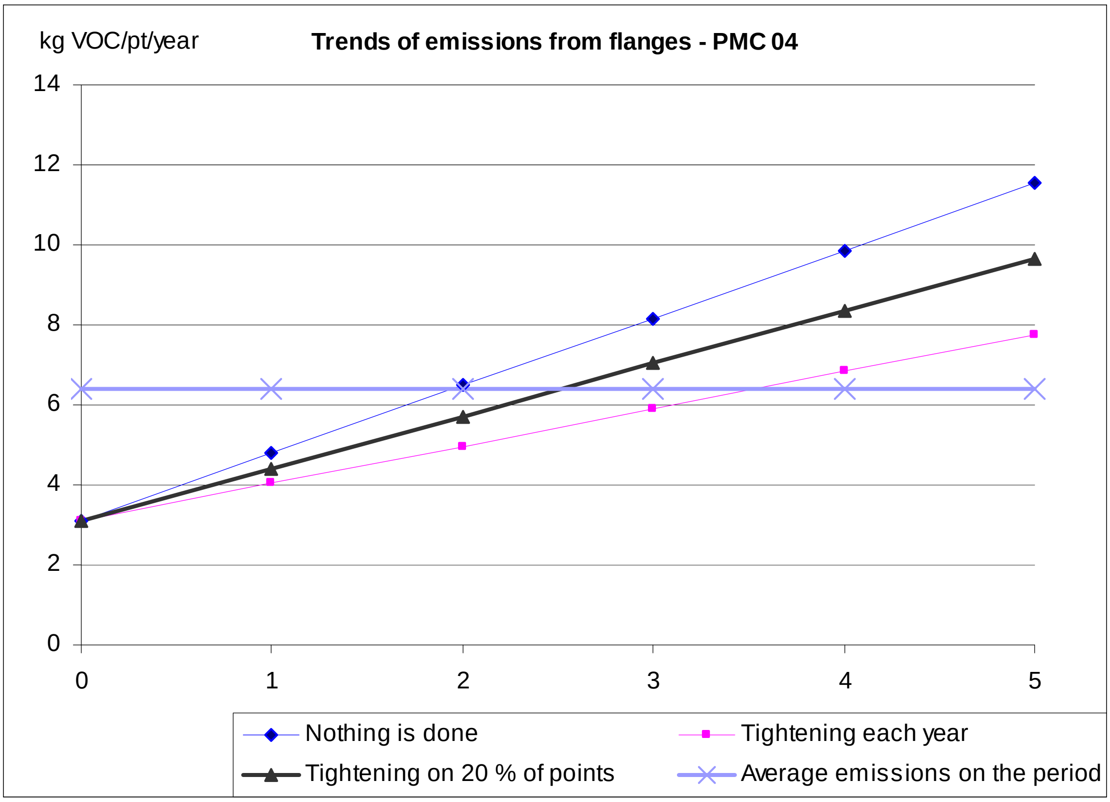


Figure 7.2.9: Accessible flanges - Calculations of average emissions for the period of 5 year - PMC 04.



Tables 7.2.9 to 7.2.12 present the calculations of emissions for the reference installation for primary measures 01 and 02.

Table 7.2.9: NMVOC emissions with primary measure 00 and primary measure 01

	Valves **NMVOC t/year**	**Flanges** **NMVOC t/year**	**Total emissions t NMVOC/y**	**NMVOC emissions kg/t ethyl.+propyl.**
Elevated flare			30	0.04
Channelled emissions			20	0.03
Fugitive emissions on inaccessible points	5000*0.08=400	5000*0.02=100	500	0.67
Fugitive emissions with PMC 00	20000*0.08=1600	20000*0.02=400	2000	2.67
Fugitive emissions with PMC 01	20000*0.0349= 699	20000*0.0077= 155	853	1.14
Emissions avoided with PMC 01	901	246	1147	1.53
Total emissions with PMC 00			**2550** (30+20+500+2000)	**3.40**
Total emissions with PMC 01			**1403** (30+20+500+853)	**1.87**

Table 7.2.10: NMVOC emissions with primary measure 00 and primary measure 02

	Valves **NMVOC t/year**	**Flanges** **NMVOC t/year**	**Total emissions t NMVOC/y**	**NMVOC emissions kg/t ethyl.+propyl.**
Elevated flare			30	0.04
Channelled emissions			20	0.03
Fugitive emissions on inaccessible points	5000*0.08=400	5000*0.02=100	500	0.67
Fugitive emissions with PMC 00	20000*0.08=1600	20000*0.02=400	2000	2.67
Fugitive emissions with PMC 02	20000*0.028= 561	20000*0.0064= 128	688	0.92
Emissions avoided with PMC 02	1039	273	1312	1.75
Total emissions with PMC 00			**2550** (30+20+500+2000)	**3.40**
Total emissions with PMC 02			**1238** (30+20+500+688)	**1.65**

Table 7.2.11: NMVOC emissions with primary measure 00 and primary measure 03

	Valves **NMVOC t/year**	**Flanges** **NMVOC t/year**	**Total emissions t NMVOC/y**	**NMVOC emissions kg/t ethyl.+propyl.**
Elevated flare			30	0.04
Channelled emissions			20	0.03
Fugitive emissions on inaccessible points	5000*0.08=400	5000*0.02=100	500	0.67
Fugitive emissions with PMC 00	20000*0.08=1600	20000*0.02=400	2000	2.67
Fugitive emissions with PMC 03	20000*0.025= 500	20000*0.0060= 120	620	0.83
Emissions avoided with PMC 03	1100	280	1380	1.84
Total emissions with PMC 00			**2550** (30+20+500+2000)	**3.40**
Total emissions with PMC 03			**1170** (30+20+500+620)	**1.56**

Table 7.2.12: NMVOC emissions with primary measure 00 and primary measure 04

	Valves **NMVOC t/year**	**Flanges** **NMVOC t/year**	**Total emissions t NMVOC/y**	**NMVOC emissions kg/t ethyl.+propyl.**
Elevated flare			30	0.04
Channelled emissions			20	0.03
Fugitive emissions on inaccessible points	5000*0.08=400	5000*0.02=100	500	0.67
Fugitive emissions with PMC 00	20000*0.08=1600	20000*0.02=400	2000	2.67
Fugitive emissions with PMC 04	20000*0.0232= 461	20000*0.0064= 128	589	0.78
Emissions avoided with PMC 04	1139	273	1412	1.88
Total emissions with PMC 00			**2550** (30+20+500+2000)	**3.40**
Total emissions with PMC 04			**1139** (30+20+500+589)	**1.52**

7.3 Derivation of costs

Cost for the database establishment : the first measurement (100 % of points), the first tightening and the first basic or heavy maintenance have been considered as **investment costs**, even if labour costs are mainly involved.

Annual operation cost is composed of the control of 20 % of points and the tightening of leaking points (leaking level depending of PMC) It includes also 20 % of the cost of basic or heavy maintenance, carried out on a five year basis during shutdown.

Costs for France are as follows (according to data collected by UIC [5])

	Composition of costs	**Labour demand per point h/pt**	**Cost for France (labour cost 24.3 €/h)**
Data base	50 % labour cost 50 % material	0.04 -	1.0 €/pt 1.0 €/pt
Control by sniffing	100 % labour cost	0.2	5.0 €/pt
Tightening including checking control	100 % labour cost	0.8	20.0 €/pt
Basic maintenance	50 % labour cost 50 % material	4.1 -	100 €/pt 100 €/pt
Heavy maintenance			2 000 €/pt

Default costs taken into account in this documents are as follows :

	Composition of costs	**Labour demand per point h/pt**	**Cost per default (labour cost 25.9 €/h)**
Data base	50 % labour cost 50 % material	0.04 -	1.1 €/pt 1.0 €/pt
Control by sniffing	100 % labour cost	0.2	5.3 €/pt
Tightening including checking control	100 % labour cost	0.8	21.3 €/pt
Basic maintenance	50 % labour cost 50 % material	4.1 -	106.6 €/pt 100 €/pt
Heavy maintenance			2 066 €/pt

Table 7.3.1 to 7.3.4 present the total costs determined respectively for PMC 01, PMC 02, PMC 03 and PMC 04

Table 7.3.1 : Total default costs determined for primary measure 01.

		Valves			Flanges			Total
		Material cost	**Labour cost**	**Total cost**	**Material cost**	**Labour cost**	**Total cost**	
Investments - Establishment of a first LDAR program								
Investment for the data base	€	20000	21317	**41317**	20000	21317	**41317**	**82634**
First monitoring of all points	€	0	106584	**106584**	0	106584	**106584**	**213169**
Tightening on leaking points > 5000 ppm	€/operation	0	76741	**76741**	0	17053	**17053**	**93794**
Basic maintenance during shutdown on leaks > 100000 ppm	€/basic maintenance	20000	21317	**41317**	7500	7994	**15494**	**56811**
Second control: Monitoring on potential leaking points	€/verification monitoring	0	19185	**19185**	0	4263	**4263**	**23449**
Total investment	**€**	**40000**	**245144**	**285144**	**27500**	**157212**	**184712**	**469856**
Annualized costs (4%)	€/year			**35158**			**22775**	**57933**
Annual costs between two scheduled shutdowns								
Yearly action on 20 % points and 0,2 basic maintenance or heavy maintenance taken into account								
Monitoring of points	€/year	0	21317	21317	0	21317	**21317**	**42634**
Tightening on leaking points > 5000 ppm	€/year	0	11170	11170	0	2430	**2430**	**13600**
Basic maintenance on leaking points > 100 000 ppm	€/year	2933	3126	6060	1100	1172	**2272**	**8332**
Second control : monitoring of potential leaking points	€/year	0	2793	2793	0	608	**608**	**3400**
Total operation cost	**€/year**	**2933**	**38406**	**41339**	**1100**	**25527**	**26627**	**67966**
Total annual cost*	**€/year**			**76497**			**49402**	**125899**
Recovered VOC **	**€/year**			**180279**			**49170**	**229449**

* Annualized cost + operation cost

** Mass of VOC recovered (t) x 200 €/t

Table 7.3.2 : Total default costs determined for primary measure 02.

		Valves			Flanges			Total
		Material cost	Labour cost	Total cost	Material cost	Labour cost	Total cost	
Investments - Establishment of a first LDAR program								
Investment for the data base	€	20000	21317	**41317**	20000	21317	**41317**	**82 634**
First monitoring of all points	€	0	106584	**106584**	0	106584	**106584**	**213 169**
Tightening on leaking points > 1000 ppm	€/operation	0	119374	**119374**	0	34107	**34107**	**153 481**
Basic maintenance during shutdown on leaks > 10 000 ppm	€/basic maintenance	80000	85267	**165267**	20000	21317	**41317**	**206 584**
Second control: Monitoring on potential leaking points	€/verification monitoring	0	29844	**29844**	0	8527	**8527**	**38 370**
Total investment	**€**	**100000**	**362387**	**462387**	**40000**	**191852**	**231852**	**694 239**
Annualized costs (4%)	€/year			**57012**			**28587**	**85 600**
Annual costs between two scheduled shutdowns								
Yearly action on 20 % points and 0,2 basic maintenance or heavy maintenance taken into account								
Monitoring of points	€/year	0	21317	21317	0	21317	**21317**	**42 634**
Tightening on leaking points > 1000 ppm	€/year	0	16542	16542	0	4775	**4775**	**21 317**
Basic maintenance on leaking points > 10 000 ppm	€/year	11733	12506	24239	2933	3126	**6060**	**30 299**
Second control : monitoring of potential leaking points	€/year	0	4135	4135	0	1194	**1194**	**5 329**
Total operation cost	**€/year**	**11733**	**54500**	**66233**	**2933**	**30412**	**33345**	**99 579**
Total annual cost*	**€/year**			**123246**			**61933**	**185 179**
Recovered VOC**	**€/year**			**207870**			**54564**	**262 434**

* Annualized cost + operation cost
** Mass of VOC recovered (t) x 200 €/t

Table 7.3.3 : Total costs determined for primary measure 03.

		Valves			Flanges			Total
		Material cost	**Labour cost**	**Total cost**	**Material cost**	**Labour cost**	**Total cost**	
Investments - Establishment of a first LDAR program								
Investment for the data base	€	20000	21317	**41317**	20000	21317	**41317**	**82634**
First monitoring of all points	€	0	106584	**106584**	0	106584	**106584**	**213169**
Tightening on leaking points > 1000 ppm	€/operation	0	119374	**119374**	0	34107	**34107**	**153481**
Basic maintenance during shutdown on leaks > 5000 ppm	€/basic maintenance	180000	191852	**371852**	40000	42634	**82634**	**454486**
Second control: Monitoring on potential leaking points	€/verification monitoring	0	29844	**29844**	0	8527	**8527**	**38370**
Total investment	**€**	**200000**	**468971**	**668971**	**60000**	**213169**	**273169**	**942140**
Annualized costs (4%)	€/year			**82484**			**33682**	**116166**
Annual costs between two scheduled shutdowns								
Yearly action on 20 % points and 0,2 basic maintenance or heavy maintenance taken into account								
Monitoring of points	€/year	0	21317	21317	0	21317	**21317**	**42634**
Tightening on leaking points > 1000 ppm	€/year	0	14837	14837	0	4434	**4434**	**19270**
Basic maintenance on leaking points > 5 000 ppm	€/year	26400	28138	54538	5867	6253	**12120**	**66658**
Second control : monitoring of potential leaking points	€/year	0	3709	3709	0	1108	**1108**	**4818**
Total operation cost	**€/year**	**26400**	**68001**	**94401**	**5867**	**33112**	**38979**	**133380**
Total annual cost*	**€/year**			**176885**			**72661**	**249546**
Recovered VOC **	**€/year**			**219935**			**56157**	**276092**

* Annualized cost + operation cost

** Mass of VOC recovered (t) x 200 €/t

Table 7.3.4 : Total costs determined for primary measure 04

		Valves			Flanges			Total
		Material cost	**Labour cost**	**Total cost**	**Material cost**	**Labour cost**	**Total cost**	
Investments - Establishment of a first LDAR program								
Investment for the data base	€	20000	21317	**41317**	20000	21317	**41317**	**82634**
First monitoring of all points	€	0	106584	**106584**	0	106584	**106584**	**213169**
Tightening on leaking points > 1000 ppm	€/operation	0	119374	**119374**	0	34107	**34107**	**153481**
Basic maintenance during shutdown on flanges with leaks > 10000 ppm	€/basic maintenance	0	0	**0**	20000	21317	**41317**	**41317**
Heavy maintenance during shutdown on valves with leaks > 10000 ppm	€/heavy maintenance	800000	852675	**1652675**	0	0		**1652675**
Second control: Monitoring on potential leaking point	€/verification monitoring	0	29844	**29844**	0	8527	**8527**	**38370**
Total investment	**€**	**820000**	**1129794**	**1949794**	**40000**	**191852**	**231852**	**2181646**
Annualized costs (4%)	€/year			**240410**			**28587**	**268997**
Annual costs between two scheduled shutdowns								
Yearly action on 20 % points and 0,2 basic maintenance or heavy maintenance taken into account								
20 % of points each year	€/year	0	21317	21317	0	21317	**21317**	**42634**
Tightening on leaking point > 1000 ppm	€/year	0	16064	16064	0	4775	**4775**	**20839**
Basic maintenance on leaking flanges > 10 000 ppm	€/year	0	0	0	2933	3126	**6060**	**6060**
Heavy maintenance on leaking valves > 10 000 ppm	€/year	102400	109142	211542	0	0	**0**	**211542**
Monitoring on potential leaking point	€/year	0	4016	4016	0	1194	**1194**	**5210**
Total operation cost	**€/year**	**102400**	**150540**	**252940**	**2933**	**30412**	**33345**	**286285**
Total annual cost	**€/year**			**493349**			**61933**	**555282**
Recovered VOC	**€/year**			**227791**			**54564**	**282354**

* Annualized cost + operation cost
** Mass of VOC recovered (t) x 200 €/t
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8 Comments

Chapter to be completed with comments received from national experts

It has been noticed the size of the reference installation has been underestimated. The capacity of production of the reference installation is not 550 kt but 750 kt. In order to be totally coherent with the references installations of the document 9, the share of valves and flanges has been changed from 46/60 to 50/50. All changes have been operated in the different chapters concerned.
The modifications give different emission factors and costs. The changes concern mainly :
Page 12 : modification of figures of production,
Page 13 : modification of the table,
Page 14 and 15 : some details
Page 17 : emission factors and costs modified,
Page 18 : emission factors and costs modified,
Table 7.2.9 to 7.2.12 modified,
Tables 7.3.1 to 7.3.4 modified.

Following re-lecture and work, some mistakes have been detected. Costs were derived from French costs (wages 24.3 €/h). The default value (25.9) for wage is taken into account to present the costs in the new version.
Corrections made are as follows:
Point 3: no sanitary impact instead of sanitary impact
Table 4.1: 50/50 instead of 40/60
Table 5.3.1: Confidence interval 100 instead of 200
New investment and operation costs
Table 5.3.2: new costs for annual total costs per tonne NMVOC non emitted and addition of a nex column for costs per activity unit.
Table 6.2.1: 25.9 instead of 24.3
Page 41 additional explanations
Tables 7.3.1 to 7.3.4 modified

9 References for steam cracking chapter

[1] MONZAIN M. (UIC) ; MONGENET F. (UIC) ; CASTRO F. (UIC): Meeting held in Paris on 21/08/02 with N. ALLEMAND and J. VINCENT from CITEPA aiming at defining the best approach for cost definition in the organic chemical sector. Minutes of the meeting.

[2] KLIMONT Z. ; AMANN M. ; COFALA J. :
Estimating costs for controlling emissions of NMVOC from stationary sources in Europe
Report IR – 00- 51
IIASA – August 2000

[3] IIASA web site for NMVOC emission documents :
http://www.iiasa.ac.at/~rains/voc_review.html

[4] IPPCB
BREF large volume organic chemical industry
February 2003

[5] MONZAIN M. (UIC), LUYTEN P. (Atofina) and MARLIER G. (UIC): data collected in France for documenting the EGTEI work and the preparation and discussion of a project of regulation of fugitive emissions on steam crackers of the French ministry of environment.

[6] MONZAIN M. (UIC) ; DE MOULIN J.M. (CEFIC); HARSHAM K. (CEFIC) ; MARLIER G. (UIC) ; SCOLES G. (Shell chemicals): Meeting held in Paris on 13/03/03 with N. ALLEMAND from CITEPA for the cost definition in steam cracking. Minutes of the meeting.

[7] EPA
Protocol for equipment leak
Emissions estimates
EPA 453-95-017 – 1995

[8] CEN TC 264
TC 264 WI 17
Measurement of fugitive emission of vapours generating from equipment and piping leaks
Paper not yet public
2003

[9] Union of Chemical industries
"Guide de mise en place d'un schema de maîtrise des emissions de COVNM des unités de production de la pétrochimie et des procédés associés".
In preparation -

PVC suspension

This section concerns the PVC production.

<u>Activity:</u> production of PVC by the suspension process.
Part of SNAP 040508.
NFR 3C
The document has been prepared on the basis of information provided by an expert group from Solvay, Atofina, LVM and SPMP [1].

1 Data from the literature

Please refer to chapter 2 of the introduction for detail.

2 Short technology description

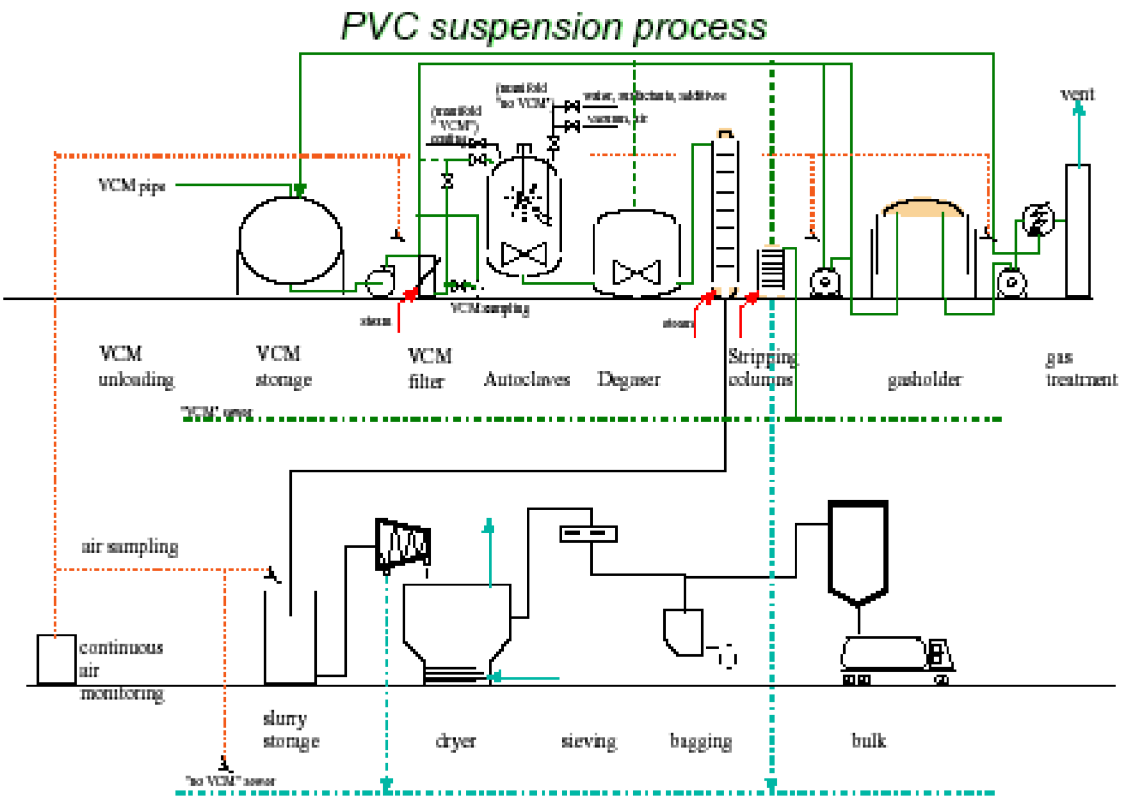
Suspension Polymerisation (Batch Process)

The suspension process for producing PVC resins is characterised by the formation of polymer in droplets of liquid vinyl chloride monomer (VCM) or other co-monomers suspended in water by agitation. Polymerisation starts by adding monomer-soluble initiators, then addition of suspension stabilisers and suspending agents minimises the coalescence of the grains.

Polyvinylchloride resin, unreacted VCM (in the water, in the headspace, and trapped in the resin) and water are the constituents remaining in the polymerisation reactor. Generally, this polymer slurry is stripped of unreacted VCM using steam and vacuum. This can be done in the reactor itself or in a separate vessel or column. The unreacted stripped VCM is purified, stored and recycled, and non-condensable gases are vented after treatment.

After stripping, the slurry of PVC containing very low amount of VCM is transferred to blend tanks which mix the batch with other batches to insure product uniformity. The mixed batches are then fed to a continuous centrifuging operation that separates the polymer from the water in the slurry. Both, mixing tanks and centrifuges are vented to the atmosphere. The centrifuge water is recycled back to the process or discharged to the plant's wastewater treatment system after stripping.

The wet cake from centrifuging is conveyed to a dryer for further removal of the remaining (usually 25 %) moisture. Drying time is generally short, but large volumes of air are released.



Emission Sources
The major emissions to air are vinyl chloride and only traces of other organics.

During the PVC suspension production, process emission sources include:

- VCM unloading and storage,
- opening of equipment for cleaning and maintenance,
- process vents, such as blending tank vents, monomer recovery system vents, and dryer exhaust vents,
- equipment leaks from valves, flanges, pumps, compressors, relief devices, sample connections, and open-ended lines,
- other diffuse sources such as gasholders and wastewater.

Most of the emission factors from the literature are obsolete, due to constant improvement of s-PVC technology and industrial practices. Common values in Western Europe for process emissions are below 100 g/Mg product after 2000 (ECVM Industry Charter for the Production of VCM and PVC – 2000). Most of VOC is VCM.
Accidental emissions by pressure relief device discharges are not included. They are reported to the local authorities.

3 EU regulation

The chemical industry is concerned by Directive IPPC. No emission limits are implemented.

4 Definition of reference installations

The reference unit is a 250 kt/yr plant, at the 1970 stage, consisting of a very basic suspension process, without any stripping or recovery of VOC.

Table 4.1: Definition of the reference installation

Reference Installation Code	Description
01	250 kt/yr plant, life time : 10 years Plant factor [h/year] : 8000

5 Emission abatement techniques and costs

5.1 Definitions of primary measures

Technical Aspects

The losses due to leakage can be limited by use of a certain type of gaskets, flanges, pumps packing and seals, and by use of continuous VCM emissions monitoring.
Such modifications have been introduced by the Western Europe s-PVC industry since 1974.

Economic Aspects

No information on costs for primary measures is available for the considered processes.

5.2 Definitions of secondary measures

Technical Aspects

- Stripping the residual VCM and vent gas treatment which are the most consistent measures in terms of COV reduction.
- Diffuse and fugitive emission treatment program according to ECVM methodologies (LDAR-Leak Detection And Repair),
- Optimisation of different emission treatments, most of them in combination, depending the specific process or local conditions (stripping, vent gas, closed lid reactor, closed sampling,…)

Table 5.2.1 : Secondary measures definition

Secondary measures	Description
01 00 00	None
01 00 01	Stripping and vent gas treatment
01 00 02	01 00 01 + Diffuse and fugitive emissions treatment program according to ECVM methodologies
01 00 03	01 00 01 + Optimised treatments (stripping, vent gas, closed lid reactor, closed sampling,…)
01 00 04	01 00 03 + Diffuse and fugitive emissions treatment program according to ECVM methodologies

Many "open reactors" have already been replaced by "closed reactors"; but this closed reactors technology cannot be generalised because it does not allow to manufacture some grades of PVC.

"Open reactor" means reactor open after each polymerisation batch for examination and cleaning if necessary; in "closed reactor", the process, depending the PVC grade manufactured, has been automated, avoiding to open the reactor, and allowing a cleaning after 30 operations or more. In both cases, the reactor is purged before opening and corresponding VCM is recycled.

5.3 Emission factors, costs data and uncertainties of the different combinations

Table 5.3.1 : Emission factors, investments and operating costs, abatement efficiency and uncertainties

Combination code	Emission Factor for VCM [g/tPVC]	Abatement efficiency %	CI %	Quality
01 00 00	30000	0	10	4
01 00 01	96	99.68	100	4
01 00 02	83	99.72	110	4
01 00 03	53	99.82	90	4
01 00 04	40	99.87	100	4

Combination Code	Investment [kEUR]	CI %	Q	Fixed Operating Cost [kEUR/a]	CI %	Q	Variable Operating Cost [kEUR/a]	CI %	Q
01 00 00	0			0			0		
01 00 01	7700	40	3	200	40	3	1200	100	3
01 00 02	7900	40	3	400	30	3	1200	100	3
01 00 03	42100	20	3	1200	30	3	1300	90	3
01 00 04	42300	20	3	1300	20	3	1300	90	3

Only the techniques specifically identified in chapter 5 (table Secondary measures/Description) have been considered in the above costs. Costs for other measures taken by the PVC industry to reduce emissions since the seventies have not been included (e.g. equipment upgrades, fixed monitoring systems for measuring VCM concentrations in the atmosphere, process improvements, special procedures, etc).

6 Data to be provided by national experts for the completion of the data basis for their country

The following tasks are required from experts:

6.1 Validation work

The national expert is invited to comment the methodology defined by the secretariat.

- Validation of the default investments provided,
- Validation of the method of derivation of operating costs,

Or

- Provide other costs for the same combination of techniques and justify them.

6.2 Provision of specific data

Tables to be filled in by national experts

- Determination of country specific data to calculate variable costs (Specific values for energy, man power… are valid for all NMVOC sectors and have to be entered in the tool only once)

- Total activity level. Table 6.2.2 must be completed. Some default values for the confidence interval are given. A Party can use them if no data is available.
The methodology used in Rains for estimating the future activity level will be described in the methodology. It can be used or information can be obtained from the industry.

Table 6.2.1: Activity levels on reference installations (t/y of PVC)

RIC	2000	CI%	2005	CI%	2010	CI%	2015	CI%	2020	CI%
01										
Default values proposed for CI		10		20		50		100		100

For explanation on the confidence interval (Refer to the methodology chapter).

- Respective percentage of combinations of reduction measures in 2000 as well as if possible, the percentage of use in 2005, 2010, 2015 and 2020 due to the NMVOC directive or national regulations and applicability according to the definition used in the RAINS model.

Table 6.2.2: Application rate and applicability factor for each combination of reduction measures

Reduction measure combination for RIC 01			**Percentage of use in 2000 %**	**Percentage of use in 2005 %**	**Applicability factor 2005 %**	**Percentage of use in 2010 %**	**Applicability factor 2010 %**	**Percentage of use in 2015 %**	**Applicability factor 2015 %**	**Percentage of use in 2020 %**	**Applicability factor 2020 %**
RIC	**PMC**	**SMC**									
01	**00**	**00**									
Default value proposed for the applicability factor					100		100		100		100
01	**00**	**01**									

Default value proposed for the applicability factor			100		100		100		100
01 00 02									
Default value proposed for the applicability factor			100		100		100		100
01 00 03									
Default value proposed for the applicability factor			100		100		100		100
01 00 04									
Default value proposed for the applicability factor			100		100		100		100
Total	**100**	**100**		**100**		**100**		**100**	

The total of percentages of each combination or reduction technique must be 100 since the three combinations are assumed to represent the different situations in this activity.
The percentage of use of the different techniques depends on the Party's regulation. According to cases, combination 00 00 could be forbidden.

In the tool the absolute terms are directly entered (% for a given combination multiplied by the total activity)

On average in Europe, application rates are or will be as follows [1] :

Combination code	1970	1990	2000	2010	
01 00 00	100	3			
01 00 01		50	40		
01 00 02				40	
01 00 03		47	60		
01 00 04				60	

Application rates in the above table are given for RAINS simulation purpose. They should be considered as indicative only of the EC PVC industry evolution perspective [1]. In eastern countries the situation could be different.

7 Explanatory notes

Investment costs and operational costs are derived from the experience of the industry.

8 Comments

Just a comment from industry indicating a mistake in the text. "After opening and corresponding VCM" is replaced by "before opening and corresponding VCM".

9 References for PVC production

[1] Expert group from PVC manufacturers : TRIOPON S. (LVM); LIEGEOIS R. (Solvay); LOUIS H. (Atofina); BINDELLE J.P. (Solvay), DE CHAMPS F. (SPMP).

Organic chemical industry except steam cracking, PVC production and active ingredient production

This document concerns a process of the organic chemistry for representing productions of chemicals except those from steam crackers, the PVC production and the speciality chemical industry.

Down stream units (following the steam cracker), (all processes of the organic chemistry except steam crackers, the PVC suspension process and the speciality chemical industry).
Activity: due to the large number of sources covered, the activity level is directly defined as **VOC emissions** declared by Parties for the sources covered by this sector.
This sector is assumed to cover the following SNAP sources:

- SNAP 04 05 03/04/05 production of 1,2 dichloroethane/vinyl chloride,
- SNAP 04 05 06/07 production of polyethylene, high and low density,
- SNAP 04 05 09 to 04 05 27 from production of polypropylene to other chemical compounds except 040522 storage and handling of chemical products (According to the cases, the VOC emissions from non pharmaceutical active ingredients could be considered under this SNAP code. In that case emissions have not to be taken into account).

NFR 3C
The document has been prepared in cooperation with the French Chemical Union (UIC) and CEFIC, and expert from ADEME [5], [6].

1 Data from the literature

Please refer to chapter 2 of introduction for detail.

2 Short technology description

A typical process cannot be described due to the large number of processes and chemical products produced.
By analogy with the reference installation used for the steam cracking, it has been considered :

VOC emissions at the flare:
No presence of flare considered.

VOC channelled emissions (other than the flare):
During normal operation, channelled VOC emissions are recycled into the process, used as a fuel or routed to associated processes on an integrated site. Channelled emissions are considered very low.

Fugitive VOC emissions:
Chemical units have high numbers of components with potential leaking points of which could potentially arise fugitive emissions. Fugitive emissions arise from: valve glands, pipe flanges, open ended lines, pressure relief valves, other piping components, pumps, compressors seals…

Other sources of VOC emissions such as storages are considered in this document.

A chemical unit is stopped at regular intervals (periodicity may range from 4 to 5 years) for controls and maintenance.

Tightening of leaking equipment is an essential operation of a **Leak Detection And Repair programme (LDAR).** It can be achieved on line with the process in operation (**tightening operation**), but suppression of most important leaks can only be achieved during planned shutdowns with isolation and degassing of the corresponding sector. Dismantling or exchange of the pieces of equipment is required.

3 EU regulation

The chemical industry is concerned by Directive IPPC. No emission limits are implemented.

4 Definition of reference installations

The reference installation has been defined on the same principles adopted for representing the steam cracker (refer to the document steam cracking if necessary) with data provided by the French Chemical Industry association [4] and CEFIC [5].

Channelled VOC emissions from the process can be assumed to be recycled at a maximum level into the process or used as a fuel or routed to associated processes.
No flare system has to be considered in this unit.

This installation has about 12 000 potentially leaking points (valves, flanges, pumps, open ends…) of which 80 % are accessible. In the scope of this study, a simplified installation with 40 % valves and 60 % flanges is considered.

Table 4.1: Definition of the reference installation

Reference Installation Code	Description
01	Chemical unit – Reference VOC emissions 230 t VOC. Channelled VOC emissions from the process assumed to be very low. Fugitive emissions: 12 000 potentially leaking points (valves, pumps, flanges, open ends…); 9 600 accessible points. 40 % valves, 60 % flanges.

These assumptions are derived from data collected by UIC at French level [5] and CEFIC at European level. The different VOC emission sources from different type of installations have been collected [5]. It has to be outline that the measurement techniques used in Europe to estimate fugitive emissions from steam cracking units and other processes of the chemical industry are not yet well defined.
Emissions depend on the methodology used. The EPA 21 method [7] is used some times. This method begins to be used in France.
There are discrepancies between emissions declared previously by industry and the emissions estimated with EPA 21 method. The EPA 21 presents several techniques for estimations. Each of these techniques gives different results **and this can have consequences on the cost effectiveness of the LDAR program.**

Fugitive emissions of the reference installation are defined with the use of correlation equations provided by US EPA for SOCMI (Synthetic Organic Chemicals Manufacturing Industry) [7]. From measurement in ppm of VOC around a leaking point, the correlations give a quantity of VOC emitted in kg/year. EPA has established the correlation (table 5.1.3). Specific correlations defined by industry especially are existing. Generally the use of specific correlations gives lower emissions than the use of general SOCMI equations provided by EPA.
The CEN [9] is presently working on the redaction of a standard for the determination of leaks of VOC from process equipment. The use of EPA correlations is recommended if user defined correlations are not available.

5 Emission abatement techniques and costs

5.1 Definitions of primary measures

As explained in chapters 2 and 4, potential reductions only exist on NMVOC fugitive emissions but not on stack emissions that are well controlled. Fugitive emissions can be reduced through a Leak Detection And Repair programme [7].

The technique for LDAR consists in measuring the concentration of VOC in the atmosphere around the potential leak, then selecting equipments leaking over a defined threshold value and finally operating a repair on those leaking items.

A LDAR programme is established according to the following principles:
5 The definition of what constitutes a leak and fixation of corresponding thresholds,
6 The fixation of the frequency of inspections,
7 The listing and identification of components included,
8 The procedures concerning repair of leaking components depending of the leak category.

Repair procedures related to leak category considered in primary measures are indicated in table 5.1.1.

4 LDAR programmes are considered for the estimation of costs in order to be coherent with measures defined for steam cracking units. They differ from the level of leak considered and type of maintenance carried out.

Table 5.1.1: Definition of leak and repair programme considered in primary measures 00 to 04

<table>
<tr><th></th><th>Leaks < 1000 ppm</th><th>Leaks from 1000 to 5000 ppm</th><th>Leaks from 5000 to 10000 ppm</th><th>Leaks from 10000 to 100000 ppm</th><th>Leaks > 100000 ppm</th></tr>
<tr><td>PMC 00</td><td colspan="5">No action on leaks</td></tr>
<tr><td>PMC 01</td><td>No action</td><td>No action</td><td>Tightening after detection</td><td>Tightening after detection</td><td>Tightening after detection and basic maintenance during sche-duled shutdown</td></tr>
<tr><td>PMC 02</td><td>No action</td><td>Tightening after detection</td><td>Tightening after detection</td><td colspan="2">Tightening after detection and basic maintenance during scheduled shutdown</td></tr>
<tr><td>PMC 03</td><td>No action</td><td>Tightening after detection</td><td colspan="3">Tightening after detection and basic maintenance during scheduled shutdown</td></tr>
<tr><td rowspan="2">PMC 04</td><td rowspan="2">No action</td><td rowspan="2">Tightening after detection</td><td rowspan="2">Tightening after detection</td><td colspan="2">Tightening after detection and basic maintenance during scheduled shutdown for flanges</td></tr>
<tr><td colspan="2">Tightening after detection and heavy maintenance during scheduled shutdown for valves</td></tr>
</table>

Refer to the definitions just after.

The following definitions have been considered:

Equipment tightening can be made with equipment **in operation** (except with remote control valves (eg tightening bolts to eliminate leaks from valves stems or flanges, installing tightening caps on open ends…).
Maintenance with dismantling equipment or exchange can only be implemented during plant shutdowns with circuits insulation and degassing. So, during plant shutdowns, two kinds of maintenance have been characterized:
Basic maintenance : maintenance on the equipment (flanges + valves) to remove some parts or to change the equipment with a new one of the same technology.
Heavy maintenance : complete change of the valves with valves of the higher grade standard, not leaking technology. Basic maintenance is maintained for the flanges.

It is considered that to **establish the LDAR program**, it is necessary to invest in a database with all potentially leaking points first measured (100 % of accessible points are considered and controlled). Then, the results of these first exhaustive measures campaign are analysed to initiate the repairing actions specific to each primary measures, including shutdown repairing. Then, each leak repaired is once again controlled to take in account the efficiency of the intervention.

For the following years, before next shutdown, the frequency of leak controls is estimated to 20 % of accessible points. Following the level of measured concentration, the leaking points (> 1 000 or 5 000 ppm depending of PMC) will be repaired by tightening on line.

At the next shutdown, the maintenance intervention (basic or heavy depending of PMC) will occur.

Table 5.1.2: Primary measure definition

Primary Measure	Description
00	No LDAR programme
01	**Establishment of the LDAR program** Inventory of all components and establishment of a database. First survey of all potential leak points of the plant (100 % of accessible points are considered and controlled), analysis of the first results of the survey. Tightening for points > 5 000 ppm Basic maintenance for 100 % points > 100 000 ppm during first shut down. **Annual control between two shutdowns** Intermediate campaign before shutdown: 20 % of accessible points are controlled each year (in five years all points are controlled). Tightening each year for 100 % controlled points > 5 000 ppm. **Next Shutdown.** Basic maintenance for 100 % measured points (during the 5 years) > 100 000 ppm.
02	**Establishment of the LDAR program** Inventory of all components and establishment of a database. First survey of all potential leak points of the plant (100 % of accessible points are considered and controlled), analysis of the first results of the survey. Tightening for points > 1000 ppm. Basic maintenance for points > 10 000 ppm during the first shut down. **Annual control between two shutdowns** Intermediate campaign before shutdown : 20 % of accessible points are controlled each year (in five years all points are controlled). Tightening each year for 100 % controlled points > 1 000 ppm. **Next Shutdown** Basic maintenance for 100 % measured points (during the 5 years) > 10 000 ppm.
03	**Establishment of the LDAR program** Inventory of all components and establishment of a database. First survey of all potential leak points of the plant (100 % of accessible points are considered and controlled), analysis of the first results of the survey. Tightening for points > 1 000 ppm . Basic maintenance for 100 % points > 5 000 ppm during the first shut down. **Annual control between two shutdowns** Intermediate campaign before shutdown : 20 % of accessible points are controlled each year (in five years all points are controlled). Tightening each year for 100 % measured points > 1 000 ppm. **Next Shutdown** Basic maintenance for 100 % measured points (during the 5 years) > 5 000 ppm.
04	**Establishment of the LDAR program** Inventory of all components and establishment of a database. First survey of all potential leak points of the plant (100 % of accessible points are considered and controlled), analysis of the first results of the survey. Tightening for points > 1 000 ppm Basic maintenance for flanges points >10 000 ppm during the first shut down. Heavy maintenance for valves points > 10 000 ppm during the first shut down. **Annual control between two shutdowns** Intermediate campaign before shutdown: 20 % of accessible points are controlled each year (in five years all points are controlled). Tightening each year for points > 1 000 ppm. **Next Shutdown** Basic maintenance for 100 % measured (during the 5 years) > 10 000 ppm. Heavy maintenance for 100 % measured (during the 5 years) > 10 000 ppm.

Correlation between ppm measurement and VOC emitted quantities :

The SOCMI correlations between screening values and emission rates are in the form [7]:

$ER = A . (SV)^B$ with ER = emission rate in kg/h/pt and SV the screening value (ppm).

These correlations are valid between 0 and 100 000 ppm. For screening value higher than 100 000 ppm a fixed or pegged value is used always given by EPA.

The value of A and B parameters for the different equipment are as follows [7]:

Table 5.1.3: value of parameters A and B and of the pegged values according to SOCMI correlations [7]

Source	Service	A	B	Pegged value > 100 000 ppm kg/h
Valve	Gas	$1.87\ 10^{-6}$	0.873	0.110
Valve	Light liquid	$6.41\ 10^{-6}$	0.797	0.150
Pump seal	Light liquid	$1.90\ 10^{-5}$	0.824	0.620
Connector	All	$3.05\ 10^{-6}$	0.885	0.220

5.2 Secondary measures

No secondary taken into account.

5.3 Emission factors, cost data and uncertainties of the different combinations

Table 5.3.1: Emission factors, investments, operating costs, abatement efficiencies and uncertainties for relevant combinations (€ 2000)

Combination Code	Emission Factor for NMVOC [t VOC/t VOC]	Abatement efficiency %	Quality	CI %
01 00 00	1		2	200
01 01 00	0,66	34	2	200
01 02 00	0,64	36	2	200
01 03 00	0,64	36	2	200
01 04 00	0,53	47	2	200

Combination Code	Investment [€]	Fixed operating cost [€/y]	Operating costs [€/y]	Recovery of products [€/y]	Quality of cost data	CI %
01 00 00						
01 01 00	79 780	No fixed operating cost taken into account	11 580	31 360	2	100
01 02 00	85 300		12 440	33 150	2	100
01 03 00	88 930		12 990	33 360	2	100
01 04 00	157 870		20 520	43 360	2	100

The table 5.3.2 presents costs expressed in €/t VOC abated

Table 5.3.2 : costs expressed in €/t VOC abated

Combination Code	Emission Factor for NMVOC [t VOC/t VOC]	Annual total cost €/t VOC non emitted	Quality	CI %
01 00 00	1		2	100
01 01 00	0.66	-127		100
01 02 00	0.64	-123		100
01 03 00	0.64	-113		100
01 04 00	0.53	-31		100

6 Data to be provided by national experts for the completion of the data basis for their country

The following tasks are required from experts:

6.1 Validation work

The national expert is invited to comment the methodology defined by the secretariat.

- Validation of the default investments provided,
- Validation of the method of derivation of operating costs,

Or

- Provide other costs for the same combination of techniques and justify them.

6.2 Provision of specific data

Tables to be filled in by national experts

- Determination of country specific data to calculate variable costs (Specific values for energy, man power… are valid for all NMVOC sectors and have to be entered in the tool only once)

Table 6.2.1: Country specific data

Parameters	Default data used for calculating costs	Country specific data
Organic compounds [€/t VOC recovered]	400	
Wages [€/h]	24.3	

- Total activity level in accordance with units used in the document: t of ethylene + t propylene (produced by steam cracking) produced. Table 6.2.2 must be completed. Some default values for the confidence interval are given. A Party can use them if no data is available. The methodology used in Rains for estimating the future activity level will be described in the methodology. It can be used or information can be obtained from the industry.

The level of activity is represented by the sum of emissions declared for the following SNAP sources covered:

- SNAP 04 05 03/04/05 production of 1,2 dichloroethane/vinyl chloride,

- SNAP 04 05 06/07 production of polyethylene, high and low density,
- SNAP 04 05 09 to 04 05 27 from production of polypropylene to other chemical compounds except 040522 storage and handling of chemical products (According to the cases, the VOC emissions from non pharmaceutical active ingredients could be considered under this SNAP code. In that case emissions have not to be taken into account).

Table 6.2.2: Activity levels on reference installations (t VOC /y)

RIC	2000	CI%	2005	CI%	2010	CI%	2015	CI%	2020	CI%
01										
Default values proposed for CI		10		20		50		100		100

For explanation on the confidence interval (Refer to the methodology chapter).

- Respective percentage of combinations of reduction measures in 2000 as well as if possible, the percentage of use in 2005, 2010, 2015 and 2020 due to the NMVOC directive or national regulations and applicability according to the definition used in the RAINS model.

Table 6.2.3: Application rate and applicability factor for each combination of reduction measures

Reduction measure combination for RIC 01			**Percentage of use in 2000 %**	**Percentage of use in 2005 %**	**Applicability factor 2005 %**	**Percentage of use in 2010 %**	**Applicability factor 2010 %**	**Percentage of use in 2015 %**	**Applicability factor 2015 %**	**Percentage of use in 2020 %**	**Applicability factor 2020 %**
RIC	**PMC**	**SMC**									
01	**00**	**00**									
Default value proposed for the applicability factor					100		100		100		100
01	**01**	**00**									
Default value proposed for the applicability factor					100		100		100		100
01	**02**	**00**									
Default value proposed for the applicability factor					100		100		100		100
01	**03**	**00**									
Default value proposed for the applicability factor					100		100		100		100
01	**04**	**00**									
Default value proposed for the applicability factor					100		100		100		100
Total			**100**	**100**		**100**		**100**		**100**	

The total of percentages of each combination or reduction technique must be 100 since the three combinations are assumed to represent the different situations in this activity.
The percentage of use of the different techniques depends on the Party's regulation. According to cases, combination 00 00 could be forbidden.
In the tool the absolute terms are directly entered (% for a given combination multiplied by the total activity)

7 Explanatory notes

7.1 Reference installation definition

The French Chemical Industry Federation UIC has carried out a study in order to supply the EGTEI work with data. A reference installation for steam cracking presented in the document on steam cracking has been defined.
On a similar basis, a reference installation for downstream chemistry has been defined but with less relevant data for defining it and mainly expert judgement.

Channelled emissions are considered negligible. No additional reduction of emissions option is available, when the best efficiency of vent collection towards the flare has been already implemented. It is considered that this situation is valid in Western Europe as well in Eastern Europe.

7.2 Definition of primary measures, derivation of emission factors

Fugitive emissions can be reduced through a Leak Detection And Repair programme (LDAR). To precise the definitions written in chapter 5.1 and to explain the cost results, it is assumed the following hypothesis :

Definition of what constitutes a leak: Table 5.1.1 presents concentration thresholds for determination of leak categories taken into account for each primary measure.
Leak classification is made from comparison between measured VOC concentration in the vicinity of leaking point and threshold values.

Inventory of equipment: A database is established. Components are classified in term of type, service and process conditions. For calculating emission factors and costs per point, only two types of equipment are taken into account for simplification reason: valves and flanges.

Non accessible leaking points: To estimate the NMVOC emission from the non accessible points, it has been considered the same average emission factor by equipment family (flanges or valves) reported to the 2 400 considered points (9600 accessible points for 12 000 points). Obviously, no reduction impact is taken into account for these points whatever the Primary Measures chosen.

Efficiency of tightening: The efficiency of tightening for the first operation is considered to be 30 % of emission reduction for leaks > 5 000 ppm (PMC 01) or > 1 000 ppm (PMC 02 – PMC 03 – PMC 04). This efficiency of the following tightening operation is lower and enables to maintain the emissions (Figure 7.2.1).

Efficiency of basic maintenance: The efficiency of basic maintenance is considered to be 50 % of emission reduction for leaks > 100 000 ppm (flanges + valves in PMC 01) or > 10 000 ppm (flanges + valves in PMC 02 – flanges in PMC 04) or > 5 000 ppm (flanges + valves in PMC 03). This efficiency is only valid for the first operation. The efficiency of the following operations is lower (Figure 7.2.1).

Efficiency of heavy maintenance: For PMC 04, the heavy intervention considered consists in replacing 100 % of valves with leak > 10 000 ppm with un-leaking valves. It has been assumed that leak higher than 100 000 ppm will appear again after that change but their number is reduced by the percentage of valve replaced.
Control is achieved on points that were detected leaking and tightening is carried out if necessary.

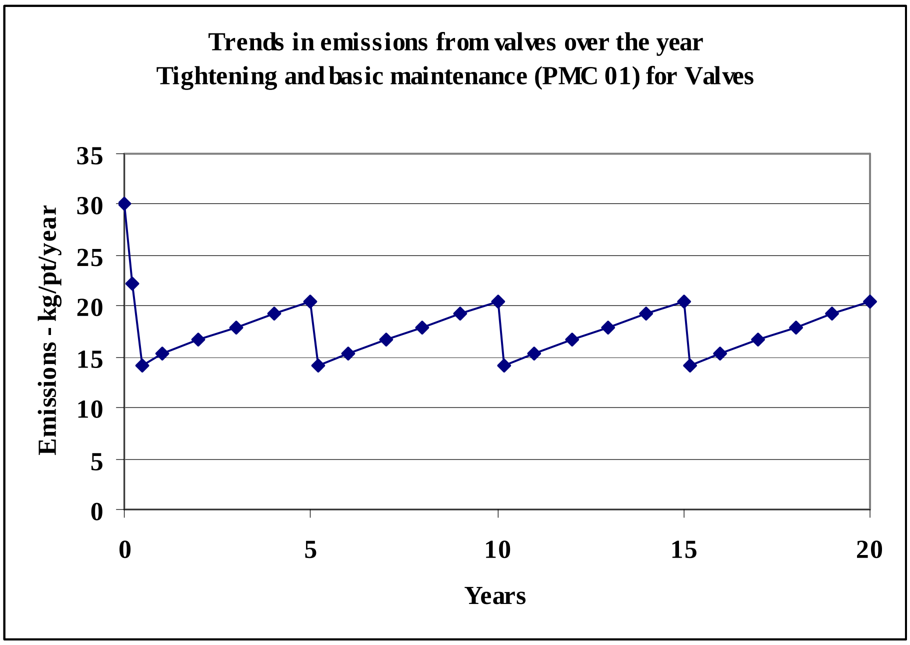
It is also assumed that the probability of emergence of new leaks is constant over time for each leak category so the average emission per point will increase linearly with time. (It is interesting to know that according to experience leaks appear in random manner). It is also assumed that if no action is taken after a maintenance campaign, the average emission value will reach the reference installation value after 10 years.
The probability of identifying medium or large leaks has been estimated on the basis of measurements made on several installations in France and Belgium [5] as well as specific emission reductions resulting from tightening or basic maintenance completed by expert judgement. The probability to meet leaks of each category is reduced after the first operation as the general standard of the installation is improved.

The efficiency of operations carried out with PMC 01, 02, 03 and 04 is presented in tables 7.2.1 to 7.2.4 for valves and in tables 7.2.5 and 7.2.8 for flanges.

References : Efficiencies are derived from the data collected by UIC [5].
UIC has provided data for the following ranges of leaks :
0-5000 ppm
5000-100 000 ppm
> 100 000 ppm

For calculation CITEPA ,in consultation with ADEME, has taken into account the following ranges :
0-1000 ppm
1000-5000ppm
5000-10 000 ppm
10 000-100 000 ppm
> 100 000 ppm

Figure 7.2.1 : Trends in emissions from accessible valves after tightening and basic maintenance from a situation where no action had been taken



It can be noticed that the first operation of tightening and basic maintenance on the leaking point (valves in downstream units) allows to reduce its emissions from 30 to about 14 kg/year. The operations of tightening and basic maintenance achieved after this first operation allow to maintain the emissions.

Table 7.2.1: Accessible valves - Hypothesis taken into account for estimating emissions of primary measure 01.

Ranges of leaks - ppm		**<1000**	**1000 to 5000**	**5000 to 10000**	**10000 to 100000**	**> 100000**
Levels of leaks		100	3500	7000	55000	pegged value
Emissions of VOC according to SOCMI equations						
Light liquid valves	kg/hr/pt	0.00025	0.00428	0.00744	0.03845	0.15
Light liquid pumps	kg/hr/pt	0.00084	0.01581	0.02800	0.15304	0.62
Average valves+pumps	kg/hr/pt	0.00055	0.01005	0.01772	0.09575	0.39
Number of hours of work	8600	h/year				
Light liquid valves	kg/year/pt	2.2	36.8	64.0	330.7	1290.0
Light liquid pumps	kg/year/pt	7.3	136.0	240.8	1316.2	5332.0
Average valves+pumps	**kg/year/pt**	**3.4**	**61.6**	**108.2**	**577.1**	**2300.5**

Ranges of leaks - ppm		**<1000**	**1000 to 5000**	**5000 to 10000**	**10000 to 100000**	**> 100000**	**Total**
Percentage of leaks according to the ranges of leaks	%	97.50%	0.70%	0.30%	0.50%	1.00%	**100.00%**
Average emissions	kg/year/pt	3.4	0.4	0.3	2.9	23.0	**30.00**
First operation - tightening of leak > 5000 ppm**							
Percentage of leaks according to the ranges of leaks	%	98.04%	0.70%	0.21%	0.35%	0.70%	**100.00%**
Average emissions	kg/year/pt	3.4	0.4	0.2	2.0	16.1	**22.2**
Changes of valves with leaks > 100 000 ppm							
Percentage of leaks according to the ranges of leaks	%	98.39%	0.70%	0.21%	0.35%	0.35%	**100.00%**
Average emissions	kg/year/pt	3.4	0.4	0.2	2.0	8.1	**14.1**
Emissions after 5 years is nothing has been done*							
Percentage of leaks according to the ranges of leaks	%	97.94%	0.70%	0.25%	0.42%	0.68%	**100.00%**
Average emissions	kg/year/pt	3.4	0.4	0.3	2.4	15.5	**22.0**
After 5 years when tightening is operated							
Percentage of leaks according to the ranges of leaks	%	98.18%	0.70%	0.21%	0.35%	0.56%	**100.00%**
Average emissions	kg/year/pt	3.4	0.4	0.2	2.0	12.8	**18.9**
Average on the five years period***							
Percentage of leaks according to the ranges of leaks	%	98.23%	0.70%	0.22%	0.37%	0.48%	**100.00%**
Average emissions	kg/year/pt	3.4	0.4	0.2	2.1	11.1	**17.3**

* In 10 years, it is assumed that the proportions of leaks reach the initial level.
** the efficiency of tightening is assumed to be the same for flanges with leak of 5000 to 100 000 ppm (50%).
*** See figure 7.2.2 for explanations on the average value on the period.

Table 7.2.2: Accessible valves - Hypothesis taken into account for estimating emissions of primary measure 02.

Ranges of leaks - ppm		**<1000**	**1000 to 5000**	**5000 to 10000**	**10000 to 100000**	**> 100000**
Levels of leaks		100	3500	7000	55000	pegged value
Emissions of VOC according to SOCMI equations						
Light liquid valves	kg/hr/pt	0.00025	0.00428	0.00744	0.03845	0.15
Light liquid pumps	kg/hr/pt	0.00084	0.01581	0.02800	0.15304	0.62
Average valves+pumps	kg/hr/pt	0.00055	0.01005	0.01772	0.09575	0.39
Number of hours of work	8600	h/year				
Light liquid valves	kg/year/pt	2.2	36.8	64.0	330.7	1290.0
Light liquid pumps	kg/year/pt	7.3	136.0	240.8	1316.2	5332.0
Average valves+pumps	kg/year/pt	3.4	61.6	108.2	577.1	2300.5

Ranges of leaks - ppm		**<1000**	**1000 to 5000**	**5000 to 10000**	**10000 to 100000**	**> 100000**	**Total**
Percentage of leaks according to the ranges of leaks	%	97.50%	0.70%	0.30%	0.50%	1.00%	**100.00%**
Average emissions	kg/year/pt	3.4	0.4	0.3	2.9	23.0	**30.00**
First operation - tightening of leak > 1000 ppm**							
Percentage of leaks according to the ranges of leaks	%	98.25%	0.49%	0.21%	0.35%	0.70%	**100.00%**
Average emissions	kg/year/pt	3.4	0.3	0.2	2.0	16.1	**22.0**
Changes of valves with leaks > 10 000 ppm							
Percentage of leaks according to the ranges of leaks	%	98.78%	0.49%	0.21%	0.18%	0.35%	**100.00%**
Average emissions	kg/year/pt	3.4	0.3	0.2	1.0	8.1	**13.0**
Emissions after 5 years is nothing has been done*							
Percentage of leaks according to the ranges of leaks	%	98.14%	0.59%	0.25%	0.34%	0.68%	**100.00%**
Average emissions	kg/year/pt	3.4	0.4	0.3	1.9	15.5	**21.5**
After 5 years when tightening is operated							
Percentage of leaks according to the ranges of leaks	%	98.46%	0.49%	0.21%	0.28%	0.56%	**100.00%**
Average emissions ***	kg/year/pt	3.4	0.3	0.2	1.6	12.8	**18.4**
Average on the five year period							
Percentage of leaks according to the ranges of leaks	%	98.54%	0.52%	0.22%	0.24%	0.48%	**100.00%**
Average emissions	kg/year/pt	3.4	0.3	0.2	1.4	11.1	**16.5**

* In 10 years, it is assumed that the proportions of leaks reach the initial level.
** the efficiency of tightening is assumed to be the same for flanges with leak of 5000 to 100 000 ppm (50%).
*** See figure 7.2.3 for explanations on the average value on the period.

Table 7.2.3: Accessible valves - Hypothesis taken into account for estimating emissions of primary measure 03.

Ranges of leaks - ppm		**<1000**	**1000 to 5000**	**5000 to 10000**	**10000 to 100000**	**> 100000**
Levels of leaks		100	3500	7000	55000	pegged value
Emissions of VOC according to SOCMI equations						
Light liquid valves	kg/hr/pt	0.00025	0.00428	0.00744	0.03845	0.15
Light liquid pumps	kg/hr/pt	0.00084	0.01581	0.02800	0.15304	0.62
Average valves+pumps	kg/hr/pt	0.00055	0.01005	0.01772	0.09575	0.39
Number of hours of work	8600	h/year				
Light liquid valves	kg/year/pt	2.2	36.8	64.0	330.7	1290.0
Light liquid pumps	kg/year/pt	7.3	136.0	240.8	1316.2	5332.0
Average valves+pumps	kg/year/pt	3.4	61.6	108.2	577.1	2300.5

Ranges of leaks - ppm		**<1000**	**1000 to 5000**	**5000 to 10000**	**10000 to 100000**	**> 100000**	**Total**
Percentage of leaks according to the ranges of leaks	%	97.50%	0.70%	0.30%	0.50%	1.00%	**100.00%**
Average emissions	kg/year/pt	3.4	0.4	0.3	2.9	23.0	**30.00**
First operation - tightening of leak > 1000 ppm**							
Percentage of leaks according to the ranges of leaks	%	98.25%	0.49%	0.21%	0.35%	0.70%	**100.00%**
Average emissions	kg/year/pt	3.4	0.3	0.2	2.0	16.1	**22.0**
Changes of valves with leaks > 5 000 ppm							
Percentage of leaks according to the ranges of leaks	%	98.88%	0.49%	0.11%	0.18%	0.35%	**100.00%**
Average emissions	kg/year/pt	3.4	0.3	0.1	1.0	8.1	**12.9**
Emissions after 5 years is nothing has been done*							
Percentage of leaks according to the ranges of leaks	%	98.19%	0.59%	0.20%	0.34%	0.68%	**100.00%**
Average emissions	kg/year/pt	3.4	0.4	0.2	1.9	15.5	**21.4**
After 5 years when tightening is operated							
Percentage of leaksaccording to the ranges of leaks	%	98.51%	0.49%	0.17%	0.28%	0.56%	**100.00%**
Average emissions	kg/year/pt	3.4	0.3	0.2	1.6	12.8	**18.3**
Average on the five year period***							
Percentage of leaks according to the ranges of leaks	%	98.61%	0.52%	0.14%	0.24%	0.48%	**100.00%**
Average emissions	kg/year/pt	3.4	0.3	0.2	1.4	11.1	**16.4**

* In 10 years, it is assumed that the proportions of leaks reach the initial level.

** the efficiency of tightening is assumed to be the same for flanges with leak of 1000 to 100 000 ppm (50%).

*** See figure 7.2.4 for explanations on the average value on the period.

Table 7.2.4: Accessible valves - Hypothesis taken into account for estimating emissions of primary measure 04.

Ranges of leaks – ppm		**<1000**	**1000 to 5000**	**5000 to 10000**	**10000 to 100000**	**> 100000**
Levels of leaks		100	3500	7000	55000	pegged value
Emissions of VOC according to SOCMI equations						
Light liquid valves	kg/hr/pt	0.00025	0.00428	0.00744	0.03845	0.15
Light liquid pumps	kg/hr/pt	0.00084	0.01581	0.02800	0.15304	0.62
Average valves+pumps	kg/hr/pt	0.00055	0.01005	0.01772	0.09575	0.39
Number of hours of work	8600	h/year				
Light liquid valves	kg/year/pt	2.2	36.8	64.0	330.7	1290.0
Light liquid pumps	kg/year/pt	7.3	136.0	240.8	1316.2	5332.0
Average valves+pumps	kg/year/pt	3.4	61.6	108.2	577.1	2300.5

Ranges of leaks - ppm		**<1000**	**1000 to 5000**	**5000 to 10000**	**10000 to 100000**	**> 100000**	**Total**
Percentage of leaks according to the ranges of leaks	%	97.50%	0.70%	0.30%	0.50%	1.00%	**100.00%**
Average emissions	kg/year/pt	3.4	0.4	0.3	2.9	23.0	**30.00**
First operation - tightening of leak > 1000 ppm**							
Percentage of leaks according to the ranges of leaks	%	98.25%	0.49%	0.21%	0.35%	0.70%	**100.00%**
Average emissions	kg/year/pt	3.4	0.3	0.2	2.0	16.1	**22.0**
Changes of valves with leaks > 10 000 ppm							
Percentage of leaks according to the ranges of leaks	%	99.30%	0.49%	0.21%	0.00%	0.00%	**100.00%**
Average emissions	kg/year/pt	3.4	0.3	0.2	0.0	0.0	**3.9**
Emissions after 5 years is nothing has been done*							
Percentage of leaks according to the ranges of leaks	%	98.41%	0.59%	0.25%	0.25%	0.49%	**100.00%**
Average emissions	kg/year/pt	3.4	0.4	0.3	1.4	11.4	**16.8**
After 5 years when tightening is operated							
Percentage of leaks according to the ranges of leaks	%	98.69%	0.49%	0.21%	0.20%	0.41%	**100.00%**
Average emissions	kg/year/pt	3.4	0.3	0.2	1.2	9.4	**14.5**
Average on the five year period***							
Percentage of leaks according to the ranges of leaks	%	98.92%	0.52%	0.22%	0.11%	0.23%	**100.00%**
Average emissions	kg/year/pt	3.4	0.3	0.2	0.7	5.2	**9.8**

* In 10 years, it is assumed that the proportions of leaks reach the initial level.
** the efficiency of tightening is assumed to be the same for flanges with leak of 5000 to 100 000 ppm (50%).
*** See figure 7.2.5 for explanations on the average value on the period.

Table 7.2.5: Accessible flanges - Hypothesis taken into account for estimating emissions of primary measure 01.

Ranges of leaks – ppm		**<1000**	**1000 to 5000**	**5000 to 10000**	**10000 to 100000**	**> 100000**
Levels of leaks		100	3500	7000	55000	pegged value
Emissions of VOC according to SOCMI equations						
Connectors	kg/hr/pt	0.00018	0.00418	0.00771	0.04781	0.22
Average valves+pumps	kg/hr/pt	0.00055	0.01005	0.01772	0.09575	0.39
Number of hours of work	8600	h/year				
Connectors	kg/year/pt	1.5	35.9	66.3	411.2	1892.0

Ranges of leaks – ppm		**<1000**	**1000 to 5000**	**5000 to 10000**	**10000 à 100000**	**> 100000**	**Total**
Percentage of leaks according to the ranges of leaks	%	98.90%	0.10%	0.25%	0.25%	0.50%	**100.00%**
Average emissions	kg/year/pt	1.5	0.0	0.2	0.8	9.5	**12.0**
First operation - tightening of leak > 5000 ppm**							
Percentage of leaks according to the ranges of leaks	%	99.20%	0.10%	0.18%	0.18%	0.35%	**100.00%**
Average emissions	kg/year/pt	1.5	0.0	0.1	0.6	6.6	**8.8**
Changes of flanges with leaks > 100 000 ppm							
Percentage of leaks according to the ranges of leaks	%	99.37%	0.10%	0.18%	0.18%	0.18%	**100.00%**
Average emissions	kg/year/pt	1.5	0.0	0.1	0.6	3.3	**5.5**
Emissions after 5 years is nothing has been done*							
Percentage of leaks according to the ranges of leaks	%	99.14%	0.10%	0.21%	0.21%	0.34%	**100.00%**
Average emissions	kg/year/pt	1.5	0.0	0.1	0.7	6.4	**8.7**
After 5 years when tightening is operated							
Percentage of leaks according to the ranges of leaks	%	99.27%	0.10%	0.18%	0.18%	0.28%	**100.00%**
Average emissions	kg/year/pt	1.5	0.0	0.1	0.6	5.3	**7.5**
Average on the five year period							
Percentage of leaks according to the ranges of leaks	%	99.29%	0.10%	0.18%	0.18%	0.24%	**100.00%**
Average emissions	kg/year/pt	1.5	0.0	0.1	0.6	4.6	**6.8**

* In 10 years, it is assumed that the proportions of leaks reach the initial level.
** the efficiency of tightening is assumed to be the same for flanges with leak of 5000 to 100 000 ppm (30%).
*** See figure 7.2.6 for explanations on the average value on the period.

Table 7.2.6: Accessible flanges - Hypothesis taken into account for estimating emissions of primary measure 02.

Ranges of leaks - ppm		**<1000**	**1000 to 5000**	**5000 to 10000**	**10000 to 100000**	**> 100000**
Levels of leaks		100	3500	7000	55000	pegged value
Emissions of VOC according to SOCMI equations						
Connectors	kg/hr/pt	0.00018	0.00418	0.00771	0.04781	0.22
Average valves+pumps	kg/hr/pt	0.00055	0.01005	0.01772	0.09575	0.39
Number of hours of work	8600	h/year				
Connectors	kg/year/pt	1.5	35.9	66.3	411.2	1892.0

Ranges of leaks - ppm		**<1000**	**1000 to 5000**	**5000 to 10000**	**10000 à 100000**	**> 100000**	**Total**
Percentage of leaks according to the ranges of leaks	%	98.90%	0.10%	0.25%	0.25%	0.50%	**100.00%**
Average emissions	kg/year/pt	1.5	0.0	0.2	0.8	9.5	**12.0**
First operation - tightening of leak > 1000 ppm**							
Percentage of leaks according to the ranges of leaks	%	99.23%	0.07%	0.18%	0.18%	0.35%	**100.00%**
Average emissions	kg/year/pt	1.5	0.0	0.1	0.6	6.6	**8.8**
Changes of flanges with leaks > 10 000 ppm							
Percentage of leaks according to the ranges of leaks	%	99.49%	0.07%	0.18%	0.09%	0.18%	**100.00%**
Average emissions	kg/year/pt	1.5	0.0	0.1	0.3	3.3	**5.2**
Emissions after 5 years is nothing has been done*							
Percentage of leaks according to the ranges of leaks	%	99.20%	0.08%	0.21%	0.17%	0.34%	**100.00%**
Average emissions	kg/year/pt	1.5	0.0	0.1	0.6	6.4	**8.6**
After 5 years when tightening is operated							
Percentage of leaks according to the ranges of leaks	%	99.34%	0.07%	0.18%	0.14%	0.28%	**100.00%**
Average emissions	kg/year/pt	1.5	0.0	0.1	0.5	5.3	**7.4**
Average on the five year period*							
Percentage of leaks according to the ranges of leaks	%	99.38%	0.07%	0.18%	0.12%	0.24%	**100.00%**
Average emissions	kg/year/pt	1.5	0.0	0.1	0.4	4.6	**6.6**

* In 10 years, it is assumed that the proportions of leaks reach the initial level.
** the efficiency of tightening is assumed to be the same for flanges with leak of 1000 to 100 000 ppm (30%).
*** See figure 7.2.7 for explanations on the average value on the period.

Table 7.2.7: Accessible flanges - Hypothesis taken into account for estimating emissions of primary measure 03.

Ranges of leaks - ppm		**<1000**	**1000 to 5000**	**5000 to 10000**	**10000 to 100000**	**> 100000**
Levels of leaks		100	3500	7000	55000	pegged value
Emissions of VOC according to SOCMI equations						
Connectors	kg/hr/pt	0.00018	0.00418	0.00771	0.04781	0.22
Average valves+pumps	kg/hr/pt	0.00055	0.01005	0.01772	0.09575	0.39
Number of hours of work	8600	h/year				
Connectors	kg/year/pt	1.5	35.9	66.3	411.2	1892.0

Ranges of leaks - ppm		**<1000**	**1000 to 5000**	**5000 to 10000**	**10000 à 100000**	**> 100000**	**Total**
Percentage of leaks according to the ranges of leaks	%	98.90%	0.10%	0.25%	0.25%	0.50%	**100.00%**
Average emissions	kg/year/pt	1.5	0.0	0.2	0.8	9.5	**12.0**
First operation - tightening of leak > 1000 ppm**							
Percentage of leaks according to the ranges of leaks	%	99.23%	0.07%	0.18%	0.18%	0.35%	**100.00%**
Average emissions	kg/year/pt	1.5	0.0	0.1	0.6	6.6	**8.8**
Changes of flanges with leaks > 5 000 ppm							
Percentage of leaks according to the ranges of leaks	%	99.58%	0.07%	0.09%	0.09%	0.18%	**100.00%**
Average emissions	kg/year/pt	1.5	0.0	0.1	0.3	3.3	**5.2**
Emissions after 5 years is nothing has been done*							
Percentage of leaks according to the ranges of leaks	%	99.24%	0.08%	0.17%	0.17%	0.34%	**100.00%**
Average emissions	kg/year/pt	1.5	0.0	0.1	0.6	6.4	**8.6**
After 5 years when tightening is operated							
Percentage of leaks according to the ranges of leaks	%	99.37%	0.07%	0.14%	0.14%	0.28%	**100.00%**
Average emissions	kg/year/pt	1.5	0.0	0.1	0.5	5.3	**7.3**
Average on the five year period**							
Percentage of leaks according to the ranges of leaks	%	99.44%	0.07%	0.12%	0.12%	0.24%	**100.00%**
Average emissions	kg/year/pt	1.5	0.02	0.1	0.4	4.6	**6.6**

* In 10 years, it is assumed that the proportions of leaks reach the initial level.
** the efficiency of tightening is assumed to be the same for flanges with leak of 1000 to 100 000 ppm (30%).
*** See figure 7.2.8 for explanations on the average value on the period.

Table 7.2.8: Accessible flanges - Hypothesis taken into account for estimating emissions of primary measure 04.

Ranges of leaks - ppm		**<1000**	**1000 to 5000**	**5000 to 10000**	**10000 to 100000**	**> 100000**
Levels of leaks		100	3500	7000	55000	pegged value
Emissions of VOC according to SOCMI equations						
Connectors	kg/hr/pt	0.00018	0.00418	0.00771	0.04781	0.22
Average valves+pumps	kg/hr/pt	0.00055	0.01005	0.01772	0.09575	0.39
Number of hours of work	8600	h/year				
Connectors	kg/year/pt	1.5	35.9	66.3	411.2	1892.0

Ranges of leaks - ppm		**<1000**	**1000 to 5000**	**5000 to 10000**	**10000 à 100000**	**> 100000**	**Total**
Percentage of leaks according to the ranges of leaks	%	98.90%	0.10%	0.25%	0.25%	0.50%	**100.00%**
Average emissions	kg/year/pt	1.5	0.0	0.2	0.8	9.5	**12.0**
First operation - tightening of leak > 1000 ppm**							
Percentage of leaks according to the ranges of leaks	%	99.23%	0.07%	0.18%	0.18%	0.35%	**100.00%**
Average emissions	kg/year/pt	1.5	0.0	0.1	0.6	6.6	**8.8**
Changes of flanges with leaks > 10 000 ppm							
Percentage of leaks according to the ranges of leaks	%	99.49%	0.07%	0.18%	0.09%	0.18%	**100.00%**
Average emissions	kg/year/pt	1.5	0.0	0.1	0.3	3.3	**5.2**
Emissions after 5 years is nothing has been done*							
Percentage of leaks according to the ranges of leaks	%	99.20%	0.08%	0.21%	0.17%	0.34%	**100.00%**
Average emissions	kg/year/pt	1.5	0.0	0.1	0.6	6.4	**8.6**
After 5 years when tightening is operated							
Percentage of leaks according to the ranges of leaks	%	99.34%	0.07%	0.18%	0.14%	0.28%	**100.00%**
Average emissions	kg/year/pt	1.5	0.0	0.1	0.5	5.3	**7.4**
Average on the five year period***							
Percentage of leaks according to the ranges of leaks	%	99.38%	0.07%	0.18%	0.12%	0.24%	**100.00%**
Average emissions	kg/year/pt	1.5	0.0	0.1	0.4	4.6	**6.6**

* In 10 years. it is assumed that the proportions of leaks reach the initial level.
** the efficiency of tightening is assumed to be the same for flanges with leak of 1000 to 100 000 ppm (30%).
*** See figure 7.2.9 for explanations on the average value on the period.

Figure 7.2.2: Accessible valves - Calculations of average emissions for the period of 5 years - PMC 01.

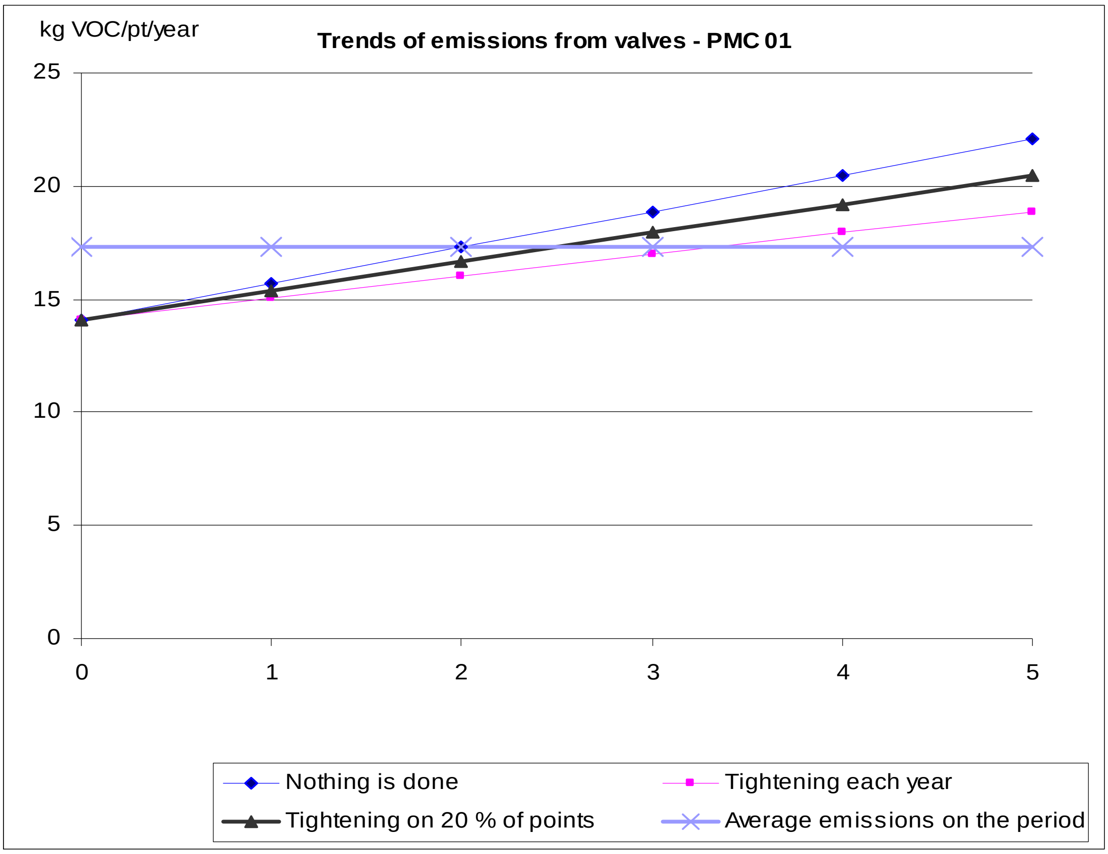


Figure 7.2.3: Accessible valves - Calculations of average emissions for the period of 5 years - PMC 02.

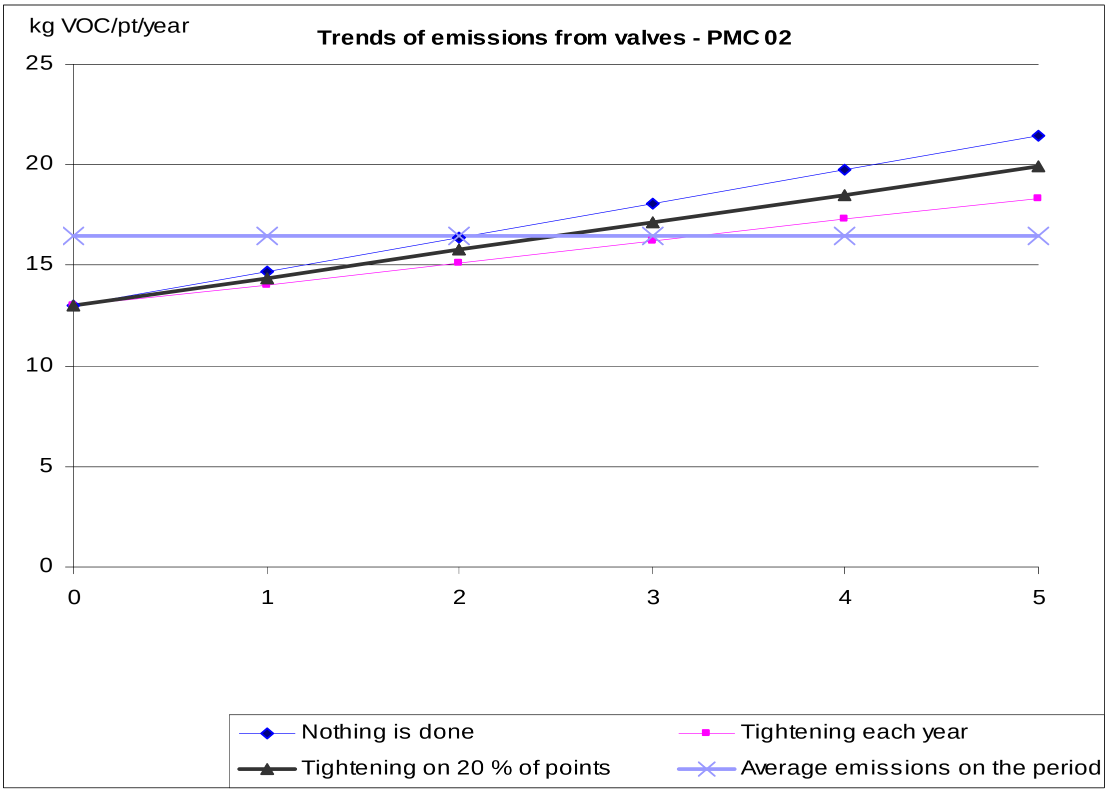


Figure 7.2.4: Accessible valves - Calculations of average emissions for the period of 5 years - PMC 03.

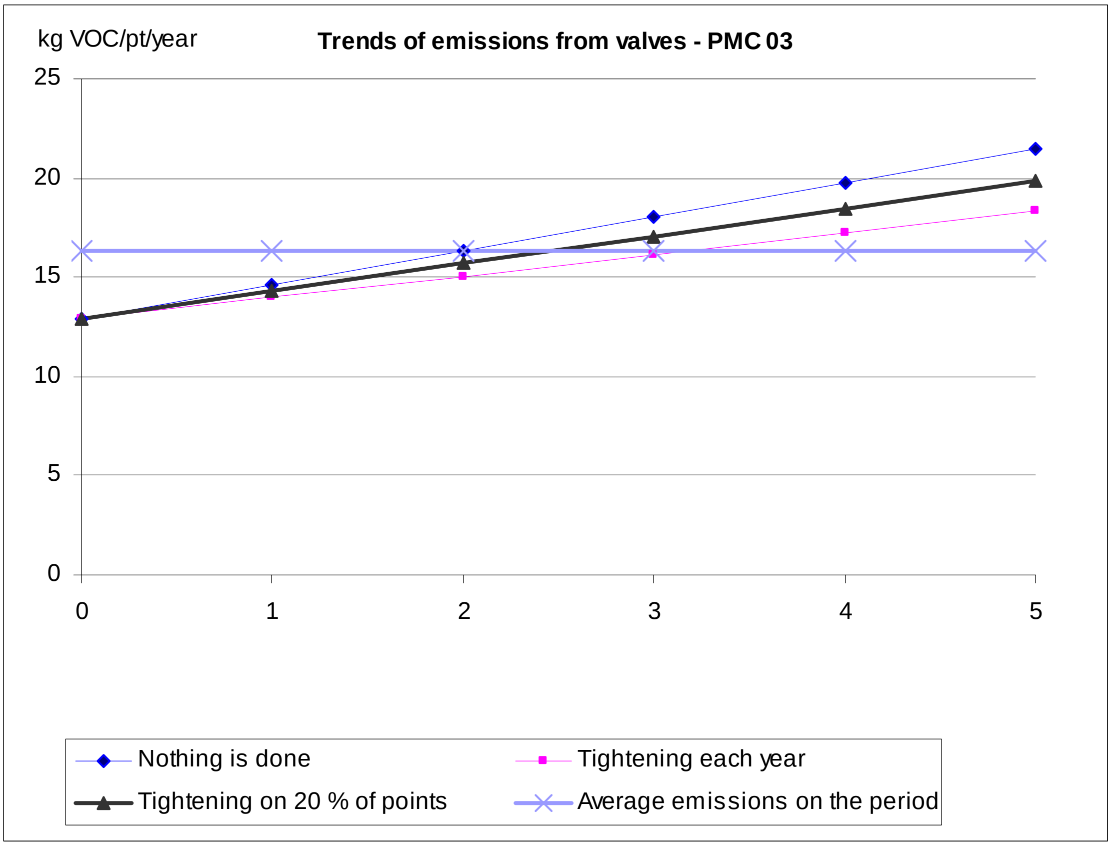


Figure 7.2.5: Accessible valves - Calculations of average emissions for the period of 5 years - PMC 04.

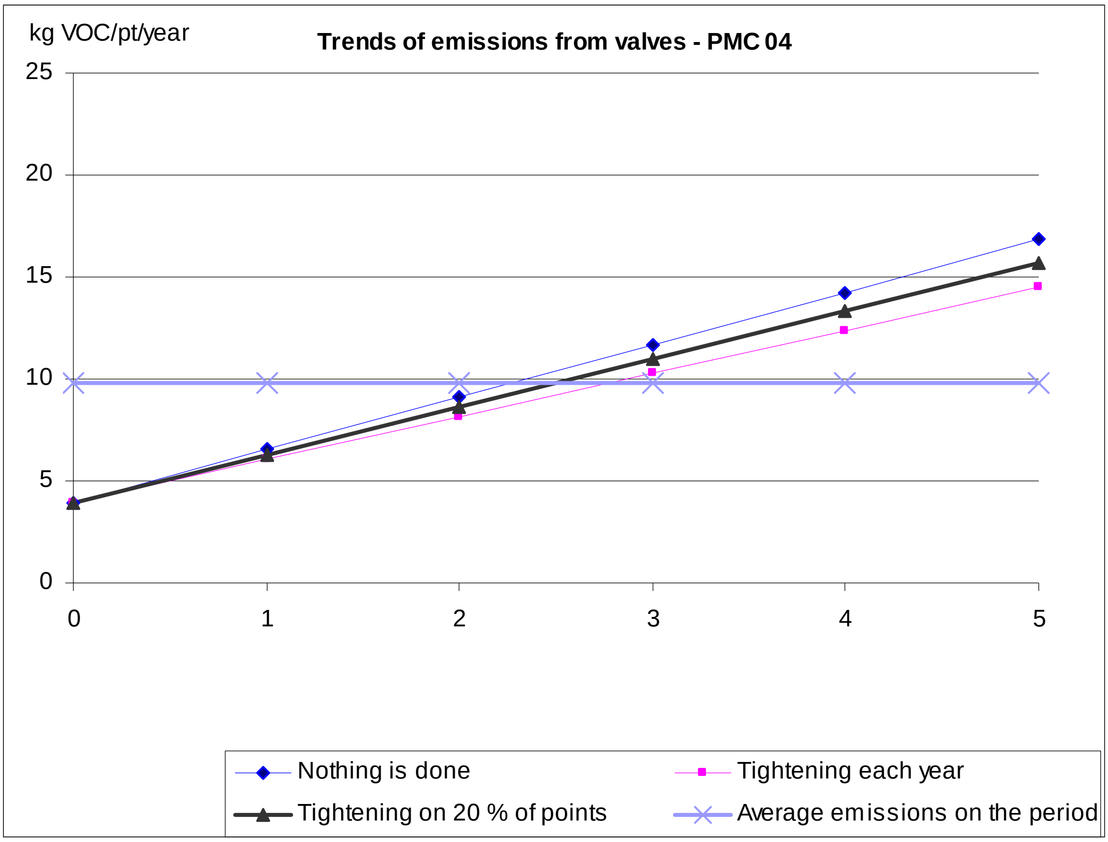


Figure 7.2.6: Accessible flanges - Calculations of average emissions for the period of 5 years - PMC 01.

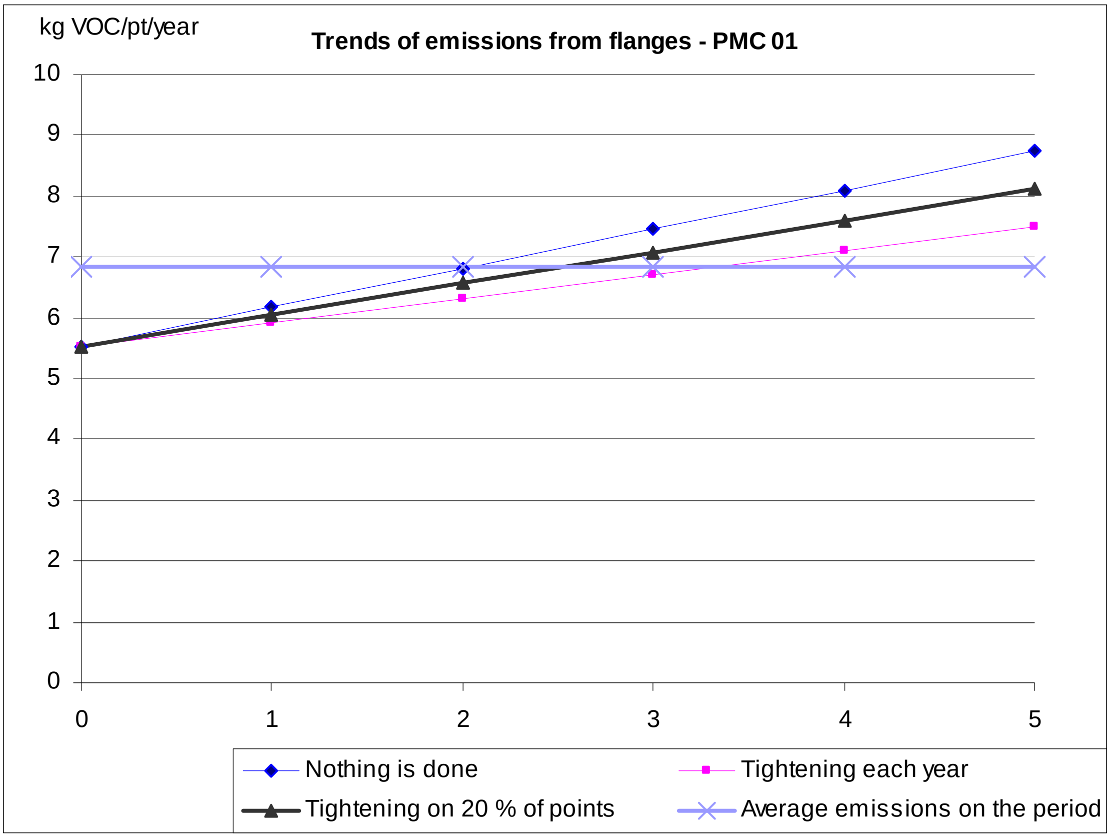


Figure 7.2.7: Accessible flanges - Calculations of average emissions for the period of 5 years - PMC 02.

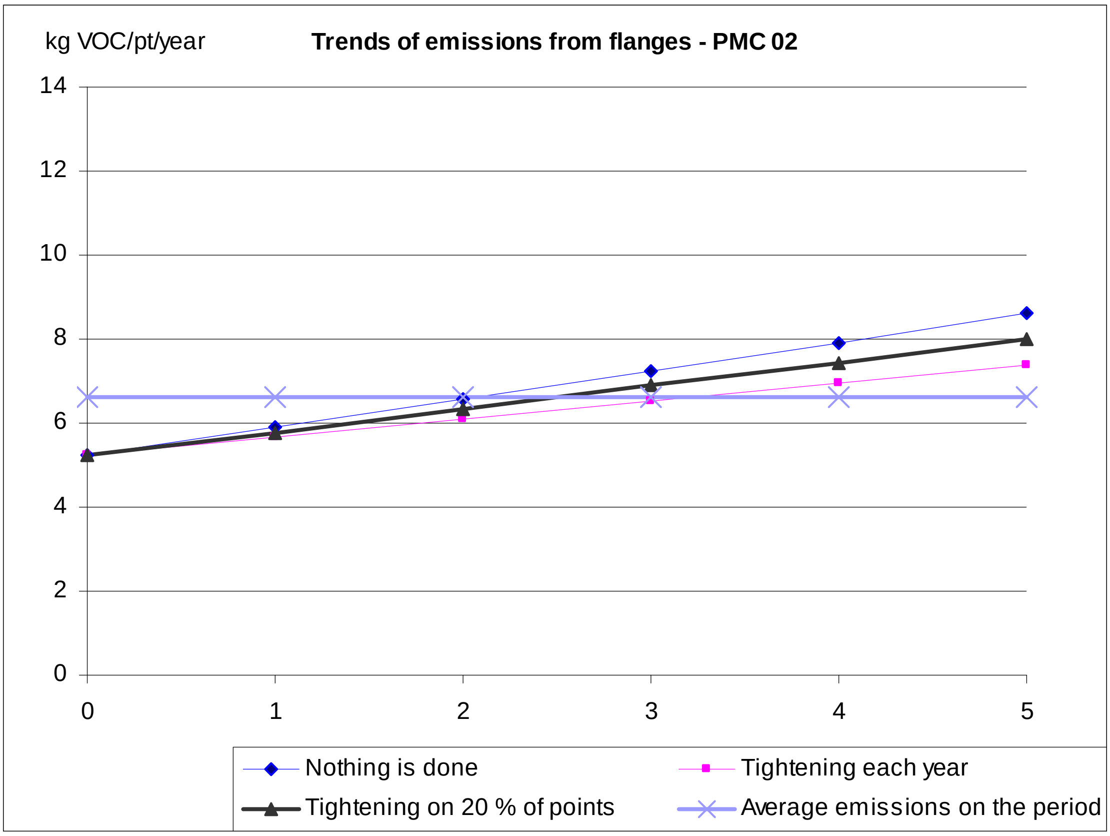


Figure 7.2.8: Accessible flanges - Calculations of average emissions for the period of 5 years - PMC 03.

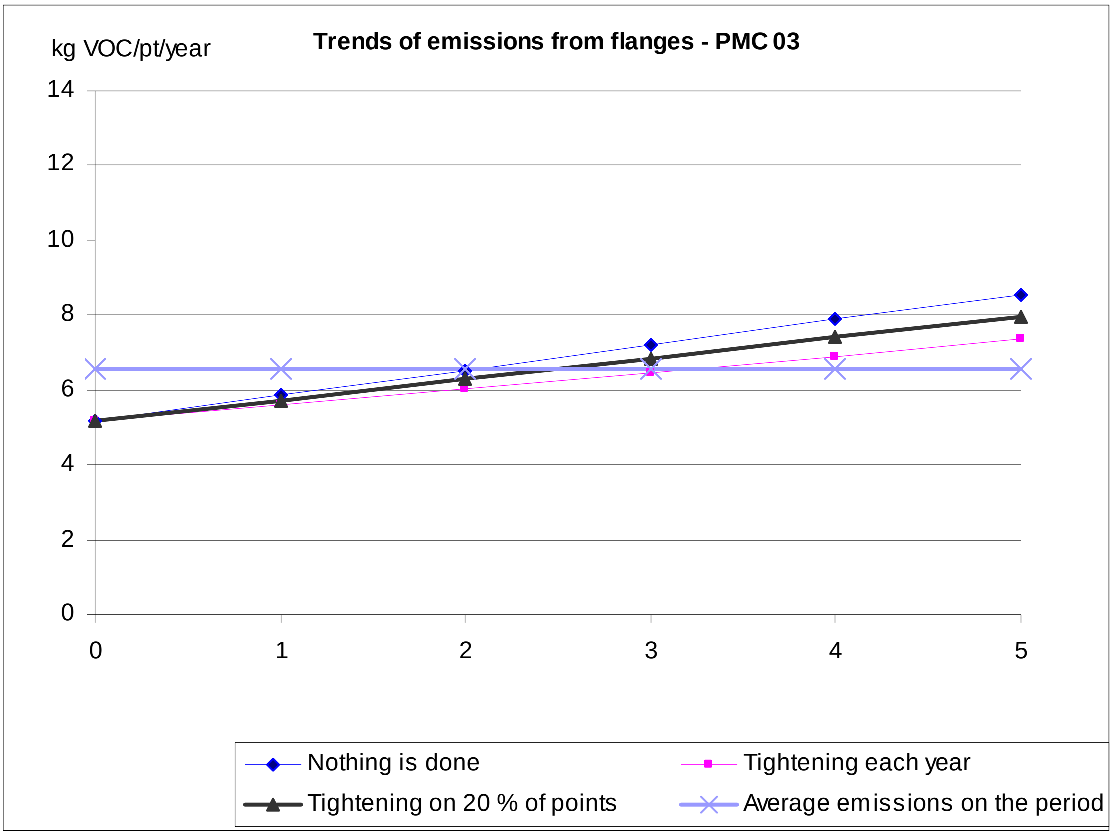
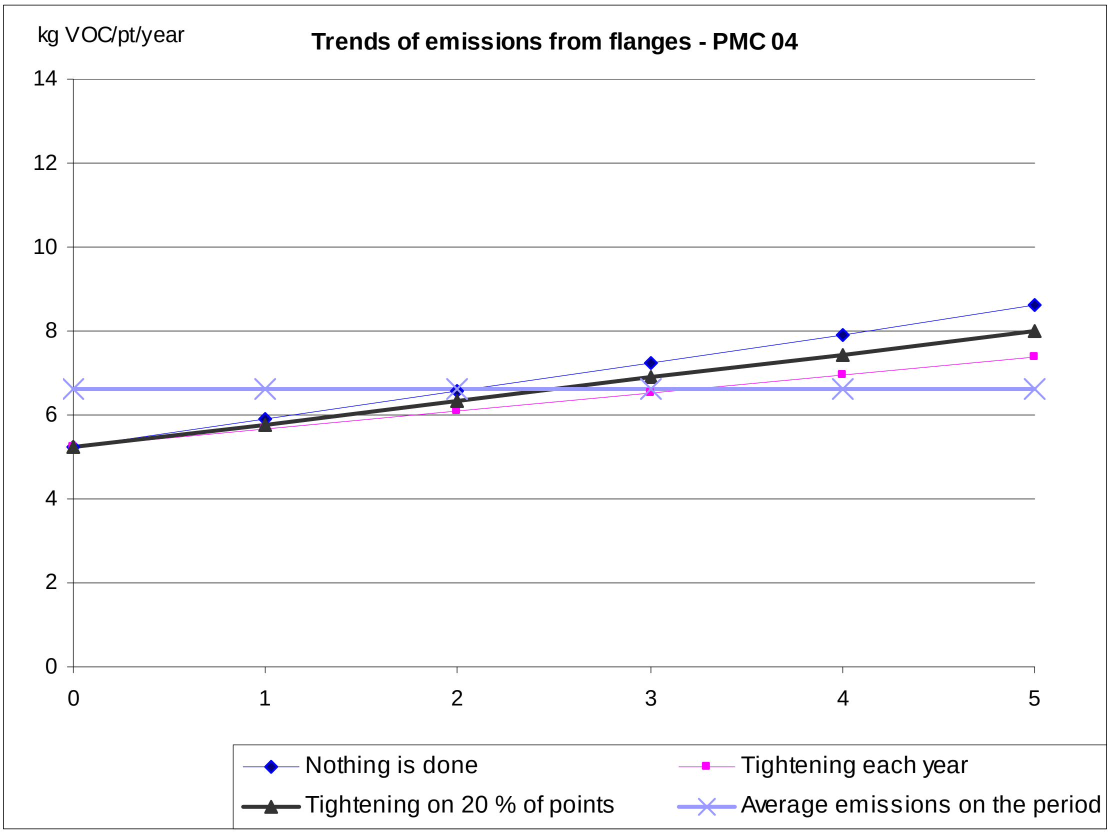


Figure 7.2.9: Accessible flanges - Calculations of average emissions for the period of 5 years - PMC 04.



Tables 7.2.9 to 7.2.12 present the calculations of emissions for the reference installation for primary measures 01 and 02.

Table 7.2.9: NMVOC emissions with primary measure 00 and primary measure 01

	Valves **NMVOC t/year**	**Flanges** **NMVOC t/year**	**Total emissions t NMVOC/y**	**NMVOC emissions t/t VOC.**
Fugitive emissions on inaccessible points	960*0.03=29	1440*0.012=17	46	
Fugitive emissions with PMC 00	3840*0.03 =115	5760*0.012 =69	184	
Fugitive emissions with PMC 01	3840*0.0173 =66	5760*0.0068 = 39	106	
Emissions avoided with PMC 01	49	30	78	
Total emissions with PMC 00			**230** (46+184)	**1.0**
Total emissions with PMC 01			**152** (46+106)	**0.66**

Table 7.2.10: NMVOC emissions with primary measure 00 and primary measure 02

	Valves **NMVOC t/year**	**Flanges** **NMVOC t/year**	**Total emissions t NMVOC/y**	**NMVOC emissions t/t VOC**
Fugitive emissions on inaccessible points	960*0.03=29	1440*0.012=17	46	
Fugitive emissions with PMC 00	3840*0.03 =115	5760*0.012 =69	184	
Fugitive emissions with PMC 02	3840*0.0165 =63	5760*0.0066 = 39	101	
Emissions avoided with PMC 02	52	31	83	
Total emissions with PMC 00			**230** (46+184)	**1.0**
Total emissions with PMC 02			**147** (46+104)	**0.64**

Table 7.2.11 NMVOC emissions with primary measure 00 and primary measure 03

	Valves **NMVOC t/year**	**Flanges** **NMVOC t/year**	**Total emissions t NMVOC/y**	**NMVOC emissions t/t VOC.**
Fugitive emissions on inaccessible points	960*0.03=29	1440*0.012=17	46	
Fugitive emissions with PMC 00	3840*0.03 =115	5760*0.012 =69	184	
Fugitive emissions with PMC 03	3840*0.0164 =63	5760*0.0066 = 38	101	
Emissions avoided with PMC 03	52	31	83	
Total emissions with PMC 00			**230** (46+184)	**1.0**
Total emissions with PMC 03			**147** (46+101)	**0..64**

Table 7.2.12 NMVOC emissions with primary measure 00 and primary measure 04

	Valves **NMVOC t/year**	**Flanges** **NMVOC t/year**	**Total emissions t NMVOC/y**	**NMVOC emissions t/t VOC**
Fugitive emissions on inaccessible points	960*0.03=29	1440*0.012=17	46	
Fugitive emissions with PMC 00	3840*0.03 =115	5760*0.012 =69	184	
Fugitive emissions with PMC 02	3840*0.0098 =38	5760*0.0066 = 38	76	
Emissions avoided with PMC 02	78	31	108	
Total emissions with PMC 00			**230** (46+184)	**1.0**
Total emissions with PMC 02			**122** (46+76)	**0.53**

7.3 Derivation of costs

Cost for the database establishment. the first measurement (100 % of points). the first basic maintenance have been considered as investment costs. even if labour costs are mainly involved.
Annual operation cost is composed of the control of 20 % of points and tightening of leaking points and takes into account 20 % of the cost of basic maintenance. carried out on a five year basis during shutdown.

Costs taken into account are as follows:

	Composition of costs	**Labour demand per point h/pt**	**Cost in France (labour cost 24.3 €/h)**
Control by sniffing	100 % labour cost	0.2	2 €/pt
Tightening	100 % labour cost	0.8	20 €/pt
Basic maintenance	50 % labour cost 50 % material	4.1 -	100 €/pt 100 €/pt

Table 7.3.1 and 7.3.4 present the total costs determined for PMC 01 to PMC 04

Table 7.3.1 : Total costs determined for primary measure 01.

		Valves			Flanges			Total
		Material cost	**Labour cost**	**Total cost**	**Material cost**	**Labour cost**	**Total cost**	
Investments - Establishment of a first LDAR program								
Investment for the data base	€	3840	3840	**7680**	5760	5760	**11520**	**19200**
First monitoring of all points	€	0	19200	**19200**	0	28800	**28800**	**48000**
Tightening on leaking points > 5000 ppm	€/operation	0	1382	**1382**	0	1152	**1152**	**2534**
Basic maintenance during shutdown on leaks > 100 000 ppm	€/basic maintenance	2688	2688	**5376**	2016	2016	**4032**	**9408**
Second control: Monitoring on potential leaking points	€/verification monitoring	0	346	**346**	0	288	**288**	**634**
Total investment	**€**	**6528**	**27456**	**33984**	**7776**	**38016**	**45792**	**79776**
Annualized costs (4%)	€/year			**4190**			**5646**	**9836**
Annual costs between two scheduled shutdowns **Yearly action on 20 % points and 0.2 basic maintenance**								
Monitoring of points	€/year	0	3840	3840	0	5760	**5760**	**9600**
Tightening on leaking points > 5000 ppm	€/year	0	208	208	0	175	**175**	**383**
Basic maintenance on leaking points > 100 000 ppm	€/year	428	428	857	321	321	**643**	**1500**
Second control : monitoring of potential leaking points	€/year	0	52	52	0	44	**44**	**96**
Total operation cost	**€/year**	**428**	**4528**	**4957**	**321**	**6300**	**6622**	**11578**
Total annual cost*	**€/year**			**9147**			**12268**	**21415**
Recovered VOC **	**€/year**			**19519**			**11846**	**31365**

* Annualized cost + operation cost.
** Mass of VOC recovered (t) x 400 €/t.

Table 7.3.2: total costs determined for primary measure 02.

		Valves			Flanges			Total
		Material cost	**Labour cost**	**Total cost**	**Material cost**	**Labour cost**	**Total cost**	
Investments - Establishment of a first LDAR program								
Investment for the data base	€	3840	3840	**7680**	5760	5760	**11520**	**19200**
First monitoring of all points	€	0	19200	**19200**	0	28800	**28800**	**48000**
Tightening on leaking points > 1000 ppm	€/operation	0	1920	**1920**	0	1267	**1267**	**3187**
Basic maintenance during shutdown on leaks > 10000 ppm	€/basic maintenance	4032	4032	**8064**	3024	3024	**6048**	**14112**
Second control: Monitoring on potential leaking points	€/verification monitoring	0	480	**480**	0	317	**317**	**797**
Total investment	**€**	**7872**	**29472**	**37344**	**8784**	**39168**	**47952**	**85296**
Annualized costs (4%)	€/year			**4605**			**5912**	**10517**
Annual costs between two scheduled shutdowns								
Yearly action on 20 % points and 0.2 basic maintenance								
Monitoring of points	€/year	0	3840	3840	0	5760	**5760**	**9600**
Tightening on leaking points > 1000 ppm	€/year	0	286	286	0	185	**185**	**471**
Basic maintenance on leaking points > 10 000 ppm	€/year	643	643	1285	482	482	**964**	**2249**
Second control : monitoring of potential leaking points	€/year	0	71	71	0	46	**46**	**118**
Total operation cost	**€/year**	**643**	**4840**	**5482**	**482**	**6473**	**6955**	**12437**
Total annual cost*	**€/year**			**10087**			**12868**	**22954**
Recovered VOC **	**€/year**			**20802**			**12345**	**33147**

* Annualized cost + operation cost.
** Mass of VOC recovered (t) x 400 €/t.

Table 7.3.3: total costs determined for primary measure 03.

		Valves			**Flanges**			**Total**
		Material cost	**Labour cost**	**Total cost**	**Material cost**	**Labour cost**	**Total cost**	
Investments - Establishment of a first LDAR program								
Investment for the data base	€	3840	3840	**7680**	5760	5760	**11520**	**19200**
First monitoring of all points	€	0	19200	**19200**	0	28800	**28800**	**48000**
Tightening on leaking points > 1000 ppm	€/operation	0	1920	**1920**	0	1267	**1267**	**3187**
Basic maintenance during shutdown on leaks > 5000 ppm	€/basic maintenance	4838	4838	**9677**	4032	4032	**8064**	**17741**
Second control: Monitoring on potential leaking points	€/verification monitoring	0	480	**480**	0	317	**317**	**797**
Total investment	**€**	**8678**	**30278**	**38957**	**9792**	**40176**	**49968**	**88925**
Annualized costs (4%)	€/year			**4803**			**6161**	**10964**
Annual costs between two scheduled shutdowns								
Yearly action on 20 % points and 0.2 basic maintenance								
20 % of points each year	€/year	0	3840	3840	0	5760	**5760**	**9600**
Tightening on leaking points > 1000 ppm	€/year	0	278	278	0	175	**175**	**453**
Basic maintenance on leaking points > 5 000 ppm	€/year	771	771	1542	643	643	**1285**	**2828**
Second control : monitoring of potential leaking points	€/year	0	69	69	0	44	**44**	**113**
Total operation cost	**€/year**	**771**	**4958**	**5729**	**643**	**6621**	**7264**	**12994**
Total annual cost*	**€/year**			**10533**			**13425**	**23958**
Recovered VOC **	**€/year**			**20924**			**12433**	**33358**

* Annualized cost + operation cost.
** Mass of VOC recovered (t) x 400 €/t.

Table 7.3.4: total costs determined for primary measure 04.

		Valves			Flanges			Total
		Material cost	**Labour cost**	**Total cost**	**Material cost**	**Labour cost**	**Total cost**	
Investments - Establishment of a first LDAR program								
Investment for the data base	€	3840	3840	**7680**	5760	5760	**11520**	**19200**
First monitoring of all points	€	0	19200	**19200**	0	28800	**28800**	**48000**
Tightening on leaking points > 1000 ppm (1000 to 10000 ppm for valves and flanges > 1000 ppm)	€/operation	0	1920	**1920**	0	1267	**1267**	**3187**
Basic maintenance during shutdown on flanges with leaks > 10000 ppm	€/basic maintenance	0	0	**0**	3024	3024	**6048**	**6048**
Heavy maintenance during shutdown on valves with leaks > 10000 ppm		40320	40320	**80640**	0	0		**80640**
Second control: Monitoring on potential leaking point	€/verification monitoring	0	480	**480**	0	317	**317**	**797**
Total investment	**€**	**44160**	**65760**	**109920**	**8784**	**39168**	**47952**	**157872**
Annualized costs (4%)	€/year			**13553**			**5912**	**19466**
Annual costs between two scheduled shutdowns								
Yearly action on 20 % points and 0.2 basic maintenance								
20 % of points each year	€/year	0	3840	3840	0	5760	**5760**	**9600**
Tightening on leaking point > 1000 ppm	€/year	0	244	244	0	185	**185**	**429**
Basic maintenance on leaking flanges > 10 000 ppm	€/year	0	0	0	482	482	**964**	**964**
Heavy maintenance on leaking valves > 10 000 ppm	€/year	4710	4710	9421	0	0	**0**	**9421**
Monitoring on potential leaking point	€/year	0	61	61	0	46	**46**	**107**
Total operation cost	**€/year**	**4710**	**8855**	**13566**	**482**	**6473**	**6955**	**20521**
Total annual cost*	**€/year**			**27119**			**12868**	**39987**
Recovered VOC **	**€/year**			**31014**			**12345**	**43359**

* Annualized cost + operation cost.
** Mass of VOC recovered (t) x 400 €/t.

8 Comments

Chapter to be completed with comments received from national experts

9 References for downstream units

[1] MONZAIN M. (UIC) ; MONGENET F. (UIC) ; CASTRO F. (UIC): Meeting held in Paris on 21/08/02 with N. ALLEMAND and J. VINCENT from CITEPA aiming at defining the best approach for cost definition in the organic chemical sector. Minutes of the meeting.

[2] KLIMONT Z. ; AMANN M. ; COFALA J. :
Estimating costs for controlling emissions of NMVOC from stationary sources in Europe
Report IR – 00- 51
IIASA – August 2000

[3] IIASA web site for NMVOC emission documents :
http://www.iiasa.ac.at/~rains/voc_review.html

[4] IPPCB
BREF large volume organic chemical industry
February 2003

[5] MONZAIN M. (UIC). LUYTEN P. (Atofina) and MARLIER G. (UIC): data collected in France for documenting the EGTEI work and the preparation and discussion of a project of regulation of fugitive emissions on steam crackers of the French ministry of environment.

[6] MONZAIN M. (UIC) ; DE MOULIN J.M. (CEFIC); HARSHAM K. (CEFIC) ; MARLIER G. (UIC) ; SCOLES G. (Shell chemicals): Meeting held in Paris on 13/03/03 with N. ALLEMAND from CITEPA for the cost definition in steam cracking. Minutes of the meeting.

[7] EPA
Protocol for equipment leak
Emission estimates
EPA 453-95-017 – 1995

[8] French ministry of Ecology and sustainable development: Project of regulatory text on fugitive emissions from petrochemical plants

[9] CEN TC 264
TC 264 WI 17
Measurement of fugitive emission of vapours generating from equipment and piping leaks
Paper not yet public
2003