Final Background Document
on the sector

Industrial applications of paints

Prepared in the framework of EGTEI

Prepared by CITEPA, Paris

Summary

Introduction (p.3)
Sectors considered in this document as well as the methodology used are defined in the introduction.

Background information (p.5)
Data currently used in RAINS are just presented for comparison reasons. Data which should be used in the new version of the model are shown later in this document.
All data provided by the BCF [1] and Trimite [2] are described in this chapter. Very detailed information has been gathered at a sub-sector level (trade coaters, general engineering, industrial equipment, furniture, original equipment, heavy engineering, plastics and ACE).
In the present document, sub-sectors have been aggregated because such detailed information is not available in most of the countries.
Three aggregated sub-sectors are described separately in the following paragraphs.

If national experts have detailed data (such as UK), they can be used directly during the bilateral consultations with IIASA.

General industry aggregated sector (p.39)

6 sub-sectors are considered in this paragraph: trade coaters, general engineering, industrial equipment, original equipment, heavy engineering and ACE. These sectors have been put together because measures considered and corresponding costs are quiet similar.

General industry aggregated sector – continuous processes (p.45)

Coating of metal furniture has to be studied separately because measures (application efficiencies) and investments are very different from the ones defined above. As no detailed information is available for drums and rigid metal packaging, these two sub-sectors are also considered in this paragraph.

General industry aggregated sector – plastic coating (p.51)

“Automotive OEM components” and “general industry –plastics” are represented in this paragraph. Data for the coating of car components have been provided by [8].
For these two sub-sectors, powder is not defined as a measure.

References (p.58)

Modifications compared to the draft background document (p.59)

Introduction

SNAP: 06 01 08 or NFR 3A Paint application

This document covers the use of paints in the sectors of the general industry (see chapter "Introduction" for explanations).

ACTIVITY: tonnes of paints consumed / year.
POLLUTANT CONSIDERED: VOC

1 Sectors which belong to the industrial application of paints

A lot of sectors can be included in the industrial application of paints. The BCF (British Coating Federation [1]) considers the following sub-sectors:
- Automotive OEM bodies,
- Automotive OEM components (primarily plastic automotive components),
- Vehicle Refinishing,
- Marine/offshore,
- High performance (protective, fire protection, anti-corrosion coatings),
- Rigid metal packaging (food, beer and beverage and general cans),
- Coil coatings,
- Drum,
- Furniture/joinery,
- Aerospace,
- ACE (Agricultural, Construction and similar Equipment),
- General Industry - trade coaters,
- General Industry – general engineering,
- General Industry – industrial equipment,
- General Industry – metal furniture,
- General Industry – original equipment,
- General Industry – heavy engineering,
- General Industry – plastics (other than those for automobiles),
- General Industry – powder.

2 Sectors considered in this document

In this document, all sectors but those already studied in other background documents (i.e. coating of cars, bus, trucks, truck cabins, wood, coil, leather, winding wires, decorative paints and other non-industrial use of paints) are considered.
Definitions of some sectors are given hereafter [1]:

- Automotive OEM components: coatings for, primarily, plastic automotive components at vehicle production lines and component manufacturers.
- Rigid metal packaging: coatings for internal and external surfaces of food, beer and beverage and general cans and caps and closures (does not include inks – see "metal decorating inks").
- Drum: coatings for application to new and refurbished drums and similar containers.
- ACE: coatings for the finishing of agricultural, construction and similar equipment.
- General Industry - trade coaters: coatings used by companies painting metal, plastic and wood components for others.
- General Industry – general engineering: coatings used by companies painting metal components for other to specified design requirements.
- General Industry – industrial equipment: coatings for manufacturers of machinery and equipment for use in other production processes.
- General Industry – metal furniture: coatings for manufacturers of metal domestic and industrial furniture.

- General Industry – original equipment: coatings for manufacturers of branded products (also use trade coaters and general engineering coaters for sub-components).
- General Industry – heavy engineering: coatings for large castings or sectional components (does not include structural steel or building components – see "high performance").
- General Industry – plastics: coatings for plastic substrate categories not covered elsewhere (e.g. in other general industrial sectors and "automotive OEM components"), including teletronics, audio equipment and vacuum metallising).
- General Industry – powder: coatings powder for use in the ACE and general industrial coating sectors above. The use of powder is not a sector by itself. Powder coatings can be used in the different sectors. It is defined as a measure to reduce VOC emissions when available.
- …

3. Representation of the sectors

3.1 General information

Most of the data for the general industry have been collected with the help of Mr NEWBOULD [1] from the BCF and Mr HENRY from the society Trimite [2]. Data have been collected at a desegregated level for 8 sub sectors of the general industry. As no data are available for other missing sub-sectors and as national experts do not have that kind of detailed information, it has been decided to represent the sector of the "application of paint in the general industry" as a whole.
Sectors have been aggregated into 3 sub-categories.

3.2 Country specific data

Total activity (consumption of paints per year) is required from 2000 to 2020 by steps of 5 years. The shares of use of the different types of coatings have to be determined (% of use of solvent based products, water based products or powder).
Situation in UK for the years 1990, 1998 and 2010 [1] is provided to guide national experts without any information. However the following points have to be highlighted:

- The situation in UK in 1990 is given since a lot of progress have been done because of national environmental constrains. This means that the situation in 1998 is already an advance situation. 1990 could represent the unabated situation of a lot of countries where no regulation has been implemented yet. In this document, the unabated situation is represented by the use of "traditional" solvent based paints.
- The shares of use of the different types of coatings are also country specific. In the sector of the paint application, the technical feasibility of using different types of coatings is driven by the type of pieces to be coated. This means that the situation in UK has to be adjusted to the different national situations.

Background information

1. Data currently used in the RAINS model [4] , [5]

Following data are just displayed for comparison reasons

"Other Industrial Use of Paints" is considered in the RAINS model. This sector concerns the ship building industry, manufacture of plastic and metal articles, wood products industry. So it is larger as the ones studied in the present background document.

1.1 Control options

In the present stage of development of RAINS, the following groups of control options are considered:

- Measure 00 : Reference case;
- Measure 01: Package of good housekeeping and other primary measures (solvent management plans, modification of spray application techniques to improve transfer efficiency) (applicability 40-45%; reduction efficiency: around 65%);
- Measure 02 : Substitution with alternative coatings (applicability : 80%; reduction efficiency : 77 to 88% depending of solvent contents of alternative coating);
- Measure 03: Add-on techniques: thermal and catalytic incineration (application potential is limited; reduction efficiency: 95%). Activated carbon adsorption and biological bed are not currently studied.

1.2 Abatement costs

Examples for three countries are displayed below:

No comments are made on the figures displayed in the following tables because no further information is available.
Data on the other countries are downloadable on
http://www.iiasa.ac.at/~rains/voc_review/single.html

Table 1.1: French situation

Activity level 1990 : 194,954 kt paint used;
2010 : 220,688 kt paint used,
VOC emission scenario business as usual : 1990 : 83,32 kt VOC;
2010 : 50,27 kt VOC.

Measure	Emission factor [kt VOC / kt of paint]	Efficiency [%]	Technical Eff. [%]	Applicability [%]	Unit cost [€$_{1990}$/t VOC]
00	0,6311	0	0	0	0
01	0,4334	31	67	47	56
02	0,3555	44	87	50	902
03	0,2414	62	95	65	2 068
01+02	0,3305	48	48	100	863
01+03	0,2315	63	63	100	2 044
01+02+03	0,1396	78	78	100	1 771

Table 1.2: German situation (Old Laender)

Activity level 1990 : 350,000 kt paint used;
2010 : 398,475 kt paint used,
VOC emission scenario business as usual : 1990 : 211,76 kt VOC;
2010 : 107,61 kt VOC.

Measure	Emission factor [kt VOC / kt of paint]	Efficiency [%]	Technical Eff. [%]	Applicability [%]	Unit cost [€$_{1990}$/t VOC]
00	0,7200	0	0	0	0
01	0,5040	30	68	44	-136
02	0,2144	70	88	80	791
03	0,2754	62	95	65	1 812
01+02	0,1880	74	74	100	6 97
01+03	0,2646	63	63	100	1 705
01+02+03	0,1698	76	76	100	1 630

Table 1.3: German situation (New Laender)

Activity level 1990 : 69,000 kt paint used;
2010 : 78,557 kt paint used,
VOC emission scenario business as usual : 1990 : 49,68 kt VOC;
2010 : 29,09 kt VOC.

Measure	Emission factor [kt VOC / kt of paint]	Efficiency [%]	Technical Eff. [%]	Applicability [%]	Unit cost [€$_{1990}$/t VOC]
00	0,7200	0	0	0	0
01	0,5040	30	68	44	-136
02	0,2144	70	88	80	791
03	0,2754	62	95	65	1 812
01+02	0,1880	74	74	100	6 97
01+03	0,2646	63	63	100	1 705
01+02+03	0,1698	76	76	100	1 630

Table 1.4: Hungarian situation

Activity level 1990 : 3,542 kt paint used;
2010 : 3,925 kt paint used,
VOC emission scenario business as usual : 1990 : 2,36 kt VOC;
2010 : 2,60 kt VOC.

Measure	Emission factor [kt VOC / kt of paint]	Efficiency [%]	Technical Eff. [%]	Applicability [%]	Unit cost [€$_{1990}$/t VOC]
00	0,7288	0	0	0	0
01	0,5047	31	68	45	27
02	0,2190	70	87	80	773
03	0,2787	62	95	65	1 791
01+02	0,1908	74	74	100	744
01+03	0,2675	63	63	100	1 760
01+02+03	0,1720	76	76	100	1 664

2. Short technology description reported from [3]

According to [3], due to the high variety of techniques used and the highly different requirements for the quality of coatings, uniform reduction techniques can not be defined.
Some examples are given hereafter to show the diversity of situations encountered in this sector:

2.1 Types of paints used [3]

The requirements of the surface coating show significant differences within the sectors of paint application.

2.1.1 Solvent based paints

Conventional solvent based paints contain approximately 30 to 80 wt. % of organic solvents.
High solid paints have a solid content above 65%.

2.1.2 Water based products

Water based paints contain 3 to 18% of organic solvents used as solubilizer and for the improvement of properties of the wet film layer.
These paints are available and are widely used. Their range of application is increasing continuously.

2.1.3 Powder coatings

Powder coatings are solvent free materials. Most often, overspray is recycled so the transfer efficiency is pretty high. For drying, the material is heated and thus merged into a film. Powder coatings are mainly applied via electrostatic assisted spraying on the work pieces. In several sectors, this technique is well established.

2.2 Varnishing of steel furniture [3]

Conventional, water based and powder coatings can be processed.

- Generally, solvent based paints are applied by an automated and manual electrostatic spraying technique. To reduce VOC emissions, air flows can be driven to an abatement device.
The advantage of these paints is the high flexibility in colouring.

- Powder varnish systems are less flexible concerning changes in colouring compared to wet varnish systems.

- Cathodic dip coating installations. This technique has high application efficiency factors, creates a homogenous layer thickness, achieves a very good corrosion protection and leads to very low VOC emissions. However, this varnishing concept is only suitable for high production rates with one colour because changes in colour are not possible.

2.3 Varnishing of shelves [3]

Typical characteristics for the varnishing of shelves are the big variety in colours and different geometries. Hence often a combined installation with automated and manual varnishing lines is used.
Conventional varnishes can be applied by spraying. Deposition of water based paints is mostly carried out within a dip coating installation for standard colours.
Powder can also be used in some cases. Energy consumption, material consumption and operating costs are currently higher than for liquid varnishes because the layer thickness is high.

2.4 Varnishing of household appliances [3]

In the production of refrigerators and stoves, coated coils are often used.

2.5 Varnishing of engine blocks [3]

Engine blocks are coated with a powder varnish based on epoxy resin with an electrostatic spraying technique. The overspray is recycled. Drying is carried out by irradiation at a temperature of 200°C.

2.6 Varnishing of windshield wipers [3]

Water based and powder coatings can be processed. The high layer thickness of powder coatings can have an impact on surface quality and also in the assembly of the parts.

2.7 Varnishing of mechanical engineering [3]

Especially resistant coatings such as conventional PUR fillers and top coatings have to be used for tool machines and other metal processing machines.
The electric dip coating technique with water based varnishes as ground coatings is the most widely used method.
Conventional and water based coatings are also applied with spraying techniques.

Typically, two top coating layers are applied in the machine varnishing. Liquid varnishes are applied predominantly manually with HVLP, airless guns.

Powder varnish systems are also in used. They can be applied directly onto the degreased substrate or as a top layer onto a ground coating. Application is usually carried out by electrostatic spraying techniques.

2.8 Varnishing of frontage parts [3]

Frontage parts have been coated with powder systems for a long time.

2.9 Varnishing of hospital furniture [3]

Hospital furniture is already coated with polyester powder coatings since it has to be disinfected, hot water and scratch resistant.

2.10 Varnishing of heating elements [3]

For varnishing of heating elements, the use of powder coatings is state of the art.

2.11 Varnishing of bike and motorbike frames [3]

Bike and motorbike frames are ground-coated with water based paints, then coated with a colouring base coating and finally coated with a liquid clear varnish. Base coat and clear coat are mostly solvent based. Powder is used increasingly though. A problem is that some adhesive bondings are not temperature resistant above 180 °C.

2.12 Varnishing in the production of TV, hi-fi and computer housings [3]

According to [3], nowadays there is a trend towards a demand of colourful products and even individual customer requests regarding the colour design. Quality requirements for the coating of the housings include essentially the resistance against alcohols, skin fat and others, the scratch and abrasion resistance as well as good optical surface properties.
State of the art is the serial use of water based coatings.

2.13 General reduction techniques [3]

The use of low solvent or solvent free coatings: water based and powder coatings are an alternative for conventional solvent based coatings for nearly all sub-sectors. The technical applicability of the different types of paints is closely related to the rate of production, the shape of the pieces to be coated and the changes in colourings.
High transfer efficiencies can also be reached with different application techniques.

3. EU regulation : Directive 1999/13/EC of 11 March 1999 [6]

Operators concerned can conform to the Directive in either of the following ways:

- By complying with the canalized and fugitive emission values.
- By introducing a reduction scheme to obtain an equivalent emission level, (in particular by replacing conventional products with high solvent content by low-solvent or solvent-free products).

The EC Directive applies to installations with a solvent consumption above 5 t per year.

Emission limits implemented are presented in table 3.1.

Table 3.1: Emission limits

Solvent consumption threshold [t / y]	**VOC emission limit value in residual gases [mg C / Nm^3]**	**Fugitive emissions [% of solvent input*]**
5-15	100	25
> 15	50 for the drying processes 75 for coating application processes	20

Coating activities which cannot be applied under contained conditions (such as shipbuilding, aircraft painting) may be exempted from these values.

All obligations of the Directive are not described in this chapter.

4 Trade coaters

4.1 Definition of the Reference Installation

Table 4.1: Reference installation [1], [2]

Reference Installation Code RIC	Description
01	Medium Reference Installation : 22 t of paints used per year

4.2 Definitions of primary measures [1], [2]

Two parameters are considered to define the primary measures: the solvent contents of the paints and the application efficiency of the technique used.

Table 4.2.1: Primary measures

Primary Measure Code PMC	Description
00	"Traditional" solvent based paints (60% solvent content). Application efficiency of 40%
01	Improved solvent based paints (55% solvent content). Application efficiency of 45%
02	Powder coatings (100% of solid content). Application efficiency : 80%

4.3 Definitions of secondary measures

When no alternative to solvent based paints is available, techniques such as thermal oxidation are available.

Table 4.3.1: Secondary measures

Secondary Measure Code SMC	Description
00	No secondary measure
01	Thermal incineration

4.4 Definition of the consumption factors

Annual paints consumptions are defined in table 4.4.1: as solid contents of the different types of paints and application techniques are different, consumptions vary from one measure to another.

Application efficiency of powder coatings is 80% as defined in table 4.2.1. However, on average, only 50% of the paint is effectively used because in practice, paint bought for a particular job can not be used for another customer.

Table 4.4.1: Paint consumption

RIC PMC	Calculations	Paint consumption (t/y)
01 00	22	22
01 01	(22 × 0,4 / 0,45) × 0,4 / 0,45	17,4
01 02	(22 × 0,4 / 1) × 0,4 / 0,5	7

4.5 Emission factors

It is assumed that:

- In installations where the application is not enclosed and without abatement devices, all the solvent used is emitted into the air : EF = 1 g solvent/g solvent consumed,
- In installations with secondary abatement devices, where the application is enclosed, only fugitive emissions occur (20 % of the total solvent consumption). Abatement techniques are assumed to have an efficiency of 95%.

According to [1] and [2], cleaning solvent consumptions are assumed to be 15% of the solvent used for PMC 00 and 8% of the solvents used for PMC 01.

To be consistent with the data used in the RAINS model, emission factors for this sector have to be compared to the reference case (PMC 00).

Table 4.5.1: Emission factors (EF) for the different combinations

PMC SMC	Calculations	Emission Factors [g solvent/kg paint]	EF [compared to PMC 00]	Efficiency [%]
01 00 00	600 × 1,15	690	690	0,00
01 00 01	690 × (0,2 + 0,8 × 0,05)	165,6	165,6	76,00
01 01 00	550 × 1,08	594	594 × 17,4/22 = 470	31,88
01 01 01	470 × (0,2 + 0,8 × 0,05)	113	113	83,62
01 02 00	0	0	0	100,00

4.6 Derivation of Cost Data [1], [2]

Primary Measures

Several cost items are taken into account. They have been derived from information provided by Mr. Henry [2]:

- ü R&D costs: according to [2], no R&D costs are incurred for this activity. Paints used by the coaters are developed their clients.
- ü Investments: for PMC 01, more efficient guns are used. Investments are around 8 200 €. For PMC 02, ovens have to be changed: total investments would be around 18000 €.
- ü Operating costs: raw materials and energy are considered.

Costs for traditional solvent based paints are derived from those of improved solvent based paints: it is assumed that cost is proportional to the solid contents of the products. Powder paints cost is lower than the one of improved solvent based paints because of the price competition between manufacturers [1].

Table 4.6.1: Costs of paints

Parameters	Default costs [2]
"Traditional" solvent based paints [€ / kg]	6,7
Improved solvent based paints [€ / kg]	7,5
Powder paints [€ / kg]	7,0
Cleaning solvents [€ / kg]	0,15

Table 4.6.2: Raw material costs

PMC	Costs of material [€/y]
00	22 [t paints] × 6 700 [€/t] + 2 [t solvent] × 150 [€/t] = 147 700
01	17,4 [t paints] × 7 500 [€/t] + 0,75 [t solvent] × 150 [€/t] = 130 600
02	7 [t paints] × 7 000 [€/t] = 49 000

According to [7], energy consumption for solvent based products (PMC 00) is as defined in table 4.6.3:
According to [2], energy consumption for powder coatings is twice higher: in fact, oven's temperature for solvent based coatings is around 85 °C when for powder coatings, it is 180 °C.

Table 4.6.3: Energy consumptions

PMC	Energy consumption [kWh/y]	Costs [€/y]
00	150 000	150 000 × 0,0686 = 10 300
01	150 000	150 000 × 0,0686 = 10 300
02	300 000	300 000 × 0,0686 = 20 600

Secondary Measures

Investments and operating costs for the secondary measures are derived from the estimated flow rate.
Annual working time: 1 780 h / y [1], [2].

The VOC-concentration in the waste gas stream is assumed to be 0,2 g/m^3.
Flow rate is calculated from the following equation:

Flow rate [m^3/h] = 0,8 × [(g COV / kg paints)] × (kg paints/y)] / [(g VOC/m^3) × (h/y)]

4.7 Default values

Table 4.7.1: Size of this sub-sector in UK in 1998 [1]

Size of this sub-sector compared to the whole sector of the industrial application of paints in 1998 [%]
3,7

Table 4.7.2: Activities in 1990, 1998, 2010 in UK [1]

Activity in 1990 [t]	Activity in 1998 [t]	Activity in 2010 [t]
9 960	9 740	10 860

Table 4.7.3: Default values corresponding to the UK situation [2]

RIC PMC SMC	Application rate in 1990 [% of activity]	Application rate in 2000 [% of activity]	Application rate in 2010 [% of activity] *	Technical Appl. [%]
01 00 00	60	0	0	0
01 00 01	0	0	0	0
01 01 00	0	50	40	40
01 01 01	0	0	0	0
01 02 00	40	50	60	60
Total RIC 01	**100**	**100**	**100**	

* In 2010, 5% of the product use is believed to be water based paints. This is not considered in this document.

5 General engineering

5.1 Definition of the Reference Installation

Table 5.1.1: Reference installation [1], [2]

Reference Installation Code RIC	Description
01	Medium Reference Installation : 22 t of paints used per year

5.2 Definitions of primary measures [1], [2]

Two parameters are considered to define the primary measures: the solvent contents of the paints and the application efficiency of the technique used. For powder coatings, transfer efficiency is higher than the one for trade coaters because overspray is recycled and reused.

Table 5.2.1: Primary measures

Primary Measure Code PMC	Description
00	"Traditional" solvent based paints (60% solvent content). Application efficiency of 40%
01	Improved solvent based paints (55% solvent content). Application efficiency of 45%
02	Powder coatings (100% of solid content). Application efficiency : 95%

5.3 Definitions of secondary measures

When no alternative to solvent based paints is available, techniques such as thermal oxidation are available.

Table 5.3.1: Secondary measures

Secondary Measure Code SMC	Description
00	No secondary measure
01	Thermal incineration

5.4 Definition of the consumption factors

Annual consumptions of paints are defined in table 5.4.1: as solid contents of the different types of paints and application techniques are different, consumptions vary from one measure to another.

Application efficiency of powder coatings is 95% as defined in table 5.2.1. However, on average only 85% of the paint used is applied (see explanations Chapter 4.4).

Table 5.4.1: Paint consumption

RIC PMC	Calculations	Paint consumption (t/y)
01 00	22	22
01 01	(22 × 0,4 / 0,45) × 0,4 / 0,45	17,4
01 02	(22 × 0,4 / 1) × 0,4 / 0,85	4,1

5.5 Emission factors

It is assumed that:

- In installations where the application is not enclosed and without abatement devices, all the solvent used is emitted into the air : EF = 1 g solvent/g solvent consumed,
- In installations with secondary abatement devices, where the application is enclosed, only fugitive emissions occur (20 % of the total solvent consumption). Abatement techniques are assumed to have an efficiency of 95%.

According to [1] and [2], cleaning solvent consumptions are assumed to be 15% of the solvents used for PMC 00 and 8% of the solvents used for PMC 01.

To be consistent with the data used in the RAINS model, emission factors for this sector have to be compared to the reference case (PMC 00).

Table 5.5.1: Emission factors for the different combinations

PMC SMC	Calculations	Emission Factors [g solvent/kg paint]	EF [compared to PMC 00]	Efficiency [%]
01 00 00	600 × 1,15	690	690	0,00
01 00 01	690 × (0,2 + 0,8 × 0,05)	165,6	165,6	76,00
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01 01 01	470 × (0,2 + 0,8 × 0,05)	113	113	83,62
01 02 00	0	0	0	100,00

5.6 Derivation of Cost Data [1], [2]

Primary Measures

Several cost items are taken into account. They have been derived from information provided by Mr. Henry [2]:

- ü R&D costs: according to [2], no R&D costs are incurred for this activity. Paints used by the coaters are developed by their clients.
- ü Investments: for PMC 01, more efficient guns are used. Investments are around 8 200 €. For PMC 02, ovens also have to be changed: total investments would be around 18 000 €.
- ü Operating costs: raw materials and energy are considered.

Costs for traditional solvent based paints are derived from the one of improved solvent based paints: it is assessed that cost is proportional to the solid contents of the products. Powder paints cost is lower than the one of improved solvent based paints because of the price competition between manufacturers [1].

Table 5.6.1: Costs of paints

Parameters	Default costs [2]
"Traditional" solvent based paints [€ / kg]	6,2
Improved solvent based paints [€ / kg]	7
Powder paints [€ / kg]	6,7
Cleaning solvents [€ / kg]	0,15

Table 5.6.2: Raw material costs

PMC	Costs of material [€/y]
00	22 [t paints] × 6 200 [€/t] + 2 [t solvent] × 150 [€/t] = 136 700
01	17,4 [t paints] × 7 000 [€/t] + 0,75 [t solvent] × 150 [€/t] = 121 910
02	4,1 [t paints] × 6 700 [t solvent] = 27 470

According to [7], energy consumption for solvent based products (PMC 00) is as presented in table 5.6.3.
According to [2], energy consumption for powder coatings is twice higher.

Table 5.6.3: Energy consumptions

PMC	Energy consumption [kWh/y]	Costs [€/y]
00	150 000	150 000 × 0,0686 = 10 300
01	150 000	150 000 × 0,0686 = 10 300
02	300 000	300 000 × 0,0686 = 20 600

Secondary Measures

Investments and operating costs for the secondary measures are derived from the estimated flow rate.
Annual working time: 1 780 h / y [1], [2].

The VOC-concentration of the waste gas stream is assumed to be 0,2 g/m^3.
Flow rate is calculated from the following equation:

Flow rate [m^3/h] = 0,8 × [(g COV / kg paints)] × (kg paints/y)] / [(g VOC/m^3) × (h/y)]

5.7 Default values

Table 5.7.1: Size of this sub-sector in UK in 1998 [1]

Size of this sub-sector compared to the whole sector of the industrial application of paints in 1998 [%]
3,5

Table 5.7.2: Activities in 1990, 1998, 2010 in UK [1]

Activity in 1990 [t]	Activity in 1998 [t]	Activity in 2010 [t]
8 600	9 040	8 600

Table 5.7.3: Default values corresponding to the UK situation [2]

RIC PMC SMC	Application rate in 1990 [% of activity]	Application rate in 2000 [% of activity]	Application rate in 2010 [% of activity] *	Technical Appl. [%]
01 00 00	65	0	0	100
01 00 01	0	0	0	100
01 01 00	0	57	51	100
01 01 01	0	0	0	100
01 02 00	35	43	47	47
Total RIC 01	**100**	**100**	**100**	

* In 2010, 6% of the product use is believed to be water based paints. This is not considered in this document.

6 Industrial equipment

6.1 Definition of the Reference Installation

Table 6.1.1: Reference installation [1], [2]

Reference Installation Code RIC	Description
01	Medium Reference Installation : 22 t of paints used per year

6.2 Definitions of primary measures [1], [2]

Two parameters are considered to define the primary measures: the solvent contents of the paints and the application efficiency of the technique used.

Table 6.2.1: Primary measures

Primary Measure Code PMC	Description
00	"Traditional" solvent based paints (65% solvent content). Application efficiency of 40%
01	Improved solvent based paints (55% solvent content). Application efficiency of 65%
02	Water based paints (5% solvent content – 35% dry matter). Application efficiency : 65%
03	Powder coatings (100% of solid content). Application efficiency : 95%

6.3 Definitions of secondary measures

When no alternative to solvent based paints is available, techniques such as thermal oxidation are available.

Table 6.3.1: Secondary measures

Secondary Measure Code SMC	Description
00	No secondary measure
01	Thermal incineration

6.4 Definition of the consumption factors

Annual consumptions of paints are defined in table 6.4.1: as solid contents of the different types of paints and application techniques are different, consumptions vary from one measure to another.

Application efficiency of powder coatings is 95% as defined in table 6.2.1. However, in average only 90% of the paint used is effectively applied (see chapter 4.4).

Table 6.4.1: Paint consumption

RIC PMC	Calculations	Paint consumption (t/y)
01 00	22	22
01 01	(22 × 0,35 / 0,45) × 0,4 / 0,65	10,5
01 02	(22 × 0,35 / 0,35) × 0,4 / 0,65	13,5
01 03	(22 × 0,35 / 1) × 0,4 / 0,9	3,4

6.5 Emission factors

It is assumed that:

- In installations where the application is not enclosed and without abatement devices, all the solvent used is emitted into the air : EF = 1 g solvent/g solvent consumed,
- In installations with secondary abatement devices, where the application is enclosed, only fugitive emissions occur (20 % of the total solvent consumption). Abatement techniques are assumed to have an efficiency of 95%.

According to [1] and [2], cleaning solvent consumptions are assumed to be 15% of the solvents used for PMC 00 and 8% of the solvents used for PMC 01.

To be consistent with the data used in the RAINS model, emission factors for this sector have to be compared to the reference case (PMC 00).

Table 6.5.1: Emission factors for the different combinations

PMC SMC	Calculations	Emission Factors [g solvent/kg paint]	EF [compared to PMC 00]	Efficiency [%]
01 00 00	650 × 1,15	750	750	0,00
01 00 01	750 × (0,2 + 0,8 × 0,05)	180	180	76,00
01 01 00	550 × 1,08	594	594 × 10,5/22 = 283,5	62,20
01 01 01	283,5 × (0,2 + 0,8 × 0,05)	68	68	90,93
01 02 00	50	50	50 × 13,5/22 = 30,7	95,91
01 03 00	0	0	0	0,00

6.6 Derivation of Cost Data [1], [2]

Primary Measures

Several cost items are taken into account. They have been derived from information provided by Mr. Henry [2]:

- ü R&D costs: according to [2], R&D costs to develop a new alternative paint (for wages and prototypes development) are around 11 500 €.
- ü Investments: for PMC 01, more efficient guns are used. Investments are around 8 200 €. For PMC 02, changes will cost around 16 300 €. For PMC 03, total investments would be around 18 000 €.
- ü Operating costs: raw materials and energy are considered.

Costs for traditional solvent based paints are derived from the one of improved solvent based paints: it is assessed that cost is proportional to the solid contents of the products.

Table 6.6.1: Costs of paints

Parameters	Default costs [2]
"Traditional" solvent based paints [€ / kg]	6,4
Improved solvent based paints [€ / kg]	8,2
Water based paints [€ / kg]	7,7
Powder paints [€ / kg]	6,5
Cleaning solvents [€ / kg]	0,15

Table 6.6.2: Raw material costs (figures are rounded)

PMC	Costs of material [€/y]
00	22 [t paints] × 6 400 [€/t] + 2 [t solvent] × 150 [€/t] = 141 100
01	10,5 [t paints] × 8 200 [€/t] + 0, 5 [t solvent] × 150 [€/t] = 86 175
02	13,5 [t paints] × 7 700 [€/t] = 103 950
03	3,4 [t paints] × 6 500 = 22 100

According to [7], energy consumption for solvent based products (PMC 00) is as presented in table 6.6.3. According to [2], energy consumption for powder coatings is twice higher and for water based products, 20% higher.

Table 6.6.3: Energy consumptions

PMC	Energy consumption [kWh/y]	Costs [€/y]
00	150 000	150 000 × 0,0686 = 10 300
01	150 000	150 000 × 0,0686 = 10 300
02	180 000	180 000 × 0,0686 = 12 300
03	300 000	300 000 × 0,0686 = 20 600

Secondary Measures

Investments and operating costs for the different secondary measures are derived from the estimated flow rate.
Annual working time: 1 780 h / y [1], [2].

The VOC-concentration of the waste gas stream is assumed to be 0,2 g/m^3.
Flow rate is calculated from the following equation:

Flow rate [m^3/h] = 0,8 × [(g COV / kg paints)] × (kg paints/y)] / [(g VOC/m^3) × (h/y)]

6.7 Default values

Table 6.7.1: Size of this sub-sector in UK in 1998 [1]

Size of this sub-sector compared to the whole sector of the industrial application of paints in 1998 [%]
4,4

Table 6.7.2: Activities in 1990, 1998, 2010 in UK [1]

Activity in 1990 [t]	Activity in 1998 [t]	Activity in 2010 [t]
15 000	11 390	11 100

Table 6.7.3: Default values corresponding to the UK situation [1]

RIC PMC SMC	Application rate in 1990 [% of activity]	Application rate in 2000 [% of activity]	Application rate in 2010 [% of activity]	Technical Appl. [%]
01 00 00	65	0	0	100
01 00 01	0	0	0	100
01 01 00	0	55	45	100
01 01 01	0	0	0	100
01 02 00	4	6	12	12
01 03 00	31	39	43	43
Total RIC 01	**100**	**100**	**100**	

7 Original equipment

This sub-sector has the same profile than the "Industrial equipment".
Differences are in the calculation of the operating costs because paint costs are different.

7.1 Costs of raw materials

Table 7.1.1: Costs of paints

Parameters	Default costs [2]
"Traditional" solvent based paints [€ / kg]	6
Improved solvent based paints [€ / kg]	7,8
Water based paints [€ / kg]	7,2
Powder paints [€ / kg]	4,7
Cleaning solvents [€ / kg]	0,15

Table 7.1.2: Raw material costs (figures are rounded)

PMC	Costs of material [€/y]
00	22 [t paints] × 6 000 [€/t] + 2 [t solvent] × 150 [€/t] = 132 300
01	10,5 [t paints] × 7 800 [€/t] + 0,5 [t solvent] × 150 [€/t] = 81 975
02	13,5 [t paints] × 7 200 [€/t] = 97 200
03	3,4 [t paints] × 7 700 = 26 180

7.2 Default values

Table 7.2.1: Size of this sub-sector in UK in 1998 [1]

Size of this sub-sector compared to the whole sector of the industrial application of paints in 1998 [%]
5,3

Table 7.2.2: Activities in 1990, 1998, 2010 in UK [1]

Activity in 1990 [t]	Activity in 1998 [t]	Activity in 2010 [t]
17 800	13 790	15 200

Table 7.2.3: Default values corresponding to the UK situation [2]

RIC PMC SMC	Application rate in 1990 [% of activity]	Application rate in 2000 [% of activity]	Application rate in 2010 [% of activity]	Technical Appl. [%]
01 00 00	70	0	0	100
01 00 01	0	0	0	100
01 01 00	0	60	45	100
01 01 01	0	0	0	100
01 02 00	5	8	15	15
01 03 00	23	32	40	40
Total RIC 01	**100**	**100**	**100**	

8 Heavy engineering

8.1 Definition of the Reference Installation

Table 8.1.1: Reference installation [1], [2]

Reference Installation Code RIC	Description
01	Medium Reference Installation : 22 t of paints used per year

8.2 Definitions of primary measures [1], [2]

Two parameters are considered to define the primary measures: the solvent contents of the paints and the application efficiency of the technique used.

Table 8.2.1: Primary measures

Primary Measure Code PMC	Description
00	"Traditional" solvent based paints (65% solvent content). Application efficiency of 50%
01	Improved solvent based paints (55% solvent content). Application efficiency of 50%
02	Improved solvent based paints (45% solvent content). Application efficiency of 60%
03	Water based paints (4% solvent content – 35% dry matter). Application efficiency : 60%
04	Powder coatings (100% of solid content). Application efficiency : 96%

8.3 Definitions of secondary measures

When no alternative to solvent based paints is available, techniques such as thermal oxidation are available.

Table 8.3.1: Secondary measures

Secondary Measure Code SMC	Description
00	No secondary measure
01	Thermal incineration

8.4 Definition of the consumption factors

Annual consumptions of paints are defined in table 8.4.1: as solid contents of the different types of paints and application techniques are different, consumptions vary from one type of paint to another.

Application efficiency of powder coatings is 96% as defined in table 8.2.1. However, in average only 90% of the paint used is effectively applied (see chapter 4.4).

Table 8.4.1: Paint consumption

RIC PMC	Calculations	Paint consumption (t/y)
01 00	22	22
01 01	(22 × 0,35 / 0,45) × 0,5 / 0,5	17,1
01 02	(22 × 0,35 / 0,55) × 0,5 / 0,6	11,7
01 03	(22 × 0,35 / 0,35) × 0,5 / 0,6	18,3
01 04	(22 × 0,35 / 1) × 0,5 / 0,90	4,3

8.5 Emission factors

It is assumed that:

- In installations where the application is not enclosed and without abatement devices, all the solvent used is emitted into the air : EF = 1 g solvent/g solvent consumed,
- In installations with secondary abatement devices, where the application is enclosed, only fugitive emissions occur (20 % of the total solvent consumption). Abatement techniques are assumed to have an efficiency of 95%.

According to [1] and [2], cleaning solvent consumptions are assumed to be 15% of the solvent used for PMC 00 and 8% of the solvents used for PMC 01 and PMC 02.

To be consistent with the data used in the RAINS model, emission factors for this sector have to be compared to the reference case (PMC 00).

Table 8.5.1: Emission factors for the different combinations

PMC SMC	Calculations	Emission Factors [g solvent/kg paint]	EF [compared to PMC 00]	Efficiency [%]
01 00 00	650 × 1,15	750	750	0,00
01 00 01	750 × (0,2 + 0,8 × 0,05)	180	180	76,00
01 01 00	550 × 1,08	594	594 × 17,1/22 = 461,7	38,44
01 01 01	461,7 × (0,2 + 0,8 × 0,05)	111	111	85,20
01 02 00	450 × 1,08	486	486 × 11,7/22 = 258	65,60
01 02 01	258 × (0,2 + 0,8 × 0,05)	62	62	91,73
01 03 00	50	50	50 × 18,3/22 = 41,6	94,45
01 04 00	0	0	0	100,00

8.6 Derivation of Cost Data [1], [2]

Primary Measures

Several cost items are taken into account. They have been derived from information provided by Mr. Henry [2]:

- ü R&D costs: according to [2], R&D to develop a new paint are around 11 500 €.
- ü Investments: for PMC 02, more efficient guns are used. Investments are around 8 200 €. For PMC 03, changes will cost around 16 300 €. For PMC 03, total investments would be around 18 000 €.
- ü Operating costs, raw materials and energy are considered.

Costs for traditional solvent based paints are derived from the one of improved solvent based paints: it is assessed that cost is proportional to the solid contents of the products.

Table 8.6.1: Costs of paints

Parameters	Default costs [2]
"Traditional" solvent based paints [€ / kg]	7
Solvent based paints (55% VOC) [€ / kg]	9
Solvent based paints (45% VOC) [€ / kg]	11
Water based paints [€ / kg]	10
Powder paints [€ / kg]	7
Cleaning solvents [€ / kg]	0,15

Table 8.6.2: Raw material costs (figures are rounded)

PMC	Costs of material [€/y]
00	22 [t paints] × 7 000 [€/t] + 2 [t solvent] × 150 [€/t] = 154 300
01	17,1 [t paints] × 9 000 [€/t] + 0,7 [t solvent] × 150 [€/t] = 154 000
02	11,7 [t paints] × 11 000 [€/t] + 0,7 [t solvent] × 150 [€/t] = 128 800
03	18,3 [t paints] × 10 000 [€/t] = 183 000
04	4,3 [t paints] × 7 000 = 30 100

According to [7], energy consumption for solvent based products (PMC 00) is presented in table 8.6.3. According to [2], energy consumption for powder coatings is twice higher and for water based products, 20% higher.

Table 8.6.3: Energy consumptions

PMC	Energy consumption [kWh/y]	Costs [€/y]
00	150 000	150 000 × 0,0686 = 10 300
01	150 000	150 000 × 0,0686 = 10 300
02	150 000	150 000 × 0,0686 = 10 300
03	180 000	180 000 × 0,0686 = 12 300
04	300 000	300 000 × 0,0686 = 20 600

Secondary Measures

Investments and operating costs for the different secondary measures are derived from the estimated flow rate.
Annual working time: 1 780 h / y [1], [2].

The VOC-concentration in the waste gas stream is assumed to be 0,2 g/m^3.
Flow rate is calculated from the following equation:

Flow rate [m^3/h] = 0,8 × [(g COV / kg paints)] × (kg paints/y)] / [(g VOC/m^3) × (h/y)]

8.7 Default values

Table 8.7.1: Size of this sub-sector in UK in 1998 [1]

Size of this sub-sector compared to the whole sector of the industrial application of paints in 1998 [%]
4,4

Table 8.7.2: Activities in 1990, 1998, 2010 in UK [1]

Activity in 1990 [t]	Activity in 1998 [t]	Activity in 2010 [t]
12 900	11 590	10 800

Table 8.7.3: Default values corresponding to the UK situation [2]

RIC PMC SMC	Application rate in 1990 [% of activity]	Application rate in 2000 [% of activity]	Application rate in 2010 [% of activity]	Technical Appl. [%]
01 00 00	70	0	0	100
01 00 01	0	0	0	100
01 01 00	0	65	0	100
01 01 01	0	0	0	100
01 02 00	0	0	50	100
01 02 01	0	0	0	100
01 03 00	5	10	22	22
01 04 00	25	25	28	28
Total RIC 01	**100**	**100**	**100**	

9 Agricultural, construction and similar equipment (ACE)

This sector is close to the Heavy engineering and the Industrial equipment sectors. The difference is that secondary measures will be used more frequently than for the two other sectors.

Table 9.1: Size of this sub-sector in UK in 1998 [1]

Size of this sub-sector compared to the whole sector of the industrial application of paints in 1998 [%]
3,6

Table 9.2: Activities in 1990, 1998, 2010 in UK [1]

Activity in 1990 [t]	Activity in 1998 [t]	Activity in 2010 [t]
11 200	9 490	8 700

10 Furniture

10.1 Definition of the Reference Installation

Table 10.1.1: Reference installation [1], [2]

Reference Installation Code RIC	Description
01	Medium Reference Installation : 45 t of paints used per year

10.2 Definitions of primary measures [1], [2]

Two parameters are considered to define the primary measures: the solvent contents of the paints and the application efficiency of the technique used.

Table 10.2.1: Primary measures

Primary Measure Code PMC	Description
00	"traditional" solvent based paints (60% solvent content). Application efficiency of 70%
01	Improved solvent based paints (50% solvent content). Application efficiency of 70%
02	Water based paints (4% solvent content – 35% dry matter). Application efficiency : 98%
03	Powder coatings (100% of solid content). Application efficiency : 96%

10.3 Definitions of secondary measures

When no alternative to solvent based paints is available, techniques such as thermal oxidation are available.

Table 10.3.1: Secondary measures

Secondary Measure Code SMC	Description
00	No secondary measure
02	Thermal incineration

10.4 Definition of the consumption factors

Annual consumptions of paints are defined in table 10.4.1: as solid contents of the different types of paints and application techniques are different, consumptions vary from one measure to another.

Application efficiency of powder coatings is 96% as defined in table 10.2.1. However, in average only 92% of the paint used is effectively applied.

Table 10.4.1: Paint consumption

RIC PMC	Calculations	Paint consumption (t/y)
01 00	45	45
01 01	45 × 0,4 / 0,5	36
01 02	(45 × 0,4 / 0,35) × 0,7 / 0,98	36,7
01 03	(45 × 0,4 / 1) × 0,7 / 0,92	13,7

10.5 Emission factors

It is assumed that:

- In installations where the application is not enclosed and without abatement devices, all the solvent used is emitted into the air : EF = 1 g solvent/g solvent consumed,
- In installations with secondary abatement devices, where the application is enclosed, only fugitive emissions occur (20 % of the total solvent consumption). Abatement techniques are assumed to have an efficiency of 95%.

According to [1] and [2], cleaning solvent consumptions are assumed to be 15% of the solvents used for PMC 00 and 8% of the solvents used for PMC 01.

To be consistent with the data used in the RAINS model, emission factors for this sector have to be compared to the reference case (PMC 00).

Table 10.5.1: Emission factors for the different combinations

PMC SMC	Calculations	Emission Factors [g solvent/kg paint]	EF [compared to PMC 00]	Efficiency [%]
01 00 00	600 × 1,15	690	690	0,00
01 00 01	690 × (0,2 + 0,8 × 0,05)	165,6	165,6	76,00
01 01 00	500 × 1,08	540	540 × 36/45 = 432	37,39
01 01 01	432 × (0,2 + 0,8 × 0,05)	104	104	84,93
01 02 00	40	40	40 × 36,7/45 = 32,6	95,27
01 03 00	0	0	0	0,00

10.6 Derivation of Cost Data [1], [2]

Primary Measures

Several cost items are taken into account. They have been derived from information provided by Mr. Henry [2]:

- ü R&D costs: according to [2], R&D to develop a new paint are around 81 500 €.
- ü Investments: for PMC 02 and PMC 03, total investments would be around 260 000 €.
- ü Operating costs: raw materials and energy are considered.

Costs for traditional solvent based paints are derived from the one of improved solvent based paints: it is assessed that cost is proportional to the solid contents of the products.

Table 10.6.1: Costs of paints

Parameters	Default costs [2]
"Traditional" solvent based paints [€ / kg]	4,2
Improved solvent based paints [€ / kg]	5,2
Water based paints [€ / kg]	4,8
Powder paints [€ / kg]	4,3
Cleaning solvents [€ / kg]	0,15

Table 10.6.2: Raw material costs (figures are rounded)

PMC	Costs of material [€/y]
00	45 [t paints] × 4 200 [€/t] + 4 [t solvent] × 150 [€/t] = 189 600
01	36 [t paints] × 5 200 [€/t] + 1,5 [t solvent] × 150 [€/t] = 187 425
02	36,7 [t paints] × 4 800 [€/t] = 176 160
03	13,7 [t paints] × 4 300 = 58 910

According to [7], energy consumption for solvent based products (PMC 00) is as presented in table 10.6.3.
According to [2], energy consumption for powder coatings is twice higher and for water based products, 20% higher.

Table 10.6.3: Energy consumptions

PMC	Energy consumption [kWh/y]	Costs [€/y]
00	307 000	307 000 × 0,0686 = 21 000
01	307 000	307 000 × 0,0686 = 21 000
02	370 000	370 000 × 0,0686 = 25 400
03	614 000	614 000 × 0,0686 = 42 100

Secondary Measures

Investments and operating costs for are derived from the estimated flow rates and VOC concentrations.
Annual working time: 1 780 h / y [1], [2].

The VOC-concentration in the waste gas stream is assumed to be 0,2 g/m^3.
Flow rate is calculated from the following equation:

Flow rate [m^3/h] = 0,8 × [(g COV / kg paints)] × (kg paints/y)] / [(g VOC/m^3) × (h/y)]

10.7 Default values

Table 10.7.1: Size of this sub-sector in UK in 1998 [1]

Size of this sub-sector compared to the whole sector of the industrial application of paints in 1998 [%]
4,1

Table 10.7.2: Activities in 1990, 1998, 2010 in UK [1]

Activity in 1990 [t]	Activity in 1998 [t]	Activity in 2010 [t]
14 300	10 690	12 240

Table 10.7.3: Default values corresponding to the UK situation [1]

RIC PMC SMC	Application rate in 1990 [% of activity]	Application rate in 2000 [% of activity]	Application rate in 2010 [% of activity]	Technical Appl. [%]
01 00 00	65	0	0	100
01 00 01	0	0	0	100
01 01 00	0	25	15	100
01 01 01	0	0	0	100
01 02 00	3	10	15	15
01 03 00	32	65	70	70
Total RIC 01	**100**	**100**	**100**	

11 Can coating

11.1 General remarks

According to [10], beverage can manufacturers will mainly experience a shift towards the use of water based coatings and should opt for the total solvent consumption limit as a proportion of solids. The use of thermal oxidisers to achieve compliance in this sector is seen as problematic as one of the main companies has experienced explosions at a UK and European site.

For food and general can manufacturers (which are smaller in size than the beverage can manufacturers) end-of-pipe abatement is seen as the preferred compliance option.

11.2 Definition of primary measures

The varnishing of cans consists of the application of exterior paint and subsequently of interior paint. In certain cases, a clear coat can be applied for a protection of the print. In between, the printing of the can body is applied by offset process. Like the complete production process, also the paint application is carried out automatically.
The interior finish is applied via compressed air spraying and the exterior paint is applied via roll coaters.
For an improvement of the workability, these materials contain organic solvents. At present, no solvent-free materials are available.
The use of gravure roll can reduce paint consumptions.

Interior water based lacquer are not always technically useable. According to [3], they have been used in the production of beverage can but in other sectors such as cans containing pharmaceutical products, such lacquers are not satisfying.

Drying of the applied paint layers takes place in conventional dryers at temperatures of 180-200°C.

No useful information on costs is available.

11.3 Default values

Table 11.3.1: Rigid metal packaging [1]

Size of this sub-sector compared to the whole sector of the industrial application of paints in 1998 [%]
13,0

Table 11.3.2: Activities in 1990, 1998, 2010 in UK for rigid metal packaging [1]

Activity in 1990 [t]	Activity in 1998 [t]	Activity in 2010 [t]
31 000	34 000	33 300

Table 11.3.3: Drums [1]

Size of this sub-sector compared to the whole sector of the industrial application of paints in 1998 [%]
1,0

Table 11.3.4: Activities in 1990, 1998, 2010 in UK for drums [1]

Activity in 1990 [t]	Activity in 1998 [t]	Activity in 2010 [t]
3 500	2 820	1 800

12 General industry - Plastics

12.1 Definition of the Reference Installation

Table 12.1.1: Reference installation [1], [2]

Reference Installation Code RIC	Description
01	Medium Reference Installation : 17 t of paints used per year

12.2 Definitions of primary measures [1], [2]

Two parameters are considered to define the primary measures: the solvent contents of the paints and the application efficiency of the technique used.
Powder coatings are not considered because it is technically very complicated to apply such coatings on plastics.

Table 12.2.1: Primary measures

Primary Measure Code PMC	Description
00	"Traditional" solvent based paints (65% solvent content). Application efficiency of 65%
01	Improved solvent based paints (60% solvent content). Application efficiency of 65%
02	Improved solvent based paints (55% solvent content). Application efficiency of 65%
03	Water based paints (5% solvent content – 35% dry matter) Application efficiency : 65%

12.3 Definitions of secondary measures

When no alternative to solvent based paints is available, techniques such as thermal oxidation are available.

Table 12.3.1: Secondary measures

Secondary Measure Code SMC	Description
00	No secondary measure
01	Thermal incineration

12.4 Definition of the consumption factors

Annual consumptions of paints are defined in table 12.4.1: as solid contents of the different types of paints and application techniques are different, consumptions vary from one measure to another.

Table 12.4.1: Consumption factors

RIC PMC	Calculations	Paint consumption (t/y)
01 00	17	17
01 01	(17 × 0,35 / 0,4) × 0,65 / 0,65	14,9
01 02	(17 × 0,35 / 0,45) × 0,65 / 0,65	13,2
01 03	(17 × 0,35 / 0,35) × 0,65 / 0,65	17

12.5 Emission factors

It is assumed that:

- In installations where the application is not enclosed and without abatement devices, all the solvent used is emitted into the air : EF = 1 g solvent/g solvent consumed,
- In installations with secondary abatement devices, where the application is enclosed, only fugitive emissions occur (20 % of the total solvent consumption). Abatement techniques are assumed to have an efficiency of 95%.

According to [1] and [2], cleaning solvent consumptions are assumed to be 15% of the solvents used for PMC 00 and 8% of the solvents used for PMC 01 and PMC 02.

To be consistent with the data used in the RAINS model, emission factors for this sector have to be compared to the reference case (PMC 00).

Table 12.5.1: Emission factors for the different combinations

PMC SMC	Calculations	Emission Factors [g solvent/kg paint]	EF [compared to PMC 00]	Efficiency [%]
01 00 00	650 × 1,15	750	750	0,00
01 00 01	750 × (0,2 + 0,8 × 0,05)	180	180	76,00
01 01 00	600 × 1,08	648	648× 14,9/17 = 568	24,27
01 01 01	648 × (0,2 + 0,8 × 0,05)	155	155	79,33
01 02 00	550 × 1,08	594	594 × 13,2/17 = 461,2	38,50
01 02 01	461,7 × (0,2 + 0,8 × 0,05)	111	111	85,20
01 03 00	50	50	50	93,33

12.6 Derivation of Cost Data [1], [2]

Primary Measures

Several cost items are taken into account. They have been derived from information provided by an expert of the industry [2]:

- ü R&D costs: according to [2], R&D to develop a new paint are around 90 000 €.
- ü Investments: for PMC 03, new application systems in stainless steel are necessary. Investment is around 13 000 €.
- ü Operating costs: raw materials and energy are considered.

Costs for traditional solvent based paints are derived from the one of improved solvent based paints: it is assessed that cost is proportional to the solid contents of the products.

Table 12.6.1: Costs of paints

Parameters	Default costs [2]
"Traditional" solvent based paints [€ / kg]	4,8
Solvent based paints (55% VOC) [€ / kg]	5,5
Solvent based paints (45% VOC) [€ / kg]	6,2
Water based paints [€ / kg]	8,0
Cleaning solvents [€ / kg]	0,15

Table 12.6.2: Raw material costs (figures are rounded)

PMC	Costs of material [€/y]
00	17 [t paints] × 4 800 [€/t] + 1,6 [t solvent] × 150 [€/t] = 81 840
01	14,9 [t paints] × 5 500 [€/t] + 0,7 [t solvent] × 150 [€/t] = 82 060
02	13,2 [t paints] × 6 200 [€/t] + 0,6 [t solvent] × 150 [€/t] = 81 930
03	17 [t paints] × 8 000 [€/t] = 136 000

According to [7], energy consumption for solvent based products (PMC 00) is as presented in table 12.6.3.
According to [2], energy consumption for water based products is 20% higher.

Table 12.6.3: Energy consumptions

PMC	Energy consumption [kWh/y]	Costs [€/y]
00	116 000	116 000 × 0,0686 = 8 000
01	116 000	116 000 × 0,0686 = 8 000
02	116 000	116 000 × 0,0686 = 8 000
03	140 000	140 000 × 0,0686 = 9 600

Secondary Measures

Investments and operating costs for the different secondary measures are derived from the estimated flow rate.
Annual working time: 1 780 h / y [1], [2].

The VOC-concentration in the waste gas stream is assumed to be 0,2 g/m^3.
Flow rate is calculated from the following equation:

Flow rate [m^3/h] = 0,8 × [(g COV / kg paints)] × (kg paints/y)] / [(g VOC/m^3) × (h/y)]

12.7 Default values

Table 12.7.1: Size of this sub-sector in UK in 1998 [1]

Size of this sub-sector compared to the whole sector of the industrial application of paints in 1998 [%]
2,6

Table 12.7.2: Activities in 1990, 1998, 2010 in UK [1]

Activity in 1990 [t]	Activity in 1998 [t]	Activity in 2010 [t]
8 500	6 800	13 500

Table 12.7.3: Default values corresponding to the UK situation [1]

RIC PMC SMC	Application rate in 1990 [% of activity]	Application rate in 2000 [% of activity]	Application rate in 2010 [% of activity]*	Technical Appl. [%]
01 00 00	85	0	0	100
01 00 01	0	0	0	100
01 01 00	0	70	0	100
01 01 01	0	0	0	100
01 02 00	0	0	42	100
01 02 01	0	0	0	100
01 03 00	15	30	58	58
Total RIC 01	**100**	**100**	**100**	

* In 2010, 2% of the product use is believed to be powder paints. This is not considered in this document.

13 Automotive OEM components

13.1 Definition of the Reference Installation

Table 13.1.1: Reference installation [8]

Reference Installation Code RIC	Description
01	Large Reference Installation : 320 t of paints used per year

13.2 Definitions of primary measures [8]

Several measures can be implemented to reduce solvent emissions: a mix of these measures allow complying with the requirement of the Directive.

Ø Techniques of application:

Varnish application is carried out automatically and manually. Application techniques can be either conventional spraying guns, electrostatic assisted spraying with HVLP guns or electrostatic bells (for base coat and clear coat applications only). Application efficiency strongly varies from 25 to 60% according to the technique used.

After each layer application, varnish layers are flashed-off and/or dried in a drying zone within a circulating air flow (at 80°C). Existing processes:
Primer – Oven – Basecoat – Flash-off –Clearcoat- Oven
Primer - Flash-off – Basecoat – Flash-off – Clearcoat – Oven
Modified basecoat – Flash-off – Clearcoat - Oven

Ø Products used:

In general, two or three varnish layers consisting of primer, base coat and clear coat are applied.

- ü Primers can be either solvent or water based.
- ü Plastics parts integrated in the car body have to be adjusted to its colouring so that transitions are invisible. Water based base coat can be used only if the client has ensured adequate colour matching for waterborne and solvent based OEM and refinishing colour shades.
- ü Only solvent based clearcoats are used by now. Technical feasibility of waterborne clearcoats has been demonstrated in projects.

Table 13.2.1: Primary measures

PMC	Description
00	Use of solvent based products (primer, base coat and clear coat with 65% solvent content) – Conventional application technique (35% application efficiency)
01	Use of water based primer and base coat (5% solvent content – 35% dry matter) and solvent based clear coats (65% solvent content) – Use of electrostatic guns for primer (45% application efficiency) and of electrostatic bells for the other varnishes (60% application efficiency)

13.3 Definitions of secondary measures

When no alternative to solvent based paints is available, techniques such as thermal oxidation are available.

Table 13.3.1: Secondary measures

Secondary Measure Code SMC	Description
00	No secondary measure
01	Thermal incineration

13.4 Definition of the consumption factors

The share of use of the different coatings varies from one installation to another. It depends on the number of layers applied and on the types of parts coated (in some cases, only base coat and clear coat are applied). However, the following example is used to calculate VOC emission reductions for each combination of measures.

Table 13.4.1: Shares of consumption of the different coating's types [3]

Type of paints	Share [%]
Primer	30
Base coat	50
Clear coat	20

Table 13.4.1: Consumption factors

RIC PMC	Calculations	Paint consumption (t/y)
01 00	320	320
01 01	320 × [(0,2+0,5)×35/60 + 0,3×35/45]	205,3

13.5 Emission factors

It is assumed that:

- In installations where the application is not enclosed and without abatement devices, all the solvent used is emitted into the air : EF = 1 g solvent/g solvent consumed,
- In installations with secondary abatement devices, where the application is enclosed, only fugitive emissions occur (20 % of the total solvent consumption). Abatement techniques are assumed to have an efficiency of 95%.

Cleaning solvent consumptions are assumed to be the same as for the other sectors (i.e. 15% of the solvents used for PMC 00 and 8% of the solvents used for PMC 01).

To be consistent with the data used in the RAINS model, emission factors for this sector have to be compared to the reference case (PMC 00).

Table 13.5.1: Emission factors for the different combinations

PMC SMC	Calculations	Emission Factors [g solvent/kg paint]	EF [compared to PMC 00]	Efficiency [%]
01 00 00	650 × 1,15	750	750	0,00
01 00 01	750 × (0,2 + 0,8 × 0,05)	180	180	76,00
01 01 00	[0,2×650×35/60 + (0,5×35/60 + 0,3×35/45)×50] × 1,08	110	110 ×205,3/320 = 70,57	90,59

13.6 Derivation of Cost Data [8], [9]

Primary Measures

- According to [8], investment for the implementation of one electrostatic bell is around 60 000€ per line. This application technique can be used for base coat and clear coat application lines. R&D and training can be accounted for 200 000€ per installation.
- For the use of water based primers, investment is around 50 000 € per installation. This accounts for new pumps, regulation of the temperature and hydrometric conditions. 150 000 € are incurred for R&D and product testing.
- For the use of water based base coats, investment for the line's modification is around 300 000€. R&D and product testing costs depend on the number of colors and products used. Around 70 different colors can be used. Considering 4 000 € per product, 280 000€ can be accounted for R&D and product testing.

Concerning operating costs, two parameters have to be considered:

- Over costs for energy are assumed to be around 10 000€ / year according to [8]. However, to remain consistent, assumptions used for the other sub-sectors are also used for this one (see table 13.6.3).
- Product costs: with more efficient application techniques, fewer products are used. This leads to savings.

According to [8], water based products are about 40% more expensive than solvent based products. Knowing solvent based products prices [9], we have deduced water based products costs.

Table 13.6.1: Costs of paints

Parameters	Default costs
Solvent based primer	6
Water based primer	8,4
Solvent based basecoat	8,2
Water based basecoat	11,5
Solvent based clear coat	7,5
Cleaning solvents	0,15

Table 13.6.2: Raw material costs (figures are rounded)

PMC	SB primer [t / year]	WB primer [t / year]	SB basecoat [t / year]	WB basecoat [t / year]	SB clear coat [t / year]	Cleaning solvents [t / year]	Total costs [€ / year]
00	96	0	160	0	64	31,2	2 372 680
01	0	74,5	0	93,5	37,5	2,6	1 982 690

According to [7], energy consumption for solvent based products (PMC 00) is as presented in table 13.6.3.
According to [2], energy consumption for water based products is 20% higher.

Table 13.6.3: Energy consumptions

PMC	Energy consumption [kWh/y]	Costs [€/y]
00	2 180 000	2 180 000 × 0,0686 = 150 000
01	2 180 000 × (0,2 + 0,8×1,2) = 2 528 800	2 528 800 × 0,0686 = 173 475

Secondary Measures

Investments and operating costs are derived from the estimated flow rates and VOC concentrations. Annual working time: 3 000 h / y [8].

Usually, VOC concentrations are very low (around 0,2 g/m^3) with very high flow rates. Air recirculation in the booth reduces considerably the flow rate and allows reaching high VOC concentrations around 2 g/m^3.

Flow rate is calculated from the following equation:

Flow rate [m^3/h] = 0,8 × [(g COV / kg paints)] × (kg paints/y)] / [(g VOC/m^3) × (h/y)]

13.7 Default values

Table 13.7.1: Size of this sub-sector in UK in 1998 [1]

Size of this sub-sector compared to the whole sector of the industrial application of paints in 1998 [%]
2,3

Table 13.7.2: Activities in 1990, 1998, 2010 in UK [1]

Activity in 1990 [t]	Activity in 1998 [t]	Activity in 2010 [t]
160	6 000	6 300

General industry aggregated sector

Sectors considered are: trade coaters, general engineering, industrial equipment, original equipment, heavy engineering and ACE

Techniques and costs are an average of all sectors studied in this paragraph. All measures are not applicable to all sub-sectors though (see chapter "background information" for more details.

1. Definition of the Reference Installation

Table 1.1: Reference installation [1], [2]

Reference Installation Code RIC	Description
01	Medium Reference Installation : 22 t of paints used per year

2. Definitions of primary measures [1], [2]

Two parameters are considered to define the primary measures: the solvent contents of the paints and the application efficiency of the technique used.

Table 2.1: Primary measures

Primary Measure Code PMC	Description
00	"Traditional" solvent based paints (65% solvent content). Application efficiency of 40%
01	Current solvent based paints (55% solvent content). Application efficiency of 50%
02	Improved solvent based paints (45% solvent content). Application efficiency of 65%
03	Water based paints (5% solvent content – 35% dry matter) – Application efficiency of 65%
04	Powder coatings (100% of solid content). Application efficiency : 90%

3. Definitions of secondary measures

When no alternative to solvent based paints is available, techniques such as thermal oxidation are available.

Table 3.1: Secondary measures

Secondary Measure Code SMC	Description
00	No secondary measure
01	Thermal incineration

4. Definition of the consumption factors

Annual paints consumptions are defined in table 4.1: as solid contents of the different types of paints and application techniques are different, consumptions vary from one measure to another.

Application efficiency of powder coatings is 90% as defined in table 2.1. However, on average, only 80% of the paint is used because in practice, paint bought for a particular job can not be used for another customer.

Table 4.1: Paint consumption

RIC PMC	Calculations	Paint consumption (t/y)
01 00	22	22,0
01 01	(22 × 0,35 / 0,45) × 0,4 / 0,5	13,7
01 02	(22 × 0,35 / 0,55) × 0,4 / 0,65	8,6
01 03	**(22 × 0,35 / 0,35) × 0,4 / 0,65**	**13,5**
01 04	(22 × 0,35 / 1) × 0,4 / 0,8	3,9

5. Emission factors and costs

It is assumed that:

- In installations where the application is not enclosed and without abatement devices, all the solvent used is emitted into the air : EF = 1 g solvent/g solvent consumed,
- In installations with secondary abatement devices, where the application is enclosed, only fugitive emissions occur (20 % of the total solvent consumption). Abatement techniques are assumed to have an efficiency of 95%.

According to [1] and [2], cleaning solvent consumptions are assumed to be 15% of the solvent used for PMC 00 and 8% of the solvents used for PMC 01 and PMC 02.

To be consistent with the data used in the RAINS model, emission factors for this sector have to be compared to the reference case (PMC 00).

Table 5.1: Emission factors (EF) for the different combinations

PMC SMC	Calculations	Emission Factors [g solvent/kg paint]	EF [compared to PMC 00]	Efficiency [%]
01 00 00	650 × 1,15	747,5	747,5	0,0
01 00 01	747,5 × (0,2 + 0,8 × 0,05)	179,4	179,4	76,0
01 01 00	550 × 1,08	594	594 × 13,7/22 = 370	50,5
01 01 01	370 × (0,2 + 0,8 × 0,05)	88,8	88,8	88,1
01 02 00	450 × 1,08	486	486 × 8,6/22 = 190	74,6
01 02 01	190 × (0,2 + 0,8 × 0,05)	45,6	45,6	93,9
01 03 00	**50**	**50**	**50 × 13,5/22 = 30,8**	**95,9**
01 04 00	0	0	0	100,0

Table 5.2: Investments and operating costs for the different combinations

RIC PMC SMC	Investment [k€]	R&D [k€]	Q	CI [%]	Variable OC [k€/y]	Fixed OC [k€/y]	Q	CI [%]
01 00 00	0	0	-	-	142,6	-	3	20
01 00 01	1 060	0	3	20	181,1	53	3	20
01 01 00	8,2	0	3	20	117,2	-	3	20
01 01 01	729,8	0	3	20	137,8	36	3	20
01 02 00	8,2	0	3	20	92,0	-	3	20
01 02 01	508,2	0	3	20	104,0	25	3	20
01 03 00	16,5	11,5	3	20	**117,6**	-	3	20
01 04 00	18	11,5	3	20	45,2	-	3	20

6. Cost data to be provided by national experts

- Determination of country specific data to calculate variable costs (they are valid for all VOC sectors and only have to be entered in the tool once).

Table 6.1: Country-specific data

Parameters	Costs used in the tool	Country specific costs
Electricity [€/kWh]	0,0686	
Natural gas [€/kWh]	0,0192	
Wages [€/h]	25,9	

Costs for "current" solvent based paints (55% VOC) are derived from [2]. For other solvent based paints, it is assumed that costs are proportional to the solid contents of the products.
Powder paints price is lower than the one of improved solvent based paints because of the price competition between manufacturers [1].

Table 6.2: Sector and country specific data

Parameters	Default costs [2]	Country specific costs
Solvent based paints (65% VOC) [€ / kg]	6,0	
Solvent based paints (55% VOC) [€ / kg]	7,8	
Solvent based paints (45% VOC) [€ / kg]	9,5	
Water based paints [€ / kg]	7,8	
Powder paints [€ / kg]	6,3	
Cleaning solvents [€ / kg]	0,15	

7. Derivation of Cost Data [1], [2]

7.1 Primary Measures

Several cost items are taken into account. They have been derived from information provided by Mr. Henry [2]:

- ü R&D costs: according to [2], R&D costs are incurred for some of the activities considered in this paragraph. However, R&D costs are assumed to be paid anyway either by the client or by the job coater. R&D costs of 11 500 € are thus taken into account for PMC 03 and PMC 04 (they are amortized on 10 years and only spent once).
- ü Investments: for PMC 01and PMC 02, more efficient guns are used. Investments are around 8 200€. For PMC 03 and PMC 04, ovens have to be changed: total investments would be around 16300 € for PMC 03 and 18 000 € for PMC 04.
- ü Operating costs: raw materials and energy are considered.

Table 7.1.1: Raw material costs

PMC	Costs of material [€/y]
00	22 [t paints] × 6 000 [€/t] + 2,15 [t solvent] × 150 [€/t] = 132 320
01	13,7 [t paints] × 7 800 [€/t] + 0,6 [t solvent] × 150 [€/t] = 106 950
02	8,6 [t paints] × 9 500 [€/t] + 0,31 [t solvent] × 150 [€/t] = 81 750
03	**13,5 [t paints] × 7 800 [€/t] = 105 300**
04	3,9 [t paints] × 6 300 [€/t] = 24 570

According to [7], energy consumption for solvent based products (PMC 00) is as defined in table 7.1.2. According to [2], energy consumption for powder coatings is twice higher (in fact, oven's temperature for solvent based coatings is around 85 °C when for powder coatings, it is 180 °C) and for water based products, 20% higher.

Table 7.1.2: Energy consumptions

PMC	Energy consumption [kWh/y]	Costs [€/y]
00	150 000	150 000 × 0,0686 = 10 300
01	150 000	150 000 × 0,0686 = 10 300
02	150 000	150 000 × 0,0686 = 10 300
03	180 000	180 000 × 0,0686 = 12 300
04	300 000	300 000 × 0,0686 = 20 600

7.2 Secondary Measures

Investments and operating costs are derived from the estimated flow rates and VOC concentrations. Annual working time: 1 780 h / y [1], [2].

The VOC-concentration in the waste gas stream is assumed to be 0,2 g/m^3.
Flow rate is calculated from the following equation:

Flow rate [m^3/h] = 0,8 × [(g COV / kg paints)] × (kg paints/y)] / [(g VOC/m^3) × (h/y)]

Theoretical flow rates and costs for the different combinations are given in table 7.2.1.

Table 7.2.1 Emission factors (EF), investments, operating costs and technical lifetime for secondary measures

RIC PMC SMC	VOC EF [kg / t paints]	Flow rate [m^3/h]	Investment [k€]	Variable OC [k€/y]	Fixed OC [k€/y]	Tech. Lifet. [y]
01 00 01	745,5	36 800	1 060	38,5	53	10
01 01 01	594	18 300	721,6	20,6	36	10
01 02 01	486	9 400	500	12,0	25	10

8. Data be provided by national experts

The following data will have to be provided: activity level, application rates and technical applicability.

Tables hereafter should help national experts to present their data.

- Total activity level carried out in 2000, 2005, 2010, 2015, 2020. Some default values for the confidence interval are given. They can be used by the Party if no data are available.

Table 8.1: Total activity levels in absolute value (tonnes of paints consumed / y) for the 6 sub-sectors considered

Total	2000	CI%	2005	CI%	2010	CI%	2015	CI%	2020	CI%
t paints										
Default values proposed for CI		10		20		50		100		100

For explanations on the coefficient of variation (CI), please refer to the Methodology.

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

Table 8.2: Application rate and Applicability

RIC PMC SMC	Application rate in 2000 [%]	Application rate in 2005 [%]	Appl. [%]	Application rate in 2010 [%]	Appl. [%]	Application rate in 2015 [%]	Appl. [%]	Application rate in 2020 [%]	Appl. [%]
01 00 00									
01 00 01									
01 01 00									
01 01 01									
01 02 00									
01 02 01									
01 03 00									
01 04 00									
Total RIC 01	**100**	**100**		**100**		**100**		**100**	

- General information

- In UK, PMC 00 corresponds to the solvent based paints used in 1990. It can be assumed that these products are still in use in some countries.
- The application of the VOC Directive in 2007 does not mean that all installations will be regulated. Only installations consuming more than 5 tonnes of solvents are concerned. Depending on the sub-sector and on the country, small installations can be very numerous.
- According to [1] and [2], secondary measures will not be used but in very special cases in large installations like for the coating of agricultural and construction equipment (ACE) for example.

General industry aggregated sector
Continuous processes

Sectors considered are: furniture, rigid metal packaging and drums

As no detailed information is available on the metal packaging and drums sectors, parameters are defined according to the sector of the coating of metal furniture.

1. Definition of the Reference Installation

Table 1.1: Reference installation [1], [2]

Reference Installation Code RIC	Description
01	Medium Reference Installation : 45 t of paints used per year

2. Definitions of primary measures [1], [2]

Two parameters are considered to define the primary measures: the solvent contents of the paints and the application efficiency of the technique used.
The use of powder coating (PMC 03) is only suitable for the coating of furniture.

Table 2.1: Primary measures

Primary Measure Code PMC	Description
00	"Traditional" solvent based paints (60% solvent content). Application efficiency of 70%
01	Improved solvent based paints (50% solvent content). Application efficiency of 70%
02	Water based paints (4% solvent content – 35% dry matter) – Application efficiency : 98%
03	Powder coatings (100% of solid content). Application efficiency : 96%

3. Definitions of secondary measures

When no alternative to solvent based paints is available, techniques such as thermal oxidation are available.

According to [10], the use of end-of-pipe abatement is seen as the preferred compliance option for smaller installations in the coating of metal packaging (see p.30 for more details). Thus, costs of thermal oxidation are defined for a medium installation (no costs have been assessed for bigger sizes of installation).

Table 3.1: Secondary measures

Secondary Measure Code SMC	Description
00	No secondary measure
01	Thermal incineration

4. Definition of the consumption factors

Annual paints consumptions are defined in table 4.1: as solid contents of the different types of paints and application techniques are different, consumptions vary from one measure to another.

Application efficiency of powder coatings is 96% as defined in table 2.1. However, in average only 92% of the paint used is effectively applied.

Table 4.1: Paint consumption

RIC PMC	Calculations	Paint consumption (t/y)
01 00	45	45,0
01 01	(45 × 0,4 / 0,5) × 0,7 / 0,7	36,0
01 02	(45 × 0,4 / 0,35) / 0,98	36,7
01 03	(45 × 0,4 / 1) × 0,7 / 0,92	13,7

5. Emission factors and costs

It is assumed that:

- In installations where the application is not enclosed and without abatement devices, all the solvent used is emitted into the air : EF = 1 g solvent/g solvent consumed,
- In installations with secondary abatement devices, where the application is enclosed, only fugitive emissions occur (20 % of the total solvent consumption). Abatement techniques are assumed to have an efficiency of 95%.

According to [1] and [2], cleaning solvent consumptions are assumed to be 15% of the solvent used for PMC 00 and 8% of the solvents used for PMC 01.

To be consistent with the data used in the RAINS model, emission factors for this sector have to be compared to the reference case (PMC 00).

Table 5.1: Emission factors for the different combinations

PMC SMC	Calculations	Emission Factors [g solvent/kg paint]	EF [compared to PMC 00]	Efficiency [%]
01 00 00	600 × 1,15	690	690	0,00
01 00 01	690 × (0,2 + 0,8 × 0,05)	165,6	165,6	76,00
01 01 00	500 × 1,08	540	540 × 36/45 = 432	37,39
01 01 01	432 × (0,2 + 0,8 × 0,05)	104	104	84,93
01 02 00	40	40	40 × 36,7/45 = 32,6	95,27
01 03 00	0	0	0	100,00

Table 5.2: Investments and operating costs for the different combinations

RIC PMC SMC	Investment [k€]	R&D [k€]	Q	CI [%]	Variable OC [k€/y]	Fixed OC [k€/y]	Q	CI [%]
01 00 00	0	0	-	-	210,6	-	3	20
01 00 01	1 510,6	0	3	20	281,3	75,5	3	20
01 01 00	0	0	3	20	208,4	-	3	20
01 01 01	1 227,2	0	3	20	257,8	61,4	3	20
01 02 00	260	81,5	2	40	201,5	-	2	40
01 03 00	260	81,5	3	30	101	-	3	30

6. Cost data to be provided by national experts

- Determination of country specific data to calculate variable costs (they are valid for all VOC sectors and only have to be entered in the tool once).

Table 6.1: Country-specific data

Parameters	Costs used in the tool	Country specific costs
Electricity [€/kWh]	0,0686	
Natural gas [€/kWh]	0,0192	
Wages [€/h]	25,9	

Costs for traditional solvent based paints are derived from the one of improved solvent based paints: it is assessed that cost is proportional to the solid contents of the products.

Table 6.2: Sector and country specific data

Parameters	Default costs [2]	Country specific costs
"Traditional" solvent based paints [€ / kg]	4,2	
Improved solvent based paints [€ / kg]	5,2	
Water based paints [€ / kg]	4,8	
Powder paints [€ / kg]	4,3	
Cleaning solvents [€ / kg]	0,15	

7. Derivation of Cost Data [1], [2]

7.1 Primary Measures

Several cost items are taken into account. They have been derived from information provided by Mr. Henry [2]:

- ü R&D costs: according to [2], R&D costs to develop a new paint are around 81 500 € (they are amortized on 10 years and occur only once).
- ü Investments: for PMC 02 and PMC 03, total investments would be around 260 000 €.
- ü Operating costs: raw materials and energy are considered.

Table 7.1.1: Raw material costs (figures are rounded)

PMC	Costs of material [€/y]
00	45 [t paints] × 4 200 [€/t] + 4 [t solvent] × 150 [€/t] = 189 600
01	36 [t paints] × 5 200 [€/t] + 1,5 [t solvent] × 150 [€/t] = 187 425
02	36,7 [t paints] × 4 800 [€/t] = 176 160
03	13,7 [t paints] × 4 300 = 58 910

According to [7], energy consumption for solvent based products (PMC 00) is as presented in table7.1.2. According to [2], energy consumption for powder coatings is twice higher and for water based products, 20% higher.

Table 7.1.2: Energy consumptions

PMC	Energy consumption [kWh/y]	Costs [€/y]
00	307 000	307 000 × 0,0686 = 21 000
01	307 000	307 000 × 0,0686 = 21 000
02	370 000	370 000 × 0,0686 = 25 400
03	614 000	614 000 × 0,0686 = 42 100

7.2 Secondary Measures

Investments and operating costs are derived from the estimated flow rates and VOC concentrations.
Annual working time: 1 780 h / y [1], [2].

The VOC-concentration in the waste gas stream is assumed to be 0,2 g/m^3.
Flow rate is calculated from the following equation:

Flow rate [m^3/h] = 0,8 × [(g COV / kg paints)] × (kg paints/y)] / [(g VOC/m^3) × (h/y)]

Theoretical flow rates and costs for the different combinations are given in table 7.2.1.

Table 7.2.1: Emission factors (EF), investments, operating costs and technical lifetime for secondary measures

RIC PMC SMC	VOC EF [kg / t paints]	Flow rate [m^3/h]	Investment [k€]	Variable OC [k€/y]	Fixed OC [k€/y]	Tech. Lifet. [y]
01 00 01	690	70 000	1 510,6	70,7	75,5	10
01 01 01	540	48 000	1 227,2	49,4	61,4	10

8. Data be provided by national experts

The following data will have to be provided: activity level, application rates and technical applicability.

Tables hereafter should help national experts to present their data.

- Total activity level carried out in 2000, 2005, 2010, 2015, 2020. Some default values for the confidence interval are given. They can be used by the Party if no data are available.

Table 8.1: Total activity levels in absolute value (tonnes of paints consumed / y) for the 3 sub-sectors considered

Total	2000	CI%	2005	CI%	2010	CI%	2015	CI%	2020	CI%
t paints										
Default values proposed for CI		10		20		50		100		100

For explanations on the coefficient of variation (CI), please refer to the Methodology.

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

Table 8.2: Application rate and Applicability

RIC PMC SMC	Application rate in 2000 [%]	Application rate in 2005 [%]	Appl. [%]	Application rate in 2010 [%]	Appl. [%]	Application rate in 2015 [%]	Appl. [%]	Application rate in 2020 [%]	Appl. [%]
01 00 00									
01 00 01									
01 01 00									
01 01 01									
01 02 00									
01 03 00									
Total RIC 01	**100**	**100**		**100**		**100**		**100**	

- Default values and information to help national experts filling in the tables

v In UK, PMC 00 corresponds to the solvent based paints used in 1990. It can be assumed that these products are still in use in some countries.

v The application of the VOC Directive in 2007 does not mean that all installations will be regulated. Only installations consuming more than 5 tonnes of solvents are concerned. Depending on the sub-sector and on the country, small installations can be very numerous.

General industry aggregated sector
Plastic coating

Sectors considered are: General industry - plastic and Automotive OEM components

Two reference installations are defined hereafter to take into account the difference between costs according to the size.

1. Definition of the Reference Installation

The size of the small installation defined on p.31 has been modified in table 1.1 hereafter for simplification reasons.

Table 1.1: Reference installations [1], [2]

Reference Installation Code RIC	Description
01	Small Reference Installation: 32 t of paints used per year
02	Large Reference Installation: 320 t of paints used per year

2. Definitions of primary measures [1], [2]

Two parameters are considered to define the primary measures: the solvent contents of the paints and the application efficiency of the technique used.
Powder coatings are not considered because it is technically very complicated to apply such coatings on plastics.

Table 2.1: Primary measures

Primary Measure Code PMC	Description
00	"Traditional" solvent based paints (65% solvent content). Application efficiency of 35%
01	"Traditional" solvent based paints (65% solvent content). Application efficiency of 65%
02	Current solvent based paints (60% solvent content). Application efficiency of 65%
03	Improved solvent based paints (55% solvent content). Application efficiency of 65%
04	Water based paints (5% solvent content – 35% dry matter) – Application efficiency : 65%
05	Powder coatings (100% of solid content). Application efficiency : 96%

3. Definitions of secondary measures

When no alternative to solvent based paints is available, techniques such as thermal oxidation are available.

Table 3.1: Secondary measures

Secondary Measure Code SMC	Description
00	No secondary measure
01	Thermal incineration

4. Definition of the consumption factors

Annual consumptions of paints are defined in table 4.1: as solid contents of the different types of paints and application techniques are different, consumptions vary from one measure to another.

Table 4.1: Consumption factors (example for RIC 01)

RIC PMC	Calculations	Paint consumption (t/y)
01 00	32	32
01 01	(32 × 0,35 / 0,35) × 0,35 / 0,65	17,2
01 02	(32 × 0,35 / 0,40) × 0,35 / 0,65	15
01 03	(32 × 0,35 / 0,45) × 0,35 / 0,65	13,4
01 04	(32 × 0,35 / 0,35) × 0,35 / 0,65	17,2
01 05	(32 × 0,35 / 1) × 0,35 / 0,96	4

5. Emission factors and costs

It is assumed that:

- In installations where the application is not enclosed and without abatement devices, all the solvent used is emitted into the air : EF = 1 g solvent/g solvent consumed,
- In installations with secondary abatement devices, where the application is enclosed, only fugitive emissions occur (20 % of the total solvent consumption). Abatement techniques are assumed to have an efficiency of 95%.

According to [1] and [2], cleaning solvent consumptions are assumed to be 15% of the solvents used for PMC 00 and PMC 01 and 8% of the solvents used for PMC 02 and PMC 03.

To be consistent with the data used in the RAINS model, emission factors for this sector have to be compared to the reference case (PMC 00).

Table 5.1: Emission factors for the different combinations

PMC SMC	Calculations	Emission Factors [g solvent/kg paint]	EF [compared to PMC 00]	Efficiency [%]
00 00	650 × 1,15	750	750	0,0
00 01	750 × (0,2 + 0,8 × 0,05)	180	180	76,0
01 00	650 × 1,15	750	750 × 17,2 / 32 = 403,1	46,3
01 01	403,1 × (0,2 + 0,8 × 0,05)	96,7	96,7	87,1
02 00	600 × 1,08	648	648 × 15 / 32 = 303,7	59,5
02 01	303,7 × (0,2 + 0,8 × 0,05)	72,9	72,9	90,3
03 00	550 × 1,08	594	594 × 13,4 / 32 = 248,7	66,8
03 01	248,7 × (0,2 + 0,8 × 0,05)	59,7	59,7	92,0
04 00	50	50	50 × 17,2 / 32 = 26,9	96,4
05 00	0	0	0	100,0

Table 5.2: Investments and operating costs for the different combinations

RIC PMC SMC	Investment [k€]	R&D [k€]	Q	CI [%]	Variable OC [k€/y]	Fixed OC [k€/y]	Q	CI [%]
01 00 00	0	0	-	-	169,0	-	3	20
01 00 01	1 310	0	3	30	224,2	65,5	3	20
01 01 00	12	0	3	30	97,8	-	3	20
01 01 01	942	0	3	30	128,8	46,5	3	20
01 02 00	12	0	3	30	97,6	-	3	20
01 02 01	806,6	0	3	30	121,6	39,7	3	20
01 03 00	12	0	3	30	98,2	-	3	20
01 03 01	724,8	0	3	30	118,4	35,6	3	20
01 04 00	25	90	3	30	155,7	-	3	20
01 05 00	26	90	3	30	60,4	-	3	20
02 00 00	0	0	3	-	1 691,6	-	3	20
02 00 01	**1 472,4**	**0**	**3**	**30**	**1 721,8**	**73,6**	**3**	**20**
02 01 00	120	0	3	30	979,1	-	3	20
02 01 01	**1 046**	**0**	**3**	**30**	**997.2**	**52,3**	**3**	**20**
02 02 00	120	0	3	30	977,0	-	3	20
02 02 01	**896,5**	**0**	**3**	**30**	**991.7**	**44,8**	**3**	**20**
02 03 00	120	0	3	30	982,6	-	3	20
02 03 01	**801,3**	**0**	**3**	**30**	**995.3**	**40,1**	**3**	**20**
02 04 00	470	630	3	30	1 557,1	-	3	20

6. Cost data to be provided by national experts

- Determination of country specific data to calculate variable costs (they are valid for all VOC sectors and only have to be entered in the tool once).

Table 6.1: Country-specific data

Parameters	Costs used in the tool	Country specific costs
Electricity [€/kWh]	0,0686	
Natural gas [€/kWh]	0,0192	
Wages [€/h]	25,9	

Costs for traditional solvent based paints are derived from the one of improved solvent based paints: it is assessed that cost is proportional to the solid contents of the products.

Table 6.2: Sector and country specific data

Parameters	Default costs [2]
"Traditional" solvent based paints [€ / kg]	4,8
Current solvent based paints (60% VOC) [€ / kg]	5,5
Improved solvent based paints (55% VOC) [€ / kg]	6,2
Water based paints [€ / kg]	8,0
Powder paints [€ / kg]	7,6
Cleaning solvents [€ / kg]	0,15

7. Derivation of Cost Data [1], [2]

7.1 Primary Measures

Several cost items are taken into account. They have been derived from information provided by an expert of the industry [2]:

- ü R&D costs: according to [2], R&D costs to develop a new paint for small installations are around 90 000 €. According to [8] these costs are around 630 000 € for large installations. R&D costs are amortized on 10 years and are spent only once.
- ü Investments: for PMC 01, 02 and 03, investments for more efficient application techniques are assessed to be around 12 000 € (calculated from data available for other sub-sectors) for small installations and 120 000 € for large installations [8].
  For PMC 04, new application systems in stainless steel are necessary. Investments are around 25 000€ for small installations [2] and 470 000 € for small installations [8].
- ü Operating costs: raw materials and energy are considered.

Costs for traditional solvent based paints are derived from the one of improved solvent based paints: it is assessed that cost is proportional to the solid contents of the products.

Table 7.1.1: Costs of paints

Parameters	Default costs [2]
"Traditional" solvent based paints [€ / kg]	4,8
Current solvent based paints (55% VOC) [€ / kg]	5,5
Improved solvent based paints (45% VOC) [€ / kg]	6,2
Water based paints [€ / kg]	8,0
Powder paints [€ / kg]	7,6
Cleaning solvents [€ / kg]	0,15

Table 7.1.2: Raw material costs (figures are rounded)

RIC PMC	Costs of material [€/y]
01 00	32 [t paints] × 4 800 [€/t] + 3,1 [t solvent] × 150 [€/t] = 154 065
01 01	17,2 [t paints] × 4 800 [€/t] + 1,7 [t solvent] × 150 [€/t] = 82 815
01 02	15 [t paints] × 5 500 [€/t] + 0,7 [t solvent] × 150 [€/t] = 82 605
01 03	13,4 [t paints] × 6 200 [€/t] + 0,6 [t solvent] × 150 [€/t] = 83 170
01 04	17,2 [t paints] × 8 000 [€/t] = 137 600
01 05	4 [t paints] × 7 600 [€/t] = 30 400
02 00	1 540 600
02 01	828 150
02 02	826 050
02 03	831 700
02 04	1 376 000

According to [7], energy consumption for solvent based products (PMC 00) is as presented in table 7.1.3. According to [2], energy consumption is 20% higher for water based paints and twice higher for powder paints.

Table 7.1.3: Energy consumptions

RIC PMC	Energy consumption [kWh/y]	Costs [€/y]
01 00	220 000	220 000 × 0,0686 = 15 000
01 01	220 000	220 000 × 0,0686 = 15 000
01 02	220 000	220 000 × 0,0686 = 15 000
01 03	220 000	220 000 × 0,0686 = 15 000
01 04	264 000	264 000 × 0,0686 = 18 100
01 05	440 000	440 000 × 0,0686 = 30 000
02 00	2 200 000	2 200 000 × 0,0686 = 150 000
02 01	2 200 000	2 200 000 × 0,0686 = 150 000
02 02	2 200 000	2 200 000 × 0,0686 = 150 000
02 03	2 200 000	2 200 000 × 0,0686 = 150 000
02 04	2 640 000	2 640 000 × 0,0686 = 181 000

7.2 Secondary Measures

Investments and operating costs are derived from the estimated flow rate and VOC concentrations.
Annual working time: 1 780 h/y [1], [2] for small installations.
3 000 h/y for large installations.

The VOC-concentration in the waste gas stream is assumed to be 0,2 g/m^3.

For large installations, air recirculation in the booth reduces considerably the flow rate and allows reaching high VOC concentrations around 2 g/m^3. In this case, the modification of the spray booth costs about one half of the incinerator's investment. Fixed costs are calculated as 5% of total investment.

Flow rate is calculated from the following equation:

Flow rate [m^3/h] = 0,8 × [(g COV / kg paints)] × (kg paints/y)] / [(g VOC/m^3) × (h/y)]

Theoretical flow rates and costs for the different combinations are given in table 7.2.1.

Table 7.2.1: Emission factors (EF), investments, operating costs and technical lifetime for secondary measures

RIC PMC SMC	VOC EF [kg / t paints]	Flow rate [m^3/h]	Investment [k€]	Optimisation [k€]	Variable OC [k€/y]	Fixed OC [k€/y]	Tech. Lifet. [y]
01 00 01	750	54 000	1 310	-	55,2	65,5	10
01 01 01	750	29 000	930	-	31	46,5	10
01 02 01	648	21 800	794,6	-	24	39,7	10
01 03 01	594	17 900	712,8	-	20,2	35,6	10
02 00 01	750	**32 000**	**981,6**	**490,8**	**31,2**	**73,6**	10
02 01 01	750	**17 200**	**697,4**	**348,7**	**19,0**	**52,3**	10
02 02 01	648	**13 000**	**597,7**	**298,9**	**15,6**	**44,8**	10
02 03 01	594	**10 600**	**534,2**	**267,9**	**13,6**	**40,1**	10

8. Data be provided by national experts

The following data will have to be provided: activity level, application rates and technical applicability.
Default values from UK [1] are presented at an aggregated level to help national experts in their work. It has to be highlighted that the situations in the different countries can differ widely according to the types of products manufactured.

Tables hereafter should help national experts to present their data.

- Total activity level carried out in 2000, 2005, 2010, 2015, 2020. Some default values for the confidence interval are given. They can be used by the Party if no data are available.

Table 8.1: Total activity levels in absolute value (tonnes of paints consumed / y) for the 2 sub-sectors considered

Total	2000	CI%	2005	CI%	2010	CI%	2015	CI%	2020	CI%
t paints										
Default values proposed for CI		10		20		50		100		100

For explanations on the coefficient of variation (CI), please refer to the Methodology.

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

Table 8.2: Application rate and Applicability

RIC PMC SMC	Application rate in 2000 [%]	Application rate in 2005 [%]	Appl. [%]	Application rate in 2010 [%]	Appl. [%]	Application rate in 2015 [%]	Appl. [%]	Application rate in 2020 [%]	Appl. [%]
01 00 00									
01 00 01									
01 01 00									
01 01 01									
01 02 00									
01 02 01									
01 03 00									
01 03 01									
01 04 00									
01 05 00									
Total RIC 01	**100**	**100**		**100**		**100**		**100**	
02 00 00									
02 00 01									
02 01 00									
02 01 01									
02 02 00									
02 02 01									
02 03 00									
02 03 01									
02 04 00									
Total RIC 02	**100**	**100**		**100**		**100**		**100**	

- Default values and information to help national experts filling in the tables

v In UK, PMC 00 corresponds to the solvent based paints used in 1990. It can be assumed that these products are still in use in some countries.

v The application of the VOC Directive in 2007 does not mean that all installations will be regulated. Only installations consuming more than 5 tonnes of solvents are concerned. Depending on the sub-sector and on the country, small installations can be very numerous.

References

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[3] N. PETERS, S. NUNGE, J. GELDERMANN, O. RENTZ. Best Available Techniques (BAT) for the Paint Application in Germany. Volume I Paint Application. DFIU/TH. Karlsruhe. August 2002. http://www.umweltdaten.de/nfp-bat-e/vol1paint.pdf

[4] Z. KLIMONT; M. AMANN; J. COFALA. Estimating costs for Controlling Emissions of Volatile Organic Compounds (VOC) from Stationary Sources in Europe. Interim Report IR-00-51. IIASA. August 1, 2000. http://www.iiasa.ac.at/~rains/voc_review/voc_ir-00-51.pdf

[5] Review of data used in RAINS-VOC model. http://www.iiasa.ac.at/~rains/voc_review/single.html

[6] Council Directive 1999/13/EC of 11 March 1999 on the limitation of emissions of volatile organic compounds due to the use of organic solvents in certain activities and installations.

[7] Anonymous industrial contact. ACE sector. 2002.

[8] Anonymous industrial contact: car component supplier. October 2002.

[9] Anonymous industrial contact: CEPE representative. May 2003.

[10] ENTEC UK Limited. Regulatory and environmental impact assessment of the EC solvent emission Directive. Final report. 20 December 1999.

Modifications compared to the draft background document

High solid paints are not considered separately. Only average solvent contents are given for the different sub-sectors. These solvent contents correspond to national average and already take into account high solvent paints.

CORRECTION from 09/02/04

Coating of plastics:
The paint denominations have been modified in table 2.1 to clearly differentiate traditional, current and improved solvent based paints.
The use of powder is now considered as primary measure for RIC01 because such paints are used in certain countries such as Belgium.

In table 7.1.3, electricity costs have been corrected for RIC 02. Total variable operating costs have also been modified in table 5.2.

CORRECTION from 14/12/04

General industry:
p.41: Water based consumption has been modified in table 4.1 (paint consumption is 13.5 tonnes/year instead of 9,5 tonnes). This leads to a different emission factor in table 5.1 (30,8 g/kg pain) instead of 21,6 in the previous version of the document. Raw material cost for the PMC 03 is thus modified in table 7.1.1 and equal to 105 300 €/year. Total variable operating costs in table 5.2 have also been modified.

Coating of plastics:
p.56: Flow rates have been corrected for the large installations: calculations have been done with 3000 h/y instead of 1780 used in the previous version of the document. This modification leads to different investments and operating costs when a secondary measure is defined. These data have been corrected on p.54 and 56 for the combinations 020001, 020101, 020201 and 020301.