Final Background Document

on the sector

Car Coating

Prepared in the framework of EGTEI

Prepared by CITEPA, Paris

Summary

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Data currently used in RAINS are displayed in this paragraph for three different countries. Data for other countries are downloadable on http://www.iiasa.ac.at/~rains/voc_review/single.html

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Table 5.3.1 summarizes the emission factors with the corresponding abatement efficiencies for each combination measure.
Table 5.3.2 summarizes investments and operating costs for each combination.

If a measure is missing in the document, national experts have to contact the Secretariat to add it in the background document.

6. Data to be provided by national experts for the completion of the database for their own country (p.12)

Tables to be filled in by national experts are displayed :
Table 6.2.1 : Activity levels of Reference Installations. Production of cars per type of reference installation (RI) is required.

- Total activity (cars/y) has to be estimated from 2000 to 2020 and distributed according to the different installations.
- If no detailed information is available in 2000, total activity can be divided equally between all RI (i.e.: 33% for each one).
- If no prevision on the structure of this sector is available (for 2005 to 2020), the proportions used in 2000 can be used. But total activity (cars/y) should evolve.

Table 6.2.2 : Application rate and applicability.

- If detailed information is available, table 6.2.2 can be filled in.
- If only sparse information is available, then table 6.2.2 can be filled in with the same "Application rates" for all RI (this corresponds to the filling of table 6.2.3).

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The default data mean can be modified in a range of ± 10%.

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Investments and operating costs have been provided by industrial experts.

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Sector : Coating of M1 Vehicles

SNAP: 06 01 01 01 or NFR3A Paint application

This source category covers the coating of cars as part of production and assembly, which are covered by the UN/ECE definition of M1-vehicles (mainly passenger cars). Emissions from painting processes originate from the spray booth, the drying ovens and the cleaning of application equipment.

This document has been prepared in close collaboration with the European Automobile Manufacturer Association (ACEA) [6]. Data have been reviewed and validated by the profession.

ACTIVITY **:** number of cars produced / year
POLLUTANT CONSIDERED **:** VOC

1 Data from bibliography

Following data are just displayed for comparison reasons

1.1 Data used in RAINS [3]

In the present stage of development of RAINS, this sector includes the coating of all vehicle types. For every countries where automobile production is relevant, RAINS uses a country-specific emission factor taking into account the specific production structure and the already applied control measures.

1.1.1 Control options

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

- NoC : Reference case
- PRM+SUB : Process modification (applied to spraying, ovens and air supply systems) and coating substitution (water-based primer and topcoat and powder paints for certain parts. (efficiency : 70%; applicability : 100% to non-controlled plants).
  New plant are assumed to apply this option by default at no extra costs.
- A_INC : Add-on abatement techniques such as adsorption and incineration (efficiency : up to 95%; but only applicable to process responsible of 25 to 30% of VOC emissions in this sector)
- PRM+SUB+A_INC : Combination of the measures displayed above (overall efficiency : 80%).

1.1.2 Abatement costs

Examples for three countries are displayed below :

Table 1.1.2.1 : French situation

Measure	Emission factor [kt VOC / kveh]	Efficiency [%]	Technical Eff. [%]	Applicability [%]	Unit cost [$€_{1990}$/t VOC]
NoC	0,0101	0	0	0	0
PRM+SUB	0,0045	55	55	100	6 546
A_INC	0,0072	29	95	30	7 329
PRM+SUB+A_INC	0,0032	68	68	100	6 331
NoC NEW*	0,0045	0	0	0	0
A_INC NEW*	0,0032	29	95	30	7 445

* New plants are assumed to apply measure 01 by default at no extra costs

Table 1.1.2.2 : German situation

Measure	Emission factor [kt VOC / kveh]	Efficiency [%]	Technical Eff. [%]	Applicability [%]	Unit cost [$€_{1990}$/t VOC]
NoC	0,0200	0	0	0	0
PRM+SUB	0,0045	78	78	100	2 336
A_INC	0,0143	29	95	30	3 685
PRM+SUB+A_INC	0,0032	84	84	100	2 573
NoC NEW*	0,0045	0	0	0	0
A_INC NEW*	0,0032	29	95	30	7 486

* New plants are assumed to apply measure 01 by default at no extra costs

Table 1.1.2.3 : Hungarian situation

Measure	Emission factor [kt VOC / kveh]	Efficiency [%]	Technical Eff. [%]	Applicability [%]	Unit cost [$€_{1990}$/t VOC]
NoC	0,0600	0	0	0	0
PRM+SUB	0,0150	75	75	100	805
A_INC	0,0429	29	95	30	1 228
PRM+SUB+A_INC	0,0107	82	82	100	876
NoC NEW*	0,0150	0	0	0	0
A_INC NEW*	0,0107	29	95	30	2 246

* New plants are assumed to apply measure 01 by default at no extra costs

1.2 Situation in the UK [4]

Vehicle manufacture in the IK is dominated by large car manufacturers. They produced around 1.5 million cars per year comparing to 10 000 vehicles for the small specialist producers.
Installations producing more than 5000 units per year already comply with the UK regulation (by the use of process modification, high volume low pressure guns, improved spray booth operations, compliant coatings using high solid and water-based paints and end-of-pipe devices) which should be sufficient to comply with the EC Directive.
Smaller manufacturer fall out of the scope of the Directive .

Then, no cost are presented in this document.

1.3 Situation in Norway [5]

This sector is studied together with the production of paints and varnishes, the production of plastics and polyester, degreasing in the mechanical industry, the pharmaceutical industry and tanneris.

The emission of solvents can be reduced by a transition to products with reduced solvent content or by cleaning the emissions. Substitution products gather high solid and water-based coatings.
According to [5], the use of water-based coatings does not significantly alter the costs related to the application of coatings, but extra costs may be incurred if it become necessary to clean the waste water.

In 1997, about 50% of all new cars are painted with water-based paints. According to [5], an 80% transition to water-based products in Western Europe should have occurred in 2000.

It is considered that the total investment of cleaning ten major and fifteen minor point emissions source is about 8 155 000 € (NOK 63 million). Annual operating costs are estimated at about 2000 € (NOK 15000). This leads to a cost effectiveness of 375 €/tonne of NMVOC.

2 Short technology description

2.1 General description

The automobile body is assembled from a number of welded metal sections. The body and the parts to be coated all pass through the same metal preparation process.
Surface coating of an automobile body is a multi-step operation carried out on an assembly line conveyor system. Although finishing processes vary from plant to plant, they have some common characteristics. Major steps of such processes may include :

- preliminary cleaning, phosphating, electrophoretic coating (also called electrocoating or electrodeposition)
- application of primer, curing of primer,
- application of topcoat(s), curing of topcoat(s),
- under body sealing and sealing of seams, cavity corrosion protection, and repair painting before assembly.

It is increasingly common to use a two-coat topcoat consisting of a basecoat and a clear coat instead of a one-coat topcoat. Within the paint process, NMVOC-emissions are emitted from the application of electrophoretic coating to the application of clear coat.

Application of a coating takes place in a dip tank or via spray booths. The air flow balance in the spray booth must be such that the solvent concentration does not exceed the prescribed maximum values for the personnel working there and that spray mist is withdrawn in order to avoid uncontrolled deposition.
Drying/curing occurs in the flash-off area and bake oven. The term ”drying” is used for the evaporation of solvent from the applied coat and the ”curing” of the paint coat by chemical reactions. The typical facilities for application and curing are contiguous in order to prevent exposure of the wet body to the ambient environment before the coating is cured.

2.2 Requirements for paints

The following requirements must be fulfilled by the coatings to meet given specifications :

- Protection : resistance against corrosion (humidity), deformations (shocks), impacts (projections of stones), scratches, sunlight, hydrocarbons, acids, etc.;
- quality of final aspect : impression of deepness in the colour, absence of paint ”grains”, brightness.

The primary purpose of electrophoretic coating is to give complete protection against corrosion inside and outside. The filler coat serves not only to improve the appearance (covering the substrate), but also and primarily to give protection against road grit (by elasticity) and to provide an intended rupture point within the filler layer. The topcoat serves not only to improve appearance (gloss, colour, brilliance), but also has important functions in protecting against chemical and physical environmental influences (sunshine, rain, chemicals, fuels, car-wash plants, and mechanical impact or stress).

2.3 Composition of Paints

In order to respect the requirements mentioned above, paints consist of :

- pigments, to give the colour and opacity to the paint;
- binders, which submit adherence and resistance against mechanical and chemical strain;
- solvents and plasticisers to ease suppleness and applicability;
- additives to improve aspect, biological properties, conservation, transports, etc.

The water-based immersion and spray paints primarily used are ethylene glycol ether, propylene glycol, ether, their esters, alcohols, and methylpyrrolidone. Solvent-based paints may additionally contain mainly esters, aromatics, white spirit, ketones and terpenes.

2.4 Application Process

A phosphating process prepares surfaces for the primer application. Since iron and steel rust readily, phosphate treatment is necessary to prevent this. Phosphating also improves the adhesion of the primer and the metal. The phosphating process occurs in a multi-stage washer, with detergent cleaning, a series of rinsings, and coating of the metal surface with zinc phosphate. The parts and bodies then pass through a water spray cooling process. Parts are then oven dried.

3 EU regulation : Directive 1999/13/EC of 11 March 1999 [2]

Operators concerned can conform to the Directive by complying with the total emission limit values. Directive applies to installations with a solvent consumption above 15 t per year.

Emission limits for application of the Directive are presented in table 3.1.

Table 3.1 : Emission limits

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

Activity (type of vehicle)	**Production threshold [number of vehicles]**	**Total emission**	
	Annual production	**New installations**	**Existing installations**
M1 vehicle coating	> 5000	45 g / m^2 or 1,3 kg/vehicle body + 33 g / m^2	60 g / m^2 or 1,9 kg/ vehicle body + 41 g / m^2
	≤ 5000 monocoques ou > 3500 chassis	90 g / m^2 or 1,5 kg/vehicle body + 70 g / m^2	90 g / m^2 or 1,5 kg/vehicle body + 70 g / m^2
Truck cabin coating	> 5000	55 g / m^2	75 g / m^2
	≤ 5000	65 g / m^2	85 g / m^2
Truck / Van coating	> 2500	70 g / m^2	90 g / m^2
	≤ 2500	90 g / m^2	120 g / m^2
Busses coating	> 2000	150 g / m^2	225 g / m^2
	≤ 2000	210 g / m^2	290 g / m^2

4 Definition of Reference Installations

Reference installations are defined according to their production of cars per year.

Reference installations are defined as ***lines of production*** *and are presented in table 4.1.*

Table 4.1 : Reference installations [1], [6]

Reference Installation Code RIC	Description
01	Small Installation: **output/line** : 5 000 cars/y; 20 % one-coat topcoat (solids coat); 80 % two-coat topcoat (basecoat/clearcoat)
02	Medium Installation: **output/line** : 20 000 cars/y; 20 % one-coat topcoat (solids coat); 80 % two-coat topcoat (basecoat/clearcoat)
03	Large Installation: **output/line** : 100 000 cars/y; 20 % one-coat topcoat (solids coat); 80 % two-coat topcoat (basecoat/clearcoat)

5 Emission abatement techniques and costs [1], [6]

5.1 Definitions of primary measures

Relevant primary measures are :

- increase of transfer efficiency of the application technique,
- use of low-solvent paints (incl. water-based paints),
- good housekeeping, solvent management.

Within the industrial coating of automobiles, high requirements do exist regarding optical quality of the coatings, and therefore, only spraying techniques are used for application of surfacers and topcoats. Currently, immersion painting is mainly used for the application of the primer (electrophoretic coating). With spraying techniques, only a part of the paint is effectively applied on the substrate (over spray). Transfer efficiencies for conventional air atomised spraying without electrostatic charge range from 18 to 35 %.
Although electrostatic application of spray paints is used for many automatic applications, it can generally not be used for hand spray applications.

Conventional solvent-based paints consist of between 40 and 80 wt.-% solvent; 40 to 50 wt.-% for primers, high solid coatings and two-coat clear coat. Basecoats in the past had solvent concentrations between 84 and 90 wt.-%, whereas modern basecoats contain between 70 and 80 wt.-% solvent. A further increase of solids concentrations in the basecoat is not in line with the customers expectations regarding paint appearance. It would also require total new paint application systems.

Recovery of purge solvent : especially where different colours are sprayed through the same paint system, a purge of the this system between each colour change is required. In the past, these purges were dumped into the spray booth water recirculation system and hence emitted. Modern paint equipment includes recovery of the purge solvents. Recovered solvent can be reclaimed and reused, at least for less critical applications.
Solvent Management Plan : a good solvent management that controls all solvents used and includes programs for improvement has proven to provide good results and substantial savings in solvent usage. As far as possible, low-solvent cleaning agents should be used, and the cleaning work should be performed in such a way that the solvents used can be separately captured and disposed of. The consumption of solvents needed for cleaning the interior of the spray booth can be reduced by adhesively covering the walls with film or sheeting, which for cleaning is then pulled off and disposed of. However, this will create waste problems.

Four primary measures are defined hereafter in table 5.1. taking product compositions and efficiencies into account.

Table 5.1 : Primary measures

Primary Measure Code PMC	Description
00	• Electrocoat: water-based (5 wt.-% solvent content) • Primer: solvent-based (45 wt.-% solvent content) - electrostatic application • Topcoat : - High solid coat (45 wt.-% solvent content) - electrostatic application, **and** - solvent-based basecoat (75 wt.-% solvent content) – pneumatic application (50 %) and electrostatic application (50 %) – and solvent-based clear coat (45 wt.-% solvent content) - electrostatic application • Solvent management plan, recovery of purge solvent
01	• Electrocoat: water-based (5 wt.-% solvent content) • Primer: water-based (8 wt.-% solvent content) - electrostatic application • Topcoat : - High solid coat (45 wt.-% solvent content) - electrostatic application, **and** - solvent-based basecoat (75 wt.-% solvent content) – pneumatic application (50 %) and electrostatic application (50 %) – and solvent-based clear coat (45 - 55 wt.-% solvent content) - electrostatic application • Solvent management plan, recovery of purge solvent
02	• Electrocoat: water-based (5 wt.-% solvent content) • Primer: solvent-based (45 wt.-% solvent content) - electrostatic application • Topcoat : - High solid coat (45 wt.-% solvent content) - electrostatic application, **and** - water-based basecoat (13 wt.-% solvent content) – electrostatic application – and solvent-based clear coat (45 - 55 wt.-% solvent content) - electrostatic application • Solvent management plan, recovery of purge solvent
03	• Electrocoat: water-based (5 wt.-% solvent content) • Primer: water-based (8 wt.-% solvent content) - electrostatic application • Topcoat : - High solid coat (45 wt.-% solvent content) - electrostatic application, **and** - water-based basecoat (15 wt.-% solvent content) – electrostatic application – and solvent-based clear coat (45 – 55 wt.-% solvent content) - electrostatic application • Solvent management plan, recovery of purge solvent

5.2 Definitions of secondary measures

Two techniques are used as secondary emission reduction measures in vehicle paint operations :

- Incineration on ovens with an efficiency of 95 %. Between 5 and 30 % of the total solvents is emitted inside the oven, higher rates only for waterborne coatings.
- Carbon adsorption on spray booth exhaust (concentration step) followed by thermal incineration. In carbon adsorption, the solvents in the exhaust air are first concentrated on the active carbon and afterwards recovered; the concentrated solvents are destroyed, in most cases in an incinerator.

Table 5.2.1 : Secondary measures

Secondary Measure Code SMC	Description
00	No secondary measure
01	Incinerator on drying oven
02	Incinerator on drying oven and activated carbon adsorption on spray booth combined with thermal incineration

Table 5.2.2 : Parts of the coating process where secondary measures are applied

PMC SMC	Part of Coating Process where Secondary Measures are Applied
01 02	application zone of electrophoresis, primer surfacer, basecoat and clearcoat
02 02	application zone of electrophoresis, basecoat and clearcoat
03 02	application zone of electrophoresis, primer surfacer and clearcoat
04 02	application zone of electrophoresis and clearcoat

5.3 Emission factors and costs data for the different combinations

Table 5.3.1 : Emission factors (EF) and abatement efficiencies for each relevant combination

RIC PMC SMC	NMVOC EF [g/m^2 car coated]	NMVOC EF [kg / car coated]	Abatement Efficiency [%]	Q	CI %
01 00 00	95	7,6	0	4	20
01 00 01	85	6,8	11	4	20
01 00 02	52	4,2	45	4	20
01 01 00	85	6,8	11	4	20
01 01 01	77	6,2	19	4	20
01 01 02	47	3,8	51	4	20
01 02 00	56	4,5	41	4	20
01 02 01	49	3,9	48	4	20
01 02 02	36	2,9	62	4	20
01 03 00	45	3,6	53	4	20
01 03 01	40	3,2	58	4	20
01 03 02	30	2,4	68	4	20
02 00 00	95	7,6	0	4	20
02 00 01	85	6,8	11	4	20
02 00 02	52	4,2	45	4	20
02 01 00	85	6,8	11	4	20
02 01 01	77	6,2	19	4	20
02 01 02	47	3,8	51	4	20
02 02 00	56	4,5	41	4	20
02 02 01	49	3,9	48	4	20
02 02 02	36	2,9	62	4	20
02 03 00	45	3,6	53	4	20
02 03 01	40	3,2	58	4	20
02 03 02	30	2,4	68	4	20
03 00 00	95	7,6	0	4	20
03 00 01	85	6,8	11	4	20
03 00 02	52	4,2	45	4	20
03 01 00	85	6,8	11	4	20
03 01 01	77	6,2	19	4	20
03 01 02	47	3,8	51	4	20
03 02 00	56	4,5	41	4	20
03 02 01	49	3,9	48	4	20
03 02 02	36	2,9	62	4	20
03 03 00	45	3,6	53	4	20
03 03 01	40	3,2	58	4	20
03 03 02	30	2,4	68	4	20

Q : Quality
CI : Coefficient of variation

Table 5.3.2 : Investments and operating costs

RIC PMC SMC	Investment [€]	Q	CI %	Variable OC [€ /y]	Q	CI %	Fixed OC [€ / y]	Savings [€ / y]	Q	CI %
01 00 00	0	4	-	0	4	-	0	0	4	-
01 00 01	300 000	4	25	30 000	4	25	15 000	0	4	-
01 00 02	6 900 000	4	25	510 000	4	25	345 000	20 000	4	25
01 01 00	900 000	4	25	5 100	4	25	0	0	4	-
01 01 01	1 212 500	4	25	35 100	4	25	15 625	0	4	-
01 01 02	7 012 500	4	25	445 100	4	25	305 625	11 300	4	25
01 02 00	3 300 000	4	25	121 000	4	25	0	0	4	-
01 02 01	3 650 000	4	25	152 000	4	25	17 500	0	4	-
01 02 02	7 650 000	4	25	452 000	4	25	217 500	11 300	4	25
01 03 00	4 500 000	4	25	126 000	4	25	0	0	4	-
01 03 01	4 875 000	4	25	159 000	4	25	18 750	0	4	-
01 03 02	7 575 000	4	25	369 000	4	25	153 750	9 000	4	25
02 00 00	0	4	-	0	4	-	0	0	4	-
02 00 01	410 000	4	25	52 000	4	25	20 500	0	4	-
02 00 02	10 910 000	4	25	855 000	4	25	545 500	35 000	4	25
02 01 00	2 100 000	4	25	20 500	4	25	0	0	4	-
02 01 01	2 520 000	4	25	73 500	4	25	21 000	0	4	-
02 01 02	11 720 000	4	25	773 500	4	25	481 000	30 000	4	25
02 02 00	7 600 000	4	25	483 900	4	25	0	0	4	-
02 02 01	8 090 000	4	25	973 900	4	25	24 500	0	4	-
02 02 02	14 390 000	4	25	1476900	4	25	339 500	25 000	4	25
02 03 00	10 400 000	4	25	504 400	4	25	0	0	4	-
02 03 01	10 910 000	4	25	562 400	4	25	25 500	0	4	-
02 03 02	15 110 000	4	25	915 400	4	25	235 500	20 000	4	25
03 00 00	0	4	-	0	4	-	0	0	4	-
03 00 01	600 000	4	25	157 000	4	25	30 000	0	4	-
03 00 02	18 800 000	4	25	1677000	4	25	940 000	88 000	4	25
03 01 00	5 500 000	4	25	102 400	4	25	0	0	4	-
03 01 01	6 125 000	4	25	261 400	4	25	31 250	0	4	-
03 01 02	22 125 000	4	25	1591400	4	25	831 250	75 000	4	25
03 02 00	20 000 000	4	25	2419500	4	25	0	0	4	-
03 02 01	20 715 000	4	25	2583500	4	25	35 750	0	4	-
03 02 02	31 215 000	4	25	3543500	4	25	580 750	62 000	4	25
03 03 00	27 300 000	4	25	2522000	4	25	0	0	4	-
03 03 01	28 050 000	4	25	2688000	4	25	37 500	0	4	-
03 03 02	35 350 000	4	25	3373000	4	25	402 500	50 000	4	25

6 Data to be provided by national experts for the completion of the database for their own country

The following tasks are required :

6.1 Validation work

For representing costs in this sector, the national expert is invited to comment the methodology defined by the Secretariat.

- Validate the default investments and operating costs provided,

Or

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

Comments have to be sent to the Secretariat in the two weeks after having received the document.

6.2 Provision of specific data

Tables to be filled in 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).

All costs have been defined at a European level [6]. No data are considered as country specific for this sector.

- Total activity level in accordance with units used in the document (number of vehicles).

In order to provide IIASA with aggregated data, the following data must be collected:

- Respective percentage of the activity level carried out on each reference installation in 2000, 2005, 2010, 2015, 2020.

- Respective percentage of combinations of reduction measures in 2000 for each 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 6.2.1 : Activity levels in absolute value per Reference Installation (number of cars / y)

RIC	2000	CI%	2005	CI%	2010	CI%	2015	CI%	2020	CI%
01										
02										
03										
Default values proposed for CI		10		20		50		100		100
Total	Calculated automatically by the tool									

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

- Total activity (number of vehicles / y) has to be estimated from 2000 to 2020 and distributed according to the different installations.
- If no detailed information is available in 2000, total activity can be divided equally between all RI (i.e.: 33% for each one).
- If no prevision on the structure of this sector is available (for 2005 to 2020), the proportions used in 2000 can be used. But total activity should evolve.

- Respective percentage of combinations of reduction measures in 2000 for each 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 6.2.2 : Application rate and Applicability for each combination of reduction measures

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 00 02									
01 01 00									
01 01 01									
01 01 02									
01 02 00									
01 02 00									
01 02 01									
01 02 02									
01 03 00									
01 03 01									
01 03 02									
Total RIC 01	**100**	**100**		**100**		**100**		**100**	
02 00 00									
…									
Total RIC 02	**100**	**100**		**100**		**100**		**100**	
03 00 00									
…									
Total RIC 03	**100**	**100**		**100**		**100**		**100**	

If detailed information is available, table 6.2.2 can be filled in.
If only sparse information is available, then table 6.2.2 can be filled in with the same "Application rates" for all RI (this corresponds to the filing of table 6.2.3).

Table 6.2.3 : Aggregated table (this table does not appear in the tool)

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. [%]
Aggreg. 00 00									
Aggreg. 00 01									
Aggreg. 00 02									
Aggreg. 01 00									
Aggreg. 01 01									
Aggreg. 01 02									
Aggreg. 02 00									
Aggreg. 02 01									
Aggreg. 02 02									
Aggreg. 03 00									
Aggreg. 03 01									
Aggreg. 03 02									
Total aggreg.	**100**	**100**		**100**		**100**		**100**	

Aggreg. : Aggregation

Table 6.2.4 : Unabated emission factor [g / m² of car coated]

Default data mean	CI %	User input mean	CI %
95	20		

The "default data mean" can be modified in a range of ± 10%.
If a measure is missing in the document, national experts have to contact the secretariat to add it in the background document.

7 Explanatory notes

7.1 Derivation of Emission Factors [1], [6]

7.1.1 Emission factors for Primary measures

Average surface of a car : 80 m^2/car

The average paint consumption for the reference case (primary measure code 00) is 200 g/m^2, which corresponds to 16 kg paint/vehicle.
The coating consumption factor is the amount paint consumed related to the surface of a car coated :

- The application efficiency of pneumatic spraying techniques is between 18 and 35 %, thus 25 % in average.
- The application efficiency of the electrostatic spraying technology is estimated as 70 % for solvent based systems and 60 % for water based systems, thus an up to 60 % reduction is realised when switching from pneumatic to electrostatic application. For basecoats, only 50 % of the application is electrostatic, the rest pneumatic; percentages are based on dry film.

Table 7.1.1.1 : Solvent contents of the different coating systems considered

Source of NMVOC/Coating Layer	Solvent Content [%]	Average [%]
Electrophoresis	2 - 10	5
Conventional primer	40 - 50	45
Conventional basecoat	70 - 80	75
Conventional clear coat	45 - 55	45
Conventional enamel polyester	40 - 50	45
Water-based basecoat	10 - 15	15
Water-based primer	6 - 10	8

Table 7.1.1.2 : Share of NMVOC for the different coating layers*

Source of NMVOC/Coating Layer	Share [%]	Average Share [%]
Electrophoresis	1 - 6	4
Primer	4 – 10	6
Basecoat	30 – 50	46
Clear coat	9 – 20	16
Solids coat	0 – 20	10
Cleaning and other minor applications	15 - 30	18

* Based on 80 % two-coat topcoat and 20 % one coat topcoat.

Table 7.1.1.3 : Solids content of some coatings

Type of Coating	Primer		Basecoat		Clearcoat
	Solvent based	Water based	Solvent based	Water based	Solvent based
Solids content [%]	50	45	25	20	45-55

Since water-based paints induce lower application efficiencies, an increased paint consumption has to be taken into account. Therefore and on hand of information summarised in Table 7.1.3, the following assumptions have been taken:

- the primer consumption for water-based coatings is about 11 % higher than for conventional solvent-based primer;
- the basecoat consumption for water-based coatings is about 25 % higher than for conventional solvent-based basecoat.

Table 7.1.1.4 : Emission factor for the reference case: primary measure 00

Layer / NMVOC Source	Coating Consumption Factor [g/m^2]	Solvent Content of Coating [%]	Emission Factor for NMVOC [g/m^2]
Electrophoresis	76	5	3,8
Primer	13	45	5,7
Basecoat	58	75	43,7
Clear coat	34	45	15,2
Solids coat	21	45	9,5
Cleaning		100	17,1
Total	**200**	**-**	**95**

Table 7.1.1.5 : Emission factor for primary measure 01

Layer / NMVOC Source	Coating Consumption Factor [g/m^2]	Solvent Content of Coating [%]	Emission Factor for NMVOC [g/m^2]
Electrophoresis	76	5	3,8
Primer	**14**	**8**	**1,1**
Basecoat	58	75	43,7
Clear coat	34	45	15,2
Solids coat	21	45	9,5
Cleaning		100	**12**
Total			**85**

Table 7.1.1.6 : Emission factor for primary measure 02

Layer / NMVOC Source	Coating Consumption Factor [g/m^2]	Solvent Content of Coating [%]	Emission Factor for NMVOC [g/m^2]
Electrophoresis	76	5	3,8
Primer	13	45	5,7
Basecoat	**73**	**15**	**11**
Clear coat	34	45	15,2
Solids coat	21	45	9,5
Cleaning		100	**12**
Total			**57**

Table 7.1.1.7 : Emission factor for primary measure 03

Layer / NMVOC Source	Coating Consumption Factor [g/m^2]	Solvent Content of Coating [%]	Emission Factor for NMVOC [g/m^2]
Electrophoresis	76	5	3,8
Primer	**14**	**8**	**1,1**
Basecoat	**73**	**13**	**9,5**
Clear coat	34	45	15,2
Solids coat	21	45	9,5
Cleaning		100	**6**
Total			**45**

7.1.2 Emission factors for secondary measures

The following assumptions have been taken :

Table 7.1.2.1 : Respective shares of NMVOC-emissions originating from spray booth and oven for the different layers

Layer	Share of NMVOC-emissions originating from spray booth [%]	Share of NMVOC-emissions originating from drying oven [%]
Electrophoresis	0	100
Primer	70	30
Basecoat	90	10
Clear coat	90	10

Table 7.1.2.2 : Efficiencies of secondary measures for different application zones

Application Zone	Efficiency [%]
Incineration on drying oven	90
Activated carbon adsorption on spray booth for the primer application zone combined with thermal incineration	80
Activated carbon adsorption on spray booth for the basecoat application zone combined with thermal incineration	70
Activated carbon adsorption on spray booth for the clear coat application zone combined with thermal incineration	75

According to these assumptions, the following abatement efficiencies have been derived :

Table 7.1.2.3 : Abatement efficiencies of secondary measures applicable to the different layers

Layer	SMC 01 [%]	SMC 02 [%]
Electrophoresis	100 × 0,90 = 90	100 × 0,90 + 0= 90
Primer	30 × 0,90 = 27	27 + 70 × 0,8 = 83
Basecoat	10 × 0,90 = 9	9 + 90 × 0,7 = 72
Clear coat	10 × 0,90 = 9	9 + 90 × 0,75 = 76,5

The following table summarises on hand of an example the way how emission factors have been calculated.

Table 7.1.2.4 : Emission factor for primary measure 00 combined with secondary measure 01

Layer / NMVOC Source	Emission Factor of PMC 00 [g/m^2]	Abatement Efficiency of SMC 01 [%]	Emission Factor of PMC 00 Combined with SMC 01 [g/m^2]
Electrophoresis	3,8	90	0,38
Primer	5,7	27	4,16
Basecoat	43,7	9	39,77
Clear coat	15,2	9	13,83
Solids coat	9,5	0	9,5
Cleaning	17,1	0	17,1
Total			**85**

7.2 Derivation of cost data

Primary measures

Investments for primary measures include the following cost components :

Table 7.2.1 : Investment components for the different primary measures

PMC	Components of Investment
00	• changes necessary to increase solids contents of materials, • HVLP guns (where practical), • emission monitoring points/access, • installation of solvent recovery, • introduction of solvent management plan
01	• additional costs of installing water-based primer spray booth and drying oven • changes necessary to increase solids contents of materials, • HVLP guns (where practical), • emission monitoring points/access, • installation of solvent recovery, • introduction of solvent management plan
02	• additional costs of installing water-based basecoat spray booth and drying oven • changes necessary to increase solids contents of materials, • HVLP guns (where practical), • emission monitoring points/access, • installation of solvent recovery, • introduction of solvent management plan
03	• additional costs of installing water-based primer and basecoat spray booth plus associated drying ovens • changes necessary to increase solids contents of materials, • HVLP guns (where practical), • emission monitoring points/access, • installation of solvent recovery, • introduction of solvent management plan

Table 7.2.2 : Investments for the considered primary measures valid for reference installation 03 [1]

RIC PMC SMC	Investments [€]
03 00 00	1 800 000
03 01 00	7 300 000
03 02 00	21 800 000
03 03 00	29 100 000

In order to derive investments for RIC 01 and 02, the figures of the table above are scaled to the respective capacities of reference installations 01 and 02 using the sixth tenth factor method (assuming a size factor of 0,6).

Table 7.2.3 : Investments for the considered primary measures valid for RIC 01 and 02

RIC PMC SMC	Investments [€]
01 00 00	1 800 000 × (5 000/100 000)^0,6 = 300 000
01 01 00	1 200 000
01 02 00	3 600 000
01 03 00	4 800 000
02 00 00	685 000
02 01 00	2 780 000
02 02 00	8 300 000
02 03 00	11 080 000

Assumptions for the calculation of related operating costs are presented in table 7.2.4 :

Table 7.2.4 : Respective share of cost components for primary measure 01, 02 and 03

Cost Component	Share of Total Operating Costs [%]
Additional paint costs	36
Increased paint usage	46
Energy consumption	18

Table 7.2.5 : Prices for different coatings [6]

Type of Coating	Primer		Basecoat		Clear coat	
	Solvent based	Water based	Solvent based	Water Based	1 K	2K (with water based basecoat)
Price [€ / kg]	3,5	4,0	6,0	7,0	4,5	7,0

Table 7.2.6 : Paint costs (only primer surfacers, basecoats and clear coats are considered) for RIC 03

RIC PMC SMC	Paint costs [€ / y]
03 00 00	(13[g/m²]×3,5[€/kg]+58[g/m²]×6,0[€/kg]+34[g/m²]×4,5[€/kg]) ×80[m²/car] × 100 000[cars] / 1 000[g/kg] = 4 372 000
03 01 00	(14[g/m²]×4,0[€/kg]+58[g/m²]×6,0[€/kg]+34[g/m²]×4,5[€/kg]) ×80[m²/car] × 100 000[cars] / 1 000[g/kg]= 4 456 000
03 02 00	(13[g/m²]×3,5[€/kg]+73[g/m²]×7,0[€/kg]+34[g/m²]×7,0[€/kg]) ×80[m²/car] × 100 000[cars] / 1 000[g/kg] = 6 356 000
03 03 00	(14[g/m²]×4,0[€/kg]+73[g/m²]×7,0[€/kg]+34[g/m²]×7,0[€/kg]) ×80[m²/car] × 100 000[cars] / 1 000[g/kg] = 6 440 000

As defined in table 7.2.4, paint costs represent 82% of additional operating costs. Total over costs are easily derived from this figure.

Table 7.2.7 : Over operating costs for RIC 03

RIC PMC SMC	Over costs for paints [€ / y]	Total over costs [€ / y]
03 00 00	0	0
03 01 00	4 456 000 – 4 372 000 = 84 000	84 000 × 100 / 82 = 102 400
03 02 00	1 984 000	2 419 500
03 03 00	2 068 000	2 522 000

Table 7.2.8 : Emission factors, investments, operating costs, abatement efficiencies and technical lifetime for primary measures

RIC PMC SMC	VOC EF [g/m^2 car coated]	Investment [€]	OC [€/y]	Abatement efficiency [%]	Tech. Life time [y]
01 00 00	95	0	0	0	20
01 01 00	85	900 000	5 100	11	20
01 02 00	57	3 300 000	121 000	40	20
01 03 00	45	4 500 000	126 000	53	20
02 00 00	95	0	0	0	20
02 01 00	85	2 100 000	20 480	11	20
02 02 00	57	7 600 000	483 900	40	20
02 03 00	45	10 400 000	504 400	53	20
03 00 00	95	0	0	0	20
03 01 00	85	5 500 000	102 400	11	20
03 02 00	57	20 000 000	2 419 500	40	20
03 03 00	45	27 300 000	2 522 000	53	20

Secondary Measures

Investments for secondary measures include the following cost components :

Table 7.2.9 : Investment components for the different secondary measures

PMC	Components of Investment
00	No secondary measure
01	• required changes to spray booths • ducting • incineration
02	• required changes to spray booths • ducting • prefiltration (wet electrofilter) • carbon adsorption • incineration

These costs have not been re-calculated and updated because they are sector specific.

Table 7.2.10 : Additional investments for the considered combinations of measures valid for reference installation 03 [1]

PMC SMC	Investments [€]
00 00	0
00 01	600 000
00 02	18 800 000
01 00	0
01 01	625 000
01 02	16 625 000
02 00	0
02 01	715 000
02 02	11 615 000
03 00	0
03 01	750 000
03 02	8 050 000

Table 7.2.11 : Emission factors, investments and operating costs for secondary measures

RIC PMC SMC	VOC EF [g/m² car coated]	Flow Rate [10³ ·m³/h]	Working Time* [h/y]	VOC-Conc. [mg/m³]	Investment [€]	Variable OC [€ / y]	Fixed OC [€ / y]
01 00 01	85	do 1.0	3 520	1 000	300 000	30 000	15 000
01 00 02	52	do 1.0 E 20 P 20 B 40 C 50	3 520 3 520	1 000 250	300 000 6 600 000	30 000 TAC 480 000 SC 20 000	345 000
01 01 01	77	do 1.0	3 520	1 000	312 500	30 000	15 625
01 01 02	47	do 1.0 E 20 B 40 C 50	3 520 3 520	1 000 250	312 500 5 800 000	30 000 TAC 410 000 SC 11 300	305 625
01 02 01	49	do 1.0	3 520	1 000	350 000	31 000	17 500
01 02 02	36	do 1.0 E 20 P 20 C 50	3 520 3 520	1 000 250	350 000 4 000 000	31 000 TAC 300 000 SC 11 300	217 500
01 03 01	40	do 1.0	3 520	1 000	375 000	33 000	18 750
01 03 02	30	do 1.0 E 20 C 50	3 520 3 520	1 000 250	375 000 2 700 000	33 000 TAC 210 000 SC 9 000	153 750
02 00 01	85	do 4	3 520	1 000	410 000	52 000	20 500
02 00 02	52	do 4 E 40 P 40 B 80 C 120	3 520 3 520	1 000 250	410 000 10 500 000	52 000 TAC 803 000 SC 35 000	545 500
02 01 01	77	do 4	3 520	1 000	420 000	53 000	21 000
02 01 02	47	do 4 E 40 B 80 C 120	3 520 3 520	1 000 250	420 000 9 200 000	53 000 TAC 700 000 SC 30 000	481 000
02 02 01	49	do 4	3 520	1 000	490 000	57 000	24 500
02 02 02	36	do 4 E 40 P 40 C 120	3 520 3 520	1 000 250	490 000 6 300 000	57 000 TAC 503 000 SC 25 000	339 500
02 03 01	40	do 4	3 520	1 000	510 000	58 000	25 500
02 03 02	30	do 4 E 40 C 120	3 520 3 520	1 000 250	510 000 4 200 000	58 000 TAC 353 000 SC 20 000	235 500
03 00 01	85	do 8.4	3 520	1,000	600 000	157,000	30 00
03 00 02	52	do 8.4 E 100 P 100 B 200 C 300	3 520 3 520	1,000 250	600 000 18 200 000	157 000 TAC 1 520 000 SC 88 000	940 000
03 01 01	77	do 8.4	3 520	1 000	625 000	159 000	31 250
03 01 02	47	do 8.4 E 100 B 200 C 300	3 520 3 520	1 000 250	625 000 16 000 000	159 000 TAC 1 330 000 SC 75 000	831 250
03 02 01	49	do 8.4	3 520	1 000	715 000	164 000	35 750

RIC PMC SMC	VOC EF [g/m² car coated]	Flow Rate [$10^3 \cdot m^3/h$]	Working Time* [h/y]	VOC-Conc. [mg/m^3]	Investment [€]	Variable OC [€ / y]	Fixed OC [€ / y]
03 02 02	36	do 8.4 E 100 P 100 C 300	3 520 3 520	1 000 250	715 000 10 900 000	164 000 TAC 960 000 SC 62 000	580 750
03 03 01	40	do 8.4	3 520	1 000	750,000	166 000	37 500
03 03 02	30	do 8.4 E 100 C 300	3 520 3 520	1 000 250	750 000 7 300 000	166 000 TAC 685 000 SC 50 000	402 500

* 16 hours per day, 220 days per year.
do = drying oven
E = electrophoresis
P = primer
B = basecoat
C = clearcoat
TAC = total annual costs
SC = saved costs

8 References

[1] Task force on the assessment of abatement options and techniques for VOC from stationary sources. Draft background document – Prepared by IFARE for UN/ECE-May 1999.

[2] 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.

[3] RAINS-VOC model, September 1998. http://www.iiasa.ac.at/~rains/databases.html

[4] Regulatory and Environmental Impact Assessment for the Implementation of the EC Solvent Emissions Directive. Final Report. Entec UK Limited. 20 December 1999.

[5] Measures for Reducing NMVOC Emissions in Norway. Cost Estimate. SFT. 1997.

[6] Common meeting ACEA – CITEPA. April 2003.

9 Modifications compared to the draft document

This background document has been prepared in close cooperation with the European Industry [6].

Reference installations are defined as ***lines of production****.*

9.1 Modifications of chapter 5

Table 5.3.1 : emission factors [kg/car coated] have been added to be in coherence with the activity.

$$EF\ [kg / car] = EF\ [g / m^2] \times 80\ [m^2 / car] / 1000\ [g / kg]$$

Table 5.3.2 : Fixed operating costs (5% of SMC investments) have been calculated and added to be in coherence with the other VOC sectors.

Fixed OC in table 7.2.11 (p.22) have been corrected to be in compliance with those presented in table 5.3.2 (p.11).