Final Background Document
on the sector

Wood coating

Prepared in the framework of EGTEI

Prepared by CITEPA, Paris

Summary

Sector : Wood coating

SNAP : 06 01 07 00 or NFR 3A Paint application

This sector covers the industrial application of paints onto wooden surfaces. Here mainly the use of paints and varnishes in the furniture and panel coating industry is considered. The domestic use of paints is covered by the chapter ”Paint application : domestic use”; the impregnation of wood is considered in the chapter ”preservation of wood”.

ACTIVITY : surface of wood coated (m^2 / year)
POLLUTANT CONSIDERED : VOC

1 Data from the bibliography

Following data are just displayed for comparison reasons

1.1 Data currently used in the RAINS model [6] , [7]

In the RAINS model, coating of wood is not considered as a separated sector. This sub-sector is covered as a part of “Industrial Use of Paints under Other Industrial Use of Paints”. This sector concerns the ship building industry, manufacture of plastic and metal articles, wood products industry.

1.1.1 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.

1.1.2 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 1.1.2.1 : 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 1.1.2.2 : 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 1.1.2.3 : 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 1.1.2.4 : 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

Situation in the UK [8]

According to [8], the use of water based and high solids coatings is likely to be the means by which the vast majority of operators will comply with the Directive requirements. Consequently, the fugitive emission limit will not require to be monitored and controlled. According to industry contacts, abatement devices will not be used.
Estimates of the costs of alternative coating systems are variable with some manufacturers claiming no additional costs, and even quality improvements, and others fearing significant cost increases.
As UK installations already have to comply with a national regulation, no over costs should be incurred as a result of the EU Directive. Then, no costs are displayed in report [8].

2 Short technology description

The coating of wooden surfaces serves mainly for surface protection and decoration. Different application technologies are used such as spraying, rolling, curtain coating, etc. Solvents used in wood coatings are usually mixtures, including ketones, esters, alcohols, aromatic hydrocarbons, glycol ethers, and others. Those most often used in water-based coatings are alcohols and glycol ethers. In most Member States, alkoxy ethanols are no longer used as solvents [9]

The technologies used range from high (75%) solvent coatings to essentially solvent free UV cured coatings. The choice of technology is determined by the geometry of the articles being painted, the scale of production, and importantly by aesthetic considerations [9]

The industry was already using low VOC coatings before the development of EU legislation to limit emissions. Generally, though, such technology has found application on the rather small number of very large wood finishing installations, where the scale of operations permits heavy capital expenditure [9].

2.1 Furniture Coating

A large variety of coatings (conventional solvent-based, high solids, UV-curing, water-based, ...) is applied by different application techniques (rolling, spraying, curtain coating, brushing, dipping, manual application, etc.). A very large proportion of facilities are small. Coated surfaces are of different shape, from large flat surfaces to very complex surfaces, which cause considerable losses of coating in the case of spraying (over spray). All kinds of wood are concerned.

2.2 Flat Wood Interior Panel Coating

Finished flat wood construction products are interior panels made of hardwood plywoods (natural and lauan), particle board, and hardboard. Some of the layers and coatings that can be factory-applied to flat woods are filler, sealer, groove coat, primer, stain, basecoat, ink, and topcoat.
Various forms of roll coating are the preferred techniques for applying coatings to flat woods. Various spray techniques and brush coating may be used as well.

Groove coatings, applied in different ways and at different points in the coating procedure, are usually pigmented low resin solids diluted with water before use, therefore yielding few, if any, emissions. Fillers, usually applied by reverse roll coating, may be of various formulations: polyester (which is ultraviolet cured), water-based, lacquer-based, polyurethane, and alkyd urea-based. Water-based fillers are in common use on printed panelling lines. Sealers may be water or solvent-based, usually applied by airless spray or direct roll coating, respectively. Basecoats, which are usually direct roll coated, generally are lacquer, synthetic, vinyl modified alkyd urea, catalysed vinyl, or water-based.
Natural hardwood plywood panels are coated with transparent or clear finishes to enhance and protect their face ply of hardwood veneer. Typical production lines are similar to those for printed interior panelling, except that a primer sealer is applied to the filled panel, usually by direct roll coating. No basecoat is required. A sealer is also applied after printing but before application of the topcoat, which may be curtain coated, although direct roll coating remains the usual technique.

3 EU regulation : Directive 1999/13/EC of 11 March 1999 [5]

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

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

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

Solvent consumption threshold [t/y]	VOC emission limit value in residual gases [mg C / Nm^3]	Fugitive emissions % of solvent input *
15-25	Application and drying : 100	25
> 25	Application : 50 Drying : 75	20

* Solvent input : quantity of organic solvents used as input into the process in the time frame over which the mass balance is being calculated (purchased solvent) + quantity of organic solvents recovered and reused as solvent input into the process (recycled solvents are counted every time they are put back into the cleaning cycle).

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

4 Definition of Reference Installations

According to [9], probably 75% of all installations have a coatings consumption of less than 5 tonnes per year. Therefore, a very small installation has been defined.

Reference installations are defined according to their production of wood coated (m^2/y) and displayed in table 4.1.

Table 4.1 : Reference installations [1], [9]

Reference Installation Code RIC	Description
01	Very Small Reference Installation: wood surface to be coated: 15 000 m^2/y
02	Small Reference Installation: wood surface to be coated: 65 000 m^2/y
03	Medium Reference Installation: wood surface to be coated: 300 000 m^2/y
04	Large Reference Installation: wood surface to be coated: 1 400 000 m^2/y

5 Emission abatement techniques and costs

5.1 Definitions of primary measures [9]

According to [10], only primary abatement measures are at all widely used, and these are very effective. Secondary measures (as thermal oxidation) are inappropriate.

5.1.1 Alternative coatings and varnishes

The main primary measure to reduce VOC emissions is to decrease the solvent content of the applied coatings and varnishes :

- *Water-based coatings* : these products contain an average solvent content of 5%. All conventional application techniques (dipping, spraying, etc.) are suitable for these products as long as they are resistant to corrosion. Replacement of mixing tanks, pumps, piping, and spray equipment may be necessary if they are not designed for water based coatings.
- *Radiation curing water-based coatings* : at 50 °C, the drying time is around 30 minutes.
- *Solvent- and water-free UV-curing coatings* : mainly acrylic and polyester types.
- *High solid coatings* : they have been commonly used for a long time and are available in several forms (e. g. polyurethane varnishes, polyester finishes, etc.).

5.1.2 Application mode

Considerable efforts are being made towards an improvement of transfer efficiencies.
The transfer efficiency of conventional spraying techniques is about 50 %.
With improved application techniques (e. g. electrostatic spraying, roller coating, curtain coating or dipping), transfer efficiencies of about 95 % may be reached for flat wood interior panel coating.

The following simplified scheme can be consider :
- ✓ Nitrocellulose coatings, solvent content around 80% (low solids systems);
- ✓ Acid catalysed coatings, solvent content around 55% (medium solids systems);
- ✓ Polyester coatings using reactive diluents, volatiles around 20% (high solids systems);
- ✓ UV and water-borne coatings, volatiles typically 5% (very high solids systems).

The following mixtures of primary measures can be considered. Primary measure 00 corresponds t the assumptions for the Reduction Scheme in Annex IIB of Directive 1999/13.

Table 5.1.1 : Primary measures [9]

Primary Measure Code PMC	Description
00	low solids systems (80% solvent content), Conventional application process with an efficiency of 35% (spray application technique).
01	low solids systems (80% solvent content) and application process with an efficiency of 75% (electrostatic, roller coating, curtain coating, dipping)
02	medium solids systems (55% solvent content), conventional application process with an efficiency of 35%
03	medium solids systems (55% solvent content), application process with an efficiency of 75%
04	high solids coating systems (20% solvent content), application process with an efficiency of 35%
05	high solids coating systems (20% solvent content), application process with an efficiency of 75%
06	very high solids systems (5% solvent content), application process with an efficiency of 35%
07	very high solids systems (5% solvent content), application process with an efficiency of 75%

Coating system consists of filler, sealer, basecoat, ink, and topcoat. The solvent content given in brackets defines the amount of solvents in wt.-% for the entire coating system.

5.2 Definitions of secondary measures

According to [9], very high abatement efficiency can be achieved by primary measures. Secondary measures are very rarely justified.

Table 5.2.1 : Secondary measures

Primary Measure Code PMC	Description
00	No secondary measure
01	Thermal oxidation

5.3 Emission factors and cost data for the different combinations

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

PMC SMC	VOC EF [g / m² wood coated]	Abattement efficiency [%]	Q	CI %
00 00	345,6	0,0	3	30
00 01	83	76	3	30
01 00	163,2	53	3	30
01 01	39	89	3	30
02 00	105,6	69	3	30
02 01	25	93	3	30
03 00	46,2	87	3	30
04 00	21,6	94	3	30
05 00	9,6	97	3	30
06 00	4,8	99	3	30
07 00	2,4	99	3	30

CI : Coefficient of variation
Q : Quality of data

Table 5.3.2 : Investments and variable operating costs

RIC PMC SMC	Investment [€]	Q	CI %	Variable OC [€ / y]	Q	CI %	Fixed OC [€ / y]	Q	CI %
01 00 00	0	2	-	16 956	3	30	-	-	-
01 00 01	333 000	2	30	24 002	3	30	16 650	3	20
01 01 00	0	2	-	8 007	3	30	-	-	-
01 01 01	219 000	2	30	12 884	3	30	10 950	3	20
01 02 00	12 837	2	30	9 756	3	30	-	-	-
01 02 01	187 837	2	30	14 000	3	30	8 750	3	20
01 03 00	12 837	2	30	4 268	3	30	-	-	-
02 00 00	0	2	-	73 476	3	30	-	-	-
02 00 01	747 000	2	30	94 082	3	30	37 350	3	20
02 01 00	0	2	-	34 697	3	30	-	-	-
02 01 01	494 000	2	30	45 992	3	30	24 700	3	20
02 02 00	30 942	2	30	42 276	3	30	-	-	-
02 02 01	421 442	2	30	50 678	3	30	19 525	3	20
02 03 00	30 942	2	30	18 496	3	30	-	-	-
02 04 00	38 678	2	30	50 076	3	30	-	-	-
02 05 00	38 678	2	30	22 256	3	30	-	-	-
02 06 00	61 884	2	30	35 438	3	30	-	-	-
02 07 00	77 355	2	30	17 719	3	30	-	-	-
03 00 00	0	2	-	339 120	3	30	-	-	-
03 00 01	1 737 000	2	30	423 637	3	30	86 850	3	20
03 01 00	0	2	-	160 140	3	30	-	-	-
03 01 01	1 150 000	2	30	201 628	3	30	57 500	3	20
03 02 00	77 460	2	30	195 120	3	30	-	-	-
03 02 01	977 460	2	30	222 958	3	30	45 000	3	20
03 03 00	77 460	2	30	85 365	3	30	-	-	-
03 04 00	96 825	2	30	231 120	3	30	-	-	-
03 05 00	96 825	2	30	102 720	3	30	-	-	-
03 06 00	154 919	2	30	163 560	3	30	-	-	-
03 07 00	193 649	2	30	81 780	3	30	-	-	-
04 00 00	0	2	-	1 582 560	3	30	-	-	-
04 00 01	2 645 000	2	30	1 969 293	3	30	132 250	3	20
04 01 00	0	2	-	747 320	3	30	-	-	-
04 01 01	1 750 000	2	30	933 410	3	30	87 500	3	20
04 02 00	195 200	2	30	910 560	3	30	-	-	-
04 02 01	1 571 200	2	30	1 033 176	3	30	68 800	3	20
04 03 00	195 200	2	30	398 370	3	30	-	-	-
04 04 00	244 000	2	30	1 078 560	3	30	-	-	-
04 05 00	244 000	2	30	479 360	3	30	-	-	-
04 06 00	390 400	2	30	763 280	3	30	-	-	-
04 07 00	488 000	2	30	381 640	3	30	-	-	-

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.

- Validation of 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).

Table 6.2.1 : Country-specific data

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

Table 6.2.2 : Country and sector specific data

Parameters	Default costs [€/kg]	Country specific costs [€/kg]
Low solids systems	2,9	
Medium solids systems	3,9	
High solids systems	8,5	
Very high solids systems	6,8	
Cleaning solvents	1,5	

- Respective shares (m² of wood coated / y) of the total activity level carried out on each reference installation 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 6.2.3 : Activity levels in absolute value per Reference Installation (m² of wood coated / year)

RIC	2000	CI%	2005	CI%	2010	CI%	2015	CI%	2020	CI%
01										
02										
03										
04										
Default values		10		20		50		100		100
Total	Calculated automatically by the tool									

- Total activity (m² of wood coated / 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.: 25% 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 m² of wood coated / y) 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 6.2.4 : 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 02 00									
01 02 01									
01 03 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 04 00									
02 05 00									
02 06 00									
02 07 00									
Total RIC 02	**100**	**100**		**100**		**100**		**100**	
03 00 00									
…									
Total RIC 03	**100**	**100**		**100**		**100**		**100**	
04 00 00									
…									
Total RIC 04	**100**	**100**		**100**		**100**		**100**	

If detailed information is available, table 6.2.4 can be filled in.
If only sparse information is available, then table 6.2.4 can be filled in with the same "Application rates" for all RI (this corresponds to the filing of table 6.2.5).

According to [9] :
- very small installations use predominantly high solvent coatings,
- very large installations use predominantly very low solvent coatings.
UK experience, where there is already a 15 tonne threshold rule, is that most installations can adapt their process to fall under the threshold.

Table 6.2.5 : Aggregated table

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. 01 00									
Aggreg. 01 01									
Aggreg. 02 00									
Aggreg. 02 01									
Aggreg. 03 00									
Aggreg. 04 00									
Aggreg. 05 00									
Aggreg. 06 00									
Aggreg. 07 00									
Total aggreg.	**100**	**100**		**100**		**100**		**100**	

Aggreg. : Aggregation

Table 6.2.6 : Unabated emission factor [g VOC / m² wood coated]

PMC SMC	Default data mean	CI %	User input mean	CI %
00 00	345,6	20		

"Default data means" 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 documents.

7 Explanatory notes

7.1 Coating consumption factors (CCF) and solvent consumption factors

According to [9], this is assumed that the average dry film thickness is 25 microns.

Consumption of cleaning solvents : 20% of the solvents contained in the coatings [1].

Table 7.1.1 : CCF and solvent consumption factors

PMC	CCF [g coating / m^2 wood]	Solvents from paints [g VOC / m^2 wood]	Cleaning solvents [g VOC / m^2 wood]	Total solvent consumption [g VOC / m^2 wood]	Abatement efficiency [%]
00	360	360 × 0,8 = 288	228 × 0,2 = 57,6	345,6	0
01	170	170 × 0,8 = 136	136 × 0,2 = 27,2	163,2	53
02	160	160 × 0,55 = 88	88 × 0,2 = 17,6	105,6	69
03	70	70 × 0,55 = 38,5	38,5 × 0,2 = 7,7	46,2	87
04	90	90 × 0,2 = 18	18 × 0,2 = 3,6	21,6	94
05	40	40 × 0,2 = 8	8 × 0,2 = 1,6	9,6	97
06	80	80 × 0,05 =4	4 × 0,2 = 0,8	4,8	99
07	40	40 × 0,05 = 2	2 × 0,2 = 0,4	2,4	99

7.2 Emission factors

- ✓ In installations without secondary abatement devices, all the solvent used is emitted into the air.
- ✓ In installations with secondary abatement devices, only fugitive emissions occur (i.e.20% of emissions are uncontained). An abatement efficiency of 95% is assumed..

Table 7.2.1 : Emission factors (EF) related to the volume of wood treated

PMC SMC	Solvent CF [g / m² of wood]	VOC EF [g VOC / m² of wood]	Abatement efficiency [%]
00 00	345,6	345,6	0,0
00 01	345,6	345,6 ×(0,8×0,05+0,2) = 83	76
01 00	163,2	163,2	53
01 01	163,2	163,2 ×(0,8×0,05+0,2) = 39	89
02 00	105,6	105,6	69
02 01	105,6	105,6 ×(0,8×0,05+0,2) = 25	93
03 00	46,2	46,2	87
04 00	21,6	21,6	94
05 00	9,6	9,6	97
06 00	4,8	4,8	99
07 00	2,4	2,4	99

7.3 Derivation of cost data

Primary measures

Costs can arise from different parameters :

- ✓ R&D for new coating systems : according to [9], R&D costs are not very relevant for this sector;
- ✓ Increased product costs : these are taken into account hereafter;
- ✓ Increased application process costs.

Investments are necessary for application process modifications. It is assumed that process modification means a switch from conventional spraying application technique to :

- airless application,
- electrostatic application,
- roller coating,
- curtain coating,
- dipping

Additional costs for RIC 04 are reported from [4]. In order to derive investments for RIC 01, 02 and 03, the sixth tenth factor method (assuming a size factor of 0,6) is used.

Table 7.3.1 : Investments for application process improvement

PMC	RIC 01 15 000 m²/y	RIC 02 65 000 m²/y	RIC 03 300 000 m²/y	RIC 04 1 400 000 m²/y
00	0	0	0	0
01	0	0	0	0
02	12 837	30 942	77 460	195 200
03	12 837	30 942	77 460	195 200
04	-	38 678	96 825	244 000
05	-	38 678	96 825	244 000
06	-	61 884	154 919	390 400
07	-	77 355	488 000 × (3/14)^0,6 = 193 649	488 000

Operating costs have also to be considered because coating systems have very different costs.
Costs presented in table 7.3.2 are all based on clear product (not pigmented) for comparison reasons.
High solid systems costs might be lower in some European countries.

Table 7.3.2 : Typical costs per coating type [9]

Coating Type	Costs for Coating [€ / l]	Density [kg/ l]	Costs for Coating [€ / kg]
Low solids systems	2,7	0,93	2,7 / 0,93 = 2,9
Medium solids systems	3,7	0,96	3,9
High solids systems	8,5	1	8,5
Very high solids systems	7,5	1,1	6,8
Cleaning solvents	1,3	0,9	1,5

Table 7.3.3 : Costs of coatings and cleaning solvents for each installation [€ / y]

PMC	RIC 01		RIC 02		RIC 03		RIC 04	
	Coatings	Cleaning solvents	Coatings	Cleaning solvents	Coatings	Cleaning solvents	Coatings	Cleaning solvents
00	15 660	1296	67 860	5 616	313 200	25 920	1 461 600	120 960
01	7 395	612	32 045	2 652	147 900	12 240	690 200	57 120
02	9 360	396	40 560	1 716	187 200	7 920	873 600	36 960
03	4 095	173	17 745	751	81 900	3 465	382 200	16 170
04	-	-	49 725	351	229 500	1 620	1 071 000	7 560
05	-	-	22 100	156	102 000	720	476 00	3 360
06	-	-	35 360	78	163 200	360	761 600	1 680
07	-	-	17 680	39	81 600	180	380 800	840

Table 7.3.4 : Total operating costs [€ / y]

PMC	RIC 01	RIC 02	RIC 03	RIC 04
00	16 956	73 476	339 120	1 582 560
01	8 007	34 697	60 140	747 320
02	9 756	42 276	195 120	910 560
03	4 268	18 496	85 365	398 370
04	-	50 076	231 120	1 078 560
05	-	22 256	102 720	479 360
06	-	35 438	163 560	763 280
07	-	17 719	81 780	381 640

Secondary measures

Costs for end-of-pipe technologies depend on the following parameters :

- flow rate [Nm^3/h],
- working time [h/y], and
- VOC-concentration in the waste gas stream to be purified [mg/m^3].

As regards the annual working time of the reference installations, the following values were taken into consideration [10] :

- Very small reference installation: 1 840 h/y,
- Small reference installation: 1 840 h/y,
- Medium reference installation: 1 840 h/y,
- Large reference installation: 4 000 h/y.

- VOC concentration : 0,5 g/m^3.

Flow rates are calculated with the following equation :

Flow rate [m^3/h] = 0,8 × [(g COV / m² coated) × (m² coated/y)] / [(g VOC/m^3) × (h/y)]

Table 7.3.5 : Emission factors, flow rates, investments, operating costs an technical lifetime for secondary measures

RIC PMC SMC	VOC EF [g / m² coated]	Flow rate [m^3/h]	Investment [€]	Variable OC [€/y]	Fixed OC [€/y]	Tech. Lifetime [y]
01 00 01	83	4 500	333 000	7 047	16 650	10
01 01 01	39	2 100	219 000	4 877	10 950	10
01 02 01	25	1 400	175 000	4 244	8 750	10
02 00 01	83	19 500	747 000	20 606	37 350	10
02 01 01	39	9 200	494 000	11 295	24 700	10
02 02 01	25	6 000	390 500	8 402	19 525	10
03 00 01	83	90 200	1 737 000	84 518	86 850	10
03 01 01	39	42 600	1 150 000	41 489	57 500	10
03 02 01	25	27 500	900 000	27 839	45 000	10
04 00 01	83	193 500	2 645 000	386 733	132 250	10
04 01 01	39	91 400	1 750 000	186 091	87 500	10
04 02 01	25	59 100	1 376 000	122 616	68 800	10

8 References

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[6] 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

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9. Modifications compared to the draft document

9.1 Modification of chapter 5

Operating costs have been modified (see explanations in chapter 7).

9.2 Modification of chapter 7

Table 7.1.1 has been modified : solvents from paints and cleaning solvents consumptions have been separated.
Table 7.3.2 : Costs of coatings have been reviewed with [9]. These costs are country specific.
Table 7.3.3 : cleaning solvent costs have changes leading to differences in total operating costs [€ / y] in **table 7.3.4**.

Table 7.3.5 : flow rates as well as fixed operating costs have been rounded off; variable costs for combination 010201 has been recalculated.