COIL COATING

SYNOPSIS SHEET

Prepared in the framework of EGTEI

1. Activity description and EGTEI contribution - summary

Coil coating (or metal coil surface) is a linear process by which protective and/or decorative organic coatings are applied to flat metal sheets or strips packaged in rolls or coils. The metal strip is sent through a coating application station, where rollers coat one or both sides of the metal strip. The strip then passes through an oven where the coatings are dried and cured. As the strip exits the oven, it is cooled by water spray and again dried. If the line is a tandem line, there is first the application of a primer, followed by another of topcoat.

Following activity and emission figures are only indicative and come from the previous version of the RAINS model. They do not correspond to any official statistics. This activity emits NMVOC originating from the use of paints containing solvents, thinners and cleaning solvents. NMVOC emissions from this sector may vary significantly from country to country according to the rate of use of thermal oxidisers and the type of paints used. At a EU25 level for the year 2000 (according to the RAINS model: version CP_CLE_Aug04(Nov04)), NMVOC emissions were in order of 6 kt representing 0.06% of total NMVOC emissions. Total activity being, 1,449 Mm² of coil coated, average emission factor is about 4.4 g NMVOC/m² coated meaning that emissions from this sector are already treated in EU25. These estimations could be modified in a near future due to information delivered by national experts during the bilateral consultation in 2005.

Coil coating is addressed by the European Directive 1999/13/EC (SED) [1] related to the reduction of NMVOC emissions from the use of solvents in some industrial activities. In order to be able to better represent the impact of this Directive in term of emission reduction and costs, **coil coating has been considered as an individual activity by EGTEI [2]**. This sector was not considered as an individual sector in the previous version of RAINS [5] and **EGTEI has been able to develop an approach for representing this sector and estimate costs of reduction techniques**. The methodology for this sector was developed in close cooperation with the European Coil Coating Association (ECCA) [3] and with an anonymous industrial operator working on powder lines [4]. Presently, RAINS has been modified and integrates EGTEI proposals. **Data provided by EGTEI (emission factors and costs) have been implemented in the new version of the RAINS model** for the modelling work carried out in the scope of the CAFÉ programme and the revision of the Gothenburg Protocol and national emission ceiling Directive.

The representative unit used is the area of coil coated annually (m²/year). The installation's size depends on the substrate to be coated (steel and aluminium). Four reference installations (RI) have been defined with ECCA to represent steel and aluminum coating as a single sector.

Three primary measures are considered based on different types of paints: solvent-based (SB) coatings, water-based (WB) coatings or powder. Solvent-based paints are commonly used and represent the reference situation. Water-based paints are considered to define very specific applications but there is no European country with substantial use of WB coatings. The general trend for WB coatings is decreasing since the 1970's due, at least partially, to the universal use of abatement by thermal oxidation. If used, this technique is sufficient to be in compliance with the SED requirements according to the reduction scheme definition (annexe IIB of the Directive). Powder coatings are not largely used as their application is still technologically (control of an adequate film thickness) and economically (low line speed) difficult: this technology is progressing but, because of higher running costs, is still not commercially viable except in niche markets. It is however described in this document to take into account potential further development: larger emission reductions than strictly required by the SED are achievable.

Thermal oxidation is considered as the unique secondary measure for this sector. This technique is indeed very well adapted to the flow rates and NMVOC concentrations in exhaust gases encountered in coil coating. Its use allows installations being in compliance with the SED requirements.

EGTEI provides default emission factors (EF) with abatement efficiencies, investments and variable and fixed operating costs (OC) as well as unit costs (€/t NMVOC abated and €/activity unit) for three primary measures and one secondary measure according to the installation size.

The use of a thermal oxidiser associated with solvent-based paints is the reduction option enabling compliance with the SED at the lowest costs (from 0.164 to 0.372 k€/t NMVOC abated or from 6.4 to 14.5 k€/Mm²). Costs for powder are significantly higher (from 6.5 to 8.3 k€/t NMVOC abated or from 283.3 to 358.7 k€/Mm²). This can be explained because this technique is only available for niche markets and small installations.

National experts have to collect 3 country specific parameters (wages, electricity and natural gas costs) and 4 country and sector specific parameters (costs of three different types of paints and cleaning solvents). The first ones can be very easily known. As ECCA is not allowed to collect or share that kind of information, national experts may directly contact paint manufacturers or coil coaters to define the different types of paints costs. EGTEI provides default costs for country and specific parameters which can be used if no better national data exist. National experts have also to provide the trends in activity level from 2000 to 2020, the activity shares according to the different RI as well as the application and applicability rates of each abatement technique.

As the representation of this sector in RAINS is based on the EGTEI proposal, it is recommended to national experts to complete ECODAT with country specific parameters which are not known from CIAM.

EGTEI proposals for the representation of coil coating and definitions of abatement techniques have been considered in the last update of RAINS [7]. In the future however, any new technology which could be developed, as new types of paints, should be considered by EGTEI in the background document to continuously improve the representation of the sector and the capacity of EGTEI to describe new technologies.

2. European regulation

As mentioned above, the European Directive 99/13/EC [1] applies to this sector (annex IIA, n°7).

Operators 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 a high solvent content with low-solvent or solvent-free products).

The SED applies to installations with a solvent consumption above 25 t per year. Emission limit values defined in the SED are presented in table 2.1. All obligations are not described in this chapter.

Table 2.1: Emission limit values for coil coating

Solvent consumption threshold [t / y]	NMVOC emission limit value in residual gases [mg C / Nm^3]	Fugitive emissions [% of solvent input*]
> 25	50 150 if use of a regenerative technique	New installations: 5 Existing installations: 10

* 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 process cycle).

The respect of the reduction scheme defined in Annexe IIB of the SED leads to the following emission factors (the annual reference emission corresponds to the total mass of solids in the quantity of paints times a multiplication factor defined in the SED (3 for coil coating). The target emission is equal to the annual reference emission multiplied by a percentage equal to the fugitive emission value + 5 for coil coating):

For existing installations, this corresponds to (90 g of paints/m^2 x 0.6g solid/g of coating x 3 g solvent/g solid) x (0.05+0.10) = 24.3 g VOC/m^2.

For new installations, this corresponds to (90 g of paints/m^2 x 0.6g solid/g of coating x 3 g solvent/g solid) x (0.05+0.050) = 16.2 g VOC/m^2.

The compliance date for existing installations is October 30th, 2007. Following the transcription of the Directive in Member States, this date can be different from country to country. For example, in France, the compliance date is October 30th, 2005.

3. Methodology developed within EGTEI to represent the sector

3.1 Definition of reference installations

Four reference installations (RI) were defined with ECCA [3]. The representative unit used is the area of coil coated annually (m²/year). **It is vitally important to define what is meant by a m²**: figures defined in this document relate to m² of coated metal which in the majority of cases have organic coatings on both sides (this corresponds to 2 m² of applied coating).

The installation's size depends on the substrate to be coated (steel and aluminium). The four reference installations considered enable to represent all the diversity of substrates to be coated (one small and one large installation per substrate). Table 3.1.1 presents the RI considered.

Table 3.1.1: Reference installations

Reference Installation Code RIC	Description	Technical characteristics
01	Very Small Installation: One coating line with an output 7 millions m² of coated metal/y coated steel or aluminium. Range: 5 to 9 millions m²/y	Full load hours: 4,000 h/y [NMVOC]: 8.25 g/m^3 Flow rate: 8,700 m^3/h Solvent input (I*): 302 t/y
02	Small Installation: One coating line with an output 13 millions m² of coated metal/y coated steel or aluminium. Range: 10 to 17 millions m²/y	Full load hours: 4,000 h/y [NMVOC]: 8.25 g/m^3 Flow rate: 16,170 m^3/h Solvent input (I*): 561 t/y
03	Medium Installation: One coating line with an output 24 millions m² of coated metal/y coated steel or aluminium. Range: 18 to 30 millions m²/y	Full load hours: 4,000 h/y [NMVOC]: 8.25 g/m^3 Flow rate: 29,850 m^3/h Solvent input (I*): 1,036 t/y
04	Large Installation: One coating line with an output 42 millions m² of coated metal/y coated steel or aluminium. Range: > 30 millions m²/y	Full load hours: 4,000 h/y [NMVOC]: 8.25 g/m^3 Flow rate: 52,230 m^3/h Solvent input (I*): 1,813 t/y

* As mentioned in the Solvent Management Plan implemented by the SED [2], inputs of organic solvents (I) equal the quantity of organic solvents or their quantity in preparations purchased (I1) + the quantity of organic solvents recovered and reused as solvent input into the process (I2). In this sector, I = I1 because no solvent is recovered. As a reference for calculation, all solvents consumed are assumed to be emitted when no add-on technique is used.

All installations defined in table 3.1.1 have a solvent consumption above the SED threshold (of 25 tonnes of solvents per year). Thus, they all have to comply with the Directive requirements.

3.2 Definition of emission abatement techniques

3.2.1 Primary measures

Three primary measures are defined according to the type of coating used (i.e. solvent-based coatings, water-based coatings or powder). Solvent-based paints are commonly used and represent the uncontrolled situation. The potential of use of the different coatings is different. There is no technical limit for the use of solvent-based paints. Water-based paints almost disappeared in the early 80s but are however considered to describe the situation in some countries. The use of powder coatings is slowed down as their application is still technologically and economically difficult. For the time being, powder line speed is about 10 m/min vs. 100 m/min for liquid paint lines. Thus, powder lines are not suitable for the construction market which represents about 68% of the total market.

Table 3.2.1.1: Primary measures

Primary Measure Code PMC	Description
00	Operation of coil coating line with solvent-based coatings (40 wt.-% solvent content) [3]
01	Operation of coil coating line with water-based coatings (10 wt.-% solvent content)
02	Operation of coil coating line with powder coating systems (solvent free)

The use of traditional solvent-based paints is not suitable to be in compliance with the SED. The use of water-based paints enables to meet the SED requirements if a reduction scheme is introduced. Powder enables to go further than the SED limits.

3.2.2 Secondary measures

A large majority of installations around EU25 are equipped with thermal oxidisers. According to ECCA, some of the newest and best equipped lines are being installed in the new Member States. This technique is the unique secondary measure considered as it is very well adapted to the flow rates and NMVOC concentrations in exhaust gases encountered in this activity. Carbon adsorption is not suitable for this activity. Thermal oxidisers enable compliance with the SED.

Table 3.2.2.1: Secondary measures

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

4. Country specific data to be collected

Different types of country specific data have to be collected to give a clear picture of the situation in each Party. EGTEI proposes default values for the economical parameters which can be modified by the national expert if better data are available.

For this activity as for all NMVOC sectors, country specific economical parameters are used to calculate variable operating costs. They are presented in table 4.1 as the default costs proposed by EGTEI (these costs are entered only once in ECODAT).

Table 4.1: Country specific costs

Parameters	Default costs provided by EGTEI	Country specific costs
Electricity [€/kWh] (net of taxes)	0.0686	To be provided by national experts
Natural gas [€/GJ] (net of taxes)	5.926	To be provided by national experts
Wages [€/h]	25.9	To be provided by national experts

For coil coating, some additional country and sector specific parameters are necessary to calculate variable operating costs. They correspond to costs of different types of paints and cleaning solvents. Default costs proposed by EGTEI are presented in table 4.2.

Table 4.2: Country and sector specific economic parameters (net of taxes)

Parameters	Default costs provided by EGTEI [€/kg]	Country and sector specific costs [€/kg]
Conventional high solvent-based paint	3.5	To be provided by national experts
Water-based paint	4.0	To be provided by national experts
Powder paint	6.5	To be provided by national experts
Cleaning solvent	1.7	To be provided by national experts

As ECCA is not allowed or collect or disseminate such data, national experts may contact directly coil coaters or paint manufacturers to get these economic parameters.

Default data are used to calculate variable and annual unit costs presented in table 5.1.

Information concerning activity levels from 2000 to 2020 as well as the description of the control strategy is also necessary (these data can be directly entered in the database ECODAT). Activity is defined as the total surface coated in each type of reference installations.

According to ECCA knowledge on the capacity of lines in Europe, the following split of capacity is observed:

Table 4.3: Activity level spilt [%] according to the reference installation size

RIC 01	RIC 02	RIC 03	RIC 04
11	13	23	53

A full definition of the work to be done by national experts is provided in the general EGTEI methodology [9].

National experts can also modify the default unabated emission factor proposed by EGTEI to represent the reference situation of the coil coating for all Parties, in a range of ± 10%. If the modification is higher than 10%, then appropriate explanations are required.

Table 4.4: Unabated emission factor [g of NMVOC / m² of coated metal]

Default emission factor	Country specific emission factor
43.2	To be provided by national expert

5. Default emission factors and cost data defined with the EGTEI methodology

Table 5.1 gives an overview of all data provided by EGTEI for the coil coating sector: default emission factors (EF) with abatement efficiencies, investments, and variable and fixed operating costs (OC) as well as unit costs per t NMVOC abated and unit costs per unit of activity.

Variable costs account for paints and electricity consumptions for the primary measures and electricity, natural gas and labour if a thermal oxidiser is used. Fixed operating costs are only considered for secondary measures and correspond to 5% of the thermal oxidiser investment (for maintenance and insurance). As no data are available, it is assumed that fixed operating costs are the same for all primary measures so no additional costs are taken into account (that is why fixed operating costs appear as 0 costs in table 5.1).

Investments and variable operating costs of secondary measures presented in table 5.1 are calculated from the equations defined in the document “derivation of secondary measure costs: thermal oxidation” downloadable on EGTEI website [6]. Energy can be recovered from exhaust gases in some cases but this assumption is not considered in the variable cost calculation. Technical characteristics of the installations are given in table 3.1.1.

Table 5.1: Default emission factors (EF), abatement efficiencies and costs for each combination

RIC PMC SMC	NMVOC EF [g NMVOC / m² coated]	Abatement efficiency [%]	Investment [k€]	Variable Operating Costs [k€ / year]	Fixed Operating Costs [k€/y]	Unit cost [k€/t NMVOC abated]	Unit cost [k€/Mm² coated]
01 00 00	43.2	0	0	0	0	0	0
01 00 01	4.2	90	480	16.0	24.0	0.363	14.2
01 01 00	10.8	75	-2,000	254.2	0	0.472	15.3
01 02 00	0.0	100	-4,000	2,277.6	0	6.558	283.3
02 00 00	43.2	0	0	0	0	0	0
02 00 01	4.2	90	674	24.2	33.7	0.278	10.8
02 01 00	10.8	75	-2,400	472.1	0	0.702	22.7
02 02 00	0.0	100	0	4,229.8	0	7.532	325.4
03 00 00	43.2	0	0	0	0	0	0
03 00 01	4.2	90	944.7	39.23	47.2	0.217	8.5
03 01 00	10.8	75	-2,800	871.6	0	0.856	27.7
03 02 00	0.0	100	4,000	7,809.0	0	7.816	337.6
04 00 00	43.2	0	0	0	0	0	0
04 00 01	4.2	90	1,285.7	63.8	64.3	0.175	6.8
04 01 00	10.8	75	-3,400	1,525.3	0	0.937	30.4
04 02 00	0.0	100	19,000	13,665.7	0	8.303	358.7

Investments correspond to the additional cost of water-based or powder lines and the cost of the thermal oxidiser, when appropriate, compared to the reference situation (use of a solvent-based line). A negative investment means that the cost of a given technique is lower than the investment of the uncontrolled measure (PMC 00/SMC 00). As powder lines are only suitable for small units, no economic assessment is available for larger installations. For medium and large production facilities, it has been consequently assumed that several lines are necessary. Powder line investments are then increasing dramatically according to the size of the installation.

Unit costs [k€/ t of NMVOC abated] are obtained by dividing the annual total additional cost of a measure by the amount of NMVOC abated (costs and emissions are compared to the uncontrolled measure PMC 00/SMC 00).

As shown in table 5.1, the cheapest way of reducing NMVOC emissions is the thermal oxidation which is the solution already commonly used in this sector.

The use of powder coatings is expensive. Data are derived from a single industrial example [4] so uncertainties on costs are quite high. According to ECCA, there are 5 powder coating lines in Europe from a total of 158. These powder lines are restricted to slow line speeds because of the inherent limitations in application, flow and cure, and have limitations in film thickness control, particularly in the range 5-20 microns demanded by much of the coil coating industry. For these reasons powder coating is not seen as a valid alternative to liquid coating for volume production, but is useful for niche products for appropriate end uses.

The use of water-based paints seems to be not cost efficient for this sector (unit costs are higher than for the thermal oxidiser with lower abatement efficiency).

Unit costs are not very different from one reference installation to another one. Consequently, if the structure of this activity in a given country cannot be defined, only the very small and the medium RI can be considered (the use of water-based paints can also be deleted). In France, for information, 92 % of the production is carried out on the largest installations considered RIC 03 and 04.

This simplification is presented in the table bellow:

Table 5.2: Simplified approach

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

Appl.: applicability factor

6. Relevance of EGTEI information for Integrated Assessment Modelling (IAM)

In the previous version of the RAINS model [5], coil coating was not studied as a separate sector. It was considered as part of “Industrial Use of Paints in Other Industrial Use of Paints” (sector gathering both ship building industry, manufacture of plastic and metal articles, wood products industry and other applications of paints). Thus, emission factors, abatement techniques and costs considered in [5] were not specific to this sector and it was very difficult to define a reduction scenario. That is why this sector was identified as a priority sector at the beginning of the EGTEI work.

EGTEI provides now an approach to consider this sector and test the impact of the current legislation as well as the maximum achievable reduction. The approach has been developed in close cooperation with industry.

Data provided by EGTEI (emission factors and costs) have been implemented in the new version of the RAINS model [7] for the modelling work carried out in the scope of the CAFÉ programme and the revision of the Gothenburg protocol.

For this activity, data provided by national experts through ECODAT can then be directly used by IIASA for introduction in the RAINS model.

7. Perspective for the future

In the future, any new technology which could be developed, as new types of paints, should be considered by EGTEI in the background document to continuously improve the representation of the sector. Research on the use of powder should be extended to estimate the practical potential use of this technique in a long term process.

8. Bibliography

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[7] Review of data used in RAINS-VOC model
http://www.iiasa.ac.at/web-apps/tap/RainsWeb/
[8] Rapport d'inventaire national au format UNECE/NFR et NEC
Rapport d'étude du CITEPA - Décembre 2003
[9] Methodology: http://citepa.org/forums/egtei/egtei_index.htm
[10] CITEPA: National reference centre for emission inventories

ANNEXE: Example of data collection and use of EGTEI data – Case of France

A. Country specific data collection and scenario CLE developed

The French national expert has been able to complete ECODAT for the coil coating with the help of CITEPA [10] and consultation of the French association of coil coating.

All collected data have been provided to CIAM for the bilateral consultation France – CIAM in March 2004.

Country and sector specific economic parameters

Country specific parameter costs have been defined from costs encountered in the medium size industry which are monthly published by official French statistic organizations.

Table A.1: French specific costs

Parameters	French specific costs
Electricity [€/kWh] (net of taxes)	0.05
Natural gas [€/GJ] (net of taxes)	5.33
Wages [€/h]	23.4

As no better product costs are available, default costs for country and sector specific parameters are taken into account for describing the French situation.

Table A.2: French and sector specific costs

Parameters	Default costs [€/kg]	French and sector specific costs [€/kg]
Conventional high solvent-based paint	3.5	3.5
Water-based paint	4.0	4.0
Powder paint	6.5	6.5
Cleaning solvent	1.7	1.7

Activity level

The trend of coil coating activities from 2000 to 2020 comes from data provided by the French coil coating association based on the results of an internal enquiry. These data have been endorsed by the French expert.

Activity is defined as the total surface coated in each type of reference installations. Respective shares (Mm² coil/y) of total activity level carried out on each reference installation in 2000, 2005, 2010, 2015, 2020 are derived from the same enquiry. The trends in coil coating activity and shares of the activity are presented in table A.3.

Table A.3: Activity levels on Reference Installations (Mm² coil / year)

RIC	2000	2005	2010	2015	2020
01	0.9	1.1	1.9	2.0	2.9
02	19.0	19.0	20.0	21.0	22.0
03	108.0	129.0	134.0	136.0	139.0
04	130.1	154.0	169.1	186.0	197.1
Total (Mm²)	258	303	325	345	361

Unabated emission factor

Default emission factors are adapted to the French situation.

Current legislation control scenario (CLE)

In the current legislation control scenario (CLE), the application rates of the different abatement techniques depend on the regulation implemented and on the dates of compliance.

In 2000, the use of secondary measures and powder is already at a maximum rate in France. The use of these techniques enables the compliance of installations with the SED and with the French regulation requirements. The use of powder is not expected to increase in the future years (information provided by the French coil coating association). The rates of use of the different reduction techniques were known by CITEPA which, in the scope of the French emission inventory (carried out for the French ministry of Ecology), gathers this type of information [10].

The application rates and applicability factors for the CLE scenario are presented in table A.4.

Table A.4: Definition of the CLE scenario

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	0	0	0	0	0	0	0	0	0
01 00 01	0	0	100	0	100	0	100	0	100
01 01 00	0	0	20	0	20	0	30	0	50
01 02 00	100	100	100	100	100	100	100	100	100
Total RIC 01	**100**	**100**	**-**	**100**	**-**	**100**	**-**	**100**	**-**
02 00 00	0	0	0	0	0	0	0	0	0
02 00 01	100	100	100	100	100	100	100	100	100
02 01 00	0	0	20	0	20	0	30	0	50
02 02 00	0	0	0	0	10	0	15	0	20
Total RIC 02	**100**	**100**	**-**	**100**	**-**	**100**	**-**	**100**	**-**
03 00 00	0	0	0	0	0	0	0	0	0
03 00 01	100	100	100	100	100	100	100	100	100
03 01 00	0	0	20	0	20	0	30	0	50
03 02 00	0	0	0	0	10	0	15	0	20
Total RIC 03	**100**	**100**	**-**	**100**	**-**	**100**	**-**	**100**	**-**
04 00 00	0	0	0	0	0	0	0	0	0
04 00 01	100	100	100	100	100	100	100	100	100
04 01 00	0	0	20	0	20	0	30	0	50
04 02 00	0	0	0	0	10	0	15	0	20
Total RIC 04	**100**	**100**	**-**	**100**	**-**	**100**	**-**	**100**	**-**

Appl.: applicability factor

B. Trends in emissions and total costs of the CLE scenario

Data shown in the table below are directly provided by ECODAT and based on input parameters defined in chapter A.

Table B.1 presents NMVOC emissions from 2000 to 2020 and total annual costs of emissions reduction for the CLE scenario.

Table B.1: Trends in emissions and total annual costs of emission reductions in the CLE scenario

	2000	2005	2010	2015	2020
NMVOC emissions	**t NMVOC**	**t NMVOC**	**t NMVOC**	**t NMVOC**	**t NMVOC**
CLE scenario	1,080	1,268	1,357	1,441	1,504
Annual total costs	**k€/year**	**k€/year**	**k€/year**	**k€/year**	**k€/year**
CLE scenario	2,161	2,527	2,908	3,076	3,443

Emissions shown in table B.1 for the year 2000 according to the CLE scenario have been calculated with EGTEI emission factors. Emissions defined in the French inventory for the year 2000 are 815 tonnes of VOC. However, emissions in 2001 (according to the French inventory) are 1,045 tonnes of VOC for an activity level of 251 Mm² which would correspond to 1,074 tonnes of VOC for 258 Mm² (this is exactly what is calculated with EGTEI data).

EGTEI approach allows representing very well NMVOC emissions from coil coating. In the French inventory, NMVOC emissions are derived from industrial annual reports.