FLEXOGRAPHY AND ROTOGRAVURE IN PACKAGING

SYNOPSIS SHEET

Prepared in the framework of EGTEI

1. Activity description and EGTEI contribution - summary

Flexography means a printing process using an image carrier of rubber or elastic photopolymers on which the printing areas are above the non-printing areas, using liquid inks that dry through the evaporation of organic solvents. The process is usually web fed and is employed for medium or long multicolour runs on a variety of substrates, including heavy paper, fiberboard, and metal and plastic foil. The major categories of the flexography market are flexible packaging and laminates, multiwall bags, milk cartons, gift wraps, folding cartons, corrugated paperboards (which is sheet fed), paper cups and plates, labels, tapes, and envelopes. Almost all milk cartons and multiwall bags and half of all flexible packaging are printed by this process. Water-based inks in flexography printing are in regular production use in some packaging applications such as paper and plastic carrier bags.

Rotogravure means a printing process using a cylindrical image carrier, in which the printing area is below the non-printing area, using liquid inks that dry through evaporation. The recesses are filled with ink and the surplus is cleaned off the non-printing area before the surface to be printed contacts the cylinder and lifts the ink from the recesses (the process is identical as the one used in the publication industry except for difference in size, speed and solvents used). Water-based inks in rotogravure printing are very rarely used.

In the larger installations, flexography and gravure may be found on the same site.

Emissions to air arise primarily from the organic solvents contained in inks. Solvents used in cleaning solutions are also important sources of NMVOC emissions.

NMVOC emissions from this sector may vary significantly from country to country according to the rate of use of secondary measures. At a EU25 level for the year 2000 (according to the RAINS model: version CP_CLE_Aug04(Nov04)), NMVOC emissions were 127.56 kt representing 1.2% of total NMVOC emissions. Total activity being, 91.69 kt of non diluted ink, average emission factor is about 1.4 kg NMVOC/kg non diluted ink. These estimations could be modified in a near future due to information delivered by national experts during the bilateral consultation in 2005.

This sector 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, **this sector has been considered as an individual activity by EGTEI [2]**. This sector was already considered as an individual sector in the previous version of RAINS [4] but new measures and abatement costs have been defined by EGTEI. The methodology for this sector was developed in close cooperation with the European Printing Association (Intergraf) [3]. Since the EGTEI document was finalised, new information has been provided by industry. A meeting has been organised in Laxenburg in 2005 with the representatives of Intergraf, IIASA and CITEPA. This new information will be taken into account in the new RAINS version (activity will be defined as non diluted ink instead of ink ready to use as it is currently done in the EGTEI document and some of the measures will be slightly modified). This new information will be used by CIAM for the modelling work carried out in the scope of the revision of the Gothenburg Protocol and national emission ceiling Directive. Thus, the EGTEI background document might be updated if modifications are too important.

In this synopsis sheet, activity is still expressed as a consumption of ready to use products (kt/year). The installation's size depends on the amount of ink consumed as well as on the type of printing process used (i.e. flexography or rotogravure). As abatement options and costs depend on the printing technique used, four reference installations (RI) have been defined with Intergraf.

Five primary measures are considered based on different ink types used. **Two secondary measures are also defined** (i.e. thermal oxidation and carbon adsorption). Different options can be used to be 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 five primary measures and two secondary measures according to the installation size.

Abatement costs to be in compliance with the SED requirements vary from 0.13 to 21.67 k€/t NMVOC abated or from 0.11 to 14.82 k€/t of ready-to-use product consumed. These ranges are very wide because unit costs depend on the type of control option chosen and on the size of the installation.

National experts have to collect only 4 country specific economic parameters (wages, electricity, natural gas and steam costs) which can be very easily known. They also have to collect one sector

specific parameter which is the cost of recovered solvents. EGTEI provides default costs 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.

Even if the representation of this sector will be slightly modified in the new RAINS version compared to the current EGTEI proposal presented in the EGTEI background document, it is recommended to national experts to complete ECODAT with country specific parameters which are not known from CIAM. These data will be a very useful to national experts to discuss this sector during the bilateral consultations.

2. European regulation

As mentioned above, the European Directive 99/13/EC [1] applies to this sector (annex IIA, n°3).

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 15 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 packaging

Solvent consumption threshold [t / y]	NMVOC emission limit value in residual gases [mg C / Nm^3]	Fugitive emissions [% of solvent input*]
15-25	100	25
> 25	100	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 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 inks times a multiplication factor defined in the SED (4 for rotogravure). The target emission is equal to the annual reference emission multiplied by a percentage equal to the fugitive emission value + 5 for publication gravure):

For installations consuming more than 15 t of solvent per year, this corresponds to (0.2 kg solid/kg of ready to use ink x 4 kg solvent/kg solid) x (0.05+0.25) = 240 g NMVOC/kg ready to use ink.

For installations consuming more than 25 t of solvent per year, this corresponds to (0.2 kg solid/kg of ready to use ink x 4 kg solvent/kg solid) x (0.05+0.20) = 200 g NMVOC/kg ready to use ink.

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 Intergraf [3]. The representative unit used is the amount of ready to use ink consumed annually (t/year).

Table 3.1.1: Reference installations

Reference Installation Code RIC	Description	Technical characteristics
01	Small flexography: Ink consumption: 28 t / y	Full load hours: 1,600 h/y [NMVOC]: 0.25 g/m^3 Flow rate: 105,000 m^3/h Solvent input (I*): 27 t/y
02	Large flexography: Ink consumption: 125 t / y	Full load hours: 3,200 h/y [NMVOC]: 1.0 g/m^3 Flow rate: 50,000 m^3/h Solvent input (I*): 100 t/y
03	Small rotogravure: Ink consumption: 313 t / y	Full load hours: 3,200 h/y [NMVOC]: 4.0 g/m^3 Flow rate: 50,000 m^3/h Solvent input (I*): 250.4 t/y
04	Large rotogravure: Ink consumption: 1,250 t / y	Full load hours: 4,800 h/y [NMVOC]: 4.0 g/m^3 Flow rate: 110,000 m^3/h Solvent input (I*): 1,000 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).

All installations defined in table 3.1.1 have a solvent consumption above the SED threshold (of 15 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

Five primary measures are defined.

Solvent based inks can have different solvent contents when bought but ready to use inks contain about 90% of solvents for RIC 01 and about 80% for RIC 02 to 04 (these figures take into account cleaning agents).

As a matter of fact, the inks are more or less the same. In the machine they contain close to 80% of solvents. The problem is however that during printing, fugitive emissions from the smallest printing unit (RIC 01) are such that viscosity increases far too much and that solvents need to be added at a much larger scale than in other plants. This is due to the very unfavorable ratio between the size of the ink unit and the actual amount of ink necessary for the image to be printed (this gives a solid-solvent ratio of 1:8 or 1:9 instead of 1:4) [3].

Substitution can be implemented with water-based products, UV curing inks and 2-components adhesives. The use of these products is not always technically feasible: it depends on the complexity of the process as well as on the substrate to be printed.

In some cases, just a portion of the products can be replaced by substitution products.

Table 3.2.1.1: Primary measures

Primary Measure Code PMC	Description
00	Conventional solvent products (content of 90 wt.-% of solvent for ready for use inks)
01	Conventional solvent products (content of 80 wt.-% of solvent for ready for use inks)
02	Water-based products (solvent content of 5 wt.-%)
03	UV curing inks (solvent content of 0 wt.-%)
04	60% of products used replaced by 2 components adhesives (solvent content of 0 wt.-%)

3.2.2 Secondary measures

When substitution is not technically feasible or not sufficient to obtain the regulation limits, thermal oxidation or carbon adsorption (when products with mono-solvent are consumed like in Italy for example) can be used to reduce NMVOC emissions.

Table 3.2.2.1: Secondary measures

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

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
Steam [€/kg] (net of taxes)	0.016	To be provided by national experts

For this sector, the cost of recovered solvents also has to be defined as shown in table 4.2.

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

Parameter	Default cost provided by EGTEI [€/kg]	Country specific cost [€/kg]
Recovered solvents	0.15	To be provided by national experts

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). 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 factors proposed by EGTEI to represent the reference situation for all Parties, in a range of ± 10%. If the modification is higher than 10%, then appropriate explanations are required.

Table 4.3: Unabated emission factor [g of NMVOC / kg ready to use ink]

Default emission factor	Country specific emission factor
900 (for RIC 01)	To be provided by national expert
800 (for RIC 02 to 04)	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: 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 natural gas, electricity and labour when a thermal oxidiser is used and electricity, labour and steam for carbon adsorption. Fixed operating costs are only considered for secondary measures and correspond to 5% of the 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 documents “derivation of secondary measure costs: thermal oxidation” and “derivation of secondary measure costs: adsorption” downloadable on EGTEI website [5], [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 / kg product ready-to-use]	Abatement efficiency [%]	Investment [k€]	Variable Operating Costs [k€ / y]	Fixed Operating Costs [k€/y]	Saved Costs [k€ / y]	Unit cost [k€/t NMVOC abated]	Unit cost [k€/t]
01 00 00	900	0	0.0	0	-	-	-	0.00
01 02 00	50	94.5	42.0	0	-	-	0.13	0.11
01 03 00	0	100	42.0	0	-	-	0.12	0.11
01 00 01	216	76	2,138.5	44.4	106.9	-	21.67	14.82
02 01 00	800	0	0.0	0	-	-	-	0.00
02 02 00	100	87.5	187.5	0	-	-	0.16	0.11
02 01 01	192	76	1,506.0	33.4	75.3	-	3.87	2.36
03 01 00	800	0	0.0	0	-	-	-	0.00
03 02 00	50	93.75	469.5	0	-	-	0.15	0.11
03 04 00	320	60	0.0	0	-	-	0.00	0.00
03 01 01	192	76	1,506.0	23.6	75.3	-	1.50	0.91
03 01 02	192	76	1,031.0	48.5	51.6	28.5	1.04	0.63
03 04 01	80	90	1,332.0	19.3	66.6	-	1.11	0.80
03 04 02	80	90	710.0	22.2	35.5	11.3	0.59	0.43
04 01 00	800	0	0.0	0	-	-	-	0.00
04 02 00	50	93.75	1,875.0	0	-	-	0.15	0.11
04 04 00	320	60	0.0	0	-	-	0.00	0.00
04 01 01	192	76	2,325.0	91.6	116.3	-	0.65	0.40
04 01 02	192	76	1,687.5	154.7	84.4	114.0	0.44	0.27
04 04 01	80	90	2,082.0	75.8	104.1	-	0.49	0.35
04 04 02	80	90	1,182.0	71.6	59.1	45.0	0.26	0.19

Investments correspond to the R&D costs, adaptation of the process equipment and water process treatment for product substitution and secondary measure cost when appropriate.

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).

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

In the previous version of RAINS [4], packaging was studied as a separate sector. Data have been updated in cooperation with a representative from the European Printing Association [3] in 2003. These data are defined in the EGTEI background document [2].

EGTEI provides an approach to consider this sector and test the impact of the current legislation as well as the maximum achievable reduction.

Data provided by EGTEI (emission factors and costs) were not implemented in the 2004 RAINS version [7] because of the tight timing. Following a new meeting with representatives from Intergraf, IIASA and CITEPA held in Laxenburg in March 2005, some of the data defined in the EGTEI background document [2] (some of the costs and the activity unit) will be modified. These updated data will be introduced in the next RAINS version for the revision of the NEC Directive and the Gothenburg Protocol.

For this activity, data provided by national experts through ECODAT will still be of interest for the completion of RAINS.

7. Perspective for the future

The EGTEI document might be modified to take into account the updated information defined in cooperation with IIASA and the industry representative.

8. Bibliography

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[4] KLIMONT; M. AMANN; J. COFALA. Estimating costs for Controlling Emissions of Volatile Organic Compounds (NMVOC) from Stationary Sources in Europe. Interim Report IR-00-51. IIASA. August 1. 2000. http://www.iiasa.ac.at/~rains/voc_review/voc_ir-00-51.pdf
[5] http://citepa.org/forums/egtei/thermal_oxidation_costs_170603.pdf
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[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 packaging sector with the help of CITEPA [10].

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

Country 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 organisations.

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
Steam [€/kg] (net of taxes)	0.0131
Wages [€/h]	23.4

Activity level

The trend of packaging activities from 2000 to 2020 comes from data provided by the French national expert.

Respective shares (t ready-to-use product consumed/y) of total activity level carried out on each reference installation in 2000, 2005, 2010, 2015, 2020 are derived from a study carried out in 2000 by CITEPA [10]. The trends in packaging activity and shares of the activity are presented in table A.2.

Table A.2: Activity levels on Reference Installations (t of ready-to-use products / year)

RIC	2000	2005	2010	2015	2020
01	4,584.3	5,217.2	5,937.4	6,757.0	7,689.8
02	9,168.6	10,434.3	11,874.7	13,514.0	15,379.5
03	18,337.2	20,868.6	23,749.4	27,028.0	30,759.0
04	59,595.9	67,823.0	77,185.6	87,841.0	99,966.8
Total (t)	91,686.0	104,343.0	118,747.0	135,140.0	153,795.0

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, secondary measures are already used in a large majority of companies because this sector is already well regulated in France. Only 6% of the activity is not controlled yet. These shares have been developed in collaboration with the French printing association. From 2005 onwards, all companies will be equipped with a thermal oxidiser to comply with the SED requirements.

The application rates and applicability factors for the CLE scenario are presented in table A.3.

Table A.3: 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	100	0	100	0	100	0	100
01 02 00	100	100	100	100	100	100	100	100	100
01 03 00	0	0	10	0	52	0	65	0	65
01 00 01	0	0	100	0	100	0	100	0	100
Total RIC 01	**100**	**100**		**100**		**100**		**100**	
02 01 00	0	0	100	0	100	0	100	0	100
02 02 00	100	100	100	100	100	100	100	100	100
02 01 01	0	0	100	0	100	0	100	0	100
Total RIC 02	**100**	**100**		**100**		**100**		**0**	
03 01 00	82	0	100	0	100	0	100	0	100
03 02 02	13	13	26	15	56	18	70	20	70
03 04 00	0	0	10	0	20	0	20	0	20
03 01 01	5	65	100	63	100	60	100	59.2	100
03 01 02	0	20.7	100	18.6	100	15.0	100	10.0	100
03 04 01	0	1.30	5	1.7	10	3.5	10	5.4	10
03 04 02	0	0	5	1.7	10	3.5	10	5.4	10
Total RIC 03	**100**	**100**		**100**		**100**		**100**	
03 01 00	79	0	100	0	100	0	100	0	100
03 02 02	0	3.5	5	4.5	5	5	10	6.5	10
03 04 00	0	0	10	0	20	0	20	0	20
03 01 01	13	65.2	100	64	100	61.5	100	60	100
03 01 02	8	30.0	100	28.1	100	26.5	100	22.7	100
03 04 01	0	1.30	10	1.7	10	3.5	10	5.4	10
03 04 02	0	0	10	1.7	10	3.5	10	5.4	10
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	53,538	17,482	19,480	21,529	23,644
Annual total costs	**k€/year**	**k€/year**	**k€/year**	**k€/year**	**k€/year**
CLE scenario	6,951	40,283	45,256	49,984	55,442

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 53,500 tonnes of VOC [8].

EGTEI approach allows representing very well NMVOC emissions from this sector.