INDUSTRIAL APPLICATIONS OF ADHESIVES

SYNOPSIS SHEET

Prepared in the framework of EGTEI

1. Activity description and EGTEI contribution - summary

Sectors using adhesives are very diverse. Production processes and application techniques are also very different. Relevant sectors are: the production of adhesive tapes, composite foils, the transportation sector (passenger cars, commercial vehicles, mobile homes, rail vehicles, and aircrafts), the manufacture of shoes and leather goods and the wood material and furniture industry.

This activity emits NMVOC originating from the use of solvent-based adhesives, thinners and cleaning solvents. NMVOC emissions from this sector may vary significantly from country to country according to the rate of use of alternative products (i.e. water based or hot-melt) or the use of end-of-pipe devices.

At a EU25 level in 2000 (according to RAINS [1]: version CP_CLEAug04(Nov04)), NMVOC emissions were 257.6 kt representing 2.4% of total NMVOC emissions. Total activity being, 680 kt of adhesives used, average emission factor is about 378.8 g NMVOC/kg of adhesives meaning that emissions from this sector are already partly treated in EU25 (unabated emission factor being 780 g/kg). These data might be modified in a near future by national experts during the bilateral consultation in 2005 with CIAM.

The application of adhesives is addressed by the European Directive 1999/13/EC (SED) [2] 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 [3]**. This sector was already considered separately in the previous RAINS version [4]. Techniques such as good housekeeping, substitution or thermal oxidation were defined but activity was given in terms of VOC emissions. **EGTEI has been able to develop a specific approach for representing this sector and estimating reduction technique costs. Data for this sector are derived from the experience of a European industrial operator [5]**.

Presently, RAINS has been modified and integrates EGTEI proposals. **Data provided by EGTEI (emission factors and costs) have been implemented in the new RAINS version for the modelling work carried out in the scope of the CAFÉ programme.**

However, this sector will be slightly modified in RAINS for the revision of the Gothenburg Protocol and national emission ceiling Directive. New data have been defined during a meeting with representatives from the German and European associations in March, 2005. These associations consider 8 sub-sectors to estimate total adhesive consumption for each European country. Only three sub-sectors (i.e. wood, manufacture of labels and other) will be used in RAINS because the four other sub-sectors are already taken into account with other activities (DIY and construction with domestic use of solvents, leather with the manufacture of shoes, paper with packaging and transport with the manufacture of cars). **However, for simplification reasons**, the **EGTEI document will remain as it is and sub-sectors will not be distinguished. The EGTEI unabated emission factor is valid at an aggregated level (for a majority of countries as discussed with the European associations) and can be modified by the national experts and abatement techniques defined can be used among all sectors.**

The representative unit used is the amount of adhesives consumed annually (kt/year). Two sub-sectors are defined in the EGTEI background document [3] (i.e. the use of "traditional adhesives" and the use of "high quality range" adhesives). This distinction was made to take into account the fact that some adhesives cannot be substituted for technical reasons: in this case, only end-of-pipe techniques can be used to reduce NMVOC emissions (at that time, it was easier to have two separate sub-sectors in RAINS). However, after discussions with CIAM in March 2005, it appears that **this distinction is not necessary anymore so only one general sector can be defined and is taken into account in this synopsis sheet. The background document is not modified because this issue does not change additional and unit costs as presented in table 5.1.**

Only one reference installation (RI) is defined to facilitate the national expert work.

Three primary measures are considered based on different adhesive types: solvent-based, water-based or hot-melt. Solvent-based adhesives are commonly used and represent the reference situation. Water-based and hot-melt can be used to go beyond the SED requirements according to the reduction scheme definition (annexe IIB of the Directive).

Thermal oxidation and activated carbon adsorption are considered as secondary measures for this sector to be in compliance with the SED requirements. The choice is based on the size of the installation and on the cost of solvents which can be recovered. 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 all the combinations of measures.

The use of hot-melts leads to negative costs (-98 €/t of adhesive consumed if R&D costs are considered) because fewer adhesives are necessary for the same job. These adhesives are only available for low quality range. Thermal oxidation and carbon adsorption are also cheap due to the large size of the installation defined (134 and 37 €/t of adhesive consumed respectively). The use of water-based adhesives is a bit more expensive due to high energy consumption for drying (541 €/t of adhesive used if R&D costs are considered).

National experts have to collect 4 country specific parameters (wages, electricity, steam and natural gas costs) and 5 country and sector specific parameters (costs of three different types of adhesives and cleaning solvents + cost of recovered solvents). The first ones can be very easily known. The second ones can be defined with the help of national adhesive manufacturer associations. EGTEI provides default costs for country and specific parameters which can be used if no better data exist. National experts have also to provide the trends in activity level from 2000 to 2020 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. Even if this sector is modified for the second round of the bilateral consultations, some data such as the cost parameters, the activity trend and the control strategy will still be used by CIAM.

In the future however, this sector should be studied in more detail to take into account its diversity in terms of installation sizes and abatement costs.

2. European regulation

As mentioned above, the European Directive 99/13/EC [2] applies to this sector (annex IIA, n°16).

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 5 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

Solvent consumption threshold [t / y]	VOC emission limit value in residual gases [mg C / Nm^3]	Fugitive emission limit values [% of solvent input**]
5-15	50 150*	25
> 15	50 150*	20

* If solvent recovery is used.
** 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 (4 for adhesive coating). The target emission is equal to the annual reference emission multiplied by a percentage equal to the fugitive emission value + 5 for adhesive coating):

> For installations with a solvent consumption between 5 and 15 t/y, this corresponds to (0.35g solid/g of adhesive x 4 g solvent/g solid) x (0.05+0.25) = 0.42 g VOC/g adhesive.

For installations with a solvent consumption above 15 t/y, this corresponds to (0.35g solid/g of adhesive x 4 g solvent/g solid) x (0.05+0.2) = 0.35 g VOC/g adhesive.

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 the reference installation

Only one reference installation (RI) is defined to simplify the work of national experts. This might lead to a problem in terms of cost definition as end-of-pipe investments are really size-dependant. The bigger the installation, the cheaper the abatement module. However, as small and medium installations preferably use substitution products, the definition of a unique RI is reasonable.

Table 3.1.1: Reference installation [5]

Reference Installation Code RIC	Description	Characteristics
01	Large Reference Installation: 6,000 t of adhesives used per year	Solvent input: 4,680 t/y Operating hours: 6,000 h/y [VOC]: 3 g/m^3 Flow rate: 200,000 m^3/h

3.2 Definition of emission abatement techniques

3.2.1 Primary measures

Dispersions, UV cross-linking adhesives and hot-melts distinguish themselves positively concerning solvent emissions. Because of their chemical and physical characteristics, hot melts are suitable for coating and packaging adhesive tapes of a lower quality range. Dispersions show better cohesiveness but have a very limited water resistance. UV cross-linking acrylates and electron beam curing systems do not show the disadvantages of hot melts and dispersions and are distinguished by high cohesiveness and high adhesion strength.

However these systems cannot be used for all products, because the cohesiveness and adhesive strength that can be achieved with solvent-based adhesives can not be reached due to shorter polymer chains.

Therefore, no alternative to the solvent-based acrylate and rubber adhesives does exist for applications that require a high stress resistance.

That is why two types of adhesives were defined in the EGTEI background document [3] (i.e. traditional and high performance). After discussion with IIASA, this distinction is no more necessary in the modelling process and even if these products have different costs, additional costs to reduce VOC emissions are the same. **Thus, only one sub-sector is considered to define this sector.**

Improvements of application efficiencies are not considered in the definition of primary measures.

Table 3.2.1.1: Primary measures

Primary Measure Code PMC	Description
00	Solvent-based adhesives (65% solvent content – 35% solid content)
01	Emulsions (2 % solvent content - 50% solid content)
02	Hot-melts or UV cross-linking acrylates or electron beam curing systems (100% solid content)

3.2.2 Secondary measures

When no alternative to solvent-based adhesives can be used, techniques such as activated carbon adsorption or thermal oxidation are available.

Table 3.2.2.1: Secondary measures

Secondary Measure Code SMC	Description
00	No secondary measure
01	Activated carbon adsorption or condensation
02	Thermal or catalytic oxidation

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
Steam [€/kg] (net of taxes)	0.016	To be provided by national experts
Wages [€/h]	25.9	To be provided by national experts

Some additional country and sector specific parameters are necessary to calculate variable operating costs. They correspond to costs of different types of adhesives, cleaning and recovered solvents. Default costs proposed by EGTEI are presented in table 4.2.

Solvent-based adhesive costs vary according to the type of product considered. Only the cost of adhesives which can be replaced by water-based or hot-melts (so-called "traditional adhesives" in [3]) has to be provided because this has an influence on the calculation of unit costs. For adhesives with high stress resistance (so-called "high performance adhesives" in [3]), for which only secondary measures can be used to reduce NMVOC emissions, unit costs only depends on the cost of the abatement module and not on the cost of the adhesive itself.

Table 4.2: Country and sector specific economic parameters

Parameters	Default costs provided by EGTEI [€/kg]	Country and sector specific costs [€/kg]
Solvent-based adhesives (so-called traditional adhesives in [3])	0.8	To be provided by national experts
Water-based adhesives	1.8	To be provided by national experts
Hot-melts	1.8	To be provided by national experts
Cleaning solvent	0.15	To be provided by national experts
Solvents recovered	0.15	To be provided by national experts

The best source of information for the determination of country and sector specific economic parameters is the national association of adhesive manufacturers and it is recommended to national experts to contact it.

Default data have been used to calculate variable and annual abatement 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 [8].

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

Table 4.3: Unabated emission factor [g of NMVOC / kg adhesive]

Default emission factor	User specific emission factor
780	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 this 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 per unit of activity.

Variable costs account for adhesive and electricity consumptions for the primary measures and electricity, natural gas, steam and labour if a secondary measure is used. Fixed operating costs are only considered for secondary measures and correspond to 5% of the secondary measure investment (for maintenance and insurance). As no economic 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 are based on the equations defined in the documents "derivation of secondary measure costs: thermal oxidation" [9] and "derivation of secondary measure costs: carbon adsorption" [10]. Energy can be recovered from exhaust gases in some cases but this assumption is not considered in the variable cost calculation.

Variable operating costs of measure 010001 take into account savings from solvent recovery. Technical characteristics of the reference installation are given in table 3.1.1.

R&D costs are also considered for the development of new adhesives (i.e. water-based and hot-melts): they correspond to 1,250 k€ for measures 010100 and 010200. These costs represent additional unit costs of about 33 €/tonne of VOC abated which have to be added to the unit costs presented in table 5.1 for a period of 10 years.

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

RIC PMC SMC	NMVOC EF [g VOC / kg adhesive]	Abatement efficiency [%]	Investment [k€]	Variable OC [k€/ year]	Fixed OC [k€/y]	Unit cost [€/t VOC abated]	Unit cost [€/t of adhesive]
01 00 00	780	0.0	0	0.00	-	-	0
01 00 01	182.7	76.0	2,100	-0.14	103	62	37
01 00 02	182.7	76.0	2,690	0.34	135	227	134
01 01 00	14	98.2	2,000	2.94	-	672	515
01 02 00	0	100.0	4,000	-1.04	-	-159	-124

Additional unit costs [k€/t of NMVOC abated] are obtained by dividing the additional annual 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 (they are negative) is the use of hot-melts because fewer adhesive quantities need to be applied for the same job. However, these adhesives are used for lower quality range than common adhesives.

Secondary measure unit costs are pretty low because the installation considered is very large.

The use of water-based adhesives is the most expensive but this can be explained by the large amount of electricity needed for the drying stage.

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

In the previous RAINS version [4], this sector was already studied separately. EGTEI provides updated data in terms of emission factors and costs. As some of the sub-sectors applying adhesives are already considered in other EGTEI documents, only the manufacture of label and tapes have been defined in [3]. After a discussion with representatives from the adhesive industry in March 2005, it turns out that remaining sectors to be covered are: wood, other and the manufacture of tapes and labels. EGTEI data are relevant for these three sub-sectors if they are considered together.

However, RAINS will be modified for the revision of the NEC Directive. 2 sub-sectors will be defined (instead on one in EGTEI): the first one corresponds to the use of adhesives in the categories wood and other which have common characteristics (average solvent content is about 50% in solvent-based adhesives and installations are small or medium). The other sector will be the manufacture of tapes and labels (with an average solvent content of 75% and large installations). Solvent-based adhesives defined in the EGTEI background document contain 65% of solvent which is an average figure suitable at an aggregated level.

National experts will have to define adhesive consumptions for these 2 new sub-sectors (for the completion of RAINS) with respective control strategies. Adhesives consumed in other sub-sectors are already considered in other EGTEI documents (i.e. manufacture of shoes, packaging, manufacture of automobiles and non-industrial use of adhesives) in terms of emissions and costs.

The EGTEI approach can still be used by national experts to define the situation in their country from 2000 to 2020. Then, total activity will just have to be split between the 2 sub-sectors to be considered in RAINS for the revision of the NEC Directive.

7. Perspective for the future

In the future, any new technology which could be developed, as new types of adhesives, should be considered by EGTEI in the background document to continuously improve the representation of the sector. National data accuracy is also very important to represent this very specific and divers sector.

8. Bibliography

[1]   Review of data used in RAINS-VOC model
        http://www.iiasa.ac.at/web-apps/tap/RainsWeb/
[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]   EGEI background document. http://citepa.org/forums/egtei/adhesive_application_081203.pdf
[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]   Anonymous industrial contact - September 2003.
[6]   Association of German adhesive manufacturers, Industrieverband Klebstoffe e.V
[7]   Association of European adhesive manufacturers. FEICA
[8]   Methodology http://citepa.org/forums/egtei/egtei_index.htm
[9]   http://citepa.org/forums/egtei/thermal_oxidation_costs_170603.pdf
[10]   http://citepa.org/forums/egtei/adsorption_costs_170603.pdf
[11]   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 industrial application of adhesives with the help of CITEPA [11].

All 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
Steam (net of taxes)	0.0131
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 data (net of taxes)

Parameters	Default costs [€/kg]	French and sector specific costs [€/kg]
Solvent-based adhesives (so-called traditional adhesives in [3])	0.8	0.8
Water-based adhesives	1.8	1.8
Hot-melts	1.8	1.8
Cleaning solvent	0.15	0.15
Solvents recovered	0.15	0.15

Unabated emission factor

The unabated emission factor is modified to be consistent with the French inventory. This factor is representative of the average solvent content on the French market.

Table A.3: Unabated emission factor [g of NMVOC / kg adhesive]

Default emission factor	French average figure
780	735

Activity level

Activity level in 2000 is defined from the annual national statistics defining the total adhesive production. A treatment of these data has to be done to exclude sub-sectors which are not covered in this document (i.e. DIY, manufacture of shoes…). The national adhesive manufacturer association should have good data on the market shares.

The activity trend from 2000 to 2020 comes from a treatment of the added value for the branch "industry". It corresponds to an annual activity increase of 3% from 2000 to 2010 and 2.5% from 2010 to 2020. These data have been endorsed by the French expert.

Table A.4: Activity levels from 2000 to 2020 (kt / year)

RIC	2000	2005	2010	2015	2020
01	115.1	133.5	154.8	175.1	198.1

On the total activity, about 22 kt of adhesives (or 19.2% of total activity) are defined as "high performance" products. It means that they cannot be replaced by substitution adhesives.

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.

About 22.5% of solvents are assumed to be consumed in installations under the SED threshold. This corresponds to 5.7% of the total activity which will remain solvent-based adhesives from 2005 onwards.

For 2000, 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 [11].

Table A.5: 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	10.7	5.7	100	5.7	100	5.7	100	5.7	100
01 00 01	5.9	6.5	100	6.5	100	6.5	100	6.5	100
01 00 02	6.8	7	100	7	100	7	100	7	100
01 01 00	45.4	49	60	49	60	49	60	49	60
01 02 00	31.2	31.8	40	31.8	40	31.8	40	31.8	40
Total RIC 01	**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 emission reduction annual costs for the CLE scenarios.

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	12,368	9,688	11,231	12,706	14,376
Annual total costs	**M€/year**	**M€/year**	**M€/year**	**M€/year**	**M€/year**
CLE scenario	26	33	38	43	49

Emissions presented 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 12,480 tonnes of VOC. These emissions are very close meaning that EGTEI data are valid for this sector.