European Commission, Brussels

Screening study to identify reductions in VOC emissions due to the restrictions in the VOC content of products

Final Report

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Contents

1 Background and objectives

Diminishing emissions of Volatile Organic Compounds (VOC) has been an important objective of EU environmental policy. Turning points in achieving this goal were the Council Directive 1999/13/EC on the limitation of emissions of volatile organic compounds due to the use of organic solvents in certain activities and installations and the Auto Oil program.

These actions were mainly focusing on production processes and their emissions. With these efforts, reduction up to 50% of the present emissions until 2010 seems to be possible according to estimations.

Products containing VOC have not yet been a major objective of EU legislation. In the field of products only the decorative paint sector and products for the vehicle-refinishing sector have been analysed with respect to VOC emissions [DECOPAINT 2000]. Against this background it is an important aim of the project to extend data and give an overview to all relevant product groups containing VOC.

Since substitution of VOC is possible for quite a lot of products, it is another important aim of the project to identify priorities and to demonstrate the corresponding reduction potentials based on technical feasibility and market demand. Following basic data, forecasts to 2010 and costs of abatement are given, being necessary information for decision making.

A major intention of the study is furthermore to assess practicable timetables for the Commission for the implementation of legislation in order to reduce VOC contents in the most promising product categories which are identified within the project.

To reach these aims an appropriate methodology and a general concept have been developed. Data and information were collected by meetings and interviews with associations and individual companies and by literature and internet investigation.

For suggestions regarding legislation VOC emission contribution of products that are not covered by Directive 1999/13/EC plays an important role. Therefore for the definition of VOC the already existing definition of Directive 1999/13/EC is taken over.

The project started on 25th of October 2001 and was finished on 31st of January 2002. Therefore a restricted time schedule had to be followed. As a consequence the screening character of the results should not be overseen.

2 Differentiation and importance of product categories containing VOC

2.1 Concept and methodology

The concept to be developed has to answer the following key questions:

1. How can VOC-containing products be described in a precise and generally accepted way?

   The answers to this question is essential for definitions in legislation in order to fulfil requirements of enforcement.

2. Which share of total VOC use is based on use of VOC-containing products outside installations regulated under 99/13/EC?

   The answer to this question is necessary to underline the importance of new legislation.

3. Which categories of VOC-containing products may be selected as subject of a possible legislation?

   The answer to this question explains a selection of certain categories of products.

Further key questions and parts of the concept are described in chapter 3.1 and in chapter 4.1.

2.1.1 How to describe VOC containing products?

Definition of "VOC"

Speaking of VOC containing products one has to define "VOC" (volatile organic compounds) first. In already existing legislation three major definitions can be found

1. Directive 1999/133/EC (EU legislation):

   Volatile organic compound (VOC) shall mean any organic compound having at 293,15 K a vapour pressure of 0,01 kPa or more, or having a corresponding volatility under the particular conditions of use. For the purpose of this Directive, the fraction of creosote which exceeds this value of vapour pressure at 293,15 K shall be considered as a VOC

2. Directive 2001/81/EC:

   "Volatile organic compounds" and "VOC" mean all organic compounds arising from human activities, other than methane, which are capable of producing photochemical oxidants by reactions with nitrogen oxides in the presence of sunlight

3. "Regulation for reducing volatile organic compound emissions from consumer products" in California:

   “Volatile Organic Compound (VOC)” means any compound containing at least one atom of carbon, excluding carbon monoxide, carbon dioxide, carbonic acid, metallic carbides or carbonates, and ammonium carbonate, and excluding the following:

   (A) Methane,

   Methylene chloride (dichloromethane),

   1,1,1-trichloroethane (methyl chloroform),

   Trichlorofluoromethane (CFC-11),

   Dichlorodifluoromethane (CFC-12),

   1,1,2-trichloro-1,2,2-trifluoroethane (CFC-113),

   1,2-dichloro-1,1,2,2-tetrafluoroethane (CFC-114),

   Chloropentafluoroethane (CFC-115),

   Chlorodifluoromethane (HCFC-22),

   1,1,1-trifluoro-2,2-dichloroethane (HCFC-123),

   1,1-dichloro-1-fluoroethane (HCFC-141b),

   1-chloro-1,1-difluoroethane (HCFC-142b),

   2-chloro-1,1,1,2-tetrafluoroethane (HCFC-124),

   Trifluoromethane (HFC-23),

   1,1,2,2-tetrafluoroethane (HFC-134),

   1,1,1,2-tetrafluoroethane (HFC-134a),

   Pentafluoroethane (HFC-125),

   1,1,1-trifluoroethane (HFC-143a),

   1,1-difluoroethane (HFC-152a),

   Cyclic, branched, or linear completely methylated siloxanes,

the following classes of perfluorocarbons:

1. Cyclic, branched, or linear, completely fluorinated alkanes;
2. Cyclic, branched, or linear, completely fluorinated ethers with no unsaturations;
3. Cyclic, branched, or linear, completely fluorinated tertiary amines with no unsaturations; and
4. Sulfur-containing perfluorocarbons with no unsaturations and with the sulfur bonds to carbon and fluorine, and

(B) The following low-reactive organic compounds which have been exempted by the U.S. EPA:

Acetone,

Ethane,

Methyl acetate,

Parachlorobenzotrifluoride (1-chloro-4-trifluoromethyl benzene),

Perchloroethylene (tetrachloroethylene).

The planned EU legislation on the reduction of the VOC content of products will focus on emissions that are not already regulated under Directive 1999/13/EC. In this way the new and the already existing legislation have a complementary character. Therefore the project team suggests to use the definition from directive 1999/13/EC for the analysis in this project. This approach was supported by most of the interview partners of ministries and industry.

Definition of product

Speaking of "products" within "VOC containing products" a definition has to fulfill three major requirements:

- It shall include official systematic and be compatible with existing data sources
- It shall fit for the discussion of the involved institutions to avoid misunderstandings and misinterpretation
- It shall support later enforcement of regulations

The following table gives an overview of the background of the proposal to definitions of VOC-containing products. It is founded on three levels

→ Product groups

→ Sub groups

→ Products

and it is mainly based on EUROSTAT´s official systematic (PRODCOM used in EUROPROM - European production and market statistics). It combines EUROSTAT's systematic approach with the selected definition of VOC:

Product Group	Product Sub Group	Product	PRODCOM
1 Paints & Inks			**24.30.xx.xx**
	1.1 Paints		
		Waterborne Paints	24.30.11.xx
		Solventborne Paints	24.30.12.xx
		1.1.1 Decorative Paints	
		1.1.2 Automotive Paints	
		1.1.3 Vehicle Refinishing Paints	
		1.1.4 Other Industrial Paints	
		1.1.5 Other	
	1.2 Inks		
		1.2.1 Black Inks	24.30.24.50
		1.2.2 Non Black Inks	24.30.24.70
	1.3 Thinners		
		1.3.1 Thinners used with Coatings and inks not based on butyl acetate	24.30.22.79
		1.3.2 Thinners based on butyl acetate	24.30.22.73
		1.3.3 VOC directly used as thinner	24.14.xxxx

2 Cosmetic & Cleaning			
	2.1 Cosmetic		
		2.1.1 Perfumes & Toilet Waters	24.52.11.xx + 24.51.41.00
		2.1.2 Deodorants, Pre- and after shave	24.52.19.xx
		2.1.3 Hair Products	24.52.16.xx
		2.1.4 Others	
	2.2 Cleaning		
		2.2.1 Industrial Cleaning	
		2.2.2 Surface-active preparations; Washing preparations and cleaning preparations	24.51.32.xx
		2.2.3 Polishes	24.51.43.xx
		2.2.4 Waxes	24.51.42.xx
		2.2.5 Others	
3 Adhesives			**24.62.10.95**
4 Additives & Impregnation			
	4.1 Textiles, Leather		
		4.1.1 Lubricants	24.66.31.55 24.66.31.79
		4.1.2 Finishing Agents	24.66.45.xx
	4.2 Buildings- & Construction materials		
		4.2.1 Additives for cements, mortar and concrete	24.66.47.50
		4.2.2 Fire-, Water-proofing and similar protective preparations	24.66.48.67
	4.3 Rubber & Plastics		
		4.3.1 Plasticisers	24.66.46.40
		4.3.2 Others	
	4.4 Wood preservation		
		4.4.1 Creosote Oils	24.14.73.65
	4.5 Paper industry finishing agents		24.66.45.80

5 Others			
	5.1 Automotive Products		
		5.1.1 Lubricants	24.66.31.57 24.66.31.75
		5.1.2 Anti-freezing and de-icing	24.66.33.50
		5.1.3 Under Coating	
		5.1.4 Others	
	5.2 Insecticides & Herbicides		
		5.2.1 Insecticides	24.20.11.xx
		5.2.2 Herbicides	24.20.12.xx
	5.4 Pharmaceutical Products		24.42.xx
	5.4 Insulating materials		
		5.4.1 Cellular plates, etc. of polymers of styrene	25.21.41.20
		5.4.2 Cellular plates of polyurethane	Part of 25.21.41.50
		5.4.3 Others	
	5.5 Miscellaneous		
		5.5.1 Prepared binders for foundry moulds or cores	24.66.47.20
		5.5.2 Refrigerating agents	24.66.48.73
		5.5.3 Anti-rust preparations (Amins)	24.66.48.27
		5.5.4 Essential Oils	24.63.10.xx
		5.5.5 Others	

Table 2-1: Definition for product groups, sub groups and products

The project team considers this definition as an appropriate way to describe products in a precise and generally accepted way – and thus gives the answer to the above mentioned key question 1.

2.1.2 How to identify the relevant VOC emissions?

Material flow analysis

The concept to find the answer to the above mentioned key question 2 (on the amount of VOC emitted from products not covered by 99/13/EC) is based on a material flow analysis as a scientific and practically proved tool.

Generally the material flow analysis offers two approaches to identify use and emissions of VOC:

- Top-down approach
- >Bottom-up approach

The two approaches use different data sources and thus give a chance to control data with a plausibility check.

Top-down approach

The top-down material flow analysis starts at the very beginning with the production (quantities) of VOC as pure chemicals (VOC categories). Identified categories of major importance are:

- Aliphates
- Ketones
- Alcohols
- Esters and acids
- Ethers
- Aromatic compounds
- Halogenated compounds

The production, imports and exports have to be considered in order to identify the amount available for the markets of the member states (“market supply”). Analysing this market supply for every VOC category four general uses/applications exist:

- Use for energy supply
- Use for synthesis resulting in VOC free products
- Use for alcohol in the food and beverage industry
- Use for VOC-containing products

According to the study aims, only the use for VOC-containing products is relevant for the subject of this study. Consequently this material flow has to be identified and followed for all VOC categories.

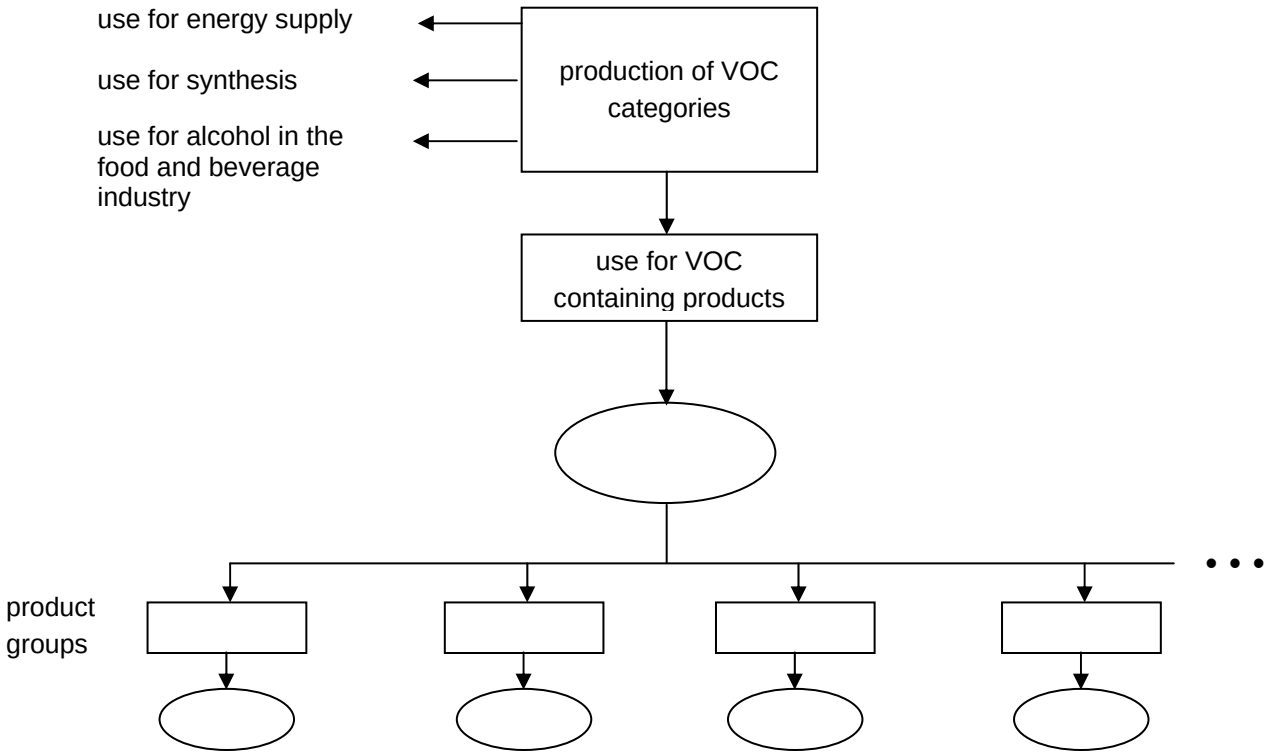


Figure 2-1: structure of the first part of the material flow

Data sources for the top-down analysis were mainly industry statistics. Results of the top-down material flow analysis are presented in chapter 2.2.

Bottom-up approach

The bottom-up material flow analysis starts in a first approach with VOC containing products. Products can be aggregated to sub groups and product groups following EUROSTAT systematic PRODCOM.

In order to fill the material flow chart PRODCOM product definitions are used as a basis for the definitions of product groups. On this stage official data of market supply (total of production, import and export) are mostly available, however, they show some deficits due to confidential data and missing or obvious wrong data from some member states and products. Therefore the project team developed a estimating methodology to overcome these difficulties. This methodology is described in an annex.

EUROPROM only provides product volumes, it does not say anything to VOC shares. Therefore literature data were taken indicating the average VOC content of products. In some cases a wide spread of these data exists and consequently total amounts can not be expected to be very precise. However, for screening purposes this procedure can be regarded appropriate.

Results have been checked with industry and no objections to the stated amounts have been communicated. Results are documented in chapter 2.3.

The principle of material flow analysis foresees plausibility checks on all stations of the material flow. Figure 2-2 illustrates how connecting the results from a top-down and an independent bottom-up approach can check the plausibility.

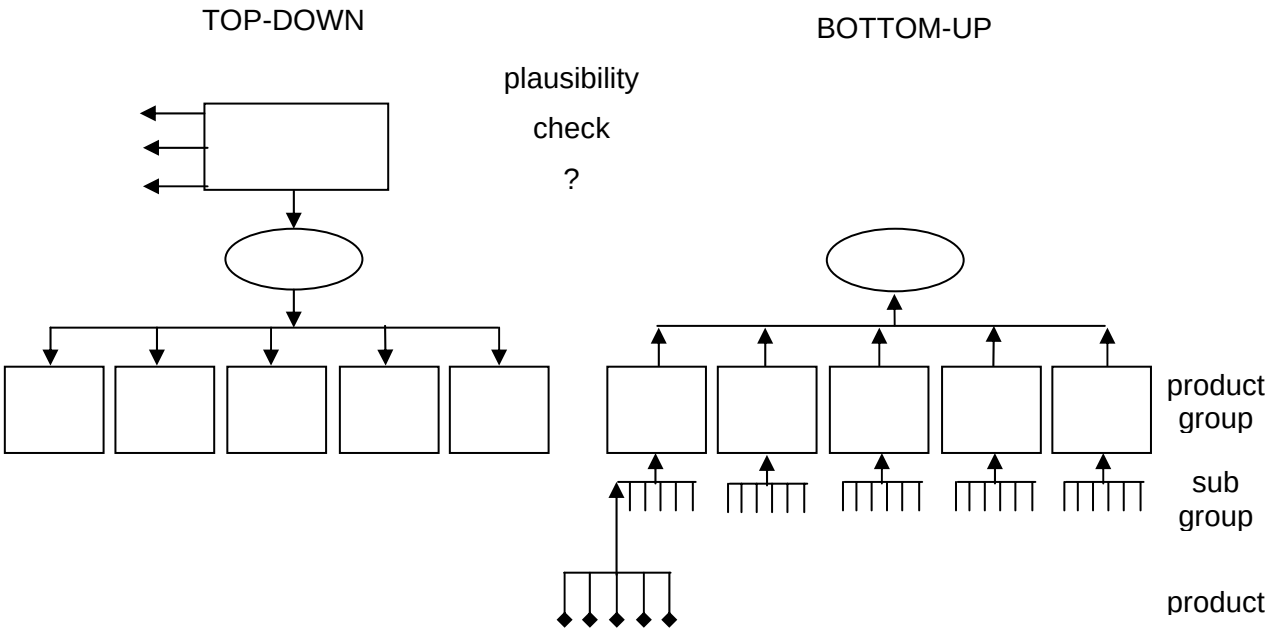


Figure 2-2: material flow approach

For the top-down approach (left side in Figure 2-2 the material flow is calculated in a top-down procedure as described above. A summation is done for all VOC categories. On the right side a material flow is calculated following an independent bottom-up procedure.

Plausibility check

Comparing the total number and the VOC-amounts for each product group can easily do the plausibility check. Differences of up to 10% are to be expected and the bottom up numbers might be higher than the top-down amount. The latter is due to the fact that solvents are in several cases directly used as they are produced (e.g. white spirit, ethanol). These amounts are not sold to producers but to users (industrial or private) directly.

This effect may be compensated partly by the use of intermediate products containing VOC by producers of end products. In some cases the producer is not aware that VOCs are part of his raw material (e.g. colour pastes), especially if the content of solvent is low and it is water soluble.

Use and emissions of VOC-containing products

In order to differentiate possible VOC emissions to air according to the project aims three basic considerations have to be respected:

1. If a product contains VOC it may be applied in installations according to Council Directive 1999/13/EC ("VOC-Directive"). The corresponding possible emissions are not subject of the study and are consequently irrelevant.

2. If a product contains VOC and is applied under "non VOC directive conditions" – i.e. application as solvent in plants which are not covered by the directive and applications to use other than the solvent properties of VOC – the VOC is not necessarily being emitted to air. It may be degraded during product use, it may become part of the waste or waste water flow or it may be eliminated from exhaust air by several technical equipment etc. Consequently, the corresponding VOC share ("no air emissions" in Figure 2-3) is irrelevant.

3. For analysing substitution and VOC reduction possibilities the application process and in this way the function of the VOC in the product has to be taken into account.

These considerations enable to differentiate the material flow for uses of VOCs and to identify the relevant VOC amounts giving reason for the VOC emissions to air, which are relevant according to the project outline. The following scheme (Figure 2-3) illustrates the differentiated material flow.

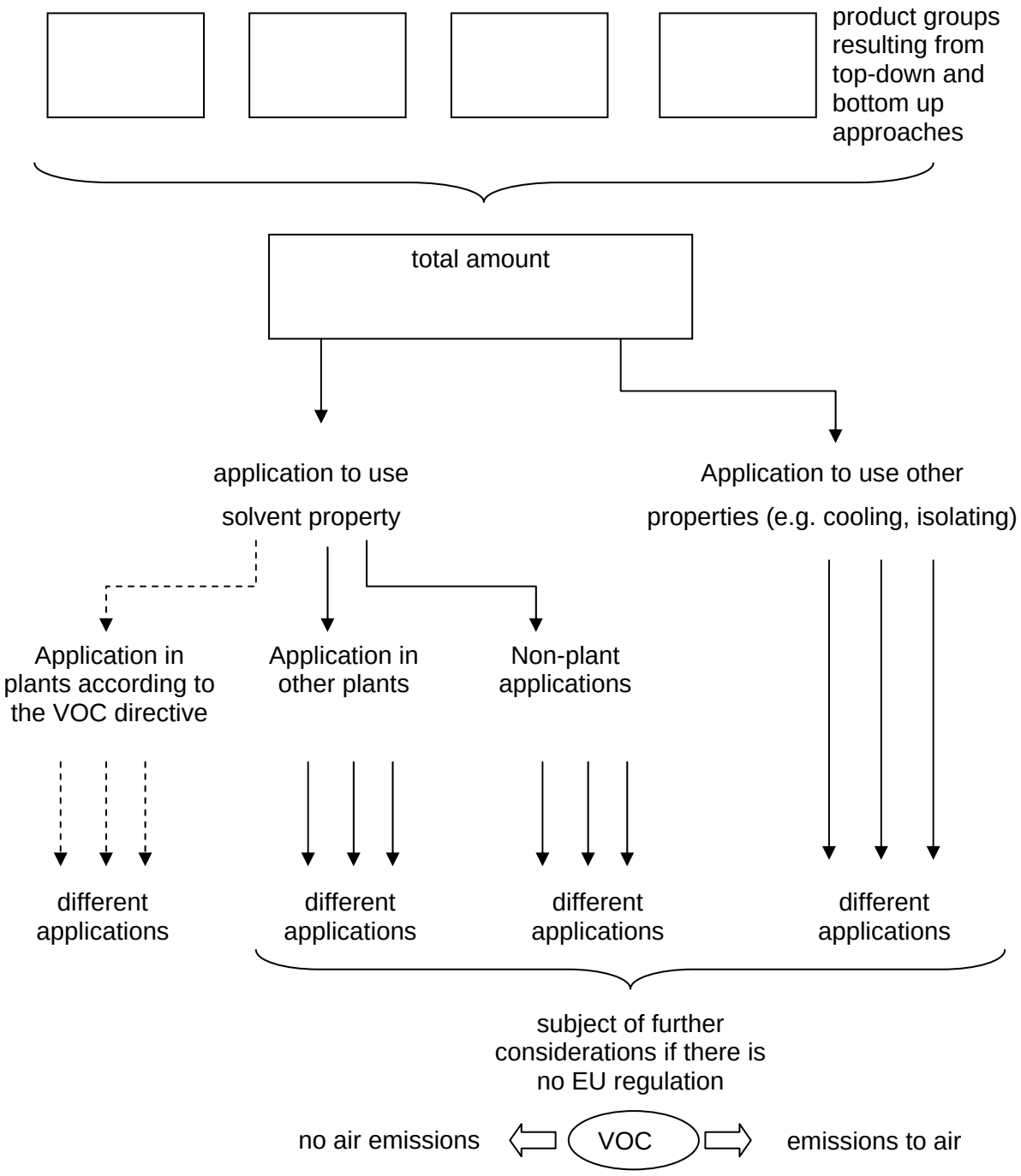


Figure 2-3: Differentiation of applications and identification of material flows

Based on the installed technologies or emission characteristics of applications the two flows (“no air emissions” and “air emissions” in Figure 2-3) can be calculated and thus the share of VOC air emissions from VOC containing products in “non VOC directive applications” can be determined. The results can be aggregated via the material flow. In this way general information on the use of VOC on emissions can be presented.

2.1.3 How to select relevant VOC containing products?

The precise quantification of emission reduction potentials requires considerable effort. In order to be able to select products with the most relevant reduction potentials a scheme for the identification of priorities is applied (see Figure 2-4). The scheme stands for a selective procedure composed by several tools.

The first step of the selective procedure consists of the above described tool of a top-down and bottom up material flow analysis. This tool enables to identify the most relevant VOC containing products.

In a second step all these relevant products are subject to a rough legal analysis. This tool examines whether there are already national or international regulations for these products established. If so, it should be taken into consideration whether corresponding regulations would be appropriate in the light of the European situation. The priority for further investigation may be consequently high (“priority 1”).

If there are no such regulations established, step 3 of the selection enters into action. The question is whether the most important share of emissions from the relevant products are already covered by Directive 99/13/EC. If the total amount of VOC emissions from certain products which are not regulated by this Directive is below 100 kt per year these products are less important (priority 2) compared to those products which are not regulated by the directive but have high VOC emissions above 100 kt per year (priority 1).

Step 4 and final tool for the selection is the market analysis for the applications and alternatives of the relevant products. If the market does not provide appropriate alternatives for certain applications or products it can be assumed to be difficult to reduce the corresponding emissions. Consequently further investigation within this study is not appropriate (priority 2). Otherwise, if applications and products can be easily replaced, the emissions may be diminished with reasonable efforts (priority 1).

The following figure shall illustrate the above described procedure in order to select the most relevant VOC containing products:

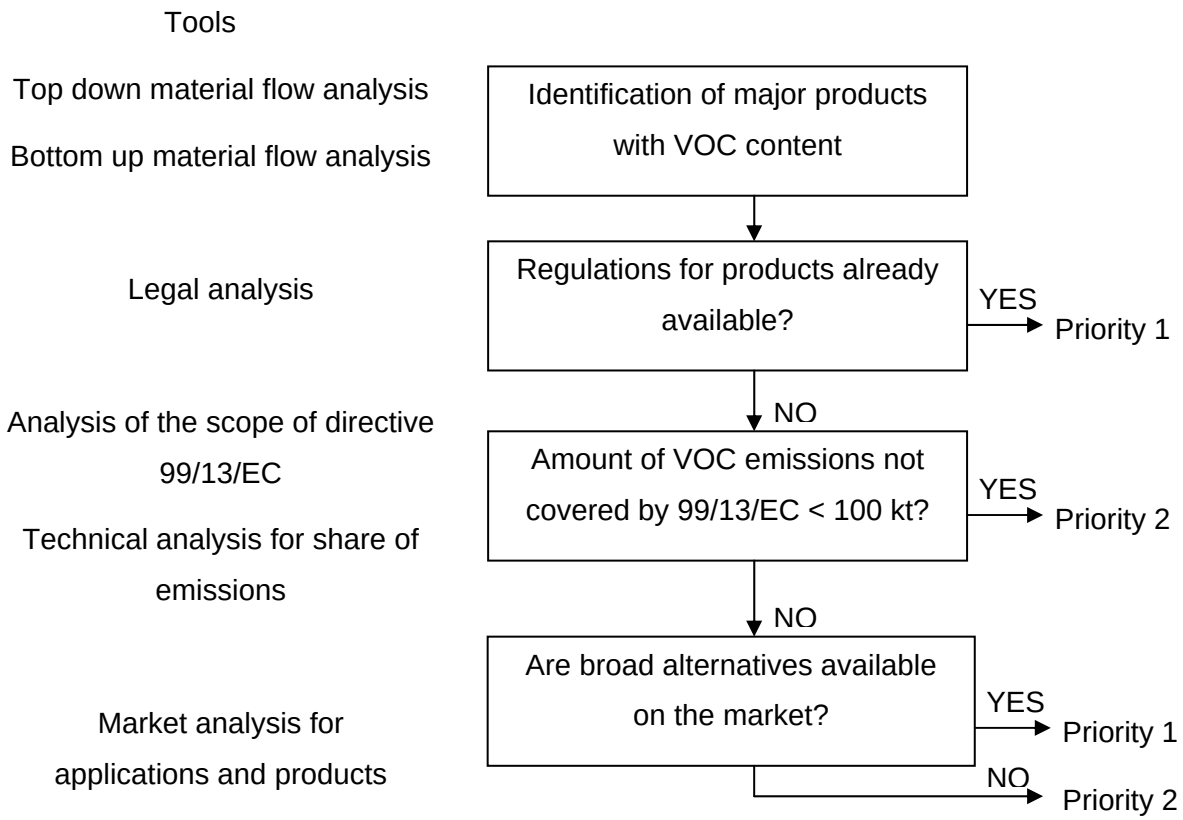


Figure 2-4: Scheme for the identification of priorities

By the means of this selective procedure the most relevant categories of VOC containing products can be proposed to become subject of regulation – the answer to the above key question 3.

2.2 Differentiation of VOC-containing product groups (bottom-up analysis)

2.2.1 Overview

The general result shows an amount of about 5 million tons VOC that are used in products. It has to be clearly underlined that this amount stands for the use of VOC and this is not comparable to emissions of VOC. Using this figure it is also important to have in mind that the 5 million tons include both, products used in installations regulated under 1999/13/EC and products not used in such installations.

The data result of a bottom-up analysis of VOC containing products based on EUROSTAT data and checked by the industry.

Composing products to sub groups and these again to product groups the importance of the product groups can be seen in Figure 2-5.

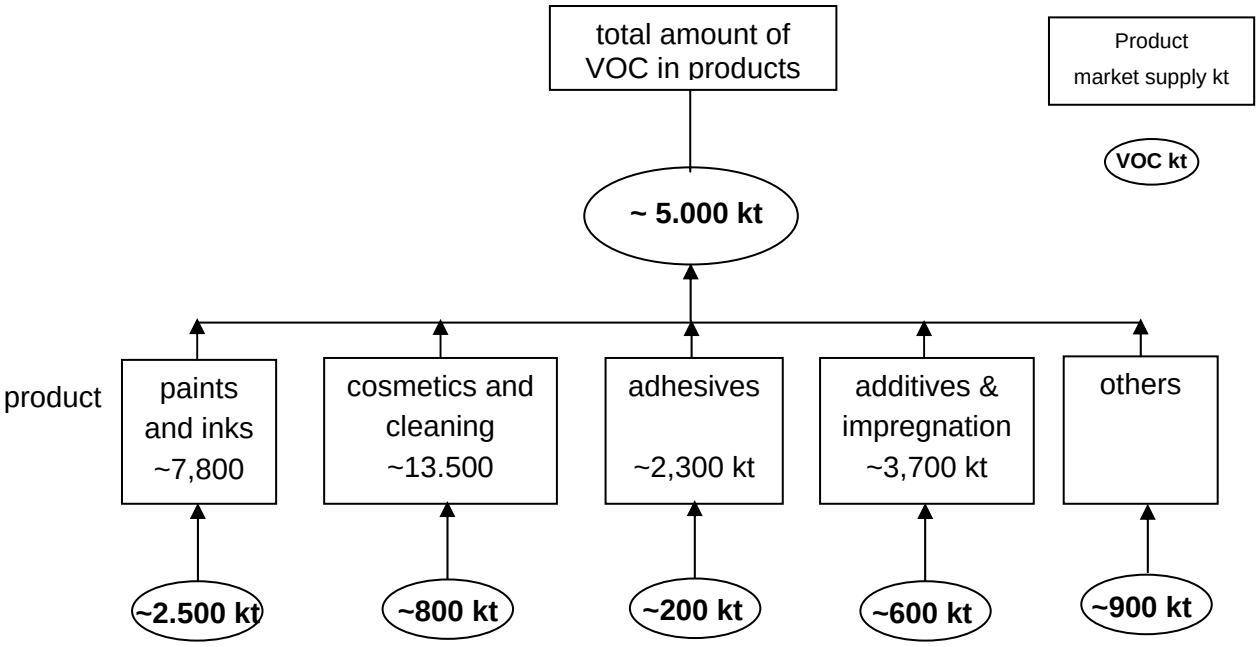
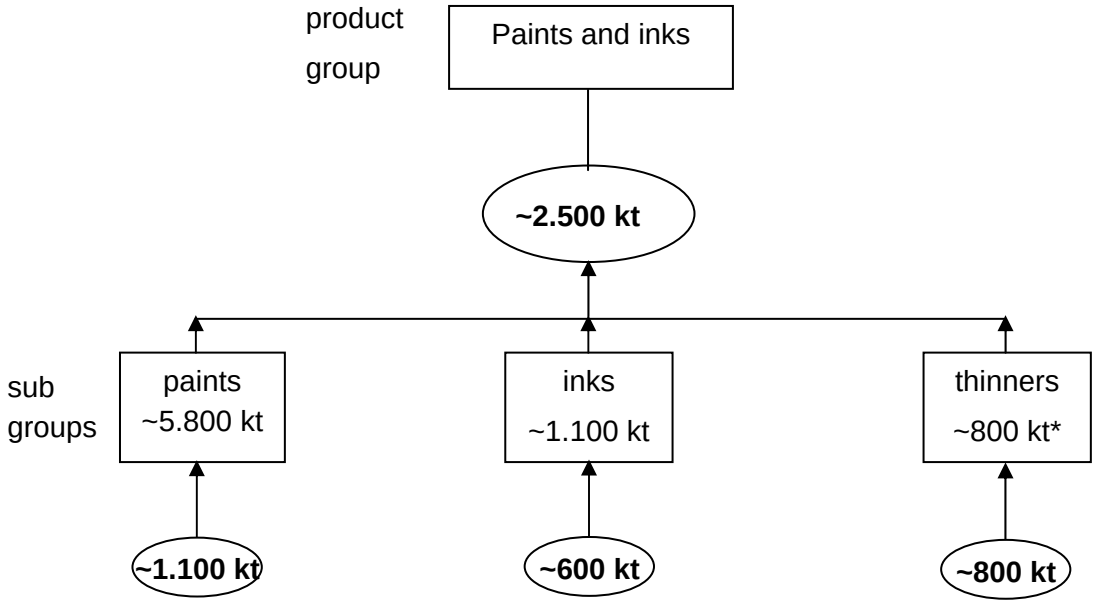


Figure 2-5: results of the bottom-up material flow

The amounts in ellipses stand for kt VOC, the amounts in boxes indicate the total product volume.

2.2.2 Paints and inks

This most important group of VOC containing products is well differentiated in the PRODCOM systematic – even if there are some inconsistencies in the English and German definitions. Waterborne and solventborne paints can be found in separated groups, thinners are differentiated in based on butyl acetate (mainly used for inks) and others. Uncertainties are in the field of VOC-based resin solutions which are used as a raw material for the production of paints.



*products with solvent function consisting only of VOC

Figure 2-6: bottom-up material flow: paints and inks

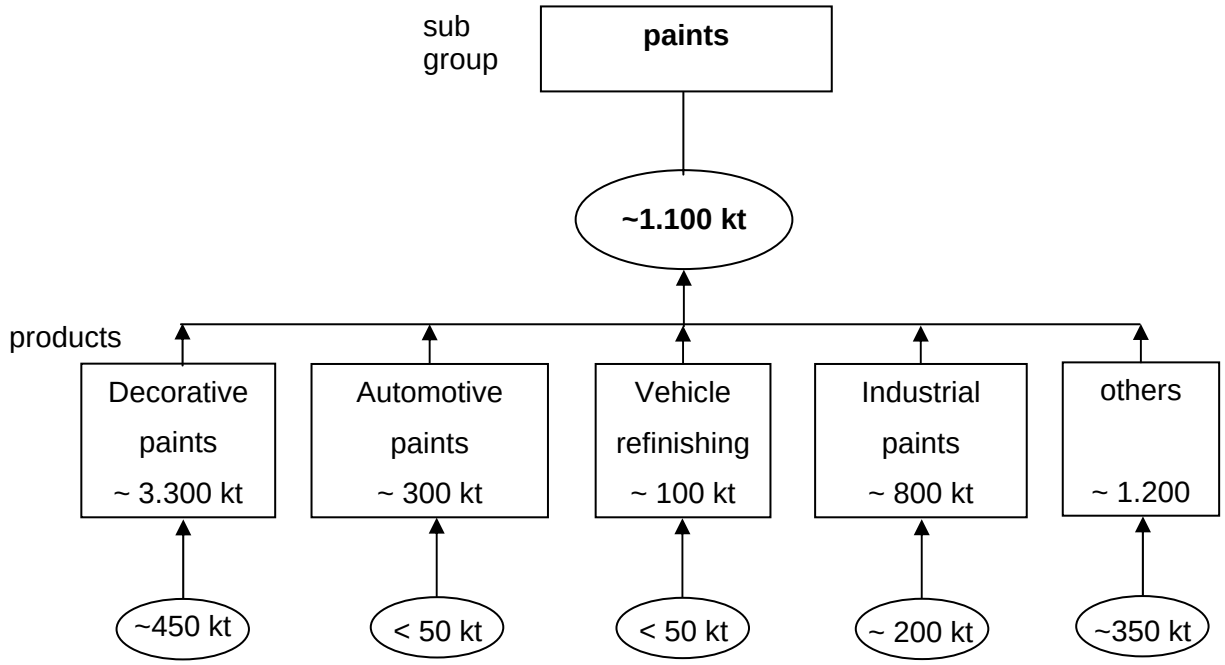


Figure 2-7 :bottom-up material flow: paints

The amount of decorative paints, automotive paints and paints for vehicle refinishing are well documented in the literature (e.g. DECOPAINT 2000, AUTOMOTIVE 2000). The uncertainty for industrial paints and other paints (mainly heavy duty paints, road markings, paints for ships) are a bit higher but the total of both groups is reasonable.

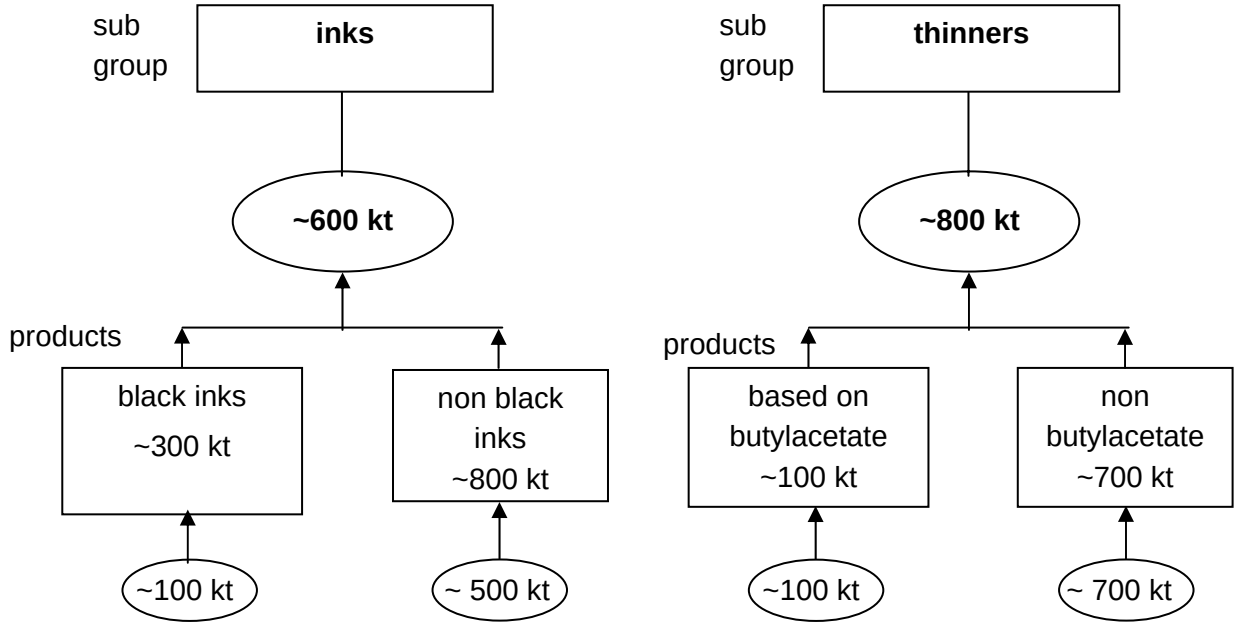


Figure 2-8: bottom-up material flow: inks and thinners

A specific problem with inks – especially black inks used in heat set rotary and cold set single sheet printing – is the definition of VOC. Many compounds of black inks have a very low vapor pressure and a boiling point in the range of 250° - 280°C.

In the field of non-black inks there are waterborne inks and UV-curing inks available on the market, which contain just a small share ore no VOC. Inks of this kind are used for special purposes only. In the sense of a worst case scenario these amounts, which can not be quantified within the frame of this study, have not been taken into account. Furthermore non-black inks are used only in plants, which are covered by the regulation 1999/13/EC.

The printing industry typically uses VOC-products like ethanol or ethyl acetate directly and not in mixtures bought as “thinners”.

2.2.3 Cosmetics and Cleaning

In the cosmetics and cleaning sector about 800 kt of VOC are used.

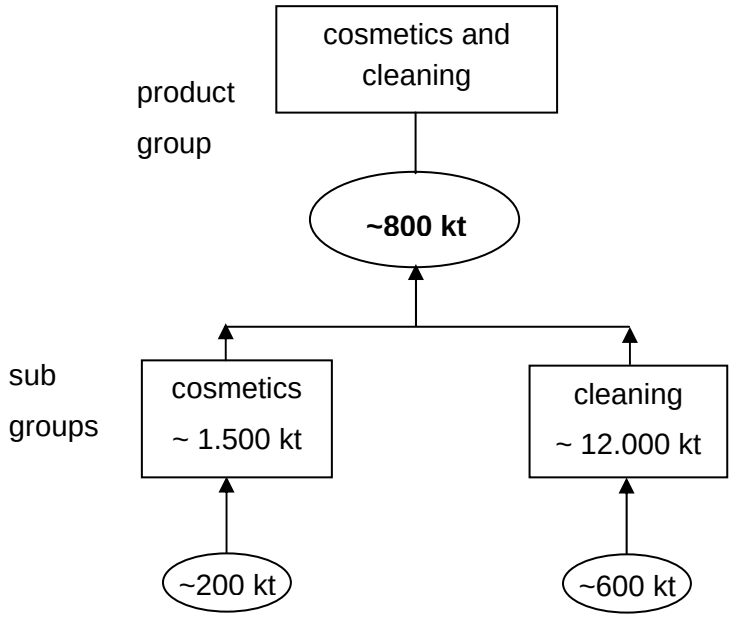


Figure 2-9: bottom-up material flow: cosmetics and cleaning

Many cosmetic products like deodorants, hair products, perfumes show relatively high VOC contents. In the cleaning sector however, VOC contents are typically relatively small, there are many products with high consumption volumes and nearly no VOC (washing powder), in other products like soaps, liquid detergents, all purpose cleaners, etc. VOC shares are typically below 20%.

In the cosmetic sub group there is a clear differentiation indicating that hair products and deodorants are by far the most important products.

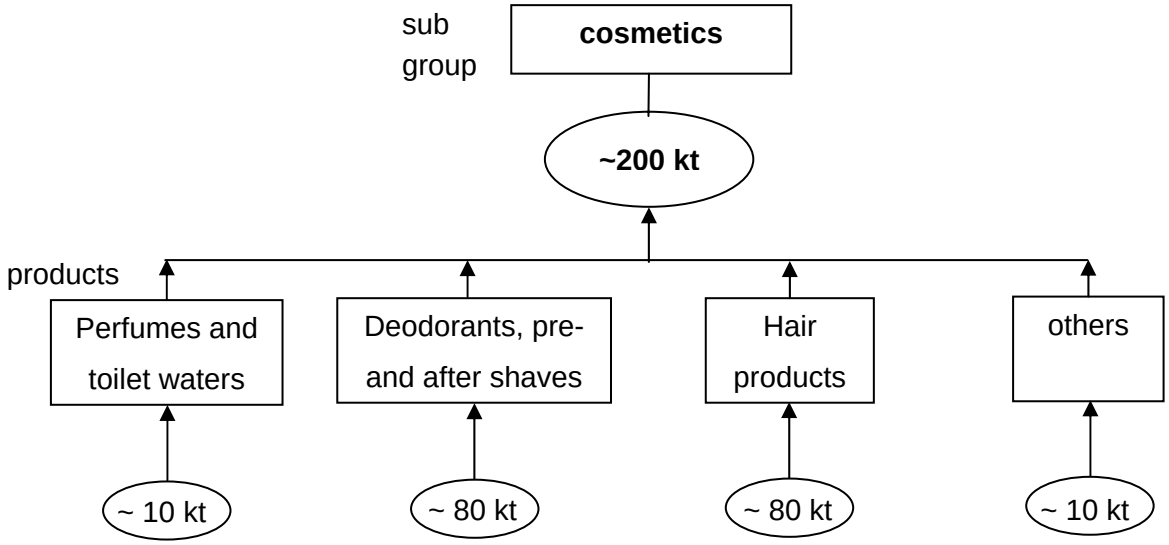


Figure 2-10: bottom-up material flow: cosmetics

For the cosmetic sub group use of VOC means emissions of VOC. There is no product use in installations regulated under 1999/13/EC so the whole cosmetic sector may become subject to new legislation.

In the cleaning sector a differentiation is necessary between industrial cleaning and other cleaning activities.

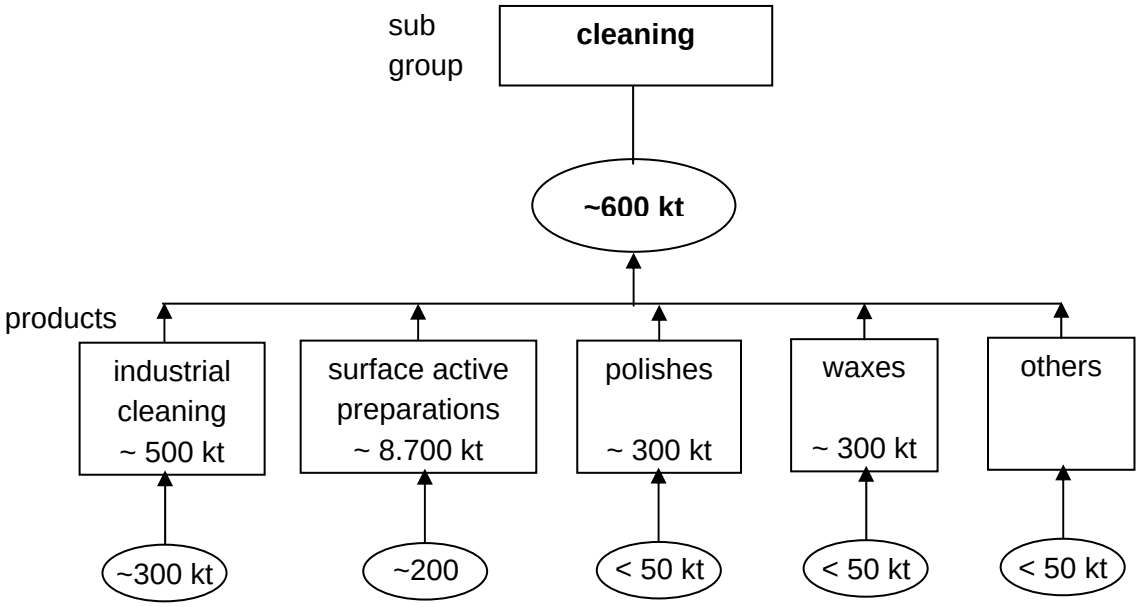


Figure 2-11: bottom-up material flow: cleaning

The relevant volume of industrial cleaning mainly belongs to already regulated installations and therefore should not be subject to further legislation. There are bigger uncertainties on the VOC amount included in surface active preparations. These substances count for a large consumption volume (~ 8.700 million tons) and it is very difficult to calculate an average VOC content. Cross checks with data of authorities indicate that 200 kt might be underestimated. On the other hand industry states that smaller VOC amounts are expected.

2.2.4 Adhesives

In this study, only organic adhesives are considered, thus inorganic adhesives and cements are not regarded. In some statistics, sealants are regarded together with adhesives, as their function can often not be clearly distinguished. However, for this study only adhesives were considered.

From the figures of Europroms, the European adhesive market supply can be estimated at 2,700 kt/a. Of these about 12 % (324 kt/a) are solvent based and 39 % (1,053 kt/a) are dispersions (percentages for Germany [BMU/VCI 1997]). Their share of use in the different industry sectors together with their mean solvent content leads to the resulting solvent input for each sector. For dispersions, a solvent content of 1.5 % was assumed for calculation.

Sector	Paper, board and related products	Building, construction, civil eng., craftsmen	Wood-working and joinery	Transpor-tation	Footwear and leather	Consumer/ Do It Yourself (retail)	Assembly operations
Solvent based adhesives	324 kt/a						
Share of solvent based adhesives	17 %	38 %	9 %	16 %	5 %	7 %	8 %
Use of solvent based adhesives	55 kt/a	123 kt/a	29 kt/a	52 kt/a	16 kt/a	23 kt/a	26 kt/a
Average solvent content	50 %	15 %	50 %	60 %	80 %	50 %	50 %
Solvent input	28 kt/a	18 kt/a	15 kt/a	31 kt/a	13 kt/a	11 kt/a	13 kt/a

Table 2-2: The use of solvent based adhesives and related solvent input in industry sectors in Europe [Derived from Europroms 1999 and UBA/VCI 1997]

Sector	Paper, board and related products	Building, construction, civil eng., craftsmen	Wood-working and joinery	Transpor-tation	Footwear and leather	Consumer/ Do It Yourself (retail)	Assembly operations
Dis-persions	1,053 kt/a						
Share of dis-persions	34 %	40 %	18 %	2 %	0,3 %	5 %	1 %
Use of dis-persions	358 kt/a	421 kt/a	190 kt/a	21 kt/a	32 kt/a	53 kt/a	11 kt/a
Average solvent content	1.5 %	1.5 %	1.5 %	1.5 %	1.5 %	1.5 %	1.5 %
Solvent input	5 kt/a	6 kt/a	3 kt/a	< 1 kt/a	< 1 kt/a	1 kt/a	< 1 kt/a

Table 2-3: The use of dispersions and related solvent input in industry sectors in Europe [Derived from PRODCOM and UBA/VCI 1997]

Regarding the described sectors, bonding in "Paper, board and related products" and "Transportation" is considered to take place exclusively in installations, whereas applications in the "Building, construction" and "Consumer/Do It Yourself" sector occur completely outside installations. The share of adhesives used in installations in the remaining sectors is unknown, so all input for these sectors is considered not to be covered by Directive 99/13/EC[1].

Additionally, the input of solvent based and dispersion adhesives for tape production is calculated. Tapes and labels are not further split up and are represented as a unified product group. An overview of the resulting quantities for solvent based adhesives is given in figure 2-12, for dispersions in figure 2-13. Adhesive quantities and related solvent from input from table 2-2 and table 2-3 are rounded.

[1] Footwear and part of the woodworking is covered by the directive, shares of consumption are unknown.

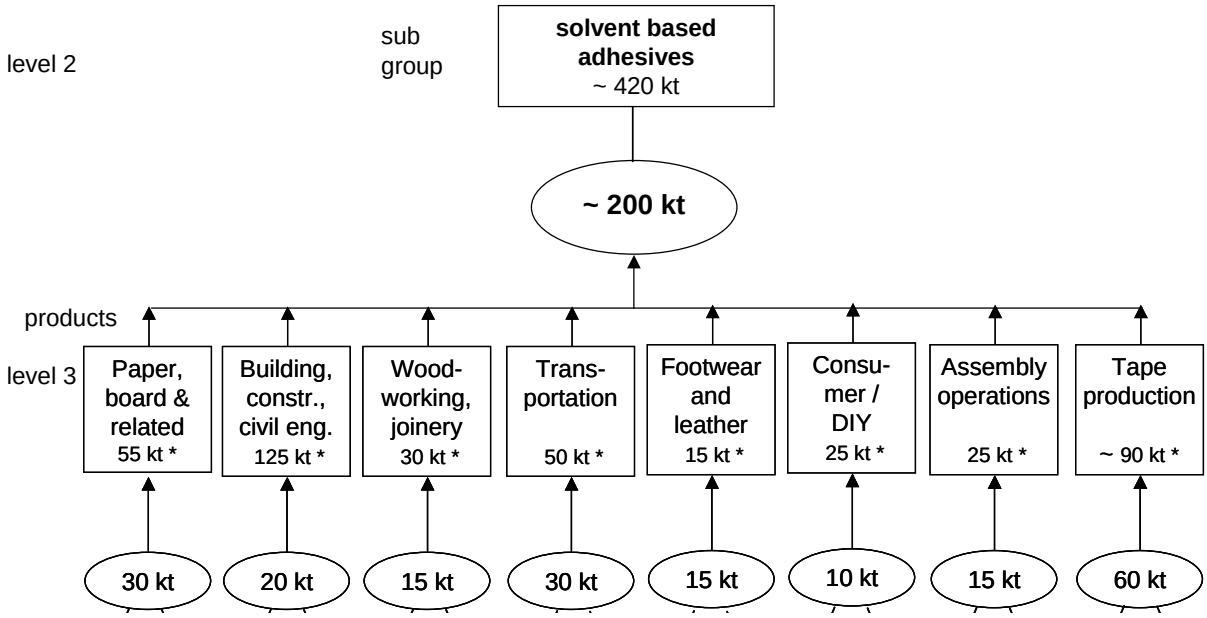
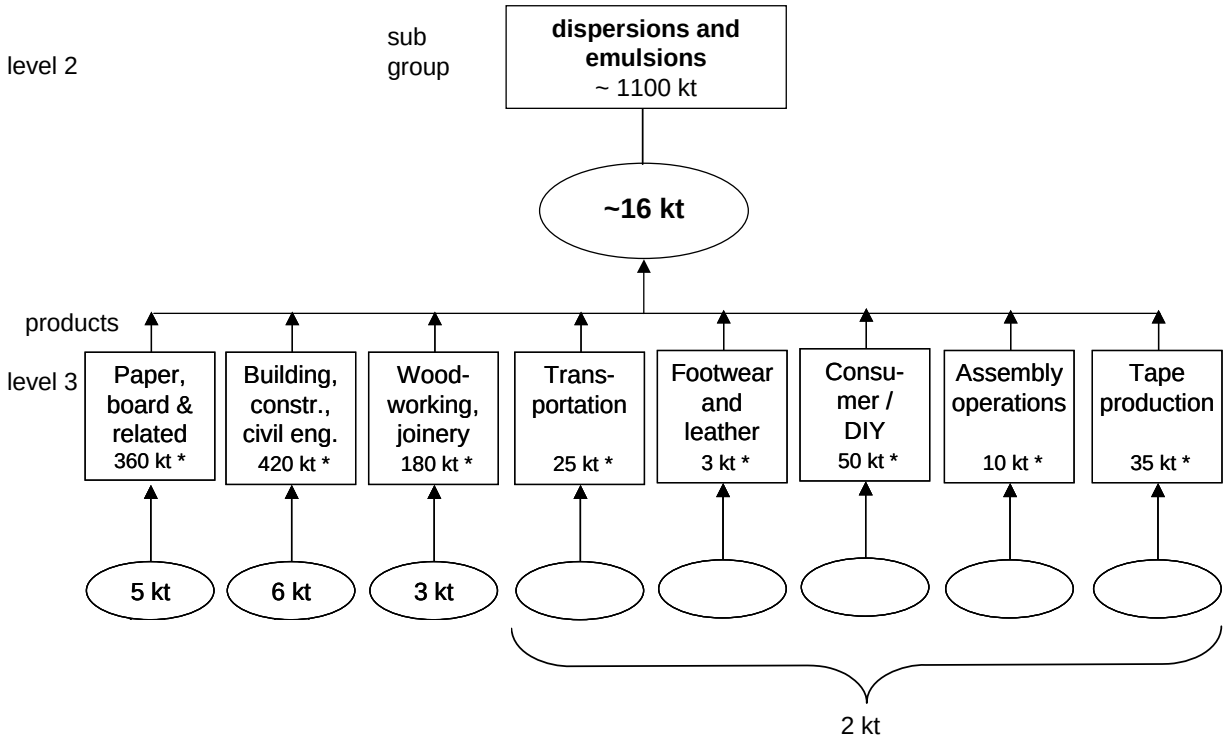


Figure 2-12: Annual adhesive and VOC input for solvent based adhesives in industry sectors in Europe [Derived from Europroms and UBA/VCI 1997]



* Adhesive input

VOC content is calculated as 1.5 % of adhesive input

Figure 2-13: Annual adhesive and VOC input for dispersions and emulsions in industry sectors in Europe [Derived from Europroms and UBA/VCI 1997]

For the total VOC balance of adhesive applications, solvent based primers are estimated to contribute for 4 kt of VOC in Europe [Derived[2] from UBA/VCI 1997]. However, because of their little importance, no alternatives and no reduction potential are discussed in this report. With these assumptions, the VOC input and emissions can be summarised as stated in figure 2-14.

[2]Where no European data were available, German figures have been extrapolated by the factor four, as Germany accounts for about one quarter of Europe's adhesive production

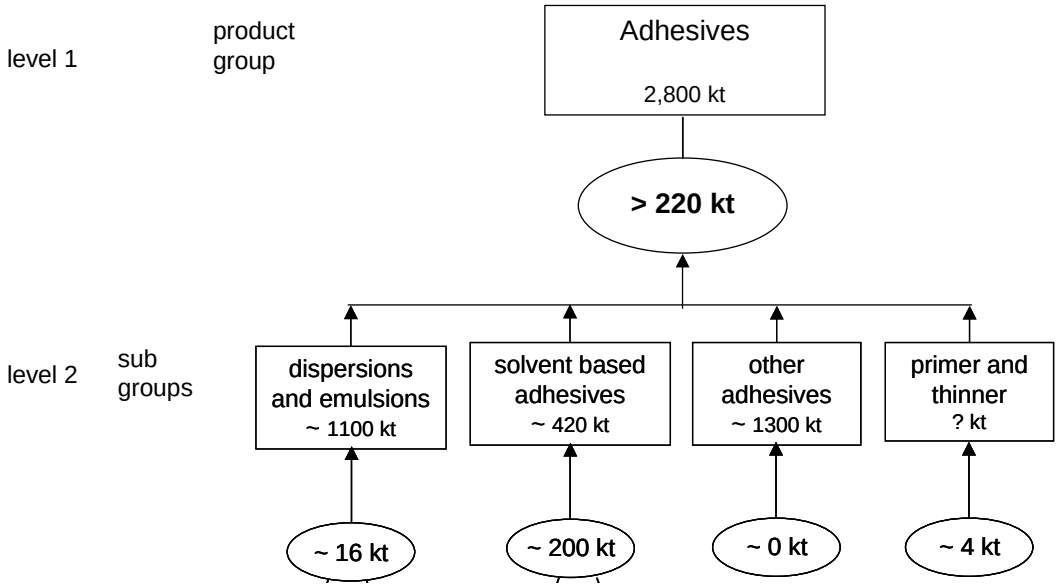


Figure 2-14: Annual VOC input for adhesive production in Europe [Derived from Europroms and UBA/VCI 1997]

2.2.5 Additives and impregnation

Additives are used in many industry branches and for very different purposes. Typically only small amounts of additives are needed in a certain process to maintain a specific property of a product. The use of impregnation agents in the textile and leather industry can be described similar. Slightly different is the impregnation of paper due to the relatively high amounts of impregnation material in relation to the base paper material Therefore additives and impregnation form together one product category.

Nevertheless the use of additives and impregnation for wood preservation and in the paper-, textile- and leather industry is covered by 1999/13/EC.

The use of solvent containing additives for buildings and constructions is related to two main purposes:

a) The enabling of working with liquid concrete at low temperatures

b) To change physical properties of concrete like curing time, hardness etc.

In most cases solvents are used for functional reasons (e.g. reducing of the freezing point). Therefore there are no or at best only minor possibilities for substitution existing in this sector.

Relatively small amounts of solvents are used for additives in the rubber and plastic industry and for related industrial purposes (e.g. production of silicon or PU-sealants). In most cases there is no relevant substitution potential. The same has to be said for other categories of additives.[3]

[3] Additives for mineral oils or for other liquids used for the same purpose as mineral oils (incl. gasoline) (excl. anti-knock preparations, additives for lubricating oils)

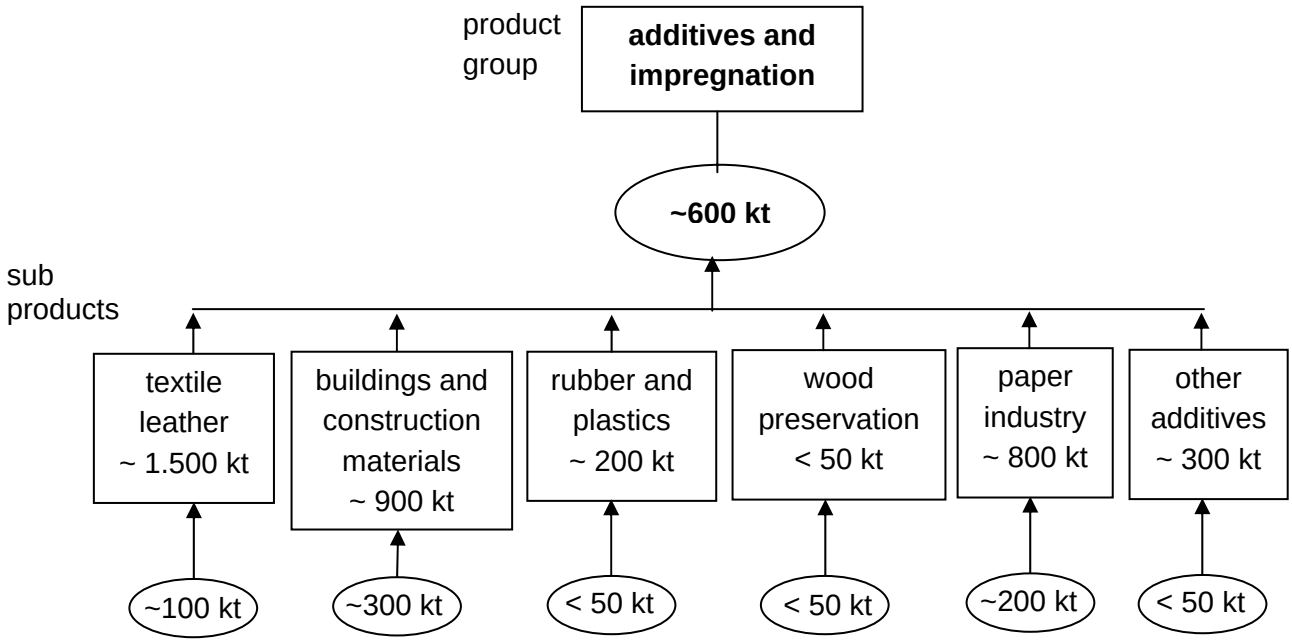


Figure 2-15: bottom-up material flow: additives and impregnation

2.2.6 Others

In the sub-group of insecticides and herbicides VOC are mainly used as propellant in aerosols and as solvent for active substances. The estimation of amounts is difficult because all available statistics are based on the weight of active substances.

Pharmaceutical Products are strictly regulated and underlie a certification process, which can last up to some years. Therefore – and because of the often functional use of VOC (e.g. as disinfectant) there is no substantial substitution potential.

Isolating materials like cellular plates or chips of polystyrene and polyurethane are containing some VOCs as a rest of the production process. The amount is estimated to be very small and depends on the used gas in the production process (CFCs, Pentane).

The sub-group “miscellaneous“ is dominated by three groups of products:

Prepared binders for foundry moulds or cores: Some of them are solvent containing resin-solutions. Foundry emissions are a technology problem and the VOC Emissions only a (small) part of it.

Anti-rust preparations (Amins) –products are used mainly for maintenance purposes.

Essential Oils are produced by a industrial branch which is part of the food industry. The products are mainly used within this industry or for the production of cosmetics. Essential Oils are from this point of view no ready-to-use product but a raw material.

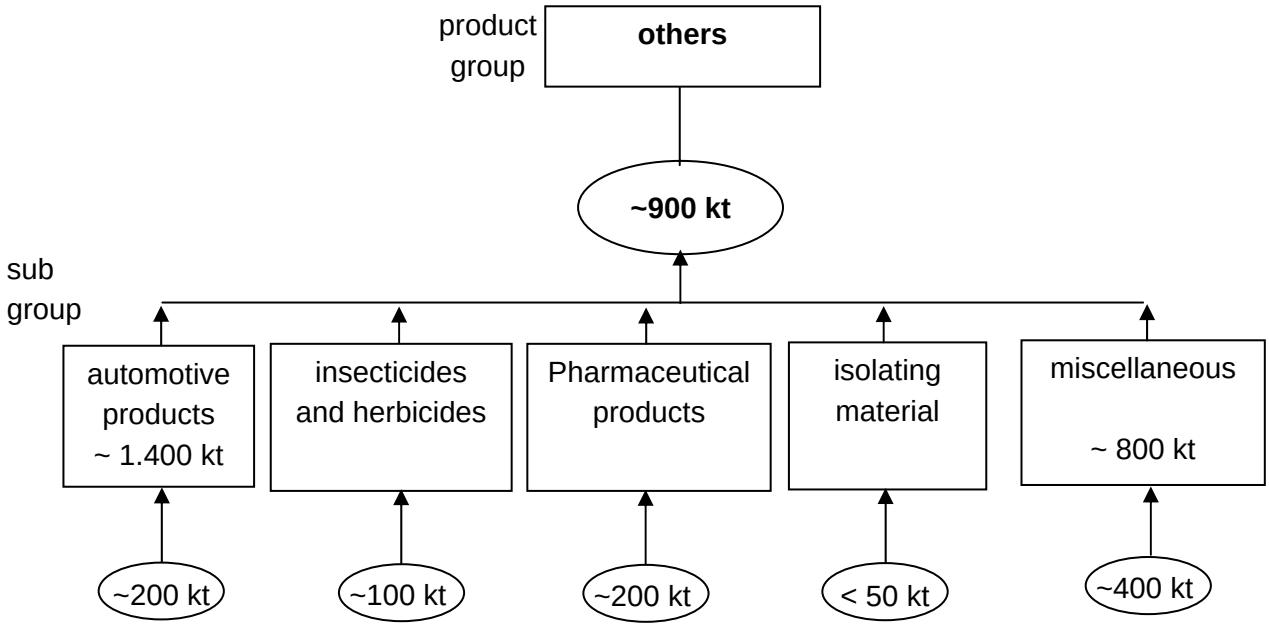


Figure 2-16: bottom-up material flow: others

VOC-Containing Automotive products can be structured in four products:

Lubricants, which are mainly used for the maintenance purposes. The same products are often used for mechanical or electrical equipment other than cars. A minor part of it – but the most relevant part from the VOC point of view – is used as aerosol.

Anti-freezing and de-icing fluids: In these product the VOC is used to provide the function of cars even by temperatures below 0°C.

Under Coatings are mostly PVC-based coatings, that are mostly used in technical units, which are regulated by 1999/13/EC (car manufacturing and repair).

Other products containing VOCs like polishes, waxes, break fluids etc.

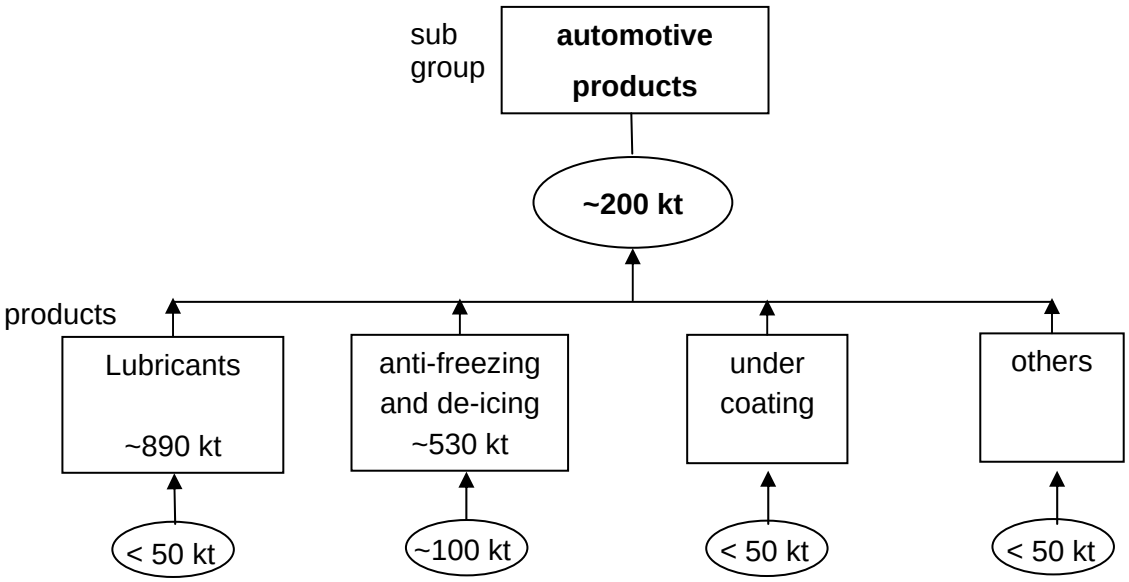


Figure 2-17: bottom-up material flow: automotive products

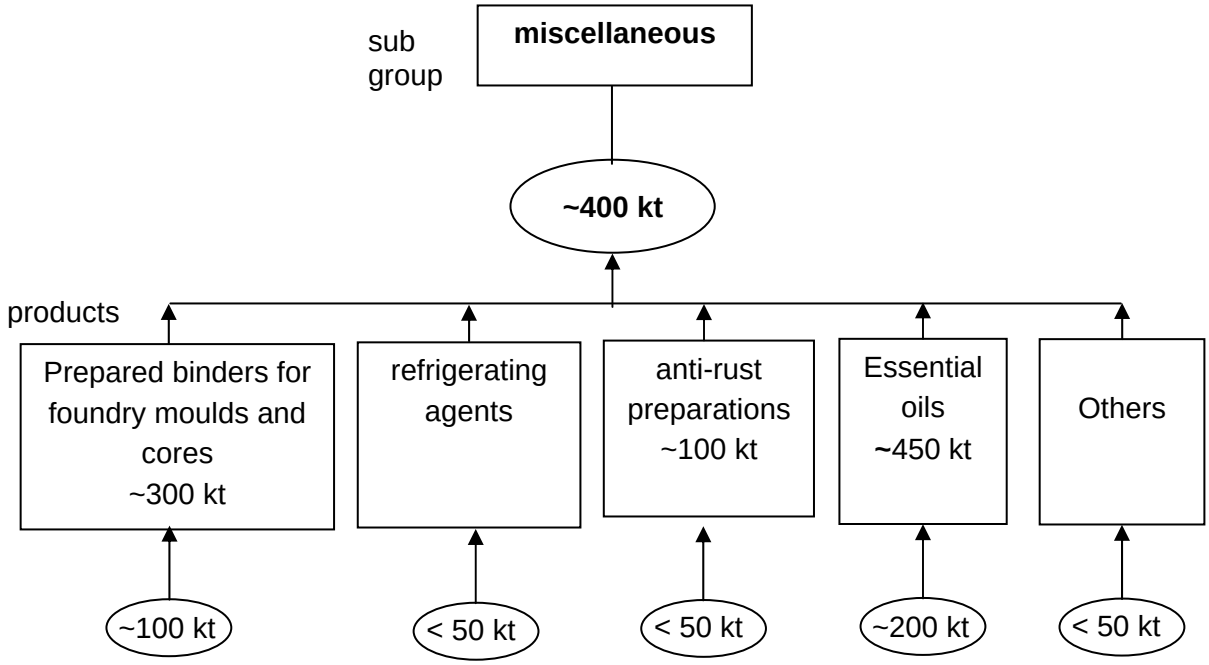


Figure 2-18: bottom-up material flow: miscellaneous

2.3 Material flows within the production of VOC-containing products (top-down analysis)

The following VOC categories are of major importance:

Type of Solvent	Production volume [kt]
Aromatic Compounds – Total	15,400
Aliphatic compounds – Total	10,200
Alcohols – Total	9,400
Ether – Total	2,600
Halogenated Compounds – Total	2,000
Ketons – Total	1,400
Acids and Ester – Total	800
GRAND TOTAL – rounded	**42,000**

Table 2-4: produced amounts of VOC in Europe

Production volumes result from Europroms data.

Taking into account the definition and the procedure described in chapter 2.1, the following figures illustrate the schematic material flows for the above mentioned VOC categories as far as data are available.

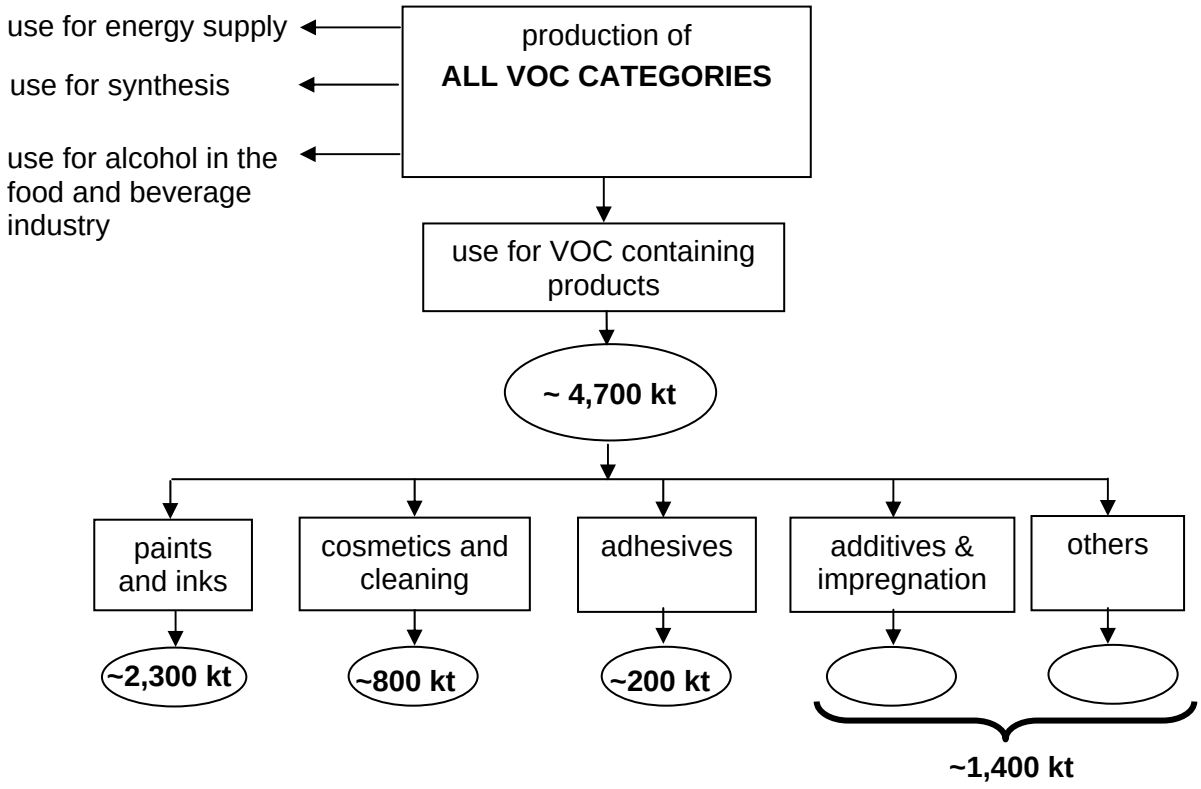


Figure 2-19: results of the top-down material flow

This data was communicated and discussed with industry representatives. First comments indicate that the range of figures can be well used for the screening of the top down material flow.

In ESIG 2000 a total of 4.300 kt for 1993 and 1995.

Main reasons for differences to the estimated 4.700 kt are:

The ESIG statistics is based on the amount of solvents used for production of many products not for the market supply.

The numbers of ESIG remained unchanged from 1993 to 1995, the top down estimate is based on Europroms data in 1999.

The ESIG number takes the directly used solvent in a sector (esp. cleaning and thinners e.g industrial cleaning and cleaning in the printing industry) not into account which was mentioned above.

The product groups shown in the picture below do not correspond completely with the product groups therefore only the general picture can be used to compare our estimates

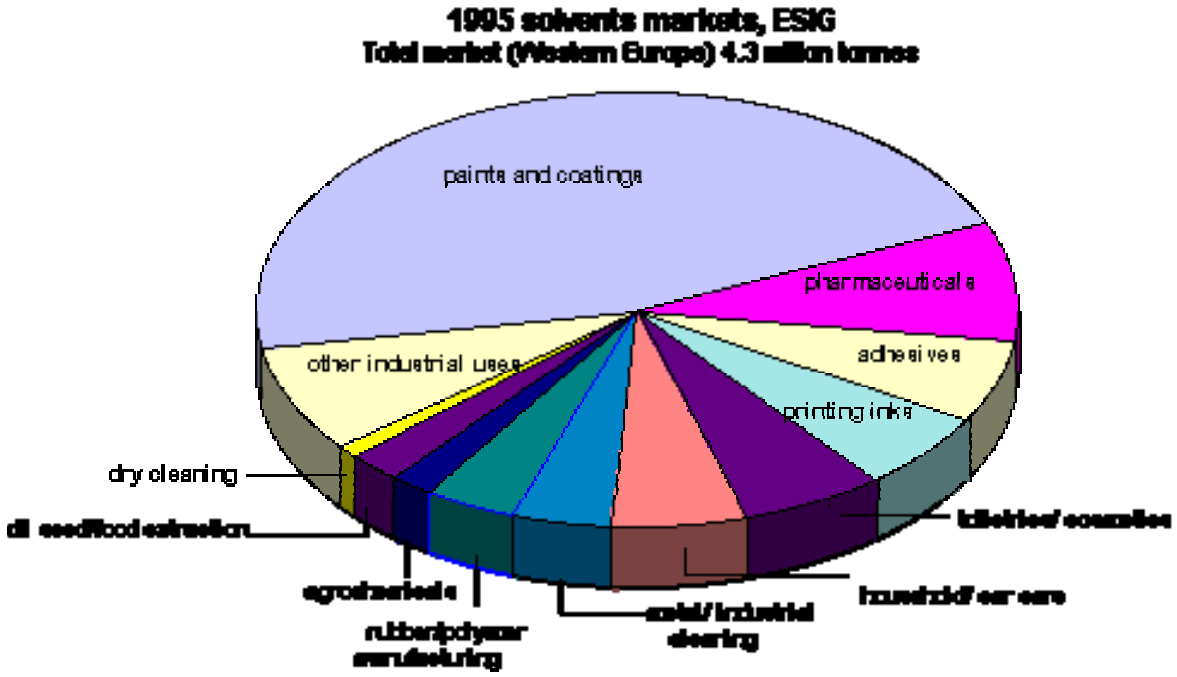


Figure 2-20: overview to the solvents market

2.4 Ranking of VOC-containing products

2.4.1 Use of VOC outside installations regulated under 1999/13/EC

The material flow analysis as presented in chapter 2.2 and chapter 2.3 comes up with results of all VOC-containing products. For further analysis and suggestions on new legislation however only those applications are important that are not yet covered by directive 1999/13/EC.

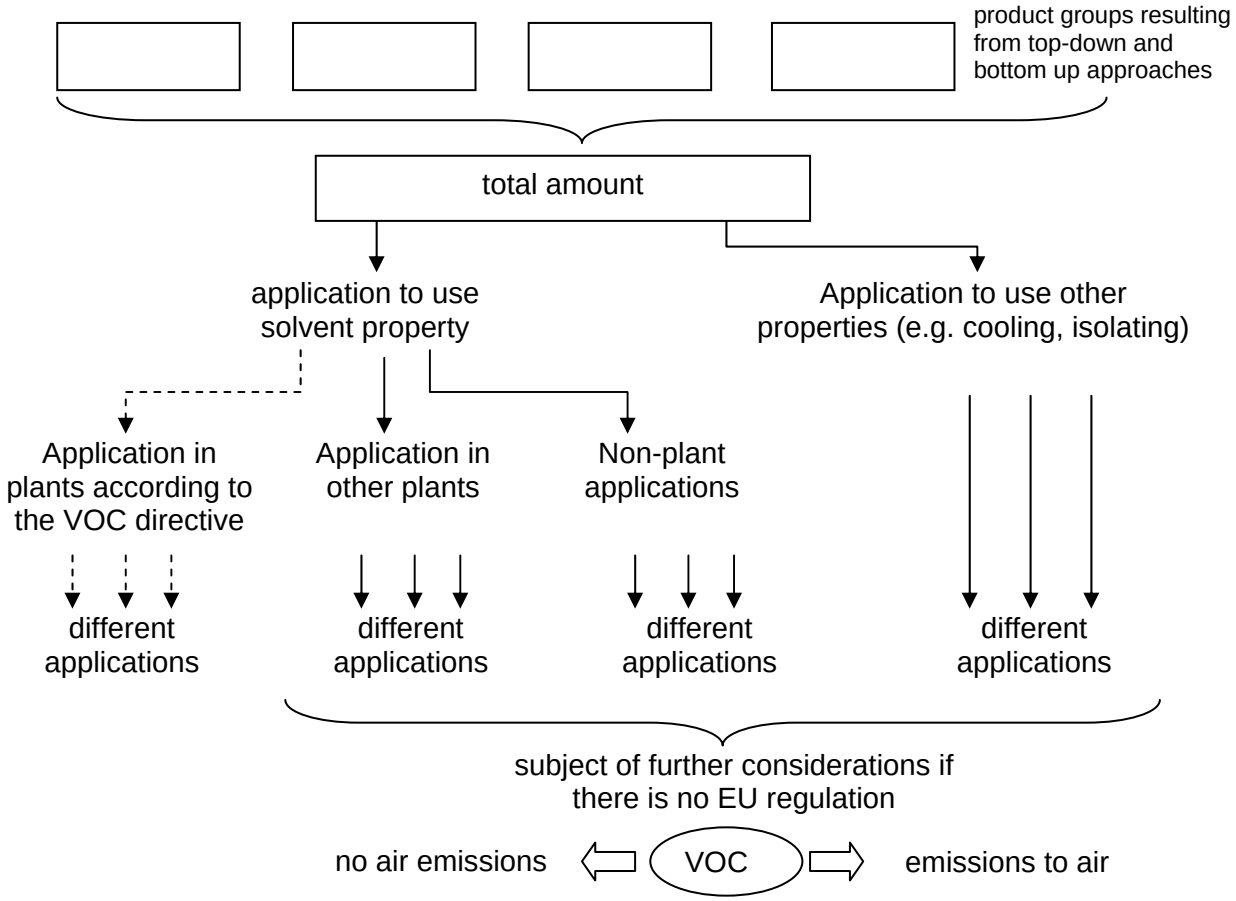


Figure 2-21: Differentiation of applications and identification of material flows

According to the results from the material flow analysis an overview on the amounts of VOC use which is covered or not covered by directive 1999/13/EC can be seen of the following chart.

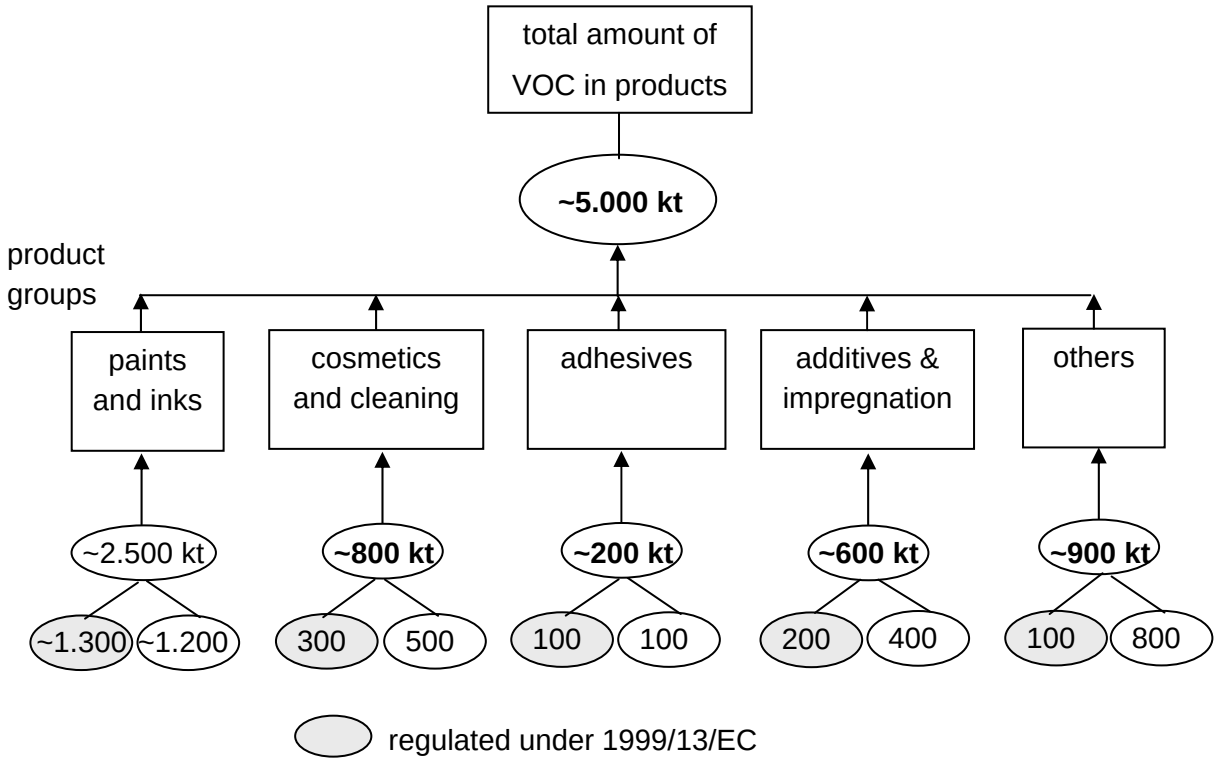


Figure 2-22: volumes of VOC used not regulated under 1999/13/EC

As a result it can be stated that about 2 million tons of VOC are used in plants regulated under 1999/13/EC and about 3 million tons of VOC are used in other applications.

The following table shows details of the sub groups (rounded figures)

	1999/13/EC	non 1999/13/EC
paints	400	700
inks	500	<10
thinners	400	500
cosmetics	0	200
cleaning	300	300
Adhesives	100	100
textile/leather	<10	~100
building construction	0	300
paper industry	150	50
automotive products	0	200
insecticides	0	100
pharmaceuticals	0	200
miscellaneous	100	300

Table 2-5: volumes of VOC used not regulated under 1999/13/EC for sub groups

The following charts provide details for the differentiations of adhesives.

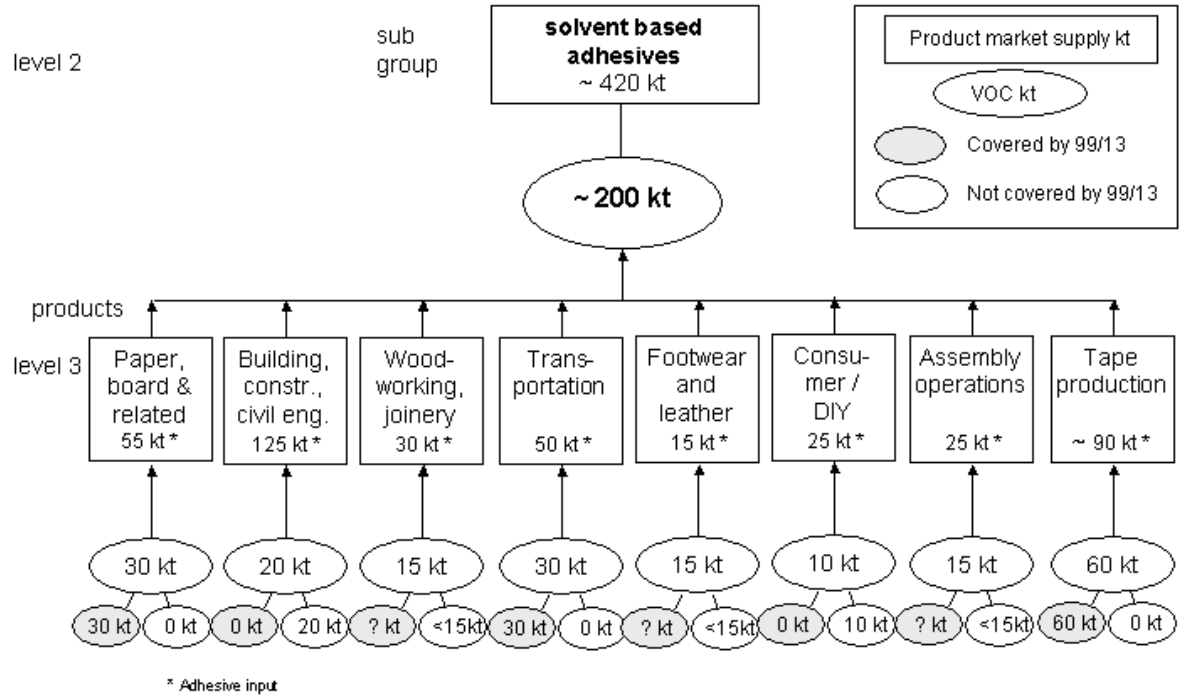


Figure 2-23: Adhesive and VOC input for solvent based adhesives in industry sectors in Europe [Derived from PRODCOM and UBA/VCI 1997]

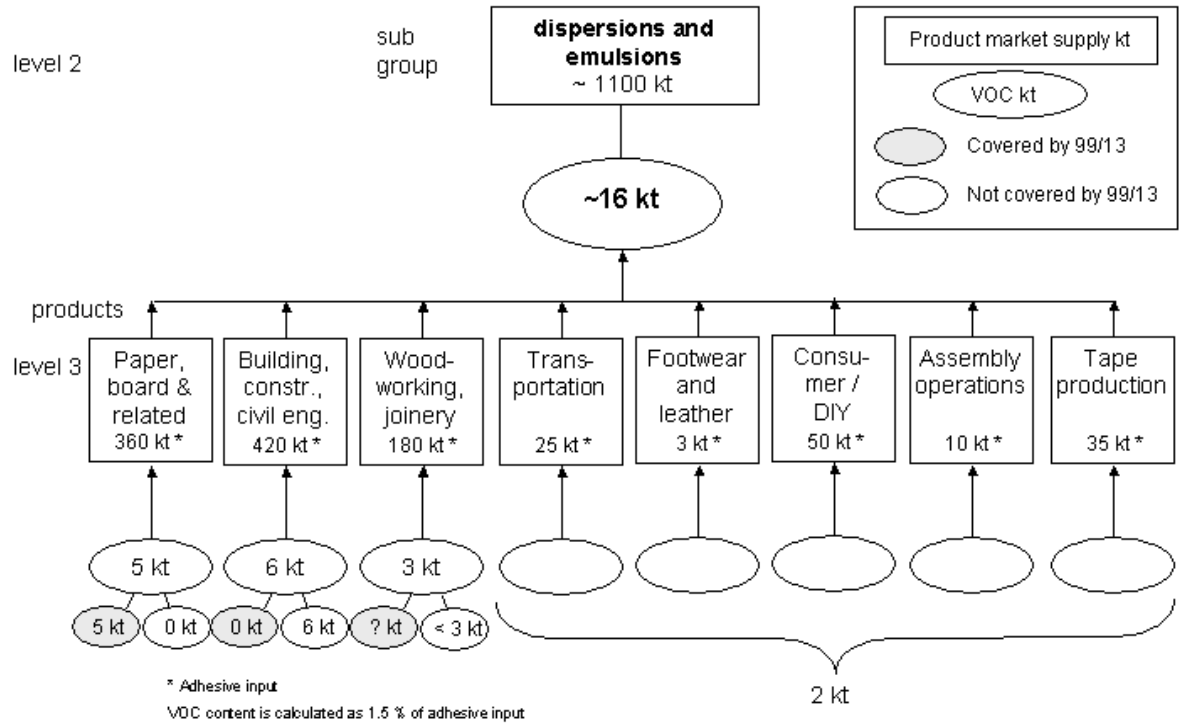


Figure 2-24: Adhesive and VOC input for dispersions and emulsions in industry sectors in Europe [Derived from PRODCOM and UBA/VCI 1997]

2.4.2 Emissions of VOC

The material flows of VOC after use show the following differentiation:

- Emission to air
- Emission to water
- Becoming part of waste (for recycling or incineration)
- Entering exhaust air cleaning

For the use of VOC outside installations typically the last mentioned alternative is not possible.

It is difficult to calculate the various material flow possibilities for all products. Within the time restrictions of the project a calculation could not be done with sufficient precision. Therefore the project team selected focal points on the basis of figures of VOC uses not covered by 1999/13/EC and calculated the various emissions for focal point candidates before finally selecting those which are significantly contributing to VOC emissions to air.. This two step procedure assures that the relevant areas are selected as focal points for further investigation.

2.4.3 Importance of selected VOC-containing products with highest priority

The application of the identification scheme for priorities to the identified material flows leads to the following prioritisation:

subgroup	Amount of VOC used[kt]	priority
Paints	1100	1
Inks	600	2
thinners	800	2
Cosmetics	200	1
Cleaning	300	1
Adhesives	200	1
Additives textile, leather	100	2
Additives building and construction material	300	2
Additives rubber and plastic	< 50	2
Additives wood preservation	< 50	2
Additives paper industry	200	2
Additives other	< 50	2
Automotive products	200	2
Insecticides	100	2
Pharmaceutical products	300	2
Miscellaneous	300	1

Table 2-6: results of prioritization

Consequently 5 product groups result from the ranking with high priority:

1.	Paints	already covered by a separate research project
2.	Cosmetics	scope for further analysis
3.	Cleaning	
4.	Adhesives	
5.	Miscellaneous	broad differentiation, poor substitution possibilities therefore not examined within the study

The emission reduction potentials of the product group “paints” have already been subject of two recent research projects “Reducing VOC emissions from the vehicle refinishing sector” [AUTOMOTIVE 2000] and “Potential for reducing emissions of VOC due to decorative paints and varnishes” [DECOPAINT 2000]. For the study on decorative paints there is a short review in the annex to this study. With respect to the sub group “miscellaneous” it has to be bared in mind that this group consists of a great number of products which show very broad differentiation. Because of this main reason a more detailed analysis can not be provided within the time schedule of the project.

Against this background the sub groups Cosmetics, Cleaning and Adhesives have been chosen as focal points for detailed potential analysis in the study.

3 Possibilities to reduce the VOC content in focal points

3.1 Concept and methodology

The concept to be developed has to answer the following key questions:

1. How can possibilities to reduce the VOC content in products be identified systematically?

   The answer to this question supports the achieved completeness and reliability of suggestions with regard to a new legislation.

2. What are the consequences of alternatives with a reduced VOC content in products?

   The answer to this question enables an assessment and provides the possibility for forecasts on the efficiency of legislative measures.

3. What are the reasons to use VOC-containing products?

   The answer to this question identifies real or removable obstacles for further legislation.

3.1.1 How to identify reduction possibilities

Object of investigation are products consequently the question might rise, whether reduction possibilities are defined by a renunciation of the concerned products. The answer to this question is not too easy.

Obviously it is not the aim of legislation to abolish perfumes, hair sprays, cleaning products, adhesives or other products (only) because they contain VOC. On the other hand it is quite clear that an alternative product available on the market with the same product performance and a lower VOC content defines a reduction potential that can be achieved by appropriate legislation.

The answers regarding the reduction potential for the mentioned extremes (prohibition; reduction of VOC content due to alternatives with the same product performance) are clear, however, between these extremes differentiation is essential. Therefore the necessity occurs to define criteria whether reduction potentials should be counted or not.

The project team suggests the following criteria to include reduction potentials of alternatives:

- "Fulfilment of product use": the product use is still fulfilled if alternatives are applied; a lower quality (technical disadvantages) does not result in the exclusion of reduction potentials

"Availability of alternatives": alternatives are available on the market; eventual economic and ecological disadvantages are not important at this stage for a reduction potential to be counted Fulfilment of product use and availability of alternatives on the market can be seen as essential conditions for counting a reduction potential. Alternatives that have not yet proven their suitability will not be considered.

The analysis on reduction potentials can not be done by simply collecting different alternatives because a huge number of different products has to be regarded. (e.g. more than 100,000 products in cosmetics) Therefore a first step is necessary to establish a structure for the different products.

The project team suggests to implement a differentiation according to the function VOCs have in products. Important functions of VOCs are:

- Aerosol
- Solvent
- Fragrance
- Disinfection
- Preservation
- Freezing point depression
- Refrigerating agent

For the three selected focal points (cosmetics, cleaning, adhesives) the structure of the use of VOCs are shown in Table 3-1:

product sub group function	cosmetics	cleaning	adhesives
aerosol	180 kt	10 kt	< 1 kt
solvent	30 kt	110 kt	100 kt
preservation	3 kt	< 1 kt	< 1 kt
fragrance	3 kt	20 kt	< 1 kt
disinfection	/	30 kt	/

Table 3-1: functional VOC matrix: functions in product sub groups and related amounts of VOC emissions to air

In this table the importance of the various functions is already indicated by the amount of VOC used for the single function. The results leading to the figures of the matrix are documented in detail in chapter 3.2.1, 3.3.1, 3.4.1 and 3.5.1.

Following the above mentioned criteria for fulfilment of product use and availability of alternatives on the level of the functions of VOCs the most obvious approach to identify possibilities is to analyse the present market situation and to identify functional alternatives.

Proceeding in this way a special focus was put on discussions with producers of alternatives. These interviews were followed by discussions with producers of VOC containing products in order to review different points of view.

An additional approach to the market analysis in functions was followed by analysing already existing legislation, mainly based on US regulations. This gave an input into discussions with industry how legal requirements could be fulfilled.

A third approach to ensure completeness and reliability of alternatives as far as possible was the investigation of existing studies and the discussions with environmental ministries in member states (due to time restrictions not in all member states).

In this way question 1 on the systematic identification of reduction potentials can be answered as broad as it was possible within the time restrictions.

3.1.2 How to assess the consequences of alternatives

As described before the analysis for technical possibilities to substitute the VOC is based on the rows and columns of the functional matrix in Table 3-1:. Having identified alternatives these have to be described in order to be able to assess consequences of the alternatives. For the project team it is important to separate the description of alternatives (chapters 3.2.2, 3.3.2, 3.4.2, 3.5.2) from the corresponding assessment (chapters 3.2.3-3.2.5, 3.3.3-3.3.4, 3.4.3-3.4.4, 3.5.3-3.5.5) of these alternatives.

The description typically includes an overview of the market situation, some explanations on the function of VOC in VOC-containing products and the types of VOC used. Alternatives are characterised by description of their function and by enumerating typical products.

The assessment of consequences includes:

- Technical assessment
- Ecological assessment
- Economic assessment

Within the technical assessment consequences of alternatives for VOC function and for the performance of the product are described. Again it has to be stressed that the availability of alternatives on the market are the basis for an analysis. Consequently hair spray containing 30% VOC is not analysed because such an alternative is not available on the market. However

the consequences of 80% VOC hair spray in comparison to 95% VOC hair spray are shown up. The analysis of technical consequences has two parts: first, general advantages or disadvantages are stated; second, advantages and problems are described for selected products or examples.

For the assessment of the ecological consequences the rough impact on the environment is estimated by assessing the effects of alternatives with respect to air, water, waste and risk. In the assessment the present environmental situation considering the present use of VOC is compared to the situation with reduced VOC application. The assessment is based on 3 effect classes:

+ positive
~ indifferent
– negative

This assessment gives first ideas in the sense of a screening. For implementing legislation further analysis is necessary.

For the assessment of the economic consequences the production costs for alternatives are compared to the original product and are indicated in costs for abatement per ton VOC. The cost analysis does not include costs of research and development, marketing, sales, etc. The aggregation of the economic consequences of single products allows developing an idea of the consequences for the whole product group.

In this way question 2 with regard to the consequences of alternatives can be answered.

3.1.3 How to identify reasons to use VOC-containing products

In the areas relevant for the reduction potential there is competition between VOC-containing and VOC reduced products on the market. To certain extent consequences of products (technical, economic, ecological) are relevant for a product to survive in the market. However, there are additional factors that give reasons for the application of products. These factors, possibly in addition with the consequences define potential obstacles for the implementation of legislation.

The project team had interviews (personally and by phone) with actors interested in selling VOC-containing products in order to take into account their arguments. These statements were condensed to find the answers for question 3.

On the other hand, interviews were made to collect the advantages of VOC reduced or VOC free alternatives. These results are included in the analysis of scenarios and reduction potentials and therefore described in chapter 4.1.

3.2 Function of VOC: aerosol in cosmetics and cleaning

3.2.1 Differentiation of function in products

A broad range of cosmetic and cleaning products are aerosol cans based on aerosol spray technology. The product is applied by propelling the product by the mean of a VOC out of the can.

The following chart gives an overview on the production of aerosol cans in the EU.

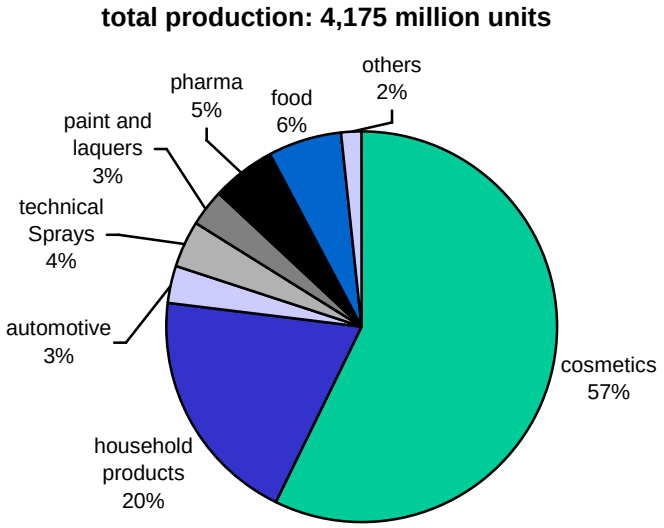


Figure 3-1: Differentiation of the range of use of aerosols of produced in Europe 2000[4]

It is obviously that cosmetics are the most important sector for the function of aerosols. Cleaning sprays are part of household products, however, their importance is much lower. Adhesive sprays do exist but are negligible with regard to their amount and are consequently not followed in the further analysis.

[4] source: Industriegemeinschaft Aerosole e.V., Frankfurt

The shares of Figure 3-1 are based on production statistics which are shown in Table 3-2.

	cosmetics	household	automotive products	technical sprays	paints & varnishes	pharma/ vet. sprays	food products	others
Austria	28.800	2.280	1.700		3.500	150		500
Belgium/ Luxembourg	103.161	55.075	7.235	28.442	6.256	490	89,289	456
Denmark	300	750	800	3.000	450			
Finland	4.717	461	388	5.868	1.743			729
France	385.000	97,000	17,000	12,000	4.000	43.000	1.000	6.,000
Germany	586.000	64.000	26.000	38.000	40.000	49.000	60.000	12.000
Greece	7.300	8.550	1.000	100	4.000	100		700
Italy	156.100	116.900	17.300	12.000	19.100	19.350	48.300	11.100
Netherlands	12.310	197.658	20.661	25.855	24.295	606	59.956	
Portugal	30.039	4.182		612		25		
Spain	104.778	61.710	5.661	1.487	4.572	6.370	2.752	16.844
Sweden	11.699	1.750	1.631	1.249	1.379	484	735	131
UK	961.400	215.340	25.300	29.8000	16.600	102.040		16.400
total	**2,391.604**	**825.656**	**124.676**	**158.413**	**125.895**	**221.415**	**262.032**	**64.860**

Table 3-2: Production figures aerosol 2000 (EU 15)

In this table the particularities of member states and the different shares of aerosol products in member states are well documented.

Taking export-import relations into consideration, the following part of the VOC function matrix can be derived of the statistics in Table 3-2.

	cosmetics	cleaning	adhesives	others[5]
aerosol	180 kt	10 kt	< 1 kt	110 kt
	Hairspray Hair mousse Deodorants/body sprays Antiperspirants Shaving lather Other personal care products	Bathroom/ kitchen mousse Oven cleaners Shoe/leather cleaners Carpet / Upholstery cleaner Other household		Air fresheners Insecticides Pharmaceuticals Lacquers De-icer

Figure 3-2: typical aerosol products

In this chart typical products for the elements of the functional matrix for aerosols are mentioned.

To come to the function "aerosol" more in detail it can be stated that depending on the product aerosol cans contain propellants as well as solvents, whereas the propellant in its liquid state is very often part of the solvent system.

Common propellants are:

- Hydrocarbons (e.g. propanebutane)
- Dimethyl ether (DME)
- HFCs-152a (not counted as VOC in some regulations)

Hydrocarbons are the most common propellants with use in almost all categories. The drawback of hydrocarbons is that they are flammable. According to [CARTER 2000] the ozone building potential of butaneand isobutene is about a factor of 2 – 2,5 higher than propan.

Dimethyl ether is at medium pressure liquefied, flammable, propellant with solvent properties which are desirable in some aerosol product formulations (e.g. hair spray). The ozone building potential is within the range of propane – butane [CARTER 2000].

HFC-152a is less flammable than hydrocarbons or DME but in comparison with other propellants much more expensive. Therefore it is mainly used for technical purposes where flammability is a concern and alternatives are not available or applicable. As HFCs are not

[5] others do not define a focal point, however, some results are available as "by-products" from the analysis

regarded as VOC in US legislation, HFCs are the propellant of choice for some consumer products to fulfil the strict legal VOC-regulations. In the European Union HFCs are not used for cosmetics.

3.2.2 Alternatives

To the function of VOC as aerosols 3 major alternatives exist:

A) systems with a pump mechanisms

B) systems with compressed gases

C) alternative application products (not-in-kind alternatives)

The substitution of VOC within alternative “A” belongs to the sub function propellant. Consequently, pump sprays may still contain VOC for the sub function solvent, however, the total VOC amount necessary for the wanted product use is lower. This is also valid for the alternative “B”.

Alternative “C” does not substitute the VOC function "propellant", it avoids this sub function and consequently also avoids the function "aerosol". Therefore not-in-kind alternatives are in some cases able to substitute VOC completely.

Description of pump mechanism

Pump mechanisms can be roughly described by the following characteristics:

- Product ingredients in the container are not under pressure
- Expel of the product only while pumping through a button, trigger or other actuator
- No propellant is necessary
- Depending on the product solvents e.g. water, alcohol are necessary
- On the market pump sprays as well as pump foamers are available for applications with a focus on cosmetics

The following products are good examples for products available with a pump system in the markets:

- Hair spray
- Deodorants/body sprays
- Air fresheners
- Bathroom and tile cleaners
- De-icer
- Furniture polishes*
- Hair mousse*
- Antiperspirants*

* very small market share

Description of compressed gas systems

Compressed gas systems show the following characteristics:

- In contrast to hydrocarbon propellants the compressed gas (e.g. nitrogen, air, N_2O) is not in a liquid state (exception: CO_2 can also be partly liquid); the compressed gas is either incorporated with the product or contained in a separate chamber within the product packaging (2-chamber system)
- After opening the valve, gas under pressure pushes the liquid product out of the can
- Over the lifetime the pressure in the can drops, therefore sometimes rests of the liquid may remain in the can
- In the case of 2-chamber systems a good evacuation of the can is possible, as the gas (normally compressed air) does not leave the system
- Available on the market for certain applications

Typical products with compressed gas systems are

- Furniture polishes, available with compressed air or nitrogen systems
- Food products (e.g. cream), available with compressed CO_2, N_2, N_2O systems
- Insect repellents, available with compressed CO_2 systems
- Shaving gels, available with compressed air system (2-chamber system)
- Hair spray*, available with compressed air or CO_2 systems
- Body deodorants*, available with CO_2 systems

* very small market share

Description of alternative application products (not-in-kind alternatives)

"Not-in-kind alternatives" can be described by the following characteristics:

- The reduction of VOC-content is realised through a change of the application form (e.g. the active ingredients are in a solid matrix form (sticks, crystals), which is directly applied on the skin)
- Most of the not-in-kind alternatives still may contain VOCs (e.g. gels) but typically smaller amounts

Typical examples for not-in-kind alternatives for aerosol products are:

Aerosol product	alternatives on the market
Hair mousse	Liquids, gels (lower VOC content)
Deodorant/body sprays	Roll-on products, sticks, powder, cream
Antiperspirants	Roll-on products, sticks powder, crystal
Shaving lather	Soap, cream, gel (low VOC content)
Insect repellents	Creams, oils
Carpet cleaner	Liquids, powder
Spot remover	Powder, paste, liquids
Air freshener	Gels, powder crystals

Table 3-3: examples for not-in-kind alternatives

3.2.3 Assessment of pump mechanism

Technical consequences

The function "propellant" is performed by VOC very well so technical advantages of pump mechanism are focused on few aspects like

- Possibility to use refilling systems
- Possibility to use smaller cans for the same product use.

Problems in general occur with the following issues:

- Quality of the product is not the same (e.g. bigger droplets, no constant distribution of droplets)
- Product has to be in a liquid phase, but some products have to be solved in -VOC solvents
- Higher amounts of solvents in some cases
- Convenience of the product outside the private sector (e.g. hair dresser)
- increase of the water content can affect the can material (corrosion), therefore a change of the material or additives is necessary

Special problems arise for example with

Hair spray:	until now non-VOC products do not reach the properties of aerosol products, i.e. water containing products are typically to wet and the drying time is to long
	wet products have a contrary effect, they can destroy the hairstyle instead of fixing it and therefore the function of the product is not given anymore
Deodorant:	formulations for pump sprays are often to wet
	reduction of the VOC content (e.g. by increasing the water content) requires in most cases a new formulation of the product

To overcome technical problems developments for new valve systems or new pump systems (micro pumps) have been started.

Ecological assessment

The results of a rough ecological assessment (screening) can be seen in Figure 3-3:

Air	water	waste	risk
+	~	~	+

Figure 3-3 ecological assessment of pump mechanisms

+ = *positive effects*

~ = *indifferent effects*

- = *negative effects*

Air: There is a clear ecological advantage regarding air emission as at least some VOC emissions (sub function propellant) are substituted by pure air.

Water: In a first approach there are no consequences to water.

Waste: There might be small ecological advantages due to refill ability of pump sprays or smaller volumes of cans. On the other hand certain ecological disadvantages can occur regarding recycling possibilities and additional waste of pump mechanism.

Risk: There are advantages due to reduced risks of flammability. That plays a role for the production and use of aerosol cans. However, it should be mentioned that due to the remaining VOC as solvents also pump systems still have a remaining risk of flammability.

Economic Assessment

The analysis of costs of abatement due to the substitution of VOC by pump mechanism is complex due to the broad variety of products concerned. For these products research and development costs for new formulations, marketing costs and investment costs occur if pump mechanisms are installed in a broader way. On the other hand there is a significant market share covered by pump mechanisms and prices for these products seem to be not higher on basis of a comparable product use.

Discussions with industry indicated that the existing production costs show a difference below 500 € per t VOC abatement costs comparing production costs for VOC containing aerosols or pump mechanism aerosol cans.

3.2.4 Assessment of compressed gas systems

Technical consequences

By compressed gas systems the following general technical problems may occur:

- Drop of pressure during lifetime, therefore no continuous outcome
- Complete evacuation of the can is due to the reduction of the pressure not always possible
- Due to prescribed wall thickness the pressure is too low for some applications
- In some cases higher amounts of solvents are necessary, due to the solvent's function of the substituted propellant.

Ecological assessment

The results of a rough ecological assessment (screening) can be seen in Figure 3-3:

Air	water	waste	risk
+/~	~	–	~

Figure 3-4 ecological assessment of compressed gas systems

+ = *positive effects*

~ = *indifferent effects*

- = *negative effects*

Air: There is an ecological advantage regarding air emission as at least some VOC emissions (sub function propellant) are substituted by ecological harmless gases. Nevertheless the type of the compressed gas has to be taken into consideration (e.g. significant ecological disadvantages with N_2O).

Water: In a first approach there are no consequences to water.

Waste: There are in some cases ecological disadvantage regarding waste due to remaining products in the can and higher amount of construction material e.g. by the 2-chamber system.

Risk: There are advantages due to reduced risks of flammability. However, it should be mentioned that due to the remaining VOC as solvents in some cases compressed gas systems still have a remaining risk of flammability.

Economic Assessment

The analysis of costs of abatement due to the substitution of VOC by compressed gas systems is complex as a broad variety of products are concerned. On the one hand compressed gases (air, nitrogen, CO_2) are generally cheaper than hydrocarbon propellants on the other hand in many cases the production costs are higher due to increased raw material costs (e.g. 2 chamber systems).

Without taking into account costs for research and development or marketing an overall increase of costs for the abatement per tonne VOC would be less than 500 €.

3.2.5 Assessment of not-in-kind alternatives

Technical consequences

An alternative application form of the product substitutes the function propellant „of VOC and in some cases also the function of“ solvent. As not-in-kind alternatives cover a wide spectrum of different products technical advantages or disadvantages mainly depend on the single product. In general problems occur with the following issues:

- Not for all aerosol products possible (e.g hair spray)
- Quality loss (e.g. use of brushes)
- Loss of the fragrance quality
- Hygienically problems with some not-in-kind alternatives (e.g. roll-on products)
- Allergic reactions are possible by the use of not-in-kind alternatives because the formulations are often composed of more different compounds than aerosol products

Ecological assessment

The results of a rough ecological assessment (screening) can be seen in Figure 3-3:

air	water	waste	risk
+	~	~	~

Figure 3-5 ecological assessment of not-in-kind alternatives in the aerosol sector

+ = *positive effects*

~ = *indifferent effects*

- = *negative effects*

Air: There is a clear ecological advantage regarding air emission as VOC emissions due to the function of "propellant" and in many cases as well the function of "solvent" can be substituted.

Water: In a first approach there are no consequences to water.

Waste: In a first approach there are no consequences to water.

Risk: In some cases disadvantage can occur due to an increased risk of allergic reactions, but there are also advantages due to inflammability.

Economic Assessment

The analysis of costs of abatement due to the substitution of VOC by not-in-kind alternatives covers a wide range of different products. Therefore a quantitative statement according to economic consequences is not possible. Regarding the already existing spectrum of not-in-kind alternatives on the market and based on discussions with industry it can be assumed that typically no significant costs of abatement occur.

3.2.6 Already existing legal restrictions

To reduce summer smog caused by NO_x and VOC the United States of America implemented a strict regulation according to the VOC-content of consumer products. The state of California and some other states with a hot climate even tighten up this national regulation by a more restrictive legislation to reduce VOC emissions from consumer products.

For an adequate understanding of the California VOC-regulation it is necessary to consider the used VOC definition as well as the exemptions. Especially the exclusion of HFCs, HCFCs and

CFC has to be regarded critically. Although these substances do not cause ground level ozone they are known for their global warming potential. For some products (e.g. hair spray) the max. prescribed VOC content without loss of their function only can be realised by the use of HFCs.

For following consumer aerosol products the maximum VOC content is regulated in California:

product	Max. allowed VOC content in California
Hair spray	55%
Hair mousses	16% (6% 2003)
Hair shine	55% (2005)
Antiperspirants (aerosols)	40% HVOC, 10% MVOC[6]
Deodorants (aerosol)	10% MVOC
Personal fragrance products < 20% fragrance > 20% fragrance	 80% 78%
General purpose cleaners (aerosol)	10%
General purpose degreasers (aerosol)	50%
Glass cleaners (aerosol)	12%
Bathroom and tile cleaners (aerosol)	7%
Carpet and upholstery cleaner (aerosol)	7%
Furniture maintenance products (aerosol)	25% (2005 17%)
Laundry prewash (aerosol/solid)	22%
Oven cleaners (aerosols/pump spray)	8%
Rubber and vinyl protectant (aerosol)	10% (2005)
Spot removers (aerosol)	25%

Table 3-4: examples for VOC limitation due to Californian legislation (aerosols)

[6] HVOC= high volatility organic compounds); MVOC = medium volatility organic compounds

3.3 Function of VOC: solvent, preservation, fragrance in cosmetics

3.3.1 Differentiation of function in products

In cosmetics different properties of VOC are used besides the functions in aerosol cans. Mainly VOC serve as solvents to dissolve components and to make products liquid or applicable. Furthermore VOC are used as preservatives or fragrances. Additional VOC also can fulfil other functions like humectants or emulsifying agents in cosmetic products. In Table 3-5 the amounts of VOC used in cosmetic products are differentiated corresponding to their main function.

product sub group function	cosmetics
solvent	30 kt
preservation	3 kt
fragrance	3 kt

Table 3-5: functional matrix – cosmetics besides aerosols

As there is no detailed data available on production volumes an overview over the importance of the different cosmetic products and their market shares has to be based on market volumes. The total market volume of cosmetic products in 2000 amounted 49.420 billion € (retail sales prices, resp. 30.193 billion €, manufacturing/ex-factory prices) [COLIPA 2000]. In the following chart the distribution of the product categories corresponding to their market share are represented.

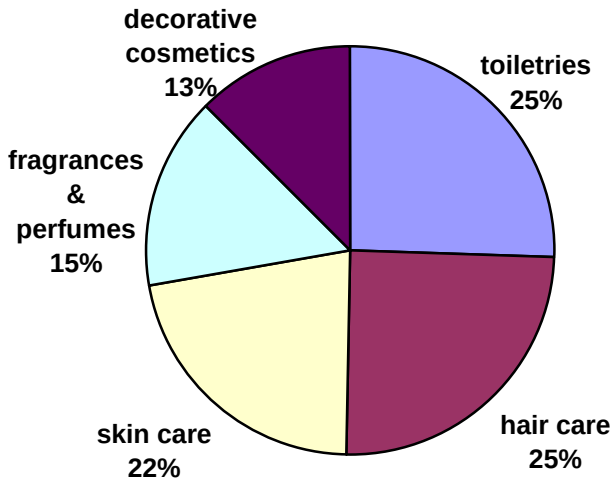


Figure 3-6: Western Europe Cosmetic and Toiletries Market (2002), market share by product category based on Retail sales prices [COLIPA 2000]

The shares of Figure 3-6 are based on the national markets volumes, which are shown in Table 3-6.

	Fragrances & perfumes	Decorative cosmetics	Skin care	Hair care	Toiletries	Total
Germany	1.355	1.131	2.120	2.664	3.186	10.456
France	1.836	1.110	2.330	2.147	1.720	9.143
United Kingdom	0.940	1.270	1.390	2.094	2.526	8.220
Italy	1.088	1.004	1.847	1.602	1.878	7.419
Spain	1.157	0.487	1.141	1.174	0.968	4.927
Netherlands	0.280	0.219	0.430	0.539	0.575	2.043
Belgium/Lux.	0.271	0.168	0.272	0.432	0.274	1.417
Austria	0.125	0.169	0.214	0.287	0.286	1.081
Sweden	0.120	0.213	0.205	0.303	0.390	1.231
Greece	0.091	0.143	0.229	0.315	0.174	952
Portugal	0.157	0.061	0.159	0.280	0.193	850
Denmark	0.122	0.089	0.118	0.232	0.148	709
Finland	0.025	0.084	0.115	0.208	0.120	552
Ireland	0.062	0.057	0.083	0.090	0.132	424
Total	7.629	6.205	10.653	12.367	12.570	1.377.339.424

Table 3-6: western european cosmetics & toiletri market 2000, national markets by product category structure billion Euro based on Retail sales prices [COLIPA 2000]

A relation between the prices and the production volumes (amounts) can not be derived, as especially in the cosmetic industry the price of a product is not related to the amount of product (e.g. perfumes).

The most important sectors are toiletries (e.g. soaps, oral hygiene, bath and shower products, deodorants, shaving products) and hair care products (e.g. shampoos, hair sprays, conditioners, hair gels) with a market share of more than 50% of the total market. The following table gives an overview on concerned products and their average range of VOC content.

	range of VOC content
Toiletries	
shaving products	0-5%
soap and bath products (shower gels, etc.)	< 1%*
deodorants / antiperspirants	3-95%
hair care products	
hair care products	10-95%
Shampoos	< 1%*
liquid hair spray (pump spray)	~ 80%
skin care products (creams, lotions)	*0-20%**
decorative cosmetics	
nail polish removers	up to 95%
fragrances (incl. aftershaves)	<80%*

* in some cases higher amounts are possible

Table 3-7: range of VOC content in selected cosmetic products

To fulfil the different requirements in cosmetic products a broad spectrum of different VOC are used, e.g.:

Ethanol

Isopropyl alcohol

Acetone (nail polish remover)

Phenoxyethanol, benzyl alcohol (preservation)

Terpenes (fragrances)

It might be important that according to [CARTER 2000] Ethanol shows about 2 times higher ozone building potential compared to isopropyl alcohol. The potential of acetone is about 5 times smaller than ethanol.

3.3.2 Alternatives

In order to avoid or reduce VOC in cosmetic products the following alternatives can be taken into consideration:

A) Alternative application products (not-in-kind alternatives)

B) Reformulations/new formulations

Description of alternative application products

As VOC in the vast majority serve as solvents a possibility to avoid VOC in cosmetic products is to change the application form. Possible alternative application forms are:

- powder, tablets, granulates

Due to given application requirements in many cases a complete change of the application form is not possible. A reduction of the VOC content may be obtained by replacing liquid products with pastes or gels which have typically a lower VOC content.

The following products are typical examples with already available not-in-kind alternatives:

Product	Alternatives
Deodorants Roll-on Pump spray Sticks	Powder, cream
Antiperspirants Roll-on Pump spray Sticks	Powder, cream
Bath products	Bath salt, tablets, granulates

Table 3-8: examples for not-in-kind alternatives - cosmetics

It has to be mentioned that the products in this table themselves are alternatives to aerosol cans. Although they have significant lower VOC contents compared to aerosol cans they still lead to more VOC emissions than the given alternatives “powder” and “cream”.

Description of the alternatives reformulations/new formulations

For most cosmetic products an avoidance or reduction of VOC only can be realised by a reformulation of the product. On the market exist already a broad range of VOC free products. Due to the large scale of different formulations and products only an overview on possible alternatives to the functions of VOC in cosmetic products can be given. A detailed analysis of

VOC substitutes was within the short time not possible. To what extend alternatives can be used depends on the formulation and specific requirements of the single product.

- Use of non-VOC or low-VOC alternatives

  Examples for alternative solvents: e.g. water, oils

  Examples for alternative emulsifiers: lecithin (from milk), soya

  Examples for alternative humectants: urea, glycerine

- Use of fragrance-free products or non-VOC fragrances

Fragrances typically do not have special care effects. They are mainly responsible for the "good" odour of the product. In some cases fragrances are used to cover the undesirable smell of necessary product compounds. Additionally some fragrances are known for their sensitising effects.

But the function "fragrance" has great influence on the product choice of consumers. Therefore a substitution of VOC by non-VOC fragrances will be more realistic.

Some product groups with alternatives already available on the market can be seen in the following table

Product	Alternatives
Liquid hair sprays (pump sprays)	Fragrance free products
shower gels	Water-based products, soap
Facial tonics	Alcohol free products are available
Creams	Alcohol free prodcuts are available
Fragrance products	Low VOC products
Deodorants	Water-based products, creams
Nail polish removers	Acetone free products
Perfume	Perfume oil, cream
Shaving gels / creams	Soap, low-VOC or VOC-free products
hair gels	VOC-free products are available

Table 3-9: examples for reformulations/new formulations - cosmetics

3.3.3 Assessment of not-in-kind alternatives

Technical consequences

Especially in the cosmetic industry the change of the application form is limited to a small range of products. The following problems complicate or even prevent the implementation of not-in-kind alternatives:

- Change of the application form is not suitable for all cosmetic products (e.g. creams)
- Change from liquid to solid products (powder, tablets) can cause allergic reactions due to dust emissions
- Solid or less liquid products in some cases still need VOC to fulfil the product requirements
- Substitution or reduction of VOC sometimes makes the use of preservatives necessary
- Risk of increased allergic reactions due to a wider range of different compounds in some products to substitute the VOC compound
- Hygienically problems (loss of the additional disinfection effects of alcohol)
- Reduction of VOC by substitution of one VOC to another might increase the total ozone building potential of the product.

Ecological assessment

Figure 3-7 summarises the results of a rough ecological screening.

Air	water	waste	Risk
+	~	+	–

Figure 3-7: ecological assessment of not-in-kind alternatives in the cosmetic sector (besides aerosols)

+ = *positive effects*

~ = *indifferent effects*

- = *negative effects*

Air: There is a clear ecological advantage regarding air emission as VOC emissions due to the function of "solvent" can be substituted or reduced.

Water: In a first approach there are no consequences to water.

Waste: Regarding waste in some cases ecological advantages can be realised by reduced packing volumes.

Risk: In some cases disadvantage can occur due to an increased risk of allergic reactions because not-in-kind alternatives are often containing a wider range of different compounds.

Economic Assessment

The analysis of costs of abatement due to the substitution of VOC by not-in-kind alternatives covers a wide range of different products. A comparison of VOC-containing products with their available not-in-kind counterparts does not lead to a significant difference in prices. Therefore cost of abatements can be assumed to be less than 500 € / t VOC without taking into account costs for research and development or marketing. Discussions with industry confirmed this estimation.

3.3.4 Assessment of reformulations, new formulations

Technical consequences

To substitute the functions of VOC in cosmetic products the vast majority of the products has to be reformulated or substituted by new formulations. By a reformulation or new formulation of products without VOC following problems might occur:

- Some components can not be dissolved in water
- Loss of quality/performance
- Higher water content in cosmetics sometimes makes the use of preservatives necessary
- Alternatives sometimes have a undesirable smell (e.g. lecithin), which has to be covered by fragrances
- Fragrance-free products typically require more expensive raw materials (non-smelling compounds)
- Risk of increased allergic reactions due to a wider range of different compounds in some products to substitute the VOC compound
- Hygienically problems (loss of the additional disinfection effects of alcohol)
- Different odour-characteristics of fragrances solved in non-VOC
- Reduction of VOC by substitution of one VOC to another might increase the total ozone building potential of the product.

To solve these problems the industry already started to develop water soluble alternatives, stabilizers and emulsifiers.

Following some specific problems according to single products are described more detailed:

Liquid hair spray (pump spray):	Long drying time loss of quality
Antiseptic solutions (aftershaves):	some components can not be dissolved in water Reduction of VOC may lead to higher amounts of raw materials
Fragrance products:	Substitution/Reduction of the VOC (alcohol) affects the fragrance quality of the product Drying time will be extended
Perfume oil, cream	Substances can affect clothes (e.g. colouring)

Ecological assessment

In Figure 3-8 the results of a rough ecological screening are summarised:

Air	Water	waste	Risk
+	~	~	–

Figure 3-8: ecological assessment of reformulations/new formulations in the cosmetic sector (besides aerosols)

+ = *positive effects*

~ = *indifferent effects*

- = *negative effects*

Air: There is an ecological advantage regarding air emission as different functions of VOC in cosmetic products can be substituted or reduced.

Water: In a first approach there are no consequences to water.

Waste: In a first approach there are no consequences to water.

Risk: In some cases disadvantage can occur due to an increased risk of allergic reactions because not-in-kind alternatives are often composed by a wider range of different compounds.

Economic Assessment

The analysis of costs of abatement due to a substitution or reduction of VOC by reformulations or new formulations is very difficult to calculate, as a substitution of VOC in sophisticated formulated products not only means a simple exchange of compounds. A change of compounds typically affects the whole composition and therefore large-scaled tests have to be initiated to prove the changed formulation. On the other hand the cosmetic industry is very dynamically and the range of products and formulations change very fast.

Based on discussions with industry the costs of abatement per ton VOC can be stated less than 500 €.

3.3.5 Already existing legal restrictions

Following cosmetic products are affected by the strict California VOC regulations:

product	Max. allowed VOC content in California
Hair styling gels	6%
Antiperspirants (non-aerosol)	0%
Deodorants (non-aerosol)	0%
Shaving creams	5%
Heavy-duty hand cleaners or soap	8%
Nail polish removers	75% (0% 2005)

Table 3-10: examples for VOC limitation due to Californian legislation – cosmetic products (besides aerosols)

3.4 Function of VOC: solvent, fragrance and disinfection in cleanings

3.4.1 Differentiation of function in products

VOC in cleaning products can be an essential component of the cleaning function (e.g. degreasing function) or serve to maintain interactions among other ingredients. Corresponding to the function matrix VOC in cleaning products are used as solvents, as fragrances or for disinfection purposes. In the following table the use of VOC according to their main function in cleaning products can be seen:

product sub group function	cleaning
Solvent	110 kt
Preservation	< 1 kt
Fragrance	20 kt
Disinfection	30 kt

Table 3-11: functional matrix – cleaning besides aerosols

Commercial and institutional used cleaning products, which are not regulated under the VOC directive are also included. As VOC in cleaning products in most cases are released into the air during the application the working staff is exposed to emissions. Therefore a reduction or limitation of the VOC content in cleaning products would reduce the indoor contamination with VOC emissions.

Concerned areas are:

-Laundry

-Kitchen & catering

-General surfaces

-Industrial hygiene

Figure 3-9 gives an overview on the market share of the different cleaning products based on retail sales prices. The total turn over in 1999 amounted 24.5 billion € [A.I.S.E. 2000].

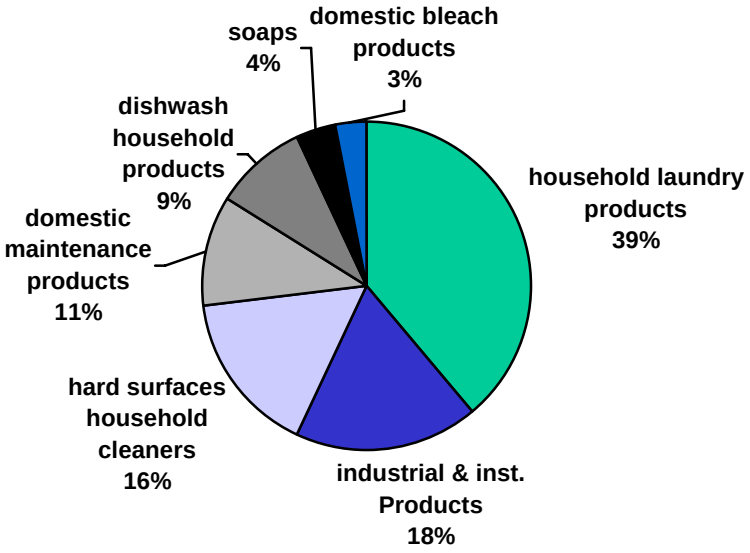


Figure 3-9: overview on market shares of cleaning products based on retail sales prices (1999)

The range of VOC containing cleaning products covers a wide spectrum of different products used in households as well as for commercial or institutional use. The VOC content of the product depends on the product type and form (solid or liquid), as well as the VOC function requirements. The following table gives an overview on important products:

product	average VOC content
All purpose cleaner	0-6%*
Glass cleaner	0-30%*
Bathroom cleaner	0-10%
WC cleaners	0-10%
Acidic cleaners	0-10%
Acidic cleaners (institutional use)	0-10%
Soap/floor cleaners	0-5%

Product	average VOC content
Abrasive cleaners	0-10%*
Furniture maintenance products	0-50%*
Carpet and upholstery cleaner	0-25%*
Shoe cream	70-80%*
Shoe emulsion liquid	5-40%*
Liquid detergents	0-15%
Clear rinse	15-30%

Table 3-12: examples for the average VOC content of selected cleaning products

The used VOC are emitted to air, to water and they can be found in wastes. Regarding air emissions applications with surface treatment are important, the corresponding products are marked with an asterisk in the table.

The following VOC are of major importance in cleaning products:

Glycols (butyl glycol, propylene glycol, dipropylene glycols)

Benzyl alcohol (general purpose cleaner)

Aliphatics (funiture polishes)

Ethanol, isopropyl alcohol, n-propyl alcohol

Phthalates

Methylethylketon

Petroleum ether

Butyl acetate

Fragrances (Terpene)

Acetic acid

3.4.2 Alternatives

Major alternatives to avoid or to reduce VOC in cleaning products are:

the following alternatives can be considered:

A) Alternative application products (Not-in-kind alternatives)

B) Reformulations/New formulations

Description of alternative application products

A possibility to avoid or to reduce VOC in cleaning products is to change the application form. In combination with mechanical devices (cloth, brush) a reduction of the use of VOC-cleaning products is also possible.

In the following table products with not-in-kind alternatives available on the market are listed

product	not-in-kind alternatives
Liquid detergent	Powder detergent, tablets
Liquid furniture maintenance products	paste form
washing-up liquid	Powder, tablets, paste form
Spot remover liquid	Powder, paste form

Table 3-13: examples for not-in-kind alternatives in the sector cleaning products

Description of the alternatives reformulations/new formulations:

A product reformulation typically consists of developing VOC-free products by modifying the chemical composition of the product. Reformulation also involves a substitution of VOC with less photochemically reactive compounds while maintaining the product's integrity

Possible Alternatives:

- Use of non-VOC or low-VOC solvents

  The most common alternative solvent is water.

- Avoidance or reduction of VOC-preservatives

  In some cleaners (e.g. all purpose cleaners) VOC are still used as preservatives although a high level of washing active substances has the same effect.

- Avoidance or substitution of VOC-fragrance (esp. terpenes)

- Substitution of VOCs with high ozone building potential (e.g. n-propyl alcohol with isopropyl alcohol, according to lit. x the potential of the latter is three times less than n-propyl alcohol)

Fragrances have no cleaning effect they are only responsible for the "good" odour of the product. Therefore an avoidance or substitution of VOC-fragrances does not affect the quality or function of the product.

The following products are typical examples with VOC-free or VOC-reduced alternatives available on the market.

Product	Alternatives
General purpose cleaner	VOC-free alternatives are available
Glass cleaner	VOC-free alternatives
Washing-up liquid	fragrance free liquids
Shoe cream	Low-VOC products are available
Liquid detergents	fragrance free products are available

Table 3-14: examples for reformulations/new formulations in the sector cleaning products

3.4.3 Assessment of not-in-kind alternatives

Technical consequences

A change of the application form can cause following problems:

- Alternative applications forms are not possible for all products
- Change from liquid products to solid (powder, tablets) can cause allergic reactions due to dust emissions

Ecological assessment

The results of a rough ecological assessment (screening) can be seen in Figure 3-10:

air	water	Waste
+	+	~

Figure 3-10: ecological assessment of not-in-kind alternatives in the cleaning sector (besides aerosols)

+ = *positive effects*

~ = *indifferent effects*

- = *negative effects*

Air: There is a clear ecological advantage regarding air emission as VOC emissions can be substitute or reduced by the use of e.g. water as solvent.

Water: Ecological advantage can be seen in a reduction of the contamination of rivers with VOC-loaded waste water.

Waste: In a first approach there are no consequences to waste.

Economic assessment

Typically no costs of abatement occur what defines a motivation for industry to minimize VOC contents.

3.4.4 Assessment of reformulations, new formulations

Technical consequences

Reformulations or the creation of new formulations are often restricted to the following problems:

- some components can not be dissolved in water
- possible reduction of shelf time without preservatives
- problems with building a two-phase liquid

Ecological assessment

Figure 3-11 summarises the results of a rough ecological assessment screening:

Air	water	waste
+	~	~

Figure 3-11: ecological assessment of reformulations/new formulations in the cleaning sector (besides aerosols)

+ = *positive effects*

~ = *indifferent effects*

- = *negative effects*

Air: There is a clear ecological advantage regarding air emission as VOC emissions due to VOC use in cleaning products can be substituted or reduced.

Water: In a first approach there are no consequences to water.

Waste: In a first approach there are no consequences to waste.

Economic assessment

According to industry the VOC content defines in many cases the price of cleaning products. Therefore a substitution or reduction of VOC typically lead to decrease of production cost.

Fragrances as ingredients may have an important influence on consumers choice of product and consequently on turnover of products.

3.4.5 Already existing legal restrictions

Following cosmetic products are affected by the strict California VOC regulations:

product	Max. allowed VOC content in California
Bathroom and tile cleaners	5%
Bug and Tar remover	40%
Carpet and upholstery cleaner Non-aerosols (dilutables) Non-aerosols (ready-to-use)	 0,1% 3%
Floor polishes/waxes -product for flexible flooring materials -products for nonresilient flooring -wood floor wax	 7% 10% 90%
Furniture maintenance products (except solid/paste form)	7%
General purpose cleaner	4% (2005)
General purpose degreaser	4% (2005)
Glass cleaner	6% (4% 2005)
Laundry prewash -aerosols/solids -all other forms	 22% 5%
Laundry starch products	5%
Metal polish/cleanser	30% (2005)
Multi-purpose lubricant (excluding solid or semisolid products)	50% (2003)
Oven cleaner (liquid)	8%
Paint Remover or Stripper	50% (2005)
Penetrant	50% (2003)
Spot remover	8%
Rubber and Vinyl protectant	3% (2003)

Table 3-15: examples for VOC limitation due to Californian legislation – cleaning products (besides aerosols)

3.5 Function of VOC: solvents in adhesives

Due to the high variability of materials and bonding requirements there are more than 250,000 adhesive formulations available on the world market. The production statistics of the Association of European Adhesives Manufacturers (Fédération Européenne des Industries de Colles et Adhésifs, FEICA) differentiate the following product groups (c.f. figure 3-12).

- Natural polymers,
- Polymer dispersions and emulsions,
- Hotmelt adhesives incl. moisture-cure types,
- Solvent based adhesives systems,
- Reactive (polymerising) systems,
- Adhesives based on water-soluble polymers, and
- Other adhesives.

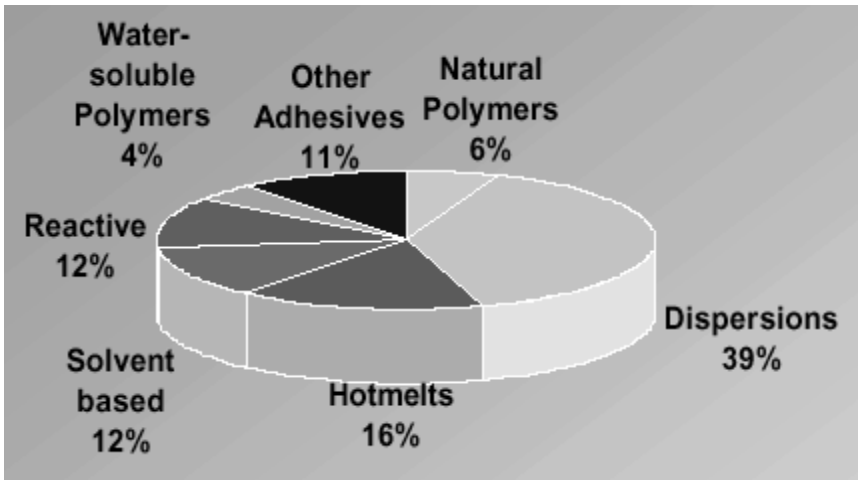


Figure 3-12: Sales quantity share for adhesives [FEICA 2000]

Furthermore, there is the important and itself highly diversified group of tapes and labels, which is not covered by the above statistic.

The chemical constituents of adhesives are binders, solvents, thinners, plasticizers, thickeners, fillers and preservatives. In addition to these constituents adhesives may contain anti-foaming agents, scents and dyes.

VOC in adhesives are almost exclusively used as solvents, thus their use for preservation, fragrance or antifreeze purposes is not regarded in this study. However, in some cases the VOC have a double function: e.g., in contrast to water-based adhesives, solvent-based adhesives can be used by freezing temperatures, so the solvent function comes along with an antifreeze function. This was not further distinguished in this study.

For the consideration of VOC emissions outside installations, solvent based adhesives are the most important product group. Their solvent content averages usually 30 - 60 %. Besides solvent based adhesives, dispersion adhesives can contain up to 10 % of organic solvents. The other adhesive types are regarded as solvent free.

The content of organic solvents in adhesives as solvent varies from 0 % (solvent free adhesives) to over 80 % (e.g. adhesives used in shoe repairing). Organic solvents used in adhesives include aromatic hydrocarbons (toluene, xylene), ketons (acetone), alcohols (methanol, ethanol, isopropanol, glycol, butanol), chlorinated hydrocarbons (methylene chloride), methylacetate, ethylacetate and mineral spirits in solvent form.

The use of chlorinated hydrocarbons as solvent is limited to very few applications in which other organic solvents or alternative adhesives cannot be applied. Due to their non-flammability they are especially used if explosion prevention is essential. The major application of adhesives based on chlorinated solvents is repair operations of band-conveyors in underground mining. Formerly they were also used for bonding of foams and upholstery, where they meanwhile have been replaced by alternative adhesives such as solvent free hot-melts. Due to their very restricted use for very special applications and the fact that there are no alternatives, adhesives containing chlorinated hydrocarbons are not farther considered.

3.5.1 Differentiation of function in products

In the manufacture of adhesives solvents are used to dissolve or dilute the filmforming constituents. Organic solvents in adhesives are used to resolve the adhesive polymers in form of a low-viscous solution. A low-viscosity is essential to ensure a sufficient wetting and penetration of material surfaces. Adhesives mostly contain not only one but a mixture of different solvents. Solvent based adhesives are often used for high performance applications when e.g.

- a high resistance against climatic conditions,
- a short processing time, or
- a high mechanical resistance in combination with great flexibility

are needed. Usually solvents do not take part in chemical reactions but are evaporated during drying or setting.

The requirements for bonding are specific for each application. The applications are in turn characteristic for certain industries. Therefore, the use of solvent based adhesives has been grouped according to major industry sectors and typical applications. In table 3-16, only sectors and important applications of solvent based adhesives outside installations are listed.

Sector	**Building, construction, civil engineering**	**Woodworking, joinery**	**Footwear and leather**	**Consumer/ Do It Yourself**	**Assembly operations**
Applications for solvent based adhesives	roofing, insulation, ceiling tiles, stud and frames, plywood floors and other floor coverings	Bonding of varnished surfaces, bonding of cushions, bonding of PVC-foils onto profiles and furniture	sole assembly, sole-fitting	bonding of wood, paper, board, rubber, synthetic materials like PVC with contact cements	electrical / electronic fabric / textiles sport equipment other

Table 3-16: Applications of solvent based adhesives outside installations

3.5.2 Alternatives

Due to the high diversification of bonding applications there is no universally applicable alternative for solvent based adhesives. For the assessment of the VOC substitution potential, each particular joining application has to be regarded. Principally, the following alternatives can be used for solvent based adhesives:

- Hot-melt adhesives
- Dispersion adhesives
- High-solid-adhesives
- Chemical reacting adhesives
- Pressure sensitive adhesives
- Not-in-kind-alternatives like mechanical fortification

Hot-melt adhesives

The hardening of hot-melt (heat setting) adhesives occurs after heat impact. The hardening temperatures vary between 100 – 250°C. Hot melt adhesives are thermoplastic. For the

application of these adhesives special application devices are necessary. Heat-setting materials are for example based on polyester, polyamide or polyolefines. Hot-melts are solvent free.

Dispersion adhesives

Dispersion cements consist of dissolved polymers and are 1-component materials. Polymers are liquefied (dissolved or dispersed) in water. Dispersions are water based but can contain small amounts of organic solvents (1- 10 %).

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Chemical reacting adhesives

Curing of chemical reacting adhesives occurs due to chemical reaction of different components. Chemical reacting adhesives are solvent free.

High-solid adhesives

High-solid adhesives have a solids content of more than 60 %. Depending on their composition, they can contain up to 40 % organic solvents. Thus, in comparison to an adhesive with a solvent content of 60 - 80 %, they count as solvent reduced.

Pressure sensitive adhesives

Pressure sensitive adhesives are used for the production of tapes in installations and may be solvent based. Very small portions of organic solvents (0.1 - 2 %) may remain in the adhesive layer as softeners. Thus the use of tapes does not cause noteworthy VOC-emissions. In the following fortification by tapes is discussed as not-in-kind-alternative.

Not-in-kind-alternatives like mechanical fortification

For some applications, mechanical fixation can be considered as an advantageous joining technique, e.g. with respect to material recycling. In some sectors however, especially in the automotive industry, other assembly technologies like welding are itself increasingly replaced by bonding, along with the trend of reducing metal components with light composite materials. As in the latter case mainly hot melts are mainly used [Hume 2001], there is no influence on VOC consumption.

The possibilities of substitution can be classified according to their harmfulness as presented in the figure 3-13.

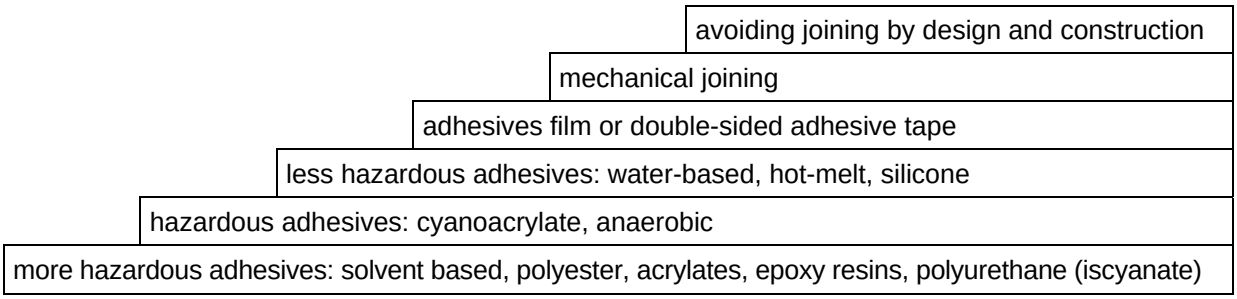

Figure 3-13: Bonding with levels of hazards [Soerensen 1998]

In the following, for each sector and its main applications an overview of the commonly used solvent based adhesives and the possible alternatives is given in form of tables.

Application	Solvent based adhesives	Alternatives	Not-in-kind alternatives
roofing	asphalt, neoprene,	asphalt hot-melt, dispersions, reactive adhesives	mechanical fortification
glass fiber and rock wool insulation, other insulation	asphalt (for polystyrol-insulation), neoprene, acrylic	reactive adhesives like moisture curing cements (for polystyrol), dispersions: polyvinylacetat	mechanical fortification
ceiling tiles	acrylate	reactive adhesives: rosin	./.
Plywood floors	caoutchuk polyurethane	dispersions, reactive adhesives	./.
Elastomer-floor covering with or without layer of foam plastics	Neoprene caoutchuk	1- and 2-component-dispersions	Laying without adhesive application
Elastomer-floor covering with structured surface and grinded, plain reverse	neoprene, caoutchuk	1- and 2-component-dispersion-adhesives and reactive adhesives: Epoxy-resins etc.	./.
Elastomer-floor covering for profiles, stairs	neoprene, cautchouk	dispersions	mechanical fixation: Double sided tapes
Cork with PVC layer	caoutchuk and neoprene	dispersions	./.
Pressed cork	caoutchuk and neoprene	dispersions	./.
Laminate	caoutchuk	reacting adhesives (1-or 2 component Polyurethane)	./.
Linoleum	caoutchuk and neoprene	dispersions and adhesives based on cement	./.
Carpet	neoprene	dispersions, reacting adhesives (polyurethane, epoxy resins), starch adhesives	mechanical fixation: Double sided tapes

Table 3-17: Alternatives overview for VOC containing adhesives used in the sector "Building, construction, civil engineering"

Parquet		Swelling capacity		
Lamination	**Type**	**low (e.g. Oak)**	**medium (e.g. birch, ash)**	**high (e.g. beech, marple)**
Single layer, solid, untreated	Rods	D	D	./.
	Plate, panels	D, R, S	D, R, S	./.
	Mosaic	D	D	D
	Lamella (on edge)	D	D	D
	10 mm solid parquet	D, R, S	D, R, S	D, R, S
Single layer, solid, treated	Small format	D, R, S	R, S	R, S
	Large size	R	R	R
Multiple layer, untreated	Two-layer	D	D	D
	Inlay-parquet	D, R, S	D, R, S	D, R, S
Multiple layer, treated	Two-layer, rods	D	D	D
	Two-layer, plates	R, S	R, S	R, S
	Triplex-parquet	D, R, S	./.	./.
S: Solvent based adhesive D: Dispersion R: reactive adhesive (e.g. polyurethane)				

Table 3-18: Alternatives overview for VOC containing adhesives used for parquet

Application	Solvent based adhesives	Alternatives
Bonding of varnished surfaces, metal, glass etc.	PVC	Dispersions
Bonding of wood leather, textiles etc.	Cellulose nitrate	Reactive adhesives
Bonding of leather, textiles, glass, metals, foam, felt etc.	Caoutchouc	Dispersions
Bonding of rubber, plastics, felt etc.	Neoprene	Dispersions, reactive adhesives
Bonding of PVC-foils on profiles and furniture	Polyurethane	Hot-melt
Upholstery	Styrol-Caoutchouc	Hot-melt, High Solid, Dispersion

Table 3-19: Alternatives overview for VOC containing adhesives used in the sector "Woodworking and joinery"

Application	Solvent based adhesives	Alternatives
Shoe upper assembly	Neoprene, Polyurethane	Dispersions, Hotmelt
Sole assembly	Contact cement, Neoprene, Polyurethane	High –solid-adhesives
Sole-fitting	Contact cement, Neoprene, Polyurethane	./.
Leather goods	Contact cement, Neoprene, Polyurethane	Dispersions, Hotmelt, High – solid-adhesives

Table 3-20: Alternatives overview for VOC containing adhesives used in the sector "Footwear and leather"

Application	Solvent based adhesives	Alternatives
Multi-purpose and contact adhesives	For e.g. polyurethane, neoprene, caoutchouc	Dispersions, reactive adhesives
Adhesives for wood	Polyurethane etc.	Reactive adhesives, dispersions
Adhesives for Paper and board	e.g. Neoprene, polyurethane etc.	Reactive adhesives e.g. Methaacrylate, epoxide resins, Dispersions e.g. acrylate, polyvinyl acetate Glue sticks: wax, dextrin Hotmelt
Adhesives for modelling and synthetic materials	e.g. Neoprene, polyurethane, nitro cellulose etc.	Instant adhesive e.g. Cyanacrylate Hotmelts e.g.: caoutchouc Reactive adhesives e.g. Methaacrylate etc.

Table 3-21: Alternatives overview for VOC containing adhesives used in the sector "Consumer and Do It Yourself"

Application	Solvent based adhesives	Alternatives
Electrical / electronic	various	Reactive adhesives: Epoxy resins, silicons, Cyanacrylates, hot-melt adhesives etc.
Fabric / textiles	various	Reactive adhesives: Epoxy resins, silicons, Cyanacrylates etc.
Sport equipment	Neoprene, polyurethane, caoutchouk etc.	Reactive adhesives: Epoxy resins, silicons, Cyanacrylates, hot-melt adhesives etc.
Toys	Neoprene, polyurethane, caoutchouk etc.	Reactive adhesives: Epoxy resins, silicons, Cyanacrylates, hot-melt adhesives etc.

Table 3-22: Alternatives overview for VOC containing adhesives used in the sector "Assembly operations"

3.5.3 Assessment of technical consequences

The general technical characteristics of the discussed alternative adhesives are listed below. For some applications also double-sided tapes or a mechanical fixation can be used instead of solvent-based adhesives. Depending on the application, these techniques may have an adverse impact on the bonding thus restricting their use. For many applications adhesives must also be technically compatible with coatings and sealants. When coatings must be applied over an adhesive, or the adhesive must adhere to a coated surface, adhesives cannot be regarded independently.

Hot-melt adhesives

- Special application devices are necessary
- Product has low cohesion
- Thermoplastic, except reactive-hot-melts
- Materials have to tolerate heat impact
- Applicable only for specific material combinations

Dispersion adhesives

- Require longer drying time
- Low resistance against water and heat
- Lower cohesion and adhesion compared to solvent based adhesives
- Applicable only for specific material combinations
- At least one material has to be absorbent
- Not applicable and storable in cold temperatures
- Can contain hazardous substances as preservatives (such as formaldehyde) and softeners
- Lower risk of inflammability

Chemical reacting adhesives

- Limited pot life
- More difficult to apply
- For moisture curing adhesives, curing time depends on humidity
- Can contain hazardous softeners

High-solid adhesives

- Lower penetration of absorbent surfaces
- Stronger layer thickness and higher material consumption
- More difficult to apply

Mechanical fixation

- Higher expenditure of human labour
- Limited to very few applications

Tape fixation

- Lower bonding strength
- Limited to very few applications

In the following, the specific technical characteristics of the alternatives limiting their use are given for each application. The applications are grouped according to the sectors (in bold letters).

Application	Alternative	Technical limitations
Construction: Roofing	Asphalt hot-melt	Limited variety of materials Emission of hazardous substances such as aromatic hydrocarbons or flame retardants
	Dispersion adhesives	Limited variety of materials Applicable only for specific temperature- and humidity conditions
	Reactive adhesives	Limited variety of materials Difficult application
Construction: Ceiling tiles, stud and framing	Reactive adhesives	Emission of hazardous substances such as softeners Difficult application
Construction: Parquet floor covering	Water based dispersions	Can cause unevenness and other irregularities due to the swelling capacity of the used wood Precise pre-treatment is necessary

Application	Alternative	Technical limitations
		Complete curing can take up to 7 days
Construction: Carpet floor covering	Water based dispersions	Can be used for most applications
	Mechanical fixation, double sided tapes	Easily removable
Construction: Cork, elastomer, linoleum, laminate floor covering	Water based dispersions	Curing can last significantly longer
	Reacting adhesives	When 2-component reactive adhesives are applied the pot life is very limited, application has to be carried out very precise and mixing ratio has to be kept exactly
Footwear and leather	Water based dispersions	Limited variety of materials Low initial bonding strength causes problems due to restoring force of materials After adhesive application parts have to be joined immediately Dryers are necessary, even though curing takes up to 40 minutes longer
	Reactive hot-melt adhesives	Limited variety of materials Special application devices necessary
Consumer and Do-It-Yourself	Water based dispersions	Limited variety of materials lower bonding strength, not applicable in cold temperatures or in high humidity low heat resistance curing takes longer
	Hot-melt adhesives	Limited variety of materials Special application devices necessary
	Reactive adhesives	Difficult application Hazardous softeners

Table 3-23: Technical consequences of alternatives for different applications

Generally, when using alternatives, the performance and functionality of solvent based adhesives cannot always be achieved. Furthermore, a more careful pre-treatment of surfaces is often necessary. With water based alternatives, there is a greater risk of mould in storage tanks and containers requiring biocides or stabilisers. On the other hand, bonding with adhesives makes repair and recycling of items and materials difficult.

3.5.4 Assessment of ecological consequences

For the assessment of the ecological consequences only the impact during or after product application is regarded, not taking into account the production process or the whole supply chain. Within this system boundaries, the possible alternatives are not unambiguous with respect to their environmental impact. The overall ecological assessment for alternative adhesive systems as well as not-in-kind alternatives is summarised in table 3-24.

alternative adhesives			
air	**water**	**waste**	**risk**
++ (-)	~	~	+ (-)
not-in-kind alternatives			
air	**water**	**waste**	**risk**
++	~	~	++

Table 3-24: Ecological consequences of alternative adhesives and not-in-kind alternatives

\+ = *positive effects*

~ = *indifferent effects*

\- = *negative effects*

Air: In general, alternative products show an ecological advantage regarding air emissions due to their reduced VOC content. On the other hand, due to the slower drying of water based dispersions, dryers are used for some applications and may cause emissions of greenhouse gases. The use of dryers also increases energy consumption, as do the heating devices for the application of hot-melt adhesives. In some cases, solvent free adhesives contain high-boiling organic substances as softeners and/or preservatives. These are not considered as VOC as they volatilise in small amounts over a long period, but they also represent a potential hazard for environment and health. Only the not-in-kind alternatives like mechanical fixation or double-sided tapes show a clear environmental advantage, as they do not evoke any (mechanical fixation) or only negligible (tapes) emissions.

Water: In a first approach there are no consequences to water.

Waste: In a first approach there are no consequences to waste.

Risk: Softeners and preservatives in alternative adhesives constitute a health risk, as well as the biocides which may be used. Additionally, alternative adhesives may contain allergens, e.g. balm resins used for floor coverings.

3.5.5 Assessment of economic consequences

The application of water based adhesives may raise costs due to the longer drying time and/or the investment in drying devises. Also alternative adhesives may raise costs due to different workflows, specific application devices (e.g. for hot-melt adhesives), higher efforts for pre-treatment, or higher material costs (e.g. for 2-component adhesives). In some cases, the use of alternatives is associated with significantly higher investments or processing costs. Mechanical fixation may require a higher expenditure of human labour and can only be used for very few specific applications.

While these examples indicate possible higher costs for the use of alternatives, a general statement concerning economic consequences is not possible because of the wide range of products .

3.5.6 Already existing legal restrictions

Related to adhesives, there are several regulations and eco-labels restricting the use of solvent based adhesives or their VOC content. In this context, it has to be pointed out that the definition for "VOC" as well as for "VOC content" is different in the described regulations. VOC are defined either by their steam pressure, their boiling point, other chemical specifications, or by listing specific substances. Also, in some cases there are exceptions from the general definition. Therefore, an immediate comparison of the limit values for VOC is not possible.

Regulation	steam pressure	boiling point	other specification	exceptions
EU Solvent Directive (99/13)	> 10 Pa			
TRGS 610 (Germany)		< 200 °C	X	
Ordinance for an Directing Impost on Volatile Organic Compounds (Switzerland)	> 10 Pa	< 240 °C		
Regulation for Reducing Volatile Organic Compound Emissions from Consumer Products (California)			X	list of substances
Rule 1168 Adhesive and Sealant Applications (Californian South Coast, S.C.A.Q.M.D)			X	list of substances
Nordic Ecolabel		< 210 °C		

Table 3-25: Definitions of VOC in different regulations

In the following, examples for existing regulations and labels concerning VOC in adhesives in Europe and America are described, not regarding regulations concerning the use of VOC containing products in installations covered by the Directive 99/13/EC.

Germany

Ordinance for the Protection against Harmful Substances (GefStoffV)

In this ordinance the production of and handling with substances which are particularly harmful for man's health and safety at work are regulated. This includes a general substitution rule for hazardous substances. Among other chemicals, there are several substances classified as VOC. Specific security regulations for the treatment of indoor surfaces include explicitly bonding applications as well.

Technical Rule for Harmful Substances 610 (Technische Regeln für Gefahrstoffe TRGS 610)

With the TRGS 610 "Substitute Materials and Processes for Primer and Adhesives with a high Solvent Content for Flooring", solvent based primer and adhesives for floor covering shall be minimised by using water based dispersions. Apart from very few exceptions the use of water based products is recommended under ecological, economical and health aspects. For professional applications, the employer is responsible for the good housekeeping of solvent based products.

GISCODE/ EMI-CODE

The labels according GISCODE/EMI-CODE to are voluntary and mostly used within the construction trade and related fields. The code labels are based on the composition of the products and indicate possible less hazardous products for substitution and which protective action is recommended during application, respectively.

For flooring materials, there are several main GISCODE groups with sub-classifications (c.f. table 3-26).

D1	Dispersion based, free of solvents
D2	Dispersion based, low solvent contents, free of aromatics
D3	Dispersion based, low solvent contents, free of toluene
D4	Dispersion based, low solvent contents, containing toluene
D5	Dispersion based, containing solvents, free of aromatics

D6	Dispersion based, containing solvents, free of toluene
D7	Dispersion based, containing solvents, containing toluene
S1	Solvent based, free of aromatics and methanol
S2	Solvent based, free of toluene and methanol
S3	Solvent based, free of toluene
S4	Solvent based, free of methanol
S5	Solvent based, free of toluene but containing methanol
S6	Solvent based, containing aromatics
RE0	Epoxy resin based
RE1	Epoxy resin based, solvent free, sensitising
RE2	Epoxy resin based, low solvent content, sensitising
RE2.5	Epoxy resin based, solvent based
RE3	Epoxy resin based, solvent based, sensitising
RU1	Polyurethane based, free of solvents
RU2	Polyurethane based, low solvent contents
RU3	Polyurethane based, containing solvents
RU4	Polyurethane, solvent based
ZP1	Containing cement, low chromate content
ZP2	Containing cement, containing chromate
CP1	Filler, based on calcium sulphate

Table 3-26: GISCODE classifications for flooring materials [Berufsgenossenschaften der Bauwirtschaft 2001]

The product classification system EMICODE was developed to enable planners, consumers and craftsmen to evaluate and select environmentally friendly floor covering materials. The EMICODE system is based on precisely defined chamber testing procedures and strict classification criteria. The EMICODE sign signifies that products were emission tested and classifies them into three classes:

EMICODE EC 1: „very low-emission“

EMICODE EC 2: „low-emission“

EMICODE EC 3: „not low-emission “

EMICODE controlled flooring installations are principally manufactured without the use of solvents.

Denmark

MAL code

In Denmark a code system (called MAL-codes) for labelling products has been established. For certain open applications of chemical products, the MAL code is compulsory for any supplier. This concerns among others adhesives.

The code numbers are determined from a list of values for chemicals or substances given by the Danish Working Environment Authority. The MAL code consists of two digits, one of them indicating the minimum safety precautions which should be taken against inhalation, the other against contact or ingestion. Danish authorities published tables with necessary control measures or even with prohibition to use certain products for some applications (especially indoors).

According to their content in percent, VOC contribute to the determination of the code number by a certain factor, which is laid down from the Threshold Limit Values with respect to the evaporation rate and the vapour pressure of the substance.

As for the user it is much easier to compare the code numbers of two products than two Material Safety Data Sheets, the system function developed to an important competition parameter in the market.

List of Undesirable substances

The Danish advisory list of chemicals "List of Undesirable substances" contains 68 chemicals or groups of chemicals whose use should be reduced or stopped in the long term. They have been selected because of their effects on health and the environment, and because of the quantities in which they are used. The list also comprises some substances which may be used as solvents in adhesives and which are mentioned because of their carcinogenic potential.

Netherlands

Regulation for Substitution of VOC-rich Paints and Glues for Indoor Printing and Carpet Laying

According to this regulation, only waterborne paints and glues may be used. Comparable regulations are under preparation for several other branches, e.g. wood and furniture.

Austria

Regulation for prohibitions and restrictions of organic solvents (Lösungsmittelverordnung 1995)

The use of chlorinated VOCs and Benzene in adhesives is prohibited (with some technical exemptions). The share of aromatic solvents is limited with 15% for contact-adhesives and 5% for all others for private use and only allowed for industrial use if it can be proved that technical needs are given. Special allowance of the authorities is necessary. After each two years a review process of the technical need to use adhesives with more than 5% (resp. 15%) aromatic compounds is necessary. There is no general limitation of VOCs in adhesives.

Northern European Countries

Nordic Ecolabel

The applies to adhesive products for hobby and leisure activities, office work, craft professions and for building. The total amount of environmentally hazardous substances in the adhesive shall not exceed 2 %. Adhesive products, with the exception of wallpaper paste, shall not contain more than 1 % of organic solvents. Wallpaper paste shall not contain organic solvents at all. The testing methods for different types of adhesives are specified.

Switzerland

Ordinance for a Steering Impost on Volatile Organic Compounds (Lenkungsabgabe)

All VOC and all VOC in products as specified in the annexes of the ordinance are subject to an impost per kg VOC. Adhesives are explicitly mentioned in annex II. Actually, the impost rate is 2 SFR/kg VOC and will increase to 3 SFR/kg VOC, effective from January 1, 2003.

United States of America

Green Seal

This environmental standard establishes environmental standard commercially used adhesives. The labelling requirements define specific VOC contents depending on adhesive type or application, respectively (c.f. Table 3-27: Product requirements concerning organic solvents for the Green Seal Label

).

Adhesive Type	VOC weight in grams/liter minus water
ABS Welding	400
Carpet Pad Installation	150
Ceramic Tile Installation	130
Contact Bond	250
Contact Bond-Specialty Substrates	400
Cove Base Installation	150
CPVC Welding	490
Indoor Floor Covering Installation	150
Multipurpose Construction	200
Nonmembrane Roof Installation/Repair	300
Other Plastic Cement Welding	510
Outdoor Floor Covering Installation	250
PVC Welding	510
Rubber Floor Installation	150
Single-Ply Roof Membrane Installation/Repair	250
Structural Glazing	100
Perimeter Bonded Sheet Vinyl Flooring Installation	660
Waterproof Resorcinol Glue	170
Wood Flooring Adhesive	150
Adhesives Application Onto Substrate	**VOC weight in grams/liter minus water**
Flexible vinyl	250
Fiberglass	200
Metal-to-Metal	30
Porous material	120
Plastic Foams	120
Rubber	250
Other substrates	250
Aerosol Adhesives	**VOC weight in grams/liter minus water**
General purpose mist spray	65% VOCs by weight
General purpose web spray	55% VOCs by weight
Special purpose aerosol adhesives (all types)	70% VOCs by weight

Table 3-27: Product requirements concerning organic solvents for the Green Seal Label

California (USA)

Regulation for Reducing Volatile Organic Compound Emissions from Consumer Products

In the regulation, for different consumer products a maximum allowed VOC content is determined. For the interpretation of the Californian limits, the different definition of VOC, the exact definitions for the adhesive classes, as well as additional requirements and exceptions which are not listed here have to be taken into account.

Product	Max. allowed VOC content
Aerosol adhesives	75 %
mist spray adhesives	65 % (2002)
web spray adhesives	55 % (2002)
special purpose spray adhesives	60-70 % (2002)
construction, panel, and floor covering	40 % (15 % in 2003)
contact adhesives	80 %
general purpose adhesives **	10 %

* "Special Purpose Spray Adhesive" means
(A) Mounting adhesive for artwork etc.
(B) Flexible vinyl adhesive
(C) Polystyrene Foam Adhesive
(D) Automobile Headliner Adhesive
(E) Polyolefin Adhesive
(F) Laminate Repair/Edgebanding Adhesive
(G) Automotive Engine Compartment Adhesive

** "General Purpose Adhesive" does not include
(A) contact adhesives,
(B) construction, panel, and floor covering adhesives,
(C) adhesives designed exclusively for application on one specific category of substrates (i.e., substrates that are composed of similar materials, such as different types of metals, paper products, ceramics, plastics, rubbers, or vinyl),
(D) adhesives designed exclusively for use on one specific category of articles (i.e., articles that may be composed of different materials but perform a specific function, such as gaskets, automotive trim, weather-stripping, or carpets).

Table 3-28: Maximum allowed VOC content of adhesives in California

South Coast Air Quality Management District (S.C.A.Q.M.D.; USA)

There are local regulations in various districts of the Californian south coast. As a further example, the Rule 1168 of the S.C.A.Q.M.D. is given.

Rule 1168 Adhesive and Sealant Applications

In this rule, a VOC limit for adhesives is specified for defined bonding applications. This corresponds to the conclusion of this study that each bonding application has to be regarded separately to assess possibilities of reducing VOC in adhesives.

As a general limit, a VOC content of 250 g/l (less water and less exempt compounds) for adhesives, adhesive bonding primers, adhesive primers, or other primers, is fixed.

Application	Current VOC Limit* [g/l]	VOC Limit* Effective 1-1-03
Architectural Applications		
Indoor Carpet Adhesives	50	./.
Carpet Pad Adhesives	50	./.
Outdoor Carpet Adhesives	150	./.
Wood Flooring Adhesive	100	./.
Rubber Floor Adhesives	60	./.
Subfloor Adhesives	50	./.
Ceramic Tile Adhesives	65	./.
VCT and Asphalt Tile Adhesives	50	./.
Dry Wall and Panel Adhesives	50	./.
Cove Base Adhesives	50	./.
Multipurpose Construction Adhesives	70	./.
Structural Glazing Adhesives	100	./.
Single Ply Roof Membrane Adhesives	250	./.
Specialty Applications		
PVC Welding	510	285
CPVC Welding	490	270
ABS Welding	400	400
Plastic Cement Welding	350	250
Adhesive Primer for Plastic	650	250
Computer Diskette Manufacturing	350	350
Contact Adhesive	250	80
Special Purpose Contact Adhesive	250	250
Tire Retread	100	100
Adhesive Primer for Traffic Marking Tape	150	150
Structural Wood Member Adhesive	140	140
Sheet Applied Rubber Lining Operations	850	850
Substrate Specific Applications		
Metal to Metal	30	./.
Plastic Foams	50	./.
Porous Material (except wood)	50	./.
Wood	30	./.
Fiberglass	80	./.
* VOC Limit, Less Water and Less Exempt Compounds in Grams per Liter. If an adhesive is used to bond dissimilar substrates together the adhesive with the highest VOC content shall be allowed.		

Table 3-29: Maximum allowed VOC content of adhesives in the South Coast Air Quality Management District

Canada

EcoLogo[M]

To get the label, adhesives must not contain aromatic or halogenated solvents at all. The overall VOC content is limited to 5 % by weight.

4 Scenarios

4.1 Concept and methodology

The concept to be developed has to answer the following key questions

1. What would happen to VOC-containing products up to 2010 if no additional legislation is implemented?

   The answers to this question are part of a decision basis for new legislation.

2. What are the beneficial and suppressing factors for achieving reduction possibilities?

   The answers to this question indicate efforts and obstacles of a future legislation and therefore can be again seen as part of a decision basis.

3. How can reduction potentials be characterized?

   The answers to this question allow comparing different categories of VOC-containing products.

4.1.1 How to calculate a business as usual scenario?

Basis for the "business as usual results" are data for the use of VOC as they have been calculated in chapter 2. These data have been aggregated in a first step.

In a second step the relevant markets in which the VOC containing products are sold were analysed on their growth potential. Point of view is the growth of amounts and not the growth of prices or turn over. Interview results and estimations of market participants were put together with an analysis of the market development for the period 1990 – 2000.

In a third step the possibilities to reduce VOC were taken into consideration with a special focus on economic key figures. It was discussed with participants which share of reduction possibilities might be realised until 2010 without further legislative pressure.

In a last step the range in which the business as usual values can be expected for 2010 is calculated by summarizing the various uncertainties.

4.1.2 How to find beneficial and suppression factors for the achievement of reduction possibilities?

Beneficial and suppression factors towards reduction possibilities are correlated to technical, ecological and economic consequences - however, they are not identical. Beneficial and suppression factors can be seen as indicators for the interests of involved parties and therefore they are subjective statements. Nevertheless, they are important because arguments in the political discussion are sometimes constructed on the basis of beneficial and suppression factors.

The project team had a lot of discussions with involved parties and therefore collected the views of discussion partners. In chapter 4.3 the factors are documented without any claim to completeness.

4.1.3 How to calculate and characterize reduction potentials?

"Reduction potentials" are often interpreted in a way that a regulatory approach is able to achieve the stated amounts. In this sense reduction possibilities that will be implemented by the industry without regulatory pressure are not counted within reduction potentials.

One basis for the calculation of reduction potentials is available with the results on reduction possibilities of chapter 3. Additionally the results of the business as usual scenarios have to be taken into consideration (chapter 4.2). With these two elements the reduction potential is defined. However, to serve as a decision base the reduction potential has to be characterised. For this purpose the results of the assessment of reduction possibilities (chapter 3) and the results of the beneficial and suppression factors are used. This leads to a differentiation of the reduction potentials.

The project team suggests introducing three categories:

I achievable; advantages and disadvantages have to be compared in detail

II possibly achievable; high efforts and disadvantages in some areas might occur

III very difficult to achieve; significant efforts and disadvantages have to be expected

The wording behind this characterization might have a preliminary and negative tone. The reason is that a detailed analysis of advantages and disadvantages needs a certain amount of time and is not feasible within a short scaled screening study. On the other hand, the involved parties are typically big companies or associations being comparatively fast to bring arguments and suppression factors against reduction possibilities. In a more detailed analysis with a longer

research period it is more realistic to detect further advantages that are not obvious in a first approach in a field with several 100,000 different products.

4.2 Business as usual scenario

4.2.1 Cosmetics

The European cosmetics industry reached a turn over of about 49.4 billion € in 2000 [COLIPA 2000]. With this turn over a use of about 220 kt VOC is correlated. This use of VOC is nearly equal to VOC emissions resulting to air.

Most important VOC emitters are hair products (~ 80 kt) and deodorants/pre- and aftershaves (~80 kt).

Regarding consumption amounts the market for cosmetics is relative highly saturated in the EU member states. However, in this industry single market segments can easily alternate due to stylish trends.

The total growth of amounts is expected to be about 10% of the present volumes up to 2010. On the other hand industry activities to bring new products and new formulations on the market may lead to a VOC reduction of up to 10% of the present volume. This will especially take place in the sector deodorants in which alternatives with lower VOC content have been developed in the last years. Combining these two factors it can be expected as a business as usual scenario to find in 2010 nearly the same amount of VOC as in 2000.

In this way the following calculation can be set up:

~220 kt	x	1,1	x	0,9	~	220 kt
present emission		growth factor		reduction due to industry activity		

The overall results for cosmetics are documented in the following chart:

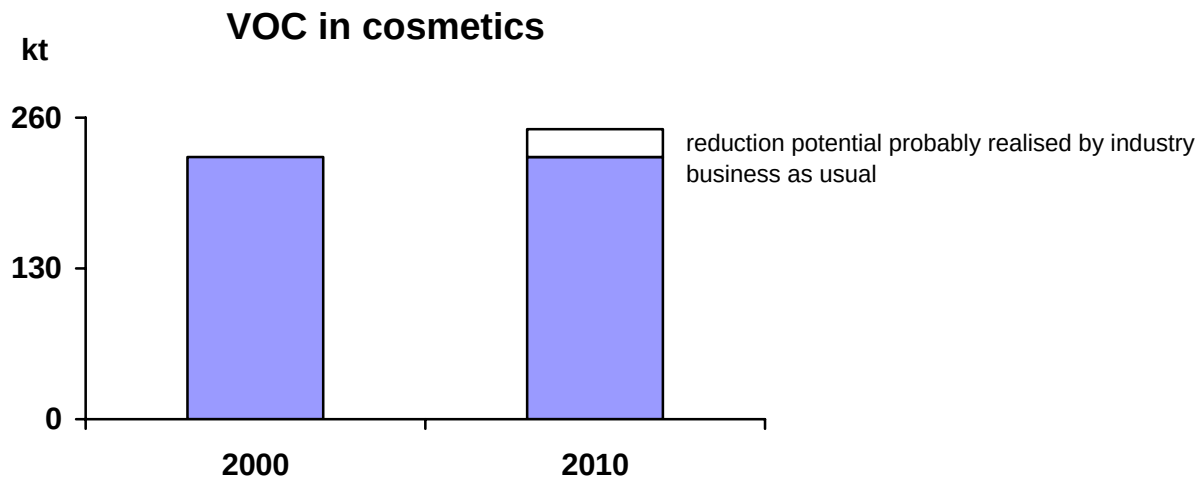

Figure 4-1: business as usual – VOC in cosmetics

These results can be divided following the function of VOC

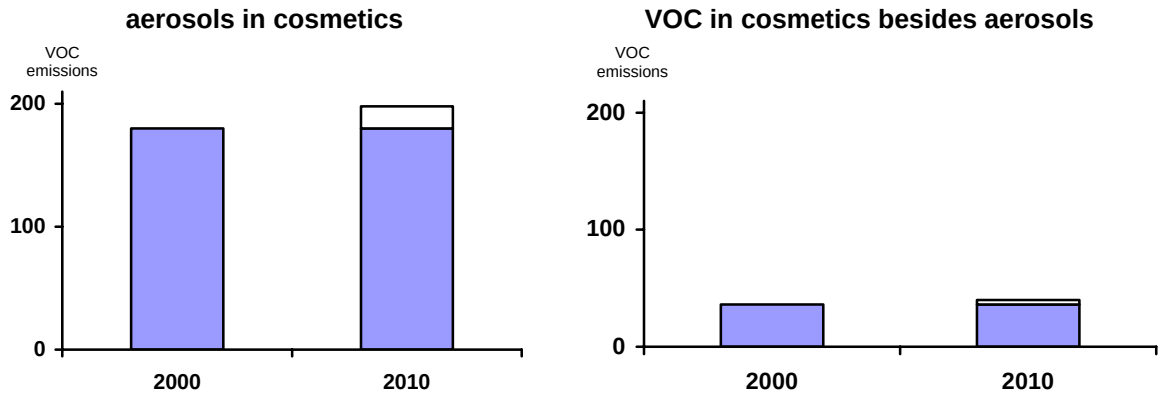

Figure 4-2: business as usual – differentiation of cosmetics

4.2.2 Cleaning

The European cleaning industry shows a turn over of about 24,5 billion € [A.I.S.E. 2000]. With this turn over a use of about 600 kt VOC is correlated. From these 600 kt only about 170 kt lead to air emissions in applications not regulated under directive 1999/13/EC. For these emission the following products are important examples:

Product	average VOC content
All purpose cleaner	0-6%*
Glass cleaner	0-30%*
Bathroom cleaner	0-10%
WC cleaners	0-10%
Acidic cleaners	0-10%
Acidic cleaners (institutional use)	0-10%
Soap/floor cleaners	0-5%

product	average VOC content
Abrasive cleaners	0-10%*
Furniture maintenance products	0-50%*
Carpet and upholstery cleaner	0-25%*
Shoe cream	70-80%*
Shoe emulsion liquid	5-40%*
Liquid detergents	0-15%
Clear rinse	15-30%

Table 4-1: Important cleaning products containing VOC

Regarding consumption amounts the market for cleaning products is relatively high saturated in the EU member states.

The total growth of amounts is expected to be below 10% of the present volumes up to 2010. Alternatives to cleaning products with less or no VOC typically lead to lower production costs and can increase profits. Therefore it can be expected that with ongoing research and substitution mechanisms about 20% of VOC reduction can be achieved without regulatory approaches.

In this way the following calculation can be set up:

170 kt	x	1,1	x	0,8	~ 150 kt
present emission		growth factor		reduction due to industry activity	

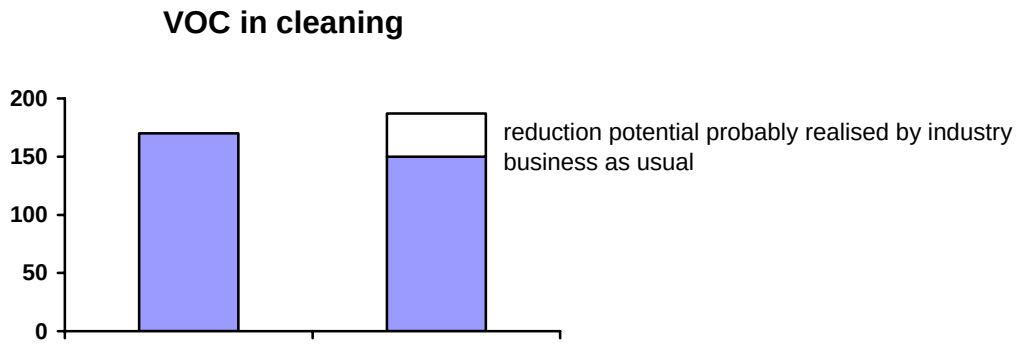

Figure 4-3: business as usual – VOC in cleaning

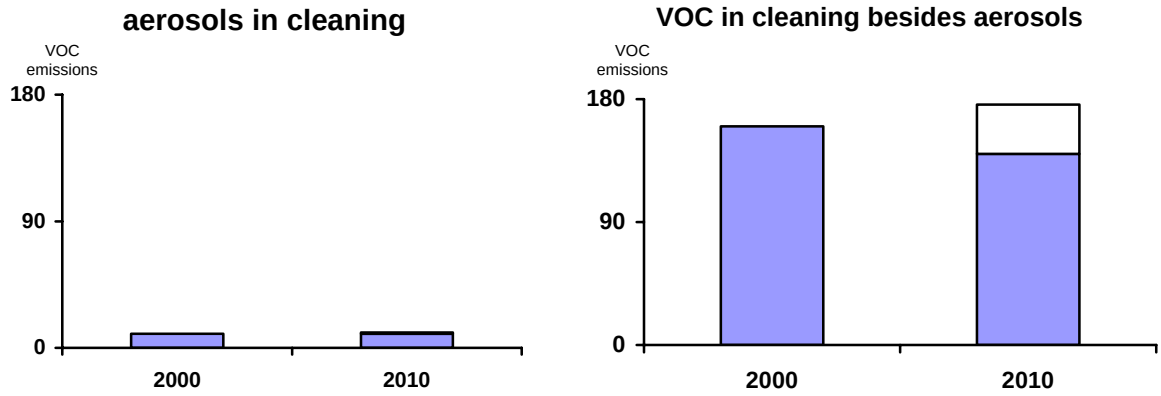

Figure 4-4: business as usual – differentiation of cleaning

4.2.3 Adhesives

In chapter 2.2.4, the total use of solvent based adhesives was estimated at 420 kt/a. Together with the use of dispersions and primer the solvent input due to solvent-relevant adhesive applications was calculated at 200 kt/a. Regarding solely the use outside installations (share not covered by Directive 99/13/EC) results in a maximum consumption of solvent based adhesives of 220 kt/a, corresponding to a solvent input of 80 kt/a. Taking into account the use of dispersion adhesives and primer, the solvent input for adhesives outside installations amounts to about 100 kt/a.

Over the past years, the production of solvent based adhesives has been continually declining by 2 % per year, together with the development and use of alternative gluing systems [FEICA 2000; Hume 2001]. Under the assumption that this trend is ongoing for the next decade, this will

lead to a consumption of solvent based adhesives of about 180 kt/a with a solvent input of 65 kt/a in 2010. Together with the solvents used for dispersions and primer, which are considered to remain at the same level, this leads to a business-as-usual scenario for solvent consumption starting from 100 kt/a for 2000 to 85 kt/a for 2010 (c.f. figure 4-5).

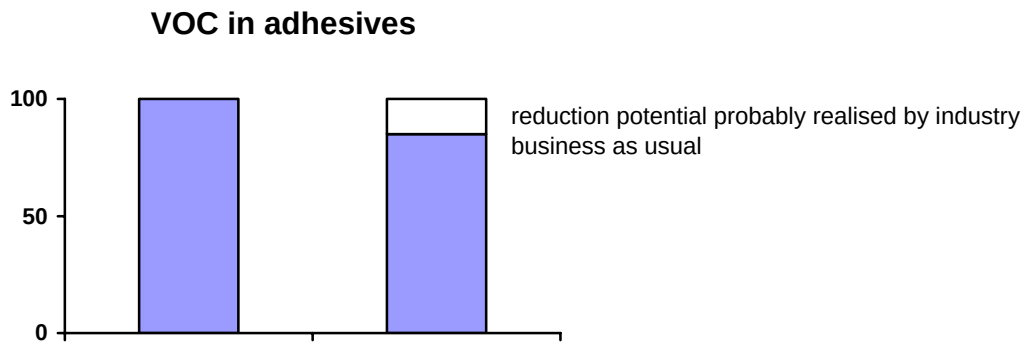

Figure 4-5: Business as usual scenario for adhesives

4.3 Beneficial and Suppression factors

4.3.1 Cosmetics

Beneficial factors

An important supporting factor to substitute VOC-containing products in the cosmetic industry is that in many cases established alternatives are already available on the market without any significant price difference. So it can be expected that producers of alternatives support the realisation of reduction potentials.

Especially in the cosmetic industry the use of certain products depends on trends. Therefore a single change in the consumer attitudes can result in changes of the application form for certain products. Therefore consumer trends might support implementation of reduction possibilities.

Suppression factors

From industry side the important suppression factors are increased cost for research and development as well as marketing costs which are necessary to introduce new products.

The loss of quality and convenience defines another major opposition to a substitution of VOC-based cosmetic aerosol products by VOC-free or VOC-reduced alternatives. Consumer often prefer performance and functionality of VOC-containing products and since CFCs are banned the motivation of buying alternatives to aerosol products is low.

Furthermore for some not-in-kind alternatives a substitution of VOC is only possible by a wider range of different compounds and therefore the risk of unwanted reactions might be higher.

4.3.2 Cleanings

Beneficial factors

According to industry statements VOC have a great impact on the production costs. Therefore the industry itself makes efforts to reduce the VOC content in cleaning products to minimize production costs.

Suppression factors

VOC have a special function as solvent in cleaning products in most cases. On the one hand they are able to dissolve the active ingredients in the cleaning products and on the other hand they have a good degreasing and cleaning effect. Therefore for certain uses a reduction or avoidance of VOC in cleaning products only can be realise by a loss of product quality.

For consumers especially the functionality and convenience (besides the price) of the cleaning products are most important. If the same cleaning effect of non-VOC products compared to VOC-containing products is only achievable by additional mechanical advices the consumer prefers VOC containing products.

If lower VOC contents can be realised only by dilution the opposition of consumers, producers and ecologists has to be expected.

4.3.3 Adhesives

Beneficial factors

The most beneficial factor for replacing solvent based adhesives is their risk to human health and environment. While this is not crucial for the use in installations with efficient solvent recovery and emission treatment, there is a lot of public concern about health impacts from volatile organic substances. Generally accepted symptoms related to solvent exposure are ranging from headache and sickness to Organic Psycho Syndrome (OPS), a serious kind of brain damage. That the reduction of solvents can have a notable effect on health can be seen in Denmark where over the last 20 years a decrease in number of brain damages caused by organic solvents is stated [Soerensen 1998].

In general, there is a lower risk of inflammability for water based adhesives. However, for specific applications with high explosion risk adhesives based on chlorinated solvents have to be used.

Bonding with adhesives makes repair and recycling of items and materials difficult, so for recycling or decomposition purposes mechanical fortification is often preferable.

Suppression factors

The decisive reason for the continued use of solvent based adhesives is that the same bonding quality is up to now not always possible with alternatives. Even if the bonding quality is comparable, it is often correlated with a more careful pre-treatment of surfaces, longer drying time, shorter pot-life, and other handling disadvantages. While this can be overcome with especially designed alternatives like hot-melts, these require in return special application devices and are thus not suitable for the private user. Solvent based adhesives are in general much more convenient to use and so consumers often prefer the performance and functionality of VOC-containing products.

Additionally, also alternatives are not free of health risks, as they may contain hazardous softeners or preservatives. These substances volatilise in low quantities over a long period and are particularly correlated to Sick Building Syndrome (SBS). Some alternatives are also known to contain substances that can provoke allergies, e.g. UV-curing binders using acrylates.

Therefore, further research is necessary to overcome the mentioned disadvantages and to assess environmental and health hazards correlated to solvent based adhesives and their alternatives in an integrated way.

4.4 Scenario for emission reduction potential

In the scenarios for emission reduction potentials the results of various steps of the analysis are included. The business as usual scenario delivers in combination with the material flow analysis the present VOC emission status, the reduction potential that will be probably realised by industry and the corresponding business as usual outcome. This point is combined with the results to the reduction possibilities, the resulting potential is divided into three parts following the outcomes of the assessment and the beneficial and suppression factors. As a general result the scenarios for emission reduction potential are available of this procedure.

4.4.1 Aerosols in cosmetic and cleaning

Staring point is the business as usual scenario with the following key data:

present VOC emissions to air	190 kt
growth of amounts up to 2010	+19 kt
reduction potential probably realised by industry	- 19 kt
resulting business as usual scenario	190 kt

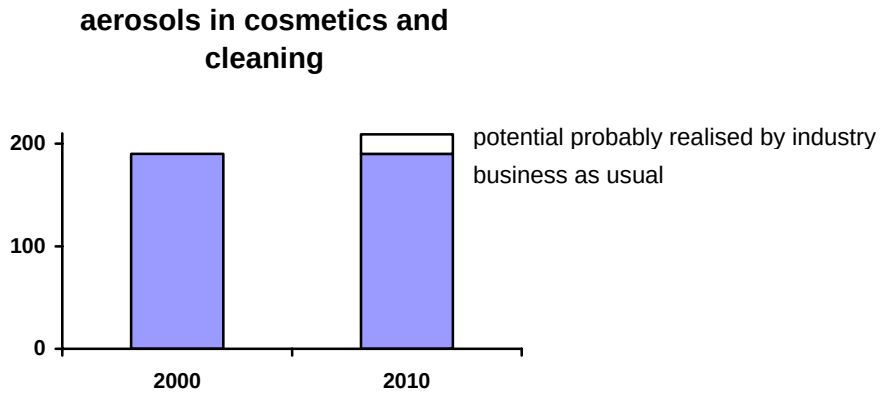

Figure 4-6: business as usual – aerosols in cosmetics and cleaning

Combination with reduction possibilities enlarges the chart due to the following figures:

	I	II	III
hair spray	5 kt	+ 24 kt	+ 45 kt
Deodorants	5 kt	+ 30 kt	+ 20 kt
Others	3 kt	+ 1 kt	+ 5 kt
Total	13 kt	+ 55 kt	+ 70 kt

Table 4-2: reduction potentials - aerosols in cosmetics and cleaning

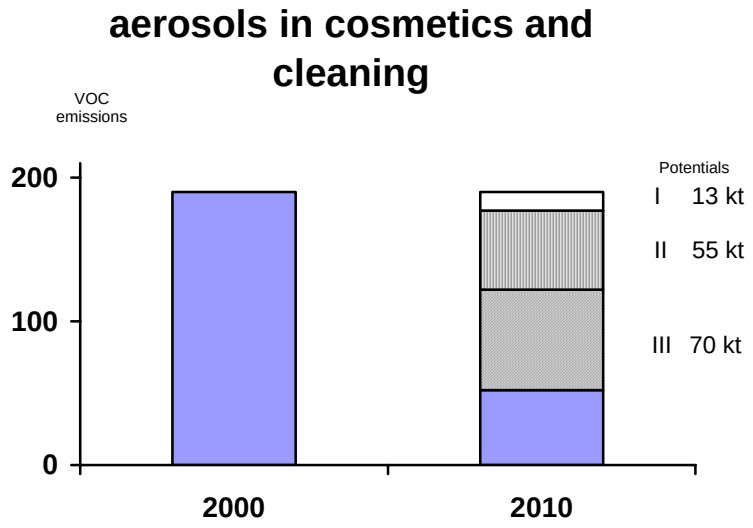

Figure 4-7: reduction potentials - aerosols in cosmetics and cleaning

4.4.2 Solvent, preservation, fragrance in cosmetics

Staring point is the business as usual scenario with the following key data:

present VOC emissions to air	36 kt
growth of amounts up to 2010	+4 kt
reduction potential probably realised by industry	- 4 kt
resulting business as usual scenario	36 kt

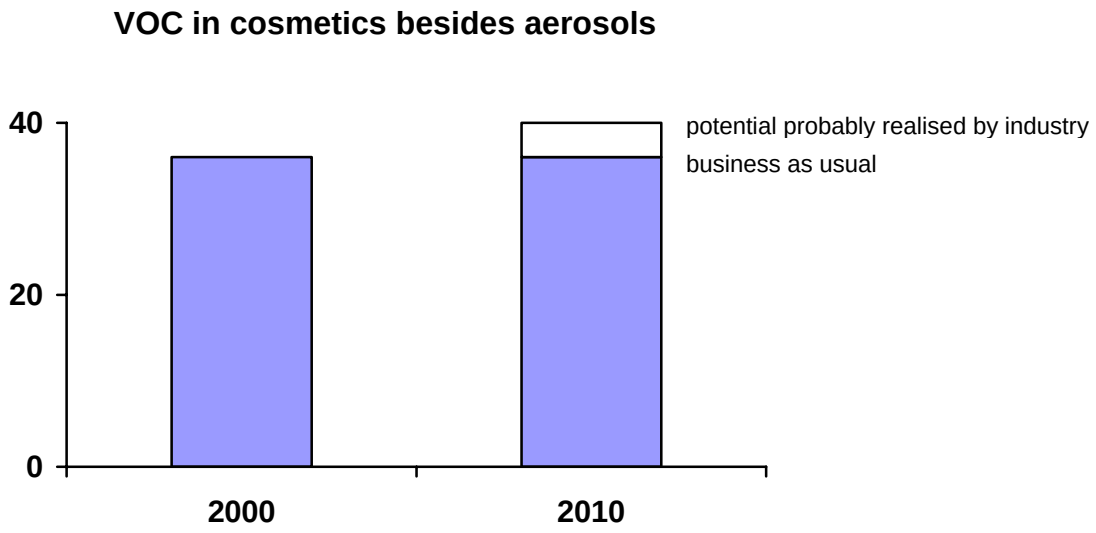

Figure 4-8: business as usual – VOC in cosmetics besides aerosols

Combination with reduction possibilities enlarges the chart due to the following figures:

	I	II	III
solvent	3 kt	+ 3 kt	+ 4 kt
preservation	0 kt	+ 0 kt	+ 0,5 kt
fragrance	0 kt	+ 0 kt	+ 0,5 kt
Total	3 kt	+ 3 kt	+ 5 kt

Table 4-3: reduction potentials - VOC in cosmetics besides aerosols

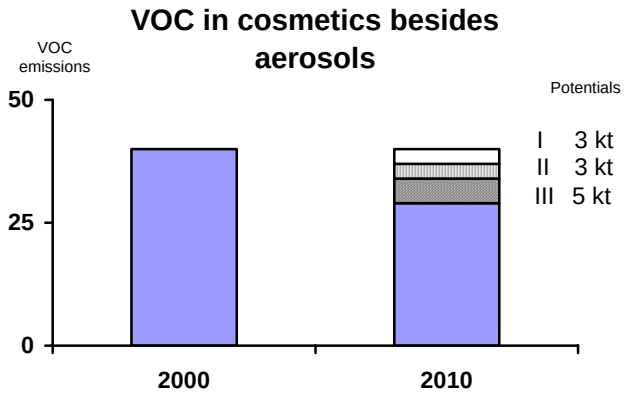

Figure 4-9: reduction potentials - VOC in cosmetics besides aerosols

4.4.3 Solvent, fragrance and disinfection in cleanings

Staring point is the business as usual scenario with the following key data:

present VOC emissions to air	160 kt
growth of amounts up to 2010	+ 16 kt
reduction potential probably realised by industry	- 36 kt
resulting business as usual scenario	140 kt

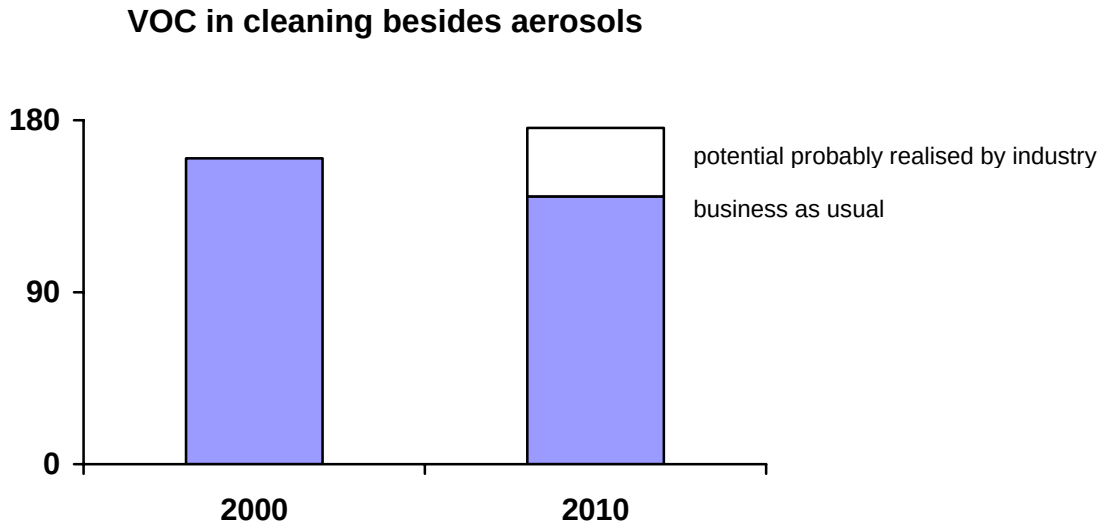

Figure 4-10: business as usual – VOC in cleaning besides aerosols

Combination with reduction possibilities enlarges the chart due to the following figures:

	I	II	III
disinfection	0 kt	0 kt	0 kt
fragrance	5 kt	+ 10 kt	+ 5 kt
solvent	10 kt	+ 10 kt	+ 40 kt
Total	15 kt	+ 20 kt	+ 45 kt

Table 4-4: reduction potentials - VOC in cleaning besides aerosols

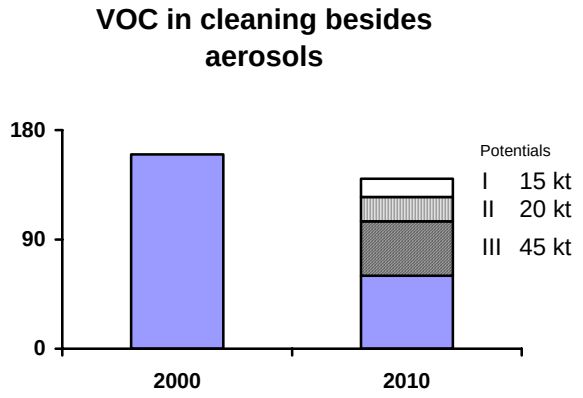

Figure 4-11: reduction potentials - VOC in cleaning besides aerosols

4.4.4 Adhesives

For the great majority of applications, the use of other than solvent based adhesives is already state-of-the-art. An overview of the share of alternatives already in use in the different sectors is given in table 4-5.

Sector	Building, construction, civil eng.	Woodworking, joinery	Footwear and leather	Consumer/ Do It Yourself	Assembly operations
use of alternatives	94 %	95 %	33 %	80 %	75 %

Table 4-5 Share of alternatives of the total adhesives by sector [BMU/VCI 1997]

As mentioned before, the use of solvent based adhesives is specific for each application. Thus, also for the estimation of the remaining reduction potential, each application has to be regarded separately. Up to now, it is not possible to substitute solvent based adhesives for all applications. Even adhesive manufacturers who had already banned solvent containing products were obliged to reintroduce solvents in some formulations, as there were no technically satisfying alternatives [Schwotzer 1999].

The quantification of the reduction potential of possible alternatives (c.f. chapter 3.5.2) is very difficult due to the lack of information about detailed consumption quantities. For Germany, the remaining reduction potential was estimated at 10 % for all sectors except for Consumer/DIY with a reduction potential of 50 %, and assembly operations with a reduction potential of 5 %, referring to the solvent input. The extrapolated reduction potential for Europe is calculated for solvent based adhesives in applications outside installations. As the share of applications covered by the Directive 1999/13/EC is not known, it is assumed that the entire solvent input volatilises with no emission control measures and therefore equals the VOC emissions. This is especially not true for the sectors "Woodworking and joinery", and "Assembly operations" and may thus lead to an overestimation of emissions outside installations as well as VOC reduction potentials.

Sector	Building, construction, civil engineering	Wood-working, joinery	Footwear and leather	Consumer/ DIY	Assembly operations	Total
Solvent input (VOC emissions) due to solvent based adhesives	20 kt	15 kt	15 kt	10 kt	15 kt	80 kt
Reduction potential	10 %	10 %	10 %	50 %	5 %	av. 15 %
Emission reduction potential	2 kt	1.5 kt	1.5 kt	5 kt	1 kt	11 kt

Table 4-6: Emission reduction potential outside installations for Europe [Derived from PRODSTAT and BMU/VCI 1997]

Following the reduction possibilities for each sector, the overall reduction potential for solvent based adhesives outside installations is estimated at about 15 % or 11 kt/a, respectively. VOC emissions resulting outside solvent based adhesives do not show reduction potentials.

There are various applications where substitution possibilities are obvious and easy to realise, at least under normal processing conditions. Solvent free or solvent reduced adhesives for these applications are dispersions (solvent content from 0 - 10 %), natural polymers, glues and pastes, and other water based adhesives.

The resting potential is considered to be only achievable with high efforts or significant disadvantages, as especially developed alternative adhesive systems have to be used. Possible high-tech alternatives consist mostly of hot-melt adhesives, reactive (one or two component) or radiation-curing systems.

Dispersion adhesives and primer are not considered to represent a relevant reduction potential (if any) and are thus not leading to any emission reduction.

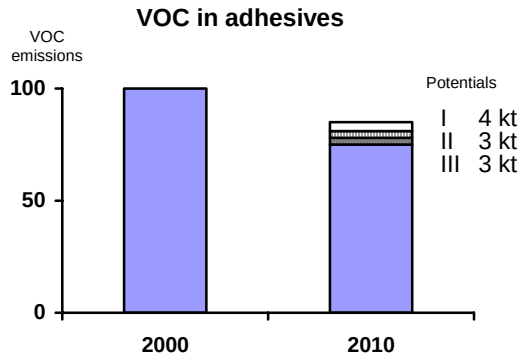

Figure 4-12: Reduction potential of VOC in adhesives in relation to the business as usual scenario

Unfortunately, for most applications neither the specific adhesive consumption nor the share of solvent based adhesives are known. Therefore, a quantification of potentials with regard to specific applications is not possible within this study. For a more detailed statement, for which application which alternative should be used, and which reduction potential can be achieved with each measure, a in-detail study of the most promising applications is recommended.

4.5 Particularities of member states

4.5.1 Cosmetics

The following table shows the market per citizen for cosmetics based on table Table 4-7.

	Fragrances & perfumes	Decorative cosmetics	Skin care	Hair care	Toiletries	Total
Germany	16,5	13,8	25,8	32,4	38,8	127,3
France	31,3	18,9	39,7	36,5	29,3	155,6
United Kingdor	15,8	21,3	23,3	35,1	42,4	137,9
Italy	18,9	17,4	32,0	27,8	32,6	128,6
Spain	29,3	12,3	28,9	29,8	24,5	124,9
Netherlands	17,7	13,8	27,1	34,0	36,2	128,8
Belgium/Lux.	25,4	15,7	25,5	40,5	25,7	132,7
Austria	15,4	20,9	26,4	35,4	35,3	133,4
Sweden	13,5	24,0	23,1	34,2	44,0	138,9
Greece	8,6	13,6	21,7	29,9	16,5	90,3
Portugal	15,7	6,1	15,9	28,0	19,3	85,0
Denmark	22,9	16,7	22,1	43,5	27,8	133,0
Finland	4,8	16,2	22,2	40,2	23,2	106,7
Ireland	16,4	15,1	22,0	23,8	35,0	112,3
Total	20,3	16,5	28,3	32,9	33,4	131,5

Table 4-7 Spending per citizen in € per year

As it can be easily seen in the table the habits of consumption can be assumed to be very inhomogeneous in the member states. Even if different prices are taken into account, ranges from 4,8 – 31,3 in perfumes or 6,1 – 24 in decorative cosmetics show that clearly. Only in the sector hair care the spending show relatively small variations.

4.5.2 Cleanings

Similar to cosmetics consumer habitant varies in the member state in a wide range. The only available source is Europroms data and besides possible ranges of 1:3 for several product groups there is no clear trend visible. Besides there is no data according to VOC available.

4.5.3 Adhesives

There is only little information available about the particularities of adhesive use in the member states. In the following chart, the adhesive consumption per capita is given for western European countries. However, there is no additional information about the specific consumption of solvent based adhesives, nor are there explications for the notable differences between the countries.

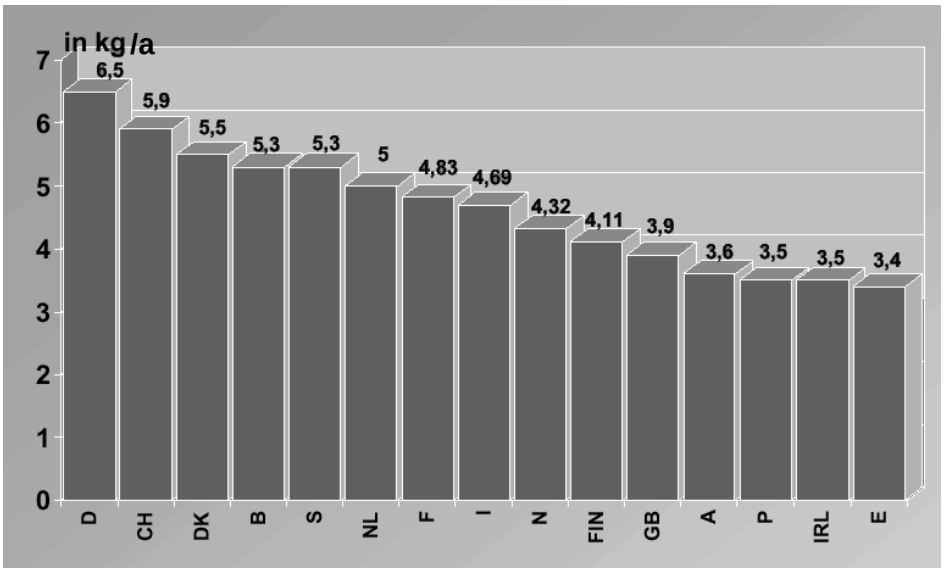

Figure 4-13: Annual adhesive consumption per capita per country [FEICA 2000]

Despite the fact that there should be some effects in those states where VOC limitations for adhesives are in force, there was no information available about how and to which extent the existing regulations had an influence on the consumption of solvent based adhesives in the last years.

5 Suggestions and recommendations

5.1 Suggestions for regulatory approach

The potentials in chapter 4 have been clearly divided in potentials that will be probably implemented by industry itself and those that will not be achieved without regulatory pressure. So the question arises what are the best regulatory approaches to put into practice the reduction potentials and which reduction potentials should be put into practice. The Table 5-1 shows a summary of the types of potentials to this question:

	aerosols in cosmetics and cleaning	other use of VOC in cosmetic	use of VOC in cleaning	us of VOC in adhesives	total
potential probably realised by industry	18 kt	4 kt	37 kt	15 kt	74 kt
Potential I	13 kt	3 kt	15 kt	4 kt	35 kt
Potential II	55 kt	3 kt	20 kt	3 kt	81 kt
Potential III	70 kt	5 kt	45 kt	3 kt	123 kt
sum	156 kt	15 kt	117 kt	25 kt	313 kt

Table 5-1: Overview on reduction potentials

The first idea before coming to a regulatory approach can be seen in an environmental agreement with industry. This was discussed with some involved parties. Conclusion of these discussions was that the chances to reach potentials by this way are pretty low. Besides the potential that will be realized by the industry on its own it can be assumed, that only potential I could be reached as a maximum with voluntary environmental agreements.

A second way would be a regulatory approach by a labeling procedure. Due to discussions with involved parties this could be a promising way of limiting VOC contents of products. The reason for the expected efficiency of this approach lies in the close connection between the relevant products and consumers. It can be expected that trading companies and consumers would reject products with a label like "This product contains 90 % VOC. VOC causes summer smog" if other products are available with a more advantageous label. To follow this idea the labeling must be valid only for products that exceed a certain VOC content.

The control of a labeling approach is comparatively easy, however, installing the labeling procedure might cause high efforts and resistances. Looking on the potentials it can be expected that potential I and at least parts of potential II could be achieved.

Another regulatory approach would be to adopt restrictions to VOC contents via a directive. According to discussions this approach seems to provide the best success. However, some aspects have to be looked on carefully. Results to reduction potentials and especially the assessment of consequences have still a screening character, which means that additional research has to be done to examine consequences more in detail. This requires time and tends to prolong the already long lasting schedule until a directive begins to work (see chapter 5.2).

On the other hand a big advantage for a directive can be seen in the fact, that a future directive for decorative paints can be easily extended to products discussed in this study by amendment and further annexes.

With a directive potentials I, II and III can be fulfilled. However, potential III might bring some significant disadvantages and it might therefore be reasonable to focus a directive only on the implementation of potentials I and II. But this depends on further research and negotiation with involved parties.

As a consequence the project team suggests a directive as regulatory approach. It therefore has worked out suggestions for annexes regulating the limitation to the VOC content of products.

A last approach that might be possible is an EC regulation. One important advantage of EC regulations is that potentials can be achieved in a shorter period. Another advantage of a regulation could be that decisions on exceptions can be taken more easily on a European level. However, an EC regulation would cause conflicts to a directive for decorative paints and would cause additional efforts. Therefore the project team does not suggest to implement an EC regulation as regulatory tool.

The following suggestions characterize what possible annexes to a directive might contain:

Annex I

VOC reduction scheme for products with VOC used as propellants

	phase I (until 2007) max. allowed VOC content	phase II (until 2010) max. allowed VOC content
hair sprays	80%	75%
deodorants	50%	20%
antiperspirants	80%	75%
cleaning sprays	10%	10%

Annex II

VOC reduction scheme for VOC in cosmetics (besides aerosols)

	phase I (until 2007) max. allowed VOC content	phase II (until 2010) max. allowed VOC content*
skin care products	20%	20%
shampoos, soap and bath products	3%	3%
shaving products	3%	3%
fragrances	80%	80%
deodorants (non aerosols)	20%	20%

* evaluation necessary within further research

VOC reduction scheme for VOC in cleaning (besides aerosols)

Limiting the VOC content might not achieve reduction potentials as they could be evaded by unwanted dilution of products with water. Therefore the project team suggests to introduce benchmarks based on standardized tests to define tolerable VOC contents for the cleaning of a standard soiled surface. This approach shows clear advantages in comparison to existing regulations in the United States. However, the efforts of implementation have to be compared with reduction possibilities.

Annex III

VOC reduction scheme for VOC used as solvent in adhesives outside installations

	phase I (until 2007) max. allowed VOC content	phase II (until 2010) max. allowed VOC content
building, construction		
roofing	solvent free [1]	solvent free [1]
insulation	solvent free [1]	solvent free [1]
ceiling tiles	30 %	30 %
plywood panelling	solvent free [1]	solvent free [1]
floor covering	8 % [1]	8 % [1]
woodworking and joinery		
wood	solvent free [1]	solvent free [1]
varnished surfaces	no limitation [2]	no limitation [2]
leather, textiles, felt	8 % [1]	8 % [1]
rubber, plastics, PVC	70 % [2]	70 % [2]
cushions and foams	8 % [1]	8 % [1]
footwear and leather		
shoe upper assembly	10 % [1]	10 % [1]
sole assembly	55 %	55 %
sole fitting	no limitation	no limitation
consumer, DIY		
wood	solvent free	solvent free
paper and board	solvent free	solvent free
multi purpose and contact adhesives	no limitation [2]	no limitation [2]
modelling and plastics	70 % [2]	70 % [2]

[1] exceptions for specific applications

[2] use of alternatives dependant on material and technical conditions

5.2 Timetable for implementation of legislation

The following ambitious time schedule is valid for an EC directive. A regulation would need 18 months less for transposition into national law of member states. To implement legislation the following steps would be recommended:

2002 - further investigation on details of focal points and discussions with the involved parties

- draft of annexes for a regulation with implementation and control dates 2007 and 2010

2003 common position

2004 adoption of the regulation

2008 end of transition periods

2010 report of the member states on achieved reductions

2012 report of the member states on achieved reductions

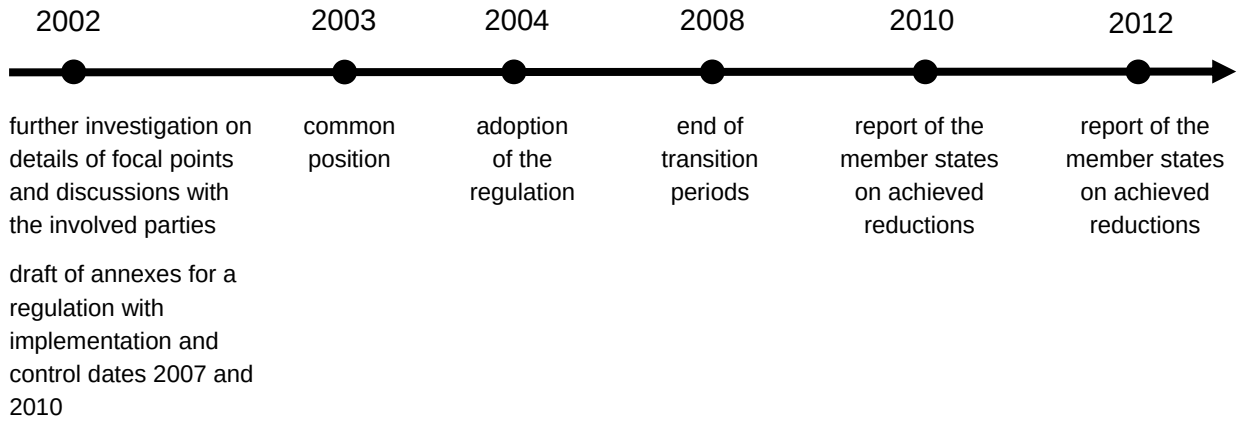

Figure 5-1: Time schedule for a directive to reduce the VOC content in selected products

5.3 Recommendations

As conclusions of this screening study the following recommendations can be summarized:

1. It is recommended to realise major parts of the identified potentials in the focal points cosmetics, cleaning and adhesives. The total reduction potentials amount to about 310 kt VOC (reduction potential planned by industry and further reduction potentials) and lies in the same dimension as the reduction potential of decorative paints and vehicle refinishing (~ 300 kt VOC/year).

   The "major parts" of the total reduction potential of 310 kt VOC/year are seen by about 190 kt VOC/year. This includes about 70 kt that will be realised by industry and 120 kt VOC/year (reduction potentials I and II) related to legislative measures.

2. It is recommended to follow the regulatory approach of a directive. Combined with the areas decorative paints and vehicle refinishing this seems to be the most promising and most effective way of limiting the VOC content of important product groups.

3. It is recommended to install a monitoring procedure to ensure that reduction potentials that will be probably realized by industry are in deed achieved. The monitoring strategy should include measures how to act if the realization of these potentials fails.

4. It is recommended to extend research to other focal points and to deepen the analysis of cosmetics, cleaning and adhesives. Due to the broad variety of products technical consequences and the ecological profiles of alternatives need to be investigated in detail to have sufficient arguments for negotiation for directive's annexes with limitations to VOC contents.

Attachment I: Method to estimate VOC-Contents

Basic Data

The basis for the results is are data from the CD “EUROPROMS - European production and market statistics” Release 7/2001 ISSN 1563-3373. The year 1999 was chosen because the data for the fourth quarter of 2000 are not complete yet.

For each product and EU-member – based on the 8-digit PRODCOM code - the following data is (or should be) available:

Sold Production

Imports (Intra- and Extra EU)

Exports (Intra- and Extra EU)

Net trade balance

Market Supply

For some Products a total Market Supply for the total of the EU-15 countries is given in the statistics. In most cases this total is missing because for one or more countries no data is available or the data is confidential (For Luxembourg in general there are no numbers in the PRODCOM). Another reason might be particularities in the member states by the correspondence of single products used in a country to the categories of products in the PRODCOM system.

For this cases estimation was done based on the calculation, which is described below.

Calculation of EU-15 total market supply

The total market supply of a product with missing data of certain member states was calculated as described in the following:

1) Addition of the available market supply data (in most cases 10 – 13 countries)
2) Addition of the number of citizens with available market supply data
3) Calculation of a weighted average of market supply per 1000 capita
4) Determinations of the maximum market supply per 1000 capita within the group of countries with available market supply data.
5) Determination of the minimum market supply per 1000 capita within the group of countries with available market supply data.

6) For each country without available market supply data 3 numbers where calculated:

   a) an average value by multiplying the weighted average (acc. to 3) with the number of citizens (divided by 1000)

   b) a maximum value by multiplying the maximum (acc. to 4) with the number of citizens (divided by 1000)

   c) a minimum value by multiplying the minimum (acc. to 5) with the number citizens (divided by 1000). This minimum value was compared with the total net trade balance. In cases where the absolute value of a negative net trade balance was higher than the calculated minimum market supply, this absolute value was used instead of the calculated minimum. This follows the idea, that a negative net trade balance indicates higher imports than exports and shows the market supply estimating there is no production of the product in the country.

The numbers for countries with given data for the market supply and the calculated numbers where added to estimated totals for the European Union giving an average, a minimum and a maximum.

The chosen method works well for products, which are produced in many plants, located all over the EU. It does not work for products, which are produced in a few plants in particular member states.

Adopting the structure of PRODCOM

In some cases the differentiation of products within the PRODCOM structure is more detailed than it is needed for the product definitions used in the study. Examples are Finishing agents for textiles, leather etc., Lubricants or Essential Oils.

In these cases the single values – calculated like described above – were added.

Restrictions using the structure and data of PRODCOM

For some of the sub-groups, which are defined in the study no comparable 8-digit code was found in the systematic of PRODCOM. Examples are all “others”, “undercoatings” and “VOCs directly used as thinners”.

More important are lacks of data especially in the product groups “cosmetics” and “insecticides and herbicides”. In the case of the cosmetics the gap was filled with intensive talks and meetings with representatives of the industry who provided useful numbers.

Insecticides and herbicides are not considered to contain substantial substitution potential and therefore not closely followed within the tight time frame of the project.

Calculating the VOC-Contend of Products

For each product an average VOC-content was estimated by multiplying the VOC-contend with the EU-15 Marked supply gives the total input of VOC.

The numbers were verified during the study by other sources as far as possible.

Attachment II: Review of paint studies

A short review of the "DECOPAINT study[7]" shows that successful efforts have been made in literature research and expert-talks resulting in a huge amount of useful data, facts, conclusions and recommendations.

The figures concerning the consumption of decorative paints (~3.340 kt in EU-15, resp. ~3.850 kt in EU-15+6) combined with a share of 57% of decorative paints of the total paint consumption leads to a total of about 5.860 kt market supply of paints within the EU-15. This figure fits very well to our own estimates based on EUROPROMS market supply data (1999: ~ 5.600kt – 6.500 kt).

The range of estimated VOC emissions (720 kt – 830 kt in EU-15+6) seems to be very reasonable. The share of thinners and cleaners is estimated with ~140 kt – 250 kt. This range seems wide, but it is probably not possible to make a more precisely estimate. Nevertheless no details according to the total use of thinners and cleaners and the VOC in waste (used cleaning solvent and waste paint) are mentioned.

The estimation of the reduction potential and the defined groups in the VOC-reduction scheme seem to be reasonable too. An interesting remaining question is, which product groups are the most important for the realization of the reduction potential.

Besides the results of the study some principal questions might be raised.

The term "decorative paints" may lead to possible misunderstandings and misinterpretations, because – as the authors of the study are mentioning – almost all painting is done for decorative and protective reasons. These problems increase taking into account, that the term "buildings" used to define the group of paints is not clear enough and it cannot be easily understood why the painting of other objects that are not painted in painting facilities in plants (for example in situ painting of technical equipment like pipes and silos, fences, antennas etc.) is excluded.

It might be useful to establish clear definitions for the evaluation of measures. Therefore two main conclusions can be made:

a) It seems to be necessary to look at all paints for the use outside of facilities, which are regulated within EU 13/99 in a first step and exclude certain products in a second one.

[7] Study on the Potential for Reducing Emissions of Volatile Organic Compounds (VOC) Due To The Use Of Decorative Paints and Varnishes for Professional and Non-professional Use

The excluded products need to be defined unambiguously which may be either easy (e.g. road-markings) or rather complicated (heavy duty or anti-corrosion paints[8])

b) The products included should be clearly defined. There are many definitions and terms existing and producers, industrial and other painters use sometimes different product-group terms for the same paint. If possible the definitions should be based on the differentiation used in the PRODCOM-Code to be able to use statistical data that is available and more or less standardised in all EU countries. The PRODCOM distinguishes waterborne and solventborne paints and varnishes as a start. The existing groups have to be differentiated in paints used in plants (covered by EU 13/99) and others in a second step. Further definitions or exclusions may be necessary but at present only a principle idea can be sketched.

The study on the vehicle refinishing sector[9] estimates a reduction potential of about 23 kt – 50 kt VOC until 2007 establishing reference coatings. The costs of abatement are estimated well above € 1.000/t VOC with up to € 6.000/t VOC in the first year. A major problem is that the expected consequences of 1999/13/EC are not described. Therefore the additional potential of reference coatings – which is certainly lower than the amounts mentioned above – remains unclear.

Nevertheless there will be a reduction of emissions due to 1999/13/EC even if many of the small bodyshops are below the threshold of 500 kg VOC/year. Modeling calculations done for this sector in Austria leads to a rough estimate of 10% - 15% reduction in 2010 based on total emissions in 2000 (~160 kt). This would lead to about 15 – 25 kt reduction/year as effect of the implementation of 1999/13/EC and would lead to a possible additional potential of about 10 – 25 kt, which might be put into practice by the mean of product regulations.

Considering the expected comparatively minor effect of a product regulation in this field – compared with decorative paints, cleaning and cosmetic products – and the fact that the vehicle refinishing sector is already regulated under 1999/13/EC - the strategy of product regulations does not seem to be an activity with high priority for EU legislation.

[8] In Austria a manual written by the authors solved this problem. This manual uses a multiple-criteria check to decide whether a certain painting is to be considered “heavy duty anti corrosion paint” or not.

[9] "Reducing VOC emissions from the vehicle refinishing sector"

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