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EFFECTS OF THE VOC INCENTIVE TAX ON INNOVATION IN SWITZERLAND
Case studies in the printing, paintmaking and metal cutting industries

This study is part of the "Taxation, Innovation and the Environment" research programme of the OECD Joint Meeting of Tax and Environment Experts. It was prepared by Alain Schoenenberger and Alexander Mack of the Swiss consultancy Eco'Diagnostic.

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FOREWORD

This study is part of the "*Taxation, Innovation and the Environmen*t" programme of the OECD's Joint Meeting of Tax and Environment Experts. It discusses the innovation impacts of the VOC tax in Switzerland, and was prepared by Alain Schoenenberger[1] and Alexander Mack[2] from the Swiss consultancy Eco'Diagnostic. The study was funded by the Federal Office for the Environment, Switzerland.

Sam Banatte assisted the authors throughout the study and contributed to the theoretical aspects of innovation. In particular, while writing his master's dissertation at Neuchâtel University, he provided certain results of his survey of cantons relating to how the tax is levied on firms and monitored.

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EFFECTS OF THE VOC INCENTIVE TAX ON INNOVATION IN SWITZERLAND

0. Introduction

1. The revision of the *Law on Environmental Protection* of July 1997 gave for the first time the possibility to apply market-based instruments for environmental policy in Switzerland. This innovation was one of several steps of a new orientation of Swiss environmental policy. Given the urgency of environmental problems, it was decided to complement traditional policy instruments by incentive-based instruments that alter market prices. In this context, Swiss authorities already had in mind to introduce an incentive-tax on volatile organic compounds (VOCs) and on light heating fuels with a sulphur content larger than 0.1%.

2. The ordinance regarding the new tax on VOC was meant to enter into force at the same time, at 1 July 1997. However, it turned out not to be possible to follow this timing. The delay of the introduction of the tax stemmed from the consultation process of the project. Several industries in particular, but also several cantons, had asked for modifications of the ordinance and a delay of at least one year of the introduction of the tax, including:

- a softening of the rules, *e.g.* regarding exemptions from the tax, limited in time, for enterprises that already had reduced their emissions below the limits set in the *Law on Environmental Protection*

- also, a formal procedure for the purchase of VOC temporarily not taxable was elaborated, to permit a time-limited exemption from the VOC tax until a recalculation of effective emissions of VOC to the environment was undertaken. In this way, the liquidity burden was reduced for enterprises through which passed a large volume of VOCs (*e.g.* wholesalers).

- in addition, it was necessary to give enterprises and cantonal authorities sufficient time to prepare properly the application of the ordinance, once the exact details of the latter had been finally decided by the Federal Council. These preparations included *e.g.* specific training of personnel in charge of the tax application and adaptation of information systems.

3. In the end, the ordinance regarding the incentive-tax on volatile organic compounds (VOCs) entered into force 1 January 1998, and the tax was levied from 1 January 2000, with a rate of CHF 2 per kg. The tax was increased, as planned, to CHF 3 per kg at the beginning of 2003.

4. The objective of the new tax on VOCs that enter the environment is to reduce their emissions, which contribute to the formation of low-level ozone. VOCs are used as solvents in many industries and can be found in various products like paints, varnishes and some detergents. Released into the atmosphere, they interact with nitrous oxides to form high concentrations of ozone at low altitude (summer smog).

5. Insofar as the tax does not curb innovation by the firms concerned but represents an opportunity for development and specialisation (in “green” production), at least in the medium term, it would achieve a “double dividend” sought in environmental policy. The double dividend of any environmental policy, and

of a policy based on environmental taxation in particular, lies in the fact that a tax (on CO_2, NO_x or VOCs) helps both to reduce emissions of harmful substances and to boost efficiency and economic growth

6. The study's first aim is to give an account of the possible (beneficial) effects on innovation and of innovation efforts by the firms liable to the tax. The main questions considered in the study are as follows.

- Has the introduction of a tax on VOCs caused changes that could be described as innovation, and if so what are the determining factors?
- When did these innovations occur (before or after the tax was introduced in 2000) and, from a dynamic standpoint, can the effects on innovation still be seen today?
- In what context, within firms, have innovations that reduce VOC emissions been made?

7. In order to answer these questions, for practical and budgetary reasons the Federal Office for the Environment (OFEV) opted to conduct interviews with twenty or so firms liable for the tax, operating in two or three industries that make relatively intensive use of VOCs. Additional information about the effects on innovation was collected from a dozen or so cantons. This report is in four parts.

- Part 1 describes how the VOC tax in Switzerland works and is levied and outlines its advantages and possible effects.
- Part 2 considers the theoretical definition and measurement of innovation and briefly describes the results of the three-yearly survey of innovation activities in Swiss firms.
- Part 3 describes how the industries that use VOCs and produce VOC emissions were chosen and how the firms to be interviewed were selected.
- Based on all this information, Part 4 contains the main results of the interviews when the study questions were put to the selected firms and cantons.

1. The tax on VOC emissions and its effects

8. The incentive or steering tax introduced in 2000 does not apply to all products classed as VOCs, partly because of the excessive administrative burden on customs clearance of all substances. The "positive list of substances" (benzene, butanes, ethers, oil, etc.) in Annex 1 of the Ordinance on the Incentive Tax on Volatile Organic Compounds (VOC Ordinance) identifies the VOCs liable for the tax. The "positive list of products" (*e.g.* solvents, colorants, paints, perfumes, beauty products) in Annex 2 does the same for products containing VOCs.

9. As emissions are difficult to measure within a given firm, VOCs are taxed on entry into production and on importation into Switzerland. Imported products containing VOCs are taxed on importation according to the quantity of VOCs they contain. Products manufactured in Switzerland are taxed indirectly through the tax already levied when VOC substances are purchased. The tax is levied on importers, manufacturers and wholesalers and on Swiss producers of VOCs. The VOCs are and remain liable for the tax if they escape into the environment or if they are sold (transferred) to Swiss consumers, either as substances or contained in products liable to the tax. It is up to users to declare in a plausible way – by means of a VOC balance sheet (see Annex 6.1) – the quantity used without harming the environment (in inventories[3] or properly eliminated).

[3] Under Article 21 of the VOC Ordinance, it is possible to acquire quantities of VOCs temporarily not liable to the tax through a "formal engagement procedure" with the authorisation of Swiss Customs, after a

10. However, the VOC Ordinance provides for exemptions. For example, VOCs exported as substances or in products not liable to the tax are exempt because they are not released into the environment in Switzerland. Exemptions likewise apply to VOCs in products whose VOC content does not exceed 3% and to VOCs in products not included in the positive list.

11. In addition, firms that have taken measures on a stationary installation and reduced emissions significantly below the limit values stipulated in the Air Protection Ordinance can be exempt from the tax. Article 9 of the VOC Ordinance provides for exemption from payment of the tax on the volume of emissions if they were 30% lower than the maximum limit at 31 December 2003 and 50% lower at 31 December 2008. This exemption has recently been extended until 2012.[4] For control and reimbursement purposes, a firm exempted from the tax (Article 9) or authorised to acquire VOCs temporarily not liable to the tax (Article 21) must keep a VOC account.

12. Thus, the tax is payable on VOCs produced in Switzerland when they leave the producer or when they are used (in products or emitted into the environment); and, for VOCs on which the tax is payable later, when the beneficiary uses them or passes them on to third parties.

13. The direct effect of the tax is to increase the cost of making products with a VOC content of more than 3%. If the tax is passed on, products intended for the domestic market become more expensive to buy. In that respect, Swiss and foreign products are treated alike in tax terms. Exemption from the tax for exported products helps to keep Swiss products with a VOC content of more than 3% competitive on export markets. That is no longer the case if production costs in Switzerland increase because VOCs that escape into the environment are taxed. Under these circumstances, Swiss products made using taxed VOCs are at a disadvantage in Switzerland in comparison with substitution products, and in other countries in comparison with competing untaxed products. The European Union, rather than imposing a tax, has drawn up elaborate and sometimes stricter rules on the use of VOCs, as is the case with the VOC content of paints.

14. On the domestic market, the increase in the relative price of products that are more expensive to produce on account of the tax discourages consumption of such environmentally harmful goods and services. Thus, final and intermediate consumers are encouraged to shun products whose manufacture is a source of emissions in favour of cheaper and potentially less harmful substitution products (if they exist). Firms can react in two ways, depending on whether the problem lies with the production process or the product.

- They can reduce VOC emissions into the environment by changing the production process. Firms may be expected to "innovate" if their current and future (discounted) direct and indirect costs are lower than the tax they would otherwise have to pay. Firms that use small quantities of VOCs and therefore pay relatively little tax thus have little incentive to innovate in order to further reduce VOC emissions.

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favourable preliminary opinion from the canton concerned. The tax is payable at a later date, when the VOCs are actually used. The procedure is available to anyone using or processing at least 50 tonnes of VOCs in such a way that they are not emitted into the atmosphere or are exported, and any person engaging in wholesale trade with an average stock of at least 50 tonnes (200 tonnes before 1 December 2002). Deferring payment of the tax helps firms that engage in wholesale trade or that process large quantities of VOCs to avoid liquidity problems.

4 The extension is justified by the substantial costs to industries like printing on packaging and chemicals that cannot reduce VOC emissions in the short term. It assumes that firms have not been able to replace or change production equipment or products since at least 1997, the year in which the tax was initially supposed to come into effect!

- They can reduce or eliminate the VOCs contained in their products (or cut the concentration of VOCs to less than 3% by volume), as long as that does not significantly alter their quality or end use. However, they are unlikely to do so if the tax represents only a small fraction of the product's value. If they change the product, the market has to accept the new one containing fewer VOCs in over the old one containing more VOCs. Introducing a new product requires an effort, either in design or in marketing.

15. The effects of environmental taxes are transmitted by market mechanisms, in contrast with strict regulation which sets mandatory thresholds and ceilings. Taxes generally enable a depollution objective to be achieved at lower cost than economic regulation. Taxation has definite advantages in comparison with regulation:[5]

- in principle, firms have a choice between paying the tax and developing products or technologies that reduce emissions (pollution). Taxes generally leave agents and emitters free to choose the best way of reducing their emissions;
- environmental taxes are a better way of controlling diffuse emissions (like VOCs) than standards. Standards may impose very complex and costly clean-up technologies, whereas incentive taxes offer a choice of depollution means and methods, just as there are many economic activities that use or make products containing VOCs. In that respect, ecotaxes spread the depollution effort more effectively since they minimise the costs of reducing emissions without the need to know the cost to each firm.

16. An incentive or steering tax thus guarantees static efficiency insofar as applying a uniform rate to sources of emissions equalises the (marginal) costs of depollution between firms. The tax encourages the use of efficient depollution measures. Firms and sectors with lower depollution costs tend to reduce their emissions more. Firms can choose between cutting emissions further if the cost of doing so is lower than the tax payable on the emissions to be cut, or paying the tax if it is lower than the (marginal) cost of depollution.

17. A tax also maintains a permanent incentive to reduce emissions (dynamic efficiency), in contrast to regulation, which requires firms to comply with limits on emissions or to use specific technologies (not necessarily the most cost-advantageous), since the tax requires the emitter to pay for residual emissions as well as the cost of reducing emission levels.

1.1 Revenue and reduction of VOCs

18. Revenue rose from CHF 67 million in 2000 to a peak of over CHF 140 million in 2005, falling back to CHF 126.7 million in 2006 and 2007. It is estimated that the figure will level off at CHF 125 million over the next three years. The tax, which is redistributed to the population, represents only 0.3% of federal revenue and 0.1% of all public authority revenue.

19. Emissions of VOCs liable to the tax fell significantly between 2001 and 2004, having already declined between 1998 and 2001. Table 1 shows the estimated reduction for the most polluting industries;

[5] The main disadvantages lie in the difficulties of administering taxes, meaning that supervision costs can be higher than with standards; the revenue generated tends to be relatively small. OECD, 2001, pp. 21-22). In many cases, however, as with the Swiss tax on VOCs, raising revenue is not an aim since it is redistributed to the population.

the reduction for all industries since 1998 is estimated to be around a third. Thus, there has been a substantial reduction in the emission factor (see Table 1).[6]

Table 1. Biggest reductions of VOCs by industry

(liable to the tax)	Change 1998-2001		Change 2001 - 2004	
	tonnes	%	tonnes	%
Industry, crafts and households	9 700	-12%	17 200	**-25%**
Paint applications	-3 100	-13%	-11 000	**-54%**
Printing	-1 800	-16%	-4 900	**-51%**
Metal cleaning	-700	-18%	-1 100	**-34%**
Wood protection applications	-270	-15%	-730	**-48%**
Emissions of solvents, miscellaneous	-200	-11%	-500	**-29%**
Hairdressing salons	40	5%	-480	**-59%**

Source: OFEV (2007).

2. Definition and measurement of innovation

20. Innovation is often associated with the notions of economic growth, economic performance and even economic development. It plays a key role in the knowledge-based economy. In the literature, innovation is associated with the idea of novelty. Yet the term novelty is used in such a wide variety of circumstances that it is difficult to say exactly what it means. Apart from the degree of novelty, innovation has many different facets and features that do not easily lend themselves to quantification, though a range of indicators to measure innovation have been developed, including the nature, activities (inputs), effects (outputs), determinants, frequency and mode of innovation.

21. In its Oslo Manual (1997), the OECD describes innovation as "a complex, diversified activity with many interacting components". The European Commission, in its Green Paper on Innovation, points out that innovation is an ambiguous notion since it applies to both the process and the outcome of the process. But at the heart of any innovation lies an idea, innovation being the act whereby the new product or production process is created. Joseph Schumpeter proposed five categories of innovation:

- the introduction of a new good or of a new quality of a good;
- the introduction of a process that is new for an industry;
- the opening of a new market;
- the development of new sources of supply of raw materials or other inputs;
- the new organisation of an industry.

22. The OECD has opted for a more restrictive definition in the Oslo Manual, limited to Schumpeter's first two categories. It is a choice that concentrates on the categories that are potentially the easiest to measure. Thus, the OECD distinguishes between two types of innovation covered by a single term: technological product and process innovation (TPP).[7]

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6 A new set of figures for 2008 is being prepared. The estimates are rough figures based, in each industry, on multiplying the emission factor and the corresponding indicator of the volume of output producing VOC emissions.

7 Organisational and marketing innovations are traditionally added to technological innovations: "Organisational innovation in the firm includes the introduction of significantly changed organisational

23. Technological product innovation is the introduction onto the market of a new or significantly improved product with the aim of achieving higher sales. This definition takes account of improvements to the technical characteristics of the product, such as components or raw materials used in manufacture, embedded software and other functional characteristics.

24. Technological process innovation is the use and implementation of new or significantly improved production or distribution methods. This category of innovation implies significant changes affecting the production chain, production technologies and inputs and human resources.

25. Innovation in general aims to improve the firm's economic performance and competitiveness, the impact on the environment being a secondary consideration (under existing regulations). Innovation activities span all scientific, technological, organisational, financial and commercial initiatives that play a part in developing technologically new or improved products or processes. They include experimental research and development, the acquisition of outside knowledge, machines, materials and other capital goods, preparations for the marketing of product innovations and training.

26. The distinctive feature of innovation is the attention paid to the "performance characteristics" of the improved products or processes. It is an important aspect because it is a way of excluding other minor improvements that should not be reckoned as "technological novelties". The Oslo Manual states that this distinction rests on the degree to which performance characteristics and their degree of novelty are an important factor in sales in the firm or industry concerned. Consequently, the definition of innovation should exclude subjective changes to a product based on personal taste, aesthetic judgment or fashion.

2.1 Eco-innovation

27. From the standpoint of a study of the incentive effects of an environmental tax on innovation, it is tempting to include environmental objectives in the OECD definition of innovation. There can be no doubt that new sources of supply or more environmentally efficient inputs used to make a new product or in the process can help to preserve the environment and deserve to be called environmental innovations, or eco-innovations. Kemp and Pontaglio (2007) define environmental innovation, or eco-innovation, as "the production, assimilation or exploitation of a product, production process, service or management or business method that is novel to the firm or user and which results, throughout its life cycle, in a reduction of environmental risk, pollution and other negative impacts of resources use (including energy use) compared to relevant alternatives". This broad definition makes it possible to include innovations whose primary purpose is to improve the environment, such as reducing emissions of toxic products, or any change that helps to reduce harm to the environment. For Frondel *et al.* (2007), however, environmental innovations – at least without incentive taxes or regulation – derive more from economic imperatives like reducing costs than from a real desire to protect the environment.

28. Taking this broad definition as a starting point, the Measuring Eco-Innovation (MEI) project funded by DG Research for the European Commission classes firms into one of four mutually exclusive categories according to the way in which they innovate: for a strategic reason or according to the mode of innovation (development or adoption/take-up of innovations). One group comprises firms that do not innovate in the environmental sphere, that have no strategy for it, but make an effort to develop innovation (through R&D, for example). The other three groups are eco-innovators to varying extents (Table 2).

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structure, the implementation of advanced management techniques [and] the implementation of new or substantially changed corporate strategic orientations" (OECD, 1997); "Marketing innovation: implementation of a new marketing method involving significant changes in product design or packaging, product placement, product promotion or pricing" (UNESCO, 2007).

Table 2. Types of eco-innovative firms

	Strategic objective	Non-strategic objective
Development of innovations (R&D)	Strategic eco-innovators operating in the environmental equipment and services sectors, developing eco-innovations to sell to other firms.	Non eco-innovating firms
Adoption, take-up of innovations	Strategic eco-adopters that intentionally implement eco-innovations developed in-house or acquired from other firms or by both means.	Passive eco-adopters that take up, but do not go looking for, process, product or organisational innovations which have a positive impact on the environment.

Source: MEI (2007) (http://www.merit.unu.edu/MEI/).

2.2 Measuring innovation

29. A study of innovation inevitably raises the difficult and sensitive question of how to measure it. The eclectic selection of references proposed here illustrates the dilemma of a researcher who has to choose the right measures to evaluate what has been innovated and the extent of the innovation. Bernauer *et al*. (2006), for example, argue that there are two ways of measuring innovation. They distinguish between binary indicators of the yes/no type (*e.g.* have you created or modified such and such a product or taken steps to reduce VOC emissions associated with it?) and indicators of intensity like patents, patent costs and R&D spending. Rogers (1998), in a study of innovation in Australian firms, says that two important sets of questions should be considered: those about successful innovations brought to market and those about innovation activities. In another article (2000), he highlights the stages of the innovation process and argues that they all have one point in common: they imply the investment of time and money. Thus, any innovation can be identified by these two factors. He distinguishes four stages: the idea originating in research, the technical and economic feasibility, integration of the innovation into production, and the marketing of its effects. McNamara *et al*. (2003) focused on successful innovations (as outcomes). To get round the difficulty of measuring the practical outcomes of innovation, Bhatnagar and Cohen (1997) came up with the idea of measuring innovation by the expected return!

30. Actually measuring the many different facets of innovation in practice is another problem. In order to find out whether a firm has "objectively" or "really" innovated, it is clearly not sufficient merely to ask it whether or what it has innovated. Ideally, consideration should also be given to a certain number of indicators about the nature, intensity and mode of innovation, the value of which can determine the different types of innovation. A good example here is the set of indicators developed by the Swiss innovation survey to measure innovation activity according to the phases of the innovation process (Table 3). Each indicator is subject to the risk of inaccuracy and concerns only a partial aspect of the innovation behaviour of firms that operate in a different economic environment (markets, competition, products, activities, regulation, etc.).

31. Although firms' innovation activities are mostly motivated by a concern for performance, they have different strategies or objectives. A first aim would be to stake out a position in a product niche that gives the firm a technological edge. A second aim lies in the fact that firms frequently try to increase supply, either by improving productivity or by increasing production capacity. A third aim may be to win new market share or enter new markets. Another important objective could be to cut costs (for example, by substituting labour for capital).

Table 3. Innovation activity indicators at the level of the firm

Input	Output	Performance on the market
Innovation effort (qualitative) - *Research* - *Development* - *Construction/Design* - *Consecutive investment* - *IT expenditure* Innovation expenditure - *R&D expenditure* - *Total spending on innovation*	Importance of product and process innovations - *technical aspect* - *economic aspect* Patents filed - *yes/no* - *number*	Degree of novelty (products) *Share in sales of* - *improved products* - *new or significantly improved products* *Share in sales of novelties* - *for the firm* - *for the industry (global novelties)* Cost reductions due to innovation (processes): - *yes/no* - *as percentage*

Source: Arvanitis *et al.*, 2007, p. 22.

32. Innovation may also have "ideological" or regulatory motives, like a sincere concern to preserve the environment (which can go hand in hand with the "marketing" of success), or health and safety concerns, for example.

2.3 Innovation in Switzerland

33. Since 1990, the Swiss Economic Institute (KOF) of the Zurich Federal Institute of Technology (ETH) has carried out a three-yearly survey of innovation in industry for the State Secretariat for Economic Affairs (SECO). For the third survey in 1996, the scope was extended to include services and construction. The methodology for the survey is based on the OECD and Eurostat harmonised catalogue of questions (Oslo Manual, 1997) and its results are comparable with those of EU member surveys coordinated by Eurostat (Community Innovation Survey, CIS). Innovation is defined subjectively: innovators decide for themselves the precise nature of the innovation (Box 1).

34. Elias (2004) summarises the main results of five surveys spanning 15 years (1990, 1993, 1996, 1999, 2002) as follows.

- All categories of firms in Swiss industry innovate extensively, from small business to multinational.
- Switzerland had a clear lead in the first surveys in comparison with other countries. It has lost ground since then but is still in the leading group with Finland, Sweden and Germany.
- Switzerland leads the way in terms of cooperation between elite higher education and the economy (knowledge transfer).
- There has been little change in the classification by sector and segment.[8] In manufacturing, the leaders are (1) power generation, instruments, vehicle parts, (2) electronics, clockmaking, construction of machines, and (3) chemicals, pharmaceuticals and synthetic products.

[8] The classification by sector as far as innovation is concerned naturally depends on the chosen indicator. For example, the most recent survey in 2005 puts the electrical industry and the manufacture of (precision) instruments in first place, after textiles (!): over 45% of firms in the sector are deemed to be innovative. The same firms in the two industries devote 3% and 5.1% respectively of their sales to R&D (the industry

- The main obstacles are the cost and risks of innovation, funding, the lack of specialised staff, and government regulation (including environmental legislation).

Box 1. Technological innovations in the Swiss survey (KOF)

Product innovations are products that are technically new or significantly improved from the firm's point of view. This means products that are new in terms of their use or quality or in terms of new physical or interactive elements required to produce them, and products that have been fundamentally improved or modified in relation to the service they provide or the way they are used.

Changes of a purely aesthetic nature such as colour or style are not regarded as product innovations, nor are variants developed in accordance with customer specifications, for example, where the technical basis and properties of the product (good or service) remain broadly unchanged.

Process innovations refer to the first utilisation within a firm of manufacturing processes or new or significantly improved technical procedures used to produce goods or provide services to persons or things. The product itself may also be modified, but the primary objective is to improve efficiency.

Production processes developed by a firm and sold to other firms are regarded as product innovations.

Source: Arvanitis *et al*. (2007, 2005 survey questionnaire).

35. Overall, the most recent survey in 2005 confirms these findings. The proportion of innovating firms in industry (all sectors), though declining, is still high: 66% in manufacturing, 47% in services. The erosion of firms' efforts to innovate appears to be attributable to recurrent economic weakness since the early 1990s. Persistent funding problems seem to be the consequence of structural pressure on margins due to globalisation and stiffer competition. Except in certain cases, obstacles caused by regulation seem to be dwindling.

36. The survey regards environmental policy, especially regulation, as a curb on innovation rather than a business opportunity. The question about government obstacles to innovation proposes a list of regulations including "environmental legislation" (answers may vary on a scale from 1 "none" to 5 "very great"). In the six surveys since 1990, the percentage of answers in the highest two brackets (4 and 5) was respectively 19.4, 26.8, 21.2, 18.0, 13.8 and 16 percent. These results are similar to those for regional development and construction regulations but behind those for domestic market regulations and other regulations. In all events, these factors are ranked well behind costs (38 percent in 2005), miscellaneous risks (18 to 25 percent) and funding problems (22 to 27 percent).

37. Although tax can be a powerful spur to innovation, firms' behaviour also depends on their general innovation strategy. In a recent study, Arvanitis (2008) looked at the determinants of innovation in Swiss firms with the help of data collected since 1996. The three key conclusions of his study are instructive in relation to the interviews conducted for this study.

average is 2.9%, compared with 7.4% for chemicals, 4.6% for clockmaking and 2.6% for textiles) – see Arvanitis *et al.* (2007).

- Demand, competition and technological potential all have a significant positive influence on the four measures of innovation activity.[9] Protection of property rights has no influence on process innovations (by nature, such innovations are not divulged outside the firm).
- As far as external sources of knowledge are concerned, suppliers of production materials, components, tools and machines logically exert a positive influence on process innovation, whereas the same is not true of other innovation indicators, including the existence or otherwise of product innovation. Customers are important for product innovation, as are documentation about patents and participation in trade fairs (also valid for R&D efforts and patent filings).
- The firm's size has an influence on the scale of innovation activity because of the diversification of activities, economies of scale and other size-related factors. The bigger the firm, the more innovation activity it tends to have, except for product innovation activities, which do not seem to be proportional to size.

3. Choice of activities and firms

38. The choice of activities (and hence of firms to interview) was based firstly on the Selected Nomenclature for Atmospheric Pollution (SNAP97). The 2007 OFEV study distinguishes 60 "activities" on the basis of the EMEP/CORINAIR list of activities (called the list of SNAP97 codes), covering all industrial activities that emit VOCs.[10] It classes statistical units – firms – according to their VOC-emitting economic activity and groups them into coherent sets, thus allowing for international comparison. The activities are chosen on the basis of overall emissions (see Table 4) and emission factors (Table 5). The emission factor measures the intensity of VOC emissions for each activity under consideration (kgs of VOCs per unit of measure of activity). Unsurprisingly, the choice focused on activities that number among the biggest emitters and also have high emission factors, since they are the activities where the tax is likely to represent a substantial cost and hence, in theory, a particular incentive for reducing emissions.

39. Major emitters, like the printing and paint industries, came to the attention of the designers of the tax, of OFEV in tracking the tax and of observers, as a result of the reactions of those concerned. That was certainly the case for printing. The Swiss print industry has already come under the microscope in several studies (Econcept, 2002b; CDF, 2008), and has also organised itself in the effort to reduce VOC emissions. Self-organisation, making the industry easy to approach, and the existence of technical documentation, providing readily available and accessible information, were two reasons for choosing a VOC-intensive industry. A generally high level of emissions and a relatively large emission factor also spoke in favour of the "metal cleaning" activity. Cleaning as part of the metalworking process is an important activity in several industries, such as automobile parts, clockmaking, medical equipment, electrical engineering and machine construction.

9 Arvanitis (2008) uses four binary variables (yes/no) to identify and categorise innovation activities: product innovations (INNOPD), process innovations (INNOPC), the presence of R&D activities (F&E) and the filing of at least one patent (PAT) during the reference period (the two years preceding the survey).

10 In this context, an activity that emits VOCs may span several economic activities or branches within the meaning of NOGA, the Swiss General Nomenclature of Economic Activities.

Table 4. The 15 activities with the highest VOC emissions (2004)

Activities (industry/commerce)	Emissions	Change 98-04
Printing	4719 t	- 58.7%
Other industrial application of paint	3105 t	- 65.4%
Application of paint: construction	2430 t	- 65.5%
Application of paint: wood	2400 t	- 47.3%
Cleaning of commercial buildings	2098 t	- 9.7%
Cleaning of metals	2065 t	- 45.4%
Sprays – industry/commerce	1470 t	+ 5.0%
Production of fine chemicals	1220 t	- 44.5%
Emissions from solvents (non-spec. ind/com)	1200 t	- 36.8%
Industrial cleaning: other	1080 t	+ 134.8%
Aircraft defrosting and other defrosting	1033 t	+ 72.7%
Other non-ind. application of paint	867 t	- 61.4%
Production of pharmaceuticals	834 t	- 16.9%
Application of gas	830 t	- 12.6%
Application of wood preservatives	803 t	- 55.4%
LU-VOC	26154 t (50% of emissions liable to the tax)	

After OFEV (2007): Anthropogene VOC-Emissionen Schweiz 1998, 2001 und 2004.

Table 5. The top 15 activities by emission factor (2004)

Activities (industry/commerce)	Emission factor (intensity)	Change 98-04
Printing	330 kg/t paint (33%)	- 43.1%
Other industrial application of paint	450 kg/t paint (45%)	- 11.8%
Application of paint: construction	60 kg/t paint (6%)	- 72.7%
Application of paint: wood	320 kg/t paint (32%)	- 54.3%
Cleaning of commercial buildings	0.52 kg/t paint (0.5%)	- 14.0%
Cleaning of metals	350 kg/t solvent (35%)	- 16.7%
Sprays – industry/commerce	---	---
Production of fine chemicals	---	---
Emissions from solvents (non-spec. i/c)	---	---
Industrial cleaning: other	---	---
Aircraft defrosting and other defrosting	350 kg/t defrosting product (35%)	- 23.9%
Other non-industrial application of paint	510 kg/t paint (51%)	± 0.0%
Production of pharmaceuticals	31 kg/t pharmaceutical (3%)	- 26.2%
Application of gas	---	---
Application of wood preservatives	110 kg/t paint (11%)	- 45.0%

After OFEV (2007): Anthropogene VOC-Emissionen Schweiz 1998, 2001 und 2004.

40. On the other hand, it was thought that it would be equally instructive to observe activities with relatively low VOC emissions that hitherto have been the subject of little if any analysis. Although perhaps less important in terms of jobs and value added, these activities are more highly specialised, represent niche outputs and may have potential for growth that the tax can curb or, on the contrary, stimulate through innovation. The chosen industry was paintmaking (448 t in 2004, emission factor of 3.7 kg/t paint). Although the industry is relatively homogeneous, it has a wide range of applications (construction, wood, etc.) that are themselves on the list of VOC-emitting activities. Some manufacturers also supply printers with ink. So by interviewing them, it was possible to collect data on other VOC-emitting activities.

41. These three activities – printing, metal cleaning/degreasing and paintmaking – were therefore chosen for the case studies (Annex 6.2).[11]

3.1 Choice of firms

42. The final choice of firms also depended on certain characteristics that influence innovation activities. Arvanitis' study (2008) provides some guidance on selection, though without suggesting that the same factors determine innovation behaviour after the tax. Membership of an international group does not appear to be important for innovation in general, but that may not necessarily apply where the environment is concerned because of a group's sensitivity to environmental issues (different regulations in different countries, image and marketing, etc.). The importance of additional costs in relation to product value is probably a decisive factor for the innovation activities induced by the tax. Ideally, it was thought that the sample of firms interviewed should include, for each VOC-emitting activity, at least one small, one medium and one large firm, one firm belonging to a foreign group and one independent firm.

43. About a third of the firms contacted finally granted an interview. Some, especially smaller firms, did not feel particularly concerned by the tax, either because they use negligible quantities of VOCs or were not motivated to take part in the survey, or because they regarded the tax as an "aberration" but were not inclined to say any more on the subject.

4. Empirical information about VOC emissions

44. This section describes the main empirical information available in Switzerland about the effects of measures to cut VOC emissions (regulation and taxation) – a single sectoral study was found – and the results of this study's survey of firms.

45. In its evaluation report, the Federal Audit Office set out to examine the tax on VOC emissions from the standpoint of its effectiveness in reducing such emissions and from an administrative and financial standpoint.[12] The activities chosen for review were the application of paint, printing and cleaning (metals, premises). The Federal Audit Office gave the following answers to the question about the economic and environmental effects of the tax.

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11 Other less important activities could have been polystyrene processing, the manufacture and marketing of sprays (industry/commerce), fine chemicals production and gluemaking. The chemical and pharmaceutical industry, despite its size, was ruled out because of the complexity of production and production processes, especially as the industry is already closely supervised and tightly regulated because of the potential pollution and fire hazards and employee health and safety issues.

12 The four evaluation questions were: What impact has the tax had on reducing VOC emissions? How are tax returns made and how is the tax collected? Is the cost-benefit ratio of the tax sufficient? How does Switzerland compare with other European countries on this issue?

- Firms have taken many measures to reduce emissions. They may be divided into three categories: stationary installations ("end-of-pipe" measures); products; measures like new production machines, transformation of production processes, recycling, etc. As a rule several measures are combined, either out of necessity or by choice, and they are more frequent among large users of VOCs than among small users, whatever the industry sector or segment.
- Several factors encourage firms to introduce measures: the VOC tax, the Air Protection Ordinance, industry-wide agreements, workplace health and safety, production process optimisation, customer demand, the firm's commitment to the environment, cost and product quality issues. Several factors may combine to influence a firm's choice. In most cases they have two or three good reasons for taking the step. A measure cannot be systematically linked to a particular factor.
- However, two trends do emerge: the VOC tax plays an important role in product substitution and the Air Protection Ordinance plays an important role in "end-of-pipe" measures.
- It is difficult to measure the effects of the VOC tax in quantitative terms. The following five findings emerge: 1) the more expensive the product, the less the impact of the VOC tax; 2) the impact of the VOC tax is greater on big VOC users than on small (for the latter, precisely because they use small amounts); 3) firms that have a stationary installation with a filter have less incentive to use alternative water-based products unless they opt for the most environmentally friendly production process (on this point, Article 9 of the VOC Ordinance granting firms exemption from the tax under certain conditions does not encourage them to further reduce emissions); 4) the incentive effect of the tax is an important booster for the cantons in relation to application of the rules contained in the Air Protection Ordinance. For example, the VOC tax encouraged firms that had been recalcitrant before 2000 to take the necessary clean-up measures in order to avoid having to pay a substantial tax; 5) higher awareness among firms and an impetus to innovate with regard to alternative products and production equipment have also been observed, though this innovation process already existed before the VOC tax was introduced.
- Whereas the tax gave firms an additional incentive to take measures to cut emissions when it was introduced in 2000, the situation is now levelling off even though many firms still have scope to reduce their emissions (the potential is greater among smaller firms than among large firms). The impact of the tax will no longer be as great in the future.

46. Econcept (2002a), through the results of a non-representative survey on the incentive effects of the tax on cantons that have gathered information on 71 firms, notes that a certain number of innovations have been made since the VOC tax was introduced, though without giving details.

47. Egger *et al.* (1992) examined the effects of environmental regulations on innovation in 37 paint and varnish makers that answered their questionnaire.[13] Half of them saw environmental regulations as an incentive to introduce technical innovations that would help them to safeguard their competitiveness in the longer term, especially those that regarded the short-term competitive disadvantages as still acceptable. Large firms clearly acknowledged the positive impact on innovation, whereas small firms feared that they did not have sufficient financial resources to confront competition from their bigger rivals.

48. Stritt and Jeanrenaud (1992) examined the effect on industrial firms of regulatory measures to control air pollution from nitrous oxides (NOx) and VOCs. The first issue they considered was the effectiveness of regulatory policy, in terms of the costs imposed on firms for a given reduction of

[13] The study potentially concerned regulations in at least 11 areas: poisons, water protection, air protection, soil protection, hazardous materials and their transport, waste processing, special waste transport, protection against noise, environmental impact studies, and protection against major and other accidents.

emissions. The second issue concerned the possible structural effects. Firms often had to invest heavily in order to comply with limit values (still valid today) set by the Air Protection Ordinance, which came into force in 1986, thus significantly increasing their production costs. The results of a survey of about 70 firms whose activity generated substantial emissions of NOx and VOCs showed that "cost-effectiveness varies by a factor of between 1 and 15 for VOCs and 1 and 24 for NOx" (Conclusion, p. 107). In other words, the unit cost of reducing a unit of gas emission varies greatly according to the firm. Replacing regulation by an economic instrument – tradable certificates, as the authors suggest, or a tax – should therefore help to reduce the cost of air protection. In the majority of cases it was not possible to detect significant distortions of competition. Apparently, measures to control air pollution did not have a great enough impact on production costs to make firms less competitive.

5. Tax and impact on innovation activities

49. Personal interviews with the selected firms using a predefined set of questions generated the necessary information to determine whether the VOC incentive tax has given rise to action that could be described as innovation. The questions were both quantitative and qualitative, sometimes dichotomic, eliciting yes/no answers. The data may reveal the intensity with which the firm implements new products or processes. Personal interviews lasting a maximum of two hours provided a framework for evaluating the innovations, or the changes in general, that have taken place since the introduction of the tax.

50. The interview was divided into five parts. Part A concerned general information about the firm's identity, operations and activities, including a final section on the firm's innovation strategy (R&D, patents). Part B contained questions about the nature and characteristics of innovations since the introduction of the tax or even before. Part C concerned the environmental and economic impacts of the innovations. Part D focused on the determinants of innovations linked to the taxation of VOCs. In Part E, firms were asked for their opinion on the taxation of VOCs.

51. Cantonal experts from a dozen or so cantons – the ones with the most firms potentially liable to the VOC tax – were questioned in parallel. One of the aims of the canton survey was to evaluate the strength of the incentive to innovate generated by cantonal air protection services in managing the VOC tax. Another aim was to see the innovation behaviour of firms liable to the VOC tax through the eyes of cantonal experts.

52. In the following pages, the answers are analysed to show, through firms' characteristics, the nature of innovations and the context in which they have been implemented. Thus, the interviews are exploited by type of activity to answer the research questions described at the beginning of this report. The profile of the firms interviewed in terms of membership of a group, number of employees, main market and presence of R&D or patents is given in Annex 6.3. They were chosen from lists kept by industry groupings or associations, first checking to ensure their membership of the chosen sector (preponderant production), the nature of their output and their size. The number of employees in the firms interviewed varied between 20 (metal cutting) and 430 (printing), but only four firms had more than the 250 employees that distinguish small and medium-sized enterprises (SME) from large firms. Four firms belonged to larger groups, especially in the printing industry. Consequently, most of the firms were independent, often family-owned small businesses. Among the many contacts made, it was not possible to find small firms with fewer than 20 employees for a lengthy personal on-site interview, for reasons ranging from "not concerned" (because using only a very small quantity of VOCs) through "nothing has changed" to "no time" and "not interested". Although the firms that agreed to be interviewed looked favourably on the approach and the survey, most had only a limited amount of time. Interviews lasted between 45 minutes and two hours and none of the firms wanted or was able to give their own detailed description of the changes that had taken place or to search for more detailed information. The exploitation of the information gathered is therefore inevitably of a qualitative nature.

53. The number of patents, a quantitative variable often used in innovation research, relating to the treatment of VOCs in Switzerland is very small and it is therefore not surprising to find that none of the firms interviewed had registered a patent. As confirmed by Swiss innovation studies, there is relatively little research and development in the printing industry but more in the other two industries under review.

5.1 Changes observed following introduction of the tax

54. Generally speaking, the VOC tax did indeed cause changes in the three sectors analysed, *i.e.* printing, paint and varnish making and metal cutting. More specifically, activities generating VOC emissions were scaled back by adapting production processes (printing, paintmaking, metal cutting) or by putting new products on the market (paints). In the first case, this mainly involved raising awareness about and making less use of products that emit VOCs, like isopropylic alcohol, washing and cleaning products and solvents, and replacing them with water-based products. That was the case for all firms interviewed. In the second case, it involved new products like water-based and solvent-free paints and paints containing few solvents (*e.g.* high solid paints).

55. In some cases, more or less sophisticated end-of-pipe scrubbing equipment was installed. Such equipment is particularly suitable for large-scale emissions when making paint. One firm among those interviewed had installed catalytic thermal incineration equipment with heat recovery. In doing so the firm, a paintmaker, had anticipated the likely introduction of the VOC tax, since the equipment had already been installed in the mid-1990s. Very few firms have installed such equipment because it requires substantial investment and entails additional energy consumption.[14] The aim of the other paint and varnish makers was to improve the retention rate and availability of gas effluent purifiers. Tanks are also increasingly being cleaned with new solvents with a lower VOC content, or even solvent-free products. In addition, firms have introduced local exhaust systems that reduce concentrations of VOCs. Paintmakers also offer an industry-wide solution to enable customers to recycle products containing VOCs. One of the paintmakers, equipped with a catalytic purifier, is even able to generate energy and heat.

56. In the metal cutting industry, there is no justification for investing in end-of-pipe equipment solely in order to treat VOC emissions. Only one firm treats exhaust air contaminated by the oil mist generated by metal-cutting machines. The amount of investment needed to reduce VOC emissions from cleaning and degreasing machined metal parts varies considerably according to the type of activity.

57. Overall, the cantons saw a substantial fall in VOC emissions, achieved above all thanks to large firms which made changes before the tax was introduced or in the early days of the tax. However, the success story was not repeated in all cantons, like those in which the main industries do not have access to existing technologies to make the changes needed to reduce VOC emissions (*e.g.* metalworking in the clockmaking industry in the canton of Neuchâtel). Likewise, the cantons observe that the low VOC content of certain products and the small amount of VOCs used in the production process do not always encourage firms to take measures to clean up their processes, given that the VOC tax represents a small fraction of costs. The cantons prefer not to express an opinion on the economic impacts, except for one canton which thinks that some firms have increased their market share.

[14] As end-of-pipe measures are remedial, they neither encourage nor truly reward innovative approaches to reducing emissions or optimising the use of resources.

Printing

58. Eight printing firms were interviewed, including seven offset sheet printers (newspapers, books, promotional items, forms, etc.) and one offset rotary printer (newspapers, magazines, etc.).[15] Generally speaking, change in processes has been continuous since the tax was introduced in 2000. Changes include a steady decrease in the use of isopropylic alcohol in printing processes, the introduction of low-VOC or VOC-free cleaning equipment, the use of low-VOC or VOC-free cleaning products and detergents and the introduction of osmosis water treatment systems. Table 6 contains a summary of changes announced by firms in the sector and indicates certain observed effects.

Table 6. Printing – announced changes

Firm	Date	Announced changes	Effects
1	Continuous change	Processes: steady reduction in alcohol use in production processes; use of low-VOC or VOC-free detergents.	2/3 less isopropylic alcohol.
2	Continuous change	Processes: *idem*; VOC-free products for print rollers; colours containing fewer VOCs; purchase of Kodak Electra printing plates (CHF 80,000).	Reduced VOC/alcohol; but alcohol-free printing is slower.
3	Since 2000	Processes: purchase of two new printing presses; VOC measuring device (CHF 12,000); low-VOC or VOC-free cleaning equipment.	Reduced VOC/alcohol; VOC-free products unsuccessfully tested.
4	2003/2005/2008	Processes: purchase of new printing presses => reduced VOC use in production processes, optimisation of cleaning.	Reduced VOC/alcohol.
5	Since 2000	Processes: 2 new presses => trials of alcohol-free printing (99% alcohol-free).	Reduced VOC/alcohol; difficulties with alcohol-free cleaning products (detergents).
6	2008	Processes: purchase of new presses, one of which can be used with alcohol-free cleaning products; osmosis water treatment system.	Reduced VOC/alcohol.
7	2005	Processes: purchase of "the most up-to-date" 5-colour offset printing press (format 75 x 105 cm).	Reduced VOC/alcohol.
8	Continuous change; a major project has been under way since 2007	Processes: 2 cleaning plants (vacuum distillation) => recovery; new closed-circuit system => no more VOCs and four fewer machines; low detergent use; cleaning of rollers; rubber rags; VOC-free colours.	Reduced VOC/alcohol; potential for further reduction in cleaning rollers (5 t).

Source: interviews with firms.

Paintmaking

59. Seven paintmakers were interviewed. They develop, make and sell industrial varnishes and paints for indoor and outdoor use, especially in the building and construction industries. One firm sells its products only in Switzerland.[16] Table 7 contains a summary of changes announced by firms in the sector and indicates certain observed effects.

15 There are 2,637 firms in the sector (2005), which represents 27,000 jobs FTE. The average firm has 10.2 employees. The largest category is non-newspaper printing, with 1,742 firms (including 1,294 offset printers) and 71% of jobs. There are 37 newspaper printing firms, representing 10% of jobs in the sector.

16 103 firms (2005) operate in the "Manufacture of paints, varnishes, printing inks and sealants" sector, representing 6,666 jobs FTE.

Table 7. Paintmaking – announced changes

Firm	Date	Announced changes	Effects
1	Continuous change	Products: solvent-free products have been developed for over 20 years. Processes: solvent-free cleaning of tanks (CHF 450,000).	Product emissions (internal): 3.3 t (5 t before); tank cleaning: -30 t of VOCs.
2	Continuous change; 1996	Products: VOC-free powder varnish; renderings: 0.1%; construction paints: reduced solvent in enamels; industrial varnishes: over half low-VOC or VOC-free; low-VOC mineral paints. Processes: catalytic/thermal air purifier to recycle VOC products (1996); local exhaust system.	The percentage of VOCs in products fell from 5% in 2000 to 3.5% in 2007.
3	Continuous change	Products: formula changes; high solid products; two products have been modified, one scrapped. Processes: cleaning: recycling => new solvents.	Reduced VOC; products compliant with the Decopaint directive; recycling: low-level loss and deduction from the balance sheet.
4	2006	Products: few changes (many products < 3% VOC); higher water content in primers. Processes: water-based cleaning since 2006 (a new separation plant for less frequent cleaning).	Reduced VOC.
5	2001/2007 and continuous change	Processes: 2001: new plant and building => introduction of a closed-circuit system; 2007: cleaning system for VOC-free cleaning (CHF 300,000). Products: development of low-VOC, VOC-free and water-based products.	Reduced VOC; VOCs are captured and recycled (filter, no combustion); reduced risk.
6	Continuous change	Products: decreasing solvent use.	Acrylic varnishes – great improvement since introduction of the tax; in future, 90% of products will be Decopaint compliant.
7	2002/2003	Products: few changes. Processes: vacuum distillation system.	Constant level of VOCs.

Source: interviews with firms.

60. Generally speaking, there has been continuous change in both processes and products since the tax was introduced in 2000. Processes include cleaning with water, the introduction of closed-circuit systems, solvent recycling and end-of-pipe measures. VOC-free, low-VOC and water-based products have been developed, like mineral paints and high solid paints and varnishes.

Metal cutting (degreasing of metal parts)

61. Seven firms in the metal cutting industry were interviewed. They make parts, varying in size between one or two millimetres and several centimetres, by cutting them from a metal bar.

Table 8. Metal cutting – announced changes

Firm	Date	Announced changes	Effects
1	Before 2000/ 2001, trials of various replacement products	Processes: benzene distillation, reducing losses during machining and recovering the benzene; purchase of benzene jars to prevent evaporation during parts inspections.	30% reduction in VOC consumption (benzene) at constant output.
2	2000 and 2003/2004	Processes: acquisition of a closed-circuit vacuum VOC industrial washer + distillation plant (following a move!); reorganisation of benzene distribution for degreasing samples.	Substantial reduction in VOC purchases, then approx. 20%.
3	Before 2000/ 2004/ forthcoming	Processes: application of the most up-to-date technology / installation of an oil mist filter with corresponding reduction in emissions / search for a way of preventing evaporation when degreasing parts for inspection.	Approx. 20% reduction in emissions since 2000 and further significant reductions expected in future, though reaching a ceiling.
4	1998/ 2002/ 2003	Processes: replacement of the open washer with a more efficient closed-circuit machine; acquisition of a benzene distilling plant; non-COV product used to clean production machines instead of petroleum.	65% reduction in VOCs at constant output, mostly due to environmental regulations.
5	2001/2007	Processes: acquisition of a plant to distil the benzene used to degrease samples; acquisition of a new vacuum washer using modified alcohol; additional purchase of benzene jars.	30% reduction in VOC emissions in proportion to output.
6	2004/ 2006/ 2008	Processes: acquisition of a closed-circuit tetra-chloroethylene washer and an intermediate washer (degreasing) using water-based products for non-finished parts; trial of a biodegradable product to replace fractionated benzene in benzene jars.	VOC consumption and emissions reduced by approx. 50% since 2004.
7	Before 2000/ 2000/ 2008	Processes: Benzene jars with spring lids; closed-circuit washer allowing for VOC recycling (Opair); use of anti-rust detergents for certain clock parts; ecological product for cleaning machines; plan to replace benzene jars with soaking in detergent; detergent-based washer for stainless materials.	Net reduction in emissions of approx. 25% since 2002 despite increased output.

Source: interviews with firms.

62. Parts are machined in small and large production runs on conventional automatic cam or digital lathes (screw-cutting machines). The machines operate under a constant flow of oil. VOCs, especially benzene, and more dangerous substances like trichloroethylene (formerly) and perchloroethylene are used to degrease the parts without residue or tarnish. Petroleum and other more corrosive products are used to clean the machines.

63. Generally speaking, many changes have taken place since 2000. They include the introduction of devices to distil oil-polluted benzene, of water-based replacement products (detergents), of closed-circuit washers that either recycle VOCs or (more rarely) use detergents, and of lidded benzene jars for intermediate parts controls. Table 8 contains a summary of the changes announced by firms in the sector and indicates the reductions in VOC emissions achieved.

5.2 Role played by the VOC tax in the changes

Printing

64. Broadly speaking and according to most of the firms interviewed, the tax on VOCs was often an important factor explaining the changes that have occurred in printers' production processes. However, the

amount of the tax sometimes seems rather small, or even negligible, in relation to the product cost or price or sales. This is particularly true for large firms. For example, printer 7 (firm 7) consumes about 7 tonnes of isopropylic alcohol a year (corresponding to a tax of CHF 21,000), individual substances containing VOCs with a value of CHF 35,000 and cleaning products with a value of CHF 25,000. The total amount, set against sales of CHF 30 million, is "not a great incentive" to consume less. Yet printer 2, with sales of CHF 10 million, admits a certain incentive to reduce the use of products containing VOCs because the amount of tax would have been relatively large (over CHF 100,000).

65. In this context, most printers would nevertheless regard abolishing the tax as a slight advantage, asserting at the same time that it would not signal a return to former production processes (*e.g.* for health reasons). On the other hand, a hypothetical increase in the tax (*e.g.* to CHF 5 per kg) would be a further disadvantage, especially with regard to foreign competition, but not really a shock. Printer 4, for example, concedes that VOC-based products are still relatively cheap, especially compared with potential substitution products.

66. All the printers interviewed agreed that a minimum level of alcohol is still necessary in printing to guarantee high quality (for colour control, for example) and to keep presses productive. Progress has been made in cleaning products and detergents, but again it often seems difficult to do away entirely with products containing VOCs, especially for productivity reasons. Another difficulty is that manufacturers of printing presses often advise against using VOC-free products, even on the latest machines, with possible consequences for the warranty.

67. Other factors cited by printers include employee health (air quality) and environmental protection. The latter is becoming an increasingly important argument in marketing and sales, even though it is very little used in connection with VOCs (unlike in papermaking, for example, where there is a possibility of international certification).

68. Customer demand obviously also plays a key role. Growing environmental awareness among customers seems to favour a move towards more environmentally friendly production processes and products. Printers 2, 5 and 6 clearly stated that the environmental argument was a factor, and sometimes an important one, for their customers. But price (and sometimes quality) concerns can militate against environmental concerns because the new products, which use fewer VOCs, often cost more. For reasons of quality, therefore, and perhaps also price, some printers – depending on their type of output (high-quality work, for example) – still appear to prefer VOC-based products.

69. Other factors that may explain the changes that have occurred in production processes include greater awareness among employees about the use of VOCs, greater know-how and the rising price of alcohol (a substitute) in relation to water. In the printing industry, the advance of digital printing may also explain some of the changes in the production process. From an environmental standpoint, however, the reduction in VOC emissions from digital printing could be partly offset by higher electricity consumption. Table 9 shows the most important factors behind the announced changes and summarises the role played by the tax in the industry concerned.

Table 9. Printing – factors of change and role of the tax

Factors
• Tax (reduction of the amount) • Employee health • Customer demand (pressure on sales) • Marketing argument • Environmental protection • Greater awareness among staff • Price of isopropylic alcohol
Role of the tax
Reducing the amount of tax payable has often been an important factor.

Source: interviews with firms.

Paintmaking

70. Most of the firms interviewed said that the VOC tax was often only one factor among others explaining the changes that have taken place in firms' products and production processes. However, the industry often uses substantial amounts of products containing VOCs, giving it a particular incentive to reduce their use. Firm 3 has reduced the amount of VOCs by about 37% in the last few years, from 260,000 kg to 190,000 kg. Likewise, firm 5 has cut its solvent consumption by 50,000 litres. The financial incentive for these firms can thus be relatively important. In this context, however, the scale of reduction of VOC use also partly depends on the range of products made (Annex 6.2). Solvents have to be used in many applications for quality reasons (drying). For paints used in construction, which are the most important products for the firms in the survey, climatic conditions (low temperatures and humidity) often mean that it is not possible to use only water-based products, especially for exterior paints. In contrast, water-based products are increasingly widely used for interior paints or paints applied to wood (doors, frames, etc.) and furniture. Other factors that have played a role in the observed changes are employee health, safety aspects like the reduction of fire and explosion risks and environmental protection in general. Another consideration is reducing smells through less solvent use in products.

71. Customer demand is of course a key factor. On the one hand, growing environmental awareness in the population seems to favour a switch to water-based products. On the other hand, painters and decorators still seem to make regular use of products containing VOCs for reasons of quality, the tax being entirely passed on to customers. European regulations, especially the Decopaint Directive (2004/42/EC), seem to be a key factor for paint and solvent makers that export some of their output to EU countries, since products must comply with the strict requirements contained in the directive before they can be sold on the European market.[17] In this context the case of firm 6, which imports the products made by its parent company in a neighbouring EU country, is particularly instructive: the VOC tax seems to play only a secondary role because the products sold in Switzerland already meet the strict criteria of the EU directive. However, products containing more solvents are also offered in order to meet demand from Swiss customers.

[17] The Decopaint Directive seeks to cut VOC emissions from paints and varnishes not covered by existing regulations on overall emissions by enterprises (over 5 tonnes a year). The new regulations set maximum values for solvent-based products between 400 and 750 g per litre from 1 January 2007 and between 30 and 750 g per litre from 1 January 2010 and for water-based products between 75 and 500 g per litre and between 30 and 200 g per litre respectively.

Table 10. Paintmaking – factors of change and role of the tax

Factors
• Tax (reduction of the amount) • Employee health • Safety aspects (explosion) • Product quality (smell) • Environmental protection • European regulations (Decopaint Directive 2004/42/EC)
Role of the tax
Reducing the amount of tax payable has been one factor among others.

Source: interviews with firms.

72. Finally, it seems that abolishing the tax would not induce changes to manufacturing processes or products. The health and safety advantages of making less use of products containing VOCs are undeniable. In addition, environmental awareness within firms has increased, partly as a result of the VOC tax, and they are increasingly starting to play the "green" card. Table 10 shows the most important factors behind the announced changes (in descending order) and summarises the role of the tax in the industry concerned.

Metal cutting

73. Most of the firms interviewed said that the VOC tax was a decisive financial incentive for changing the way they cleaned parts. Distilling plants, benzene jars and replacement cleaning products, which did not require large-scale investment, enabled them to reduce their emissions by an appreciable amount, perhaps by around 10 to 20 percent. Emissions can be reduced substantially at the end of the production process by using high-speed closed-circuit vacuum washers, which cost CHF 150,000 – 200,000. Most used and hence polluted substances are purified and recycled every one to two years. Recycling generates an appreciable one-off reduction in VOC purchases. Overall, firms estimated that they had reduced VOC emissions by between 20 and 60 percent. Four of the seven firms interviewed had acquired a closed-circuit vacuum washer before the tax was introduced in 2000 – one as early as 1993 – and the three others acquired one in 2000, 2004 and 2007 respectively.

74. There is still scope for further reductions by replacing VOC products with detergents at various stages in the production process, from the degreasing of parts for quality controls during production to washing before the finished parts are delivered to customers. Efforts have been and are being made in that direction, especially by the larger firms, but it is acknowledged that the use of non-COV substitutes and the necessary changes to procedures are tricky, partly because the quality of degreasing and drying is often not (yet) guaranteed and partly because parts made of steel or iron begin to rust on contact with water, an irreversible process. These problems, the time lost in lengthy drying and residues and tarnish on parts after drying are obstacles to the large-scale and extensive use of detergents.

75. The metal cutting industry made active attempts to stop the introduction of the VOC tax, arguing that a large number of firms would have to pay the tax which, with other factors, would increase production costs. Although there are several hundred metal cutting firms in Switzerland,[18] the market is not homogeneous: overall, there are large numbers of relatively small firms that compete on Swiss and global markets for standard products that do not require precision of a few microns. However, the firms

[18] It is not possible in the current classification of economic activities (NOGA) to identify and count metal cutting firms, since they are classified among mechanical engineering workshops in the machining activity of manufacturing industry and in the clockmaking industry.

interviewed said that they provided high-precision metal cutting on niche markets and that there are relatively few competitors in certain segments. The production of parts for clockmaking is "protected", at least from foreign competition, by the requirements of the "Swiss made" label. The interviewed firms' other major client sectors are, in order of importance, interfacing/electronics, carmaking and medical equipment. Paradoxically, few clients care about how products made as long as they are assured of the quality. Consequently, foreign regulations are never mentioned as an incentive for reducing VOC emissions, though firms are aware that the new European REACH regulation may have a certain influence on operations in Switzerland by 2010.[19]

76. Despite their determined opposition to introduction of the tax, most firms – initially reluctant – acknowledge that it has changed mindsets among both managers and staff, who are now better informed about the risks of VOCs for employees' health and well-being at work. The reductions in VOC emissions observed by firms to date bear witness to the tax's success in environmental terms, although environmental protection was only a secondary factor for some, especially in the early years of the tax. Almost all the firms interviewed recognise the positive impact of the tax despite everything and would not try to return to their old ways if the tax was reduced or abolished.

77. Table 11 shows the most important factors behind the announced changes (in descending order) and summarises the role played by the tax in the industry concerned.

Table 11. Metal cutting – factors of change and role of the tax

Factors
• Tax (reduction of the amount)
• Employee health
• Safety aspects
• Environmental protection
• Unimportant: *e.g.* clients, European regulations, certification
Role of the tax
Trigger, but measures taken in context (relocation, redevelopment, investment).

Source: interviews with firms.

5.3 Are the announced changes innovations?

78. A distinction is drawn between two types of innovation, defined as technological product and process (TPP) innovation. The first type concerns improvements to the technical characteristics of the product, like the components and raw materials used to make it. The second type implies significant changes to the production chain, production technologies and inputs and human resources. In general, the purpose of innovation is to improve the firm's economic performance and competitiveness, the environmental impact being secondary.

79. The distinction between product and process innovation is not always entirely clear-cut. A new product often requires (major) changes to production chains and processes and vice versa. For the industries and firms involved in this study, it does not seem possible to classify the observed changes according to these two types of innovation without careful thought. Sometimes innovation, defined at the level of the firm, is made for purely environmental reasons (eco-innovation).

[19] REACH, which came into force in June 2007, is the new European Regulation on Registration, Evaluation, Authorisation and Restriction of Chemicals (http://ec.europa.eu/enterprise/reach/index_fr.htm).

Printing

80. At first sight, most of the changes that have taken place are based on the introduction of existing formulae or technologies that reduce VOC consumption and emissions throughout the production process. In the printing industry, less use is made of isopropylic alcohol in production processes, both in printing per se and in cleaning products (used to clean the rollers in offset printing). The printing presses are often the same (Heidelberger Druckmaschinen AG has 40% of the global market for paper offset printers) and it is up to the printers to find the right dose of alcohol. That is the level at which firms may themselves make changes, seeking a technical solution to minimise the use of VOCs by varying the printing technique, the VOC content of colours and the water quality.

81. Apart from making less use of products containing VOCs when cleaning the equipment after each print run, the challenge consists in reducing the alcohol content responsible for reducing the surface tension of the water in the ink on contact with the print medium. Thus, printers are increasingly moving towards zero alcohol use in ink and colours, even though the goal is still difficult to achieve (technically and financially) for the same level of quality. One problem in this context also lies in Swiss firms' lack of influence on foreign manufacturers of printing machines, who often advise against the use of VOC-free inks and colours. In contrast, where colours are concerned, producers seem more inclined to listen.

82. Efforts have been made to reduce VOCs in the products used to clean the rollers, but none of the firms in the study has been able to entirely eliminate products containing VOCs. However, the brand new press installed in firm 6 in 2008 can be cleaned with alcohol-free products. The same firm also uses an osmosis device to soften its water, which also cuts alcohol consumption and hence VOC emissions.

83. Thus, the changes observed in the printing industry seem mostly to belong to the second category of innovation (technological process innovation), since they concern machines, developed by the manufacturers, and production inputs: less and less isopropylic alcohol is used in the production process. Changes can also be observed among staff: printing with little or no alcohol is becoming an integral part of a printer's know-how and there is a growing awareness of the need to use VOCs sparingly.

84. Testing new machines to achieve low-VOC production (in this case, less use of isopropylic alcohol) is often an expensive business for firms. The main problem lies in the quality of the finished product, which is difficult to maintain while using less alcohol. However, tests carried out by individual firms lead to changes in production processes that can be qualified as innovations, or even eco-innovations. According to the MEI typology of eco-innovating firms, most printers seem to belong to the category of firms that adopt and take up innovations, often with a strategic objective, though sometimes not. Most innovation seems to take place upstream, among the makers of printing machinery. None of the firms interviewed had an R&D unit, reflecting the general situation in the industry.

Paintmaking

85. Changes in the paintmaking industry tend to involve the introduction of processes that make less use of VOCs. The use of solvents in manufacturing processes has often been greatly reduced (*e.g.* in acrylic varnishes) or entirely replaced by water-based products. In addition, low-VOC or VOC-free products are increasingly used during production, especially to clean tanks. For example, firm 1 has introduced a solvent-free tank cleaning system that cost CHF 450,000 but has enabled the firm to reduce its VOC emissions by 30 tonnes.

86. Similarly, in 2007 firm 5 bought a new cleaning device for CHF 300,000 in order to clean tanks used for products that do not contain VOCs. Other benefits of this measure include less risk of accident, less risk to health and a reduction in smells. Changes in manufacturing processes here also affect the end

product. Some products can therefore be classed as new (*e.g.* high solid and aqueous varnishes), thus representing technological product innovations. This was the case for four of the seven firms interviewed, without counting innovations by the parent of one firm outside Switzerland. As long ago as the 1980s, the Swiss paint and varnish industry had already set itself the goal of reducing or even completely eliminating VOC-based solvents.

87. The introduction of existing exhaust air-purifying technology or, in the case of one firm, of end-of-pipe scrubbing represents a change that can be qualified as innovation or eco-innovation. An industry-wide recycling scheme for customers is another major change.

Metal cutting

88. VOC emissions can be reduced by two changes in the production process:

- replacing VOCs (traditionally used to degrease metal parts without residue by evaporation and, in much smaller quantities, to clean machines) with water-based detergents or bacterial systems;
- using VOCs only in closed recipients and devices so that they can no longer escape into the atmosphere, including used product recycling. Emissions can be further reduced by changing working practices involving VOCs and recycling used substances.

89. Replacement means changing degreasing processes. More needs to be done to identify and select detergents suited to the types and materials of manufactured parts, by repeated on-site testing. In many cases, the replacement products and procedures are not (yet) entirely satisfactory, and what works for one firm does not necessarily work for all. Not all the firms interviewed systematically cooperate with others in the same industry: each one has its own "recipes" and firms neither cooperate on research or share their experience. Switching to detergents sometimes involves relatively substantial investment, like buying a detergent-based washer instead of or in addition to existing VOC-based equipment.

90. Closed-circuit degreasing devices are now standard in the metal cutting industry: the firms interviewed made the change before the tax was introduced or during the early years (2000-2001). Production equipment benefits from technical advances made by manufacturers and suppliers, who are at least partially in tune with the environmental demands of clients and politicians. Greatly encouraged by the tax, lidded benzene jars are used extensively for regular controls of manufactured parts. However, quality control staff often do not close the lid after dipping the parts, since the operation may be repeated dozens or hundreds of times a day.

91. Only two of the firms interviewed have a research and development activity *per se*. R&D concerns improvements to existing equipment, the construction of specific inspection devices and greater efforts to optimise production processes. The biggest firm in the sample has joined forces with a manufacturer to develop a prototype benzene jar with an automatic lid that would be entirely airtight, to prevent evaporation, and use a shower system to degrease parts rather than having to dip them into the liquid by hand.

92. Unsurprisingly, the relatively large number of changes announced by firms in the industry relate entirely to technological process innovations. Changes are driven by the acquisition of new plant and equipment incorporating technological advances and by the introduction of new procedures. All the firms have learnt and invested in new degreasing techniques after more or less extensive on-site testing. These changes are innovations, even if firms say that as a rule they have had either no economic impact or a very limited benefit.

93. In contrast, the tax seems to have significantly reduced VOC emissions. According to the typology of eco-innovating firms (MEI, 2005), metal cutters appear to belong to the category of firms that adopt and take up innovations without necessarily having a strategic objective. Three categories of firms can be distinguished:

- the three large firms in the sample, which have been dealing with environmental issues for twenty years or more and included the aim of reducing VOC emissions in their "strategic" concerns when or before the VOC tax was introduced, by bringing in the most up-to-date production technologies, thinking about the issues as a whole, adopting cutting-edge technologies in other environmental matters like water and waste treatment, etc.
- two firms that became aware of the environmental problem of VOCs (and of other issues like workplace health and safety) when they had to start paying the tax and took measures relatively quickly;
- two firms that have taken what they describe as "restrictive" measures to reduce emissions and the amount of tax payable, without being convinced of the administrative or technical efficacy of the tax.

Cantons' viewpoint

94. The cantons consulted put forward a large number of examples of technological product and process innovation according to their dominant industries. Above all, they mentioned product improvements in paints, colours and solvents. Most of the cantons that took part in the study also noticed a clear reduction in the VOC content of cleaning products and detergents. But the downside of these successes is often the risk of a reduction in quality that in some cases cannot be tolerated, as in metal cleaning, for example. Given the current state of technology and existing substitution products, it is difficult for these activities to eliminate VOCs altogether.

95. Two types of process innovation have been introduced. The first, end-of-pipe innovations, were generally introduced by big firms in large-scale installations before the VOC Ordinance came into effect *e.g.* an incinerator at a cigarette maker, a biological washer in a chemicals and pharmaceuticals plant). The second type of innovation concerns continuous improvement of the production process (printing).

5.4 Factors explaining the differences in firms' innovation behaviour

96. Several factors seem to explain the differences in firms' innovation behaviour. The most important seem to be the firm's products (*e.g.* book or newspaper printing, interior or exterior paints, oil paints and the impossibility of eliminating VOCs from some products), customer demand (customers may be more or less environmentally demanding), the size of the firm (smaller firms seem to have to make more effort to innovate), the existence of an R&D unit (generally the case with paintmakers) and, last but not least, the firm's own attitude towards the environment (integrated environmental strategy).

97. Many medium-sized and family firms take advantage of the need to renew technologically and economically obsolescent plant and equipment to take steps to reduce VOCs. However, considerable thought and consideration is given to the present and future financial impacts of investment. For the smallest firms in the sample, some innovations were not made, or were made only partially, because of the cost (problem of funding), except in the metal cutting industry; for others, some innovations like the installation of filters or the capture of VOC emissions are simply not financially viable. The financial obstacle is correlated to the size of the firm and whether or not it belongs to a group (national or international). Table 12 shows the main factors explaining the differences in firms' innovation behaviour.

Table 12. Factors explaining differences in innovation behaviour

Main factors explaining the differences in firms' innovation behaviour
• Types of product offered
• Customer demand
• Size of the firm
• Existence of an R&D unit
• Membership of a group
• Pro-environmental attitude

Source: interviews with firms.

Cantons' viewpoint

98. At canton level, the determinants of VOC innovation are very variable. The perception of them may depend on the structure of the canton's economy and the presence of activities that generate VOC emissions. The factor most often mentioned is workplace health and safety, though other factors include the supplier and market demand, green credentials, the Air Protection Ordinance, competition and international standards. Two cantons emphasised the importance of the tax as a factor favouring innovation because without it, they said, nothing would happen.

99. All the cantons agreed that the frequency and mode of innovation depend to a very large extent on financial resources. Investing in green innovation is often too expensive for small businesses, while some big firms simply do not see any interest in it.

100. Firms very often innovate of their own accord or follow innovations developed by suppliers. One canton noted that from 2009, small businesses will be able to get together to declare their emissions and obtain reimbursement, giving them a better basis for cooperation. Another canton with a dominant pharmaceutical industry said that many firms do R&D and develop innovations for other firms.

101. Few firms have suffered economic difficulties on account of the tax. No firm has moved, changed business or totally ceased production. But many, especially small firms, have not taken any measure that could be qualified as innovation because the tax is so small. Cantonal administrations also mention the problems of the quality of substitution products or technologically modified products.

102. All the cantons consulted found that there has been a definite improvement in products and processes in certain industries but that reducing VOCs does not seem to have been the main driver of innovation. Fewer than half the cantons interviewed had noticed any real change of behaviour in favour of the environment, and only one said that a small number of firms had innovated solely from a concern for the environment.

5.5 Does the incentive to make changes persist?

103. In the printing industry, the process of continuously adapting existing technologies certainly facilitates innovation and change. In order to remain competitive, especially in terms of printing speed, printers change their presses relatively often. This feature of the industry helps to explain what appears to be a very dynamic process. The costs of reducing VOC consumption generated by the various changes made are often negligible because the technology would be replaced in any case. Consequently, firms are not in a position to put a figure on the cost. In contrast, firms underline the regular effort that needs to be made to reduce VOC levels or keep them low. In compensation, they can sometimes reduce production costs because they use less alcohol. For these different reasons, the VOC tax can therefore act as an incentive to change or innovate, and environment-related technological aspects (in this case less use of VOCs) are included in the considerations driving change.

104. Innovation in the paint and varnish making industry also seems to be a dynamic process, but the link with the VOC tax sometimes seems less obvious. For the reasons already mentioned (health and safety, cost, quality, concern for the environment), and for reasons of compliance with EU regulations, for example, firms are continuing to reduce the use of products containing VOCs. However, for reasons of quality and climate (low temperatures, humidity) and according to usage (interior or exterior), it does not seem possible at present to eliminate solvents altogether.

105. Five of the eight metal cutters interviewed had no coherent environmental strategy. With the introduction of the tax they discovered a problem with VOCs which, while known, had not required any response or action on their part. While some may regret the heavy administrative burden, particularly of completing the VOC balance sheet, and see the tax as an additional factor undermining their competitiveness, they all recognise that something had to be done, even if only for the health and welfare of their employees. Measures have been taken continuously at a more or less rapid pace, creating an impetus for innovation, though not without taking profitability into account. Other measures to reduce VOC emissions are still possible, especially by using substitute products, though there is limited scope for substitution in a significant proportion of cleaning and degreasing activities.

106. If the tax were to be abolished, none of the firms interviewed would turn back the page.[20] They seem increasingly to be playing the "green" card, which also increasingly corresponds to what customers expect. Low-VOC products could become a marketing plus, as is the case for other pollutants like CO_2, except perhaps in the metal cutting industry. Health and safety considerations in the production process also militate against any return to the previous situation.

107. End-of-pipe measures often seem too expensive in the industries under consideration. The biggest printing firm interviewed, with over 400 employees, decided not to take end-of-pipe measures on cost grounds. One paintmaker with a catalytic/thermal air purifier regrets the high cost of the equipment and the associated energy consumption. The firm, which draws up a VOC balance sheet, thinks that abolishing the VOC tax could even encourage some firms to stop using their equipment.

6. Conclusion and recommendations

108. Broadly speaking, the VOC incentive tax seems to have had a positive effect on innovation in the three industries under consideration. In printing and metal cutting, for example, changes have taken place in production processes that can be classified as innovation. In printing, this mainly concerns less use of products containing VOCs and of isopropylic alcohol; in metal cutting, it involves more efficient processes that reduce VOC emissions, including the use of substitutes. But as preserving end-product quality is vital, it is often not possible to entirely eliminate VOCs or products containing VOCs. In paintmaking, innovation has taken place not only in production processes (less use of products containing VOCs, especially solvents) but also in products (water-based products and products containing less solvent). In the industry, the tax seems to have been one factor among others (health, safety, Decopaint directive, etc.) encouraging innovation.

109. As well as stimulating many innovations, the tax has also managed to cut VOC emissions and use by 20 to 50 percent in five to eight years in the firms interviewed and generated greater awareness of the environmental and other problems of VOCs (workplace health and safety). Innovations have not had a positive impact on the market; in other words, the firms interviewed have not so far really won customers because of their commitment – not always voluntary – to reduce VOC emissions. Typically, all the firms

[20] On the other hand, increasing the tax by two-thirds to CHF 5 would not really seem to come as a shock, even if it were regarded as an additional handicap. In other words, such an increase does not seem likely to trigger another wave of innovation.

are passive eco-innovators which introduce innovations with a favourable environmental impact, though that is not the effect they sought primarily. The relatively small amount of the tax means that it is not a major factor in making products more expensive; the innovations are often profitable in themselves and neutral in terms of productivity.

110. Firms often regard the tax and the VOC balance sheet as a (heavy) administrative burden. In addition, many firms, especially the smaller ones, are ill-informed about how the tax works (VOC balance sheet, possibilities of exemption, etc.). There is also considerable displeasure about how the tax revenue is used; one proposal is that it should be used for projects to reduce VOCs.

111. As innovations – in processes or products according to the activity – can be seen in the three industries studied throughout the review period, the VOC tax may be said to have created a certain impetus. Some changes had already been made before the tax was introduced in 2000, others spanned the entire review period from 2000 to 2008. A minority of firms have already planned future changes to reduce VOC emissions or the use of products containing VOCs. Potential for further reduction still exists, especially in processes, because product quality requirements often mean that no more can be done for the time being. However, although reducing emissions and the amount of tax payable continues to be a concern, the effect seems to be dissipating. Some firms have indicated avenues of innovation in the near future.

- Paintmaking: The main changes relate to processes (cleaning with water, closed-circuit systems, solvent recycling) and products, *i.e.* the development of low-VOC, VOC-free and water-based products (mineral paints, high solid paints and varnishes).
- Printing: The chief concern is to continue reducing the use of isopropylic alcohol in printing processes while maintaining a given level of quality. Other possibilities include using low-VOC or VOC-free cleaning products, detergents and cleaning systems, and using osmosis water treatment systems.
- Metal cutting: The options for reducing VOC emissions are known; mostly they involve replacing the VOC with detergents for cleaning and degreasing parts and recycling used substances. One firm is trying to improve benzene jars with a shower system; another, with suppliers, is working on the use of detergents for parts liable to rust on contact with water. For these firms, however, the main concern is to optimise processes in order to reduce VOC emissions, with a limited reduction in the amount of tax payable.

112. Even taking account of the reserves mentioned above, keeping the tax – to which the firms have become accustomed – is advised in order to keep up the pressure on firms and, indirectly, on suppliers and the makers of products and equipment. It would be helpful in this regard to contact the printing machine manufacturers, raising awareness among them at international level of the environmental benefits of making equipment that can be used with VOC-free products.

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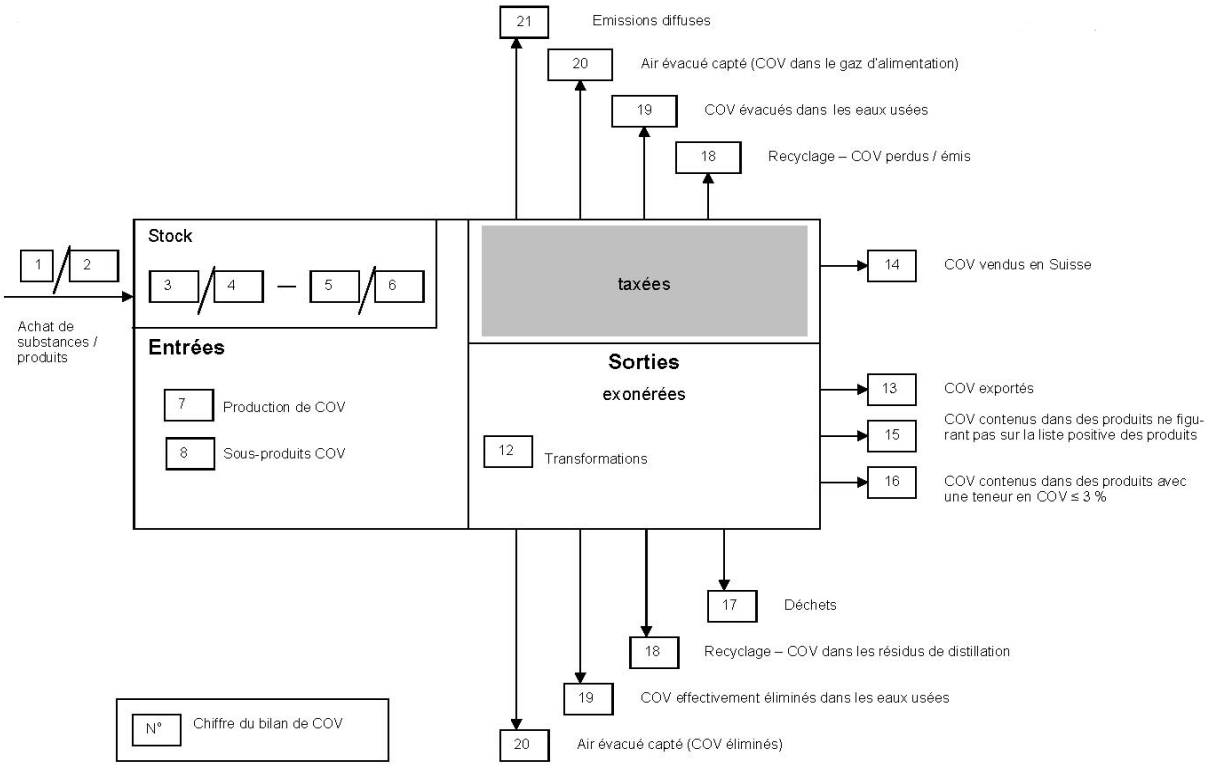
ANNEXES

Principle of a VOC balance sheet

113. The diagram shows the principle for drawing up an annual balance sheet to justify exemption from or deferred payment of the tax on the amount of VOCs emitted into the environment or transferred to customers.

Table A1. Diagram of the VOC balance sheet



Source: Federal Customs Administration, Instruction for establishing a VOC balance sheet (10.2007).

114. The input side of the VOC balance sheet comprises purchases of VOC substances and products containing VOCs (1/2), variations in inventories of such products (3/4 – 5/6) and own production of VOCs and VOC sub-products (7/8). On the output side are to be found various operations exempt from the tax: transformations of VOC substances (12), exports as substances or in products (13), VOCs contained in products not on the positive list of taxed products (15) VOCs contained in products with a VOC content of less than 3% (16), VOCs finally eliminated in waste (17), recycled (18, alcohol for example), eliminated in waste water (19) and extracted from the air (20). For firms that benefit from Article 9, all outputs of VOCs are exempt. VOCs transferred to customers or finally emitted into the environment are taxed. That applies to VOCs sold in Switzerland as such or in products with a VOC content of more than 3% (14), VOCs lost

in recycling (18), VOCs not eliminated in waste water (19), VOCs not extracted by extraction devices like filters and combustion cells (20), and diffuse emissions (21). Item 21 constitutes the balance of inputs and outputs, the respective volumes of which are duly estimated and documented.

Description of the three VOC activities

Printing (offset)

115. Offset is currently the most widely used printing technique. Its success is due to its flexibility and its capacity to adapt to a wide variety of products; in addition, it can be used for runs of just a few hundred or several million copies. Offset printing is an improvement on its predecessor, lithography, thanks to the addition of a rubber blanket between the plate cylinder and the paper.

116. Offset printing produces high-quality results at relatively low cost. Applications include publications of all sorts (daily newspapers and periodicals, advertising, books, catalogues, brochures, etc.) and packaging (boxes, labels, etc.). The technique can also be used to print on various media (paper, cardboard, polymers, metals).

117. The ink from the ink fountain is spread by the ink train. Distributor rollers distribute the film of ink. Damping rollers in contact with the form deposit ink on the appropriate areas of the offset plate. The flow of ink needed to print the document is regulated by means of manually adjustable screws or remotely controlled fountain segments. Several rollers ensure that the ink film is spread evenly.

118. The ink is then deposited on the offset plate, remaining only on the printing surfaces (the others are protected by water in conventional offset printing and by a layer of silicone in waterless printing). The ink is then transmitted by pressure to the blanket, a rubbery material which improves the quality of the transfer of the ink film from the plate to the paper. The use of a blanket is necessary: it prevents the offset plate from becoming prematurely worn and introduces a compressible element which improves the transfer of ink and helps to correct any surface flaws on the print medium.

119. In offset, unlike in other printing techniques, the form is almost flat (it is hollow for photogravure and in relief for flexography). The distinction between image and non-image areas depends entirely on the different physical and chemical properties of the areas in question.

120. Conventional wet offset printing is based on the fact that oil and water do not mix, creating an emulsion between the damping solution and the ink. The aluminium plate transfers the image to a blanket, which in turn sets the ink off onto the paper.

121. The image areas are transferred by a photomechanical process onto a polymetallic printing form so that they appear on copper (lipophilic) or a polymer emulsion, while the non-image areas remain on aluminium (hydrophilic). The plate is successively dampened then inked: the aluminium accepts the water and repels the ink, while the copper or the polymer layer accepts the ink and repels the water. The ink is transferred by a double process: from the plate onto the rubber blanket, then from the blanket onto the paper.

122. Presses can comprise one or more groups (four in the case of a quadricolour press), a group being a complete print block. Presses exist with six groups (for hexachrome printing) or more, allowing for the addition of a Pantone colour or a varnish. Presses can also be recto-verso (reprint or direct).

Source: http://fr.wikipedia.org/wiki/Offset_(imprimerie).

Paint and varnish making

123. The paint and varnish industry provides other industries, crafts and the general public with a wide range of different products. Classic chemical techniques – dissolution, mixing, pasting, dispersion, filtration, conditioning, etc. – are used to make paints and varnishes. Only a handful of larger firms synthesise some of their own raw materials, mainly resins.

124. As consumers have become increasingly sophisticated, the paint and varnish industry has had to develop greatly differentiated formulations, using a wide variety of raw materials. This has shaped the production process, the main characteristics of which are discrete processing, relatively small batches, limited automation and extensive cleaning. Paint and varnish factories have several points where shop air or used air is discharged into the atmosphere, since formulations of different types or for different purposes are often made in separate shops.

125. Products are mixtures of many different components that can be grouped into four families.

- Binders are considered to be the most important components. Products are generally classified according to the chemical makeup of the binders (*e.g.* alkyd paint).

- Additives are incorporated to modify certain characteristics of the formulation or bring new properties.

- Powdery materials: the pigments used in paints generally give opacity, colour and sometimes special properties (*e.g.* anti-corrosion, fire-retardant, etc.). Extenders generally play a simpler role, adding resilience or adapting brilliancy, for example.

- Solvents provide fluidity, enabling paints and varnishes to be made and applied. Once these stages have been completed, they must be entirely eliminated from the film, otherwise they reduce the product's performance and durability. About 200 volatile chemical compounds can be used as solvents in paints and varnishes, temporarily participating in the product lifecycle.

126. The possibilities for substitution depend on how and under what conditions the products are to be used. Table A2 shows the number of solvent- and water-based products made (and sold) by one of the firms interviewed.

Table A2. Paint product categories

Product categories	Number of water-based products	Number of solvent-based products	Total
Application on wood	20	27	47
- base coat and dressing	*2*	*3*	*5*
- glazing	*1*	*6*	*7*
- impregnation, protection	*1*	*4*	*5*
- coating	*3*	*1*	*4*
- mass colour	*3*	*0*	*3*
- varnish	*0*	*5*	*5*
- undercoats	*2*	*2*	*4*
- lacquers	*8*	*6*	*14*
Enamels	2	6	8
Decorative coatings	6	0	6
Paints for façades and exterior walls	19	2	21
- renderings and exterior synthetic coatings	*10*	*0*	*10*
- exterior dispersions	*5*	*0*	*5*
- exterior mineral paints	*2*	*0*	*2*
- exterior silicone paints	*1*	*0*	*1*
- exterior synthetic paints	*0*	*2*	*2*
- varnishes	*1*	*0*	*1*
Industrial and special paints	5	8	13
Floor paints	3	3	6
Roof paints	1	0	1
Support preparations	24	17	41
- base for rough plastering	*3*	*3*	*6*
- sealants, coatings and smoothing products	*7*	*1*	*8*
- cleaning and preparation products	*5*	*3*	*8*
- insulation, binding and base coat products	*7*	*8*	*15*
- special conservation products	*2*	*2*	*4*
Coatings for metal supports	0	5	5
Sprays	10	11	21
Total	**90**	**79**	**169**

Metal cleaning/degreasing

127. Metal cleaning and degreasing takes place in all industries where production processes involve making and/or assembling metal parts (*e.g.* automobile, aeronautical and railway industries, household electrical goods, clock and watchmaking). Metal parts are cleaned at the various stages of the production

process in order to eliminate any oil, flux or grease on the surface. For a detailed description of the activity, see EEA (2006, su060201).

Profile of interviewed firms

Printing	Number of employees / Sales	Status (group, independent)	Main market	R&D / patents
Firm 1	290 / --	Independent	Switzerland	D / no
Firm 2	55 / CHF 10m	Independent	Switzerland	no / no
Firm 3	55 / CHF 11.5m	Independent	Switzerland	no / no
Firm 4	120 / CHF 24m	Independent	Switzerland	(R) / no
Firm 5	430 / CHF 105m	Group	Switzerland	no / no
Firm 6	60 / CHF 13m	Independent	Switzerland	no / no
Firm 7	120 / CHF 30m	Group	Switzerland	no / no
Firm 8	297 / --	Group	Switzerland	no / no
Paintmaking	**Number of employees / Sales**	**Status (group, independent)**	**Main market**	**R&D / patents**
Firm 1	129 / CHF 44.5m	Independent	Switzerland	(R)&D / no
Firm 2	250 / CHF 110m	Independent	Switzerland + D, F, I	yes / no
Firm 3	80 / --	Independent	Switzerland	yes / no
Firm 4	35 / CHF 10m	Independent	Switzerland	yes / (no)
Firm 5	90 / CHF 40m	Independent	Switzerland + D	yes / no
Firm 6	90 / CHF 40m	Group	Switzerland	yes / yes (parent)
Firm 7	50 / --	Independent.	Switzerland (60%)	yes / no
Metal cleaning	**Number of employees / Sales**	**Status (group, independent)**	**Main market**	**R&D / patents**
Firm 1	130 / CHF 16m	Independent	Switzerland	yes / no
Firm 2	55 / CHF 8m	Family-owned group	Switzerland (50%)	no / no
Firm 3	275 / CHF 30m	Independent	Switzerland	yes / no
Firm 4	20 / CHF 2.8m	Independent	USA and GB (60%)	no / no
Firm 5	40 / CHF 6.5m	Independent	Switzerland (90%)	no / no
Firm 6	40 / --	Independent	Switzerland	no / no
Firm 7	100 / CHF 22m	Independent	Switzerland (60%)	no / no

Source: interviews with firms.