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Socio-Economic Analysis (SEA) in authorisation and restriction under REACH: Assessment of abatement costs of chemicals – ex ante and ex post

- Final Report -

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Abstract

The authorisation and the restriction of chemicals are defined as measures for regulating hazardous substances in the REACH regulation. For a dossier to be submitted to the European Chemicals Agency (ECHA), a solid data base on the uses and respective volumes, as well as the inherent hazards, has to be generated. When impacts on human health and the environment cannot be quantified, the instrument of cost-effectiveness analysis (CEA) can be applied for assessing the costs associated with emission reduction or the use of a hazardous substance. CEA is widely used to determine the least cost means of achieving pre-set targets or goals among a set of alternative options that all achieve the targets.

To transfer this concept of abatement costs, commonly used in the field of air pollution and climate policy, and apply it to the field of chemicals in the context of REACH, has been explicitly envisaged in the ECHA Guidances on socio-economic analysis with regard to restrictions and authorisations. In order to gain practice with this instrument, six suitable case studies of substances and their uses were selected and analysed. Producers, associations and further stakeholders have been contacted and asked for information on cost structure.

Several methodological issues and challenges were discussed concerning data availability and gathering, cost effects and their reflection in prices, as well as the transferability of the abatement costs concept to the use of chemicals in general. In a common expert workshop experiences with a similar study commissioned by ECHA on abatement costs were exchanged, and overall conclusions and recommendations derived.

Kurzbeschreibung

Die Zulassung und Beschränkung von Chemikalien sind in der REACH-Verordnung als Maßnahmen vorgesehen, gefährliche Substanzen zu regulieren. Um ein Dossier bei der ECHA einzureichen, muss eine solide Datenbasis über die Verwendungen und deren Mengen, wie auch die inhärenten Gefahren der Substanzen generiert werden. Wenn Auswirkungen auf Umwelt und menschliche Gesundheit nicht quantifiziert werden können, kann auch das Instrument der Kostenwirksamkeitsanalyse angewandt werden, um die Kosten abzuschätzen, die mit der Verringerung von Emissionen oder der Verwendung einer gefährlichen Substanz verbunden sind. Die Kostenwirksamkeitsanalyse ist weit verbreitet, um die Kombination mit minimalen Kosten zu bestimmen, die vorgegebene Ziele unter einer Auswahl alternativer Optionen erfüllt.

Dieses Konzept der Vermeidungskosten, das auf den Gebieten der Luftverschmutzung und Klimapolitik üblicherweise angewandt wird, zu übertragen und für den Gegenstand von Chemikalien im Kontext von REACH anzuwenden, wird explizit in den ECHA-Leitlinien zur sozioökonomischen Analyse für Beschränkungs- und Zulassungsanträge vorgeschlagen. Um dieses Instrument anzuwenden, wurden sechs geeignete Fallstudien mit chemischen Substanzen und ihren Anwendungen ausgewählt und analysiert. Produzenten und Verbände wurden identifiziert, kontaktiert und um strukturierte Auskunft zu Kostendaten gebeten.

Methodische Fragen und Herausforderungen wurden diskutiert, etwa zu Datenverfügbarkeit und Strategien der Datengewinnung, oder inwiefern Kosteneffekte und –einflüsse in Marktpreisen wiederzufinden sind. In einem Expertenworkshop wurden Erfahrungen mit einer ähnlichen Studie zu Vermeidungskosten im Auftrag der ECHA ausgetauscht, und generelle Schlussfolgerungen und Empfehlungen abgeleitet.

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1 Goals of socio-economic analysis

Chemicals that pose a particularly high risk to humans and the environment require special attention. In this context, two instruments regulating hazardous substances have been set out in the framework of the REACH regulation: the authorisation and restriction of chemicals. In order to find an adequate balance between risks of use of substances on the one side and economic consequences of a substitution (or other regulation) on the other side, socio-economic analysis has been introduced as the tool of choice to support the decision-making in REACH. As part of socio-economic analysis, in principle the economic effects which would result from the use or restriction of a substance are offset against each other in a balance sheet. Hence, the costs or the cost savings achieved for businesses and/or end consumers are compared to the costs and risks associated with human health and the environment. The result – preferably a monetary value – is to serve as basis for further decision making regarding restrictions or authorisations of chemicals.

A prerequisite of the restriction and authorisation processes is that a solid data base exists, e.g. summarising the use(s) of the substance as well as its volume of use and inherent hazards, presented in a dossier submitted to the European Chemicals Agency (ECHA). For many substances, a solid data base exists specifying their harmful effects, whereby causes and effects are often interconnected through a direct dose-response relationship. For most substances, however, the data available is insufficient to quantify their adverse effects in the environment or humans (e.g. PBT substances, endocrine disrupters). In these cases, a cost-benefit analysis therefore cannot be applied.

Within the restriction process of REACH, this problem can be circumvented by taking into account a cost-effectiveness analysis instead of cost-benefit analysis. Under the condition that adequate data are available for a cost assessment of emission reduction or avoidance, the ratio of costs of a measure and its effectiveness can be calculated.

The costs that arise in connection with activities aimed at implementing substance and non-substance alternatives or end-of-pipe technologies in order to prevent emissions (abatement costs), may serve as a basis for establishing cost models. These cost models, in turn, facilitate the selection of the most cost-effective or efficient emission reduction method, and hence would be of considerable assistance to the decision-maker.

Abatement costs are also an important element of methodology for evaluating forthcoming applications for authorisation under REACH. A solid cost assessment of alternatives and of the non-use scenario of a substance is inevitable to identify the benefits of continued use and whether there are viable alternatives available that can be valuated as economically feasible, or not. With such an assessment, the industry in charge has the chance to illustrate the socio-economic benefit of using a substance when making an application for authorisation.

Within REACH for substances of potential interest for risk management, substances of very high concern (SVHC) for example, such a solid data base has not been designed so far. The aim of this project has therefore been to fill this knowledge gap on the basis of exemplary and representative scenarios of selected chemicals and their calculated abatement costs.

The methodological basis followed corresponds to the guidance documents of ECHA on socio-economic analysis. The guidance with regard to restrictions (ECHA 2008)[1] is aimed at Member State Authorities or Agencies but also other interested parties supporting or otherwise affected by a restriction proposal. ECHA has also issued in 2011 another guidance document on the preparation of socio-economic analysis as part of an application for authorisation (ECHA 2011)[2], which was transferred without major changes from the guidance for restrictions, but contains some more detailed descriptions of assessment approaches and tools.

2 Approach and framework

2.1 Methodical approach of abatement costs

The approach to be followed is within the framework of a cost-effectiveness analysis. In the ECHA Guidance on socio-economic analysis this approach has been defined in the glossary:

"Cost-effectiveness analysis (CEA) is widely used (but not restricted to) to determine the least cost means of achieving pre-set targets or goals. CEA can be aimed to identify the least cost option among a set of alternative options that all achieve the targets. In more complicated cases, CEA can be used to identify combinations of measures that will achieve the specified target."

As a specific case of abatement costs, the "standard price approach", which is based on the implicit values to policy makers (here the political decision makers under REACH), estimates the revealed preferences of these policy makers. This concept was further elaborated and applied to evaluate the environmental impacts of acidification and eutrophication on ecosystems within the EU research project "New Elements for the Assessment of External Costs from Energy Technologies" (NewExt).[3] It calculates the benefits of emission reduction, as perceived by these policy makers, based on the abatement costs, in order to reach a well-defined emission reduction target.

A similar target has also been specified in the case of REACH. In this situation, the target specified is to ensure a high level of protection of human health and the environment by reducing the risks of chemicals to an acceptable level (restriction) and by the gradual substitution of hazardous chemicals, i.e. SVHC (authorisation).

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1 http://echa.europa.eu/documents/10162/13641/sea_restrictions_en.pdf

2 http://echa.europa.eu/documents/10162/13643/sea_authorisation_en.pdf

3 See the NewExt project report (European Commission 2004), Chapter 5: Valuation of environmental impacts based on preferences revealed in political negotiations and public referenda. http://www.ier.uni-stuttgart.de/forschung/projektwebsites/newext/newext_final.pdf

Both application fields of the abatement costs concept have in common the principle that these costs are a proxy for the benefits that policy makers attribute to these reductions, as it is assumed that policy makers act as rational decision makers who carefully balance the abatement costs of emission reductions (or a constraint in the use of a chemical) with the benefits of these emissions or constraints.

This so-called "second-best" method gives useful data for comparison of technologies because it gives us 'shadow prices' for a non-market scarcity. It is usually applied as an alternative to cost-benefit analysis in studies on the external costs of energy and transport, especially for the impacts on global warming and on acidification and eutrophication, where the estimation of damage costs is associated with a high uncertainty.[4]

The abatement costs can thus include a private as well as a social component. Private costs may occur for producers of the substances under investigation as well as for downstream users. Society incurs social costs which often include external costs. In the case of substitution of a substance due to a restriction or authorisation, the social benefits due to reduced health and environmental damages might exceed the social costs, because the restriction or authorisation has the goal of eliminating the use of substances dangerous to human health.

The private cost component of abatement costs is therefore similar to the term "compliance costs" which is defined in the ECHA guidance on socio-economic analysis in particular for authorisation as:

the difference in the cost to the applicant and the up and downstream users (i.e. the supply chain) complying with a "non-use" scenario as compared to the "applied for use" scenario. Compliance costs include the capital and operating costs that would accrue to the sectors affected by the "non-use" scenario.

2.2 Development of an analytical framework and a transferable and traceable total cost model including different relevant cost categories

The determination of the economic impacts of regulation requires the collection of a variety of cost data throughout the affected supply chains. A clear differentiation is complicated by the large number of processes, firms and products that are influenced by the restriction[5] of a given substance. In order to be able to analyse findings in a coherent way, a model approach was developed to give a structure to the cost categories in question. The consequences of a potential restriction of a substance are approximated by comparing cost data in (at least) two different scenarios. The first one, often referred to as "baseline scenario", is supposed to reflect the

4 For impacts on global warming, the standard-price approach is described in the ExternE Methodology Update (Bickel and Friedrich 2005, pp. 191-199). http://www.externe.info/externe_d7/sites/default/files/methup05a.pdf

5 The term 'restriction' as it is used here does include any regulatory constraint in using a substance, i.e. with regard to REACH restrictions as well as rejected authorisation applications.

prospective cost structures if no restriction is implemented. The second scenario is an attempt to simulate the cost structures that are expected to develop if the restriction is to be introduced. The determination of values for both scenarios then makes it possible to determine the expected change to various cost categories associated with the envisioned restriction. Dividing the total product costs into relatively detailed cost categories enables the identification of impacts on other actors in the respective supply chain. Generally speaking, the abatement costs consist of all cost changes that are directly associated with the installation of new substances or processes and their operation. While such installations are a frequent consequence of regulation measures, they also occur when a process is replaced for other reasons, such as technological advances, changes in costs or wear and tear of existing equipment. It would be inappropriate to attribute the whole investment in a process to the compliance costs of regulation. Therefore, in a more detailed differentiation only the costs of being forced to carry out an investment a few years before a regular replacement are observed as costs truly associated with the restriction. This consideration would be sufficient if both the equipment required and the product quality before and after the introduction of the restriction is roughly comparable.

Cost categories that should be included are shown and described in Table 1:

Table 1: Systematics of potential abatement cost categories to be included, following economic impact categories in the ECHA guidances on Socio-Economic Analysis (ECHA 2008 and 2011)

Cost category	**Items included**
Materials and services	Transportation, storage, distribution, packaging and labelling, replacement parts, chemicals, water, environmental services
Labour	Operating, supervision, training
Energy	Electricity, heat
Maintenance	Sample testing, monitoring, insurance premium, marketing, permits & licences, on site emergency services, overhead
Investment	Research and development, performance testing, property rights, equipment, modification, general site and operations, decommissioning

Special attention should be paid to costs that arise if entirely different processes are needed, in which case some equipment may become redundant. In this case, the costs resulting from the depreciation of redundant equipment have to be added to the determined direct changes to production costs. To adequately include these costs, also referred to as “sunk costs”, into abatement calculations, it has to be clarified whether the equipment in question is in fact usable for another purpose and therefore retains some of its value in spite of the introduction of a regulation. Another important item of abatement costs concerns other indirect costs such as those resulting from differences in product quality or adaptation costs like on-the-job-training.

In an ideal analysis, all these cost categories should be included. In practical investigations, however, lack of time, and potentially of transparency and availability, is likely to make it impossible to obtain data for all these items. In order to facilitate the filling in of the questionnaires sent out to companies as part of this project (see Annexes) and to avoid confusion concerning economic nomenclature, all questions were directed towards “cost” terms. This means that e.g. in case of investments, only the resulting investment-related costs are being asked for, instead of the volume of the investment itself. Investment-related costs include capital costs, depreciation and similar items. As the aim of the study is to determine abatement costs, only comparable cost items may be considered, not investments which are expected to result in a payback in the future. Large one-time sums may still occur, e.g. when process equipment loses its value to the firm and is written off as a whole in a single year.

If one or more cost items are unknown, it is dubious whether the obtained sums are sufficiently close to the actual costs bestowed upon firms and consumers. To compensate for this particular uncertainty, an investigation into the resulting product prices can help to validate the obtained data, as prices can be expressed as the sum of production costs plus profit margin. While profit margins are unknown, prices (ideally from several independent producers in a competitive market) should at least serve as a rough indicator for the costs of production.

For the estimation and analysis of abatement costs, at the beginning of the project a distinction between an “ex-ante” and an “ex-post” assessment for abatement costs was assumed, and within each assessment a selection of three to five suitable substances were identified. These options were discussed with regard to data availability, specific interests of authorities involved, but also caveats and reservations, and some of these decisions were modified and revised during the project.

As documented in the Annex (Section 6.1), questionnaires were first developed for the “ex-ante” substances, using the cost category systematics as described in Table 1 and adapted to the respective substance or substance group. From first experience and feedback of these questionnaires, adapted and customised questionnaires for ex-post substances have been developed in a later stage.

However, later in the course of the project a strict partition of ex-ante and ex-post substances was abandoned. When the case studies were examined and analysed in-depth, it was understood that there has been often a smooth transition between an ex-ante- and an ex-post situation of a substitution, and in many cases also these situations existed in parallel, i.e. a substance had already been replaced in some applications whereas it was still used in others. This becomes obvious in particular within the six case studies described in the following Chapter 3, and has led to general conclusions, as explained in Chapter 4.1.

3 Identification, estimation and analysis of abatement costs – Case studies

3.1 Lead chromate, lead sulfochromate yellow and lead chromate molybdate sulphate red

Lead(II) chromate (chrome yellow; $PbCrO_4$) has been produced and used since 1818 for centuries as a pigment, although being highly toxic, containing lead and hexavalent chromium. Since the development of yellow azo pigments (C.I. Pigment Yellow 1 and 3) by Hoechst in 1909 lead(II) chromate has no longer been used in house and artist paint, but it is still in use in marine and industrial paints and for adding colour to plastics such as PVC, polyethylene, and polyesters, especially outside of Europe. In higher quantities than as pure lead chromate, it is used as a mixed crystal in combination with lead(II) sulfate (lead sulfochromate yellow; C.I. Pigment Yellow 34) or lead(II) sulfate and lead molybdate (lead chromate molybdate sulphate red; C.I. Pigment Red 104).

These three substances have been identified as SVHC in a grouping approach since they chemically belong to the same family and they share a similar hazard profile, similar classification and labelling, similar technical performances as well as similar uses. An overview of these three substances is given in Table 2.

Table 2: Lead chromate pigments in the grouping approach and their characteristics

Substance	Lead (II) chromate	Lead sulfochromate yellow	Lead chromate molybdate sulfate red
Formula	$PbCrO_4$ ($CrH_2O_4.Pb$)	$Pb(Cr,S)O_4$	$Pb(Cr,S,Mo)O_4$
Content	lead(2+) chromate (100%)	variable solid mixed phase crystal containing lead chromate (average 68%) and lead sulfate (av. 29%)	variable solid mixed phase crystal containing lead chromate (av. 75%), lead sulfate (av. 12%) and lead molybdate (av. 5%) in varying proportions
EC Number	231-846-0	215-693-7	235-759-9
CAS Number	7758-97-6	1344-37-2	12656-85-8
Alternative name	-	C.I Pigment Yellow 34	C.I Pigment Red 104
REACH registrations and applications for authorisation undertaken	no	yes	yes
Production volumes in % (2008)	negligible	65% (19,500 tons)	35% (10,500 tons)
Import volumes (range)	100 – 1,000 tons	1,000 – 10,000 tons	100 – 1,000 tons

All three lead containing pigments have been prioritised for being added to Annex XIV. In its recommendation of 17 December 2010, the European Chemicals Agency (ECHA) has recommended that these three substances are to be included in Annex XIV of the REACH Regulation, and by Regulation (EU) 125/2012 of 14 February 2012 the authorisation procedure was officially opened for the lead chromate pigments.

A first overview on estimations for substitution options (with regard e.g. to anti-corrosive characteristics, application in technical fields of use) has been developed and summarised in the Annex XV documents (France 2009a, 2009b). After the sunset date of 21 May 2015, all users of these pigments need an authorisation for their specific technical uses.

Lead sulfochromate yellow (C.I. Pigment Yellow 34) and lead chromate molybdate sulphate red (C.I. Pigment Red 104) appear as the more relevant compounds, because they are used on a larger volume. Due to its poor colour stability, pure lead chromate was never of important technical use compared to C.I Pigment Yellow 34 and C.I Pigment Red 104 (ECHA 2010e). It should be highlighted that pure lead chromate is often confused with lead sulfochromate yellow (C.I. Pigment Yellow 34), even e.g. in Wikipedia entries.

Two arguments have been brought forward as crucial for the ECHA decision at that time to prioritise also pure lead chromate in the candidate list:

- Considering regulatory effectiveness, it cannot be excluded that the substance could be used to replace Pigment C.I. Yellow 34 in some of its uses (ECHA 2010e)
- The information gathered on previously existing imports and uses up to the year 2010[6]

Information on uses of lead chromate compounds suggests the following ongoing uses (ECHA 2010e):

- Manufacture of paints and varnishes (for vehicles, farming material, boat/ships, industrial paint products, civil engineering material, road sign and road painting, as well as quick dry enamels and floor paints)
- Manufacture of plastic masterbatches
- Manufacture of art conservation colours, use in conservation of arts
- In leather finishing mixtures
- Manufacture of pyrotechnics (pyrotechnic delay compositions for ammunition, ignition compositions for ammunitions, and delay detonators for the mining and demolition sectors)

Downstream applications related to these uses mentioned were also confirmed. Other potential uses (not confirmed) include: manufacture of other pigments, use in detergents, embalming products, tattoo inks, photosensitive materials, printing fabrics, and in decorating porcelain (ECHA 2010e).

[6] According to the results of the prioritisation of the SVHCs on the Candidate List “impacts of lead chromate as a pigment in the range of 1000 – 1,000 t/y were confirmed by a non-EU company. The above reported volume of imported lead chromate pigment is consumed by masterbatch producers. In addition to this, the use of lead chromate in paints is estimated by the European Council of producers and importers of paints (CEPE) to roughly exceed 100 t/yr.” (ECHA 2010e). Data on consumption that is available for some EU countries show a clear trend to decrease.

Nevertheless, due to these findings in the ECHA documents, it was decided that data for all three pigment substances under examination have been asked for in the questionnaire, in order to check whether lead chromate might still be used in small amounts, and also because ex-post data on the substitution costs is of interest for estimating abatement costs.

For pure lead chromate there have been no REACH registrations, but one application for authorisation was submitted to ECHA after the latest application date (21 November 2013) and the finalisation of the research work of this project. The application covered a very specific industrial use of lead chromate in only small amounts[7]. This leads to the suggestion that (apart from small amounts used in laboratories, for research and development, which are exempted from an authorisation) uses of pure lead chromate have either been substituted (indicating that this was possible without substantial additional costs) or abandoned by the sunset date.

3.1.1 Analysis of data availability and quality for the total cost model

The ECHA background documents for these substances[8] report production volumes of 30,000 tons in Europe in 2008, with 65% representing C.I. Pigment Yellow 34 and 35% representing C.I. Pigment Red 104. Estimated global production of both pigments is 50,000 tons per year. For lead chromate, a production volume within the EU is only known for Slovenia (111 tons in 2007, 51 tons in 2008), and there has been definitely no production anymore in France (ECHA 2010e).

Import volumes are known for 2008 in the range of 1,000 – 10,000 tons for C.I. Pigment Yellow 34 and in the range of 100 – 1,000 tons for C.I. Pigment Red 104. For both substances more than 80% have been non-encapsulated, and less than 20% encapsulated (i.e. their surface is completely coated by another substance in order to maintain the coloration function but prevent the pigment from release)[9]. These figures refer to one non-European manufacturer only. For lead chromate in the form of a pigment, imports from one non-EU company have been in the range of 100 – 1,000 tons as well.

The use of C.I. Pigment Yellow 34 and C.I. Pigment Red 104 in Europe was lower in 2008 than the volume manufactured. All lead chromate pigments placed on the EU market are encapsulated. It is therefore assumed that the imported non-encapsulated pigments have been encapsulated within the EU before placed on the market. About three-quarter of the volumes consumed correspond to C.I. Pigment Yellow 34, one quarter of the volumes consumed to C.I. Pigment Red 104 (ECHA 2010c,d). For lead chromate as pure substance, volumes for consumption amount to less than 60 tonnes per year (ECHA 2010b).

According to the background documents (ECHA 2010c, d, e), the current uses of C.I. Pigment Yellow 34 and C.I. Pigment Red 104 include two main categories (see Table 3) which have been

7 Manufacture of pyrotechnical delay devices contained into ammunition for naval self-protection (ECHA 2015)

8 ECHA Background documents for lead chromate and for lead sulfochromate yellow of 17 December 2010 (ECHA 2010b,c), for lead chromate molybdate sulfate red of 1 July 2010 (ECHA 2010d).

9 „Coated“ is often used as a synonym for „encapsulated“. We will not use the term “coated” in this report further, in order not to cause confusion with the use category of these pigments in coatings.

confirmed by company information, one further specialist use in dentistry for C.I. Pigment Red 104 only, and another category of uses which have been found in literature but not confirmed by the information source of the importer.

In addition to the questionnaires for the producers, for each of the two main use categories (colouration of plastics and coatings/paints/varnishes) some representative downstream users have been envisaged to be asked for valuable information on costs from their perspective.

Table 3: Categories of current uses of C.I. Pigment Yellow 34 and C.I. Pigment Red 104 in the EU (ECHA 2010c,d,e)

Use category	Contains	Percentage of EU market
Coloration of plastics	Each type of plastic material and composite (polyolefins, PVC, nylon) Each modeling process (injection, extrusion, etc.) Applications: Industrial carpet fibres, automotive interiors, non-food packaging, rust resistant furniture, electronic housing.	Ca. 60%
Coatings/ paints/ varnishes	Applications: Vehicles not covered by the ELV directive Agricultural equipment Civil engineering material Boats / Ships Road sign and road painting, thermoplastic road marking, airport horizontal painting General industrial: skips, plant and machinery; industrial doors, pumps, machinery; large steel structures; gas cylinders; offshore steel structures (e.g. drilling rigs) Camouflage/ammunition, interior coatings for military equipment Aeronautics Coil coating Coating of plastic material (PVC, PP, ABS edge bands) GRP constructions (boats, auto parts, silos) Coatings applied to industrial surfaces by printing, such as decals (e.g. used for commercial identification) Thermochromic paint	Ca. 40%
Additional use of C.I. Pigment Red 104 only	Constituent of a product used in dentistry at 5-10% concentration, used as protection for defined parts of surfaces to prevent them of covering with metal during galvanization processes	Unknown (probably close to 0%)
Other uses (potential, not confirmed)	Textile printing/leather finishing/ printing inks Tattoo inks Artists paints Mastics	Probably close to 0%

Use category	Contains	Percentage of EU market
	Paper Linoleum/flooring compounds/ Colouring of rubber/Wall covering	

According to information from the former European Manufacturers of Lead Chromate and Lead Molybdate Pigments e.V. (EMLC), which was abrogated in the year 2012[10], it is not foreseen to apply new uses other than listed in the two categories “Coloration of plastics” and “Coatings/paints/varnishes”.

Uses of regular grades of lead chromate pigments are restricted to processes with temperatures up to 260 °C. Silica-encapsulated pigments can be used in plastics or coatings applications at temperatures up to 300 °C, with more than 90% used for coatings (e.g. coil coatings and signage) (ECHA 2010c,d).

From the Annex XV dossiers submitted by France, a set of six producers and importers have been listed (see Table 4).

Table 4: Producers and importers in Europe (Annex XV dossiers, France 2009a,b)

Company	C.I. P.Y. 34 *)	C.I. P.R. 104 *)	Comment / status
1	X	X	No authorisation envisaged
2	X	X	Decision on authorisation in 2012 still pending; no authorisation by the end of this project
3	X	X	No more production of these pigments since 2010; produces lead-free substitution products
4	X	X	Company absorbed by another one; no more production of these pigments in EU
5	X	-	No recent address/website, probably company does no longer exist
6	X	-	No more production of these pigments in EU

*) X = (previously) in product range; - = not in product range

The source of these data quoted by the Annex XV dossiers (France 2009a,b) was a database named HPV (High production volume) chemical program of OECD.[11]

The most relevant active producer of this pigment group in the EU communicates in a press release that the company envisages to stop producing lead chromate pigments by 2014 and not to start an authorisation under REACH. Customers have been informed on that change and alternatives recommended.

10 See http://www.farbeundlack.de/Markt-Branche/Koepfe-Karrieren/Robert-Fischer-wird-65

11 See http://webnet.oecd.org/hpv/ui/Default.aspx for the description of the OECD Existing Chemicals Database.

The second producer explained that the decision on an authorisation has yet to be made. In case of a decision for no authorisation, there is no incentive to put efforts on an analysis of abatement costs, and in case of an authorisation this will have to be done later, if based on a legal obligation.

All other (former) producers quoted by name in the Annex XV dossier have stopped their production in EU but some of them still own production sites outside of the EU. In case they intend to continue the import after the sunset date, the need for an authorisation procedure (either by the users themselves or by suppliers as a service for their customers) will still be relevant for them as well.

Therefore, the next step to be taken has been to focus also on importers of these substances (comprising also companies owning production sites in non-EU countries). For this purpose, the originally developed questionnaire has been expanded by a section on imports (similar to the section on production) and questions comprising imports as well. Three of the companies listed in Table 4 have thus been addressees for the final questionnaire including imports.

In addition, some potential or further typical downstream users from the two main categories of Table 3 (coloration of plastics; coatings/paints/varnishes) have been asked as well for the use of heavy metals (both lead and cadmium, see also Chapter 3.4). An overview has been given in Table 5.

Table 5: Contacts and information gathered by lead chromate pigment users

Use category	Specific application	Response / Information given by personal communication
Coloration of plastics (60% of EU market):	Market-leading user for specialist applications such as automotive interiors	Lead chromate pigments have not been used there, only a few Cadmium containing pigments in paints (see Chapter 3.4), but no longer in the past 5 years.
Coatings/ paints / varnishes (40% of EU market)	Users of coatings for the production of agricultural equipment	Three large producers of agricultural engines have been contacted by E-Mail, no reply after reminder
	Producers of road sign and road painting, thermo-plastic road marking, airport horizontal painting	Reply of a market-leading producer: Producers for road and airport marking materials have already started at the end of the 1980s to replace heavy metals and aromatics by organic pigment blendings in coloured, especially yellow, road marking paints, a process which has been finalised by 1993. Before that date, Pb_3O_4 (red lead) was used. Anyway, road marking paints are by 85% in white shade of colour, containing titanium dioxide; coloured paints are only produced in low tonnage, using appropriate organic pigment blendings. Therefore, in this field of application there are no more actual and relevant data for abatement costs.
		Another producer has been contacted by E-Mail, no reply after reminder

Before the finalisation of this project, the latest application date of the lead chromate pigment grouping has expired on 21 November 2013. Subsequently, ECHA has published the non-confidential documents on the applications for authorisation that have undergone public consultation on their website.[12]

The only applicant that has applied for uses has been acting as Only Representative for an importer. This company has already been identified and contacted within this project.

The following uses have been applied for:

Table 6: Uses applied for in applications for authorisation for lead chromate pigments
Source: echa.europa.eu website (10 June 2014)

Use applied for No. in AfA	C.I. P. Yellow 34	C.I. P. Red 104	Use name applied for
1	X	X	Distribution and mixing pigment powder in an industrial environment into solvent-based paints for non-consumer use (Reader is referred to AoA and SEA of uses No. 2 und No. 3)
2	X	X	Industrial application of paints on metal surfaces (such as machines vehicles, structures, signs, road furniture, coil coating etc.)
3	X	X	Professional, non-consumer application of paints on metal surfaces (such as machines, vehicles, structures, signs, road furniture etc.) or as road marking
4	X	X	Distribution and mixing pigment powder in an industrial environment into liquid or solid premix to colour plastic/ plasticised articles for non consumer use (Reader is referred to AoA and SEA of uses No. 5 and No. 6)
5	X	X	Industrial use of solid or liquid colour premixes and pre-compounds containing pigment to colour plastic or plasticised articles for non-consumer use
6	X	X	Professional use of solid or liquid colour premixes and pre-compounds containing pigment in the application of hotmelt road marking

It has to be emphasised that all of these six uses specified refer to both substances

- Lead sulfochromate yellow (C.I. Pigment Yellow 34)
- Lead chromate molybdate sulphate red (C.I. Pigment Red 104)

However, pure lead chromate as the third substance of the grouping has not been listed in any of the uses applied for. This confirms what has been already identified at the beginning of Chapter 3.1 that pure lead chromate will, due to its characteristics, not play an important role in the applications for authorisation.

12 The website "Adopted opinions and previous consultations on applications for authorization" of ECHA has been last analysed at the status of 10 June 2014.

Uses 1, 2 and 3 pertain to the use category “coatings/paints/varnishes” which currently has a percentage of about 40% within the EU market, uses 4, 5 and 6 pertain to the use category “coloration of plastics” with a current percentage of 60% within the EU market (see Table 3). In the document of use 6 it is emphasised by the submitter that hotmelt road marking is characterised as a plastics application and not a paint/coating (DCC 2014a). This differs to the ECHA systematics shown in Table 3, where road marking was counted as part of the coatings/paints/varnishes category.

Uses 1 and 4 (distribution and mixing pigment powder) describe the respective formulation processes formally as uses of their own. However, for the formulation itself no separate detailed AoA and SEA have been elaborated, which was not regarded as meaningful. Instead, the formulation of solvent-based paints (Use 1) has been included in the AoA and SEA of the corresponding uses 2 and 3, and the formulation of pigment powder into liquid or solid premix to colour plastic/plasticised articles (Use 4) has been included in the AoA and SEA of the corresponding uses 5 and 6.

As a consequence of the applications for authorisation by the finalisation of this project, it can be concluded that all other companies involved in the production of this substance group have decided during this process not to apply for an authorisation. This means they have either successfully followed a strategy of substitution, or they have decided to abandon the product line of lead chromate pigments because the additional effort of an authorisation does not outweigh the loss of profits from these products in future.

Compared to the findings of this project hitherto, the interim result of this application for authorisation within the authorisation process has been analysed and discussed in the following in order to draw some general conclusions on abatement costs. However, it was decided that details of these documents now available at the very end of this project (analysis of alternatives and socio-economic analysis), as well as the processes of commenting these documents and responding to the comments, have not been analysed any more in the frame of this project.

3.1.2 Identification of substance and non-substance alternatives and end-of-pipe technologies

According to the Annex XV dossiers (France 2009a,b), potential alternatives concentrate on substances only (i.e. pigments covering the same colour spectrum), not on different technologies, which are indicated as “not known”. Based on information of EMLC and the French trade union of paints, inks, colours, pastes and adhesives (FIPEC), there are for most relevant uses no economically feasible alternatives to lead chromate pigments with the same application properties.[13] This information source reveals that alternatives and similar colour pigments are available but not for all applications, due to the following qualities lacking:

- Specific application requirements (especially weather resistance, light fastness, opaqueness capacity) are not met

13 Further ECHA documents (ECHA 2010c,d,e) only repeat part of the information of the Annex XV documents on substitution options without adding new information.

- Technical implementation is difficult and leads to a lack of stability and therefore to a higher reject rate
- Costs of alternatives are 4 to 10 times higher, which is an economic burden for both professional end users and consumers. Since these estimations stem from answers of confidential consultations, it cannot be estimated how these additional costs are exactly distributed along the value chain. However, at least in the short term it can be assumed that producers and importers can to a large extent shift their cost increases downstream along the value chain.

Information on different applications and their chances of a successful substitution remain rather general in the ECHA documents available during this early phase of the authorisation process, because the sources available to the submitter, especially from outside of France, seem to be limited and to some extent confidential. Further information became only available from the documents of the applications for authorisation (see Table 6). However, in two specialist applications, explicitly mentioned in (France 2009a and 2009b), both lead containing pigments under examination are reported to be substituted successfully:

- For road marking, substitution has been achieved by the two most important French companies. This is also congruent with the information gathered by a German producer of road marking (see Table 5).
- In electrical and electronic equipment, substitution can be achieved by yellow pigments based on bismuth vanadate or organic pigments.

In comparison of both pigments, C.I. Pigment Red 104 already shows a much better potential for complete and efficient substitution by colouring solvents and other mineral pigments. This has been referenced in France in the sectors of paints manufacturing, thermoplastics colouring and painting applications.

For C.I. Pigment Yellow 34, however, complete substitution has not been achieved.[14] Reasons are (according to information of FIPEC) lack of permanent efficiency, economic costs and lower specific colour and brightness properties. Alternatives are also used in Sweden as decorative paints, but other uses of C.I. Pigment Yellow 34 (car touch-up and “high solid” paints) cannot be substituted due to alternative substances lacking requirements of colour and coverage.

For those fields of application where a change from solvent-based to water-thinnable paints can be implemented, lead-containing pigments are expected to be substituted.[15]

A French database offering substitution options for carcinogenic, mutagenic and reprotoxic substances[16], produces the following information for C.I. Pigment Yellow 34 (Table 7) and for C.I. Pigment Red 104 (Table 8), with the specific advantages and disadvantages listed:

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14 http://www.substitution-cmr.fr/ (detailed results shown in the following)

15 For Sweden: Information of KEMI (2007), the Swedish Chemicals Agency. See: http://www2.kemi.se/upload/trycksaker/pdf/rapporter/report5_07_lead_in_articles.pdf

Table 7: Alternative substances for C.I. Pigment Yellow 34

Substance	Advantages	Disadvantages
Lysopac rouge 7030C	Environment and health	Costs (much more expensive)
Paliotan yellow L 2045	Environment and health	Costs (much more expensive)
Holcoplast Jaune WP 27 and Holcoplast Vert WP 27	Environment and health	Costs

Table 8: Alternative substances for C.I. Pigment Red 104

Substance	Advantages	Disadvantages
Pigment Orange 5 PR 1033	(no comment)	(no comment)
Pigment Red 112 (Irgalithe Red 3RS)	(no comment)	(no comment)
Lysopac Rouge 7030C	Environment and health	Costs and effectivity (practical application more difficult)
Rouge Aquacolors 62154	(no comment)	(no comment)
Monoazo Pigment (PV Rouge Solide HGR VP2641)	Price, resistance against light and weather, widened compatibility (sign ambiguous)	
Pigment Red 254 (Cromophtal Red 1030-P)	Price, better compatibility, resistance against light and weather	(no comment)
Pigment Violet 19 (PV Rouge Solide ESB)	Price, better compatibility, resistance against light and weather	(no comment)
Solvent Red 135 (Kenawax Red 2GSP (HD))	Price, better compatibility, resistance against light and weather	(no comment)
Pigment Red 166 (Ecarlate microlithe R-T)	No CMR substance	(no comment)

C.I. Pigment Red 104 has been successfully substituted in France. Further information on these substances was provided by the French Agency for Food, Environmental and Occupational Health & Safety (ANSES). ANSES has performed two surveys between 2008 and 2010 to collect "successful substitution stories" from companies. These examples (one of which is explained in the following) have been used to feed the French database on substitution and to distribute this information via this database to industry in order to improve their substitution processes. ANSES confirmed that the database contains physico-chemical, toxicological and ecotoxicological

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16 http://www.substitution-cmr.fr/, also referred to in the Annex XV documents (France 2009a,b). The respective search results of Table 7 can be directly found at http://www.substitution-cmr.fr/index.php?id=112&tx_kleecmr_pi3[uid]=17&cHash=8d 99963d44, results of Table 8 at http://www.substitution-cmr.fr/index.php?id=112& tx_klee cmr_pi3[uid]=16&cHash=d44efd20cd (accessed on 27 April 2012).

information, but no data on substitution cost.[17] Therefore, this contact with ANSES request did not lead to additional information.

One company with "successful substitution stories" (listed in Table 4) promotes on their website their product range of pigments suitable to replace lead chromates.

Table 9: Lead free pigments offered by a EU company

Substance	Suitable for
Replacing C.I. Pigment Yellow 34:	
Lysopac Yellow 3910C	Automotive, Decorative, Industrial, Powder
Lysopac Yellow 6615B	Automotive, Decorative, Industrial, Powder
Lysopac Yellow 8313P	Decorative, Industrial, Powder
Lysopac Yellow 8312P	Decorative, Industrial, Powder
Lysopac Yellow 6616B	Automotive, Decorative, Industrial, Powder
Acetanil Yellow 2GO 7415C	Decorative, Industrial
Acetanil Yellow R 6514C	Decorative, Industrial
Replacing C.I. Pigment Red 104:	
Lysopac Red 7031P	Automotive, Decorative, Industrial, Powder
Lysopac Red 7030C	Automotive, Decorative, Industrial, Powder
Naphthol Red 7034C	Decorative, Industrial, Powder
Naphthol Red B 7032C	Decorative, Industrial, Powder
Lysopac Orange 3421C	Decorative, Industrial, Powder
Lysopac Orange 3620C	Automotive, Decorative, Industrial, Powder
Lysopac Orange 3621C	Automotive, Decorative, Industrial, Powder
Lysopac Orange 3420C	Decorative, Industrial, Powder

According to the website information it can be assumed that this globally oriented company has a quantitatively relevant or even market-leading position in such lead-free pigments, and therefore probably has gained a competitive advantage against competitors in other EU Member States.

3.1.3 Compilation of feasible and constructive scenarios

As already explained, the scenarios can be restricted to the two mixed crystal pigments C.I. Pigment Yellow 34 and C.I. Pigment Red 104, since the quantitative applications of pure lead chromate are negligible compared to mixed pigments.

17 E-mail information by ANSES, France, of 4 December 2012 (contacted by the German SEAC member at the Umweltbundesamt)

The scenarios to be used in the analysis of alternatives and in particular in the socio-economic analysis of the application for authorisation (as already existing for a set of uses, see Table 6), generally consist of:

- a baseline or business-as-usual scenario, in the REACH terminology named "applied-for use scenario": In this one these two pigments will remain unregulated.
- a restriction scenario (or more precisely authorisation scenario), potentially with several variants, where the authorisation comes into force and the use of these two pigments is no longer allowed after the sunset date. In the case of the lead chromate pigment group, this sunset date is fixed for 21 May 2015, 18 months after the latest application date.

For the time frame of abatement cost estimations, this sunset date, as well as the envisaged review period of an authorisation, are decisive parameters. The review period determines the temporary validity of an authorisation once granted until the revision in view of technical progress and development of substitution options. From currently developing practice of authorisations, according to ECHA communication the most common review periods will be in the range of 4, 7 or 12 years, depending among others how the development perspectives of alternatives are judged.

The AoA documents and their findings are very similar for the uses 2, 3, 5 and 6 applied for in Table 6.; C.I. Pigment Yellow 34 and C.I. Pigment Red 104 are dealt with together in the same documents, respectively. For the following explanations see exemplarily for all uses DCC (2014b). Current uses where C.I. Pigment Yellow 34 and C.I. Pigment Red 104 are still used have all very high demands on the technical criteria. For the estimation of alternatives and costs occurring to producers and importers, as well as other economic subjects affected in case of a complete substitution, the following considerations and parameters have been relevant in the case of C.I. Pigment Yellow 34 and C.I. Pigment Red 104. These considerations are oriented on a set of specific desirable properties of C.I. Pigment Yellow 34 and C.I. Pigment Red 104 for the respective uses under examination:

- **Technical considerations:** chroma comparisons, opacity issues demonstrated, weather fastness, heat stability, dispersibility
- **Sustainability:** dangerous or pollutive production processes, toxic constituents
- **Availability:** e.g. limited supply
- **Economic considerations**

Potential alternative substances identified have been compared with C.I. Pigment Yellow 34 and C.I. Pigment Red 104 with regard to all these criteria; see for details in particular the appendices of DCC (2014b).

In the SEAs of the applications for authorisation (see exemplarily: DCC (2014c, 2014d)), it was decided, based on input provided by a customer of the applicant, to replace C.I. Pigment Yellow 34 and C.I. Pigment Red 104 by the following substances in the restriction scenario (Table 10):

Table 10: Alternatives used for the applied-for use scenario and the non-use scenario for the estimation of economic impacts in the socio-economic analysis

Uses applied for No. in SEA	Applied-for-use scenario	Non-use scenario
1, 2, 3 (formulation and industrial and professional application of paints on metal surfaces)	C.I. Pigment Yellow 34	Pigment Yellow 184 (Bismuth vanadate)
	C.I. Pigment Red 104	Pigment Orange 73 and Pigment Orange 67
4, 5, 6 (formulation and industrial use for coloration of plastics and plasticised articles, including the application of hotmelt road marking)	Master batches based on C.I. Pigment Yellow 34 (concentration 5% in the final product)	Pigment Yellow 34-free master batches (concentration 7% in the final product); composition based on information provided by the applicant's consumer
	Master batches based on C.I. Pigment Red 104 (concentration 5% in the final product)	Pigment Yellow 104-free master batches (concentration 7% in the final product); composition based on information provided by the applicant's consumer

3.1.4 Estimation and ranking of abatement costs

Due to the lack of quantitative data provided by companies to the project team, it was not possible to estimate an abatement cost curve in quantitative terms. According to qualitative information on uses and alternatives, e.g. from the French database and company website, it can only be supposed that an estimation and ranking of abatement costs level, if possible, would be use-specific and have a span of zero or close to zero to a level of considerable costs (that are probably not (yet) economically feasible for some companies).

Information has not been provided by (former) producers and/or importers in EU due to missing responses to the questionnaire, even after several reminders. From information gathered hitherto, practical experience of substitution must already be available in France, Belgium and Sweden. German producers have still been in an ongoing decision process with regard to an application for authorisation. One crucial issue mentioned was that a final decision factor for EU competitors will be the decision of the main current non-EU producing company whether it will submit an authorisation request or not.

What can, however, be stated is that, in case that abatement cost curves could be quantified, they are supposed to be rather complex. As arising from Table 7 and Table 8, the advantages and disadvantages of several alternatives available are related to both costs, environment and health, and specific application characteristics required such as better compatibility, resistance against light and weather or compatibility. Moreover, even within the use categories of coloration of plastics, and especially coatings, paints and varnishes, there is – both across and within the automotive, decorative, industrial and powder application field – a huge variety of specific requirement profiles, depending on the materials envisaged for, outdoor versus indoor use, mainstream versus specialist uses etc.

So it was reported that in road marking and electrical and electronic equipment specific substitution solutions have already been achieved. It can be assumed that further target-specific solutions will be developed or have already been developed-by competitors in case a ban comes into force. Therefore, the theoretical abatement cost curve is not supposed to be flat but (in case that complete information is available) rather to consist of small intercepts at high resolution.

In addition, there will not be a fixed abatement cost curve over time but a trend due to research and development, and learning and experience processes. This influence of the time component will also become obvious in another case study of lead-containing stabilisers in polyvinyl chloride (Chapter 3.6) where the industry association in charge proved more cooperative to disclose aggregated data. In this first case study, however, the behavior of relevant producers and importers in competition was comprehensible not willing to provide internal knowledge on a voluntary basis.

This might be different in case that an authorisation process is already under way and industry has to cooperate within a consortium and develop an application for authorisation. However, the project team could – apart from the non-confidential summary documents published for the comment process – not get an insight into the internal process how the application for authorisation (finally published) was developed and information gathered.

In order to update for completeness the results of the ongoing authorization process, in the "economic impacts" chapter of the SEA, based on the assumptions summarized in Table 10, ranges of quantitative "compliance costs expected under the non-use scenario" have been calculated for the respective uses (DCC 2014c, 2014d). The total effect on costs consists of both price and quantity effects, as exemplified for the case of uses 2 and 3 in paints:

- **Price effect:** Costs per kg vary between the C.I. Pigment Yellow 34 and the more expensive substitute Pigment Yellow 184 (first and direct economic impact of the non-use scenario)
- **Quantity effect:** More coats are required, it is necessary to paint more often, i.e. in the end a greater quantity of pigment is required to achieve the color spectrum close to the one obtained with Pigment Yellow 34.

A similar cost structure results for the case of C.I. Pigment Red 104, as well as in principle for the applications of both pigments in master batches for the coloration of plastics and plasticised articles. Since the assumptions used in these SEA documents, only recently available, are still being discussed and will yet be finally evaluated within the authorisation process, they have only been explained with regard to their basic structure here and not analysed quantitatively.

3.1.5 Results and limitations

Beside contacting the producers and importers of lead chromate pigments, further request for support from SEAC authorities in other EU Member States was asked for, but did not lead to additional information that was not already obtained by own research. Therefore, in addition an another customised and abridged questionnaire has been distributed to selected downstream users in the two main use categories of C.I. Pigment Yellow 34 and C.I. Pigment Red 104 - coloration of plastics and coatings/paints/varnishes. It has been supposed that these downstream users have further valuable experience and information available on costs. These might refer both to one-time costs due to the production switch and to permanent (annual) costs. Additional information from feedback has been described and analysed (summarised in Table 5).

The grouping of lead chromate pigments was in the beginning of the project regarded and selected as an “ex-ante case” for a substance. Information gathering made apparent that the substitution, in particular of C.I. Pigment Red 104, has already been going on and partly complete.

Some additional final insights could be gathered by the information on the applications for authorisation, published by ECHA after the latest application date. This shows that:

The producers and importers, previously being competitors on the market for the lead chromate pigment group, have obviously not been at the same level with regard to their cost structure of production, but also with regard to the available know-how, the development and availability of alternatives. We have to assume that the technical and economic situation described in the AoA and SEA documents of the six uses applied for does only hold for the company applying for an authorisation according to their available information, individual situation and company strategy, and probably not for the other competitors identified (such as listed in Table 4). The other companies having been in the same decision situation with regard to an authorisation came to a different yes-no-decision, namely not to apply for an authorisation of C.I. Pigment Yellow 34 and C.I. Pigment Red 104 by the latest application date. This might have evolved from a set of different reasons in detail for each company, including aspects of the respective consumer as well as supplier structure, the product range and portfolio, as well as the general long-term strategies followed by the companies, may they be initiated more or less by the REACH Regulation or have other motivations.

One further interpretation of the analysis of alternatives (DCC 2014a, 2014b) might be that also the specific requirements of the downstream uses are crucial, i.e. qualitative differences of potential alternatives are essential as well that are not quantifiable in abatement costs alone. For all uses 2, 3, 5 and 6 the AoA documents came to the conclusion in the summary that “every potential alternative fails on at least 3 (and generally many more) criteria in comparison to the existing pigments. In addition to failing on the basis of technical criteria, possible alternatives often have important downsides from environmental, human health, sustainability or availability perspectives” (DCC 2014b).

This evaluation, however, has been a conclusion of one company only, acting as importer and Only Representative. Some other companies seemed to have no problems with substitution by alternatives. This authorisation process has not been finalised, and the final decision by the European Commission is still outstanding.

The results of the investigation of this case study only allow a qualitative rather than a quantitative appraisal on the magnitude of abatement costs for the three lead chromate substances under examination. Although the primary approach was to ask for potentially relevant cost components of production, it may prove more helpful to involve also the industrial customers, i.e. the downstream users of these pigments, from the beginning. At least the cost component that is forwarded to customers can thus be identified, although it can only be supposed how large is this share compared to total additional costs – and thus which side of the market will bear the higher share of abatement costs. On the other side, customers receive use-specific support and advice by the customer consultant of their supplier that may not be available as public information.

Anyway, to come to a more comprehensive evaluation of the abatement costs of lead chromate based pigments, either improved incentives or legally binding measures provided by the REACH regulation are probably necessary for the affected companies to cooperate.

3.1.6 Conclusions concerning the lead chromate grouping

During the authorisation process with regard to this substance group, going on in parallel during the duration of this project, all companies involved have all been in an individual strategic competitive position that did not make it advisable to disclose and share more information than necessary and required by law. For example, the company offering the alternatives listed in Table 9 (as a globally oriented company and with a probably market-leading position in lead free pigments) should have ex-post cost estimations for abatement costs available. The strategic position and competitive advantage over competitors with regard to lead-free substitution products might be one reason not to reveal further data.

Detailed qualitative information on a range of potential substance substitutes showed that an estimation and ranking of abatement cost levels will be highly use- as well as company-specific and have a span of (close to) zero or also negative to a level of considerable costs that are probably not (yet) economically feasible for some companies. Therefore it might be expected that the majority of uses may be substituted, whereas a potential future authorisation will be diversified according to uses specified in particular. This will in the first instance concern specific actual uses of C.I. Pigment Yellow 34, because C.I. Pigment Red 104 already shows more success in a substitution, and pure lead(II) chromate will no longer be relevant for uses on the market in quantitative terms due to lacking REACH registrations and applications for authorisation.

3.2 Tris(2-chloroethyl)phosphate (TCEP)

TCEP is mainly used as an additive plasticiser and viscosity regulator with flame retarding properties for foams, polyesters and other polymers (e.g. polyurethane, polyvinyl chloride and polyisocyanurate). It is used in plastics, textiles, adhesives, building insulation, coatings, paints and varnishes.

The comprehensive risk assessment report for TCEP (EU RAR 2009) mentions the reduction of brittleness, and the simultaneous flame-resistant finishing, of polyurethane in the production of celled, rigid or semi-rigid foam, as the largest field of application of TCEP (80-90 % of the quantity produced) in the past. Additionally TCEP was also used as an intermediate for the production of wax additives on a small scale. Further application fields of TCEP, accounting for 10 – 20 % of the total quantity include:

- Acetyl cellulose
- paints and varnishes
- thermoplastics (foils, extrusion)
- Ethyl cellulose (foils)
- Nitrocellulose (paints and varnishes)

- Polyvinyl acetate (paints and varnishes)
- Polystyrole (adhesives for polyurethane foam)
- Polyvinyl chloride

3.2.1 Analysis of available data and its consequences for the total cost model

According to ECHA (2010e), it is difficult to estimate the volume of TCEP currently manufactured, imported, exported and used in the EU, from the data available. ECHA (2010e) assumes that a high volume (range 1,000 – 10,000 t/yr) is supplied in the EU to uses which are in the scope of REACH.

- **Production**

In 1998, TCEP was produced in the EU in quantities of about 2000 t/a (EU RAR 2009). However, the production has ceased in the EU in 2001/2002 according to the EU RAR (2009). This assumption does not take into account the manufacture in Poland for 2004, which is estimated to amount to 300 - 500 t/yr, of which 300 to 400 t are exported from the EU) (ECHA 2010e).

Globally, production of TCEP still takes place. Companies in China are offering TCEP as flame retardant in PU, PVC, UPR etc. (e.g. Hebei Zhenxing Chemical and Rubber Co., Ltd or Jiande Huahai Chemical Co., Ltd.).[18]

- **Use**

The use of TCEP has already declined in the 1990s for occupational health and safety reasons; this was based on a recommendation of ISOPA because of an R 40 classification of TCEP (Leisewitz and Schwarz 2000). Global TCEP consumption peaked at over 9000 tonnes in 1989 but had declined to below 4000 tonnes by 1997 (WHO 1998).

Main uses of TCEP are as a flame retardant (additive plasticiser and viscosity regulator with flame retarding properties) in polyurethane, polyesters, polyvinyl chloride and other polymers. Nowadays it is mainly used in the production of unsaturated polyester resins (~80%). Other fields of application are acrylic resins, adhesives and coatings (EU RAR 2009). The EU RAR (2009) estimates the amount used in the EU to be 1007 t/a (for allocation to the uses, see Table 2). This does not take into account the amounts of TCEP produced and used in the new member states. For EU-27, ECHA (2010e) estimates a consumption of 1,000–1,200 tonnes in 2004.

Table 11: Estimated percentages and tonnages of TCEP in main uses (ECHA 2010a)

Use	Percentage (tonnage per year)

18 http://www.alibaba.com/showroom/115--96--8.html (accessed 23.02.2012)

Polymers	94% (947 t/y)
Intermediate of wax additive	5% (50 t/y)
Paints	1% (10 t/y)
Sum	**100% (1007 t/y)**

According to the EU RAR (2009) there were three companies importing TCEP; all of these importers are exclusively traders of TCEP.

The main industrial branches to use TCEP as a flame-retardant plasticizer, are the building industry (roof insulation; for fields of application see Table 3), it is also used in the manufacture of furniture, textile, cars, railways and aircrafts (EU RAR 2009). There are no data available on amounts of TCEP in products.

Table 12: Fields of application given by one company (representing 44% of EU tonnage; EU RAR 2009)

Type	**Application**	**%**
Unsaturated polyester resin	Building industry, e.g. roofing	83
Acrylic resin	Roadside safety barriers	2
Adhesives	Building industry	5
Paints (wood and roofings)	Building industry, e.g. fire protection of roofs	< 1
Polyurethane foam	Furniture	< 1
Others (unknown)	Unknown	9
Cellulose acetate	Transport	1
Textile coating	Upholstery	0

- **Imports/exports of the substance**

In 2002, the three companies imported a total of 1150 t TCEP into the EU-15 (partly from Russia and Poland). A tonnage of 143 t was exported outside the EU in 2002. The total EU tonnage at present can be estimated to be 1007 t/y (EU RAR 2009).

3.2.2 Identification of substance and non-substance alternatives and end-of-pipe technologies

(ECHA 2010e) mentions that according to information obtained from industry, TCEP is not manufactured anymore in the EU (European countries before May 2004).

According to (Leisewitz, Kruse and Schramm 2000) until the mid-1990s, a mixture of tris(2-chloroethyl)phosphate (TCEP) and tris(chloropropyl) phosphate (TCPP) in a ratio of 1:1 was most usual in PUR formulations. However, in recent years, TCEP, which has the higher chlorine and phosphorus content (36.7% chlorine, 10.8% phosphorus) and is more effective in contrast to TCPP, has been replaced with TCPP in Germany for occupational health and safety reasons (R40 classification, "possible risks of irreversible effects"). The two German manufacturers have discontinued production. For this reason, 90% of the additive flame retardants are currently accounted for by TCPP. TCPP, like TCEP, is classified as a ‘water polluting substance’, but it lacks the other classifications attributed to TCEP (‘environmentally dangerous’ and R40).

TCPP is the cheapest of all additive flame retardants. It should be noted that this statement, quoted from (Leisewitz, Kruse and Schramm 2000) reflects the understanding as to how TCPP prices compare to those of other flame retardants in 2000. Price ranges for TCEP and TCPP were also compared in the course of this project through virtual commerce websites. According to the Alibaba commercial platform [19] price ranges were found as follows: for TCEP - 1500-2500 € and for TCPP - 1550-2350 €. Though the price range at present is similar, it is assumed that this reflects the phase out of TCEP through the application of TCPP, and its impact on the market price. This is understood to be a result of a change in production costs per unit, in light of the reduction in production following phase-out.

The Irish RAR for TCPP (Rapporteur Ireland/UK 2008) states that TCPP is a drop-in substitute for TCEP and that there is a move away from use of TCEP by industry.

The ECHA Background document for TCEP from 2010 (ECHA 2010a) concludes that based on statements of industry, the replacement has been completed for all the applications for which replacement is possible.

TCPP is less effective than TCEP and the most economic (cheap) of the additive flame retardants (Leisewitz, Kruse and Schramm 2000). A Risk Assessment Report for TCPP (Rapporteur Ireland/UK 2008) is available indicating manufacturing volumes above 30,000 t/y. The production of TCPP is increasing in recent years due to the substitution of TCEP and brominated flame retardants with TCPP. The TCPP EU RAR (Rapporteur Ireland/UK 2008) concluded that there is a need for limiting the risks for workers.

3.2.3 Compilation of feasible and constructive scenarios

In the case of TCEP used as a flame-retardant in polyurethane foams, TCPP has been implemented as a substitute. AS TCPP has proved to be a “drop in” substitute that thus does not require substantial costs besides development and testing of substance compounds for various applications, it seems that the possible scenarios are straightforward. Either TCEP remains

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19 http://www.alibaba.com/showroom/tcep-price.html (retrieved September 2012)

unregulated (business as usual scenario), or it is included in the lists of restricted substances (restriction scenario).

3.2.4 Estimation and ranking of abatement costs

Some initial cost information was provided by company no. 1 who stated that the costs of substitution correlate with the "extent" of change necessary for a successful substance substitution. TCEP was used in many compounds in the production of different kinds of foams. In the case of TCEP it was possible to develop a "drop-in-solution". That means the "extent" of redesign was focused mainly on the development of substitutes for the compounds used.

In other substitution cases, capital investments might be necessary; e.g. if a non–flammable chemical (e.g. HCFC) is substituted by a flammable chemical (pentane), significant capital investments may become necessary all along the value chain.

In the case of TCEP, company no. 1 mentioned 3 main categories of cost:

- Basic research, in the case of TCEP for each product category: e.g. 2 – 3 Fire categories for each application like spray foam, continuous rigid board etc. Assuming each competitor had to do basic research for about 10 product categories, costs are estimated at around 300 – 500 000 Euro for each supplier of the preparations.
- Production tests[20] with customers: 7500 Euro incl. raw-materials, personal, machine time, phys-testing, travelling – costs. For each TCEP the contact person of a customer assumed 3 – 10 production tests would be needed before a decision could be made as to the supplier and the substitute compound.
- Final regulatory testing: Product testing, large scale fire testing - this is assumed to sum up to 100 000 Euro, but must be undertaken only for the products going to market.

The customer contact person further stressed that TCEP substitution had concerned many customers, but had proved to be a less complex drop–in solution case which did not trigger additional millions due to capital costs. It should further be noted that in products manufactured for the automotive or aviation sectors, final testing may take several years (based on an E-Mail communication).

As the number of responses is so far limited to general data provided by one manufacturer that has completed the replacement of TCEP with TCPP the above results need to be interpreted with caution.

One thing can clearly be ascertained, concerning TCPP being a "drop-in" substitute for TCEP. In this sense it can be presumed that further cost data would probably detail cost components concerning the development and testing of various applicable compounds.

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20 The wording is quoted and is understood to concern testing of the use of TCPP in specific products, performed to establish the applicability of TCPP as a substance-substitute for TCEP in terms of product performance, reliability, etc.

3.2.5 Results and limitations

Though TCEP was first regarded as a substance to be considered through the course of this work as an ex-ante case, during further research it became apparent that the substitution of TCEP is already to a most part underway if not complete.

Recent literature lists TCPP as a drop in substitute for TCEP, especially where the production of PUR foams, the main application of TCEP, is concerned. This was further confirmed by the TCEP and PUR product manufacturers who were approached as sources for obtaining substitution cost information.

Further research showed that TCPP has also been mentioned in the context of its environmental risks and a risk assessment was carried out in Ireland and the UK to assess the scale of risk attributed to this substance. A draft report became available in 2008, and though an official final report was not available, it has been confirmed that the draft version is at present the final version of this work. This work is to serve as the background for concluding if TCPP should be authorised under REACH regulation or not. According to the EU RAR draft (Rapporteur Ireland/UK 2008), TCPP has the following classifications:

Human health: R 22 Harmful if swallowed

Environment: R 52/53 (harmful to aquatic organisms, may cause long-term adverse effects in the aquatic environment) WGK 2 (German water hazard class 2; voluntary classification of manufacturers)

Though industry representatives are hesitant to regard TCPP as a substance that may shortly require substitution, the new information clearly requires rethinking how TCEP should be regarded in the course of this work. As it appears that the TCEP – TCPP pair could serve as a valid case for covering both ex-ante and ex-post perspectives, further detail is provided for TCPP concerning its areas of application and possible substitutes.

Although the availability of information is still unclear, a new approach is under consideration, in which the use of halogenated flame retardants in PUR products could serve as an example that could be considered both from an ex-ante as well as an ex-post perspective. In this case, TCEP would be researched as an ex-post substance, whereas its substitute, TCPP, would be regarded as ex-ante.

From a short review of the literature for TCPP, it seems a few substitutes have been named for various applications, though some substitutes prove to be worse than TCPP and none of these have reached an implementation stage. Possible substitutes and some respective information are listed in Table 13:

Table 13: Possible substitutes for TCPP applications

Substance	Relevant Application	Comparative toxicology and eco toxicity	Costs	Volatility
Halogen-free trialkyl- and triaryl phosphates		substitutes are halogen-free, which is in principle advantageous from an environmental point of view		triaryl phosphates are, like TCPP, relevant in indoor spaces

Substance	Relevant Application	Comparative toxicology and eco toxicity	Costs	Volatility
triethylphosphate (TEP)	insulation foams	TEP is considered preferable over TCPP.		
TEP (triethylphosphate diethylethylphosphonate (DEEP), triphenyl phosphate (TPP) and diphenylcresylphosphate (DPK)	one-component foams	TEP is considered preferable over TCPP DPK (mixture) is considered preferable over TCPP. DEEP and TPP are considered are given a less positive classification as they are environmentally hazardous.	TEP & DPK; 1 component foams - generally 15-20% more expensive for consumer	
Phosphoric polyols	flexible foam			
Ammonium Poly Phosphate	Block and slabstock foams equipped with APP as flame retardant can be produced in acceptable quality only as of a bulk density of approx. 40 kilos.			

During the search for TCEP substitution costs, a first contact was made with the former owner of the manufacturing site. In the past this site both produced TCEP as well as polyurethane products in which TCEP was used as a flame retardant. This contact had previously stated that they could provide some cost information concerning the actual costs of substitution, and possibly also concerning the assumed costs that had been produced prior to substitution implementation. However, as of yet the various data had not been found. This is attributed to the fact that TCEP was substituted quite a few years ago and the ownership of the site was terminated. It is possible that the data may still be recovered and made available, however at this time it cannot be determined if and when such information will become available.

Another representative contact confirmed that company 1 too had completed the full substitution of TCEP with TCPP. In an initial correspondence, general costs that should be considered in this case of substitution were provided (cf. section 3.2.4 above). Further pursuit of more detailed information concerning TCEP substitution has, however, been unsuccessful.

A further recommendation was made to approach the TCPP REACH Consortium, under the assumption that current TCPP manufacturers and users had in the past manufactured and/or used TCEP and could therefore possibly provide expected and actual costs of substitution. The consortium was established by various TCPP producers and users for the purpose of assembling a joint registration dossier, required under the REACH regulation. The Consortium spokesperson agreed to send a request for information to all consortium partners, in search for TCPP manufactures and users who would agree to make substitution cost data available concerning TCEP, referring them to the research team. No further contacts have resulted from this effort.

3.2.6 Conclusions concerning TCEP and TCPP

As it seems little thought has been given at present by industry to the substitution of TCPP, collecting substitution costs presumed by industry should be problematic, however perhaps a review of disadvantages attributed by industry to possible substitutes, shall give some insight as to the "alternative" costs of substitution.

In case a positive decision is reached concerning the authorisation of TCPP, it seems that either substitution has not been closely considered by producers and users, or that there is reluctance to share information. In this sense it might provide useful to approach the task of collecting cost data from a different direction, looking into the costs of products that constitute alternatives for TCPP containing polyurethane foam products as a method to realize the price of elimination. Analysis of such data shall focus around the differing costs of interchangeable products based on alternative substances.

3.3 Azo dyes in tattoo inks

Named after the chemically characteristical azo-group (–N=N-), azo dyes are among the most significant classes of dyes. They are usually derivatives of azo-benzene which are being produced by the so-called azo coupling.[21] Azo dyes can be used for a broad range of colours in an equally wide range of applications. Due to their versatility and wide-spread use, they have also been the basis for numerous tattoo inks in the past.

After it was discovered that certain azo dyes could be subject to cleavage into potentially carcinogenic substances, the use of such azo dyes in tattoo inks has gradually become subject to regulation and prohibition in many countries.

In Germany, the Consumer Goods Ordinance was adapted in 1998 to ban azo dyes which can be cleaved to yield potentially carcinogenic amines, among them 3,3-Dichlorobenzidine, for use in a number of consumer goods.[22] On a European level, azo dyes that can be cleaved into aromatic amines on a similar list, which also includes o-Ansidine, were banned from use in consumer goods as well.[23]

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21 Breitmeier, Jung, Organische Chemie, Thieme Verlag, 2001

22 Bedarfsgegenständeverordnung, Bundesgesetzblatt, 1998, Teil 1 Nr. 1, pp. 5-36

23 Directive 2002/61/EC, 19th Amendment of Council Directive 76/769/EEC, ETAD Information Notice No. 6 (Revised February 2008)

An explicit regulation for azo dyes in tattoo inks for Germany followed in 2009, with a new "Tätowiermittelverordnung". This tattoo ink ordinance also included a list of cleavage product amines as well as an explicit list of azo dyes that were prohibited from use. In addition to 3,3-Dichlorobenzidine, o-Ansidine and numerous other amines, o-Diansidine was also named among the amines that could be produced from azo-cleavage.[24]

Later in 2009, a Swiss study was published which discovered that five azo dye pigments, which consist of the three amines mentioned, do not reveal significant concentrations of cleavage products when tested with the proposed methods.[25] A German study published in November 2009 came to a very similar result. In this study, it was explicitly stated that the EN 14362 standard for the detection of aromatic amines in textile dyes was unfit to dissolve a number of pigments which are therefore "not accessible for cleavage". Five pigments for which this is the case were explicitly listed, namely C.I. 21095 (Yellow 14), C.I. 21110 (Orange 13), C.I. 11741 (Yellow 74), C.I. 21115 (Orange 34) and C.I. 21160 (Orange 16). It therefore appears unclear whether sunlight or UV-B radiation, which lead to much higher concentrations in similar experiments, might result in the cleavage of these pigments in tattoo applications.[26] Accordingly, a restriction of these pigments may be considered in the future. With exception of Yellow 14, which is to some extent already among the prohibited pigments of the TätoV, these pigments were therefore chosen to be investigated in this abatement cost study.

3.3.1 Analysis of data availability and quality for the total cost model

The large number of tattoo ink manufacturers and the even greater number of inks make it a challenging task to

a) identify inks that would be affected by a restriction and
b) identify potential substitutes for these inks

Material Safety Data Sheets from several tattoo ink manufacturers and individual inks, which are available online, made it possible to compose a list of exemplary inks which contain the pigments in question. It should be noted, however, that this means that the following tables cannot nearly be a complete enumeration of inks, as only a limited number of material safety data sheets could be obtained. Most of the corresponding manufacturers are from the USA, with the exception of Futura Ink, from Milan, Italy (see Table 9).

Table 14: Location of ink manufacturers with available material safety data sheets

Manufacturer	Location

[24] Verordnung über Mittel zum Tätowieren einschließlich bestimmter vergleichbarer Stoffe und Zubereitungen aus Stoffen (Tätowiermittel-Verordnung), TätoV, Ausfertigungsdatum: 13.11.2008

[25] Konformität von Tätowier- und Permanent-Make-up-Farben nicht zufriedenstellend, BAG, 2009

[26] First Meeting of the Ad Hoc Committee "Tattooing Agents" of the BfR Cosmetics Committee, BfR, 2009

Dynamic Color Co.	Ft. Lauderdale, Florida, USA
Futura Ink	Milano, Italy
Intenze	Rochelle Park, NJ, USA
Millenium Colorworks	Babylon NY, USA
Radiant Colors	Los Angeles, CA, USA
Starbrite	Enfield, CT, USA

The pigment C.I. 11741 is used in yellow and green colours of various manufacturers, as shown in Table 15.

Table 15: Tattoo inks that contain C.I. 11741, Yellow 74

Tattoo Ink	**Manufacturer**
Canary Yellow	Starbrite
Golden Yellow	Radiant Colors
Leaf Green	Radiant Colors
Lemon Yellow	Radiant Colors
Lime Green	Radiant Colors
Lite Green	Radiant Colors
Medium Green	Radiant Colors
Tattoo Paint No. LFG	Dynamic Color Co.
Tattoo Paint No. LYM	Dynamic Color Co.
Tattoo Paint No. YD-4	Dynamic Color Co.
Tattoo Paint No. BRO	Dynamic Color Co.
Dragon Turquoise	Intenze

Orange 13 (C.I. 21110) was used for orange and brown colours by two American manufacturers (see Table 16).

Table 16: Tattoo inks that contain C.I. 21110, Orange 13

Tattoo Ink	**Manufacturer**
Soft Orange	Intenze
Copper	Radiant Colors
Dark Brown	Radiant Colors
Sienna	Radiant Colors

C.I. 21115, or Orange 34, is used in nine orange colours by Italian manufacturer Futura Ink. Of the four pigments in question, it is therefore the only one that has been found to still be officially used within the European Union (see Table 17).

Table 17: Tattoo inks that contain C.I. 21115, Orange 34

Tattoo Ink	**Manufacturer**
Opaque Orange	Futura Ink
Orange	Futura Ink
Dirty Orange	Futura Ink
Orange	Futura Ink
Over Lyer Orange	Futura Ink
Ink Power Orange	Futura Ink
Pumkin Puree	Futura Ink
Red Orange	Futura Ink
Reddy	Futura Ink

Orange 16 (C.I. 21160) is used by several American manufacturers (see Table 18):

Table 18: Tattoo inks that contain C.I. 21160, Orange 16

Tattoo Ink	Manufacturer
14 KT Gold	Millenium Colorworks
Brite/Bright Orange	Starbrite
Steel Blue	Radiant Colors
Tattoo Paint No. BRN	Dynamic Color Co.
Tattoo Paint No. BRO	Dynamic Color Co.
Tattoo Paint No. LBR	Dynamic Color Co.
Tattoo Paint No. OD-5	Dynamic Color Co.

Given the state of the investigation as shown in Table 15 to Table 18, the availability of ex-ante cost data from within the European Union so far depends on the cooperation of Futura Ink. Attempts to contact the firm have not been successful so far, but are ongoing. Two German manufacturers of tattoo inks have stated that they have already successfully replaced the four azo pigments by alternative pigments. In this case, according to the earlier definitions, the results for the azo dyes in question would have to be treated as ex-post, instead of ex-ante, data.

3.3.2 Identification of substance and non-substance alternatives and end-of-pipe technologies

Due to the successful substitution of the potentially dangerous pigments with alternative ones (whose health effects are entirely unknown to the authors of this SEA), it appears reasonable to assume that a substitution is possible in general. A publication of 2009 stated that the colours could be preserved by identifying fitting substitutes.[27] While this statement clearly refers to the azo dyes that were already explicitly regulated by the TätoV, the list of ingredients supplied in the publication was also free of any of the four azo dyes that are subject of this analysis (C.I. 21110, C.I. 11741, C.I. 21115 and C.I. 21160). In correspondence with a second manufacturer, as well as in the questionnaire, it became apparent that the wording of the TätoV was taken very seriously, implying that more azo dyes have already been replaced in the inks than the TätoV explicitly required.[28]

When asked for the substitutes that they have chosen to replace C.I. 21110 (Orange 13), C.I. 11741 (Yellow 74), C.I. 21115 (Orange 34) and C.I. 21160 (Orange 16), Deep Colours named C.I. 11767 (Yellow 97), C.I. 561110, C.I. 561170 (Orange 73) and C.I. 56300 (Yellow 138) as

27 Hautcutür Infosendung Tätowierfarben, 2009

28 “Investment-related costs already spent by serious manufacturers”, questionnaire P.3

substitutes. The publication by the manufacturer, in which they disclose the ingredients of their 5 ml promotion inks, also included Orange 73 and Yellow 138.[29]

3.3.3 Compilation of feasible and constructive scenarios

The apparent ease with which the azo dyes in question can be replaced leads to a simple choice of scenarios: Either the pigments continue to be unregulated (baseline scenario), or they are included into the negative list of substances that must not be used in tattoo inks (restriction scenario).

3.3.4 Estimation and ranking of abatement costs

In order to quantify and evaluate abatement costs, different stakeholders have to be considered. From a consumer perspective, the tattoo inks are only a part of the total cost of the tattoo. Therefore, the effect of a price increase is diluted by e.g. the share of costs for labour and equipment. It is therefore apparent that any price increase for the end consumer will be less grave than the price effect further up the supply chain. In theory, the most significant effects will be felt by the manufacturers of the pigments themselves, while the effects will decrease for every link of the supply chain, as other cost items remain unaffected. The current approach in this SEA is to investigate changes on the tattoo ink manufacturing level, which is an intermediate between the pigment manufacturer and the end consumer.

Online prices, e.g. for Starbrite tattoo inks, are in the range of $ 12 per ounce, which corresponds to 10 € per 30 ml.[30] A specific gravity of 1.1 to 1.4 is stated in Starbrite's material safety data sheets. If a specific gravity of 1.25 is assumed for the purpose of calculating prices per mass unit, this translates to 267 € per kg.

3.3.5 Results and limitations

As the number of responses is so far limited to one questionnaire filled in by a manufacturer that has already replaced the azo dyes in question and the aforementioned publications, the following results need to be interpreted with caution. A broader data base was aimed for in the course of the SEA, but proved impossible due to lack of cooperation by the approached firms.

According to the questionnaire answers, additional annual material and services costs of "less than 30 €/100 kg" are estimated. In relation to the price of tattoo ink per kilogram calculated in the previous sub-chapter (267 €/kg, i.e. 26.700 €/100kg), this is in the range of a 0.1 % price increase. In a comment concerning the other actors along the value chain, the following statement was given:

"No significant raise of production costs.

Price increase expected, but not based on regulation (Regulation will be used for price increase regardless real situation as demonstrated in other branches)"

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29 Hautcutür Infosendung Tätowierfarben, 2009

30 http://www.painfulpleasures.com/xcart/customer/product.php?productid=4310&cat=310&page=1

Therefore, based on the available results of the investigation, abatement costs for C.I. 21110 (Orange 13), C.I. 11741 (Yellow 74), C.I. 21115 (Orange 34) and C.I. 21160 (Orange 16) appear to be negligible.

With the results obtained so far, the most uncertain aspect appears to be whether the quality of the pigments can be matched by their substitutes and whether it can be verified that the price increase is as negligible as indicated. While the two German manufacturers suggest that substitution is possible without significant loss of quality or price increase, statements from manufacturers that still use the pigments could not be made available.

3.3.6 Conclusions

The results of the investigation are insufficient to allow for a final verdict on the magnitude of abatement costs for the four investigated azo dyes. In the future, it appears consequential to also contact firms that supply the azo dyes to the tattoo ink manufacturers. For such firms, the impact of a regulation may be much more severe than for tattoo ink manufacturers, whose exposure to regulation seems to be very limited.

While it is uncertain whether these approaches will be fruitful, they are deemed necessary to come to a more comprehensive evaluation of the abatement costs of azo dyes. The answers that could (or could not) be received indicate that the effort to complete the questionnaire may have a crucial impact on a firm's willingness to participate in such a survey. While the success of the questionnaires in this study has been limited, we continue to believe that it may be helpful a) to give various options for the determination of individual items (e.g. to either answer questions on costs or prices as indicated in chapter 4.2), b) to create a credible survey scheme that ensures that confidential data cannot leak to competitors and c) to improve the overall incentives for firms to participate in such investigations.

3.4 Cadmium

Following a request from the European Commission, the European Chemicals Agency (ECHA) has examined the case for expanding the restriction on cadmium in plastics from the current 16 specific plastic materials listed in Annex XVII of REACH to all plastic materials. Based on this, in the year 2013 ECHA has asked for evidence to assess the impact of an eventual expanding of restriction requirements on cadmium and its compounds in plastic materials. Affected actors had been given a chance to submit any usable information by 11 February 2013 via an online questionnaire available on the ECHA website.

In order to obtain an overview of quantities of cadmium that is currently placed on the European market, several independent sources have been consulted, namely the European Union Risk Assessment Report for Cadmium Oxide and Cadmium Metal (2007) and the Socio-Economic Impact of a Potential Update of the Restrictions on the Marketing and Use of Cadmium (as prepared by Risk & Policy Analysts Limited (RPA) in 2009 for European Commission Directorate-General Enterprise and Industry), and have been considered for a further evaluation.

The EU Risk Assessment Report includes figures on the quantities of produced cadmium metal and cadmium oxide for the years 1996 and 2002, respectively. The RPA report includes on the contrary quantities for the year 2009 (as reference year) – therefore the figures from this report have been considered for a further in-depth overview.

3.4.1 Analysis of data availability and quality for the total cost model

- **Production**

According to the RPA report and the cited quantities therein, the worldwide cadmium metal production has decreased from a period from the years 2005 to 2007. A major decrease has especially been observed in Europe where 2,650 tonnes (reference year: 2009) have been produced in six European countries.

Based on figures from ICdA (International Cadmium Association) which have been used in the RPA Report, the following overview on produced quantities per Member State (reference year: 2008/2009) can be given (Table 19):

Table 19: Primary Cadmium Production Plants Operating in the EU in 2008-2009

Country	**Production (t/y)**
Bulgaria	400
Germany	500
Italy	450
Netherlands	600
Norway	200
Poland	350
Romania	<100
Total	2,650

Source: Zarogiannis et al. 2010, p. 5.

These figures are compared with the accumulated tonnage band which is disseminated on ECHA´s website for registered substances. As the indicated tonnage band (1,000 – 10,000 t/y) is too unspecific, it is currently not possible to verify whether the indicated quantities in the RPA report have changed remarkably since the reference year of 2009. A verification or comparison of the cited quantities with the currently manufactured quantities of cadmium would only be possible if the respective data from the registration dossiers would be available. Cadmium is mainly produced as a by-product from Zinc production. Additionally to the manufactured quantities of cadmium metal, also quantities of recycled and imported metal have to be considered, too.

Based on the provided data in the RPA report, 100 - 200 tonnes of cadmium metal and 900 – 1,000 tonnes of CdO are recycled from NiCd batteries. However, these quantities can almost be neglected if compared to those quantities which are imported into the EU. According to the provided data in the RPA report, 9,020 tonnes cadmium have been imported in a period from 2007 – 2008 (as included in concentrates, as metal net flow or in NiCd batteries); in the same period 6,897 tonnes of cadmium metal have been exported (included – amongst others – in pigments, cadmium oxide, NiCd batteries). Referring to the same report 5,000 tonnes of cadmium are transferred into cadmium oxide which is then exported from Europe. By comparison of manufactured/recycled/imported quantities with exported quantities of cadmium metal it can be concluded that 2,123 tonnes of cadmium remain in Europe (for various applications).

Shortly before ECHA has received a request from the Commission to prepare an Annex XV report for cadmium and cadmium compounds in plastics, a preparatory report on this issue has been published (ECHA 2012). Based on the information provided therein, ECHA has received registrations for cadmium and the following nine cadmium compounds: cadmium carbonate, cadmium oxide, cadmium hydroxide, cadmium sulphide, cadmium chloride, cadmium sulphate, cadmium nitrate, cadmium tin oxide and dicadmium tin tetraoxide. The quoted figures on imported and exported volumes of cadmium in the RPA report do not allow distinguishing between various cadmium compounds. Therefore only ECHA and/or the Member State Competent Authorities have a clear overview on volumes of cadmium compounds which are placed on the EU market via production or import.

- **Uses**

According to the already cited RPA report, uses for CdO can be allocated as follows (Table 20):

Table 20: Overview of consumption and use of cadmium oxide worldwide and in Europe

Application	Global (2005)		EU (2007-2008)	
	Tonnes	%	Tonnes	%
Batteries	13,240	82	1,700	89
Pigments	1,615	10	140	7
Plating	969	6	10	0.5
Stabilisers	242	1.5	0	0
Other	81	0,5	Photovoltaics: 50 Alloys: 10	3
Total	16,146	100	1,910	100

Source: Zarogiannis et al. (2010), p. 7.

Whereas 242 t of CdO have worldwide been used for the application as stabilisers (reference year: 2005), this application plays no role anymore in Europe in the year 2007/2008 (0 tonnes of CdO used for this application).

According to entry No. 23 of the current REACH Regulation cadmium and its compounds are currently restricted for use in

- mixtures and articles of plastic material
- paints
- plating of metallic cadmium on metallic surfaces of equipment/machinery applied in the food production sector, agricultural sector, for cooling and freezing, for printing and book-binding, for production of household goods and furniture, production of sanitary

ware and central heating, production of air conditioning plant, production of paper and board, textiles and clothing, production of industrial handling equipment and machinery, production of road and agricultural vehicles, production of rolling stock and vessels.

- brazing fillers
- metal beads and other metal components for jewellery making.

Depending on the sector in which cadmium and its compounds are applied, threshold concentrations of either 0.01 % or 0.1 % are defined as maximum values. The restrictions of cadmium and its compounds, as stated in entry No. 23 of Annex XVII of the REACH Regulation, have been amended by Commission Regulation (EU) No. 494/2011 of 20 May 2011. In the course of efforts to extend the scope of restriction to all plastic materials, it became apparent that small or niche application for cadmium compounds exist (such as colouring of some engineering plastics) and adequate alternatives are not available.

Against this background ECHA received a request from the Commission on 19 November 2012 to prepare an Annex XV report in which it should be assessed whether the existing restriction on cadmium and cadmium compounds can be widened to cover all plastic materials. In order to achieve this task information gathering has been proceeded in order to provide new insights into any remaining uses of cadmium compounds in plastic materials which are currently not covered by provisions of this restriction. A special focus is thereby laid on identification of any cadmium compound and its corresponding use which are currently not subjected to restrictions in plastic materials. The gathered information on the identity of cadmium compounds and its uses in plastic materials has subsequently been subjected to a risk assessment and assessment with respect to the technical and economic feasibility of potential alternatives.

During the progression of this project, on 17 January 2014 ECHA announced that this restriction intention has been withdrawn and ECHA will not submit a proposal to restrict cadmium and its compound in plastics as a broadening of the existing restriction.[31]

Referring to ECHA´s preparatory report (ECHA 2012), registrations have been received for cadmium and following cadmium compounds: cadmium carbonate, cadmium oxide, cadmium hydroxide, cadmium sulphide, cadmium chloride, cadmium sulphate, cadmium nitrate, cadmium tin oxide and dicadmium tin tetraoxide.

According to the publicly available information for registered substances via ECHA´s website, the following overview on identified uses can be given (Table 21):

Table 21: Uses of cadmium and its compounds as indicated in joint submission dossiers

Substance	Use
Cadmium	- Additive for production of inorganic catalysts - Melting, alloying and casting - Wire and rods manufacturing

31 See the information on http://echa.europa.eu/de/registry-of-withdrawn-restriction-proposal-intentions-and-submissions.

Substance	Use
	- Component for brazing products - Downstream use of cadmium based brazing products - Cadmium (alloyed) powder manufacturing - Use of fine powders for mechanical plating - Manufacturing of cadmium containing-alloys - Use of cadmium containing Ag alloys - Electroplating - Production of "targets" by (EB) PVD - Component for soldering products - Downstream use of cadmium-based soldering products - Powders for contact materials - Use of active powders for batteries - PVD / coating - Use in brazing fillers > 0.01w/w % (with exceptions) is advised against
Cadmium oxide	- Component for production of inorganic cadmium compounds - Laboratory reagent - Component for production of organic cadmium compounds - Component for production of Inorganic pigments - Additive for production of frits - Additive for production of glass - Additive in the manufacturing of electronic components - Use of CdO-containing catalysts - Electrogalvanizing - Electroplating - CdO in electrotechnical contact material - Batteries/fuel cells - Component for polymer-matrices, plastics and related preparations - Use of CdO-containing polymers for cable protecting & isolating coatings - Use of CdO-containing polymers for tube & sheet articles - Use of CdO-containing polymers for molded articles
Cadmium carbonate	- Component for production of inorganic cadmium compounds - Laboratory reagent - Component for production of organic cadmium compounds - Component for production of inorganic pigments - Additive for production of glass - Use of $CdCO_3$-containing catalysts - Component for polymer-matrices, plastics and related preparations - Use of $CdCO_3$-containing polymers for cable protecting & isolating coatings - Use of $CdCO_3$-containing polymers for tube & sheet articles - Use of $CdCO_3$-containing polymers for molded articles
Cadmium hydroxide	- Component for production of inorganic cadmium compounds - Laboratory reagent - Component for production of organic cadmium compounds - Component for production of inorganic pigments - Electrogalvanizing - Electroplating - Batteries/fuel cells
Cadmium sulphide	- Component for production of inorganic cadmium compounds - Laboratory reagent - Component for production of organic cadmium compounds - Component for production of PV modules - Component for production of inorganic pigments - Additive for production of frits - Additive for production of glass - Additive in the manufacturing of electronic components - Use of CdS-containing catalysts

Substance	Use
Cadmium chloride	- Component for production of inorganic cadmium compounds - Electrogalvanizing - Electroplating - Laboratory reagent - Component for production of organic cadmium compounds - Component for production of PV modules - Laboratory chemical - Solar panel manufacturing - Use in brazing fillers > 0.01w/w % (with exceptions) is advised against
Cadmium sulphate	- Use of cadmium sulphate as component for production of inorganic cadmium compounds - Use as laboratory reagent
Cadmium nitrate	- Component for production of inorganic cadmium compounds - Laboratory reagent - Component for production of organic cadmium compounds - Component for production of inorganic pigments - Additive for production of ceramics - Additive for production of glass - Use of $Cd(NO_3)_2$-containing catalysts - Batteries/fuel cells - Use of $Cd(NO_3)_2$-containing photographic emulsions
Cadmium tin oxide	Not yet publicly available
dicadmium tin tetraoxide	Not yet publicly available

According to the outlined information in the RPA report, main applications of cadmium can be summarised as follows:

- **Use of cadmium as starting material for production of cadmium oxide**

This in particular comprises the quantitatively dominating use of CdO in batteries and fuel cells, as listed in Table 21.

- **Use of cadmium in brazing alloys (in model engineering, e.g. copper boiler manufacture) and for brazing fillers**

Cadmium in brazing fillers reduces the brazing temperature, shortens the duration of brazing and suppresses the cost of brazing. These cadmium-bearing alloys find numerous applications, such as model engineering (consumer application) or metal joining in the plumbing, refrigeration, heating, ventilation and air conditioning, tooling and other sectors (applications for professional users). An estimated amount of approximately 10 t (containing up to 2.5 tonnes cadmium) is used annually by consumers while the amount of cadmium-bearing alloys, used by professional users, is quantified to 90 – 140 t/y (containing up to 22.5-35 tonnes of cadmium).

Referring to Zarogiannis et al. (2010), "...there have been efforts to replace them (cadmium-bearing alloys) with cadmium-free alternatives (which have been available since the 1940s)" (Webb 2009).

As it has been stated in the aforementioned brochure of Johnson Matthey (Webb 2009), "cadmium-free products tend to have higher and longer melting ranges, which result in a marginal increase in process times and brazing temperatures." Furthermore, cadmium-free brazing materials contain a higher degree of silver than the corresponding cadmium-bearing materials. This has consequently impacts on the purchase price: At current rates a 1% increase in silver represents an increase of between £1.25 and £1.75 per kilo in filler metal cost.

The authors of the RPA study (Zarogiannis et al. 2010) have collected a good overview on a broad range of applications for cadmium-bearing alloys, which are presented in a tabular form in the follows (Table 22):

Table 22: Confirmed applications of cadmium-bearing brazing alloys in the EU

Application	Confirmed use by suppliers	
	Professional	**Do-it-yourself**
Electrical conductors and electrical resistances (incl. gas appliances)	✓	-
Heat exchangers	✓	-
Tooling (tungsten carbide)	✓	-
Engineering work such as bicycle repairs	✓	-
Model engineering (e.g. model trains)	✓	✓
HVAC / Refrigeration (piping)	✓	-
Plumbing	✓	-
Electrical motors – transport (e.g. used for example in end rings of rotor bar joints	✓	-
Silverware and allied trade incl. plating	✓	-
Brassware – taps, shower parts, etc.	✓	-
Flexible hoses – hydraulic parts (e.g. for automotive uses/ for fittings brazed together with a rubber-based hose in-between)	✓	-
Gas cutting torches / burners	✓	-
Power conversion – motors, turbines etc. (turbines: for lacing wires between individual blades and for erosion shields)	✓	-
Aerospace/defense (e.g. navy: ship pipework for transporting seawater) Limited application which may relate to old technical drawings that have not been changed	✓	-
Sensors, gauges and controls	✓	-
Source: Personal communication with EU suppliers/manufacturers		

From Table 22 it is apparent that consumer use of cadmium-bearing alloys plays a negligible role. Professional/industrial applications, such as tooling, heat exchangers, HVAC (Heating, Ventilation, & Air Conditioning)/refrigeration, plumbing and electrical components appear to be the most widespread.

- **Use of cadmium in jewellery by application of cadmium-bearing solders and cadmium-containing jewellery**

Cadmium may be included as part of the main jewellery alloy, in a solder, in gold coatings (electroforming/electroplating) or as a pigment or stabiliser in non-metal components of a jewellery article. This issue is especially of interest due to imported jewelleries from non-EU countries. As stated in Zarogiannis et al. (2010), use of cadmium in the jewellery industry is significant especially for countries outside the EU, such as India. At the time of the elaboration of the RPA report an annual imported volume of up to 273 tonnes may be placed on the EU market from outside the EU.

- **Use of cadmium in PVC**

Organic cadmium-based compounds have been used as a stabiliser for PVC-products. They are added during the PVC-manufacturing process in order to retard degradation processes which occur upon exposure to heat and UV light.

PVC producers committed themselves not to use cadmium as a stabiliser in PVC after 2001 in a voluntary commitment called Vinyl 2010, which was well achieved during the first time frame of this commitment. This substitution process was a minor challenge (and had a much smaller quantitative extent anyway up to the year 2000) than the replacement of lead-based stabilizers in PVC within the same overall commitment and its successor program of PVC producers. This example of the substitution of lead-based stabilisers has been examined as a separate case study in detail in Chapter 3.6 of this report.

3.4.2 Identification of substance and non-substance alternatives and end-of-pipe technologies

The following alternatives concentrate on the two main applications: the production of Nickel-cadmium (NiCd) batteries and cadmium-based pigments, especially used in plastics.

For NiCd batteries in battery technologies, especially applied in cordless power tools (CPTs) in Europe, the following two alternatives to NiCd batteries have been identified and examined:

- Lithium-ion (Li-ion) batteries
- Nickel-metal hydride (NiMH) batteries

This example representing the quantitatively dominating use of cadmium has already been examined in detail and documented in an existing study of ESWI (2010) and therefore offers the most detailed and complete data evaluation. It can serve to exemplify in detail the SEA steps to be carried into execution, which are described and specified in the following chapters 3.4.3 and 3.4.4.

For the use of heavy metals (both cadmium and lead) in paints, communication feedback from downstream users from the use groups cited in the documents showed the following two statements that in some particular applications they have been replaced already for a longer time:

- Producers for road and airport marking materials have already started at the end of the 1980s to replace heavy metals and aromatics by organic pigment blendings in coloured, especially yellow, road marking paints, a process which has been finalised by 1993. Therefore, in this field of application there are no more actual and relevant data for abatement costs.
- A market-leading user for the coloration of plastics in special applications, e.g. in particular for automotive interiors, explained that they used very rarely a few Cadmium containing pigments until about 5 years ago, but since then cadmium has no longer been used and will not be used in future for pigments in all uses within this company anymore.

For the use of cadmium covering the whole use sector of plastics, the restriction procedure recently terminated shows a concrete and structured approach how to gather abatement costs data, which deliberately is depicted in the following. During the preparation of the restriction dossier by ECHA, an intention which was withdrawn in January 2014, the current interim status of the use of cadmium and its alternatives has been described in ECHA (2013a). In the context of the first call for evidence, ECHA has appointed a consultant (Risk & Policy Analysts Ltd.) to undertake a study on cadmium in plastics.[32] The study performed at the beginning of 2013 had the goals to

- identify the uses/presence of cadmium and its compounds in plastic materials currently not covered by the restriction, produced in or imported into the EU, as well as the technical and economic feasibility of alternatives, and to
- assess the risks of cadmium and its compounds, as well as of their alternatives, arising from the relevant uses in plastics.

By July 2013 "… ECHA has received very little information on whether and how cadmium and its compounds and in particular cadmium-based pigments are used in plastic materials, with the exception of some articles coloured with cadmium for safety reasons" (ECHA 2013b). Therefore, ECHA has started a second call for evidence. The public consultation has asked the following structure of questions:

1. Do you produce or use plastics which contain cadmium-based pigments and which are not currently restricted under REACH?
2. If yes, which non-restricted plastics do you produce/use, and for which applications?
3. Could you use other than cadmium-based pigments for colouring these plastics? Would there be technical or economic implications to you or your clients if you substitute to cadmium free alternatives? Please give details.
4. Do you regard these applications as safety uses? If yes, give details.
5. Do you produce or use non-restricted plastics which contain cadmium for any other reason? if yes, please give details.

32 See for information on this study the website http://www.rpaltd.co.uk/news-cadmium.shtml.

RPA has received responses, among others with regard to abatement costs of cadmium in pigments, which have not been made public. Some quantitative results, however, have been disclosed in the status report of ECHA. This report refers to a draft discussion document of RPA to ECHA containing information that "the replacing red cadmium pigments is not only the most difficult from a technical point of view but is also the most expensive with cost estimates of a 40-50% increase in pigment costs. It is also suggested that alternatives to yellow (and orange) cadmium pigments be more expensive with estimates of 10-20% increase in pigment costs." (ECHA 2013a, pp. 12f.)

Obviously, among others the order of magnitude of these price differences supported the final decision to withdraw the intention of a further restriction. Since no more detailed data are public for this example, the following two chapters concentrate on the use for Nickel-cadmium batteries.

3.4.3 Compilation of feasible and constructive scenarios

As shown in Table 20, the quantitatively dominating uses of cadmium in the EU are still the production of Nickel-cadmium (NiCd) batteries and the application in pigments; both uses together amount to 96 % in total. As explained in Chapter 3.4.2, the use of cadmium in pigments has been subject of a restriction procedure until recently still ongoing (until the finalisation in January 2014), where no data were publicly available on a disaggregated basis beyond the quoted overview on results published by ECHA.

However, the use of cadmium in NiCd batteries has already been the subject of examination for some years; therefore, the following results available concentrate on this application in detail.

A study on the decision to continue the existing exemption for the use of cadmium in portable batteries and accumulators (referring to the Batteries Directive 2006/66/EC) examined economic impacts, but also environmental and social impacts (ESWI 2010)[33]. This example is summarised briefly here; it shows an extensive case because a series of potential abatement costs for different market actors have been assessed.

Currently, this exemption is still existing without a temporal limitation; however, an in a proposal for a directive of the European Parliament and of the Council amending Directive 2006/66/EC (European Commission 2012) it is envisaged to limit the exemption for cordless power tools until 31 December 2015. This proposal is still in discussion within the EU authorities.

Due to the shares of battery technologies applied in cordless power tools (CPTs) in Europe, the following two alternatives to NiCd batteries have been examined:

- Lithium-ion (Li-ion) batteries

[33] Note that the version of this report of 26 January 2010 published at the website of the European Commission http://ec.europa.eu/environment/consultations/pdf/batteries_study.pdf is not the latest version but was amended on 23 April 23 2010; changes in the amended version highlighted in yellow. The section on the economic impacts, however, did not show changes compared to the previous version. ESWI has been a consortium under the leadership of the contractor BiPRO GmbH.

- Nickel-metal hydride (NiMH) batteries

Both options have been estimated for the two extreme cases that all NiCd batteries used in CPTs will be replaced either by NiMH batteries or by Li-ion batteries.

Economic impacts have been estimated for five groups: raw material suppliers, battery manufacturers, cordless power tool manufacturers, consumers and the waste management sector.

- Raw material suppliers:

Even in case of a replacement of all NiCd batteries used in CPTs worldwide the reserves of the corresponding markets (cobalt and lithium in the cases of Li-ion and NiMH, in addition nickel and rare earths in the case of Li-ion only) are estimated as large enough to guarantee supply for future decades. Increases in the market volumes are estimated as between 1.0% and 8% (highest for the cobalt market in the case of a replacement by Li-ion batteries. Price volatilities, however, may be expected as high.

- Battery manufacturers:

There is only one producer of NiCd cells left, however no longer producing NiCd cells for batteries intended for the use in CPTs. All NiCd batteries used in CPTs are imported from Asia. Therefore, a ban will not cause disadvantages for EU manufacturers of batteries. It will rather support and accelerate the market development already ongoing that the rechargeable NiCd market is shrinking anyway.

- CPT manufacturers

Several different cost effects, but also increases of turnover have been discussed and estimated, both one-time and annual ones. This is explained in detail in the following section.

- Consumers

The main effect is identified as a range of cost increases for the purchasers and users of cordless power tools. This is also shown in the following section.

- Waste management sector

This sector has usually not been examined in most abatement cost studies. However, with regard to NiCd batteries differences in the amounts of waste but also the collection, recycling and disposal efforts is relevant. Since the waste management sector is affected not only by additional costs but mainly by loss of turnover and workplaces, most of the effects in the waste management sector should rather be attributed to the category “wider economic impacts” of the ECHA Guidances. Impacts estimated comprise:

  - Impacts due to altered amounts of waste by Li-ion batteries compared to NiCd batteries: ambiguous due to uncertainty in the estimations of the lifetime of Li-ion batteries
  - Additional costs for the disposal of NiCd batteries as hazardous waste
  - Loss of turnover for three European companies that currently recycle NiCd batteries: 20 – 30 mio.€/year and loss of 70 to 90 workplaces

- o NiCd battery waste will be reduced to zero by around the year 2026. Part of the market share of NiCd recyclers will shift to other battery types in case of a ban.
- o In the medium term the waste management sector will profit from the elimination of one most hazardous substance.

3.4.4 Estimation and ranking of abatement costs

Abatement costs have been identified for manufacturers of CPTs, for consumers and for the waste management sector due to the disposal of NiCd batteries as hazardous waste.

There is a range of uncertainty due to different estimations in the lifetime of the batteries (see Table 23) which has as a consequence a large gap between the lower and upper bound of cost increases for the customer:

Table 23: Lifetime of alternative battery technologies after regular use

Battery technology	Estimated lifetime	Comment
Nickel-cadmium (NiCd)	7 years	
Lithium-ion (Li-ion)	4.3 years – 7 years	Deviation in different sources (of personal communication): 4.3 years -EPTA (2009) 7 years: Bosch (2009)
Nickel-metal hydride (NiMH)	4.2 years	o

Source: ESWI (2010)

In the case of an equal lifetime (7 years) for Li-ion and NiCd batteries, the cost increase is only 10% for the consumer, in case of a shorter lifetime of 4.3 years, the additional costs are 49% in Euro. Cost increase in case of NiMH is 57% compared to NiCd. The cost increase in case of Li-ion is opposed to added value during use: The Li-ion tool is lighter and needs to be recharged less frequently.

Relevant one-time and running costs estimated for different sectors are shown in Table 24:

Table 24: Costs of substitution for different sectors (one-time and annual): Components, tendencies and sum

Actor group / sector	One-time costs		Running costs and other effects (per year)	
Cordless power tools manufacturers	Adaption of assembly lines due to change from NiCd to Li-ion battery systems	60 mio.€	Turnover increase: more powerful and expensive CPTs (decreasing over time) replacement of charging equipment for existing tools (until existing replacement is replaced)	65 – 326 mio.€/y 6.4 mio.€/y
Consumers	n/a		Cost increase of retail prices (dependent on Li-ion lifetime: 7 years or 4.3 years)	65 – 326 mio.€/y
Waste management sector			Additional costs for the disposal of NiCd batteries as hazardous waste (average per year over 10 years)	0.26 to 0.4 mio.€/y

Source: ESWI (2010)

Part of the additional costs is caused by system changes, both product development and waste management, and will decrease over the years. On the other hand, additional costs for final consumers is also reflected both in added value for the consumers and in a benefit of cordless power tool producers in Europe. It also has to be emphasised that waste management may also play a role for other restrictions and authorisations.

3.4.5 Results and limitations

For the main use of NiCd batteries, during the study of ESWI (2010) several producers, associations and other stakeholders have been contacted for verification of assumptions. At this time the decision has been taken to continue the exemption for the production of NiCd batteries in cordless power tools.

For the use of cadmium and its compounds in plastics, the call for evidence and the public consultation has served for an improvement of the data base available. This has recently been recorded and analysed by ECHA and not been accessible during the ongoing process. However, as already explained, the data gathering by and on behalf of ECHA led to the consequent decision to drop the intended restriction dossier for cadmium in plastics.

In this case, cadmium was originally selected for the ex-post perspective; however it showed that the cost estimation for the main use (NiCd in batteries) refers to an ex-ante perspective. Comparing the different effects due to a ban of NiCd in batteries for use in cordless power tools shows that parts of them are quantifiable costs, parts are spreading out into the category of “wider economic effects”, and parts also describe differences in functionality and characteristics for the customers. They might be better addressed by different ways of economic valuation, such as the differences in consumer surplus.

3.4.6 Conclusions concerning cadmium

In total, the variety of uses of cadmium and cadmium compounds, as well as the ongoing procedures to expand the restriction on cadmium and its compounds in plastics, showed that this case study proved in the end as less fruitful than e.g. the following two ones (see Chapters 3.5 and 3.6). However, what proved as a special case is that here also costs to the waste management sector was identified as relevant. For other substances, the question of waste treatment might be underrepresented or disregarded although relevant as well.

3.5 Perflourooctane sulfonate (PFOS)

Perfluorooctane sulfonate (PFOS) ($C_8F_{17}SO_3$) is a fully fluorinated (eight-carbon chain length) anion (see also **Fehler! Verweisquelle konnte nicht gefunden werden.**), which is commonly used as a salt or incorporated into polymers. PFOS and its related compounds[34], which may

34 Different number of PFOS-related substances was proposed by SFS (2005), UK_DEFRA (2004), OECD (2002), OPPAR (2002)

contain PFOS impurities or substances that can result in PFOS when degrading, are members of the large family of perfluoroalkyl sulfonate substances (PFAS).

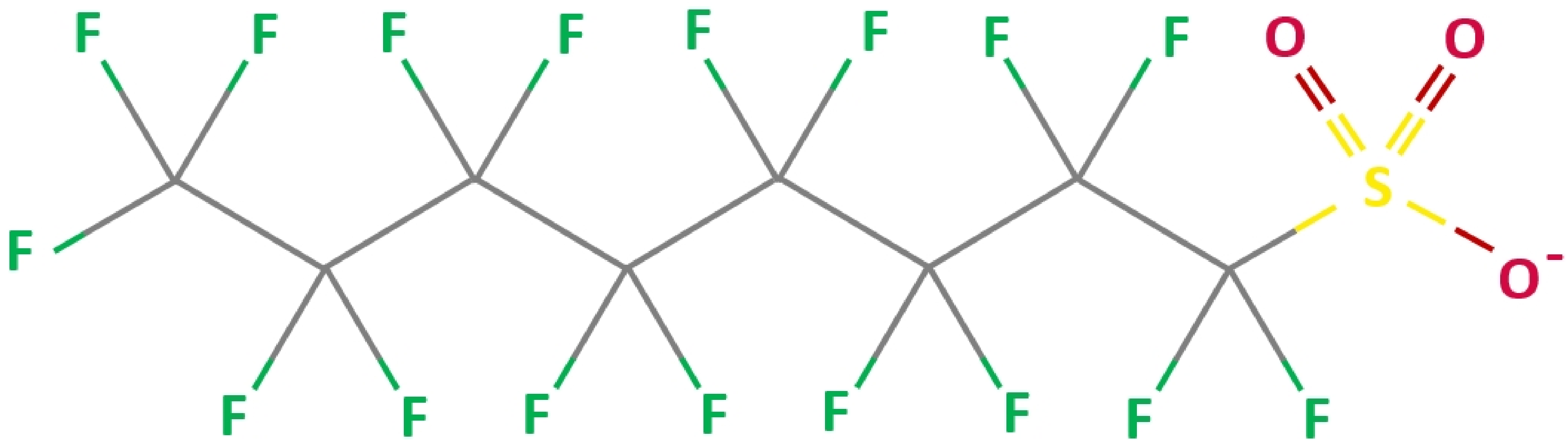

Figure 1: Structural formula of PFOS
Source: authors' own graph

PFOS related substances were produced by electrochemical fluorination (ECF) resulting in the synthetic precursor perfluorooctane sulfonyl fluoride (PFOSF). In addition to the PFOSF production the ECF process results in a mixture of by-products (e.g. n-methyl or n-ethylperfluorooctanesulphonamide (FOSA), n-methyl or n-ethylperfluorooctanesulphonamidoethanol (FOSE), see also **Fehler! Verweisquelle konnte nicht gefunden werden.**.).

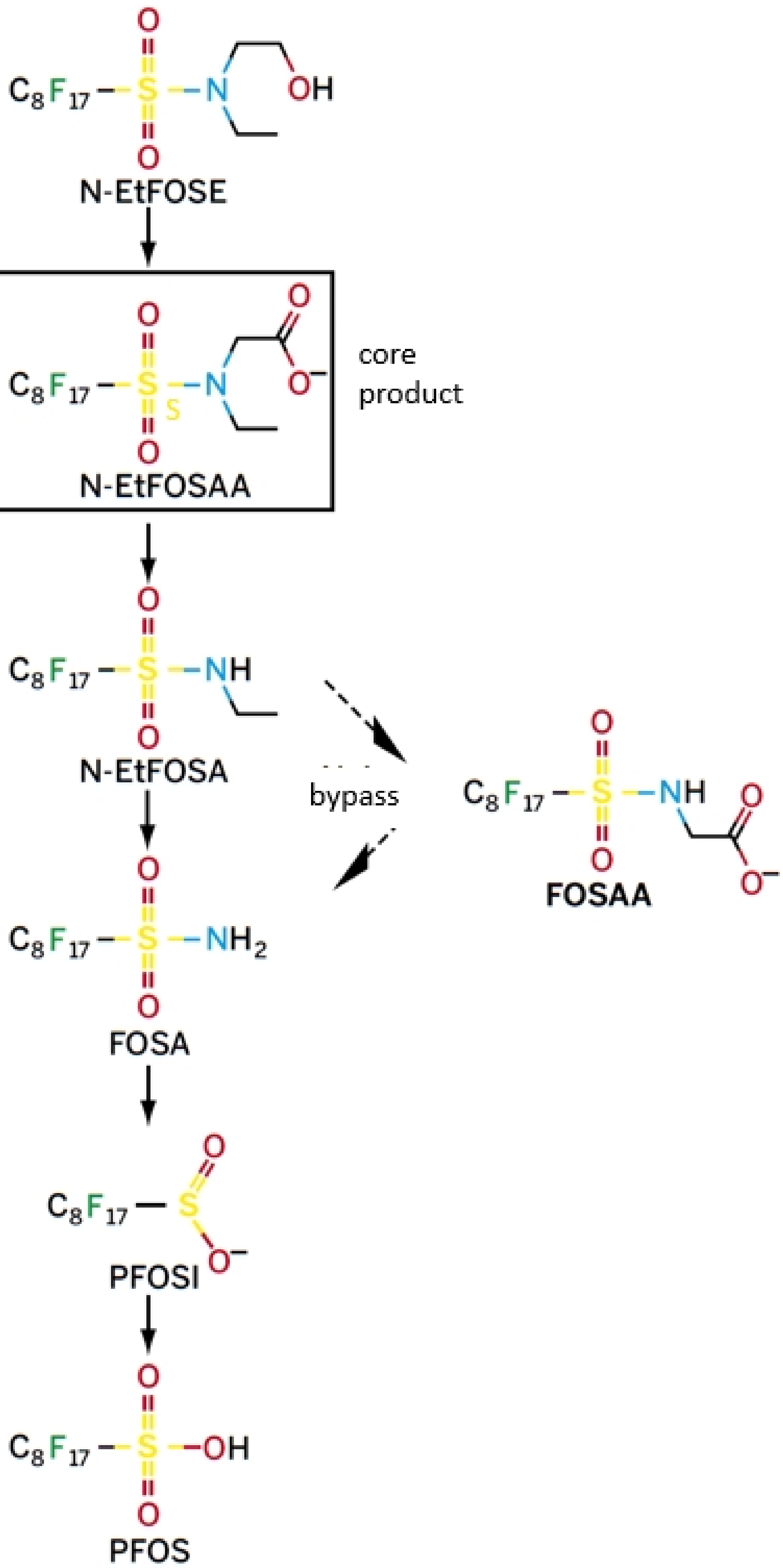

Figure 2: By-Products and Degradation of EtFOSE to PFOS
Source: LANUV (2011), p. 12, with translations by the authors

Some of the commercially important PFOS related substances are detailed below (UK_DEFRA 2004):

- Perfluorooctane sulphonic acid (CAS No. 1763-23-1)
- Potassium salt (CAS No. 2795-39-3)
- Diethanolamine salt (CAS No. 70225-39-5)
- Ammonium salt (CAS No. 29081-56-9)
- Lithium salt (CAS No. 29457-72-5)

PFOS is extremely persistent and has substantial bioaccumulating and biomagnifying properties. It has a capacity to undergo long-range transport and it also meets the toxicity criteria of the Stockholm Convention on Persistent Organic Pollutants (POPs). The Executive Body of the UNECE LRTAP (POPs Protocol to the Long-Range Transboundary Air Pollution Convention)[35] agreed to consider PFOS to be defined as POP under the Protocol on POPs. In May 2009, perfluorooctane sulfonate (PFOS) was added to the list of banned substances of the Stockholm Convention.[36]

PFOS and PFOS-related substances can be released to the environment during the production phase, during their use in industrial and consumer applications as a result of disposal of chemicals, products or articles containing PFOS, at the end of use phase (UNEP POPRC 2007).

Per- and polyfluorinated compounds (PFCs) like PFOS are widely used or have been used in a wide variety of applications and consumer products, due to their thermic and chemical stability, their resistance to UV radiation and weathering and their soil-, colour-, grease-, oil- and water-repellent properties (Fricke and Lahl 2005).

PFOS or PFOS related substances were and exceptionally are still used in the following applications:

- Metal plating
- Photographic industry
- Medical devices
- semiconductor industry
- Fire fighting foams and use of existing fire fighting foam stock (storage until 27 June 2011)
- Carpets
- Leather/apparel
- Textiles/upholstery
- Paper and packaging

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35 http://www.unece.org/env/lrtap/pops_h1.html

36 http://chm.pops.int/Convention/ThePOPs/TheNewPOPs/tabid/2511/Default.aspx

- Coatings and coating additives
- Industrial and household cleaning products (e.g. waxes and floor polishes)
- Oil production and mining
- Pesticides and insecticides (insect baits for control of leaf-cutting ants and insecticides for control of red imported fire ants and termites)

In 2010, the Persistent Organic Pollutant Regulation (EC) 850/2004 (as amended) brought into force the control and monitoring of the use of PFOS across Europe. Its production, supply and use are now prohibited, apart from a few limited exceptions.

The PFOS ban currently exempts the following uses:

- photoresists or anti-reflective coatings for photolithography processes
- photographic coatings applied to films, papers, or printing plates
- mist suppressants for non-decorative hard chromium (VI) plating and wetting agents for use in controlled electroplating systems where the amount of PFOS released into the environment is minimised
- hydraulic fluids for aviation

The former major manufacturer of PFOS, already had voluntarily stopped production[37], completing its phase-out of PFOS production in 2002[38]. As this production was mainly applied in surface treatment and paper protection applications, the use of PFOS in these applications decreased significantly thereafter, although the potential market for use remains since there are other known suppliers and manufactures. This manufacturer developed new technologies for these two areas that enabled the company to reformulate many of the products affected by the phase out. In other words, as the manufacturer directly provided substitutes for the uses relevant to its market share, it did not create an opportunity for other suppliers to enlarge their market share where it phased-out the application of PFOS. Concerning PFOS, the manufacturer delivered the Persistent Organic Pollutants Review Committee (POPRC) (UNEP POPRC 2006), government policy makers, scientists and regulators with PFOS relevant data, which enabled balanced evaluation of the chemical properties (3M 1999) and usage patterns, including the adverse effects of the chemical. This co-operation of industry helped greatly in forming the risk profile and socio-economic assessment of PFOS, supporting the addition of PFOS to Annex B of the Stockholm Convention (Öko-Institut 2012). However, most alternatives on the markets were mainly derivatives of perfluoroalkyl sulfonates with a shorter alkyl chain and C8-based fluorotelomers. Currently, C6-fluorotelomers dominate the trade. Thus far it has been difficult for non-fluorinated alternatives to establish in the market, partly because of established supplier relationships (UNEP POPRC 2011).

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37 The production was mostly for surface treatment (textile, carpets, leather, upholstery) and for paper protection

38 http://solutions.3m.com/wps/portal/3M/en_US/PFOS/PFOA/Information/phase-out-technologies/

At present China is the main global producer and the main user of PFOS substances for applications (e.g. in metal plating, photolithography, hydraulic fluid additives) for which it is difficult to find substitutes (UNIDO 2009).

3.5.1 Analysis of data availability and quality for the total cost model

Currently in Europe PFOS is mainly being used in mist suppressants for non-decorative hard chromium (VI) plating, hydraulic fluids, in the photographic industry and in the photolithography and semiconductor industry. Furthermore, PFOS compounds may be contained in products and articles that were produced in connection with “historical” applications and that are still in circulation. This mainly concerns products reaching the end-of-life stage, which could be a source of emissions if not handled properly. It is also possible that PFOS compounds are present in supply stocks of applications manufactured in the past. The main applications relevant in this regard include paper and coated material – mainly textiles, carpets and leather.

The total production of PFOS has been significantly reduced in between 2000 and 2005 as result of a voluntary phase out by industry.

The current demand (2004, 2010) in the European Union has been estimated for the on-going industrial/professional use of PFOS and related substances and is detailed in Table 25.

Table 25: Estimated Current Demand for PFOS and related Substances in the EU

Industry Sector / Application	**Quantity (kg/year) in 2004 (UNEP POPRC 2006)**	**Quantity (kg/year) in 2010 (BiPRO 2011)**
Photo imaging industry	1,000 kg	562 kg/y used +~1,280 kg from historical storage
Semiconductor industry	470 kg	9,3 kg
Hydraulic fluids in aviation industry	730 kg	730 kg
Metal plating	10,000 kg	6,500 kg
Fire fighting foam stock (storage until 27 June 2011)	n.a.	90.000 kg

In a different study, Öko-Institut (2012) collected data in order to estimate;

- for which uses and in which amounts PFOS is currently still in use
- which articles containing PFOS are still in circulation/ placed on the market
- and when such articles are expected to be completely replaced with PFOS-free alternatives.

The amount of PFOS released to the environment in 2010 primarily originated from the applications that are still permitted in accordance with the specific derogations, including in particular the use of PFOS in metal plating, in hydraulic fluids, in the aircraft industry, the photographic industry, the semiconductor industry, as well as firefighting foams (used until June 2011). Table 26below, details the quantities of PFOS used in Germany for the various applications, estimated in the 2012 Öko-Institut study. Amounting to about 25 tonnes used in Germany (approx. 88%), fire-fighting foams[39] still had the largest volume share in 2010, followed by the electroplating and surface treatment industry with 3.4 tonnes (about 12%) and the photographic industry, the aircraft industry and the semiconductor industry with shares below 1% (see Table 26).

Table 26: PFOS quantities used in applications and uses in 2010 in Germany (Source: Öko-Institut 2012)

Sector	PFOS quantity for uses [t/a]	PFOS quantity for uses [%]
Metal plating	3,4	11,92
Fire fighting foams	25 (3,5-46)	87,64
Photo imaging industry,	0,075	0,26
Hydraulic fluids in aviation industry	0,05 (0,03325-0,0665)	0,18
Semiconductor industry	0,00187	0,01
Amount of PFOS in total	28,527	100

Today, China is the main producer and user of PFOS. It is reported that the Chinese chrome plating industry uses 25 tonnes of PFOS a year (UNIDO 2009).

The focus of this study has been on applications where PFOS is still in use, namely the **photo imaging industry** as well as its use for metal plating, i.e., **non-decorative hard chromium (VI) plating.** In both sectors / applications, the associations initially showed interest in cooperation.

3.5.2 Identification of substance and non-substance alternatives and end-of-pipe technologies

Photographic applications

Possible alternative technologies or substances that would eliminate the need for using PFOS identified for the **photo imaging industry** are:

- alternative technologies: digital techniques

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39 As indicated above meanwhile the application of firefighting foams discontinued completely, the values in the table therefore represent the past consumption levels.

- alternative substances: non-perfluorinated chemicals such as hydrocarbon surfactants and silicone products, chemicals with short and long perfluorinated chains (C3 - C8), telomer-based products

According to the European - Imaging and Printing Association e.V. (I&P Europe), while PFOS and PFOS-related substances can be replaced in several uses, there are currently no alternatives available that would allow for complete substitution of PFOS in critical and high quality applications. For instance, PFOS is still used in X-ray film for photo imaging for medical and industrial uses where high resolution images are needed, such as in coatings applied to films, papers, and printing plates (UNEP POPRC (2011)[40].

Properties that alternative substances must have in order to match quality of PFOS and related substances include dynamic surface tension capability, solubility, photo-inactivity and stability against heat and chemicals (UNEP POPRC 2011). With regard to potential environmental or health risks of alternative substances (e.g. telomer-based products, C3 and C4 perfluorinated compounds, hydrocarbon surfactants and silicone products) there is only little knowledge about their hazards and pathways into the environment and to humans.

Decorative and hard metal plating

PFOS is useful as a surfactant, wetting agent and mist suppressing agent for chrome plating to decrease aerosol emission and improve the work environment (UNIDO 2011). As explained below the use of PFOS in the metal plating sector may have decreased further in the last years, as there has been a common shift to PFOS free products.

Alternatives for abatement of PFOS in this industry may be divided into 3 main groups:

- Substance alternatives (substitution) for PFOS and/or Cr(VI)
- Technology alternatives (elimination)
- End of pipe technologies (prevention)

The various alternatives are further discussed below

An alternative process already exists for decorative chromium plating. In this new technical process, Cr(III) is used as an alternative substance to Cr(VI) and neither PFOS nor PFOS related substances are necessary. For hard chrome plating, however, the process with Cr(III) does not provide a comparable performance as with Cr(VI) and PFOS. Instead larger closed tanks, or increased ventilation combined with extraction of Cr(VI), are suggested as technological alternative solutions for eliminating Cr(VI) emissions in applications where the use of Cr(III) is not possible yet, thus PFOS is still needed in these cases. (Poulsen et al. 2011)

Today, the PFOS-related substances most commonly used in chrome plating are tetraethylammonium perfluorooctane sulfonate (CAS No. 56773-42-3), with trade names such as

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40 According to informal communication of the German UBA with I&P Europe in 2014 it is understood that some manufacturers no longer use PFOS in the remaining photographic applications. It is thus possible that phase-out of PFOS in this area has been completed, or is to be completed in the short term.

Fluorotenside-248) and potassium perfluorooctane sulfonate (CAS No. 2795-39-3), with trade name FC-80).

Substance alternatives (substitution) for PFOS and related substances, used as mist suppressants in hard chrome plating, include both fluorinated and non-fluorinated substances.

From a short review of the literature for PFOS, it seems a few alternative substances have been named for various applications. Non-fluorinated surfactants (see detail below) are successfully used during the production process for decorative chrome plating. They are not toxic and easily biodegradable.

A selection of main alternatives[41] for the use of PFOS in metal plating is listed below:

- non-fluorinated substances: mainly alkane sulfonates,(e.g. wetting agent SLOTOCHROM SV 31), TIB Chemicals (trade name, TIB Suract HR-H)
- fluorinated substances
  - H4PFOS (=6:2-Fluorotelomer sulfonate (6:2 FTS)) which is only a partly fluorinated octane sulphate. H4PFOS is not resistant to hard chromium plating process and less effective in decorative chromium plating. Thus 6:2 FTS is not considered as equivalent to the performance.
  - Fumetrol 21 (1*H*,1*H*, 2*H*,2*H*perfluorooctane sulfonic acid) from Atotech, (CAS No. 27619-97-2)
  - Germany, Bayowet FT 248 R, (056773-42-3)
  - Chinese alternative products (e.g. F53 - Potassium 1,1,2,2-tetrafluoro-2-(perfluorohexyloxo) ethane sulfonate, F-53B - Potassium 2-(6-chloro-1,1,2,2,3,3,4,4,5,5,6,6-dodecafluorohexyloxy)-1,1,2,2-tetraflouroethane sulfonate)

The fluorinated substances can be expected to be stable in the electrolyte bath[42], therefore this kind of substances will be technically easy to implement in production (e.g. Fumetrol® 21) (UNEP POPRC 2010). However, most of the fluorinated products are likely to be persistent in the environment and toxicity data is very limited. From an environmental point of view, fluorinated substances thus are not necessarily better alternatives in comparison with PFOS.

According to industry, non-fluorinated substances require more technical monitoring and therefore more human resources for hard chrome processes compared to the use of PFOS (Blepp et al. 2013). Additionally there is no long-term experience with these substances concerning technical aspects, environmental impacts, safety measures etc. These effects must be assessed for each alternative (fluorinated and non-fluorinated substances) concerning application in hard chrome plating processes. More research is needed to develop equal or better alternatives to PFOS in order to phase out PFOS in metal plating.

41 There are more non-PFOS alternatives listed in UNEP (2012), UNEP POPRC (2011) and Poulsen et al. (2011).

42 Hard chrome plating is an electrolytic process utilizing a chromic acid based electrolyte bath.

According to Poulsen et al. (2011) **technological alternatives** could be appealing solutions in comparison with chemical alternatives, as most chemical alternatives are fluorine based, potentially harmful to the environment or unstable in the electrolyte. Three mechanisms are discussed by Poulsen that may possibly prevent chromium emissions without requiring the use of PFOS (Poulsen et al. 2011):

- Avoid formation of aerosols
- Promote condensation of aerosols close to the electrolyte surface
- Avoid transportation of aerosols from the surface of the electrolyte

Further alternative options are **end of pipe technologies** used to reduce PFOS emissions to effluents (Fath 2008):

- By selecting suitable activated carbon and optimizing flow rates, up to 99% of PFOS can be removed from wastewater by adsorption onto activated carbon.
- Moreover, strongly acidic wastewater streams with a high content of PFOS can be treated with an electrochemical process using lead electrodes in batch mode. PFOS is thereby destroyed by up to 99%.

3.5.3 Compilation of feasible and constructive scenarios

The current continued use of PFOS is generally limited to those areas where suitable alternatives have been difficult to identify. Therefore the scenarios below focus on two remaining application areas of PFOS and related substances: the photo imaging industry and the metal plating sector.

Regarding the photo imaging industry, since the year 2000 a reduction of >83% of the use of PFOS and related compounds within the imaging and printing industry has been achieved[43]. This reduction is primarily due to the development of digital techniques. As the increase in market share of digital cameras has reduced film use, the use of PFOS in this area is also expected to decrease. This leads to a simple choice of scenarios: Either

1. The remaining exemption will continue until comparable digital technology can be placed on the market replacing analogue technology in those areas where PFOS and related substances are still applied. Due to the fact that redesign of devices as well as their introduction on the market require considerably more time in the medical sector (where PFOS related articles are still necessary), this may take more than 10 years[44].
2. The exemption is to expire, in which case in areas where PFOS is still necessary in analogue technologies, obligatory replacement with digital technology will result in lower imaging quality. As remaining applications are in the medical and radiology sector, there

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43 See also footnote 40, it is possible that a larger reduction in use has already occurred.

44 This estimation is derived from the consultants‘ experiences regarding Directive 2011/65/EU (RoHS 2) exemptions, where medical devices shall come into scope in 2014. In preparation, the medical sector has requested several exemptions in the past few years.

might be a health impact to the patients as well as additional costs for the medical sector where new devices have to be purchased earlier.

This raises a question concerning the cost of substituting the remaining critical and high quality applications in light of the expectation for the scope of these applications to continue to decrease with further development of digital techniques. It is possible that the use of remaining applications will decrease to the point where demand will no longer suffice to support economically feasible production. In this case, industry could discontinue production, eliminating the use of PFOS, however resulting in negative impacts for the medical sector and for patients (health). Please note that this is only an assumption suggested by the writers which could not be confirmed by the stakeholders.

Regarding the hard metal plating sector, three different scenarios are conceivable:

1. The remaining exemption for PFOS will continue in order to avoid an unintended increase of risks concerning Cr-VI aerosols in the work environment. Through end of pipe technologies PFOS emissions are to be reduced from the effluents. It is possible that in some areas, the need for PFOS shall be eliminated in light of the substitution of Cr-VI where this is possible, decreasing the quantities of PFOS applied for hard metal plating.
2. PFOS and related substances are banned. This scenario will probably mainly enhance the application of fluorinated substance alternatives like 1H,1H,2H,2H-perfluoroctane sulfonic acid (H4PFOS) as non-fluorinated alternatives are expected not to be stable in the hard chrome bath (UNEP POPRC 2010).
3. All kind of fluorinated substances (PFOS and related substances as well as fluorotelomer derivates) are banned. In order to preserve the safety level of the work environment in this case larger closed tanks and increased ventilation combined with extraction of Cr-VI from filters will be implemented because it is assumed that the use of non-fluorinated alternatives will not meet the requirements. This shall result in higher costs for manufacture (for equipment and personnel), which may be transferred to consumers.

3.5.4 Estimation and ranking of abatement costs

Photographic applications

According to UK_DEFRA 2004 the costs for reduction of PFOS and related substances by 83% in the EU photographic industry are estimated to be in the range of € 20-40 M for the full range of imaging products. The cost to be incurred from further work on replacements (for the remaining 17%) is expected to be significantly higher than the above figure as the replacement work is increasingly more difficult." (UK_DEFRA 2004)

Further reductions will cost more per unit since the uses that are easy to substitute have been eliminated first and the remaining are most likely to be more difficult to substitute (UNEP POPRC 2011), i.e., as substitution has started where costs were lower, the marginal value of each additional unit elimination is estimated to increase.

However, it is not possible to break down these cost data to the individual alternatives (i.e. digital techniques, telomere-based products, C3 and C4 perfluorinated substances, etc.). Therefore the attribution of costs to the defined scenarios could not be conducted.

Hard metal plating

The cost differences between the above defined scenarios 1 and 2 are depending on, the main cost factors, which are:

- Costs of PFOS compared to the cost of alternative substances;
- The amount of substance needed during use;
- Costs for the transition during substitution (costs of changes to production lines and supporting systems);
- Costs of waste water treatment within production facility and at municipal wastewater treatment plants;
- Possible continuous changes to staff costs;
- Costs related to possible break down of a continuous addition technical feasibility.

According to the literature and some surveys the price for the PFOS products in solution used as mist suppressant for non-decorative hard chrome plating is 13 – 27 € per liter. The price depends on the substance concentration which ranges between 2 - 7% PFOS (Poulsen et al. 2011). Thus some products are cheaper and others are more expensive.

The costs for PFOS products are further connected to the prices of PFOS for manufacturing the basic substance (laboratory chemicals). According to the POPRC document the PFOS laboratory price (UNEP POPRC 2011) amounts to 1122 € per 100g.

Some alternatives may be priced comparably to one another but be more expensive than PFOS derivatives. Some price examples for laboratory chemicals are shown in Table 27. The table shows that C6-fluorochemistry alternatives may often be more expensive than C8-fluorochemistry alternatives, which are subject to a phase-out. In this context it has to be taken into account that from experience the typical prices of bulk materials which are less pure than laboratory chemicals are considerably lower. However this well-known factor relates to all of chemicals listed below.

Table 27: Prices of selected basic polyfluorinated laboratory chemicals (Source: UNEP POPRC 2011)

Chemical	CAS No.	Molecular weight	Price in € per 100 g
Perfluorobutane sulfonyl fluoride (PFBSF)	375-72-4	303.09	136
Perfluorobutane sulfonic acid (PFBS)	59933-66-3	300.10	1,800
Perfluorobutane sulfonyl fluoride (PFBSF)	1763-23-1	500.13	1,122
Perfluorobutane sulfonyl fluoride (PFBSF)	307-35-7	502.12	92
Fluorotelomer 6:2 alcohol	647-42-7	364.10	130
Fluorotelomer 8:2 alcohol	678-39-7	464.12	187

Fluorotelomer 10:2 alcohol	865-86-1	564.14	1,440
Methyl nonafluorobutyl ether	163702-07-6	250.06	745

An important comparable factor when regarding substitution remains the amounts of alternative substance required for use in comparison to PFOS based products. The fact that PFOS can be substituted with a cheaper substance still cannot reflect on the cost of substitution so long as it is not clarified if the use of a substitute requires the same amount. In this sense, if a small amount of PFOS is substituted for a large amount of a substitute, the costs may be comparable or even higher. However, no specific information concerning costs of alternatives was available to clarify how original costs compared to those of substitution. Only Poulsen et al. 2011 stated a general price of around 16 € per litre for alternative, however it is not specified what alternative is meant, in what quantity or what its possible fields of application are.

Some suppliers stated that their alternative was cheaper to use compared to PFOS and others stated that their alternative was more expensive to use compared to PFOS (Poulsen et al. 2012). It is assumed that this regards the actual cost of the PFOS or substitutes as a raw material and it is thus unclear what further costs would be relevant in these cases for adapting production lines or other equipment to the use of alternatives, nor is it clear how costs of end-products would be affected.

Regarding the cost differences between scenario 1 and scenario 3, data from other sources can be used: RPA stated that the total costs for changing the process (alternative technology - e.g. improved ventilation with extraction) are in support of PFOS-free based mist suppressants, and have been calculated to be € 3400 per year in each production unit, in which case the investment period is 15 years. Unfortunately these data are not reported in relation neither to the bath volume nor to the amount of PFOS and related substances being substituted. Assuming a few hundred units in the EU the total cost would be one or two million Euros (UK_DEFRA 2004). This sum reflects annual costs for such substitution, if it were to be implemented throughout the EU. Further breakdown of costs was not available.

3.5.5 Results and limitations

As a result of evaluating the available information, it has become clear that abatement costs must regard not only the specific application of a substance but also the possible scenarios in which it may be addressed in future regulation

The present data has been based solely on the literature. Some additional information on a more general level has been provided through communication with stakeholders, however this did not include exact costs, and as such, verification of such data was not performed. Though a questionnaire for collecting cost information was distributed, the various stakeholders did not provide cost information. It was therefore not possible to compile a more detailed data base.

With the transfer from film to digital technology there have been increasing reports that analogue photography and film industries are struggling to survive on the market. Against this background, experts from this sector were not able to provide further cost information.

One of the manufacturers of the photographic industry explained the inability to provide further detailed data with the current uncertainty of the industry:

"in consultation with our members involved, it is unfortunately due to the reasons already outlined in our phone conversation, not possible to give input to the ex-post analysis of PFOS.

According to the I&P Europe - Imaging and Printing Association e.V., while new techniques are being developed where PFOS-related substances are not being used, there are no alternatives available that would allow for comprehensive substitution of PFOS in critical applications.

PFOS and its compounds are only used in a few film applications in low concentrations. As the photographic business is moving towards digital imaging, the applicable films are decreasing quite substantially in the European market and with that the amount of PFOS used. Photographic companies are strongly reorganizing and therefore the current interest to contribute to your survey is very limited."

Correspondence with stakeholders revealed that currently not much information is available in addition to the information in the existing literature. Therefore, in relation to the alternatives to PFOS, its salts and PFOSF, the revised guidance document developed by the POPs Review Committee on alternatives for PFOS and its derivatives was a major source of information. Information from the guidance document was used in elaborating the current study.

3.5.6 Conclusions Concerning PFOS

If PFOS is added to Annex XIV of the REACH regulation it can be expected that a few authorisations for specific uses will be submitted, whereas for the majority of uses substitutes are available. The responses received from various industries indicated that no technically feasible alternatives are available in the following sectors: photo imaging[45], photo mask, semi-conductor, aviation hydraulic fluids. Responses also indicated that in the following sectors some alternatives are available but would have to be gradually phased in: metal plating and fire fighting foam.

The current state of the investigation is insufficient to estimate the magnitude of abatement costs for the investigated sectors of photo imaging industry and non-decorative hard chromium (VI) plating. Based on the low number of received responses it is assumed that the information on PFOS is rather scarce and its compilation would require a significant effort from stakeholders. Without detailed information from stakeholders, it is anticipated that further elaboration will be difficult if at all possible. However, it seems that at present such cooperation cannot be counted on, as for the most part, the remaining applications of PFOS relate to areas where applicable substitutes could not be found, creating a disincentive for stakeholders to provide additional information if this requires a substantial effort on their side:

In the context of the REACH regulation, a SEA is not mandatory when applying for an authorisation of use, if the applicant can demonstrate that there are no possible alternatives to the substance in question. Furthermore, the remaining areas of application in which PFOS is still

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45 In the photo imaging industry, some phase out has occurred through the development of digital techniques, eliminating many of the applications for which PFOS was in use, this is however not due to substitutes but rather that the industry has developed in an alternative direction.

in use, are excluded at present from other relevant regulations and conventions (i.e., use is allowed as limitations do not apply to excluded uses of PFOS), and stakeholders are not required at present to further establish the necessity of PFOS in such applications. Therefore it is assumed that stakeholders lack an incentive to provide further support for estimating (ex-ante) or compiling (ex-post)substitution costs, as this would require a significant effort on their behalf, for which further use (i.e. to their benefit) is not expected.

Another concern rising from the investigation of PFOS substitution alternatives concerns the characteristics of substitutes. As has often been the case in surface product applications, sometimes, PFOS can be substituted with compounds that are similar in form and hence also in the technical qualities that they provide for the product. In this sense, substitutes are also fluorinated and though it can be assumed that they do not have the same impacts on the environment as PFOS, it cannot be ruled out that they have certain impacts that could be similar to those of PFOS in character as well as in severity. Such substitution therefore does not ensure that similarities do not exist in terms of environmental behaviour and persistence of the substance and its degraded forms, resulting in an incomplete abatement. Only a detailed analysis of possible impacts would prove that such substitution is indeed beneficial from an environmental and health point of view and not just an economical way to comply with PFOS substance restrictions.

It thus needs to be emphasized that when PFOS is substituted for an alternative fluorinated substance, it still cannot be automatically assumed that environmental impacts have been prevented in full. This could have higher significance in cases where a small amount of PFOS is substituted for a large amount of fluorinated substitute, as it is sometimes possible that overall impacts remain comparable, since as mentioned above, most fluorinated substances are associated with some degree of risk; many of them remain persistent in the environment – either directly or through degraded compounds. In such cases, costs resulting of such substitution would only represent partial costs of abatement.

3.6 Lead containing stabilisers in polyvinyl chloride

Polyvinyl chloride (PVC) on its own is brittle and unstable and cannot be used without a range of additives. Due to its instability stabilisers based on heavy metals (lead, cadmium, tin, barium and zinc) have been added to prevent the decomposition of PVC during the processing and make it resistant to light, weathering and heat.

Lead compounds have the longest history as stabilisers for PVC because of their cost effectivity. They have excellent stabilising effects, especially for PVC products with a long service life and required to endure long hours of fabrication and heating. For an optimal performance in specific applications different lead compounds are used with different lead contents:

Table 28: Types of lead-based stabilisers and respective lead contents

Type of stabiliser	Lead content
Tetra-basic lead sulphate	85%
Tri-basic lead sulphate	82%
Di-basic lead sulphate	82%
Di-basic lead phthalate	75%
Di-basic lead stearate	51%
Normal lead stearate	28%

Source: http://www.pvc.org/en/p/lead-stabilisers

Due to concerns about possible adverse effects of lead on health and the environment, in 2000 the stabiliser producers committed to phasing-out lead-based stabilisers completely by the end of 2015 in the EU-15, with an interim target of a 50% reduction by 2010. The commitment of 100% phase-out by the end of 2015 was extended to the EU-27 in 2007.

The phase-out of lead-based stabilisers was initiated as one integral component within the framework of the Voluntary Commitment of the European PVC industry, Vinyl 2010, a 10-year programme to move the PVC industry towards sustainability by minimising the environmental impact of production and promoting responsible use of additives.

It has to be mentioned that this case study (not originally envisaged in the beginning of the project) does not have an immediate REACH context (at least the substitution was not induced by REACH in the beginning), since the development of the phase-out process had its origin long before REACH became manifest. However, due to the favourable circumstances and the interest of the industry association to communicate their success story, this example showed expedient and presentable results for abatement costs.

Since 2000, the progressive substitution of lead-based stabilisers has been monitored through sales statistics provided by the members of ESPA. Overall, lead-based stabiliser consumption has decreased by 76% in the EU-27. At the same time there is a corresponding increase in the use of calcium based stabilisers, used as an alternative to lead-based stabilisers.

The stabilisers industry, by engaging itself in this substitution process, devoted considerable time and resources to the research and development of alternative stabilisers applicable to the widely used lead-based systems.

The substitution plan required and still requires many efforts from manufacturers of stabilisers and from the downstream customer sectors, to ensure that the target will be achieved. Close cooperation between manufacturers and downstream users is essential in this process.

In the context of this project, ESPA has in a first stage submitted a summary concerning the lead-based stabiliser substitution case, presenting the challenges, deadlines, interim volumes and replacement targets.

In addition, the lead stabiliser manufacturers have provided more specific individual input for aggregation, to obtain a representative EU picture of the substitution case. They have been provided with the questionnaire and sent information to ESPA which has aggregated the information provided by member companies.

3.6.1 Analysis of data availability and quality for the total cost model

Data provided by ELSA in the questionnaire have been responding to the cost categories given in the questionnaire design, as far as applicable. As agreed upon with ELSA in advance, the input of the six member companies of ELSA has been consolidated, so that confidentiality of the individual company data is ensured.

Within the general costs of substitution, the categories of both one-time costs and running costs per year have been described in qualitative terms. For one-time costs, for confidentiality reasons cost figures for the categories “materials and services”, “labour”, “maintenance”, and “investment-related costs” have been aggregated in one sum. Running costs have been specified and estimated separately for the two relevant categories “materials and services” and “investment-related costs”.

In addition, two cost categories of adopting substitute for use in production processes for other actors along the value chain have been identified and described qualitatively. For downstream users, one category of increased costs has been identified and estimated as percentage cost increase.

In addition, the quantitative amounts in tonnes from the years 2000 to 2012 both for lead-based and for calcium-based stabilisers have been shown graphically for the EU-15, as well as for the EU-27 as existing from 2007 to 2012. This shows the gradual successful process of substitution during these years. Thus, an attribution of costs to quantities already substituted and further to be substituted up to year 2015 can be done.

For this case study, therefore, data provided can be regarded as commendable, and they allow a consistent relationship of costs and referring quantities.

However, ELSA has emphasised a few context-related characteristics and thus limitations of the data that have to be kept in mind when interpreting the results:

- The Voluntary Commitment on the lead phase-out (VinylPlus) officially started in the year 2000. However the lead stabilisers producers started evaluating and producing alternative stabilisers before 2000. The investments engaged before 2000 are not reflected in the ELSA submission which covers the period 2000 - 2012.
- The substitution of lead-based stabilisers by calcium-based stabilisers can be considered to be an easy substitution case, though not a straight “drop-in”.

- The costs given in the questionnaire are based on inputs from ELSA members when available and/or extrapolated. Therefore the margin of error may be significant.
- It has to be noted that the costs for substitution were not constant per ton of formulated stabilizer, but costs were higher during the first years and decreasing over time. Therefore the numbers presented in the questionnaire are an average over the last 12 years.
- These costs have to be considered as minimum costs, as companies did not record precisely all investments made throughout more than a decade.

Seven different lead-based stabilisers have been registered under REACH, to match the needs of the various applications (see Table 29).

Table 29: Lead-based stabilisers registered under REACH and main applications:

Substance name	EC No.	CAS RN	Sector of main application
Pentalead tetraoxide sulphate	235-067-7	12065-90-6	Cables
Trilead dioxide phosphonate	235-252-2	12141-20-7	Window profiles
Tetralead trioxide sulphate (tribasic lead sulphate)	235-380-9	12202-17-4	Window profiles & pipes
Dioxobis(stearato)trilead	235-702-8	12578-12-0	Window profiles & pipes
Sulfurous acid, lead salt, dibasic	263-467-1	62229-08-7	Window profiles
[Phthalato(2-)]dioxotrilead	273-688-5	69011-06-9	Cables
Fatty acids, C16-18, lead salts	292-966-7	91031-62-8	Window profiles & pipes

Source: ELSA Questionnaire, Appendix 3

A more detailed split by different applications was not undertaken. The CMR properties (carcinogenic, mutagenic or toxic for reproduction) of all these molecules are only due to the element Pb and not to the other moiety of the molecules.

The European Lead Stabilisers Association (ELSA) consists of six member companies and is itself a sub-group of the European Stabiliser Producers Association (ESPA), which represents 12 companies which produce more than 98% of the PVC stabilisers (lead and other types of stabilisers) sold in Europe. ESPA members in total employ approximately 5,000 people.

3.6.2 Identification of substance and non-substance alternatives and end-of-pipe technologies

As the only substance substitute calcium-based stabilisers have been specified by ELSA. This substance has been characterised as being not a full “drop in” substitute, but nevertheless as a substitution case that proved itself relatively easy.

Within the EU-15 and EU-27 also sales of tin stabilisers and liquid stabilisers have been reported by VinylPlus. Sales of tin stabilisers within the EU-15 plus Norway, Switzerland and Turkey slightly decreased from 14,666 tons in 2000 to 11,436 tons in 2012. There was a similar decrease for liquid stabilisers – Ba/Zn or Ca/Zn from 16,709 tons in 2000 to 14,032 tons in 2012.[46] Differences in development between EU-15 and EU-27 data are minor and show the same tendency.

Due to the following reasons tin stabilisers and liquid stabilisers (Ba/Zn or Ca/Zn) have not been regarded as relevant alternatives to lead-based stabilisers:[47]

- Tin stabilisers: Although tin stabilisers are used for pipes in some other areas of the world they have never been popular in the EU for this application. Furthermore tin mercaptides can create a discoloration problem both during parallel processing with lead-stabilised ones and then, while recycled together. When lead substitution started in 2000, the use of Ca-based stabilisers had already been started in the EU. Therefore the pipes producers just carried on and substituted lead by calcium-based stabilisers.
- Liquid stabilisers are principally used for a wide range of flexible (=plasticized) PVC applications, calendered sheets and flooring, but not in pipes and typical applications for lead-based stabilisers.

Non-substance alternatives are not existent. The simple reason is that polyvinyl chloride (PVC) cannot be processed without stabilisers; otherwise it decomposes.

3.6.3 Compilation of feasible and constructive scenarios

As already explained, Vinyl 2010 and VinylPlus have been voluntary programme packages anticipating potential future political developments and restrictions but not being a reaction to an actual restriction. Therefore, the real-life scenario describes a gradual substitution and phase-out of lead-based stabilisators over a period from 2000 that is scheduled to find its completion by the year 2015. The development over time is shown in **Fehler! Verweisquelle onnte nicht gefunden werden.**.

46 See http://www.vinylplus.eu/en_GB/sustainable-development/measuring-our-progress/2012-progress/Challenge-3-2013

47 E-mail communication with the Communications Counsellor Plastic Additives, The European Chemical Industry Council (Cefic), Brussels (Belgium), 18 September 2013.

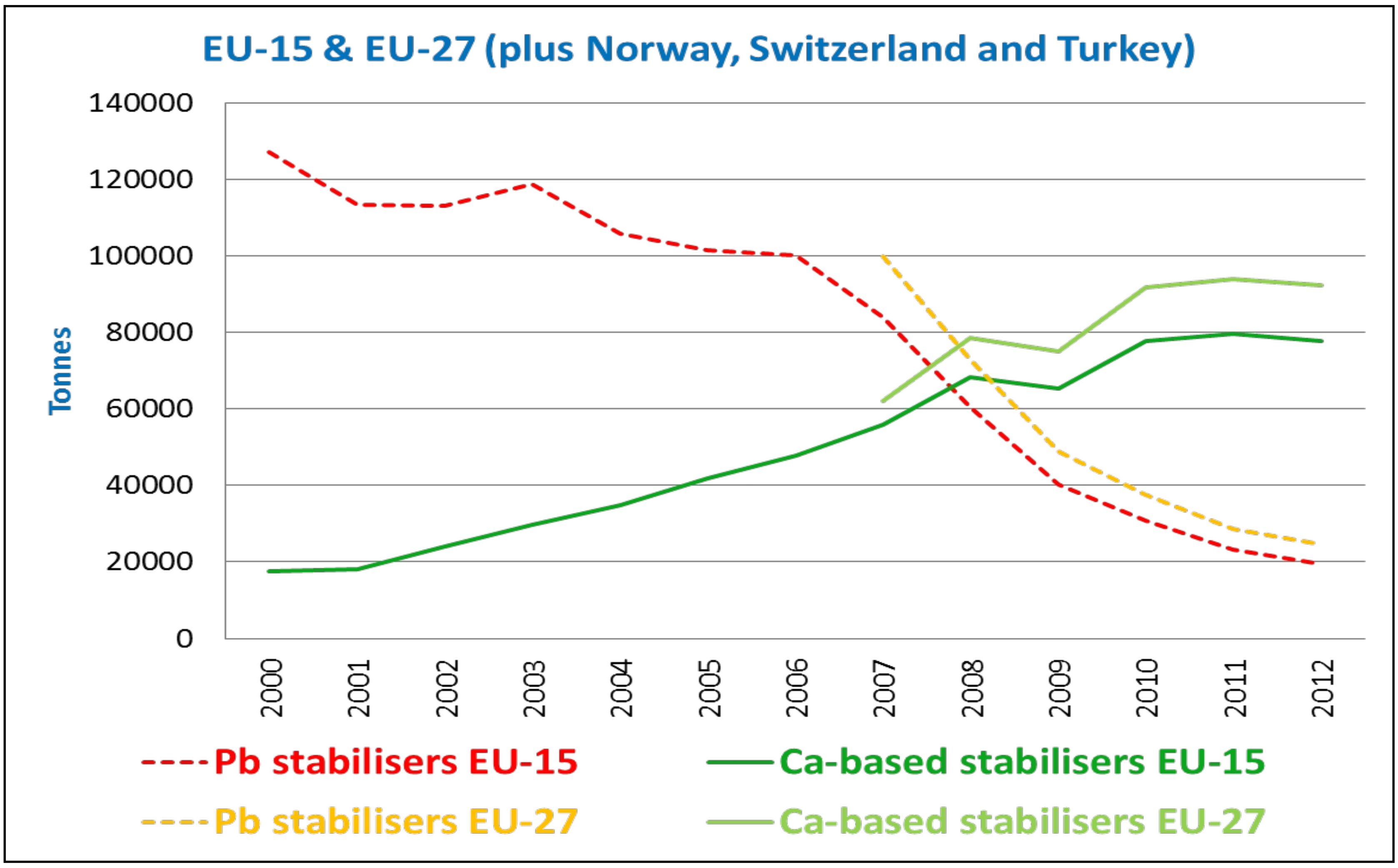

Figure 3: Lead-based stabilisers replacement trend and calcium-based stabilisers growth

Source: ELSA, internal document provided by E-Mail communication

By the end of 2012, globally already 80%of lead-based stabilisers have been phased out since 2000. The degree of phase-out, however, differs from one application to another. This is shown in Table 30.

Table 30: Phase-out of lead-based stabilisers by applications in the EU-27

Application	Residual share of Pb stabilisers in % to be replaced by the end of 2015
Cables	Totally replaced
Pipes	Between 5% and 30% *)
Window profiles	Between 10% and 20% *)
Other applications	Almost totally replaced

*) The percentage of stabilisers needed in a window formulation is higher than for pipes. Hence, the average substitution rate cannot directly be calculated from the substitution rates of each application. Source: ELSA Questionnaire, Appendix 4

The hypothetical baseline scenario describes a status quo without any change of the production and use of lead-based stabilisers. The questionnaire asks for changes compared to the original production costs, both one-time and running (annual) costs. This means, cost increases to be expected within the baseline scenario can be neglected, or it is assumed that they are implicitly taken into respect in the estimations of incremental costs due to a substitution.

3.6.4 Estimation and ranking of abatement costs

Changes in costs due to the substitutions, i.e. abatement costs of a use of lead-based stabilisers, have been identified and estimated both for the producers (the ELSA members aggregated) and for further actors along the value chain. For producers, the general statements of cost changes are shown in Table 31:

Table 31: Costs of substitution for producers of stabilisers (one-time and annual): Components, tendencies and sum

Cost category	One-time costs		Running costs (per year)	
Materials and services	Supply chain costs increase	+	Lower blood level monitoring, gloves, respiratory protection equipment, air and water emission control 1 mio. €/year	-
Labour (including operating, supervisory maintenance and training)	Training costs for employees working in the new production plants dedicated to Ca-based stabilisers	+		O
Energy	No significant difference	O	No significant difference	O
Maintenance, sampling, monitoring, marketing, general overhead	Additional testing, sampling, monitoring	+		O
Investment-related costs		+	Higher research and development costs	+
Sum of all costs	**52 mio.€ (minimum; not all investments have been recorded)**	**+**	**7.2 mio. €/year (average over past 12 years, decreasing over time)**	**+**

Source: ELSA Questionnaire feedback, Section 4.1.

ELSA also confirmed that there has been no significant change in the total annual quantity of applications produced with either lead-based stabilisers or calcium-based stabilisers, that means a substitution was in principle possible for all relevant uses. Therefore, there have been no remarkable changes in revenues compared to the original production set up in cases where substitutes were adopted for use in processes.

According to the statements of ELSA on costs of substitution the following effect has to be highlighted: In theory of abatement costs, it is always efficient to start abatement cost measures with lowest (or if existent, highest negative) marginal incremental costs and go on stepwise to further substitution options with higher abatement costs. This occurs at least in a “perfect world”, i.e. in the ideal (and theoretical) case of a decision under perfect information. This means, the abatement cost curve is known to all decision-makers.

In the real case it is stated that abatement costs (both one-time and running costs) have been in tendency highest at the beginning, i.e. for the first years of substitution, and then decreased over the 12 years of this substitution process. This is not contradictory to the original case but simply shows a learning and experience curve during a typical product life cycle. On the other hand, the succession and speed of substitution within different applications has been different, as can be seen from Table 30. Thus, substitution of Pb-based stabilisers in cables and other applications has been completed at an earlier point of time than for pipes and window profiles.

In total ELSA has estimated substitution costs for the replacement of lead-based stabilisers by calcium-based stabilisers over the years from 2000 to 2012. This leads to the following relationship between monetary values of costs and reductions in use:

- Total additional costs in 2000 – 2012: 129 Mio. €
- Total amount of calcium-based stabilisers over this period: 710 kt
- (Average) cost of substitution per kg of stabiliser used: 0.18 €/kg.

Marginal costs of substitution are not available, due to the high aggregation level provided (over different uses as well as companies) and the overlap of the learning and experience effect over time with the typical sequence of substitution.

In addition, costs of adopting the substitute for use in production processes for other actors along the value chain have been identified and estimated. Two different actor groups are mentioned that, according to the support service and experience with their customers, have to cope with additional efforts and costs. These are the conversion sector in particular (comprising the extrusion of pipes and profiles and moulding) and in general the downstream users.

During discussions of ELSA with converters producing water pipes stabilized with calcium-based stabilizers, it was brought to their attention that the switch from lead-based stabilizers caused some additional recurrent costs. Indeed with the new formulations, there is more downtime to clean the machines for working properly, which translated in an additional cost of 2% or even more. As this is likely the case for any extrusion process, it is assumed that a similar situation is applicable for other applications like window profiles, etc.[48]

However, similar to the production, there is also a reduction in costs due to safety measures for employees; especially blood lead monitoring is no longer required.

Table 32: Substitution costs of adopting substitute for use in production processes for other actors along the value chain

Actors along the value chain	Cost increases		Cost decreases	
Converters (extrusion of pipes & profiles, moulding)	Costs for reformulation and testing	+	Lower costs for safety at work (no blood lead monitoring)	-
Downstream users (all applications)	Cost increase (≥ 2%) on the finished article due to higher machine downtime for cleaning	+	none	o

Source: ELSA Questionnaire feedback, Section 5.

48 E-mail communication with the Communications Counsellor Plastic Additives, The European Chemical Industry Council (Cefic), Brussels (Belgium), 12 June 2013.

According to the statements of ELSA, there will be in the end no implications for the consumers, e.g. with regard to the lifetime of the end products as well as the effectiveness, quality, availability and choice of the end product. It is also assumed there will be no significant effect on the market price. It might be assumed that the additional costs of the stabilisator as one component of PVC will only constitute a minor share of the value added to the final product.

3.6.5 Results and limitations

In this case, we have to rely that the estimations provided by ELSA are realistic and not strategically biased. This also applies to the estimation of costs for other actors along the value chain (converters – extrusion of pipes and profiles; moulding) and downstream users. It can be assumed that the ELSA member companies have been in intensive contact and consultation with their customers and understand their adaptation requirements and challenges during this process.

The information provided by the questionnaires are partly also reflected in publicly available information in the VinylPlus reports or website, but some particular information has been provided in more detail and directly estimated by member companies and aggregated in order to guarantee confidentiality among the competitors.

Thus, results are available on a qualitative and partly also on a quantitative, aggregated basis. What was able to estimate are both the total costs over the past twelve years and average costs per kg of stabiliser replaced.

It has to be kept in mind that efforts of substitution have already started before the year 2000 but were not systematically monitored in this early phase before the official start of the proclaimed programme Vinyl 2010. Also the cost of substitution (0.18 €/kg of stabiliser used) is an average over all applications, over all ELSA member companies and over time; it comprises several different components, some of them one-time, some of them permanent.

3.6.6 Conclusions concerning lead-based and calcium-based stabilisers

Although the process of substitution has not been completed, from the developments shown in the progress reports of the VinylPlus programme, it can be forecast that the goal of a total substitution in the EU-27 by the year 2015 has a good chance of realisation. This goal is not standing alone but is only integral part of one of the five main focuses or “challenges” named “Sustainable Additives” within VinylPlus. The total programme is both internally accompanied by an independent Monitoring Committee, with the majority of members being external stakeholders (representatives from the European Parliament, the European Commission, trade unions and consumer organisations), and subject to external audits and verification by independent third parties.[49] Therefore, it can be assumed that interim monitoring results can be taken as serious and valid.

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[49] According to the information on the Vinyl Plus website: http://www.vinylplus.eu/en_GB/about-vinylplus

4 Summary of results, discussion and conclusions

4.1 Discussion on ex-ante analysis versus ex-post analysis of abatement costs – Overlap of ongoing processes of substitution?

As already mentioned in Chapter 2.2, it was originally envisaged in the project that an ex-ante analysis and an ex-post analysis of abatement costs shall be performed in parallel based on different sample cases. In contrast to “ex-ante substances”, substances suitable for an ex-post analysis should be in a more advanced stage towards the end of the phase-out cycle, i.e. they already have been substituted in several applications, which provides the possibility to compare estimates of costs before and after substitution has taken place. While substitution may be induced by the REACH process or an anticipation of its consequences by industry, it can also be initiated by other legal framework or technological developments in general.

However, from the case studies two main lessons have been learned:

- A strict classification of ex-ante and ex-post cases does not adequately reflect the facts of ongoing dynamic substitution processes. This can be elucidated by the following examples:
    - In cases where substances have become relevant or interesting for an ex-ante analysis within the context of REACH (as this was the motivation of this study), some companies will have already anticipated potential future regulation and developed alternatives in order to gain a competitive advantage at an early stage and a pioneering role in the case of future regulation. Other competitors are still behind in the development of their portfolio. This means that ex-post results are already available in parallel to ex-ante results. For example, this became obvious during the analysis of the group of lead chromate pigments (Chapter 3.1) and the finding that, apart from one company, most former producers and importers have decided not to submit an application for authorisation for further uses of these pigments.
    - Also, in other cases in some categories or applications substances can be regarded as ex-post and in others still as ex-ante examples. This was in particular the case for PFOS (Chapter 3.5). In this case it also became obvious that it is often not possible to use substitutes from one area of application in another one, nor to conclude from experience in one application as to the costs of substitution in another.
- For a quantitative comparison of ex-ante and ex-post estimates of abatement costs, empirical data that was made available in the course of this project has been insufficient. Firstly, in some cases this is due to the dynamics of the ongoing REACH processes and the interdependency of the competitors leading industry to keep data on substitution costs confidential. Secondly, subsequent to the successful substitution of a substance being achieved in the past, data and estimates of substitution costs of these historic examples are often no longer available and retrievable from the respective companies.

4.2 Methodological considerations and challenges of assessing abatement costs

Most of the case studies under examination were characterised by a set of typical methodological challenges. This became obvious by the case studies of this report but also by a study on the same topic regarding different substances, commissioned by ECHA (ECHA 2013c). An intensive discussion at the workshop on the assessment of abatement costs of chemicals (see Annex 6.2), merging the interim experience of this study and the one commissioned by ECHA, revealed that a few focal points can be clustered with regard to insights on problems observed. They are outlined in the following.

Some general significant gaps were identified between the theory of abatement costs in environmental economics and the practice of estimating abatement costs in the specific applications of chemical substances. Several reasons have been identified and can be grouped. These are summarised below:

- **Static and dynamic environment of abatement costs, especially in the context of chemicals under REACH**

  In the theory of abatement costs, the optimisation problem, although it may consist of a complex system of parameters and restrictions, is (under idealised conditions) of a static nature, assuming information is complete, e.g. with a set of known and constant (although often estimated) technological data, such as efficiency ratios, CO_2 emission factors and other relevant parameters. Even if a dynamic aspect of a time horizon is described, the development follows clearly defined (e.g. constant annual) rates of growth.

  In the case studies under examination, an additional aspect concerns the dynamics of the market, which have already been explicitly addressed in the tender specifications of this study. The dynamics are determined both by an

  - endogenous technical progress, making the production or the use of chemicals more efficient over time, and
  - exogenous constraints due to political regulation, in this case mainly due to the REACH regulation. This comprises specific induced technical progress, especially the development of entrepreneurial substitution and evasion strategies.

  This means that abatement costs usually are use-and context-specific and may change over time.

- **General aspects and methodology**

  - REACH and other applications of the concept of abatement costs

    The concept of abatement costs has proven to be rather broad and complex, as it does not only comprise end-of-pipe technologies. In principle, this does not only apply to chemicals but also e.g. to the abatement of greenhouse gases. An aspect that makes it different when applying this concept within REACH compared to other applications is that the data basis available is much more limited, and there are no or only few standard data sets (such as databases for emission factors) to refer to. Furthermore, there is a crucial difference between emission reduction by using end-of-pipe technologies and by substituting a chemical substance, as chemicals provide a certain technical function that has to be replaced, which has to be taken into account when assessing abatement costs.

Abatement cost data of a chemical can be very useful when assessing different risk management options (RMO) for that substance, i.e. before the actual decision for a certain RMO (e.g. authorisation, restriction), and what its target or scope should be, has been made. However, in this stage authorities often do not have any cost information.

- The context and complexity of substitution

  The definition of abatement costs also depends on the context of substitution, e.g. the alternatives that have to be considered.

  In general, it turned out to be difficult to develop the methodology of assessing abatement costs of chemicals further while producing data for current restriction or authorisation cases at the same time, as the sample cases selected were not always suitable for this particular purpose. However, the information gathered was still useful in the preparation of restriction reports or for applications for authorisation.

- Costs versus prices

  There are two principal approaches to approximate costs: from the producer's perspective (which was mainly applied in the questionnaires developed in this study), or via market prices.

  It is assumed that in the case of a competitive market with an inelastic demand curve the price of the end product should reflect the change of the costs. In the ideal case, a rough estimation can be made by comparing bottom-up data based on producers/manufacturers with price changes, in order to verify the results. However, under monopolistic or oligopolistic market conditions market prices are less meaningful to assess costs. Furthermore, prices vary both over time and between suppliers, so that its value to assess costs is limited.

- **Assessing abatement costs and the use of cost curves**

  - Private versus social abatement costs

    Discussions on costs also comprised the aspect in how far the costs to entrepreneurs correspond to the costs to society as a whole. In this regard, it needs to be clarified that social and private abatement cost curves may differ significantly, for instance because firms face higher discount rates or prices which do not reflect opportunity costs. Moreover, there is often incomplete knowledge of private costs and benefits, i.e. costs to one company may lead to benefits for another company, which are often not known. This means that abatement options which are best for society will not necessarily be best for firms, so they will not be adopted. REACH gives incentives to look for new approaches to adequately include these costs. However, the cost data that are usually available are the compliance costs, which mainly reflect private costs.

- Amounts used versus amounts emitted - reference parameter to determine abatement cost

  When discussing abatement costs, the abatement cost curve of a chemical may vary significantly, depending on whether the focus is on "amounts used" or on "amounts emitted". Cost curves for remaining consumption can be almost linear since marginal costs for reduction of consumption may not vary much for different applications, but marginal costs, in €/t emission reduction, may show higher variability between uses. From the emission reduction perspective, it is "cheaper" and more efficient to start substituting a substance first in those processes with high emissions. This is logical, as uses with high emissions pose higher risks to human health and the environment than closed-loop applications with no or negligible leakage. Furthermore, abatement technologies will often have an advantage of scales property, further supporting that treatment in areas where larger emission volumes are of relevance is often "easier to swallow" for industry.

- The treatment of "sunk costs"

  The issue of how to deal with costs resulting from equipment or capital becoming redundant because of an authorisation/restriction process (referred to in microeconomic theory as "sunk costs") has been raised again and again in this context, with no clear-cut final answer how to deal with them. In general the question of sunk costs concerns a distributional impact and is therefore not a matter of efficiency. If capital cannot be sold, then it implies that its opportunity cost is zero – and hence the capital is sunk. Even if costs are sunk, they clearly still represent a distributional cost for firms - a write-down of the book value of their assets. Depending on market structure, the firm may or may not be able to pass this cost on to its customers by increasing the price of its product. In the latter case these costs result in lower profit and income for the producers. In the former case prices to consumers are higher than they should be. If this is the case, this value should be reflected in the assessment of abatement costs.

  In cases of doubt, it is recommended to explain the incidence of sunk costs in the context of a restriction or non-use scenario, as well as their consequences for particular market participants, if relevant, within the category "wider economic impacts" that is specified in the ECHA Guidance on the preparation of socio-economic analysis (ECHA 2008; ECHA 2011).

In addition to these methodological issues, practical problems of data gaps and data gathering (which were also identified as a fundamental outcome of this project) will be addressed and analysed in detail in the following Chapter 4.3.

4.3 Aspects and strategies of information and data gathering

In theory, a complete and consistent scenario analysis and cost framework with (potentially) relevant categories is available. This becomes obvious in "classical" applications of estimating abatement costs, such as abatement costs for greenhouse gas emissions, acidification or eutrophication. In the latter example, shadow prices for impacts on ecosystems from emissions of SO_2, NO_X and NH_3 have been estimated, expressed per ton of pollutant emitted when critical loads are exceeded due to emissions.[50] For this purpose, all data necessary could be gathered from revealed preferences in policy negotiations, applying the standard-price method.

For the application of this approach in the context of the REACH Regulation, however, the main problem in practice is how to obtain cost data and close information gaps. An external consultant is usually not in the position to gain insights into internal market and price information. Reasons for this are summarised below:

- Non-cooperative behaviour of companies and potential explanations

  It is obvious that, without a legal obligation or other kind of pressure to disclose data and information, companies sometimes lack motivation to cooperate in such a study. This also arises when examining the information available from REACH authorisation or restriction processes (e.g. Annex XV dossiers or applications for authorisation), which is often based on only one or few producers or importers (see in particular Chapter 3.1 on lead chromate pigments.).

  Some well comprehensible explanations for this behaviour have been identified:

  1. Lack of time and resources for voluntary additional work, especially:
     - for small and medium sized enterprises (SMEs) which are already struggling to cope with their current duties in the context of REACH
     - in cases of manufacturers experiencing a degree of phase-out and financial set-back, tied to the elimination of substances through new technologies
     - In cases where supplying socio-economic information to support authorisations is not mandatory, the preference is usually to avoid such analysis, as it is quite time consuming.
  2. In an oligopolistic market structure, decisions are highly dependent on those of the competitors. In case of a forthcoming authorisation, manufacturers may assume a passive strategy instead of a proactive one, and better react in an optimal manner to forthcoming decisions of their competitors or authorities.
  3. A critical factor is confidentiality of data: Manufacturers are usually reluctant to provide information concerning planned actions, for fear of losing competitive advantages and disclosing commercial intentions.

50 See European Commission 2004 (NewExt), Chapter 5: Valuation of environmental impacts based on preferences revealed in political negotiations and public referenda. http://www.ier.uni-stuttgart.de/forschung/projektwebsites/newext/newext_final.pdf

4. Companies have different interests and aims than public authorities, e.g. with regard to REACH procedures. Therefore, they may suspect that information disclosed to an authority may be used for decisions to the disadvantage of the company.
5. (Ideal) data requirements are too detailed for companies to answer or would require the collection and further processing of information from different sources within the company.
6. Accessing archived data which supported past decisions of substitution or elimination is not an easy task as such information is often no longer available. Furthermore, the former decision-makers and contemporary witnesses who might be able to provide information of the past have often retired, left the company or changed their professional capacity.

While screening cost information from REACH processes, it becomes obvious that relevant facts and figures are often based on only a single or just a few producers or importers that disclosed information. In this sense, it is difficult to estimate in which cases such data adequately reflects trends concerning a whole industry and in which it is more case specific.

Assessing a completed historical process would have proved in this case easier than focusing on a currently ongoing one with yet uncertain outcome: Although there was hope in the beginning that enterprises take the “chance to test the guidance to the companies on the preparation of socio-economic analysis as part of an application for authorisation and thereby to (obtain) practical experience with SEA, identify problems in preparing an SEA and develop solutions to these problems” (as was appealed in the letter of support), most companies were rather reluctant worrying that any voluntary information disclosure might be to their disadvantage.

When asked for information in particular, the following more differentiated experiences with behaviour of companies were shared over most of the case studies:

In some cases it became obvious that companies do not disclose whether they have archived any experiences on replaced substances.

Further attention should be given to the approach of various management levels in a company to the sharing of data. Sometimes companies were positive as to sharing experience and cost information when approached on the lower hierarchy, e.g. the production site basis. However later involvement of the higher management hierarchy halted initiatives before they could bear fruit in terms of data and information.

It can be understood that at different levels other interests of the firm may be of concern. However, a key to obtaining data may often be in understanding who to approach and how certain levels may assist in creating an understanding in higher hierarchies in light of possible benefits that may arise from cooperation. At present, cooperation in terms of data sharing is not trivial, and it seems that industry in general has yet to be persuaded of the benefits that could arise, e.g. information to identify uses to be exempted from a restriction. This cooperation is supposed to ameliorate when deadlines advance and common applications for authorisations are going to be prepared.

- Market expertise essential

  It is evident that the experience and comprehension of the relevant market has an essential impact on the quality and reliability of the results. If market experience and relevant contacts are not sufficiently available, or if contacts identified have proven to be inaccessible (this might be the case when the market is very specialised, regionally specified and concentrated), further information gathering proves very difficult. In cases of multiple uses differing from each other in terms of the possibilities for substitution, it is not always straightforward to conclude from partial information of a few uses to other uses for which information is not available. The PFOS example demonstrated this problem (see Chapter 3.5). Without a wider data set including all relevant applications, in such cases it could be difficult to draw clear conclusions on the overall costs, even if some manufacturers supply information, as costs may vary widely. In this context, abatement costs may differ between cases where one chemical can be replaced with another (drop-in) and cases demanding the subsequent adaptation of manufacturing facilities and processes in order to substitute.

- Strategies for information and data gathering

  Furthermore, the practical question arose how easy it is to gather prices of the substances in question. In most of the case studies, prices were gathered from the internet (e.g. databases for products on offer, such as alibaba.com), and by asking companies for price effects. Even without looking into the reliability aspects of various virtual databases, this approach towards obtaining price information usually results in a relatively wide price range where the same substance could cost e.g. twice as much in one database than in another. In such databases, information is not always easily accessible. This makes it difficult to gain an understanding of whether such differences are based on technical properties (concentration, quality, mixture, etc.) or more on the market forces in action. Therefore, it may be recommended to interpret such information with caution as indicative information that should further be affirmed where possible. Such factors may serve as objects for sensitivity testing in later stages of cost compilation.

  In some cases it has proven helpful to include relevant associations and contact them in advance. Although they usually do not know all the quantitative details of the market, they can recommend appropriate member companies to collaborate in a study (see Chapter 3.6. on lead containing stabilisers in polyvinyl chloride where this strategy proved successful). On the other hand, associations work as a filter, so it is unclear what kind of information is passed on to the companies, and where associations compile information. Therefore, it may be difficult to understand in retrospect how significant the data provided by the industry or of single manufacturers is. Another area that needs to be considered is how cases where associations represent members with conflicting interests are reflected in the compiled data.

It is helpful to first identify a responsible contact person and then send the questionnaire. Likewise, a comprehensive questionnaire is likely to be perceived as “a mountain of work” and deter further cooperation or reference to further contacts. For future studies of this kind, it may be useful to present a short list of areas of relevance, and then initiate a meeting in which the interviewer (in person or per phone) can relay the requested detail of questions to the response of interviewees.

4.4 Overall conclusions and recommendations

In general, the conclusions and recommendations are consistent with those of a parallel study conducted on behalf of ECHA (ECHA 2013c). The first intermediate insights and results were discussed during a common workshop (documented and analysed in Section 6.2 of the Annex).

In the compilation of abatement costs, results often depend on the complexity of uses and the comparability of substitutes. It is rarely possible to use substitutes from one area of application in another, since the requirements profiles of the uses differ significantly. Therefore, a deduction from single cases or special uses to others can be complicated and challenging.

The following steps may assist in the first stages of an estimation of abatement costs, in demarcating the areas which shall require more effort in terms of modelling, in the light of lack of information, uniqueness of application etc.:

1. Map the status of substitutes implemented in various areas of application
2. Estimate what areas have the highest potential concerning access to actual abatement costs (or access to existing estimations of future costs)
3. Estimate what areas have the highest potential for substitution – i.e. large volume of application + substitutes are available + abatement involves applying a single substitute/technology and should therefore be more straightforward to breakdown in terms of cost factors, indirect impacts etc.
4. In such areas, what is the potential for estimating such costs based on information from other fields of application? Which similarities exist, e.g. same substance formulation, similar technology etc.?

In this project, the first stage of the selection process of the case studies was to identify substances under on-going discussion in the context of REACH, that could in some cases be perceived retrospectively (ex-post), as well as substances still under discussion, that could be subject of an ex-ante review. Therefore the possible practical application (e.g. a restriction proposal) has been considered in determining the scope of the analysis. Against this background the focus on methodological questions with regard to abatement costs is not purely academic.

In some cases abatement cost curves can be a useful and quick decision tool. A well-grounded cost curve facilitates to define the way that a restriction dossier can be drawn up. The shape of a cost curve can help identifying the scope of potential derogations. However, it should be kept in mind that in cases where lack of cost information is an issue, cost curves may at best represent an incomplete picture.

A successful strategy for data gathering depends on the specific industry sector concerned; there is no universal approach that can be recommended.

In addition to a sound assessment of the financial costs, some knowledge of other effects of substituting a substance that are not directly reflected in market costs is needed, to clarify the context of results, e.g. when alternatives do not provide exactly the same functionalities or properties as the original chemical. Information should allow understanding of how this may influence the market and consumers. If this knowledge does not exist, quantitative monetary costs may not reflect the real economic cost of substitution. A change in functional value of alternatives due to different or additional characteristics, in addition to price effects, is difficult to observe, measure and estimate in order to be included in the quantitative cost assessment. In such cases, this qualitative cost information in addition to quantitative cost data could be important to put the benefits for human health and the environment into perspective.

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6 Annexes

6.1 Questionnaires

Depending on the addressees, questionnaires were sent to producers/importers and downstream users in English and/or German language. The following examples document different targeted versions used for the case studies:

- Lead chromate, lead sulfochromate yellow and lead chromate molybdate sulphate red (questionnaire for ex-ante analysis, to producers/importers)
- Lead chromate, lead sulfochromate yellow and lead chromate molybdate sulphate red, combined with cadmium containing pigments (combined questionnaire, to downstream users)
- Perfluorooctane sulfonate (PFOS) (questionnaire for ex-post analysis, to downstream users)

Questionnaire to the project "Socio-Economic Analysis (SEA) in authorisation and restriction under REACH:
Assessment of abatement costs of chemicals – ex ante and ex post"

Project on behalf of the German Federal Environmental Agency (Umweltbundesamt), July 2012

We would be very grateful if you could send the questionnaire back until **17 August 2012** to alexander.gressmann@bipro.de. Please state if you prefer to provide some information only under terms of confidentiality.

In case any questions arise please contact Alexander Gressmann (+49-89-189790 50)

If you have any related information in form of reports, brochures, etc. we would be very grateful if you could forward them to us together with the questionnaire.

Please also attach further text for explanation if needed.

Data will be used only for the purpose of the project and will be treated as confidential. Data protection will be ensured; only aggregated data will be published.

1. General information

Company/Organisation:	
Branch:	
Contact person:	
Telephone number:	
E-mail:	
Core competence:	

2. Production of lead containing pigments

Do you produce (at a production site within the EU-27) lead containing pigments for the EU-27 market?	no	■	yes	■	Amount In kg (2011):	

Which types of lead containing pigments do you produce for the EU-27 market?					
Lead chromate (CAS No. 7758-97-6) (LC):		no	■	yes	■
Lead sulfochromate yellow (C.I. Pigment Yellow 34) (CAS No. 1344-37-2) (PY34):		no	■	yes	■
Lead chromate molybdate sulphate red (C.I. Pigment Red 104) (CAS No. 12656-85-8) (PR104):		no	■	yes	■
Other:		no	■	yes	■

Comment:	

3. Import of lead containing pigments

Do you import lead containing pigments for the EU-27 market from outside the EU?	no	■	yes	■	Amount In kg (2011):	

Which types of lead containing pigments do you import for the EU-27 market?					
Lead chromate (CAS No. 7758-97-6) (LC):		no	■	yes	■
Lead sulfochromate yellow (C.I. Pigment Yellow 34) (CAS No. 1344-37-2) (PY34):		no	■	yes	■
Lead chromate molybdate sulphate red (C.I. Pigment Red 104) (CAS No. 12656-85-8) (PR104):		no	■	yes	■
Other:		no	■	yes	■
Comment:					

4. Production/import of substitution options for lead containing pigments

Do you already produce or import other substances or use other technologies which can serve as substitution alternatives for the substances mentioned, e.g. in case regulation for mentioned substances comes into force?	yes	■	no	■
Which types of alternative substances do you produce or import for the EU market?				
Which types of non-substance (e.g. technological) alternatives do you use for the EU market?				

Further comments:	

5. Estimation of the costs of substitution processes for lead containing pigments

Can you provide an estimation in which cost categories there may be changes compared to present costs, in case substitutes are adopted for use in existing production processes?	No	■	Yes	■	For which of the substances listed above?	

Cost category	Yes	No	€ Please specify all costs with a "+" sign and benefits (cost reductions) with a "-" sign.	
			One-time costs (e.g. training)	Running costs (per year)
Materials and services (including auxiliary costs, transportation/storage/ distribution/packaging and labelling/ safety at work/replacement part/ environmental service costs)	■	■		

Labour (including operating labour, supervisory maintenance staff and training costs)	■	■		
Energy (including electricity, natural gas, petroleum products, coal or other solid fuel costs)	■	■		
Maintenance (including sampling testing and monitoring, insurance premium, marketing, licence, emergency provision and other general overhead costs)	■	■		
Investment-related costs (including R&D, performance testing, property rights, equipment, modification, site and operations and decommissioning costs) 1)	■	■		
Other cost components (please specify in the comment field):	■	■		
Comments (e.g. sub-categories):				

1) In order to determine the costs resulting from investments correctly, we would like to ask you to sum up figures such as depreciation, weighted average cost of capital (WACC) and similar items. Depreciation of existing equipment that is no longer necessary would therefore belong to "one-time costs", while annual depreciation of new equipment is part of the "running costs".

Can you give an estimation whether there may be changes in revenues compared to the present set up in case of substitutes are adopted for use in processes?	Yes	No	€ (please specify: total / per year / per kg) additional costs: + / benefits: -
Total annual produced quantity (in units, e.g. tonnes)	■	■	
Change in total price of production	■	■	
Change per unit	■	■	
Change in revenue: quantities sold	■	■	
Change in revenue: sales	■	■	
Change in revenue: other (including production efficiency, downtime, interest on working capital, residual value of equipment)	■	■	
Any other risks, impacts and external effects (also non-monetary) related to production that need to be considered?	■	■	
Comment:			

6. <u>Estimation of the costs of adopting substitute for use in production processes for other actors along the value chain</u>

Please provide an estimation for which other actors besides your company there may be changes compared to the present situation in case substitutes are used in processes?	Type of cost or benefit that actors are likely to have	For which of the substances listed above? (In case of more than one please indicate: LC/PY34/PR104 where applicable)

User/actor category	Yes	No	€ (please specify: total / per year / per kg) additional costs: + / benefits: -
Downstream users (please specify in the comment field) (including aspects such as: - lifetime of the product - changes to market price - Changes to annual maintenance and repair costs - Impacts on effectiveness of the product (this could lead to use of more or less of a substance) - impacts on availability and choice Please feel free to explain effects in a detailed annex if adequate. Where detailed information does not exist cost may be aggregated in a total cost rubric.	■	■	
Consumers (including lifetime of the end product, market price, annual maintenance and repair costs, effectiveness of the end product, availability and choice)	■	■	
Other economic actors (please specify in the comment field – e.g. health risks, environmental risks, damage to crops, etc.)	■	■	
Other economic actors (further)	■	■	
Comments:			

7. <u>Relevant company data</u>

Please provide data about your company as far as possible:

Company size:		
- Turnover		
- Personnel		
Location of production		
Which share (in %) of total turnover of your company is accounted to the substances specified above?		

Thank you very much in advance for filling in the questionnaire!

An additional questionnaire was sent to selected users of pigments in the two main categories of current uses (English language only). This questionnaire has been combined with asking for the use of cadmium in pigments (Chapter 3.4), since this use has very similar characteristics – both cases represent pigments in the yellow/orange/red spectrum:

Due to the experience with previous questionnaires that have proved too detailed, the option was offered to take the questionnaire rather as a guideline and respond in an informal way.

Questionnaire to the project "Socio-Economic Analysis (SEA) in authorisation and restriction under REACH:
Assessment of abatement costs of chemicals – ex ante and ex post"

Project on behalf of the German Federal Environmental Agency (Umweltbundesamt), September 2013

We would be very grateful if you could send the questionnaire back until **31 October 2013** to **alexander.gressmann@bipro.de**. Please state if you prefer to provide some information only under terms of confidentiality.

In case any questions arise please contact Alexander Gressmann (+49-89-189790 50)

If you have any related information in form of reports, brochures, etc. we would be very grateful if you could forward them to us together with the questionnaire.

Please also attach further text for explanation if needed.

Data will be used only for the purpose of the project and will be treated as confidential. Data protection will be ensured; only aggregated data will be published.

1. General information

Company/Organisation:	
Branch:	
Contact person:	
Telephone number:	
E-mail:	
Core competence:	

2. Use of lead containing pigments

Do you use (at a production site within the EU-27) lead containing pigments or cadmium containing pigments for the EU-27 market?	no	■	yes	■	Amount In kg (2011):	

Which types of lead containing pigments do you use or have you used?						
Lead chromate (CAS No. 7758-97-6) (LC):	never	■	no more	■	yes	■
Lead sulfochromate yellow (C.I. Pigment Yellow 34) (CAS No. 1344-37-2) (PY34):	never	■	no more	■	yes	■
Lead chromate molybdate sulphate red (C.I. Pigment Red 104) (CAS No. 12656-85-8) (PR104):	never	■	no more	■	yes	■

Cadmium sulphoselenide red (CAS No. 58339-34-7)	never	■	no more	■	yes	■
Cadmium mercury sulphide red (CAS No. 1345-09-1)	never	■	no more	■	yes	■
Cadmium sulphoselenide orange (CAS No. 12656-57-4)	never	■	no more	■	yes	■
Cadmium sulphide yellow (CAS No. 1306-23-6)	never	■	no more	■	yes	■
Cadmium zinc sulphide yellow (CAS No. 8048-07-5)	never	■	no more	■	yes	■
Other:		No more ■ yes ■				
Comment:						

3. <u>Estimation of the costs of adopting substitute for use in production processes (e.g. price increases in the product but also e.g. due to process changes)</u>

Please provide an estimation whether there may be or have been changes compared to the previous situation in case substitutes are used in processes?	Type of cost or benefit that users are likely to have	For which of the substances listed above? (In case of more than one please indicate: e.g. LC/PY34/PR104 where applicable)

User/actor category	Yes	No	€ (please specify: total / per year / per kg) additional costs: + / benefits: -
For your company as a user, have there been changes in aspects such as (please specify in the comment field): - lifetime of the product - changes to market price - Changes to annual maintenance and repair costs - Impacts on effectiveness of the product (this could lead to use of more or less of a substance) - impacts on availability and choice Please feel free to explain effects in a detailed annex if adequate.	■	■	

Where detailed information does not exist cost may be aggregated in a total cost rubric.			
Consumers (including lifetime of the end product, market price, annual maintenance and repair costs, effectiveness of the end product, availability and choice)	■	■	
Other economic actors (please specify in the comment field – e.g. health risks, environmental risks, damage to crops, etc.)	■	■	
Other economic actors (further)	■	■	
Comments:			

4. Relevant company data

Please provide data about your company as far as possible:

Company size:	
- Turnover	
- Personnel	
Location of production	
Which share (in %) of total turnover of your company is accounted to the substances specified above?	

Thank you very much in advance for filling in the questionnaire!

Questionnaire to the project "Socio-Economic Analysis (SEA) for assessment of abatement costs of chemicals – ex ante and ex post"

Project on behalf of the German Federal Environmental Agency (Umweltbundesamt), November 2012

We would be very grateful if you could send the questionnaire back until **05 Dezember 2012** to **m.blepp@oeko.de**.

In case any questions arise please contact Markus Blepp (+49-761-45295 237)

If you have any related information in form of reports, brochures, etc. we would be very grateful if you could forward them to us together with the questionnaire.

Please also attach further text for explanation if needed.

Data will be used only for the purpose of the project and will be treated as confidential. Data protection will be ensured; only aggregated data will be published. Please state if data may be delivered to project contractor or is solely to be used by project team.

The German Federal Environmental agency (Umweltbundesamt) has commissioned BiPRO GMBH, Öko-Institut e.V. and the Georg August University of Göttingen with a project to analyse the abatement costs of chemical emissions, on the basis of selected case studies. The focus of the project shall lay on assessing the costs of substituting certain substances with alternative substances and/or production techniques. The objective of this project is to broaden the data base concerning abatement cost of dangerous substances and their emissions and to gain more detailed insight into the influential parameters for the cost of substitution processes. Case studies shall be reviewed both in cases of substances currently in use that are soon to be substituted (ex-ante) as well as in cases of substances that have already been substituted (ex-post).

This questionnaire has been prepared **for ex-post analysis of Perfluorooctane Sulfonate (PFOS)**, in which ideally a comparison of expected costs prior to substitution and actual costs incurred through the process of substitution may be compared. However if the available data is not sufficient to allow the comparison, we kindly ask you to specify if the provided data refers to expected or actual cost information.

1. General information

Company/Organisation:	
Branch:	
Contact person:	

Function / responsibility	
Telephone number:	
E-mail:	

2. Production of Perfluorooctane Sulfonate (PFOS)

Did your company use PFOS for applications produced for the EU-27 market, in the past?	Yes	■	No	■	Amount in kg (please state for last year of full capacity production_____):	
Has PFOS use been phased out completely?	Yes	■	No	■	To what degree (in relation to your production) has PFOS use been phased out?	%
Please state if there are applications for which PFOS is still used (please specify target market, i.e. EU or non EU)					What proportion of your production do these applications represent?	%
Please provide information concerning the amount of PFOS used per annum during the years of substance phase out					_____	
					_____	
					_____	
					_____	
					_____	
					_____	
					_____	
					_____	
					_____	

Did you use various compositions of Perfluorooctane Sulfonate (PFOS) in applications manufactured for the EU-27 market (various mixtures of isomers or various concentration solutions)? Please provide information which composition was in use for which application and what proportion of production they represent	
Type:	Proportion of total production
	%
	%
	%
	%
	%
Comment:	

3. Are possible substitutes for Perfluorooctane Sulfonate (PFOS) available?

Which types of alternative substances are used for the EU market? (Please state whether substances are "drop in" [1] concerning production processes)				
Do you substitute PFOS with other (or additional) substances? Please refer to section 3.2	yes	■	no	■
Which types of non-substance (e.g. technological) alternatives do you use for the EU market? If so please refer to section 3.3				

1) If a substitute is drop-in, replacing the original substance or technology with it, will not require complete redesign of the product or of the production line and hence will not entail significant costs that would be associated with redesign

3.1. Use of other substitutes for Perfluorooctane Sulfonate (PFOS)

What other substances are used to substitute PFOS? Please specify				
In what applications are substitute substances named above used? Please specify				
Are substitute substances named above "drop in" substances for all PFOS applications? Please specify applications for which the substance was not "drop in"	yes	■	no	■

3.2. Use of non-substance alternatives (technologies) for TCEP substitution

What non-substance alternatives are used to substitute PFOS use? Please specify				
In what applications are non-substitute alternatives named above applied? Please specify				
Please specify (per application) if the use of the non-substitute alternatives named above required a change to production lines?	yes	■	no	■

4. Actual cost information for the substitution processes for Perfluorooctane Sulfonate (PFOS)

Can you provide cost information for categories in which there were changes compared to the original production costs, in cases where substitutes have been adopted for use in existing production processes?	Yes	■	No	■	For which of the substances listed above?	

- Please provide general production costs in section 4.1. If more than one substitute is in use and costs can be associated to specific substitutes, please provide in separate tables.
- Please provide specific costs for substitution with substance in section 4.2 (and 4.3, if applicable).
- Please provide costs for substitution with technology in section 4.4.

4.1. General Costs of Substitution

Please indicate if costs refer to all substitution costs or concern only costs of the shift towards use of a certain substituting substance (If so, which?)				
Cost category –	Yes	No	€ (Please specify all costs with a "+" sign and benefits (cost reductions) with a "-" sign.	
			One-time costs (e.g. training)	Running costs (per year)
Materials and services (including auxiliary costs, transportation/storage/ distribution/packaging and labelling/ safety at work/replacement part/ environmental service costs)	■	■		
Labour (including operating labour, supervisory maintenance staff and training costs)	■	■		
Energy (including electricity, natural gas, petroleum products, coal or other solid fuel costs)	■	■		
Maintenance (including sampling testing and monitoring, insurance premium, marketing, licence, emergency provision and other general overhead costs)	■	■		
Investment-related costs (including R&D, performance testing, property rights, equipment, modification, site and operations and decommissioning costs) [2]	■	■		
Other cost components (please specify in the comment field):	■	■		
Comments (e.g. sub-categories):				

[2] In order to determine the costs resulting from investments correctly, we would like to ask you to sum up figures such as depreciation, weighted average cost of capital (WACC) and similar items. Depreciation of existing equipment that is no longer necessary would therefore belong to "one-time costs", while annual depreciation of new equipment is part of the "running costs".

4.2. Costs of substitution with substance (main substance used)

Can you provide information whether there were changes in revenues compared to the original production set up in cases where substitutes were adopted for use in processes?	Yes	No	€ (please specify: total / per year / per kg) additional costs: + / benefits: -
Total annual quantity of applications produced with PFOS during last full capacity production year (in units, e.g. tonnes)	■	■	
Total cost of the production of PFOS applications (last full capacity production year)	■	■	
In cases where substitution is incomplete: **Total annual quantity of applications produced with PFOS at present (in units, e.g. tonnes)**			

Total annual cost of the current production of PFOS applications	■	■	
Total annual quantity of production of substitute substance applications in representative full capacity production year (in units, e.g. tonnes)	■	■	
Total cost of producing substitute substance applications			
Change in total cost of production (considering depreciation)	■	■	
Change per unit	■	■	
Change in revenue: quantities sold	■	■	
Change in revenue: sales	■	■	
Change in revenue: other (including production efficiency, downtime, interest on working capital, residual value of equipment)	■	■	
Any other risks, impacts and external effects (also non-monetary) related to production that need to be considered?	■	■	
Comment:			

4.3. <u>Costs of substitution with substance (secondary substance used ____________)</u>

Can you provide information whether there were changes in revenues compared to the original production set up in cases where substitutes were adopted for use in processes?	Yes	No	€ (please specify: total / per year / per kg) additional costs: + / benefits: -
Total annual quantity of applications produced with PFOS during last full capacity production year (in units, e.g. tonnes)	■	■	
Total cost of the production of PFOS applications (last full capacity production year)	■	■	
Total annual quantity of applications produced with PFOS at present (in units, e.g. tonnes) In cases where substitution is incomplete			
Total annual cost of the current production of PFOS applications	■	■	
Total annual quantity of production of substitute substance applications in representative full capacity production year (in units, e.g. tonnes)	■	■	
Total cost of producing substitute substance applications			
Change in total cost of production (considering depreciation)	■	■	
Change per unit	■	■	
Change in revenue: quantities sold	■	■	
Change in revenue: sales	■	■	
Change in revenue: other (including production	■	■	

efficiency, downtime, interest on working capital, residual value of equipment)			
Any other risks, impacts and external effects (also non-monetary) related to production that need to be considered?	■	■	
Comment:			

4.4. <u>Costs of substitution with non-substance (replacement technology used)</u>

Can you provide information whether there were changes in revenues compared to the original production set up in cases where substitutes were adopted for use in processes?	Yes	No	€ (please specify: total / per year / per kg) additional costs: + / benefits: -
Total annual quantity of applications produced with PFOS during last full capacity production year (in units, e.g. tonnes)	■	■	
Total cost of the production of PFOS applications (last full capacity production year)	■	■	
Total annual quantity of applications produced with PFOS at present (in units, e.g. tonnes) In cases where substitution is incomplete			
Total annual cost of the current production of PFOS applications	■	■	
Total annual quantity of production of substitute substance applications in representative full capacity production year (in units, e.g. tonnes)	■	■	
Total cost of producing substitute substance applications			
Change in total cost of production (considering depreciation)	■	■	
Change per unit	■	■	
Change in revenue: quantities sold	■	■	
Change in revenue: sales	■	■	
Change in revenue: other (including production efficiency, downtime, interest on working capital, residual value of equipment)	■	■	
Any other risks, impacts and external effects (also non-monetary) related to production that need to be considered?	■	■	
Comment:			

5. <u>Estimation of costs of adopting substitute for use in production processes for other actors along the value chain</u>
   <u>When more than one substitute is in use, please specify, where applicable, if costs refer to a specific substitute</u>

Please provide an estimation for which other actors besides your company there may have been changes compared to the past situation in case substitutes have been applied in processes?	Type of cost or benefit that actors are likely to have	For which of the substances listed above? (In case of more than one please indicate where applicable)

User/actor category	Yes	No	€ (please specify: total / per year / per kg) additional costs: + / benefits: -
Downstream users (please specify in the comment field) (including aspects such as: - lifetime of the product - changes to market price - Changes to annual maintenance and repair costs - Impacts on effectiveness of the product (this could lead to use of more or less of a substance) - impacts on availability and choice Please feel free to explain effects in a detailed annex if adequate.	■	■	
Consumers (including lifetime of the end product, market price, annual maintenance and repair costs, effectiveness of the end product, availability and choice)	■	■	
Other economic actors (please specify in the comment field – e.g. health risks, environmental risks, damage to crops, etc.)	■	■	
Other economic actors (further)	■	■	
Comments:			

6. Relevant data for comparison of expected and actual costs

Can you provide information for comparing expected costs (estimated prior to substitution) and actual costs (identified during or after the process of substitution and attributed to substitution) concerning the below mentioned categories? (Please provide only for categories where actual costs differ from expected costs by more than 5%)	Yes	■	No	■

When more than one substitute is in use, please specify where applicable if costs refer to a specific substitute

Did actual costs differ from expected costs by more than 5%? Cost categories	Yes	No	€ Please specify all costs with a "+" sign and benefits (cost reductions) with a "-" sign. Please specify if costs are onetime costs or annual running costs	
			Expected costs	Actual costs
Materials and services (including auxiliary costs, transportation/storage/ distribution/packaging and labelling/ safety at work/replacement part/ environmental service costs)	■	■		
Labour (including operating labour, supervisory maintenance staff and training costs)	■	■		
Energy (including electricity, natural gas, petroleum products, coal or other solid fuel costs)	■	■		
Maintenance (including sampling testing and monitoring, insurance premium, marketing, licence, emergency provision and other general overhead costs)	■	■		
Investment-related costs (including R&D, performance testing, property rights, equipment, modification, site and operations and decommissioning costs) [3)]	■	■		
Other cost components (please specify in the comment field):	■	■		
Comments (e.g. sub-categories):				

[3)] In order to determine the costs resulting from investments correctly, we would like to ask you to sum up figures such as depreciation, weighted average cost of capital (WACC) and similar items. Depreciation of existing equipment that is no longer necessary would therefore belong to "one-time costs", while annual depreciation of new equipment is part of the "running costs".

7. Relevant company data

Please provide data about your company as far as possible:

Company size:	
- Turnover	
- Personnel	
Location of production	

Which share (in %) of total turnover of your company is accounted to the substances specified above?	

Thank you very much in advance for filling in the questionnaire!

6.2 Expert workshop on the assessment of abatement costs of chemicals – Final Report

Workshop on the assessment of abatement costs of chemicals

15 March 2013, 10.00 – 17.00 h

Location: Öko-Institut e.V.,
Schicklerstrasse 5-7, 10179 Berlin

Umwelt Bundes Amt
For our Environment

1. Background

Emission reduction is a central goal in the risk management of chemicals. The cost-effectiveness of measures to reduce emissions plays an important role to inform decision-making on the options for risk management.

Building on previous work by the UK Environment Agency and ECHA, the German Federal Environmental Agency (Umweltbundesamt) has commissioned a research project in order to analyse, on the basis of selected case studies, abatement costs of chemical emissions, in particular with regard to restrictions and authorisations under REACH. The contractor is a project team consisting of BiPRO GmbH, Munich (project leader), Öko-Institut e.V., Freiburg and Georg August University of Göttingen, Chair of Production and Logistics.

Compared to other environmental topics (e.g. climate protection), in chemicals regulation abatement costs of hazardous substances and their emissions have hardly been analysed in-depth up to now. Therefore, the objective of the project is to broaden the database on this topic and to gain more detailed insights into the influential parameters for the costs of substitution processes. The focus of the project work is on the costs of using alternative substances or techniques (i.e. other processes as well as products).

As sample cases substances have been selected that are currently in use (ex-ante analysis) as well as substances that have already been substituted in selected uses (ex-post analysis). Accordingly, six different case studies for substances or substance groups and their respective applications have been examined:

- Lead chromate, lead sulfochromate yellow and lead chromate molybdate sulphate red: pigments for coloration of plastics and in coatings/paints/varnishes
- Tris(2-chloroethyl)phosphate (TCEP) and tris(chloropropyl) phosphate (TCPP): flame-retardant plasticizer, regarded in this study mainly concerning its uses in the construction industry
- Azo dyes in tattoo inks
- Cadmium: use in brazing alloys and for brazing fillers, in jewellery and in polyvinyl chloride

- Perfluorooctane sulfonate (PFOS): regarded in this study mainly concerning its uses in the photographic industry and in the metal plating industry
- Lead: use in stabilizers in polyvinyl chloride

2. Workshop objectives

In the workshop it was the main objective to review the results of recent work carried out on the assessment of abatement costs of chemicals. Based on these results, the second goal was to discuss the possibilities to use abatement cost data under REACH and the potential and limitations to develop cost curves.

3. Overview of presentations[51]

3.1. Welcome and introduction (Karen Thiele, UBA)

Abatement costs are defined as (marginal or total) costs associated with reducing or avoiding emissions of a pollutant and gathered by the comparison of baseline and reduction scenarios. They are commonly used in environmental economics such as the evaluation of air pollution and climate policies. The transfer of the concept of abatement costs to chemicals control, for example in the assessment of risk management options within REACH, has first been tested in a pilot study commissioned by the UK Environment Agency, and was the topic of a workshop at ECHA in 2010. In order to test the usefulness of this application, the two projects that will be presented in this workshop have been commissioned in 2011, one by ECHA and another one by the German UBA, focussing on different sample cases.

3.2. Presentation of results of abatement cost project of UBA + discussion (Alexander Gressmann, BiPRO GmbH; Yifaat Baron, Öko-Institut e.V.; Lars-Peter Lauven, University of Göttingen)

The overall concept of the project and the approach, analytical framework as well as the potentially relevant cost categories of the total cost model were explained. Overall, six substances or substance groups with their relevant uses were selected, three of them for an ex-ante (i.e. before substitution) and three for an ex-post (i.e. after substitution) perspective of abatement costs. The preliminary results of these case studies were presented as well as the particular difficulties in data gathering. A draft summary and conclusions as well as methodological issues and challenges to tackle were addressed.

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[51] The slides of the different presentations will be made publicly available on a corresponding website.

3.3. Presentation of results of abatement cost project of ECHA + discussion (Kalle Kivelä, ECHA)

The six case studies were chosen by ECHA already for the tender description, based on their relevance for REACH, with the objective to improve capability and understanding in assessing costs. For each of these case studies, each with differing complexity and project budget, the context, the main observations as well as the marginal (and in some cases cumulative) cost curves were shown.

The case studies will be published on the ECHA website with a discussion on the findings and observations on the results.

3.4. Experiences on data gathering and quality + discussion (UBA Contractors)

The case study on PFOS was explained in detail in view on experience with data gathering. The main uses of PFOS were explained, referring to the status of use, publicly available information as to relevant applications as well as available information about manufacturers and their willingness to contribute to the gathering of information and data. Three uses were elaborated on: the surface protection industry, the photographic industry, and the metal plating industry. This was done to demonstrate the variety of circumstances that may influence the availability of data and the interests of manufacturers to contribute to data collection efforts. These cases also demonstrated the difficulty in obtaining information from manufacturers and the limitations tied to basing conclusion concerning abatement costs on publicly available information.

3.5. Possibilities and limitations to use abatement costs in REACH (Richard Dubourg, ECHA)

The relationship between the textbook view and the application in this field was sketched, and the conclusions of the 2010 workshop summarised. Initial findings and limitations from the review of the ECHA study were explained. Possible explanations for the limitations can be categorised under the headings: a. limited resources allocated to work; b. narrow scope of uses and alternatives assessed; and, c. unobservable cost drivers. Methodological lessons were summarised. It was suggested that the degree of complexity and scope of the abatement cost study (e.g. number of uses covered) affects the potential for the results of the study to be ‘interesting’ from a policy-making perspective. However, complexity and scope also affect the difficulty, effort and resources needed to collect accurate data. There might be a tradeoff between feasibility and ‘policy interest’. Possible implications for usefulness, value and resource requirements were discussed and some final observations summarised, including challenges and limitations.

4. Summary of the discussion

In the following, the key questions and conclusions that came up during the discussion at the workshop are summarised.

4.1. General aspects / Methodology

Is the concept of abatement costs (well-known for other applications such as climate change or emissions to air) equally applicable to socio-economic analysis under REACH?

What is the crucial difference in the application of abatement costs between a reduction of emissions by end-of-pipe measures and the regulation and ban on chemicals?

What is the context of substitution? Which are the alternatives?

How complex is the decision situation? Are only costs or also added values and performance of chemicals and alternatives affected?

Is there a fundamental difference between the application of abatement costs in a restriction proposal and in an application for authorisation?

Shall abatement costs in the first instance refer to the producer's/user's perspective, i.e. to detailed cost categories and cost elements (such as suggested in the ECHA Guidelines?)

How can market price changes also reflect changes in costs?

How can both approaches be compared for consistency?

- **REACH and further applications of the concept of abatement costs**

The concept of “abatement costs” proved to be rather broad and complex as it does not only comprise end-of-pipe technologies. In principle, this does not only apply to REACH but also e.g. to climate action. However, what makes it different when applying this concept within REACH compared to other applications is that the data basis available is much more scarce, and there are no or only few standard data sets (such as databases for emission factors) to refer to. Furthermore, there is a crucial difference between emission reduction by using end-of-pipe technologies and by substituting a chemical substance, as chemicals provide a certain technical function that has to be replaced, which basically has to be taken into account when assessing abatement costs.

Abatement cost data of a chemical could be very useful when assessing different risk management options (RMO) for that substance, i.e. before the actual decision for a certain

RMO (e.g. Authorisation, Restriction ...), and what its target/scope should be, has been made. However, in this stage authorities usually do not have any cost information.

- **The context and complexity of substitution**

The definition of abatement costs also depends on the context of substitution, e.g. what are the alternatives to be considered.

In general, it turned out to be difficult to develop the methodology of assessing abatement costs of chemicals further while producing data for current restriction/authorisation cases at the same time, as the sample cases selected were not always suitable for that purpose. However, the information gathered was still useful in the preparation of restriction reports.

The challenges/observations in developing cost curves of the case studies commissioned by ECHA included: Marginal costs were horizontal because there was only one relevant alternative and marginal costs of abatement did not vary with the quantity of abatement; alternatives do not provide exactly the same functionality, and this was not reflected in the cost curves; some results suggest cost savings for some users; products are mainly used in those parts of Europe where there is no substantiated knowledge of the market.

- **Costs versus prices**

There are two principal approaches to approximate costs: from the producer’s perspective (such as mainly applied in the questionnaires used by the contractor of the study commissioned by UBA), or via market prices.

The practical question was raised how easy it is to get prices. For some of the cases, prices were gained via the internet (e.g. databases such as alibaba.com) and asking companies for price effects.

It is assumed that in the normal case (a competitive market with an inelastic demand curve) the price of the end product should reflect the change of the costs. In the ideal case, a rough estimation can be made by comparing bottom-up data based on producers/manufacturers with price changes in order to verify the results.

An Annex XV dossier for restrictions often contains lots of price information, but prices vary both over time and between suppliers, so that its value to assess costs is limited.

4.2. Assessing abatement costs and the use of cost curves

Are costs to entrepreneurs a good approximation of social costs?

Should abatement costs of chemicals be related to “amounts used” or to “amounts emitted”?

Should “sunk costs” be included in the determination of abatement costs?

- **Private versus social abatement costs**

It was discussed in how far the costs to entrepreneurs correspond to the costs to society as a whole. In this regard, it needs to be clarified that social and private abatement cost curves may differ significantly, for instance because firms face higher discount rates or prices which do not reflect opportunity costs. This means that abatement options which are best for society will not necessarily be best for firms, so they will not get adopted. REACH gives incentives to look for new approaches to adequately include these costs. However, the cost data that is usually available are the compliance costs, which mainly reflect private costs.

- **Amounts used vs amounts emitted - reference parameter to determine abatement cost**

When discussing abatement costs, it must be kept in mind that the abatement cost curve of a chemical is significantly different depending on whether the focus is on “amounts used” versus “amounts emitted”, as shown by the cost curves for the case study of DEHP. Cost curves for remaining consumption can be almost linear since marginal costs for reduction of consumption may not vary much for different applications, but marginal costs in €/t emission reduction may show high variability between uses. This indicates that the shares of emission per tonne of the same substance consumed may highly differ from one use to another. Thus, from the emission point of view, it is cheaper and more efficient to start substituting a substance first in those processes with high emissions.

- **The treatment of “sunk costs”**

The issue how to deal with costs resulting from equipment/capital becoming redundant because of an authorisation/restriction process (referred to as “sunk costs”) was raised. In general the question of sunk costs concerns a distributional impact and not a matter of efficiency. If capital cannot be sold, then it implies that its opportunity cost is zero – and hence the capital is sunk. Even if costs are sunk, they clearly still represent a distributional cost for firms (a write-down of the book value of their assets). Depending on market structure, the firm may or may not be able to pass this cost on to its customers by increasing the price of its product. In the latter case these costs result in lower profit and income for the producers. In the former case prices to consumers are higher than they should be. If this is the case, this value should be reflected in the assessment of abatement costs. The discussion did not come to a final answer on how to do that.

4.3. Information and data gathering

1) In the context of SEA under REACH-, which type of relevant data can be identified (partly beyond cost data in the narrow sense)? (Market share, description of actors on the market, production volumes, quantitative description of use pattern, cost data, emission profiles etc.)

2) For which type of these data is it particularly challenging to get access to?

3) Are there general strategies to proceed with these challenges or is it necessary to develop a strategy case by case?

4) How can unavoidable data gaps be dealt with?

5) Cost-Benefit transfer is often used in other fields, when applying economic analysis such as cost benefit analysis, to make up for information gaps. In what cases can costs or the factors underlining their estimation be transferred from one substance use to another (it is assumed that transfer between substances could only become relevant once experience enabled a wider database for such transfers)?

6) Can conclusions be drawn for the questions mentioned above referring to similarities in data collection and data transfer between certain types of chemicals (chemical families)?

- **Market expertise essential**

There was evidence that the experience and comprehension of the relevant market has an essential impact on the quality and reliability of the results. If market experience, contacts and intelligence is not sufficiently available (e.g. because the market is very specialised and regionally specified and concentrated), consultants have to start from scratch. In cases of multiple uses differing from each other in terms of the possibilities for substitution it is not always straightforward to conclude from partial information of a few uses to other uses for which information is not available (the PFOS example of the study for UBA demonstrated this problem). Without a wide data set including all relevant applications, in such cases it could be difficult to draw clear conclusions on the overall costs, even if some manufacturers supply information as costs may vary widely. In this context, abatement costs may differ between cases where one chemical can be replaced with another and cases demanding the subsequent adaptation of manufacturing facilities.

- **Behaviour of companies when asked for information**

Discussion and information exchange revealed the following experiences:

In some cases it became obvious that companies do not disclose whether they have archived some experiences on replaced substances.

Further attention should be given to the approach of various management levels in a company to the sharing of data. Sometimes companies were positive as to sharing experience and cost information when approached on the lower hierarchy production site basis. However later involvement of the higher hierarchy halted initiatives before they could bear fruit in terms of data and information.

It can be understood that at different levels, other interests of the firm may be of concern, however a key to obtaining data may often be in understanding who to approach and how certain levels may assist in creating an understanding in higher hierarchies as possible benefits that may arise from cooperation. At present, cooperation in terms of data sharing is not trivial, and it seems that industry has yet to be persuaded of benefits that could arise, e.g. provide information to identify uses to be exempted from a restriction.

- **Strategies for information and data gathering**

The practical question was raised how easy it is to get prices of the substances. In most of the case studies, prices were gained via the internet (e.g. databases such as alibaba.com) and by asking companies for price effects. Even without looking into the reliability aspects of various virtual databases, this approach towards obtaining price information usually resulted in a relatively wide price range where the same substance could cost twice as much for the purchaser. In such data bases, information is not always easily accessible, to understand if such differences are based on technical properties (concentration, quality, mixture, etc.) or more on the market forces in action. Therefore it may be recommended to interpret such information with caution as indicative information that should further be affirmed where possible. Such factors may serve as objects for sensitivity testing in later stages of cost compilation.

In some cases it has proved helpful to include relevant associations and contact them in advance. Although they often do not know the quantitative details of the market, they can recommend their member companies to collaborate in a study. On the other hand, associations work as a filter, so it is unclear what information is passed on to the companies, and where associations compile information. Therefore, it may be difficult to understand in retrospect, how significant the data provided by the industry or of single manufacturers is. Another area that needs to be considered is how cases where associations represent members with conflicting interests are reflected in the compiled data.

Problems how to identify the relevant contact persons for gathering information may become obvious even if a market sector seems well organised (apart from the two studies on behalf of the Umweltbundesamt and of ECHA presented at the workshop, experience with another study on cobalt was mentioned).

It is helpful to first identify a responsible contact person and then send the questionnaire. Likewise, a comprehensive questionnaire is likely to be perceived as “a mountain of work” and deter further cooperation or reference to further contacts. It may be useful to present a short list of areas of relevance, and then initiate a meeting in which the interviewer (in person or per phone) can relay the requested detail of questions to the response of interviewees.

5. Conclusions

The context of estimating abatement costs is always a special, concrete interest in a substance. This means it is a question for practical application (e.g. a restriction proposal), which determines the scope of the analysis. Therefore, there should not be an academic focus on methodological questions with regard to abatement costs only.

In practice, abatement cost curves can be a useful and quick decision tool. A well-grounded cost curve facilitates to define the way that a restriction dossier can be drawn up. In a first screening step, it can be checked where to use limited resources in an efficient way. Furthermore, the shape of a cost curve can help identifying the scope of potential derogations. However, several limitations of the analysis – particularly due to lack of cost information - often create an incomplete picture; this comprises the input of resources, a narrow scope of uses and available alternatives, especially in the analysis of risk management options, and unobservable cost drivers.

A successful strategy for data gathering depends on the specific industry sector concerned, there is no universal approach that can be recommended.

In addition to a sound assessment of the financial costs some knowledge of other effects of substituting a substance that are not directly reflected in market process is needed to put the costs into perspective, e.g. when alternatives do not provide exactly the same functionalities or properties as the original chemical. If this knowledge does not exist, quantitative monetary costs may not reflect the real economic cost of substitution. For example, in the case of 1,4-DCB within the study for ECHA, the odour masking and cleaning properties of alternative 1,4-DCB free products have been perceived as different and not of equal value. This change in functional value of alternatives; is difficult to observe, measure and estimate to be included in the quantitative cost assessment. In such cases, this qualitative cost information in addition to quantitative cost data could important to put the benefits for human health and the environment into perspective.

Annexes

A.1 Agenda

10.00 – 10.45 Welcome and introduction to the background

Karen Thiele, UBA

10.45 – 12.00 Presentation of results of abatement cost project of UBA + discussion

Alexander Gressmann, BiPRO GmbH

Yifaat Baron, Markus Blepp, Öko-Institut e.V.
Lars-Peter Lauven, University of Göttingen

12.00 – 13.00 Presentation of results of abatement cost project of ECHA + discussion

Kalle Kivelä, ECHA

13.00 – 14.00 Lunch

14.00 – 14.45 Experiences on data gathering and quality + discussion

UBA Contractors/ECHA

14.45 – 15.30 Possibilities and limitations to use abatement costs in REACH

Richard Dubourg, ECHA

15.30 – 15.45 Coffee break

15.45 – 16.45 Closing discussion and conclusions