WCSR Advice 2017-11

SCIENTIFIC COMMITTEE REACH (WCSR)

ADVICE ON SOCIO-ECONOMIC ASSESSMENT METHODOLOGY

WCSR Advice 2017-11

Members of the Scientific Committee

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Conflict of interest

No member has declared any conflict of interest.

Rapporteur

The Scientific Committee REACH thanks the rapporteur Steven Broekx.

Adoption of the advice

The Scientific Committee REACH advice was adopted by consensus on the meeting of 19/4/2018.

Legal framework of the advice

Cooperation agreement of 17 October 2011 between the Federal State, the Flemish Region, the Walloon Region and the Brussels Capital Region concerning the Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH)

Ministerial decree of 8 July 2014 appointing the members of the Scientific Committee REACH established under Article 3, § 3 of the Cooperation Agreement of 17 October 2011 between the Federal State, the Flemish Region, the Walloon Region and the Brussels Capital

Region concerning the Registration, Evaluation, Authorisation and restriction of Chemicals (REACH)

Ministerial decree of 2 June 2016 on dismissal and appointment of members of the Scientific Committee REACH

Ministerial decree of 5 October 2016 on appointment of members of the Scientific Committee REACH

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The Scientific Committee REACH reserves, at any time, the right to change this advice when new information and data become available after the publication of this version.

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1 Context

The present request for advice pertains to the '**Socio-Economic Assessment**' (SEA) field of expertise, applied to the context of the regulatory actions for the management of hazardous chemicals.

As mandated so based on the REACH regulation, the REACH SEAC (REACH Socio-Economic Committee) issues opinions on the Restriction dossiers and on the requests for Authorisation granting (https://echa.europa.eu/fr/support/socio-economic-analysis-in-reach). We focus the scope of the present request to the activities relating to the SEAC opinions on the **Restriction dossiers**.

REACH Guidances for SEAC are the regulatory basis for the assessment. Nevertheless SEAC activities include the development of the methodology, in particular in relation to the CBA techniques applied to the field of the hazardous chemicals.

The work initiated by the OECD referenced as the **Sacame project** (Socio-economic Analysis of Chemicals by Allowing a better quantification and monetisation of Morbidity and Environmental impacts: http://www.oecd.org/environment/tools-evaluation/sacame.htm) brings useful clarifications, guidances as well as literature references. This joint venture with the OECD task force appears as an important milestone in the view of future development of the SEAC methodology.

The main target for the present request consists in commenting the SACAME-paper: Measuring the economic value of the effects of chemicals on ecological systems and human health (A Alberini, 2/3/2017) OECD doc. http://www.oecd-ilibrary.org/environment/measuring-the-economic-value-of-the-effects-of-chemicals-on-ecological-systems-and-human-health_9dc90f8d-en). Health effects discussed are not limited to morbidity effects and also include mortality effects.

The WCSR deliverable should offer BECA **practical ways for Belgium to contribute to the OECD developments of these methodological subjects in the context of the chemical regulation framework**.

The deliverable to the present request should present the comments in a readily readable manner in the sense these should be drafted to correspond to the structure of the document (down to the level of actual text amendment if adequate and workable), with possible additional information resources provided as annex to the comment main text.

Additionally comments are requested on **two individual cases** published by the OECD in the SACAME project: the **Formaldehyde** dossier focuses on the health costs/benefits; the **Mercury** dossier gives consideration of the MvE +ENV benefits.

2 Specific request for advice and points of concern

In order to allow Belgium to participate (to some extent) to these developments, a number of concepts/ideas (as presented in the next subsection) need to be considered more in depth:

- **Multidisciplinarity** of the experts in the process of development of methodology of CBA techniques (including the representation of all domains of the 'social sciences') aiming at the interdisciplinary assessment of the impact (e.g. to take into account biodiversity impacts, social impacts etc)
- **Adequacy of the CBA techniques** for the decision making
- Ensuring the **diversity of the interviewees** to the whole process of developing SEA methodology (stakeholders and civil society)
- Considerations around the 'Willingness To Pay' (**WTP**) techniques that are used to monetize the value of an environmental/health resource.
- Considerations around the **Cost of Inaction** (in particular in relation to the 'benefit' to take a regulatory action)
- Considerations around the need for Environment and Health impact modelling to assess the benefits on a **scientific basis** (comparatively to appraisal based on WTP (and similar) techniques)

Besides, in order to reflect the society general interests, the following concepts should be taken into consideration:

- The possible bias of the **monetarization of 'non-market goods'** (in reference to "public goods")
- The even **distribution** pattern (among the society actors) of the cost and benefits
- The adequacy to use economic techniques such as the '**Discounting factor**' (applying to long-term (ENV/health) anticipated degradations vs. to short-term economic impacts).

An important remark is that these suggested concepts/ideas are not specifically addressed in the Alberini, 2017 paper. This is why in section 3 a review is included on Alberini, 2017 and in section 4 more general methodological considerations regarding the questions raised above are discussed. Section 5 provides some detailed comments on 2 case studies reviewed in the Sacame project (Formaldehyde and Lead).

3 Review of Alberini, 2017

3.1 Summary of the article

Cost-benefit analyses of proposed regulations require estimating the social benefits of the regulations and comparing them with the social costs of the regulations. The paper reviews and discusses the existing methods to estimate the social benefits of restricting chemicals, more specifically for placing a value on the effects of chemicals on human health and the environment. It surveys both market methods and non-market methods, discussing their advantage and limitations. Market methods are based on market prices. In most cases, however, environmental quality, ecological systems and environmental assets are not bought and sold in regular markets, and so it is necessary to use non-market valuation methods. A summary on the types of benefits and discussed valuation methods is included in the table below.

Table 1: Categories of benefits from regulating chemicals (*Alberini, 2017*)

Type	Type of exposure /effect (population experiencing the effects)	Specific types of benefits	Methods
A. Effects on environment and ecosystems	-Effects on agriculture and other harvestable resources sold on regular markets (producers, consumers) -Effects on resources with recreational use (current and potential users of the resource) -aesthetic values -Changes in non-use values (general population) - Effects on ecosystem functions (parties affected by the ecosystem functions) - Avoided treatment costs	- Consumer and producer surplus change -Consumer welfare, WTP for access and use of the resource -WTP -Value of the ecosystem functions	Market methods -Non-market valuation methods -Cost of alternate supplies of ecosystem functions
B. Human health effects	-Workers exposed in the workplace -General population exposed through product use and/or environment	WTP to avoid or reduce: - Acute illnesses - Non-fatal chronic illness - Mortality effects - Cancer (fatal and non-fatal) - Reproductive effects - Developmental and neurodevelopmental effects	Non-market methods
C. Other worker productivity effects	-Workers exposed in the workplace -General population exposed through product use and/or environment	Loss of productivity at work, even when symptoms are subclinical	Market methods.

Non-market valuation methods discussed in detail include:

- **Revealed preference:**
  - **Travel cost method**: If a substance affects the quality of natural resources that have recreational use (for example, a chemical or pollutant affects fish abundance in bodies of water used by recreational anglers), the travel cost method can be used to estimate the welfare change associated with a change in quality at the affected sites.
  - **Hedonics**: Hedonic pricing methods seek to identify the value markets place on each attribute of a good or a service – including, when possible, its environmental and health effects. The most typical example of hedonics is the impact on real estate value.
- **Stated preference methods**: Methods whereby people are asked how much they would be willing to pay to maintain or improve an environmental feature.

It is also important to note that the **same categories of benefits can be captured through more than one valuation method**, and that deploying more than one method provides an excellent check of the validity of the benefit estimates. One must be careful, however, to avoid double counting.

After presenting the theory and discussing some pros and cons of these valuation methods, specific attention is given on **valuing human health effects and changes in productivity**. Important aspects from an application perspective are the different components that are part of the Willingness to Pay to avoid pollution: (i) marginal lost earnings, (ii) marginal medical expenditures, (iii) the marginal cost of the averting activity, and (iv) the disutility of illness. Reference is made to the US EPA cost of illness handbook with cost-of-illness valuation results for a variety of health endpoint linked with pollution (air pollution and otherwise) (*US EPA, 2007*) and the European *ExternE project (Friedrich and Bickel, 2005)*, where the Impact-Pathway approach was applied to value the external costs of Energy (and air pollution in general). Important remark is that these studies only focus on lost earnings and medical expenditures (first two categories) and provide a lower bound for the true WTP to avoid the illness, and as such they understate the true costs of environmental damage. Some references where the full WTP and cost of illness approaches are compared, confirm that the full WTP is two to four times larger than the cost of illness alone. The only way to capture the full WTP to avoid illness is to conduct stated-preference studies, i.e. surveys where individuals are asked to report their WTP to reduce chemical pollution or avoid the illness associated with exposure. Case study valuation results are presented for different end points such as productivity losses, low birth weights, reproductive effects, mortality in general (value of statistical life) and cancer.

An **example case** demonstrates how net benefits are estimated. The case specifically concerns **US national emissions standards for hazardous air pollutants** and covers fossil-fuel fired power plants, and industrial-commercial-institutional and small industrial-commercial-institutional steam generating units. The rule is expected to reduce emissions of hazardous air pollutants, including mercury (Hg), from the electric power industry. The majority of the benefits is however linked to reduced premature mortality risks associated with exposure to air pollution (PM2.5). Besides monetized benefits also non-monetized benefits are mentioned in the final CBA. Different types of discount rates are applied as a sensitivity analysis.

It is concluded in general that the **human health benefits are likely to account for the majority of the benefits** of regulating chemicals, and that there are many **unresolved issues and uncertainties** in the valuation of mortality risks, gains and losses in remaining expected lifetime, and cancer. Nevertheless, the public is often prepared to pay to reduce health or ecological risks even when they are highly uncertain. There is ample evidence of this from a variety of settings. This report's interpretation of the existing research about ambiguity aversion in the context of health risks is that it is unlikely that uncertainty aversion (the fact that people do not like uncertainty) has a major effect on the willingness to pay to avoid or reduce these risks, and on the associated benefit-cost analyses.

3.2 Advice - General comments

The paper provides a comprehensive and balanced overview of valuation techniques, its pros and cons, and some examples on studies that applied these techniques for estimating the benefits of restricting the use of chemicals. The paper is prepared by a well-known academic expert in the field of environmental economics, econometrics and specifically stated and revealed preference valuation techniques.

However, the document has some major shortcomings mainly related to the structure, readability, relevance for chemicals and links to other SACAME papers (Chiu, 2017; Navrud, 2017).

Structure: During the introduction, it would help to describe the target audience and provide some context on why this document was written. The structure and linkages between chapters are not always clear. A more detailed outline in the introduction would help. Especially the link between section 2 and section 3 is difficult to make.

Readability: The document provides a fairly theoretical discussion of valuation techniques in section 2 and a very large number of equations which makes it less accessible to the non-expert (if this is the target audience). Also for an expert, these equations are only useful once they start applying the methodology. Should this be the purpose, more information and specific guidance is needed anyhow to be of added value. Instead when to use and not to use which type of methodology is not explicitly mentioned.

Relevance for chemicals: A lot of references are included on the valuation of different health end points, which is interesting to get an overview of all the concepts and the state of the art in health related valuation studies. No examples are given on other benefits such as the effects on the environment and ecosystems. It is not clear whether this is because of the scope or because the limited amount of examples. The document also misses reflections based on previous studies applied on chemicals. References included mostly do not relate to chemicals but to more typical applications such as air pollution. To start from this paper and apply a CBA/SEA for chemicals restriction is still a very big leap. It would help to include reflections on the use of valuation techniques for a CBA, thereby referring to specific aspects such as scoping (time and space), how to take into account exogenous factors such as economic and population growth, effects outside the scope of the CBA, etc.

No links are made to the other SACAME publications (Chiu, 2017; Navrud, 2017) which would increase the readability. Clear links can be made to *Chiu, 2017* where more focus is put on risk characterization and health effects which need to be combined with valuation of health effects to assess health benefits. Also links with *Navrud, 2017* on the availability of valuation studies and how results from valuation studies can be transferred to other areas are not mentioned.

Though references on hedonic wage analysis are included in the examples (for instance link between birth weight and earnings) hedonic wage analysis is not discussed in detail as a separate valuation technique.

3.3 Advice - Detailed comments and links with other reference documents

3.3.1 Section 1 Introduction

Table 1 uses the term ecosystem functions instead of ecosystem services, which is mentioned in the text before and more commonly used in practice. Functions and services are not the same (see for instance Haines-Young and Potschin, 2011). Functions refer to to some capacity or capability of the ecosystem to do something. Whether this function is regarded as an actual service depends upon whether it contributes to human wellbeing and is considered as a benefit.

The description of the effects on the environment can be largely improved. There is a large overlap in categories. Ecosystem services also include food production, recreation, non-use values, etc. The text before suggests that it is limited here to regulating services. Perhaps it is better to stick to this classification and distinguish provisioning, regulating and cultural ecosystem services. Avoided treatment costs as it is mentioned here is more a valuation method than a specific effect. Biodiversity is not mentioned.

Table 1 also includes the valuation method “costs of alternate supplies of ecosystem services”. This is not a valuation method. This can be valued based on a combination of market and non-market valuation methods (see for instance section 4.2.3.4), depending on the specific ecosystem service considered.

Valuation methods: the distinction market / non-market provides little detail. It would be better to also include the actual method (travel cost, …) mentioned in section 2 to better understand the link with the next chapter in the text. This is for example performed in section 4.2.3.4)

3.3.2 Section 2 Valuation methods

Much detail is given on revealed preference approaches: travel costs and hedonics, a bit less on stated preference and much less on market pricing methods. This is peculiar as the first two methods are probably the least applicable to value the benefits of restricting chemicals and are rarely used to value health impacts as mentioned in section 4.2.3.1. Methods such as avoided (damage) costs, production function methods, averting behavior are also not mentioned, which is for instance the case in *ECHA, 2008* and *TEEB, 2010* (see overview in *table 8* in annex). Not enough links are made to chemicals in the description. When to use which method is not clear enough. It is also not clear how this section links to section 3.

A Market methods

Refers only to food, wood, fish which will probably be minor benefits compared to health. Why are health and worker productivity benefits not mentioned here as they are also mostly valued based on market methods (cost of illness, productivity).

B Travel cost methods

"Difficulties associated with the travel cost method include the definition of the market, namely the population over which the consumer surplus must be aggregated"

It is worthwhile to add that this is a difficulty which is highly relevant for most valuation techniques. This is also linked strongly to the benefits transfer discussion (*Navrud, 2017 – Sacame project*)

Whether or not this technique is suitable for valuation of the impact of chemicals is not really discussed. This technique is only relevant when visitors experience a noticeable change due to the presence of a specific chemical. The question is 1) in how many cases is this noticeable by a visitor and 2) if it is noticeable, to what extent can this be linked to the presence of a chemical? This combination of factors implies that this methodology is only applicable in a very small amount of cases.

If relevant, some examples would help to understand the relevance of this technique.

C Hedonics

"Structural characteristics usually account for most of the variation in the value of the home, whereas environmental quality usually picks up a smaller—and yet, often still meaningful—portion of the variation in the value of the home."

Please provide some examples. Examples on noise hindrance, accessibility to green areas, houses nearby water are widely available. However examples for chemicals are less available to my knowledge.

It is assumed, without testing, that real estate market participants are informed about the changes in the environmental quality as measured by the analyst.

Suggest to add: “at the time of the transaction”

Hedonic wage analysis is lacking in the text.

D Stated preference methods

Very little discussion on methodology, pros and cons and suitability for using this in chemical restriction dossiers. This is unfortunate as stated preferences are an important valuation method for valuing health effects (see also section 4.2.2.3).

3.3.3 Section 3 Valuing human health effects and changes in productivity

Introduction is not very consistent. It is about exposure and not about valuing health effects. Links need to be made to the topic of the section to assist the reader in understanding the content. Reference can be made to impact-pathway approach to understand the different steps needed to value health effects. This also helps explain why the next sections are relevant.

A. Nature of the human health endpoints

It would help if reference is made to the next sections as this explains why it is relevant to distinguish these categories.

B. Valuing morbidity: Acute illnesses

“what is the individual’s willingness to pay (WTP) to reduce pollution?”

This is always discussed from a perspective of the individual to personally avoid pain and suffering, but how about WTP for avoiding pain and suffering for other people (family, friends)?

“different components that are part of the Willingness to Pay to avoid pollution: (i) marginal lost earnings, (ii) marginal medical expenditures, (iii) the marginal cost of the averting activity, and (iv) the disutility of illness”

How to deal with double counting? This is often mentioned in the text but never approached in depth. If people perform an averting activity, they avoid medical expenditures. What is then the best approach: estimate the avoided medical expenditure or the cost of the averting activity or both?

An effect not discussed in this section is the difference between individual medical expenditure and total medical expenditure, as the majority of these expenditures might be covered by a public health care system. How is this benefit reflected in the analysis?

C. Effects on productivity

No comments

D. Developmental effects, low birth weights, and other infant and child outcome

Value of A Statistical Life Year (VOLY) and the Value of a Statistical Life (VSL) are for the first time introduced in this section without framing. Make reference to section F.

E. Reproductive effects

No comments

F. Mortality effects

Discussions include the importance of age but not of income. Due to different levels of income, VSL differs between countries, regions, etc. How to deal with this in a cost-benefit analysis?

4. Valuing cancer outcomes

No comments

5. Chemicals as emerging pollutants

No comments

6. An Example: The US EPA NESHAP emissions rule

It would be more useful to discover how all benefits are estimated (which type of valuation methods, unit values) instead of discussing how the exposure and costs are estimated. The results demonstrate that the so called co benefits (benefits not directly related to reducing the chemical emissions but due to the reduced air emissions) are much higher compared to the actual benefits. Is the conclusion in this case that the net benefits of the policy are indeed high and that we should go ahead or should we aim for another type of analysis focusing on cost effective pathways to reduce air pollution?

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4 Generic concerns about the use of cba for decision making on restriction dossiers

4.1 Role of the cba in a decision making process

Cost-benefit analysis (CBA) is a technique that is used to estimate and sum up (in present value terms) the future flows of benefits and costs of society's resource allocation decisions or policy alternatives to establish the worthiness of undertaking the stipulated activity or alternative, and inform the decision maker about socio-economic efficiency. CBA addresses the question of whether the objective (or action) is economically worthwhile and finding the efficient level of emissions: do the benefits exceed the costs and are net benefits maximized (Balana et al., 2011)?

CBA is the approach which underpins the ECHA SEA guidance document on restriction dossiers (ECHA, 2008). The SEA guidance document provides a pragmatic stepwise approach to perform a socio-economic analysis on restriction dossiers. Compared to the OECD Sacame working papers réf ,, much more attention is given to the fact that often many important impacts cannot be quantified. They will have to be presented alongside the quantified impact in an equal manner. More attention is also given to social impacts and equity.

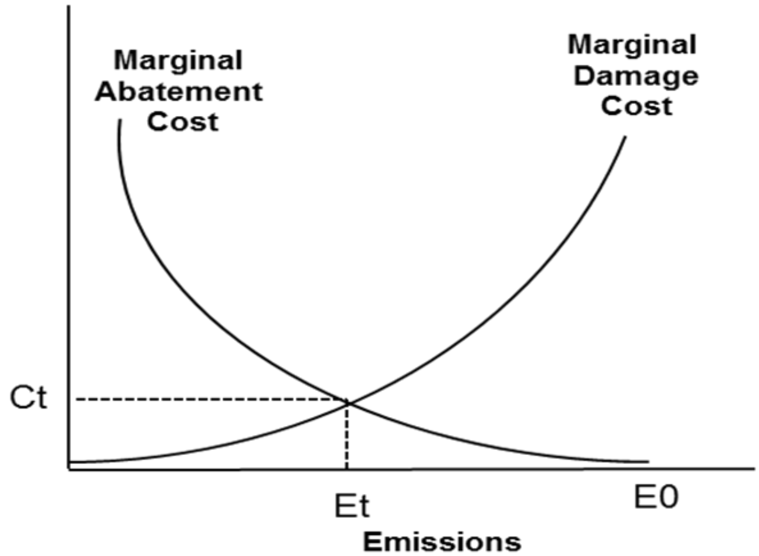
In the context of REACH, the major role of the SEA is:

1) to describe and analyse all relevant impacts (i.e. both positive and negative effects) of imposing a restriction compared to continued use. Effects can be direct and indirect (so called benefits and co-benefits). Co-benefits or ancillary benefits are the additional benefits that occur because of the actions we take to restrict chemicals beyond the direct benefits of the restricted use of chemicals (e.g. actions also having impact on air pollution).
2) to facilitate an assessment of whether the proposed Community-wide restriction is the most appropriate action as compared to other risk management options. Relevant parameters for SEAC advice are: Effectiveness, EU wide basis, Proportionality, Monitorability, Enforceability.

The assessment part requires a comparison of different sorts of costs and benefits and implies a weighting (monetary valuation) of different sorts of impacts, which can add a large amount of uncertainty to the assessment.

The most used evaluation criterion to compare scenario's in a CBA is the net present value (NPV) or "net benefits" criterion which is the discounted sum of all benefits minus costs during the considered time period. More information on discounting can be found in 4.3. The correct rule according to OECD, 2006 is to adopt any project with a positive NPV and to rank projects by their NPVs. Theoretically, the NPV is highest when marginal benefits equal marginal costs. The efficient level of emissions is in this case the level of emissions where marginal abatement costs equal marginal damage costs. A marginal abatement cost curve describes the additional costs of achieving one more unit of reducing emissions. It rises from right to left, depicting increasing marginal costs of reducing emissions further and further away from the existing emission level E0 without measures towards the target level of emissions Et. The higher the emission reduction, the greater the marginal abatement cost. A marginal damage cost function describes the additional damage caused by an additional unit of emission. It shows the change in damages or negative impacts as a result of the degradation of environment from a unit change in emissions. The curve rises from left to right. It assumes that marginal damage increases with increasing emissions.

Figure 1: The efficient level of emissions in a cost benefit analysis



Setting up marginal abatement cost and marginal damage cost functions in practice is very hard. Identifying the NPV point supposes lots of data and knowledge on both costs and benefits (ie emissions here to draw the curbs). In practice benefits and costs are compared for a limited set of scenarios with varying ambition levels for environmental quality.

Another approach is to rank according to benefit-cost ratios (B/C) or to divide discounted benefits by discounted costs. Compared to a ranking based on the NPV, low cost scenarios which achieve relatively high amounts of benefits are more favored (highest return on investment). Other possibilities are calculating the internal rate of return (IRR) or the interest rate at which the net present value of all the benefits and costs equal zero, which avoids the use of a fixed discounting procedure or (discounted) payback period, which avoids predefining a timespan for the cba. A lot of guidance is available both in scientific literature and in policy guidance documents.

Advice on the role and transparency of CBA to support decision making:

A cost-benefit analysis facilitates, integrates all quantifiable impacts and provides decision support. It allows decision makers to benchmark different dossiers to better prioritize policy decisions. However, decision makers should be made aware of the challenges and potential weaknesses of a CBA. Major challenges in a cost-benefit analysis are besides the monetisation of impacts, discounting, equity (distribution effects) and dealing with uncertainties.

Transparency on the methodology, on assumptions made and on parameters used is crucial to overcome these challenges. Policy makers should be made aware to not only strongly focus on one specific evaluation criterion (e.g. highest net present value). Instead using multiple evaluation criteria and performing a sensitivity analysis to test how outcomes are influenced when assumptions and parameters are changed are important.

Valuation techniques have limitations that are as yet unresolved. Valuation practioners should present their results as such (including missing benefits and limitations and margins of error indications on included benefits), and policy makers should interpret and use valuation data accordingly (TEEB, 2010). Non quantitative arguments are for instance also crucial to consider by decision makers and they are not included in a cost-benefit analysis.

Another aspect to consider is distributional impacts (also often referred to as equity).

These aspects are discussed more in detail in the next paragraphs.

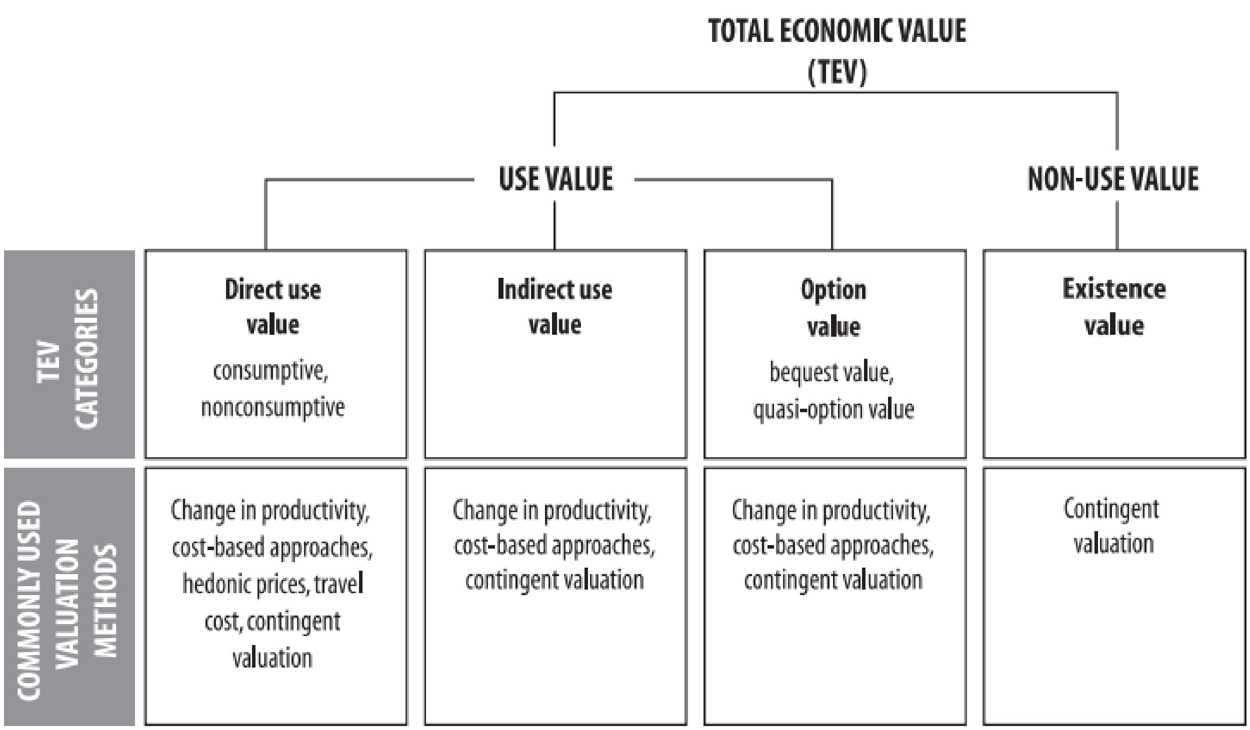
4.2 Monetary valuation

The monetization of impacts is one of the challenges for a cost-benefit analysis. We discuss the different types of values and available valuation techniques.

4.2.1 Total economic value framework

The concept of total economic value (TEV) is a widely used framework for looking at values. Use value refers to the values that are used by humans for consumption or production purposes. It includes tangible and intangible services of ecosystems that are either currently used directly or indirectly or that have a potential to provide future use values. Non-use values are also usually known as existence value. Humans ascribe value to knowing that something exists, even if they never use it directly. Depending on the type of value, different types of valuation methodologies can be applied (see next section).

Figure 2: Total economic value framework and commonly used valuation methods (Millenium Ecosystem Assessment, 2000 based on Pearce and Warford, 1993)



4.2.2 Valuation techniques

4.2.2.1 Market versus non-market valuation methods

Costs and benefits should normally be based on market prices as they usually reflect the most satisfactory measure of economic value. If the market is dominated by monopoly suppliers, or is significantly distorted by taxes or subsidies, prices will not reflect the economic value and adjustments may be required (*UK HM Treasury, 2011*). In many cases, however, environmental quality, ecological systems and environmental assets are not bought and sold in regular markets, and so it is necessary to use non-market valuation methods (*Alberini, 2017*). Non-market valuation methods are applied to determine the willingness to pay for non-market goods. Revealed preference techniques derive values based on consumer behavior. Examples include hedonic pricing techniques and travel cost methods. Stated preference techniques are based on asking people what they would be willing to pay for a particular benefit. Overviews of valuation techniques, their pros and cons can for instance be found in Pierce and Turner, 1990; Hanley and Barbier, 2009; Hadley et al., 2011). The description here is largely based on Liekens et al., 2013.

4.2.2.2 Revealed preference techniques

Typical revealed preferences methods, mentioned in table 3, are the hedonic pricing method and the travel cost method.

Hedonic pricing is based on the fact that the prices paid for goods or services that have environmental attributes differ depending on those attributes. Thus, a house in a clean environment will sell for more than an otherwise identical house in a polluted neighbourhood. Hedonic price analysis compares the prices of similar goods to extract the implicit value ("shadow price") that buyers place on the environmental attributes. A similar approach applied for health impacts are **hedonic wage analyses**. This methodology builds on the fact that a competitive labor market will generate higher wages in return for less desirable working conditions, such as hazardous conditions (exposure to chemicals) or poorer on-the-job amenities. These methods assume that markets are transparent and work reasonably well, and it would not be applicable where markets are distorted by policy or market failures. Moreover, these methods require a very large number of observations, are very data intensive and statistically complex to analyse. Its applicability is limited to environmental attributes. The advantage of the method is that it is a well-established technique and is based on actual observed behaviour.

The travel cost method enables the economic value of recreational use (an element of direct use value) for a specific site to be estimated. The method requires that the costs incurred by individuals travelling to recreation sites - in terms of both travel expenses (fuel, fares etc.) and time (e.g. foregone earnings) - is collected. The basic assumption is that these costs of travel serve as a proxy for the recreational value of visiting a particular site. The advantage of the method is that it is a well established technique and is based on actual observed behaviour. Disadvantages are that it is only applicable to recreational sites, it is difficult to account for the possible benefits derived from travel and multipurpose trips. It is very resource intensive and statistically complex to analyse.

4.2.2.3 Stated preference techniques

Stated preference is based on what people say rather than what they do, but it is more flexible than revealed preference and can potentially be applied in almost any valuation context.

Contingent valuation is an example of a stated preference technique, mentioned in table 3. It is carried out by asking consumers directly about their WTP to obtain an environmental service (or, in some circumstances, their willingness-to-accept). A detailed description of the service and how it will be delivered is provided. The valuation can be obtained in a number of ways, such as asking respondents to name a figure (classical CV), asking them whether they would pay a specific amount (dichotomous or polychotomous choice) or having them choose from several options (choice modelling). Hypothetical payment scenarios can be defined in great detail in order to produce conclusions about people's willingness to pay for either specific aspects or the entirety of goods, services or other things that are relevant to the decision (*UK HM Treasury, 2011*). Only stated preference methods capture non-use values, i.e., the value that people place on a resource because of its existence ("existence value"), because they wish to preserve it for future generation ("bequest values"), and just in case they may want to use it themselves in the future ("option value") (*Alberini, 2017*). Non-use values are subjective and can thus be very different between individuals and subjective to change in time.

Some important concerns about stated preference techniques can be raised.

Because of the need to describe in detail the service being valued, interviews in CV surveys are time-consuming. In designing CV surveys it is important to identify the relevant population to ensure that the sample is representative, and to pre-test the questionnaire to avoid bias. A potentially important limitation when applying these methods is that respondents cannot make informed choices if they have a limited understanding of the issue in question. Choosing the right approach to improve the sample group's understanding of complexity and the question at hand without biasing respondents, is a challenge for stated preference methods. The hypothetical market needs to be realistic and relevant to people. Respondents need to be able to understand what they are valuing. This means that directly asking the WTP to avoid emissions of a particular chemical is difficult as respondents do not understand the technicalities behind it, the possible impacts caused by the chemical and hence tend to underestimate its importance. Asking the WTP to avoid illnesses will reduce some of the differences in interpretation between individual respondents and hence provide more trustworthy results. ,

Stated Preference methods require statistically representative samples of populations. Typically (as in many surveys), children, elderly and low income groups are underrepresented. On the other hand, higher educated groups and environmentalists are overrepresented.

4.2.2.4 Benefits transfer

Benefits transfer involves transferring economic estimates from previous studies (often termed study sites) of similar changes in environmental quality and public health to value the change in the quality or quantity of theses public goods at the policy site. As original valuation studies are often time consuming and costly, this technique is mostly applied in a cost-benefit analysis. Equally important as the valuation of the impact (for a specific health or ecosystem end point) itself is how these values can be applied to estimate impacts on a national, continental or global scale. Benefits transfer remains controversial and the potential risk for transfer errors remains (Brouwer, 2000).

A separate (excellent) chapter is devoted on this topic in the SACAME project (Navrud, 2017).

The three main techniques for spatial and temporal value transfer are:

i) unit value with or without income adjustments, e.g. a fixed value per episode;

ii) value function transfer: a WTP function instead of a single WTP value including other explaining variables to correct for when transferring values to other sites. Typical examples include distance and availability of substitutes for WTP for nature and water restoration (see examples in Eftec, 2010; Liekens et al., 2013)

iii) meta-analysis: results from several valuation studies could be combined in a meta-analysis to estimate one common value function. (see examples in Brander et al., 2011).

Specifically for WTP estimates this proves to be challenging, especially for environmental impacts, as WTP often includes a time dimension (amount one-time, per month or per year) and the WTP is often reported for one or more specified discrete changes in an ecosystem, and not on a marginal (e.g. per ha) basis. Usually, the WTP is non-linear and the WTP for a 2 ha status improvement of an ecosystem is not double the WTP for a 1 ha improvement.

The individual is the natural unit for value transfer of health impacts. Morbidity impacts are often transferred in terms of unit values for a symptom day or an illness episode for acute illnesses, and per case for chronic illnesses. However, for transferring values across countries, it is common practice to correct for differences in income levels, exchange rate and purchasing power parities. Preferably, social (e.g. dietary habits), economic (e.g. income levels) and health characteristics of the population and/or the environmental quality or ecosystem service change in question are as similar as possible when selecting original valuation studies to start from.

Navrud, 2017 identifies 8 steps to perform a value transfer, which are explained more in detail.

1. Identify the environmental and health endpoints or impacts to be valued at the policy site;

2. Identify the affected population (i.e. the population thought to experience welfare loss from the impact) at the policy site, and the characteristics likely to influence their values of the respective impact;

3. Conduct a literature review (from databases of primary studies and other sources) in order to identify relevant primary studies; preferably of a population with similar characteristics as the population at the policy site;

4. Assess the relevance and quality of study site values for transfer;

5. Select and summarise the data available from the study site(s);

6. Transfer value estimate from study site(s) to policy site;

7. Calculate total social benefits or costs; aggregated over the affected population and geographical area if WTP/household is expressed per unit of area for environmental goods and over time, in terms of their Present Value (PV); and

8. Assess the uncertainty and transfer errors.

Interesting points of attention include the transfer of values over time (usually corrected based on consumer price index.or purchasing power parity. Also the “adding-up”-issue is considered. Moving from benefit assessment of regulating one chemical to also address a larger groups of chemicals covered by regulations like REACH, one need to take account of possible interactions between these chemicals in all stages of the damage function and impact pathway approach used.

4.2.3 Impacts and available monetary valuation techniques

The SEA guidance document (ECHA, 2008) distinguishes the following impacts to be considered for chemical restrictions:

Human health and environmental impacts (benefits): all possible effects directly related to the toxic, ecotoxic or physicochemical properties of the substance proposed for restriction or any alternative substance, as well as any other health and environmental impacts occurring in all affected supply chains in relation to the introduction of alternative substances or technologies

- Economic impacts (costs): These are the net costs or savings to manufacturers, importers, downstream users, distributors and consumers in the supply chains of the substance and the alternatives.
- Social impacts: These are all relevant impacts which may affect: workers, consumers and the general public and are not covered under health, environmental or economic impacts (e.g. employment, working conditions, job satisfaction, education of workers and social security). Impacts on certain social groups may need to be considered.

The scope in Alberini, 2017 is limited to the valuation of human health and environmental impacts as social impacts are rarely valued in monetary terms and partially captured in the other impact categories (see section 4.2.3.3).

4.2.3.1 Health impacts

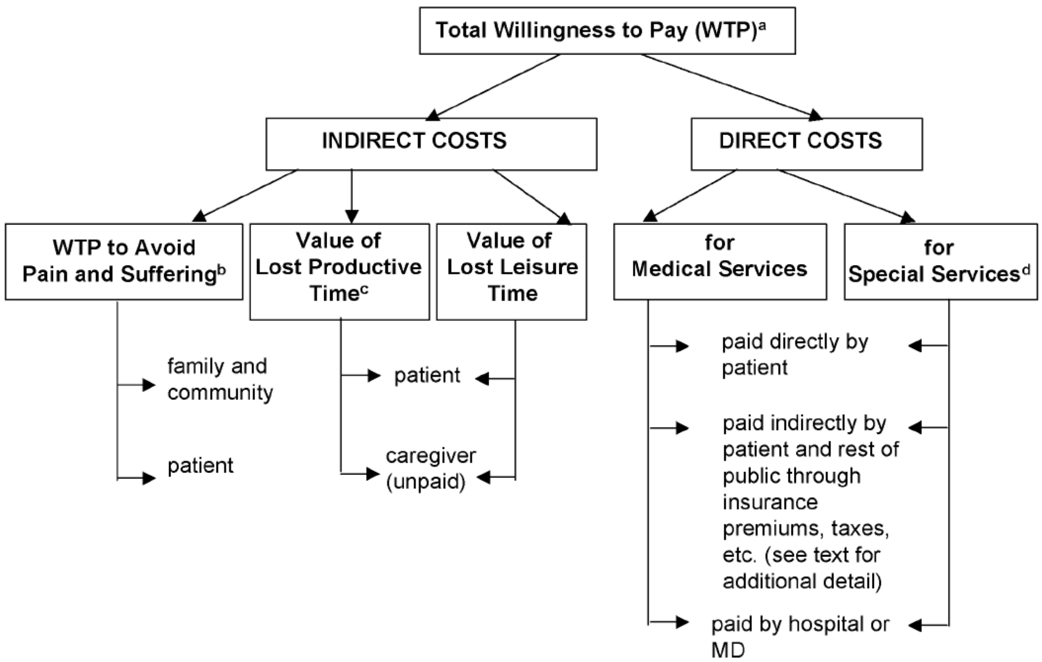
Health impacts are probably the most important impact category in a cost-benefit analysis for restricting chemicals. Typically, **benefits** on health (theoretically captured in the total economic value of avoiding illnesses) include **direct costs for medical services** and specialized education, equipment and transportation due to illness. Important to note is that the WTP here is closely related to the concept of total economic value which ideally covers all consequences of illnesses and is not related to the WTP estimated solely by stated preference surveys.

Direct **costs** are estimated based on observed data of medical expenditures (cost of illness-market prices). This type of estimation is relatively easy to perform and it is likely to provide relatively accurate estimates. The major drawback is that important components of the WTP are omitted. Specifically, the WTP to avoid pain and suffering which can be considerably important, is omitted (EPA, 2007). Besides direct costs, also **indirect costs due to loss of leisure and productive time** (opportunity costs) to the patient or others are part of the total WTP. The loss of productive time can still be valued by market prices (average gross wages x period of productivity loss/absence at work) but valuing the loss of leisure time requires a valuation of 1h of leisure time. Different methods exist. The market rate for 1h of service performed by a professional housekeeping company was applied in Broekx et al., 2011 (replacement cost method) but this is a minimum estimate. Revealed and stated preference methods are also commonly applied to estimate value of leisure time.

The WTP to avoid specific illnesses as derived from stated preference techniques, is assumed to cover indirect costs and direct costs for medical services. As such, avoided medical expenditures and WTP estimates cannot be summed. An important remark is that it is mostly limited to costs covered by the patient itself and thus it does not include the costs covered by public healthcare systems or insurances. The reliability of stated preference results is questioned by many economists (EPA, 2007). The approach is also resource intensive and costly, it requires careful design and interpretation of questionnaires. Consequently, revealed preference methods including market based methods are in general preferred over stated preference techniques. For instance, the UK Green Book (*HM Treasury, 2011*) specifically defines the use of stated preference techniques only when other techniques are not available. However also market based methods have their deficiencies (often only a partial value, markets can also be heavily distorted). Combination of methods therefore lead to more robust estimates.

The schedule (EPA, 2007. Cost of illness handbook) below also indicates who bears the costs. An important aspect is that direct costs are paid by the patient but also through insurance premiums and taxes. In some cases it can be complex to trace back compensations paid by different public and private organizations. It can also be difficult to attribute costs to specific illnesses. As the coverage of healthcare systems and insurance premiums can be very different across countries. This does not only lead to differences in distribution of costs but can also cause differences in access to healthcare services and differences in treatment protocols.

Figure 3: Elements of costs of illness (EPA, 2007)



* Total Willingness to Pay is in this schedule closely linked to the total economic value concept and is not to be confused with Willingness to Pay estimations based on stated preference.

4.2.3.2 Environmental impacts (ecosystems)

Environmental benefits of restriction of chemicals includes the reduced impacts due to restricted use on all environmental compartments (water, air, soils and sediments, ecosystems). Describing and quantifying the value of environmental compartments and as such valuing the benefits of reducing damages caused by chemicals is mostly not valued directly. Valuation techniques are rarely applied to put a direct value on air, water or an ecosystem, but instead it is common practice to value the (ecosystem) services delivered to society and how this level of service delivery is influenced by specific policies. A rapidly increasing amount of scientific literature is being produced on how to describe and value these ecosystem services. First attempts on how to use this concept for chemicals (risk assessments, valuation of impacts) are being made (Ecetoc, 2015; Cefic, 2015) but the amount of available applications is much less compared to health impacts.

Important to remark is that these ecosystem services also include health impacts (for instance, due to exposure to chemicals ecosystems are damaged, which causes losses in the services the ecosystem delivers such as capturing fine particles or purifying water, which in turn causes negative health impacts). A clear distinction with previously discussed health impacts is that impacts are not direct due to exposure to the specific chemical but indirectly due to damages in other environmental compartments or ecosystems.

To get an understanding on which type of impacts can be considered and valuation techniques, inspiration can be found in literature on ecosystem services and the benefits of nature conservation. The most cited examples include the *Millenium Ecosystem Assessment*, *TEEB (table 2)*, *CICES* and recent work by *the Intergovernmental Platform on Biodiversity and Ecosystem Services*.

Biodiversity as such is not considered as a separate ecosystem service. The table below mentions habitat services which are closely linked to biodiversity but more recent classifications (CICES) do no longer distinguish these supporting services as a separate category. The links between biodiversity and ecosystem services are explained more in depth in TEEB, 2010. Since ecosystem services are the benefits that people get from ecosystems, it follows that changes in ecosystem services associated with changes in biodiversity will have implications for human wellbeing. The value of biodiversity derives from its role in the provision of ecosystem services, and from peoples" demand for those services. There is clear evidence for a central role of biodiversity in the delivery of services. We can state with high certainty that maintaining functioning ecosystems capable of delivering multiple services requires a general approach to sustaining biodiversity in the long-term.

The ecosystem services concept is the instrumental framework to value the impacts of biodiversity on human wellbeing. In general, the richness of biodiversity and the total value of ecosystem services are positively correlated, if a sufficiently wide range of ecosystem services is considered (especially regulating and cultural services besides the provisioning services). The links between biodiversity and ecosystem services are however still subject of scientific debate (see for instance overview in Harrison et al., 2014). Relationships are found to be highly complex and service dependent.

Table 2: Classification of services provided by ecosystems to society (TEEB, 2010)

	Main service types
	PROVISIONING SERVICES
1	**Food** (e.g. fish, game, fruit)
2	**Water** (e.g. for drinking, irrigation, cooling)
3	**Raw Materials** (e.g. fiber, timber, fuel wood, fodder, fertilizer)
4	**Genetic resources** (e.g. for crop-improvement and medicinal purposes)
5	**Medicinal resources** (e.g. biochemical products, models & test-organisms)
6	**Ornamental resources** (e.g. artisan work, décorative plants, pet animals, fashion)
	REGULATING SERVICES
7	**Air quality regulation** (e.g. capturing (fine)dust, chemicals, etc)
8	**Climate regulation** (incl. C-sequestration, influence of vegetation on rainfall, etc.)
9	**Moderation of extreme events** (eg. storm protection and flood prevention)
10	**Regulation of water flows** (e.g. natural drainage, irrigation and drought prevention)
11	**Waste treatment** (especially water purification)
12	**Erosion prevention**
13	**Maintenance of soil fertility** (incl. soil formation)
14	**Pollination**
15	**Biological control** (e.g. seed dispersal, pest and disease control)
	HABITAT SERVICES
16	**Maintenance of life cycles of migratory species** (incl. nursery service)
17	**Maintenance of genetic diversity** (especially in gene pool protection)
	CULTURAL & AMENITY SERVICES
18	**Aesthetic information**
19	**Opportunities for recreation & tourism**
20	**Inspiration for culture, art and design**
21	**Spiritual experience**
22	**Information for cognitive development**

TEEB, 2010 also provides interesting overviews of valuation methodologies and for which services they can be used as presented in table 3 below. Market prices are typically used for provisioning services (food, wood, water production). Avoided and replacement cost methods are mostly applied for regulating services whereby specific markets or government expenditures are influenced. Revealed preferences (travel cost methods, hedonic pricing methods) are more focusing on regulating and cultural services that impact the price of real estate such as noise buffering and aesthetics or the amount of time people are willing to travel. Stated preference techniques or simulated valuation techniques such as contingent valuation, choice modelling and group valuation are typically oriented towards cultural services and non-use values. Table 8 in annex provides a review on the advantages and disadvantages of different methods listed in the table below.

Table 3: Valuation methodologies applied for ecosystem services (TEEB, 2010)

Method			Comment /example	References
Market valuation	Market Price		Mainly applicable to the "goods" (e.g. fish) but also some cultural (e.g. recreation) and regulating services (e.g. pollination).	Brown et al. 1990; Kanazawa 1993
	Cost based	Avoided cost	The value of the flood control service can be derived from the estimated damage if flooding would occur.	Gunawardena & Rowan 2005; Ammour et al. 2000; Breaux et al. 1995; Gren 1993
		Replace-ment cost	The value of groundwater recharge can be estimated from the costs of obtaining water from another source (substitute costs).	
		Mitigation/ restoration costs	E.g. cost of preventive expenditures in absence of wetland service (e.g. flood barriers) or relocation.	
	Production function / factor income		How soil fertility improves crop yield and therefore the income of the farmers, and how water quality improve-ments increase commercial fisheries catch and thereby incomes of fishermen.	Pattanayak & Kramer 2001
Revealed preferences	Travel Cost Method		E.g. part of the recreational value of a site is reflected in the amount of time and money that people spend while traveling to the site.	Whitten & Bennet 2002; Martín-López et al. 2009b
	Hedonic Pricing Method		For example: clean air, presence of water and aesthetic views will increase the price of surrounding real estate.	Bolitzer & Netusil 2000; Garrod & Willis 1991
Simulated valuation	Contingent Valuation Method (CVM)		It is often the only way to estimate non-use values. For example, a survey questionnaire might ask respondents to express their willingness to increase the level of wa-ter quality in a stream, lake or river so that they might enjoy activities like swimming, boating, or fishing.	Wilson & Carpenter 2000; Martín-López et al. 2007
	Choice modelling		It can be applied through different methods, which include choice experiments, contingent ranking, contingent rating and pair comparison.	Hanley & Wright 1998; Lii et al. 2004; Philip & MacMillan 2005
	Group valuation		It allows addressing shortcomings of revealed pre-ference methods such as preference construction during the survey and lack of knowledge of respondents about what they are being asked to allocate values.	Wilson & Howarth 2002; Spash 2008

4.2.3.3 Social impacts

Social impacts are the impacts which are the most difficult to grasp and to define what it exactly includes. Mostly, these impacts are also not included in a cost-benefit analysis or not distinguished as a separate impact category. They are also not considered in *Alberini, 2017, as discussed in chapter 3*.

The SEA guidance on restrictions (*ECHA, 2008*) defines social impacts as all relevant impacts which may affect: workers (mentioned as employment in table 4), consumers and the general public (mentioned as quality of life in table 4) and are not analyzed under human health and environmental risks and economic impacts. They are not necessarily benefits due to restriction and also include costs on employment (unemployment, changes in working conditions, job satisfaction, education of workers and social security) and possible changes to the quality of life (change in availability and quality of consumers products). This definition implies that these impacts are also highly linked to distributional effects. To get a better understanding on what can be understood by social impacts, inspiration needs to be found outside the cost-benefit analysis literature. Social impact assessments are assessments specifically focusing on changes in the well-being of people and communities that are caused by a given choice of action or policy (*Vanclay, 2003*). Social impacts overlap with economic and health impacts in terms of affecting the well-being of local community members. Specific impact indicators differ between applications. A review of scientific literature by *Beames et al., 2016* on urban renewal and sustainable urban development identified six key social impact areas. The impact categories include 1) Accessibility and Mobility, 2) Community Health and Safety, 3) Human Capital, 4) Livability and Convenience, 5) Social Cohesion and 6) Urban Aesthetics.

Though the topic of the review is focused on redevelopment of brownfields and not on restriction of chemicals, the different impact categories which can be considered relevant are similar. They can be largely grouped in employment and quality of life indicators. Most of the indicators are also partially included in the health and environmental impacts but in this case a specific focus is put on vulnerable groups and surrounding communities (in this case of polluted sites).

Besides social impacts and social impact assessment, inspiration can be found on Well-Being Indicators, though the scope of this type of indicators is less broad and they are mostly used to compare countries instead of performing impact assessments. The OECD framework on wellbeing indicators distinguishes material living conditions (or „economic well-being"), quality of life defined as the set of non-monetary attributes of individuals, and the sustainability of the socio-economic and natural systems where people live and work is critical for well-being to last over time.

Social impacts included in the Impact Assessment Guidelines published by the European Commission (*European Commission, 2009*) go further in detail, but largely are focused on employment and quality of life for specific target groups. Additionally, the quality of public institutions, culture and safety are considered as important social impacts:

- Employment and labour markets
- Standards and rights related to job quality
- Social inclusion and protection of particular groups
- Gender equality, equality treatment and opportunities, non -discrimination
- Individuals, private and family life, personal data
- Governance, participation, good administration, access to justice, media and ethics
- Public health and safety

- Crime, Terrorism and Security
- Access to and effects on social protection, health and educational systems
- Culture
- Social impacts in third countries

4.2.3.4 Advice – Summary on typical impact categories in restriction dossiers and suitable valuation techniques

The table below is a personal synthesis of the previous paragraphs and combines typical listings of impact categories and how these impact categories can be valued. Non-monetary valuation techniques are indicators which are an indication of the importance but are not expressed in money values. Also target groups for which these impacts are relevant are included (distributional aspects).

Table 4: Summary of typical impacts, valuation techniques and distributional aspects included in a cost-benefit analysis and socio economic analysis for restriction of chemicals

Impact category	**Impact**	**Valuation techniques**	**Relevant for:**
Health – occupational and public	Directly avoided medical expenditures and special services	Market prices	Citizens – patient Insurance companies Government
	Value of lost productive time	Market prices	Citizens – patient Employer Government
	Value of lost leisure time	Replacement costs, revealed and stated preference	Citizens – patient
	WTP to avoid pain and suffering	Stated preference	Citizens – patient and family and friends
Ecosystem and its services, biodiversity (environment)	Provisioning services: food, wood, water	Market prices, production function approaches	Citizens – general public Agriculture, fisheries
	Regulating services: air, floods, noise, heat, global climate regulation, water and soil quality	Replacement costs, avoided costs, restoration costs, hedonics, stated preferences, travel cost methods	Citizens – general public Government
	Cultural services: recreation, aesthetics, education, cultural heritage	Travel cost methods, stated preferences, hedonic prices	Citizens – general public, visitors, surrounding community
	Habitat or supporting services: species and genetic diversity	Offsetting costs, non-monetary valuation, stated preferences	General public (non use)
Social impacts	Employment, working conditions, job	Non-monetary indicators	Citizens – workers

	satisfaction, social security		
	Quality of life for specific target groups: local community, vulnerable groups	Non-monetary indicators	Citizens – consumers

Health impacts typically include medical expenditures, loss of productivity, loss of leisure time and the WTP to avoid pain and suffering. This is not necessarily restricted to citizens, but also includes impacts for insurance companies (less compensations), government (compensations by a social welfare system) and employers (loss of added value). Ecosystems and the services they deliver are as mentioned previously typically distinguished in provisioning, regulating and cultural services. Habit or supporting services are also mentioned separately but not valued separately to avoid double counting. Ecosystem services are mostly enjoyed by the general public or specific citizens visiting or living nearby ecosystems. Social impacts are typically not valued in monetary indicators and limited to specific groups of citizens.

4.2.4 Is monetary valuation a necessity?

Monetary valuation is necessary if multiple types of benefits are taken into account in a single cost-benefit analysis. To avoid monetary valuation, other types of assessment tools are required. Typical impact assessment techniques used to compare scenarios and support decision making besides a cost-benefit analysis are a cost-effectiveness analysis (CEA) and a multi-criteria analysis (MCA).

If only a single effect category is considered, a CEA is an alternative option to benchmark restriction cases. CEA is widely used to determine the least cost means of achieving pre-set targets or goals. Typically, cost effect ratios are estimated and ranked but also more complicated optimization techniques are used to estimate combinations of measures to achieve one (or even multiple) objectives at the lowest cost achievable. The result however does not answer the question whether the benefits of regulation outweigh the costs.

In MCA, the actual measurement of indicators is often based on the quantitative analysis (through scoring, ranking and weighting) of a wide range of qualitative and quantitative impact categories and criteria. Different environmental and social indicators may be developed side by side with economic costs and benefits and MCA provides techniques for comparing and ranking different outcomes, even though a variety of indictors are used (*ECHA, 2008*). Multi-criteria analysis is also often seen as a possible alternative to a cost-benefit analysis as it combines monetary and non-monetary indicators as mentioned in table 5 but it poses other challenges to identify and weight different impact categories.

Considering the fact that REACH restriction dossiers of chemicals are largely initiated by human health concerns it is interesting to explore the options of other weighting procedures specifically focused on health. The SEA guidance document (ECHA, 2008) also mentions the possibility to use weights based on disability or quality adjusted life years (DALY or QALY), in order to aggregate health impacts. With DALYs and QALYs it is possible to carry out cost-effectiveness analysis as the benefits are in the units of “years” and costs in the units of “euros”. This approach is similar compared to health care decision making where cost per QALY indicators are estimated to support decision making in refunding medication by the public healthcare system. Benchmarks can be defined whether specific types of medication should certainly be refundable or not refundable or subject of further research. However, the use of fixed thresholds are also subject of debate in this field and questions are raised about methodological issues regarding the calculation of QALYs, and not considering ethical and equity issues (European Commission, 2013). Though a cost per QALY or DALY indicator is certainly useful to get a feeling of the effectiveness of restriction scenario's for different chemicals, it is more difficult to assess how far restriction should go and to compare different types of scenarios for the same chemical. No judgement is made on whether net benefits still increase in more far going restrictions.

Multi-criteria analysis (MCA) describes any structured approach used to determine overall preferences among alternative options, where the options have several types of impacts and/or accomplish several objectives (ECHA, 2008). In MCA, desirable objectives are specified and corresponding attributes or indicators are identified. The actual measurement of indicators is often based on the quantitative analysis (through scoring, ranking and weighting) of a wide range of qualitative and quantitative impact categories and criteria. This need not be done in monetary terms. Explicit recognition is given to the fact that a variety of both monetary and non-monetary objectives may serve policy decisions.

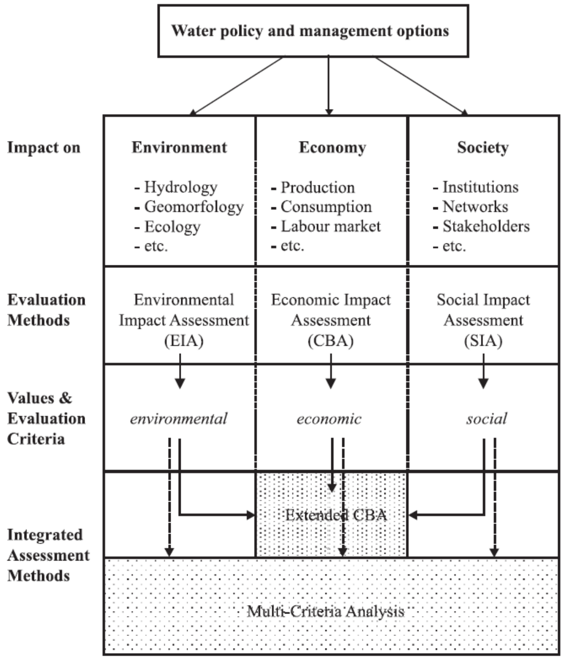
The pros and cons of MCA vs. CBA are widely discussed in scientific literature. Typical weaknesses mentioned by authors promoting the use of MCA are the scientific robustness of the methodologies such as value transfer methodologies where monetary value estimates are taken to hold for other times, places, and ecosystems, the fact that environmental economics only works for marginal changes and not for "once-and-for-all" circumstances (non-linear ecosystem responses, tipping points) and the fact that monetisation is insufficiently capable in prioritising human needs, in particular those of the poor and this can result in serious social and environmental inequity (Vatn, 2010; Cornell, 2011; Spangenberg, 2012). Most of these arguments are indeed valid, but multi-criteria analysis (which is often suggested by these same authors as alternative) suffers from the same difficulties. Outcomes of a multi-criteria analysis are equally influenced by choices made by the researchers (e.g. criteria selection and weighting individual criteria) or at best a limited group of stakeholders. The choice of criteria, scoring and weighting for each criterion is subjective.

Beria et al., 2012 correctly claim that MCA is specifically more suited to assess micro-scale scenario's as local stakeholders can be involved more easily during the selection of criteria, weighting and discussing/finetuning results, whereas CBA is much more focused on desktop macroscopic quantifications, primarily suited to compare large-scale scenario's where it is much more difficult to identify and take into account specific concerns of all stakeholders. Contrary to for instance biodiversity management and restoration projects which are organized on a local scale (individual nature restoration areas), chemical restrictions are largely discussed on a macroscopic scale which makes it more difficult for a MCA to comprehend.

Advice on using the principles of CBA in restriction dossiers:

To conclude, the basic steps in a CBA are rightfully selected to serve as a basis to underpin the SEA guidelines (ECHA, 2008). Additional attention is given to non-quantifiable impacts, social impacts and equity to overcome some of its weaknesses. In practice this means that the typical outcomes of a CBA (net present value and individual costs and benefits) are extended with non-monetary value indicators to perform a MCA as for instance is applied in Brouwer and Van Ek, 2004.

Figure 4: Combination of CBA and MCA in one integrated framework (Brouwer and Van Ek, 2004)



Outcome of the MCA procedure based on ecological, economic and social criteria

Alternative	Criteria			Aggregate score	Ranking
	Ecology[a] (%)	Economy[b] (billions Dfl.)	Society[c] (±)		
Dike strengthening	0.0	− 0.8	o	0.45	1
Land use change and floodplain restoration	22.2	− 5.5	−	0.33	2

[a] Contribution to nature conservation policy.
[b] The minus indicates that these are costs.
[c] Aggregate social score (−, negative; o, neutral;+, positive) based on expert judgement.

Typically health impacts are included the most in socio economic analyses. Social impacts and impacts on ecosystems are less represented. In general the comparability and level of interpretation of results would benefit from a standard list of impact indicators reporting also indicators not included in the assessment and potentially important for the chemical under examination.

Finding suitable valuation methods for specific impact indicators can be very costly. However, the absence of available valuation numbers should not be an excuse to not value impacts at all. The proportionality principle or the question on the amount of research we expect depending on the characteristics of the chemical (amount of health end points, size of population exposed, geographical scope, economic importance of the sector, …) is important to apply. For important dossiers it is advised to go beyond simple benefits transfer techniques and potentially apply original modeling studies and valuation studies.

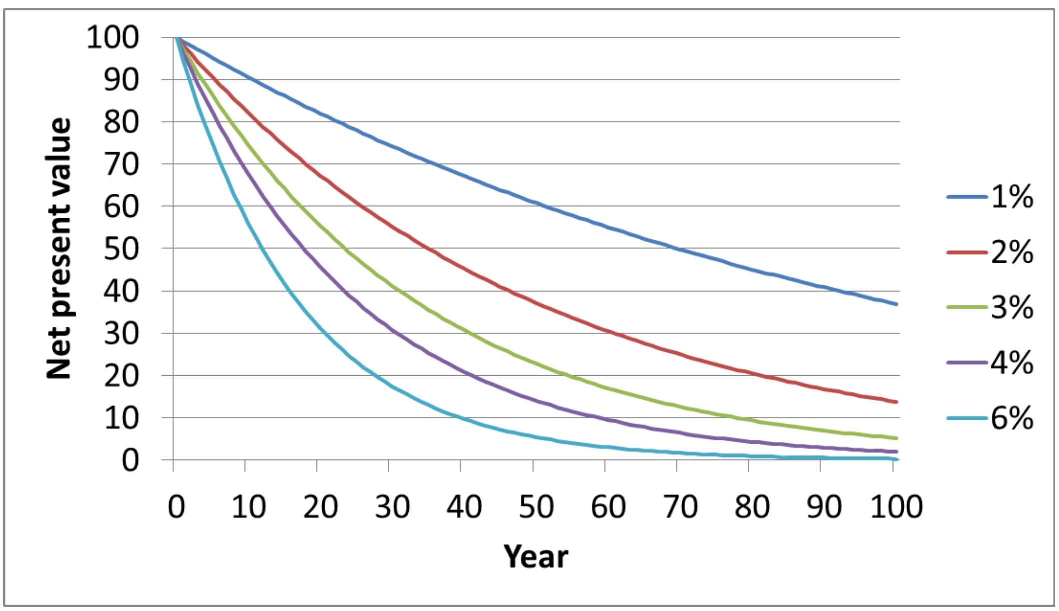
Comparability between different dossiers will help evaluators to judge the quality of the analysis. To achieve this, a minimum set of guidelines required in assessing social costs of chemicals is required that goes beyond the specific research steps but also specifies the boundary conditions of the SEA (discount rates, minimum time period to consider, standard impact indicators and potential values to apply for specific health end points). Some indicators (such as values for health end points) can/should be provided by the regulating authority.

4.3 Discounting

In economic analyses the most common method used to compare costs and benefits over time is called discounting. Discounting makes it possible to calculate equivalent amounts in today's terms, i.e. the 'present value', or at any other fixed point in time. The further away in time a cost or benefit occurs, the lower its present value becomes. The size of the reduction in the present value depends on the discount rate: future costs or benefits estimated using a higher discount rate will have a lower present value (ECHA, 2008). Typical discount rates for public investment decisions vary between 1 and 7% as mentioned in different guidance documents (Rebel en Mint, 2013; Eijgenraam et al., 2000; UK HM Treasury, 2011; Broekx et al., 2011). Though discounting has a theoretical rationale in the underlying welfare economics of CBA, it has consequences that many find morally unacceptable. This unacceptability arises from the fact that distant future costs and benefits may appear as insignificant present values when discounting is practiced (OECD, 2006). To many non-economists, the shrinking of future values with the discounting technique conflicts with the core idea of intergenerational equity that is central to sustainability (Skou Andersen and Owain Clubb, 2013).

The impact of the selection of the discount rate is demonstrated in the figure below. A benefit of 100€ occurring in 100 years from now has a net present value of 37€ for a 1% discount rate or 0,29 for a 6% discount rate. As costs for restriction usually occur on a short term (investments, changing manufacturing processes) and the benefits (health, environment) are more evenly spread across time, the selection of the discount rate has a large influence.

Figure 5: Net present value of a benefit of 100€ for different years of the benefit and discount rates



A simple approach is to use low or even negative discount rates (0.5%; 1%) as a sensitivity analysis whereby long term impacts are valued higher. Recent advances to tackle this issue are applying hyperbolic discounting or a declining discount rate through time (for instance adviced in the UK Treasury Green Book).

Advice on discounting:

Important to notice is that the SEA guidance document (ECHA, 2008) advises to use a 4% discount rate. If costs and benefits occur beyond 30 years it is recommended to perform a sensitivity analysis using either a 1% discount rate or declining discount rate in addition to the default 4% discount rate. Typically costs are experienced on a relative short term (<10 years) whereas benefits occur on a longer term (50-100 years and beyond), which means that applying high discount rates will lead to the selection of scenarios with a reduced level of restriction measures.

As 4% drastically reduces long term impacts and the time period to consider is not predefined, it is recommended to perform a sensitivity analysis and estimate net present values using low and high discount rates (e.g. 1% and 7%) in all cases or to predefine a minimum time period to consider, which would increase comparability between dossiers.

4.4 Distributional effects

The equity rationale relates to the distributional impacts of a scenario. If certain groups are affected by increased unemployment, for example, this can be seen as a negative distributional impact, even if employment is offset (to some degree) elsewhere. Economic impacts can and ideally should be assessed based on efficiency and equity. Other distributional impacts might consider specific sectors or vulnerable groups. In European Water Policy (EU Water Framework Directive) for instance, agriculture, households and industry should at least be considered as separate groups to achieve a reasonable level of cost recovery. Mostly, also vulnerable income groups (10 percentile income levels) are considered when evaluating whether the costs of measures can be considered disproportionate and specific compensation measures might be required to keep measures affordable. Typical groups to consider in transport infrastructure projects for instance include users, surrounding neighbourhoods, regional and international differences and the private versus public sector (Eijgenraam, 2000; Rebel en Mint, 2013).

Robinson et al., 2014 reviewed several CBAs in the US and clearly demonstrate that most CBAs hardly provide information on distributional effects and focus mostly on overall efficiency. Possible explanations for this lack of information given in this paper is mostly philosophic. Regulators may believe they should choose the option that maximizes net benefits as long as the health of these particular groups is not harmed. Other reasons may be more pragmatic. Regulators may worry that reporting the distribution of the impacts will raise issues they lack the legal authority to address; they may believe that distributional impacts are too small to warrant attention; or they may lack needed data, technical guidance, time, or resources.

An affordability check is a possible way to consider distributional effects for specific sectors or vulnerable groups. Again for the European Water Framework Directive, affordability criteria are sometimes used in combination with a cost-benefit analysis to assess whether specific scenarios are disproportionately costly. Though some find these criteria highly debatable (there is little scientific basics for these criteria and related thresholds), they are regularly applied in different European Member States.

Advice on incorporating distributional concerns:

Incorporating distributional concerns directly in a cost benefit analysis implies initially identifying and then possibly weighting the costs and benefits of individuals and groups on the basis of differences in some characteristic of interest (such as income or wealth). (OECD, 2006) Providing the “correct” magnitudes of distributional weights is however a new challenge and it can be questioned whether including such a weighting procedure is an added value for decision making. In general, this type of corrections is not advised in cba guidelines. More often and adviceable is to compare costs and benefits separately for individual target groups which leaves it up to decision makers to decide on the relative importance of achieving positive or avoiding negative impacts for specific target groups.

4.5 Dealing with uncertainty and the cost of inaction

Especially in restriction dossiers uncertainty of impacts caused by specific chemicals on a short and especially longterm can be high. From a precautionary principle however, it is important to also consider warning signals in a worst case scenario which does not necessarily have the label of “scientific proof”. When it comes to substances for which the knowledge base is less developed, it will be necessary to explore the potential costs of inaction by relying on evidence from early warning signals. These harm costs could for instance be calculated by looking first at the already-proven impacts of high doses in the work environment, and then scaling linearly to low doses (Skou Anderson and Owain Clubb, 2013). The precautionary principle implies that where significant or irreversible ecological risks are involved, any lack of scientific evidence with respect to cause and effect should not be used as a reason for not taking appropriate action to prevent ecological degradation (Silvis and Van der heide, 2013).

Addressing the 'costs of inaction' involves the same methods used to account for benefits in conventional cost-benefit analysis. The cost of inaction is considered the same as the benefits of action. Crucial is however to come up with lower and higher bound estimates relying in some cases on early warning signals and some overly simplified extrapolation of impacts. This is however important to get a feeling on the relevance of a potential restriction, instead of simply describing the lack of evidence or listing impacts not considered in the SEA.

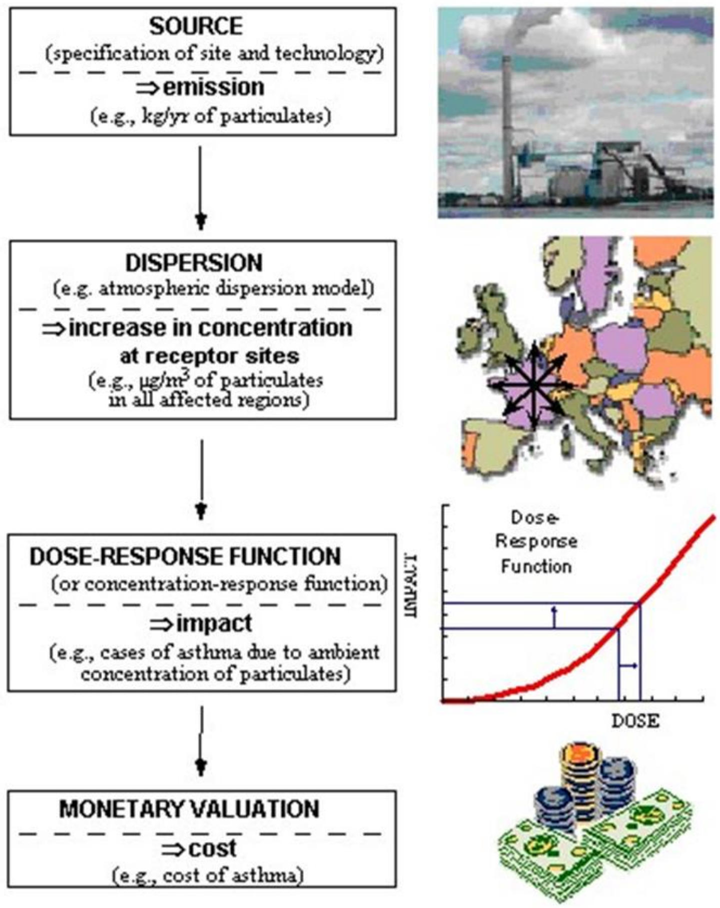
4.6 Multi-disciplinary of the involved experts developing the CBA

4.6.1 Impact pathway

A cost-benefit analysis (CBA) is used to analyse, estimate and compare the future flows of benefits and costs. Whereas the economists typically define the analysis framework, perform monetary valuation techniques and compare benefits and costs for different scenarios, a broad range of other disciplines is required to define scenarios, provide the necessary input data, discuss results and potentially alternative scenario's interesting to explore. Impact assessments in general are preferably performed by multi-disciplinary teams.

An example on how multiple disciplines are required to value benefits is presented for air pollution in figure 6. Technology experts, engineers, GIS specialists and transport modelers are typically involved to predict the impact of policy on emissions caused by households, industry and transportation. Social scientists (sociologists, philosophers) and economists are included to perform the valuation of impacts. This result is used as an input for the dispersion modelling, which is typically performed by climatologists and air quality modelers. The resulting change in air quality (concentration levels at different locations) is typically combined with population data to evaluate differences in exposure levels to air pollution. This is combined with information provided by epidemiologists (dose-response functions for specific health end points) to predict the resulting health impacts and in a final step this is multiplied by unit values per health end point to estimate the monetary health impact. Not all impacts will require the same amount of disciplines, but the set up helps to clarify how a single monetary value presents the result of a multi-disciplinary team effort.

Figure 6: Impact-pathway approach for valuation of benefits of reduced air pollution (Bickel and Friedrich, 2005)



4.6.2 Integrated valuation of multiple types of values to support decision making

Whereas the previous paragraph stresses the importance of involving non-economic experts in the valuation of health impacts and in performing a CBA, this section discusses the importance of involving social scientists in performing a more integrated form of valuation, combining monetary and non-monetary valuation techniques.

Integrated valuation can be defined as a valuation on the basis of a consistent integration of multiple types of value (e.g.ecological, cultural and monetary) to inform decision making processes. Integrated valuation typically involves an interdisciplinary effort comprising multiple expert domains from both the social and the natural sciences (EU FP7 OpenNESS Project, 2014; Jacobs et al., 2016). Inherently, this means combining monetary and non-monetary (or often also called social) valuation techniques. Specific points of attention which distinguishes integrated valuation from monetary valuation is that it relies both on qualitative and quantitative information and that it should feed on different knowledge systems, not necessarily limited to the research community but also considering practicioners and local actors. In practice this means opening up the typical valuation practices towards social network analysis, role playing, photo-elication surveys and all sorts of alternative approaches applied by social scientists. As the concept is still relatively new and the usability of social valuation techniques in combination with monetary valuation techniques still is subject of ongoing research, statements on the applicability for chemical restriction dossiers are difficult to make. In any case, broad stakeholder involvement seems to be an essential part in addition to a typical desktop cost-benefit analysis (Jacobs et al., 2016) which is, if time permits, of added value in all sorts of decision making.

5 Review specific cases from the SACAME project: Formaldehyde (Hunt and Dale, 2017) and Mercury (Dubourg, 2017)

5.1 Economic Valuation in Formaldehyde Regulation

5.1.1 Summary

The study focuses on formaldehyde which was chosen due to the recent and on-going developments in its risk management and regulation especially in the United States in the context of standards for composite wood products and in the EU in the context of REACH substance evaluation. The particular aim is to review available economic assessments for formaldehyde in order to provide the best estimates of the social costs of impacts caused by their production, use and disposal, and to inform on the use of economic valuations related to countries' risk management.

Formaldehyde is used as an important chemical building block in a great number of applications. It is extensively produced industrially worldwide for use in the manufacture of resins, as a disinfectant and fixative and as a preservative in consumer products. Sectors, upstream forms, intermediate uses and end products that contain formaldehyde are situated in the construction, automotive, aircraft, clothing and healthcare industries. The global formaldehyde market was valued at about USD 10.9 billion in revenue generated in 2011. Possible health hazards relating to formaldehyde, include acute and chronic effects. Of particular note is its classification as a human carcinogen (Group 1) by IARC based on evidence of nasopharyngeal cancer and myeloid leukaemia. Evidence on environmental risks from formaldehyde is more scarce than for health risks. Existing evidence suggests that typical releases of formaldehyde are unlikely to affect plants and wildlife in the vicinity since it is quickly removed from the air by reaction in the atmosphere and broken down in water and soil.

To quantify the benefits of restrictions of Formaldehyde few studies exist. The most comprehensive assessment of social benefits of regulation, and one of the only such studies focusing on formaldehyde found in the literature review, was undertaken for the US regulation of composite wood products, cf. US EPA (2013, 2016). The general approach of this analysis was to predict the number of cases avoided for two health effects (nasopharyngeal cancer and eye irritation) and monetises the benefits. Total human health benefits for avoided eye irritation and nasopharyngeal cancer resulting from reductions in formaldehyde exposure attributable to the final rule were estimated as USD 64 million to USD 186 million per year using a 3% discount rate, and USD 26 million to USD 79 million per year using a 7% discount rate. Additional benefits due to avoided myeloid leukaemia, respiratory-related effects and reduced fertility were not quantified due to insufficient information on their relationship with formaldehyde exposure. Some studies have used DALY estimates in the assessment of avoided health impacts due to regulation of formaldehyde. Perouel (2011) estimated a gain of a total of 700 DALYs for three health effects before implementation and 136 after implementation of a restriction scenario. The Schuur et al. (2008) found no DALYs to report for plywood and textiles, and insufficient evidence for cosmetics. Cost assessments are more available. The general approach has been to estimate costs of compliance to industry through, for example, changes to production processes, use of raw materials costs of testing, certification and labelling. The US EPA estimated the costs to laminated product producers of testing, certification, and switching to a resin with no added formaldehyde at USD 26 million to USD 72 million with a 3% discount rate, and USD 26 million to USD 62 million with a 7% discount rate. Economic assessment of regulation of Formaldehyde is in its infancy.

A critical review of the limited studies available (one study in the US - US EPA (2013) and one in the EU - TNO/RPA (2013)) stresses the risk of bias towards over-estimation, given that the businesses that are potentially negatively impacted may have an incentive to exaggerate the cost relative to the benefits. The EU estimates are largely based on responses to questionnaires by some 20 companies. The US estimates are based on extrapolation of unit costs with an unclear origin (assumed to be derived from surveys or limited group of experts). The US EPA study is the only study to include quantitative estimates of benefits in its overall appraisal of the regulations considered. Benefits are also incomplete and unit value estimations for the considered health end points (non-fatal nasopharyngeal cancer) are transferred from other health end points (chronic bronchitis and curable lymph cancer) due to a lack of available values leading to a WTP of USD 0.82 per micro-risk reduction and a high surrogate estimate of USD 5.69. Studies for both fatal and non-fatal health end-points are also rather dated.

A last section of the paper focuses on the benefit estimation and possible updates / improvements. This is focused on the valuation of cancer and eye irritation. For cancer, the survey of the US evidence suggests that a premium of 50% on top of the base VSL currently used may be suitable for cancer-related mortality risk. A second suggestion is focusing on the WTP to avoid a risk of cancer and to use methods which combine morbidity and mortality components to estimate the value of a statistical cancer case (VSCC). A last suggestion is to perform new empirical research deriving WTP for a range of cancers specific to the chemical(s) of interest. For eye irritation, now valued at 16 USD per day, suggestions are made to look at more substantial literature regarding skin irritation (valued at 240USD per acute episode). Also location-specific studies that evolve current stated preference methods should be undertaken. Lastly, there remain a number of health impacts of formaldehyde that are thought to be relevant to regulatory assessment but which – due to lack of epidemiological evidence - are not currently quantifiable. These health impacts include nose/mouth/throat irritation, risks to female fertility, bronchitis, pulmonary function, skin allergies and asthma attacks. It is expected that as epidemiological evidence develops, valuation data for these end-points will be needed.

The conclusion focuses on the limited coverage of the two studies. Due to data limitations, even the most comprehensive study on impacts of formaldehyde regulation (US EPA, 2016[25]) could only value benefits from two health effects whereas the draft 2010 IRIS assessment identified seven categories of potential non-cancer health outcomes from formaldehyde exposure. It is suggested that there currently exist estimates or close proxy estimates for 4 end-points that could be adopted in future analyses. Another important suggestion concerns the geographical scope. Given that there is significant production and consumption of formaldehyde in Asia (shown in Figure 1) and a seeming lack of economic analysis of health impacts it is suggested that economic analysis of both the cost and benefit components be expanded into this region.

5.1.2 Advice - General comments

The two reference studies from the EU and the US, discussed in the paper, are still very limited in scope and set up. **The main conclusion that can be drawn from these studies is that the evidence on costs and benefits provided by these studies is not sufficient to draw conclusions on the future of an 11 billion dollar industry** (annually!). It can be questioned whether this is due to a lack of available data or due to the relatively small research effort (based on the set up reported in the review, I roughly estimate the maximum budget for these studies at 200-500k€) is proportionate to the questions at stake. Compared to public investment decisions of that order of magnitude (e.g. traffic infrastructure) it is fair to say that the research performed is rather minimalistic. Traffic infrastructure investment decisions are mostly supported by environmental impact assessments and cost benefit analyses based on transport model studies (travel costs), estimations of the impact on travel time and emissions, model predictions on how different scenarios will impact air quality and related health effects and related benefit estimations, basically exploring the entire impact pathway based on detailed modeling and if necessary original valuation studies. A quickscan, back of an envelope calculation is always an interesting first step to explore potentially important impacts to examine more in detail, major uncertainties, etc. However, it is a first step. In the formaldehyde case study this seems to be also the final step.

Table 5: overview of data used in two reference studies

Reference	Cost estimation	Benefit estimation
EU: TNO, RPA 2013	Survey data of +/- 20 to 50 companies	No benefit estimation
US: EPA, 2013	Unclear. Probably expert based	2/7 identified health end points valued, values based on benefits transfer from other health end points

Concerning the benefits it would be helpful to start from a long list of potential end impacts to be studies (health, ecosystem, social), get an overview on the different health end points studied in literature, whether they are included in the benefit estimation, and if not, why (no effect found, no effect studies available, no unit values available).

The suggestions made in the review paper focus largely on the estimation of the unit values of the different health end points. Though some valid points are made, I wonder how relevant these suggestions are for decision making purposes. Also here the proportionality principle should be applied. It should be relatively easy to identify comparable health endpoints for which unit values do exist and use these values to identify the relative importance of the specific health endpoint for comparing scenarios. Based on the precautionary principle, there should be little doubt that these other health end points do not lead to an underestimation of the potential health benefits. Using chronic bronchitis as a proxy for non-fatal nasopharyngeal cancer as performed in EPA, 2013 seems to be an underestimation.

The debate on possible improvements should therefore not start from developing new unit values, but from the proportionality principle and the amount of research effort that should be expected depending on the characteristics of the chemical (amount of health end points, size of population exposed, geographical scope, economic importance of the sector, …). How much elements of the impact pathway do we expect to be covered to support decision making and to what extent should this be based on original modeling and valuation studies? (dispersion modeling for different pathways, original valuation studies versus benefits transfer).

An important discussion is also on the distribution of research efforts. Can industry decide themselves on the unit values for different health end points or should it be up to public authorities to pre-define unit values? Pre-defined unit values, combined with specific guidelines on how to perform the cba, would increase the comparability between cases which makes it easier to benchmark. Research efforts performed for specific cases can then also focus more on costs and health/ecosystem impact assessments of the potential restriction scenarios.

5.1.3 Advice - Detailed comments

No detailed comments.

5.2 Economic assessments of the benefits of regulating mercury

5.2.1 Summary

The objectives of the paper are to give an overview of the available economic assessments regarding mercury compounds, to discuss their completeness from a social cost point of view, and to discuss the relative magnitudes of the values attached to mercury compounds in different contexts.

The ability to make this comparison is limited by the significant variations in the complexity of analysis across different studies. A relatively small number of highly complex studies tend to provide results which are used by other, simpler ones. Mercury was chosen to be part of the project because it was judged to provide an opportunity for comparative analysis of valuation approaches between jurisdictions within a more data-rich environment than other chemicals.

Coal-burning continues to be the largest source of mercury emissions in the developed world, although it has been declining in volume over time. Artisanal small-scale gold mining and coal-burning are the largest sources of mercury emissions globally. The majority occurs particularly in south-east Asia, South America and sub-Saharan Africa. The primary routes of human health impacts from mercury exposure are through direct inhalation of mercury vapour, and through ingestion of methylmercury. The former is the primary route for those working in the ASGM sector. The second route is the single major route for public health purposes, since the principal source of ingestion of methylmercury is the consumption of fish. This means that the benefits of mercury emissions reductions are subject to potentially complex pathways, from the source of the emissions to deposition into marine environments, take-up by fish and subsequent human consumption.

The neurological development impacts of foetal exposure to methylmercury through maternal fish consumption is the primary focus (directly or indirectly) of all studies considered in this review. The primary source of evidence for those impacts is three epidemiological studies conducted in the Faroe Islands, New Zealand and the Seychelles. These studies considered various measures of foetal mercury exposure and a range of neuro-developmental outcomes. The focus on neurological development means that the primary measure of economic impact has been the effect of IQ changes on labour market performance. Other potential outcomes associated with neurological development impacts have received comparatively little (or no) consideration. A small number of studies have also considered the possibility of impacts of methylmercury ingestion (via fish consumption) on cardiovascular health in the general population, based on a limited number of small epidemiological studies. The decision to include them or not is important since, even if small, general population changes in cardiovascular risks can have high value when measured in terms of willingness-to-pay for mortality risk reductions ("the value of statistical life"). Lastly, regarding environmental impacts, a review by the US EPA (2011[7]) states that, although numerous studies have been undertaken, many of the resulting data are anecdotal in nature and incomplete.

The literature on existing benefit assessments is led by a small number of relatively detailed studies, which provide the basis for other, simpler pieces. These studies are impact-pathway studies, which consider the processes affecting exposure, from emissions, through deposition, to uptake by fish populations, consumption, generating methylmercury exposure in unborn children and potentially in the general population. The US EPA provided a highly detailed analysis of the impacts of reducing mercury emissions from power stations under the Clean Air Mercury Rule (CAMR) and is the benchmark study. This study combines modelling geographical depositions for different emissions scenarios, estimating changes in fish mercury concentrations, changes in mercury intake for the relevant population at risk, changes in maternal hair mercury, IQ decrements and earnings losses over the population at risk. These values were discounted to reflect the adjustment time between changes in deposition and the content of fish. A whole range of studies is discussed which applied/improved specific steps of this calculation including the consideration of additional exposure routes and health impacts, using the "environmental attributable fraction" to estimate the proportion of this cost which might have been caused by emissions, changing unit values, the functional form of the dose-response function, transferring values to other countries, discussions on whether a discount factor should be introduced to account for ecosystem lags. Also reference is made to a study providing "a clear upper bound estimate", performed by the EPA in 2005, which was again corrected to an even higher value in 2006. Purpose was to conclude that a specific scenario did not pass a benefit-cost test was robust to the most severe stress-testing Rice and Hammitt (2005[10]) is another complex impact-pathway study discussed in detail. It is similar to the US EPA (2005[6]) study in many respects, but differs in some important ways such as not considering time lags between emissions and health impacts, applying other dose-response functions, differences in consumption patterns of fish, other unit values for health endpoints. Spadaro and Rabl (2008) is also discussed in detail as it is one of the few papers to provide an estimate of the mean global costs of mercury exposure based on a fairly simple approach. emissions of mercury vary across the globe, so the ingestion of (exposure to) methylmercury varies in direct proportion, a linear functional exposure-response function an assumed 15-year delay (at 3% per year) between a change in emissions and a change in impacts

Table 6: Present value of the benefits of reducing per capita daily methylmercury exposures by 0.1µg from different studies (Rice et al., 2010)

Rice et al. (2010[24])	5th percentile	USD 1.60 per 0.1µg per capita
	50th percentile	USD 7.30 per 0.1µg per capita
	95th percentile	USD 116 per 0.1µg per capita
Gayer and Hahn (2006[25])	"Low"	USD 1.07 per 0.1µg per capita
	"High"	USD 1.57 per 0.1µg per capita
US EPA (2005[22]) and (2006[23])	5th percentile	USD 1.10 per 0.1µg per capita
	50th percentile	USD 4.67 per 0.1µg per capita
	95th percentile	USD 7.67 per 0.1µg per capita
Spadaro and Rabl (2008[11])	5th percentile	USD 1.07 per 0.1µg per capita
	50th percentile	USD 5.33 per 0.1µg per capita
	95th percentile	USD 26.33 per 0.1µg per capita

None of these other studies includes a valuation of cardiovascular impacts, which presumably is the principal reason why the Rice et al. (2010[24]) estimate is the highest of these four. Rice et al. (2010[24]) noted that the value of cardiovascular benefits was likely to exceed the value of IQ benefits as long as it was judged that the probability that the cardiovascular effect of mercury is true was greater than 10%. This reflects the relatively large size and value of the cardiovascular impact compared with IQ loss.

A number of applications of results of other studies in impact assessments of government regulations governing mercury are also discussed (Canada, Australia, European Union). The

Canadian case demonstrated that though lower estimates of benefits are used, the estimated benefits would still be twice as large as the discounted costs. The Australian case applies a PPP-based GDP ratio to estimate benefits for Australia based on US benefits estimations. The resulting benefits are quite high, however attaching a 10-year ecosystem delay to the presented benefits reduces the benefits by +/- 2/3, especially due to the application of a relatively high discount rate (7%). The European applications, published by ECHA, estimated costs per kg of mercury avoided between zero and over EUR 19 000, with a weighted average of EUR 4 100 per kg. The expected health benefits were estimated based on Rice and Hammitt (2005) of between USD 3 900 and USD 194 500 per kg mercury reduced. No formal comparison of costs and benefits was undertaken.

A final discussion stresses the fact that no studies included environmental endpoints due to the absence of strong evidence. A suggested fall-back is to describe impacts in qualitative terms, thereby excluding them from the socio-economic analysis (implicitly giving them the value of zero) or including them but recognizing their uncertainty e.g. by taking into account probabilities.

Important additional discussion points focus on the geographical and temporal coverage of analyses. Including effects in other countries and taking into account time lags are important considerations which largely influence results. The different studies discussed in this paper apply very different approaches. Also using different dose-response assumptions (particular the slope and functional form, and whether a threshold is employed) can cause values to increase by an order of magnitude (although variation within impact-pathway studies specifically is smaller).

Finally, it is concluded that it is not considered currently possible to make generalisations about the “best values” to be used in future socio-economic analyses. Useful future analysis would undertake a systematic, quantitative assessment of how the various value-relevant parameters affect transferability, and indicate what adjustments might be appropriate to make transfers more accurate.

5.2.2 Advice - General comments

The study provides a very detailed overview of different studies valuing the benefits of regulating mercury. It is examined in detail which methodological steps were taken and how they differ from previous studies.

This case is very different compared to the previous case because of the large data availability and longer tradition in estimating benefits of regulating mercury based on impact-pathway approaches. This provides us with a new challenge: if many studies exist, how to select the best value to estimate benefits of regulation? The study concludes that is currently not possible to make generalisations about the “best values” to be used in future socio-economic analyses, which is a rather disappointing conclusion as this suggests that even for data rich substances socio-economic analyses are difficult, or even impossible to perform.

This is a disappointing conclusion and I do not agree with this. A perfect solution probably does not exist and applying a “zero value” until we find it is not an option. The overview does make it possible to compare the relative magnitudes of the values and check how values are influenced if specific methodological changes are performed. It also allows to identify the entire range of benefit estimates and the outlier studies. If we cannot derive a suitable value range based on this very thorough review, it can be questioned whether this will ever be possible. Estimating the benefits of reducing air pollution is also highly uncertain and a broad range of benefit estimates exists. This has however not prevented their use in policy decision making.

The overview made in Rice et al., 2010 and also presented above suggests that differences between median values are not so significant. It would be interesting to include a similar overview in this study (table) of all estimated unit values and add information on applied methodologies in the different steps of the calculation.

5.2.3 Advice - Detailed comments

An interesting estimate is the EPA, 2005 study providing a “clear upper bound estimate” of USD 168 million. However, already one year later this clear upper bound estimate increased to USD 210 million following a correction to the dose-response calculations. It did not change the conclusion of the cost-benefit analysis. Does it demonstrate that the upper bound was calculated too cautiously? It would be interesting to give some more details about this update and how public authorities respond to this.

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7 Annex

Table 8: Valuation methods and their potential use (TEEB, 2010)

Valuation Technique	Advantage	Disadvantages
Market prices method. Use prevailing prices for goods and services traded in domestic or international.	Market prices reflect the private willingness to pay for wetland costs and benefits that are traded (e.g., fish, timber, fuelwood, recreation). They may be used to construct financial accounts to compare alternative wetland uses from the perspective of the individual or company con-cerned with private profit and losses. Price data are relatively easy to obtain.	Market imperfections and/or policy failures may distort market prices, which will therefore fail to reflect the economic value of goods or services to society as a whole. Seasonal variations and other effects on prices need to be considered when market prices are used in economic analysis.
Efficiency (shadow) prices method. Use of market prices but adjusted for transfer payments, market imperfections and policy distortions. May also incorporate distribution weights, where equa-lity concerns are made explicit. Shadow prices may also be calcu-lated for non-marketed goods.	Efficiency prices reflect the true economic value or opportunity cost, to society as a whole, of goods and services that are traded in domestic or international markets (e.g., fish, fuelwood, peat).	Derivation of efficiency prices is complex and may require substantial data. Decision-makers may not accept 'artificial' prices.
Hedonic pricing method. The value of an environmental ame-nity (such as a view) is obtained from property or labor markets. The basic assumption is that the observed property value (or wage) reflects a stream or benefits (or working conditions) and that it is possible to isolate the value of the relevant environmental amenity or attribute.	Hedonic pricing has the potential to value certain wetland functions (e.g., storm protection, groundwater recharge) in terms of their impact on land values, assuming that the wetland functions are fully reflected in land prices.	Application of hedonic pricing to the environmental functions of wetlands requires that these values are reflected in surrogate markets. The approach may be limited where markets are distorted, choices are constrained by income, information about environ-mentтal conditions is not widespread and data are scarce.
Travel cost approach. The travel cost approach derives willingness to pay for environmental benefits at a specific location by using information on the amount of money and time that people spend to visit the location.	Widely used to estimate the value of recreational sites including public parks and wildlife services in developed countries. It could be used to estimate willingness to pay for eco-tourism to tropical wetlands in some developing countries.	Data intensive; restrictive assumptions about consumer behavior (e.g. multifunctional trips); results highly sensitive to statistical methods used to specify the demand relation-ship.
Production function approach. Estimates the value of a non-marketed resource or ecological function in terms of changes in economic activity by modeling the physical contribution of the resource or function to economic output.	Widely used to estimate the impact of wetlands and reef destruction, deforestation and water pollution, etc., on productive activities such as fishing, hunting and farming.	Requires explicit modeling of the 'dose-response' relationship be-tween the resources and some eco-nomic output. Application of the approach is most straightforward in the case of single use systems but becomes more complicated with multiple use systems. Problems may arise from multi-specification of the ecological-economic relationship or double counting.

Valuation Technique	**Advantage**	**Disadvantages**
Constructed market techniques. Measure of willingness to pay by directly eliciting consumer preferences.	Directly estimates Hicksian welfare measure – provides best theoretical measure of willingness to pay.	Practical limitations of constructed market techniques may detract from theoretical advantages, leading to poor estimates of true willingness to pay.
Simulated market (SM) constructs an experimental market in which money actually changes hands.	Controlled experimental setting permits close study of factors determining preferences.	Sophisticated decision and implementation may limit application in developing countries.
Contingent valuation methods (CVM) construct a hypothetical market to elicit respondents' willingness to pay.	Only method that can measure option and existence values and provide a true measure of total economic value.	Results sensitive to numerous sources of bias in survey design and implementation.
Contingent ranking (CR) ranks and scores relative preferences for amenities in quantitative rather than monetary terms.	Generates value estimate for a range of products and services without having to elicit willingness to pay for each.	Does not elicit willingness to pay directly, hence lacks theoretical advantages of other approaches. Being qualitative, can not be used directlyin policies (say for fixing cess, taxes etc.)
Cost-based valuation. Based on assumption that the cost of maintaining an environmental benefit is a reasonable estimate of its value. To estimate willingness to pay:	It is easier to measure the costs of producing benefits than the benefits themselves, when goods, services and benefits are non-marked. Approaches are less data and resource-intensive.	These second- best approaches assume that expenditure provides positive benefits and net benefits generated by expenditure match the original level of benefits. Even when these conditions are met, costs are usually not an accurate measure of benefits. So long as it's not clear whether it's worth it to replace a lost of damaged asset, the cost of doing so is an inadequate measure of damage.
Restoration cost (RSC) method uses costs of restoring ecosystem goods or services.	Potentially useful in valuing particular environmental functions.	Diminishing returns and difficulty of restoring previous ecosystem conditions make application of RSC questionable.
Replacement cost (RPC) method uses cost of artificial substitutes for environmental goods or services.	Useful in estimating indirect use benefits when ecological data are not available for estimating damage functions with first-best methods.	Difficult to ensure that net benefits of the replacement do not exceed those of the original function. May overstate willingness to pay if only physical indicators of benefits are available.
Relocation cost (RLC) method uses costs of relocating threatened communities.	Only useful in valuing environmental amenities in the face of mass dislocation such as a dam project and establishment of protected areas.	In practice, benefits provided by the new location are unlikely to match those of the original location.
Preventive expenditure (PE) approach uses the costs of preventing damage or degradation of environmental benefits.	Useful in estimating indirect use benefits with prevention technologies	Mismatching the benefits of investment in prevention to the original level of benefits may lead to spurious estimates of willingness to pay.

Valuation Technique	Advantage	Disadvantages
Damage costs avoided (D) approach relies on the assumption that damage estimates are a measure of value. It is not a cost-based approach as it relies on the use of valuation methods described above.	Precautionary principle applied here	Data or resource limitations may rule out first-best valuation methods.

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