Methodologies for monetary valuation of environmental impacts
- State of the art

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Introduction

The need for a better environment is today acknowledged in society and numerous actions have evolved with the intention of promoting a sustainable development. Over the past years the interest for monetarizing environmental impacts has increased around the world. This can be seen in the internalization trend as well as in business strategies. The understanding of how externalities will affect future business is unknown, but sooner or later someone has to pay for the external costs. Depleted ecosystems will affect future business performance and in the future firms may have to pay (i.e. compensate) for the services that nature provides for "free". Considering depleted ecosystems today can lead to future advantages in terms of reduced business risk, costs and savings. Companies that recognize and address external costs today may not only endure when paying for them becomes a reality but also to prosper (KPMG, 2012).

Today, many methodologies and reports about valuation of externalities can be found. These have been developed for different reasons with different aims and goals. To better understand how to use them it has been of high value to provide an overview of some of the most common methodologies and reports that calculate external costs, which has been the aim of this report.

This report has been developed within the Swedish Life Cycle Center's working group "Get the prices right", with financial support from VINNOVA, Sweden's innovation agency. Fourteen different methodologies and reports for monetary valuation of externalities have been studied, which are:

- ASEK
- Eco-cost 99
- Ecotax02
- Ecovalue12
- EPS2000d
- ExternE/NewExt/Needs/EcoSenceWeb
- LIME
- PUMA – Environmental Profit and Loss Account
- Stepwise 2006
- Stern Review
- TEEB – The Economic of Ecosystem Systems and Biodiversity

We have included methods such as the EPS system as it is one of the first monetary valuation methods developed. ExternE and its following methods[1] are included because they are the most common methods for monetary valuation of externalities in Europe. Further, Ecotax02 and Ecovalue12 are included because they are Swedish methods, whereas the LIME method is included in order to give an example of a non-European method. Moreover, two reports, the Stern Review and The Economics of Ecosystem and Biodiversity (TEEB), have been

[1] NewExt, NEEDS and EcoSenceWeb

included, although they are not general methodologies, they have made a valuation of the costs and risks of climate change and biodiversity, respectively. In addition, we have included Puma's Environmental Profit& Loss in which Puma have estimated their environmental impact in monetary terms.

The analysis showed that different methodologies and reports provide different kinds of information. The methodologies and reports consider a wide range of different midpoint[2] and endpoint impact categories but there are some similarities. *Acidification, Eutrophication and Global warming, Human toxicity and Ozone* where considered important midpoint impact categories by all LCA midpoint models and *Human Health and the Environment* where considered important by all LCA endpoint models. Further the analysis showed wide differences in spatial boundaries and in the choice of Environmental valuation method. Lastly, we summarized the different CO_2 values found in the methodologies and reports to give an overview on how the reports value it.

Stern and TEEB argue for immediate action otherwise there will be impacts on the climate system that are irreversible.

[2] The definition of midpoint and endpoint impact category can be found on the next page.

Terms and definitions

Terms	Explanations
CBA	Cost-Benefit Analysis
Characterization factors	Factor that an inventory flow is multiplied with to get an impact category result
CO_2	Carbon dioxide
Damage cost	A monetary value ascribed to damage
Discounting	Interest rate used when assessing the present value of future impacts
Elementary flows (emissions and resources)	Material or energy entering the system being studied that has been drawn from the environment without previous human transformation, or material or energy leaving the system being studied that is released into the environment without subsequent human transformation
Environmental damage	A change in environment that is experienced as negative
Environmental damage cost	A monetary value ascribed to an environmental damage
Equity	Do all humans have the same economic value (=yes) or are the values specific to primary statements so that people with low income get a lower value (=no)
External cost	Cost of an externality
Externalities	1) A consequence of an economic activity that is experienced by unrelated third parties. An externality can be either positive or negative; 2) In economics, an externality, or transaction spillover, is a cost or benefit that is not transmitted through prices in that it is incurred by a party who was not involved as either a buyer or seller of the goods or services causing the cost or benefit. The cost of an externality is a negative externality, or external cost, while the benefit of an externality is a positive externality, or external benefit
GHG	Greenhouse gas
Impact categories (endpoint):	Class at endpoint level representing environmental issues of concern to which life cycle inventory results may be assigned. The endpoint level represents typically issues that may be experienced and observed by laymen in everyday life, such as mortality and decreased harvests
Impact categories (midpoint):	Class at midpoint level representing environmental issues of concern to which life cycle inventory results may be assigned. Midpoint level is typically representing a mechanism where several substances may contribute to the same impact, e.g. acidification or global warming
Intended application (Goal)	As requested in ISO 14044: for what use is the LCA intended?
Intended audience (Scope)	As requested by ISO 14044: for whom is the LCA made?
LCA	Life Cycle Assessment
LCIA	Life Cycle Impact Assessment
Life cycle assessment (LCA)	Compilation and evaluation of inputs, outputs and the potential environmental impacts of a product system throughout its life cycle (ISO 14040)
Monetarization	Monetary valuation

Safe guard subjects	Areas worth protecting, such as human health
Spatial boundaries of impact models	Area/boundary for which impacts are modeled
Temporal boundaries of impact models	Time period for which impacts are modeled
Traceability (Transparency of results)	It the method published and easily available? Is it well structured and using consistent modeling?
Type of value (based by)	E.g. market value, willingness to pay (WTP), prevention costs, etc.
Unit	Unit in which external cost is expressed
VOLY	Value of life year
VSL	Value of a statistical life
Weighting factors	Factor that an impact indicator is multiplied with to get a weighted result; here an external cost
Whose value	Group for which the values are representative
WTP	Willingness To Pay

Method

This report gives an overview of the most common methodologies and reports that calculate external costs. Focus has been on existing methodologies and reports that are publicly available. The selection has resulted in a wide mixture of methodologies; some are specified on product and design others on economies. The aim of this report is to help firms and organizations to be better informed about which methods they can use when evaluating their external costs in order to lower risk and support them to be more competitive over time.

There are many impact assessment models and this report does not aim at describing all existing methodologies. The selections of methodologies included in this study were chosen during meetings with the Swedish Life Cycle Center's working group "Get the prices right". The working group agreed on these fourteen methodologies and reports as they were considered as the most known and useful. The information was gathered through a literature review.

We have not taken a stand on whether one method is superior to all others; instead the aim of the report is to provide guidance on which method or report that might best suit your firm's or organization's needs. Thus, the report describes the methodologies and reports in the most informative way possible for non-experts.

In order to get an indication and to simplify the comparison of different methods to estimate external costs for use in, or as used for, weighting in LCA, a matrix has been developed where different methodological features are shortly described. The features are chosen to be of importance for the weighted result of an LCA and to be in line with the recommendation and requirements of the LCA framework standards (ISO 14040 and 14044). In this way you can look up what kinds of variables the different methodologies have and then suit them up against you firm or organization's choice.

Below is a short description of the fourteen methodologies and reports. Each methodology or report has a short background description, a description of the method and results. In most cases we have also been able to present criticisms of the different methodologies and reports (this has not been found for all methods). The section begins with an analysis of ASEK and is followed by thirteen other methodologies and reports (in alphabetical order) assessing environmental impacts.

ASEK

Since the mid-1980s efforts to develop methods for economic valuation of air pollution effects on health and the environment have been conducted in Sweden. In the mid-1990s a Swedish method was developed by Arbetsgruppen för samhällsekonomiska kalkyl- och analysmetoder (ASEK). The work was to begin with led by Statens Institut för Kommunikationsanalys (SIKA), but as of April 2010 ASEK is led by Trafikverket[3]. Today, ASEK is a standard method for economic valuation of air pollution in Sweden. In addition to air pollution ASEK also includes valuation of road safety, noise and the time and cost of freight and passenger traffic.

The purpose of ASEK is to create a common platform for consistency and comparability of economic analysis within various parts of the transport sector. ASEK gives recommendations on calculation values and methods that should be used by transport agencies. ASEK is among responsible for proposing cost-benefit methods for analyzing different types of measures in the transport sector and to recommend the input that will be used for traffic forecasts and economic analysis (Trafikverket.se).

Method

The method and the costs used in ASEK are based on results from the SHAPE[4]-project (Stockholm Study on the Health Effects of Air Pollution and their Economic Consequences) and Leksell (1999[5], 2000) (Forslund et al., 2007). ASEK uses different methods for calculating external costs from air pollution at local and regional scale.

Air pollution at local levels[6] mainly includes the economic valuation of health effects. The valuations have been conducted by applying the Impact Pathway Approach (IPA)[7] which was developed in ExternE, including a dose-response relationship, exposure and value of a statistical life (VSL). The calculations on local levels (i.e. not Stockholm, since those values are found through SHAPE) are made in two steps; in the first step the number of individuals who are exposed to an annual increase of substance 1 µg/m3 per kg emission is calculated. Thereafter, the number of people who are exposed is multiplied by a certain emission value (e.g.1.8 for NO_X), giving the following formula; SEK/kg emission = specific exposure * value/exposure unit.

The regional effects[8] measured in ASEK consist of both direct and indirect effects of air pollution. The indirect effect arises because the primary air pollutants undergo chemical reactions in the ambient air and are converted to new substances i.e. secondary air pollution. In contrast to the local effects the regional effects include besides health effects also effects on the ecosystem i.e. acidification and eutrophication (SIKA, 2008).

[3] Beside trafikverket representatives from Naturvårdsverket, Sjöfartsverket, Svensk kollektivtrafik, Transportstyrelsen, Vinnova and Trafikanalys
[4] The values from the SHAPE-project only give results for the Stockholm region
[5] Leksell (1999) estimates the values using WTP
[6] How pollutants affect people living in rural areas are not included in ASEK's valuation.
[7] A more thorough analysis of the Impact Pathway Approach can be found under ExternE
[8] Effects arising from air pollution in the range of 10 to 1000km from the emission source.

The regional effects calculated in ASEK differ from the IPA in the sense that they are not based on the effects that a particular emission causes, instead they are determined through politically set goals to achieve Swedish environmental objectives (Leksell, 1999). Thus, the abatement costs do not properly reflect the cost that different pollutants fuel causes. Instead, they are a "second best" solution for situations where it is not possible to calculate the cost of the damage that a particular emission causes (Lindblad, 2011).

Results

ASEK provides values as a number of scenarios represented by Stockholm, Uppsala, Falun, Södertälje and Laholm. The calculated values in ASEK are externalities in urban areas given in SEK per kilo. The valuations show the value on health effects due to changes in emission and to some extent also the value of pollution, degradations and effects on ecosystems.

Table 1: ASEK

Safe guard subjects	Human, ecosystems and materials
Impact categories (midpoint):	Acidification and eutrophication
Impact categories (endpoint):	Mortality and morbidity
Elementary flows (emissions and resources)	Particulates, SO_2 NO_2 and VOC
Spatial boundaries of impact models	Sweden
Temporal boundaries of impact models	Not specified in this method
Discounting	A discounting rate of 4% is used
Unit	Swedish Kronor (SEK)
Type of value (based by)	Damage cost for local effects and through politically set goals to achieve Swedish environmental objectives for regional affects i.e. abatement costs
Whose value	Swedish inhabitants
Equity	No equity considerations found
Intended application (Goal)	ASEK gives recommendations on calculation values and methods that should be used by transport agencies. ASEK is among other things responsible for proposing cost-benefit methods for analyzing different types of measures in the transport sector and to recommend the input that will be used for traffic forecasts and economic analysis
Intended audience (Scope)	Policy making in transport sector
Traceability (Transparency of results)	Published, but the data lacks transparency which makes it is difficult to follow the calculations with the current method. This also makes it almost impossible to continuously update the model with new research

Criticism

The ASEK-method has been criticized for not being able to obtain reliable calculations on particulates and nitrogen oxides. But it is the lack of transparency that is the biggest problem with the method. This has been identified by among others Forslund et al (2007), Melin and Nerhagen (2010) who argue that it is difficult to follow the calculations that have been made with the current method. This makes it almost impossible to continuously update the model with new research.

Other concerns include coarse particulates, which are not included in ASEK, yet. This is of huge concern as research has shown that these types of pollutants can have severe health effects in particular in Sweden where studded tires periodically lead to very high levels of coarse particulates in urban areas.

In addition, the ASEK-method is outdated and the values have not been changed since the proposal was developed by Leksell (1999). An update should include accurate estimates and calculations of concentrations and exposure (Lindblad, 2011).

References

Forslund, J., Marklund, P-O., Samakovlis, E. (2007). Samhällsekonomiska värderingar av luft – och bullerrelaterade hälsoproblem – en sammanställning av underlag för konsekvensanalyser. Specialstudie nr. 13, december, Konjunkturinstitutet.

Leksell, I.(1999). Ekonomisk värdering av luftföroreningar från trafiken. Del 1. Värdering av exponeringar samt sammanfattning. Underlag till ASEK, SIKA Rapport 1999:6.

Lindblad. M. (2011). Värdering av luftföroreningar från transporter. ”Möjligheter till uppdatering av metod och underliggande data för Sverige”.

Mellin, A. and Nerhagen, L. (2010). Health Effects of Transport Emissions – A Review of the state of the art of methods and data used for external cost calculations. Centre for Transport Studies Stockholm.

SIKA. (2008). Samhällsekonomiska principer och kalkylvärden för transportsektorn: ASEK 4, SIKA PM 2008:3.

Trafikverket.se

Eco-cost 99

The complexity of interpreting and communicating Life Cycle Assessment (LCA) results to others (e.g. designers, politicians and governments) than experts has led to the development of a new model. The *Virtual Pollution Prevention costs 99* is a single LCA-based indicator for the environmental burden i.e. an indicator that shows to what degree a product throughout the life cycle does not fulfill the requirements of a sustainable society (Vogtländer& Bijma, 2000). The model was developed by Vogtländer& Bijma in 2000 and has been designed on the basis of two criteria; the model should be easily understandable to non-specialists and the model must be "transparent" for a specialist (i.e. experts can follow the steps of the calculations and judge if they agree on the data used). The eco-cost is applied by designers and engineers as a decision-making tool to find the best product design in terms of ecological impact or to find the best sustainable strategy.

Through an estimation based on technical measures to prevent pollution and resource depletion to a sustainable level, the eco-cost was developed. The eco-costs are "virtual" costs, meaning that these costs are related to the degree of action that is needed to make a product[9] in line with earth's estimated carrying capacity (Vogtländer& Bijma, 2000). The estimation of eco-costs is based on a "what if we already had taken the measures now" condition, thus, they relate to the present and not the future. Therefore, the eco-costs can be regarded as "hidden obligations" and not external costs (Vogtländer& Bijma, 2000).

Method

The calculation of eco-cost was done by taking into consideration both the direct and indirect[10] environmental impacts. With the eco-cost system calculations for end of life and recycling can be computed. The model is based on *marginal prevention costs*, i.e. the maximum costs of a list of selected measures which are assumed to be sufficient to create a sustainable situation. The marginal preventions costs are assessed for seven impact categories[11] on the basis for prevention measures (West European price levels) which are based on readily available technologies at current price levels (Vogtländer& Bijma, 2000).

For instance for global warming, one of the seven impact categories, 114€/1000kg CO_2 equivalent has been proposed as marginal prevention cost to reduce GHG: s. At this price level a list[12] of technically applicable and non-applicable measures are shown. For instance at this price level (114€/1000kg CO_2) the Kyoto norm can be met at 80€/1000kg CO_2 equivalent and renewables at a price level of 80-114/1000kg CO_2 equivalent. However at this price level some measures are not feasible, like biofuel for cars (140€/1000kg CO_2) and Photo Electric Cell (660€/1000kg CO_2) since both measures exceed the marginal prevention cost. These values reflect current best practices and are available as choices to the transition towards a

[9] I.e. pollution and material depletion
[10] Two main indirect components; labour (environmental impacts of office heating, lighting, computers etc.) and production assets (transport vehicles, equipment, buildings etc.).
[11] The impact categories can be found on the next page.
[12] The list applies to the Netherlands, but the list for Western Europe is very similar.

sustainable society, but with future research[13] the values can be modified (Vogtländer& Bijma, 2000).

Results

The list is a summary of prevention measures to reduce emissions that are technically feasible at current price levels. The results of preventions costs can then applied in the design of products and or service systems (Vogtländer& Hendriks, 2004). In this way the eco-costs allows you to compare the sustainability of numerous product types with the same function. The model has been updated twice in 2007 and 2012.

Table 2: Eco-cost 99

Safe guard subjects	There are no safeguards in this method
Impact categories (midpoint):	The impact categories in this study are; Acidification, eutrophication, heavy metals, carcinogenics, summer smog, winter smog, global warming
Impact categories (endpoint):	There are no endpoint impact categories in this method
Elementary flows (emissions and resources)	Comprehensive list of emissions and resources
Spatial boundaries of impact models	Netherlands and Europe
Temporal boundaries of impact models	Not included in this method
Discounting	Not included in this method
Unit	The monetary values are given in €
Type of value (based by)	A prevention cost is used, i.e. a cost to prevent emissions which is assumed to be sufficient to create a sustainable situation
Whose value	Netherlands and western Europe inhabitants
Equity	Not included in this method
Intended application (Goal)	The results of preventions costs are then applied in the design of products and or service systems
Intended audience (Scope)	The intended audience is the government, companies and consumers/citizens to make the right decisions that will support a sustainable society
Traceability (Transparency of results)	Published, and easy to find

[13] Future meaning everything after 1999.

Criticism

In the framework of this project we have not been able to find any critical reports. However several features may be questioned, like the use of the Kyoto agreement as a measure of sustainability, and the use of abatement costs as measures of external costs.

References

Vogtlander. J.G & Bijma.A.(2000). The 'Virtual Pollution Prevention Costs ‘99'. A Single LCA-Based Indicator for Emissions.

Ecotax02

The Ecotax02 is a method developed by Johansson, (1999)[14] that examines a new set of weighting factors within LCA for different impact categories[15] using Swedish environmental taxes and fees. The aim is to use environmental taxes and fees, which are based on political decisions, to make a quantitative valuation of the environment. The different environmental taxes and fees in the Swedish tax system are linked to an impact category to make a valuation method for LCA (Johansson, 1999). The taxes and fees are expressions of the willingness to pay (WTP) society puts on resource use and emissions.

Method

The weighting is conducted using nine different impact categories and linking a tax or fee on a relevant substance to the impact category in order to get a reference equivalent weight.

Example: to reduce emissions of CO_2, a tax has been set for fossil fuels and a valuation weighting factor between 0.09-0.37[16] SEK/kg CO_2. The tax on CO_2 is used as reference for Global Warming Potential (Johansson, 1999).

In some cases recalculations have to be made.

For example: a substance valuation weighting factor is combined with different characterization factors in order to obtain a monetary weighting factor that is directly applicable e.g. an emission of 1kg methane is equivalent to 56kg of carbon dioxide over a 20 year time. Thus, using the valuation weighting factor for carbon dioxide one can calculate the value of methane (56SEK/kg* 0.37SKr/per kg) = 21 SEK/kg (Johansson, 1999). This value is a one-step weighting factor that can be used in the life cycle inventory. In this way Johansson (1999) presents a method which collects values that are solely derived from taxes and fees.

The method has been updated twice, the original was named Ecotax98, the second update was Ecotax02 (Eldh, 2003) and the third and latest update was Ecotax12[17]. The updates include recalculations of the weighting factors and the weighting of reference values. This is due to changes in laws and regulations (Eldh, 2003).

Results

To test the method it was applied to three case studies, and a comparison to the existing weighting sets, Ecoindicator99 and EPS2000 was conducted. The idea was to evaluate what the different weighting sets identify as the most important environmental impacts due to environmental impacts from the waste management, agriculture and grenade. The results show that the political Ecotax02 estimate suggests that toxicological impacts, resource issues and climate change are the most important environmental problems associated with the Swedish waste management system. For the agricultural production system it finds eutrophication as key problem and in the third case (grenade) it finds toxicological impacts as the dominating environmental problem. Whereas for instance EPS2000 finds climate change

[14] Ecotax02 is the updated version, the original was Ecotax98.
[15] The impact categories can be found on the next page in the matrix.
[16] This value has been updated to 1.08 SEK/kg CO_2 (2012).
[17] Personal information from Göran Finnveden.

and the use of abiotic resources as the two most important impacts in all three case studies. Ecoindicator99 overall seems to identify resources and the traditional inorganic air pollutants as the most important impacts (Finnveden et al, 2006).

Table 3: Ecotax02

Safe guard subjects	Not included in this method
Impact categories (midpoint):	The impact categories in this study are; Abiotic resources, biotic resources, Global warming, Depletion of stratospheric ozone, Photochemical oxidation, Acidification, Eutrophication, Fresh water aquatic ecotoxicity, Marine aquatic ecotoxicity, Terrestrial ecotoxicity, and Human toxicity
Impact categories (endpoint):	Not included in this method
Elementary flows (emissions and resources)	All that has equivalency figures in used impact categories
Spatial boundaries of impact models	The research and calculations have been based on the Swedish tax system. Thus, it is implemented as mechanism for sustainable development in Europe
Temporal boundaries of impact models	Not included in this method
Discounting	Not included in this method
Unit	The monetary valuations are given in Swedish Kronor (SEK)
Type of value (based by)	Damage cost is based on taking out a tax, based on the Swedish tax system
Whose value	It is argued that the size of the tax or fee reflect the marginal value and not the total value of the environmental asset, meaning society's least willingness to pay to avoid environmental damage
Equity	No equity considerations found
Intended application (Goal)	Weighting factors for Swedish LCA
Intended audience (Scope)	The intended audiences are Swedish LCA practitioners
Traceability (Transparency of results)	The data is traceable, Swedish environmental taxes and fees have been used

Criticism

The Ecotax02 is based on environmental laws and regulations, i.e. taxes and fees and because of this some impact categories will become invalid due to changes in taxes and fees, which do change frequently. Another concern is the lack of taxes and fees in many cases for environmental problems. Further, Zamagni et al (2006) argue that one cannot prove that taxes resemble the external costs, since the real external costs are unknown.

References

Eldh.P. (2003). Ecotax02 – An Update of A Life Cycle Assessment Weighting Method With A Case Study on Waste Management.

Finnveden et al., (2006). Weighting in LCA Based on Ecotaxes Development of a Mid-point Method and Experiences from Case Studies.

Johansson. J. (1999). A Monetary Valuation Weighting Method for Life Cycle Assessment Based on Environmental Taxes and Fees.

Zamagni. A. (2006). Critical review of the current research needs and limitations related to ISO-LCA practice.

Ecovalue12

Ahlroth and Finnveden (2009) have developed a weighting set, i.e. an assessment of impacts from different projects and products. This new weighting set, Ecovalue12[18] converts different impacts to a common unit, which enables a comparison between different impacts. Ecovalue12 uses monetary values based on actual (market price) or hypothetical i.e. stated preference methods to value environmental degradation and depletion (Ahlroth & Finnveden 2011). The values for environmental quality are based on WTP estimates and resource depletion is based on market prices.

The purpose with Ecovalue12 is to develop a weighting set for environmental impacts, based on estimates of loss of benefits due to environmental degradation (Ahlroth & Finnveden, 2009). That is to form a consistent weighting set that is useful in different environmental systems analysis tools like LCA and CBA and to value the damage from different pollutants in a consistent way.

Method

The Ecolvalue12 method is divided into two steps. In the first step, the different emissions and resource uses are aggregated within impact categories[19]. In the second step the impact categories are weighted against each other. Thus, the damage costs estimated with WTP and market prices are used to value the impact categories. The advantage with the method is that this two-step approach only needs to derive valuation factors for one emission or resource use in each impact category (Ahlroth & Finnveden 2011).

Examples:
Global warming has a proposed mean weighting factor of 2.85 SEK/kg CO2-equivalents [20] and a maximum value of 5.6 SEK/kg CO2- equivalents.

Ecovalue08 was updated in 2012 (Ecovalue12) and now includes two new impact categories and updated weighting factors.

Results

To test the method (in this case Ecovalue08) it was applied to three case studies, and a comparison to the existing weighting sets Ecotax02, Ecoindicator99 and EPS2000 was conducted. The idea was to evaluate what the different weighting sets identify as the most important environmental impacts due to environmental impacts from waste management, agriculture and grenade.

[18] The information was found in Ecovalue08 (Ahlroth & Finnveden 2011), but the same information applies for Ecovalue12.
[19] Damage values for Eutrophication, Acidification, and Human health are valued through Contingent Valuation (CV). Whereas Global warming and Depletion of abiotic resources are valued through market prices, Forming of tropospherical ozone is valued by both contingent valuation and market prices (The health impacts are valued with CV studies, and the crop losses are valued with market prices)
[20] These values are from Ecovalue12.

The results show that overall the political (Ecotax02) and the individual WTP (Ecovalue08) estimates find a similar ranking of impacts, whereas the two other methods identify different impact categories as the most important factors (Ahlroth & Finnveden, 2009).

Table 4: Ecovalue12

Safe guard subjects	There are no safe guard subjects specified in this method
Impact categories (midpoint):	There are 6 different impact categories in this method; Depletion of abiotic resources, Global warming, Forming of tropospherical ozone, Acidification, Eutrophication, Human toxicity, Marine toxicity and Particluates
Impact categories (endpoint):	No systematic list is published. Endpoint categories are determined by the referenced impact models from literature
Elementary flows (emissions and resources)	All that has equivalency figures in used impact categories
Spatial boundaries of impact models	The Spatial boundaries differ: The values for acidification and eutrophication are derived for Sweden, the rest of the impact categories are derived for Europe
Temporal boundaries of impact models	Varying dependent on the study referenced
Discounting	Not specified; dependent on the study referenced
Unit	The monetary valuations are given in Swedish Kronor (SEK)
Type of value (based by)	The estimations of the value of damage are found using stated preference methods and market prices
Whose value	For Swedish inhabitants on the values on acidification and eutrophication. Global market values for the other impact categories
Equity	Not included in this method
Intended application (Goal)	The intended application for estimates of welfare impacts for ex post and ex ante impact assessment. Can be used for cost-benefit analysis and weighting of results from LCA, SEA and other tools. It can also be used both as generic point estimates and for site-specific analyses
Intended audience (Scope)	The intended audiences are Swedish inhabitants
Traceability (Transparency of results)	Published. Background report with detailed information on the calculations and assumptions

Criticism

Some uncertainties with the method have been found in the framework of this project. There are no real markets for environmental goods and services; as such the "true" value cannot be captured. The valuation method only gives an estimate of the welfare loss. To test the validation of the values, they compared it to other studies that value the same goods, but it is still difficult to know which of the studies that is closest to the "true" value (Ahlroth, 2009).

References

Ahlroth, S, & Finnveden, G. (2011). Ecovalue08-A new valuation set for environmental systems analysis tools.

Ahlroth, S. (2009). Developing a weighting set based on monetary damage estimates. Method and case studies.

Finnveden, G et al. (2012). New set of valuation factors for LCA and LCC based on damage costs-Ecovalue12.

EPS2000d

The Environmental Priority Strategies in product design (EPS) system was initiated in 1989. The EPS was developed on demand from Volvo Automotive Company and as a co-operation between Volvo, IVL Swedish Environmental Research Institute and the Swedish Federation of Industries.

Method

The EPS system is based on Life Cycle Assessment (LCA) methodology (Steen, 1994). The purpose was to use EPS within the product development process as a tool to help assess the environmental performance of products. EPS is used by companies as a tool for internal product development i.e. to assist designers and product developers on which product that has the least impact on the environment. The idea is to make the designer and engineer aware of their material or process environmental cost, and thus, enable the designer or engineer to choose a design with lower environmental impact (Steen, 1994).

EPS uses inventory data (kg of substance x), characterization factors (impact/kg of substance x) and weighting factors (cost/impact) to calculate the external costs or values of an elementary flow from a product. By multiplying the characterization factor with the weighting factor, an impact index is obtained (cost/kg of substance x), which describes the costs/values related to the emission/resource flow of a certain substance (Westerdahl et al., 2011).

The EPS evaluates the environmental impact on five different safeguard subjects; human health, abiotic stock resources, ecosystem production capacity, biodiversity and cultural and recreational values (Steen, 1994). The EPS2000d method is the third and latest update in EPS system[21].

Results

The EPS calculates actual environmental damages i.e. endpoint oriented modeling[22]. The damage on the five safeguards due to e.g. emissions of CO_2 can be quantified and later valued in order to calculate the valuation weighting factor (i.e. WTP to restore impacts on the five safeguard subjects).

Table 5: EPS2000d

Safe guard subjects	The EPS2000d evaluates the environmental impact using five different safeguard subjects; human health, abiotic stock resources, ecosystem production capacity, biodiversity and cultural and recreational values
Impact categories (midpoint):	Not included in this method
Impact categories (endpoint):	YOLL, Severe morbidity, morbidity, severe nuisance, nuisance; production capacity for crop, fish&meat and wood; Normalized Extinction of Species, commercial minerals, water production capacity

[21] The first version of the model was developed in 1991-92 and the latest update was made in 2000.

[22] The endpoint categories can be found in the matrix below

Elementary flows (emissions and resources)	All with known impacts on defined categories as global averages
Spatial boundaries of impact models	Global
Temporal boundaries of impact models	As long as the impact prevails
Discounting	The discount rate of 0% is used, this means that we as well as future generations are equally worth
Unit	The monetary valuations are given in Environmental Load Unit (ELU) =EUR in WTP
Type of value (based by)	The willingness to pay for damage avoidance
Whose value	The WTP is measured in 1998's OECD population, and applied to all those, who are affected by a change
Equity	Not included in this method
Intended application (Goal)	The intended application is design and product development
Intended audience (Scope)	The intended audiences are design and product developers
Traceability (Transparency of results)	All the data is traceable and easy to find

Criticism

In the framework of this project we have not been able to find any critical reports.

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ExternE / NewExt / NEEDS / EcoSenceWeb

In 1991, European and American experts conducted a joint project, the EC/US Fuel Cycles Study, to evaluate the externalities of energy use (EC, 2005). In1995, a framework assessing external costs of energy technology was completed, named Externalities of Energy (ExternE), in Europe. By combining scientific and economic information the project established an extensive application and is today applied by different types of national studies, to advice e.g. policy makers on environmental, energy and transport policies (EC, 2005).

ExternE

ExternE is a method that internalizes external costs, from various technologies and fuels in the electricity generation, through their production to consumption (i.e. the entire fuel cycle) into monetary values. This enables policy makers to rank different fuels and technologies according to its impact on the environment. In addition, health risks, primarily deaths, have been included in the calculation of external costs (Starfelt &Wikdahl, 2001).

Method – The Impact Pathway Approach

In order to quantify environmental impacts the Impact Pathway Approach (IPA) was developed. The IPA is a bottom-up approach, in which environmental benefits and costs are estimated. The principle is to track the impact from source emission through the chemical transformation effect on receptors such as air, soil and water to physical impact, before being expressed in monetary terms (EC, 2005).

More specifically, there are four steps in asserting the IPA. The first step is the *source of pollutant*, which includes the specific site (e.g. Ringhals) and technology (e.g. power plant) and the amount of emission, (e.g.kg of NOx). The second step is the *dispersion* i.e. the chemical conversion in the atmosphere, which is the quantification of the increased amount of pollutants in the affected areas. The third step is the *dose-response function* which is the effect on different receptors (e.g. population, forest, buildings) to the physical damage that a pollutant causes on a receptor (increased number of hospitalizations). The fourth and last step is the *monetary valuation* e.g. the monetary value of asthma in terms of medical treatment cost and the willingness to pay in order to avoid the residual suffering i.e. welfare loss for the individual (EC, 2005).

Results

In case of morbidity, ExternE estimates costs of various diseases and care efforts. These are summarized from the costs of the disease, cost of illness (COI) and willingness to pay to avoid illness. In most cases COI represents the largest part of the total cost. For instance if the health outcome is *hospitalization for respiratory issues*, the recommended cost has been valued to 2000€/ hospitalization. In case of *doctor's appointment* the recommended cost has been valued to 53€/consultation and *hospital visits for asthma attack* the recommended cost has been valued to 670€/visit.

For *costs for mortality* ExternE uses a value of life year which is estimate to € 50,000. ExternE uses the dose-response relationship where a 5% increase in mortality per concentration increase of 10mg/m3 PM2.5 or PM10. Besides effects on health ExternE also evaluates effects on agricultural crops, ecosystems, buildings and global warming.

Table 6: ExternE

Safe guard subjects	Not included in this method
Impact categories (midpoint):	Not included in this method
Impact categories (endpoint):	Within ExternE, there are seven main endpoint impact categories, human health (fatal and non-fatal), biodiversity, crop yield, material damage (e.g. mechanical weakness and leakage of buildings) and land use, amenity losses and global warming
Elementary flows (emissions and resources)	The ExternE method includes all that of relevance for electricity generation e.g. fuels and technologies as well as the transport fuel cycles
Spatial boundaries of impact models	The research and calculations have been conducted on power generation technologies around different reference sites in Europe. Thus, it is implemented as mechanism for sustainable development in Europe
Temporal boundaries of impact models	Varying, highest for radionuceids, 100000 years
Discounting	In ExternE, the discount rates 0%, 3% and 10% have been used. However, it is argued that none of the three rates are satisfactory with regard to climate change; a discount rate of 3% or 10% lead to a negligible figure in distant future, however a discount rate of 0% can lead to overestimation of damages (EC, 1999)
Unit	The monetary valuations are given in €
Type of value (based by)	Damage cost and a prevention cost are determined, i.e. what is the cost of reducing life years lost (morbidity or premature mortality, due to for example asthma) and the WTP to avoid suffering. (EC, 2005).When valuing the risk of mortality, the cost is determined through the value of prevented fatality (VPF), i.e. the "WTP to avoid the risk of an anonymous premature death". The VPF is used when evaluating accidental deaths. However, when evaluating the cost associated with e.g. air pollution one uses the loss of life expectancy (LE), because it is difficult to prove that one has died only due to the exposition to air pollution. In order to value LE you base it on the value of a life year (VOLY). The recommended values for valuing a life is in the range €1 to 5 million and €50,000 for valuing a life year. Other types of values are Willingness to Accept (WTA) and value of statistical life (VSL)
Whose value	The values represent local inhabitants and Western Europeans respectively
Equity	Not included in this method
Intended application (Goal)	The intended application is to guide policy making in the energy sector
Intended audience	Similarly, the intended audiences are politicians and officials on e.g.

(Scope)	what choice of electricity generation technology to use
Traceability (Transparency of results)	The ExternE is published but changes and updates are made during projects, for example, updates on scientific development or new knowledge on health impacts

NewExt

The New Element for the Assessment of External Costs from Energy Technologies (NewExt) is a follow-up project to ExternE, it was developed with the main objective to improve the assessment of externalities developed in the ExternE project (Preiss & Klotz, 2007).Thereby, support decision making in the field of energy and environmental policy.

NewExt has focused on improving four key areas, which are considered as most relevant for the assessment of external costs, and which are expected to be primarily affected by new scientific findings. These are: an improved method for the monetary valuation of mortality impacts from air pollution, a method for the assessment of effects from multi-media (air/water/soil) impact pathways, a method and a related database for the assessment of externalities from major accidents in non-nuclear fuel chains and valuation of environmental impacts based on preferences revealed in (1) political negotiations (global warming, acidification and eutrophication) and (2) public referenda (global warming) (NEEDS, 2004). The latest update was made in 2004.

NEEDS

New Energy Externalities Development for Sustainability (NEEDS) was a five year project that ended in 2009, the project is based on past work in ExternE and the further developed work in NewExt. The objective of NEEDS was to continue to develop the costs and benefits of energy policies and of future energy systems, both for individual countries and for EU as a whole. NEEDS meant great progress for the state of knowledge in areas of; Life Cycle Assessment of energy technology, monetary valuation of externalities associated with energy production, transportation and conversion.

In addition the IPA developed within the ExternE project was further improved in NEEDS, in terms of atmospheric models, examination of the causal links between pollution and health effects, assessment of biodiversity loss and measurement of environmental and health impacts from fuel extraction and transportation.

EcoSenseWeb

The EcoSenseWeb is a web-based software tool developed as part of the ExternE project in order to analyze single energy sources (electricity and heat production) in Europe. As well as to support the assessment of the environmental impact and resulting external costs that originates from electricity generation (Preiss and Klotz, 2008).

The aim of the EcoSenseWeb was to create a simple system that can perform highly standardized impact assessment with as little data input from the user. The EcoSenseWeb provides all the data except for the technical data of the facility, which the user has to complement (Preiss and Klotz, 2008). The EcoSenseWeb uses the IPA developed in ExternE, further developed by NewExt and the latest development in NEEDS to calculate the external costs resulting from airborne pollutants on endpoint impact categories [23](Preiss and Klotz, 2008).

Criticism

The criticisms to EcoSenceWeb are similar to those of the ExternE, meaning that much of the criticism regards the uncertainty in data and model (e.g. impact on human health and the environment). However, there have been developments made in reducing the uncertainties since ExternE, NewExt and NEEDS and the uncertainties will continue to reduce with on-going research.

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[23] The endpoint impact categories can be found in the matrix

LIME

The Life-cycle Impact assessment Method based on Endpoint modeling (LIME) project was a national Japanese project. The aim was to develop a database that allows industry to conduct reliable LCA and to develop a method that could quantify environmental impacts which comes from the amount of environmental loading in Japan (Itsubo et al., 2004). The LCIA (Life Cycle Impact Assessment) committee in LCA National Project of Japan wanted to develop a Japanese version of the life cycle impact assessment system method. In 2003 LCA National Project launched an own impact assessment system, LIME.

Method

LIME is used to evaluate the damage on different endpoints caused by eleven impact categories[24] within the LIME project. This could for instance be how global warming and resource consumption (impact categories) cause damage on e.g. human health and biodiversity (endpoints). The different endpoint categories are grouped into four areas of protection i.e. four safeguards (human health, social welfare, biodiversity, and plant production).

Furthermore, the monetary valuation in LIME is based on a conjoint analysis where respondents were asked for their WTP to avoid a unit quantity of damage to a safeguard object. The weighting factors developed within LIME are given in Japanese Yen (Itsubo et al., 2004).

Moreover, in 2006 LIME2 was developed, as a revision and improvement of LIME1. LIME2 includes two more impact categories *transport noise* and *indoor pollution* and improvements of representativeness and credibility of weighting factors for integration (based on a panel survey of about 1000 respondents). The aims of LIME2 were to develop new weighting factors which fulfill the following requirements: (1) to accurately represent the environmental attitudes of the Japanese public and (2) to measure the variability between each individual's environmental thoughts and reflect them in the choice of suitable weighting factors (Itsubo et al., 2012).

Results

Several Japanese companies have used LIME for the LCA of their products such as electric and electronic equipment, transport equipment, construction and construction materials. LIME is not only used to measure the environmental performance of products but also measure the environmental performance of companies.

Table 7: LIME

Safe guard subjects	Four safeguard subjects are included human health, social welfare, biodiversity and primary productivity
Impact categories (midpoint):	There are eleven impact categories in this method air pollution, human toxicity, ozone layer depletion, global warming, ecotoxicity,

[24] The impact categories can be found in table 7.

	acidification, eutrophication, ozone creation, land use, waste and resource consumption
Impact categories (endpoint):	Thermal stress, Malaria, Infectious diseases, starvation, natural disasters, Cataract, Skin cancer, Other cancer, Respiratory defects Biodiversity (terrestrial), Biodiversity (aquatic),Plant, Benthos, Fishery, Crop, Materials, Mineral Resources and Energy resources
Elementary flows (emissions and resources)	Not included in this method
Spatial boundaries of impact models	Japan
Temporal boundaries of impact models	Present
Discounting	No information found
Unit	The monetary valuations are given in YEN
Type of value (based by)	WTP to avoid a unit quantity of damage to four different safeguard objects
Whose value	Japanese inhabitants
Equity	There are equity considerations in this method
Intended application (Goal)	The intended application is design and product development
Intended audience (Scope)	The intended audiences are design and product developers
Traceability (Transparency of results)	Difficult only sketchy publication in English

Criticism

In the framework of this project we have not been able to find any critical reports. Lime is as mentioned a Japanese model and there are, only sketchy publications on the method made in English, thus it is difficult to find critic of the method.

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Puma – Environmental Profit and Loss Account

In 2010[25] a team of experts conducted an Environmental Profit and Loss Account (E P&L) i.e. a monetary valuation on the environmental impact of a company's impact from operations and supply chain. The aim with this account was to quantify the environmental impact that Puma's products create throughout the entire supply chain from production to consumption (Puma's E P&L 2011). The E P&L gives managers and stakeholders an understanding of the environmental impacts and where in the supply chain they occur. The account also allows Puma to become more effective in terms of not only their environmental impact e.g. find more sustainable materials, but also in terms of business risks, costs and savings and thereby produce a long-term sustainability program and a business strategy (Puma's E P&L 2011).

Method

The team of experts used an environmental extended input-output model (EIO) and sourcing location information limited to the country level as a model. The E P&L builds on the average of different studies such as TEEB (UN study on The Economics of Ecosystems and Biodiversity) and also other studies of environmental and resource economics (Puma's E P&L 2011).

Results

The results showed that Puma's environmental impact in 2010 was € 145 million, but only €8 million come from their direct operations such as offices, shops, business travels etc. (Puma's E P&L 2011). In addition €13 million was caused by their direct suppliers, shoes, and accessory and apparel manufacturers. Thus, €124 million or 85% of the impact comes from their suppliers and not areas in which they have direct control over i.e. raw material, processing and outsourcing (Puma's E P&L 2011).

These results from the E P&L allows the company to identify and quantify its impacts and select suppliers accordingly so that they can reduce their impacts and thereby take sustainability initiatives.

Table 8: PUMA – Environmental Profit and Loss Account

Safe guard subjects	A three stage process that looks at Puma's supply chains environmental, social and economic impacts
Impact categories (midpoint):	Not included in this report
Impact categories (endpoint):	Not included in this report
Elementary flows (emissions and resources)	The results of the E P&L cover Greenhouse gases, water use, land use, air pollution (PM, NH3, SO2, CO, NOx, VOC and waste disposal
Spatial boundaries of impact models	Countries, where PUMA has its activities and it suppliers i.e. widely distributed over the world
Temporal boundaries of	Not stated

[25] But published in 2011.

impact models	
Discounting	The pure time discount rate of 0% is used, this means that we as well as future generations are equally worth. The overall social discount rate applied in the analysis was 3.4%
Unit	The monetary valuations are given in €
Type of value (based by)	Mixed (damage costs)
Whose value	Average of several studies
Equity	Not included in this report
Intended application (Goal)	The intended application is for Puma to embrace responsibility for its impact on the environment; it can be seen as a corporate social responsibility reporting
Intended audience (Scope)	The intended audiences are Puma and their stakeholders. But also to pave way for other companies to embrace responsibility for their environmental impact and move towards a sustainable approach
Traceability (Transparency of results)	The study uses averages from many other studies, therefore difficult to trace data

Criticism

The concept of the E P&L has received much support and has been seen as an innovative corporate initiative and a reasonable method to case environmental issues for business. However, in order to take the next step in the development phase, Puma's parent company (PPR) brought in a group of experts that reviewed Puma's E P&L.

The expert panel agreed that the E P&L was an excellent first step in developing a sustainable use of natural capital. But that is more of a "backward looking indicator" than a long term indicator of welfare impact (Expert Review, 2012). Further, there were some concerns regarding the use of the extended input output model, the experts argue that the lack of data on national level rather than the preferred location specific data, means that the method relies too much on estimation techniques (Expert Review 2012). The EIO is a very good starting point to calculate impact along an entire supply chain, but not great, more data from suppliers would have been preferable.

Additionally, the experts argue that there lacks transparency in the description of how the model was set up and applied and that the initial approach relied too much on LCA databases and should instead have included more primary data (e.g. from Puma's supply chain beyond Tier 1[26]).

Further, the experts argue that Puma has probably underestimated the profits and losses associated with waste due to the restricted capacity to differentiate between high and low quality practices (Ibid, 2012).

[26] There are four different Tiers in Puma's supply chain and they cover all significant environmental impacts from the production of raw materials through to the point of sale.

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Stepwise2006

Stepwise2006 is a life cycle impact assessment (LCIA) method based on the LCIA methods EDIP-2003 and IMPACT-2002+, but with some modifications (e.g. new impact categories). The purpose with the method is to reduce the uncertainties and incompleteness accompanied with monetarizating environmental impacts.

Method

Stepwise2006 is an endpoint life cycle impact assessment tool that provides impact pathways that result in a physical score for three safeguard subjects; humans, ecosystems and resources. The safeguards are provided by LCIA method "EcoIndicator 99", which through impact pathways found a physical score for each of the three safeguards (Weidema, 2009). In Stepwise2006 the safeguards are re-defined, i.e. the damage categories are measured in Quality Adjusted Life Years (QALY's) for impacts on human well-being, Biodiversity Adjusted Hectare Years (BAHYs) for impacts on ecosystems, and monetary units ($€_{2003}$) for impacts on resource productivity.

The impacts of ecosystems can be expressed in terms of either human well-being (QALY/BAHY) i.e. our well-being that we are willing to sacrifice to protect the ecosystems or monetary units (€/BAHY) (Weidema, 2009). Human well-being can in turn be defined as (€/QALY), this enables an aggregation for all endpoint indicators in a single impact category measured either in QALY or in monetary terms to determine the economic externalities (Weidema, 2009). In this way resources and ecosystem impacts can be expressed in the same units as impacts on human well-being and vice-versa[27] and thus, a comparison can made. As a result a new impact assessment method with an optional choice between QALY and monetary units as endpoint is developed (Weidema, 2009).

Most other studies have combined different methods for monetization. For instance ExternE uses damages values for e.g. health, preferences revealed in political negotiations for e.g. ecosystems and a third mixed approach for other global warming impacts, which increases the risk of inconsistencies (Weidema, 2009). However, by using one indicator, as Stepwise2006 does, it reduces the risk of inconsistency and increases the transparency of the assumptions made.

Table 9: Stepwise2006

Safe guard subjects	There are three safeguards in this method: human, ecosystems and resources

[27] QALY can be converted to BAHY and € and vice versa, in this way one can compare and transform between the different valuations units.

Impact categories (midpoint):	The impact categories in this study are; Acidification, Ecotoxicity, aquatic Ecotoxicity, terrestrial, Eutrophication, aquatic Eutrophication, terrestrial Global warming, Human toxicity, Injuries, road or work, Ionizing radiation, Mineral extraction, Nature occupation, Ozone layer depletion, Photochemical ozone – Vegetation, Respiratory inorganics, and Respiratory organics
Impact categories (endpoint):	Based on impact models of revised versions of Ecoindicator99 and EDIP1997, called Impact2002+ and EDIP 2003
Elementary flows (emissions and resources)	CO_2 CO NO_X $PM_{2.5}$ PM_{10} SO_2 and VOC
Spatial boundaries of impact models	Europe
Temporal boundaries of impact models	Not included in this method
Discounting	No information found
Unit	Either monetary units (€) or QALYs
Type of value (based by)	Damage cost is restricted by personal budget
Whose value	It is argued that the size of the tax or fee reflect the marginal value and not the total value of the environmental asset, meaning society's least willingness to pay to avoid environmental damage
Equity	No equity considerations found
Intended application (Goal)	A new impact assessment method for LCA and CBA
Intended audience (Scope)	The intended audiences are LCA practitioners
Tracebility (Transparency of results)	All the data is traceable and easy to find

Criticism

Unfortunately, in the framework of this project we have not been able to find any critical reports.

References

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Stern Review

The Stern Review (2006) examines the science and economics of global climate change as a guide to develop government policy. The review was conducted on behalf of British chancellor Gordon Brown in order to understand the climate changes effects on future economic activity and how to deal with the economic challenges .

Stern (2006) states that we need to take action today, by delaying action the costs will progressively increase and lead to irreversible impacts on the climate system.

Method

The price we pay to reduce climate change can be seen as a future investment (Stern, 2006). Moreover, the review elaborates about national policy options as well as the role of international agreements, as the climate change is a global problem.

To estimate the climate change damage cost, an Integrated Assessment Model, PAGE2002 is used. The model deals with uncertainty through a 'Monte Carlo' simulation. To estimate the mitigation costs and effects of the transition to low-carbon energy systems, macroeconomic models are used.

Results

The results from the Stern Review (2006) shows that in the case of business as usual, i.e. no action is taken; the costs and risks of climate change will be 5% of global GDP each year. However, it is more likely cost 20% of global GDP each year. This is due to; *equity weighting* i.e. global warming will have more severe impacts on poor countries due to geography, their stronger dependence on agriculture and their vulnerability. *Catastrophic risk* i.e. that the climate system may be more responsive to greenhouse gas emissions than previously thought and *non-market damages* i.e. direct impacts on the environment and human health (Stern, 2006). But, if action was to take place and we were to reduce the emission of greenhouse gases (stabilizing at 550ppm) the damages can be avoided at a cost of 1%[28] of global GDP by 2050 according to Stern (2006).

Stern states that "climate change is the greatest market failure the world has ever seen" (Stern, 2006). Three essential elements are suggested to address the issue; pricing for carbon (tax, trading or regulation), innovation and "action to remove barriers to energy efficiency, and to inform, educate and persuade individuals about what they can do to respond to climate change" (Stern, 2006).

Stern concludes that the results of the science and economics show that we need to act now in order to tackle the consequences of the climate change.

[28] This value has retrospectively been adjusted to 2% by Stern, as he and IPCC underestimate the risk and the speed at which the climate change is occurring.

Table 7: Stern Review

Safe guard subjects	Stern argues that the challenges of the climate change will be severe and our focus should be on promoting a number of safe guards, such as: consumption, health, education and, the environment
Impact categories (midpoint):	This report takes its starting point in one of the midpoint categories: greenhouse gases
Impact categories (endpoint):	The threats from climate change are severe, potentially causing millions of people to suffer from malnutrition and heat stress. Increasing risks of malaria and dengue fever spreading (vector bourne), an increase in sea level due to melting glaciers will increase the likelihood of flooding and declining crop yields. Altering the livelihood by reducing ability to produce or purchase food. Other factors are reduced water supplies, extreme weather such as storms and hurricanes, reduced fish stocks
Elementary flows (emissions and resources)	Stern examines the action needed to reduce emissions from greenhouse gases
Spatial boundaries of impact models	The review adopts a global perspective of the climate change. The climate change is a global problem that needs strong international action
Temporal boundaries of impact models	The review analyses the potential consequences of climate change in the coming 100 years
Discounting	Stern uses a pure time discount rate of 0.1%. This essentially means that we as well as future generations are almost equally worth. Stern's choice of discount rate has been heavily criticized. With Stern's discount rate the costs of the climate change will be much higher than if for example a 3% discount rate, which is the most common, would be used
Unit	$
Type of value (based by)	Market values (real for consumption and estimated by different methods for non-market goods) and control costs
Whose value	Although it is not evident for which group the values are representative, the model most likely represents the values from a western perspective
Equity	The report argues that if society cares about equity, the poor should receive help to adapt and be compensated, as they are the ones that will suffer the most and have least responsibility for past emissions. Thus, Stern argues that we should add equity weighting
Intended application (Goal)	The review aims to guide policy makers to stabilize the emission of greenhouse gases. Stern argues that we need to take action today, by delaying action it will be more costly and lead to irreversible impacts on the climate system
Intended audience (Scope)	The Stern Review intends to guide politicians, officials and the public on the necessities to combat the effects of the climate change, making everyone aware of the problem and to take measures. Because climate change is a global problem it demands global response, a shared understanding is needed in order to tackle the challenge
Traceability (Transparency of results)	The review was published in October 2006, however it is difficult to trace or find specific data and models

Criticism

The first and foremost critique proposed towards Stern's review is his choice of discount rate (Naturvårdsverket, 2007). Stern uses a discount rate of 0.1%, meaning that future generations almost have the same value as current. Most other studies have used a discount rate of 3%. With Stern's discount rate the costs of the climate change will be much higher than if the 3% discount rate would be used. Therefore the critics argue that Stern's discount rate makes the future problems more central today, essentially overestimating the costs of the climate change (Ackerman, 2007) and (Nordhaus, 2007).

Another critique directed towards Stern concerns the total damage due to climate change. Stern argues that the consequences from the climate change will increase gradually and the most severe effects of the climate change will occur in the far future. Critiques argue that Stern underestimates the risks and speed of the climate change, thus failing to predict that the damages have already begun. Professor Bill Mcguire argued that "the scariest thing about the Stern report is that it may not be scary enough" (BBC news). Stern later responded to the criticism of the Review (Planetark, 2008) admitting that he indeed underestimated the risks and the speed of the climate change, which led him to revise the costs. His new findings indicate the costs are 2% of GDP instead of the initial 1% reported in the review (Planetark, 2008).

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TEEB - The Economics of Ecosystems and Biodiversity

In March 2007, the G8+5 environment ministers met in Potsdam, Germany. At the meeting, the German Government proposed a global study to analyze the global economic benefit of biodiversity. This proposal was endorsed by G8+5 leaders at the Heiligendamm Summit on 6-8 June 2007. The project was titled The Economics of Ecosystems and Biodiversity (TEEB). Inspired by the Stern Review[29], the loss of ecosystems and biodiversity, and the failure to take protective measures versus the costs of effective conservation was explored (TEEB Interim report, 2008). The study was organized by Sigmar Gabriel, Germany's Minister for the Environment and Stavros Dimas, the European Commissioner for the Environment.

The lack of valuation for nature has according to experts led to degradation of ecosystems and loss of biodiversity (TEEB Interim report, 2008). With this as an underlying cause, the purpose was to evaluate the global economic benefits of biodiversity and the costs of biodiversity loss and ecosystem degradation. In addition, the report presented a substantial economic case for conservation of ecosystems and biodiversity and provided a better understanding of the economic value of ecosystem services (TEEB Interim report, 2008).

Method

The TEEB project is divided into three phases where *Phase I*, which is the one that we have focused on, demonstrates the importance of ecosystems and biodiversity and the consequences to human welfare if no actions to reduce damage and losses are engaged (TEEB Interim report, 2008). *Phase II*, in turn, addresses the challenges from Phase I, i.e. the decline of biodiversity and degradation of ecosystems. In particular, Phase II presents policy makers with the proper tools to integrate the true value of ecosystem services into the decision making and it shows that economics can be a powerful instrument in biodiversity policy. In doing so Phase II provides five deliverables[30], which aim to assess, communicate and mainstream the urgency of action (TEEB Interim report, 2008). *Phase III* focuses on communication and outreach activities, supporting TEEB national and sectorial studies that where inspired by TEEB reports and it also aims to implement TEEB in five developing countries (Europa.eu)

TEEB is not a research project, no new methods have been developed, and they have used a range of methodologies for monetary valuation, for instance, market prices, revealed preferences and stated preferences.

Results

The results of the Interim report show that biodiversity losses will have severe consequences to human health and welfare. More specifically, to the health and welfare of the world's poor, as they are the ones that rely most on ecosystem services (e.g. fishing, animal husbandry,

[29] Stern Review of the Economics of Climate Change presented an economic case for early action on climate change.

[30] D0: science and economic foundations, policy costs and costs of inaction, D1: national and international policy makers D2: decision support for local administrators, D3: business risks D4: citizen and consumer ownership.

subsistence farming). In addition, the loss of biodiversity has also led to the rise on commodity and food prices.

Besides obvious effects of biodiversity loss, e.g. distinction of species, biodiversity provides huge health benefits, and therefore also economic benefits. Despite this knowledge hundreds of medical plants are threatened with extinction and will continue with inaction. Therefore, experts call for action to "secure the future of global healthcare" i.e. business as usual is not an option (TEEB Interim report, 2008).

Further, the report estimates that the loss of natural capital due to deforestation and degradation is US$2-4.5 trillion annually. Other findings include; 11% of the natural areas remaining in 2000 could be lost, due to conversion of agriculture, expansion of infrastructure and climate change. About 60% of coral reefs could be lost, by 2030, due to fishing, pollution, diseases, invasive alien species and coral bleaching due to climate change (TEEB Interim report, 2008).

In summary, inaction is not a solution; we need to take action today. If we continue with a business as usual approach and no polices are adopted the decline in biodiversity and all the related consequences of ecosystem services are not only going to continue but also accelerate to the extent that damage is beyond repairable. Countries should not take decisions that are based on short term gains, instead build foundations for a sustainable development (TEEB Interim report, 2008). The report highlights that there is a need to safeguard our natural capital and to acknowledge that nature has limits and rules of its own. For instance a policy against deforestation is not only cost effective in terms of mitigation but also one that provides a further supply of valuable ecosystem services.

As mentioned in the introduction, the TEEB is not a method but a report, therefore it does not include all the different methodological features.

Table 11: TEEB

Safe guard subjects	There are no safeguards in this report
Impact categories (midpoint):	Loss of biodiversity and ecosystems from land use changes
Impact categories (endpoint):	There are no endpoint impact categories in this report
Elementary flows (emissions and resources)	No elementary flows
Spatial boundaries of impact models	The report adopts a global perspective of the effects on biodiversity and ecosystem
Temporal boundaries of impact models	The review analyses the potential effects of biodiversity and ecosystem loss by 2050, thus the temporal boundary is 50 years
Discounting	The report uses a pure time discount rate of 0%. This means that we as

	well as future generations are equally worth. It is even argued that the discount rate should be negative, on the basis that future generations will be poorer in environmental terms than those living today
Unit	€
Type of value (based by)	Market values (real for consumption and estimated by different methods for non-market goods) and control costs
Whose value	Although it is not evident for which group the values are representative, the model most likely represents the values from a western perspective
Equity	Not included in this report
Intended application (Goal)	The review aims to guide policy makers, local authorities, companies and individuals (e.g. guidance on how to reduce their impact on wild nature) in making decisions with respect to their responsibilities in safeguarding biodiversity
Intended audience (Scope)	The report intends to guide politicians, officials and the public on the necessities to combat the loss of biodiversity and ecosystems
Traceability (Transparency of results)	Phase1 i.e. the Interim report was published in May 2008, the first volume of Phase II was published in October 2011and the other volumes over the course of 2011

Criticism

Unfortunately, in the framework of this project we have not been able to find any critical reports.

References

The Economics of Ecosystems and Biodiversity. An Interim report 2008

Internet sources

<http://ec.europa.eu/environment/nature/biodiversity/economics/ > (2013-06-07)

Analysis and discussion

Different methods can lead to very different results, and consequently different methods can provide different kinds of information to the decision making process (Bengtsson, 2000). In this section we have therefore tried to summarize and analyze the similarities and differences between the methodologies and reports. An overview of this can be found in table 12 below.

The table shows that ASEK, EPS system, LIME and Stern are the only ones that have safeguard subjects and that they all assess costs of impacts to *Human health* and *Ecosystems*. The EPS system and LIME also address costs related to *Biodiversity* whereas ASEK and Stern focus on damages to the *built environment* and effects on *consumption* and *education*, respectively.

Further, there are the large variations on the choices of impact categories between the methodologies. However, there are some similarities all LCA methodologies find; *Acidification, Eutrophication, Global warming, Human toxicity and Ozone,* as important midpoint impact categories. ASEK however only includes *Acidification and Eutrophication*. Ecotax02 does not include land use and biodiversity, instead it uses a variety of toxicity groups. Table 12 also shows that Ecovalue12 is the only method that includes depletion of abiotic resources as midpoint impact category. The endpoint models valuate externalities directed towards an extensive selection of endpoints but they are all similar in the sense that they assess costs of impacts that can affect *Human health* (e.g. infectious diseases and VSL) and the *Environment* (e.g. crop yield, water supplies and biodiversity etc.).

Moreover, the methodologies use different methods for assessing damage costs, but almost half of the methodologies have obtained their values from stated preferences or from revealed preferences (i.e.WTP). While other methods combine a number of different methods for monetarization (e.g. Stepwise2006 and Ecovalue12).

The spatial boundary differs between the methodologies and reports, some are global, and others are limited to Europe, whereas others are limited to a specific country (e.g. Sweden or Japan).

The Stern Review and the TEEB are both reviews that aim to draw attention to the environment. Stern reviews the economics of climate change and TEEB the economic benefits of biodiversity, and the growing costs of biodiversity loss and ecosystem degradation. The two reports both argue that inaction (e.g. business as usual) is not an option. By delaying action the costs will progressively increase and lead to irreversible impacts on the climate system. In addition, all the related consequences of ecosystem services are not only going to continue but also accelerate to the extent that damage is beyond repairable.

Table 82: Different monetarization methods cover different types of economic values:

Methods	Environmental valuation method	Safeguard	Midpoint	Endpoint
ASEK (Sweden)[31]	SHAPE-project and Leksell (1999)	Ecosystems, Human health, Materials	Acidification and Eutrophication	Mortality and morbidity
Eco-cost 99 (Netherlands and Europe)	Marginal prevention costs	No safeguards	Acidification, Carcinogenics, Eutrophication, Global warming, Heavy metals, Summer smog,Winter smog	No endpoint impacts
Ecotax02 (Sweden)	Swedish environmental taxes and fees	No safeguards	Abiotic resources, Acidification, Biotic resources, Depletion of stratospheric ozone, Eutrophication, Fresh water aquatic ecotoxicity, Global warming, Human toxicity, Marine aquatic ecotoxicity, Photochemical oxidation and Terrestrial ecotoxicity	No endpoint impacts
Ecovalue12 (Sweden and Europe[32])	WTP and market prices	No safeguards	Acidification, Depletion of abiotic resources, Eutrophication, Forming of tropospherical, Global warming, Human toxicity and Ozone	No endpoint impacts
EPS2000d (Global)	Environmental damage cost expressed in Environmental Load Unit	Abiotic stock resources, Biodiversity, Cultural and recreational values, Ecosystem production capacity, Human health	No midpoint impacts	Fish&meat and wood Severe morbidity, Morbidity, Severe nuisance, Water production capacity, YOLL
ExternE / NewExt / NEEDS / EcoSenceWeb (Europe)	WTP, WTA and market prices	No safeguards	No midpoint impacts	Amenity losses, Biodiversity, Crop yield, Global warming, Human health (fatal and non-fatal), Land use, Material damage
LIME (Japan)	WTP	Biodiversity, Human health, Primary productivity and social welfare	Acidification, Air pollution, Ecotoxicity, Eutrophication, Global warming, Human toxicity, Land use, Resource consumption, Ozone creation, Ozone layer depletion and	Benthos, Biodiversity (terrestrial), Biodiversity (aquatic), Cataract, Crop, Fishery, Infectious diseases, Malaria starvation, Materials, Mineral Resources and energy

[31] The parenthesis shows the spatial boundaries of the methodologies and reports.
[32] Depends on the impact category, for Acidification and Eutrophication the Spatial boundary is Sweden for other impact categories it is Europe.

			Waste	resource, Natural disasters, Other cancer, Plant, Respiratory defects, Skin cancer and thermal stress
Puma	-	-	-	-
Stepwise2006 (Europe)	QALY, BAHY and €	No safeguards	Acidification, Aquatic ecotoxicity, Aquatic Eutrophication, Eutrophication, Global warming, Human toxicity, Injuries, Ionizing radiation, Mineral extraction, Nature occupation, Ozone layer depletion, Photochemical ozone – Vegetation, Respiratory Terrestrial ecotoxicity	No endpoint impacts
Stern Review (Global)	-	Consumption, Education, Environment and Health	Greenhouse gases	Crop yield, Extreme weather, Fish stock, Flooding, Heat stress, Vector borne diseases and Water supplies,
TEEB (Global)	Market prices, revealed preferences and stated preferences.	-	Biodiversity and ecosystems	-

The monetary weighting factors presented for carbon dioxide in the different methodologies and reports are quite similar in size. However, the comparisons between the CO_2 prices per method, table 13 below, are not meant to be a comparison since the different methods have different prices years. The table just gives a spot on how the method's and report's CO_2 prices are valued. The calculation was made using historical rate in order to give the CO_2 price in the same currency value, and for this we chose Euro.

Table 139: CO_2 comparison between the methodologies and reports.

Methodologies and reports	**CO_2 data found in the reports**	**€/kg CO_2**	**Price year**
ASEK	1.08 SEK/kg CO_2	0.113*	2010
Ecotax02***	1.08 SEK/kg CO_2	0.113*	2010
Ecovalue12	2.85 SEK/kg CO_2	0.298*	2010
PUMA	0.063 €/kg CO_2	0.063	2010
Stepwise2006	0.083 €/kg CO_2	0.083	2003
ExternE	0.019 €/kg CO_2	0.019	2000
Stern	0.085 $/kg CO_2	0.092**	2000
Eco-cost'99	0.114 €/kg CO_2	0.114	1999
EPS	0.108 ELU/kg CO_2	0.108 (ELU/kg CO_2)	1998
LIME	No information found	No information found	

TEEB	No CO_2 costs found	No CO_2 costs found	

*calculated from SEK_{2010} to $EURO_{2010}$ with http://www.oanda.com/lang/sv/currency/historical-rates/
**calculated from $USdollar_{2000}$ to $EURO_{2000\ with}$ http://www.oanda.com/lang/sv/currency/historical-rates/
***updated version: Ecotax02 is updated to Ecotax12, however only for the CO_2 value.

Conclusion

There are many LCA methodologies developed for different fields of application. In this report we have summarized fourteen methodologies and reports that provide monetary valuation of externalities. Table 12 above shows that different valuation methods for LCA consider a wide range of different impact and endpoint categories. It was found that although the methodologies used different valuation methods, WTP-methods were the most common. Furthermore, the spatial boundaries differ between the methodologies and reports.

The two reports, Stern and TEEB, conclude that the science shows that immediate action is necessary to tackle the consequences of the climate change.

References

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