COMPREHENSIVE IN-SUPPLY CHAIN LIFE CYCLE ASSESSMENT OF THE PREVENTATIVE COST-BASED EXTERNALITIES OF PRODUCTS.

An assessment methodology as first step to a sustainable and responsible true price economy: “Oiconomy”

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An assessment methodology as first step to a sustainable and responsible true price economy: "Oiconomy"

Uitgebreide levenscyclusanalyse in de toeleveringsketen van de preventie-kosten gebaseerde externaliteiten van producten.

Een beoordelingsmethodiek als eerste stap naar een duurzame en verantwoorde prijseconomie: "Oiconomy"

(met een samenvatting in het Nederlands)

Proefschrift

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PREFACE

In January 2007, a truck took a right turn, overlooking a cyclist. Two months later, I woke up from coma with my loved ones around me. I remembered a near death experience and a dream of fighting back. Mobility and communication were almost impossible. I only had my loved ones and my own thoughts. I remained hospitalized for about 15 months. But very soon after the accident, my wife and I decided that our old life was over and that we had received the obligation or even opportunity to start a new life. True to that new life, we wrote a letter of forgiveness to the truck driver and got a very positive response by his company, strengthening our belief in love, positivity and new opportunities. I considered my near death experience a "peak experience".

In November 2007, due to a newspaper article about the footprint that my wife, Fenna, had told me about the day before, in another peak experience, I suddenly got an insight looking like spiritual information on the working of the universe, mankind and the earth with the keyword "footprint" and at the same time a kind of instruction of how to develop a system containing the preconditions for a sustainable economy. I immediately called Fenna and got my next important lesson. I could not really explain to her what I had experienced, although it was only minutes ago. The reality of a dream is not that of real life. I lost the spiritual meaning and replaced that with the logic of awake thinking, but at the same time, the dream left a life changing imprint. Such dreams and experiences may well have been the origin of fairytales, myth's and even religions. So, why not listen and do something with it? Practical problem was that at the time I knew nothing about sustainability. I decided to write down my experiences and gradually realized that the course of my life and experience did make more sense for elaborating the idea than I initially thought. That realization gave another positive meaning to the accident.

After my graduation in 1976 as a food scientist at the Wageningen University, I choose a business career, first as product development manager and later as quality assurance manager for several food companies and finally became lead auditor for the Dutch Accreditation Council. During my career I became experienced in the business world and especially in standards, certification and particularly in HACCP (Hazard Analysis and Critical Control Points), a certifiable food safety system that changed global food safety. HACCP requires to analyze all points in food operations where hazards may originate, and thereafter create "critical control points" where it can be made certain that the hazard is prevented. Because suppliers are potential hazards, these on their turn, are also required to demonstrate (e.g. by certification) compliance with the HACCP principles. This way, trickling top-down, almost all food value chains accomplished a huge step towards food-safety with every actor demonstrating HACCP compliance to the next actor. And after major parts of the food value chain adopted HACCP, downstream actors could simply bottom-up select food safety certified suppliers. Why not use a similar system for sustainability? Why not develop a standard and a certification system enabling supply chain actors to, in a uniform and aggregable manner, calculate the extra costs for a fully sustainable and responsible version of their product, in other words, a product without negative impacts on the environment or people?

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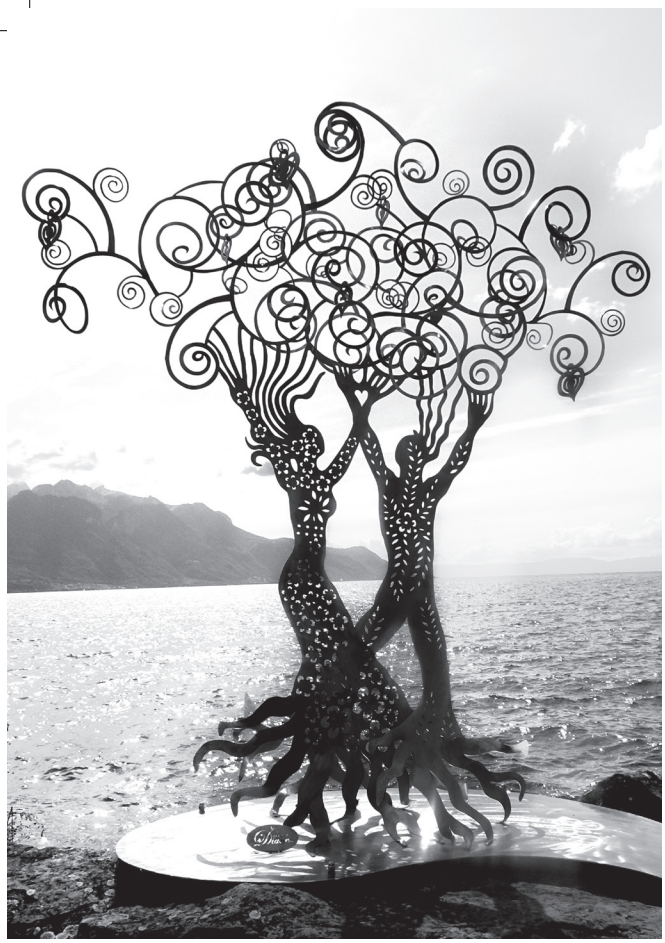
TERMS AND ACRONYMS

AIChE	American Institute of Chemical Engineers
ANS	Adjusted Net SavingsBackground data Averages, from sources other than from the specific supply chain
Bottom Up LCA	A life cycle assessment, using foreground data, starting from origin suppliers and transmitted through the specific supply chain
B2B	Business to Business
CEO	Chief Executive Officer
CO_2	Carbon Dioxide
CSR	Corporate Social Responsibility
C2C	Cradle to Cradle
Comprehensive LCA	LCA,integrating environmental, social and economic aspects
Default data	Data that shall be used in absence of specific data.
Degrowth	A movement with anti-consumerist and anti- capitalistic ideas, focusing
	On the limits of growth
DALY	Disability Adjusted Life Year
EF	Ecological Footprint
LCA	Life Cycle Assessment
EcoCost system	A Preventative Cost-based LCA methodology (abbreviation from EcoCost/Value system)
E-LCA	Environmental Life Cycle Assessment
Endpoint indicator	Indicator on the result for all aggregated sustainability aspect categories
End-producer	The owner/supply chain actor selling the product to the consumer (excluding the retailer)
EPD	Environmental Product Declaration
EPI	Ecological Performance Index
ESCU	Eco Social Cost Unit
eSNI	environmentally Sustainable National Income
ESI	Environmental Sustainability Index
ETR	Environmental Taxation Reform
Externality	Cost or benefit for others than involved in the economic transaction, but including internalities that unwillingly damage consumers, (see chapter 6)
EYR	Emergy Yield Ratio

FAO	Food and Agriculture Organization of the United Nations
FBR	Footprint Biocapacity Ratio
Foreground data	Specific data, obtained from the self-controlled supply chain
GDP	Gross Domestic Product
GEI	Government Effectiveness Indicator
Gha	Global Hectare
GINI	Coefficient Indicator on income inequality
GNI	Gross National Income
GPI	Genuine Progress Indicator
GRI	Global Reporting Initiative
GS	Genuine Savings
HACCP	Hazard Analysis and Critical Control Points
HDI	Human Development Index
HLY	Happy Life Years Index
HPI	Happy Planet Index
HSDI	Human Sustainable Development Index
IEA	International Energy Agency
IIRC	International Integrated Reporting Council
IMF	International Monetary Fund
Internality	Cost or impact that unwillingly affects the customer/consumer
IR	Integrated Reporting
ISEW	Index of Sustainable Economic Welfare
IPCC	Intergovernmental Panel on Climate Change
ISO	International Organization for Standardization
IT	Information Technology
JRC	Joint Research Centre of the European Committee
Km	Kilometer
LCA	Life Cycle Assessment
LCC	Life Cycle Costing
LCIA	Life Cycle Inventory Analysis
LCSA	Life Cycle Sustainability Assessment
MAIR	Maximum Acceptable Inequality Ratio
MEW	Measure of Economic Welfare
Midpoint indicator	Indicator on an individual sustainability aspect category
NAMEA	National Accounting Matrix including Environmental Accounts
NGO	Non-Governmental Organization
OECD	Organization for Economic Cooperation and Development
OHS	Occupational Health and Safety
“Oiconomy”	A sustainable full price economy
Oiconomy Method	The tool for supply chain actors to assess sustainability

Oiconomy	The combined systems to create, maintain and justify the tool Methodology
Oiconomy Project	The project, subject of this thesis
Oiconomy System	The combined Oiconomy methods and methodologies
Oiconomy consumer	Consumer that seeks the lowest price for a sustainable product
O.S.	Oiconomy Standard
PCR	Product Category Rules
PDCA	Plan-Do-Check-Act
PPP	Planet, People, Prosperity
Precautionary	Principle that lack of scientific proof should not be used to prevent Principle when serious damage may be expected
Preventative costs	The precautionary costs, necessary to prevent damage
Product	is used in its widest sense, either tangible or a service
PRP	Performance Reference Point
RoO	Rules of Origin
SD	Sustainable Development
SDG	Sustainable Development Goal
SEEA	System of Environmental-Economic Accounts
SGAP	Sustainability gap
S-LCA	Social Life Cycle Assessment
SMEW	Sustainable Measure of Economic Welfare
Specific product	The product as it is presented to the consumer/user
SSI	Sustainable Society Index
SSI-EcW	Sustainable Society Index - Economic Wellbeing
SSI-EW	Sustainable Society Index - Environmental Wellbeing
SSI-HW	Sustainable Society Index - Human Wellbeing
TBL	Triple Bottom Line
TCR's	Tasks, Competences and Responsibilities
TEEB	The Economics of Ecosystems and Biodiversity
TI	Transparency International
Top-down LCA	A life cycle assessment, using background data for upstream supplychains.
TwH	Terawatt hour
UN	United Nations
UNDP	United Nations Development Program
UNEP	United Nations Environment Program
WBCSD	World Business Centre for Sustainable Development
WRI	World Resources Institute
WWF	World Wildlife Fund



Controlling nature is at the source of human development. Lack of controlling ourselves the end?

An inherently sustainable economy can only exist if both producers and consumers act sustainably out of their own interest.

HISTORY AND STRUCTURE OF THIS STUDY

At the start of my personal research journey in 2008, the Sustainable Development Goals were not yet agreed upon, Social Life Cycle Assessment was still in its infancy and by lack of internet in the hospital, I was still unaware of Life Cycle Assessment and the EcoCost system (Vogtländer *et al.*, 2000). I developed the first version of the "Oiconomy Standard", based on my long experience as quality assurance manager and auditor and my knowledge of HACCP (ISO, 2005) and various ISO standards. Returned from hospital, I investigated the potential of the idea and joined People 4 Earth for a period, an organization striving to serve as facilitator and accelerator for sustainable development in food supply chains, that at the time was developing product sustainability standards. In 2013, it became a PhD project. During this long time, the project developed and was adapted to the lessons learnt several times. In 2015, the first article was published, describing the system: "Comprehensive life cycle assessment by transferring of preventative costs in the supply chain of products". This article is included in chapter 2. However, the introduction to this PhD thesis, written in 2019, contains some doubling of information, arguments and citations of later date than in chapter 2 included Oiconomy system describing article.

After my introduction to the EcoCost system (Vogtländer *et al.*, 2000), this system appeared to provide both a sound scientific methodology for the determination of preventative costs, and data on environmental aspects. Therefore, the EcoCost method and most of the environmental data were adopted in this PhD thesis. However, because the EcoCost system, as a more conventional LCA system, lacked data on social and economic aspects, it became clear that the research of this PhD thesis would have to focus on social and economic aspects. Study resulted in the conclusion that the EcoCost method could in principle be applied on these aspects. However, adaptations were required:

- For some social aspects, well defined precise reference points were lacking, especially what is "a fair minimum wage" and what is "fair inequality". To fill this gap, two articles were published and included in the chapters 3 and 4.
- Absence of a methodology for aspects without a precise quantitative measure, such as corruption. A methodology for filling this gap was published and included chapter 5.

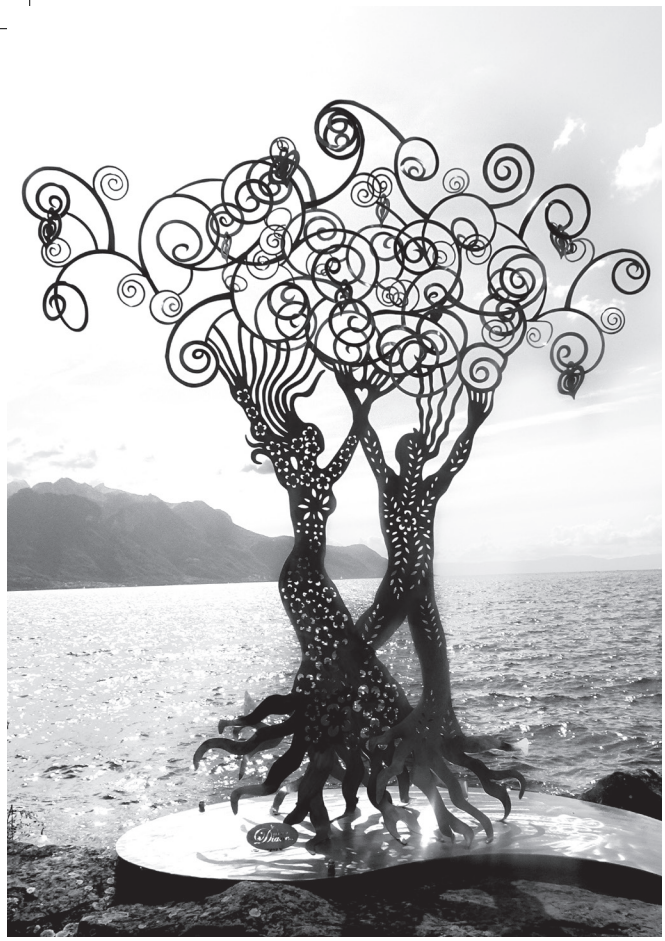
Also these articles contain some doubling with the introduction and reflections of this PhD thesis. Continuously, the Oiconomy Standard (Croes, 2020b) was adapted to the insights and developments of the project and the Oiconomy database (Croes, 2020a) filled with data.

In the course of the project, pilots were executed by M.Sc. students, conferences were attended and huge amounts of literature studied, resulting in changes and new considerations, two of which required action: 1. The development in the S-LCA community of introducing positive assessment, including internalities; 2. An in my opinion incomplete assessment of land use in the EcoCost system and LCA in general, with serious consequences on the assessment results. An article on the assessment of positive impacts was submitted in 2019 and included in chapter 6. An article on the assessment of land occupation is planned for 2021. Preliminary positons on land use, water depletion and other unpublished aspects are described in section 8.4.

Pilots were conducted on a cotton T-shirt, a pig feed and a safety shoe. The purpose of the pilots was to assess the functioning of the Oiconomy method and its distinctive features, possibilities and limitations, the results of which are included in chapter 7. In the discussion (chapter 8), the

aspect of land use and some social and economic aspects, about which no in depth research was executed, will be shortly discussed. These aspects obtained preliminary values in the database, but need further research to justify or replace these. Last, chapter 9 describes the conclusions referring back to the research question.

However, to start, chapter 1 introduces the subject of this thesis, the need and requirements for a new type of life cycle assessment, the research question, the selection of included aspects, and the relation to the EcoCost system.



What is a more logical first step towards a sustainable economy than that every actor calculates the extra costs for the sustainable version of his product and shares these with his customers?

The least responsible party, the one that is most successful in transferring externalities to third parties, is selected by the consumer.
If we don't reverse that to selection of the most responsible party, the worst parties will rule the world.

CHAPTER 1

INTRODUCTION: THE NEED FOR A NEW COMPREHENSIVE LCA

1.1. ECONOMIC SYSTEM IMPERFECTIONS

In 1776, Adam Smith presented his doctrine that because all resources are scarce and people perform best in their self-interest, a free market, like "an invisible hand", promotes an effective society better than if people would directly promote such society (Smith 1776, p.364). Much later, Pareto described maximum economic satisfaction as that free market equilibrium where no resource allocations are possible making improvements for one person without making it worse for another (Pareto 1909, p.251-279; 451-456), later called "Pareto efficiency" or "Pareto optimum". One of today's leading economists, Stiglitz, wrote: "I suspect that Smith would have been astonished how effectively the invisible hand had served to increase the wealth of nations. But in the face of such achievements, he would, I think, have looked on with astonishment at those exaggerated claims - meant to be interpretations of his invisible hand conjecture - that the market economy was Nirvana on earth and that resources were always and instantaneously allocated in a Pareto efficient manner" (Stiglitz 1991, p.40). In the 21th century, welfare in the developed world is at an astonishing level, however not without repercussions in all three pillars of Planet, People and Prosperity (see below), such as large groups of the global population not sharing this welfare (World Bank Group, 2018), climate change (IPCC, 2018), rapid insect decline (Hallmann *et al.*, 2017), exploding human consumption (Bradford Delong, 2000), continuing loss of tropical forest and biodiversity (World Wildlife Fund, 2018), pervasive corruption threatening democracy (Transparency International, 2018), huge marine pollution with plastics (Villarrubia-Gómez *et al.*, 2018), and other severe threats to human wellbeing. There are those who do not believe in the free market at all, but others argue that the negative effects are caused by free market imperfections. There are different types of market imperfections, such as information inequality, externalities, public services and market power effects. Although power effects by monopolies are reasonably regulated by national and international legislation, e.g. by the Council of the European Union (2003) and the USA Federal Trade Commission (2019), they still play an important role both at country- and intercompany level. Information inequality and external effects are poorly controlled and causing externalities. Also some public services, like waste collection, may be considered externalities if costs are paid by others than by the economic transaction partners. Considering the fact that in 2015, measured by the World Bank €1.90 poverty line, still 10% of the global population, and measured by the more recent €3.20 poverty line even 26.3% (World Bank Group, 2018) lived in extreme poverty, and that irresponsible, sometimes even called "predatory", financial behavior could cause a global financial crisis (The Financial Crisis Inquiry Commission, 2011), we may conclude that a Pareto optimum has never been achieved.

Kapp pointed out that already Adam Smith described three preconditions required for a perfect market efficiency: really free competition, moral sentiments and "governments' obligation to provide necessary services, that a small number of individuals could never erect or maintain in a profitable manner" (Kapp 1963, p.29). In practice, where completely free competition and optimal governance are already tough and never fully achieved, especially the combination of a presumed equilibrium existing from action out of self-interest and the required moral constraints seem a contradictive challenge for mankind. (Inter)national bodies and governance were implemented to provide some moral boundaries, but insufficient to ensure well-being to everybody or even to the global majority, and to prevent destruction of our natural environment. Therefore, a major challenge is to investigate how this invisible hand of competition can be

made visible in the contemporary complex global economy and used to gently push the homo economicus (sellers and buyers) into the direction of pursuing common interest by giving this hand a tool to identify and measure the full costs of human production and consumption, including the hidden costs, in other words: "let this hand use its forefinger".

According to Stiglitz (1991, p.32-40), even a slight information inequality causes a Pareto imperfection. On the supply side, it is easy to see how lack of information may lead to exploitation of people and extreme inequality. And on the demand side: would the consumer's wants be the same if he would have full knowledge and understanding of the consequences of his purchase and how his action may backfire on himself or his children? Without full internalization of all non-market impacts, the economy cannot grow indefinitely without repercussions. By means of the ecological footprint, Lin et al. (2018) report that in 2014 the global ecological footprint exceeded biocapacity with 70%, which means that at least the high income part of the world is prospering at the expense of others, the environment and future wellbeing. This is surely not a Pareto optimum. The current imperfect economy, full of externalities, has already outgrown itself. The current global population, all growing to live at western consumption patterns, would not be sustainable (Ekins 2011, p.629-631), let alone a future population of 9 to 10 billion. Some of mankind's major challenges, most of which can be seen as a direct result of free market imperfections, are:

- Climate change (United Nations 1998; Wackernagel et al. 2005; Stern 2007; IPCC 2018). There probably are tipping points very close to the current situation, after which changes become irreversible or are very difficult to correct (Lenton et al., 2008, 2019).
- Loss of ecosystems and biodiversity (Grooten et al. 2012; Ewing et al. 2010; Prescott-Allen 2001; UNEP 2006; Toropova et al. 2010; FAO 2010; IUCN 2019). Also in ecosystems, there may be tipping points, leading to sudden collapse (e.g. Laurance et al., 2011).
- The 2008 financial crisis (Colander et al., 2009; The Financial Crisis Inquiry Commission, 2011). Have the lessons been learnt and can repetition be prevented?
- Depletion of mineral oil, phosphates, fertile soil, rear earth metals, and other critical mineral resources (Arrow et al. 2004; Giljum et al. 2009; Coulomb et al. 2015).
- Loss of arable land (Gilland, 2007; Von Braun, 2007; FAO, 2010; Chartres et al., 2011; Saad et al., 2011).
- Pollution, overfishing, acidification and plastic pollution of the seas (Mathiesen, 2010; Villarrubia-Gómez, Cornell and Fabres, 2018).
- Depletion of water resources (Ewing, Moore, et al., 2010; Mekonnen and Hoekstra, 2010a, 2010b; Hoekstra, 2012; Hoekstra and Mekonnen, 2012; Davis et al., 2017).
- Persistent poverty, inequality and corruption (Sala-i-Martín 2002a; Sala-i-Martín 2002b; Talberth 2008; Melchior 2001; Jenkin 2011; Chusseau & Hellier 2012; Sumner 2012; World Bank Group 2018).
- Pervasive population growth (United Nations World Commission on Environment and Development 1987; Davis et al. 2011).

Considering the observation that shortages in essential needs usually lead to war (Pegg, 2003; De Soysa and Neumayer, 2007; UNEP, 2009), that climate change and loss of ecosystems may

lead to decreased habitability of large populated areas, that depletion of minerals, water and land may lead to high food and energy prices (Dyson, 2001; Zhang *et al.*, 2007; TEEB, 2010; Zhang, 2013), and that cultures have collapsed before due to excessive use of the environment (Diamond, 2005), disasters and war seem far from impossible results of current developments. Stiglitz argues that market imperfections are pervasive (Stiglitz, 1991). Short term interests prevail and individual countries do not seem to feel responsible or are able to lead the international community to change. Instead of leading to a global Pareto optimum, the economic system based on everybody fulfilling his own individual needs without sufficient and reliable information and moral constraints, drives humanity to continue on a path towards destruction. Many short term good actions for ourselves have repercussions on a greater scale and may even backfire at ourselves, our children or grandchildren. Humanity seems in serious danger and therefore the precautionary principle requires action: "Where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation" described in the Rio Declaration on Environment and Development (United Nations, 1992, principle 15).

Without a major change and without well enforced standards and boundaries, or perfect and reliable information, there is a high risk that people, as consumers, buy the cheapest solution for their wants, helping the least responsible supplier to become the winner, where they, as citizens, would object to the consequences. "Higher costs to the planet do not translate to higher cost to the consumer" (Chouinard *et al.*, 2011). Although rapidly growing, in 2015, organic agriculture only had a 1.1% share of global agricultural land use (Golijan and Dimitrijević, 2019) and fair trade sales was smaller than 0.01% of global GDP (calculated from Lernoud & Willer 2017). Mankind may not yet have the responsibility that is required for market freedom. Consumers, industry, politicians and countries are worldwide stuck in a system of fulfilling their short term needs, even at the expense of others and of future generations.

Has society become uncontrollable? Industry, understandably, is reluctant to start paying for formerly artificially free resources if the competitor does not. As understandably, poor people and countries resist to bear the necessary burden while inequality is rising and 1% owns 47% of worlds wealth (Shorrocks *et al.*, 2018) and while the carbon footprint of the rich is a multiple of that of the poor, both between and within countries, and in addition, the rich are less sensitive to the consequences of climate change than the poor (Oxfam, 2015). Even in high income countries, only a limited proportion of consumers is willing to pay a premium for sustainable products (Manget et al. 2009, p.14) and people in low income countries first want their fair share of the cake before limiting their material opportunities (Parks and Tommons Roberts, 2009). In addition, President Franklin D. Roosevelt's famous expression: "necessitous men are not free men" (Roosevelt, 1944) expresses how easily the weak are exploited and how difficult a transition to a responsible world is. In his movie "an inconvenient truth", Al Gore argues that we are like frogs in a heating pan, slowly waiting for what will happen next (Gore, 2006).

What then are possible solutions? One real possibility is the hard way of nature: survival of the fittest, but is that modern humanity's moral sentiment? Many have their hope on technological solutions and argue that for instance food shortages have been forecasted before (Meadows *et al.*, 1972), but were prevented by technology and expansion of agricultural land, even though these often occurred at the (further) expense of ecosystems. On the environmental pillar, indeed, technological advances towards solutions are published regularly, but the interconnected social

and economic prerequisite conditions are far more difficult to accomplish. Already De Sismondi warned for technology related market imperfections, especially for the social consequences (De Sismondi, 1827). Technology will surely provide solutions, but is also one of the root causes of many of the present issues, and will undoubtedly cause new threats. Recent technology-related threats or concerns are for instance insect eradication, probably caused by pesticides, intensive agriculture and climate change (Hallmann et al. 2017; Sánchez-Bayo & Wyckhuys 2019), drones dehumanizing war (Berkowitz, 2014), internet technology, increasingly leading to cyber-crime (Brundage *et al.*, 2018), fake news, threats and scolding, becoming normal on social media and threatening democratic processes (Lazer *et al.*, 2018; Persily, 2018), antibiotic use leading to resistant microorganisms (Smith and Coast, 2013), engineered nanoparticles in food (McClements and Xiao, 2017), plastic waste in the oceans (Smith and Coast, 2013), artificial intelligence with unknown consequences in both positive and negative directions (Smith and Coast, 2013), and 3D printing, presenting both great potential for sustainability improvement and disruptive threats (Sánchez-Bayo and Wyckhuys, 2019). A positive development is the "net positive" initiative, a group of large companies that strive to give more to the world than they take (Forum for the Future *et al.*, 2019). Although their intentions are debated (see e.g. Sustainable Brands, 2014; The Guardian, 2013), we consider this an important step because it increases the chance that stakeholders will hold these companies to their words. But will such company-initiatives be enough? Probably not, because companies tend to hold on to their core business while the needed huge transition requires many of them to leave or transform their core business. Just to name some examples: Fossil energy companies should direct their major investments towards renewable energy, long distance tourism dependent air carriers and airports should either find a way to use renewable energy or reduce demand considerably, communication- and IT companies should completely focus on connecting people and avoid dividing them, governments and car manufacturers should focus on public transport instead of electric cars, meat and dairy industry should change to plant-based foods and diets, the complete financial sector should return to financing opportunities instead of facilitating speculation, food should be of local origin, the soda industry should move away from transporting water in bottles, and because all this is likely to reduce employment, governments and international bodies should focus on inequality and the creation of a new fair economy, based on decreasing employment, because sooner or later, labor can no longer be the major means of distribution of wealth. That moment may well coincide with the transition to sustainability.

Another regularly mentioned solution is "degrowth" (e.g. Latouche, 2009; Schneider *et al.*, 2010; Kallis, 2011). Advocates of degrowth pursue a more sustainable society by a more conscious lifestyle, more self-sufficient, reducing consumption in general and in use of resources in particular, more focused on wellbeing than on material welfare, but opponents of degrowth argue that focus on the mitigation of the quantitative aspect of production and consumption does not necessarily lead to sustainability and may even backfire as an economic crisis, causing more unemployment and poverty and decrease in investments in sustainability. For example, Van den Bergh (2011) distinguishes five interpretations of degrowth with objections to all of these and some positive comments:

1. GDP degrowth, a reduction in the GDP, or in other words in economic activity. Objections are: This type of reduction is not sustainability selective and decreasing incomes are unpopular.

2. Consumption degrowth, (voluntary) consumption restraint: Objections are: This type of reduction is not sustainability selective, causes large rebound effects and is based on unpopular consumption limitations.
3. Work-time degrowth, reduction of work-hours as has been done before. Objections are: Also this type is not sustainability selective and is little effective in aging populations. Positive is that the reduced income both mitigates consumption and increases leisure time.
4. Radical degrowth, a radical change of life-style. Objections are: The reductions are not specifically sustainability focused, are very unpopular and give very uncertain results at probably huge costs.
5. Physical degrowth; less use of materials: This type could be effective if implemented in a sustainability selective way, for instance regulated by price.

Van den Bergh's objections against degrowth are contra-objected by Kallis, who argues that degrowth should not be interpreted as for instance an enforced GDP- or consumption reduction, but that such reductions are the consequences of implementing policies, like pricing and taxation measures, work-hour reduction, better regulation of international money transfer and labor policies enhancing employment (Kallis 2011). Both van den Bergh and Kallis introduce social aspects in their considerations, not as sustainability aspects, but as necessary preconditions for environmental impact mitigation and social consequences of degrowth. For most degrowth categories, Van den Bergh's objection is that they are not sustainability selective, and both Van den Bergh and Kallis agree on the need of pricing as a selective and more effective means of achieving impact mitigation, but both also mention the interdependence of environmental and social aspects.

Another option towards sustainability may be an international political agreement forcing consumers and industry into sustainable behavior by law, but this may be far too late to prevent tipping points to be exceeded, because many politicians, voters, companies and countries tend to prevail and fiercely protect their own short term interests over preventing long term- and sometimes not 100% proven threats. The precautionary principle (Rio Conference on Environment and Development, United Nations (1992, principle 15) and self-responsibility of enterprises and citizens are politically underexposed and poorly enforced. There are several other initiatives towards transition by changing consumers' lifestyle, e.g.: "steady state economy" or symbiotic economy (García-Olivares and Solé, 2015), "voluntary simplicity" (Alexander and Ussher, 2012), and trials of groups to withdraw themselves into limited pockets of resilient economies, such as by energy, care or an own currency (Seyfang and Longhurst, 2013). Similar but a broader concept is "the transition movement", advocating sustainable and responsible behavior and building resilience locally, but with the intention to become spreading centers of a positive vision (Hopkins, 2008). Although these types of initiatives may present local solutions and provide wider consumer consciousness, they can hardly provide a coordinated global solution.

Where Adam Smith's free market doctrine requires moral standards and responsibility, Marxism and Communism, in principle existing of moral considerations, clearly demonstrated the risks of limiting market freedom too far. Maybe only the required and before-described prerequisites for a free market should be better met. In almost all sustainability challenges, the sustainability of products and their supply chains play a major role. Consumers want high quality products

against low prices without the risk of negative consequences for them, and many consumers and company leaders, if unleashed from the rat race to profitability and competition, do have moral sentiments and, in my opinion, would consider external impacts if these would be clear and enforced within an equal playing field. However, for consumers, and even for experts and product supply chain players, the modern world is too complex and supply chains' impacts are too indirect and temporally or spatially distant, making it almost impossible to properly assess product quality, including all negative impacts and consequences of materials and processes related to the product life cycle.

Stiglitz showed that information inequality is an important cause of market imperfections (Stiglitz 1991, p.32-40), but at the same time, the modern consumer is already overloaded with information. Hardly any individual can or even wants to process and comprehend all information on all products. Already Pigou presented a potential solution, proposing a correction of free market imperfections by means of systematic internalization of the external costs, but he also recognized the difficulty to measure the exact magnitude of products' external costs and the need to compensate higher product costs for the poor (Pigou 1920, p.149-179). Aforementioned was already, that the degrowth community also points into this direction. The idea of internalization is that, in a free, full price economy, consumers and producers will automatically make sustainable choices and create a sustainable economy. Internalization is nothing other than embedding the correct information in the price of products and a correction of the malfunctioning of the market. Removal of the externalities empowers a sustainable economy. Therefore, whether actual internalization will ever be implemented or not, the magnitude of the externalities, representing the "cost distance" to sustainability, or in other words the price gap between the current and the sustainable version, provides a perfect measure of unsustainability.

In principle, "cost distance" can be defined by four different indicators: the costs of the inflicted damage (impact), prevention, compensation and of restauration. The costs of impact are closest to the juridical, political and consumer perspective of the principle of "the polluter pays" and therefore gives a perception of justice. Unfortunately, the costs of impact are very difficult to determine, because of their complexity and because impact usually lays in the unknown future (Smulders, 2012), although the probable impact can often be derived from statistics on earlier experiences. In addition, impact also has spatial dependencies, unexpected interactions with other aspects, and consequences for other people or ecosystems than directly investigated. For instance, people that become disabled by a health & safety issue will usually be accounted for, but not the consequences for the education and future chances of their children. Another important limitation of costs of impact is that its complexity limits the ability of an average supply chain player and consumer to self-understand the cause-effect relationship which makes him completely depend on scientists and default data and on often incorrect communications in social media.

The second potential indicator of cost distance is made by the costs of prevention. Although the concept of prevention- or abatement costs lacks the same perception of justice as impact costs, defining cost distance to sustainability by preventative cost has many advantages, such as:

- Calculating costs for alternatives is standard in business operations. The concept is easy to understand and to explain to the consumer.
- Costs of prevention can be far more certain than of impact, especially if foreground data can be made available. In addition, prevention is always in the present. Even if issues cannot be abated for 100% in practice, the residual impact remains to be measured by default values.
- Preventative costs from suppliers provide the actors with a magnitude of the extra price for the sustainable alternative.
- Preventative costs, starting with calculations and transparency, represent the true failed responsibility of every actor in the supply chain of products.
- Supply chain actors' attention is directed towards preventative actions and sustainable investments.
- Communicating preventative costs within the supply chain enables determination of the most efficient route to sustainability.

Compensation and restoration are in principle corrective. Restoration returns something damaged to its original state, but compensation by often financial means may be used as an alternative, which may be sensitive to subjective or legal assessments. For the involved business, the concepts of compensation- and restoration costs are close to that of impact costs. But sometimes they can be considered preventative costs, especially if the obligation to compensate or restore has a preventative effect, or if the impact of for instance carbon emissions is compensated by mitigation of methane emissions or by growing trees.

To date, no system exists for the measurement of the externalities, related to the world's billions of products and comprising all three pillars of planet, people and prosperity. Therefore, we argue that a method is required to measure how much more a both 100% ecologically sustainable and socially responsible product would cost, this way providing the consumer and value chain players with simple information. If these external costs would then be internalized by for instance taxation, the economic system itself would change into a direction that business and consumers automatically make better Pareto efficient choices, at least according to economic principles. In the long run, the market might fully function, but within moral boundaries. Consumers and industry are expected to move to a sustainable full price economy, which we, in the "Oiconomy project", will call "Oiconomy" [1].

1.2. THE NEED FOR COMPREHENSIVENESS IN SUSTAINABILITY ASSESSMENT

At the moment of writing this PhD thesis, many countries are desperately looking for ways to comply with the 2015 Paris agreements on climate change (United Nations, 2015), which will be a costly transition that many civilians are not willing or able to pay. Governments are

1 "Oikos" is the Greek word for "house" and "Nemein" for management. "Oikonomia" was used by the ancient Greek philosophers for "household management", but contrary to the current word "economy" included ethics (Leshem, 2016).

under pressure of populists denying climate change and thereby using the inconvenience of the truth (refering to Gore, 2006), and demonstrations (Farand, 2019), making the transition extra difficult. Di Paola et al. (2018) argue that the cause of the success of populist parties is not necessarily the climate issue, but more in general the dissatisfaction about the functioning of democracy and addressing people's needs, such as poverty and inequality, while Paskov and Dewilde (2012) show that income inequality diminishes solidarity. In the preface of the World Risk Report 2019, Børge Brende, President of the World Economic Forum, states: "The world is facing a growing number of complex and interconnected challenges from slowing global growth and persistent economic inequality to climate change, geopolitical tensions and the accelerating pace of the Fourth Industrial Revolution. (Collins, 2019)". The Brundtland 1987 report states: "Many parts of the world are caught in a vicious downwards spiral: Poverty forces people to overuse environmental resources to survive from day to day, and the degradation of their environment further impoverishes them, making their survival ever more difficult and uncertain. The prosperity attained in some parts of the world is often precarious, as it has been secured through farming, forestry and industrial practices that bring profit and progress only over the short term." (United Nations World Commission on Environment and Development, 1987). Principe 25 of The Rio declaration 1992, states: "Peace, development and environmental protection are interdependent and indivisible" (United Nations, 1992). Point 13 of the introduction of the Declaration of the UN assembly, where the 17 Sustainable Development Goals (SDG's) were agreed, states: "The challenges and commitments identified at these major conferences and summits are interrelated and call for integrated solutions. To address them effectively, a new approach is needed. Sustainable development recognizes that eradicating poverty in all its forms and dimensions, combating inequality within and among countries, preserving the planet, creating sustained, inclusive and sustainable economic growth and fostering social inclusion are linked to each other and are interdependent." (United Nations General Assembly, 2015). The 17 sustainable development goals in itself make a comprehensive network of interdependent goals or aspirations.

The great issues of mankind are interrelated and cannot be resolved individually, which means that also the measurement of sustainability needs to be comprehensive and include all major global issues. For the same reason, Elkington coined his famous principle of the Triple Bottom Line (TBL) of Planet, People, Profit/Prosperity[2] (PPP), about which he states: "We felt that the social and economic dimensions of the agenda – which had already been flagged in 1987's Brundtland Report (United Nations World Commission on Environment and Development, 1987) – would have to be addressed in a more integrated way if real environmental progress was to be made. Because "Sustain-Ability" mainly works, by choice, with business, we felt that the language would have to resonate with business brains". Vermeulen visualizes these three dimensions of sustainable development (SD) in a Rubik's Cube (see figure 1.1). This Rubik's Cube shows the interconnectedness of the three dimensions and highlights that true sustainability should attend all matters included (Vermeulen, 2018). A final reason for comprehensive measurement for industry is to be prepared for all possible comments and actions by stakeholders and avoid to be pulled from one issue to another.

2 The term "Triple Bottom Line" was first introduced as "Planet, People, Profit" (Elkington, 2004), but in the Johannesburg top in on sustainability (2002), "profit" was replaced by "prosperity" (United Nations Department of Economic and Social Affairs, 2002), indicating the importance of people's welfare instead of profit alone.

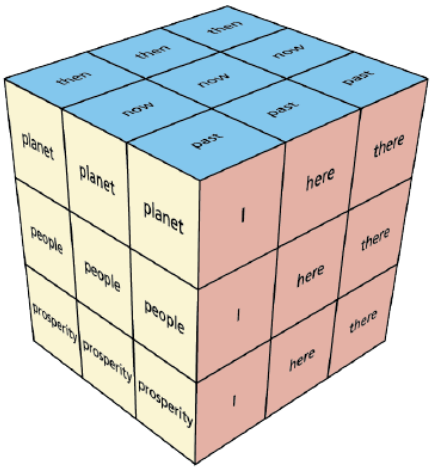


Figure 1.1. The three dimensions of Sustainable Development: aspects (PPP), time and place (Vermeulen, 2018, p.3).

But current sustainability assessment still is insufficiently comprehensive, addressing sustainability by separate aspects (for instance climate change) or by pillar (e.g. only environmental or only social). However, there are also disadvantages of comprehensive measurement. In aggregated or averaged form, comprehensiveness may provide a measure of weak sustainability for the individual aspects or dimensions, because the mix of information, especially if aggregated, on the different aspects allows for compensation of a bad score for one aspect by a better score for another aspect, an effect that is even fortified if a composite sustainability indicator includes positive impacts. In addition, every added aspect tends to flatten the indicator and decrease its distinguishing power. TBL, as incorporated in the Global Reporting Initiative (GRI) (GRI, 2016), was criticized by Sridhar and Jones. Based on a literature review on TBL and a study of GRI reports, these authors find various limitations in the comprehensive TBL approach: 1. The problematic weighting of different aspects; 2. Lack of attention for the interdependence of the aspects; 3. Lack of objectivity and reliability and that companies tend to report on processes instead of on the absolute status; 4. Lack of system thinking, and; 5. Lack of a common unit and lack of a possibility of aggregation. These authors argue that TBL falls short on Elkington's original claims of easy measurability and aggregability. They still value the idea, but recommend to better define the TBL approach (Sridhar and Jones, 2013). Also Shnayder *et al.*, (2015) criticize how companies in the packaged food industry self-report on TBL. They report that their Corporate Social Responsibility (CSR) focus is on people, the pillar (as opposed to the pillars of planet and prosperity) that requires the least amount of real structural change. Shnayder et al. also report that focus on the planet pillar requires the most effort because the required actions tend to go beyond normal business practice. A final disadvantage of comprehensiveness is its complexity and workload, in my own experience a general fear of businesses and an excuse to reject or postpone systems. From all these arguments it can be concluded that there surely is a need for a method to comprehensively measure product sustainability, including all three PPP pillars. However, it must be well defined, aggregable, and especially, by keeping transparency on the individual aspects, it should keep a focus on strong sustainability on each of the aspects. Note that it will probably need some force to be implemented.

1.3. THE CONCEPT AND MEASUREMENT OF EXTERNALITIES

In economic terms, externalities are always paid by someone other than the transaction partners. In economic terms, "internalities" are not internalized externalities, but unexpected, undesired, or ignored impacts to the buyer. An example is the impact of smoking. For LCA purposes, however, it is reasonable to include these internalities in the concept of externalities. This confusing concept of "internalities" is further discussed in chapter 6. In the following, the concept of "externalities" will include unexpected, undesired or ignored impacts to the buyer/ user. Various reviews on "social or external costs" are available, (e.g. Kapp, 1963; Hueting, 1980; Hamilton, 1994; Bebbington *et al.*, 2001; Tukker *et al.*, 2006; Hecht, 2007). We will here only discuss some developments relevant for the Oiconomy project. Where today the concept of externalities is usually used for environmental aspects, the concept actually started as a concept of social costs by socialist authors. E.g. Karl Marx describes profit as an evil surplus. He argues that the difference between the added value by labor and the market value belongs to the workers instead of creating capital for the entrepreneur. Marx believed that labor was the only right way to create value and that entrepreneurs unrightfully accumulated the fruits of the workers labor as capital (Marx, 1867). The surplus concept had actually been developed before by De Sismondi, who in principle saw this surplus capital as a possibility to be reinvested and as a necessary tool for welfare. He warned for the danger of "the social evil" of exploitation of the laborer (De Sismondi 1827, p.50), but also for other market imperfections and he had a more general idea of externalities than Marx. Marshal probably was the first to use the expression "external economies" for social consequences (Marshall 1890, p.152). He opposed Smith's doctrine arguing: "It does not give proper justice to the moral man". In 2008, more than one century later, the economy in a financial crisis, caused by unlimited greed and irresponsibility, in a time that great masses of people are getting less ignorant and rise against politicians, corruption and inequality, and with a looming environmental crisis, it seems that selfishness and short-termism indeed has ruled the economy too much (Dobbs, 2009). As aforementioned, in 1920, Pigou argued that theoretically, negative social costs, e.g. for pollution, can be compensated by a (later called) "Pigouvian tax" and positive market imperfections (e.g. for development of medicines) by a "Pigouvian subsidy" (Pigou, 1920, p.149-179). Major challenge, already noted by Pigou himself, is how to determine the exact magnitude of the required taxation or subsidy. To date, the idea of correction with taxation and subsidies usually refers to carbon and environmental taxes (Groothuis Wavemaker, 1996; WBCSD, 2010; Tietenberg, 2013; Lagarde, 2014), but the exact required compensation was never completely elaborated and surely not comprehensively including all other PPP aspects of sustainability.

To date, quite some experience has been obtained with "Environmental Taxation Reform" (ETR) (OECD, 2011b), however almost exclusively applied to the aspects of energy resources and carbon emissions. In the Netherlands and in the UK, some consulting companies are specializing in promoting "true costs" (Trucost, 2015; True Price, 2015). But also large financial consultants like Price Waterhouse Cooper, Deloitte and Ernst& Young are involved (Sipkens *et al.*, 2016). The World Business Council for Sustainable Development envisions business based on true prices for 2050 (WBCSD, 2010), and the CEO's of companies like Patagonia and Blue Skye argue that successful business is synonymous with sustainable business, leading to true pricing (Chouinard *et al.*, 2011). ETR is proven effective, although sometimes with limited impacts, because of the still limited and cautious application, the rebound effect (people

spending less on one product spending their money on other damaging products or activities), and because of lack of international application and trade of products with embedded impact (Andersen *et al.*, 2007; Ekins *et al.*, 2009; Blom *et al.*, 2010; European Environment Agency, 2011; Tietenberg, 2013). We see convincing arguments in the effectiveness of pricing carbon by the more than double carbon emission per capita of the USA compared to Europe (OECD Stats, 2016), two areas with similar development patterns but very different energy taxation, and in addition, the recent sharp rise of investments in renewable energy after sufficient costs reductions of the technology (IRENA, 2018, p.19) shows the price sensitivity of at least energy related technology.

Externalities can be related to activities, organizations, countries (or regions) or to products. On the national level, most common indicators for the measurement of economic progress is the Gross Domestic Product (GDP) and its variations. Discussing degrowth, we already mentioned concerns by various authors about the purely economic character of these politically important indicators, but disregarding the hidden externalities and the growingly unequal distribution of wealth within countries. In the late 20th century, answering to this concern, various alternative systems of national accounting were developed, including externalities, first only including environmental accounts, such as the National Accounting Matrix including Environmental Accounts (NAMEA) (De Haan and Kee, 1996) and the System of Environmental-Economic Accounts (SEEA) and later more comprehensive and monetized GDP alternatives. One of the most comprehensive of these alternatives is the Index of Sustainable Economic Welfare (ISEW) or Genuine Progress Indicator (GPI) (Cobb and Daly, 1989; Talberth *et al.*, 2007). In chapter 4, searching for income reference points, most relevant national indicators are discussed more extensively. Relevant for the concept and measurement of externalities in general, we notice that for instance in the ISEW (Cobb and Daly, 1989), aspects like inequality and community services are recognized as externalities. Shortcomings of these national indicators are lack of standardization between countries (Lawn, 2003) and the fact that national statistics are residential because they do not systematically include the life cycle of residentially consumed products and neglect the responsibility of the consumer (or the consuming country) for internationally traded products, e.g. well demonstrated for the UK by Helm et al. (2007).

On the organizational level, several initiatives and tools have been developed, intended to increase the social and environmental performance of businesses by focusing on transparency, accountability and sustainability, such as the Global Reporting Initiative (GRI, 2016), Integrated Reporting (IIRC, 2015) and the Balanced Scorecard for sustainability (Kaplan and Norton, 1993; Figge *et al.*, 2002). Especially the GRI has become an important source of information on sustainability- and responsibility reporting with over 46.000 reports in the database (GRI, 2018) and resulting in studies on Social Accounting based on GRI reports, (e.g. Turker and Altuntas, 2014). The GRI comprehensively includes guidelines for aspects in all three PPP pillars, although their actual reporting depends on organization's own materiality assessment. However, the GRI requires reporting more on what has been done, than on what needs to be done, limits itself to data currently available to the organization and does not require in depth life cycle assessment of its activities. In addition, for many aspects, it requires narrative organization-chosen reporting instead of standardized quantitative measurement of the organization level externalities. The GRI has chosen a practical and acceptable way for business and has become an influential sustainability reporting medium. However, concerns have been raised about the

reliability and greenwashing possibilities of unverified voluntary self-reporting by businesses (Laufer, 2003;Shnayder et al., 2015). Unfortunately, the GRI recommends but does not require external assurance for sustainability reports. In addition, any external or internal verification requires a well-defined set of criteria and data to be verified. Although the GRI is a step forwards in sustainability reporting and focus on sustainability by corporations, it still does not yet provide an objective measure of externalities and especially not of the distance to sustainability that the reporting organizations still need to bridge.

Another initiative, Integrated Reporting (IR), was developed by the International Integrated Reporting Council, a global coalition of regulators, investors, companies, standard setters, the accounting professionals and NGOs. IR strives to integrated reporting of both financial and non-financial indicators, both internal costs and externalities. The main objective is to report on the created value resulting from used resources and created capacity. Non-financial aspects do not need to be reported in monetary or aggregable indicators, but should be fit for comparison of companies. Although this initiative only has a fraction of the reporting companies compared to the GRI ("over 1600 (IIRC, 2018))", it shares the purpose with the GRI to strive towards integrated financial and non-financial company-reporting to become the de-facto standard.

Another step in organizational awareness of sustainability was the concept of "eco-efficiency" by Schmidheiny & Zorraquin 1998, and further developed by BASF. Using terms like efficiency and producing more with less, it talks business language. Eco-efficiency can be illustrated as the value of products, organizations or regions per sum of environmental pressures. Extensive explanations of the eco-efficiency method can be found in Seppälä et al. (2005) and Lehni (2000). Primarily intended for organization's decisions, eco-efficiency is a way of thinking, leaving the exact methodologies to the organization. The typical result is a graphical fingerprint or matrix of the impacts of a selection of aspects. To solve the all present problem of valuing environmental pressures, BASF takes the normalization approach by using two weighting factors: a relevance factor and a societal factor. For the relevance factor, the proportion to total national impact is used and for the societal factor a combination of public- (by polling) and expert opinions. For total weighting, the two factors are multiplied. For costs, the obtained factors are compared to an economic indicator such as the total sales value of the product (Kicherer et al. 2007, p.539). This normalized approach results in an indicator similar to the "population equivalent" known as a measure for water pollution. Eco-efficiency analysis provides only relative comparisons, although such an equivalent can be transformed into a monetary unit by comparison with the global GDP per capita.

Fierce criticism on eco-efficiency came from McDonough and Braungart, who argue that eco-efficiency "does not reach deep enough and works within the same system that caused the problem in the first place. It presents little more than an illusion of change" (McDonough & Braungart 1998, p.3). These zero-waste focused developers of Cradle to Cradle argue that eco-efficiency leads to "downcycling" instead of to recycling and prevention, and hence to a continuation of unsustainability. Interesting is that BASF was able to assess carbon emission data for 90% of its purchased products, mainly from their supply chains (WRI and WBCSD, 2011), indicating that, although with the power of a big company, this can be accomplished.

Taking action brings both costs and benefits. Interesting for our purpose is that the system of eco-efficiency has been developed to measure and base sustainability decisions on a balance of costs and benefits. There are many examples where even the internal benefits equal or even exceed

internal costs (Henson 2008). A quarter of a century of experiences in pollution prevention practices has shown that systematic attention to environmental impacts in the design of products and processes generate savings rather than additional costs (Allen and Rosselot, 1994; Ochsner *et al.*, 1995; Durfee, 1999; Bartholomew *et al.*, 2008; Miller *et al.*, 2008; Sam, 2010; Granek, 2011). This brings extra motivation for industry to internalize their externalities.

1.4. LIFE CYCLE ASSESSMENT

Measuring externalities or sustainability on the product level probably is the most difficult challenge. Supply chains may be extremely complex and impacts specific, local or subjectively depending on the impacted person or group. While on the national level, statistics are relatively available and constant, data on specific supply chains are far more difficult to collect and rapidly changing (e.g. in the fashion industry). There are only 195 countries, but billions of products and most products involve a multiple of supply chains. To date, no comprehensive system to measure both environmental and social externalities of products, expressed in a monetary unit, is available. However, much progress has been made in life cycle assessment (LCA), which may very well serve as a foundation for such a measurement. The most used method of measuring sustainability of products is Environmental Life Cycle Assessment (E-LCA). Its strength, by no doubt, is the life cycle approach and the inclusion of all activities and materials, from cradle to grave or even back to cradle. LCA is widely used by companies, governmental bodies and scholars. The ISO standards 14040 and 14044 present a framework for LCA systems (ISO, 2006c, 2006b) that supports the use and regulation of LCA. LCA was originally developed as a consequential tool for the comparison of products or activities on a limited number of environmental aspects, and is therefore also called "E-LCA" as opposed to "S-LCA" for the assessment of social aspects. But for the purpose of the assessment of specific products, the current impact-based LCA suffers from some fundamental shortcomings, which will be described in chapter 2. Here, only a summary of its major shortcomings is provided:

- The impact-based character, with its inherent complexity and uncertainty of the future.
- The lack of standardization.
- Lack of systematic comprehensive inclusion of social and economic aspects.
- Difficult objective aggregation of different aspects.
- The top down approach, therefore depending on generic databases and lacking certainty for product or company-specific data.

A step into the direction of standardization was the introduction of Environmental Product Declarations (EPDs) (ISO, 2006a), by offering a standardized way of quantifying the environmental impact of a product. In order to develop EPDs, Product Category Rules (PCRs) were drawn, which provide a set of specific rules, included aspects, system boundaries, requirements and guidelines for developing an EPD. Global alignment of PCRs is necessary to achieve comparability of product claims, but this alignment also still remains a challenge (Del Borghi, 2013). However, EPDs and PCRs are not themselves performance measurement systems and can "only" guide life cycle studies by setting rules for product categories, or harmonize and communicate the environmental information (Del Borghi, 2013). In addition, to date, EPD's and PCR's have been limited to environmental aspects and the resulting data for different aspects cannot be aggregated.

Additionally, there have been several initiatives by industry sectors to harmonize sector specific data streams, like the Higg Index (Sustainable Apparel Coalition, 2017b) for the apparel industry and the AIChE sustainability index for the chemical industry (Institute for Sustainability, 2019). Judging from their websites and especially our pilot in the apparel industry (see chapter 7), these initiatives demonstrate that sharing sustainability data among peers and supply chain actors is already practiced and provides an effective means for sustainability development within industry sectors. However, these indexes are still in development, and not coordinated and comparable between industry sectors.

1.5. ECOCOSTS – PREVENTATIVE COST-BASED ASSESSMENT

A step forwards towards measuring product related sustainability is the EcoCost/Value rating method (Vogtländer, 2001; Vogtländer and Bijma, 2000; Vogtländer, Hendriks and Brezet, 2001), further referred to as "EcoCost system". EcoCosts for a sustainability aspect are the product of the quantity of an impact and the marginal preventative costs per unit for the impact category. The indicator of marginal preventative costs is best explained with an example. If the target to reduce GHG emissions would be 80% reduction of all worldwide emissions measured by global warming potential (GWP), aggregation of various forms of renewable energy are required because neither will be sufficient to reach the 80% reduction goal. Assuming that the cheapest technologies will be used first, the marginal preventative measure is the most expensive (the last deployed) measure required to globally reach the target, also expressed by figure 1.2.

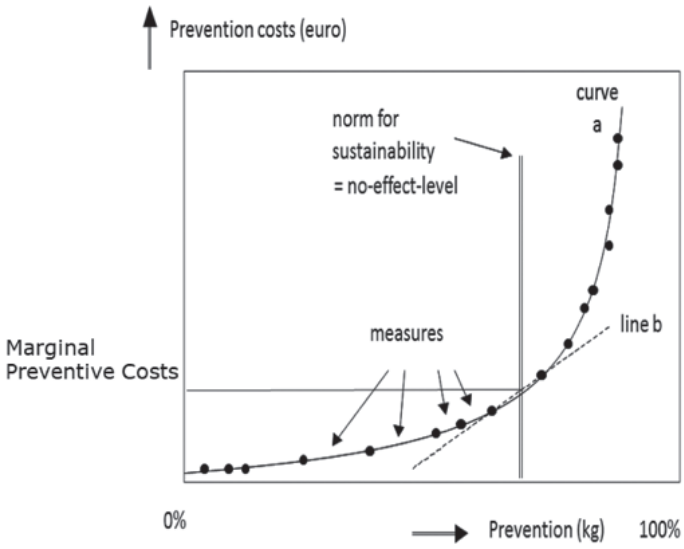


Figure 1.2: Marginal Preventative costs - EcoCost system (Vogtländer, Bijma and Brezet, 2002, p.60)

The EcoCost system has the following major advantages over impact-based LCA.

- Preventative costs are business language. Impact assessment provides the knowledge, but action requires financial accounting.
- Preventative costs are objective and represent business responsibility.
- Preventative costs do not know temporal issues. All assessments represent the moment of prevention, which should be the current time.
- Preventative costs enable comprehensive comparison and aggregation of very different sustainability aspects, because all aspects are expressed in one monetary unit.

Major shortcomings of the EcoCost system for the purpose of the comprehensive assessment of product sustainability, are:

- The EcoCost system still is a top-down type of LCA, mainly based on background data. It lacks a system challenging the supply chain players to self-investigate how to prevent the impact and calculate their specific foreground data.
- Because of its top-down character and lack of traceability, the EcoCost system has difficulties to include socio-economic aspects, which are far more location- and company specific than environmental aspects. One recent article was published on social EcoCosts, but based on generic data (Van der Velden and Vogtländer, 2017).
- It lacks standardization on e.g. system boundaries and requirements on the choice of included impact categories.
- EcoCosts provide the marginal preventative costs for an impact instead of the preventative costs for the specific activity or item. In practice, the specific preventative costs of for instance methane emission from cows may be very different from a quantity with equal global warming potential from a power plant's CO2 emission.

1.6. SOCIAL LIFE CYCLE ASSESSMENT

Social Life Cycle Assessment (S-LCA) may be called the social counterpart of Environmental LCA (E-LCA). Where E-LCA is a methodology for the assessment of environmental impacts of products and activities, S-LCA is the same for the assessment of the social impacts of products and developing to include socio-economic aspects. As before-mentioned, preventative costs for most environmental aspects are available in the EcoCosts system. For social aspects, no EcoCosts were available at the time that we did our analysis presented in chapters 3, 4 and 5. For the quantification of aspects in S-LCA and also in any preventative cost-based LCA, a performance reference point (PRP) is required. For the most important social aspects, such as poverty, inequality and corruption, no well-defined PRP's, suitable to determine the distance to sustainability, were available. At best, we had international conventions, usually expressed in vague principles. Therefore, the main body of this PhD thesis focuses on the development of more absolute and precise PRP's for social aspects and moved in the direction of developing S-LCA methodology. It must be noted, that although at the start of our project, no EcoCosts were available for social aspects, some EcoCosts were proposed by the EcoCost scholars after our articles on fair inequality, fair wages and corruption

were published. However, Van der Velden and Vogtländer, (2017), in line with their methodology, proposed to quantify social aspects by means of characterization of the impact-based indicator of the DALY and a value for a human life year, which is very different from the preventative cost-based methodology presented in this thesis.

Both E-LCA and S-LCA serve a double purpose, the scientific goal to collect knowledge and the practical goal to serve as a management tool for businesses. Understanding the impacts and cause-effect pathways is important for the awareness of the issues and the development of preventative and corrective measures or alternatives, but at the same time, because especially social impacts are extremely complex, science may lose the intended audience of businesses.

Iofrida et al. (2018) studied the interpretivist or post-positivist oriented character of S-LCA studies and conclude that engineers, chemists and physicians constitute the majority of S-LCA scholars and that "urgently, reinforcement of the theoretical basis of S-LCA is needed". Sotanpour et al. (2019) raise the question whether the area of protection in S-LCA is the individual or society. S-LCA needs further robustness in sustainability science (Sala et al., 2013) and social sciences to improve its grounding (Grubert, 2018). As scientists, these scholars argue that the scientific grounding of S-LCA has tremendous challenges to unravel the complexity of social impacts. But at the same time, one may question if such research serves the goal of S-LCA as a management tool in businesses. One does not need to know all the details and consequences of poverty, corruption or poor occupational safety conditions, before taking action. Business' practical interest is more in cause-effect pathways in their specific case, preventative measures and related costs. In preventative cost-based S-LCA, after an impact has been identified as an externality, the real importance is how to measure and mitigate it and at what costs. S-LCA provides important insights in the social consequences of the life cycle of products. It also answers to the afore-described importance of comprehensiveness in LCA to include social aspects. In addition, increasingly, it enables a risk assessment of social aspects by the use of databases like the hotspot database (Benoît, 2014; Benoît *et al.*, 2010), both on a general and regional level. But the goal of this research is to develop a methodology enabling industry to determine the cost distance to a sustainable and responsible version of a specific product, for which current impact-based S-LCA does not yet provide the right tools. Therefore, in order to build on earlier developments in S-LCA, it was necessary to get an overview of its limitations for our purpose. Some of these will be discussed in more detail in our chapter 5 in relation to the assessment of corruption, and questions on current S-LCA are raised in appendix 1. Here, only a summary of the extra challenges in S-LCA is provided, on top of the afore-listed shortcomings of general limitations of LCA for the assessment of products, for which solutions must be found.

- Social impacts are extremely complex and assessments therefore often uncertain.
- Social impacts, more than environmental impacts may affect stakeholder groups not only negatively, but also positively, with several practical and moral implications, which, need to be studied before including positive impacts.
- Assessment of impact to future stakeholders in impact based S-LCA is not practiced yet, although according to the Brundtland declaration it should.
- Social impacts may be based on stakeholder surveys, which may result in subjective and fast changing results.

- Concrete Performance Reference Points are lacking for important aspects, such as for a fair wage and fair inequality?
- Some social aspects are very difficult to quantify, such as corruption and the quality of management.

1.7. LESSONS LEARNT

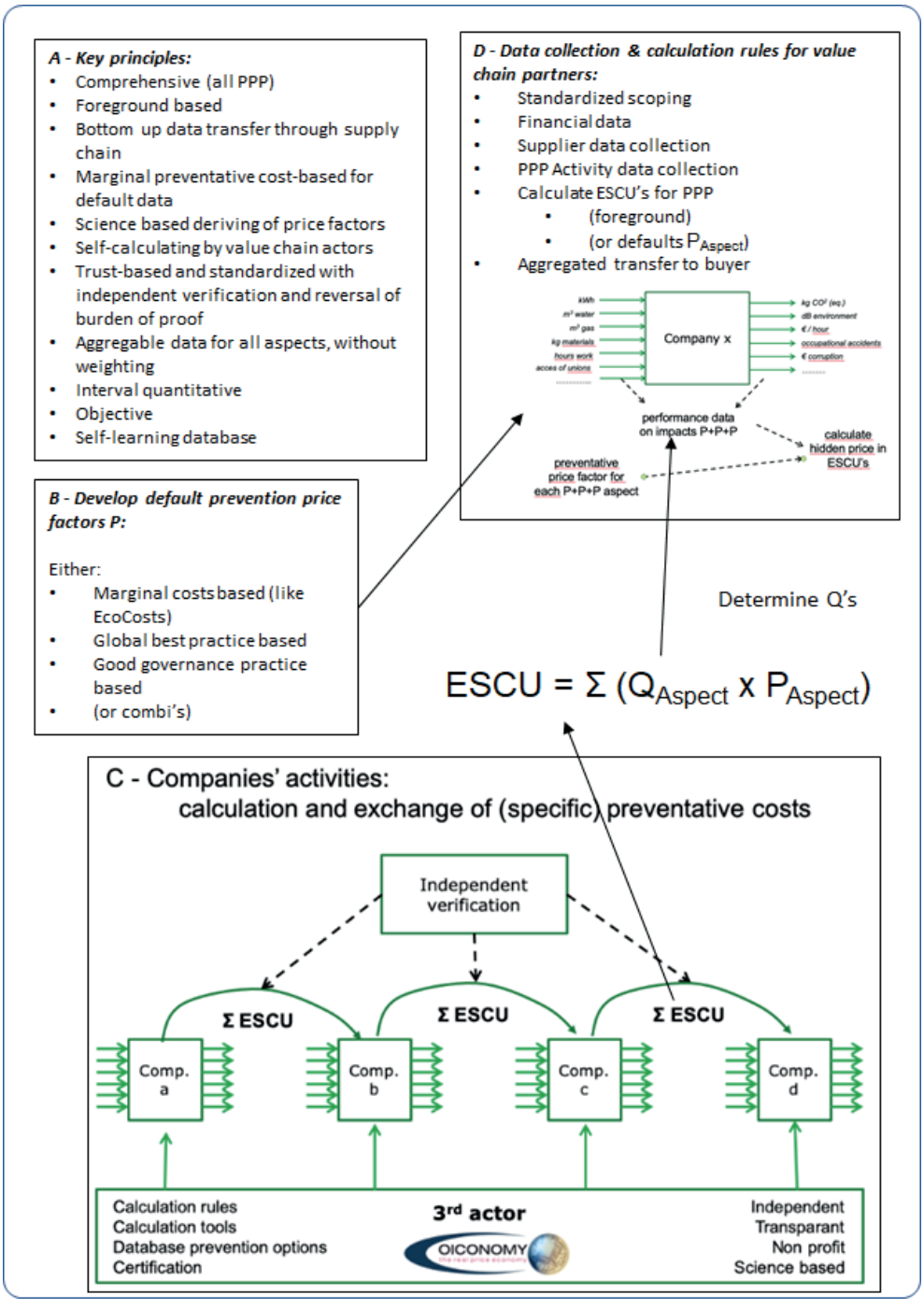
From the above, it is clear that global development in the scenario of business as usual risks disasters and war. Several influential economists point to economic externalities as one of the important causes, and hence call for a standardized method of objective measurement of externalities as a step towards correction of externalities by taxation. Environmental, social and economic aspects are so interconnected that insufficiently comprehensive inclusion of aspects has a high risk of leading to incomplete or erratic decisions. On the other side, comprehensiveness could lead to measuring weak sustainability, to a flat indicator and to increased complexity. On the national accounting level, some reasonably comprehensive and standards methods were developed, but these are residential, while a considerable part of global externalities is embedded in internationally traded products. About 30% of global GDP is exported (World Bank Data, 2019), which already is a huge quantity, but the impact of competition reaches even further, because externalities exercise an unjust pressure on competitors. In a globalized world, supply chains have become incredibly complex. In most industry sectors, traceability, which is a prerequisite for knowing and controlling supply chains", is hard to find. What would be a more logical, simple and responsible Life Cycle Assessment than that all supply chain actors calculate the extra costs for the sustainable version, in a standardized, aggregable and verified way and transfer these to the next actor? This would be very similar to cost calculations and bookkeeping, verified by accountants, which is standard procedure for businesses. It would be very educational, because all involved actors would be continuously confronted with all aspects of sustainability. To date, no initiatives exist of such standardized transmission and aggregation of product sustainability indicators through the supply chain. However, LCA may very well serve as a fundament for further development of such a system, which brings us to the research question of this thesis.

1.8. RESEARCH QUESTION AND OICONOMY SYSTEM REQUIREMENTS

The research question of this PhD thesis is: "How to enable supply chain actors the comprehensive sustainability assessment of products by determination and bottom-up transfer along the supply chain of the aggregated preventative cost-based externalities, based on a consistent scientific methodology and science- and convention based data?" Such new type of LCA should provide solutions for as many as possible before-summarized issues of current LCA and S-LCA and provide an indicator, interval quantitative, objective, certain, distinctive for a specific product or company and aggregable within and between the different sustainability aspects of all 3 PPP's, and data collection must be feasible for industry.

Figure 1.3: Charcoal sketch - 1 of a bottom-up foreground, preventative cost-based life cycle

SUSTAINABILITY ASSESSMENT METHODOLOGY FOR PRODUCTS



In the EcoCost system we found a solid scientific methodology to replace impact as (un) sustainability indicator by marginal preventative costs and a database of default values for environmental aspects (Delft University of Technology, 2019). The EcoCost methodology provides solutions for the LCA issues as objectivity, aggregability of data within and between aspect categories and temporal issues, and improvements in certainty and cost-focus of industry. However, the EcoCost system is a top-down system that provides default data, but lacks the standardization required for reliable and comparable collection and transfer of foreground data and also lacks a methodology for the determination of performance reference points for foreground data on social and economic sustainability aspects.

Therefore, building on the preventative cost-based EcoCost system, the next chapters of this thesis will describe a new methodology, the "Oiconomy system". The idea for the system came in seconds, as described in the preface. It was Dr. Walter Vermeulen to challenge me to develop a science based methodology in a PhD project.

The envisioned Oiconomy system is depicted in figure 1.3. Box A shows the key principles of the envisioned Oiconomy system, Box C and D depict the intended in-supply chain collection of data and transfer of data through the supply chain. In addition, Box B shows the required research for lacking preventative price factors. Methodologies need to be developed for the principles of the system itself, suitable for application on in this thesis studied sustainability aspects, and for future research on other aspects. In addition, practical means for supply chain actors need to be developed for the envisioned uniform collection and transfer of data by supply chain actors, including default data and workable instructions.

In more detail, this research question includes the following sub-goals:

1. Development of scientifically sound methodologies for the determination of performance reference points for social and economic aspects.
2. Enabling standardized verifiable measurement of product embedded externalities, equal to the costs of impact prevention in the total life cycle of a product, while copying standard economic cost calculations, bookkeeping and transfer of prices through the supply chain.
3. Enabling comprehensive and aggregable assessment of environmental, social and economic sustainability aspects, including the 17 Sustainable Development Goals, GRI reporting aspects and criteria of the ISO 26000 guideline.
4. Provision of a database with default background values for lacking foreground data (price factors). This database should be fit to become "self-learning" by feeding it with anonymized data from participants.
5. Enabling supply chain actors the uniform self-assessment of their product-specific preventative costs and thereby enable the communication of the extra costs for the sustainable versions of their products and together determine the most efficient route to sustainability.
6. Based on the developed methodologies, proposals for well-defined and science based performance reference points and assessment methods for some of the most important socio-economic aspects.

In order to accomplish these challenges, a standard had to be developed, not consisting of criteria for features of products or conduct of companies, but of criteria for what and how to

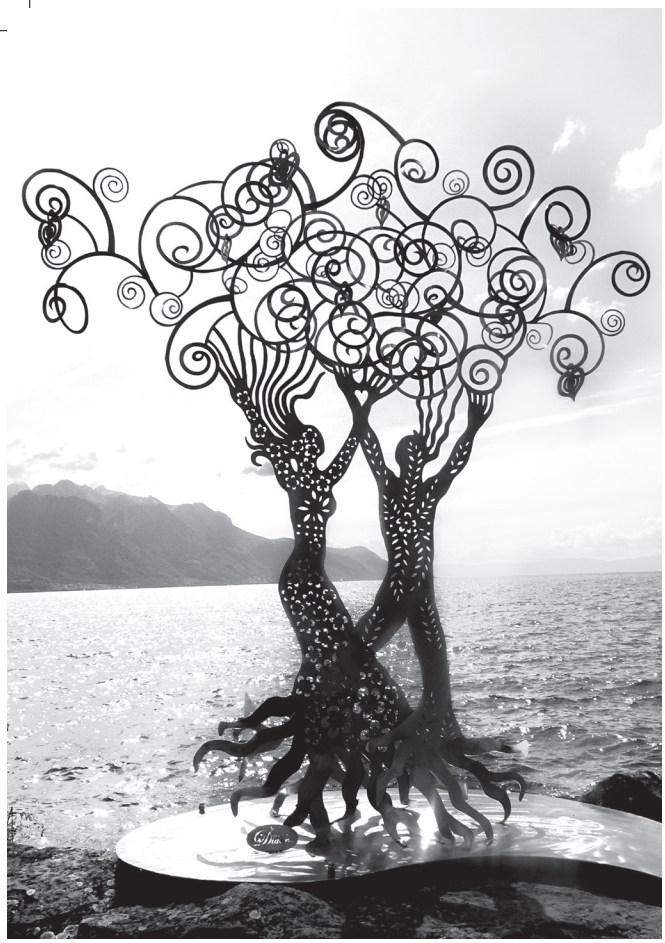
measure and communicate as indicator for (un)sustainability. Methods were required to embed the choice of considered aspects in the standard and for quantification of the aspects. In the EcoCost system (Vogtländer, 2001), a coherent methodology was found to quantify aspects using marginal preventative costs. For most environmental aspects, the EcoCost system obtains its targets or performance reference points (PRP's) from scientifically determined and agreed no-effect levels on human or environmental toxicity, or for the aspect of depletion from the market value of the resource. Because for many social aspects, no such PRP's were available, a major effort of this thesis was to determine these, for which the used methods will also be explained in the relevant chapters. In chapter 2, the Oiconomy system itself as a new type of bottom-up LCA, transferring data through the supply chain will be described, after which in the next chapters, the determination of PRP's and resulting ESCU's for the most important social aspects will be elaborated. For further explanation of the structure of this thesis, I refer to the afore-provided section "History and Structure of this Study".

1.9. INFORMATION- AND DATA COLLECTION

This thesis is an effort of system development, based on searching, assessing and combining previous research, and finding science based solutions for shortcomings of current Life Cycle Assessment systems. Methods will be described in the different chapters of this thesis.

The major sources of information for this thesis were literature, searched and accessed via search engines (Mainly Google Scholar and Scopus and incidentally Picarta), Mendeley, various certification standards, journal notification systems, review articles, article-references and citation indexes, newspapers, documents by the European Commission, the USA, various other countries, NGO's and companies. A key source of information was provided by the publications of Dr. Vogtländer on the EcoCost/Value system.

The major sources of data were a sundry of databases, such as from the EcoCost system (Idemat), the Worldbank, IMF, ILO, WHO, UNEP, UNDP, United Nations, WageIndicator, SSI, FAOSTAT, the Exiobase, WIOD, WRI, Unicef, Social Hotspot database, Transparency International, IEA, and some published articles, which all can be found in the list of references of in a list included in the Oiconomy Database. Data on Occupational Health and Safety (see section 8.4.4) were obtained by research in companies. In addition, some data and information was obtained by our pilots in three companies.



The Oiconomy system aims to enable supply chain partners to together seek the most efficient route to sustainability.

The business world has grown to a situation where anything that is not forbidden by law is permitted.
Where has self-responsibility gone?

CHAPTER 2

COMPREHENSIVE LIFE CYCLE ASSESSMENT BY TRANSFERRING OF PREVENTATIVE COSTS IN THE SUPPLY CHAIN OF PRODUCTS[3]

3 This chapter is based on: Croes, P. R. and Vermeulen, W. J. V. (2015) "Life Cycle Assessment by Transfer of Preventative Costs in the Supply Chain of Products. A first draft of the Oiconomy system," *J. Cleaner Prod.*, 102, pp. 178–187. Updated were the sections 2.4, 2.5.1 and 2.6.1. The chapter was edited to fit in the book structure. Therefore, a the introduction was moved to chapter 1 and here replaced by a short preparation to the chapter.

2.1. INTRODUCTION

As demonstrated in chapter 1, aspects like climate change, pollution, depletion of biodiversity, mineral resources and fresh water, land degradation, poverty, corruption, inequality, human population growth and financial irresponsibility present serious threats to humanity. Because these aspects are strongly interrelated for a great part caused by the current way of producing, selling and using of products, there is an increasing need for a comprehensive method for the measurement of the sustainability of products. In the current version of the free market, considerable costs of damage to the environment and people are not included in the economy and therefore called "externalities". A frequently proposed solution is the internalization of externalities, e.g. by taxation, already proposed a long time, by for instance Pigou 1920, Mishan 1967, Bithas 2011 and Van den Bergh 2010. However, there still is a need for a comprehensive system of measuring the magnitude of these product related externalities. Based on the lessons learnt, in chapter 1, a research question was defined and a sketch was presented of an envisioned new type of life cycle assessment answering to this need. In this chapter, we present the "Oiconomy project" which elaborates the envisioned system.

In the following chapters, some terms will be regularly used that may need explanation, although they are also explained in the section of terms and acronyms.

The term "Oiconomy" is used for "a sustainable full price economy, "comprehensive" refers to integrating environmental, social and economic aspects, "product" is defined in its widest sense; it may be tangible or a service, intended for consumers or for organizations. "Specific products" refers to the end-products as they are presented to the consumer/user. "Foreground data" are product specific data obtained from the specific supply chain itself. "Background" data are averages, obtained from others than the specific supply chain itself (JRC 2010, P.97). "Bottom-up" refers to a LCA by data determination and transfer through the supply chain from cradle-to-grave by the supply chain actors themselves, and "top-down" refers to a LCA where the practitioner takes the initiative to investigate the upstream supply chain" Note that our concepts of "top-down" and "bottom up" refer to the way that data are collected. "Top-down" obtained data usually are "background" and "bottom-up" collection provides "foreground data". "Preventative costs" are defined by the precautionary costs necessary to prevent damage. "Default data" are data, that shall be used in absence of supply chain data and are background data.

"Oiconomy project" designates the project of developing the Oiconomy system.

"Oiconomy method" designates the tool for the practitioner to assess product sustainability.

"Oiconomy methodology" designates the combined methodologies to create, maintain and justify the tool.

"Oiconomy system" designates the combined Oiconomy method and methodology.

"Oiconomy Standard (O.S.)" designates the standard, containing the measurement criteria and instructions for the practitioner.

2.2. METHODS AND STRUCTURE OF THIS CHAPTER

To date, the methods closest to the proposed comprehensive measuring system of product sustainability are life cycle assessment methods (LCA) and life cycle sustainability assessment (LCSA) (UNEP and SETAC, 2011). We therefore extensively reviewed the literature, based

upon searches via Google Scholar, Picarta and Scopus. We extensively used previous reviews, and bi-directionally followed references and citing of papers on the strength and weaknesses of current methodologies of LCA and LCSA and assessing these on their use for the comprehensive sustainability measurement of specific products.

We found that current impact assessment-based LCA and LCSA have major shortcomings if used for our purpose, including: their impact-based character, the lack of considering social aspects, the lack of standardization of the system boundaries, measurement and methods of transfer of verified data through the supply chain.

Because successful global certification systems exist on a wide spectrum of issues, which can support the standardization, verification and transfer of data through supply chains, we proceeded to develop a model for a product sustainability measuring standard and system (Croes, 2020b). For this purpose, we searched literature for existing conventions, standards, guidelines and initiatives for the creation of a comprehensive selection of sustainability criteria. We used the issues found in LCA system boundaries for supporting our proposed approach for standardized system boundaries for our purpose of product assessment.

In section 2.3, the strengths and weaknesses of current LCA, if used for the comprehensive sustainability measurement of specific products are discussed. In the sections 2.4 and 2.5 we present a new type of LCA, which is designed to overcome most of the found shortcomings and discuss the system properties and boundaries. In section 2.6 we discuss the next steps of the project and reflected on its research challenges and limitations.

2.3. STRENGTHS AND WEAKNESSES OF CURRENT LCA FOR THE PURPOSE OF COMPREHENSIVE ASSESSMENT OF PRODUCTS

Currently, LCA is widely used by companies, governmental bodies and scholars. The ISO standards 14040 and 14044 present a framework for LCA systems (ISO, 2006c, 2006b). LCA was developed as an assessment tool to compare the environmental impact of different alternatives and has proven to be a useful tool for assist in making management decisions. It is also useful for helping to provide a life cycle focus and to increase scientific knowledge on the environmental impact of products and processes.

However, for the purpose of seeking to achieve comprehensive sustainability measurement of specific products, current LCA systems suffer from some fundamental shortcomings, which are discussed in the following sections. Subsequently, we describe how the proposed system might help to overcome those shortcomings.

2.3.1. INADEQUATE CONSIDERATION OF SOCIAL ASPECTS

LCA is currently limited to environmental sustainability aspects. Social LCA is under development (Benoît and Vickery-Niederman, 2011), but thus far a functional system is not available (Guinée *et al.*, 2011). As extensively discussed in chapter 1, without considering social aspects, LCA's may lead to seriously incomplete conclusions, because many environmental and social aspects are causally interrelated. E.g. neglecting social aspects means that a seemingly environmentally sound product may be made using child labor or inadequately remuneration of members of the supply chain. Such a product may cause poverty and illiteracy, a social sustainability issue by itself, but also one that may cause future land degradation and climate issues, e.g. by unsustainable

harvesting of timber and home biomass cooking emissions (Smith *et al.*, 2000). On the other side, decreasing poverty may, result in increased meat consumption and consequently have impacts upon land use and upon climate related issues.

2.3.2. LACK OF CERTAINTY AND OBJECTIVITY IN IMPACT-BASED LCA

Most current LCAs are damage- or impact-based, but sustainability impact is extremely complex to determine, it needs a long-term scope, and "large uncertainty is general to any model that relies on long-term forecasting" (Weidema et al. 2009, p.23); damage may occur at considerable spatial and time distance from the cause, and one cause may have an impact on several aspects. End-of-life assessment of long lifetime products with inherently uncertain future disposal technologies is especially difficult (Höjer et al. 2008, p.1964).

Many of the required impact data are unknown (Reap et al. 2008, p.294). Social impacts are not easily quantifiable (Udo de Haes et al. 2004, p.4). The impact of health-related issues is usually characterized by the "disability-adjusted life year (DALY)", the calculation of which uses subjective and time- and location-dependent assumptions. DALYs not only lack objectivity and depend on time and location, but also change, e.g. because they depend on a people's development (Goedkoop et al. 2009, p.7). An advantage of an impact-based measurement is that it relates to the consumer-oriented "polluter pays" principle, but industry thinks in terms of the balance of their internal required preventative costs and their internal benefits, which together make their actual extra costs needed for a sustainable product. Increasingly, companies become aware of the external benefits, but can only base their decisions on these if they can be really internalized and incorporated in their products' prices. The problems of subjectivity and of updating difficulties even increase if different aspects are compared or aggregated and a weighting step is used for the severity of the issues, even if that weighting is based on research on the opinion of large groups. The fast changing results of national elections present evidence of individual's and people's different and changing opinions. Also monetary weighting by preventative costs, the method that is proposed in this chapter, is a choice giving equal materiality to all aspects. However, it objectively represents the hidden distance to the price of an issue free product and can be easily understood by consumers. See Finnveden, 1999 for an extensive review of weighting aspects and related problems in LCA.

2.3.3. THE LACK OF STANDARDIZATION

There is no comprehensive standard for the measurement and verification of comparative 'product' sustainability, nor for defining the functional unit and scope, the choice of impact categories and the system boundaries (Reap et al. 2008, p.292-293). Without a standard for what and how to measure and for the system boundaries, the objectivity and comparability of LCA results may be seriously questioned. Because both functional unit and scope are the LCA-practitioner's choice, without a modelling standard, this first step already leads to differences and incompatible results (Thorn et al. 2011, p.5). Allocation of impact to a product or process, defined as the functional unit, is especially difficult if the product or process has multiple functions (Reap et al. 2008, p.292). Although taking the functional unit, as a starting point is logical for the decision-taker, it is less so for the consumer, who usually takes far more than one type of functionality into consideration. The ISO standard requires flows to be related to a reference flow, but provides no standard for how to do so (Heijungs et al. 2012, p.2). Therefore,

although it is a step in the right direction, it lacks standardized system boundaries.

2.3.4. QUALITY AND AVAILABILITY OF DATA

Current LCAs are either generic data-dependent or are very laborious to perform because there is no standardized way to transfer reliable data through the supply chain. Every link in the chain must be developed by the researcher via her/his top-down LCA, without the possibility to bottom-up use verified data of its specific supply chain actors (Guinée et al. 2001, p.6), unless the practitioner has complete control over the supply chain her/himself. Because current LCAs are based on generic databases, it is difficult to measure the specific sustainability performance of an individual product at a specific location at a specific time (Udo de Haes et al. 2004, p.2). E.g. a LCA database may contain data on the average GHG emissions involved in processing cocoa beans to cocoa powder, but miss that these emissions depend on the specific processing of a specific type of cocoa powder. Similar examples are present in all industrial sectors. For more upstream links in the supply chain it is virtually impossible to include specific downstream consequences.

The databases are seldom up to date (Thorn et al. 2011, p.5). The generic data that are used for current LCAs are subject to continuous changes and are therefore, difficult and expensive to maintain. Technologies, knowledge and insights on impact, industries, people's preferences, and even of the impacts themselves change, e.g. if a type of disease becomes curable.

2.3.5. LCA IN THEORY AND PRACTICE

In a paper on "LCA in theory and practice", twenty-two university and industry experts on LCA state that most of the LCA work published is from academia and not from industry. They state that industry needs for them suitable LCA methods, and they conclude that "standardization of procedures is the key to ensure a common interpretation of results within the chain links" (Baitz *et al.*, 2013). Gmelin & Seuring 2014, p.6 argue that practitioners can hardly manage differences and inconsistencies in data, and Chkanikova & Kogg 2015, p.2 argue that implementation of life cycle management is challenging due to difficulties in collecting and interpreting the required large amounts of data. In this context, the authors of this paper doubt if current impact-based LCA develops in a useful way for industry. Scientists, by the nature of their work, reveal ever more complexity of the real world by demonstrating how impacts depend on spatial, temporal and inter-relational factors and by trying to broaden and deepen LCA tools, approaches and applications.

Although LCA tools are very effective in increasing the scientific knowledge on sustainability, it becomes increasingly difficult, if not impossible, for industry-practitioners to understand the issues and data as provided by the databases, and for them to effectively assess the validity of the data for their particular cases.

We conclude that current LCA is a useful tool for comparative assessment of different products or processes at the development state of a product, for providing a total supply chain picture of individual environmental aspects. But it is not suitable for sustainability measurement of specific products or for comprehensive measurements of the externalities resulting from products' life cycles.

For a more complete life cycle sustainability assessment (LCSA) and for promoting a balanced assessment of environmental (planet), social (people) and economic (profit) aspects, Klöpffer proposed to combine LCA with social LCA (S-LCA) and Life cycle costing (LCC) (Klöpffer, 2008). UNEP called for further development in these directions (UNEP and SETAC, 2011). LCSA includes social aspects in the assessment and uses LCC for the costs aspect. However,

S-LCA is still in its infancy and, without a bottom-up system to transfer verifiable sustainability data through the supply chain, reliable data will always be very difficult, if not impossible, to obtain without control over the specific supply chain. LCC assesses the costs of a product from the perspective of the producer and user and was designed to include externalities that are anticipated to be internalized in the decision-relevant future (Hunkeler & Rebitzer 2005, p.306), but it still has many of the same limitations as LCA. For instance, LCC is impact-based with all its consequent uncertainty problems; also in LCC, usually alternatives are studied instead of specific products (Swarr et al. 2011, p.42); there is no standard on what to include or on how to value; costs are usually determined by rather subjective methods like "willingness to pay". See Horn for a more comprehensive summary of the difficulties with LCC (Horn, 2014).

We have key questions about if there is a way to 'solve' these limitations of average data and impact-based assessments. In our view, it is crucial to move beyond the impact-based perspective to the prevention-based perspective. In this sense, a large step forward towards the objective measurement of product-related externalities is the EcoCost – Value rating method (Vogtländer and Bijma, 2000; Vogtländer *et al.*, 2001). This LCA method uses the marginal preventative costs to reach a target as the sustainability measure. Expressing every sustainability aspect as a monetary value, the method is suitable for comprehensive measurement and aggregation of very different aspects. But, in 2015, such a system has not been developed for social aspects and continues to be a top-down type of LCA. However, embedded in a different context of data collection it can be useful and we build on this method in the "Oiconomy project".

Many of the current LCA shortcomings for the measurement of specific products are related to the limited possibilities to transfer objective, reliable and up-to-date data through the often-complex supply chains of products. However, industry has demonstrated the ability to maintain a self-imposed and effective global system of standardization and verification. Trust in supply chain data is achieved by compliance with standards, verified by certification. The often hard to achieve own control over upstream supply chain actors is replaced by collective and standardized control. Certification on food safety is an example of how private standards can evolve, in a few decades, to a system playing a fundamental role in global food safety (Hatanaka *et al.*, 2008; Henson, 2008). Chkanikova & Kogg 2015, p.12 recommend industry to also consider certification for supply chain sustainability data collection. One of the strengths of certification is the reversal of the burden of proof, to which organizations submit themselves. Without evidence of compliance, no certificate is issued and non-compliance may be assumed. The idea of the "Oiconomy project" is to utilize this type of system for the standardized and verifiable measurement and transparent transfer of preventative cost-based externalities through product supply chains, and thus we hope to make progress on LCA of specific products.

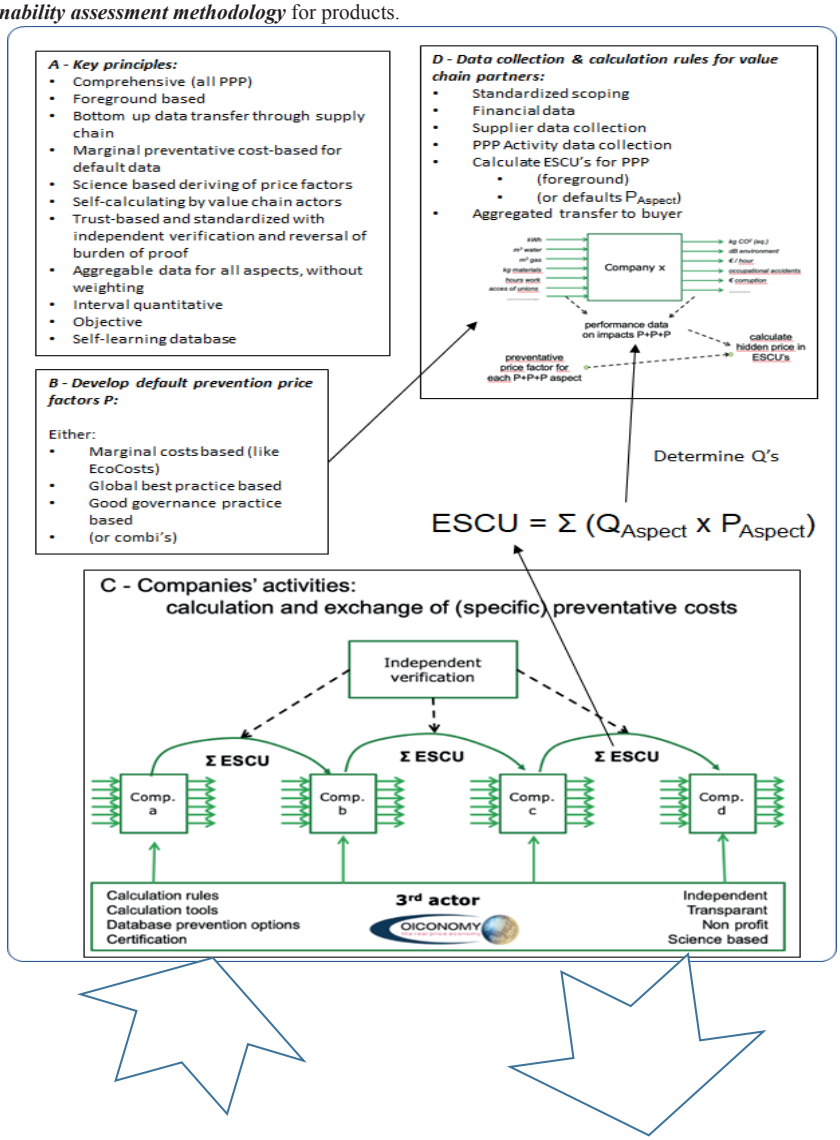
2.4. A NEW TYPE OF BOTTOM-UP LCA: THE OICONOMY PROJECT

The Oiconomy Project is comprised of four stages. The first stage, presented in this chapter, is the development of a new type of bottom up, standardized and comprehensive LCA. In the second stage the necessary data will be collected and we will show how such a system could make it possible to effectively combine environmental and social aspects in a LCA. In an envisioned third stage, the system will be tested in different industry sectors, necessary software needs will be developed and a certification scheme created. In the fourth stage, a running system, the actors in a supply chain will measure, document and transfer the externalities related to a product,

which will build up in the value chain, just like standard prices, until the end product, where the total hidden costs are disclosed to the consumer. Figure 2.1 shows the envisioned Oiconomy system, as sketched before in figure 1.3, but here in relation to its development stages and future functions.

Fig. 2.2 shows the envisioned matrix for each supply chain actor of calculated, aggregated and transferred ESCU's. In principle, the system also enables transfer of ESCU's for all separate aspect categories, all expressed in preventative costs, which we recommend because of the before-discussed need of comprehensiveness.

Figure 2.1: Extended charcoal sketch-2 of a bottom-up foreground, preventative cost-based life cycle ***sustainability assessment methodology*** for products.



Development phases:
1 - developing methods for boxes B & D
2 - illustration
3 - testing
4 – implementation of box C

Potential future phase
5 – market reform / tax reform

Future system functions:
1 – chain actors calculate ESCUs
2 – chain actors (inter)act on ESCUs
3 – apply on company level
4 – apply as procurement tool
5 – use for sustainability claims to stakeholders (incl. consumer)
6 – price adjustment
7 – taxation

Fig. 2.2. Matrix of ESCU's to be calculated, aggregated and transferred.

	ESCU's										
	Planet					People			Prosperity		
Category	Pollution	Depletion	Land	Biodiversity	Waste	Public Health	Labor	Various Social Aspects	Economic	Corruption	Total
Suppliers	Purchase-Pollution	Purchase-Depletion	Purchase-Land	Purchase-Biodiversity	Purchase-Waste	Purchase-Public Health	Purchase-Labor	Purchase-Various Social	Purchase-Economic	Purchase-Corruption	ESCU - Purchase
Gate to Gate	Gate to gate-Pollution	Gate to gate-Depletion	Gate to gate-Land	Gate to gate-Biodiversity	Gate to gate-Waste	Gate to gate-Third Parties' Health	Gate to gate-Labor	Gate to gate-Various Social	Gate to gate-Economic	Gate to gate-Corruption	ESCU - Gate to Gate
Product use	Use-Pollution	Use-Depletion			Use-Waste	Use-Public Health		Use-Social Responsibility			ESCU - Use
End of Life	End of Life-Pollution				End of Life-Waste						ESCU - End of Life
Bonus	Bonus-Pollution		Bonus-Land	Bonus-Biodiversity	Bonus-Waste	Bonus-Public Health	Bonus-Labor	Bonus-Various Social	Bonus-Economic		ESCU - Bonus
Total	Total-Pollution	Total-Depletion	Total-Land	Total-Biodiversity	Total-Waste	Total-Public Health	Total-Labor	Total-Various Social	Total-Economic	Total-Corruption	ESCU - Total

The desired future effect of the Oiconomy system is that consumers and producers will gradually change to sustainable production and consumption. However, probably, as a fifth stage, a tax reform is necessary to convince the mainstream consumer to buy sustainable products (see figure 2.1). Other existing internalization systems, such as tradable emission rights, are hard to imagine for social aspects. But even without tax reform "Oiconomy", a sustainable, full price economy, already exists as that part of the economy made by "Oiconomy consumers". This is a consumer who is seeking the lowest price for a product that causes zero damage on any environmental or social aspect in its complete product life cycle, who considers sustainability a required quality aspect of the product, and who, either under pressure of taxation or other internalization systems, or voluntarily, pays for the required preventative measures. The "Oiconomy producer" is a responsible organization willing to deliver Oiconomy consumer wants, and willing to submit itself to third party verification (see also Chouinard, Ellison and Ridgeway, 2011).

2.4.1. THE ECO SOCIAL COST UNIT AS UNIT OF PRODUCT SUSTAINABILITY

Hidden costs can be measured as costs of damage, restoration, compensation or prevention. Comprehensive measurement of more than one type of impact requires a weighting step. Because weighting by damage, restoration or compensation is far more difficult and subjective than of weighting by preventative costs, the latter represents the most objective method. Industry thinks in terms of the costs required for precautionary measures and therefore, these preventative costs represent the magnitude of their industries' hidden obligation to society.

The Oiconomy Standard (O.S.) (Croes, 2020b) is our proposed model for the standardized measurement of all aspects of product unsustainability, expressed in a monetary unit, the Eco Social Cost Unit (ESCU), aiming to fill the need for standardization described in section 2.3.3. The O.S. uses the principles of standard financial accounting for seeking to determine the hidden preventative costs of products at all links of the supply chain and for transferring these through the supply chain in a similar manner to standard costs. The ESCU's will be determined by the supply chain actors themselves according to a normalized, third-party-verified method.

This way, the O.S. aims to provide solutions to the shortcomings of impact-based LCA (see section 2.3). The certification system will enable bottom-up transfer of verified sustainability data through complex supply chains and therewith present a solution of the current top-down character of most current LCA's. This all is depicted in the boxes A and D of the figures 1.3 and 2.1. The O.S. considers all aspects of the Sustainable Development Goals, the GRI and ISO 26000. The ESCU is the sum of the preventative costs for all aspects, described with the formula: ESCU = Σ (Q_{Aspect} x P_{Aspect}) (see figures 1.3 and 2.1). Q_{Aspect} is the quantitative factor of an aspect expressed in the relative unit and P_{Aspect} is the price factor of one unit, preferably representing the actual foreground costs of prevention for the relevant product, or otherwise a default background value.

2.4.2. DETERMINATION OF THE QUANTITATIVE FACTORS

The O.S. provides a normalized measuring method for the quantitative aspect (Q_{aspect}) of unsustainability in all its aspects, both environmental and social, and regulates these to be multiplied with the relevant price factors (P_{aspect}).

The O.S. groups aspects in categories, several with subcategories. The goals of its aspect categorization are to systematically lead the practitioner through the various categories, and to group aspects by applicable measuring methods. Following the criteria of the O.S., the practitioner obtains one comprehensive ESCU score that quantifies the total hidden preventative costs per unit of a product, and also provides a matrix of separate aspect category scores, as depicted in fig. 2.2. The O.S. categorizes environmental aspects similarly to most current LCAs, although special attention is paid to categorize them by root causes instead of strictly by midpoints and endpoints. This can best be explained with an example. With the first generation of biodiesels, the aspect of land use was underestimated, by mainly considering energy itself as the issue instead of a combination of a variety of root causes, which are included in the O.S.- categories of pollution (GHG's), resource depletion and land occupation. The same problem may cause incomplete sustainability assessment of organic food products. At present, the O.S. is a model, which may evolve in subsequent stages of the project and during later stakeholder consultation. Even its categorization may change, but without affecting the core philosophy of the system.

Considering social aspects, the O.S. includes the commonly discussed categories related to economic aspects and labor conditions, but adds aspects that in industry are typically covered by governance programs (e.g. compliance programs on corruption and quality), because verification on such aspects becomes possible with the system of certification.

Currently, the O.S. recognizes ten fundamental categories, comprising all types of regularly described environmental, social and economic aspects (see fig. 2.2): 1. Pollution; 2. Resources; 3. Land occupation; 4. Biodiversity and nature degradation; 5. Public health; 6. Waste and disposal; 7. Economic responsibility; 8. Labor conditions; 9. Corruption and violence; 10. Various social responsibilities (Croes, 2020b). Next to the total ESCU score, these ten category scores are advised to be transferred through the supply chain.

2.4.3. DETERMINATION OF THE PRICE FACTORS.

The O.S. requires the practitioner to allocate ESCU's based on a database with default price factors, unless she/he can demonstrate product-specific lower preventative costs. In section 2.3.5, we addressed the problem that in current impact-based LCA the common industry-

practitioner has not enough knowledge of the complex nature of the impact to be able to judge its applicability to his/her specific product, location and processes. In contrast, because calculating costs of measures and changes is a core activity of any business, in our proposed system, the industry practitioner will calculate and correct default values and contribute to the system. Directing industry focus to research into how to prevent damage and the related costs, is part of the goal of this project.

In theory, if a complete supply chain consists of knowledgeable practitioners, the system could run without a database with default values, because every practitioner in the supply chain could determine the preventative cost-based price factors her/himself. Because such verified (anonymized) new market-obtained data can be used for updating the database price factors, the system becomes self-learning, one of the features of the proposed Oiconomy system (see figure 1.3, box A). This principle means that the price factors need to be based on market prices. The O.S. includes criteria controlling the quality of market-obtained new price factors. Initially however, default values for the price factors need to be predetermined for all aspect categories. For this determination, a fundamental question is: to which level must unsustainability reduction be measured? Not all issues need to be reduced to the zero level because earth and mankind may have a certain resilience on the relevant aspect. An option is to set the standard to the best available practice. Disadvantages hereof are that even the best practice may not be good enough, that the relevant practice is not sufficiently available to make a difference and that it may be unrealistically expensive. A more feasible option is the EcoCost/Value ratio method, which uses the marginal preventative costs to reach a target or standard as a measure (Vogtländer *et al.*, 2000). The best way to explain the method is with an example. If the target on reduction of GHG emissions was an 80% reduction of global emissions, several major options of renewable energy generation, energy use efficiency improvements and life-style changes would be required because each of them alone will be insufficient to reach that target. Reasonably assuming that the cheapest technologies/changes will be used first, the marginal preventative measure is the most expensive (last deployed) major measure required to globally reach the target. ("major preventative measure" is defined as a measure that theoretically has the potential to globally make a difference).

Marginal preventative costs are determined for impact categories (similar to the midpoint categories in current LCA (Wolf et al. 2012, p.41)), (Joint Research Centre of the European Commission et al. 2012, p.41) characterized by a categorization factor (e.g. climate change by the global warming potential). The different components (e.g. methane, CO_2) within the category are weighted by their characterization factor. Delft University of Technology, 2019 already maintains a database for most environmental aspects. (EcoCost categorization is not the same as the one used in the O.S. for the determination of the price factors, because of its totally different goals described in section 2.4.2). The concept of using marginal preventative costs was also proposed for the national accounting level by Ekins and Simon, 2001), calling it "distance to sustainability". De Bruyn *et al.*, 2010 produced "shadow prices" for a large range of pollutants, based on both preventative costs and impact costs. So far (2015), the preventative cost-based method was used for environmental aspects only. The Oiconomy system was designed to use the EcoCost/Value ratio system for the determination of the default price factors, but to extend it for social aspects, make it bottom-up, make the databases self–learning, and make it suitable for specific product assessment.

Considering the envisioned self-learning character of the database with default price factors and to enable industry to generate more specific price factors than existing default values, subcategories are not predefined. Industry may develop subcategories based on more specific impact definitions, product groups, industry sectors or processes. However, new subcategories may not be used for the purpose of hiding specific unfavorable situations in a larger category, which must be part of the verification process.

Procedure for the determination of price factors for ESCU's.

In order to facilitate a uniform determination of the price factors, we suggest the following 5-step procedure (also summarized in Box B of the figures 1.3 and 2.1):

1. Definition of the impact category or subcategory considered, together with the characterization factor, the indicator characterizing the relative weight within the category (e.g. the global warming potential for GHG emissions).
2. Determination of the specific standard or target to be achieved.
    - Assessment of available effective international standards and conventions. (In some cases, science has already demonstrated that existing international standards and conventions are not effective; in these cases, a scientific no-effect level can be used)
    - Without an effective international standard or no-effect level, set the target at 80% reduction of the impact (relative to 1998, the year after the Kyoto Protocol) or, if concrete measurement of that reduction level is not feasible, at the average level of the 20% best performers (e.g. countries).
    - Where no such concrete target can be defined, determine the cost distance to perfect governance on the aspect.
3. Listing of major available preventative measures.
4. Determination of the costs and net effects of available preventative measures and sorting the list by the costs per one unit of the characterization factor, with the lowest on top.
5. Assessment of which preventative measures are required to globally reach the target. The last and most expensive preventative measure to be employed shows the marginal preventative costs.

2.5. SYSTEM BOUNDARIES FOR THE OICONOMY SYSTEM

One of the major shortcomings of LCA, if used for specific products and the transfer of coherent data through the supply chain, is the lack of standardization in the choice of system boundaries. Although the Oiconomy system is envisioned to become as objective as possible, some choices will have to be made and system boundaries will have to be set, if only by means of definitions and by the choice of categorization of considered aspects and system boundaries. First, we need to realize that taking preventative costs as a measure is a choice that gives implicit impact preference to all aspect categories, with the probable consequence, that industry will improve first on the aspects with the best balance of preventative costs and benefits. However, in our opinion, this is much more objective than impact-based systems basing themselves on panel opinions or DALYs, because even the largest possible polls, those of national elections, demonstrate large and rapid changes in people's opinions. Preventative costs also change, but because costs are the core of normal business, can be maintained and updated much easier.

2.5.1. THE INCLUDED SUSTAINABILITY ASPECTS

Central in the concept of sustainability is the Brundtland Report definition "*Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs"* (United Nations World Commission on Environment and Development, 1987, p.15). However, this definition is a statement in very generic terms with little direction for the different aspects of sustainability. The original version if this chapter, a paper, published in 2015, was originally written before the sustainable development goals (SDG's) were established. After the establishment of the SDG's, these provided a framework of sustainable development goals after which this section was rewritten for this thesis.

Answering to the afore-discussed importance of comprehensiveness in product-sustainability assessment, a set of aspects had to be selected to be included in the Oiconomy Standard. The set needed to include both environmental, social and economic aspects and include all important externalities and product features that unwillingly negatively affect the user/consumer (see definitions of "externality and "internality" and chapter 6). All included aspects needed to be relevant in the life cycle of products.

For the choice of aspects in the first version of the Oiconomy Standard, a wide range of standards, conventions, treaties, legislations and issue labels were available. Well recognized standards were and are available on quality, environment, health and safety governance, on product safety and many other aspects, (e.g. ISO 2004; OSHAS 2007). Examples of issue labels, industry sector labels and product labels are the labels of Fair Trade (Fairtrade International, 2011), MSC (Marine Stewardship Council, 2010), FSC (Forest Stewardship Council A.C., 1996), and the EU Ecolabel system (SMK and SV&A, 2006; Der Blaue Engel, 2013). Also available are various conventions, treaties and legislations, providing standards and principles on both environmental and social aspects, such as the Universal Declaration on Human Rights (UN General Assembly, 1948), the ILO Declaration on the Fundamental Principles and Rights at Work (ILO, 1998), the Codex Alimentarius (WHO & FAO, 2013) and the 2001 Stockholm Convention on Persistent Organic Pollutants (The Secretariat of the Stockholm Convention, 2009). Most of these initiatives only cover a limited number of aspects. But, the IISD provided a recent and comprehensive review of sustainability initiatives (Potts *et al.*, 2014), which was used to ensure to cover all existing aspects.

Two more comprehensive initiatives already receive considerable international recognition: ISO 26000 (ISO, 2004) and the GRI (GRI, 2013). ISO 26000, written as a business guideline instead of a standard, provides a very comprehensive framework of sustainability aspects, covering almost all regular discussed environmental and social aspects. However, economic responsibility is underrepresented, although corruption is considered. The GRI offers a choice between a core option of aspects to be reported on by companies, and a comprehensive option, including a very complete set of environmental, social and economic aspects. The GRI focuses on transparent reporting, without assessment of the accomplished level of sustainability. The first version of the O.S. already included all aspects of both ISO 26000 and the GRI, if applicable to the product level and potentially representing an externality.

In 2015, the United Nations General Assembly agreed on the 17 SDG's (United Nations General Assembly, 2015) and therewith provided a comprehensive set of sustainable development goals

and a framework for the Oiconomy Standard's choice of aspects. The main underlying goal of the SDG's however, was not conceptualized for measuring product sustainability or perform life cycle assessments, but for transitions on more general and especially national levels. But because a large part of unsustainability is embedded in internationally traded products, it is of paramount importance to cover the SDG's in LCA and the O.S. However, like the Brundtland statement and almost all international conventions, the SDG's are described in very general statements, which need to be related to common LCA principles in a logical way. In principle, for preventative cost-based sustainability assessment, the common aspect – midpoint – endpoint reasoning is less obvious than for impact-based assessment. In impact-based LCA, even if foreground quantitative data on causes are available, the determination of the impact is determined by following cause-effect pathways. A long term goal of the Oiconomy system is to gradually develop to a mainly foreground system and challenge companies to study and implement preventative measures, but on the way to that ideal, background default data are still required. For foreground data in the Oiconomy system, enough knowledge is needed of the cause-effect pathway to develop preventative measures and calculate their costs, but quantification of the impact itself is not necessary. However, for background data in general and for the EcoCost system in particular, the marginal preventative costs are still categorized by means of the midpoint – endpoint reasoning and quantified by their impact-based characterization factor. Vermeulen describes the logical relation between the SDG's and the common LCA midpoint – endpoint categorization (Vermeulen, 2018, p.59-90), including a scheme (appendix 2) in which the aspect categories of the Oiconomy Standard were added. Because ISO 26000, as a guideline to serve the community instead of only avoiding harm, goes beyond avoiding externalities, some minor aspects, concerning internal costs, are excluded from the O.S. Also from the GRI, some aspects, irrelevant for the product level, or concerning internal costs, were excluded. As a result, the Oiconomy system comprises all product- and externalities related aspects considered in the 17 SDG's, ISO 26000 and the GRI. However, because the goal and character of the Oiconomy system is different from ISO 26000 and the GRI, the covered sub-items, categorization and quantification methods are very different. The resulting correspondences of aspects between the GRI, ISO 26000 and the Oiconomy System are depicted in the appendices 2, 3 and 4. Remarkable was that the earlier version of the Oiconomy Standard required very little adaptation to the newly available SDG's, which demonstrates that especially ISO 26000 was already covering most of the SDG's.

A last remark on the choice of aspects in the Oiconomy Standard, is the addition of some criteria on economic aspects and financial responsibility and a group of more recently emerging social responsibilities, such as speculation in basic needs, manipulation of financial markets, internet related privacy violations, timely payment, spam and unjustifiable product claims.

2.5.2. TO WHAT DETAIL NEEDS TO BE MEASURED?

Product life cycles may comprise a multiple of items, activities and services, many of which are irrelevant and complicate the system. Details need to be truncated. The Oiconomy Standard (O.S.) sets its truncation level at 80% as a preliminary, which is also the minimum stated for LCA by the JRC (European Commission *et al.*, 2010), and means that we propose that initially, the 20% most minor details need not to be included in the calculations. Because there are financially and physically minor activities that still may have a major sustainability impact (e.g. emission of highly toxic chemicals), the O.S. excludes a series of high impact items and activities from this detail truncation. In a running system, it will always be possible to slowly raise the percentage, e.g.

to 95%, which is a more usual truncation level in LCA and advised by the JRC. A preliminarily low detail truncation level was chosen because the O.S. considers far more aspects than current LCA, which may become too demanding for the practitioner.

2.5.3. DEFINITION OF ORIGIN AND END OF THE SUPPLY CHAIN

Unlimited upstream investigating supply chains never end, and may even lead to endless circles (e.g. iron ore mined with steel machines). The same may apply downstream, because materials may be recycled forever. Therefore, both the origin and end of the life cycle need to be defined. "Origin" may be defined as the location of extraction, being a mine, land (agriculture or nature) or sea. But this definition is insufficient where many resources are purchased for the process of extraction. For example, for dairy products, the animals may be fed with either farm-grown grass, or with externally sourced feedstuffs. In the grass case, the farm is the logical origin, but not in the external feed case. For trade and tariff considerations, so called "Rules of Origin" (RoO) are used. There are no GATT agreements on RoO, but four criteria are commonly used (Krishna, 2005):

1. Requirements in terms of addition of content, which may be value or physical.
2. Requirements in terms of change in tariff heading in a classification system.
3. Requirements in terms of processes.
4. The requirement of the last "substantial transformation".

These RoO are primarily used for economic reasons and intended for countries rather than for industry. For the purpose of this project, the definition "substantial transformation" is too vague; requirements in terms of processes would require a huge database for all the different cases, and the system of changes in a classification system has little relation to our purposes. However, the first option can be applied at company level and in any situation and seems the best criterion of truncation for the Oiconomy system. Applying our proposal of detail truncation at 80%, these projects' rules of origin then lead to the following proposal: "*The life cycle shall be investigated upstream to the stage of extraction (mining, agriculture, fishing and sea exploration) and even further back until that stage at which both physical weight- and value addition to the product are over 80%"*. (This proposal was developed in 2015, but adapted slightly after the lessons learnt in pilots on the system, described in chapter 7 of this thesis).

Also the concept of "grave" needs to be defined. Ideally recycling leaves no waste at all. But in practice at least two issues need to be considered:

1. Recycling may cause downgrading, limiting future use, recycling or future value. Therefore, the O.S. divides ESCU's between the original and recycling material proportionally to their market value.
2. Recycling processes may have substantial impact themselves, which effect is covered by the O.S. because recycling processes are explicitly addressed.

2.5.4. THE SETTING OF THE TEMPORAL BOUNDARIES

Current LCA is subject to temporal problems, the four most important of which are:

1. Targets and costs depending on the temporal scope (e.g. considering depletion issues). In literature only one of such temporal choices could be found where the IPCC has set a (not

very hard) scope of 100 years (United Nations, 1998; United Nations Framework Convention on Climate Change, 1998) for the global warming potential of the various greenhouse gases (GHG's). In this project, where temporal truncation is required, we use this 100-year scope.

2. Present issues with future impact (e.g. cancer and climate change) present a serious problem in current impact-based LCA. Preventative cost-based systems do not experience this problem and are always based on present costs.
3. Impact occurring by the later use of the product (e.g. fuel for a car). In most cases, the O.S. allocates future energy ESCU's to the energy source and ESCU's for preventative utensil adaptations to the utensil. The aspect is further discussed in section 2.5.10 on double counting. For any ESCU allocation for future impact, the O.S. truncates at a maximum of 100 years' use of a product.
4. Impact depending on future disposal technology (for long life products). Preventative cost-based methods overcome the problem by using costs of current prevention.

2.5.5. ADDRESSING BOTH COSTS AND BENEFITS OF PREVENTATIVE MEASURES?

As numerous pollution prevention practices have shown (Gallup and Marcotte, 2004; Cagno *et al.*, 2005), prevention usually not only brings costs, but also benefits. For example, good quality governance saves on failure costs, good health and safety governance saves on lost hours, good sustainability and responsibility may prevent future restoration costs and claims and improve the reputation of the company, and good waste and recycle management prevents disposal costs and saves on purchasing virgin raw materials. In these arguments we see both prevention- and an impact orientation. Various systems of eco-efficiency measurement (Schmidheiny and Zorraquin, 1998) and environmental management accounting (e.g. Jasch 2006) have been developed to assess and base decisions on a balance of costs and benefits. There are many examples where even the internal balance of costs and benefits is positive, especially if savings can be made on reducing waste and procurement (e.g. US Environmental Protection Agency 2014; Jasch 2003). In such cases, including benefits in the ESCU's would make them negative. Obviously these situations currently do not hurt or inspire the involved companies enough to make a change. Because internal benefits are often very case specific, they cannot be included in the default ESCU values.

However, there is an abundance of opportunities for "Bonus ESCU's" for proven foreground external benefits. But there are also serious moral and practical implications of inclusion of external benefits or "positives" in any type of LCA, which we will discuss in chapter 6.

2.5.6. THE SETTING OF TARGETS FOR SUSTAINABILITY ASPECTS

As before-discussed in section 2.4.3, for the determination of the price factors and marginal costs, targets/standards are required. For many aspects, targets are available (e.g. for most hazardous chemicals a certain concentration; for child labor and corruption, zero). If no suitable target is available, or for example, if for political reasons, available targets are insufficient to be really effective, the following procedure is proposed for the determination of targets and marginal costs:

1. If available, on environmental aspects, the no-effect level is taken as the target. Without a no-effect level, 80% global reduction of the 1990 (year of the Kyoto protocol) impact is

taken as the target. However, if all potential practices together are insufficient to reach the target, the most expensive major preventative practice will be taken as the standard.

2. On social aspects, where possible, the same procedure is to be followed, or else, the average performance in a benchmark of the 20% best performers on preventing the issue is to be taken as a target. For various social aspects for which this procedure will be used as the target-setting method (e.g. for the setting of a fair wage), countries will be the performing units. For this purpose, by an assessment of available indicators in country performance, in chapter 3, we propose a benchmark group of countries, based on the Sustainable Society Index (Van de Kerk and Manuel, 2012). Where no target making methods are available these may be derived from democratically grown practices in this benchmark group.
3. If no concrete target can be determined, the O.S. takes a perfect governance system as the target, using the principles of well-developed risk-based certification standards on aspects like quality, labor conditions and health and safety. The costs of such a system, including all its consequences, show our marginal preventative costs.

2.5.7. DEFAULT PRICE FACTORS BASED ON NET EFFECT

The preventative costs of a measure must be based on the net effect. For example, in the assessment of solar panels intended to reduce GHG emissions, all emissions during the lifecycle of the panels must be considered. Even best practices rarely have zero issues. Sustainability is a multi-aspect concept. Ideally, assessing a best practice on a specific aspect, both the impact reduction of the relevant aspect and the impact on other sustainability aspects are considered.

Initially however, it would be far too complex to take all the other involved issues into account at the initial determining of default values of the marginal preventative costs/price factors. However, in a running system, following the principles of the O.S., self-learning and specifically designed for comprehensive assessment, all the other aspects will gradually be included and preventative costs corrected. A preventative measure against child labor is to employ a fairly paid adult enabling her/him to provide proper education to his children; a windmill as a measure against climate change, may be have been produced based on polluting mining.

2.5.8. THE EFFECT OF SPATIAL AND TEMPORAL IMPACT DIFFERENCES

Potting and Hauschild, 2006 point out that the level of impact may be location-dependent. E.g. water is not scarce everywhere and halve times, eutrophication, photochemical ozone formation and ecosystem resilience depend on temperatures. The impact may also be time-dependent. E.g. a disease may become curable and new recycling technologies may develop. In impact-based measuring systems, spatial and temporal differentiation would be required, but not in preventative cost-based systems, unless at a specific location an impact is totally absent. The O.S. includes a general criterion permitting the applicant to demonstrate such location-specific exemption.

2.5.9. THE ISSUE OF DOUBLE COUNTING

If a product has an impact in different categories, prevented by one single measure (e.g. oil depletion and GHG emission, both prevented by using renewable energy) ESCU's will be allocated in different categories, causing double counting. As much as possible, the O.S. avoids double counting by means of its categorization. In addition, the O.S. includes a criterion allowing avoidance of double counting if that can be demonstrated by the practitioner. Another type of

double counting may occur where utensils and consumption items are causally related, e.g. a car needing fuel. The car is the direct cause of GHG emissions, because the purchase of the car predetermines an average impact during its lifetime of use of the fuel. If the Oiconomy system were to be used only for sustainability *measurement* of a product, ESCU's will be allocated to both car and fuel for driving the car, without double counting being an issue. If, however, in a future stage, ESCU's are used for real internalization of currently externalized costs, the consumer will be confronted with ESCU's both for the car and for the fuel. In this case we have a case of double counting and ESCU allocations must be corrected, e.g. by reducing the ESCU allocations to the car with the average ESCU's internalized in the energy sources.

2.6. NEXT STEPS: RESEARCH CHALLENGES AND LIMITATIONS

After having described the principles, rules and the proposed system boundaries of the proposed Oiconomy system as a product specific, comprehensive and bottom-up type of LCA, we now discuss the next steps of the project, some research challenges and the limitations of the system that we did not discuss before.

2.6.1. FILLING THE DATABASE WITH THE DEFAULT PRICE FACTORS

In the following chapters, the necessary default price factors will be collected and we will show how the system allows for inclusion of social aspects into LCA. A model of the database, preliminarily called "Oiconomy Foundation (O.F.) Database" is presented at http://oiconomy.geo.uu.nl/. Because the Oiconomy system follows the ideas of the EcoCost/Value ratio system, price factors for most environmental aspects are available and maintained by the (Delft University of Technology, 2019). However, on the aspects of land use and water depletion, some adaptations were made, described in section 8.4.2, because the Oiconomy system is intended to be more location specific and more socially inclusive than the Ecosystem

In the chapters 3,4 and 5, the principles described in this chapter are practiced for the determination of the price factors of the social aspects of a fair income, fair inequality, child labor, fair transactions and corruption.

2.6.2. CERTIFICATION/ VERIFICATION SYSTEMS

We argued before, that the Oiconomy system makes LCA far less complex for the practitioner, which is undoubtedly true in a successfully operational system, because in fully certified supply chains all ESCU's can simply be obtained from certified direct suppliers. The Oiconomy standard was envisioned to use the global system of certification and accreditation for the verification of compliance with the standard in the supply chain, but the total system and aspects to be verified are much larger than usual and therefore, undoubtedly more expensive than most current certification schemes. Challenges for the development of a certification scheme will be discussed in section 8.5 of this thesis.

2.6.3. USE OF ESCU'S FOR INTERNALIZATION OF EXTERNALITIES

The primary goal of the Oiconomy system is to provide a comprehensive sustainability measure of specific products, equal to the product life cycles' embedded externalities. We have used the measure of the preventative cost-based externalities because they may represent consumers' and industries' collective hidden responsibility to nature and the weak. Although already practiced

and proven effective, the internalization of externalities by means of a tax reform is still in its infancy and limited to energy use and carbon emissions. Taxation systems affect many more aspects of communities than only sustainability and are the responsibility of politicians. Until now, the absence of a system for the measurement of product related externalities may have contributed to the lack of internalization, which limitation we hope to eliminate with this project. More on the potential opportunities of use of the Oiconomy system will be discussed in section 8.7 of this thesis.

2.6.4. OBJECTIVITY OF THE SYSTEM

The proposed Oiconomy system is not completely without value choices. The chosen preventative costs as quantitative measure in itself is a choice that makes an issue independent of the perceived magnitude of impact. However, it is designed on some generic, one-time chosen, system choices, all described in this paper, limiting individual choices of researchers and practitioners to a minimum and thereby, potentially providing a more objective comprehensive product sustainability measurement system than what is possible with the current LCA tools. Also with other system choices, the methodology remains the same. In the discussion in section 8.1.2, we will further describe the most important value choices that have been made.

2.6.5. PRICE LEVEL CHOICE CONSIDERING SPATIAL COST DIFFERENCES

Product supply chains may be extremely complex and involve many countries. Price levels show great spatial variation. Which price level of preventative measures should be chosen as a measure for the price factors? In the opinion of the leaders of the Oiconomy project's long-term goals, ESCU's should be at the lowest level that makes mainstream consumers and industry change to more sustainable production and consumption. The consumer's location determines the price level of ESCU's required to result in a mainstream change. Most global consumption is still in high income countries, and price levels in emerging markets tend to develop towards high price levels (Halpern and Wyplosz, 2001; Hofrichter, 2012). Price levels in low income countries are often so much lower that even doubling or tripling of, for instance, land prices would not lead to major consumption changes in high income countries. This would favor the option of using developed countries' prices. However, there are more arguments in favor of freely using market prices, e.g. many goods are only produced in low income countries which in their development depend on their low labor costs and the Oiconomy system is not intended to be used for protectionist purposes; for the self-learning aspect of the system, the price factors need to be based on market prices (see section 2.4.3); the price factors are based on the costs of preventative measures with the potential to globally make a difference (see section 2.4.3), which limits short term and local price variations; every product has its price in the current economy and a hidden price, outside the current economy. Hidden costs depend on, and should vary according to, actual costs. Weighting these arguments, we consider the actual market cost the only logical choice. But doing so, it is important to use our proposed method comprehensively indeed, including the social aspect of fair wages, because without comprising that aspect, the system would not lead to proper development of low income countries.

2.6.6. MEASURING ASPECTS WITHOUT CONCRETE TARGETS

On some aspects no generic concrete targets or preventative measures are available, e.g. on the aspects of quality and occupational health and safety. Control on such aspects is commonly achieved by third party-verified risk-based management systems, like the OSHAS health and safety standard (OSHAS, 2007). A simple criteria weighting is commonly applied by distinguishing "key criteria" and "other criteria". However, these standards only measure compliance or non-compliance, where we want to measure the cost distance to a very high level of performance. One idea to accomplish this is to score companies on the different governance criteria and study the relation between the measured level of governance and the cost distance to full compliance to the governance criteria. This idea presents three research challenges. The first is to, based on the opinion of certification and industry experts, develop a rating system measuring the quality of governance. The second challenge is to determine, in different industry branches, the costs difference between perfect and poor performance on the relevant issues. The third challenge is to determine the cost-distance to such perfection at different levels of governance as determined by scoring the compliance to governance criteria. As argued in section 2.4.3 the system could in principle run without default values, relying on industries' own, but verifiable, calculations of the preventative costs on an issue. If above method proves not feasible, a standard, such as the O.S., will have to require such calculations for the aspects without concrete default values.

2.7. DISCUSSION AND CONCLUSIONS

To date (2015), no method exists for the comprehensive measurement of product sustainability, including both environmental, social and economic aspects. Our literature review showed that current LCA, if used for this purpose, has serious shortcomings. The most important shortcomings are: the lack of a measuring standard, the lack of inclusively considering social aspects, the top-down approach, the weighting of different aspects, the very laborious procedures of addressing specific supply chains, its limitation to environmental aspects, the very complex nature of impact-based data, and difficult data maintenance.

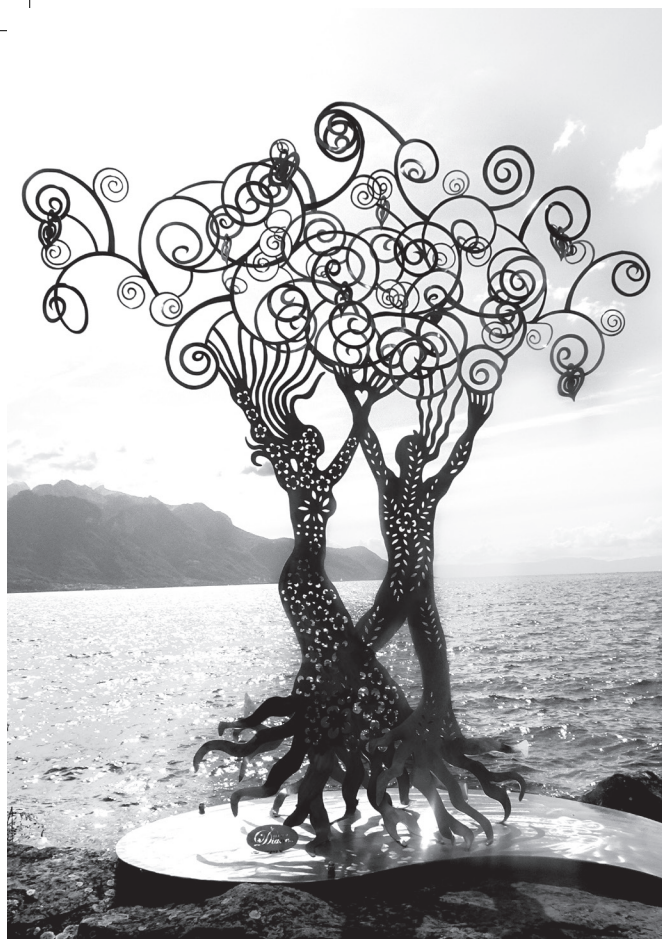
Internalization of currently externalized costs is a frequently mentioned solution in a free market economy for correcting sustainability aspects. The product embedded externalities, representing their cost distance to sustainability, may be a measure for product sustainability. Prices of end products have been established by gradual transfer of prices in the supply chain; various certification systems demonstrate industries' ability to verify supply chain data, and the EcoCost/Value rating system (Vogtländer *et al.*, 2000) demonstrates how preventative cost-based weighting allows for comparison and aggregation of different aspects.We therefore propose a system for the measurement of product sustainability by copying the normal mechanism for transfer of prices through the supply chain for the currently hidden, preventative cost-based "Eco Social Cost Units" (ESCU's). The ESCU is the sum of the preventative costs for all aspects, described with the formula: $ESCU = \Sigma (Q_{Aspect} \times P_{Aspect})$. Q_{Aspect} is the quantitative factor of an aspect expressed in the relative unit and P_{Aspect} is the price factor of one unit.

By the introduction of the Oiconomy standard as a first model standard for the measurement and transfer through the supply chain of preventative cost-based externalities, controlled by certification, most shortcomings of current LCA can be solved. The standard systematically

leads the practitioner through all aspect categories and the involved production process stages, determining the quantitative factor and a database provides default values of the price factors. The measuring standard may be useful to help to overcome differences between definitions of the functional unit, scope and measuring methods, thus making results comparable and allowing for aggregation of different aspects. Certification may make it possible to reliably transfer sustainability data through the supply chain, to verify supply chain-specific aspects, and to help create a self-learning database, which may be more accurate and easier to maintain than current LCA databases. Many social aspects become verifiable and measurable.

Where impact assessment is extremely complex and mostly out of industry comprehension, costs are their core business, enabling them to correct default price factors. Preventative costs are not subject to the inherent uncertainty and temporal problems of impact-based assessment. Although using preventative costs is a choice, for seeking to consider all aspects to be equally important, they do not depend on subjective weighting systems like “willingness to pay”.

Standardized system boundaries are an absolute requirement for uniform measurement of product sustainability. In this chapter, we present our vision of the system boundaries for the Oiconomy system and the processes for the determination of the price factors. Price factors for most environmental aspects are available, as are EcoCosts from the Delft University. Most challenging for the determination of price factors of social aspects was to set the necessary targets. Chapters 3 will elaborate the methodology, proposed in section 2.5.6 for setting reasonably objective targets based on the practices of the 20% top performing countries, and puts this into practice for the aspect of inequality. The methodology for the determination of the default price factor for governance-measured aspects will be elaborated in chapter 5 for the aspect of corruption.



If the world fails in mitigating climate change, it will be by lack of political will and insufficient focus on poverty, inequality, corruption and the role of finance

Externalities exercise unjust pressure on competitors, the most forgotten stakeholder in LCA

CHAPTER 3

A REFERENCE POINT FOR THE ASPECT OF FAIR INCOME INEQUALITY[4]

4 This chapter is based on: Croes, P. R. and Vermeulen, W. J. V. (2016a) "In search of income reference points for S-LCA using a country level sustainability benchmark (part 1): fair inequality. A contribution to the Oiconomy project," *Int. J. Life Cycle Assess.*, 21(3), pp. 349–362. A section 3.3.5 was added, considering ESCU calculations on inequality. The chapter was slightly edited to fit in the book structure.

3.1. INTRODUCTION

Disputes concerning global labor practices are at the core of contemporary debates regarding globalization and sustainable development. Critics have charged multinational enterprises with the unjust exploitation of workers in the developing world (Arnold and Hartman, 2006). It is increasingly recognized that companies, (e.g. Chouinard, Ellison and Ridgeway, 2011), can make a major contribution to sustainable development by being environmentally and socially responsible, and that tools associated with these concepts can enhance their competitiveness and economic performance. It is believed to be a new imperative to develop sound sourcing and fair trading relationships. This includes issues associated with fair trade (including aspects of human rights, fair wages, inequality, sustainability reporting procedures and ethics) and associated tools (guaranteed prices, codes of conduct and end-price audits) (Welford *et al.*, 2003).

Davies et al. estimated "for the year 2000 that the richest 2% of adult individuals in the world owned more than half of global wealth, with the richest one per cent alone accounting for 40% (Davies *et al.*, 2008). In 2014, 0.7% owned 44% (Shorrocks *et al.*, 2014), indicating that inequality is rising. Although inequality is gradually decreasing across countries, it is especially rising within countries (Sala-i-Martín, 2002a; Belser and Sobeck, 2012). The Davos Economic Forum in 2011 considered economic disparity and global governance as amongst the world's greatest challenges (Davis et al. 2011, p.6). Although the causal relations are debated, there is strong evidence of significant correlations between inequality and social unrest (Wayne Nafziger and Auvinen, 2002; Wilkinson and Pickett, 2009; Justino, 2012). Especially uncertainty and perceived injustice is suggested to be a cause of extremism (Doosje *et al.*, 2013; Hogg *et al.*, 2013). There is also strong evidence of a significant correlation between inequality and negative health impacts (Wilkinson and Pickett, 2011; Bocoum *et al.*, 2015). Because health is considered an important endpoint category in LCA (Jolliet *et al.*, 2004) and S-LCA (Norris, 2006; Klöpffer, 2008; Benoît Norris *et al.*, 2009), and human well-being is considered the main area of protection to assess social impacts of products (Neugebauer *et al.*, 2014), it is important to include inequality in social LCA (S-LCA). Boccoum et al. even describe a pathway between child mortality as health indicator and the GINI coefficient as inequality indicator, for potential use in S-LCA, but they also note that many more of such pathways on social aspects need to come available before a complete S-LCA can be made (Bocoum *et al.*, 2015). The use of the GINI coefficient for S-LCA purposes was suggested before by Finkbeiner et al., (2010).

Current LCA systems, if applied on consumer products, are very dependent on reliable data on the upstream supply chain. Missing specific supply chain data, in environmental LCA (E-LCA), can often be found in generic databases. The impact of social aspects however, may be site specific (Benoît, Norris, Valdivia, *et al.*, 2010; Parent *et al.*, 2010), or even personal (Jørgensen, Finkbeiner, *et al.*, 2010) and therefore extremely difficult to quantify. Current impact-based LCIA on social aspects are therefore at the best nominally quantitative, which is useful for its original purpose of assessing alternatives on a limited number of aspects, but not for the comprehensive assessment of complete products.

Key questions are how to characterize and how to determine performance reference points (PRP's) and weight the impact of different social aspects, not only weighting them against other social aspects, but also against environmental aspects, and thereafter how to standardize these in order to make assessments by different practitioners comparable. In E-LCA a large

step towards normalization and objective and comparable assessment is the EcoCost system (Vogtländer *et al.*, 2000) by not measuring impact, but marginal preventative costs, providing one sustainability measuring unit for the different aspects. However, a preventative cost-based system is not available, and seems unthinkable, for social aspects without a system of onsite verification.

UNEP & SETAC (2009. p.37) defines S-LCA as "a social impact assessment technique". Major issues with impact assessment in S-LCA are the complexity, the lack of data, especially on the specific supply chains (Lehmann et al. 2013, p.1590), and the vague nature of international standards, at the most allowing for semi-quantitative indicators (Parent et al. 2010, p.167). Key missing approaches in S-LCA in general and surely for the aspect of inequality, are methods for reliable and verifiable collection of data and determination of concrete quantitative PRP's.

The "Oiconomy system" however, is based on certification, which allows to make many data "foreground", because they are verified data on the specific supply chain, where they otherwise would have been "background" data from databases, which usually are averages. Where the goal of most LCA's is to compare different product related alternatives, usually on a limited number of sustainability aspects, the Oiconomy system is designed to measure the comprehensive (un) sustainability of end products, destined for the consumer or user. The Oiconomy system is extensively described in chapter 2. Where, due to the difficult quantification of social impact, most S-LCA's are qualitative or at the most nominally quantitative, the Oiconomy system makes it possible to quantify data on social aspects with the interval indicator of preventative costs.

Both the EcoCosts system and the Oiconomy system use the cost distance to a target as (un) sustainability indicator for every aspect. Therefore, we here use the word "target", although it expresses almost the same as a Performance Reference Point (PRP), more commonly used in S-LCA (Benoît 2014, p.263; Parent et al. 2010, p.166-167). The difference is that in the EcoCosts- and Oiconomy systems it really concerns a target to which an interval quantitative distance is determined, where in impact-based LCA it just serves as a performance reference to which any system of comparison may be used. Where the EcoCost system is a more conventional system always using predetermined data in a database, the Oiconomy system allows the practitioner to provide case specific, onsite verified data. This means that the EcoCost system is always based on *marginal* preventative costs, the costs of the last and most expensive employed preventive measure to globally reach the target, assuming that the cheapest measures are employed first. The Oiconomy system only uses the marginal preventative costs as default values, to be used if the practitioner cannot demonstrate more specific and verified data.

For most environmental aspects and for various social aspects such targets are provided by conventions, legislation and standards, however, not for all. There is for instance no international standard for the important social questions of what is a "fair wage" and what is a "fair inequality". Without an existing standard, industry often seeks best practices as benchmark (e.g. Fiksel et al. 1999).

A concept in the system, essential for the subject of this paper is the "Oiconomy consumer", who requires full sustainability as a quality aspect of the product and wants to know the cost distance to the sustainable product. Considering poverty, all current theories on poverty analysis and all current countries' choices are based on the assumption of continuation of the existing fierce competition on labor costs, even below the poverty line. The Oiconomy consumer however,

requires all hidden costs of sub-fair wages and too high inequality to be included in the price of the product, with the consequence that competition is limited to above a threshold standard. For the aspect of inequality of wages, countries seem the best performing units. We propose to use the practices in a benchmark group of the 20% top performing countries, but first we need to select the indicator best suited to develop that benchmark.

The purpose of this chapter is to first develop a well-founded benchmark group of the 20% best performing countries and thereafter, based on practices in this benchmark group, propose a well-founded benchmark for the aspect of inequality of wages, for preventative cost-based LCA, but also for S-LCA in general and for other uses. In chapter 4 we make a proposal for fair minimum wages.

3.2. METHOD

In order to propose a well-founded benchmark of the 20% best performing countries, in the sections 3.3.1 and 3.3.2 we first give an overview of relevant country-level sustainability indicators, first discussing monetary indicators and thereafter non-monetary indicators. In section 3.3.3 we present an assessment for a proposal for the indicator to be used for the benchmark for LCA purposes in general and S-LCA purposes particularly. The assessment criteria were based on the following ideal indicator properties:

- Regular updating and available for a large majority of countries.
- Comprising both environmental, social and economic aspects of sustainable development.
- Measuring strong sustainability in a sense that social and environmental aspects may not compensate each other.
- Because of our goal of a target for policies we prefer governance and policy measuring indicators over status measuring indicators.
- Adequate sensitivity and sound normalization, aggregation, and weighting methods.

In section 3.3.2, using the 20% top performing democracies in the selected indicator, and assuming that the ratio between the highest and lowest remuneration in democratic governments represent a democratic concept of "fair inequality", a benchmark for fair inequality in governmental wages was determined based on the average ratio in our benchmark group. Using cautious developments in some top performing countries towards wider limitation of top wages, we made a proposal for top ratios for governmentally ruled companies and for industry, and finally we made a proposal of how to use these as inequality PRP in preventative cost-based S-LCA. Because the 20% benchmark size is an assumption of the authors, in line with the Oiconomy system, we compared the results of this choice with calculations based on lower percentages.

3.3. RESULTS

3.3.1. REVIEWING MONETARY INDICATORS

GDP AND DERIVATIVES

Most common indicators for the measurement of welfare and economic progress are the Gross Domestic Product (GDP) and its variations. The GDP is a monetary measure of the goods and services annually produced by domestically located factors of production (Lawn, 2003, p.106).

A variation on the GDP is the Gross National Income (GNI), which includes international financial flows like interest and cross border incomes (Lequiller & Blades, 2006, p.285). The Gross National Savings (GNS) is the GDP minus the gross national expenditures or consumption (Kaufmann *et al.*, 2011), in other words an indicator for the profitability of a country. Data on the GDP and GNI are readily available and updated for all countries e.g. by the World Bank and the International Monetary Fund.

Greening national account systems

Because of a growing concern about the purely economic character of these politically important indicators, totally disregarding the hidden parts of the economy, national account system alternatives including externality measurement were developed.

In the last decade of the 20th century in the Netherlands the NAMEA (National Accounting Matrix including Environmental Accounts) was developed (De Haan and Kee, 1996) and in 1993, in an international cooperation, the System of Environmental-Economic Accounts (SEEA) (United Nations *et al.*, 2003). The NAMEA provides objective national statistics on both economic and environmental data, without weighting or interpretation; the SEEA also includes social data. By both input-output based flow data, and stock differences, the SEEA provides an overview of a countries' developments in economic, social and environmental performance. The data are not aggregated or presented in a comprehensive indicator, but in matrix form. As purely statistical data, The NAMEA and SEEA leave assessment and the construction of comprehensive indicators to politicians. The NAMEA and SEEA are applied by a limited number of, mainly OECD, countries only.

Also in the late 20th century, comprehensive monetary alternatives for the GDP were developed. The first work into this direction was by Nordhaus and Tobin, (1972). They argued that not production, which the GDP is based on, but consumption is the goal of economic activity, and use national consumption as the base of their Measure of Economic Welfare (MEW). Positive contributions to national consumption (such as leisure and work at home) are added and negative subtracted. Where the flow of such contributions cannot be measured directly, capital stocks at the start and end of the year are compared. This lead to the Sustainable MEW (SMEW), a measure of welfare while preserving capital stock. But Nordhaus and Tobin found themselves struggling to collect the required data and valuing the stocks of environmental capital. Gradually different methods were proposed for valuing these environmental externalities, such as for ecosystem services, expenditures for environmental protection and hypothetically invested resource rents for new discoveries and for changes in resource stocks. Using the idea of adding positive contributions and subtracting the negative, the World Bank developed the Adjusted Net Savings (ANS) or Genuine Savings (GS) as an indicator for economic progress. Starting from Gross National Savings (GDP minus local consumption), subtracted are depreciation of physical capital, the rent from depletion of natural resources and the damage from CO_2 emission. Added are expenditures on education (Bolt, Matete, & Clemens, 2002, p.5). One of the most important criticisms against the GS is that it is based on "weak sustainability". The concept of weak sustainability finds its origin in the idea that the value of extracted non-renewable resources can be reinvested in produced capital (Dietz & Neumayer 2007, p.5). Weak sustainability assumes full substitutability between different types of capital or issues and for instance allows to compensate forest loss with education and allows environmental degradation if compensated.

By contrast, strong sustainability means that ecological capital remains intact (Pillarisetti 2005, p.600). In addition, where for depletion of resources only the rent is subtracted, the full expenditures of education are added. This, in our view, is not consistent, because education capital is continuously lost (people forget, get pensioned and die) and a quantity of expenditures is required for maintaining a constant level of education capital, which should not be counted as savings. Also Pillarisetti argues that education takes too much weight in the GS, making it an unbalanced indicator. MEW and SMEW are hardly used; the World bank maintains data on the GS for 110 countries, but because the GS only comprises environmental and economic indicators and therefore is not suited for our purpose.

A far more comprehensive GDP alternative is the ISEW, created by Cobb and Daly, or Genuine Progress Indicator (GPI), (Cobb & Daly 1989; Talberth et al. 2007). The ISEW first applies to the GDP a correction coefficient to personal consumption expenditures for inequality, because high inequality can be detrimental to welfare. Thereafter, like the MEW and GS, the ISEW corrects for positive and negative impacts. Augmentations are for estimated values for the services of households and volunteer labor, consumer durables, community services like streets and some private and community investments. Subtractions are for a list of issues like health and education expenditures, investment in consumer durables, car accidents, the costs of various types of environmental degradation and pollution, loss of wetlands and forests, depletion of non-renewable resources, costs of crime and underemployment. Positive for our purpose is that the ISEW includes both environmental, economic and social aspects. Mentioned shortcomings of the ISEW are about the specific calculation methods, choices of included index components and the fact that also this indicator is based on weak sustainability. The ISEW is used by a limited number of countries only.

A general shortcoming of environmental aspects comprising national accounts, is that they are by far not practiced by a majority of countries, and, due to lack of coordination and standardization, not in a harmonized way.

3.3.2. REVIEWING NON-MONETARY INDICATORS

There are too many non-monetary indices on country sustainability performance to discuss them all. Many reviews are available, such as (Mayer 2008; Olafsson et al. 2014; Parris & Kates 2003; Mori & Christodoulou 2012; Singh et al. 2012; Saisana & Philippas 2012; Adelle & Pallemaerts 2009; Böhringer & Jochem 2007; Phillis & Kouikoglou 2010; Booysen 2002; Street & Sharpe 1999; Stiglitz et al. 2009). We narrow our selection to those indices that include more than 100 countries and are regularly updated, listed in table 3.1.

Ecological Footprint

The Ecological Footprint (EF) measures the global hectares (gha) that are required for something, heavily weighting carbon emission and the impact on the environment (Ewing, Reed, *et al.*, 2010). As unilateral the economic indicators are on the economic aspects, as unilateral is the EF on ecological aspect and even more on the climate aspect. The EF can be calculated on all levels, from products to countries. Best performing 10 countries (with lowest EF) are developing countries with low life satisfaction and low government effectiveness. An interesting indicator is the EF - Biocapacity Ratio (FBR), providing a measure of the overshoot of a country. In 2008, the global Footprint per capita was 2.7 gha with a range from

0.44 gha (Timor) to 11.7 gha (Qatar). The globally available biocapacity per capita was 1.78 gha (Grooten et al. 2012, p.141). At a minimum, sustainability requires the avoidance of global overshoot, or a FBR no greater than 1. The top 10 performing countries (lowest FBR) consist of 8 developing countries and Brazil and Argentina, and not far below one finds Australia and Canada, indicating that country size and population density play a cardinal role in the results measured by this indicator. Menke developed a monetary variation on the ecological footprint. By dividing the global GDP by the globally available productive global hectares, he derived a value of US$ 4.500,- (2009) for one gha by which a footprint can be expressed in a monetary unit (Menke 2010, p.26). The EF and FBR are by far the most used ecological indicators.

Table 3.1. Regularly updated SD indices including >100 countries. Data used from (Booysen 2002, p.132-137; Singh et al. 2012, p.296-297; Van de Kerk & Manuel 2012, p.7)

Index	Developers	Dimensions (S = social; E = environmental)	Countries (& Regions)	Number of Indicators	Last Report
Ecological Footprint	Wackernagel & Rees	E	232	6	2012
Environmental Performance Index	Columbia and Yale Universities	E	132	22	2014
Emergy	University of Florida	E	105	1	2008
Human Development Index	UNEP	S	187	4	2013
Human Sustainable Development Index	UNEP	S+E	163	5	2013
Happy Life Years Index	Veenhofen, R. Erasmus University	S	155	2	2009
Happy Planet Index	Friends of the Earth; New Economics Foundation	S+E	151	3	2011
Government Effectiveness indicator	World Bank	S	210	18	2013
Sustainable Society Index	Kerk & Manuel	S+E	151	21	2012

Ecological Performance Index

A very different indicator is the Ecological Performance Index, developed by the Yale Centre for Environmental Law and Policy and Columbia University (Esty *et al.*, 2006), predeceased by the Environmental Sustainability Index (ESI). The EPI aggregates 20 indicators, divided in two categories (subdivided in 6 policy subcategories): human health impacting environmental issues and ecosystem vitality. All indicators are determined by country ranking on a distance to target scale, where the targets are determined by international conventions. In the aggregation, subcategories and indicators are quite evenly weighted. Using policy categories and targets, the EPI is, far more than the EF, a governance oriented indicator and therefore more suitable

for S-LCA purposes. However, also the EPI is a purely environmental indicator. In addition, its ranking principle is criticized for presenting developed countries performance optimistically (Stiglitz et al. 2009, p.238). Best scoring are, very different from the EF, developed countries like Switzerland, Luxemburg, Australia and Singapore.

Emergy

Emergy is calculated as the solar energy that is needed or used up to create a resource. Emergy is an indicator on the embodied energy of something, or nature's effort required to create a resource. Where the EF is an indicator on the consumption end of the economy, emergy is about the origin of everything. The concept was developed by Odum, (1996) and further developed and maintained by Emergy Systems, University of Florida (Center for Environmental Policy, 2013). Important advantage of the emergy concept is that it provides a scientifically sound and objective quantification of almost any desired product or activity, where other indicators usually apply more subjective weighting of different aspects (Hau & Bakshi 2002, p.4). Emergy objectively quantifies both natural resources and human activities. An emergy derived performance country indicator is the Emergy Yield Ratio (EYR), a measure for the released (or lost) emergy per invested emergy. Best (lowest) scoring are Belgium, Switzerland, Belarus, Israel, Finland, Lithuania and Denmark, but Canada and the USA score much lower. In principle, emergy is an ecological indicator expressed in the "solar equivalent joule", but, like the EF, emergy can be monetized by comparison with the GDP. Although the EYR seems one of the most objective country indicators, it currently lacks data, especially from developing countries, is highly debated, and insufficiently regularly updated to become our current country indicator.

HDI and HSDI

With the UNDP scheme of International Human Development Indicators (UNDP, 2013) everyone's preferred indicator can be composed from a large choice of indicators on the aspects of health, education, income, inequality, poverty, gender and sustainability. The Human Development Index (HDI) is UNDP's widely recognized choice, consisting of life expectancy representing health, years of schooling representing education, and the GNI per capita as indicator for income, equally weighting health, education and income with one third. Ranking countries to the HDI results in a list headed by high income countries like Norway, Austria, The Netherlands, United States and New Zealand. The UNDP considers the group of countries with an index score of 0.8 (on a scale from 0 to 1) highly developed countries. Major criticism on the HDI is the lack of an environmental indicator. Therefore recently the Human Sustainable Development Index (HSDI) (Togtokh and Gaffney, 2010) was created by the addition of the CO_2 emission per capita. Comparing the HSDI with the HDI we see the USA and Canada sinking from 3th and 8th place to 24th and 23th and Australia from second to 10$^{th.}$ However, because only 6 out of 36 countries are replaced in the top 20% and both replacing and replaced countries are developed countries, this top 20% does not significantly change.

Wackernagel plots the HDI against the EF (Wackernagel et al. 2005, p.11) and draws two lines as thresholds or targets, as presented in figure 3.1. One is the UNDP 0.8 criterion for high human development and the other is the 1.8 hectares global biocapacity per capita expressed in the available arable land per capita. Wackernagel demonstrates that human development and

footprint do not match and that currently not any country has reached both human development and footprint thresholds, which is demonstrated by the empty quadrant on the right below.

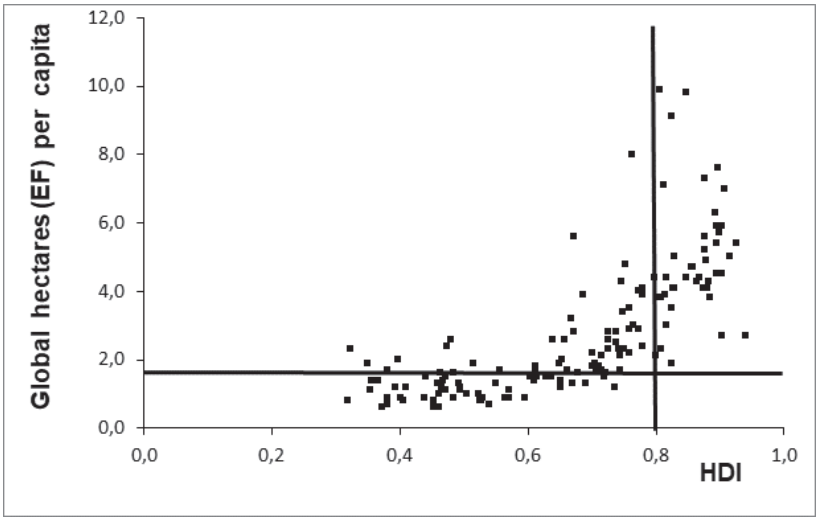


Figure 3.1. Ecological Footprint versus HDI (2009 data from the Global Footprint Network and 2010 data from UNDP (Covering the 2009-2010 time span)

Happy Life Years Index

A long and happy life probably is the most common wish of human beings. Happiness is a subjective emotion subject to fast change and depending on conditions, but by regular measuring on large groups, a reasonably reliable indicator was created by Veenhoven by his Happy Life Years Index (HLY), measured by multiplying life expectancy with a 1-10 happiness score. Happiness is measured as experienced wellbeing (Veenhoven, 1996, 2012). The top ten happiest countries, according to this index are Western European countries with the exception of Costa Rica that is heading the index. The index is an indicator on current happiness saying little about the sustainability of that happiness.

So far indicators were discussed that are rather unilateral, either on aspects of the economy, environment or happiness. For our purpose we need more comprehensive indicators. As mentioned above, UNEP presents a tool to compose a personalized indicator. A wealth of reliable data is available from the World Bank, IMF, Central Intelligence Agency (CIA) and the United Nations (UN) and using these and other data, various authors have developed composite indicators.

Happy Planet Index

The Happy Planet Index (HPI) is the product of life expectancy and life satisfaction, measured globally by the Gallop Poll (Deaton, 2008), divided by the ecological footprint. Top ranking are Southern and Middle American countries like Costa Rica, Colombia, Belize, El Salvador, Jamaica and Panama, accompanied by Vietnam. The HPI reflects the average years of happy life produced by a given society per unit of planetary resources consumed (Abdallah *et al.*, 2012), or in other words in terms of the ecological price paid.

Government Effectiveness Indicator

The World Bank Government Effectiveness Indicator (GEI) measures the quality of governance in a country by a large series of aspects effecting living conditions (Kaufmann *et al.*, 2010). This is a limited indicator on the effectiveness of a government in people's daily life or on how well a country is organized. It is part of a series of World Bank governance indicators measured for 215 countries and regions, also comprising voice and accountability, political stability, regulatory quality, rule of law and control of corruption. Sustainability indicators mostly tell something about the status of a country, but most are poor indicators on the reasons for that status. The GEI is an indicator on the extent that a status is coincidence or the consequence of governance and that is the reason we discuss this indicator. Not surprisingly all top GEI ranking countries are developed high income countries, like the USA and Canada, western European countries, New Zealand and Australia, Japan and South Korea.

Sustainable Society Index

The Sustainable Society Index (SSI) is a composite indicator, equally weighting society aspects (Van de Kerk and Manuel, 2008, 2012). This index does not measure experienced wellbeing, but more objectively 21 components of human, environmental and economic wellbeing.Top ranking in the SSI are developed countries like Switzerland, Sweden, Norway, Austria and New Zealand. The SSI actually is a composite of 3 indices: the SSI Human Wellbeing (SSI HW), the SSI Environmental Wellbeing (SSI EW) and the SSI Economic Wellbeing (SSI EcW), all 3 composed of a balanced variation of indicators. The SSI HW is composed of indicators on sufficient food and drink supply, safe sanitation, health, clean air, clean water, education, gender equality, income distribution and good governance (GEI). The SSI EW is composed of air quality, biodiversity, renewable water resources, consumption, renewable energy and greenhouse gasses. The SSI EcW is composed of organic farming, genuine savings, GDP, employment and public debt. Unfortunately, the SSI does not include population growth and recently emerged financial issues. The idea of separately presenting human and environmental wellbeing was earlier proposed by Prescott Allen who presented his human and environmental wellbeing indices in his influential book "the Wellbeing of Nations" (Prescott-Allen, 2001). However, these indices were only published ones.

3.3.3. INDICATOR ASSESSMENT

On social aspects, like fair payment and inequality, we propose to use the "best practice" benchmark made by the practices in the 20% top performing countries, exactly as we proposed in chapter 3. In order to determine which group of countries make that benchmark, these indicators will now be further assessed on their applicability for the purpose of a PRP for S-LCA.

Economic indicators, such as the GDP and GNI per capita, show clear correlations with key sustainability aspects. Clearly positive (but in effect negative) is the correlation of the GDP with the ecological footprint (figure 3.2). This correlation is linear and indicates that at "business as usual", the footprint per person rises with about 1.12 hectares for every € 10.000 of yearly income per capita. The GDP and GNI are purely economic indicators and all existing greening national accounting systems lack uniform execution in a majority of countries. The EF, EPI, Emergy and LPI are purely environmental indicators. All of these indicators disregard social aspects and are not suited for the creation of our intended top 20% country benchmark.

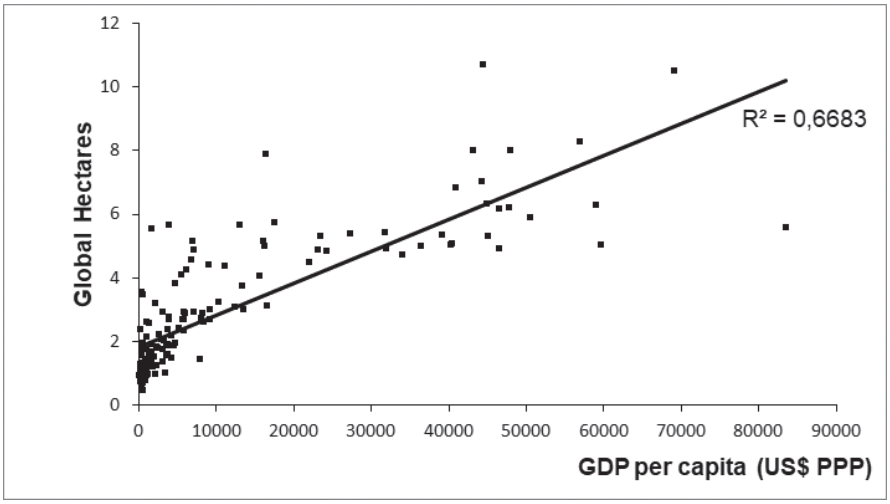


Figure 3.2. Ecological Footprint versus GDP per Capita. Data for 2007 from Global Footprint Network and World Bank

The Happy Life Years Index seems a better indicator for the current wellbeing of the people of a country than the economic indicators, because it relates to the ultimate goal of all human beings, a long and happy life. However, happiness must be sustainable and available to future generations which is not measured by this indicator. Also the Happy Planet Index is of limited value for S-LCA because it is composed of too few aspects and neglects most sustainability and economic aspects.

The HDI, as a combination of health, educational and economic indicators currently is the most used composite indicator for human development, but does not include environmental indicators. The HSDI only includes one limited environmental aspect of sustainability: CO_2 emission.

The Sustainable Society Index (SSI) demonstrates why one comprehensive indicator for all aspects currently is not very discriminative on country performance. The SSI HW (human wellbeing), plotted against the SSI EW and the SSI EcW (figures 3.3 and 3.4), shows a positive correlation with economic wellbeing and a negative correlation with environmental wellbeing. Human wellbeing goes well with economic wellbeing, but not with environmental wellbeing. The relevance for the assessment of indicators is that indicators on human and economic wellbeing can easily be exchanged or combined, but the aggregation of either of them with an environmental indicator will not make a sensitive benchmarking indicator. This is confirmed by the footprint quadrant method described above that already showed that there currently are no countries with satisfactory scores on both human and environmental wellbeing.

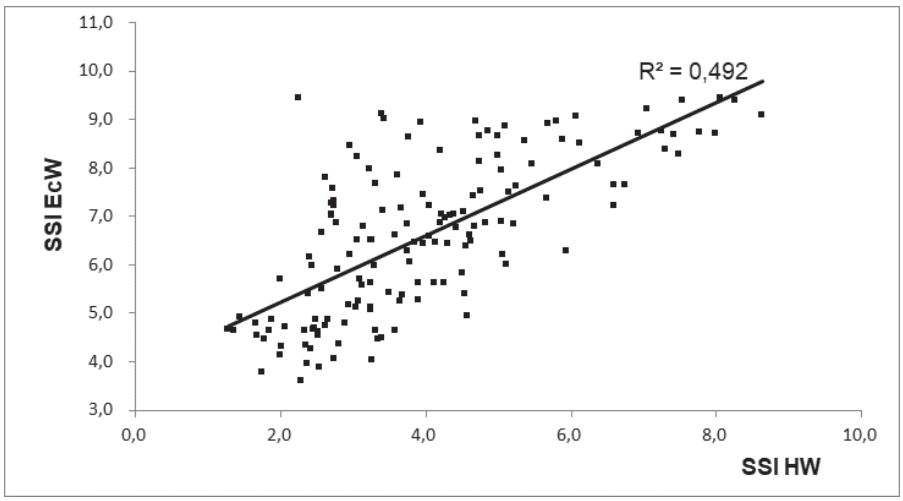


Figure 3.3 SSI Economic Wellbeing (SSI EcW) versus Human Wellbeing (SSI HW). Data from Van de Kerk & Manuel 2012

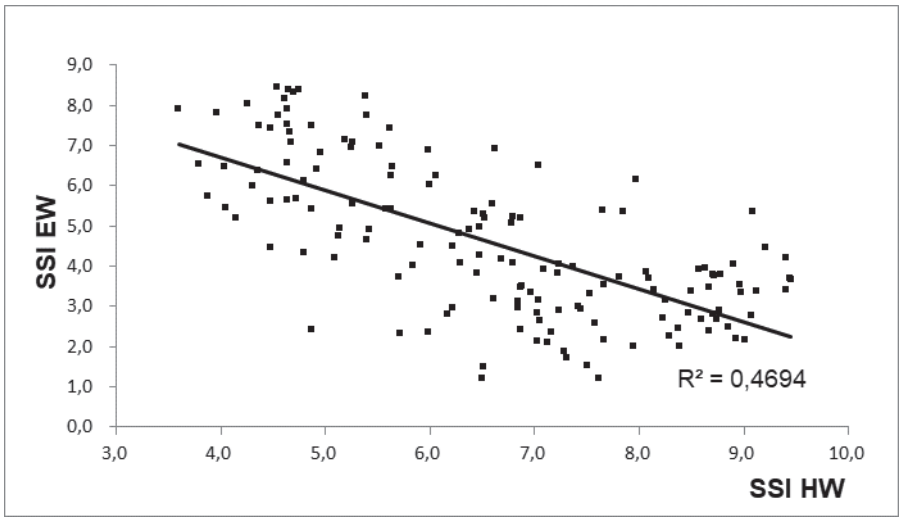


Figure 3.4 SSI Environmental (SSI EW) versus SSI Human Wellbeing (SSI HW). Data from Van de Kerk & Manuel 2012

Remarkable is that most of the composite sustainability or development indicators do not consider the aspect of population growth, which undoubtedly is one of the core sustainability aspects. Another major limitation of all described indicators is that they are just aggregations of data and may not really represent what is the result of countries' governance. E.g. the footprint-biocapacity ratio gives a very high ratio to the Congo. Such countries have a good environmental

performance simply because they have a low population density and low development and not because of their good governance. They are anything but a policy benchmark.

LCA is intended to help making policies and decisions and therefore, we need a benchmark group of countries that has accomplished best performance as a result of their governance.The Government Effectiveness indicator plotted against SSI HW and SSI EW (figure 3.5) shows that countries' governance currently has a strong positive correlation with human wellbeing. A last important observation is that the indicators HDI and SSI HW have a relation that, with a very high correlation coefficient of 0.80, is following the formula SSI HW = 9.05 * HDI (figure 3.6), which means that either can be used, but also that the HDI, composed of few indicators, matches the much more complete SSI HW. Although the HDI and SSI HW have the elements of health and education in common, the SSI aspects not included in the HDI, seem not to disturb this correlation. This suggests that good governance may be the ruling indicator. Also the CO_2 emission including HSDI has a strong positive correlation with the SSI HW. Considering the negative correlation of the HDI and ecological footprint, this suggests that the environmental weight in the HSDI simply is insufficient to make a difference, which clearly shows the importance of weighting in such composite indices.

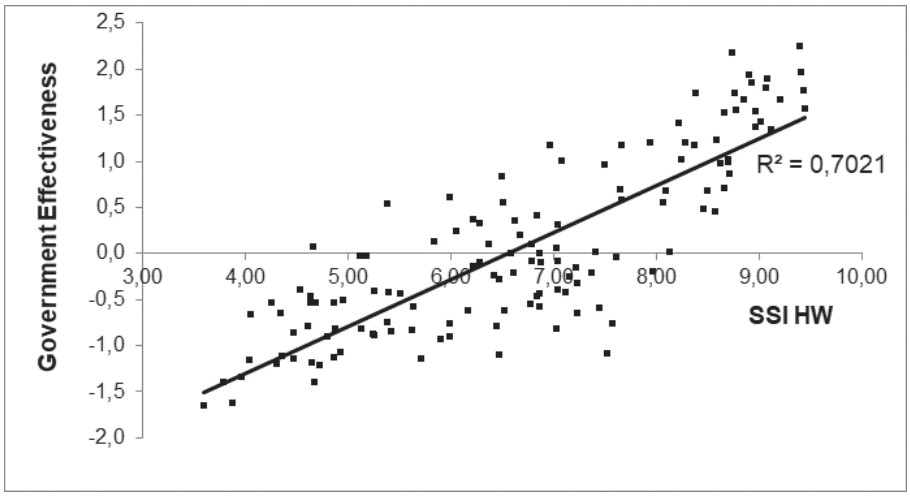


Figure 3.5. Government Effectiveness versus SSI Human Wellbeing (SSI HW). Data for 2012 from Van de Kerk & Manual 2012 and Kaufmann et al. 2011

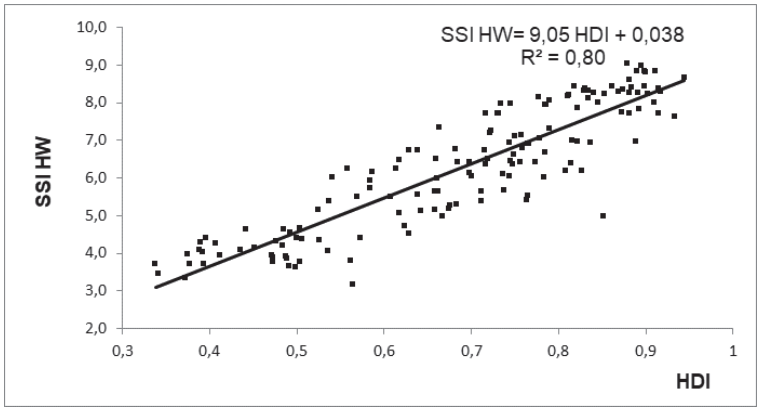


Figure 3.6. SSI Human Wellbeing versus HDI. Data for 2013-14 from Van de Kerk &Manual 2012 and UNDP 2013

We conclude that the indicator to be used for the benchmark group of countries cannot be one and the same for all sustainability aspects, but can best be selected per aspect category. For social aspects both the HDI and the SSI HW can be used. Because the SSI HW is the most complete index of both and has a well-balanced relation with the 2 sister indices on environmental wellbeing and economic wellbeing, the SSI seems the best option for the country benchmark. The 2 sister indices can be used when a country-level indicator is required for setting benchmarks for environmental and economic aspects without currently available standards. The SSI was audited and approved by the JRC on its sound methods, normalisation, aggregation and sensitivity (Saisana and Philippas, 2012), which completes our assessment requirements. As a last check we would like to plot the SSI HW against social unrest and people's happiness. On social unrest insufficient reliable data are available. However, the SSI shows a strong positive correlation with happiness, if plotted against the Happy Life Years Index (figure 3.7). Considering all discussed arguments, we conclude that the SSI HW is the best currently available indicator for determining benchmark group of countries for setting targets for social aspects for which no agreed targets exist. The 20% top performing countries in this index are listed in table 3.2.

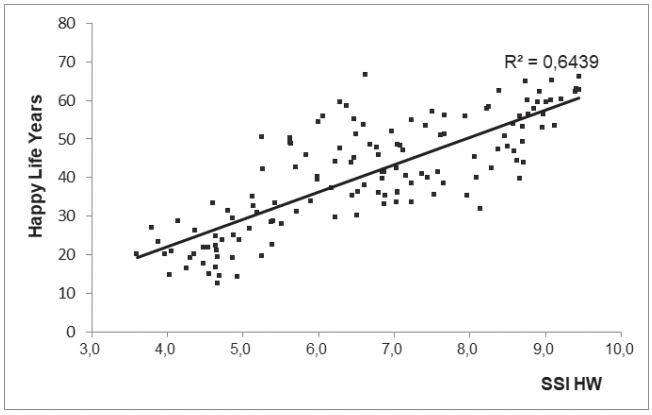


Figure.3.7. Happy Life Years versus SSI Human Wellbeing (SSI HW). Data for 2012 from Van de Kerk & Manuel 2012 and Veenhofen 2012

Austria, Belarus, Belgium, Bulgaria, Canada, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Japan, South Korea, Lithuania, Luxembourg, Malta, Montenegro, Netherlands, New Zealand, Norway, Poland, Portugal, Serbia, Slovakia, Slovenia, Sweden, Switzerland, Ukraine, United Kingdom.

Table 3.2. List of the benchmark group of countries, representing the top 20% sorted by the SSI HW 2012 from (Van de Kerk and Manuel, 2012).

3.3.4. INEQUALITY OF WAGES

In the absence of an international standard on inequality we apply the above developed 20% best country benchmark. We can now look what is actually happening nowadays in this group of countries. In June 2012 France's finance minister announced plans to limit executive pay at state-owned companies to €450.000 per year (Visot, 2012). The measure is meant to hold executive pay to a maximum of 20 times the average of the lowest salaries at the main state companies. In Switzerland extremely high CEO salaries lead to a Swiss vote for shareholder determination of CEO salaries (Schweizerische Bundeskanzlei, 2013). In November 2013 in Switzerland an initiative (Schweizerische Bundeskanzlei, 2012) to cap maximum salaries in industry to 12 times the lowest salaries, was rejected by 65%, but also voted in favour by 34%.

The Netherlands legally set the "Balkenende standard", which is the highest allowed governmental income, expanded to governmental ruled companies with a 30% extra allowance, (Staatsblad van het Koninkrijk der Nederlanden, 2012). It can be argued that the Netherlands democratically determined a maximum acceptable inequality ratio (MAIR) between the highest income and the lowest income for governmental and semi-governmental functions at about a factor of 10.

In March 2014 in Italy, premier Renzi announced a salary cap of € 238.000 for the public sector and € 311.000 for government ruled companies (La Gazetta del Mezzogiono, 2014). In Sweden, one of the world's most competitive countries, industry executives have very moderate salaries and the issue of maximum salaries is widely discussed in many other countries. Bankers bonuses are widely considered to have contributed to shortermism and are now limited in various countries. High bonuses in general regularly cause outrage.

In order to improve corporate governance, avoid shortermism and enhance long term sustainability, the European commission announces a similar proposal (European Commission, 2014). Although the commission is not proposing a binding cap on executive's remuneration, the measure would lead to more transparency and give shareholders more "say on their pay". Even outside the group of top 20% countries we see similar developments. In June 2014 Egypt's president El Sisi announced a salary cap of about 35 times the minimum wage for public sector employees (Esterman and Charbel, 2014).

Expanding the idea of setting a maximum ratio between highest and lowest salaries one could argue that the existing ratio between the income of the highest governmental official and the minimum wage in other democratic countries is their MAIR, because both are under direct influence of the countries' parliaments. For 90 countries the premiers or president's salary could be found on the internet. In our benchmark group of 20 % top SSI HW countries (2012), for 26

countries data on both president's salary and statutory minimum wage were available, creating a benchmark of 26 countries. The MAIR of the benchmark group varies from 3.7 to 31.0 with an average of 14.1. Top ratios are found in Switzerland, Austria and the USA and lowest ratios in some former eastern European countries. Outside the benchmark group the ratio's go up to 180 for Mexico and 515 for Kenya.

The Netherlands has set a 30% higher MAIR for semi-governmental institutions. This results in a ratio of 1.3 * 14.1 = 18.3, reasonably close to the French planned ratio of 20. Following the Dutch reasoning it seems reasonable to grant another 30% for private enterprises, which makes MAIR = 1.3 * 1.3 * 14.1 = 23.8, or in other words the lowest wage within a private organization should not be below 1/23.8 or 4.2 % of the highest, which figures we propose as a standard for the maximum inequality of wages. These last 30% percentages are of course value choices, for which other values can be chosen.

3.3.5. PREVENTATIVE MEASURES AND CONVERSION TO ESCU'S

For the determination of the (un)sustainability score in preventative cost-based S-LCA, one more parameter must be determined, the ESCU's, equal to the cost distance between the actual income inequality and fair inequality. With a known target for fair inequality, there are two possible preventative measures against unfair inequality: lower the highest income within the organization to the product of the maximum fair inequality ratio, or raise all insufficient wages to the minimum fraction of the highest. Because the latter is the highest and therefore the marginal measure, we propose as ESCU's the costs of raising all wages to the fair fraction of the highest remuneration within the organization. To date, we unfortunately have insufficient default values for actual inequality ratio's in enterprises, which requires more research. Average CEO remunerations in the Netherlands are between € 65.000 and € 348.000 (www.payscale.com, 2020). Because this remains below 23.8 x the minimum wage, no ESCU's will be allocated for the average income inequality in the Netherlands. However, CEO's of Dutch companies with a revenue of 1-5 billion euro's receive a median pay of about 5 million euro's, which will lead to a huge allocation of ESCU's.

3.4. DISCUSSION AND CONCLUSIONS

In the introduction, section 3.1, we argued that the aspect of inequality should be addressed in S-LCA. As one of the key missing approaches we identified a method to identify concrete and quantitative PRP's. The debate on income inequality however, is a highly political aspect, also in relation to LCA. Discussing ethical values in LCA, Guinée *et al.*, (2009) compare the positions of Brundtland (United Nations World Commission on Environment and Development, 1987) and Rawls (Rawls, 1971). Brundtland puts the highest priority at the poor, because the poor suffer the most from environmental degradation. Rawls argues that if allowing higher inequality improves the position of the poor, a trade-off between criteria may be made. Because of the political nature, an objective performance reference point in S-LCA for the aspect of inequality must be based on democratic choices and practices. In absence of an agreed standard or PRP for "fair inequality", we therefore elaborated the use of average democratically chosen practices in a benchmark group of the 20% best performing countries as the benchmark. Because environmental and social aspects are very much interrelated (Dreyer et al. 2006, p.1), one of our criteria for an ideal indicator for such benchmark was the inclusion of both environmental and social aspects. One of

the results of our indicator assessment was that such ideal indicator would be not very sensitive because indicators environmental and social aspects are negatively correlated. However, in the Sustainable Society Index a well-balanced composition of 3 indices was found, together covering the total sustainability spectrum of environmental, social and economic aspects, the separate use of which we propose to use. A satisfying country indicator for target setting purposes for S-LCA was found in the Sustainable Society Index Human Wellbeing.

However, our choice of using the indices separately depending on the aspect, has consequences. The fact that environmental and social indices are negatively correlated calls for cautious application of E-LCA and S-LCA separately. If sustainable production is considered as activities that meet the needs of the current generation without compromising the wellbeing of future generations, we need to stress the importance of assessing product sustainability as comprehensively as possible, applying both E-LCA and S-LCA. In our opinion, this limitation applies to LCA in general, if used to assess product sustainability. Assessing any aspect individually, not considering the consequences on other aspects, may provide useful information on the various alternatives considering that aspect, but does not say much about the comprehensive sustainability of a product or an activity.

Using democratically determined inequality ratios in the benchmark group, it proved possible to derive an objective target for inequality in governmental institutions. Our proposed augmentations for government ruled companies are in a range that some countries are already proposing. Considering the further augmentation for industry, which is a value choice, we should keep in mind that the goal of sustainability measurement of products is not to set a political standard, but to provide the inequality conscious consumer with a measure of the costs of preventing harm from his purchase choices. For this consumer, that considers a harm free product a quality requirement of the product, and who is, as a voter, a contributor to governmental standards, the here proposed maximum inequality ratios of 14.1 for governmental organisations, 18.3 for government ruled companies, and 23.8 for other organizations, seem very reasonable. These proposals are for inequality of wages and do not include income from a companies' ownership.

In current impact-based LCA concrete interval quantification of social aspects in one comparable unit is hardly possible. The preventative cost-based LCA systems of EcoCosts quantifies aspects by the marginal costs to prevent the damage, and the Oiconomy system, based on onsite verification, extends the applicability of this system to social aspects. In principle inequality above the target can be prevented by either lowering the top wages or by raising the bottom wages. Because marginal costs are "the highest cost of all measures needed to be employed to reach the target", for these preventative cost-based LCA systems, the authors of this paper propose to use as measure of unsustainability the costs necessary to raise all remunerations in an organisation and related to the measured product, to a level of 1/23.8, or 4.2% of the highest. Of course the proposed reference points and method of determination of future reference points can be used in other types of S-LCA and for instance by fair trade organisations, but it is out of the scope of this chapter to elaborate on these possibilities.

Finally, we discuss the validity and some limitations of our proposed method and data. First, the presented incomes of top governmental officials are just indicative, probably including many differences in extra allowances, tax regimes and corruption. However, since the benchmark group mostly consists of good governance countries, transparent about governmental incomes,

most of which' top salaries are reported by a reliable source (WageIndicator Foundation, 2013), the top gross salaries in this group may be considered fairly reliable. Because these publicly known presidents/premier salaries fairly well represent the people's idea of their president's income, we propose to use these data until reliable better data are available.

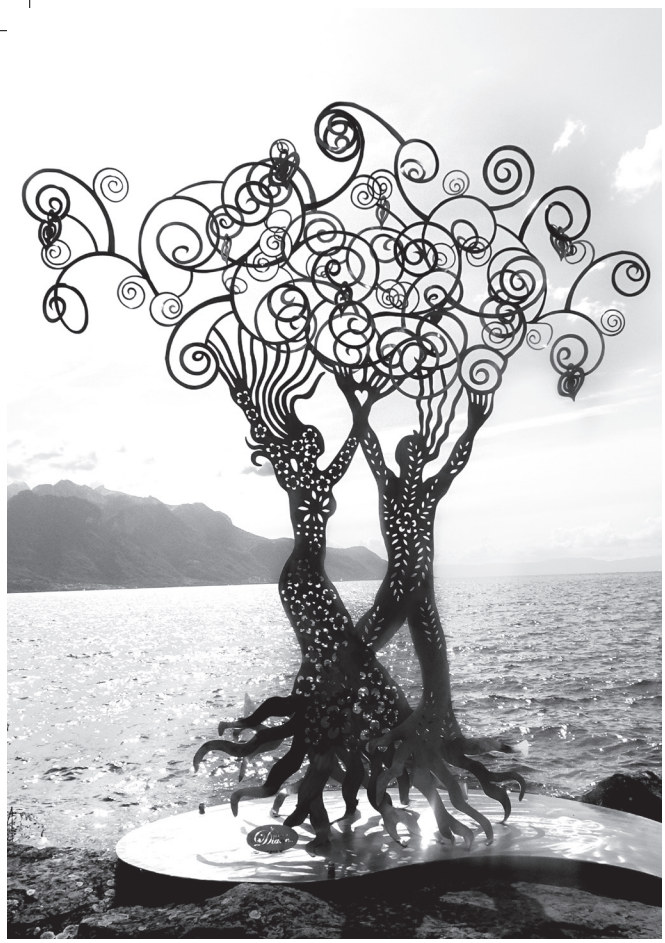
Second, the benchmark comprises relatively high income countries only. Therefore, one may question if these ratios can equally be applied to inequality of wages in low income countries. We argue that they can, because there are several middle and low income countries with governmental ratios within the 3.7 - 31 range of the benchmark countries, e.g. China, India, Bangladesh, Nepal, Egypt, Ecuador, Cambodia, the Philippines and Sri Lanka.

Third, we investigated the consequences of our choices of using the standard average instead of the population weighted average, of the fairly wide top 20% benchmark group instead of a smaller group, and even of choosing the SSI HW instead of the therewith highly correlated HDI. Our calculations are based on the SSI HW data report 2012 (Van de Kerk and Manuel, 2012). In 2014, the composition of the index was changed due to availability of data. Due to this, together with the change in the scores of some countries, some countries in our benchmark group of the top 20% performing were replaced by others. The USA, the largest country in the 2012 group, fell out of the group. We calculated the MAIR's based on different benchmark group options and methods of averaging, but all based on the income data. Table 3.3 demonstrates the results. Considering the effect of the type of average, the standard average gives a MAIR that is not very sensitive to the indicator choice and in- or exclusion of the USA. Not unexpectedly however, using the population weighted average, the sensitivity becomes considerably higher, which is mainly caused by the in- or exclusion of the USA and higher influence of a small number of big countries. Considering the size of the benchmark group, we see that the MAIR becomes lower with a smaller SSI – HW based group, but not so with a HDI based group. This is due to the fact that in the SSI HW some of the countries with high MAIR's are in the bottom of the SSI HW group, but score higher in the HDI. The standard average represents a more democratic principle between countries and lower dependence on a few large countries, but is less democratic considering the total population of all benchmark countries. Concluding, because the standard average gives a more stable indicator than the population weighted average we stick to our proposal of using the top 20% performing countries in the SSI HW as benchmark.

Table 3.3. Maximum acceptable inequality ratio's (MAIR) related to size of the country benchmark group, the index it was determined from, and the type of averaging. (PW average = population weighted average).

		Top 20% countries		**Top 15% countries**		**Top 10% countries**	
Year	**Indicator**	**Average**	**PW average**	**Average**	**PW average**	**Average**	**PW average**
2012	**SSI HW 2012**	14.1	17.6	13.8	13.8	11.4	12.7
2014	**SSI HW 2014**	14.2	14.8	13.8	13.2	12.0	13.1
2013	**HDI 2013**	13.4	17.5	13.2	17.9	13.1	19.0

And last, we need to stress one of the disadvantages of a best practices based method, is that the data need regular updating. However, following the methods of this paper they are not difficult to determine, especially not if countries' top governmental incomes would become better documented.



Capitalism is effective because it is based on an all too real quality of man: egoism. But it turned out not to be Adam Smith's invisible hand or lead to a fair world

Current "Fair trade" is without a well defined definition for what is "fair" Is it fair to consider the living wage as fair ?

CHAPTER 4

REFERENCE POINTS FOR A FAIR MINIMUM WAGE [5]

5 This chapter is based on: Croes, P. R. and Vermeulen, W. J. V. (2016b) 'In search of Income Reference Points for S-LCA using a Country Level Sustainability Benchmark (part 2): Fair Minimum Wage. A Contribution to the Oiconomy project', Int. J. Life Cycle Assess., 21(3), pp. 363–377. The chapter was slightly edited to fit in the book structure.

4.1. INTRODUCTION

There is little doubt that the aspect of sub-fair remuneration of labor and products should be included in S-LCA. The UNEP/SETAC guidelines for S-LCA of products states: "development of a "meaning" database, which would include the necessary data for interpretation (e.g. minimum wage and living wage by country) would represent a major advancement for S-LCA practice" (Benoît Norris, Mazijn and et al., 2009, p.84), and various authors discuss the income issue in S-LCA, (e.g. Norris, 2006; Feschet *et al.*, 2013; Neugebauer *et al.*, 2014). Neugebauer et al. consider a fair minimum wage as a key pathway to addressing social well-being and social justice in Social LCA (S-LCA) and propose to use ILO conventions and the living wage as starting points, which proposal we will elaborate in this chapter.

Parent et al. 2010, p.167 distinguish type 1 and type 2 S-LCA. Type 1 S-LCA uses performance reference points (PRP's) "to help understand the magnitude and significance of the collected data". In current impact-based type 1 S-LCA, data and PRP's are at best used for qualitative assessment or nominal quantitative point systems, (e.g. Hsu *et al.*, 2013). Type 2 S-LCA seeks cause-effect impact pathways to quantitatively link a factor to one of the endpoint indicators. However, because impact pathways related to income issues are extremely complex and reach far into the uncertain future, it will be quite a challenge to present an accurate pathway derived measure for sub-fair wages.

However, preventative cost-based S-LCA is an interval quantitative assessment method without the need for cause-effect pathways. Chapter 2 gives a short introduction on the principles of the preventative cost-based EcoCost LCA system (Vogtländer *et al.*, 2000) and an extensive description of the Oiconomy system. For preventative cost-based LCA, concrete targets (or PRP's) are an absolute requirement. Currently missing still is a method for setting concrete PRP for "a fair minimum wage". In this chapter the fair minimum wage will be based on the market consisting of "Oiconomy consumers". This is a consumer that requires a damage free product as a quality aspect of the product and is willing to pay the required extra costs for that quality.

The goal of this chapter is to provide a fair minimum wage standard, which enables the determination of the preventative costs distance to target, in the Oiconomy system expressed in "Eco Social Cost Units" (ESCU), for the impact category of unfair prices for labor in preventative cost-based S-LCA.

4.2. METHOD

For the determination of the marginal preventative costs for the impact categories of unfair prices for labor in preventative cost-based S-LCA, the following procedure was followed, derived from the EcoCost method and equal to the Oiconomy method, in 5 steps:

1. Definition of the impact category and characterization factor.
2. Determination of the fair minimum wage target of reference point.
   a. Literature assessment of international standards, discourse and practices on poverty, minimum wages and living wages.
   b. Proposal of a fair minimum wage based on available international standards and a country level benchmark.
3. Listing of available preventative measures, ranked by costs with lowest on top.

4. Determination of the costs of the available preventative measures.
5. Assessment of which preventative measures are required to globally reach the target. The last and most expensive determined measure presents the marginal preventative costs.

In section 4.3.1 (step 1) we present our definition of the impact category and characterization factor. In section 4.3.2 (step 2a) we review current standards, conventions and debates on the concept and measurement of poverty and the practice of minimum wages and living wages and we discuss the pros and cons of the various approaches. In section 4.3.3 (step 2b), based on our findings and the fact that there is no universally applicable method for fixing a minimum wage, we present our alternative methods allowing the determination of fair minimum wages for every country, and provide justification by comparison with other methods. Given the different outcomes for the various systems in low-income and high-income countries, we apply a system based on two principles: an adjusted absolute value on the lower side and a relative value on the higher side. We then also need to have good grounds to identify the threshold point for both approaches. First, we will explain the lower side, then the threshold point and finally the higher side. We propose a method based on the available internationally agreed conventions on human rights and labor conditions and on the minimum wage practices in a benchmark group of the 20% top performing countries, using a benchmark group, proposed in chapter 3. Thereafter, a concrete fair minimum wage could be proposed for 183 countries as PRP in S-LCA in general.

In section 4.3.4 (step 3, 4 and 5), with a set definition and standard for fair payment, we describe how the difference between the found reference point of the fair minimum wage and the actually paid sub-fair wage can be used for the determination of ESCU's as measure of (un)sustainability in preventative cost-based S-LCA. For this purpose, we investigate literature on the level of currently paid sub-fair wages.

4.3. RESULTS

4.3.1. IMPACT CATEGORY AND CHARACTERIZATION FACTOR (STEP 1)

The impact category is product-related poverty, characterized by underpaid dollars or other currencies, and the target to keep the worker, either company- or self-employed, and his family, out of poverty.

4.3.2. INTERNATIONAL STANDARDS, DISCOURSE AND PRACTICES (STEP 2A)

Poverty and fair payment

The right to a fair remuneration for a worker and his family has been agreed upon in a range of international conventions and translated into national regulations. Anker gives an excellent overview of living wage conventions (UN, American and European), national constitutions, major ILO documents, NGOs and corporations' position papers and statements (Anker, 2011). Article 25.1 of the United Nations Universal Declaration of Human Rights of 1948 states: "Everyone has the right to a standard of living adequate for the health and well-being of himself and of his family, including food, clothing, housing, medical care, necessary social services, and the right to security...", and article 23: "everyone who works has the right to just and favourable remuneration ensuring for himself and his family an existence worthy of human dignity" (UN General Assembly, 1948). Summarizing, article 25.1 states that nobody should be in poverty and article 23 asserts that work should be an adequate means to provide a secure life and to prevent

poverty. The preamble to the ILO constitution notes that peace and harmony in the world require "the provision of an adequate living wage" (ILO, 1944). The 2008 ILO Declaration on Social Justice for a Fair Globalization, building on earlier 1919 and 1944 declarations and concerning the aims of the ILO, emphasizes its obligation to develop and enhance "policies in regard to wages and earnings, hours and other conditions of work, designed to ensure a just share of the fruits of progress to all and a minimum living wage to all employed and in need of such protection", in this way addressing the aspect of inequality (International Labour Office, 2008, p.10). The right to a minimum wage was further formalized in ILO conventions in 1928, 1951 and 1970. Poverty reduction is one of the most important United Nations' Millennium Development Goals (United Nations, 2007, p.21) and one of the primary objectives of the World Bank. These conventions and statements demonstrate international agreement on the right to a decent minimum wage. In practice however, apart from the fact that the minimum wage is widely disrespected and poorly enforced, statutory minimum wages of many countries are below a living wage (definition below). The conventions all agree on the right to a fair remuneration for the worker and his family. However, wordings utilized are vague, like "decent", "favourable", "worthy of", adequate", "basic needs" and "just". Also national constitutions remain vague, although they sometimes add statements, like: "Equal pay for equal work" (USA), "Maintaining a certain purchasing power" (Brazil), "Share of social enjoyments of cultural and social opportunities" (India, Namibia) and "Sufficient for the education of the families' children" (Mexico) (Anker, 2011, page 67-83). ILO conventions define requirements on working hours, overtime, collective bargaining systems and labor conditions, but also remain vague in their wordings on the level of the minimum wages. Various NGOs like ETI (Ethical Trading Initiative, 2012), SAI (Social Accountability International, 2008), FLA (Fair Labor Association, 2011) and GSCP (Global Social Compliance Programme, 2010) tend to follow ILO conventions and include requirements on work hours, information, collective bargaining systems, financial disciplinary measures, subcontracting, fixed term contracting, labor conditions, paid leave arrangements and other arrangements. However, none of these NGOs has a clear definition of the living wage. Companies publish position papers and comments on their responsibility. Many support the concept of the living wage, but also use lack of a proper measurement and of a concrete definition as an excuse for not executing their aspirations (Anker 2011, p.7,8). Many pay statutory minimum wages, even if these are lower than a living wage. Some state that it is not them, but governments who are responsible for setting the minimum wage at a proper living wage, or that minimum wages should be determined by negotiations between workers and management, which is understandable for reasons of competition. We conclude that supranational conventions and NGOs agree on the need for a minimum wage based on the living wage, but are very vague in their definitions and lack concrete criteria. Companies and countries support the living wage in words, but are lacking a concrete common definition. Fierce competition and fear of capital relocation make countries to set their minimum wages below and sometimes far below a living wage. No properly enforced minimum wage system exists that globally eliminates competition below a fair threshold level.

Various authors describe the pros and cons of establishing a minimum wage. (Wu and Liu, 1999; Rutkowski, 2003; Neumark and Wascher, 2007; Haughton and Khandker, 2009). Frequently mentioned arguments in favour are:

- Providing a worker and his family with their needs for a decent minimum standard of living.
- Prevention of exploitation of workers by employers.
- Reduction of inequality and a fairer wage structure.
- Stimulation of the economy because low income families spend a higher percentage of their income than high income families.
- Stimulus for business to continuously increase technical efficiency.

Frequently mentioned arguments against are:

- Higher unemployment due to relocation of jobs to locations with lower wages and to automation and reduction of the country's competitiveness. However, the author also notes that this effect is not valid for moderate minimum wages (Rutkowski, 2003, p.12).
- Minimum wages in the current economy are not an efficient means to reduce poverty because the majority of families in poverty are not workers (Rutkowski 2003, p.12).
- Excessively high minimum wages may lead to a high non-compliance problem and increase the shadow economy (Rutkowski, 2003, p.7).
- Fear of economic decline.

A great majority of countries has set a statutory minimum wage system, and in some developed countries a well-functioning bargaining system between employers and employees has achieved a working minimum wage system without statutory regulations (e.g. Norway). However, many countries have set their minimum wage below a living wage (Anker, 2006).

Causes of poverty are manifold, including poor education, poor social care and governance, family size, corruption and violence, exploitation of workers, unfair pay, climate change, ethnic or gender discrimination, living in a remote area, and debt problems. Most people in poverty deal with at least one of the following four situations: unfair wages, unfair prices for their manufactured products or services, unemployment, and self–employment insufficient for subsistence. Therefore, poverty can only be effectively addressed if (preferably) all four of these conditions are addressed together without repercussions on each other. The issues of competition and the comprehensive measurement of these issues can be addressed in the Oiconomy system, in which the Oiconomy consumer requires evidence, based on certification, with onsite verification, as proposed in chapter 2.

What we need for preventative cost-based S-LCA, aiming to reveal the hidden costs for the aspect of fair wages, is a target, or PRP, for determining the cost distance to a fair minimum wage. There are two major ways determining such target: from the point of view of absolute poverty and of relative poverty.

Absolute Poverty

There is extensive literature on poverty and its measurement, e.g. by the World Bank and the

ILO (Ravallion, 1992, 2011; World Bank, 2005; International Training Centre of the ILO, 2008; Haughton and Khandker, 2009). The World Bank regularly publishes progress reports on global poverty, (e.g. Chen and Ravallion, 2008, 2012). This paper will limit itself to a summary of poverty-related issues relevant to the purpose of the creation of a standard for fair remuneration.

Basically two types of poverty are distinguished: absolute poverty and relative poverty and two main concepts of wage thresholds have been widely discussed: the minimum wage and the living wage. Absolute poverty and the therefrom derived living wage is usually measured by the costs of a basket of basic needs of a person. However, an abundance of researchers has demonstrated that living wages differ by country, culture, development level, region, and even by town, arguing that it is impossible to set one universally applicable and fair global minimum wage. (Brenner *et al.*, 2002; Anker, 2006, 2011; Boeri, 2009; Ravallion, 2010; Belser and Sobeck, 2012). Even within the group of high income countries it is difficult to use one and the same poverty line, because food choices, prices, cultures and climate conditions vary greatly. The World Bank solves the price issue by the use of the purchase power parity (PPP) which compares what people in the different locations can buy with their local currency with the value of one US$ in a set reference year. Different food choices are covered by looking at the local foodstuffs required for a minimum caloric intake (Ravallion, 1992; Haughton and Khandker, 2009). Relative poverty relates to the ability to function in a certain community and is usually measured as a proportion of the national income. It will be discussed in a separate section below.

Living wage

The concept of the living wage also varies amongst the different authors, some relating the living wage to absolute poverty and others to relative poverty.

Anker relates the living wage to absolute poverty by his definition: "*the poverty line is the income necessary for a household to afford a low-cost nutritious diet and non-food necessities at levels considered acceptable in a given country; the living wage is the hourly wage rate required to support a household at the poverty line*" (Anker 2006a, p.312). The words "necessities" and "acceptable", however, remain open to interpretation and the definition includes fewer elements than the earlier cited human rights principles. The NGO 'Labour Behind the Label' goes a little further and defines the living wage as "*one which enables workers to meet their needs for nutritious food and clean water, shelter, clothes, education, healthcare and transport, as well as providing a discretionary income. It should take into account the cost of living, social security benefits and the standard of living of others nearby*". By the inclusion of the standard of living of others, this NGO defines the living wage as to prevent relative poverty (Labour Behind the Label, 2013). The latter is more in line with Human Rights article 22, stating: "*everyone, as a member of society, has the right to social security and is entitled to realization, through national effort and international co-operation and in accordance with the organization and resources of each State, of the economic, social and cultural rights indispensable for his dignity and the free development of his personality*" (UN General Assembly, 1948).

Although at present, there is neither a generally accepted definition of what a living wage is, nor a generally agreed methodology on how to measure it, the World Bank poverty statistics are based on a global poverty line. Based on the average of the national poverty lines of the 15 world's

poorest countries (Ravallion et al. 2008, p.16), determined by the method of a basket of basic needs, the absolute poverty line was set at $ 1.25 (2005 US$ PPP) per person per day. People living below this line are considered in extreme poverty. Increasingly the World Bank uses $ 2 (2005 US$ PPP) as moderate poverty line, determined as the median of the poverty line of all (75) developing countries (Ravallion *et al.*, 2008). However, Pritchett argues that this $ 2 has not much justification (Pritchett 2006, P.2). Some authors describing shortcomings of the World Bank's absolute poverty lines propose to use a range of poverty lines. Concluding, the World Bank's $ 2 moderate poverty line is unfit for universal application, but, preferably with some better justification, may be useful for setting the very bottom global threshold for our purpose.

Relative Poverty

Analysis of relative poverty shows that poverty occurs not only in low-income countries, but also in other countries, even though their bottom wages are far above the World Bank poverty lines. Even in most developed countries, minimum wages are regularly below the living wage (Belser and Sobeck, 2012; Gentilini and Sumner, 2012) and there is a clear trend of increasing poverty in middle income countries (Sumner, 2010, 2012). The ILO's Minimum Wage Fixing Convention (No. 131), 1970, sets six criteria for determining the level of a statutory minimum wage (ILO, 1992): the needs of workers and their families, the general level of wages in a country, the cost of living, social security benefits, the relative living standards of social groups, and economic factors such as economic development and maintenance of employment. Relative poverty is usually measured in a far more simple way than absolute poverty as a proportion of the mean or median income or consumption. The definition for relative poverty given by the European Union is: "*People are said to be living in poverty if their income and resources are so inadequate as to preclude them from having a standard of living considered acceptable in the society in which they live.*" (Council of the European Union 2004, p.8). Most OECD countries use the median income as an indicator for poverty and the OECD uses the indicator of 60 % of the median income as the "risk-of-poverty" rate (Atkinson et al. 2004, p.55; International Labour Office 2010). The European Commission states: "*the proportion of individuals living in households where equivalized income is below the threshold of 60% of the national equivalized median income is taken as an indicator of relative poverty".* (Council of the European Union 2004, p.13). The European Trade Union Confederation recommends "*that the effective national minimum wage should be at least equal to 50% of the average wage, or 60% of the median wage*" (ETUC 2012, p.8). Ravallion (World Bank) points out that measured by the use of the mean or median, poverty is not reduced by economic growth (Ravallion 2010, p.17). However, the relative method seems very useful for the determination of a fair wage that does not necessarily need to be the poverty line, because it deals with inequality and has a direct relation to the size of the available cake to be shared by a country's population. Sweat Free Communities uses a constant percentage of the GDP per capita as the living wage (SweatFree Communities, 2014). This NGO takes the USA national minimum wage +20% as a starting point and applies the proportion of the obtained living wage relative to the USA GDP per capita for all countries, ignoring the fact that by this method, living wages become unrealistically low in very poor countries (Anker 2011, p.43). The ILO's Global Wage Report 2008/09 shows that countries, with data on mean wages available, most frequently set their minimum wages at between 35 per cent and 45 per cent of mean wages. "In

the smaller set of countries for which data on median wages are available, the minimum wage is most frequently set at about 50 to 60 per cent of the median wage" (Belser & Sobeck 2012, p.122). Mentioned advantages of a consistently executed relative poverty-based system over an absolute system are:

- It better addresses inequality and the responsibility of governments to fairly distribute the national income.
- It avoids complex calculations of living wages, which will always be inaccurate (Pritchett 2006, p.7).
- It better addresses automatic adaptation to the cost of living and its development in a country (Ravallion 2010, p.15)
- It better addresses the costs of social inclusion (Ravallion 2010, p.15).

Disadvantages are:

- It leads to unacceptably low minimum wages in developing countries (Anker 2011, p.43; Ravallion 2010, p.17).
- It does not give the possibility of addressing differences within countries, such as between rural and urban costs of living.
- It does not address individual or country-specific family sizes and women's participation.

Typical examples of the absolute and relative measurement are demonstrated by the different approaches of the USA and the EU. The USA has set an absolute minimum wage. Because it is not regularly adjusted to rising living costs, the USA now has a minimum wage below the living wage (Luce, 2012). The EU has taken the approach of a poverty line at 60% of the median income (Council of the European Union 2004, p.14).

4.3.3. DETERMINATION OF THE FAIR MINIMUM WAGE TARGET (STEP 2B)

Fair minimum wage

The *living wage* is the wage keeping a worker and his family out of poverty and may be considered a direct consequence of human rights (UN General Assembly, 1948, article 22, 23, 25, 26). The *minimum wage* is a more political instrument and ideally should not be below the living wage. However, most low-income countries simply don't have the means to set their minimum wages at this level and high-income countries and emerging middle income countries also tend to keep their minimum wages low, for reasons of competition. Data and comparison of living- and minimum wages, including their calculation methods, demonstrating this observation, are reported by WageIndicator Foundation, 2013 and by Anker, 2006. This raises the question of what would then be a *fair minimum wage*. One could argue that a minimum wage set at living wage level, even if that is based on the poverty line of $ 2 per person per day, is a fair wage in low income countries that do not have the means for a higher minimum wage. However, for a product destined for a high income country and for an Oiconomy consumer one could also argue that the relevant means are available. Another way is to take the relative point of view and look at the relation between a country's minimum wage and its Gross National Income per capita (GNI_{Cap}).

In order to be able to set target values and to compare values with a benchmark, the average of the 20% best performing countries is proposed as a norm. For this purpose, in chapter 3, we proposed a benchmark group of the 20% best performing countries in the Sustainable Society Index Human Wellbeing (SSI HW) (Van de Kerk and Manuel, 2012).

The average percentage of the minimum wage relative to the GNI_{Cap} (in PPP) of all countries in a group of 149 countries with statutory minimum yearly wage, is 54.1%. The benchmark group has an average percentage of 44.4%, and 26 countries have unrealistic percentages of over 80% and 18 countries of even over 100%. Figure 4.1 shows how the minimum wage/(GNI_{Cap}) percentages of the benchmark group of countries relate to the total group, and appendix 3 shows the statutory minimum wages of all countries.

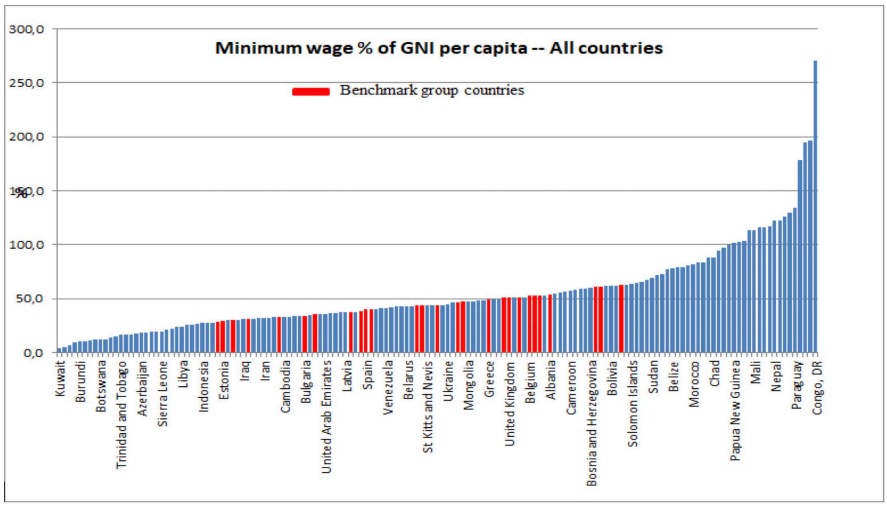


Figure 4.1. 2011 PPP Minimum Wage % of GNI per capita (World Bank 2011 PPP) per country. Minimum wages obtained most from OECD 2011; ILO 2011, and where not available, from minimum-wage.org and wageindicator and for Bangladesh and Taiwan from Fairware and Taiwan Congress Library.

Various large emerging countries keep their minimum wages relatively low. China has a percentage of about 17% (measured by the lowest minimum wage of China's provinces), Indonesia 27.2%, Vietnam 36.2%, Mexico 12.0%, Brazil 31.6% and South Africa 33.5%. But the USA also has a very low percentage of 30.9%, far below the high income countries' average. India, the country with the highest contribution to global poverty, has a very complex and poorly enforced system of 1171 different minimum wages, depending on location, industry sector and companies. Also other developing countries in Asia, Africa and Latin America tend to have multiple and poorly enforced minimum wages, whereas developed countries usually have better enforced national minimum wages (Rani and Belser, 2012). Their low labor costs help low income countries develop, which seems fair for the country as a whole, but not for the affected sub-living wage workers, and because such countries usually show high and rising inequality and corruption, the fairness of the distribution of the new wealth is questionable. In both cases of countries with minimum wages set above their abilities and those with low percentages, it is clear that in setting the minimum wage, political considerations play an important role, limiting the achievement of a fair minimum wage.

From our literature review, we conclude that there is no agreed international system or standard available for the determination of a fair minimum wage. No universally applicable absolute fair minimum wage can be determined for both low and high income countries. A consistent relative system would lead to unacceptably low minimum wages in the lowest income countries. Already in 1992, Ravallion argued that poverty measurement using a dual system of both a relative and an absolute poverty line would be a straightforward method for poverty measurement (Ravallion 1992, p.35), but the idea was not elaborated. Likewise, we now propose to use the relative method bottom cut-off by an absolute minimum for low income countries as target for the Oiconomy system, but also as PRP in S-LCA in general and even outside the field of applying LCA.

Determining the Absolute Minimum Wage

For the proposal of a fair absolute minimum wage, we need to consider the number of working hours, family size, labor participation and the poverty line. In practice various approaches make arbitrary choices and sometimes only look at a part of the issue. We suggest that by integrally addressing working hours, family size, labor participation and the poverty bottom line we can justify a fair Absolute Minimum Wage as the bottom line.

Working hours and days

The ILO C047 - Forty-Hour Week Convention in 1935, ratified by 15 countries, agreed on the principle of a 40 hour working week (ILO, 1935). The ILO recommendation no. 116 of 1962 states (summarized): "*Each member should promote and, where possible, ensure the application of the principle of the progressive reduction of normal hours of work with a view to attaining the 40 hour week, without any reduction in the wages of workers:* and *"where the duration of the normal working week exceeds 48 hours, immediate steps should be taken to bring it down to this level, without any reduction in the wages of the workers*" (ILO, 1962). The ILO C132 - Holidays with Pay Convention, 1970, ratified by 36 countries, states: "*Every person to whom the convention applies is entitled to an annual paid holiday which shall in no case be less than three working weeks for one year of service",* and *"public and customary holidays are not counted as part of the minimum annual holiday with pay of three weeks*" (ILO, 1970). The ILO conventions agree on a standard workweek of 40 hours and a maximum of 48 hours and also on a maximum of 49 workweeks, on paid public holidays, and on a standard workday of 8 hours. The average number of public holidays in 62 countries as collected by Mercer is 12 days. (Mercer, 2011). Therefore, an ILO conventions-derived standard for a working year can be calculated as (49 * 40) – (12 * 8) = 1864 hours and as 1.864/8 = 233 workdays.

In practice, it seems very difficult to maintain these conventions. Only 15 countries ratified the 40-hour week convention. Many low and middle income countries and even most NGOs and the Asia Floor Wage Alliance use 48 hours as a maximum workweek. Based on a 48-hour week and the ILO agreed holiday system, a standard work year would consist of 2237 hours. The yearly work hours in 2012 in OECD countries varied from 1381 hours (Netherlands) to 2226 hours (Mexico). In 2012 the OECD average was 1766 hours (OECD Stat Extracts, 2012). USA living wage calculations are based on 2080 hours/year (Luce 2012, p.13-14). Not all of the variation is due to different perceptions of what a standard workweek should be. Labor participation rate, voluntary part-time work in developed countries, and other cultural differences heavily influence

the average workweek. For a measuring method, an absolute minimum must be based on one and the same number of working hours, where possible based on international agreements. Therefore, we propose to use the above described ILO derived 1.864-hour work year.

Family size

The discussion on family size is a morally difficult one. "The minimum wage should allow the worker and his family an acceptable standard of living" (Anker, 2006). The principles of "equal pay for equal work" (UN General Assembly, 1948, article 23) and "a wage should allow an acceptable standard of living" are somewhat contradictory. Some religious and cultural practices oppose birth control. In practice, low birth control increases the risk of poverty, although low income families to tend to receive assistance from their social networks (Edin & Lein 1997, p.258). Because population growth is a major sustainability threat, it seems reasonable to base family size on a more or less constant population size with 2 births per woman. Systems have been developed for the number and weighting of family members, by which household size is defined in terms of "adult equivalents". In the scale used by the World Bank and the OECD, the first adult in a family counts as one adult, the second adult counts as 0.7 adults and children are given a weighting of 0.5. In this scale, a family of 2 adults and 2 children is counted as a family size 2.7 adult equivalents (World Bank 2005, p.34). The Asia Floor Wage Alliance, a joint effort of Asian labor unions, determined their absolute floor wage based on a family of 2+2 persons, while counting children as 0.5 adult, resulting in 3 adult equivalents for a standard family (Bhattacharjee & Roy 2012, p.78).

Labor participation

According to Anker there is no consensus in the assumption of the number of income-providing family workers. Anker gives an overview of 13 methods and assumptions, which vary from 1 to 2 full-time providing workers per family. Cultural aspects, the level of development, but also the unemployment rates all influence labor participation levels in practice. In Anker's opinion, 1.5 workers is a good assumption (Anker 2011, p.47), but he is clear on the poor substantiation of this assumption. The Oiconomy consumer enables market players to prevent unfair pay, but does not interfere with actual choices and practices. Parents provide for their children and children for their elderly parents, either directly via family or community care or via institutional systems such as pensions, healthcare and education subsidies. How countries organize this is the responsibility of their politicians. Following this logic, a very simple system can be applied, combining the aspects of family size and labor participation. The average life expectancy at birth (LE) in our benchmark group of countries is 78.34 years and the average number of working years in these countries is 46.21 years. This means that on average in his working life every person has to gain 78.34/46.21 = 1.70 times a living income. (The number of working years was calculated as the mean retirement age minus 18 years, which for the minimum wage purpose is reasonable, because longer education commonly leads to higher incomes). However, the raising of children prevents at least one of the parents from raising a full income. It is remarkable that almost all authors discussing the labor participation rate in relation to setting the minimum wage base their methods on a family situation, neglecting the full lifetime of people, although that is partly compensated by weighting children as 0.5 adult equivalents.

With a family with 2 children, it seems reasonable to assume that one of the parents can only gain a half income, as Anker proposes, but only during half of the 46.66 working years. This means that, following the working years/life expectancy logic, the average worker has to gain the 25% lost income of one other person, which makes us propose a fair minimum wage of 1.70 * 1.25 = 2.12 times the living income for one person. Anker estimates average labor participation rates in 12 investigated countries at 1.27 (Anker 2006a, p.322), very close to the above assumed factor of 1.25.

A World Bank poverty line-derived absolute minimum wage

The World Bank proposes an absolute line for extreme poverty at $ 1.25 and one for moderate poverty line (MPL) at $ 2.00 (2005 US$ PPP) per person per day (Ravallion *et al.*, 2008). Because, according to the World Bank, below the line of $ 2 people are still in poverty and the $ 1.25 line cannot be considered "fair", we choose to use the $ 2 line. This $ 2 absolute poverty line needs to be translated into an absolute yearly minimum wage (AMW). Following the same logic as above for the required labor contribution to other people, a simple formula translating the MPL into an AMW_y is: AMW_y = (365 * MPL * LCR * (LE/WY), where LCR is the labor contribution ratio, LE the life expectancy and WY the working years. Using this formula with the averages of the benchmark group, the AMW_y becomes: 365 * $ 2 * 1.25 * (78,34/ 46.21) = $ 1546.96 per year. Using the above derived standards for working hours and working days, this translates into an hourly AMW (AMW_h) of $ 1546.96/ 1.864 = $ 0.830, a daily AMW (AMW_d) of $ 1546.96/ 233 = $ 6.64 and a monthly AMW (AMW_m) of $ 1546.96/12 = $ 128.91, all in 2005 US$ PPP. AMWs in current currencies must be multiplied by the exchange rate compared to the value of the 2005 US$ PPP.

Validity and Comparison

In 2014, the developers of the SSI changed the composition of the SSI HW because of limited availability of sub-indicators, with the consequence that some countries, including the USA, in our benchmark group fell out of our benchmark group. This gave us the opportunity to test the sensitivity of our proposed fair minimum wages to the composition of the group. We also tested the sensitivity to the benchmark size and against using a population weighted averaging of country data instead of straight averaging. The results are presented in table 4.2.

One can question whether this approach leads to extreme outcomes. We will now assess this issue by comparing our approach with other methods. The Asia Floor Wage Alliance (AFW) advocates a global minimum wage based on the living wage (Merk, 2009; Bhattacharjee and Roy, 2012). The AFW determined the living wage for a group of Asian countries comprising Bangladesh, India, China, Indonesia, Thailand and Sri Lanka. The starting points for the AFW living wage are the costs of a basket of basic foodstuffs required for the intake of 3.000 kCal per day and 3 adult equivalents per family. Basing itself on "Engels law", the AFW multiplies the obtained food costs with a factor 2 for non-food needs. "Engels law" of consumption is the observation that as income rises, a lower percentage is spent on food. In high income countries food expenditures total less than 20% of family expenditures, but in low-income countries "well over 50%", which percentage explains the factor 2. For 2012, the AFW determined a living wage of $ 540 (PPP) per month, or $ 6.480 per year, which is more than 4 times the above calculated $ 2 poverty line-based absolute minimum wage. Because the AFW chooses "not to

lower the standard of any country" their starting point was set high. 3.000 kcal as an average daily energy need indeed seems far too high. A joint FAO/WHO/UNU report shows that these 3.000 kcal's is true for quite active male adults, but is far lower for women, children and the elderly (FAO et al. 2001, p.41-43). The Dutch Nutrition Centre gives an average for adults of 2.250 kcal (Voedingscentrum, 2014). 3 adult equivalents per worker are far more than the average factor of 2.12 calculated above. Correcting the Asia Floor Wage for these parameters gives a floor wage of $6480 * (2.250/3.000) * (2.12/3) = $ 3.434. However, because 3 countries in the AFW research group (China, Thailand and Sri Lanka) do not belong to the very poorest countries, even this reduced value may still not be realistic for the poorest countries. Using this paper's methodology, these countries fall under the relative system. As presented later, the proposed minimum wage for China is $ 3.714, for Thailand $ 3.701 and for Sri Lanka $ 2.444, far closer to the here corrected AFW proposal.

Another method was developed by Anker for an estimation of the living wage (Anker, 2006). Like the Asia Floor Wage Alliance, he starts with expenditure for food requirements. But Anker adds non-food expenditures, which for low-income countries are estimated at about 30%. Anker estimates the living wage in low-income countries at about $ 1.70 per hour, which is double the above derived absolute minimum wage. However, Anker chooses to base his calculations on peak family sizes, the period in the life of an average family raising children, and on actual family sizes. Because the distribution of income over different life periods of a person and local labor participation customs is a private and local political responsibility, and because the Oiconomy consumer cannot be expected to pay for unsustainable birth rate situations, also Anker's system is not suited for our purpose.

The threshold: Kink Point theory

Edward derives an "ethical poverty line" based on the "Preston curve". Various authors argue that it is not income but health and life expectancy (LE) that make the most important development indicator. Preston demonstrated that LE plotted against the GDP per capita (GDP/Cap) gives a logarithmic-looking curve, showing a sharp rise at low GDP/Cap and remaining almost constant at high GDP/Cap, the "Preston curve" (Preston 1975, p.235). Deaton found that inequality is not the direct cause of this relation, leaving absolute poverty itself as a probable determining factor (Deaton 2003, p.151). Also (Wilkinson & Pickett 2009, p.499) and (Pritchett & Viarengo 2010, p.3) describe this relation between income and LE. (Pritchett & Viarengo 2010, p.3) and (Feschet *et al.*, 2013) demonstrate that the relation is not only valid across countries, but also for individual countries, although there is some time delay between the rising of the GDP/Cap and the increase in LE. In the S-LCA community, the Preston curve is discussed as a possibility to determine a pathway between socio-economic factors and health (Norris, 2006; Feschet *et al.*, 2013; Bocoum *et al.*, 2015).

The Preston curve may also be interpreted as having a kink point above which' GDP/Cap, LE hardly rises, or in other words above which more wealth hardly leads to more life years (Edward, 2006). By mathematical analysis of the curve Edward determined this kink point "somewhere between $ 2.70 and $ 3.90 per day" and proposes an "ethical poverty line" at $ 2.70 per day in 2002 US$ PPP. Visually the Preston curve for the year 2011 shows 3 sections, with 2 kink points. We added the linear trend curves to these sections and determined the intersections. The curve (figures 4.2 and 4.3) shows a rapid rise in LE with increasing GDP/Cap until approximately 68

years at a GDP/Cap of about $ 3.500, followed by a slow rise to 79 years at a GDP/Cap of about $ 30.000, and remaining more or less constant from that point. In our benchmark group of the top 20% countries ranked by the SSI HW, on average, the statutory minimum wage is 42.7% of the GDP/Cap. Taking this $ 3.500 as a benchmark minimum wage would result in 0.427 x $ 3.500 = $ 1.495, remarkably close to the World Bank $ 2 based $ 1.547 as proposed above.

Feschet et al. however, describe the curve sharply rising up to a GDP/Cap of about $ 10.000, and Norris of $ 5.000, quite different from our $ 3.500. These authors however, do not discuss the curve from a kink point of view, but as a means to develop a pathway between socio-economic factors and health, one of the most important endpoint indicators in LCA. To investigate the validity of using the Preston curve as an indicator, in figure 4.4 we present a variation by plotting not life years against the GDP/Cap, but *happy* life years, LE multiplied with a happiness score (Veenhoven, 2012). If we want to see a kink point in this figure, it would be at a GDP/Cap of about $ 25.000, a different location again. We will further discuss the implications of this in the discussion section of this chapter.

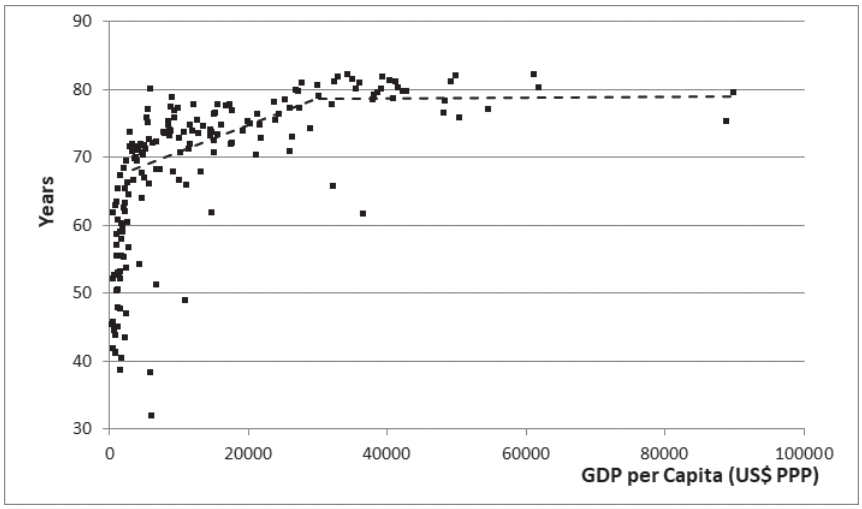


Figure 4.2. The Preston curve: Life Expectancy (CIA factbook 2011) versus GDP per Capita (World Bank 2011). The dotted lines are the linear trendlines for GDP/cap. = $3.000 - $30.000, and from $30.000 up, crossing at a GDP/cap. of about $30.000.

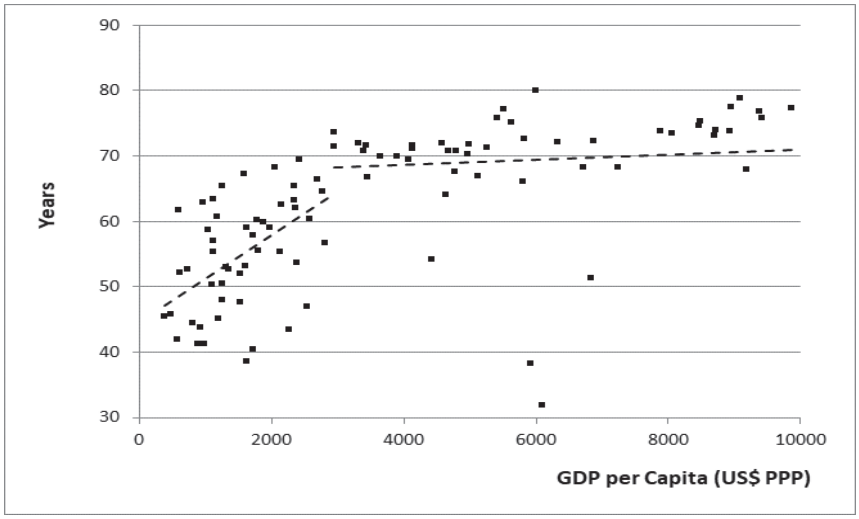


Figure 4.3. The Preston curve, enlarged for GDP/Cap < 10000: Life Expectancy (CIA factbook 2011) versus GDP per Capita (World Bank 2011). The dotted lines are the linear trendlines for GDP/cap.= $0-$3.000 and $3.000 - $10.000, crossing at a GDP/cap. of about $3.500.

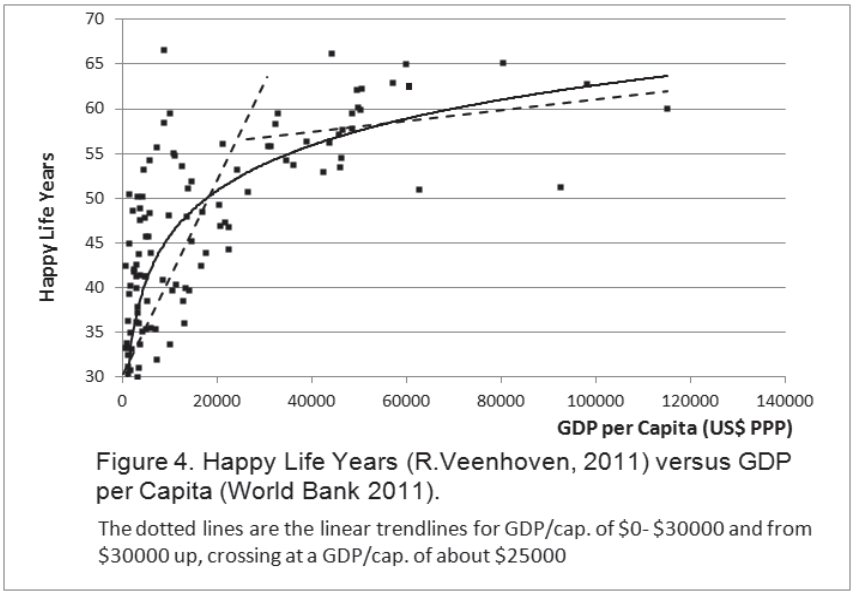


Figure 4.4. Happy Life Years (R. Veenhoven, 2011) versus GDP per Capita (World Bank 2011).

The dotted lines are the linear trend lines for GDP/cap. of $0- $30.000 and from $30.000 up, crossing at a GDP/cap. of about $25.000.

Determining the Relative Minimum Wage

Let us now look at the higher end of the income spectrum, where we will apply a relative value approach. As we saw in section 4.3.2, a country's relative poverty line is usually measured by a constant proportion of an economic wealth indicator. In this section the same benchmark group of countries as described in section 4.3.3, will be used.

A relative minimum wage needs a constant proportion of an economic indicator. Because the GNI adds financial flows to the GDP, the GNI_{Cap} makes the better indicator of national wealth. Therefore, the mean ratio between minimum wages and the GNI_{Cap} in the chosen benchmark countries is selected as the best ratio. However, statistics on international minimum wages are complex. There are great differences in data and minimum wage systems. Table 4.1 shows a survey of these differences including how this paper deals with these. OECD and ILO data were used in preference, but because these databases are not complete, additional data were obtained from (WageIndicator Foundation, 2013) and (Minimum-wage.org, 2013). The data for the benchmark group that determines the proportion, are all from OECD or ILO databases. In our benchmark group of countries, the average proportion of the minimum wage relative to GNI_{Cap} in 2011 was 44.4%.

Table 4.1. Methods used by different countries to set and describe their minimum wage systems. (MW = minimum wage)

Differences by	Relevance and position
Currency	All presented data are in US$ PPP 2011
Defined period and differences in working hours and days the data refer to.	The MW may be set per year/month/day or hour. In addition, yearly, monthly and weekly data vary greatly on the working hours or days they refer to. Where yearly MWs were set and reported, as for almost all OECD data, these were used. Hourly, daily and monthly MWs were normalized to yearly MWs using the factors of 1864 hours, 233 days and 12 months per year. Where data on several periods were available, the highest result was used.
Rural or municipal MWs; Regionally fixed MWs; Special MWs for agriculture.	Such differences do not occur in the benchmark group. For other countries the lowest MW in the country was used.
Industry branch, skills or education level or private/public employment	Such differences do not occur in the benchmark group. For other countries the lowest MW in the country was used.
Number of employees	Such differences do not occur in the benchmark group. For other countries the lowest MW in the country was used.
Years of employment or temporary, permanent or probationary contracts	The lowest MW in the country was used.
Age	Almost all countries have a system for lower wages for young people. The Oiconomy standard follows the ILO conventions. This paper only considers minimum wages for adults. The adult threshold varies per country (ILO, 1992); this paper does not address reductions for young people and apprentices.
Exemptions	Some low income countries have exemptions from standard MWs for domestic work and jobs only for watching premises. Because these jobs often aim at not much more than community involvement, the MWs of these exemptions were not considered the lowest MW.

Appendix 5 presents for 183 countries the proposed fair minimum wages for 2011 in US$ PPP, calculated as 44.4% of GNI_{Cap} expressed in 2011 US$ PPP, bottom cut-off by the above proposed absolute minimum wage of $ 1.547 in 2005 PPP US$, which remains, as US$, the same for 2011. In addition, the appendix lists the statutory minimum wage in 2011 US$ PPP, and the ratio between the statutory minimum wage and the proposed fair minimum wage.

4.3.4. PREVENTATIVE MEASURES AND CONVERTING INTO ESCU'S (STEP 3, 4 AND 5)

For the determination of the (un)sustainability score in preventative cost-based S-LCA, one more parameter must be determined, the cost distance between the actual sub-fair wage and the fair minimum wage, the ESCU's. With a known target for the fair minimum wage for every country, there is only one possible preventative measure against underpayment: raise the actual wages of all sub-fair paid people involved in activities related to the product, to the target. But what level of actual wages must be used, if foreground data are not available? Not many data are available on actual sub-minimum wages, because many of these are not compliant with national legislation and try to be invisible. An exception is the work of Wageindicator, an organization that

in cooperation with Dutch and local universities provides valuable data on actual wages all over the world. In 10 reports on wages in developing countries (Benin, Costa Rica, Ghana, Guinea, Honduras, Indonesia, Madagascar, Sri Lanka, Ruanda and Uganda), Wageindicator reports that an average of 34% of the investigated wages were below minimum wage (Cambodia Institute of Development Study, 2011; Perinelli and Beker, 2011; Besamusca, Palma and Arenas, 2012; Besamusca, Palma, Arenas, *et al.*, 2012; Besamusca, Tijdens, *et al.*, 2012; Besamusca, Tijdens, Alinsato, *et al.*, 2013; Besamusca, Tijdens, Mbassana, *et al.*, 2013; Besamusca, Tijdens, Tingum and Diallo, 2013; Besamusca, Tijdens, Tingum and Ravelosoa, 2013).

The lowest reported actual wages per country (medians for lowest paid groups) showed great variation, with an average of about 43% of the national minimum wage, and the very lowest reported (Indonesia) was only 6% of the local minimum wage, indicating that exploitation of the necessitous almost goes to the zero limit. Interestingly, the same reports also demonstrate that the lowest wages are not paid by multinationals, but by small local companies. This however, does not exclude the possibility that local companies are used by multinationals, and that involved products reach Oiconomy consumers. Figure 4.5 shows the actual- to fair wage ratio, the statutory minimum wage percentage of our calculated fair minimum wage, for all countries with a statutory minimum wage. The graph shows that the complete range between 0 and 1 occurs and that all benchmark group countries have a ratio of over 60%. Because the fair minimum wage was calculated from the average minimum wage / (GNI_{Cap}) ratio of the benchmark group countries, not all countries of this group have a fair minimum wage.

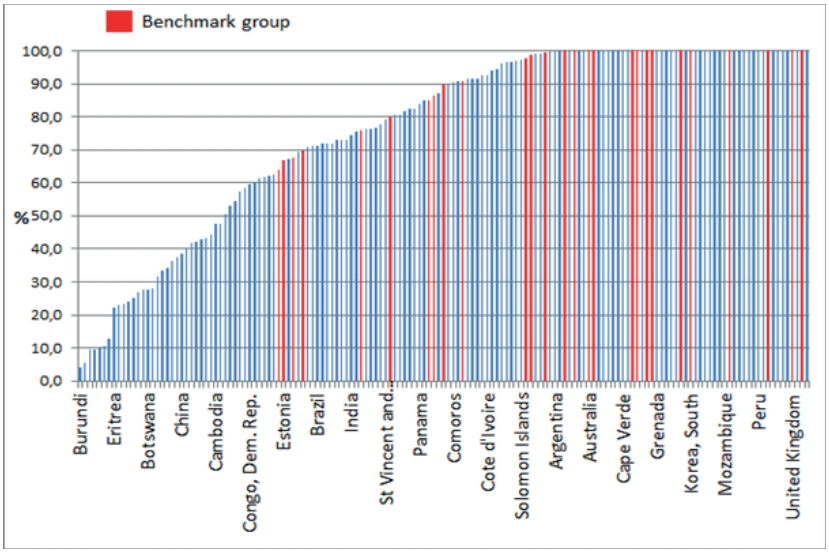


Figure 4.5 Actual minimum wage to Fair minimum wage ratio in percentages .

The (un)sustainability measure in preventative cost-based S-LCA is equal to the costs involved to raise all wages of the people involved in the product life cycle to the level of the fair minimum wage. In most types of LCA these data will be very hard to collect and verify. In the Oiconomy system however, ESCU's are determined by every actor in the supply chain and verified in a certification system, which also verifies the actor's governance. We propose the following

procedure: If a supply chain actor cannot demonstrate good governance on wages, ESCU's are allocated equal to the difference between the actual wage and the fair minimum wage. If the actual wage is unknown, or unreliable because of bad governance, the worst case value needs to be used. Without an objectively determined worst case in the relevant country, such as by Wageindicator, we propose to assume the zero level.

4.4. DISCUSSION AND CONCLUSIONS

In this chapter, based on ILO standards, the $ 2 World Bank moderate poverty line, and the average practices in a benchmark of the 20% top performing countries in the Sustainable Society Index Human Wellbeing, a method was developed for the determination of a fair minimum wage standard. This resulted in a proposal for a fair minimum wage of a relative measure of 44.4 % of the GNI_{Cap}, bottom cut-off for the lowest income countries by an absolute fair minimum wage (AMW) of $ 1547 (PPP) per year and $ 0.830 (PPP) per hour. The method and proposed fair minimum wage are primarily intended for the determination of the marginal preventative costs for the aspect of unfair prices for labor in preventative cost-based S-LCA, but can also be used as a PRP in S-LCA in general. Although currently fair trade products are common in the market, there is no agreed standard for a fair minimum wage. Therefore, we also suggest that the here proposed fair minimum standard can be directly used for fair trade purposes.

Investigating alternative methods for justification of our proposed $ 1547 for the AMW, a striking match of $ 1495 was found if the AMW would have been derived from the Preston curve kink point. However, the location of that kink point requires further discussion. Our own analyses demonstrated rather 2 kink points than 1, at a GDP/Cap of $ 3500 and of $30.000. If instead of life years, happy life years are plotted against the GDP/Cap, we find a much slower rise of the curve and a possible kink point at about $ 25.000, but we also find a small group of countries having reached a high score of happy life years at much lower levels of $ 5.000 - $15.000. Quite commonly in impact-based E-LCA and S-LCA, health, for which LE is an indicator, is taken as an important endpoint indicator (Jolliet *et al.*, 2004). We demonstrated that just taking a slightly different, but very justifiable, endpoint, the results are hugely different.

What are the implications for our proposal? Our proposed AMW was derived from the World Bank $ 2 moderate poverty line, which is the average living wage in world's 75 poorest countries. The living wage is based on a basket of basic needs. It tells little about happiness. Where the original Preston curve finds its major rise below a GDP/Cap of $ 3.000, it takes up to $ 25.000 to get to high happy life year scores. In addition, after the first kink point, also life years slowly keep rising to about $ 30.000. So, not surprisingly, the World Bank $ 2 poverty line only takes countries to the first LE kink point, the living wage level. But for global country level equality in life years and happy life years far higher incomes are required. However, in our proposed system, if a countries' income rises above the cut-off point the relative system applies, resulting in a higher fair minimum wage. Therefore, we conclude that our proposed AMW is justifiable, but does not represent full equality in human well-being.

The proposed proportion for the relative system is justified by the high development of the selected benchmark group of countries.

Lastly we like to discuss the validity and limitations of our methods and data. Minimum wages have been set by the majority of countries, but what these include may differ. Although the data

used in this investigation are from World Bank and IMF databases, taxation systems and other provisions differ too much to be sure that the minimum wages of all different countries have exactly the same consequences for the workers.

Trusting World Bank and IMF data screening, in this investigation these differences were neglected. The data as presented in appendix 5 are indicative and must be interpreted as gross wages, including health care, pension schemes, insurances, education and tax.

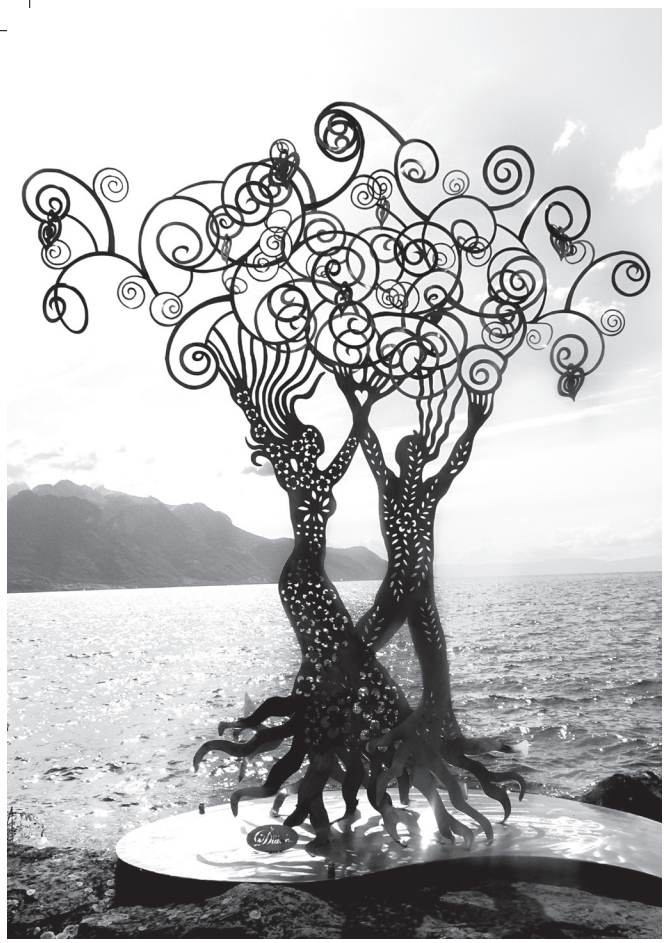
Our proposed fair wages are based on the practices of the top 20% performers in the SSI HW. In time, the composition of countries in this index will change, as will the minimum wages in these countries. The changes in the minimum wages are limited, in OECD countries to an average 1.5% growth per year (OECD Stat Extracts, 2012). The index however, demonstrates greater changes. In this paper we have used the top 20% from 2012 (Van de Kerk and Manuel, 2012), including the USA. In 2014 however, the USA dropped out of the top 20%. Other choices that need discussion is our fairly wide choice of using the top 20%, and of using simple country averages instead. Therefore, table 4.2 presents the results for some alternative choices.

Table 4.2. Sensitivity of AMWy (in US$ 2011 PPP) and the Average Ratio MW/GNI_{cap} to the country benchmark size, type of average, and the inclusion of the USA. (AMW_y is the proposed "absolute yearly minimum wage", MW is the minimum wage and GNI_{cap} the gross national income. The countries represent the countries with statutory minimum wage only).

Country Index	Number of Countries	Type of average	AMW_y	Average Ratio MW/GNI_{cap}
2013 HDI	22	standard average	1.554	0.446
2012 SSI HW	26	standard average	1.545	0.442
2014 SSI HW	25	standard average	1.548	0.451
2013 HDI	22	population weighted average	1.550	0.399
2012 SSI HW	26	population weighted average	1.574	0.343
2014 SSI HW	25	population weighted average	1.595	0.451
2013 HDI	16	standard average	1.564	0.458
2012 SSI HW	19	standard average	1.558	0.452
2014 SSI HW	18	standard average	1.552	0.458
2013 HDI	11	standard average	1.557	0.462
2012 SSI HW	13	standard average	1.543	0.458
2014 SSI HW	12	standard average	1.544	0.443

From this table we observe that the AMW_Y hardly changes if calculated for the top 15% or 10% of countries, and for 2012 and 2014, even if calculated as the population weighted average. Even if calculated using another index, the UNDP Human Development Index 2013, the AMW_Y remains constant. The reason is that the ratio between life expectancy and working years, the only index dependent variable in our method for the AMW, is fairly constant. But also the more politically influenced MW/GNI_{cap} ratio remains stable in most of these alternatives. Only if calculated as population weighted averages, we see not only lower ratio's,

but also greater variation between the years and with HDI derived ratio's, which is mainly caused by in- or excluding of the highly populated USA. We propose to use the difference between the actual wages and the here proposed fair minimum wages as indicator of (un)sustainability in S-LCA. However, that is only possible if a practitioner has either complete own control over the supply chain of a product, or by using a certification based LCA system, such as the Oiconomy system, in which every actor in the supply chain determines and transfers uniformly measured and verifiable data through the supply chain.



We should be equally eager to heal the cancer of corruption as the cancer in our body

The ultimate but very necessary measure to eliminate corruption is discontinuing the business

CHAPTER 5

QUANTIFICATION OF CORRUPTION IN PREVENTATIVE COSTS BASED S-LCA [6]

6 This chapter is based on the publication: Croes, P. R. and Vermeulen, W. J. V. (2019) "Quantification of corruption in preventative cost-based S-LCA: a contribution to the Oiconomy project," The International Journal of Life Cycle Assessment, 24(1), pp. 142–159. One section of the original, explaining the Oiconomy system, was removed. The chapter was slightly edited to fit in the book structure.

5.1. INTRODUCTION

The definition of corruption by the United Nations Global Compact, Transparency International and the World Bank is: "The abuse of entrusted power for private gain" (United Nations Global Compact & Transparency International 2009; World Bank 2008, p.16), including bribery of public officials, embezzlement, trading in influence, abuse of function, illicit enrichment by public officials, money laundering, and obstruction of justice (United Nations Global Compact 2010, p.13). But tax evasion, support of politicians or political parties by businesses, and even lobbying are also regularly perceived as corruption (OECD, 2013). Corruption, defined as a crime by the 2004 UN Convention against Corruption, signed by 140 countries and legally implemented by many countries, extends the concept of private gain to also "another person or entity", this way including the various types of favoritism (United Nations Office on Drugs and Crime 2004, article 15), such as nepotism, clientelism and cronyism. Although an OECD convention regulates information transfer on taxes between countries (OECD and The Council of Europe, 2012), there is no international agreement on aspects like tax evasion and political involvement. Because company-specific data on their involvement in bribery- and favoritism-related activities usually are illicit, but data on their paid taxes available, quantification of these aspects requires different methods. Therefore, for the purpose of this chapter we choose to define "corruption" as all bribery- and favoritism-related activities, and exclude the aspect of tax evasion.

On December 17, 2010, the Tunisian graduate Mohamed Bouazizi, previously bullied by the police and desperate because he had insufficient money to bribe the police for allowing him to sell produce from his unlicensed vegetable cart, set himself on fire (BBC News, 2011). The subsequent protests grew to revolt and war in the Arabic world, causing hundreds of thousands of deaths, millions of wounded and displaced people and religion- and migration- based fear and hatred, infecting greater parts of the world. Although the underlying causes are multiple, this is a clear example of the huge impact that corruption may have. It also illustrates that measuring or predicting the impact of a social stressor with some certainty is a very challenging task.

A large body of literature demonstrates the detrimental impact of corruption. The World Bank's website calls corruption the single greatest obstacle to economic and social development (World Bank, 2016), and various authors point to the fact that corruption shifts governments spending away from health, education and infrastructure maintenance, (e.g. Mauro, 1997; Wei, 1999; Campos and Pradhan, 2007; International Chamber of Commerce *et al.*, 2008; Søreide, 2014). Transparency International states that there is clear evidence that corruption is one of the primary causes of Millennium Development Goals being off-track (Fagan and et al., 2010). Corruption has a detrimental influence in all three sustainability pillars, which are often referred to as the Triple Bottom Line "PPP": Planet, People, Profit (Elkington, 2004), but more recently as "Planet, People and Prosperity", stressing the structural causes of inequality and poverty, and also explicitly addressed in the UN's Sustainable Development Goals (European Commission, 2002; Barkemeyer *et al.*, 2014; SDSN, 2015; Gupta and Vegelin, 2016; Vermeulen and Witjes, 2016).

Considering the planet category, the first striking fact is that many of the major oil producing countries score as very corrupt in the Corruption Perceptions ranking, e.g. China (77), Mexico (135), Russia (135), Iran (130), Nigeria (148), Venezuela (169), Iraq (169), Libya (171) (Transparency International, 2017). But the oil business is just an example of the mining industry, which, according

to Transparency International, is one of the business sectors most likely to be sensitive to bribery. Because green industry also heavily depends on mining, corruption may be expected. Gallium for photovoltaic cells, tantalum for microelectronics, rear-earth metals for magnets in windmills, platinum for catalysts and many other mined resources used in green industry, are sourced in countries with very high corruption perceptions ranking scores (Transparency International 2013, p.199). For both climate and biodiversity, loss of forests is one of the major threats. According to various authors, corruption is one of the root causes of forest degradation. (Hicks 2013; Koyunen & Yilmaz 2009; Transparency International 2013; FAO 2001).

Considering the people category, corruption plays a key role in health and social wellbeing. In the first place it has an impact on poverty, as demonstrated by Gupta et al. (2002). In 1996, the then-president of the World Bank, James D. Wolfensohn, declared: "For developing countries to achieve growth and poverty reduction, we need to deal with the cancer of corruption" (Bhargava 2006, p.1). Corruption especially affects health, because in development countries it prevails in water and sanitation management and in the health sector itself, in this way representing a direct death toll, especially of children (Azfar and Gurgur, 2008; Hanf *et al.*, 2011; Factor and Kang, 2015). We also find a corruption-related death toll in natural disasters, because of its impact from supposedly disaster-proof constructions, causing landslides and collapsing dikes and buildings. And finally, in development countries corruption affects education, (e.g. Hallak and Poisson, 2005; Azfar and Gurgur, 2008).

Considering the prosperity category, estimates show that the cost of corruption equals more than 5% of global GDP (US $2.6 trillion), with over US $1 trillion paid in bribes each year. Corruption adds up to 10% to the total cost of doing business globally, and up to 25% to the cost of procurement contracts in developing countries" (International Chamber of Commerce et al. 2008, p.1). "Corruption is shown to have a significant negative effect on entrepreneurship, and businesses see themselves as victims of corruption" (Hameed & Magpile 2014, p.1). Bribery and taxation are closely related. By corruption, tax systems are biased (Gupta et al. 2002, p.25), and low taxes in "tax paradises" impact taxation in the countries of production. However, there is a body of literature indicating that in some cases corruption "greases the wheels" of economic growth, especially under conditions of low quality governmental institutions and low economic freedom, the effect of which however, decreases or even reverses at improving institutions and economic freedom, e.g. Heckelman & Powell (2008, p.17).

LCA LITERATURE ON CORRUPTION

The UNEP guidelines for Social Life Cycle Assessment (S-LCA) of products mention corruption as a subcategory (Benoît & Mazijn 2009, p.49). But to date, the literature on addressing corruption in LCA is very limited. Some authors, usually citing the guidelines, mention corruption as an aspect to be studied, (e.g. Grießhammer et al. (2006); Benoît et al. (2010). Dreyer et al. (2010), describing a method for labor conditions, mentions its applicability for corruption. Ekener-Petersen & Finnveden (2013) identify corruption as a potential hotspot in the life cycle of a laptop computer. No attempt at further quantification of the specific aspect of corruption or research into potential indicators for that purpose could be found in the literature. We may conclude that there is a research gap in the quantification of corruption in S-LCA.

OBJECTIVE

This chapter is a contribution to the Oiconomy project, comprising the development of a LCA system based on the costs of prevention instead of the assessment of the impact itself. The Oiconomy system comprises both environmental, social, and economic sustainability aspects and intends to use a certification system for the transfer of foreground data through the supply chain of products. The system is fully explained in chapter 2. The objective of this chapter is to investigate literature on the available options to (preferably interval-) quantify corruption in S-LCA, distinctive for specific products and use the options and ideas found to make a first proposal for quantification for preventative cost-based S-LCA.

5.2. METHOD

As a first step, literature was investigated on potential S-LCA assessment methods of corruption. Combining the words "corruption", with "S-LCA", "Social LCA" or "life cycle assessment", with Scopus 3 articles were found and with Google Scholar 256 articles. However, none of these dealt with quantification of corruption. Also the words "bribery" and "tax evasion" instead of corruption did not result in relevant articles. Therefore, using literature reviews, their leads and references of scholars in the field, the 12 most used of which are listed in the results section, S-LCA methods were assessed more generally on described concepts and ideas, and assessed on the following five criteria:

1. The method should give a (preferably interval) quantitative, objective and certain measure.
2. The required data must be available and data collection preferably feasible for industry.
3. The measure must be distinctive for a specific product or company.
4. The results must be aggregable with those for other environmental and social-economic aspects.
5. The method must be suitable to be used for the aspect of corruption.

These 5 criteria were chosen in order to assess the feasibility of the investigated S-LCA methods for the quantification of the social sustainability, including corruption, of specific products, generically applicable for different sustainability aspects and different product categories. Subsequently, using the obtained conclusions and ideas, a proposal for the quantification of corruption for the preventative cost-based Oiconomy system was developed, following the Oiconomy methodology (chapter 2), which is very similar to the method used in the regularly EcoCost methodology (Vogtländer *et al.*, 2000) and consists of five steps:

Step 1. Definition of the impact category and characterization factor.
Step 2. Determination of the corruption target, or performance reference point.
Step 3. Literature study of available preventative measures.
Step 4. Determination of the costs of the available preventative measures.
Step 5. Assessment of which preventative measures are required to globally reach the target.

The last and most expensive determined this way, presents the marginal preventative costs, which in the EcoCost and Oiconomy systems serve as cost distance to target, and represent our proposal for the quantification of corruption.

5.3. RESULTS – LITERATURE REVIEW

The UNEP guideline on LCA only mentions corruption as a subcategory under the stakeholder category of "society" (Benoît & Mazijn 2009, p.49). The Global Reporting Initiative (GRI) dedicate a more quantitative guideline on corruption, requiring members to report concrete numbers of operations assessed and of risks identified, numbers and percentages of internal people and external organizations to whom the company has communicated its policy, numbers of internal and external people who have received training on anti-corruption, and also to report the number of confirmed incidents (GRI 2013, p.204-209). As mentioned in the introduction, section 5.1, no literature could be found on the quantification of the specific aspect of corruption, or research into potential indicators for that purpose. Therefore, we will continue investigating S-LCA methodology in general, on which several literature reviews have been written, (e.g. Jørgensen et al. 2008; Macombe et al. 2013; Benoît and Vickery-Niederman 2011; Chhipi-Shrestha et al. 2015; Swarr 2009; Hsu et al. 2013; Hauschild et al. 2008; Benoît Norris 2012; Hutchins & Sutherland 2008; Jørgensen, Lai, et al. 2010; Finkbeiner et al. 2010). Not included in these reviews is preventative cost-based LCA (Vogtländer *et al.*, 2000), extended to S-LCA (see chapter 2).

Basically, one could assess environmental and socio-economic stressors by their impact, by the measures required to compensate the impact, or by the measures required to prevent them. ISO 14040 defines LCA as: "The compilation and evaluation of the inputs, outputs and the potential environmental *impacts of* a product system throughout its life cycle" (ISO 2006, p.2). The UNEP guidelines define socio-economic LCA as: "A social *impact* assessment technique that aims to assess the social and socio-economic aspects of products and their potential positive and negative impacts along their life cycle" (Benoît & Mazijn 2009, p.37). Both the ISO standard and the UNEP guidelines intend to increase firms' and governments' knowledge and awareness of impacts and provide them with tools to assess the consequences of various alternatives for their products, activities and decisions. Therefore, the main body of LCA and S-LCA literature is impact-based. In impact-based S-LCA (IB-S-LCA) basically two types of methodologies are used, identified by the UNEP guidelines (Benoît & Mazijn 2009, p.71) as Type-I, based on the distance to Performance Reference Points (PRP's) and categorized in themes of stakeholder's interests, and Type-II, based on cause-effect pathways.

5.3.1. TYPE-I S-LCA ASSESSMENT METHODOLOGIES

CHECKLIST- AND SCORING METHODS.

Checklist methods use ticks for a series of indicators usually first belonging to a midpoint impact category and from there to an endpoint category. They assess, for a number of aspects or subcategories, the yes or no presence of impact in the endpoint categories. Scoring methods add a weighting score to the ticks. Franze & Ciroth (2011) compare the social impact of cut roses from Ecuador and from the Netherlands. Based on the number of ticks and the authors' weighting of the seriousness, a final assessment is made in five grades per aspect. The ticks are based on the authors' investigation of the involved country and industry sector performance on the area of protection (AoP). Franze & Ciroth apply the method in an indiscriminating way, ticking complete subcategories in order to asses the endpoint of human wellbeing. However, in principle the method can be applied to a midpoint category such as occupational health and safety, or corruption, provided that a balanced set of criteria can be defined as indicators for the impact or status of control. For further improvement, various authors developed techniques to

quantify these dichotomous indicators more precisely, e.g. by means of measuring the opinions of stakeholders and/or experts on the companies' performance on an indicator. For example Manik et al. (2013) developed an interval scoring variable for the measurement of the social impact of biodiesel production in Indonesia. By means of questionnaires, for a series of criteria, they determined the distance between a stakeholder's perceived and expected impact, for each criterion multiplied by an expert panel's obtained weighting score. A similar technique was used by Foolmaun & Ramjeeawon (2013), studying alternatives for the disposal of PET bottles in Mauritius. They score criteria by the percentage of interviewed stakeholders answering "yes" to questions on their opinion on impact presence. By thereafter transforming these percentages into a five- grade score by equally dividing the 0 – 100% range into five parts, in principle they introduce a way to aggregate scores for different categories. The authors however, point to the fact that all aggregated categories carry equal weight. Ekener-Petersen & Finnveden (2013), assessing the social impact of the production of a laptop computer, developed a method of scoring a product by a combination of the relative quantity of activities for a product in the different countries along the supply chain, and a rough scoring of the severity of the relevant aspects for the allocation of scores to the product. The activity contribution of countries was determined by the physical weight of the laptop, and by the global producer share of the used resources and manufacturing steps. Weighting was executed by defining hotspots using country performance data on social aspects. However, the authors conclude that data collection is a major issue.

LCAA

Life Cycle Attribute Assessment (LCAA) was developed by Norris (2006) and further elaborated by Andrews et al. (2009). The technique determines the share of an attribute, such as compliance to a certificate or "child labor-free", in the supply chain of a product. It is a technique in two steps: 1. Determination of yes or no presence of the attribute and 2: Weighting of the presence by an activity factor, for which Norris takes workhours, as does Hunkeler (2006), but also other factors can be taken (Andrews *et al.*, 2009). The results of LCAA are conclusions such as "the percentage of labor hours that is child labor-free". However, where Hunkeler only uses country level background data, LCAA is based on both foreground, e.g. by measuring compliance percentages to certificates, and background data, e.g. from Input-Output databases. LCAA uses the simplification of a dichotomous variable per step in a product's life cycle, inherently normalizes by measuring data as a percentage, and equally weights aspects and steps in the life cycle. Therefore, LCAA gains certainty, especially if combined with certification, but loses accuracy because of lack of gradation. A disadvantage is that the activity factor limits the applicability to aspects that are closely related to the activity factor and therefore also limits the aggregability over different categories.

SOCIAL HOTSPOT METHOD

Because data on specific companies are lacking, more generic country level data are often proposed as an indicator for the risk of an impact. For instance, the risk of child labor is greater in a country where child labor is common (a "hotspot"), than in a country where it is not common. The disadvantage is of course that these data are very generic and by no means specific for a company or product. Benoit-Norris et al. developed the social hotspot database, which contains both data on social hotspots and on labor intensity for a great number of combinations

of countries and sectors (Benoît Norris *et al.*, 2010, 2012). By the inclusion of data on labor intensity per country-specific industry sectors, the determination of worker-related positive or negative effects is facilitated. Although by inclusion of sector data, the granularity of the hotspot method is much improved, it still is far from company specifity. The content of the hotspot database is a strong indicator of the risk of an impact, and useful for risk assessment, but does not really provide data for concrete product- or company assessment before it really has reached company level granularity. That however, can only be accomplished by the supply chain actors themselves, combined with a system of independent verification, e.g. certification. Because auditing large numbers of social criteria is expensive, a "risk-based certification system" could be applied, in which frequency, audit time and verified criteria depend on the specific local risk, for which the Hotspot database would be valuable.

Assessing the checklist and scoring methods (CSMs) on our five criteria, we recognize three data sources: Generic country (or region) level data, stakeholders' and experts' obtained data, and company obtained data, which sources determine the quality of the assessment. Criterion 1: CSMs are quantitative, sometimes even interval quantitative, although usually via a nominal quantitative scoring method. The models based on country-level data are objective and certain if considered as the result for an average product, because contrary to the empirical models (see below) the country-level data used here really refer to the specific country. The data based on stakeholders' opinions are in the international arena and are fast changing opinions, either biased or very laborious to collect and maintain. Although most of the described CSMs (Franze and Ciroth, 2011; Ekener-Petersen and Finnveden, 2013; Manik *et al.*, 2013) gave very little granularity, with available foreground data and well-defined sets of criteria these methods can be used for much more detailed assessments, which principle was used by Dreyer et al. (2010) (see below). Criteria 2 and 3: The data required for CSMs become more difficult to collect, the more certain and specific one wishes them to be. Country-level data-based methods do not discriminate on specific company and product level. The stakeholder-based models are more discriminating, but very laborious and far less certain unless applied on a very limited choice of studied aspects and system boundaries, e.g. used for the aspect of occupational health and safety with the relevant workers interviewed. The hotspot database helps to improve data granularity but will almost by definition never reach company- or product granularity. Criterion 4: CSMs are suitable for aggregation within the supply chain for one studied impact category, e.g. employment, but not between categories unless a common relevant normalization denominator can be found applicable to all studied categories. Criterion 5: Ignoring the shortcomings on accuracy, certainty and specificity, for the aspect of corruption the country-level data-based models are in principle suitable because country-level data are available from the Transparency International Corruption Perceptions Index (further called "corruption index"). Stakeholder data-based models seem less suitable for corruption, because the stakeholder group is complex, existing of the society and international suppliers and customers, but also of unknown potential business partners who did not take the risk of being involved in corruption.

5.3.2. TYPE-II S-LCA ASSESSMENT METHODOLOGIES

Chhipi-Shrestha et al. (2015) recognize two types of quantitative Type-II models: 1. The "empirical model" and 2. the "ELCI-database" model. The empirical model constructs an empirical cause-

effect pathway based on correlations between established (usually country-level) indicators. The ELCI-database model tries to follow the standard environmental-LCA (E-LCA) procedure from life cycle inventory to characterization and sometimes even uses the LCI databases developed for E-LCA.

EMPIRICAL TYPE-II MODELS

Considering the empirical model, Norris (2006, p.99) described a pathway from per capita income to health in the mathematical formula that describes the "Preston curve" relation between income and life expectancy, using World Bank country-level data, but saw too many shortcomings. Feschet et al. (2013) however, argue that, using the Preston curve, and assuming that the specific country location on the curve fully applies to that country, the health increment related to the added value of an activity in a country can be calculated and used as an empirical pathway. They demonstrate that the method works, although only for low income countries, because the Preston curve is almost flat for high income countries. In a similar way, Hutchins & Sutherland (2008) demonstrate a pathway from per capita income to child mortality, enabling a comparison of the effect of added value in different countries to child mortality, and Bocoum et al. (2015) used the relation between the country level GINI (inequality) coefficient and child mortality to develop a pathway from added value to health.

Empirical models are based on a correlation between a single available, but objective, country indicator, such as the GDP or the GINI coefficient, and a S-LCA midpoint category. Most of the authors themselves point out that reality is far more complex, involving a multi-criteria relationship instead. In addition, it is very questionable if the used correlations are causal. For instance, considering the Preston curve, showing the relation between the GDP per capita and life expectancy, there are several other indicators showing a similar relation to life expectancy, for example, relevant for this study, corruption. Figure 5.1 shows the typical Preston type of relation between the corruption index and the GDP per capita for the year 2011. But figure 5.2, showing a much weaker correlation between the same indicators for the year 2016/17, strengthens our doubt about a causal relationship between corruption and GDP. On the other side, Wu et al. (2015) show, based on multi-criteria statistical techniques, that although there is no significant direct causal relation between income and health, there is a significant indirect pathway from income, via health expenditures to health. However, they did not study governance in general and in our intuitive opinion, it is very likely that governmental governance in general is the leading indicator, leading to Preston-curve like relations with life expectancy for several of its components. Jørgensen, Lai, et al., (2010) argue: "If there is no valid impact pathway, there is no way of telling whether and to what extent the indicators that we apply in S-LCA actually represent damage or benefits to the Area of Protection". Jørgensen, Finkbeiner, et al. (2010) studied the validity of the pathway from child labor to wellbeing and from employment to wellbeing and conclude that too many variables and unknowns affect the pathways to develop a valid pathway.

Although recognizing these difficulties, Weidema (2006) is quite optimistic about finding valid pathways and argues that it is better to develop valid pathways for the less complex categories and use other techniques for the more complex categories. Following the common E-LCA technique of using concrete biophysical pathways towards the endpoint category of health, expressed in disability-adjusted life years (DALYs), he proposes quality-adjusted life years

(QALYs) as a characterization factor for S-LCA. By extending existing disability and disease classification systems (as a percentage of lost life years) with factors for the various social stressors, all established impact pathways leading to human well-being may be effectively interval quantified.

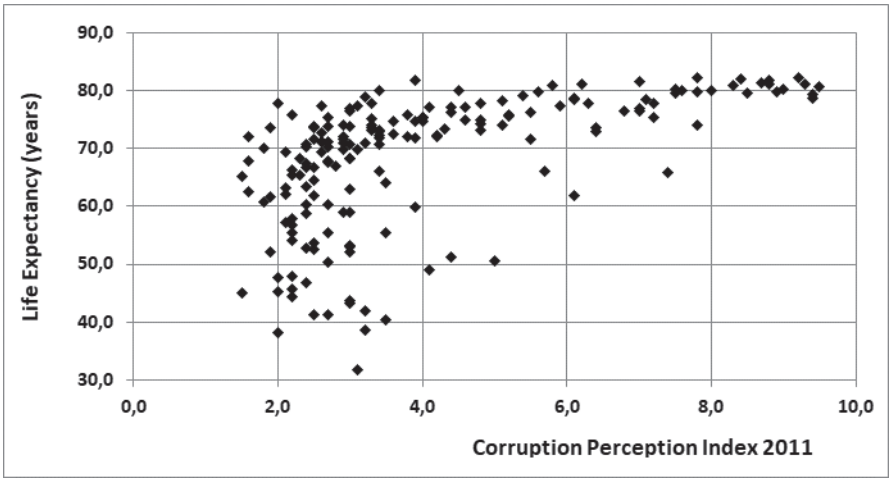


Figure 5.1: Life Expectancy Index versus Corruption Perception Index. Data from Transparency International, 2011 and World Bank (http://databank.worldbank.org/data/home.aspx), 2011.

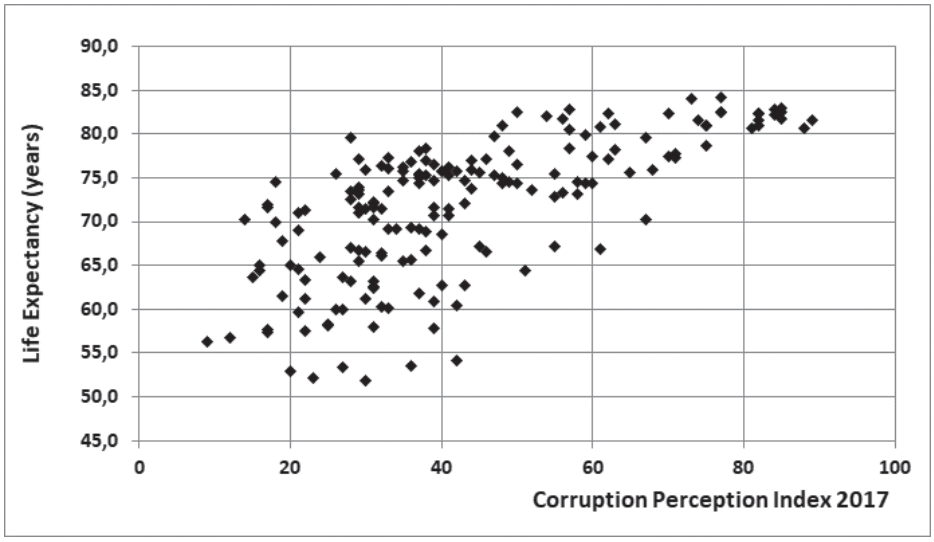


Figure 5.2: Life Expectancy Index versus Corruption Perception Index. Data from Transparency International, 2017 and World Bank, 2016

We will now assess the empirical Type-II models on our five criteria. Criterion 1: Empirical models are objective and do provide an interval quantitative indicator, because they are based on country statistics, but they lack certainty due to questionable causality and relevance of the correlation formula for the specific country. Criterion 2: Although depending on the aspect, data are often available and relatively easy to collect. Criterion 3: Country-level data are not at all distinctive for a specific company or product. Although the Feschet- and Boccoum models are based on the added value of a specific activity, the applied country data assume generically applicable income-health relations, which they are not. Criterion 4: The resulting data from empirical models are suitable for aggregation within the supply chain for the one aspect, e.g. weighted by workhours, but not between aspects. Criterion 5: Using the empirical relation between corruption and life expectancy (as health indicator) shown in figure 5.1 and figure 5.2 for corruption would be very insensitive, because at low index values it shows an almost vertical line and at high index values an almost horizontal line. In addition, for our purpose we would need a monetary midpoint- or endpoint indicator.

ELCI-DATABASE- TYPE-II MODELS

Quite a number of ELCI-database- Type-II models have been described. Because of the scope of this chapter, we will only discuss three of the most quantitative models. Baumann et al. (2013) follow standard E-LCA methodology transforming the inventory data of an airbag in automobiles, into DALYs. They calculate both the lost DALYs in the production stage of the airbag, and the saved DALYs during the use of them. Following the S-LCA guideline of assessing both the positive and the negative effects, they herewith express occupational health and safety aspects in the LCA endpoints of human health. Hunkeler (2006) however, assessing the social impact of two different detergents and considering employment a key factor to social wellbeing, proposes breaking up the life cycle inventory into labor hours, divided over different countries. Thereafter, the hours are comparatively weighted by the relative labor intensity factor in the different countries or regions, and thereafter characterized by the number of workhours a person needs, to locally access a combination of societal needs. This way an assessment is made of where a company's activity would have the most positive effect on people's ability to fulfill their needs. Labuschagne et al. (2006) developed a model of four social Areas of Protection, leading via a quite comprehensive list of midpoint categories to concrete characterization factors. They distinguish both quantitative and qualitative categories. Results for most categories are quantitative and made aggregable by normalizing the indicators against regional conditions and weighting by comparison with stakeholders' perceived- and target conditions. Their quantitative indicators are concrete (e.g. number of accidents and the number of employment opportunities) and based on data availability, but therefore not necessarily the most relevant to assess the aspect. In a test on three projects, the authors attempted to collect data for both company and country levels, but concluded that at the time of testing the model, insufficient data were available. Normalization is achieved by the determination of the fraction of the results on the specific studied unit relative to those in a larger reference system, such as the GDP, regional practices, or sector output. This type of normalization is especially effective to assess the relative importance of different aspects, because it gives a comparison of the relative contribution of different aspects in a greater system (e.g. 1% of a country's CO_2 emissions and 5% of the country's child labor), which is lost in aggregation. Normalization however, often comes with an undesired

weighting effect. For example, considering corruption, it will make a huge difference, if in the international arena the results are compared with the standards of a corrupt production location or with those of a conscientious consumer or supplier in a country with low corruption, in which both are stakeholders. In addition, aggregation makes little sense if used for different aspects, and not all aspects are substantively related to the reference system.

We will now assess these ELCI-database methods with our five criteria. Criterion 1: All three methods are interval quantitative. The Bauman method is quantitative and objective because data are fully based on LCIA databases and accident statistics. The data are quite certain, but only if applied under the very narrow system boundaries of only assessing direct health effects and a product that is intended to protect human health. In addition, the Hunkeler method is quantitative, objective and certain if accurate generic data are available. The Labuschagne model is not fully objective and certain because of the stakeholders' opinion-dependent normalization and weighting. Criterion 2: Without full knowledge of the specific supply chain the labor hour data for the Hunkeler method will not be easy to collect, and the data for the Labuschagne method depend on stakeholders' opinions, which are laborious to obtain in a relevant way and subject to fast changes. The data for the Bauman method are easier to collect because they are based on available statistics, but only if the method is applied under narrow system boundaries. Criterion 3: The Hunkeler method is not at all distinctive for a specific company or product; the Bauman case seems more distinctive, but again only under its very narrow system boundaries. Both systems could become product-distinctive with full knowledge of the specific supply chain. The Labuschagne model was meant to be distinctive for a specific company or product, but at the time not feasible because of lack of the specific data. Criterion 4: The Bauman method is suitable for aggregation within the supply chain and with other categories characterized by DALYs; the Hunkeler method is only suitable for aggregation of work-related aspects, but not between different aspects; the Labuschagne model was designed to aggregate different categories by its normalization. Criterion 5: None of these methods seems applicable to corruption; the Hunkeler method because corruption affects the whole society, not just the workers, the Bauman method because to date not enough data are available to determine corruption-related DALYs, and the Labuschagne model because of limited data availability.

Summarizing the above, quantitative impact-based S-LCA remains unsatisfactory for our goal of quantification of the aspect of corruption. In addition, the above described Tunisian incident demonstrates that if people become desperate, the consequences are totally unpredictable and that there are social tipping points, the exceeding of which may result in consequences never to be grasped in any statistical analysis. However, next to the Oiconomy system, there is one other development towards company- and prevention-based assessment: the "Dreyer – company assessment".

5.3.3. DREYER – COMPANY ASSESSMENT

Dreyer et al. (2006, p.96) and Dreyer et al. (2010) argue that contrary to the assessment of environmental aspects, where the impact can be directly derived from the physical flows and processes in the life cycle of a product, social impacts are generally determined by the conduct of the companies which are engaged in the life cycle and the required specific data can only be obtained from the companies themselves. To accomplish this, a method is required both for the assessment of the companies and for the allocation of the companies'

scores to the product. Inspired by common certification standards, the authors argue that company performance can better be assessed by their efforts to prevent impact than by the impact itself, and propose an assessment method of the risk that a company presents, based on a combination of the company's own governance quality and its contextual circumstances. For the company assessment, the authors developed an extensive checklist and scoring system of "managerial measures" on three necessary "efforts": planning, communication and active establishment and control. The three efforts are each scored one of three degrees of implementation for all managerial measures, added up and converted to a score between 0 and 1 by comparison with the maximum possible score and thereafter converted into one company risk factor by means of a complex system of division scores into risk classes and multiplication of the three effort scores, for which we refer to Dreyer et al. (2010). A strong aspect, in our opinion, is the division in efforts and multiplicative effect of these three efforts, because non-compliance with any of the three efforts, means that governance is not effective. However, comparing their managerial measures with the criteria in risk-based certification standards, the authors only use part of these, and choose to mix these general governance types of criteria with concrete subject-related managerial measures. In contrast, the standards leave the subject-related measures to the company, including the obligation to define these in one of the criteria, but apply, instead of three efforts, a system of more than 60 general governance criteria. It must be noted that Dreyer et al. describe a system for labor rights, where most subject-related requirements are well defined by ILO conventions. For other aspects, like safety and corruption, managerial measures may be far more company-specific, therefore less easily pre-definable and therefore better left to the company. Because of their choices, Dreyer et al., in our opinion, miss the opportunity to measure the degree of company performance by means of checking and ticking the complete set of criteria and therefore apply a complex system of scoring which turns a potentially interval quantitative score into a nominal quantitative score.

After the determination of a company score, according to Dreyer et al. (2010), a share factor is required to determine the relevance of the company score for the product and, if more than one product is produced, to distribute the company impact over the different products. In principle there are various ways to determine a share factor, but, without a standardized and verified system it will be very difficult to consistently execute such calculation over all supply chain actors. Where Hunkeler (2006, Norris (2006 and Andrews et al. (2009) usually use workhours as the activity factor to determine the contribution or distribution of an impact in the supply chain, Dreyer et al. (2006, p.90) and Hauschild et al. (2008, p.23) argue that there is no single objective choice of an activity factor, and mention physical weight, cost contribution, value contribution and workhours as options for the distribution of a company score to a product. The disadvantage of any choice is however, the same, which is the limited applicability to aspects and share- or activity factors that are relevant to each other (Hauschild *et al.*, 2008). For example, one cannot use workhour distribution for the allocation of scores of the bribery type of corruption, because bribery negatively affects the society and competitors more than the workers.

We assess this method on our five criteria: criterion 1. The system is nominal quantitative, objective and certain (if the data are verified). Criterion 2. Reliable data are in principle available for investigated (foreground) companies, but very difficult to obtain from background supply chain players without a certification system. Criterion 3. Part of the system is company-specific. However, the use of the generic contextual risk factor reduces its specificity. Criterion 4. If

applied over a larger system in the supply chain the data are in principle technically aggregable for all aspects which are technically best quantified by the quality of the company's governance system, and even for several aspects together, but because the result is expressed in a one risk factor value between 0 and 1, by aggregation it would totally lose its meaning. The data are not aggregable with interval quantitative data on other aspects. Criterion 5. Being based on governance principles the system is suitable for the aspect of corruption, which the authors also mention themselves (Dreyer et al. 2010b, p.258). Making this assessment however, it must be noted that the method was intended for risk assessment, not for measuring the actual status of an aspect. In order to give an overview and comparison of our assessment of the different S-LCA methods, a summary is presented in table 5.1. However, we stress that this is a simplification, not fully valuing all aspects of the assessed articles.

	Criterion	1. Indicator quality			2. Data		3. Distinc-tiveness	4. Aggregability		5. Suitability	Authors/ articles involved
	Sub-criterion / Method	Objectivity	Certainty	Type	Background (b) / Foreground (f)	Availability		Within aspect category	Between categories	For Corruption Assessment	
Type I Checklist and scoring methods	Researchers' based country level assessments on aspects/midpoints	strong for generic data	strong for generic data	nominal	b	strong for generic data	weak	strong	weak	strong for generic data	[1] [2]
	Survey based country level assessments on aspects/midpoints	based on stakeholders ' perceptions	low for stakeholder obtained data	nominal + interval	f + b	survey based; laborious	moderate	strong	weak	weak	[2] [3] [4]
	LCAA	strong for generic- or company data	strong for company data, low for generic data	interval	f + b	depending on case	depending on case and data requirements	strong	weak	Moderate	[5]
	SHDB	strong for generic data	strong for generic data	interval	b	global data set	weak	strong	weak	strong for generic data	[6]
Type II methods	Type II Empirical model	strong	weak	interval	b	strong	weak	strong	weak	weak	[7] [8] [9] {10][11] [12] [13]
	Type II ELCI - database model	conditional	conditional	interval	f + b	only under narrow system boundaries	conditional	strong	weak	weak	[14] [15] [16]
	Dreyer's Company Assessment	potentially strong	potentially strong	nominal	f	conditional	moderate	weak	weak	strong	[17] [18]

Legend: [1] = Franze & Ciroth (2011); [2] = Ekener-Petersen & Finnveden (2013); [3] = Manik et al. (2013); [4] = Foolmaun & Ramjeeawon (2013); [5] = Norris (2006) and Andrews et al. (2009); [6] = Benoît Norris et al. 2010; Benoît Norris et al. 2012; [7] = Norris (2006); [8] = Feschet et al. (2013); [9] = Hutchins & Sutherland (2008); 10 = Wu et al. (2015); 11 = Jørgensen, Lai, et al. (2010); 12 = Jørgensen, Finkbeiner, et al. (2010); [13 = Weidema (2006); [14] = Baumann et al. (2013); [15] = Hunkeler (2006); [16] = Labuschagne et al. (2006); [17] = Dreyer et al. (2006); [18] = Dreyer et al. (2010).

Table 5.1. Assessment summary of S-LCA methodology

5.4. RESULTS - PROPOSAL FOR QUANTIFICATION OF CORRUPTION IN THE OICONOMY SYSTEM

We follow the standard five-step Oiconomy procedure for the determination of the marginal preventative costs (see chapter 2), shortly described in the section on methods.

IMPACT CATEGORY AND CHARACTERIZATION FACTOR (STEP 1).

The impact category is product-related corruption, characterized by the costs required to prevent corruption.

TARGET, OR PERFORMANCE REFERENCE POINT (STEP 2).

Because corruption is defined as a crime by the 2004 UN Convention against Corruption and by most countries' legislation, the legal target or PRP must be zero corruption. However, no country is without corruption and figure 5.2 demonstrates that an index score of 43 in the Corruption Index presents a quite sharp index score above which corruption does not seem (on average) to have a severe impact on life expectancy (as indicator for health). However, if we, equally justifiably, replace life expectancy with the happy life years' index (figure 5.3), which multiplies life expectancy with an indicator on life satisfaction, this point becomes less sharp and shifts to higher values, demonstrating that we may not exclude a corruption-induced impact on wellbeing below an index score of 64, which is only accomplished in a very limited number of countries. We therefore propose a zero target for the company but a calculation and verification tolerance in countries with a score > 64, based on data from the year 2011.

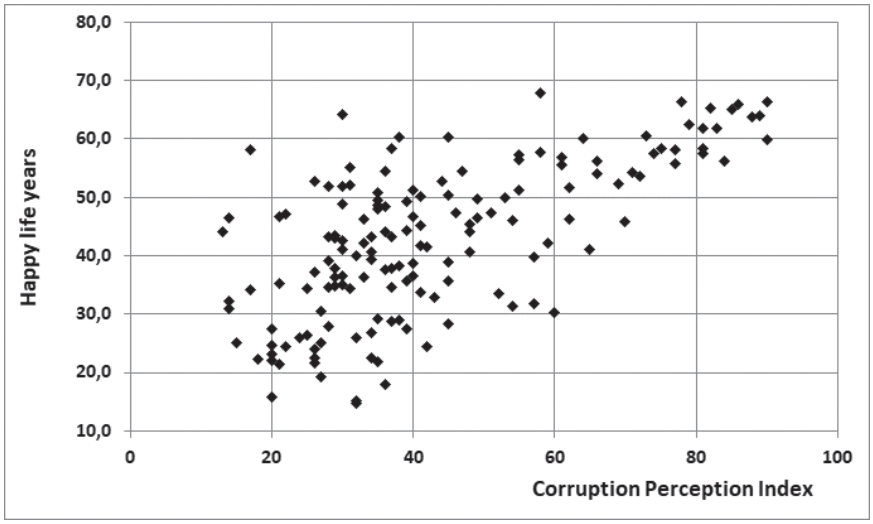


Figure 5.3: Happy Life Years versus Corruption Perception Index. Data from Transparency International, 2011 and Happy Planet Index (http://www.happyplanetindex.org), 2012

LITERATURE STUDY OF AVAILABLE PREVENTATIVE MEASURES (STEP 3).

Palmier (1985, p.271) identified three important causes for corruption: Low salaries, opportunities and low risk of detection and punishment, factors which according to Palmier should be addressed all three together. Quah (2011, p.17- 20) points to the cause that in many

countries, civil servants' salaries are by far insufficient to sustain their families and often lower than in the private sector. Governmental bureaucracy and regulations on the access to resources and activities provide opportunities, and if police and other members of the juridical system are also underpaid, policing against corruption will be inadequate. Important factors in prevention are transparency, political will and the example of the leadership. With corrupt leaders and policing officers, the chances of being detected and punished are perceived to be small. Although governmental bureaucracy and public officers commonly provide the demand side of corruption and business see themselves as victims (Hameed & Magpile 2014. p.5), business usually does provide the supply side of corruption (Myint 2000, p.42). In addition, corruption between private companies, with businesses on both the demand and supply side, is perceived to be just as common (Heinrich & Hardoon 2011, p.19)**.** Because corruption is an illicit activity, it is much easier to measure an organization's preventative measures against corruption than its actual involvement in corruption incidents. There is quite a body of literature on combatting corruption (e.g. World Bank, 1997, 2008; Tanzi, 1998; World Economic Forum, 2005; International Chamber of Commerce *et al.*, 2008; Transparency International, 2009; Asian Development Bank, 2010; United Nations Global Compact, 2010; OECD, 2011a; Walcher *et al.*, 2013; Runde *et al.*, 2014). All this literature demonstrates that good governance principles are key to combatting corruption. Well-developed governance systems and standards on various subjects are available, suitable for independent verification, (e.g. ISO, 2004; OSHAS, 2007). However, the costs of establishing and maintaining good governance are difficult to estimate, and are dependent on factors such as location and culture, availability of qualified people, size, sector, complexity, capital- and labor intensity, and experience with other operational standards.

By its business principles for countering bribery, Transparency International (2009) (TI) provides a comprehensive standard on organizational governance. The World Bank distinguishes three levels of combatting corruption for an organization. 1. Internal: Assessment of the internal risk, implementation of anti-corruption measures as part of an overall compliance program, and provision of guidance to the managers within the organization. 2. External: Share the internal policies with stakeholders. 3. Collective: Reach out externally via neutral facilitators to joint activities to fight corruption (World Bank, 2008). Based on these principles, United Nations Global Compact (2010) provides comprehensive guidance in anti-corruption practices approaching the different stakeholders with corruption challenges. But Sedex & Verité (2013, p.9) recommend to use the principles of common risk-based management systems, such as ISO 14001, to address ethical aspects.

Because of dependence on the location, the size of the organization and specific activity, the industry sector, the stakeholders and internal organization, on collective cooperation, and the highly multi-aspect character of combatting corruption, the direct costs of measures against corruption will be very different to determine. The magnitude and persistence of bribes often depend on the ease with which the organization could relocate its activities to a less corrupt environment, which is one of the major reasons why location-dependent activities such as mining and forestry, are corruption-sensitive sectors (Bai et al. 2015; Svensson 2003, p.211; World Bank 1997, p.18). However, this also means that the ultimate measure against corruption is to refuse to pay bribes and accept the potential necessity to refrain from the activity altogether, or relocate activities away from the corrupt environment.

DETERMINATION OF THE GLOBALLY MARGINAL COSTS PREVENTING CORRUPTION (STEPS 4 AND 5).

To obtain the marginal preventative costs, we need to sort the available preventative measures by their costs and deploy them starting from the cheapest until the target is reached. The last deployed measure presents the marginal preventative costs. From our literature study of currently proposed preventative measures against corruption we recognize four cost levels.

1. Good governance costs, consisting of the costs of internal, external and collective actions.
2. Verified good governance costs, comprising governance costs, compliance to defined criteria, and external audits, which together we will call "compliance costs".
3. Costs of refusing to pay bribes and taking the ultimate consequence of refraining from the activities.
4. Costs of actual relocation or developing alternatives for products or resources.

Considering the first level of costs, no direct data on costs of compliance to corruption criteria could be found in literature. However, the Ponemon Institute (2011, p.13) studied compliance costs of USA industry to USA legislation, such as on privacy, data protection and regulations. The report finds a range of yearly per capita compliance costs of $ 134 - $ 535, inversely related to the size of the companies. At an average yearly labor cost of about $ 60.000 per capita, that would represent about 0.22% – 0.89% of the wages. Considering the second cost level, more studies have been made on costs of compliance to taxation. Allers (1994) reports, based on a 1989 survey, an average compliance costs of 3% of the wage sum in the Netherlands (including costs of the tax office itself). The European Commission (2004, p.4) reports compliance costs of 0.02% of sales for large companies and of 2.6% for small and medium sized companies. These costs are very inaccurate, but this is irrelevant for our purpose, because they are lower than the costs of the marginal measure necessary to globally reduce corruption to the target level. The third level of costs for refusing to pay bribes and if necessary take the consequence of refraining from or relocating the activity, needs to be deployed. In fact, these consequences are already widely taken by all the companies that previously decided not to enter, or left corrupt markets. Fourth level costs will only be an option if these are lower than the profit margin. Therefore, we argue that, because in the long term companies will always end their activities when no profits are made, the margin made on a product represents the marginal preventative costs for the aspect of corruption. However, profit margins are volatile and may be unequally shared by companies in the supply chain, e.g. by the use of subcontractors, and multi-year product-specific averages are unusable in the case of fast moving products. Therefore, we propose to use the local five-year sector average net profit margin as a maximum default value but, without public availability of reliable local sector averages, to take the readily available S&P 500 data. An indication of the magnitude is presented in table 5.2 showing the five-year sector average net profit margins in the S&P 500, from April 2016. If a company can demonstrate reliable data on all its products' profit margins, product distinctiveness could be further improved by using the product's share in companies' profit as a share factor.

Sector	Net Profit Margins (%)
Basic materials	16.47
Consumer Goods	10.48
Financials	34.03
Health care	8.71
Industrial Goods	6.89
Services	10.48
Technology	9.43
Utilities	20.08

(www.reuters.com 2016, accessed april 22, 2016)
The 10 year average net profit margin in the S&P 500 from 2004 – 2014 was 8.4% (Butters 2014, p.22)
Table 5.2. 5-year sector average net profit margins in the S&P 500

The question left now is how to derive specific company- and product ESCU's from this maximum value. Literature demonstrates that, before taking the ultimate measure of exiting or relocating, good governance is the way to combat corruption. As described above, Dreyer et al. propose a system of scoring the degree of compliance to a set of managerial measures for the determination of a company risk factor. However, they do not use the complete set of general governance criteria commonly used in risk-based certification standards, and thereby, in our opinion and because they do not base their system on actual certification, miss the opportunity to interval quantify the effort scores. Weighting profitability against preventative measures is typically a top management responsibility. Therefore, it seems fair to set the actual preventative costs at a proportion of the measured quality of management preventative efforts. Therefore, for the Oiconomy system we propose a modification of the Dreyer system as follows:

1. 63 common standards' general governance criteria of equal weight are divided into four effort classes:
   I. Plan (11 criteria, covering policy, risk analysis, legal requirement analysis, goals, resources).One of the criteria is determination of all required subject-related managerial risks and managerial measures to which all other criteria apply. The Oiconomy standard lists a number of obligatory aspects to be addressed, based on the three levels of internal, external and collective actions (World Bank, 2008) and the guidance of United Nations Global Compact (2010).
   II. Do (32 criteria, covering knowledge and training, communication, documentation, document control; operational control)
   III. Check (16 criteria, covering emergency procedures, monitoring, evaluation, corrective measures, registration, internal audit)
   IV. Act (4 criteria: management review)
2. The company governance is assessed, yes or no, ticking all criteria and considering all relevant risks and managerial measures, and the scores are determined for the four effort classes. The company must realize that for a yes ticking, the criterion must be demonstrated as under control and effective.
3. The company risk (CR) is determined by the formula: CR = (Plan score/11) x (Do score/32) x (Check score/16) x (Act score/4).

4. The company ESCU score is calculated as: ESCU = (1-CR) x 5-year average net profit.
5. In the monetary Oiconomy system, ESCU allocation to a product occurs exactly copying companies' standard cost allocation methods.

The scoring system, filled with example scores, is presented in appendix 6. The first three effort classes are very similar to Dreyers' efforts. We added the fourth effort class for three reasons. 1. In common standards, the management review probably is the most important criterion, because it demonstrates continuous management commitment, evaluation and correction and requires top management to be included in audits. 2. The multiplication with an extra effort score adds to fast reduction of the company risk score with non-conformances, which is in accordance with certification practices of rejecting a certificate already with very few non-conformances. 3. The Plan-Do-Check-Act (PDCA) principles are the core of most well recognized governance standards. The formula gives equal weight to all 4 effort classes, because compliance of all four need is necessary for effective governance. However, within the classes the criteria carry more weight the lower the number of criteria in the effort class. This answers well to the above mentioned importance of the management review with only 4 criteria in the effort class.

An explanation is required about the Oiconomy ESCU allocation of indirect costs to companies' different products in action 5. The Oiconomy system is a bookkeeping system for hidden preventative costs, as much as possible copying companies' financial bookkeeping. To enable companies to exactly use their standard bookkeeping and cost allocation methods, and to avoid special "greenwashing" allocations for S-LCA purposes, for the Oiconomy system we propose to require an exact copy of companies' standard financial cost allocation methods. The mentioned advantages outweigh the disadvantage of a not fully harmonized allocation to products, because it only concerns indirect costs (e.g. overhead). All direct costs can be allocated directly to the product.

We do not need Dreyer's generic contextual company risk factor, because the Oiconomy system is based on actual and verified company data. Instead, as mentioned before in step 2, in order to avoid unnecessary burdens to the supply chain actors we propose to allocate zero ESCU's in countries with a corruption index score above 64, which also means that in a risk-based certification system the aspect needs no verification in such countries.

5.5. DISCUSSION AND CONCLUSIONS

Our literature review in the introduction, section 5.1, clearly demonstrates that corruption is one of the key social issues, heavily impacting all three PPP impact pillars of sustainability and therefore essential to be included in S-LCA. Our assessment demonstrates that impact-based S-LCA (IB-S-LCA) methods are not suitable for product-specific interval quantification of social aspects in general and for the aspect of corruption in particular. Various authors on S-LCA have already argued that social aspects are better assessed at company level than at product level and that company performance is better determined by its preventative governance than by impact. However, for accurate product- or company-specific quantification, standardization and onsite verification are absolute requirements. The Oiconomy system (chapter 2) answers to the limitations of IB-S-LCA by standardized building up the hidden preventative costs, expressed in "Eco Social Cost Units" (ESCU's) by the supply chain actors themselves, and verification

of the trustworthiness of the reported data in a certification system. The major challenge of the Oiconomy system is however, that it depends on voluntary industry submission to certification and willingness to transparent transfer of the data. In the Oiconomy system the measure of unsustainability, related to an aspect, is characterized by the marginal costs to prevent the issue. From the literature on combatting corruption we could derive that the marginal preventative measure against corruption is the refusal to pay bribes and take the ultimate consequence of refraining from the business, or in other words, from making a profit involving corruption. Therefore, for preventative cost-based LCA, we propose to use the 5-year sector average net profit margin, a readily available statistic, on the product as the maximum quantitative measure for the aspect of corruption. In addition, inspired by Dreyer et al., we developed a new scoring method for the quality of a company's governance based on ticking and scoring common criteria four PDCA effort classes in risk-based certification standards, such as ISO 14001.

We will now assess our proposed method and the envisioned Oiconomy system as described in chapter 2 on our five criteria for quantification, and discuss the limitations, consequences and potential objections to the system.

Criterion 1: Objectivity, quantitative character and certainty. The Oiconomy system in general is interval quantitative and objective, and designed to become ever more certain, because it challenges the supply chain actors to calculate their actual product-specific preventative costs on each aspect and share their (anonymized) data with the system. Representing preventative costs, ESCU's for all different aspects are expressed in one monetary unit and do not need further normalization or weighting. The system has an inherent share factor from company- to product performance, proportionally to the products' financial share for direct costs, and equal to companies' standard financial allocation methods for indirect costs. Unfortunately, the certainty of our proposed system is limited, because multiplication of the profit margin with our company risk factor will not exactly represent the specific companies' preventative costs. In addition, for the inherently illicit aspect of corruption, we propose an exception to the possibility for the company to present its own specific preventative costs. Therefore, for this specific aspect the ESCU scores cannot become more certain than the proposed calculation.

Criterion 2: Data availability and -complexity. By means of certification the Oiconomy system intends to make full product life cycles to foreground systems. This way, the required data for our proposed system, consisting of companies' profit margins and assessment of compliance to a set of criteria can in principle always be made available. However, it takes a qualified auditor for a proper assessment. The creation of the required certification system itself is more complex, but there are many examples of successful certified supply chains, e.g. HACCP (food safety principles) certified food chains. The system depends on consumer pressure and the willingness of business to submit itself to a third party certification system and a double bookkeeping, one for their standard costs and one for the ESCU's.

Criterion 3: Aggregability. In the Oiconomy system, including our proposed method for corruption, the ESCU's for the different aspect categories, all representing preventative costs, are inherently normalized to preventative costs and therefore fully aggregable, both within the supply chain and between aspect categories.

Criterion 4: Distinctiveness for specific companies and products. Using foreground data, the Oiconomy system does not need an activity variable such as workhours with the problems

described in our assessment of the ELCI-database methods. The ESCU score for every sustainability aspect is the product of the quantity and the price. In our proposed method for corruption, the quantity is calculated as the product of the sector-specific profit margin and a company-specific governance level-derived risk factor, totaling to a satisfactory company definition of the resulting quantification of corruption.

Before making our assessment on criterion five, the suitability of the Oiconomy system and the method proposed here for the aspect of corruption, some more limitations, consequences of, and potential objections against our methods need to be discussed. In principle, in the Oiconomy system aspects are characterized by the costs of a concrete preventative measure, just as the Oiconomy system requires. The marginal measure against production is not paying the bribe, but the proposed indicator is the calculated proportion of the potentially corruption-infected profit margin. However, in our opinion this is sufficiently close to concrete preventative costs.

Assessing social aspects involves ethical and economic considerations. In literature on S-LCA we encountered assessments based on the supposed higher positive effect of employment on human wellbeing in low income countries than in high income countries. We are strongly opposed to such assessments, because, although employment under conditions of corruption, in conflict areas, and even under poor working conditions may provide some direct income to the community, it justifies and often finances those conditions, keeps the perpetrators in power and increases the risk on suboptimal performance and therefore on future damage. In addition, in our opinion, S-LCA should avoid comparing beneficial impacts to one stakeholder group with the negatives to another group. Regarding aspects like corruption or conflict conditions, companies find themselves choosing between being involved in the aspect, therewith enabling, playing down or even justifying corruption and preventing real long-term development, and at least providing some direct income to the poor. Companies active in corrupt or conflict areas may use the former as an excuse and object to our proposal and often even compensate by making other beneficial contributions to the community. Another excuse may be that required resources can hardly be obtained from non-corrupt countries. But profitability remains the main driver of being involved, continuing corruption-infected business as usual is not sustainable, and there is always the choice of exiting. In addition, the Oiconomy System, just like any LCA, is a measuring method; not a compliance-requiring standard.

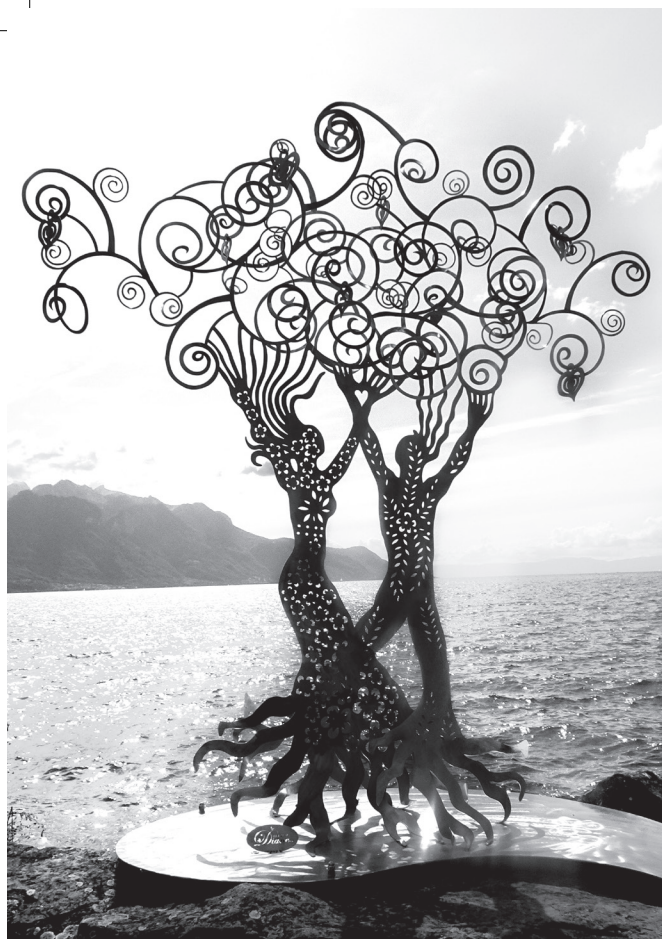
A second point of consideration is that profits can be manipulated by the use of non-market prices and interests between interrelated businesses. Therefore, our proposals should always be used including an assessment of such manipulations, including all types of money transfers between interrelated businesses. Because certification processes are usually executed on juridical units, we stress that for a proper assessment of corruption all juridical units with related major ownerships, to or from which money transfers are made, should be included in the assessment. This can be done by the external auditor by requiring audits at the related juridical unit when there are any doubts about money transfers.

Another objection could be that, following the reasoning of this paper, the profit margin presents the costs of the marginal preventative measure for all sustainability aspects, and even for the aggregated total. Therefore, it would imply double counting. But profit is not an absolute value; it varies with the product's prices. The costs of prevention should really be spent on prevention, and the product's prices and margins adapted to the new costs.

A last objection could be that companies may try to hide their corruption-related activities even from the auditors. However, it is not only these direct activities that are measured, but the complete anti-corruption organization, communication, consistency, transparency and continuous improvement in the company (see appendix 6). If there is one weakness in current certification, it is the fact that audits are usually announced. Therefore, we advise that applicants to the system should accept the possibility of unannounced audits.

Concluding in Criterion 5: Suitability for quantifying corruption. In our opinion our proposed method of applying a measured governance quality-dependent factor (calculated by the model in appendix 6) to a maximum default value, equal to the marginal preventative costs, is not perfect, but probably the best possible for the Oiconomy system to assess social aspects that are best prevented by good governance, such as corruption, health and safety aspects, and labor conditions. Our proposed method stands the test for all but one of our five criteria: certainty. In a situation of poor governance against corruption in a high risk context, or if all managerial measures prove in vain, the indicator is certain because in that case the company should exit and lose its profit margin, if only because other companies that consciously did not enter the market, refrained from that profit. However, our proposed calculation of a governance quality-dependent fraction of that profit margin undoubtedly does not represent an exact relation between preventative costs and governance quality. However, it rewards companies' efforts towards good governance, but also, by the multiplication effect of the four effort class scores, answers to common certification practice of refusing a certificate with even a few non-conformances.

Some words need to be said on the applicability and validity of our proposed method for the quantification of corruption in LCA. At the time of the publication that this chapter is based on, the Oiconomy system is in development. Sharing data with the operational EcoCost system, it is in principle suitable to become operational on environmental aspects. However, distinguishing itself by its foreground character, the Oiconomy system especially opens opportunities to include social and economic aspects to LCA. In earlier chapters we have already proposed methods for the social aspects of fair wages, fair trade, child labor and inequality (chapters 3 and 4). This chapter is an important further step, not only because it covers the aspect of corruption, but also because we introduced a method more generally applicable to aspects that are better measured by a company's preventative governance quality than by impact or concrete performance data. In addition, our proposed method for the aspect of corruption is already applicable to the foreground part of any S-LCA. Based on the method, supply chain managers could have suppliers assessed, scored on corruption, and optimize their procurement based on corruption. However, the system is not applicable for background data based LCA-systems, because it really needs onsite assessment to determine the quality of governance.



The most urgent positive action of supply chain actors is to avoid damage

The next challenge for mankind is to include moral sentiments in its economic considerations

CHAPTER 6

THE ASSESSMENT OF POSITIVE IMPACTS IN LCA IN GENERAL AND IN PREVENTATIVE COST-BASED LCA IN PARTICULAR [7]

7 This chapter is based on: Croes, P. R. and Vermeulen, W. J. V. (2020) "The Assessment of Positive Impacts in LCA in general and in Preventative Cost-based LCA in particular . A contribution to the Oiconomy Project,"*, forthcoming in Int. J. Life Cycle Assess, 2020.* The chapter was slightly edited to fit in the book structure.

6.1. PURPOSE

The purpose of the submitted article, which this chapter is based on: 1. to open a discussion on the implications and challenges of inclusion of positive impacts in Life Cycle Assessment of products, and 2. to make a preliminary proposal for inclusion of positive impacts in the Oiconomy system. Main reason for opening a discussion is the recent development to include positive impacts, especially in S-LCA, with, in our opinion, risks and consequences that need discussion.

6.2. INTRODUCTION

The UNEP Guidelines for S-LCA (Benoît Norris, Mazijn and et al., 2009, p.100), define S-LCA as: "a social impact assessment technique that aims to assess the social and socio-economic aspects of products and their positive and negative impacts along their life cycle". Because at the time of writing this paper, the UNEP Guidelines are in the process of updating, we will further refer to these as "original UNEP Guidelines". Di Cesare et al. (2018) and Petti et al. (2014) provide reviews of publications including positive impacts, all of which are very recent, and Ekener-Petersen et al. (2016) provide an extensive discussion on the implications.

The original UNEP Guidelines also state: "An externality occurs when a decision within the value chain imposes costs or benefits on others which are not reflected in the prices charged for the goods and services being provided by the value chain", and "until now, no commonly accepted methodology for assessing internalities and externalities of the production of goods and services for "people" and "profit/prosperity" was available. That is precisely what the tool presented in these guidelines wants to deliver" (Benoît Norris, Mazijn and et al., 2009, p.16). From this text, it is not clear if or how the original UNEP Guidelines intended to include both internalities and externalities for positive impacts. It is not even clear what is meant with the term "internalities", the economic concept of unwanted impacts of traded products, or the concept of product features, already monetized by economic transactions. In this paper we will use the latter interpretation until we make a proposal for a better specified definition for LCA purposes in section 6.4.1.2. To date, the major body of both E-LCA's and S-LCA's assesses negative externalities. Naturally, industry prefers positives that can be used as marketing tools and may find support in the argument by Di Cesare et al., 2018, p.417 that maximizing positive results might be more important than minimizing the damage originating from negative impacts. However, if positives are included in either S-LCA or E-LCA, there is a great risk that such arguments will be used to justify business as usual, greenwashing and reliance on technological solutions and even that the credibility of the assessment is jeopardized. At the Shine "Net Positive" conference in Boston (Shine, 2017), attended by the authors of this article, companies in the tourist business presented their positive labor conditions without mentioning that most of their customers need air transport. However, the 2019 user guide of the Net Positive Project states: "Focusing on areas of biggest impact and opportunity, a company inevitably must consider shifts to its core business or operating model" (Net Positive Project, 2019, p.14).

In literature, articles appear, descriptively correct, but the ethics of which must really be questioned (see section 4.1.1). Also Ekener-Petersen et al. (2016), in their discussion of the implications of assessing positives in S-LCA, do not systematically discuss the ethics and consequences of inclusion of positives in S-LCA's, assess these against the underlying objectives of S-LCA, or propose criteria for inclusion of positives. Although the original UNEP Guidelines

state that only those positive impacts beyond compliance to legal or other standards may be included, this limitation and the original UNEP Guidelines' distinction between internalities and externalities do not seem to be systematic criteria. Actually, literature describes few systematic criteria for which positive impacts to include and which not.

6.3. METHODS

Recently, three reviews were published on the assessment of positive impacts in LCA: (Petti *et al.*, 2014; Di Cesare *et al.*, 2018; Ekener-Petersen *et al.*, 2018). We checked for later publications by following their citings in Google Scholar and by searching for "positive impact" or "benefits" and "LCA" or "Life Cycle Assessment" in Google Scholar and Scopus and included one more relevant article for our assessment: Benoit Norris et al. (2020), on the net positive initiative. In our results section, using the existing literature, guided by the reviews, but also by our own experience, we assessed and listed challenges, inconsistancies and potential problems of inclusion positive impacts for the various mentioned categories and subcategories of aspects. For our assessment, we used both theoretical and practical considerations. In addition, we assessed if existing goals, standards and interpretations are clear, lead to useful information, and if they can be misused, e.g. for greenwashing (Ramus, 2005; Parguel *et al.*, 2011; Stecker, 2016). Because a consistent standard or guideline is lacking and that gap is exactly what this paper wants to address, we used our own logic. Based on this assessment, a set of criteria is proposed for the assessment of positive impacts in LCA in general and S-LCA in particular in the results section.

6.4. RESULTS AND DISCUSSION

6.4.1. CHALLENGES OF INCLUSION OF POSITIVE IMPACTS IN LCA

In their article "Does the Production of an Airbag injure more people than the airbag saves in traffic?", Baumann et al. (2013), already in their title, compare the saved injuries to users of airbags with the inflicted injuries in the supply chain. Although we recognize that both these individual positive and negative impacts are descriptively relevant, there are serious ethical objections against comparison of negative impacts to one stakeholder group with the benefits for another group, especially in S-LCA. By definition, all marketed products, and therefore all involved activities in the supply chain have some positive effect, expressed by their market value. The goal of both E-LCA and S-LCA is to support decisions into the direction of sustainable development, but the underlying intention is to help decision makers reduce negative impacts to zero, especially to other stakeholders than the supply chain actors themselves. There cannot be any justification for saving one's life at the expense of another. In addition, in a broader perspective, such comparison does not make sense. Without food production, the total global population would die. Also other industry sectors, like pharmacy, plastics, energy, construction, communication and transport could easily argue that their products have positive and even lifesaving impacts on human wellbeing. Di Cesare et al., 2018, p.417 state that "maximizing positive results might be more important than minimizing the damage originating from negative impacts". It is indeed undeniable that modern agriculture and industry improved human wellbeing and reduced famine and epidemics. But these also caused environmental and social issues, severe enough to exceed tipping points in earth- or human resilience which could destroy

much of the accomplished. Mankind has arrived at the challenge of achieving the same for all, without compromising the ability of any stakeholder groups to meet their needs. One basic difference between positives and negatives is that positives are usually far better known than negatives. Because the practical goal of both E-LCA and S-LCA is to fill this information gap for decision makers (see also section 4.1.2), and not to become a marketing tool for already known positives, in our opinion, the scientific community should be very cautious with inclusion of positives in their assessments, and set criteria.

Literature is not very specific in defining criteria for positive impacts, using terms like:

- "Negatives are "burdening" and positives a "unburdening" (Zore *et al.*, 2017).
- "Providing a win-win situation" (Petti *et al.*, 2014; UNDP, 2015; Di Cesare *et al.*, 2018).
- "Contributing to countries' improvement in Sustainability Development Goals (SDG's)" (Benoît Norris *et al.*, 2009; Di Cesare *et al.*, 2018).
- "Social improvements related to a previous situation, but beyond compliance (Petti *et al.*, 2014)".

Such criteria are usually just loose arguments, potentially valuable, but also vague, sometimes confusing, incomplete or insufficient. For instance, the mentioned criteria considering "(un) burdening" and "social improvements related to a previous situation" lack a statement on a consistent reference point; a "win-win situation", by definition, occurs by any economic transaction and "contributing to countries' improvement in SDG's" may refer to both externalities and internalities. Petti et al. (2014, p.40) already showed that there is no shared definition of positive social impacts as part of the S-LCA methodology, which also applies to E-LCA. In our opinion, without a more systematic set of criteria, inclusion of positives in either E-LCA's or S-LCA's could make the these vulnerable to creative marketing and greenwashing. Therefore, acknowledging the need to include positives in LCA in general, we made a more systematic assessment on the implications and challenges of inclusion of positives in LCA, before proposing a position, at least for the Oiconomy system, but probably as valuable for LCA in general.

6.4.1.1. THE DESCRIPTIVE AND PRESCRIPTIVE NATURE OF LCA

In origin, LCA is a descriptive scientific analysis of the impact in the life cycle of a product, but as an applied science, its practical goal is prescriptive by providing information for decisions in the direction of sustainable development. The Oiconomy system is emphatically prescriptive in its goal, but as much as possible based on analytical and descriptive research in its methodology and data.

In principle, descriptive science has no morality. But can LCA be purely descriptive? Already the choice of aspects is influenced by moral considerations and the choice of system boundaries depends on the practitioner's objective. The ISO 14040 standard on LCA reflects the different scientific characters of LCA. Its title: "Environmental management — Life cycle assessment — Principles and framework", already explains the intended use of LCA in environmental management, which tends to be prescriptive. The determination of the functional unit and system

boundaries may be considered a means of defining the study and belonging to the analytical phase, but in its choices can be highly subjective and prescriptive. The next phase, the Life Cycle Inventory analysis, is purely descriptive, but the following Life Cycle Impact Assessment can be both descriptive and prescriptive, depending on the assessment methods. The interpretation phase and the paramount important requirement of transparency as stated in ISO 14040, are purely prescriptive (ISO, 2006b). In E-LCA, aggregation of positive and negative impacts makes sense provided that the impacts are not spatially specific, but in S-LCA, the descriptive and practical characters of the assessment become wringing and grinding at the inclusion of positive impacts. For instance, a comparison of a positive impact on one stakeholder group with a negative impact on another stakeholder group, as described above, makes descriptive sense, but is prescriptive utterly immoral. Actually, especially in S-LCA, comparing similar social impacts with different size or direction by definition implies a redistributive effect between groups of people and thus leads to intrinsic ethical issues. The following sections are based on the prescriptive and therefore ethical goal of sustainable development.

6.4.1.2. EXTERNALITIES – INTERNALITIES

In the definition of the original UNEP Guidelines, "externalities", or in the words of Pigou: "divergences between private and social costs" (Pigou, 1920. p.159), "occur when a decision within the value chain imposes costs or benefits on others which are not reflected in the prices charged for the goods and services being provided by the value chain" (Benoît Norris, Mazijn and et al., 2009, p.16).

Negative externalities are abundant, the major subject of current LCA's, and often hidden. One could even argue that one of the major shortcomings of the current economy is that it favors those actors that are best in transferring hidden costs to external parties. "Internalities", as first defined by Herrnstein *et al.*, 1993 p.150, "occur when a person underweights or ignores a consequence of his or her own behavior for him- or herself". In economic terms, internalities are included in the product's price because the consumer is assumed to have rationally considered all private impacts and costs (Gruber, 2014, p.52). A classic example of a negative internality in these economic terms is the health impact of smoking. This, in our opinion, poses a definition problem for LCA purposes. The buyer of the cigarette does not rationally buy the cancer, but unwillingly gets it as a side effect of the smoke. Gruber, 2014, p.54 even argues that in practice, "tomorrow's self bears the costs of today's self", almost as an externality.

Confusing and impractical for LCA purposes is also that in economic terms an internalized externality is not an "internality". E.g. Allcott and Sunstein, 2015, p.6 use the two concepts additional to each other. Various authors on negative internalities show the similarities in effect between using measures such as taxation against both externalities and negative internalities, (e.g. Allcott et al. 2011, 2012; Gruber, 2014, 2015; Marron, 2015).

Key in the discussion is the question if the buyer is well informed and about the future costs and effects of his purchase. Without rational consideration of negative consequences of a transaction, defining the resulting negatives as internalities is at least confusing. The goal of LCA is to provide information for a better consideration of sustainability in decisions. Therefore, for LCA purposes, we would rather consider the cancer by smoking as an externality instead of as an internality. The same applies to the noise of tools and machines and even to the health impact of mycotoxins or pesticides in food. We mention the last example because there is a

difference between buying your own misfortune knowingly or not, because in the latter case, the economic assumption of rational consideration of the issue is false and for LCA studies, reliably distinguishing between known and unknown features of a product is not feasible. The safety of a products' utility is the producers' responsibility and should be included in the price, which makes unsafety an externality. In addition, private costs regularly become social costs, e.g. by community health care, loss of labor or via insurances, which effect causes a divergence between private and social costs.

Positive externalities have a totally different nature. Only beneficial impacts that are not included in the price agreed in the seller-buyer transaction, can be characterized as positive externalities. Literally taken, any commercial activity leading to a seller-buyer transaction is an internality because the consumer pays for its benefit, with the consequence that inclusion of positives in LCA would result in a kind of double counting, which should be avoided in LCA, according to ISO 14044 (ISO, 2006b, p.19). If a product that the consumer consciously decided for is included in an LCA, it is one time assessed in the standard economy in the transaction decision and one time in the LCA. On the contrary, externalities, by their nature, lack the assessment in the standard economy, but are hidden imposed, which the LCA intends to reveal. Positives are also far less hidden than negatives, because companies don't tend to emphasize the latter in their marketing. And when a LCA uncovers a hidden benefit, thereafter advertising it theoretically makes it an internality, serving the sales of the product and informing the buyer. Disadvantage of this point of view is of course, that it counteracts advertising that could accelerate the development of positives that are real externalities. Transparency on positive and negative internalities should be equal, but this is against the natural interest of businesses. Characterizing aspects as internalities or externalities is not always easy. For instance, the aspect of community education is an externality for a mining company, but an internality for a paid private school. Paying a fair wage to a cocoa farmer in Ivory Coast is not an externality, but helping him to sustainably raise his sustainability, quality and yield, described by Porter et al., 2011, p.5 as a "shared value", is.

To avoid the confusion an about the term "internalities", we propose to, for LCA purposes, to distinguish two types of positive internalities, Type 1: Benefits considered by the transaction partners and included in the price, and type 2: Benefits, not considered, neglected by the transaction partners or underestimated and not affecting the price. Type 1 internalities, including all resources and costs leading to the product and its price, in our opinion, do not belong in LCA's. In principle, type 2 may be included, but examples are difficult to find, because by nature, these are often unknown, but one example would be the social contacts belonging to a job. Table 6.1 presents our resulting definitions of positive and negative internalities and externalities for LCA purposes, as an alternative for the table shown in the original UNEP Guidelines (Benoît Norris, Mazijn and et al., 2009, p.17) and applicable both on environmental and social aspects. However, it remains unclear what the original guidelines have meant with the term "internalities" in their wish to deliver a commonly accepted methodology for the assessment of internalities and externalities (Benoît Norris, Mazijn and et al., 2009, p.16).

Table 6.1. Positive and negative internalities and externalities for LCA purposes

		Internality	Externality
Positive	Type 1	Benefits considered by the transaction partners	Benefits to others than the transaction partners
	Type 2	Benefits, not considered by the transaction partners and not affecting the price (unknown, underestimated)	
Negative	Unknown, underestimated or ignored harm to the transaction partners		Harm to others than the transaction partners

Not to be considered in LCA
To be considered in LCA

6.4.1.3. MEASUREMENT BY STATUS OR BY CHANGE

A recent development is the "Net Positive Project", with participants like Dow, CAP Gemini, Levi-Strauss & Co and Kingfisher (Net Positive Project, 2019). Advocates argue that only abatement of negative contributions is not enough and that companies should strive to have a larger positive than negative contribution. (Forum for the Future *et al.*, 2019; Hollender, 2019). An article in the Guardian defines "net positive" as "Businesses have impacts on the environment and society. Some are negative, some positive. For a company to be net positive, the latter need to outweigh the former" (The Guardian, 2013). Benoit-Norris argues: "*Net positive = Handprint - Footprint*" and could be measured by the inclusion of positive contributions in S-LCA (Benoit Norris *et al.*, 2020, p.36). "Footprint" is defined as the negative impact of an actor by sustaining himself and "handprint" as the positive changes outside of the actors' footprint (Norris, 2019) and therefore as externalities. Norris argues that there are two ways to create handprints: "Be a cause of reduction of some other actors' footprint", and "create positive impacts which are measurable in footprint units". The Net Positive Project challenges companies to "put back more than you take out" (Norris, 2019), but combining measuring by status (LCA, footprint) and by change (handprint), as in the formula of a *Handprint – Footprint*, presents caution, especially in S-LCA. Norris describes criteria for combining handprints and footprints:

- The use of the same baseline for footprint and handprint.
- The shared responsibility for footprints and shared credit for handprints if several actors are involved.
- The need of setting a time scale for future impacts (Norris, 2019).

An equal baseline is needed for a comparable scale for the distance to the goal, but "business as usual", currently the most used baseline in business reports, provides no comparable baseline. In addition, a shared responsibility and credit for negatives and positives is needed to avoid double counting at the probably best opportunity to become net-positive, namely to be the cause of a positive change at suppliers beyond the company purchased products of services. However, for

correct quantification, it will be very hard to divide the shared credit of such positive impact on a supplier between that suppliers' different customers and the improving actor himself. Here we see a clear advantage of the Oiconomy system where all positives and negatives are transferred to the next actor, so automatically, responsibility for negatives and credit for positives are shared by the supply chain without the risk of double counting. A LCA or footprint measures the current status. For quantifying a change, a time frame is required for how long the actor may claim credit for a positive change. However, because future developments and impacts are uncertain, current assessments about that time frame will be inherently uncertain. In addition, without a solid reference point, such credit does not hold if an even better alternative enters the market.

In our opinion, the only possibility for a sensible assessment of change is by regularly repeated assessment of the status. For measurement by change without such repetition, criteria are required for the temporal scope and for the maintenance of the improvement (see section 6.4.1.7).

Another important issue is the word "net" if not all sustainability aspects are included. In principle, the word could be used with validity for separate aspects, which indeed is the current focus in sustainability reports by the involved companies. The net positive initiative as such, striving to become more restorative than damaging, is in our opinion a valuable step. It creates ideas and development and increases the chance that stakeholders hold the companies to their promises. However, current company reports on positives still are narrative and focused on achieved and planned improvements, lacking a comprehensive, reliable and objective assessment of their status (The International EDP System, 2019). The last issue we want to mention is that a measure by change without a comparable reference point loses the ability to compare companies and products. In fact, measured by change, a bad performer has a better chance to become net positive than a good performer, and, in our opinion, a change that is not enough to accomplish the timely end-result should not be considered a positive. Therefore, for transparency reasons, a handprint should not be presented without the footprint or in other words the positives never without the negatives and a change never without the status. Concluding, we argue that the best way of measuring by change in LCA is by repeated assessments of the status.

6.4.1.4. ABSENCE OF A NEGATIVE IMPACT

Scholars agree that absence of a negative should never be considered a positive in S-LCA, (e.g. Petti et al. 2014, p.39). Although we did not find a reference, we believe that this also applies to E-LCA. If the negatives are properly assessed, there is no need for putting another value on their absence. In addition, positives are not always easy to distinguish from absence of negatives. For instance, how to distinguish between the suggested (Di Cesare et al., 2018, p.407) positive aspect of a healthy building environment from absence of issues like weak structures, noise, bad ventilation or lack of light, proper maintenance and fire prevention. This requirement for LCA's distinguishes it from economic concepts of positives. For instance Porter & Kramer, in their concept of "shared value", describe many examples of shared value which actually are better characterized as absence of negatives. See (Porter *et al.*, 2011).

Current LCA's on negatives are usually based on background data, using default data from databases. Default values always include the risk that a specific case does not comply with generic rules. Because of the risks of greenwashing and the need that positives must be considerably better than average, we argue that in absence of demonstrable foreground data, positives must should not be included in LCA's.

6.4.1.5. TEMPORAL SCOPE

For both positives and negatives, certainty decreases with the temporal scope. Long term negative impacts of short-term positives are often overlooked or underestimated. One incident or one thought may change and regularly has changed the course of history. Many new technologies exist from positive opportunities, but later develop serious negative consequences. Fossil fuels were at the source of the industrial revolution, but much later also of climate change. Intensive agriculture was at the source of a huge expansion of food availability, but now seriously endangers biodiversity. The internet provided world changing communication opportunities, but later also internet criminality, terror and fake news. Business as usual, regularly labeled as positive as expressed by the sentence "never change a winning team", proves unsustainable. Therefore, before characterizing something as positive, as much as possible, also its long term potential negative impacts should be assessed. However, in practice, this will prove very difficult, because that requires a view into the future. Who in the 19th century could have expected climate change and who in the eighties of the 20th century internet criminality? S-LCA should be based on performance reference points (PRP's) that preferably are based on legislation, international standards or the sustainable development goals. These usually are based on scientific knowledge on the long-term impacts of for instance child labor or poor working conditions. But desperate victimized workers and communities themselves often have short term needs, that make them accept issues like child labor, (e.g. Dewulf *et al.*, 2013). In addition, the victims don't always know the long-term effects of the aspects that are burdening on them or have cultural reasons to disagree with the impact. S-LCA scholars may find themselves in a dilemma between adhering to international and western standards, and lowering standards for low income countries. In the first case, the assessments may be accused of patronizing and unfit for low income countries, and in the second case of inconsistency. Concluding, because of the huge long-term uncertainty of the negative consequences of seemingly positive developments, LCA practitioners should be extremely cautious with including positives that are based on new developments.

6.4.1.6. DIFFERENT AFFECTED STAKEHOLDER GROUPS

In our introduction, section 6.1), we already mentioned the ethical issue of comparing positive impacts for one stakeholder group with negatives for another. Questions arise like: "do the interests of the many outweigh those of the few"; "do the interests of the rich outweigh those of the poor, or the interests of shareholders those of the workers"; "do social positives outweigh environmental negatives, or the reverse"; and "may improvements in the working conditions in a coal mine with great effect on climate change, be considered as positives"?

The concept of sustainability is defined by the Brundtland statement: "sustainable development meets the needs of the present without compromising the ability of future generations to meet their own needs" (United Nations World Commission on Environment and Development, 1987). In our opinion, especially for LCA purposes, this statement should be complemented with: "sustainable activities meet the needs of one stakeholder group without compromising the ability of other stakeholder groups, including future generations, to meet their needs". In the Oiconomy system, international standards are used as PRP's and if those are not available, we propose to use the performance on an aspect set by the methods of the 20% best performers (mostly countries). Ekener-Petersen et al. (2016) consider the ethical aspect of different effects as a scientific challenge that may be solved e.g. by weighting methods, which would imply a weighting between the interests of current and future generations. However, we emphasize extreme caution in comparing

or aggregating positives and negatives with any chance that different stakeholder groups are affected, although we recognize that this is a prescriptive point of view (see section 6.4.1.1).

Another question raised by the Brundtland statement in combination with the here discussed subject of positives is if we should interpret "without compromising the ability of other stakeholder groups" for each single aspect separately, or may we compensate one with another aspect? This is the same question as "should we go for strong or for weak sustainability?" For the Oiconomy system, we choose for strong sustainability for all categories of aspects, which means that the intention is that in the Oiconomy system, ESCU's are transferred for all aspect categories.

6.4.1.7. MAINTENANCE OR CAPACITY RAISING?

Various authors argue that if the "capacity", such as a raised ability of a subsistence farmer to maintain a decent income, is not raised by a product or activity, its positive character is questionable, (e.g. Benoît Norris et al., 2009; Garrabé *et al.*, 2014; Ekener-Petersen *et al.*, 2016; Petti, Serreli and Di Cesare, 2018). In our opinion, this means that only capacity raising activities can be considered positives and not only maintaining of an aspect at the same level. Two related questions about maintenance should be considered. First: Should a positive be long term sustainable? And second: Can maintaining a beneficial aspect at the same level be a positive in LCA? The answer on the former question is rather easy. An improvement does not make sense if it is not maintained. For instance, planted trees as compensation for flying should be considered positive without long term protection of the planted forest, because of the long term risk that the investment will be in vain. But also the latter question should in our opinion be answered "no". A good example is education. Without a certain level of education, the capacity or education capital of a country decreases. Without maintenance it will be lost by forgetting, pensioning and death of people, and should not be considered a positive. Others however, may use the same argument that without maintenance things will deteriorate, and therefore consider maintenance as a positive. We oppose the latter reasoning for two reasons: 1. Lack of maintenance" should be assessed a negative, just like it would be considering occupational health and safety aspects of equipment in industry. 2. Maintenance as a positive would create a far too big and common positive. A challenge in the assessment of positives will be to determine which part of an activity is maintenance and which part capacity raising. The same difficulty applies for instance to commercial R&D activities on environmental or social improvements, where often a part of the activities is for maintenance or efficiency purposes (see also section 6.4.1.11). We stress this point of maintenance because if positives are included in LCA, very easily, maintaining a certain status as business as usual, may be characterized as positive, this way undermining the credibility of Life Cycle Assessment as tool for sustainable development.

A last argument in this section we like to mention is that activities that are the natural obligation of governments with sufficient capacity, cannot be positives for commercial bodies. An example is building infrastructure in developed countries.

6.4.1.8. REBOUND EFFECTS

The rebound effect is caused when money saved by impact reducing goods or measures (such as less driving and insulation of houses) is spent on other CO_2 emitting goods and activities. Therefore, positives may not be as effective as they seem. Petti *et al.*, 2018 give the example of the use of 3D printers saving transport and waste, but also saving costs which will be spent on

other things. There are countless other examples, such as to use skype instead of traveling to a friend abroad and spending the saved money on a holiday. In fact, a large part of saved money on anything will be spent elsewhere. Druckman et al. estimate at unchanged household preferences the rebound effects on carbon emission mitigating measures in the UK at about 34% (Druckman *et al.*, 2010, p.24). Rebound effects reduce the effectiveness of impact mitigating measures by alternative use of money as result of an impact reducing measure. In literature, the rebound effect usually refers to the compensating negative effect on one specific environmental aspect, usually related to resource and energy use and climate change. In our opinion, the interacting impacts of different environmental and social aspects need equal consideration. However, because little quantitative data are available on interacting effects of the different sustainability aspects themselves, extension to social aspects and inclusion of interactions in the rebound effect in LCA currently seems a bridge to far. Usually the concept is used for saved money used elsewhere, but in principle, can also work the other way, causing impact by reduction of the available money. For instance, an increased price of diesel, meant to mitigate carbon and particulate matter emissions of cars, may lead to spending less on healthy food and thus to increased malnutrition. Our conclusion on dealing with the rebound effect is that, although causing potentially significant reductions of the efficiency of positives, far more research is required for inclusion in LCA's with reasonable certainty.

6.4.1.9. EMPLOYMENT A POSITIVE?

To date, the most commonly used positive in S-LCA studies is local employment (Ekener-Petersen *et al.*, 2018; Petti, Serreli, *et al.*, 2018). Most employment however, is a type 1 positive internality, because the costs are included in the price of the product. In addition, one may seriously question if employment at sub-fair wages, or favoring privileged groups because of corruption, may be called a positive or negative impact. In addition, in a competing world, the gained employment may be at the expense of another employer or in the international context, of another country, which even may be a more responsible employer. In fact, the impact of unsustainable behavior on competitors, a forgotten stakeholder group in the original UNEP Guidelines, may be considered a cause of "the race to the bottom" and major contributor to all unsustainability. The global labor share is over 50% of the gross global product (ILO, 2019, p.26). That means that if all employment would count as a positive, a huge positive would be created, with the danger to be used for compensating and justifying negatives. Most employment is maintenance of business as usual, and distinguishing what employment would raise a regions' capacity and what not, seems very difficult. And last, in a healthy economy, loss of employment in one sector is usually compensated by growth in another sector. If employment would be characterized as positive, it should, in our opinion, at least comply with the criteria, described in our examples of positives in S-LCA in section 6.5.1.

In practice, these criteria would mean that employment would seldom lead to a positive assessment in low income countries, which is in contrast to one of the the reasons of including positives in LCA (Benoît Norris, Mazijn and et al., 2009, p.76). The same applies to wages, which are also frequently mentioned as possible positives (Benoît Norris *et al.*, 2009; Jørgensen, Lai, *et al.*, 2010; Petti *et al.*, 2014; Di Cesare *et al.*, 2018; Ekener-Petersen *et al.*, 2018). Because of all these reasons, we recommend not to characterize employment and wages as such as positive in S-LCA, without other criteria.

Aforementioned was already that employment for the activities of an organization is a type 1 positive internality, not be included in LCA's. On the other side, we like to mention an example of an employment that is a positive externality, consisting of the "second order" employment expansion in the communities around the organization's operations, not concerning the local suppliers (type 1 positive internalities), but due to the local expenditures of employees. But this expansion may only be assessed as a positive if it can be demonstrated that it gives a sustainable net positive employment in the local community, which is not the case in the presence of sufficient local competition or at a high local employment rate. In addition, because for quantification of this local expenditures dependent effect, expenditures on region-imported goods should be subtracted from the locally gained incomes, this positive can only be applied for poor and closed communities, for which data availability will probably be limited. Therefore, as aforementioned, we propose to assess as positive, the employment in the 20% poorest countries only, and only if the aspects of the fair minimum wage (chapter 4) and fair inequality (chapter 3) are properly included in the assessment.

6.4.1.10. UTILITY OF PRODUCTS

Life cycle assessments on negative impacts of product utilities are quite common, such as on the emission of transport means. But every product also has a positive utility, which is the mere reason of its existence. Various papers (Baumann *et al.*, 2013; Ekener-Petersen and Moberg, 2013; Wilhelm *et al.*, 2015) include utilities of goods as a positive impact. We already discussed our concerns about the Baumann case of airbags. But on the other side, the airbag was especially developed for a positive utility, that needs appreciation, just like windmills, solar panels, medicines and food. Two types of users need to be distinguished: Businesses and consumers. In business applications the utility is appreciated by mitigating the negative impacts in the downstream supply chain. The effects will appear by less negatives in LCA's of these downstream products. In the Oiconomy system, which transfers data through the supply chain, inclusion of utility before the stage of the end-producer would cause double counting. For consumer utility positives, as explained in section 6.4.1.1, we distinguish 3 groups: 1. Positive *utility-externalities*, benefiting others than involved in the economic transaction. An example, perfect for inclusion in LCA, is a company purchased fire truck at the disposal of the community. 2. *Type 1 positive utility-internalities* that are part of the considerations at a seller-buyer transaction and which should be excluded from LCA's. 3. *Type 2 positive utility-internalities* that have not been considered and not affect the price. An example would be the private honey that a farmer obtains from a beehive that he purchased for pollination purposes. In principle, such positives could be included in LCA's, but, as the example shows, will by definition be irrelevant. However, the utility of technology, that is especially intended for impact mitigation, such as a windmill, presents a more complex situation. We argue that R&D and installation of impact abating technology are capacity raising and therefore the depreciation and interest positives (see sections 6.4.1.7 and 6.4.1.11), but the utility is not, because of the here described reasons.

6.4.1.11. RESEARCH AND DEVELOPMENT

Several times aforementioned were R&D activities. These present extra difficult and contradicting considerations. Literally taken, R&D activities by commercial actors are type 1 positive

internalities, which should not be part of LCA. This becomes very clear in the pharmaceutical industry, but also in information technology, where a major part of the price of the product is for financing the internal R&D costs. But on the other side, the Agenda 2030, formulated by the United Nations, stresses the importance of research to achieve the 17 SDG's (United Nations General Assembly, 2015). Therefore, we argue that R&D activities that are really focused on sustainable development deserve a positive characterization. However, because it will be very difficult to determine verifiable and reliable criteria for quantification of the positive impact of R&D activities, we propose to characterize of R&D as positive for products and activities that are (almost) exclusively intended for sustainable development, and are externalities or type 2 internalities. Examples would be the development of renewable energy or recycling technology and life cycle assessments themselves. We have no proposal yet for R&D activities that are less exclusively intended for sustainable development. We suggest to limit inclusion of positive R&D activities to well defined contributions to one of the 17 SDG's, or more granularly, defined to the 27 midpoints as defined by Vermeulen, 2018, p.24.

6.4.2. A PROPOSAL OF CRITERIA FOR POSITIVES TO BE INCLUDED IN LCA

By definition, the positive impact of products is automatically valued by their market price. Unfortunately, the hidden negative externalities are not. And unfortunately, there is no way to objectively weight the importance of the impact of different aspects, negative or positive. Even democracy is an insufficient weighting instrument, because future generations have no vote and short term interests predominate. Even the LCA guidelines admit that the inclusion of positives was influenced by negative perceptions of low income countries considering LCA as "anti-development", insufficiently addressing their most significant short term problems like poverty, unemployment, accidents and other immediate issues" (Benoît et al. 2009, p.18). But on the other side, just like the market does not value the hidden negatives, it may not value all positives enough to achieve the balance of human wellbeing for all, which in principle the "invisible hand" of (Smith, 1776) should do. Any commercial company would like scientific recognition, proof and attention about its positive contributions. Therefore, inclusion of positives in LCA may help to get LCA accepted and applied by industry. Sustainability assessment of positives may help to focus on sustainable development and help politicians in decisions on which developments to support. In theory, it is possible that LCA's disclose yet unknown positives. An in our opinion valuable use of LCA would be to assess the real positive value of features claimed as positive by industry. However, inclusion of positives also presents a great risk. By nature, industry focusses on unique selling points, and getting the opportunity, may more focus on maximizing positives than on minimizing the negatives. Without rules on how and when to assess positives, LCA may be used for greenwashing and become a wild medium of seemingly scientific marketing arguments and justifications of negatives. Therefore, in our opinion, inclusion of positives in LCA could be helpful, but for a credible LCA, a way must be found to overcome as much as possible the above described issues and to develop criteria for positives in LCA. Based on the results of our assessment and our definitions of positive and negative internalities as presented in table 6.1, we propose a set of core criteria for the assessment of positives in E-LCA and S-LCA. These criteria are meant for prescriptive LCA's with the purpose to support sustainable decision taking. Note that not all of below described criteria also apply to purely descriptive science. Thereafter, we will give list of examples of concrete activities and products that, based on these criteria, could be characterized as positives

6.4.3. PROPOSED CORE CRITERIA FOR POSITIVES INCLUDED IN A PRESCRIPTIVE LCA

1. Positives must be externalities (section 6.4.1.2), beneficial to stakeholders outside the seller-buyer transaction, or type 2 positive internalities. However:
    - Advertising a positive makes it a type 1 positive internality that should not be included in LCA. However, we suggest to exempt advertising Accreditation Council and ISEAL accredited certificates and other universally recognized means of evidence.
    - R&D activities (almost) exclusively intended for environmental or social improvements are positives if the envisioned results are beneficial also to others than than those involved in the economic transaction. For the assessment of R&D activities that are less exclusively intended for sustainable development, we currently have no proposals, especially not for how to assess their externality share.
    - Products which utility is (almost) exclusively unburdening (e.g. solar panels), are positives. Only the capacity raising investments (depreciation + interest) are positives; not the utility itself, unless that positive utility is free of charge. Note that for instance an electric car, measured by status is not unburdening, because its utility is driving.
2. Positives cannot be absence or mitigation of negatives (section 6.4.1.4).
3. Positives are products or services, sustainably raising the capacity of a stakeholder group to meet their needs (section 6.4.1.7).
    - Positives must perform beyond compliance stipulated by laws, international agreements and certification standards (Benoît Norris *et al.*, 2009).
    - Positives must raise the capacity of a stakeholder group to advance on one or more of the Sustainable Development Goals.
    - Positives must be sustainable and maintaining the achieved capacity at the higher level.
4. Positives have demonstrable capacity raising impact on supply chain actors, exceeding the needs of the parties involved in the economic transaction (section 6.4.1.3). For instance a company may require from a supplier to renounce pesticides, child labor or under-fair mininum wage payment for his total production, larger than intended for the company itself.
5. Positives to one stakeholder group may not compromise the ability of other (including future-) stakeholder groups to meet their needs (section 6.4.1.6).
6. Rebound effects should not be included in LCA's before reliable assessment methods and data are available (section 6.4.1.8).
7. No aspect or impact can be a positive that is general to a great number of products or activities, or necessary for maintaining an aspect on a certain level, e.g. employment (section 6.4.1.7).
8. A positive is only the demonstrable better part than average. We would even prefer a benchmark of the top 20% performers (section 6.4.1.12).
9. A service by a commercial body is only a positive if the activity is not a natural obligation of a government, rich enough to provide it (e.g. provision of infrastructure). We propose to limit positives based on such services to the 20% poorest countries (section 6.4.1.7).
10. No positives can be allocated for activities or products that have very negative impact

on other aspects than the assessed, unless a process of significant improvements can be demonstrated (not only planned but demonstrably in execution, which actually means that the relevant other aspect is also assessed) (section 6.4.1.6).

11. Employment and minimum wages higher than the fair minimum wage can only be considered a positive in the 20% poorest countries and if equally applied for all personnel (section 6.4.1.9).
12. Utilities that are beneficial to stakeholders not involved in the economic transaction, are positives, but only if also the burdens caused by the product are included in the assessment. An example is an aquifer depleting fresh water provision installation for a company that also provides free water access to the community (section 6.4.1.11). An example of a positive utility assessment for a consumer product is hard to find because of the requirement that they may not be absence of negatives and they are almost always type 1 positive internalities.

Upon allocation of ESCU's in the Oiconomy system, an essential difference arises between ESCU's for negative and for positive impact. For negative impacts, ESCU allocations are based on lack of good governance. The ESCU's are may be based on planned but not actualized preventative measures. ESCU's for positive impacts however, cannot be based on plans, but only on the actual status.

Based on our proposed core criteria, we will now list some activities, that we propose as positives for the Oiconomy System, but that also may be considered in the EcoCost system and impact-based LCA. The listed activities include aspects mentioned in literature aspects contributing to the Sustainable Development Goals (SDG's), but exclude SDG's that commonly are governmental- instead of industry responsibilities. Also excluded are activitiescts that are made by absence of negatives.

6.4.4. EXAMPLES OF PRODUCTS AND ACTIVITIES FIT FOR POSITIVE ASSESSMENT

Table 6.2. Examples of positive and negative impacts for internalities and externalities in impact-based LCA and the preventative cost-based Oiconomy system

Pillars		Type of LCA	Examples		
			People	Planet	Prosperity
Type 2 Internalities	Costs (Negatives)	Impact based LCA	Noise of a lawn mower	Existing efforts to comply with to anti-pollution laws	Profits lost by compliance to anti-corruption rules
		Oiconomy system	Costs to reduce the noise to zero effect level	Expenditures on pollution prevention	Profits lost by compliance to anti-corruption rules
	Benefits (Positives)	Impact based LCA	The social contacts by a job	Long term capture of CO_2 in wooden buildings	Honey for private use from keeping bees for pollinating
		Oiconomy system	Zero	Saved costs for CO_2 capture	The prevented costs of buying honey
Externalities	Costs (Negatives)	Impact based LCA	Impact of unsafe working conditions	Emitted CO_2	Impact of corruption and of unfair transactions
		Oiconomy system	Costs of a perfect Occupational Health and Safety system	Prevention costs of CO_2 emission	Profit obtained by corruption and unfair transactions
	Benefits (Positives)	Impact based LCA	Tourist resorts given free access to their private beaches	Restoration of an ecosystem	Employment by employee's local expenditures
		Oiconomy system	Tourist resorts given free access to their private beaches	Expenditures on restoration of an ecosystem	Employee's local expenditures minus costs of therefore "imported" products

This table does not include type 1 internalities, as depicted in table 6.1. The following examples in the table deserve some discussion: Characterizing long term CO_2 capture in buildings as a positive type 2 internality assumes that the CO_2 capture was intended, not more expensive than using other materials and the wood sustainably grown. However, if building in wood is more expensive and the argument of CO_2 capture is an argument in the economic transaction, this capture would be a type 1 internality. This shows that in practice, there will always be cases that need careful assessment before characterizing them as positive in LCA. Another example to discuss is the characterization as a positive internality in impact-based LCA of social contacts in a job, while in the Oiconomy system the quantification is zero, because the social contacts represent no monetized benefit, which shows that the measured effect depends on the type of LCA.

In addition to table 6.2, we can give a short list of categories of activities that would be applicable as 'positives' both in the field of environmental LCA (E-LCA) and social LCA (S-LCA).

E-LCA

1. Recycling of old waste (not of current waste, because that would be "absence of negatives" (SDG-11,12).
2. Recovery or restoration previously caused damage (SDG-11,12).
3. R&D, investment and installation for impact mitigating products or technology (SDG -6,7,9,13), but only if one or both of the following applies:
   a. The technology is especially designed for the impact mitigating purpose.
   b. Best 20% mitigating performance on the aspect in the market can be demonstrated.

   The development and investment of sustainable capturing of CO_2 or other GHG's would be a positive. The capturing itself would also be a positive if taken from the atmosphere, but not if used for prevention of industrial emissions, because that would be "mitigation of negatives".
4. Restauration and/or long-term protection of natural ecosystems, or upgrading of soil- or water systems (SDG -14,15), other than damage caused by actor's own activities.
5. Over-average crop-yields in agriculture, compared to the yields by country, listed in (FAO, 2019) (SDG -15), but only if the agricultural negatives are also included in the assessment.
6. Under-normal cost price provided beneficial by-products (e.g. heat from a power- or chemical plant, used for municipal heating), sustainably mitigating impacts (SDG -12,13,14,15).
7. Payments for ecosystem services (UNDP, 2015) and of enviromental taxes.

S-LCA

1. Poverty reducing activities by capacity/ability improving means (e.g. micro-credits) or by other means, or hunger relief in the 20% lowest income countries (SDG -1,2).
2. Healthcare (Srinivasan, O'Fallon and Dearry, 2003; Ekener-Petersen et al. 2016) (SDG -3), other than for inflicted harm in the supply chain itself.
3. Capacity building, e.g. education and training in the community, either intern or extern (excluding "on the job") (Ekener-Petersen *et al.*, 2018) (SDG -4).
4. Helping underdeveloped actors to sustainably raise quality, yields or sustainability also for others than involved in the relevant supply chain (Various SDG's).
5. Reducing gender inequality and empowerment of woman and girls outside of the own company (SDG -5).
6. Improving water safety and availability in the 20% lowest income countries (SDG-6).
7. Employment, but only if all of the following applies:
   - The country or region has a (far) below-average employment ratio.
   - The employment is locally net-positive, which means: Not at the expense of other local employers.
   - The employment is long term and the involved companies/industry sectors have no history of short term displacements.
   - The involved country has a high corruption perceptions index (low corruption) or the company can demonstrate absence of corruption (reversal of the burden of proof).

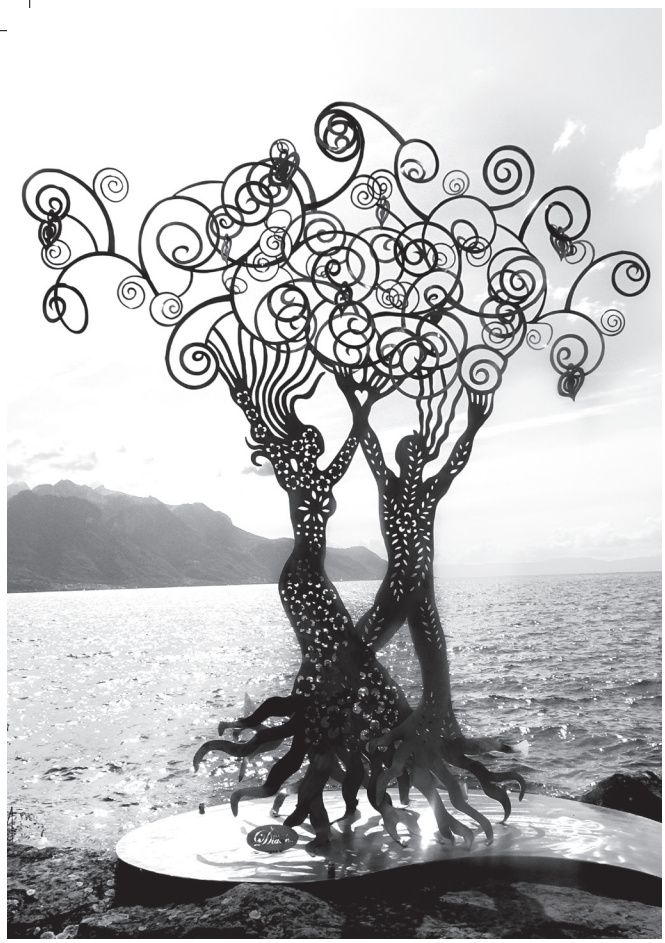
- The fair minimum wage (chapter 4) is paid to all employees and the country has an almost zero child labor percentage or the company can demonstrate zero child labor (reversal of the burden of proof).
- Good Occupational Health and Safety conditions can be demonstrated, e.g. by certification to ISO 45001. (SDG -8)

8. "Second order" local employment in the 20% lowest income countries, caused by the local expenditures of a companies's employees.
9. Employing of people with distance to the labor market by a mental or physical handicap (SDG -8,10).
10. Donations to recognized and effective sustainability pursuing NGO's, but excluding political entities (SDG-17).
11. Providing beneficial products below cost price, e.g. medicines for the underprivileged (SDG-1).
12. Providing free services, e.g. internet services with positive sustainability impact, but only if the related negative aspects (e.g. invasion of privacy; spam) are also assessed.
13. Emergency relief, freely at the disposal of the community (SDG-3,11).
14. Protection of cultural heritage and indigenous peoples and stimulation of cultural activities that do not harm sustainability (SDG-11).
15. Sustainable contributions to the local community (infrastructure in the 20% poorest countries, nature, sponsoring, cleaning, sport (Schulenkorf and Edwards, 2012), art and other cultural aspects (Archer *et al.*, 2005; Belfiore and Bennett, 2007) (SDG-11,17).

6.5. CONCLUSIONS

This study demonstrates several serious ethical and practical issues and challenges to consider before including positive impacts in LCA and especially S-LCA. Based on these, a set of core-criteria for inclusion of positives was proposed and examples given of activities and products that could be characterized as positives. Our goal is, next to developing the assessment of positives for the Oiconomy system, to open a discussion on setting criteria for inclusion of positives in LCA in general. We showed that LCA includes both conflicting characters of descriptive and prescriptive science, with the risk that descriptive features seriously hurt the ethical goals of prescriptive LCA as described in ISO 14040. An especially difficult question is to how strictly interpret the economic concepts of "externalities" and "internalities" in relation to LCA. The major body of LCA's assesses externalities, but also negative impacts of products' utilities. However, utilities that affect the buyer of the product, are in economic terms internalities. We demonstrated good reasons why internalities positively affecting the seller-buyer transaction partners and affecting the price, should not become part of LCA's. Therefore, we proposed to, for LCA purposes, to define positive internalities in two groups: Type 1, benefits considered by the transaction partners and type 2: not considered, neglected or underestimated by the transaction partners and not affecting the price, which type could be included in LCA. Another important question is how to deal with the regularly mentioned requirement of a "capacity raising" impact, indicating that a positive should bring an aspect to a higher level. We showed the importance of this criterion, but also some of the difficulties of distinguishing capacity raising from maintaining the current status. On three issues we are more conclusive: First, in our opinion, employment should not be included as a positive in LCA without a range of additional

criteria. Second, especially in S-LCA, is the danger of comparing the positives for one stakeholder group with the negatives for another stakeholder group, because that easily becomes unethical and against the principles of prescriptive LCA. And third: LCA should not mix measurement by change with measurement by status without extra criteria, and rather keep track of a change by repetition of measurement by status. Given the issues found in this study, imprudent inclusion of positives in LCA, could easily result in reduction of its discriminate meaning, whitewashing and loss of its credibility. A possible result of a debate in the LCA community, could be to not include positives in LCA at all. Another option is to consistently separate positives out of LCA, but assess these in another system, for instance "handprinting", proposed by Norris, (2015), but then not use the direct comparison by the proposed formula of [Net positive = Handprint – Footprint] (Benoit Norris *et al.*, 2020). A third option would be to describe in the goal of an LCA if that goal is descriptive or prescriptive, but then also consistently follow the chosen principle. Our preference would be to include positives in LCA and S-LCA, but carefully limited to very clear positives, complying to strict criteria, for which we made a first proposal in this paper. This also applies to the Oiconomy system, in which we will implement the criteria obtained from this assessment.



The Three T's: Transparency, Traceability and True costs are prerequisites for sustainability

Shareholders have rights and power, but limited liability for misconduct of the involved company

CHAPTER 7

PILOTS

7.1. INTRODUCTION

Central in the research question of this thesis is: "How to enable supply chain actors to assess the comprehensive sustainability of products by determination and bottom-up transfer through the supply chain of the preventative cost-based externalities" (section 1.8). Needed for such operation were a methodology and central in that methodology is standardization. In chapter 2, explained were the functionality, operational features and system boundaries of the Oiconomy System as answer to this goal. The Oiconomy Standard was developed for the standardized measurement and aggregated transfer of sustainability data through the supply chain of products, expressed in a monetary indicator, the Eco Social Cost Unit (ESCU). Every ESCU score for a sustainability aspect is obtained by the product of a quantitative factor and a price factor. The quantitative factor is determined by the supply chain actors themselves, guided by the Oiconomy Standard. The actors are challenged to determine their own specific costs of prevention as price factors, but the Oiconomy Database provides default values for lacking price factors, for the time being, the major source of data, but envisioned to be replaced by actual foreground price factors. Key distinguishing features of the Oiconomy System are the standardized and bottom-up character of sustainability assessment along the supply chain, the preventative cost based indicator and the focus on foreground data.

As third stage of the Oiconomy Project (see section 2.4 and the figures. 1.3 and 2.1), three pilots were conducted by M. Sc. students in volunteering companies. The purposes of these pilots were to test the feasibility of the Oiconomy method as a comprehensive product life cycle assessment method and guidance, to study expected and unexpected results and characteristics of the system and results, and to find and correct shortcomings and ambiguities in the Oiconomy Standard. Because of these goals, little extra guidance was given to the students, accepting occurring errors as learning items for the system. Assessed products were a pig feed (Karapinar, 2017), a safety shoe (Moonilal, 2018) and a cotton T-shirt (Van Hoof, 2018). Because of confidentiality reasons, these reports are not publicly accessible.

The pilot on the pig feed considered a for sustainability assessment very complex product with fast changing composition, suppliers and transport means. The participating company was an enthusiast and cooperating contributor to the pilot and an example of an extremely cost-focused and well organized company. The researching student reported "that the conception of sustainability within the company is that an efficient production leads to a decrease in impact on the environment, since less ingredients and energy are used". They share this understanding with most of their customers, the farmers. All aspects of food safety, quality and occupational health and safety were top priorities and all first tier suppliers audited and approved.

The pilot on the leather shoe considered a comparison of different varieties of that shoe, for the pilot the most important of which a circular shoe. The company employs disabled people and is very focused and experienced in the social aspects, but had little data and experience on environmental aspects, which was completely outsourced to a consultant. Unfortunately, due to confidentiality reasons and poor availability of the consultant, and little allowance of the researching student to self-contact suppliers, this pilot did not result in many valuable lessons for the project. In the following, this pilot is only incidentally referred to. Important contribution of this pilot however, was its effect on the decision to include assessment of benefits in the Oiconomy Standard.

The pilot on the cotton T-shirt resulted in the most complete assessment, with a major brand/retailer in the Netherlands as the initiating and investigated actor together with their cooperating main apparel manufacturing supplier in Turkey. In order to study different supply chains for the same product, four versions of the T-shirt were assessed with different cotton sources: conventional cotton, "better cotton", organic cotton and recycled cotton. Most of the lessons learnt and therefore reported below were derived from the cotton T-shirt pilot.

7.2. METHODS

Data were collected by M.Sc. students following the instructions by the Oiconomy Standard.

For the students, the goal was to independently conduct an O.S.- based assessment on a limited number of aspects, but for the Oiconomy project as a whole, the students were pilot-researchers working with the O.S. Foreground data were obtained by means of interviews and access to companies' internal data and by means of sending questionnaires to suppliers. Some foreground data were obtained from external databases, filled and shared by various companies. An example of such database is the Higg Index, an initiative by the Sustainable Apparel Coalition, 2019 (SAC). The Higg Index acts as an open database in the apparel industry, where all members share their sustainability data (Radhakrishnan, 2015). The existence and working of such indexes strengthens the feasibility of making the Oiconomy Database self-learning. Foreground supplier data, which in the envisioned Oiconomy system should be collected from all suppliers, were obtained from the main supplier in the T-shirt case. However, also the suppliers' data were raw data, which were used to calculate ESCU's instead of provided as ESCU's by the suppliers themselves as is envisioned for the future.

Background quantitative data were gathered from general data sources, such as the European Product Declarations (The International EPD System, 2019) and Environmental Product Category Rules (European Commission, 2018) and peer-reviewed scientific LCA studies, which on their turn used global life cycle inventory databases for LCAs, such as Ecoinvent (Swiss Centre for Life Cycle Inventories, 2019) and GaBi (GABI Software).

ESCU's were calculated, as instructed by the O.S., using the background country-specific price factors provided by the Oiconomy Database (Croes, 2020a). In the case of the T-shirt pilot, earlier LCA's were only used to collect raw background data in order to calculate ESCU's. These LCA's were conducted by Marks & Spencer (Collins and Aumonier, 2002) and (Levi Strauss & CO., 2015) and in addition several scholars (Van Der Velden et al., 2014; Baydar et al., 2015; Kozlowski et al., 2015; Roos, Posner, et al., 2015; Roos, Sandin, et al., 2015; Zhang et al., 2015; Van der Velden and Vogtländer, 2017).

7.3. RESULTS AND LESSONS LEARNT

The objectives of the pilots were accomplished. Most important result of the pilots was that it was demonstrated that the Oiconomy system is a feasible methodology for product life cycle assessment along the supply chain. The Oiconomy Standard proved a workable guidance for supply chain actors to systematically and comprehensively assess the sustainability of their product. In the pilot of the pig feed, two suppliers were asked the necessary data by means of Oiconomy Standard derived questionnaires. One was not willing to participate, but the supplier of an amino acid for the pig feed, without any help, answered all questions from the provided

questionnaire with all required data, both environmental and social in all details, which could all be converted into ESCU's by the student. The company even provided data on aspects that are not commonly assessed, such as personnel commuting distances and involvement in conflict situations. Therewith, this supplier provided hard proof that at least the Oiconomy Questionnaire is understandable and workable. Because all questions in the questionnaire represent the core of the criteria of the standard, we may safely assume that the same applies to the Oiconomy standard. The pilots also demonstrated the characteristics that are typical for a comprehensive, bottom up and preventative cost-based assessment, but also the potential challenges and some research needs that lay ahead in implementing the system, which will be discussed in the following sections.

The participating companies in the T-shirt and pig-feed pilots showed considerable interest in the Oiconomy system and transparently shared their foreground data, including their confidential financial data, but were not strong or willing enough to put enough pressure on first and further tier suppliers to participate in the pilots and provide the necessary foreground data, except, in the case of the cotton T-shirt on the first tier main manufacturer of the T-shirt.

The O.S. was designed to aggregate the ESCU's bottom-up along the supply chain. In the envisioned fully developed Oiconomy system, no default values are necessary and one step traceability exists at any step in the supply chain. However, for our pilots this meant that currently, no quantitative foreground data were available on much of the upstream supply chains and gathering background data as a standard top-down LCA is not the goal of the Oiconomy project. Therefore, this chapter only reports on the lessons learnt from our pilots, disregarding specific data from the executed assessments. Our pilots had the following limitations:

- No attempt was made to investigate if one preventative measure could prevent impacts on several aspects.
- No real transfer of ESCU's was made between supply chain actors, although raw data were transferred.
- The method of quantification by the assessment of governance quality could not be tested.
- No pressure was exerted on suppliers to fully contribute and provide ESCU's.
- The pilots were not completely comprehensive; not all aspects were included.
- The sensitive issue of income-inequality was not tested, nor the willingness of companies to assess this aspect.

7.3.1. ENGAGEMENT OF COMPANIES

In our search for pilots and conversations with industries, we noticed several reasons for hesitations to participate in the pilots, which may also play a role in efforts to put the system into practice: 1. The expectation of our participants that their suppliers would not be willing to participate. 2. Companies just adopted another system of measurement or improvement of sustainability. 3. Lack of belief in a future internationally equal level playing field. 4. Other issues in the company, such as mergers and reorganizations were top of mind. In addition, there are general obstacles for transition. Some opinions from leaders were collected by Belhaj-bouabdallah, 2017, e.g. King: "The inertia of the global socioeconomic system, the lack of a clear way forwards and counteracting industries", and Steffen: "lack of a sense of urgency

before things become really bad".

But, on the positive side, there are the successful transitions of quality and food safety. The HACCP food safety system (Motarjemi et al., 1996), that was an example for the Oiconomy system, took about 20 years after development to become widely introduced, but is to date key to global food safety. Also the engagement of HACCP was first accomplished by trickling back upstream through the supply chain of the requirement to adopt the principles of HACCP, starting from the pressure of major retailers and brands, and later by the force of legislation. Therefore, although we have not been able to test the transfer of data from farm to fork or from mine to machine, we were able to test the system and find shortcomings, limitations and result-characteristics and could optimize the system. No actor-self-determined specific preventative costs were determined.

7.3.2. WORKING WITH THE OICONOMY SYSTEM

Most investigated foreground data on both environmental, social and economic aspects that were available in the investigated companies could be collected and converted to ESCU's, by following the instructions of the Oiconomy Standard, except for data that required specific analysis that companies, in these pilot cases, were not prepared for, such as analysis of specific on-site pollution.

Background data on upstream environmental aspects could be collected. However, reliable background social and economic data from the upstream supply chain were, as expected, more difficult to find. On the one side, this supports the need of the Oiconomy system for providing foreground data, but on the other side makes it difficult to make a complete assessment before enough pressure on the complete supply chain is exerted.

At the start of the pilots, it was difficult to find the right places, databases and persons to collect the data. Students and companies had to be convinced that financial data are key to determine the scope of the assessments. An issue was the combination of the large number of criteria and the level of detail in the criteria. In the first pilot, a simple questionnaire was requested next to the 60 pages comprising Oiconomy Standard, as a simpler guide for practitioners. A questionnaire was provided, with a double sided result in the following pilots: On the one side, some misinterpretations were made due to insufficient reading of the standard because of the availability of the questionnaire, but on the other side a request for an even more simple questionnaire was made. Like with most standards, there is a tension about the level of details in the criteria of the Oiconomy Standard. If they are not detailed enough, they are difficult to understand and ill prepared for all kinds of situations and exemptions; if they are too detailed, they become too much, confusing and less legible.

An option, also used in existing certification standards, is to limit the standard itself and create guidance documents with more detailed description of the criteria. Other options are to develop sector specific standards, questionnaires and product category rules, software with questions self-adapting to characteristics of products and organizations, industry sectors, location, size of companies, and certificates. Such software should also be able to self-search the Oiconomy database for the relevant price factors and other databases for quantitative data. The pilots showed that especially for services with limited and specialized activities, such as transport, simple questionnaires are required. The same applies to the Oiconomy Database, in which it

is not always easy to find the applicable data. Both standard and database need continuous improvement, but the pilots also showed that it requires some experience to use the standard and database. There are serious similarities between Quality Assurance (QA) and Sustainability Assurance (SA) (Siva et al., 2016). Also working with quality standards requires experience, qualified personnel and adaptation of the routines and documentation of companies. SA is lagging 50 years behind but and experiences with QA can be used for SA (Aquilani *et al.*, 2016). One major extra difficulty for SA to overcome, is that quality issues more directly affects consumers than most sustainability issues, which makes it more difficult to convince companies to adopt the system.

The students executing the pilots, made remarks that the Oiconomy system lacks information on which external databases to consult for quantitative data and how to use these databases. Considered are input-output databases that are used like WIOD, 2020 and Exiobase, 2015, the Social Hotspot Database (Benoît, Norris, Aulisio, et al., 2010), and Agricultural databases like the Coolfarmtool (Cool Farm Alliance, 2019). For instance, input-output databases may be used for the determination of the potential sources of materials more precisely than standard default values based on marginal costs on a global level. Developments in this direction are already made (e.g. Hall and Suh, 2018). Another remark was that the list of approved certificates in the Oiconomy Database is incomplete. A survey of all relevant certificates should be a future addition to the database.

To users, it was not clear what level of ESCU's is sustainable for an aspect. Indeed, the Oiconomy Standard does not contain a list of no effect levels and PRP's, because it serves no purpose for the user to know the global target that the ESCU's are based on. For the user, "zero ESCUs" should the ultimate concept of "sustainable". A sentence was added in the O.S., indicating that the O.S. only contains criteria on the measurement and communication but no criteria on required sustainability achievements.

One student-researcher expressed concerns that companies may be reluctant to have external auditors inspect their financial data. Although probably true, this is standard operation in accountancy and various certifications, who's auditors are bound to strict confidentiality rules.

7.3.3. SYSTEM- AND DATA CHARACTERISTICS

Location Sensitivity of Social and Economic Aspects

The pilots showed high location sensitivity in the Oiconomy system assessment. Only for background environmental data with low geographic granularity, the ESCU's have limited location sensitivity. Foreground ESCU's on social and economic aspects are highly dependent on the location and company. Particularly after preventative measures have been taken, the Oiconomy system enables companies to demonstrate their improvements. But also for environmental aspects like water depletion and power consumption, for which ESCU's heavily depend on the specific location, the system enables companies to tailor their procurement to sources with least impact.

However, in absence of foreground data, the ESCU allocations are based on marginal preventative cost based price factors and worst case quantitative data, with the consequence of usually high ESCU scores. This however is the logical consequence of lack of traceability and transparency, prerequisites for sustainability.

In our pilots, comparing different upstream supply chains, it stood out that high ESCU's on social aspects occurred in countries with middle high income. One of the causes was that the O.S. did set the default wage for child labor at the worst case, which is zero wage. This resulted in relatively high ESCU's in countries with middle high income and -development but not yet completely eradicated child labor. This effect only occurs at background data, because the assumption of zero wage only applies in absence of foreground data. To correct this unintended effect, the O.S. was adapted by replacing the zero level default child labor wage by the product of the local minimum wage and the Human Development Index HDI), a well-recognized indicator on countries' stage of development and therefore also for compliance to minimum wages. (Unfortunately, the Sustainable Society Index -Human Wellbeing (SSI-HW), assessed as best indicator in chapter 3, has stopped being updated since 2018, but in chapter 3 it was already noted that the HDI can replace the SSI-HW). This way, a previous assumption was replaced by a better assumption, which still is open for further improvement and especially for country specific data on actual wages for child labor.

A similar location sensitive effect was that the ESCU's for unfair wages were higher in a high income country (e.g. USA) than in a low income country (e.g. India) if in both countries the paid wages are below the fair minimum wage and if equal labor intensity was assumed. It is far more expensive to raise the wages to the fair minimum wage in the USA than in India. In practice, this only applies to cases of similar labor intensity because in most cases, higher labor costs in the USA are compensated by lower labor intensity, which then also applies to ESCU's. But products may exist with more similar labor intensity than in our pilots. The pilots demonstrated the special characteristic of the Oiconomy system that it considers unfair wages in high income countries, because ESCU's are based on relative poverty, bottom truncated by an indicator on absolute poverty, where other assessment methods only account for absolute poverty (see chapter 4).

Another price level related issue occurs when calculating background ESCU's for corruption. In our cotton T-shirt pilot, a higher ESCU's score appeared for operations in Turkey, compared to countries with higher corruption risk, for instance Uzbekistan or India. The ESCU's for corruption are determined by the product of the profit margin and a reducing calculation factor (CF) depending on the governance level on countering corruption (see chapter 5). In countries with a Corruption Perception Index (CPI) > 64 (Transparency International, 2019), the Oiconomy system assumes the risk for corruption negligible (see chapter 5). Providing foreground data, also companies in countries with lower CPI, are enabled to avoid ESCU allocations based by demonstrating good governance against corruption. However, for background data without demonstrable good governance, governance against corruption is assumed absent, CF becomes equal to 1 and ESCU's equal to 100% of the average profit in the sector. In that case, companies in countries with relatively but not sufficiently high CPI, are allocated the same ESCU's, equal to 100% of their profit margin. Below a CPI score of 64, the O.S. considers all countries to have equal corruption risk. Considering the same issue for child labor, we decided to adapt the ESCU's by multiplying with the reducing factor of the Human Development Index, but decided not to do so for the aspect of corruption, because verification of absence of child labor by unannounced audits is feasible, but not for corruption.

Location Sensitivity of Environmental Aspects

On environmental aspects, the pilots exposed the following advantages and sometimes unexpected results of the focus of the Oiconomy system on local or country specific data.

a. Water.

   The ESCU's for water depletion depend both on the used quantity, the local scarcity and on the costs of supply of water, depending on the distance and quality of the available water. Because the marginal preventative measure for local water depletion is to transport desalinated seawater (with renewable energy), the costs heavily depend on the elevation and distance to the sea. In the T-shirt pilot, this demonstrated considerably higher ESCU's for cotton cultivation in Uzbekistan than in the USA.

b. Electricity and emissions.

   The ESCU's for emissions from electricity depend on the local power mix, which varies from € 0,0012/KWh for Albania to € 0,2166/KWh for India. Because the marginal preventative measure for water depletion is power intensive sea water desalination, in our pilot, the organic cotton version of the 4 versions in our T-shirt pilot with cotton from water stressed India had by far the highest ESCU score.

c. Waste.

   The pilot on the circular shoe brought into attention an issue of how to assess purchased materials that already contain recycled materials, in this case polyurethane. In common assessment methods, such specific upstream data are very hard to grasp, but in the Oiconomy system included in the suppliers' ESCU's. The participating company wished to maximize the recycled materials already reworked into its purchased materials, and its own reuse and recyclability, but could not demonstrate all involved flows. It was recognized that the Oiconomy system bases foreground data only on traceable waste flows or demonstrable averages from for instance governmentally organized waste flows, and otherwise assumes "not circular".

   The Oiconomy system recognizes three waste flows: production waste, end-product disposal and use-caused waste (e.g. batteries). For foreground data on recycling, the O.S. divides the upstream ESCU's for recycled production waste between the original and the new product, because the waste-part belongs to the supply chain of the new product that it is processed in. Animal feed, often containing waste flows of human food production, is a good example of the question on how to divide the impact of the common upstream supply chain. Unfortunately, neither in the recycled version of the cotton T-shirt pilot, nor in our pig feed pilot case, the origin of the recycled materials was investigated. We realized that in any LCA, recycled materials, as in the pilots, may easily be considered having a zero upstream supply chain impact. We recognize two possible systems concerning the upstream supply chain of recycled waste:

   1. A part of the ESCU's from the upstream supply chain belongs to the recycled waste. This reasoning especially applies to manufacturing waste, existing from processing virgin materials. Different streams are put into use and value is added. Examples are the different parts of meat from an animal, saw dust for chipboards and MDF boards and glycerol from biodiesel production. The O.S. criterion on manufacturing waste

was adapted to division of upstream ESCU's proportionally to the financial yields of the streams. An advantage of this system for the waste producer is that its upstream ESCU's are allocated to the waste flow. However, the user/buyer of the waste flow, starts with a proportional ESCU value.

2. The ESCU's are zero, because the recycled material replaces virgin material, which would otherwise have carried the total upstream ESCU burden. This reasoning seems the only possible in cases where no division of ESCU's can be made, such as for flows from untraceable disposed products at end of life. However, if companies or cooperation's of companies take end-of life operations in their own hands and put the disposed materials into value, they could benefit from the first system.

Another issue is that recycled material may have lost quality and value, or cannot be recycled indefinitely. In system 1, this value loss will be reflected in the price of the waste, but in system 2 this is more difficult and needs further research and consideration.

Companies' remarks

Companies expressed interest in the system, but also several reasons to be reluctant to adopt the system or to use pressure on suppliers.

- Companies fear that the system will lead to real internalization of ESCU's without an internationally equal playing field. With such equal playing field, the system was found an interesting possibility. Real adoption of the system was not discussed with any company, because of the development stage of the project.
- Companies were already using various systems for measuring and communicating sustainability data, such as the Product Environmental Foot (PEF), Environmental Product Declarations and Product Category Rules. We were advised to join such systems, because coordination and adoption of the Oiconomy system is only possible with the power of legislation or companies with large purchasing power.
- The participating company in our pig feed pilot uses fast changing suppliers, reacting on availability and prices. In addition, supplies of raw materials are often blends of different suppliers or even origins, particularly, but not exclusively, in food-, feed- and energy supply chains. This fast changing and blending complicates traceability and the gathering of foreground data. However, traceability is key to product-sustainability, which means that these sectors will have to make major changes if they wish to demonstrate their sustainability, but that also means that they may be reluctant to use the Oiconomy system.

In practice, various other complex situations exist in supply chains considering ownership, procurement, responsibility for data and transparency. Examples are lease contracts, where use and ownership are separated, e.g. transport means where dealers or lease companies remain ownership, or light in a company with the lamps in ownership of the supplier, or cattle raised at a farm, but in ownership of a meat- or dairy company, mentioned in our pig feed pilot. Some adaptations in the O.S. were made. We learnt that there are so many different relationships concerning the responsibility for product and sustainability, that the only criterion in foreground cases, covering all situations is to require well defined and documented agreements over these between the involved parties in all relationships, aberrant from standard legal situations.

Exposing lack of traceability

In the pilot case of the shoe, a circular version of the shoe was assessed. The company was implementing the C2C principles (Cradle to Cradle Products Innovation Institute, 2020). A major difference between C2C and the Oiconomy system stood out. The C2C standard has requirements on 4 different levels of circularity (Bronze, Silver, Gold and Platinum). A C2C certificate below the platinum stage is based on recycling compatibility, not accounting for the loss of value occurring at recycling materials, and declares a product circular based on demonstration of recycling pathways. Even at platinum circularity, recycling of the technically achievable maximum is accepted without the need to communicate that technical level. The Oiconomy Standard however, considers all streams as litter (the worst condition) for which no traceable destination can be demonstrated (although demonstrable percentages for disposed products are accepted).

High default ESCU values for social and economic aspects

The Oiconomy system is intended to bottom-up transfer sustainability ESCU's through the supply chain, which requires full traceability to the first tier suppliers and customers, including manufacturing waste flows, and aggregated ESCU's on the complete upstream supply chains. In absence of foreground quantitative data, worst case background data are assumed, if the relevant actor cannot demonstrate better data.

In all three pilots, it stood out that this method of assessment results in relatively high scores for background data on socio-economic aspects like child labor and corruption, which is caused by the fact that quantitative background data for most environmental aspects are less location dependent and therefore more often available than data on socio-economic aspects. We consider this effect a justifiable quality of the Oiconomy system, because no sustainability can be demonstrated without traceability. However, in practice and also demonstrated in our pilots, worst cases can be limited by either improve traceability or limit the amount of potential sources by means of input-output databases. Other reason of high ESCU's for social aspects is that labor usually is the most expensive factor contributing to the costs of products.

The concept of "normal use"

The Oiconomy method does not use the concept of the functional unit, because that always is the product as sold to the customer. Instead, end-producers are required to investigate and define "normal use", which is the most common practice of use and disposal of the product. This definition is used at the assessment of the use phase of products, but also in the O.S. sections on transparency and various other sections where impacts, product life, or waste quantities depend on the use of the product. In the pilots of the pig feed and the cotton T-shirt, the "normal use" was defined and described. In the case of the pig feed, in the conceptual understanding of the company and their farmer-customers, the feed is even key for sustainability, affecting the feed efficiency and health of the pigs.

Interesting is that the companies' conceptual argument on sustainability based on the quality and efficiency of the feed is not wrong. Indeed, the less feed is needed per kg. of meat, the lower the ESCU score on these aspects. However, the assessment needs to be comprehensive and the total life cycle ESCU's count. On the negative side, animal welfare could affect the ESCU score. and

in the society, the meat supply chain could be compared with direct human consumption of the vegetable proteins instead of via pigs. But on the positive side, the feed may contain inedible waste flows of human food.

In the case of the T-shirt, the "normal use" determined the amount of washes and the T-shirt's product life, as belongs to the intention of the definition. However, because the use-phase was not included in these pilots, the calculation of ESCU's for the use phase were not tested.

The origin-cut-off point and supplier inventory

Because the Oiconomy system is intended for the comparable assessment of product sustainability, a common origin-cut-off point is required. Before the pilots, the O.S. had set this point on the stage where the supplier contribution, both in weight and value numbers is lower than 20% (see section 2.5.3). In the T-shirt pilot, gathering background data, a cotton farm was assumed to be the origin-cut-off point, although the costs of fertilizers, seed and chemicals are close to and possibly in some cases over 20% (Foreman, 2012). But in cases where the ginning process is an external service to the farm, the supplier contribution raises to about 40%, which according to the O.S. required to set the cut-off point further upstream. Here, it was discovered that the origin cut-off point may depended on how a business is organized, in this case depending on the either or inclusion of outsourcing of the ginning at farm level. This shortcoming was corrected in the O.S., by means of extra rules for outsourced activities under ownership or responsibility of the unfinished product.

The supply chain impact diagram (SCID) - inventory

The "SCID list" is a method, introduced by the O.S. to determine the inventory of purchased tangible materials and non-tangible services that require upstream assessment. It selects the top 80% items by their purchased financial contribution to the product, including both tangible materials and intangible services. It prevents companies the burden of assessment of minor contributors, except for high impact items that always need to be included. The outcome is a 'SCID-list', which is used to create a *S*upply *C*hain *I*mpact *D*iagram and to provide the inventory of the purchased items and related suppliers that need to be included in the upstream assessment. By the pilots, some ambiguities and inconsistences in the O.S. were discovered and corrected. Originally, the O.S. selected the top 80% items on the SCID list by their share of the *products' turnover*. Due to remarks by a researching student, this was changed into their share of the total *purchased value* in order to avoid effects of the products' margin.

Capital goods

A student researcher argued that the Oiconomy system is not really comprehensive if capital goods such as buildings are not included. To date, no method for that purpose is available and it is questionable if one can be developed for existing capital goods, because their creation was in the past and the involved suppliers may not exist anymore. The O.S. was adapted in section 12.6.3, preliminarily exempting capital goods from upstream ESCU allocations, however with an exemption on this exemption for equipment especially intended for sustainability, because in that case, the life cycle of capital goods is too important for the assessment of their effectivity.

Frischknecht *et al.*, 2007 studied the share of impacts caused by capital goods, resulting in a high variation of share, depending on the industry sector and environmental aspect. For several aspect/sector combinations, Frischknecht et al. found the impact-based share "major". Therefore, there is good reason for research on the share of ESCU's for capital goods.

Consequences of Preventative Costs based allocations

Whenever ESCU's have to be divided over several products, e.g. for services, capital goods, waste treatment, land occupation, water use and personnel, the O.S. allocation method is proportional to the product's share to the turnover or equal to organization's financial allocation methods. One researcher in our pilots, confronted with this criterion, argued that turnovers are volatile, which is also mentioned as weakness of economic allocations by Goedkoop et al., 2015, p.13, who discuss the various allocation possibilities with strengths and weaknesses. For socio-economic aspects, added value would be a better option, because usually labor is the highest contributing factor to the added value, but for environmental aspects, the material flow is usually the most determining factor.

In our opinion, financial allocation is the best allocation for the Oiconomy system, because:

- The O.S. is totally based on financial data.
- Financial allocation expresses the relative importance of the different products, also mentioned by Goedkoop *et al.*, 2015.
- A good way to distinguish waste from product output, also mentioned by Goedkoop et al.
- Purchased ratio's and upstream ESCU's change parallel to turnovers.
- The O.S. is not intended for a one-time life cycle assessment, but for yearly assessment, together with financial reporting.
- Division equal to organization financial allocation methods or proportionally to turnovers is the best way to avoid greenwashing ESCU's away to less important products.

Deciding between the two financial options of turnover and added value is a choice, which however must be made for a uniform assessment. We have chosen for the turnover, because that requires the least calculations and effort.

7.3.4. SUSTAINABILITY ASPECTS

Climate change and Other pollution related aspects

The O.S. does not exactly use the common categorization by impact midpoints because in the Oiconomy system, not the impact but the costs of prevention are the leading indicator and O.S. is meant as a standard and guide for the supply chain actors themselves and specially to lead them to assessment of their own foreground or background ESCU's. The O.S. wants to lead the actors to self- understand the issues that they are responsible for and lead them to calculate the ESCU's and to preventative measures in an equal manner that they do for their normal operations. In the O.S., the impact midpoint category of "climate change", belongs to the subcategory of "emission of bulk gasses" within the category of "pollution". It is the emission of these gasses that should be prevented.

The aspect category of pollution consists of 5 subcategories:

A. Air Pollution by the emission of bulk gasses, (i.e. GHG's).
B. Pollution of land or water by agricultural practices, not easily measurable, which are best prevented by best practices, and best measured by the level of governance.
C. Pollution of air, land or water, with measurable quantities of harmful substances.
D. Heat pollution.
E. Potential pollution by incident-caused emissions of any type.

The ESCU's for Climate Change are part of type A pollution and are determined by data on energy use (electricity, gas and coal), and the transport of goods and people. For the emissions for power generation, country electricity-specific carbon factors (kg. CO_2/kWh) are used, listed in the Oiconomy database and derived from Brander et al., 2011.

Most of the foreground data and ESCU calculations, following the instructions of the O.S. for the aspect of climate change were obtained without difficulties. ESCU's for transport of goods were based on the assumed locations of the different cotton growing areas and manufacturing. Data on commuting distances of personnel, also required by the O.S., were not available from our participating companies, because the companies were not prepared to collect and document these, but surprisingly, one of the questioned suppliers was prepared.

The student researcher in the T-shirt pilot did not take into account the emissions from the cotton fields, although these are significant. This was caused by the afore-described incomplete (but thereafter corrected) definition of the origin cut-off point in the O.S. Also added to the O.S. was a citation to a calculation tool for background emission data especially for agricultural products at (Cool Farm Alliance, 2019). This and other databases should be assessed on their suitability for default background data. In addition, we recommend to make a survey of other potentially useful databases for background data.

The O.S. distinguishes two types of chemical pollution: type B: agricultural pollution, best prevented by good practices and best measured by the level of governance, for which a method was developed and described in chapter 5, and type C: Measurable quantities of pollution. Unfortunately, in our pilots, no tests could be executed on measuring the governance level of an organization. Although auditing governance quality is standard operation in various common standards, and the developed method uses the same yes/no criteria to score, a test still needs to be executed. In our pilots, an example of type B pollution would have been eutrophication by the use of nutrients in cotton cultivation for which it is difficult to determine how much remains in the soil and groundwater.

Type C polluting chemicals are emitted during the dyeing and printing at the manufacturing phase of a cotton T-shirt and measurable amounts of pesticides. The involved companies in our pilot could not provide foreground data on measured emissions, indicating that active measurement of chemical emissions is not common yet, which sustains the need of a system like the Oiconomy system that directs companies towards self-assessment. Lacking foreground data, background data were used, based on an earlier LCA (Roos, Sandin, et al., 2015). Here we notice one of the disadvantages of the use of background data in the EcoCost system and the lack of knowledge on the potential specific preventative measures in a particular case. In the EcoCost system, the EcoCosts for the different impacts of emission of a chemical are

aggregated, e.g. climate, depletion, acidification, eco-toxicity and human toxicity. In practice, in specific cases, several of these impacts may be prevented by one and the same preventative measure, a possibility that the O.S. specifically provides a correction for.

Depletion of Water

Our pilot on 4 versions of a cotton T-shirt with different cotton sources clearly demonstrated that water depletion certainly is one of the most expensive issues to avoid.

As cotton cultivation requires high water quantities and is typically grown in hot and dry areas, water depletion was the largest contributor to the ESCU's for a cotton T-shirt. As before-mentioned, the sustainability of cotton as measured according to the O.S., heavily depends on local scarcity and distance to water resources, because the marginal preventative measure against water depletion is the expensive replenishment with seawater desalinated water.

Especially striking was that the version fabricated of organic cotton from India, in peoples' perception the most sustainable version, had a much higher ESCU score for environmental aspects than the conventional version made of conventional cotton from the USA. This is caused by the much higher water scarcity factor, distance from the sea and elevation of the cotton growing area in India than in the USA, and in addition, a much more carbon intensive power mix in India.

Fair Wages

The O.S. makes a distinction between legally set minimum wages and actual fair minimum wages, as "not all legal minimum wages are also fair wages". The ESCUs are determined by the cost-distance between the fair minimum wage (see chapter 4) and the lower actual wage.

In our cotton T-shirt pilot, the cost-distance to the fair minimum wage could be verified in the Netherlands and the first tier manufacturer in Turkey, both resulting in zero ESCU's. No actual wages could be assessed at further upstream suppliers and assumptions were made. For the wages of manual workers, the legal minimum wages in the involved countries were used and for the quantity of hours, from literature (e.g. Viotti, 2015) provided yields per workhour for activities like cotton picking in low income countries, the quantitative factor could be roughly determined. With data available, the ESCU calculations proved simple. Like with any S-LCA, collection of the precise data is the limiting factor. However, in the envisioned fully operational Oiconomy system, where companies are certified, it should be quite possible to verify the actual paid wages. In our cotton T-shirt pilot, an assumption of equal labor intensity in cotton harvesting in the USA and India caused a striking but correct much higher allocation of ESCU's in the USA, which was already discussed before. This finding also emphasizes the need for a product- and location specific assessment method. Also demonstrated here is the unique dynamic character of our described method of setting an absolute fair minimum wage (FMW) for low income countries and a relative FMW for middle- and high income countries instead of assuming that all minimum wages outside of the really poor countries are fair.

Child Labor

Child labor is one of the most difficult aspects to assess. Therefore, the O.S. defines two different situations: 1. Solid proof of absence of child labor, with a prescribed choice of accepted

evidences and a list of countries that may be considered free of child labor; 2. Initially, without such evidence, child labor is assumed and a method of calculation of the ESCU's prescribed, assuming that all manual work is child labor. The pilot showed that this assumption was seriously unfair for companies in countries that are underway to eliminate child labor relative to countries with high labor engagement of children. Therefore, in the O.S., the assumed total amount of labor was reduced by multiplication by the Human Development Index for the country, doing right to the stage of development of the country.

Subject for research is to replace this by an indicator specifically on child labor. Data on the percentage of children engaged in child labor are available (e.g. at www.nationmaster.com), but no properly developed indicator.

Further improvements may be possible, for instance considering industry sector- and regional dependent data from the Social Hotspot database (Benoît Norris *et al.*, 2020).

In our T-shirt pilot, evidence was demonstrated for the organizations in the Netherlands and the first tier supplier in Turkey and for conventional cotton and better cotton farms in the USA and Australia. However, the O.S. did not yet include a complete list of approved certificates, including that child labor is prohibited in organic agriculture. Therefore, erratically, for organic cotton in India, a country with 12% of children engaged in child labor (Unicef, 2018), ESCU's were determined. The omission on the O.S. was corrected. But by making background ESCU calculations, based on external data on the workhours for spinning (Viotti, 2015), discovered was that calculating ESCU's for both unfair wages and for child labor, causes a case of double counting, because ESCU's are allocated for the same workhour twice, both based on the same PRP. The O.S. was corrected for this effect. Still required is a complete survey of certification standards and included aspects that could be approved for the Oiconomy system.

Fair Transactions

The responsible organization takes into account not only the interests of its employees and customers, but also of its low developed suppliers (LDS). In the T-shirt pilot, background data on this aspect on cotton cultivation was assessed. In Australia and the U.S., this risk of underpayment of an LDS is less apparent, as cotton is mostly produced by large cotton farms (Foreman, 2012; Cotton Australia, 2018). But in India, cotton cultivation is mainly practiced by smallholders, with a clear risk of underpayment (Grosscurt, C. et al. 2016). Therefore, the ESCUs, as the extra costs necessary to guarantee the LDS and its workers a fair income, were calculated for our cotton T-shirt pilot as in the same way that ESCUs are calculated for the aspect of fair wages, using background data on yield per hour and assumptions on actual incomes per hour. As expected, this proved perfectly possible. However, not included yet was the feasibility of determining foreground data by actual testing the amount of labor at an LDS. Not yet included in the O.S. is an assessment of to be approved certification standards, such as on organic agriculture, including criteria on fair wages and fair trade, that cover the O.S. criteria.

7.3.5. DISCUSSION AND CONCLUSIONS

Our pilots demonstrated that the Oiconomy system performs best as intended, building up in the supply chain from aggregated standardized foreground data and then provide unique opportunities to demonstrate specific conditions and progress in sustainability.

Positive was that assessment instructions and criteria of the Oiconomy Standard and – Database proved understandable and workable to follow, although some remarks were made on the need or wish for simpler questionnaires. The researchers in the pilots were students in the master program, which have good understanding of sustainability aspects, but no practical experience in a company. Common standards often require qualified or trained personnel on for instance quality, food safety and occupational health and safety. Both will undoubtedly be necessary for the Oiconomy system, but exact knowledge and experience requirements depend on the size and complexity of the company, product and involved risks.

The degree of details in the standard shows a tension between the willingness to comprehensively read the standard and the risk of misunderstanding. For complex organizations, qualified personnel is required. For less developed organizations, simple questionnaires and guidance documents are required.

The system provides accessible and easy to understand price factors for most sustainability aspects, for environmental aspects provided by the EcoCost system and for social and economic aspects determined in this thesis. However, default values for quantitative factors are not always available and had to be collected from either the EcoCost system, earlier LCA's or from external databases. An instruction of which databases to use and how to search these was requested and should be a subject for future improvement of the O.S.

The pilots demonstrated that the Oiconomy system performs well in exposing location- and company dependent issues, enabling supply chain actors to demonstrate their progress in sustainability and tailor their choice of supply chains. While this is for foreground data no surprise, the systems also proves sensitive to every increase of granularity in background data.

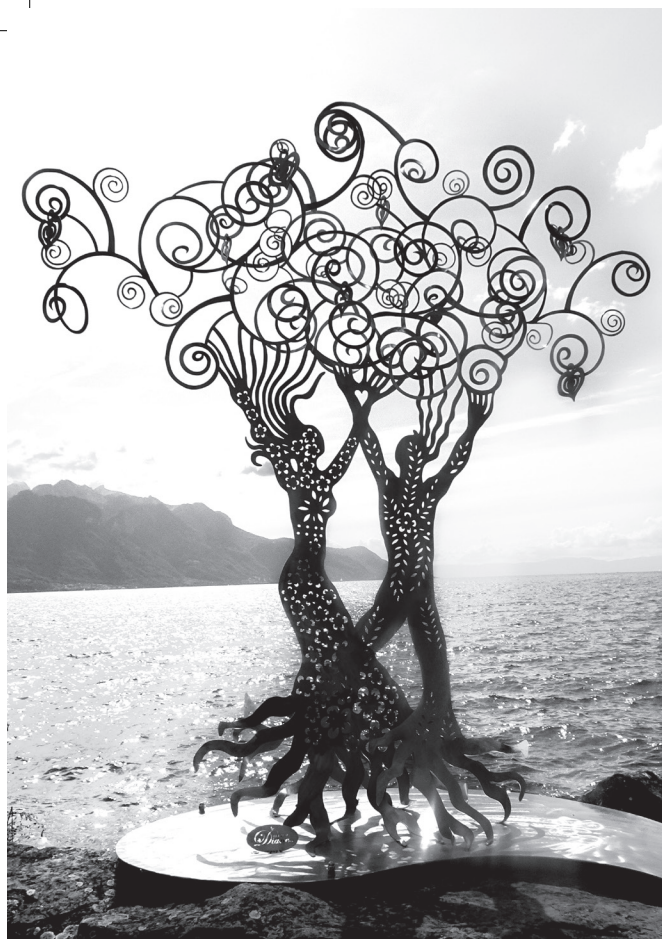
Considering the character of the results of an Oiconomy Standard based assessment, four features stood out from the pilots: 1. The probable need of the power of governments or companies with great purchasing power to be widely adopted. 2. The high sensitivity to local conditions caused by the use of country specific data. 3. The sensitivity to the income- and price level of countries, which is a logic consequence of a cost based indicator. 4. The consideration of relative poverty at the aspect of fair wages, which leads to ESCU allocations for wages in high income countries with fair minimum wage deficit in their legal minimum wage.

Local differences in risks are extra exposed by the Oiconomy system if no foreground data are available. For default values, without demonstration of a measurement and without traceability, worst cases must be assumed. This effect belongs to the character of the Oiconomy system, challenging companies to self-assessments, and can always be avoided by providing verified foreground data. Our pilots demonstrated that this effect is especially large in middle income countries where the income has risen, but issues like child labor and corruption are not completely eradicated. The Oiconomy standard was adapted to remove this effect for the aspect of child labor, but not for corruption.

Another important characteristic of the Oiconomy system, that really showed in the pilots, is that the system does not assess sustainability by its impact, but by the costs to avoid impact. This showed for instance that water depletion in a drought plagued country with high distance to the sea, the ESCU's for water depletion may be higher than for issues like child labor, by many considered worse than water depletion.

The pilots revealed various shortcomings and ambiguities in the Oiconomy Standard, which

were corrected and described in this chapter. Further adaptations to the standard, questionnaire and database should gradually be made depending on arising experiences and questions. The main demonstrated challenge, is the lack of willingness.at least in the pilot stage, to use purchasing power on suppliers to cooperate with the system.



In a sustainable economy, capital is used for investments; not for fast money

Without major changes on the consumption side, land will be short to both feed the world and maintain biodiversity.

CHAPTER 8

DISCUSSION AND OUTLOOK

8.1. METHODOLOGICAL REFLECTIONS

8.1.1. METHODOLOGICAL DEVELOPMENT AND FEATURES

Considering the methodology (sub-goal no.1 described in section 1.8), we distinguish the developed *methodologies* for the assessment of the sustainability of specific products (figure 1.3, box B), and for the determination of performance reference points and assessment social aspects, and the provided *methods* for sustainability measurement (figure 1.3, box C and D). The methodology is intended to be used for further improvement and maintenance of the system or extend it by studies on yet uncovered sustainability aspects, or by businesses to create price factors for more precise aspect-subcategories. The methods are the tools intended for supply chain actors, calculating ESCU's.

The methodology for the Oiconomy system gradually developed during the project. The key characteristics of the system are depicted in figure 1.3, box A. The first and most important four steps were: First, the decision to use preventative costs as indicator for (un)sustainability instead of impact-based indicators. Second, the introduction of standardized measurement of (un)sustainability. Third, the bottom-up transfer of data through the supply chain by means of a standard. Fourth, the adoption of the EcoCost methodology (Vogtländer, 2001) of using marginal preventative costs for the default values. However, there are three major differences between the EcoCosts- and Oiconomy systems:

1. EcoCosts are basically meant for top-down life cycle assessments, mostly based on background data. The Oiconomy system is intended to be executed bottom-up by transfer of foreground data through the supply chain, and uses the EcoCost system where no foreground data are available.
2. EcoCosts are calculated as the costs of mitigating the impact characterized by the leading indicator for the aspect, compensating the impact by the actual cause. This is a practical way, because it is applicable in top-down assessment without knowledge of the endless number of specific foreground situations. But it must be realized that for other than the leading indicator-cause itself, EcoCosts represent compensating costs instead of the preventative costs (e.g. the impact of methane emission is calculated as compensating the impact by mitigation of CO_2 emissions). The Oiconomy system gratefully uses the same method for background default values, but is built as criteria and instructions for the supply chain players for foreground assessment challenging and enabling the actors to calculate the costs of prevention for the specific impacting indicator in the specific situation.
3. Especially considering social and economic aspects, the difference described in point 2 also has methodological consequences. A good example of the methodological difference is found in the assessment of occupational health and safety (OHS). The EcoCost methodology approaches the issue by means of the DALY, an impact-based indicator, and assumptions on the acceptable costs of saving a human life year (Van der Velden and Vogtländer, 2017), where the Oiconomy methodology rather approaches the issue by the costs that companies need for optimal OHS governance and assessment of the governance quality of the company as an indicator to the distance to optimal OHS governance.

For the Oiconomy system, at the start of the project, it was decided to stay as close as possible to preventative costs as indicator and to instructive criteria enabling self-assessment by the

supply chain actors (sub-goal 2). This was accomplished, although for some aspects, it proved necessary to widen the concept of "preventative costs" with the financial burden of avoiding the impacting activity or accepting a lower yield. The elaborated example, described in chapter 5, is the aspect of corruption, for which discontinuing the corruption related activity or abandoning the country, and the consequential loss of earnings, was defined as the marginal preventative measure.

Another change that was made during the project was that originally, the authors intended to only transfer one total ESCU value through the supply chain. However, during the project this was changed to transfer of ESCU's for the 10 different aspect categories defined in the Oiconomy Standard (see fig. 2.2). Main reason is that presenting only one comprehensive value would lead to an indicator of weak sustainability that could hide critical issues, and is insufficiently transparent and informative for other actors in the supply chain.

For every ESCU value, a quantitative- and a price factor is required. The quantitative factor is preferably determined by the supply chain actors themselves, e.g. by means of verifiable investment proposals. The challenge to do so and thereby provide the customer with a kind of quotation for the sustainable version, is a clear opportunity of using the Oiconomy system. It is the first logical step towards sustainable products, enables transaction partners to communicate and negotiate price and sustainability in a similar economic way, and provides transaction partners and society with an economic measure of the distance to sustainability and thus with a tool to determine and decide on the most efficient route to sustainability. Without such foreground quantitative factors, the actors should use default data. A database with default price factors for environmental aspects was already available in the EcoCost system, which was gratefully used in the Oiconomy system. The EcoCost system also provides a database with EcoCosts for materials and activities, consisting of price factors multiplied by default quantitative factors, aggregated for the various environmental aspects. These however, are not referred to in the Oiconomy Standard for the following reasons: 1. The Oiconomy system is primarily intended for industry to self-calculate the own foreground preventative costs and self- investigate the quantitative factors. 2. The pre-aggregated EcoCosts may in foreground situations include some double counting in case that one measure mitigates impacts on several aspects (e.g. climate change and depletion of mineral energy resources).

Because our pilots showed that without external force, companies are yet ill-prepared to comprehensively study the preventative costs, it has been tempting to include in the project the development of methods for the determination of quantitative default values for social and economic aspects, which yet proved too difficult. E.g. data on aspects like the specific income inequality, paid wages and amount of child labor are highly company- or even product-specific. Adding this to common lack of traceability, high uncertainty of such data is unavoidable. However, various public databases and published life cycle assessments are available, such as input-output databases (e.g. Exiobase Consortium, 2015; WIOD, 2020) and hotspot databases (e.g. Benoît Norris *et al.*, 2020) to get some indication of the worst case supply chain aspect's magnitude. There is some recent development that may be useful for this purpose in a paper by Hall, 2019.

Because in absence of foreground data, background based ESCU's are allocated, calculated as the marginal preventative costs multiplied by a worst case quantitative scenario, not including internal benefits, in most cases, companies will be able to find measures against lower

foreground costs than the default values, which presents an extra challenge to self-research realistic preventative costs. The price factor is determined by the preventative cost-based distance per unit of the aspect to a performance reference point, which is preferably determined by international conventions. However, not all aspects are covered by conventions. Important key definitions were lacking, e.g. "what is a *fair* wage" and "what is *fair* income inequality", the determination of which became a major challenge for this thesis. Therefore, one very important addition was to use the average ways of the top 20% performing countries as reference point for issues without well-defined available and recognized reference points. For the determination of the countries belonging to this group, available indicators and indices were assessed on a number of criteria and the Sustainable Society Index selected (Van de Kerk and Manuel, 2007). This assessment is described in section 3.1 of this thesis. The choice of 20% is based on the in this case wishful 80-20 rule that the top 20% show the way for the other 80%. However, the method of using a percentage of top performers as benchmark proved feasible. Also with other choices of the percentages, because of the wide variety of available country level data, e.g. from the World Bank, CIA, IMF, Transparency International and Wage Indicator.

In addition, there are socio-economic aspects without any possibility of precise quantification, such as corruption or aspects better defined by the quality of precautionary governance than by impacts, such as occupational health and safety. For this purpose, a quantification of the quality of companies' governance on the aspect was developed, derived from earlier work by Dreyer et al., 2010 and the criteria of Plan-Do-Check-Act based good governance, assuming a linear relationship between the obtained governance indicator and the preventative costs. In reality, this relationship probably is not linear.

Another remark on the methodology and the rules for the determination of the marginal preventative costs has to be made about the listing of all preventative measures and sorting these by costs, a method obtained from the EcoCost System (Vogtländer and Bijma, 2000). In this research, this proved not workable to be exactly followed for social aspects. However, for the aspects, studied in this thesis, it proved possible to determine the marginal preventative cost, still using the original principle, but making literature supported shortcuts to the obvious most expensive major preventative measures without detailed listing and investigating all measures. E.g. for the aspect of fair wages, the obvious marginal measure is to pay every worker at least the fair minimum wage and for corruption to leave the corrupt country and abandon the corruptly obtained profit.

Summarizing, the developed Oiconomy methodology consists of five combined parts: 1. The use of standardized measurement, bookkeeping and transfer of preventative costs through the supply chain, 2. Marginal preventative costs for the default values, 3. Use as performance reference points of scientific no-effect levels and international conventions where these are available, and without such availability the average of the top 20% performers, 4. Governance quality as quantitative indicator when no more precise indicator is available. 5. Inclusion of the possibility to update default values based on data from certified supply chain actors (see also figure 1.3. boxes A and B).

This means that the foundation of the Oiconomy system as means for the determination and aggregated transfer of foreground sustainability data through the supply chain has been established including the required methodology for further additions and continuous

improvement. Pending research needs on sustainability aspects are discussed in section 8.4 and certification requirements in section 8.5.

8.1.2. VALUE CHOICES

The Oiconomy methodology is in our opinion the most objective sustainability product-assessment methodology possible. Because at correct and comprehensive use of the Oiconomy System, the measurements and system boundaries are standardized, measured by costs, and the data independently verified, the results of the assessment are not affected by practitioners. However, some choices have been made in the development stage of the system. Eight major choices have been made, used throughout the system. Although some of these may seem rather obvious, they remain choices. The first major choice is the assessment by preventative costs. Although this avoids any discussion on the urgency or materiality of an aspect, it is a choice in itself with the consequence that one cannot assess the impact and its importance by the calculation of ESCU's. Another consequence is that impact-wise all aspects are equally important which in some cases may lead to high scores for in some peoples' opinion unimportant aspects. On the other side, ESCU's may lead to materiality by costs and to the cost-wise most efficient route to sustainability. And a third consequence, as was shown in our pilot described in chapter 7, is that externalities occurring in high income countries may result in higher ESCU scores than in low income countries. Besides, the United Nations declare all SDG's important without any preference (United Nations General Assembly, 2015).

The second major choice, used in the methodology was made for setting targets for social issues without an agreed performance reference point. Developing scientifically sound and objective targets for social aspects, in principle a political responsibility, we chose to use the average politically chosen ways of the 20% best performing countries. The choice of 20% is the wishful use of the 80/20 rule where in this case the 20% best performers show the ways for all. Which countries belong to the best performers was objectively determined by the assessment of available indexes, described in chapter 3.

The third major choice was to be comprehensive. In the introduction, section 1.2 of this thesis, we show that comprehensiveness is a need without which no real sustainability can be accomplished. However, it is of course debatable if that applies to all aspects included in the very comprehensive Oiconomy Standard. In one particular case, the matter of land use, this choice lead the authors to correct earlier LCA-methods, one-sidedly focused on biodiversity and denying food needs of future generations (see section 8.4.2). But a similar interdependence applies to other issues. To name one: Plastics pollute the seas and emit carbon during their production, but simultaneously are very important for food supply and – safety and hygiene and health care. Important for a consistent methodology, is that we do not choose to assess aspects like food supply and food safety as positive impacts, but the lack of providing food and securing food safety as a negative impact. The motivations for this choice are extensively described in chapter 6.

The fourth major choice was to consider issues like unfair wages, child labor, unlimited inequality, unsafe labor conditions as unsustainable, but also that is debatable. Because in capitalism, labor intensive industries like the apparel sector, continuously seek the cheapest labor, some countries raised themselves out of poverty disregarding underpayment, appalling labor conditions and huge pollution. Although other countries remain in poverty despite of

offering the same conditions, one may question if for instance China could have developed itself without submitting a generation of people to conditions, which are called "unsustainable" in this thesis. On inequality we also realize that many of the most admired touristic places were created by the super-rich few, and exploitation of the many. However, the Brundtland declaration states: "Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own". In this thesis, answering to the principles of sustainable development, the SDG's and the goals that we have set in section 1.8, we have chosen to interpret this as that both the needs of current generations may not harm those of future generations, but also current generations may not suffer for the needs of the future.

The fifth major choice was made in chapter 5, where for aspects that are best measured by the level of governance, this governance level as measured by the developed method is assumed to have a linear relationship with the preventative costs, which may not be correct.

The sixth major choice, described in chapter 2, was to set the cut-off point of details for which upstream supply chains to be assessed at 80% of the purchased value and to set the origin-cut-off point on that point where both added weight and added value are over 80% and to cut-off supplier assessments at 80% of the purchased value. After considerable practice with the system has been obtained, the exact percentages may have to be adjusted to accomplish its goal to on one side include all relevant externalities and on the other side avoid vicious circles without a defined cut-off point. Based on our pilots, for nutrients and pesticides in agriculture and for chemicals used for mining, the cut-off point was already set back to the manufacturing of the individual chemicals.

The seventh major choice, discussed in section 2.6.5, was to base ESCU calculations on market price levels of preventative costs in a world of great spatial price differences, wherever the costs are made. Foreground data will always be based on local market prices. However, EcoCosts, and therefore the environmental default values in the Oiconomy Database, are mainly based on European prevention costs (Vogtländer *et al.*, 2002). An important feature of the Oiconomy system is however, that the practitioners have the opportunity and are encouraged to correct these with their verified own foreground local prevention costs.

The eighth major choice is the choice of the financial turnover as share-factor for dividing ESCU's over several products where no more specific foreground division data are available. Other possibilities are for instance to weight by impact or by added value. The limited objectivity of any choice of the share factor was discussed in section 5.3.3.

Next to these eight major choices, a large number of preliminary minor choices were made in the O.S. Common characteristic of these choices is that they can and should be discussed based on stakeholder consultation, without methodological consequences. Examples if such choices are the maximum temporal scope in years for the use of products, an extra minimum payment target in percentages for overwork and for company payment of health insurance, etc.

8.2. THE OICONOMY STANDARD AND -DATABASE

Central in the Oiconomy system is the Oiconomy Standard (O.S.) (Croes, 2020b), which serves three of the main goals of the Oiconomy project: First, to standardize the verifiable measurements and transfer of data throughout the supply chain of products (sub-goals 2; 5).

Second, to enable comprehensiveness (sub-goal 3) of the assessment, and third, to challenge companies to self-research preventative measures and -costs (sub-goal 5). The O.S. was inspired by HACCP- and various ISO standards, but instead of criteria on the status of aspects, the O.S. contains criteria on the collection and measurement of the aspects and for transfer of data. The O.S. is a preliminary standard until it is accepted by an accreditation body as a certifiable standard and will probably need adaptations for that purpose. The O.S. comprises all aspects covered in the SDG's, ISO 26000 and the GRI and some additional aspects from NGO's, e.g. the Sustainable Finance lab (Sustainable Finance Lab, 2015). Gradually, the different aspects were studied, price factors determined and described in this thesis, and the O.S. further developed and adapted where necessary.

The Delft University provides a database for environmental aspects (Delft University of Technology, 2019), which with a few exceptions were included in the Oiconomy Database.

Also the Oiconomy Database was gradually developed and improved with the new data and insights obtained from the executed studies. For most aspects that were not covered by in depth studies, preliminary values were included in the Oiconomy Database, with reference to sources.

Aspects like income inequality and corruption, but also traceability and foreground data in general are easily considered hard or even impossible to assess (e.g. Van der Velden and Vogtländer, 2017), partly because of the sensitivity of the data. But, as argued in the section 1.1, minor changes are not enough for a transition to a sustainable economy. Core businesses will have to be changed and transparency and traceability will need to become prerequisites of trust and sustainability.

Main principle of certification is to obtain *trust* by means of verification and reversal of the burden of proof (see figures 1.3, box A). The supply chain actor shall be able to demonstrate data and reliable and trustworthy measurements according to the criteria of the standard. Without such demonstration, default price factors are used and multiplied by worst case quantitative factors. For environmental aspects, default price factors are available as EcoCosts (Delft University of Technology, 2019), also used in the Oiconomy database (Croes, 2020a), equal to the marginal preventative costs. For social and economic aspects, we have been able to provide the price factors for some aspects, but no complete set of ESCU's for materials, activities or products, because of the lack or low granularity of data. But the Oiconomy system was also developed to enable the Oiconomy Database to become self-learning by feeding and improving it with anonymized data, trustworthy because of the certification and resulting from industrial cooperation. An example of an already existing self-learning database filled by and for the apparel industry is the Higg index (Sustainable Apparel Coalition, 2017).

The O.S. does not follow the LCA-common categorization by midpoints and endpoints. For instance, the aspect of climate change is categorized under "pollution", subcategorized to measurability and cause. Another example is that the O.S. recognizes three practical origins of waste: manufacturing, the product-use phase and the product-disposal phase. Reason is that the common categorization as used in LCA is impact-based, while the Oiconomy system focusses on measurements and calculation instructions, which may be different for the various causes of emissions or for industry sectors. Compliance to the Oiconomy Standard leads to a bookkeeping system of externalities expressed by the monetary indicator of ESCU's (see fig. 2.2), representing preventative costs instead of to a report on impacts, and challenges industries

to study preventative measures and costs in order to make the next step of implementation.

The current Oiconomy Database consists of default data representing the marginal preventative costs based price factors with currently an unknown deviation from the exact prices for the sustainable specific product. ESCU's do not include margins, while in practice margins may be added. But on the other side, ESCU's do also not include the internal financial benefits of the preventative measures. Because usually, restoration or adaptation is much more expensive than prevention, in the long term, the costs of inaction for the society as a whole will undoubtedly be considerably higher than the costs of action, (e.g. Stern, 2007, p.2, Nkonya *et al.*, 2012, p.6,7; Brown et al. 2012) which may also be expected to be partially translated to lower taxes for industry in a situation of action. However, because by definition, the costs of externalities are borne by others than the transaction partners, the results per company or product depend on the magnitude and involved aspects of their caused or embedded externalities. In addition, it is likely that preventative sustainability actions will also result in direct internal cost savings, such as by less waste, lower energy costs, better qualified and motivated personnel, lower accident rates and - sick leave (see also section 2.5.5).

Our third sub-goal as stated in section 1.8, of enabling balanced comprehensive assessment of all aspects named in the SDG's, GRI and ISO 26000 was also achieved. Important for this goal is especially the choice of preventative costs as determining indicator for the ESCU's. This monetary indicator is aggregable both within and between aspects and within the complete supply chain; it is objective and does not need weighting. The certification aspect of the methodology potentially allows for full comprehensive inclusion of the company dependent socio-economic aspects. Depending on the number of contributing participants, the methodology also allows for continuous creation and improvement of data. Because aspects on all three PPP sustainability pillars are expressed by the costs distance to the targets, the ESCU's provide a balanced and objective sustainability indicator. Comprehensive ESCU's provide a B2B tool for supply chain actors to together determine the most efficient way to sustainability. However, ESCU's do not provide any assessment of materiality, and leaves that to the supply chain actors themselves.

8.3. PERFORMANCE REFERENCE POINTS AND METHODS FOR SOCIO-ECONOMIC ASPECTS

Already at the start of the project, it became clear that the EcoCost system provides a database on marginal preventative costs, based on scientifically defined targets, but that such performance reference points (PRP's) for important social and economic aspects were at best expressed in vague wordings in international conventions, unfit for quantitative determination of a preventative cost distance to the target. For a really comprehensive assessment methodology, there was a need for well-defined PRP's and assessment methods for the most important social and economic aspects. The authors' ambitious goal was to at least study the possibilities for the aspects of: A fair Wage, Child Labor, Fair Income Inequality, Corruption, Occupational Health and Safety and Responsible Finance (sub-goal 6). During the project, methods and PRP's were developed and published for the aspects of a Fair wage and Child Labor (chapter 4), Fair Income Inequality (chapter 3) and Corruption (chapter 5). Because the O.S. already included a section on positive contributions (Croes, 2020b, section 12.7) and during the project, the S-LCA community gradually moved towards in our opinion unorganized and sometimes doubtful

inclusion of the assessment of positive impacts, we submitted an article on the implications of this inclusion in S-LCA, while applying the results of the study in the O.S.

A preparatory study was executed by M.Sc. student Allers on Occupational Health and Safety, resulting in a preliminary method for the measurement of ESCU's for the aspect, which was shortly discussed in section 8.4.4. So far, no in depth study was executed on responsible finance. Some preliminary thoughts about the aspect are discussed in section 8.4.5.

8.4. A PREVIEW ON UNDERSTUDIED ASPECTS AND RESEARCH NEEDS

Not all sustainability aspects listed in section 2.5.1 and appendix 2 were covered yet by an in depth study. This section describes the preliminary data, assessment methods and research needs on yet insufficiently investigated sustainability aspects.

In our opinion, the most important aspects, still to cover are: Fresh water depletion, Land use, Fair Transactions, Occupational Health and Safety, and Sustainable Finance. Land use is mentioned because in our opinion, current LCA methodology on land use, including the EcoCost system (Vogtländer, 2001), is unbalanced on the aspect. A short discussion on the aspect of fresh water depletion is included, although covered by the EcoCost method, in order to make the assessment more suitable for self-calculation and to value local conditions.

Not discussed in this thesis are other environmental sustainability and of waste and circularity for which' aspects we thankfully use the EcoCosts, although these are approached in a somewhat different way via the criteria of the Oiconomy standard.

8.4.1. FRESH WATER DEPLETION

There is consensus in the scientific community that an indicator on water use should depend on the local scarcity (Pfister *et al.*, 2017; Boulay *et al.*, 2018). One of the most used water scarcity indicators is the consumption/discharge ratio. In addition, the Aqueduct Atlas (WRI, 2019) provides globally complete access to this ratio with high granularity. For ESCU calculations on water depletion, the O.S. uses the formula:

ESCU's = Max{(BWD-0.1) x Q x (WDC+CT),0},

representing the costs of desalination of seawater and transport to the location of need, both with renewable energy, which is the marginal preventative measure for avoiding fresh water depletion (Delft University of Technology, 2019).

BWD is the Baseline Water Depletion in the Aqueduct Atlas (WRI, 2019) and Q the quantity of extracted water. WDC is the Sea-Water Desalination Costs with renewable energy. CT is the Costs of Transport (pumping) of the water from sea to the location with renewable energy, depending on horizontal and vertical distance (Zhou and Tol, 2005). The deduction from BWD of 0.1 in the formula is used because water is not considered scarce at a consumption/discharge ratio below 10% (Frischknecht and Büsser Knöpfel, 2013, p.178; Vorosmarty *et al.*, 2000, p.285; Roos *et al.*, 2015), although others use "below 20%" (Damkjaer and Taylor, 2017). BWD represents consumed water, excluding water that is returned to its source.

Vogtländer already determined that seawater desalination represents the marginal preventative measure and based the EcoCosts of WDC on use of locally generated solar energy with PV panels (Vogtländer, 2019), which we follow if use of renewable energy can be demonstrated.

Otherwise, in order to account for the country specific emissions for power generation, the Oiconomy database provides country specific values for WDC. Without knowledge of even the country, the worst case country must be assumed.

The water discharge of the BWD includes both green water (rain) and blue water (rivers, lakes and ground water), but no grey water (water to dilute pollution to safe target levels), in order to prevent double counting because the O.S. covers this in the section of pollution. These values must be considered default values. In practice, the costs of water use severely depends a series of variables, such as the project to build the facilities for water supply (Inocencio *et al.*, 2007) and the quantities of desalinated and transported water involved, the salinity and temperature of the seawater, toxicity and options to dispose of the brine, the political and geographic conditions between sea and location, economic conditions of the country and the local renewable energy supply. In practice, the organization may demonstrate more favorable foreground data, but also the costs of completely different options, like transport from a distant river, lake or aquifer with a very low BWD.

8.4.2. LAND USE

Land use is one of the most difficult to assess environmental aspects in LCA's. A preliminary literature review was conducted in order to determine the implications for the Oiconomy system. Most used methodologies, including the EcoCost system, are based on land degradation, characterized by species richness (e.g. De Baan et al. 2012; Lindeijer 2000; Teixeira et al. 2015; Vogtländer et al. 2000; Weidema 2001) or by impacts on ecosystem services (Milà i Canals et al. 2012; De Baan et al. 2012; Thoma et al. 2015). In our opinion, this is one-sided, not sufficiently accounting for the endpoint of current and future human wellbeing, because it is very questionable if alternative land uses can provide enough food, energy and other resources. A probable cause of this shortcoming is that land use is usually approached from an ecological point of view by an E-LCA, while the responsibility to provide food and other essential goods is a socio-economic aspect. Agriculture (including forestry) accounts for about 90% of human land use (Hurni et al. 2009; Lambin & Meyfroidt 2011). Therefore, we limit our considerations to agriculture.

The first fundamental question to consider is if there is a real risk of land scarcity. A literature study convincingly resulted in the answer: "Without major changes on the consumption side and human behavior (e.g. by significant global reductions of meat- and dairy consumption, energy use, food waste, population growth), that risk is substantial". Literature shows a fierce debate on the question if the most sustainable way towards sustainable land use is via "land sparing" or via "land sharing" (Fischer *et al.*, 2014). Advocates of land sparing argue that high yields by intensive agriculture saves land for high quality biodiversity elsewhere and believe in technology, business as usual in developed countries and closing the yield gap in development countries. Keulemans et al., 2019, p.20 state: "Land use for agriculture is inevitably related to loss of biodiversity. Management techniques such as use of plant protection products have by definition a negative impact on biodiversity, but this loss is by far surpassed by the higher land use in extensive production systems". Advocates of land sharing in the form of organic agriculture strive for high biodiversity on arable land (e.g. Balmford et al. 2005; Phalan et al. 2011; Fischer et al. 2014; Tscharntke et al. 2012).

The second fundamental question is whether organic agriculture, by many regarded as a

biodiversity friendly option, is able to feed the world without considerable transformation of new land into arable land and consequential GHG emissions and loss of ecosystems. Some authors argue that it is possible (Vasilikiotis 2000; IFOAM Organics International 2008), but others argue that the involved research did not properly include yield losses due to required crop rotations for green manure, or the dependence on animal manure ((Kirchmann et al. 2008; Bergström et al. 2008; Diaz-Ambrona & Maletta 2014). On this question, literature is ambiguous, with articles, contra-articles and confusing or contradictory research. Our conclusion is that, without further transformation of valuable ecosystems, major technological breakthroughs or consumption constraints, there will not be enough land in 2050 for organic agriculture to become mainstream, while breakthroughs by genetic engineering are excluded under current definitions of organic agriculture and legislation in some parts of the world, especially Europe.

More recently, a third option is discussed, that of "sustainable intensification (SI)" (Pretty, 1997; Tilman *et al.*, 2011; Godfray, 2015; Petersen and Snapp, 2015; Rockström *et al.*, 2017), which should develop towards intensive, land sparing agriculture while reducing the environmental impact, "combining the benefits of conventional, organic and other agricultural systems" (Clark and Tilman, 2017, p.5). Although the issue of extensive and intensive agriculture is discussed in impact based LCA literature (e.g. Nemecek *et al.*, 2011; Garnett, 2014), an assessment system is lacking in preventative cost-based LCA where precisely this aggregable type of LCA potentially can become a tool, leading to sustainable intensification by the balanced assessment of both biodiversity and yields. Land use has to be assessed based on two indicators, one on loss of biodiversity and one on yield deficits. For the loss of biodiversity we use the EcoCost system, based on the costs of restoration of degraded land natural biodiversity (based on costs in the Netherlands) (Vogtländer *et al.*, 2004). For the yield deficit, we propose to use the difference between the average yield of the crop in the country as listed in FAOSTAT (FAO, 2019) and an multi-year average on the actual yields. The marginal preventative costs will be determined by means of the standard 5-step method. The probable marginal measure to prevent loss of biodiversity caused by yield deficits is to finance production of the lost crop in drylands with long distance pumped desalinated seawater.

8.4.3. FAIR TRANSACTIONS

A unique opportunity of the foreground character of the Oiconomy system is to not only assess fair wages, but also fair transactions, because much of global poverty occurs in the informal sector (Rutkowski, 2003), e.g. caused by underpayment of small "Low Developed Suppliers (LDS)". A LDS is often a private person or family, a workshop or small cooperative without a clear management structure. We argue that responsibility for stakeholders means that an organization not only holds responsibility for fair payment to its own workers, but also to its suppliers. Well-developed suppliers are assumed have enough bargaining power themselves, but responsible companies don't misuse their unequal bargaining power towards a LDS, and pay a fair price for purchased products, allowing the LDS and its workers to earn a fair minimum wage. Dealing with LDS's such as apparel workshops, companies should determine the number of hours, necessary for the required activities and pay at least the fair minimum hourly wage, as determined by the O.S. The same test and calculation can be executed in the Oiconomy assessment resulting in ESCU's equal to the distance to a fair transaction. For background data, indications of yields per hour can often be found in literature (e.g. ICAC, 2018C for cotton

cultivation) and of lowest wages (e.g. at Wage Indicator Foundation, 2013), but more research is required for the determination of the best possible default values by country and industry sector. The assessment of the aspect of fair transactions is nothing else than an extension of the fair wage aspect, described in chapter 4.

8.4.4. OCCUPATIONAL HEALTH AND SAFETY

Another key aspect that needs to be covered in the Oiconomy system is the aspect of Occupational Health and Safety (OHS). A method has already been developed and a preliminary study executed. OHS is an aspect that in practice is already assessed by certification bodies on a risk-based standard, such as ISO 45001. OHS is one of the aspects where good governance is the overall preventative measure and therefore also our marginal preventative measure. For the aspect of corruption, described in chapter 5, a method of ESCU allocations was already developed existing the product of a governance quality dependent risk factor and the maximum costs of prevention. Determination of the risk factor for OHS can be executed by any accredited OHS auditor. The idea is to determine the costs for OHS in top performing companies and multiply these with the measured factor, to obtain the ESCU's for the aspect of OHS. An indicative literature search by the author of this thesis on costs of OHS yielded many articles on the costs of failing OHS, but surprisingly very few on the costs of prevention or good governance and available studies had a narrow definition of OHS in the sense of included preventative measures (e.g. Rzepecki, 2012). Usually included are for instance protective equipment and training, but for instance not the higher investment and maintenance costs of used machinery, procedural measures, and loss of time for inspections. Therefore, a first research in companies in the Netherlands was conducted into preventative costs by (Allers, 2019) in two steps. First, an OHS prevention cost model was developed. In the model the costs are split in different cost categories, which together give the complete overview of the prevention costs for OHS. Two in-depth case studies were conducted to gather data about the OHS management of two leading organizations in this area, one in the food industry and one in the construction sector. The model is used to create an overview of the expenses that come with a high OHS performance. Creating such an overview proved difficult as organizations do not tend to document specific costs spent on OHS, which may well cause the lack of literature on the costs of widely defined OHS governance. Because this was anticipated, one of the goals of these case studies was to learn and improve the survey. The improved survey was tested with two additional organizations, one of which was able to provide all needed data without additional support. The results, indicative because of the very low size of the sample, show that a large production industry with high OHS performance will spend about 10% of labor costs on OHS prevention and a service based organization about 2.4%. Small organizations were found to spend higher percentages, which can be up to three times as high. Future research should be executed to enlarge the sample and differentiate between industry sectors.

The aspect of OHS is a typical example of how an aspect can be assessed by a combination of two parts of the Oiconomy methodology: the use of a benchmark group of top performers and rating of the governance quality.

On this subject, Van der Velden and Vogtländer (2017) propose a method to determine "S-EcoCosts" for the social aspects of child labor, extreme poverty, excessive working hours and OHS, using the Disability Adjusted Life Year (DALY) as quantitative indicator and common

maximum acceptable medical costs for saving a life year as price factor. Although, in our opinion, the impact-based DALY's, combined with a value for a human life year is too far from realistic industrial preventative costs, for the aspect of OHS, a study of the relation between the DALY quantity and governance quality may provide a suitable indicator to derive default ESCU's for different industry sectors.

8.4.5. FINANCE AND COMPANY ASSESSMENT

A major cause of all unsustainability is the way that businesses are financed. For the aspect of sustainable finance, we distinguish two issues: First, the power and responsibility of shareholders; Second, financial conduct with risks for others than involved in the transaction or for the society as a whole. A special responsibility rests with the shareholders. Ultimately, they determine the course of the company. Even company leaders that are willing to invest in sustainability may be limited in their options by their shareholders (Sjafjell *et al.*, 2013). The income of a CEO is often determined by the extent he/she represents the interests of the shareholders. Sustainable finance requires a return from speculation to investment, from shortermism to long term shareholders value. Capitalism has been successful in a time of unlimited resources and has proven to lead countries to great wealth and health, but does not seem to have a stop button. In his chapter on "unbridled capitalism", Schlesinger argues: "Although the concept of capitalism rests on equilibrium, in practice, it's very virtues lead to disequilibrium" (Schlesinger, 1997). Globalization, although also bringing people together, causes great spatial, mental and moral distances between investors and companies and between producers and consumers. Impacts are far from shareholders' homes. Many shareholders, investing via investment funds, private equity companies and via pension funds, probably have no idea what they invest in, let alone its sustainability, and let alone that they are interested in more than profitability (Dincer, 2011). Although some changes are noticeable e.g. by the existence of fair finance guides (Fair Finance International, 2020), shareholders are still mainly guided by money. Therefore, if there is any product where sustainability-selective taxation could be effective on the short term, it is on the stock market. On the other side, the interest in profitability prevents redundancy in the sense that it answers to market demands and probably is the most efficient tool to bring about changes and sustainable development. All corporates' unsustainability is embedded in its shares. More than for corporates' products and services, the shareholder himself determines the sustainability of the share, but in current legal systems, bears no liability for misconduct of the company. But also a share is a product of which the sustainability for which an ESCU value can be determined. In the case of relatively simple supply chains, determination of ESCU's for complete companies is perfectly possible, and sometimes even easier than for products, because the complete flow of materials, energy use, emissions, wages and policies can be assessed without the need to divide the ESCU's between the different products. The total ESCU's for a company can be computed either by aggregation of ESCU's for all companies' products, or directly based on the total flow of materials, services and activities. These total ESCU's represent the companies' yearly costs that the company should spend on sustainability, the costs that should be compensated by either raising product prices or by a lower profit, unless these costs are internally compensated by greater efficiency, lower waste or other internal benefits. These costs can be expressed simply as ESCU's per share and provide a good performance based indicator for a share's sustainability. Company assessment becomes far more difficult in the case that it is involved in a multiple of

complex supply chains, surely in the early stages of the development of the Oiconomy system, where all multi-tier suppliers have to be convinced to fully cooperate.

The second issue: Unsustainable financial conduct, risking external damage, does need consideration. Capital and the financial market should evolve back to long term investments in real value and move away from accumulating money by money with financial derivatives, by speculation in basic needs, by investments in unsustainable products, companies or states, or by manipulation of markets. The O.S. includes preliminary criteria on unsustainable investments and banking, tax evasion, remuneration risking irresponsible conduct and irresponsible treatment of acquired companies. In a preventative cost-based assessment, the determination of the price factors for economic aspects is not as complicated as for other aspects. The marginal preventative measure is usually the loss of the maximum common profit obtained by the irresponsible activity. A literature search on Google Scholar and Scopus on life cycle assessment in relation to financial management of companies or their products provided zero results. A search for sustainable financial management usually leads to principles for responsible banking and investments, but not in measuring the sustainability of financial management of companies. Considering the aforementioned importance and probable root-cause of many sustainability issues in financial management, we conclude that there is an urgent need for research on the possibilities of inclusion of the aspect of (un)sustainable finance in LCA. The main challenge for the assessment of financial aspects is the determination of the criteria and performance reference points that define sustainable finance. But with these defined, the ESCU's can usually be determined as a percentage of the profit margin, a method proposed in chapter 5 for the aspect of corruption. As an example, we preliminary propose for various unsustainable investments an ESCU allocation of 16.5 % of the invested capital, which is a common interest gap between a Moody's AAA and junk rating and therefore a good measure for irresponsibly obtained margins, not taken from a convention, but created by the financial market itself.

To conclude, we quote the call for a new framework on sustainable finance by Fatemi and Fooladi (2013), nicely covering the goal of the Oiconomy system: "We argue that our current approach to shareholder wealth maximization is no longer a valid guide to creation of sustainable wealth: An emphasis on short-term results has had the unintended consequence of forcing many firms to externalize their social and environmental costs. An unwavering faith in markets' ability to efficiently uncover long-term value implications of short-term results has created many unacceptable outcomes. Given the social and environmental challenges ahead, such practices and their unacceptable outcomes cannot be sustained. Therefore, a shift in paradigm is called for. We propose a sustainable value creation framework, within which all social and environmental costs and benefits are to be explicitly accounted for."

8.4.6. VARIOUS SOCIO-ECONOMIC RESPONSIBILITIES

There is a wide range of irresponsible conduct that in our opinion should be part of S-LCA. At the moment of writing this thesis, the O.S. includes 28 of such responsibilities, all grouped together in one category of "various social responsibilities". Examples are discrimination, participation of minorities, physical or mental harassment, noise, damage to cultural heritage, timely payment, respect for property rights and privacy, use of incorrect product claims, animal welfare and misinformation. The individual aspects of this group have yet not been studied in this thesis and research on these aspects is recommended. Preliminarily, because most of these aspects are very difficult to quantify,

the O.S. uses the assessment of the level of governance on this whole aspect category instead, developed for the aspect of corruption, described in chapter 5. In a later stage, the more important aspects can be studied separately or use the EcoCost system, characterizing the individual aspects within the category relative to a leading indicator-aspect.

For our research question for this section and based on these preliminarily studied aspects, we foresee that the Oiconomy methodology is applicable for all sustainability aspects. For water depletion we could demonstrate how in a dynamic way the assessment can be made more specific depending on the degree of traceability. For land use, the standard 5-step methodology of determination of the marginal preventative costs is expected to add a PRP and ESCU's for lost yield and together with the EcoCost derived indicator on biodiversity provide a balanced indicator for land use. The assessment of fair transactions proved a simple extension from the in chapter 4 developed assessment of fair wages. The aspect of OHS is a typical example of how an aspect can be assessed by a combination of two parts of the Oiconomy methodology: the use of a benchmark group of top performers and rating of the governance quality. For financial and economic aspects, the major challenge is to find internationally accepted or acceptable PRP's and criteria, but after establishment of these, the preventative measure of reducing the issue to the PRP is already expressed in a monetary unit.

8.5. THE CERTIFICATION SCHEME

A pending challenge will be the creation of a certification scheme and acceptation of the standard by an accreditation body. Major needs for that purpose are:

- A guidance document on the standard with requirements, regulations and guidance for certification bodies.
- A stakeholder consultation body.
- Adaptation of the standard based on the remarks of the accreditation body and stakeholders.
- Organization of both scientific and practical maintenance of the standard and database.
- Facilitating tools, software and website.
- A public database of certified products and their ESCU's.

Here, only some of the major challenges considering the certification will be discussed.

In practice, certification is a globally functioning system, for the greater part perfectly safeguarding the trustworthiness of the criteria of a great variety of standards. Nevertheless, there always are the exceptions that bypass or bend the rules or hide their defects. An audit is not a complete verification of a company's operations, but a sample. Although a certification scheme usually consists of a series of audits, investigating all criteria, the quality of audits heavily depends on the size of the sample, available auditing time and qualification of the auditor. Major threats to the trustworthiness of certification are in my opinion and experience: 1. The cost related pressure on audit time, and 2. The preannouncement of audits.

The certification of comprehensive sustainability will be expensive, because many aspects are involved. In addition, aspects like child labor, waste treatment, health & safety and labor conditions require unannounced audits. Probably, adaptations to common certification schemes have to be developed to reduce the required audit time, while maintaining reliability.

Standard certification schemes already use regulations with audit time and frequency depending on previous results. However, these may be insufficient for the Oiconomy system. Ideas to investigate are:

1. Unannounced audits, in my opinion a prerequisite for a reliable assessment of sensitive aspects.
2. Risk-Based Auditing: The frequency, audit time and included aspects could depend on the risk. For instance the Social Hotspot Database (Benoît, Norris, Aulisio, *et al.*, 2010) could serve for risk assessment, as could long term results on other relevant certificates.
3. Sector-subcategorization: Sub-standards could be developed for industry sectors, limiting to sector relevant aspects. Simple sector specific sub-standards could be developed for smallholders with limited complexity (e.g. bakeries, apparel workshops and cocoa farms).
4. Collective Certification: Groups of similar companies could decide to be audited by peers or local experts and subject themselves to collective assessment by a certification body. That body samples members from the group, but all members subject to the result.
5. Certificate acceptation: For several aspects, the O.S. already accepts the result of other certificates. E.g. a certificate on ISO 45001 is accepted for the aspect of occupational health and safety.
6. Data analysis on the ESCU's of products could alert certification bodies about irregular or suspect values. One of the requirements in the certification scheme must surely be, that all the ESCU's for all aspect categories are communicated to the certification body before the audit, because the intention is self-assessment, and not that the auditor determines the ESCU's.
7. The best opportunity is of course that supply chain actors force themselves and their upstream supply chain to base their ESCU's on foreground data and use these as a base for real quotations for the sustainable version of their product. Such quotation is a sufficiently strong commitment to justify a limited audit.

8.6. MANAGING THE OICONOMY SYSTEM IN THE SUPPLY CHAIN

The most logical way of an actors' determining ESCU's is to self-research the investments and extra costs of production without externalities, just as for his existing internal operations.

Therefore, any supply chain actor, able to calculate standard costs, should be able to calculate ESCU's, if only he is aware of all sustainability issues, the making of which is an important function of the Oiconomy Standard. The certification system and available ESCU's facilitate making sustainable choices of suppliers, in a similar way that in the food industry, a company will not easily work with a supplier without a proven HACCP system.

The most logical way to maintain and improve the standard and database is mainstream use of the system, which enables a fully operational body for stakeholder consultation, maintenance of the system and especially continuous updating of the database with market data.

However, before the Oiconomy system can be mainstreamed, there are major challenges:

- The system has been designed to work bottom-up, following the supply chain. It should start at the cradle, such as mines and farms, with ESCU's working their way downstream to the end-product and consumer, exactly like standard economic prices, but without the

margins. In our pilots, most interested were those companies that are more at the end of the supply chain and closer to consumers and users. Although willing to share their own data, they were not willing or able to put enough pressure on their suppliers to participate and in turn interest the second and further tier suppliers. This may be caused by the pilot-character of the cases, but it is also likely that governmental or large retailers' and end-producers' force is necessary to get the system accepted. However, HACCP is an example of a system, based on transfer of demonstrated food safety governance along the supply chain, that exactly did get that force and made it to worlds' major food safety system. Various safety-related issues, such as on food, pharmacy, transport means, electrical appliances are already heavily regulated and audited in certification systems or inspected by governmental bodies, be it with focus on specific aspects instead of on a comprehensive collection of sustainability aspects. Therefore, one may question why on several categories of externalities, by definition harming, the society seems to allow anything that is not specifically forbidden.

In our opinion, it is just a matter of time and disasters before similar systems are introduced on sustainability and the required force is provided. Hopeful is that retailers and other influential companies or governmental institutions and also sustainability certifications, have been the necessary initiators before (Konefal *et al.*, 2005; Havinga, 2006). In addition, NGO's, certification bodies and consultants may be helpful guiding the system towards application. Also helpful and hopeful is the observation, discussed in section 1.3 on experiences with the system of eco-efficiency, that there are many examples that internal savings of actions exceed the internalized costs.

- Because of its comprehensiveness, initially, it will burden companies with extra work, which they usually are allergic to. However, after the first assessment, that work will be reduced considerably, because most data don't change quickly. The system becomes routine and software may be developed to automate most of the work, again in a similar way to standard bookkeeping. In a more developed Oiconomy system, ESCU's can simply be obtained from suppliers, which may even be selected based on ESCU's.

  In principle, it is possible to use the system for any number of individual categories, or even aspects. It probably even is a practical way to set a scheme of starting with a limited number of categories and gradually expand to totally comprehensive assessment. However, it must be stressed that a sustainable economy can only be obtained by addressing all categories and that any incomplete execution may fail to improve global sustainable development as a whole.
- Industries may fear the sustainability-prerequisites, like transparency and traceability, and legal measures, costs and even internalization of externalities. They may fear that transparency may harm their competitive technological advantage and that they may weaken their negotiation power with customers that know too much. However, we argue that this risk is minimal, because only the aggregated ESCU's are transferred and market derived default data will always be based on a variety of data, under removal of internal benefits.

  On the costs, we argue that in the long term, the costs of action will be far lower than the costs of inaction. However, right because these costs consider externalities,

a major part of the advantages will occur on others than the producers. Although the Oiconomy system itself already contains criteria on the assessment of fair incomes, fair trade and fair income inequality, the road to a fair and sustainable economy, will surely cause redistribution of wealth and incomes and therefore needs political guidance.

On the other side, we argue that internal benefits reduce or even exceed the costs and that the market will undoubtedly change giving the early adapters an opportunity to become the winners of the new market. At full internalization of the externalities, the sustainable products will become mainstream and the unsustainable the minority, which is already what governments intend to achieve in their pursuit of an energy transition. The Oiconomy system may be used to extend the transition focus to all SDG's. In chapter 1, we argue that this is even a necessity, even for the issue of climate change, because of the interdependence of the various sustainability aspects.

- Another major challenge will be the management and maintenance of the standard and database and the science behind the methodology and data. Next to the normal management of a certification scheme, the Oiconomy system needs scientific maintenance:
    - The Oiconomy Database needs continuous updating.
        - Marginal preventative costs change, e.g. because of inflation, new technologies or effects of scale.
        - Performance reference points change, e.g. because the group of 20% best performing countries change or new scientific insights appear (e.g. on the acceptable CO_2 level in the atmosphere).
        - Foreground data and originating companies must be assessed on their suitability for use as default data in the database. Undoubtedly, challenges will come up in the process. One will be that in practice, often no 100% abatement of impacts can be achieved. In that case, for ESCU calculations, the O.S. requires a realistic estimate of the degree of abatement. For the expected abatement, the foreground price factor is used, but for the remainder the default value. But criteria need to be developed for using the new foreground data as default data, such as on the percentage of abatement accomplished, the quality of the companies, the universal applicability of the data, and the amount required of data and involved companies.
    - The scientific community may provide in depth studies on yet uncovered aspects.
    - Industries are intended to provide specific data on preventative costs that need assessment for wider applicability for the self-learning character of the databases.
    - Subcategorization of aspects may be proposed for more accurate price factors, e.g. for emission of methane instead of using its CO_2 compared global warming potential. Such proposals need scientific assessment.
    - Special versions of the Oiconomy Standard may be developed for industry sectors or product categories. Also such versions need scientific assessment.

Especially the last option also provides a means to limit the burden to industries. The Environmental Product Declarations system is an example of how Product Category Rules (PCR's) can be drawn up and followed for product categories (The International EPD System,

2019). For specific product categories, countries and smallholders, not all criteria in the O.S. may be applicable and for various products or activities, common default values can be made available and measurement requirements can often be simplified. But these category-specific O.S. versions may also become sector specific guidelines and participants' attention to specific risks, e.g. about common emissions in the sector. However, great care is necessary on the coordination of developments in the different industry sectors, because almost all industry sectors belong to the supply chains of other sectors, which requires uniform determination and transfer of ESCU's.

8.7. OICONOMY SYSTEM OPPORTUNITIES

After completion of the first three stages of the Oiconomy Project, as formulated in section 2.4, we will now elaborate on the fourth stage, the running system, where supply chain actors are enabled to measure, document and transfer the externalities related to a product, building up in the value chain, just like standard prices, until the end product.

Most important direct use of the Oiconomy system after the development of a certification scheme, is the verified in-supply chain self-assessment and transfer of ESCU's in the supply chain, enabling them to together determine and practice the most efficient route to sustainability. In a later stage, politicians could use the data to create a real price economy.

In section 2.3, an extensive review was given on the limitations of current product-LCA and why a new type of LCA is needed, which we here only summarize: Current product-LCA provides a limited picture, mostly based on default data and subject to variations in impact assessment and weighting. It is mostly top-down, initiated from the end-product and executed by scientists or experts, with no or minimal involvement of the upstream supply chain players. It lacks standardization, limiting comparability and aggregability of data, and inadequately includes social aspects, especially because of the lack of traceability and consequently of specific upstream data. Of course, there is a good reason for these limitations, which is the fear of industry for an unequal international playing field and addition of costs where competitors don't bear these. Lacking an enforced need to provide all the necessary data as standard requirement in business, LCA was developed top-down and as a scientific effort. Lacking well founded PRP's for important social aspects and lacking standardization requiring verification, current S-LCA is based on averages and probabilities instead of on in supply chain obtained facts and details.

This thesis however, by means of the Oiconomy system, provides industry with a B2B tool for standardized and verifiable assessment, aggregation and transfer of sustainability data, through the supply chain. Each indicator is based on scientific knowledge or principles based on international conventions. It enables industry to select supply chains based on the sustainability indicator of ESCU's. It leads industries to focus on prevention and solutions and enables negotiations on sustainability on an equal level as price and quality. ESCU's may even gradually evolve to quotations for the sustainable alternative for a product. As sustainability measurement tool of externalities, it provides the most logical method possible, where every actor in the supply chain systematically details his externalities in all its aspects, calculates his costs of preventative action and transfers these as ESCU's to the next actor. Because an externality damages others than the actor, he should have done that anyway.

The Oiconomy system does not know materiality, circumnavigating the subjectivity trap in the stakeholder based materiality of some current approaches. All aspects are equally important. In practice, one may question materiality anyway, because the importance of aspects is variable and subject to what is in the media and depending on the activities of politicians and NGO's. The Oiconomy system does not provide an indicator on the impact, but on the costs of avoiding the impact. The Oiconomy system is comprehensive in all three PPP pillars and therefore provides a guide into all aspects of sustainability and social responsibility. Externalities are liabilities and can turn against a business. The systems' comprehensiveness prevents surprises with always new issues coming up and also prevents issues to be solved with negative consequences for other aspects.

ESCU's represent either the costs of action for a specific product, or a default value equal to the marginal preventative costs. The default values do not standard include potential internal benefits which often occur when preventative actions are taken, such as energy savings, less waste, better qualified personnel, lower sick leave, higher quality products, better reputation and less negative publicity (see section 2.1). However, at presenting calculations for specific products, companies may decide to include such benefits in order to lower the ESCU's. In order to prevent greenwashing, in section 2.5.5 it was determined that sound calculations and consequential decisions including the benefits shall be demonstrated to the verifying certification body. However, if in the self-learning database, default values are adapted based on such market values, care is required to filter these benefits out, unless it can be made certain that they apply to all.

An important challenge for companies is to create transparency by means of ESCU's, leading to communication of truly social and environmental superiority. However, due to the nature of externalities, a part of the savings of their prevention and potential internalization may in the short term favor others than the supply chain actors. In the long term it may be expected that savings will benefit all, because usually the costs of action are much lower of inaction.

An important characteristic of the Oiconomy system, as for certification in general, is that it uses the principle of reversal of the burden of proof (see section 2.3.5) and that an organization is always required to have made its own preparation and calculations to be verified by the certification body. Only if an actor demonstrates a specific ESCU value, based on verifiable measurements and calculations, that value may be used. Without such demonstration a default value is allocated, equal to the usually higher marginal preventative costs. This principle leaves the responsibility of how to comply to the practitioner and forces him to self-understand and explain the reasons why things are in good order.

The ultimate potential use of the Oiconomy system is to provide the data for internalization of the externalities in the economy, thereby encouraging companies to work with suppliers to prevent their impact, by including the preventative costs of a product's negative impact. This may raise the visible market price, but reduce the hidden price (of externalities), resulting in a fair and sustainable economy. In the introduction (section 1.1), we have demonstrated that several leading economists have pointed to this option in the past, but also contemporary economists describe this as a criterion for sustainable finance, (e.g. Schoenmaker, 2017).

But artificially changing prices always has consequences. Prices control the quantities and quality of products. Consumers will always seek the best price-quality ratio and companies will

always seek profit/risk optimization. The market should do its work. Advocates of capitalism will even argue that the market itself will correct externalities, forced by reputation, worried consumers and the possibility of profitable sustainability. However, in a time of a huge overshoot of the ecological footprint in relation to the earth biocapacity (see section 3.3.2), depletion of resources and a climate change crisis, the risk of passing tipping points is too high to trust a timely correction by the market itself. In order to bring sustainability into the picture, the market should move to a situation that consumers, driven by moral or economic considerations lower their material consumption. Therefore, important for this problem is that true prices are introduced comprehensively on all products and in all countries, with an equal level playing field so that the economy really becomes sustainability selective.

Although indeed, the ultimate potential use of the Oiconomy system is to create a real price economy, it is not recommended to do this in a too early stage, because it will take considerable time to comprehensively include all aspects and supply chains in the self-learning database. In addition, at internalization by means of taxation, one feature of certification that is an advantage in the measurement stage, becomes an issue. The principle of reversal of proof instead of "not guilty until proven guilty", imposed by governments may need serious consideration by law makers.

We therefore recommend to start using the system within supply chains to determine the most efficient way towards sustainability and thereafter invest to put that way into practice.

8.8. REFLECTIONS ON THE REQUIREMENTS FOR A SUSTAINABLE ECONOMY AND THE POTENTIAL ROLE OF THE OICONOMY SYSTEM

In the introduction of this thesis, section 1.1, we have shown that several leading economists have pointed into the direction of a real price economy to address the economic system imperfections and sustainable development. This justified the development of the Oiconomy system and this thesis. At the moment of writing this last section, the world is in the middle of the COVID-19 pandemic crisis and already caused 750.000 deaths, with a suspected relation with unsustainable interaction with nature (Everard et al., 2020) and exposing the effects of inequality (e.g. Ali et al. 2020; Marmot and Allen, 2020).

The original idea (see preface) for a sustainable economy actually consisted of two parts, only one of which was the measurement of the preventative cost distance to sustainability, elaborated in this thesis. The other part was about economic adaptations, necessary for a sustainable economy, of which the Oiconomy system could be a part. I shortly discuss the issues that are related to the idea of the Oiconomy system:

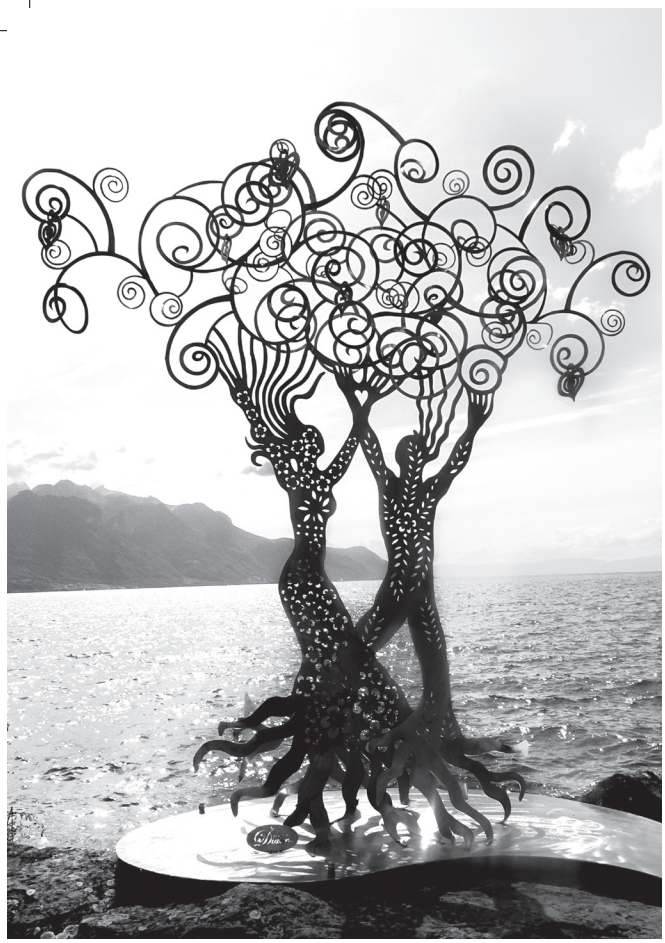
1. One of the major challenges in a real price economy is that inequality and poverty should not increase by internalization of externalities and resulting higher prices, relative to a scenario of business as usual. In the long term, that risk is limited because on average the costs of action will be far lower than the costs no action. This is also one of the reasons why the sustainability assessment should be comprehensive, including the aspects of fair wages, fair transactions, fair income inequality of incomes and health and safety. In addition, the Oiconomy system is envisioned to drive the supply chain actors towards action, which will undoubtedly at least partly lead to solutions without cost raising or even to net benefits.

Furthermore, there is a growing interest in some form of universal basic income (UBI) (e.g. Hall *et al.*, 2019; Malmaeus et al. 2020), which could be a means to compensate inclusion of externalities.

2. The two drivers for costs are labor and capital. Without inflation, internalized costs that lead to higher prices are divided between labor and capital. Inflation by internalization is unlikely because in the long term, the costs of action are usually lower than the costs of inaction and the market will turn the newly added costs into added value. The internalized externalities that are used by extra labor costs will raise incomes or employment, which means that on a global average, at constant inequality, these will not cause a net increase in poverty. Therefore, only if the internalization of externalities is accompanied with a change between the capital and labor share in favor of capital, the average degree of poverty will rise. However, if internalization of externalities based on ESCU's are implemented without margin, as they are calculated, capital intensity is more likely to decrease than increase. It is important that the financial market recognizes or is regulated to its responsibility as one of the major drivers of both unsustainability and of the transitions to sustainability. As important is that politicians look into the short term and spatial and imbalances that undoubtedly accompany such transition. For instance, countries that have a one-sided economy based on unsustainable activities may be hit hard.
3. Unsustainability is one of the world's most dangerous export products. Not only affects it low income countries, but also high income countries. Material emissions spread all over the world, but irresponsible business does so, too. Externalities in de form of irresponsibly achieved low prices internationally force competitors towards the same or other unsustainable ways. But "compliance" is not enough. All products used in high income countries should reflect the life cycle highest standards in all PPP's. Also international conventions leading to residential commitments for countries are not enough, because too much unsustainability is embedded in cross border traded products.
4. Mandatory traceability for all products, accessible for the supply chain actors and auditors. As potential means for improving traceability, the blockchain technology is suggested (e.g. Kamble et al. 2020; Wang *et al.*, 2019), but great care is required to protect industrial intellectual property and trust in the supply chain, because trust is the fundament of certification.

Major challenge for all these needs for a sustainable economy, is that they require international agreement and enforcement. Therefore, for the time being, the most practical use of the Oiconomy system is to serve as a product life cycle assessment tool for supply chains and become a natural tool in the communication and negotiations between supply chain actors.

8



Tomorrows generations bear the costs and fruits of todays' generation

Let the economy do its work by removing the externalities.

CHAPTER 9

CONCLUSIONS

In the above chapter, the research question for this thesis (section 1.8) has been answered: A consistent and standardized methodology to calculate ESCU's has been presented, enabling the supply chain actors the comprehensive determination and bottom up transfer of aggregated preventative cost-based externalities along a products life cycle. Furthermore, the six sub-goals required for this research question, as described in section 1.8, were accomplished, as follows:

Sub-goal 1; figure 1.3, box B. A methodology for the determination of PRP's for social and economic aspects was presented consisting of three principles, applied singular or in combinations: 1. Use of International agreements, laid down in legislation, conventions and norms set by international organizations. 2. Use of the ways of 20% top performers on an aspect as a benchmark. 3. Scoring of an organizations' governance on common PDCA grouped criteria against top governance on the aspect.

Sub-goal 2; figure 1.3, box A, D . The uniform, preventative cost based and aggregable assessment of product sustainability requires standardization and methodologies to determine the cost distance to the PRP. A standard was developed enabling supply chain actors the verifiable measurement of product embedded externalities, equal to the costs of impact prevention in the total life cycle of a product, while copying standard economic cost calculations, bookkeeping and transfer of prices through the supply chain. The developed "Oiconomy Standard" (O.S.) was tested in three pilots and proved understandable, workable and a good guidance for the comprehensive assessment of product sustainability, but still needs to undergo stakeholder consultation and acceptation by an accreditation body to become a certifiable standard.

Sub-goal 3; figure 1.3, box A. Comprehensive assessment of environmental, social and economic sustainability aspects, is enabled by inclusion of the 17 Sustainable Development Goals, GRI reporting aspects and criteria of the ISO 26000 guideline. Environmental aspects are covered by the EcoCost system. For the aspects of fair wages, fair income inequality, fair transactions, child labor and corruption, methodologies were presented in the chapters 3,4 and 5. In addition, using the developed methodologies, some preliminary development was executed on a series of not yet covered aspects, presented in section 8.4. The developed methodologies, sometimes with some minor adaptations proved applicable for the investigated aspects and provided preliminary data.

Sub-goal 4; figure 1.3, box A. A database with default background price factors for lacking foreground data was provided. This "Oiconomy Database" is in principle fit to become "self-learning" by feeding it with anonymized data from participants, but that will only become an option after the system has had a considerable period of a fully operational system. The database contains default data, representing marginal preventative costs, a principle adopted from the EcoCost system. Environmental data are also taken from the EcoCost system, although adapted for the typical Oiconomy character of guidance and location sensitivity. Country specific data are included for the aspects of fair wages, child labor and corruption, water depletion and carbon intensity of electricity derived from available databases from international organizations or literature.

Sub-goal 5; figure 1.3, box C. A system was created, challenging the supply chain actors to self-determine both quantitative- and price factors and therewith the externalities embedded in the product, based on their actual costs. With the envisioned fully foreground, uniform and aggregated ESCU's, very similar to quotations of the sustainable version of the product (but without margin), the supply chain actors have a tool to together determine the most efficient route to sustainability.

Sub-goal 6; figure 1.3, box B. Based on the developed methodologies and democratic principles, PRPs were proposed for some important social aspects.

For a fair wage, a system was developed consisting of a fair relative minimum wage, bottom truncated by an absolute fair minimum wage for the poorest countries. A list of fair minimum wages by country is presented. ESCU's are determined by the cost distance to the fair minimum wages. For the aspects of child labor and fair trade, assessment methods were derived from the fair wages. For the aspect of fair income inequality, a maximum fair ratio is proposed based on the parliamentary determined maximum and minimum incomes (wage prime minster / minimum wage), multiplied with fair-market based factors for semi-governmental organizations and industry, resulting in a proposal of a maximum ratio of 23.8. ESCU's are determined by the raising all too low incomes to the fair income inequality ratio.

For the aspect of corruption with a legally set but unverifiable PRP of zero, a PRP was developed of perfect governance against corruption, the maximum preventative costs equal to the average profit margin in the sector. ESCU's are determined by multiplication of the maximum costs by a reducing factor based on scoring the governance quality.

Discussed were some options for the assessment of occupational health and safety, sustainable finance and company assessment, and on adaptations of EcoCosts for land use and water depletion for foreground ESCU's.

Furthermore, a chapter is presented, based on an assessment of the moral and practical implications of including positives (benefits) in LCA's. A list of proposed benefits is presented and included in the O.S. Dissuaded are especially the inclusion of industry-internal positives, positive weighting positive impacts to one stakeholder against negative impacts of another group, employment and product's beneficial utilities.

Demonstrated was that the developed methodologies are applicable, sometimes with minor adaptations, to all three pillars of Planet, People and Prosperity, and to probably all 17 SDG's. The provided sustainability indicator, the ESCU, fulfills the requirements, formulated in section 1.8, by being interval quantitative, objective, aggregable. In principle the indicator can be made certain and product specific by industry self-collection of foreground data, verified by means of certification. Because that goal of certain foreground data will take years to be achieved, a database with background data is available for gradual development towards the envisioned goal.

Major challenges are to organize a certification system and specially to obtain some force from large retailers and industries to push the system through supply chains.

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ABSTRACT ENGLISH

This thesis describes a new type of LCA, enabling supply chain actors the comprehensive sustainability assessment of products by determination and bottom-up transfer along the supply chain of the aggregated preventative cost-based externalities.

An assessment provides an indicator, the "Eco Social Cost Unit" (ESCU), equal to the extra costs for the sustainable version of the product, subdivided in 10 aspect-categories, comprehensively including both environmental, social and economic aspects and including all 17 sustainable development goals. The system provides a method for the uniform calculation and bookkeeping of the product-embedded externalities. Every supply chain actor collects the extra costs for sustainable supplies, calculates his own and transfers the aggregated result to the next actor. This enables the supply chain actors together to determine the most efficient route to sustainability and invest to put that into practice.

The research question of this PhD thesis is: "How to enable supply chain actors the comprehensive sustainability assessment of products by determination and bottom-up transfer along the supply chain of the aggregated preventative cost-based externalities, based on a consistent scientific methodology and science- and convention based data?"

Chapter 1 describes the need for such new comprehensive type of Product Life Cycle Assessment (LCA). Summarized is how economic system imperfections heave lead to a currently unsustainable economy in all three PPP pillars of People, Planet and Prosperity. A major part of global unsustainability is embedded in trade, consumption and the processes involved in the lifecycle of products, and is caused by "externalities", hidden costs for others than the transaction partners. Literature on potential solutions is described, showing that a real price economy is regularly suggested. But there is currently no comprehensive, standardized, objective and in-supply chain method for product-sustainability assessment, necessary for the determination of the magnitude of the required costs for avoiding the impact. This requires a supply chain collective life cycle approach, which current LCA systems cannot provide.

Chapter 2 presents the Oiconomy system: a new type of "bottom-up"- and "product-specific LCA" along the supply chain for the comprehensive measurement of the hidden environmental, social and economic externalities embedded in products, the externalities. Every supply chain actor collects the upstream caused externalities from his suppliers, calculates and adds its own and transfers the aggregated result to the next actor by means of a monetary unit, the "Eco Social Cost Unit" (ESCU). Every ESCU allocation is the product of a quantitative factor and a price factor for an issue. The "Oiconomy Standard" was developed for the verifiable, uniform and aggregable measurement and transfer of ESCU's through the supply chain. In the envisioned operational system, both factors should be determined by the supply chain actors themselves. The price factor is equal to the costs of preventing their specific impact and should also be determined by the supply chain actor, verified by means of certification. Without such "foreground" preventative costs, a default price factor based on "background" data is provided by a database, representing the marginal preventative price factors for the aspect category. Envisioned is continuous adaptation of the database by company data, creating a self-learning database of the price factors. Described are the principles of the system, advantages, research challenges, limitations, and system boundaries.

Key differences with other LCA systems are the "bottom-up" character of standardized in-supply chain measurement and aggregated transfer of ESCU's through the supply chain. Key prerequisite

is external verification of the self-assessment by the actors, resulting in trustworthy "foreground data". Several features and environmental background data were derived from the EcoCost/ Value system, maintained by the Delft University. Still required for social and economic aspects were performance reference points (PRP's) and a method for the determination of default price factors. Therefore, in this chapter, an EcoCost system derived 5-step method is proposed for the determination of price factors and a method of using the relevant characteristics of a benchmark group of the 20% best performers (mostly countries) for background data without available well-defined internationally accepted PRP's.

In chapter 3, the country-benchmark method is put into practice, using the characteristics of a benchmark group of the 20 % best performing countries for the determination of a Performance Reference Point. A benchmark was determined based on an assessment of available country-indicators and indices. For the aspect of income inequality, based on the average ratio between the highest and lowest democratically determined wages in the benchmark group, a maximum ratio for "fair income inequality" is proposed of 14.1 for governmental organizations, 18.3 for semi-governmental organizations and 23.8 for private enterprises. The ESCU's to be allocated are the costs of raising all remunerations within the organization to within that maximum fair ratio.

In Chapter 4, using the same benchmark group of countries, a well-founded "fair minimum wage" standard is proposed, which enables the determination of the preventative costs for the impact category of unfair prices for labor, child labor and transactions with low developed suppliers. What is a fair minimum wage? Because literature showed that an absolute minimum wage is most suited for the lowest-income countries and a relative minimum wage for higher income countries, a relative system is proposed, bottom cut-off by an absolute fair minimum wage. The average proportion of the minimum wage of the gross national income (GNI) per capita in the benchmark group, is proposed as the PRP for the relative fair minimum wage. The proposed absolute minimum wage is based on the 2005 World Bank $2 (PPP) poverty line. The proposed relative system, based on 2011 data, results in a fair minimum wage of 44.4 % of a country's GNI per capita, and the proposed absolute minimum wage is $1547 (PPP) per year and $0.830 (PPP) per hour. For ESCU allocations we propose to use the difference between actual payment and the here determined PRP. These targets have meanwhile been updated in the Oiconomy database.

Chapter 5 describes the development of an assessment method for the aspect of corruption. In absence of literature on S-LCA of corruption, more generally, S-LCA methods were assessed on their suitability for the aspect. Dreyers et al.' argue that various social aspects, including corruption, are better assessed by companies' preventative efforts than by their impact (Dreyer *et al.*, 2010). Therefore, and following the methods described in chapter 2, an indicator is proposed composed of the product of the marginal preventative costs and a risk factor depending on the quality level of a companies' preventative governance. For the aspect of corruption, the internationally accepted target is "zero tolerance". Because profitability is the main driver for companies, refraining from the business is proposed as the marginal preventative measure, and the related profit as the maximum quantitative indicator. For the risk factor, a technique is proposed based on scoring a company's governance quality by checking the four Plan-Do-Check-Act (PDCA) effort classes of common risk-based certification standards' criteria. The ESCU's to be allocated are equal to the lost profits at abandoning the corrupt business, multiplied by [1-P], where P represents the proportion of the maximum PDCA score.

Chapter 6 discusses the implications of inclusion of external positive impacts in S-LCA. Gradually, assessments of positive impacts appear in S-LCA literature with moral and practical implications for LCA in general and especially for the externality measuring Oiconomy system. Therefore, a discussion paper was submitted discussing the implications and challenges of including positive impacts in LCA's of products and to propose a set of criteria for their inclusion. Discussed are the conflicting descriptive and prescriptive character of LCA, inclusion of internalities, considering "absence of negative impacts" as positive, measuring by status or by change and the therewith involved temporal scope, moral consequences of comparing positive and negative impacts to different stakeholder groups, the requirement of a capacity raising character and maintenance of a positive impact, rebound effects, R&D, background and foreground data on positive impacts, and the inclusion of employment and product utilities as positive impacts. Based on this assessment, a set of criteria is proposed for the assessment of positive impacts in Life Cycle Assessment in general and especially of positive contributions in the Oiconomy system.

This study demonstrates several serious ethical and practical issues and challenges related to inclusion of positive impacts in LCA. A question arose how to interpret the economic concepts of "externalities" and "internalities" in relation to LCA. A special definition of in- and externalities for LCA purposes is proposed. The importance of a "capacity raising" character of a positive impact is demonstrated, but also some of the difficulties of distinguishing capacity raising from maintaining the current status. Important outcomes are that for a consistent LCA, inclusion of most internalities and "absence of negative impacts" must be dissuaded, which also applies to employment and wages without a range of additional criteria. Great caution must be taken with inclusion of a positive product utility, comparing positives for one stakeholder group with the negatives for another, and mixing measurement by status with measurement by change.

Chapter 7 describes pilots, executed by M.Sc. students' internals with volunteering companies. These pilots demonstrated that the Oiconomy system performs best as intended, building up in the supply chain from aggregated standardized foreground data. Assessment instructions and criteria of the Oiconomy Standard and – Database proved understandable and workable, although some remarks were made on the wish for simpler questionnaires.

The pilots demonstrated five important features of the Oiconomy system: 1. The probable need of the power of governments or companies with great purchasing power to become widely adopted. 2. High sensitivity to local conditions caused by the use of country specific data. 3. Sensitivity to the income- and price level of countries, which is a logic consequence of the cost-based indicator. 4. The target of a relative fair minimum wage, bottom cut-off by an absolute fair minimum wage may lead to ESCU allocations for wages in both rich and poor countries. 5. In absence of foreground data, existing risks may lead to high ESCU allocations, because for default values, worst cases must be assumed.

Another important characteristic of the Oiconomy system, demonstrated by the pilots, is that the system does not assess sustainability by its impact, but by the costs to avoid impact.

Therefore, ESCU scores may differ considerably from common materiality perceptions.

The pilots revealed various shortcomings and ambiguities in the Oiconomy Standard, which were corrected and described. Further adaptations to the standard, questionnaire and database should gradually be made depending on arising experiences and questions.

In chapter 8, we reflect on the developed methodologies and methods, on the development of a

certification scheme, on future research needs and on the potential use of the Oiconomy system. In our opinion, the Oiconomy System provides a method for the most natural way of assessment of product sustainability, building up along the supply chain. Major challenge for the system is that it probably needs the power of legislators or companies with major purchasing power to convince their multi-tier suppliers to join the system. Major opportunity of the system is the focus on prevention and transparent communication of the involved costs. Major example for the system is how HACCP, the food safety system that by means of a standard, certification and the power of major food- and retail companies and legislation, globally improved food safety.

In section 8.4, some sustainability aspects are discussed, which were not covered by a detailed study in this thesis, but still included in the Oiconomy Standard. The preliminary positions taken in the O.S. are described for the aspects of water depletion, land use, fair transactions, occupational health and safety, finance, company assessment, and a category of various social responsibilities.

The aspects of water depletion and land use, also covered by the EcoCost system, were included because the Oiconomy system needs a more location sensitive and instructive method than provided by EcoCosts and because, in our opinion, the EcoCost method, like current impact-based LCA's on land one-sidedly focus on the environmental impact, disregarding the social need to provide.

The inclusion of the aspect of fair transactions was directly derived from the developed method on fair wages (chapter 4). We argue that the organization has the responsibility for fair transactions with low developed suppliers, such as workshops and small farmers, and grant them an income, at least equal to the fair minimum wage. The proposed ESCU's are equal to the cost distance to that fair transaction.

The costs of Occupational Health and Safety governance were studied by M.Sc. student internals in 2 large companies and extended by questionnaire surveys in 2 more companies, resulting in preliminary data, which need to be further extended in a larger group of companies and industry sectors. As a last category, the O.S. covers a large group of "various responsibilities", which are quantified by means of the organizations' governance level.

Chapter 9 summarizes the conclusions. The research question for this thesis (section 1.8) has been answered: A consistent and standardized methodology to calculate ESCU's has been presented, enabling the supply chain actors the comprehensive determination and bottom up transfer of aggregated preventative cost-based externalities along a products life cycle. Furthermore, the six sub-goals required for this research question, as described in section 1.8, were accomplished:

The required consistent and science based methodology was developed and practiced.

Standardized and verifiable assessment was enabled by means of the Oiconomy Standard.

Comprehensive assessment on all three PPP pillars and including the 17 SDG's was enabled.

The Oiconomy Database is provided for default price factors

Transfer of aggregated ESCU's along the supply chain, challenging to transfer foreground data, but in absence of which with worst case based default data, was enabled.

The methodology for the determination of PRP's and ESCU's was successfully practiced for the aspects of fair inequality, fair wages, child labor and corruption and further tested by preliminary studies on various other aspects.

Major remaining challenges are the implementation of a certification system and to obtain enough power from governments or major enterprises to convince complete supply chains to adopt the system.

SAMENVATTING NEDERLANDS

Dit proefschrift beschrijft een nieuwe vorm van LCA die het bedrijven mogelijk maakt om de duurzaamheid van producten te bepalen en door te geven in de leveringsketen, uitgedrukt in de opgetelde op preventiekosten gebaseerde "externaliteiten", vergelijkbaar met normale kostenopbouw in de leveringsketen van producten.

Een beoordeling resulteert in een indicator, de Eco Social Cost Units (ESCU), gelijk aan de extra kosten voor de duurzame versie van het product, onderverdeeld in 10 categorieën van duurzaamheids-aspecten, zowel op milieu-, sociaal en economische gebied en inclusief de 17 doelstellingen voor duurzame ontwikkeling. Het systeem biedt een gestandaardiseerde meting en boekhouding van de verborgen preventie-kosten in de levenscyclus van producten. Elke ketenpartner verzamelt de extra kosten voor duurzame inkopen, telt zijn eigen kosten erbij op en geeft deze opgeteld door aan de volgende in de keten. Dit stelt bedrijven in de keten in staat om samen de meest efficiënte weg naar duurzaamheid te bepalen.

Hoofdstuk 1 beschrijft de behoefte aan een nieuw alomvattend type van Product Levens Cyclus Analyse (LCA). Samengevat wordt hoe systeem-gebreken hebben geleid tot een onduurzame economie in alle drie pijlers van "People, Planet en Prosperity" (PPP). Een groot deel van de wereldwijde on-duurzaamheid is toe te schrijven aan handel, consumptie en de processen in de levenscyclus van producten, en wordt veroorzaakt door "externaliteiten", verborgen kosten voor anderen dan de transactiepartners. Als oplossing hiervoor wordt in de literatuur regelmatig een reële prijseconomie gesuggereerd. Maar er bestaat nog geen alomvattende, objectieve en gestandaardiseerde methode voor de meting van de benodigde kosten voor het verduurzamen van producten. Dit vraagt om een collectieve levenscyclus-benadering in de leveringsketen, wat met de huidige LCA-systemen nog niet mogelijk is.

De onderzoeksvraag van deze PhD thesis is: Hoe kunnen bedrijven in de leveringsketen in staat gesteld worden om de alle aspecten omvattende duurzaamheid van producten te bepalen door de op preventiekosten gebaseerde externaliteiten te meten en in de keten door te geven, gebaseerd op een consequente wetenschappelijke methode en op wetenschap- of conventie gebaseerde gegevens.

Hoofdstuk 2 presenteert het Oiconomy-systeem, een nieuw type "bottom-up-" en "product-specifieke LCA" voor de alomvattende meting van de externaliteiten, gemeten als preventieve kosten. Elk bedrijf verzamelt de verborgen preventie-kosten van de voorgaande leveringsketens, berekent zijn eigen bijdrage en geeft het opgetelde resultaat door aan de volgende in de keten door middel van een monetaire eenheid, de "Eco Social Cost Unit" (ESCU). Elke ESCU-toewijzing is het product van een kwantitatieve factor en een prijsfactor, net als in de zichtbare economie. De "Oiconomy Standard" werd ontwikkeld voor de verifieerbare en uniforme meting en overdracht van ESCU's door de leveringsketen. In het beoogde operationele systeem wordt de prijsfactor bepaald door de bedrijven in de leveringsketen zelf, gelijk aan de onafhankelijk geverifieerde kosten voor preventie van de door hen veroorzaakte schade. Zonder beschikbaarheid van "voorgrond" preventie-kosten wordt een standaard ("achtergrond") prijsfactor toegewezen uit een database, gelijk aan de marginale preventieve kosten voor

de aspectcategorie. Daarnaast is voorzien in een continue aanpassing van de database met bedrijfsgegevens, waardoor een zelflerende database van prijsfactoren kan ontstaan. Behandeld in dit hoofdstuk worden de principes van het systeem, de voordelen, onderzoeks-behoeften, beperkingen, en de systeemgrenzen.

Het belangrijkste verschil met andere LCA-systemen is het 'bottom-up'-karakter van gestandaardiseerde meting en de overdracht van opgetelde gegevens door de bedrijven in de leveringsketen. Belangrijkste voorwaarde is externe verificatie van deze zelfbeoordeling, resulterend in betrouwbare "voorgrondgegevens". Verschillende kenmerken en milieu-achtergrondgegevens zijn afgeleid van het EcoCost/Value-systeem, dat wordt beheerd door de TU Delft. Voor diverse sociale en economische aspecten ontbraken nog prestatie referentie punten (PRP's) en een methode voor de bepaling van de achtergrond prijsfactoren. Daarom worden in dit hoofdstuk een van het EcoCost systeem afgeleide 5-stappenmethode voorgesteld voor het bepalen van prijsfactoren en het gebruik van de relevante kenmerken van een benchmark van de 20% best presterende (meest landen) voor PRP's voor aspecten zonder beschikbare internationaal erkende normen.

In hoofdstuk 3 wordt een methode gepresenteerd en in de praktijk gebracht, waarbij de kenmerken van een benchmarkgroep van de 20% best presterende landen worden gebruikt voor de bepaling van een Performance Reference Point. Op basis van een beoordeling van beschikbare indicatoren en indexen werd een benchmarkgroep van best presterende landen bepaald. Voor het aspect van inkomensongelijkheid wordt, op basis van de gemiddelde ratio tussen het hoogste en laagste democratisch bepaalde loon in deze benchmarkgroep, een maximale ratio voor "eerlijke inkomensongelijkheid" voorgesteld van 14.1 voor overheidsorganisaties, 18.3 voor semi- overheidsorganisaties en 23.8 voor particuliere ondernemingen. De toe te kennen ESCU's zijn de kosten van het verhogen van alle vergoedingen binnen de organisatie tot binnen die maximale billijke verhouding.

In hoofdstuk 4 wordt, op basis van dezelfde methode en benchmarkgroep van landen, een goed gefundeerde norm voor een eerlijk minimumloon voorgesteld om daarmee de preventieve kosten voor de impactcategorie van oneerlijk loon. Wat is een eerlijk minimumloon? Omdat uit de literatuur is gebleken dat een absoluut minimumloon alleen geschikt is voor de landen met de laagste inkomens en een relatief minimumloon alleen voor de landen met een hoger inkomen, wordt een relatief systeem voorgesteld, met een bodem van een absoluut minimumloon. Het gemiddelde percentage van het minimumloon van het bruto nationaal inkomen (BNI) per hoofd van de bevolking wordt voorgesteld als het principe voor het eerlijk relatieve minimumloon voor landen met een redelijk BNI. Het voorgestelde absolute minimumloon is gebaseerd op de Wereldbank armoedegrens van 2005 van $ 2,- (PPP). Het relatieve systeem, gebaseerd op gegevens uit 2011, resulteert in een eerlijk minimumloon van 44.4% van het BNI per hoofd van de bevolking terwijl het absolute minimumloon komt op $ 1.547 (PPP) per jaar en $ 0.830 (PPP) per uur. Voor ESCU-toewijzing wordt het verschil tussen de daadwerkelijke betaling en de hier bepaalde PRP voorgesteld. Inmiddels (2020) zijn deze doelen in de Oiconomy bijgewerkt.

Hoofdstuk 5 beschrijft de ontwikkeling van een beoordelingsmethode voor het aspect corruptie. Bij gebrek aan literatuur over S-LCA's met betrekking tot corruptie, werden meer in het algemeen S-LCA-methoden beoordeeld op hun geschiktheid voor dit aspect. Geïnspireerd door een scoringsmethode van Dreyer e.a., die stellen dat diverse sociale aspecten, waaronder corruptie,

beter kunnen worden gemeten aan de kwaliteit van management van bedrijven dan aan hun impact (Dreyer *et al.*, 2010), wordt een indicator voorgesteld van het product van de marginale preventieve kosten en een risicofactor. Voor het aspect van corruptie is het internationaal overeengekomen doel "nultolerantie". Omdat winst de belangrijkste drijfveer is voor bedrijven, wordt voor de marginale preventieve maatregel af te zien van de betreffende activiteiten voorgesteld, en voor de maximale kwantitatieve indicator de daardoor gederfde winst. Voor de risicofactor wordt een techniek voorgesteld die gebaseerd is op het scoren van het beheersen van corruptie door het bedrijf op de vier Plan-Do-Check-Act (PDCA) inspanningsklassen uit risico gebaseerde certificeringsnormen. De toe te kennen ESCU's zijn gelijk aan de gederfde winst vermenigvuldigd met [1-P], waar P de proportie is van de maximaal haalbare PDCA-score.

Hoofdstuk 6 bespreekt de implicaties van het mee-beoordelen van positieve effecten in S-LCA. Geleidelijk verschijnen in de literatuur artikelen waarin positieve effecten in S-LCA-literatuur worden opgenomen, met morele en praktische implicaties voor LCA in het algemeen en vooral voor het op externaliteiten gebaseerde Oiconomy-systeem. Daarom werd een discussie-artikel ingediend over de implicaties en uitdagingen van het opnemen van positieve effecten in LCA's van producten met een voorstel voor een reeks criteria voor hun opname. Besproken worden de tegenstrijdige beschrijvende en normatieve karakters van LCA, het opnemen van "internaliteiten", het als positief beschouwen van "afwezigheid van negatieve effecten", het meten van de status of van verandering en de daarmee gepaard gaande betreffende verschillende tijdspannes, de morele aspecten van het vergelijken van positieve en negatieve effecten met verschillende belangengroepen, de vereiste van een capaciteit verhogend karakter en onderhoud van een positief effect, "rebound effecten", R&D, verschil tussen de aard van achtergrond- of voorgrond-positieven, en het meenemen van werkgelegenheid en de gebruiksfase van producten met positieve effecten. Op basis van deze studie wordt een reeks criteria voorgesteld voor het mee-beoordelen van positieve effecten in LCA's in het algemeen en in het Oiconomy-systeem in het bijzonder.

Deze studie toont verscheidene ernstige ethische en praktische problemen en uitdagingen betreffend het opnemen van positieve effecten in LCA. Een vraagstuk is hoe de economische begrippen "externaliteiten" en "internaliteiten" in relatie tot LCA moeten worden geïnterpreteerd. Daarom werd een speciale definitie voor in- en externaliteiten voor LCA-doeleinden voorgesteld. Belangrijke resultaten zijn dat voor een consistente LCA, de mede beoordeling van de meeste internaliteiten en "afwezigheid van negatieve effecten" moeten worden afgeraden, wat, zonder een reeks aanvullende criteria, ook geldt voor werkgelegenheid en lonen. Er moet grote voorzichtigheid worden betracht bij het mede beoordelen van het positief gebruiksnut van producten in LCA's, het vergelijken van de positieve punten voor de ene stakeholdergroep met de negatieve voor de andere, en het combineren van metingen op status met metingen door veranderingen.

Het belang van een "capaciteit verhogend" karakter met een positieve impact wordt aangetoond, maar ook enkele van de moeilijkheden om capaciteitsverhoging te onderscheiden van het behoud van de huidige status.

Hoofdstuk 7 beschrijft praktijktesten, uitgevoerd door M.Sc.-studenten in stage bij bedrijven. Deze pilots toonden aan dat het Oiconomy-systeem het beste presteert zoals bedoeld, als een B2B methode om foreground duurzaamheidsdata in leveringsketen op gestandaardiseerde wijze te verzamelen, aan te vullen en opgeteld aan de volgende door te geven. De meeste beoordelingsinstructies en criteria van de Oiconomy Standard en - Database bleken begrijpelijk en werkbaar, hoewel toch

ook vraag was naar eenvoudigere vragenlijsten, vooral voor kleine bedrijven. De praktijktesten toonden aan dat het Oiconomy-systeem locatie- en bedrijfsafhankelijke verschillen goed tot uiting laat komen. Hoewel dit voor voorgrondgegevens geen verrassing is, blijken de systemen ook gevoelig voor elke toename van fijnmazigheid in de achtergrondgegevens.

Op basis van de testen onderscheidt een beoordeling met de Oiconomy-standaard zich in vijf kenmerken: 1. De waarschijnlijke behoefte aan overredingskracht van overheden of bedrijven met veel koopkracht om op grote schaal te worden toegepast. 2. Hoge gevoeligheid voor lokale omstandigheden veroorzaakt door het gebruik van bedrijfs- en land-specifieke gegevens. 3. Gevoeligheid voor het inkomens- en prijsniveau van landen, wat een logisch gevolg is van de op kosten gebaseerde indicator. 4. Het systeem van relatieve eerlijke minimumlonen, met een bodem van absolute minimumlonen, wat kan leiden tot ESCU-toewijzingen in zowel in rijke als arme landen. 5. In afwezigheid van voorgrondgegevens kunnen risico's tot een hoge ESCU's leiden, omdat voor standaardwaarden uitgegaan moet worden van slechtste condities.

Een ander belangrijk kenmerk van het Oiconomy-systeem is, aangetoond door de pilots, is dat het systeem niet beoordeelt op impact, maar op kosten van preventie van impact en dat ESCU-scores aanzienlijk kunnen verschillen van de algemene perceptie van het belang van de verschillende aspecten. De pilots brachten verschillende tekortkomingen en onduidelijkheden aan het licht in de Oiconomy Standard, die zijn gecorrigeerd. Verdere aanpassingen aan de standaard, vragenlijst en database moeten geleidelijk worden gemaakt, afhankelijk van opkomende ervaringen en vragen.

In hoofdstuk 8 wordt gereflecteerd op de ontwikkelde methodologieën en methoden, op de ontwikkeling van een certificatieschema, op de nog aanwezige research uitdagingen en op de gebruiksmogelijkheden van het Oiconomy-systeem. Naar onze mening biedt het Oiconomy-systeem de meest natuurlijke manier om de duurzaamheid van producten te beoordelen door het opbouwen van data in de toeleveringsketen. Grote uitdaging voor het systeem is dat het waarschijnlijk de macht van wetgevers van bedrijven met een grote koopkracht nodig heeft om hele leveringsketens te overtuigen om het systeem te gaan gebruiken. Grootste nut van het systeem is de focus op preventie en transparante communicatie van de betrokken kosten. Grote voorbeeld voor het systeem is HACCP, het systeem voor levensmiddelenveiligheid, dat via normen, certificatie en de kracht van grote bedrijven en wetgeving na geruime tijd nu wereldwijd de levensmiddelenveiligheid verbeterde.

In hoofdstuk 8.4 worden enkele aspecten besproken, die niet werden behandeld in een gedetailleerde studie in dit proefschrift, maar wel zijn opgenomen in de Oiconomy Standard. De voorlopige standpunten in de O.S. worden beschreven voor de aspecten van watertekorten, landgebruik, eerlijke transacties, gezondheid en veiligheid op het werk, financiën, doormeten van bedrijven in plaats van producten, en een categorie van diverse sociale verantwoordelijkheden.

De aspecten van watertekorten en landgebruik, ook gedekt door het EcoCost-systeem, worden besproken omdat het Oiconomy-systeem een meer locatiegevoelige en instructieve methode nodig heeft dan door EcoCosts wordt geboden en omdat, naar onze mening, huidige LCA's inclusief de EcoCost-methode voor landgebruik eenzijdig het milieuaspect beoordelen, zonder rekening te houden met de maatschappelijke noodzaak om te voorzien in levensbehoeften.

De opname van het aspect van eerlijke transacties is rechtstreeks afgeleid van de ontwikkelde methode voor eerlijke lonen (hoofdstuk 4). Wij betogen dat bedrijven verantwoordelijkheid

dragen van eerlijke transacties met laagontwikkelde leveranciers, zoals werkplaatsen en kleine boeren, zodat deze een inkomen opleveren, dat minimaal gelijk is aan het eerlijke minimumloon. De voorgestelde ESCU's zijn dan gelijk aan de afstand tot die eerlijke transactie.

De kosten van gezondheid en veiligheid op het werk werden onderzocht door stages van een M.Sc. student in 2 grote bedrijven in de bouw en de levensmiddelenindustrie en uitgebreid met vragenlijstonderzoeken bij 2 andere bedrijven, wat resulteerde in voorlopige gegevens, die verder moeten worden uitgebreid in een grotere groep bedrijven en bedrijfstakken. Als een laatste categorie omvat de O.S. een grote groep van "diverse verantwoordelijkheden", die worden gekwantificeerd door scoring van de kwaliteit van management van bedrijven.

Hoofdstuk 9 omvat de conclusies. De onderzoeksvraag voor deze thesis (sectie 1.8) is beantwoord: Een consequente en gestandaardiseerde methodologie werd gepresenteerd om ESCU's te berekenen, welke bedrijven in de leveringsketen in staat stelt om alomvattend de schade preventie-kosten te bepalen en in opgetelde vorm in de leveringsketen van producten door te geven. Daarnaast zijn de zes subdoelen, geformuleerd in sectie 1.8, bereikt:

Een consequente wetenschappelijke methodologie is ontwikkeld en in de praktijk gebracht.

Gestandaardiseerde beoordeling werd bereikt door middel van de Oiconomy Standaard.

All-in beoordeling in alle 3 PPP pijlers en inclusief alle 17 SDG's werd bereikt.

De Oiconomy Database met prijsfactoren is beschikbaar gemaakt.

Een systeem leidt tot overdracht van opgetelde ESCU's door de leveringsketen. Het daagt uit tot gebruik van voorgrond gegevens, maar zonder die met op slechtste scenario gebaseerde achtergrond gegevens

De methodologie voor bepaling van PRP's werd succesvol in de praktijk gebracht voor de aspecten van inkomensongelijkheid, eerlijke lonen, kinderarbeid en corruptie, en verder getest met voorlopige studies op enkele andere aspecten.

De belangrijkste uitdagingen zijn de organisatie van een certificatie systeem en om voldoende steun van overheden of bedrijven te krijgen om hele leveringsketens te overreden het systeem te omarmen.

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Still hospitalized, based on my 31 years of experience, I wrote a first version of the "Oiconomy Standard". In 2010, temporarily working with People 4 Earth, an organization with the goal to drive markets and organizations to sustainability, I met two people that I thank for their important contribution and with whom I discussed the ideas. In Ed Mönchens' opinion I had "reinvented Life Cycle Assessment", but in a different manner, possibly more practical and better suited for industry. Also Ward de Groote, founder of UTZ Certified, saw new possibilities with the Oiconomy Standard and principles. I am very grateful to both Ward and Ed for their support and especially their inspiration to continue on the new path. Ward introduced me to Dr. Walter Vermeulen, who challenged me to further professionalize the Oiconomy system as a PhD project at the at the Copernicus Institute, Environmental Sciences, Utrecht University. 31 years after my graduation, life had made the changes that I did not make myself, and I took the challenge. I cannot thank Walter enough for introducing me in sustainability sciences, ideas, helping me structuring the project and endless discussions about the numerous involved aspects of environmental, social and economic sustainability. While studying, I soon met Dr. Joost Vogtländer, developer of the EcoCost system at the Delft University, which system I soon decided to incorporate in my further developments, who helped me with numerous questions on LCA and data. During the study a large group of students worked on the project and enriched me with ideas and problems that needed improvement, which I thank them for. At the end of the research, Prof. Dr. Ernst Worrell enriched me with his valuable views. Very important was also the freemasonry with all my "brothers" continuously supporting me after the accident, but also by our rituals and mores. Freemasonry rituals depict every person's life as lessons and challenges, which present themselves as very recognizable and steadfast pillars if they happen in real life. And especially, every meeting ends with the call (in other words): "Go back to real life and behave as a freemason", which means: "make yourself useful to your own abilities, whatever these are". And last but not least I thank my wife, Fenna, mostly for her patience and support, while not getting the expected pensioned, but an always working husband with his mind at the project.

APPENDICES

Appendix 1: Fundamental Questions about Impact-Based S-LCA

1. Is impact-based assessment of specific products feasible? Jørgensen et al. (2010) argue: "Further filling the research gaps, complexity is increased and applicability of S-LCA decreased".
    - Is accomplishing impact-based assessment with reasonable certainty not an illusion, because impact is too complex and in the uncertain future, and are all different aspects not too interdependent?
    - Will it ever be possible to assess the impact of exceeding social tipping points (e.g. desperation, revolutions, terror, war, political changes)?
    - How do we solve the paradox of on the one hand the lack of further embedding S-LCA in social sciences and on the other hand make it to a useful and practical tool?
    - Location- and company specific social impacts are very difficult to assess with background data. How to make the change to foreground data?
    - How do we deal with aspects that depend on politics, religion or culture?
    - How do we determine performance reference points for social issues like what is a fair wage, what is fair inequality?
2. The UNEP Guidelines for S-LCA state: "Social and socio-economic aspects assessed in S-LCA are those that may directly affect stakeholders positively or negatively during the life cycle of a product" (Benoît & Mazijn 2009, p. 37).
    - In the scientific approach, any assessment adds knowledge and is justified, but intended as management tool, any suggestion of comparing positives and negatives between different stakeholder groups is in our opinion unethical (see chapter 6). Is limitation of S-LCA to the same stakeholder groups or to negative impacts only, a solution?
    - The standard economy rewards beneficial effects by definition. Why should LCA include what is already valued by the market? Should LCA not be limited to revealing the hidden negative impacts, the externalities?
3. The Brundtland declaration states: "Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own" (United Nations World Commission on Environment and Development, 1987), and the UNEP Guidelines for S-LCA state: "The ultimate goal of sustainable development is human wellbeing, contributing to the needs of current and future generations" (Benoît & Mazijn 2009, p.16). Combining E-LCA and S-LCA, or in other words considering S-LCA as part of LCA, the following questions may be raised:
    - Does S-LCA include future needs, should it and is that feasible? The currently most considered stakeholder group in current S-LCA's are the workers (Petti et al., 2014), or in other words: individuals directly involved in the production system (Sotanpour et al., 2019).
    - If future needs are included, what is then the temporal scope?
4. The stakeholder approach:

Stakeholders are considered in S-LCA in two ways: 1. As categories of potentially affected groups of people that need to be addressed in S-LCA's according to the S-LCA Guidelines (Benoît Norris *et al.*, 2009). 2. As groups of people that can be studied or interviewed to collect

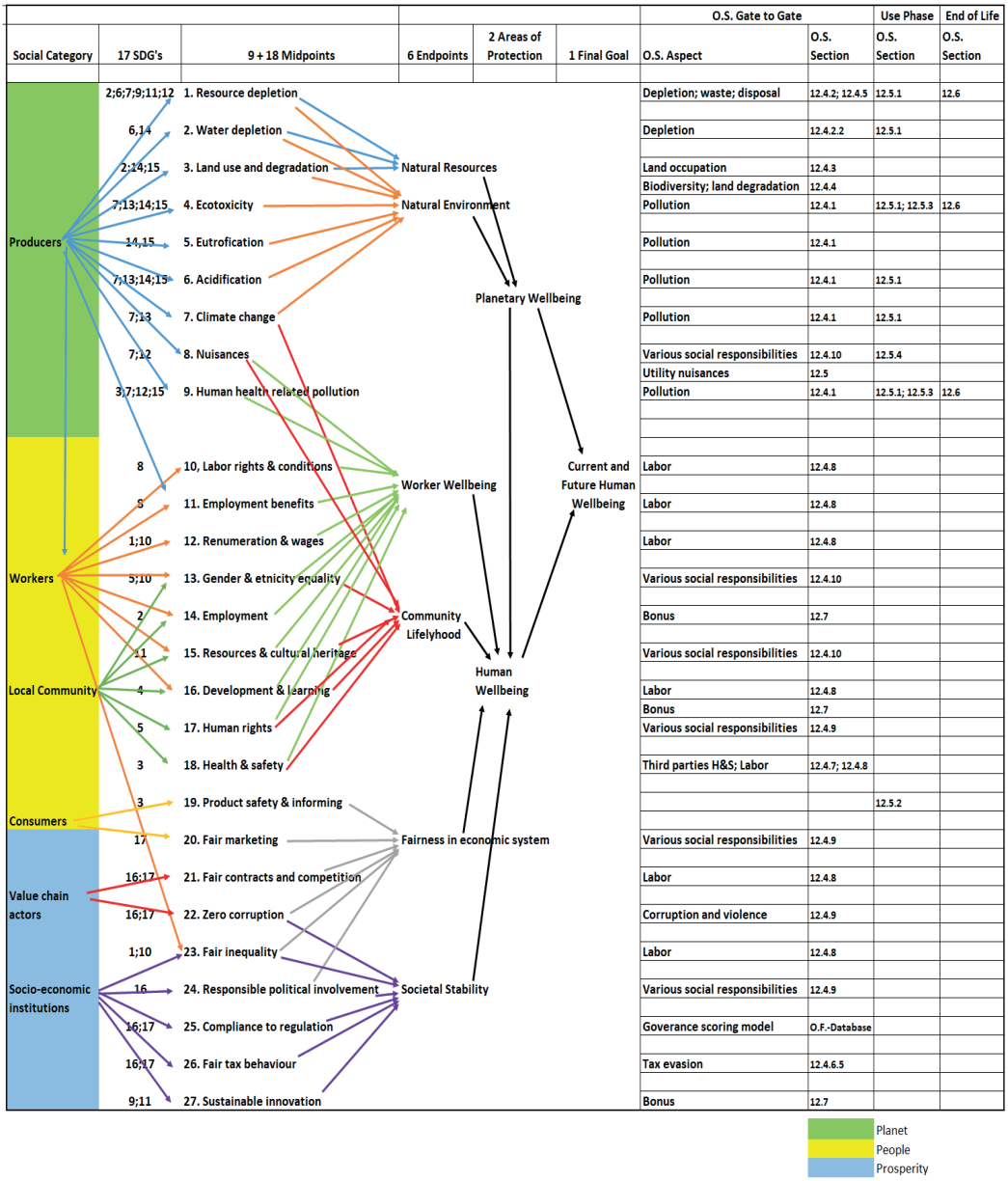
data. In the following points, this is indicated by "(1)" or "(2)".

- (1) How to weight the importance of impacting different stakeholder groups?
- (1) How acceptable is it to exclude a stakeholder group in assessing an impact and can we ever be complete? There always are indirectly affected and unexpected stakeholder groups, such as the children of affected workers, but also competitors and their workers, affected by unjust or unsustainable price pressure, caused by externalities.
- (2) What is stakeholders' temporal scope? Will surveyed stakeholders include (far) future needs? Is not one of the reasons of existence of at least E-LCA that the current market, consisting of the different stakeholders, insufficiently considers future needs? Is not one of the fundamental goals of LCA to better assess future impacts than occurs in the standard economy, caused by currently short term thinking stakeholders?
- (2) How to be objective and accurate in the field of fast changing opinions? Is it, in the international arena, possible to properly conduct stakeholder-based data collection?

5. In current S-LCA, work hours are proposed as activity variable (Benoît & Mazijn 2009, p.50) or share factor, but are also considered as beneficial effect itself.
   - Is a work hour always beneficial (child labor; sub-fair wages; dangerous work)? What if a workhour comes at the expense of a workhour at a socially better employer?
6. Scope determination. The Guidelines state: "Justification needs to be presented when a subcategory is not included in the study" (Benoît & Mazijn 2009, p. 39).
   - Does the scientific S-LCA community keep itself to this criterion?
   - Is it feasible for reviewers to assess articles on this criterion?
   - How to measure improvement on an issue at the expense of another issue?
7. In E-LCA, the most discussed sustainability aspects impact the large human community, such as the climate, loss of biodiversity, overfishing, pollution of the seas, and depletion of minerals. But for instance pollution may be very local with different stakeholders profiting or impacted. How do we deal with the much greater spatial disparities of benefits and burdens in S-LCA, which may even be a deliberate means of competition? E.g. companies easily displace their operations looking for the cheapest labor, and corrupt governments negotiate health and safety requirements and -enforcement.
8. Environmental impacts are usually scientifically quantifiable and globally relatively equal. But how do we deal in S-LCA with aspects, that heavily depend on politics, location, development, culture, history and religion (e.g. Baumann *et al.*, 2013, p.518)? For instance, Arabic countries declared to value Sharia over the universal human rights (Prahalad and Hart, 2002) and according to the World Bank, there are 104 economies with labor laws that restrict the types of jobs women can undertake (World Bank, 2018). Child labor, although almost all countries ratified the 1998 UN convention on the rights of the child, it still is a locally accepted phenomenon in various countries (Nieuwenhuys, 1996).
9. For most environmental aspects, a reference status or -flow is available, such as a maximum temperature for climate change or a no-effect level for eco- and human toxicity of a chemical. For various social aspects however, no precise reference points or targets are available. International conventions are often stated in very general and vague wordings

and markets have gradually introduced standards of questionable value. For instance, for the concept of "fair trade", the market has arbitrarily adopted the "living wage" as fair, which in our opinion, is very questionable.

Appendix 2: Logical aspect scheme (modified from Vermeulen, 2018, p.24)



Appendix 3: Correspondence between the GRI and the Oiconomy Standard, by GRI number

SDG nr.	Sustainable Development Goal	Pillar	Midpoints	O.S. Aspects	O.S. Sections
1	No poverty	People	12	Labor - wages; fair transaction; child labor;	12.4.8.1; 12.4.6.1; 12.4.8.4
2	Zero hunger	People	1,3,14	Pollution; Depletion; land occupation; biodiversity land/water; bonus	12.4.1; 12.4.2; 12.4.3; 12.4.4; 12.7
3	Good health and wellbeing	People	18,19	Pollution; health and safety 2x (public and occupational); product safety	12.4.1; 12.4.7; 12.4.8.4; 12.5.2
4	Quality education	People	16	Labor conditions	12.4.8.1
5	Gender equality	People	13,17	Labor conditions; various social responsibilities	12.4.8.3; 12.4.10
6	Clean water and sanitation	Planet	2	Depletion; health 2x (public and occupational)	12.4.2.2
7	Affordable and clean energy	Planet	1,4,6,7,8,9	Pollution; depletion; land occupation	12.4.1; 12.4.2; 12.4.3; 12.5.3
8	Decent work and economic growth	Prosperity	10,11	Labor; various social responsibilities	12.4.8; 12.4.10
9	Industry, innovation and infrastructure	Prosperity	27	Bonus	12.7
10	Reduced inequalities	People	12,13,23	Labor; various social responsibilities	12.4.8.3; 12.4.10
11	Sustainable cities and communities	People	27	Various social responsibilities	12.4.10; 12.7
12	Responsible consumption and production	Planet	1,8,9	Depletion; land occupation; biodiversity land/water; waste prod/use/end of life; product life; various economic responsibilities	12.4.2; 12.4.3; 12.4.4; 12.4.5; 12.5.3; 12.5.4; 12.6; 12.4.6.4; 12.4.6.6
13	Climate action	Planet	4,6,7	Pollution; energy	12.4.1
14	Life below water	Planet	2,3,4,5,6	Biodiversity water systems	12.4.4
15	Life on land	Planet	3,4,5,6,9	Biodiversity land systems	12.4.4
16	Peace, justice and strong institutions	Prosperity	21,22	Economic responsibility; corruption and violence	12.4.6; 12.4.9; 12.5.4
17	Partnership for the goals	Prosperity	All	Oiconomy system	All sections

Appendix 4: Correspondence between the O.S., GRI and ISO 26000, by O.S. section

O.S. Section	O.S. Section nr.	O.S. Aspects	SDG nr.	ISO 26000	GRI
Gate to Gate	**12.4**				
Pollution and climate change	**12.4.1**	**Considering:**			
	12.4.1.1	Air by bulk gasses	3,7,13,14,15	Yes	Yes
	12.4.1.2	Land or water by agricultural practices	2,3,13,14,15	Yes	Yes
	12.4.1.3	Air, land or water pollution	2,3,13,14,15	Yes	Yes
	12.4.1.4	Water by heat	14	No	No
	12.4.1.5	Incident-caused emissions of any type	3,14,15	Yes	No
Depletion of resources	**12.4.2**	**Considering:**			
	12.4.2.1	Mineral- and natural resources	2,7,11,12	Yes	Yes
	12.4.2.2	Fresh water	3,6	Yes	Yes
Land occupation	**12.4.3**	**Land occupation - efficiency responsibility**	2,7,12,15	No	No
Biodiversity and land degradation	**12.4.4**	**Considering:**			
	12.4.4.1	Biodiversity of water ecosystems	2,6,12,14	Yes	Yes
	12.4.4.1	Biodiversity at land and Land degradation	2,6,12,15	Yes	Yes
Waste	**12.4.5**	**Waste from gate to gate operations**	12	Yes	Yes
Economic responsibility	**12.4.6**	**Considering:**			
	12.4.6.1	Fair transactions	1,16	Yes	Yes
	12.4.6.2	Transparency	16	Yes	Yes
	12.4.6.3	Finance	16	Yes	No
	12.5.4.4	Tax evasion	16	Yes	No
	12.5.4.5	Subsidies	No	No	Yes
Public health and safety	**12.4.7**	**Community health and safety**	3	Yes	Yes
Labor	**12.4.8**	**Considering:**			
	12.4.8.1	Wages	1,8	Yes	Yes
	12.4.8.1	Inequality	10	Yes	No
	12.4.8.1	Employment benefits	3,4,8	Yes	Yes
	12.4.8.2	Occupational health and safety	3	Yes	Yes
	12.4.8.3	Labor conditions	5,8	Yes	Yes
	12.4.8.4	Child labor	1,8,10	Yes	Yes
Corruption and violence	**12.4.9**	**Considering:**			
	12.4.9.1	Corruption	16,17	Yes	Yes
	12.4.9.2	Conflict and violence	16,17	Yes	Yes
	12.4.9.3	Political involvement and opinion awareness	16,17	Yes	Yes
Various social responsibilities	**12.4.10**	**Considering:**			
	12.4.10.3	Animal welfare	12,16	Yes	No
	12.4.10.1	Various social responsibilities	5,16,17	Yes	+/-
Use Phase	**12.5**				
Energy resources and emissions	12.5.1	Use related emissions and depletion	3,7,13,14,15	Yes	Yes
Product health and safety aspects	12.5.2	Use related health and safety	3	Yes	Yes
Pollution and waste	12.5.3	Use related pollution and waste	3,6,14,15	Yes	Yes
Use related social responsibilities	12.5.4	**Considering:**			
	12.5.4.1	Noise	12	Yes	No
	12.5.4.2	Use instructions	12	No	No
	12.5.4.3	Quality	12	Yes	No
	12.5.4.4	Warrenties	12	No	No
Consumption items	12.5.4.6	Energy, emissions	12	Yes	Yes
End of Life	**12.6**	**Considering:**			
	12.6.1	Disposal	12	Yes	Yes
	12.6.1	Optimal product life time	12	Yes	No
Positive Contributions	**12.7**	**Considering:**			
	12.7	Externalities	No	Yes	Yes
	no	Internalities (type 1 - see section 6.4.1.2)	No	Yes	Yes

Appendix 5: Minimum wages, proposed fair minimum wages and minimum to fair wage ratios per country.

- All values in (2011 US$ PPP).
- Fair minimum wages (FMW) are based on the calculation method explained in chapter 4.
- For the calculation of the gross minimum wages (GMW) the following data were used:
  - Minimum wages, from OECD (2011) and ILO (2011; 2012); for 8 countries data from Wageindicator.org (1), Minimum-wage.org (6) and Taiwan Law Library (1) were used.
  - World Bank 2011 PPP conversion rates.
- Actual/Fair minimum wage = Max (GMW; 100 x GMW/ FMW)

Country	Top 20% in 2012 SSI HW	Statutory gross minimum wage (2011 US$ PPP)	Fair Yearly Minimum Wage (2011 US$ PPP)	Fair hourly minimum wage (2011 US$ PPP)	Actual/ Fair Minimum wage (%)
Afghanistan		1109	1547	0.83	71.8
Albania	X	4710	4710	2.53	100.0
Algeria		4073	4073	2.19	100.0
Angola		1335	2322	1.25	57.5
Antigua and Barbuda		7681	7948	4.26	96.6
Argentina		10739	10739	5.76	100.0
Armenia		2959	2959	1.59	100.0
Australia	X	19320	19320	10.36	100.0
Austria	X	n.a.	18670	10.02	n.a.
Azerbaijan		1667	3978	2.13	41.9
Bahamas, The		10651	13227	7.10	80.5
Bahrein		n.a.	9413	5.05	n.a.
Bangladesh		1410	1547	0.83	91.3
Barbados		6853	8392	4.50	81.7
Belarus		6191	6420	3.44	96.4
Belgium	X	20539	20539	11.02	100.0
Belize		4736	4736	2.54	100.0
Benin		1622	1622	0.87	100.0
Bhutan		1244	2473	1.33	50.3
Bolivia		3029	3029	1.63	100.0
Bosnia and Herzegovina		5488	5488	2.94	100.0
Botswana		1789	6460	3.47	27.7
Brazil		3613	5070	2.72	71,3

Country	Top 20% in 2012 SSI HW	Statutory gross minimum wage (2011 US$ PPP)	Fair Yearly Minimum Wage (2011 US$ PPP)	Fair hourly minimum wage (2011 US$ PPP)	Actual/ Fair Minimum wage (%)
Brunei		n.a.	22160	11.89	n.a.
Bulgaria	X	4765	6287	3.37	75.8
Burkina Faso		1690	1690	0.91	100.0
Burundi		62	1547	0.83	4.0
Cambodia		732	1547	0.83	47.4
Cameroon		1343	1547	0.83	87.0
Canada	X	15187	17609	9.45	86.2
Cape Verde		1957	1957	1.05	100.0
Central African Republic		358	1547	0.83	23.2
Chad		1197	1547	0.83	77.5
Chile		5281	7251	3.89	72.8
China		1432	3725	2.00	38.4
Colombia		4915	4915	2.64	100.0
Comoros		1395	1547	0.83	90.3
Congo, Democratic Republic of the		920	1547	0.83	59.6
Congo, Republic of the		n.a.	1547	0.83	n.a.
Costa Rica		4950	5266	2.83	94.0
Cote d'Ivoire		1431	1547	0.83	92.7
Croatia	X	8681	8681	4.66	100.0
Cyprus	X	n.a.	13751	7.38	n.a.
Czech Republic	X	6906	10820	5.80	63.8
Denmark	X	25458	25458	13.66	100.0
Djibouti		n.a.	1547	0.83	n.a.
Dominica		3367	5772	3.10	58.3
Dominican Republic		5785	5785	3.10	100.0
Ecuador		6092	6092	3.27	100.0
Egypt		1825	2717	1.46	67.2
El Salvador		2697	2948	1.58	91.5
Equatorial Guinea		3196	11375	6.10	28.1
Eritrea		341	1547	0.83	22.1
Estonia	X	6178	9257	4.97	66.7
Ethiopia		n.a.	1547	0.83	n.a.
Fiji		n.a.	2047	1.10	n.a.
Finland	X	n.a.	16725	8.97	n.a.

Country	Top 20% in 2012 SSI HW	Statutory gross minimum wage (2011 US$ PPP)	Fair Yearly Minimum Wage (2011 US$ PPP)	Fair hourly minimum wage (2011 US$ PPP)	Actual/ Fair Minimum wage (%)
France	X	18861	18861	10.12	100.0
Gabon		2902	6101	3.27	47.6
Gambia, The		1414	1547	0.83	91.6
Georgia		242	2375	1.27	10.2
Germany	X	n.a.	17862	9.58	n.a.
Ghana		684	1547	0.83	44.3
Greece	X	12230	12230	6.56	100.0
Grenada		5765	5765	3.09	100.0
Guatemala		2957	2957	1.59	100.0
Guinea		n.a.	1547	0.83	n.a.
Guinea-Bissau		956	1547	0.83	61.9
Guyana		2247	2247	1.21	100.0
Haïti		2321	2321	1.25	100.0
Honduras		3959	3959	2.12	100.0
Hong Kong		7936	23243	12.47	34.1
Hungary	X	7650	9018	4.84	84.8
Iceland	X	n.a.	13773	7.39	n.a.
India		1185	1594	0.86	74.3
Indonesia		1225	1998	1.07	61.3
Iran		3642	5070	2.72	71.8
Iraq		1154	1665	0.89	69.3
Ireland	X	21336	21336	11.45	100.0
Israël		11896	12037	6.46	98.8
Italy	X	n.a.	14386	7.72	n.a.
Jamaica		n.a.	1547	0.83	n.a.
Japan	X	14255	15687	8.42	90.9
Jordan		3214	3214	1.72	100.0
Kazakhstan		n.a.	4995	2.68	n.a.
Kenya		1498	1547	0.83	97.0
Kiribati		n.a.	1547	0.83	n.a.
Korea, South	X	14277	14277	7.66	100.0
Kosovo		n.a.	1547	0.83	n.a.
Kuwait		2250	23852	12.80	9.4
Kyrgyzstan		197	1547	0.83	12.8
Lao PDR		1096	1547	0.83	71.0

Country	Top 20% in 2012 SSI HW	Statutory gross minimum wage (2011 US$ PPP)	Fair Yearly Minimum Wage (2011 US$ PPP)	Fair hourly minimum wage (2011 US$ PPP)	Actual/ Fair Minimum wage (%)
Latvia		6667	7859	4.22	84.8
Lebanon		6177	6425	3.45	96.1
Lesotho		2319	2319	1.24	100.0
Liberia		n.a.	1547	0.83	n.a.
Libya		4054	7459	4.00	54.3
Lithuania	X	5890	8720	4.68	67.5
Luxembourg	X	22819	28531	15.31	80.0
Macedonia		n.a.	4924	2.64	n.a.
Madagascar		1110	1547	0.83	71.9
Malawi		517	1547	0.83	33.5
Malaysia		n.a.	6949	3.73	n.a.
Maldives		2960	3299	1.77	89.7
Mali		1181	1547	0.83	76.5
Malta		14249	14249	7.64	100.0
Mauretania		2003	2003	1.07	100.0
Mauritius		2383	6363	3.41	37.5
Mexico		1845	6833	3.67	27.0
Moldova		1927	1927	1.03	100.0
Mongolia		2018	2018	1.08	100.0
Montenegro		n.a.	6083	3.26	n.a.
Morocco		3975	3975	2.13	100.0
Mozambique		1731	1731	0.93	100.0
Myanmar		144	1547	0.83	9.3
Namibia		n.a.	2913	1.56	n.a.
Nepal		1539	1547	0.83	99.7
Netherlands	X	22063	22063	11.84	100.0
New Zealand	X	17588	17588	9.44	100.0
Nicaragua		3529	3529	1.89	100.0
Niger		1400	1547	0.83	90.7
Nigeria		2354	2354	1.26	100.0
Norway	X	n.a.	27288	14.64	n.a.
Oman		4941	11420	6.13	43.3
Pakistan		2260	2260	1.21	100.0
Panama		5408	6442	3.46	83.9
Papua New Guinea		2619	2619	1.40	100.0

Country	Top 20% in 2012 SSI HW	Statutory gross minimum wage (2011 US$ PPP)	Fair Yearly Minimum Wage (2011 US$ PPP)	Fair hourly minimum wage (2011 US$ PPP)	Actual/ Fair Minimum wage (%)
Paraguay		7210	7210	3.87	100.0
Peru		4815	4815	2/58	100.0
Philippines		1824	1838	0.99	99.2
Poland	X	8847	9071	4.87	97.5
Portugal	X	10778	10851	5.82	99.3
Qatar		n.a.	38379	20.59	n.a.
Romania		4757	6713	3.60	70.9
Russia		2871	9129	4.90	31.4
Rwanda		427	1547	0.83	27.7
Samoa		2026	2026	1.09	100,0
Sao Tome and Principe		624	1547	0.83	40.4
Saudi Arabia		n.a.	10967	5.88	n.a.
Senegal		1270	1547	0.83	82.3
Serbia		5312	5312	2.85	100.0
Seychelles		6674	11162	5.99	59.8
Sierra Leone		165	1547	0.83	10.7
Singapore		n.a.	26365	14.14	n.a.
Slovakia	X	7177	9826	5.27	73.0
Slovenia	X	13983	13983	7.50	100.0
Solomon Islands		1502	1547	0.83	97.3
South Africa		3585	4755	2.55	75.4
Spain	X	12474	13942	7.48	89.5
Sri Lanka		1032	2451	1.31	42.1
St Kitts and Nevis		7239	7313	3.92	99.0
St Lucia		1150	4982	2.67	23.1
St Vincent and Grenadines		3664	4635	2.49	79.0
Sudan		1455	1547	0.83	94.2
Suriname		2500	3423	1.84	73.0
Swaziland		1128	2633	1.41	42.8
Sweden	X	n.a.	18737	10.05	n.a.
Switserland	X	n.a.	23341	12.52	n.a.
Syria		3402	3402	1.83	100.0
Taiwan	X	12221	12221	6.56	100.0
Tajikistan		389	1547	0.83	25.2
Tanzania		1735	1735	0.93	100.0

Country	Top 20% in 2012 SSI HW	Statutory gross minimum wage (2011 US$ PPP)	Fair Yearly Minimum Wage (2011 US$ PPP)	Fair hourly minimum wage (2011 US$ PPP)	Actual/ Fair Minimum wage (%)
Thailand		1966	3712	1.99	53.0
Timor-Leste		n.a.	2309	1.24	n.a.
Togo		1270	1547	0.83	82.3
Tonga		n.a.	2220	1.19	n.a.
Trinidad and Tobago		3938	10811	5.80	36.4
Tunisia		4339	4339	2.33	100.0
Turkey		9516	9516	5.10	100.0
Turkmenistan		2386	3858	2.07	61.8
Uganda		86	1547	0.83	5.5
Ukraine		3132	3132	1.68	100.0
United Arab Emirates		17143	21263	11.41	80.6
United Kingdom	X	18266	18266	9.80	100.0
United States	X	15080	21676	11.63	69.6
Uruguay		4054	6500	3.49	62.4
Uzbekistan		373	1547	0.83	24.1
Vanuatu		5016	5016	2.69	100.0
Venezuela		5104	5519	2.96	92.5
Vietnam		1177	1547	0.83	76.3
Yemen		n.a.	1547	0.83	n.a.
Zambia		1176	1547	0.83	76.2
Zimbabwe		n.a.	1547	0.83	n.a.

Appendix 6. Governance Level Scoring Model

Filled criteria-scores (0 or 1) are an example. The scores of the PDCA Effort Categories are calculated from the criteria scores. All criteria to be assessed considering the aspect of corruption.

PDCA Class and nr.	Criterion (demonstrated and effective)	Scores
	Plan Category = Sum Plan-criteria / Number Plan-criteria	0.91
	Do Category = Sum Do-criteria / Number Do-criteria	0.59
	Check Category = Sum Check-criteria / Number Check-criteria	0.88
	Act Category = Sum Act-criteria / Number Act-criteria	0.75
	Company Score = Plan x Do x Check x Act	0.35
	Calculation factor to be multiplied with maximum ESCU score (= 1- company score)	**0.65**
Plan	**Policy.**	**criteria scores (0 or 1)**
1.1	Policy defined, appropriate and up-to-date, and approved by the highest local management and by the highest corporate management.	1
1.2	Policy is aimed at continuous improvement.	1
1.3	Policy includes compliance to the national law and to the requirements of the Oiconomy Standard.	1
1.4	Documented, maintained and implemented plan of goals in a (at least five years) plan. Decision structure and Tasks, Responsibilities (T.C.R.s) defined.	1
Plan	**Risk analysis**	
2.1	Procedure for a risk analysis.	1
2.2	Analysis of the relevant risks for all stakeholders.	1
2.2	All risks and measures listed in the relevant section of the Oiconomy Standard included in the analysis.	1
2.3	Risks are ranked and priorities are set based on the seriousness and frequency (or ease) of occurrence.	0
Plan	**Legal requirements**	
3.1	Analysis of the relevant legal requirements and international declarations and for which activities related to the product these requirements are relevant.	1
Plan	**Goals**	
4.1	Conversion of the policy goals into SMART goals. (Specific, Measurable, Acceptable, Realistic, Time limited)	1
4.2	Plan of implementation and monitoring on the SMART goals.	1
Do	**Resources available**	
5.1	Qualified people with defined T.C.R. s, funds, time and investments.	0
5.2	Qualified coordinator with access to the highest local and corporate management.	1
5.3	Top management commitment demonstrated by the documentation and communication.	1
5.4	Required capital investments determined, and approved by the highest (corporate) management, and in the planned stage of execution.	0
Do	**Knowledge and training**	
6.1	Required knowledge and skills throughout the organization defined and made available.	1
6.2	Needs for training analyzed and training provided where necessary.	1
6.3	Availability of knowledge documents and, where necessary, contacts with relevant experts.	0

Do	Internal and external communication	
7.1	The plan and T.C.R.s are communicated internally and planned externally.	1
7.2	Consciousness and relevant knowledge on the relevant aspect throughout the organization.	1
7.3	Analysis of all internal and external stakeholders that may have an interest or influence on the relevant aspect.	1
7.4	Analysis of all internal and external stakeholders that may experience an adverse effect regarding the relevant aspect.	0
7.5	Plan of communication with all defined stakeholders.	1
7.6	All risks and information are communicated to the relevant stakeholders in a clear, readily accessible, understandable, unambiguous way. The company is readily available for complaints.	0
Do	**Documentation**	
8.1	Policy, scope and working of the relevant management system are documented.	1
8.2	Documents required by the Oiconomy Standard for ESCU registration.	1
8.4	Procedures that regulate the working of the system.	1
8.4	Methods of measuring and sampling.	1
8.5	Descriptions of functions, T.C.R.s and the organization structure.	0
Do	**Document control**	
9.1	Authorization of documents for first use and for revision.	1
9.2	Documents identifiable, up-to-date, legible and readily available where needed.	1
9.3	Prevention of use of unauthorized documents.	1
9.4	Identification of required external documents and controlled distribution thereof to the relevant locations and functions.	1
Do	**Operational control**	
10.1	Criteria identified based on requirements, risk analysis and goals.	1
10.2	System of preventative measures on identified risks. Analysis of those (critical control) points internally (and if necessary externally) where absolute prevention can be achieved. Effective prevention systems on these points.	1
10.3	Procedures to discover shortcomings and to convert these into improvements, including a procedure for handling complaints and incidents with a time limit for completing these, and including a procedure for protection of whistleblowers.	1
10.4	Control of the influence of third parties on the relevant aspect, including a procedure to monitor and evaluate the quality of the suppliers and the transparency of their communication.	0
Do	**Emergency plans**	
11.1	Action plans for incidents of corruption and non-compliance.	0
11.2	Yearly evaluation of incidents of corruption and non-compliance.	0
11.3	Yearly tests of emergency situations where practical.	0
11.4	Traceability at least one step backwards and one step forwards, including waste flows.	0
11.5	Procedure of internal and external communication in case of a corruption incident, -request or -threat.	0
11.6	Yearly test of traceability (including waste) and communication procedure.	0
Check	**Monitoring and measurement on the relevant aspect.**	
12.1	Plan and execution of monitoring (what, when, where and how), fit for demonstration that the control system is effective. Inclusion of near-incidents.	0
12.2	Use of independent persons for monitoring and avoidance of personal involvement of these persons.	0

Check	Evaluation of the relevant aspect.	
13.1	Procedures for periodical evaluation of the monitoring results against the requirements and goals.	1
13.2	Procedures for registration and communication of the monitoring results and of the conclusions of the evaluation.	1
Check	**Preventive and corrective measures on the relevant aspect.**	
14.1	Procedures to discover the root causes of shortcomings, incidents and complaints and to prevent repetition thereof. (Consider the possibility that top management may ultimately be the root cause, especially on repetition of the shortcoming).	1
14.2	Procedures for preventive measurements based upon the risks found in the risk analysis.	1
14.3	Procedures to analyze trends in incidents, shortcomings and complaints and to improve the policy.	1
14.4	Procedures to compensate, remove or minimize the damage that has been caused by incidents or shortcomings.	1
14.5	Monitoring on and registration of preventive and corrective measures.	1
14.6	Procedures to regularly verify and evaluate the adequacy of earlier taken preventive and corrective measures.	1
Check	**Registration and control.**	
15.1	Meeting the requirements is demonstrable by registered data.	1
15.2	Registered data are traceable, stored in a protected way, available for at least five years, legible and identifiable.	1
15.3	Coherent and communicated system of registration locations.	1
Check	**Internal audit on the relevant aspect.**	
16.1	At least yearly internal audit by independent (no auditing of people's own responsibilities), objective and qualified persons against the requirements.	1
16.2	Written report with information to the management.	1
16.3	Audit procedure with criteria, scope, method, frequency, reporting, shortcomings, requirements for evaluation and corrective measures.	1
Act	**Management review on the relevant aspect.**	
17.1	At least yearly management review.	1
17.2	Top management responsibility is demonstrable in practice.	1
17.3	Documented input: Internal audit, complaints, incidents, relevant communication with authorities and other stakeholders, evaluations, status of preventive and corrective measures, result of the decisions of the last MR, changes in this standard, legislation and other requirements and improvement propositions.	0
17.4	Documented output: assessment of the effectiveness of the system, decisions for improvement; adjustments in the policy, goals and plans.	1