WITH CHEMICAL LEASING TOWARDS A STRONG SUSTAINABILITY APPROACH

Tesis de Maestría
en Economía Ambiental y Ecológica

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To my friend Miguel Alejandro Mendez Mariano.

List of Charts and Graphics

List of Abbreviations

B2B – Business to Business

CAC – Command and Control

ChL – Chemical Leasing

CSR – Corporate Social Responsibility

e.g. – For Example (abbr. of Latin: exempli gratia)

et al. – And Others (abbr. of Latin: et alii)

EFA – Energy Flow Accounting

EI – Economic Incentive

etc. – et cetera

GHS – Globally Harmonized System of Classification and Labeling of Chemicals

HANPP – Human Appropriation of Net Primary Production

ICCM – International Conference on Chemicals Management

ibid – Ibidem

ILO – International Labor Organization

LCA – Life-Cycle Assessment

MFA – Material Flow Accounting

MEFA – Material and Energy Flow Analysis

NCPC – National Cleaner Production Center

NGO – Non-Governmental Organization

OECD – Organization for Economic Co-operation and Development

q.v. – Quod Vide

RECP – Program on Resource Efficient and Cleaner Production

SAICM – Strategic Approach to International Chemicals Management

TÜV – Technical Control Board (abbr. of German: Technischer Überwachungsverein)

UNEP – United Nations Environment Programme

UNIDO – United Nations Industrial Development Organization

Introduction

Increasing environmental catastrophes, climate change and pollution show that the current approach of weak sustainability is not enough to provide current and future human generations with vital services. Business corporations are the main actors in an economy that transform natural capital into man-made capital and thus, could play the most important role in the transition towards an economy with a strong sustainable development. Nevertheless there is a lack of concrete guidelines for single business units and most business follow a weak sustainability approach, based on eco-efficiency.

Industrial Ecology with its integrated concept of industrial metabolism tries to translate the theory into a concrete proposal of how the economy should look like to create a strongly sustainable economic system on the planet. It proposes a three step model that leads companies towards strong sustainability. The crucial step is the implementation of inter-firm relationships, which permit resource sharing, conservation, waste stream reuse, recycling and by-product cascading. Facilitating those connections through economic incentives and a trustful legal framework could lead to an organic growth of connections among companies and to the establishment of an industrial ecosystem with (almost) closed material and energy flows.

There is a need for alternative business models, which incentives these interactions and collaborations to achieve the step from the firm level to the inter-firm level. The collaboration must give economic incentives to dematerialize, decarbonize and to create the basis for a self-organizing systems towards eco-industrial parks.

Chemical Leasing is a service oriented business model which's promotion forms part of the UNIDO strategy towards Cleaner Production. Beside the immediate economical and ecological benefits by reducing and reusing chemicals, the author argues that the potential of Chemical Leasing is the creation of expertise networks that could lead to Industrial Ecosystems. Chemical Leasing gives economic incentives to collaborate and is based on a TÜV-certificated collaboration framework, which provides transparency and trust among cooperating business units.

This thesis examines the role of business units towards a strong sustainability approach. Due to the lack of alternatives it uses the concept of Industrial Ecology as a guideline how businesses can achieve a strong sustainable development. The following normative research question was formulated:

Does Chemical Leasing contribute to align single business units with a strong sustainability approach?

This central question is elaborated in further 3 sets of questions that describe and analyze the implementation of strong sustainability in companies:

1.) What are sustainability approaches that companies can strive for and what are their challenges?

2.) What are the indicators for a development towards strong sustainability in the industry?

3.) What can be concluded about the aspects of the business model of Chemical Leasing leading towards a sustainable development? Does it give evidence for strong sustainability?

These questions will be examined in the following order. The theoretical part will answer the first question. It presents the two main concepts of sustainability, weak and strong and shows why weak sustainability is not an option neither on the long term nor on a larger scale. Instead the concept of strong sustainability is explored. The principles of Industrial Ecology are used to find recommendations for businesses to align their activities.

In the second part a methodology is established to measure the contribution of a certain project or business model towards strong sustainability. Indicators are determined to measure a project's contribution on the micro, meso and macro level. On the micro level, the criteria of eco-efficiency and good house-keeping indicate the effectiveness of strong sustainability efforts inside the business unit. The meso level explores the establishment of business relationships. It finds a way to indicate if a network is fostered by a project/model and if collaboration effects regional and global dematerialization and decarbonization. The macro level focuses on the intended learning process given by the policy framework.

In the third part, UNIDO's Chemical Leasing program is tested under the established indicators to analyze whether it contributes to a strong sustainable economy. Eight case studies give insight into the micro and meso level and the general concept of Chemical Leasing is used for the macro level.

I. Theoretical Framework

1. Different Concepts of Sustainability

Increased environmental catastrophes, climate change and water and air pollution can indicate deterioration of our ecosystems as a result of human industrial activities. There are two different approaches among economists to address the limits of environmental depletion: the optimistic (weak sustainability approach) and the pessimistic view (strong sustainability approach). The former supposes that there are no limits to economic growth and that man-made capital can supplant natural capital, while the latter opposes by arguing the necessity to guarantee a certain level of ecosystem functionality, which provides as a whole, services for human society (Cabeza Gutes 1996).

The publication of the 1987 Brundtland Report on "Our common Future" is deemed to be the beginning of the worldwide discourse on sustainability and sustainable development in order to find a suitable way to align human industrial activity with the environment. The Brundtland Report calls for greater inter- and intra-generational equity and a dynamic improvement in the balance between economy and ecology. The aspect of intra-generational deals with the question how we can guarantee the satisfaction of present generations' need without lower those of future generations.

In response to the broad environmental and social movement of the 1970s and 1980s managers of big- and medium-sized companies have become aware of the necessity to deal with their responsibility towards environment and society. In the last decades they have developed and implemented business strategies to deal with the issue of sustainability, in order to respond to their clients' demands. In dependence on the Brundtland Report, the International Institute for Sustainable Development in conjunction with Deloitte & Touche and the World Business Council for Sustainable Development recommend to adopt "[...] business strategies and activities that meet the needs of the enterprise and its stakeholder today, while protecting, sustaining and enhancing the human and natural resources that will be needed in the future."

Companies address through Corporate Social Responsibility/ Corporate Citizenship practices the desired balance between the economic, social and environmental dimension of sustainability; but as mentioned before there are different forms of sustainability, weak and strong. The positive impact of a company on the aspect of sustainability depends on its approach. In the following the difference between weak and strong sustainability is explained and it is argued why a strong sustainability approach is preferable.

1.1. Weak Sustainability

Utility is an indicator for sustainability in the context of economic activity. A company operates sustainable, "if its activity does not decrease the capacity to provide non-declining/capita utility for infinity" (Neumayer, 2003, p.7). To understand the difference between weak and strong sustainability one has to understand the different forms of capital, which can provide utility: natural, human, social and man-made capital. Natural- and man-made-capital are the key elements to understand the difference between both concepts. Natural capital refers to non- or renewable natural resources, while man-made-capital is the objectivation of man's knowledge, such as the creation of technology or products and services in general.

The concept of weak sustainability can be seen as an extension of the neoclassical theory of economic growth, by taking into account exhaustible resources as a production factor (Cabeza Gutes 1996). The work of Dasgupta and Heal (1974), Hartwick (1977) and Solow (1974) contribute to establish rules on economic growth to calculate how much of non-renewable resources can be consumed and how much has to be invested in man-made capital to compensate natural capital loss and to increase consumption later, in order to guarantee non-decreasing utility on the long term, and therefore, perpetual welfare. Welfare is guaranteed, if the capital stock is increased or maintained. The welfare of an economy, which capital is based on natural non-renewable resources will decline on the long term, because at some point it will reach the point when the capital stock falls to zero (Solow 1974). Therefore, Hartwick (1977) derived the rule that rents from non-renewable resource depletion, should be reinvested in man-made capital, such as technology. This means that the loss of natural capital can be compensated by man-made capital to provide a maintaining total net stock. The Hartwick-Solow model shows through a Cobb-Douglas production function the constant and unitary elasticity of substitution between natural capital and man-made capital. Thus, weak-sustainability is based on the assumptions that a sustainable economy is guaranteed (Dietz/Neumayer 2009),

- if the natural resources are super-abundant
- or the elasticity of substitution between natural and man-made capital is greater than or equal to unity
- or the technology progress can increase the productivity of natural capital stock faster than it is being depleted.

From this perspective it is recommended to invest in technology in order to create man-made capital, which is able to compensate natural resources. Plus, it becomes necessary to shift from non-renewable to renewable natural resources.

In order to measure if an economy is considered weakly sustainable, Pearce and Atkinson (1993) created a weak sustainable index as an indicator of sustainable development. The weak sustainability index is calculated by the difference between savings rate and the sum of the depreciation rate of natural and man-made capital. If the weak sustainability index is greater than zero, an economy is considered (weakly) sustainable.

1.2. Strong Sustainability

Supporter of strong sustainability are less permissive and argue that natural capital can't be generally substituted by man-made capital. Natural resources must not be seen as single units but as a system. The complexity of the interaction between different player – the ecosystem – is what provides essential functions for human society. The substitution may cause irreversible harm. Pearce (1988) states that, although the total capital is maintained through aggregation of different types of capital it is necessary to sustain a certain amount of available natural capital. Otherwise, the substitution may cause irreversible harm (ibid.) and threatens the functionality of ecosystem services.

Ekins and Simon (2003) and Pearce and Turner (1990) identify four different categories of those services provided by the ecosystem:

- Source Function: Natural resources are input for production and used for direct consumption such as food, timber and fossil fuels.
- Sink Function: The possibility to deposit waste and the ecosystem's ability to assimilate incurred waste from human production and consumption
- Human health and welfare function: Amenity services, which allows spiritual and cultural interaction with nature.
- Life support function: A set of function performed through the interaction of land, water and air, which allows human life on earth.

The fourth category is of primary value, as it does not only provide life support functions for human life, but also it is the primary factor to guarantee the other three subordinate functions.

In order to illustrate the difficulty of natural capital substitution, each of the fourth categories will be briefly analyzed. Natural resources are input for production and consumption. Although "[...] in the past the economy has consistently overcome production and consumption resource constraints" (Neumayer 2000), the economic process still depends on this input. The input to produce a man-made capital substitute comes from natural resources, energy and raw materials to transform them in goods and services. One day we might be able to artificially create a system which provides sink function or amenity services. From an environmental point of view this is critical, because as Victor (1991, quoted in Pearce/Atkinson 1993, p.142) states it “the easier it is to substitute manufactured capital for depleting resources for a degraded environment, the less concern there need to be about the capacity of the environment to sustain development.” The most critical part is that of life support function. The ecosystem is very complex, which makes it difficult to substitute it with man-made capital and with the current knowledge it is impossible (Barbier et al. 1994). Life support functions include e.g. the regulation of local and global climate, hydrological and biochemical cycle and the maintenance of the other three functions.

In the literature often natural capital is divided into two subcategories, non-critical and critical natural capital. The latter refers to non- or hardly substitutable resources. Nevertheless, in practice it is hard to distinguish and classify natural capital. Risk and uncertainty are other important factors, which have to be considered. Thus far human society does not have the knowledge and tools to create a complete functioning and artificial eco-system; thus, there can’t be made any prediction of the effect of natural resource exploitation and depletion. Current and upcoming extinction of species may represent an irreversible loss of natural capital.

Representatives of strong sustainability use the concept of safe minimum standards (Ciriacy-Wantrup 1952) (Costanza/Perrings 1990) and adaptive management (Holling 1978, Walters 1986, Lee 1993, and Gunderson *et al.* 1995) in order to address uncertainty and complexity of ecosystem and sustainability in general. The concept of safe minimum standards deals with low uncertainty and assures through a monetary deposit the compensation of environmental loss. Before the implementation of a project a fund is created. If the project hasn’t caused harm through its implementation, the deposit is returned; if any environmental threads have occurred, than the deposit is used to compensate or prevent damage. This strategy internalizes externalities and gives incentive for managers to deal more carefully with environmental risks. Fundamental or complete uncertainty is managed through the adaptive management approach, which deals with the complexity of a system and improves its functionality by learning from errors through the process of experimental research, monitoring, learning processes, and policy choices. Adaptive management requires the interaction between various stakeholders and experts from different academic fields.

The current limits to substitution of natural resources by man-made capital and due to the uncertainty which and to what extend natural resources are needed to provide current and future human generations with vital services (Ekins et al. 2003), the present work sees strong sustainability as a necessary approach for businesses to align their activities.

1.3. General Strong Sustainability Implications for Companies

Business corporations are the main actors in an economy that transform natural capital into man-made capital and thus, could play the most important role in the transition towards an economy with a strong sustainable development (van Kleef/Roome 2007). A weak-sustainable economy is based on eco-efficiency, which pretends to produce the same amount of products and services while using less environmental input. It takes into account only relative measures by evaluating the created value, a product's service in comparison to the spent natural resources or its caused harm. This concept improves the efficiency of a product or service but it doesn't include the limits of ecosystem functionality. A strong sustainability approach uses absolute measures to show a corporation's contribution to a sustainable development beyond eco-efficiency (Figge/Hahn 2004). It calculates the benefits of a product or service by subtracting the caused internal and external costs.

Several authors have come up with different necessary criteria for a strong sustainable development linking economic demands with environmental limits by focusing on resource and energy conservation and the reduction of waste (Daly/Cobb 1990, DeGroene/Hermans 1998, Heeres et al. 2004, Wallner 1999). The first three requirements have been defined by Daly and Cobb (1990). They claim the necessity that the exploitation rate of renewable resources is at an equal or lower rate than their regeneration level; non-renewable resources shouldn't be depleted at a greater rate than the development of their renewable substitutes; the limits of ecosystem functionality with its absorption and regeneration capacity shouldn't be surpassed. Based on this basic and very general assumption various corporately more tangible recommendations have come up. Scholars of Ecological Economics – such as Daly (1999), Costanza et al. (2002) - hold that a strongly sustainable economy has to act inside its social and environmental boundaries. They recommend eco-cyclic economies, where a determined amount of resources from environment and society is assigned to the economy and cyclically reused, ideally without waste flows or deprecation (Ehrenfeld/Gertler 1997). Following the functionality of the ecosystem, the only input is solar energy (Odum 1971), because it is the only energy source that is not connected to the economic or environmental production process, but it is an external source (Wallner 1999, van Weenen 1995).

Industrial Ecology with its integrated concept of industrial metabolism tries to translate this recommendation into a concrete proposal of how the economy should look like to create a strongly sustainable economic system on the planet.

2. Industrial Ecology

The concept of Industrial Ecology considers the impact of human activity on biophysical environment in order to create sustainable strategies for industrial design, processes and implementation. It uses a system perspective to examine industrial activity not as an isolated unit, but in concert with its surrounding. Environmental issues are as important as and connected to technologies, processes, economics and inter-relationship of businesses. Industrial Ecology aims to optimize the material and energy flow by designing closed material cycle. That is the radical decrease of waste by re-integrating it again as a resource into the material cycle.

The first notion of Industrial Ecology can be traced back to the 1970's. Using the ecological metabolism as a role model, Ayres et al. started with research on material and energy flows in the industry, naming it industrial metabolism (Ayres/Kneese 1969). At the same time Watanabe was in charge of an Industry-Ecology Working Group, set up by the Japanese Ministry of International Trade and Industry, to further develop the idea of a reinterpretation of the industrial system in terms of scientific ecology (Watanabe 1972). The breakthrough of the concept came with the article “Strategies for manufacturing” by Frosch and Gallopoulos, who introduced in 1989 the concept of industrial ecosystems in the western academic world (Frosch/Gallopoulos 1989).

They emphasized on the necessity to adopt an analogue of biological ecosystems, and create industrial ecosystems (Frosch/Gallopoulos 1989 p. 95). The biological analogy refers to the biophysical nutrient cycle, where waste of one species serves as the input for another one, without depreciating resources. Therefore, they claimed that:

"The traditional model of industrial activity - in which individual manufacturing processes take in raw materials and generate products to be sold plus waste to be disposed of - should be transformed into a more integrated model: an industrial ecosystem. In such a system the consumption of energy materials is optimized, waste generation is minimized and the effluents of one process may serve as the raw material for another process." (ibid.)

The analogy can be seen as an inspiration for a creative process towards sustainability (Benyus 1997 quoted by Ehrenfeld 2004). On the one hand it gives a framework to create a sustainable lifecycle of a concrete product (Levine 1999) and on other hand a model to create organizational interactions that allow the reintegration of effluents into another product cycle (Graedel 1996).

Differently than other sustainable concepts, Industrial Ecology seeks not only a product based approach, but also takes into account a geographical based approach (Boons/Baas 1997; Korhonen 2002). The former relates to intra-firm strategies to increase industry efficiency while conserve resources and prevent pollution. While the latter centers on analyzing local or regional networks of material and energy flows (Ehrendfeld/Gertler 1997, Côté and Smolenaars 1997). The geographical approach does not only include flows between companies or industries, but also includes human activity in relation to its natural environment (Erkman 1997; Ehrenfeld 2000). Ecological Industry uses a system perspective, where the focus does not lie on a product or a company, but they are viewed in concert with their surrounding system, regarding other companies and industries (industrial ecosystem) and regarding the natural ecosystem; “interaction between human activities and the environment are systematically analyzed” (Graedel 1994, p.23). Industrial Ecology sees different industries as subsystems and requires their integration and coordination, in order to form an industrial ecosystem, similar to the function of its biophysical role model, the natural ecosystem. If the waste of one company should be used in another process, than “individual manufacturing processes cannot be considered in isolation”(Frosch/Gallopoulos 1989, p.99).

This led to the need of closed material loops, where all materials are reintegrated in the production cycle without depletion. Material closure of one company can be improved by material reuse and recycling within firms. Therefore, the establishment of a system of waste exchange can extend eco-efficiency. This exchange is also called material and energy cascading: wastes from one industry are transported and used as input in a nearby industry. Constant exchange of information, energy and materials between industries and its external environment favors the formation and improvement of the industrial ecosystem (Guo et al., 2013, p. 14047), reaching every time less resource depletion and irrevocable waste.

Jelinski et al. (1992) describe the transition from a linear material flow towards cyclic material flows in a three type model. Type I is a linear flow model, where the material flow from one stage to another is independent of all other flows. In this model resources and carrying capacity of waste are seen as unlimited and provided by the natural ecosystem. In the next step, the system type II takes up a quasi-cyclic material flow. Resources are seen as limited, such as the carrying capacity of waste; energy is seen as an unlimited separate input. Type II is seen as a semi-matured state of Industrial Ecology, which is more efficient but still not sustainable over the long term. Type III is the ideal economic system, where there is no input of further resources, but all resources are reused and recycled without depletion or irrevocable waste. Analogical to the ecosystem, the only external input is the sun’s energy. It is a mature and materially closed ecosystem that is ultimately sustainable through almost the complete cyclic nature of material flows.

To achieve this third type it is necessary to “reduce environmental degradation associated with each unit of resource used. Applying a system approach implies different operational elements at different levels: at the firm or unit process level (1), at the inter-firm, district or sector level (2) and at the regional, national or global level (3) (Lifset/Graedel 2002,p.10).

(1) At the firm level industrial ecologists seek to avoid environmental impact and/or minimize the cost by applying several tools (ibid). One is to incorporate environmental issues already at the primary stage of product and process design (design for environment). Contemplating this at the primary stage can prevent pollution (pollution prevention) and increases eco-efficiency by creating goods and services, while using less resources and generate fewer waste and pollution. Green accounting integrates environmental costs into the financial results of operation; thus, it considers both economical and environmental factors. In Industrial Ecology firms are viewed as environment improving agents (ibid, p.3). Their duty is to apply their technological expertise to create environmentally informed design of product and processes in order to achieve environmental improvement.

(2) Synergetic relationships between various industries permit resource sharing, conservation, waste stream reuse and recycling and furthermore cost savings. The creation of industrial synergies, where at least two partners exchange materials, energy or information in a mutual beneficial manner, can lead to more complex forms, eco-industrial parks. In these different firms collaborate in managing environmental and resource issues through material, water, energy and by-products cascading. The whole process is monitored and evaluated by life-cycle-assessment; this includes all stages of a product’s life: material extraction and processing, manufacture, distribution, use, repair and maintenance, and disposal (cradle to grave) reintegration in the life cycle (cradle to cradle). "To optimize resource use and to minimize waste flows back to the environment, managers need a better understanding of the metabolism (use and transformation) of materials and energy in industrial ecosystems, better

information about potential waste sources and uses, and improved mechanisms (markets, incentives, and regulatory structures) that encourage systems optimization of materials and energy use" (Frosch/Uenohara 1994, p.2). Industrial sector initiatives, such as trainings and research can improve the adaptability towards an industrial ecosystem.

(3) Eco-industrial parks can cooperate with each other regionally, nationally and globally and form Eco-Industrial Networks. Due to globalization materials and energy flows have become international; therefore, its analysis has to cover regional, national and international aspects. Material and Energy Flow Analysis analyzes the so called industrial metabolism (Ayres/Knees 1969) by tracking materials and energy flows. Through different local and global efforts, Industrial Ecology seeks dematerialization and decarbonization. Dematerialization is the effort of reducing total material and energy throughput in product and service based business models; de-coupling of economic growth and consumption rate of resources is a great issue. The same applies to de-carbonization, the reduction of carbon dioxide emissions and is closely related to dematerialization, because a minimized resource use leads to reduced emissions.

In Industrial Ecology firms are viewed as environment improving agents. Their duty is to apply their technological expertise to create environmentally informed design of product and process to achieve the transition from type I to type III. Ayres (2002) points out four necessary conditions in order to achieve this transition.

"First, a fairly large scale of operation is required. This means that at least one first-tier exporter must be present to achieve the necessary scale. Second, at least one other major firm (or industrial sector) must be present locally to utilize the major waste of the exporter, after conversion to useful form. Third, one or more specialized 'satellite' firms will be required to convert the wastes of the first-tier exporter into useful raw materials for the consumer, and to convert the latter's wastes into marketable commodities, secondary inputs to other local firms, or final wastes for disposal. A final condition, of great importance (and difficult to achieve in practice) is that a reliable mechanism be established to ensure close and long-term cooperation- that is information sharing- at

the technical level among the participating firms. The guarantor of this cooperation must either be the first –tier exporter itself, a major bank, a major marketing organization or a public agency." (Ayres 2002, p.44)

2.1. The Challenges of Implementing Strong Sustainability

Although there are certain guidelines for business entities, "it is still difficult to operationalize and measure strong sustainability in practice on the micro (e.g. company) level (Málovics et al.2008). It has to be stated that Industrial Ecology leaks an omnipotent measurement of strong sustainability, due to the complexity of the ecosystem, which makes it still impossible to identify particular elements of critical natural capital (Ekins 2003). O'Rourke et al (1996, in Baas 2005, p.90) criticizes Industrial Ecology in five main points: its poor definition, the methodological weakness of its tools, the strategies do not often support goals, the implementation, to date, does not reflect ideas expressed in the literature, and technical analyses of energy issues and socio-political analyses of means to transform industry are extremely limited. Nevertheless in the literature the concept of Industrial Ecology is one of the most mentioned and used concepts in the context of strong sustainability. Boons and Baas (1997) highlight important implications from the industry-ecology analogy: Strong sustainable development has to be considered as a constant improving industrial transformation process, where the different actors and activities are interrelated and there is a need for intentional action to achieve this process of improvement. Following the metaphor of an ecosystem, the adaption of an industrial system can only be achieved through the consideration of all factors and only the establishment of a closely cooperating network of business entities and society can provide a more holistic approach on sustainable development. Thus, the creation of an industrial eco-system provides the necessary connections and ensured input and interactions of multiple stakeholders to constantly improve and to adapt the structure of the system.

The approach of Industrial Ecology stipulates the creation of synergetic relationships between business entities and other stakeholders to establish eco-industrial parks. Its way to measure sustainability is based on regional and global energy and material flows. In the concept of IE, strong sustainability can only be reached in conjunction of different entities. Industrial Ecology seeks a three step model, from economy type I to III, and gives recommendation at the firm or unit process level, at the inter-firm, district or sector level and at the regional, national or global level (Lifset/Graedel 2002, p.10). Nevertheless its suggestions on the firm level are based on eco-efficiency and it does not provide measurements of strong sustainability for a business unit. Handfield et al. (2002) doubt that strong sustainability can be measured on the level of business organizations, because there is a lack of necessary framework conditions to determine a strong sustainable organization and to give advices how this standards can be met by the unit. It would be needed to calculate the limits of resource for each single company on the planet, but the current scientific measurements are not able to do so. Málowics et al. (2008) criticizes the different environmental reporting standards and methods. This results in incompatible sustainability indicators, and different processes in one business unity and business activities among a business sector or among regional, national and global level can be hardly compared with each other (ibid.). Due to these difficulties it is currently not possible to establish strong sustainability standards for single business units; therefore, following the concept of Industrial Ecology, to achieve a sustainable economy the implementation of a co-operational approach is necessary.

Since the emergence of Industrial Ecology only little projects could be implemented successfully, such as the exemplary eco-industrial park Kalundborg. The problem of establishing an industrial park is that it does not only depend on physical, chemical and energy flows and the associated technology to technically establish cyclic material flows (Côté/ Cohen-Rosenthal 1998). Another important issue is the establishment of human and business relationships based on trust and transparency. Industrial Ecology concepts can only occur inside a business framework, and the complex part is to create those collaborations (ibid). There is no one and only recipe but different ways to do so. Allenby (2002) points out the difficulty of implementing cross-sectoral, company and/or product collaborations, regarding meaningful incentives for the companies and the legal framework to ensure the collaboration. "The adjustment of different processes towards each other and towards their (natural) environment does not result from autonomous processes, but can only be achieved by intentional action" (Baas 2005, p.90).

The most attractive incentives for companies are those of monetary terms. If there is a business model, which allows a company to be economically more efficient and if the legal framework is given to ensure liability and build trust among this collaboration, then business units would be incentivized to cooperate. The construction of an industrial eco-system involves an interaction of different actors, organizations and activities from the public and private sector.

Given these basic conditions a self-organizing system could be created. Facilitating those connections through economic incentives and a trustful legal framework could lead to an organic growth of connections among companies and furthermore "to a larger range of connections, greater ownership over the process and higher results over a broader range of measures" (Côté and Cohen-Rosenthal 1998, p.5).

There is a need for alternative business models, which incentives these interactions and collaborations to achieve the step from the firm level to the inter-firm level. The collaboration has to be in that way that there are economic incentives to dematerialize and decarbonize and to create the basis for a self-organizing systems towards eco-industrial parks.

In the following it is examined if an alternative business model, called Chemical Leasing could help to give this incentives and how it contributes towards a strong sustainable development.

3. Chemicals and Sustainability

Since the 1970s different political approaches and tools have been applied and tested to mitigate the impact of chemical use. The two most important recent approaches are Cleaner Production and Industrial Ecology (Baas 2005). Since 2006 United Nation Industrial Development Organization promotes inside its Cleaner Production Program the concept of Chemical Leasing (Jakl 2008). It aligns incentives for chemical producers and users to shift from a conventional seller-buyer relationship towards a service relationship so that the seller becomes a service provider while the buyer becomes the service user. The incentives of this service oriented business model, called Chemical Leasing is the resulting environmental and economical win-win situation for the supplies and demander of the chemical (Jakl/Schwager 2008). Hence it is an attractive market oriented tool with various incentives for companies to apply it.

Chemical Leasing forms part of the official worldwide Cleaner Production Program, nevertheless the author argues that Chemical Leasing gives foundation for a more integrative approach, Industrial Ecology. Due to its necessary collaboration amongst supplier, demander and other partners (Joas 2008), it allows not only the mitigation and improvement of the life cycle management of a chemical inside a company but seeks to realign the relationship between chemical provider and customer in order to form a collaborative and specialized network of different companies to reduce, reuse and recycle chemical substances (Antonnen 2010) by establishing long-term collaborations.

The attempt to integrate Chemical Leasing into the concept of Industrial Ecology aligns with the claim of Lozano, Carpenter and Lozano (2014), who argue that "Chemical Leasing needs to be part of a holistic approach, so that the economic, environmental, social and time dimensions of sustainability are fully addressed"(ibid., p.53).

3.1. Overview of Environmental Regulations

The very first environmental laws and regulations, at the beginning of the 1970s were based on command and control mechanisms, basically permits to control air, water, soil and noise pollution. For the first time companies had to respond for the ecological damages of their industrial activity, but the implementation had been little radical and provoked only little changes. Furthermore, according to Bruijn/Lulofs (Baas, 2005 quoted from Bruijn/Lulofs, 1996) permits were discussed based on set strategic decisions, and permits dealt with repairing ecological consequences rather than preventing them. These regulations led to the emergence of *end-of-pipe technology* and *clean-up technology*. In the former companies invested in added-on technology to treat emissions and hazardous waste streams, to mitigate the environmental and human health impact at the firm's place of location, the latter technology is used to recover polluted air, water and soil through remediation. In a later step *Environmental technology* were implemented, using technologies, processes and products that reduce and prevent environmental pollution throughout the production process. Greener production in this sense has been associated with additional production cost and contamination with externalities, a non-business related cost internalized through political measurements.

3.1.1. Cleaner Production

In the late 1980s- 1990s both industry and international governments became acquainted with the concept of greener production and shifted towards a more precautious, integrative and preventive approach (Jackson 1993), called *Cleaner Production.*[1] Former environmental strategies focused on specific pollutants in a particular environmental medium, basically air, water or soil, at a specific production step, mainly end-of-pipe. Thus Cleaner Production aims to consider the whole production process, from design to production to market activities. Cleaner Production integrates production processes inside a company, trying to prevent pollution from the very beginning, the design stage, and mitigating over the whole life cycle. UNEP defined in 1991 Cleaner Production as "[...] the continuous application of an integrated preventative environmental strategy to processes, products and services to increase efficiency and reduce risks to humans and the environment" (UNEP 2013). Since then, the concept of Cleaner Production has evolved and the current definition includes 8 key points (q.v. Chart 1).

[1] The concept of Industrial Ecology has aroused at about the same time than Cleaner Production but at the beginning it has been implemented primary in Japan

Chart 1: Characteristics of Cleaner Production
Source: UNIDO 2013

1. Good Housekeeping: appropriate provisions to prevent leaks and spills and to achieve proper, standardized operation and maintenance procedures and practices;
2. Input Material Change: replacement of hazardous or non-renewable inputs by less hazardous or renewable materials or by materials with a longer service life-time;
3. Better Process Control: modification of the working procedures, machine instructions and process record keeping for operating the processes at higher efficiency and lower rates of waste and emission generation;
4. Equipment Modification: modification of the production equipment so as to run the processes at higher efficiency and lower rates of waste and emission generation;
5. Technology Change: replacement of the technology, processing sequence and/or synthesis pathway in order to minimize the rates of waste and emission generation during production;
6. On-Site Recovery/Reuse: reuse of the wasted materials in the same process or for another useful application within the company;
7. Production of Useful By-Products: transformation of previously discarded wastes into materials that can be reused or recycled for another application outside the company; and
8. Product Modification: modification of product characteristics in order to minimize the environmental impacts of the product during or after its use (disposal) or to minimize the environmental impacts of its production.

In summary Cleaner Production stands for the integration of environmental management into company management by applying strategies for more efficient use and re-use of resources and energy. On the conceptual level different techniques are used to change behavioral patterns in the micro and macro level towards pollution reduction and prevention. On the execution level clean or cleaner technologies are introduced with higher resource efficiency, minor emission and less energy use. In this sense greener production has been associated not only with environmental benefits but also financial benefits that enhances firm's competitiveness in the market. Together with the United Nation Industrial Development Organization (UNIDO) UNEP promotes cleaner production across the world.

In 1994 UNIDO and UNEP launched a joint Program on Resource Efficient and Cleaner Production (RECP) to establish National Cleaner Production Centers. Its target is to promote cleaner production at the national level through different training programs for industry and government, introducing new technologies and giving recommendations to improve national policy framework to favor cleaner production. The three core activities are (UNIDO 2013):

- Resource Efficiency by improving energy, materials and water use
- Waste & Pollution Prevention by preventing waste and emission generation, including sound management of chemicals and Chemical Leasing
- Safe and Responsible Production by addressing occupational and community environmental health and safety through the creation of green jobs, and skill and capacity development

Nowadays the UNIDO–UNEP RECP Program builds upon the capacities of 47 National Cleaner Production Centers and Programs established in Africa, Asia, Central and South America, and Europe.

According to Jackson (2002) the borderline between the two concepts Cleaner Production and Industrial Ecology is blurred and it depends on the author's specific conception of both terms. Based on the eight key points of Cleaner Production (UNIDO 2013) a clear difference can be seen in the addressed sector. While Cleaner Production focuses on one sector or even one company, Industrial Ecology follows an integrated system-perspective of industry (Sagar/Frosch 1997), which "examines the relationship between producer, consumer, other entities and the natural world" (ibid.). The system borders of Cleaner production are inside the industrial entity; therefore, eco-efficiency is achieved through technology and process improvement inside the entity. In contrast, Industrial Ecology aims, in addition to eco-efficiency inside the entity, to further reduce material and energy flows as a whole, which is the overall natural resource intensity of a process or product, also referred to as the ecological rucksack (Schmidt-Bleek, 1999). These hidden flows consist of all materials and energy that is removed from nature in order to create a product, which includes the total production process along the supply chain from raw or starting material extraction until the product is ready for use. Pauli (1997) points out that Cleaner Production can learn from Industrial Ecology, the importance of cooperative relationships between individual firms in the drive for sustainable development. Thus, Industrial Ecology requires a strong cooperative network between and inside productive and consuming actors in order to reduce material and energy flow along the supply chain.

3.2. International Programs on Chemical Management

At the 1992 United Nation Conference on Environment and Development, the International Labor Organization (ILO), the Organization for Economic Co-operation and Development (OECD), various governments and other stakeholders decided on the Globally Harmonized System of Classification and Labeling of Chemicals (GHS) (UNCED 1992). GHS promotes worldwide common and consistent criteria for classifying chemicals according to their health, physical and environmental hazards. Based on the resulting classification they developed compatible labeling, safety data sheet for workers and other security information. Before this convention standards and regulations differed throughout countries. A worldwide approach was needed due to increasing international trade in chemicals that entailed potential risk for neighboring countries with lax controls. The international provided infrastructure on classification and labeling is particularly attractive for developing countries, which do not dispose on resources for an own chemical management system.

GHS ensures minimization of risk to human health and environment through information exchange between supplier and user. Chemicals management and adequate labeling reduces the risk of unintended release of chemicals and provides information and knowledge to ensure its safe handling throughout its life cycle.

In 2002 at the Johannesburg World Summit on Sustainable Development governments of UN agreed on a convention that by 2020 production and use of chemicals had to be regulated to significantly reduce adverse impacts on the environment and human health. To achieve this goal a multi-stakeholder and multi-sectoral Preparatory Committee developed a new policy framework, called Strategic Approach to International Chemicals Management (SAICM) at the 2006 International Conference on Chemicals Management (ICCM). SAIM aims to coordinate, catalyze and facilitate all efforts for better international chemical management system. However SAICM does not replace existing national and international institutions and mechanisms, it has no legal bound, but gives recommendations to further integrate Chemical Sound Management into national legislation. The progress in SAICM implementation is constantly reviewed at successive ICCM sessions.

3.3. Chemical Leasing

3.3.1. The Concept

The Concept of Chemical Leasing goes back to Jakl et al. who published their first book "Chemical Leasing – An intelligent and Integrated Business Model with a View to Sustainable Development in Materials Management" in 2004 (Jakl et al. 2004). They highlighted the economic and ecological potential of applying service-oriented business models to the chemical sector.

The experience and successful implementation of Austrian pilot project lead to its further promotion. In the first half of 2006, when Austria held the Presidency of the European Union, chemical policy was on the top of the environmental agenda (Jakl 2008), pushing forward EU's negotiation on SAICM. At the 2006 International Conference on Chemicals Management (ICCM) in Dubai, Austrian Federal Minister for the Environment and UNIDO Director General committed themselves to Chemical Leasing as their common political priority (ibid.). With the help of UNIDO's National Cleaner Production Centers the concept of Chemical Leasing has been introduced to different countries, with the first international pilot projects in Austria, Egypt, Mexico and Russia.

Production, application and disposal of chemicals come along with impacts on environment. In a conventional model, reducing environmental impacts means to reduce the amount of chemicals and this necessarily leads to a decrease in profit for the chemical producer. Thus conventional environmental policies stand in conflict with economical aims of chemical industry. For the chemical producer there are no economical incentives to prevent over-consumption, or inform its clients on more efficient use, less hazardous alternatives and effective recycling of chemicals (Ohl/Moser, 2007). The concept of Chemical Leasing provides a shift towards a different business approach which leads to a win-win situation, for the seller, the user and the environment, by offering chemical solutions instead of chemical products. Chemical Leasing is a service-oriented business model that abandons the conventional supplier-buyer relationship, where the supplier aims high sales volumes to increase profit.

Instead it creates incentives so that the supplier becomes a service provider and the buyer becomes the service user based on a long-term relationship, achieving economical benefits for the producer by providing a cleaning service instead of selling a product, the chemical. The producer of the chemical, now offering its service, is paid for the provided service, while remaining the owner of the chemical. For example instead of selling a certain volume of cleaning chemicals, the cubic meter of cleaned surface becomes the entity to establish a service rate. The experience of the implemented pilot projects has shown that the implementation of Chemical Leasing implies in average a reduction of 15% in total costs (Jakl/Schwager 2008). This business model uses a value-added approach, where the economic advantages are shared between supplier and user (Joas, 2008). Hence, Chemical Leasing provides competitive advantage for both, supplier and user.

Chemical producers can increase their profit through specialized services, while users receive an adequate cleaning treatment without paying extra. Through the decoupling of sales volume and profit Chemical Leasing not only leads to higher earnings but also to increased efficiency in the application of the chemical within a specific production process, because now the producer/supplier has an interest in reducing chemicals to reduce its cost in the service management. Specialized handling of chemicals facilitates the reduction and substitution of hazardous material and provides adequate risk management and environmental advantages. Thus, the associated expertise is a key point in Chemical Leasing. In the service model, the manufacturer remains the owner of the chemical and extends his responsibility: while in the conventional model his responsibility ends with the delivery of the chemical, in Chemical Leasing he may is included in the management of the entire life cycle of the chemical.

Jakl and Schwager (2008) identify three different models of Chemical Leasing. The first one includes only two actors, the supplier and the user. The supplier produces the chemical, offers an adequate service to the user and is in charge of recycling or disposal. In addition the service may include a third party (2nd model) or various partners (3rd model) to optimize or modify the existing process by bringing in more know how or more specialized technology through e.g. the cooperation with equipment manufacturers or recycling companies. Different to other management services Lozano, Carpenter and

Satric (2013) point out that the Chemical Leasing model is based on knowledge and information transfer on chemicals between the collaborating partners. This fosters the cooperation between the parties by creating a relationship of openness and trust, which enables them to an adequate management on hazards and risks. Thus, the most important element of Chemical Leasing is not the focus on scientific/technological or policy changes but in particular on business relationships (Lozano/Carpenter and Satric 2013).

Not all processes are suitable for the implementation of Chemical Leasing. Schwager and Moser (2005) point out that the chemical should not form part of the final product. In this case the chemical and its application does not form part of the user's core business and there are higher possibilities of improvement. Furthermore high risk and high value substances with a superior concentration in waste are potential chemicals for the application of Chemical Leasing (ibid.); Chemicals in former pilot projects have been mainly non-reactants and were, to a great extent, easy to recover.

3.3.2. The Political Embedment

UNIDO embeds the concept of Chemical Leasing in its strategy of Sustainable Industrial Resource Management (SIRM). Similar to the concept of Ecological Industry SIRM promotes the idea of implementing circular material and energy flows in the entire production chain. It bases on the idea that total material cycles can be optimized and modeled on the self-sustaining cycles of nature (Schwager 2008). The main approach is to close material and energy loops, based on two concrete principles: Reuse/Recycling, and Substitution.

Chemical Leasing is categorized by UNIDO as a tool for Cleaner Production (Jakl et al. 2002, Schwager 2008) and each Chemical Leasing project aims to accomplish the mentioned eight key points. Nevertheless the author believes that the concept of Chemical Leasing and its implementation has the potential to create relationships between different companies originating capabilities for industrial ecosystems. The line between the concept of Cleaner Production and Industrial Ecosystem is blurred and its distinction varies between authors (Jackson 2002). The core element of Industrial

Ecology, the focus on closed life cycle (Lifset/Graedel 2002), has been adapted already at SIRM and is a major goal in Chemical Leasing.

The concern of this thesis is not pinpointing the distinction and classification of Chemical Leasing in a set concept but the demonstration of its potential towards an integrative mitigation approach in the meaning of strong sustainability.

II. Methodology

In order to analyze whether Chemical Leasing leads to strong sustainability or not, there is a need to define what are driving forces towards strong sustainability. In the following a methodic framework is established. The division of Baas (2002) is used to analyze strong sustainability from its micro meso and macro perspective. The micro level focuses on companies' effort towards strong sustainability, while the meso level explores the establishment of business relationships, which lead to cluster management and at the macro level the focus lies on the policy framework to implement the learning process of sustainability. At the end a matrix is presented, which summarizes the indicators of the analysis.

1. From Sustainable Companies Towards Sustainable Regions

The environmental approach of a business can be examined from different viewpoints. There are actors inside, between and outside the company, which influence decision-making process. Inside the company, there can be identified e.g. employees, between companies, there are suppliers along the supply chain and outside companies, there is society in general terms and specifically governmental and non-governmental institutions and organizations and clients and non-clients. Actors inside, between and outside the company can have important roles of influence in the aspect of the company's sustainability, to push forward sustainable approach and learning. Employees, most notably managers, with a different, greener mindset can institutionalize change. In the business to business marketplace (B2B) a company e.g. can influence the environmental behavior of a supplier company by demanding certain environmental standards. Furthermore, the company has to fulfill governmental environmental standards, while it tries to address its client's concerns through corporate social responsibilities activities.

Baas (2002) distinguishes three levels of sustainability from a business perspective, the micro, the meso and the macro level. On each level there are different stakeholders, which determine the willingness and the capacity to change.

The efforts of sustainability on the micro level lead to sustainable companies. There are a variety of actions a business unit can take, and it will be discussed later which kind of actions follow a weak or a strong sustainability approach. The approaches on the company level can be seen in the context of the concept of cleaner production. Cleaner production emerged from a transition process from a pollution control approach towards pollution prevention. At the early stage and still many companies use greener technology inside an economic driven motivation; pollution prevention has simply become less expensive than pollution control. This has led to only marginal changes in the operational mode of a business unit. The concept has to drive not only technical marginal changes but has to be institutionalized through a integrated learning process and has to be integrated in a company's mission, vision and strategic action.

Sustainability on the meso level addresses cluster management and sustainable regions. This can be seen as the industrial ecology state of sustainability. It goes beyond the borders of a single business unit by using a system perspective and creating sustainable regions. Starting with different meaningful connections along the supply chain in order to optimize material and energy flow, the transition culminates in the dialogue of regional stakeholders about institutional frameworks to integrate environmental management into new routines and procedures towards closed cycles.

The macro level examines the condition framework of how the learning process at the micro and macro level is influenced through strategic policy development. Changes at the private and public organizational level are highly influenced by the society. Sustainability is the integration and balance between the economic, ecologic and social dimension. It seems that the social dimension has its key aspect in the macro level, while the ecologic dimension is highly addressed on the meso level, and the economic dimension is more present in the micro level.

1.1. Micro Level

1.1.1. Cleaner Production

Since the beginning of the 1970s the technological approach has changed from pure waste treatment (end-of-pipe-, and clean-up- technology) towards the prevention of pollution at source (environmental technology) and furthermore the reduction of energy and raw material use inside the company (cleaner production).

Strong sustainability seeks a learning process inside the business unit to provoke a continuous adaptation process of environmental improvement. In the view of strong sustainability cleaner production has to fulfill two aims: cleaner technology and good housekeeping. The former refers to research and development efforts and the application of clean or cleaner technology, which works more eco-efficiently. This means it uses less energy and raw materials than comparable technology, while at the same time contaminating less. The creation of this technology is facilitated by good housekeeping, which refers to the institutionalization of clean production throughout the production cycle among different stakeholders. In this sense cleaner production can be seen as the conceptual dimension of integrating environmental management into a company (good housekeeping), which stimulates the technical development of cleaner technology inside the company.

The most critical stage of the production process is the product and process design. Cleaner Production requires a design for environment approach, where in each stage of the development process the environmental aspects are considered equally as traditional product values such as profit, functionality, aesthetics, ergonomics, image and overall quality (Rose 2000). Those stages include the whole life cycle of a product: material extraction, manufacturing, transportation, usage and end-of-life phases. The inclusion of environmental aspects diminishes the product's environmental impact towards its lowest level in each stage throughout their entire life cycle (van Hemel 1998).

Gee (1994) identifies four principles of cleaner production: precautionary, preventative, integrative and democratic, which help to institutionalize the concept. Precautionary implies a proactive approach, which leads from a "problem- based" towards a "solution-based" environmental policy (Tickner/Geiser 2004). The aspect of pollution prevention emerged with the increased awareness of the inefficient and ineffective nature of pollution control technologies and the need for a preventive approach that led into a win-win situation for economy and ecology (Gavrilescu (2004). Integrative means that the issue of sustainability is not marginalized but is a process of concept development that involves all divisions of the company. This implies research on the topic, awareness rising and education of staff and board members. Informed employees are the basis for a democratic process of learning and decision making. Like this new actors can be involved and can enrich the organization's change process towards sustainability.

Cleaner production itself lacks the potential to contribute to sustainable development. It can develop its full potential in the context of industrial networks. Thus, there is a need to connect highly eco-efficient companies in a highly innovative network, the meso level.

1.2. Meso Level

In the concept of IE, strong sustainability can only be reached in conjunction of different entities. Thus, the meso level refers to the creation of synergetic relationships between business entities and other stakeholders in order to establish eco-industrial parks. There are two main factors that need to be taken into account to analyze the degree of sustainability regarding the synergetic relationships: the physical terms of improving environmental impact and the learning process on the creation of synergetic relationships. The former is based on measuring regional and global energy and material flows and the latter uses system boundaries in their static and dynamic dimensions to analyze what influences regional eco-industrial development. In the following it will be shown on which elements these relationships are build on and what indicators are used to measure sustainability in physical terms on the meso level.

1.2.1. Industrial Synergies in Physical Terms

Synergetic relationships are those established on the inter-firm, district or sector level and on the regional, national or global level between various industries. These collaborations permit on the physical term to resource sharing, conservation, waste stream reuse and recycling which can lead in the financial context to cost savings. The simple form is the one of industrial synergy, where at least two partners exchange materials, energy or information in a mutual beneficial manner. This can lead to more complex forms, eco-industrial parks, where different firms collaborate in managing environmental and resource issues through material, water, energy and by-products cascading. Eco-industrial parks can form eco-industrial networks by cooperating among each other regionally, nationally and globally.

Two methods help analyzing sustainability on the meso level regarding physical terms: life-cycle assessment (LCA) and material and energy flow analysis (MEFA). LCA focuses on the life cycle of one specific product from cradle to grave, which runs through different companies and processes along the value chain. MEFA analyzes the material and energy flows in general, accounting all flows of simple and complex industrial synergies on the inter-firm level, district level, sector level or between industries on a regional, national or global scale.

Rochat et al. (2013) state the advantages of combining both tools, due to the dual perspective. The integration of LCA and MEFA presents a wider panorama of the system by combining data from the process level (LCA) with the dynamics of the (e.g.) regional system (MEFA). Like this each process can be linked to the dynamics of the region. This is especially interesting regarding the problems of defining system boundaries (ibid.).

(1) Life-cycle Assessment

"Life-cycle assessment evaluates the environmental impact of a product, of a process or of a system in relation to its precise function" (Rochat et al. 2013, p.644). It evaluates the environmental impact of a product or system throughout its life cycle to find points for optimization. LCA monitors and evaluates the whole production process throughout all stages of a product's life. This starts with material extraction and processing, followed by manufacture, distribution, use, repair and maintenance, and final finishes at the disposal (cradle to grave) or is reintegrated in the life cycle (cradle to cradle). It aims to facilitate a system view in product and system evaluation to integrate more and more life cycle thinking into business decision making. The guidelines and principles for LCA are set under ISO 14001 and 14004 (2004).

The mathematic structure behind LCA is an input-output analysis, where the interdependencies across different sectors of the economy are represented by a set of linear equations. Although it is conceptually simple, the implementation of LCAs is difficult. The main problem is the capture of a large number of diverse inputs, which are often interdependent and require specific modeling.

There are different approaches to analyze the life cycle, including or excluding different aspects or using dissimilar programming techniques. Guillén-Gosálbez and Grossman (2010) present a strategy for the multi-objective optimization specialized on chemical supply chains. Gerber et al. (2011) have come up with a systematic methodology to integrate Life Cycle Assessment in Industrial Ecology Principles.

(2) Material and Energy Flow

Dematerialization and decarbonization are keywords of strong sustainability. Dematerialization is the effort of reducing total material and energy throughput in product and service based business models. Decarbonization is closely related to dematerialization and focuses explicitly on the reduction of carbon dioxide emissions. They are interrelated in that way that a minimized resource use also leads to reduced emissions. Material and Energy Flow Analysis (MEFA) are used in order to measure whether an economy dematerializes/decarbonizes. MEFA analyzes the so called industrial metabolism (Ayres/Knees 1969) by tracking materials and energy flows. Human economic activity is taken as an organism with inputs (raw materials) and outputs (wastes and emissions) and MEFA measures the size of this industrial metabolism. It allows an analysis of biophysical aspects of a society using an ecosystem compartment. It compiles information on material stocks and the flows between the ecologic system and the biophysical structure of society. The measurement of energy flows goes back to ecological anthropology (Rappaport 1971, Kemp 1971). Boulding (1973) and Ayres and Kneese (1969) were pioneers to apply this approach in a compatible way to established tools of social and economic statistics in order to link socioeconomic variable with biophysical patterns and processes.

The MEFA framework is constantly developing. Currently it comprises three aspects: Material flow accounting (MFA), Energy flow accounting (EFA) and Human

Appropriation of Net Primary Production (HANPP). MFA is a method to systematically account flows and stocks of materials or elements within a system defined in time and space (Eurostat 2001). EFA have been applied on the same method than MFA (Haberl 2001). HANPP addresses the lack of integrating land use in the socio-economic metabolism, by conceptualizing it as "colonization of terrestrial ecosystems" (Fischer-Kowalski/Haberl 1998) and as such including it in the MEFA framework. HANPP analyses land-use related changes in ecosystem patterns and processes by comparing it with results that would be expected without human intervention (Vitousek et al. 1986). New accounting tools are under development, a main effort is based on carbon flow (Haberl et al. 2004).

Due to globalization, materials and energy flows have become international; therefore, its analysis has to cover regional, national and international aspects. The MEFA framework can be applied on several spatial scales. There have been MEFA studies on the national level (Eurostat 2001) on the supranational level (Eurostat 2002) and on sub national entities such as economic sectors (Schandl/Zangerl-Weisz 1997) cities or regions (Brunner et al. 1994). Thus MEFA can be seen as an indicator for the progress towards strong sustainability on the meso level. Haberl et al. (2004) identify two MEFA-based assessments which allow an interpretation as progress towards sustainability: a reduction in the yearly flows of renewable resources and reductions in outflows (emissions and waste).

1.2.2. System Boundaries

An industrial eco-system is an analytical construct. In order to analyze improvements towards sustainability there is a need to delimit precise boundaries to examine processes and outcomes inside those defined limits (Boons and Baas 1997). Baas (2005) uses static and dynamic dimensions of systems boundaries to analyze their consequences on regional industrial development. Industrial Ecology proposes an industrial eco-system of constant adaption and changes; therefore, it is argued (ibid., p. 265) that the dynamic dimension is necessary.

1.2.2.1. Static Issues

On the meso level we can identify three different system boundaries: the product chain, the industry sector, and the regional industrial system. Actors and companies along the product chain and inside the same industry sector are interdependent and have strong incentives to collaborate. Outside these accustomed boundaries, collaborations are rarely found, because it consists of actors, whose core activities do not automatically depend on one another. Industrial Ecology concepts can only occur inside a business framework, and the complex part is to create those collaborations among actors outside the usual product chain and between different industry sectors. Business relations are linked to risks. Co-operations imply exchange of confidential information, the core of the enterprise. There is a need for meaningful incentives for companies (Allenby 2002) in order to overcome their risk-aversion.

So the question is: why should these actors collaborate? Maybe there are some authoritative institutions which can create the first connections, but there is a need to find common problems and goals among those actors to create dependency and to establish relationships among entities and between entities and the society.

The concept of cluster management is used to explore further the interaction of stakeholders, based on the notion of Industrial Ecology, which promotes the formation of ecologically compatible industrial clusters (Wallner 1998). Complementary industries can form zero-emissions cluster (Ehrenfeld/Gertler 1997) by actively networking on the basis of material and energy flows.

The concept of clusters come from agglomerative economics and started in the 1920s with the concept of industrial districts (Terstriep 2007). “Clusters are geographic concentrations of interconnected companies and institutions[...]” (Porter 1998, p.78), which include a wide range of different stakeholders. “[...] the enduring competitive advantages in a global economy lie increasingly in local things – knowledge, relationships, motivation – that distant rivals cannot match. Competitive advantage rests on making more productive use of inputs, which requires continuous innovation [...].” (ibid., p.78ff).

Taking the risk of cooperation becomes the solution for market risks, because a concentrated customer base lowers risk and facilitates to spot market opportunities. Cooperation gives access to “[...] suppliers of specialized inputs such as components, machinery, and services, and providers or specialized infrastructure” (ibid.). Cooperation network improves the contact with customers and manufactures (B2B and B2C) and gives insight in skills, technologies or common inputs. The contact to “[...] governmental and other institutions – such as universities, standards-setting agencies, think tanks, vocational training providers, and trade associations – [...] provide specialized training, education, information, research and technical support” (ibid.). Industrial sector initiatives, such as trainings and research can improve the adaptability towards an industrial ecosystem.

Nevertheless clusters do promote both cooperation and competition. Actors share resources and commit themselves to common goals in certain domains, but at the same time they also compete by taking independent positions in other domains and among different players.

The density of the network influences the benefits for the actors. The denser the network the easier is the interchange of information and other resources, which help to develop trust and shared norms and rules among cluster participants. These agreements on the other side are the basis for a trustful exchange of information. The creation of these clusters is not a fixed process of set steps. It may start with low risk relationships by cooperating in sectors which are not vital for the business entity. However, collaborations among more important issues create stronger connections and builds stronger foundation for the development towards a bigger network (Baas 2005). A legal framework helps to ensure the collaboration (Allenby 2002) and to further minimize the risk and motivate companies to cooperate. This collaboration and the creation of an eco-industrial park do not result from an autonomous process but has to be stimulated by intentional actions (Baas 2005). Sectoral organizations and governmental agencies play an important role in stimulating those progresses of networking (Best 1990).

1.2.2.2. Dynamic Issues

"Rather than establishing a completely new network of connections, industrial ecology initiatives build on – and are thus influenced by – the existing connections between the organizations involved" (Boons and Berends, 2001, in Baas 2005, p.268). Once the foundation of an industrial ecosystem is existent, the system creates its own dynamic of improvement and to increase the density of the network. There are a number of processes of dynamics, which lead to the establishment, maintenance and change of industrial ecosystems. Those will be explored in the following. There can be identified three different dynamics in relation to this topic (Baas 2005): networks as learning contexts(1), incrementalism (2) and the phases of industrial ecology (3).

(1) Networks as Learning Contexts

Organizations can use their networks to improve their learning in a collective manner. The interchange of information allows them to receive new data in an easier way. Based on this information they can develop new ideas and cooperate in this creative process. Crucial for the flow of information and knowledge are the density of the network and its diversity of stakeholders and organizations from different backgrounds and industrial sectors. In order to establish a functioning network of information channels of interaction, Bruce (in Baas 2005, p.269) identifies four critical required phases. In a first step a new management practice is created, and the advantages of this new idea have to be identified. In a second step an adaption and transfer towards other sites takes place. If the manager at the other site is willing and able the innovation is applied in the final step. The transfer and application of the new idea entails capable and skilled individuals, who identify innovations and are able to institutionalize them in their respective organizations.

(2) Incrementalism

Incrementalism describes the gradual adaption of changes. The success and risk of cooperating organizations highly depend on the progress inside each individual organization. In order to reduce risk and to test cooperation, participation in industrial ecology projects often starts with collaborations on non-core activities. The main incentive to overcome risk is the perceived gain that results from cooperating through industrial ecosystems. Thus, networks must be performed in a way that it leads to gain for all network partners and that it allows gradually intensification of the network through denser collaboration or by adding new members.

Incrementalism means a gradual increase of complexity of the industrial system. This refers to all levels of aggregation: at the local, urban regional, national, international and global level (Wallner 1998). This complexity can be measured by the number of enterprises in the system, the diversity of the enterprises (business types and distributon of different-sized businesses), the interactions (density and intensity) (ibid.).

(3) Phases of Industrial Ecology

Boons and Berens (2001 in Baas 2005, p.269) came up with a three stage model to show the development of an industrial ecology initiative from zero. The first stage, regional efficiency consists of autonomous firms, which collaborate in certain sectors to decrease eco-inefficiencies (e.g. shared infrastructure). This may be supported by local government (e.g. the creation of industrial parks) and institutionalized arrangements between entrepreneurs. Collaborating firms indentify and make use of these existing win-win situations through cooperation.

The second phase is regional learning, which is based on mutual recognition and trust. This allows the involved stakeholders to exchange knowledge and to broaden their definition of sustainability on which they act. This stage does not only engage companies but also stakeholders that represent society and the environment. The wider the range and diversity of different stakeholders, the more likely is to achieve regional significance and the more likely it is to be sustainable on the long term (Wallner 1998). Thus, not only stakeholders within the industrial enterprises should actively participate in the creation of the industrial ecosystem, but also interest groups, labor market service, planners, NGOs, initiatives, administration etc. (ibid.).

In the third phase, sustainable industrial district, the stakeholders develop an evolving strategic vision on sustainability and base their activities on this vision.

1.3. Macro Level

1.3.1. Command and Control vs. Economic Incentives

To change consumption and production behavior policy-maker can base their policy-strategies on regulatory approaches (Command and Control) that sets specific pollution limits, or market-based approaches (Economic Incentive) that establish incentives on market forces to correct production and consumption habits (Harrington/Morgenstern 2004).

Command and Control (CAC) is a regulatory approach that has been used traditionally. Regulation approaches can basically address two different standards, focusing whether on technology and design or on company's performance. The former indicates certain technology requirements in order to produce inside emission limits. The latter releases companies to use their preferred technology as long as they meet policy standards.

Economic Incentive (EI) is a voluntary approach and comparatively new. It continuously encourages companies to establish greener technologies and production processes, reducing hazardous emissions. Incited by monetary and near-monetary inducements, entities are willing to integrate pollution abatement in their management strategy, searching for innovative and efficient ways to decrease emissions. Examples for Economic Incentives are e.g. subsidies and emission taxes.

Policy makers often combine EI and CAC, establishing e.g. a specified pollution standard to guarantee human and environmental health and encourage further reduction through voluntary incentives to go beyond mandatory standards.

Efficiency plays an important role in environmental policy. Although it is commonly believed that EI has an efficiency advantage over CAC, it actually depends on two circumstances: Marginal Abatement Costs and the stringency of CAC implementations. If regulations are very stringent, there is little scope to choose the most cost-effective ones and therefore EI does not achieve significant savings over CAC. CAC is efficient if marginal abatement costs are equal to marginal social costs of pollution. This is the level when the cost for an additional unit to abate is the same than the cost of an additional unit of contamination for society. With market incentives, firms will reduce their emissions as long as it is financially valuable for them to do so, and this generally happens at a point where marginal abatement costs are equated across all regulated firms. The main disadvantage associated with economic incentives is that they can be inappropriate for dealing with environmental issues that pose equity concerns. Emissions trading programs, for example, could have the unintended consequence of concentrating pollution in economically-disadvantaged areas.

A general problem of CAC on technology regulations is that promoting technology prevents or postpones the discovery or use of new and effective technologies. CAC deals with a set emission level, therefore firms will start to search for the lowest cost technology that still satisfies the emission standard. On the other side EI provides a stimulus for companies to invest in research on emission-reductive and cost-reductive technologies.

Firms often prefer CAC policies, because of its perceived lower private costs (Harrington/Morgenstern 2004). Regulated companies pay higher costs under EI than CAC, because under EI they have to pay abatement costs plus an extra fee for remaining pollutions. Therefore government often implements politics where fee payments for contamination are used to subsidize investment in abatement technology. Fur the public sector CAC may come along with higher administrative costs than EI, because for CAC research is necessary to identify and justify an adequate emission level. To guarantee emission reduction EI has to be attractive to companies, while CAC somehow guarantees per se the reduction to a set level. In case of a significant irreversible future, where firms may not be able to finance pollution control or damage mitigation risk policymakers may wish to ensure clean-up through a CAC method.

Command and Control mechanism tend to lead to pollution control, while Economic Incentives tend to lead to an improvement in environmental technology to avoid the generation of pollution. Strong sustainability can only be reached through the integration of environmental management within and throughout companies. There is a need for policies that facilitates learning processes and creates networks and collaboration among different stakeholders at the firm or unit process level, at the inter-firm, district or sector level and at the regional, national or global level (Lifset/Graedel 2002, p.10).

Instead of pure regulatory or market based mechanisms there is a need for combined regulation and stakeholder policies (Baas 2005, p.302).

1.3.2. Learning Processes Towards Strong Sustainability

Taking the biologic analogy of Industrial Ecology, a sustainable development only can be reached through a continuous learning process of adaption. In order to originate sustainable development, we need a structural transformation of our economic system, a transition towards strong sustainability. This is a long-term process with multi-level changes (micro, meso and macro) among a variety of participants (stakeholders) through multi-phases. The system approach of Industrial Ecology requires not only behavioral changes among stakeholders but also systemic innovations, changes in the structure of the system and the relationship among its members (Loorbach/Rotmans 2004). These systemic innovations create the framework for innovations at the micro level, regarding product, process and project innovations (Weaver et al. 2000). Thus, there is a need to analyze the macro level to understand what gives impulses for a transition towards strong sustainability.

"A transition... is the shift from an initial dynamic equilibrium to a new dynamic equilibrium ... is characterized by fast and slow developments as a result of interacting processes of structural change ... involves innovation in an important part of a societal subsystem." (Kemp/Loorbach 2003, p.9)

A transition is pushed (not created) by events, which accelerate or slower the process of change (Loorbach/Rotmans 2004). The Bhopal accident, considered as the world's worst chemical disaster, accelerated international laws and regulations on chemicals. On the other side the ignorance of organic fertilizer alternatives slows its divulgence. Transitions can be guided through intentional steering mechanism on the public and/or private sector towards a certain goal or vision. Those goals and visions, such as the steering mechanisms are results of the sociopolitical framework in which they are embedded. Developments in society influence the changing process on the micro, meso and macro level. Thus, transitions can be managed in terms of influencing and adjusting, but due to its multi-layer characteristics, it cannot be controlled completely.

There are three coordination mechanisms how to influence directly or indirectly the change process towards sustainability: markets, plans and institutions. Market based mechanisms rely on price mechanisms and decentralized decision-making; they give economic incentives towards a sustainable change. Plans help to formulate the transition goal in policy strategies in order to coordinate economic activities. Through this general strategy more specific policies can be developed to coordinate transition on an institutional level and to set concrete agendas and goals to involve gradually more stakeholders.

1.3.3. Transition Towards Strong Sustainability

The concept of transition management is used to explore the macro level of sustainability, because it offers a new policy perspective that combines the power of markets and planning to impulse institutional change towards strong sustainability. This new approach uses regulation and pricing mechanisms inside a broader approach in order to foresee and adapt sociopolitical dynamics to sustainability goals. This leads to a new role of governmental organization with the need to align policies and policy goals to a wider spectrum of visions of sustainability to assure the inclusion of different stakeholders. This can be reached through transition agendas and the use of process management.

The inclusion of different stakeholders (multi-actors), from different fields (multi-domain) and at different scales (multi-level) requires systems-thinking. Only a multifaceted approach allows capturing the aspect of sustainability in its whole and helps to align former contradictory parties. This entails the active participation from and interaction between stakeholders from a wide range of academic and non-academic fields. The transition process is a learning phase, which can be visualized as a corkscrew curl development line with back- and fore-casting. The learning process of learning by doing and doing by learning invites to experiment and trial and error can arouse system innovations. In order to guarantee the success of the outcome, the transition process has to be thought on the long term, with shaping short term policy mechanisms that guides the process. The transition process takes place in learning cycles of several rounds. The experience and knowledge of the preceding rounds is used to improve the next phase.

Loorbach/Rotmans (2004) identify four main activities in order to support a transition towards strong sustainability: establishing and further developing a transition arena for a specific transition theme (1); the development of a long-term vision for sustainable development and a common transition agenda (2); the initiation and execution of transition experiments (3); and the monitoring and evaluation of the transition process (4).

(1) Establishment and further developing a transition arena for a specific transition theme

There is a need for transition managers, who act as mediators bringing together experts from different fields and facilitate their interaction through coordinating their activities. Their task is to guarantee the balanced representation of stakeholders from various fields, providing equilibrium between private and public sector, academic and non-academic field such as producer and consumers. The accretion of new participants with other expertise can enrich the transition process.

The participants of the transition arena need to be visionaries, who can deal with complexity and have the capability to think out of the box. They have to be experts in their field but also they have to be able to work in an interdisciplinary and or intercultural environment. Each of them operates as drivers of change in their respective institutions to establish and to further develop visions that have been concerted in the transition arena. This requires their willingness to dedicate time and energy to this project and to assume their responsibility as active change makers. Thus, participants have to be selected carefully.

Periods of stagnancy are normal occurrences along the transition process. The role of transition managers is to facilitate and motivate the participants. The exchange of information and the training of participants effect a reciprocal collaboration among participants. This outside support helps the participants to work inside a set framework to establish the transition in time and space and in a multilevel setting. Participants need to be able to share the same problem but enrich the group with their point of view of problem solving, regarding to their specific background.

(2) The development of sustainability visions and a common transition agenda

The development of sustainability visions is a difficult task, because there are still opposing thoughts about its definition and its implications. First of all there has to be a common agreement on these terms to create a long-term vision of sustainability. Once a vision statement has been formulated, short-term and long-term objectives can be defined to start implementing the process. Kantabutra (2008) identifies seven characteristics of a successful vision statement. They have to be concise and clear, to facilitate its understanding in and outside the transition peer-group. It has a future orientation and is stable among time. It is abstract and includes a challenge – the purpose of transition – which needs to be formulated in that way that it inspires a broad range of actors to take part in this process and to become active. Due to the issue of diversity in the theme of sustainability regarding different stakeholders from different fields it is desirable to create a consensus about the long-term purpose of the vision while allowing diversity on the short term, which leads to the aim of common sense.

The difference of transition management in contrast to usual policy making is that they contain qualitative as well as semi-quantitative goals and measures and the short term objectives are derived from long-term ones. There are different forms of objectives on the short- term base: content, process and learning objectives (Loorbach/Rotmans ?). This leads to a global approach which is not only content oriented but also includes the speed and quality of the transition process and the identification of challenges and new knowledge. Together with a shared vision this global approach leads towards a process, which all its members can identify with and form part of the solution.

This joint action program consists, as mentioned, of various participants. Therefore it is necessary to have a clear structure of responsibilities and activities of the participants, which provides misunderstanding. The participants have to have certain deadlines to guarantee the progress of the process but need certain flexibility to create their own dynamic of learning and implementing. This flexibility is also needed, because each institution works differently and the participants themselves know best how to implement the global strategy in their work field. With a firm vision the transition agenda develops and themes, goals, means and instruments can change, always if the objective of the long term vision is underwritten. The transition builds the framework for all the little actions that will take place in the associated institutions.

(3) The initiation and execution of transition experiments

"Learning-by-doing and doing-by-learning is the essence of transition management. Learning-by-doing concerns the development of theoretical knowledge from practice, whereas doing-by-learning is the development of practical knowledge from theory." (Loorbach/Rotmans 2004, p.16).

In order to stimulate this accumulation of theoretical and practical knowledge there is a need for transition experiments. Transition experiments are actions that can contribute to the sustainability vision. Therefore it is necessary to establish sound criteria, which measure the extent of the contribution of the experiment towards the long-term goal and its contribution to the success of another experiment. These experiments need to be coordinated and executed in a systematic manner to ensure its cohesion for the bigger vision. The contacts and relationships of participants can be used to test projects in their representative organizations. The experiments are part of a learning process and the feedback of the participating organizations can help to improve the results and increase knowledge and skills. Therefore, it is essential to execute the experiments in a systematic manner to capture the experience of implementation and share it with the whole transition team, so that it can form part of a global learning process.

(4) Monitoring and evaluation of the transition process

Monitoring and evaluation is fundamental for the learning process. Not only the transition process itself, has to be monitored but also the transition management, which allows a meta-perspective of the progress. The monitoring process has to capture micro, meso and macro activities and learning processes. This starts with the individuals, the participants, their individual attitude and activeness and their relationship between each other. Another important aspect is the monitoring of their actions, the effectiveness of how they use instruments and implement goals and projects. This leads to the global aspect of the monitoring of the general evolvement of the overall goal, the transition as such and its learning process. Identifying challenges and necessary steps for the process can help to improve the transition. Explicit learning goals and formulated desired outcomes help to ease the monitoring process and to evaluate it.

The evaluation is important for the transparency of the project. The progress of the long term objectives can be analyzed through the evaluation of short-term objectives. Set-backs and hold-ups are analyzed on internal and external factors and can help for the following transition management cycle to be prepared for problems and to enhance the outcome.

2. Overview of The Applied Methodology

Now that the indicators have been defined on the micro meso and macro level there is a need to define the parameter of the analysis. The parameters present the magnitude of each indicator and are divided in four parts -, +, ++, +++. One plus denotes a small contribution, two pluses denote a medium contribution and three pluses denote a high contribution towards strong sustainability. A minus denotes the absence of or a negative contribution towards strong sustainability. Chart 2 gives an overview of the used indicators. In the following it is explained how each indicator is analyzed and how the parameters are defined.

Chart 2: Indicators of Strong Sustainability in the Industry

Source: own compilation

MICRO	MESO	MACRO
Eco-efficiency • less energy • less raw material • less contamination	**Physical terms** • Dematerialization • Decarbonization on the inter-firm level, district level, sector level or between industries on a regional, national or global scale	• development of a long-term vision for sustainable • development and a common transition agenda • initiation and execution of transition experiments • the monitoring and evaluation of the transition process
Good house-keeping • precautionary • preventative • integrative • democratic	**System boundaries** **Static issues** • economic incentives • legal framework **Dynamic issues** • Networks as learning contexts • Incrementalism • Phases of industrial ecology	

2.1. Micro Level

The main indicators on the micro level are eco-efficiency and good house-keeping. Eco-efficiency is reached if, in comparison with conventional technology, there is less energy and raw material consumption and less contamination. The parameters for the three indicators are presented in Chart 3a.

Chart 3a: Parameters of Eco-efficiency

Source: own compilation

	-	+	++	+++
Energy consumption	<1% of reduction or augmentation	>1% < 33% of reduction	>34% < 66% of reduction	> 66% of reduction
Raw material consumption	<1% of reduction or augmentation	>1% < 33% of reduction	>34% < 66% of reduction	> 66% of reduction
Contamination	<1% of reduction or augmentation	>1% < 33% of reduction	>34% < 66% of reduction	> 66% of reduction

Good housekeeping requires precautionary, preventative, integrative and democratic principles (Gee 1994), which help to institutionalize strong sustainability. The first two (precautionary and preventative) refer to a different use of techniques or a change of behavioral pattern in the organization in order to prevent or reduce pollution. There are different types of green technologies, which reflect the behavioral sustainability pattern of a company and the extent of the precautionary and preventative principle. End-of-pipe technology treats or manages emissions and waste streams and clean up technology is used to recover polluted soil, water or air. Both focus on the end of the production cycle without changing production patterns. Environmental technologies are all those technologies, processes and products that further reduce or prevent pollution throughout the whole production cycle. The key issue of cleaner technologies is to further implement closing loop strategies, through reuse and recycling.

Chart 3b: Paramters of Good housekeeping I
Source: own compilation

	-	+	++	+++
precautionary and preventative principle	no green technology	Implementation of end-of-pipe technology and clean up technology only (emission treatment)	further implementation of environmental technologies (reduction)	further implementation of Cleaner technologies (closing loops through reuse and recycling)

The last two refer to the way the different stakeholders inside a company are involved in the learning and decision making process. Strong sustainability entails the involvement of all stakeholders. Integrative means that the aspect of greener technology is not marginalized but involves all divisions of the company. This implies research on the topic, awareness rising and education of staff and board members to form informed employees, who can participate in a democratic process of learning and decision making. Thus, the integrative and democratic principle can be measured by analyzing who is involve in the learning and decision making process.

Chart 3c: Paramters of Good Housekeeping II
Source: own compilation

	-	+	++	+++
integrative and democratic principle	no involvement	management	management and staff of a specific area	all company members

2.2. Meso Level

Dematerialization and Dematerialization on the different layers can be measured by applying Life-cycle-assessment on the product level and Material and Energy Flow Analysis on the production, before and after the implementation of a new environmental policy.

Chart 4a: Parameters of Physical Terms

Source: own compilation

	-	+	++	+++
Input-Output (LCA)	<1% of improvement	>1% < 33% of improvement	>34% < 66% of improvement	> 66% of improvement
Material Flow	<1% of reduction or augmentation	>1% < 33% of reduction	>34% < 66% of reduction	> 66% of reduction
Energy Flow	<1% of reduction or augmentation	>1% < 33% of reduction	>34% < 66% of reduction	> 66% of reduction

The concept of system boundary is used to analyze the framework conditions on the meso level, which influence the collaboration on the inter-firm level and district level, sector level or between industries on a regional, national or global scale. On the static dimension, the two indicators: economic incentives and legal framework are identified.

A company is more likely to overcome the risk of collaboration if it implies an economic benefit (economic incentives). The higher the benefit the higher is the risk- proclivity. A legal framework reduces risk for the cooperating parties. The stronger the legal framework the less likely one of the collaborating partners takes advantage of it and risk can be minimized. A legal arrangement can be insured by an outside assessment or by an independent certification.

Chart 4b: Parameters of Static Issues

Source: own compilation

	-	+	++	+++
Economic Incentives	no benefit	>1% < 33% of cost reduction	>34% < 66% of cost reduction	> 66% of cost reduction
Legal Framework	no legal framework	legal arrangement between companies	legal arrangement + outside assessment	legal arrangement + outside assessment + independent certification

The dynamic dimension can be analyzed by three factors of influence: Phases of industrial ecology, incrementalism, networks as learning contexts.

The phases of industrial ecology as defined by Baas Boons and Berens (2001 in Baas 2005, p.269) mark three steps towards strong sustainability. Again the wide involvement of stakeholders improves the inclusiveness and democratization of the learning and decision-making process. On the basis of mutual knowledge and idea exchange, the cooperation can evolve, includes a wider range of perspectives and interests and is more likely to be supported by the whole community. Taking into account the three levels of industrial ecology the stakeholder involvement on the meso level must be as follows.

Chart 4c: Parameters of Dynamic Issues I

Source: own compilation

	-	+	++	+++
Phases of industrial ecology	no collaboration	regional efficiency: Collaborating firms indentify and make use of existing win-win situations	regional learning: stakeholders in and outside the company exchange knowledge to broaden their horizon of sustainability	sustainable industrial district: stakeholders develop an evolving strategic vision on sustainability and base their activities on this vision.

Incrementalism means a gradual increase of complexity of the industrial system. This refers to all levels of aggregation (Wallner 1998). The analysis takes into account whether the business model gives incentives to increment the collaboration on the sector, regional and/or international level.

Chart 4d: Parameters of Dynamic Issues II

Source: own compilation

	-	+	++	+++
Incrementalism in number, diversity and interaction	no incentives for incrementalism (stable interaction)	sector outreach	sector and regional outreach	sector, regional and international outreach

Networks can help organizations to improve their learning throughout the formed system. The interchange of information allows them to receive new data in an easier way. Based on this information they can develop new ideas and cooperate in this creative process. A strongly sustainable network has the ability to share, transfer and apply new technologies or practices in another collaborating firm.

Chart 4e: Parameters of Dynamic Issues III

Source: own compilation

	-	+	++	+++
networks as learning context	no learning context	willingness to share new ideas	willingness to share new ideas and possibility of transfer to another firm	willingness to share new ideas, possibility of transfer to another firm and willingness and ability of application in another firm

2.3. Macro Level

There is a need for a long-term vision of sustainability, in order to align short-term and mid-term objectives towards a common goal.

Chart 5a: Parameters of Macro Level I

Source: own compilation

	-	+	++	+++
vision	no vision	only short-term	short and middle term	short, middle and long-term vision

The strategic work needs to combine stakeholders from various fields, providing equilibrium between private and public sector, academic and non-academic field such as producer and consumers. The accretion of different participants enriches the transition process. Stakeholders from the macro level are important to coordinate the group and to assure the approximation towards the long-term goal. Stakeholders from the meso level give insights in challenges and learning process regarding collaboration. Feedback on the micro level enriches the learning process from the firm perspective.

Chart 5b: Parameters of Macro Level II

Source: own compilation

	-	+	++	+++
transition agenda	no involvement	involves stakeholders on the macro level	involves stakeholders on the macro and meso level	involves stakeholders on the macro, meso and micro level

In order to stimulate this accumulation of theoretical and practical knowledge there is a need for transition experiments. Theory and practice have to accompany each other.

Chart 5c: Parameters of Macro Level III

Source: own compilation

	-	+	++	+++
transition experiments	no learning process	knowledge transfer from practice to theory	knowledge transfer from theory to practice	learning by doing and doing by learning

The monitoring process has to capture micro, meso and macro activities and learning processes. Not only the transition process itself, has to be monitored but also the transition management, which allows a meta-perspective of the progress.

Chart 5d: Parameters of Macro Level IV

Source: own compilation

	-	+	++	+++
monitoring	no monitoring	only on the micro level	on the micro and meso level	on the micro, meso and macro level

III. Analysis

The analysis uses the results of eight published case studies from pilot projects on Chemical Leasing implemented in Austria, Egypt, Mexico and Russia (Jakl/ Schwager 2008) to evaluate the micro and meso level. The case studies cover a broad variety of services, such as cleaning, coating, coloring and degreasing. The international and the multi-dimensional (variety of services) aspect allows to derive more general conclusions about the concept of Chemical Leasing in general terms. Other official articles and publications on Chemical Leasing are used to further analyze the conditional policy framework that influences the micro, meso and macro level. The case studies are not documented in a uniform way; thus, some case studies give insights in areas that others don’t.

Chart 6: Case Studies of Chemical Leasing

Source: own compilation based on Jakl/Schwager 2008

Branch of Industry	Country	Involved Partners	
		Suppliers	**User**
Cleaning of metal parts	Austria	SAFECHEM Europe GmbH; PERO AG	Automobilbautechnik Blau
Paint Stripping	Austria	Tiefenbacher GmbH	Alfit AG
Powder Coating	Egypt	Akzo Nobel Powder Coatings S.A.E.	ABB ARAB
Cleaning of Painting Equipment	Egypt	Dr. Badawi Chemical Work	GM Egypt
Zinc Galvanization (Hot Dip Galvanization)	Egypt	Zinc Misr Company	El Sewedy Company
Sugar Mill	Mexico	Chemical Mc Oil, S.A. de C.V.; Suministro de Materiales Industriales, S.A. de C.V.	Fideicomiso Ingenio San Cristóbal
Electroplating	Mexico	MARDI Inc., S.A. de C.V.	Cromadora Delgado,S.A. de C.V.
Water Purification	Russia	ERG	Henkel-ERA

1. Micro Level

1.1. Eco-efficiency

In a conventional business model there are possibilities to reduce and reuse chemical substances. The problem is that the reduction of environmental impact is at odds with the profit for the chemical producer. To reduce the amount of chemicals, and thus, the environmental impact means to reduce the amount of chemicals, which leads to a decrease of earnings. In a conventional producer- user relationship, the producer does not have any economical incentives to prevent over-consumption, or inform its clients on more efficient use, less hazardous alternatives and effective recycling of chemicals (Ohl/Moser, 2007).

In Chemical Leasing the chemical supplier is not paid for its product but for its provided service, while remaining the owner of the chemical. For example instead of selling a certain volume of cleaning chemicals, the cubic meter of cleaned surface becomes the entity to establish a service rate. The chemical supplier has an interest in reducing its service costs. He can do so by reducing the amount of chemicals, which are used to provide the service. The core business of the service supplier is on chemicals. Therefore, he is an expert and knows to which minimum amount the chemical can be reduced while still providing a satisfactory result. Efficiency does not only depend on the chemical, the important aspect is an optimized production process adjusted to the relevant chemical. This reduces not only the amount of chemicals but can further decrease additional factors, such as energy consumption. The offered service, thus, can contribute to create a more eco-efficient production process, which is of interest for the chemical user. Hence, both partners have an economic motivation to find a joint solution to optimize the process.

The table below demonstrates Chemical Leasing's contribution towards more eco-efficient companies. It clearly shows that the implementation of the service business model, Chemical Leasing provoked a reduction in energy consumption, raw material use and contamination. Chemical Leasing creates a win-win situation for the economy and the environment that increases eco-efficiency inside a company.

Chart 7a: Eco-efficiency of Chemical Leasing I

Source: own compilation based on Jakl/Schwager 2008

Case study	Eco-efficiency
Cleaning of metal parts	• Energy: reduced by 50.1% • Materials: reduced by 120kg/year ■ Spare parts and services: reduced by 66.4% ■ Solvents: reduced by 71.7% ■ Stabilisers: reduced by 76.9% and 55% respectively • Contamination: ■ Hazardous: no hazardous waste ■ Emission: reduced by 97%
Paint Stripping	• Energy: no information • Materials: reduced by 50% ■ Solvents: reduced by 50% • Contamination: ■ Hazardous waste: reduced by 100% ■ Emission: 0
Electrostatic Powder Coating	• Energy: less consumption by reduction of pressure of the powder guns • Materials: reduced by 20% ■ Raw material: saving by reduction in powder loss from 12% to 5% • Contamination: reduced by 100% (66,6% through reduction and 33,3% through recycling)
Cleaning of Painting Equipment	• Energy: no information • Material: reduced by 15- 20% ■ Saving of raw material ■ Solvent consumption: reduced from 1.5l to 1l per vehicle • Contamination: ■ Hazardous waste: reduced by 80%-100% ■ Emission: reduced by 15%
Zinc Galvanization (Hot Dip Galvanization)	• Energy: no information • Material: ■ Reduction in hard zinc and zinc ash production • Contamination: no information
Sugar Mill	• Energy; no information • Material: reduced by 50% • Contamination: ■ Hazardous waste: reduced by 25% ■ Emission: reduced by 25%
Electroplating	• Energy: no information • Material:reduced by 22% • Nickel consumption: reduced by 22% • Conatmination: ■ Hazardous material: reduced by 60 %by drag and 25% by deposition
Water Purification	• Energy: no information • Material: reduced by 50% • Contamination: ■ Hazardous waste: decreased concentration less than the maximum permissible concentration established by law ■ Emissions: reduced organic compounds up to 98%

Only the first case study gives information about the amount of energy reduction (50.1%). This data will be used for the analysis, knowing that there is the need to further explore the energy consumption in other pilot projects. There is no concrete data about the raw material reduction, thus the quantity of new product that could be reduced is used to indicate the reduction of material. The contamination is divided into hazardous material and emission.

Chart 7b: Eco-efficiency of Chemical Leasing II
Source: own compilation based on Jakl/Schwager 2008

	-	+	++	+++
Energy consumption	<1% of reduction or augmentation	>1% < 33% of reduction	>34% < 66% of reduction	> 66% of reduction
ChL			50%	
Raw material consumption	<1% of reduction or augmentation	>1% < 33% of reduction	>34% < 66% of reduction	> 66% of reduction
ChL			40%	
Contamination	<1% of reduction or augmentation	>1% < 33% of reduction	>34% < 66% of reduction	> 66% of reduction
ChL				
Hazardous:				75%
Emission:			59%	

1.2. Good Housekeeping

1.2.1. Precautionary and Preventative Principle

The service provider (often) has the know-how to reuse, recover or recycle chemical substances, which again can reduce costs. The substitution of a chemical with a less hazardous one can reduce disposal costs. Once more the expertise of the service provider is needed to implement this replacement without putting into risk the quality of the service outcome. Environmentally safe supply of chemicals, internal recycling, increase of lifetime by means of stabilizers, analyses of used product and recovery of resources are services, which help the supplier to further decrease its costs (Erbel 2008). With this economic benefits also come along environmental benefits. The reduction and reuse of chemicals implies less environmental impact throughout the lifecycle of this chemical substance. Recycling and recovery may (not necessarily) have the same effect. The substitution with less hazardous substance can significantly reduce emission and complex waste treatment. In some cases even, the implementation of advanced technology is only profitable when applying a service business model, Chemical Leasing, since the amount of supplied chemicals is significantly reduced (Startsev/ Schott 2008). Chemical Leasing, due to its business model, gives economic incentives to switch from emission treatment, towards reduction and to further implementing cleaner technologies.

The parameters to analyze the precautionary and preventative principles are waste treatment, reduction and closing-loops strategies. The reduction of energy and material consumption and contamination has been demonstrated already by showing the eco-efficiency; thus, the below table focuses on waste treatment and closing-loop strategies.

Chart 8a: Good Housekeeping of Chemical Leasing I

Source: own compilation based on Jakl/Schwager 2008

Case studies	Waste treatment, reduction and closing loops
Cleaning of metal parts	• Waste treatment: supplier provides waste management • Reduction: yes • Closing loops: supplier implements environmentally safe supply of chemicals, internal recycling, increase of lifetime by means of stabilisers, analyses of used prouct and recovery of resources
Paint Stripping	• Waste treatment: changed from complex to trouble free • Reduction: yes • Closing loops:50% of the solvents remain in the process, due to recycling
Electrostatic Powder Coating	• Waste treatment: compliance with environmental regulations related to waste management • Reduction: yes • Closing loops:: supplier recycles powder waste , enhancement of supply chain management and onther environmental management systems
Cleaning of Painting Equipment	• Waste treatment: better hazardous waste management in accordance to environmental regulations and international environmental corporate policy • Reduction: yes • Closing loops: recycling of solvent waste by supplier and stop dumping; enhancement of supply chain management and other environmental management systems
Zinc Galvanization (Hot Dip Galvanization)	• Waste treatment: stop discharging to sewer system • Reduction: yes • Closing loops: recovery of flux waste, closing the loop of solid waste (Zinc ash recovery and hard Zinc recycling)
Sugar Mill	• Waste: not specified • Reduction: yes • Closing loops: Increase in equipment life-cycles by reducing machinery wear
Electroplating	• Waste: not specified • Reduction: yes • Closing loops: not specified
Water Purification	• Waste: Meet sanitary standards, waste disposal by supplier • Reduction: yes • Closing loop: not specified

Chart 8b: Good-housekeeping of Chemical Leasing II

Source: own compilation based on Jakl/Schwager 2008

	-	+	++	+++
precautionary and preventative principle	no green technology	Implementation of end-of-pipe technology and clean up technology only (emission treatment)	further implementation of environmental technologies (reduction)	further implementation of Cleaner technologies (closing loops through reuse and recycling)
ChL				+++

1.2.2. The Integrative and Democratic Principle

Chemical Leasing takes places in a specific part of the company, where the service is provided and where the specific chemical is applied. The service provider trains the service user's personnel in the handling of the chemical to ease the on-firm collaboration. This implies the exchange of specific know-how including not only process information, but also environmental information regarding disposal and waste treatment.
The integrative and democratic principle implies the participation of all company's stakeholders in the learning and decision making process towards strong sustainability. The contribution of Chemical Leasing towards strong sustainability is measured by the involvement of different stakeholder groups inside a company regarding the aspect of sustainability. The analysis shows that the model promotes staff trainings on the chemical to improve the economic and environmental aspect of its handling.

Chemical Leasing focuses on a non-core business activity thus the proper management does only have little expertise about the handling of this specific process. The service provider has the necessary expertise to instruct the staff. The new knowledge can increase the awareness towards sustainability.

Chart 8c: Good-housekeeping of Chemical Leasing III

Source: own compilation based on Jakl/Schwager 2008

Case studies	Waste treatment, reduction and closing loops
Cleaning of metal parts	• Staff training on the provider side
Paint Stripping	• Service recipient gives regular instructions of the employees
Electrostatic Powder Coating	• Service provider trains the user's operational staff of the powder coating line • Identified organizational benefits: Capacity building of operation staff by sharing know-how
Cleaning of Painting Equipment	• Service user nominates a cleaning stuff to be supervised and followed up regularly by the service provider • Identified organizational benefits: Capacity building and awareness of operation staff
Zinc Galvanization (Hot Dip Galvanization)	• Service user nominates fluxing process staff to be supervised and followed up by the service provider • Identified operational benefits: Skilled and well trained operational staff at the user's plant in fluxing process
Sugar Mill	• Service provider provides lubrication training for personnel
Electroplating	• Service provider gives necessary technical support to the personnel f the user
Water Purification	• Service provider takes care of the user's personnel training in the new process operation, the residual solid wastes transportation and disposal

Chart 8d: Good-housekeeping of Chemical Leasing IV

Source: own compilation based on Jakl/Schwager 2008

	-	+	++	+++
integrative and democratic principle	no involvement	management	management and staff of a specific area	all company members
ChL			++	

2. Meso Level

2.1. Physical Terms

The realization of an input-output analysis or a material and energy flow analysis is extremely laborious and costly. So far none of this analysis has been implemented to demonstrate the improvement due to Chemical Leasing on the inter-firm level, district level, sector level or between industries on a regional, national or global scale. Thus, no statement can be made in this point.

Chart 9: Physical Terms of Chemical Leasing

Source: own compilation based on Jakl/Schwager 2008

	-	+	++	+++
Input-Output (LCA)	<1% of improvement	>1% < 33% of improvement	>34% < 66% of improvement	> 66% of improvement
Material Flow	<1% of reduction or augmentation	>1% < 33% of reduction	>34% < 66% of reduction	> 66% of reduction
Energy Flow	<1% of reduction or augmentation	>1% < 33% of reduction	>34% < 66% of reduction	> 66% of reduction

2.2. System Boundaries

2.2.1. Static Issues

2.2.1.1. Economic Incentives

Ecological aspects are (often) only considered if a new technology, product, service, or business model provides a more cost-effective solution. The experience of the implemented pilot projects has shown that the implementation of Chemical Leasing implies, in average, a reduction of 15% in total costs (Jakl/ Schwager 2008). This can be achieved because it combines know-how of the user about the production of the final good and know-how of the supplier about the chemical substance, its application and its recovery (reuse and recycle). Know-how of the supplier can lead to reduced amounts of chemicals and to the reduction or elimination of hazardous waste disposal; both lead to a reduction in costs. The supplier charge for its expertise, but in general terms the cost for the user is lower than in the traditional business model of purchasing.

The business model uses the concept of fair sharing of added-value to guarantee that both, supplier and user benefit from the collaboration. An added value expresses the theoretical saving of the user by increasing the efficiency of the adapted process, less amortization and operational costs, plus the difference of gross profit for the supplier before and after implementing Chemical Leasing (Schott 2008, p.116). "Fair sharing of added-value means that the added-value is shared by the partners equally and the loss of gross profit for the producer – compared to a conventional business model – is compensated if there is any" (ibid). This is regulated by establishing a price per unit of service.

Chart 10a: Static Issues of Chemical Leasing I

Source: own compilation based on Jakl/Schwager 2008

Case studies	Economic incentives
Cleaning of metal parts	• ChL is competitive from the 2nd year on lower costs, higher earnings
Paint Stripping	• cost reduction
Electrostatic Powder Coating	• cost reduction of coating process per sqm from 3.8 to 3.2 per sqm • Forecast direct savings: US$ 68000 per year • less maintenance cost • higher competitiveness
Cleaning of Painting Equipment	• 15% cost reduction • high potential for cost saving by more efficient process • competitiveness
Zinc Galvanization (Hot Dip Galvanization)	• Expecting direct annual benefit of US $ 200000
Sugar Mill	• Increase of process efficiency
Electroplating	• Savings of around US$ 10000/year
Water Purification	• Cost reduction from 27€/m³ to 13€/m³ of wastewater purification

Chart 10b: Static Issues of Chemical Leasing II

Source: own compilation based on Jakl/Schwager 2008

	-	+	++	+++
Economic Incentives	no benefit	>1% < 33% of cost reduction	>34% < 66% of cost reduction	> 66% of cost reduction
ChL		+		

2.2.1.2. Legal framework

The successful implementation of Chemical Leasing depends on the mutual trust of the partners and the transparency of their interaction. This regards not only the cost-structure of producer and user but also the exchange of know-how. The external and neutral support given by the national cleaner production centers and their international team of experts can initially ensure mutual economic added value and the confidentiality over shared know-how.

The relationship between supplier and user is established through a contract. It defines that the service "supplier [...] undertakes to make the benefit of the chemical substances available to the user, and to take over, if require, certain further services in connection with the use of this chemical substances" (Wittmann 2008, p.125). The contract is designed as a long-term obligation, which ensures the productive needs of the user and the client security for the service provider. The service provider keeps ownership of the chemical substances to be used throughout the whole life cycle and it is his responsibility to collect and treat hazardous waste inside its national waste management law. The extent of the contract depends on the desired integration, time period or production volume; thus, the way supplier and user legally work together can strongly vary.

In order to control and guarantee the benefit for user and supplier, rules and contractual penalties are necessary. This implies exact knowledge on the plant, the process and the specific conditions of the company. Again, the independent party, UNIDO national cleaner production center, helps to gather necessary information, establish a scheme of payment and defines obligations and responsibilities of user and service provider.

Apart from the UNIDO organizations, there are initiatives, such as ChemKit and other private consulting companies who provide independent consulting services to suppliers and users. There service can include advice in technical and chemical process optimization, comprehensive legal advice on contract design, and ongoing process monitoring. This relieves the UNIDO national cleaner production centers, and enables them to concentrate on the promotion of the concept. Furthermore the successful involvement of the private sector demonstrates that the business model can work also without the strong financial support of the public organization, UNIDO.

To prevent fraud and misuse and to obtain the opportunities offered by this service-oriented business model, quality assurance is a must task. UNIDO collaborates with the TÜV SÜD Management Service GmbH. The developed standard, “Certified Chemical Leasing [...], ideally integrates quality, environmental and occupational health and safety elements with specific requirements of the chemical industry” (Nagel/Schaff 2008, p.111). The quality assurance, provided by TÜV SÜD Management Service GmbH, regulates roles and responsibilities regarding technical issues, but also legal compliance and effectiveness. Regular assessments, on an annual basis, sampling approaches and repeated certification process, every four years verifies that supplier and user continue complying the requirements. This helps strengthening the basis of trust between stakeholders, increases the acceptance of Chemical Leasing among third parties and the staff involved, and widens existing interest in the model (ibid).

Chart 10c: Static Issues of Chemical Leasing III

Source: own compilation based on Jakl/Schwager 2008

Case studies	Legal Framework
Cleaning of metal parts	• long-term contract
Paint Stripping	• contract • involvement of a consultant
Electrostatic Powder Coating	• regularly monitored contract • Involvement of Egypt Cleaner Production Center
Cleaning of Painting Equipment	• Ensure long term business relationship based on long contract • Involvement of Egypt Cleaner Production Centre
Zinc Galvanization (Hot Dip Galvanization)	• Involvement of Egypt Cleaner Production Centre
Sugar Mill	• Mexican Cleaner Production Centre evaluates functionality of the scheme of payment
Electroplating	• Mexican Cleaner Production Centre evaluates functionality of the scheme of payment
Water Purification	• Involvement of North-Western International Cleaner Production Centre

Chart 10d: Static Issues of Chemical Leasing IV

Source: own compilation based on Jakl/Schwager 2008

	-	+	++	+++
Legal Framework	no legal framework	legal arrangement between companies	legal arrangement + outside assessment	legal arrangement + outside assessment + independent certification
ChL				+++

2.2.2. Dynamic Issues

2.2.2.1. Networks as Learning contexts

In a traditional business model the seller/producer of the chemical is the only source, who has the necessary information about the substance. The problem is that by transferring know-how to the user, the user's production process becomes more efficient and the amount of demanded chemicals decreases. This leads to a profit loss for the producer /seller. Thus, in a traditional business model there are no incentives for know-how sharing and it is even likely that it fosters situations of asymmetric information. Chemical Leasing is different it does give incentives to share information on the substances. The service provider is rewarded, through the service rate for sharing its knowledge. He has an incentive to create the service more efficient, because a more efficient process leads to cost reduction for the service provider. Transferring its know-how to the user and its staff can increase the efficiency of the process and thus, know-how sharing becomes profitable for the service provider.

The case studies show that service providers have a willingness to share their technology (way of carrying out the chemical process), because they are rewarded for it by receiving a service rate, which covers not only the material costs but also the added-value. Know-how is transferred to the user firm, to create a more profitable process for both, user and supplier. The user has an interest to apply this new technology, due to the economic benefit. Trainings of user's staff, offered by the supplier help to implement the new technology in the user's firm.

Chart 11a: Dynamic Issues of Chemical Leasing I

Source: own compilation based on Jakl/Schwager 2008

Case studies	Networks of Learning Contexts
Cleaning of metal parts	• not specified
Paint Stripping	• not specified
Electrostatic Powder Coating	• know-how transfer • provider provides information and data
Cleaning of Painting Equipment	• Know-how transfer to the user, especially in handling and application of hydrocarbon solvent in the cleaning processes of equipment
Zinc Galvanization (Hot Dip Galvanization)	• know-how and experience sharing related to flux application
Sugar Mill	• Collaboration
Electroplating	• not specified
Water Purification	• effective introduction of innovations and know-how

Chart 11b: Dynamic Issues of Chemical Leasing II

Source: own compilation based on Jakl/Schwager 2008

	-	+	++	+++
networks as learning context	no learning context	willingness to share new ideas	willingness to share new ideas and possibility of transfer to another firm	willingness to share new ideas, possibility of transfer to another firm and willingness and ability of application in another firm
ChL				+++

2.2.2.2. Incrementalism

The aspect of incrementalism of Chemical Leasing can be analyzed in two aspects: the first covers the international promotion of the concept and its diffusion around the globe, the second covers the regional dynamics, which create a network among users and suppliers.

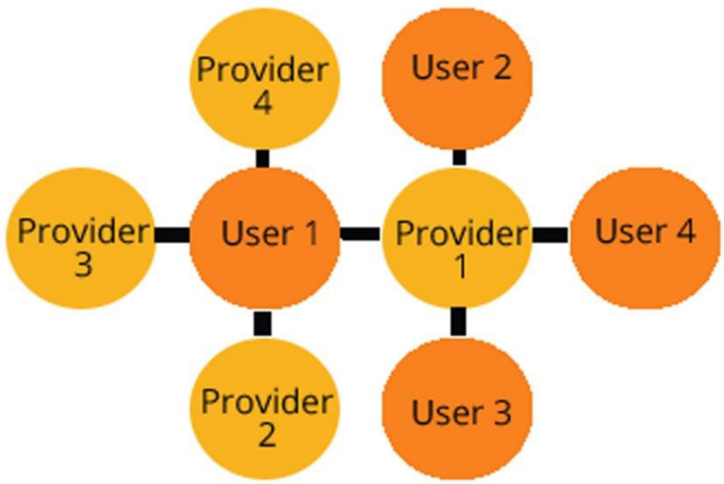
UNIDO continues promoting the concept of Chemical Leasing through its national cleaner production centers. Since the first implementation in 2005, thirty-three pilot projects have been implemented. The pilot projects present a wide variety with applied business models in fourteen different sectors and twenty-four processes in countries all over the world, including Austria, Brazil, Colombia, Croatia, Egypt, Germany, India, Mexico, Nicaragua, Russia, Serbia, Slovenia, Sri Lanka, UK, Ukraine and Uganda. This demonstrates impressively the international outreach of the concept and that the success of the concept is independent of a countries developing level.

The holding of national events on Chemical Leasing and the creation of the Global Chemical Leasing Award brings more attention towards the concept and promotes its diffusion, by acknowledging best practice and inspire companies and individuals around the globe to apply Chemical Leasing. The award has four different categories: Case studies (for companies), consulting services, scientific publications, and public relation. The recognition through the award gives incentives for the national cleaner production centers to further implement and promote the concept to start or continue participating with new pilot projects.

The case studies significantly show that all companies (users and service supplier) would implement the business model once again. Predominantly it was indicated that participated companies (user and service supplier) want to use the model for other products. This allows the assumption for possible ways of incrementalism on the sector, regional, national and international level, focusing on possible networks of user and supplier collaboration. The network can grow from a user and from a provider perspective. After a positive first chemical leasing experience, the user can search for another area with a different process and start collaborating with another service provider, specialized in this specific chemical process. A provider on the other hand, can diversify its service or offer the same service to different users. After having participated with a national entity in one country global players (such as Coca-Cola, Ecolab, Carlsberg, Safechem, etc.) have started spreading information about the model through their international networks to further establish the concept of Chemical Leasing in other countries. Like this a collaborating network is created on the regional, national and international level.

Graphic 1: Collaborating Network of Chemical Leasing

Source: own compilation



Four out of eight participating supplier companies indicated (possible) new customers to apply the business model again. Furthermore, the participating companies indicated (except one) that the model is also suitable for very small enterprises and/or small product quantities. Thus, Chemical Leasing allows the integration of different companies, in size and expertise.

Chart 11c: Dynamic Issues of Chemical Leasing III

Source: own compilation based on Jakl/Schwager 2008

Case studies	Incrementalism
Cleaning of metal parts	• experience could be used for other products and offers • stronger customer relationship
Paint Stripping	• business model will be used for other products, too. • three more companies have accepted the new business model • stronger customer relationship
Electrostatic Powder Coating	• long term relationship • three pipeline companies have accepted to the new business model • Business model will be used for other products • National Cleaner Production Center promotes progress and results
Cleaning of Painting Equipment	• National Cleaner Production Center promotes progress and results • There is a possibility to involve another six automotive companies in the new model. Additionally two clients in the electroplating sector and aluminum sector are ready to cooperate in ChL projects
Zinc Galvanization (Hot Dip Galvanization)	• not specified
Sugar Mill	• supplier and user would implement the business model also for other products
Electroplating	• Provider would not implement business model for other products, but again with the same service. Service user would use the service also in other areas
Water Purification	• North-Western International Cleaner Production Centre promoted the national and international support of the project • 5 new users have accepted the new business model • supplier and user want to implement this model in all treatment stations of the plant

Chart 11d: Dynamic Issues of Chemical Leasing IV

Source: own compilation based on Jakl/Schwager 2008

	-	+	++	+++
Incrementalism in number, diversity and interaction	no incentives for incrementalism (stable interaction)	sector outreach	sector and regional outreach	sector, regional and international outreach
ChL				+++

2.2.2.3. Phases of Industrial Ecology

The participating companies identify in the questionnaires that chemical leasing is competitive, contributes to a cost reduction (Beyer 2008, p.234) and that it creates a win-win situation for the company and the environment. To further encourage regional learning and the establishment of sustainable industrial district it would be preferable to further include outside stakeholders to strengthen regional learning and to develop an evolving strategic vision on sustainability.

Chart 11e: Dynamic Issues of Chemical Leasing V

Source: own compilation based on Jakl/Schwager 2008

	-	+	++	+++
Phases of industrial ecology	no collaboration	regional efficiency: Collaborating firms indentify and make use of existing win-win situations	regional learning: stakeholders in and outside the company exchange knowledge to broaden their horizon of sustainability	sustainable industrial district: stakeholders develop an evolving strategic vision on sustainability and base their activities on this vision.
ChL		+		

3. Macro Level

3.1. Vision

The 2013 Lima Declaration of the UNIDO General Conference contains guidelines and the vision of an inclusive and sustainable industrial development. UNIDO is the head-organization behind chemical leasing and its vision is a long term perspective which includes chemical leasing as one strategy. UNIDO's vision of sustainable development is captured in its three dimensions – economic, social and environmental- and tries to balance them. Nevertheless it is based on the assumption that there is a need for an economic and industrial growth. This stands in contrast with the concept of strong sustainability, which promotes economic activity inside its ecological and social limits.

UNIDO's Cleaner Production Centers are used to implement the concept of cleaner production on the national level. One specific activity is the promotion and implementation of Chemical Leasing. The sustainability mission of the National Cleaner Production Centers is to

a) increase productivity by ensuring a more efficient use of raw materials, energy and water
b) promote better environmental performance through reduction at source of waste and emissions

c) reduce the environmental impact of products throughout their life cycle by the design of environmentally friendly and cost-effective products

The concept of Chemical Leasing promotes sustainability under defined characteristics:

a) Reduction of adverse impacts for environment, health, energy and resource consumption caused by chemicals and their application and production processes
b) Improved handling and storage of chemicals to prevent and minimize risks
c) No substitution of chemicals by substances with a higher risk
d) Economic and social benefits are generated; a contract should contain the objective of continuous improvements and should enable a fair and transparent sharing of the benefits between the partners
e) Monitoring of the improvements needs to be possible

Chemical Leasing projects are evaluated and negotiated on these criteria. They have been successfully applied to ten case studies in seven different countries. The four criteria do not stand in conflict with the concept of strong sustainability and give guidelines for the short and middle term.

Chart 12a: Macro Level of Chemical Leasing I

Source: own compilation based on Jakl/Schwager 2008

	-	+	++	+++
vision towards strong sustainability	no vision	only short-term	short and middle term	short, middle and long-term vision
ChL			++	

3.2. Transition Agenda

The activities on the concept of chemical leasing are coordinated on different levels. An international working group acts on the macro level. It consists of an international multi-stakeholder working group, which includes representatives of national administrations, technical inspection agencies, industry, the consultant sector and UNIDO. The group meets annually and further holds continuous communication and exchange of experiences within telephone conferences and e-mail exchange. Its task is to find strategies to globally promote chemical leasing and develop ways of implementation.

On the meso level there are 50 National Cleaner Production Centers, which are partners of the UNIDO/UNEP Global Resource and Efficient Cleaner Production Network. The national pilot projects are implemented in close cooperation with the NCPCs. Their staff receives technical assistance and trainings from the international multi-stakeholder working group. The NCPC's staff promotes Chemical Leasing on the national level and acts as the direct contact person for the interested companies. They assess participating companies and provide necessary information and expertise to implement pilot projects.

National working groups exist in several countries; one representative is invited to participate at the annual meeting of the international multi-stakeholder working group to report and contribute from a national (meso) and case (micro) perspective.

Chart 12b: Macro Level of Chemical Leasing II

Source: own compilation based on Jakl/Schwager 2008

	-	+	++	+++
transition agenda	no involvement	involves stakeholders on the macro level	involves stakeholders on the macro and meso level	involves stakeholders on the macro, meso and micro level
ChL				+++

3.3. Transition Experiments

The concept of Chemical Leasing goes back to Jakl et al. (2004) who published the first theoretical conceptualization on Chemical Leasing and draw assumption on potential economic and environmental benefits. The concept was presented inter alia at the International Conference on Experiences and Perspectives of Service-oriented Strategies in the Chemicals Industry and Related Areas. The feedback of this presentation helped, to improve the framework of the implementation of Chemical Leasing, especially the legal framework of collaboration and the legal nature of the chemical throughout its life-cycle (Jakl 2008, p.4). The Austrian Federal Ministry of Agriculture, Forestry, Environment and Water Management supported the establishment of six pilot projects in Austria with a wide range of applications and technologies. The experience of these Austrian pilot projects have been used to internationalize the concept. In 2007 UNIDO with its National Cleaner Production Centers started to co-operate by implementing pilots in Egypt, Mexico and Russia, supported by former consultants of Austrian pilot projects. After the success of the first projects, UNDIO picked up the idea to further promote and internationalize Chemical Leasing and continued with projects in Sri Lanka, Serbia and Colombia. Based on the experience obtained in seven pilot countries a UNIDO Chemical Leasing Tool Kit has been created to provide a systematic approach to the implementation of Chemical Leasing business models at company level.

Thus, the concept has its theoretical basis and counts on the experience of pilot projects to adjust the model to the necessities of each project. Conferences and the creation of the award further engage the continuous learning process, where theoretical knowledge and practical experiences are exchanged and new ideas created in order to improve the application and implementation of the Chemical Leasing business model.

Chart 12c: Macro Level of Chemical Leasing III

Source: own compilation based on Jakl/Schwager 2008

	-	+	++	+++
transition experiments	no learning process	knowledge transfer from practice to theory	knowledge transfer from theory to practice	learning by doing and doing by learning
ChL				+++

3.4. Monitoring

UNIDO’s international multi-stakeholder working group monitors existing activities at the national (meso) level. While National Cleaner Production Centers monitor pilot projects on the micro level.

Based on the concept of the Deming Cycle, Chemical Leasing projects pass through different stages of planning, implementation, evaluation and dissemination. In the first phase discussion take place regarding the leasing model, its environmental and economical costs and benefits and the framework condition. An audit, consistent of national and international experts, creates a report outlining potential for improvements and defining key performance indicators, which is presented to the user management. Once an agreement has been made on the scope and conditions, the unit of payment, roles and responsibilities a contract is signed. The service provider supervises the product process, where the specific chemical is involved, transporting and managing the inventory, laboratory management, improving process controls, record keeping and workers' training. Periodic checks by the National Cleaner Production Center staff and/ or TÜV staff help to verify the correct implementation. At the end of the implementation phase, the progress s evaluated in co-operation with the participating parties. Results and feedback of service provider, user and NCPC staff is documented and used for future projects.

Chart 12d: Macro Level of Chemical Leasing IV

Source: own compilation based on Jakl/Schwager 2008

Case studies	Monitoring
Cleaning of metal parts	• not specified
Paint Stripping	• not specified
Electrostatic Powder Coating	• supplier supervises powder coating process UNIDO-Egypt National Cleaner Production Centre: • provides project management • performs CBA • support for the implementation and documentation • responsible for process audits • technical assistance • monitoring for one year • promotes progress and results
Cleaning of Painting Equipment	UNIDO-Egypt National Cleaner Production Center (ENCPC): • provides project management • performs CBA • support for implementation and documentation of the project by national and international experts • monitoring for one year
Zinc Galvanization (Hot Dip Galvanization)	• supplier supervises and manages fluxing process + assigns and nominates a person to be responsible for supervising the fluxing process at the user's plant ENCPC • is responsible for project management • applies CBA • gives support for implementation and documentation of the project by national and international experts • monitoring for one year • promotes progress and results
Sugar Mill	• Mexican Cleaner Production Center evaluates the actual performance
Electroplating	• Mexican Cleaner Production Center evaluates the actual performance
Water Purification	• The North-Western International Cleaner Production Centre act as project coordinator between representatives of service provider and recipient

Chart 12e: Macro Level of Chemical Leasing V

Source: own compilation based on Jakl/Schwager 2008

	-	+	++	+++
monitoring	no monitoring	only on the micro level	on the micro and meso level	on the micro, meso and macro level
ChL			++	

4. Synopsis of the Analysis

The analysis of the case studies shows Chemical Leasing's positive contribution towards strong sustainability. This is presented in all (measureable) aspects on the micro, meso and macro level. Chemical Leasing, due to its business model, gives economic incentives to switch from emission treatment, towards reduction and to further implement cleaner technologies. Its political framework provides incentives to strategies of closing loops. This results in an improvement of eco-efficiency and forms part of a precautionary and preventative strategy. Trainings on sustainable improvement for the involved staff elevates participation of company's stakeholders in the learning and decision making process towards strong sustainability. An expansion of the sustainable learning process towards the whole personal is desirable to transfer new knowledge into other divisions.

On the meso level we find a medium contribution towards strong sustainability. The critical issue is that there are no results on Input-Output, Material or Energy Flows. Analysis needs to be implemented to demonstrate a possible improvement due to Chemical Leasing on the inter-firm level, district level, sector level or between industries on a regional, national or global scale.

Nevertheless there are other strong indicators on the Meso Level which show positive contribution. The average of 15% cost reduction and the concept of fair sharing of added-value give strong economic incentives for supplier and user. A very strong legal framework, supported by international institutions guarantees the fairness and legality of the inter-firm collaboration. This also eases the know-how transfer from supplier to user, which creates a more profitable process for both, user and supplier, but wouldn't be possible without a strong legal basis of trust. An important aspect is the given incrementalism of the network. After a positive first chemical leasing experience, the user can search for another area with a different process and start collaborating with another service provider, specialized in this specific chemical process. A provider on the other hand, can diversify its service or offer the same service to different users. Like this the concept and its implementation are spread without further efforts from a central promoting institution (UNIDO etc.). Preferable this could lead to a stronger connection on the regional level to encourage a learning process and the establishment of a sustainable industrial district. Still this is not the case.

On the macro level we find a rather high contribution towards strong sustainability. Chemical Leasing is imbedded in an international strategy which connects and includes stakeholders from the private and public sector. The UNIDO vision of sustainability leads to short and middle term goals for Chemical Leasing. The interaction of experimental learning and academic contribution combined with international exchange leads to a continuous improvement of the model and an evolving learning process towards strong sustainability. Based on the concept of the Deming Cycle, Chemical Leasing projects pass through different stages of planning, implementation, evaluation and dissemination. This way of monitoring leads to evolving iteration loops on the micro and meso level. An monitoring on the meso level couldn't be identified.

Chart 13: Analysis of Chemical Leasing

Source: own compilation based

Micro Level			++		
Energy consumption			++		
Raw material consumption			++		
Contamination			++		
precautionary and preventative principle					+++
integrative and democratic principle			++		
Meso Level			++		
Input-Output (LCA)					
Material Flow					
Energy Flow					
Economic Incentives	+				
Legal Framework					+++
Phases of industrial ecology	+				
Incrementalism in number, diversity and interaction					+++
networks as learning context					+++
Macro Level		++		+++	
vision		++			
transition agenda				+++	
transition experiments				+++	
monitoring		++			

IV. Conclusions

1. Driving Forces of Chemical Leasing Towards Strong Sustainability

The academic question of this research was if Chemical Leasing contributes to align single business units with a strong sustainability approach? This has been examined in three steps. The first part dealt with the different sustainability approaches for businesses. The second part presented indicators which identify evidences for a development towards strong sustainability. And the third part analyzed the business model of Chemical Leasing on the defined indicators.

The theoretical part presented the two main concepts of sustainability, weak and strong. It was argued that weak sustainability is not an option on the long term and/or on a larger scale. Its recommendation to stick to eco-efficiency may only be useful if the focus is on the process inside the business unit on the short term. There is a high uncertainty of which and to which extend natural resources are needed to provide current and future generations with vital services and technology faces limits to substitute natural resources by man-made capital. This makes it necessary to not only reduce our emission and use of resources, but to create a new system which allows us to stay inside the earth's and the society's limits. This requires a concept with a holistic view, implementing sustainability on the micro, meso and macro level. Thus, strong sustainability must be the necessary approach for businesses to align their activities. Industrial Ecology was used to break down the concept of strong sustainability into concrete recommendations for economic activities. It follows a system approach, which asks for the integration of different operational elements at the firm or unit process level, at the inter-firm, district or sector level and at the regional, national or global level.

These recommendations have been used to establish a methodological framework. The division of Baas (2002) has been used to analyze strong sustainability from its micro meso and macro perspective. On the micro level, eco-efficiency and good house-keeping criteria indicate the effectiveness of strong sustainability efforts inside the business unit. Eco-efficiency is a quantitative measurement from the weak sustainability context. Combined with qualitative indicators (precautionary, preventative, integrative and democratic principle), it provides also insight into the system changes towards strong sustainability inside the company. The meso level explores the establishment of business relationships. On the one hand it indicates if these networks are fostered and if the established collaboration effect regional and global dematerialization and decarbonization.

The macro level shows if the policy framework pushes a learning process of sustainability. The concept of transition was used to define the criteria of long-term vision, common transition agenda, transition experiments and monitoring/evaluation. A scale (-, +, ++, +++) helped to analyze each criteria, based on a certain indicator. The parameter go from no (-), to small (+), to medium (++) and high (+++) contribution towards strong sustainability.

In the third part, with the help of eight case studies, Chemical Leasing has been analyzed under these indicators. The results show that Chemical Leasing contributes to a strong sustainability. All applicable indicators show a positive contribution. This work shows that Chemical Leasing goes even beyond eco-efficiency and the integrity of life cycle management inside an operating unit, by starting an integration on the cross-product and cross-sectoral level. Allenby (2002) points out the difficulty of implementing cross-sectoral, company and/or product collaborations, regarding meaningful incentives for the companies and the legal framework to ensure the collaboration. Chemical Leasing can be seen as a cross-sectoral, company and/or product cooperation insofar that it connects a non-chemical-focused company (the service-demander) with a chemical-focused company (the service-supplier) through a service model. The commitment of the service-supplier to SIRM, with its main approach to close material and energy loops and substitute hazardous for less or non-hazardous substances, and its economical incentive of reduction, reuse and recycling of the substance, due to the nature of the concept of Chemical Leasing[2], leads towards a cross-sectoral system of closing loops. Depending on the size and production process of the demanding entity, the service-provider can treat several different chemical flows inside the entity and/or specialize on a chemical and offer similar treatments to different entities, benefiting

[2] The supplier, with its technical know-how, can reuse chemical substances in other occasion and hence save capital, therefore he has a economical incentive to reuse and recycle chemical substances.

again from profitable reuse and recycling of the chemical. Hence, a web is generated connecting different firms and sectors on the basis of different chemical flows.

UNIDO and its NCPC's provide the framework, the macro perspective of this transition process towards strong sustainability. Chemical Leasing is embedded in an international and clear formulated vision with concrete goals for the short and middle term. The implementation is based on a multi-layer and multi-disciplinary group of stakeholders, which represent different aspects and provide different viewpoints on the scenario. The concept of Chemical Leasing is constantly evolving. New pilots from different areas and different countries bring new input into the learning process. International conferences, such as the award create a learning pool to exchange experience and to give and receive feedback. The multi-layer cooperation makes it possible to monitor the different activities around the world. UNIDO's international multi-stakeholder working group monitors existing activities at the national (meso) level, while National Cleaner Production Centers monitor pilot projects on the micro level. This helps improving the transition process by creating a communication line which goes bottom-up and top-down.

2. Challenges of Chemical Leasing towards Strong Sustainability

Not all processes are suitable for the implementation of Chemical Leasing. Schwager and Moser (2005) point out that the chemical should not form part of the final product. In this case if the chemical and its application does not form part of the user's core business, there are higher possibilities of improvement. Furthermore high risk and high value substances with a superior concentration in waste are potential chemicals for the application of Chemical Leasing (ibid.); Chemicals in former pilot projects have been mainly non-reactants and were, to a great extent, easy to recover. Therefore, Chemical Leasing cannot be applied as a common all-purpose-weapon to establish strong sustainable networks, but can be applied only on specific chemicals and specific treatments.

However, it shows ways how alternative business model can lead companies towards an eco-efficient solution. Chemical Leasing clearly presents an efficient advantage over conventional business models and the promotion of it pushes the interest of companies to apply Chemical Leasing. In case Chemical Leasing is not suitable for a specific company, at least it shows the possibility of eco-efficient alternatives. Success stories of Chemical Leasing could lead to adaption or to the research of other eco-efficient market-based alternatives that bring an economic and environmental benefit.

Another problem is that Chemical Leasing does not per se give any economic incentives to exchange hazardous substances for less-hazardous ones. If less-hazardous chemicals are more expensive than hazardous ones, suppliers will continue using hazardous chemicals. Hence, strong policy are necessary (such as REACH in the European Union) to work as a framework condition for Chemical Leasing, to guarantee an acceptable level of risk. Chemical Leasing shouldn't be seen as an alternative to regulate chemicals but as an efficient business model that gives economic incentives to reduce, reuse and substitute chemicals through collaborations.

The biggest challenge of Strong Sustainability and Chemical Leasing is to create incentives for collaboration. There is a need to overcome aversion of change and to generate among management and workers the willingness to collaborate on the cross-product and cross-sectoral level. The willingness enables to think and act beyond its own business unit and create and continue creating connections and collabrations. Chemical Leasing provides economic incentives and expertise to reduce aversion on the management level. The professional support, provided by UNIDO and its Cleaner Production Centers further eases the implementation on the operative level. Nevertheless, suppliers report certain resistance to change on the part of the end user, which is partly leading to the failure of the project (e.g. Arreola-Valerio et al. 2008, p.98). The management of both, user and supplier have to coordinate and gear up for changes in management responsibilities. Workers need to be willing and able to implement the new strategy. Missing preparation and guidance lead to strong resistance and opposition. Trust and convincing are crucial to start the process with and between supplier and user. Although, UNIDO provides a team of experts to implement Chemical Leasing, business culture is an operative point which has to be taken into account.

Beyer (2008) points out that the "[...] new financial basis for cost charging was considered to be a substantial problem field during the introduction of Chemical Leasing" (ibid.). This goes along with technical problems; business units and employees are often not qualified or don't fulfill technical standards to easily adapt to the new business model. At some sites equipment shows technical defects and bad conditions for collaborations. This is a majoritarian problem for projects in developing countries.

If the period of technical and operational adaptation and optimization is too time consuming or takes too long, the success of the project may be put at risk. The development of a collaboration of trust, the development of a contract and its agreement are essential but time consuming, and have been rated by participants as being too tedious (ibid.).

Chemical Leasing projects are still highly dependent on public funds. The projects are mostly accompanied and conducted by the NCPC's staff. They assess participating companies and provide necessary information and expertise to implement pilot projects for free. Thus, the analyzed case studies did not consider consulting costs in the economic efficiency calculation of the project.

However, the high reduction of costs due to Chemical Leasing, lead one to assume that in most cases, the cost of consulting services could have been absorbed. There is a need to create a market for these services by strongly including the private sector. There exist some intentions to create a profit oriented agency to offer consulting services from a private sector (e.g.ChemKit GmbH, (Sissi Chen et.al.2008)). In addition, there are also established consulting companies starting to collaborate with UNIDO and including consulting services for Chemical Leasing in their portfolio (e.g. GAIA Group Ltd.). Nevertheless, still most projects are conducted by NCPC. The participation for companies in the official Chemical Leasing program is for free, and consulting services are not reimbursed.

The next step, to further research how much Chemical Leasing contributes to strong sustainability, must be to establish an analysis on material and energy flows for pilot projects. This is the only way to demonstrate whether there is a significant improvement in dematerialization and decarbonization on the inter-firm level, district level, sector level or between industries on a regional, national or global scale.

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