United Nations Industrial Development Organization
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UNIDO RECP Study

Chemical Leasing within industrial and service sector cleaning operations

A viable business model with potential to reduce chemical use and negative environmental impacts

Final report

March 2015

Executive summary

Background

Chemical suppliers' income and profit traditionally depend on how much they sell. Customers that use more chemicals buy more and hence generate more income. Ergo, inefficient use of chemicals by the customer generates more income to the supplier through increased sales. Chemical leasing (ChL) is a business model that decouples the supplier's income from volume sold, as the customer pays for the results the chemical use generates, not the volume of chemicals used.

In ChL, the target is to create economic advantages for both involved partners through linking payments to performance, thereby simultaneously generating more profit for the chemical supplier and reduce costs for the chemical user. The desired functional, environmental and /or health related performance determines the payment basis. This creates a joint impetus to work together to manage the chemical use as efficiently and sustainably as possible. Reducing chemical volumes and environmental impacts or risk through using more efficient processes, materials or methods as well as recycling and re-use of resources and materials can form essential parts in implementing this business models. Additionally, ChL could positively benefit workers through reduced negative health impacts.

The ChL business model has successfully been applied across the globe in several different processes in the last decade, often as a part of larger service package. Successful examples are based on a variety of approaches, include introducing new, processes, transition to closed processes, recycling and reuse of the chemicals, or dosage optimisation.

A wide adoption of the circular economy concept through practical approaches such as the ChL business model, could reduce environmental impact through reduced chemical discharges, emissions and waste locally, and contribute to a global reduction of chemical use. However, the business model has not yet achieved mainstream success, and is still viewed with some scepticism by potential users and suppliers.

Study aim and objectives

This study explores the potential for and the required conditions to achieve a wider adoption of the business model. The overall aim of the study was to provide a basis for discussing how to unlock the ChL potential and achieve a leap from individual pilot or case studies to a mainstream way of doing business.

Chemical use requires knowledge. When using chemicals in processes that are not part of the core expertise of the user, there may be considerable potential for efficiency improvements and/or reduction of negative health, safety and environmental impacts. Cleaning is a prime example of such an essential operation, which often is outside the core expertise of the user. Hence the focus of this study was put on cleaning, specifically on four different, widely applied cleaning applications: 1) cleaning of metal parts, 2) cleaning of vessels, bottles and pipes,3) industrial wastewater treatment and 4) cleaning operations in the service sector.

The study objectives were to:

1. *Evaluate the results of applying ChL in four selected applications through a case study approach;*
2. *Exemplify the environmental impacts of applying ChL more widely within these applications through a scenario approach; and*
3. *Discuss the necessary conditions and the potential obstacles for wider adoption of ChL in the selected industrial and service sector cleaning operations, based on interviews with involved companies and national centres for cleaner production.*
4. *Discuss the potential of ChL to contribute to a reduction of global chemical use in and chemical impact on the environment and health from the selected operations.*

ChL and decrease of chemical volumes in the studied applications

In some of the studied cases, chemical consumption was reduced by over 80% and waste by up to 98%. It is unclear just how much of these reductions that are directly attributable to ChL contracts. The changes in consumption are ultimately due to changes in the process, such as substituting the chemicals used, introducing new analytical methods, switching to more efficient machinery, moving from open batch application to closed loop systems, or other changes in the process or housekeeping procedures. These types of changes can also be instigated in other types of business models, for example through including service costs or setting risk reduction targets as part of the contract. It should also be noted that, according to the interviewees, the general trend appears anyway to be towards more service-orientated solutions. Note also that this study has not specifically compared ChL against other service-based business models.

ChL and the potential for environmental and health benefits

The results from the studied cases within all four cleaning applications indicate environmental, and in some case health, benefits are achievable through ChL. It appears that when parties enter into ChL contracts, a key to meaningful and desired gain is the linkage of payment to case specific, meaningful environmental (and health) Key Performance Indicators (KPI). These act as drivers that pushes the supplier to actively explore and engage in R&D to find even more effective methods of reducing chemical volumes, waste and discharges. Health related KPIs were not as extensively used as environmental KPIs.

The case studies were analysed for how chemical volumes reduced after applying the ChL model and the effects on specific KPI such as waste or energy. Two scenarios were created to extrapolate and further approximate on the overall environmental benefits that occur. These were based on data from two ChL user cases.

I. *Environmental impacts of chemical reduction through switching to ChL at a large hotel in Brazil. As a result of decreased chemicals production and resources thus saved and emissions thus decreased, the hotel prevented 11 000 kg emissions of CO2 equivalents per year, decreased the water footprint with 8 000 m3 per year and reduced the eutrophication potential with 9 kg per year.*

II. *Environmental impacts of chemical reduction through switching to ChL at the corrosion treatment stage of a car manufacturing plant in Colombia. The car manufacturing plant prevented 8 000 kg emissions of CO2 equivalents per year, decreased the water footprint with 20 000 m3 per year and reduced the eutrophication potential with 3 kg per year.*

ChL and the potential for financial gain

All case studies show reductions in the usage of chemical volume, with results ranging from 10% to over 80%. The reduction in chemical volumes achieved in the cases indicate that each unit (e.g. ton) of chemical used, the supplier's profit margin has the potential to be higher.

The overall financial gains achieved were much more difficult to appraise, largely due to a fully understandable reluctance of parties to disclose profits, margins or costs. Impacts from the ChL with direct effect on the user's costs also include savings in energy, waste and for example lesser requirements for environmental permits.

Some of the cases included in the study however indicate that when entering into a new ChL contract, the supplier's service costs typically increase. This is a result of the increase in work hours allocated e.g. to optimise the functionality. These costs offset the financial gains achieved. However, these costs decrease over time as experience and knowledge accumulates of a particular user's applications and requirements. Overall time spent on service may also proportionally decrease when entering into ChL contracts with more customers and in more processes.

The interviewees pointed out that knowledge sharing becomes easier with the ChL contract and through using ChL as the overall approach, service oriented solutions are easier to tailor to the customer's specific needs. There are, however, clear demands on the supplier in relation to the chemical know-how and technical capacity and understanding of the customers processes. Hence, the model may not be directly suitable for all suppliers.

Overall the potential to gain from using ChL in the four studied operations is considerable, both from a suppliers and users point of view. Where users can see direct enhancements in their processes, suppliers stand to gain better/longer term relationships with their customers. Consequently, there is considerable untapped financial gain potential for both customers and suppliers.

Identified challenges for wider adoption of ChL

The existence of a potential to achieve benefits does not mean that such opportunities will be automatically realised whenever parties engage in a ChL contract. Several obstacles to a more widespread adoption of ChL were identified, including terminology, legal obstacles mainly concerning liability, rigid purchasing policies and often simply a reluctance to change. The reluctance to change is perhaps surprisingly most difficult one to overcome. For example, widening the application of ChL can be difficult even within organisations where use of ChL already indicate good results.

None of the companies interviewed had experienced any legal problems. However, the fear of legal issues was perceived as a problem, i.e., according to the interviewees from the national centres for cleaner production this increases the threshold to try ChL.

It appears to be the case that ChL implementation is a long process where slow progress is required. All companies interviewed had adopted a method of implementing the business model one step at a time, with continuous meetings and measurements to check if the plans were followed and whether changes were needed to the model.

The potential of contributing to more sustainable industries and a reduced global chemical footprint with ChL

The case study results indicate that the reduction in the environmental footprint of a specific process can be significant, both for a specific user, for an industry and consequently contribute to the reduction of chemical use on a global scale. Consequently, a considerable potential to achieve environmental and health benefits through application of ChL can be identified.

The studied industrial and service sector applications show that such benefits were achieved, although there are also, according to e.g. interviewees, cases where ChL has had good operational effects but little significant effect on KPI. As a means of reducing pollution, the business model has large potential to be effective. However, it should be noted that no comparison with the effectiveness of other service-orientated models of chemical sales or risk management strategies within specific companies has been made in this work.

Reliable quantification of benefits vs. what was done in the cases and hence a firm basis for extrapolation of results to global level, was however not possible. This stems from both a lack of comparable baseline data for the cases studied and a lack of comparability between the cases. In the cases, different chemicals and different technologies have been applied, with significantly different results in measured variables.

The potential impacts within a certain application were therefore exemplified with the help of the two scenarios mentioned earlier: the hotel case in Brazil extrapolated to more hotels in Brazil, and the car manufacturing plant in Colombia. [1] [2]

I. *If all four and five star hotels in the top 12 tourist destinations in Brazil were able to achieve 50% of the savings that the hotel in the case study reported, the total impacts would be 0,5 million kg emissions of CO2 equivalents prevented per year, a decreased water footprint of 0,3 million m3 per year and a reduction of the eutrophication potential with 400 kg per year.*
II. *If all car manufacturers in the world were able to achieve similar savings, the global impacts would be 5.1 million kg emissions of CO2 equivalents prevented per year, a decreased water footprint of 13 million m3 per year and a reduction of the eutrophication potential with 2000 kg per year.*

[1] Scenarios and the assumptions made are described in detail in chapters 5 and 7.
[2] *NOTE: The scenarios calculations only serve as examples, and as both scenarios are based on the savings reported from only one case study respectively, no statistical conclusions can be drawn. Other companies could be using either less or more resources, thus resulting in different saving potentials, and no information has been collected on average consumption in the specific cleaning operations*

Recommendations

If there is a desire to set a target to reduce the global chemical footprint and other negative environmental/health impacts through wider adoption of ChL, much more emphasis on marketing the model to users is needed. Specifically, users in a high enough position within their organisations that they can induce a change in the corporate purchasing behaviour must be reached, and the potential for benefits clearly communicated. To achieve this, the following recommendations are presented:

1. ***Create market pull and make it easy for potential users to grasp ChL***
    - A. *Target top management in large user companies to create more pull*
    - B. *Understand the psychological barriers towards changing business models/purchasing policy and use the insight to create a more business driven awareness campaign*
    - C. *Provide a set of tools and material that allow company top management to do a quick assessments for financial and sustainability potential*
    - D. *Provide an easily accessible library of case studies that are both comparable and max 1 page long, with focus on the business as well as environmental and health benefits in addition to more complete case studies giving technical and process details.*
    - E. *Provide tools and examples of how to take ChL into purchasing (e.g. how to remove IT obstacles, especially for companies using software to run purchasing)*
2. ***Support chemical companies in offering ChL***
    - A. *Support smaller specialist chemical companies through concrete examples such as how to present the model in proposals and to customers*
    - B. *Provide tools and support for turning ChL from a concept into a suite of products, that have a clear marketing message*
    - C. *Encourage the use of trade names for ChL products and a move away from the term "leasing"*
3. ***Make the available guidance and examples easy and accessible***
    - A. *If mainstreaming is to be achieved, there is a need to simplify the complex and very broad set of instructions and guidance available today*
    - B. *Provide more market-orientated and less technical guidance also, where focus is on a step by step vision of how users and suppliers can gain. This type of material should have much less focus on the ins and outs of the business model/contract concept, which can be in separate "technical manuals".*
4. ***Link to current trends in concepts and terminology***
    - A. *Link chemical leasing business model more firmly to the global drive for e.g. circular economy concepts and reduction of carbon risk and sustainability risk.*
    - B. *Incorporate and make use of the notion of reduced chemical footprint, providing tools and visual means of presenting the achievements*
    - C. *Embed the Chemical Leasing Programme in the UNIDOs Inclusive Sustainable Industrial Development Programme*

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Terminology and abbreviations

Chemical footprint *is a term used for the environmental impacts of the toxic chemicals released by the production and consumption of goods.*

Chemical Leasing (ChL*) is a service-oriented business model that shifts the focus from increasing sales volume of chemicals, toward a value-added approach.*

Cleaning chemicals *is here used as a common term for chemicals used within cleaning of metal parts, cleaning of vessels, bottles and pipes, cleaning of wastewater and cleaning in the service sector. It is noted that the term is very broad, and contains very different types of chemicals, such as different solvents, detergents, flocculants, polymers etc. depending on the cleaning task in hand*

Eutrophication potential *is the potential for enrichment of chemical nutrients, typically phosphorous and nitrogen, in an ecosystem.*

Green Industry *approach. The approach strives towards decoupling resource use and pollution from industrial development, and at the same time promoting the sustainable growth of productive sectors in developing and transition countries. The initiative was launched by UNIDO.*

Greenhouse gas emissions *are emissions of gases that trap heat in the atmosphere.*

HSE statements *stand for health, safety and environmental statements and describe the hazardous properties of chemicals.*

Industrial cleaning processes *are here defined as processes that use chemicals to clean particular items or volumes of water to a certain cleanliness standard. Examples of cleaning processes include pipe and reactor cleaning, degreasing metal parts, washing textiles and treatment of industrial wastewater.*

KPI *Key Performance Indicators are here used to describe the quantifiable measures that a company or industry uses to gauge or compare performance in terms of meeting their strategic and operational goals. KPIs vary between companies and industries, depending on their priorities or performance criteria.*

NCPC *National Cleaner Production Centres contribute to improved environmental performance and resource efficiency of enterprises and other organizations, which also increases productivity and competitiveness. The NCPCs are professional centres that deliver and coordinate services concerning cleaner production (CP) methods, policies, practices and technologies.*

RECP *Resource Efficient and Cleaner Production concept*

UNEP *United Nations Environment Programme is an environmental authority, within the United Nations system, which acts as a catalyst, advocate, educator and facilitator to promote the wise use and sustainable development of the global environment.*

UNIDO *United Nations Industrial Development Organization, is the specialized agency of the United Nations that promotes industrial development for poverty reduction, inclusive globalization and environmental sustainability*

Water footprint *is a measure of how much water is consumed in the production of products and which direct and indirect environmental impacts result from this.*

1 Introduction to Chemical Leasing

Chemical Leasing (ChL) is a business model based on the preventive Resource Efficient and Cleaner Production (RECP) concept[3]. ChL is in line with the UNIDO Green Industry approach that strives towards decoupling resource use and pollution from industrial development, and at the same time promoting the sustainable growth of productive sectors in developing and transition countries.[4] ChL is a practical concept that promotes the development of more efficient industrial processes and reduction of hazardous chemicals consumption. ChL contributes to circular economy goals through e.g. closing loops and minimising waste.

Definition of Chemical Leasing (ChL)[5]

ChL is a service-oriented business model that shifts the focus from increasing sales volume of chemicals, toward a value-added approach. The producer mainly sells the functions performed by the chemical, and functional units are the main basis for payment. Functions performed by a chemical could be e.g. number of pieces cleaned, amount of area coated. Within the ChL business models, the chemical producer becomes a service provider, with extended responsibilities, which may include the management of the entire life cycle. ChL aims to increase the efficient use of chemicals while reducing the risks of chemicals, and protecting human health. It improves the economic and environmental performance of participating companies, and enhances their access to new markets. Key elements of successful ChL business models are proper benefit sharing, high-quality standards and mutual trust between participating companies.

In essence, the business model decouples payment from volume. The user pays for the results of using the chemical, e.g. per vessel cleaned or per litre of water separated from product stream. The chemical material used becomes a cost rather than revenue factor for the supplier. As a result, there is a direct business interest and incentive for the supplier to harness their expertise to reduce the amount of chemical consumed and increase the customer's process efficiency. Incentives to enhance the environmental and health impacts from chemical use are a vital part of ChL, and these are built into the model with Key Performance Indicators (KPIs)

There are various means for reducing chemical consumption. Chemical means include improving reactions and choosing less harmful and/or more efficient reactants, biological means include the help of microorganisms to break down components, while mechanical means such as controlling heating temperature, residence time, separation methods, mechanical cleaning and recirculation systems can help to reduce chemical consumption. Note that if the chemicals are eliminated from the process, the term ChL is somewhat misleading.

A ChL contract should contain the objective of continuous[6] improvements and enable fair and transparent sharing of benefits between the partners. The main target of the process is to reduce pollution, hence it is essential to set sustainability criteria and link these to the payments. Hence

[3] See e.g. UNIDO (2014b)
[4] See UNIDO (2014a)
[5] As adapted from UNIDO (2011)
[6] Note that all processes may not be susceptible to continuous improvement after a certain stage. Nevertheless, the principle of continuous improvement is an important one in ChL.

monitoring of the improvements must be possible. Successful, high standard ChL contracts should take into account the following targets[7]:

- **Reduction of adverse impacts** for environment, health, energy and resource consumption caused by chemicals and their application and production processes;
- **Reduction of risk**, through improved handling and storage of chemicals, no substitution of chemicals by substances with a higher risk; and
- **Generation of economic and social benefits**.

The ChL business model provides a systematic approach to drive both user and supplier to work towards these targets. Outsourcing[8] the operation might comply with the ChL criteria of linking result to payment, but still not be in line with the other aspects of ChL: continuous improvements and fair and transparent sharing of benefits between partners. A more distanced relationship between the user and supplier might impede knowledge transfer and make the results more difficult to achieve.

2 Study aim, objectives and focus

This study explores the potential for and the required conditions to achieve a wider adoption of the ChL business model. The study contributes to UNIDO's Green Industry approach objective to decouple resource use and pollution from industrial development and aims to raise global awareness of ChL benefits.

The overall aim of the study was to discuss the extent of the ChL potential and how to harness this potential to achieve economic, environmental and health related benefits in the reviewed processes. In order to do so, the study identifies and discusses requirements for activating industry and the service sector to take the leap from individual pilot or case studies to a mainstream way of doing business.

The study objectives were to:

1. Evaluate the results of applying ChL in four selected applications through a case study approach;
2. Exemplify the environmental impacts of applying ChL more widely within these applications through a scenario approach; and
3. Discuss the necessary conditions and the potential obstacles for wider adoption of ChL in the selected industrial and service sector cleaning operations, based on interviews with involved companies and national centres for cleaner production.
4. Discuss the potential of ChL to contribute to a reduction of global chemical use in and chemical impact on the environment and health from the selected operations.

[7] See e.g. Chemical Leasing (2014)

[8] Investopedia defines **outsourcing** as "A practice used by different companies to reduce costs by transferring portions of work to outside suppliers rather than completing it internally." Outsourcing often implies a transfer of responsibility, which is not the goal in ChL, but rather a shared responsibility, with clearly defined tasks.

3 Methodology

3.1 Working methods and notes on data limitation

The work undertaken included the following types of methods

1. Literature and case study review
2. Interviews with case study participants and National Cleaner Production Centres (NCPC)
3. Working discussions with experts and UNIDO for reflection and peer review of indicative results
4. Expert analysis

The study data contains extrapolations based on case studies and scenarios, and is therefore accompanied by a degree of uncertainty. Case and scenario specific uncertainties are further described in Chapter 5.

3.2 Choice of study focus

3.2.1 Process type

In order to keep the results comparable, it was decided to focus on a specific type of processes. When choosing which processes to focus on, an important criterion was to ensure that the results would be widely applicable. Experience from use of ChL contracts in different processes and industries indicate that the potential of ChL to lead to good results for all parties can be particularly high when applied to processes or tasks that are not the chemical user's core activity.

Examples of such non-core processes where chemicals are used in a similar way within many industries, include industrial cleaning, lubrication, fixation, flocculation, corrosion protection, separation processes, use of colorants and dyes, and pH regulation. The user that requires these non-core processes generally has considerable expertise in what the outcome should be and why, but not the expertise in how to ensure the outcome. To oversimplify it, an example is that a car manufacturer will know how clean the parts need to be and why, but does not know how to go about cleaning them.

3.2.2 Selection of cleaning operations in the industrial and service sectors

This study discusses the wider potential of ChL through experience gathered from specific ChL projects. In order to do so, the target was to find a set of industrial and service sector operations, where existing results indicate that the business model is successful.

Industrial cleaning operations or processes are required in many different types of industries, but cleaning is seldom the core processes. There are also several case studies of using the ChL business model for cleaning and wastewater treatment processes or operations in different industries. Hence, industrial cleaning was chosen as the initial focus for this study by UNIDO[9]. Later on in the work, it was also decided to include results from cleaning within the hospitality and health sector.

[9] UNIDO internal review meetings of existing case studies, which took place in 2012-2013

Criteria for choosing the case studies were derived from the definition of what a ChL contract should achieve. The choice of criteria was done together with UNIDO. The focus was then tested against the chosen criteria, as shown in Table 1.

Table 1: Selection criteria

Criteria applied	Industrial cleaning and waste water treatment processes
Potential to have a **global impact**	✓ The need for industrial cleaning and waste water treatment processes is widespread ✓ Applicable to several industries across many countries ✓ Health and hospitality cleaning is also needed across the globe
Potential to lead to a **reduction of adverse impacts** for environment, health, energy and resource consumption caused by chemicals and their application and production processes	✓ Significant amounts of a range of chemicals that are potentially harmful to the environment and/or health are used. ✓ Case study results indicate that these amounts can be reduced through ChL ✓ Indications of enhanced functionality /process optimisation and consequent reduction of chemical volumes used has emerged from several case studies.
Generation of economic and social benefits.	✓ Economic benefits seen directly in at least some of the cases
Reduction of risk, through improved handling and storage of chemicals, no substitution of chemicals by substances with a higher risk;	✓ Moving towards closed systems reduce risk ✓ Reduction of harmful chemical volumes
Reduction potentials and efficiency improvement have been shown to be possible, e.g., ChL successful application case stories that already exist.	Yes, there are case studies for the following four types of cleaning operations: 1. *Cleaning of metal parts* 2. *Cleaning of vessels and pipes* 3. *Industrial wastewater treatment* 4. *Cleaning operations in the service sector*

The four operations chosen for this study and the case study industries are presented in Table 2.

Table 2: Cleaning operations selected and the case study industries and sectors

Chosen cleaning operations	Industrial and service sectors involved in the case studies
Cleaning of metal parts	Automotive industry, metal part suppliers
Cleaning of vessels, bottles and pipes	Food industry
Wastewater treatment	Ceramic industry, oil production
Cleaning operations in the service sector	Hotel, hospital

Future analysis could, for example, look at ChL and cleaning of textiles, plastics, cleaning of air (emission reduction) or other cleaning activities.

3.3 Analytical methodologies

3.3.1 Case study analysis

Existing ChL case studies were analysed for the following variables:

1. Unit of payment
2. Key performance indicators (KPI) used
3. Financial and resource efficiency results
4. Technical results
5. Safety results (mainly occupational health and safety)
6. Environmental results

Where possible, data in the literature has been verified directly from the original source using interviews, e.g. the suppliers and users were further interviewed to include the views on the business model, obstacles and outlooks. In order to protect the business interests of the parties, results are presented anonymously.

Cases were further analysed to find the potential for enhancing the specific processes. It is recognised that the application potential of the model may depend on the type and size of the participating companies, and how many companies are involved in a particular case. The application potential in various permutations of the user-suppliers has therefore been discussed in relation to the following permutations on different types of supplier-users.

Chemical supplier:

- Chemical manufacturer acts as supplier and service provider
- Distributor acts as service provider
- Chemical manufacturer and equipment provider or other separate service provider work together as supplier and service provider

Chemical User:

- Very large, multinational company
- Large company with many sites and many processes
- Medium, few sites, few processes
- Small, one main process/one site

3.3.2 Estimation of ChL contribution to reduction of global chemical use

The study aim originally was to create also quantitative estimates of the future global potential of using ChL. In order to relate the data from individual cases of ChL application to a larger picture, it would have been ideal to use industrial statistics and financial models and base the discussion on how much chemicals are used for cleaning operations. A quantitative estimation of the global potential, however, is not possible based on the following:

- Quantifying the benefits:
    - A review of the case studies showed that ChL has, in some cases, become an integrated part of the service concepts based business models of the chemical suppliers. The isolation of the financial effects of ChL alone would require in-depth

analysis of the provided service and benefits achieved with longer contracts and more stability in the order books.

- The baseline of the environmental, health and financial parts was in several cases not established prior to entering into a ChL contract. Hence benefits cannot be accurately quantified.
- ChL benefits are in many cases intertwined with benefits achievable from new technology development. In some cases ChL is a driver for technology development, although this cannot always be seen as the case. The isolation of the effects of ChL alone is therefore not possible.

- Relating the results to the global chemical consumption:
  - Whilst in most cases the chemicals or at least the amounts saved are known, these chemicals are also used for other purposes and in other processes. Hence, it is not possible to extrapolate the results to reductions in specific chemicals on a global level, without sales data describing the sales between chemical suppliers and specific companies in specific industries.
- There is too little comparable data on the environmental and health benefits, as the cases reviewed differ in contaminants, chemicals used and required degree of cleanliness.

The case study data itself is scant in exact details of chemical consumption or cost. According to an NCPC, this situation currently hinders the understanding of the actual benefits and how the process was implemented in cases from other countries. This hampers the cross-use of experiences and successful replication of them. The interviews aimed to add to this data, but in particular cost, profit and price details were, not surprisingly, generally viewed as confidential data and not shared in detail. Any extrapolation to ChL from general chemical use or cost statistics would therefore contain far too many assumptions and be unreliable or be based on too few cases.

Based on the above, a different approach was needed for estimating the global potentials. Hence hypothetical scenarios were built, derived from cases (see Chapter 4). These were then analysed in relation to the hypothetical assumption that all actors in the same sector would use the same methods and chemicals. The hypothetical scenarios chosen were the following:

- **Scenario 1:** *All similar size hotels in Brazil's top 12 destinations would use the same cleaning agents as the hotel in Case 10 and would be able to achieve 50% of the savings reported by the case hotel, if changing to ChL.*
- **Scenario 2:** *All automobile manufacturers would use the same chemical for cleaning before corrosion treatment as the case factory and would be able to achieve similar savings as the case factory in Case 5, if changing to ChL.*

The scenarios, assumptions, and calculations are presented in more detail in Appendix 1. These scenarios were then further used to illustrate the extent of negative environmental impacts that could be avoided by decreasing chemicals consumption as presented by the scenario. The hotel scenarios are based on data from cases in Brazil and the application of the scenario is done to similar hotels in Brazil. The car part cleaning scenario is based in Colombia, but as the car manufacturing industry is global and uses similar processes, the scenario was the applied to global car manufacturing.

3.3.3 Analysing the environmental impact of reducing the usage of chemicals

Using chemicals affects the environment in many ways and during many stages of the chemical's lifetime. The production of the chemical requires resources, such as water, energy and material. The transportation of the chemical from the production site to the user requires energy. In most cases, the operation where the chemical is used consumes electricity, heat and water. At all stages, waste is produced, which must be treated by treatment operations that themselves require the same resources and additional chemicals. Furthermore, the chemicals, or the emissions from volatile components, may be hazardous to the environment or to human health and safety at all stages of the chemical's lifetime.

In general, the stage, which requires most resources, is the production process. For cleaning chemicals, the resources used together with the chemical in the cleaning operation, may also be significant when looking at the environmental impact. These resources are usually water and energy for heating, mixing and pumping water. Likewise, emissions at the cleaning operation stage are important. For cleaning operations which use water, wastewater treatment is essential, and for cleaning operations with other solvents, emissions to air may have large impacts.

Taking into account the restrictions presented in the previous section, the hypothetical scenarios were used to illustrate the potential of ChL to contribute to a reduction of negative environmental impacts from chemical use. Numerous methods and indicators for assessing and comparing sustainability of chemicals are available, based on quantitative or qualitative data. In this study, six indicators were chosen to be used to describe the savings that could be obtained if ChL would be applied more widely in the cleaning operation in a larger context. The choice of indicators was based on expert judgement.

Calculation of greenhouse gas emissions, water footprint and eutrophication potential related to specific chemicals production was performed with the LCA calculation software Simapro. The values given are data for average processes, with the choice of production countries following the current situation at the market or in some cases an example plant. The qualitative indicators are based on the hazard statements given to the particular chemical or mixture

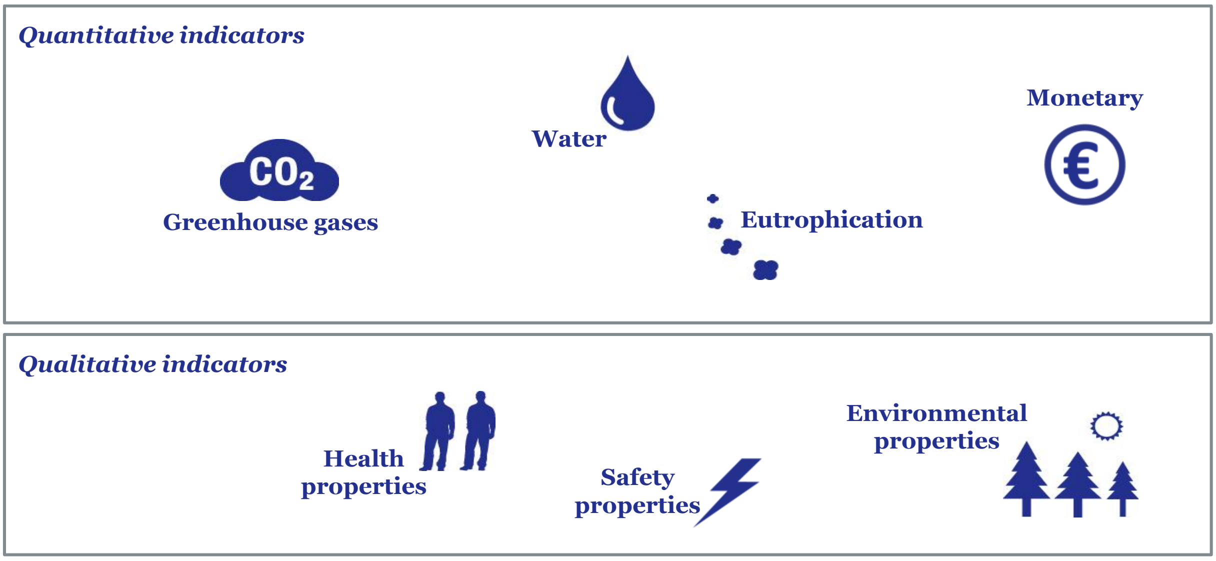

Figure 1 Indicators used for illustrating ChL potential to reduce the negative environmental impacts resulting from use of chemicals.

Indicators included are: *Greenhouse gas emissions*[10], *Water footprint*[11], *Eutrophication potential*[12], *Health properties*[13], *Safety properties*[14] and *Environmental properties*[15], all presented in Figure 1.

4 Chemical Leasing results in the studied applications

In this Chapter, each of the analysed cleaning operations are briefly presented in relation to the industries using the process, the technology and the process itself. This is followed by a summary of the case studies, including KPI used and unit of payment. After this, the tangible results from the case studies for the operation in question are presented, followed by a discussion on how ChL has helped to reach the presented benefits in the specific operation. The observations on potential and requirements for wider adoption of ChL that the case studies gave rise to are discussed in Chapters 5 and 6.

[10] **Greenhouse gas emissions.** Climate change is one of the grand global challenges of our time and the need to reduce the greenhouse gas (GHG) emissions is immediate.
Calculation of GHG emissions is well established and common indicator also for assessing sustainability of chemicals or chemical products. Calculations are usually based on databases that contain information on, for example, different raw materials, production processes and end uses. In this study the GHG emission indicator takes into account

- Total energy, and energy sources, used for the production of the cleaning agents (calculated as the sum of each chemical)
- Total direct greenhouse gas emissions from production of these cleaning agents (sum of each chemical)
- CO2 emissions from transportation

In other words, this indicators tells about the impacts that the choice of chemicals have on the climate change and could be used for comparing the sustainability of two alternative chemicals. Although the value is expressed as GHG emissions, it reflects the use of fossil fuels in production and transportation. The analysis is done according to the LCA 100 method.

[11] **Water footprint.** A water footprint is a method of assessing the potential environmental impacts certain activities have on water. It is a measure of how much water is consumed in the production of products and which direct and indirect environmental impacts result from this. It takes into account the damage to freshwater resources, ecosystems and human health. The analysis is done according to the method of Hoekstra et al 2012 (Water Scarcity).

[12] **Eutrophication potential.** Enrichment of chemical nutrients, typically phosphorous and nitrogen, in an ecosystem. The analysis is done according to the 3 Recipe Midpoint H Europe –method.

[13] **Health properties** show the stated impacts the chemical may have on human health. These are given in the safety data sheets (sds) of the chemical in use or substituted. Chemicals with health statements would be included in the chemical footprint.

[14] **Safety properties** show the stated risks which are associated with the handling of the chemical. These are given in the sds of the chemical in use or substituted. Chemicals with safety statements would be included in the chemical footprint.

[15] **Environmental properties** show the stated impacts the chemical may have on the environment. These are given in the sds of the chemical in use or substituted. Chemicals with environmental statements would be included in the chemical footprint.

4.1 Cleaning of metal parts

4.1.1 Industry sectors

Cleaning of metal parts is widely done in many different industries, including in the automobile, ship and aviation industry, as well as in the household appliance industry. The metal parts, from which the products will be assembled, can be contaminated with different types of substances, including organic, inorganic, metal corrosion products or for example dust, dirt or smoke particles.[16] Industries that use various metal parts within their products require these parts to be clean prior to treatments such as painting before assembly into the final product. Each of the industries also require the metal parts to be of a specified minimum degree of purity without surface damage.

4.1.2 The cleaning operation

The type and extent of the cleaning operation required depends on at least the following parameters[17]:

- Size and geometry of parts to be cleaned
- Contamination level
- Type and composition of the contamination, including aggregation
- Target level of cleanliness
- Cleaning process itself (manual, mechanical, automatic, robot supported)

The manual Choosing a cleaning process[18] published by the American Society for Testing and Materials (ASTM) categorises contaminations in six groups and also discusses the applicability of cleaning methods for a given contaminate. The groups of contaminants include pigmented drawing compounds, unpigmented oil and grease, chips and cutting fluids, polishing and buffing compounds, rust and scale and miscellaneous surface contaminants.

Cleaning of metal parts includes all six groups of contaminants. The cleaning operation is based on **s**urface chemistry and solvent choice, and there are compelling reasons for industry to optimise the cleaning process, of which waste minimisation is an example. A British guide on surface cleaning and preparation[19] emphasises that the main drivers for optimising cleaning processes are to achieve significant cost savings; improve efficiency; and eliminate waste at source. This guide further lists waste categories from surface preparation, where ChL can provide a path to significant savings. These are:

- Loss of cleaning chemicals
    - Spent surface preparation agents, e.g. contaminated solvents, spent acid;
    - Solutions and spent blasting media;
    - Direct loss of surface preparation agents from the process, e.g. solvent losses from degreasers
- Loss of material
    - Loss to drain of metallic compounds from conversion baths;
- Inefficient cleaning methods leading to excess use of resources: water, energy

[16] See amongst others e.g. Dibble, K. et al (1998)
[17] See e.g. Envirowise, and New Zeeland Insitute of Chemistry
[18] ASM International (1996)
[19] Envirowise (2002)

- Inefficient or excessive use of water in rinse baths and in cooling process tanks;
- Poor quality work giving rise to the need for rework;
- Energy losses during the heating of process tanks;
- Overuse and leaks of compressed air used for agitating baths and with air knives;
- Wasted effort

4.1.3 The technology

There are several different types of technology for cleaning metal parts on the market. They range from simple washing machines with a filter and recycling system to hermetically closed machines with high vacuum. The choice of technology is dependent on the cleaning process requirements. Other factors influencing the choice could include cost of technology and legal requirements.

In developed countries, environmental and workers health regulations act as efficient drivers for designing the operation environment for safety. Hence for example cleaning of metal parts using hazardous chemicals are carried out using closed systems, which enable a more controlled environment, higher efficiency and reduction of emissions to air, potential discharges to water as well as minimisation of workers exposure to the chemicals. Moving from open batch systems to closed cleaning reduces the cost of the chemical, but may increase the cost of the overall operation through costs for the machinery etc. A closed loop also requires measurements, analysis and expertise of when cleaning agents should optimally be changed. In developing countries, the regulatory drivers may not be so strong, and so-called open batch cleaning is still in use.

Successful example of closing the loop

When switching from open cleaning to a closed system, the supplier managed to reduce the consumption of solvent from 754 kg to 160 kg for a batch cleaning sequence (79% reduction). As a consequence, the emissions to air were reduced from 520 kg to 10 kg (98% reduction), and the waste produced was reduced from 233 kg to 150 kg (33% reduction). The largest effect comes from preventing volatiles from escaping.

A closed cleaning system usually consists of a main cleaning chamber. The parts for cleaning are located within this chamber. There are also commonly a number of tanks for different types of cleaning chemicals, each with its proper characteristics and function, and the cleaning process proceeds step-wise, for example as follows:

1. The cleaning chamber is flooded with the first cleaning chemicals. The target is to remove a large proportion of the contaminants. The used chemical is then pumped out of the cleaning chamber.
2. In the second step, a different cleaning chemical is flooded into the cleaning chamber and consequently pumped out as in the first step. This may be to remove a different set of contaminants.
3. The final cleaning step introduces chemical vapour into the chamber to remove any remaining contaminants. After this, the metal parts are ready for use.

Keeping different cleaning chemicals in different chambers will reduce contamination and facilitate reuse. Whilst there are other methods for cleaning metal parts, most closed cleaning systems work according to the principle described above. The main differences occur in the methods for recycling and stabilising the chemicals and/or reducing emissions.

4.1.4 Optimising the cleaning process

Optimisation should be based on a joint understanding of the required degree of cleanliness. Once this frame is established, an in-depth understanding of the metal and the contaminants will allow optimisation of the process, the chemistry and the use of chemicals.

Important considerations when deciding on which chemicals and which technology to use to clean metal parts include at least the following aspects

- Does the process get rid of impurities that would affect the final product in a negative way?
- Will these impurities, once removed from the cleaned parts, affect the machine in a detrimental way?
- How does the process and machinery ensure that any discharges are within discharge limits/do not affect the environment negatively?
- How is risk to workers from e.g. chemical exposure controlled and minimised?

Cleaning efficiently, with optimum amount of chemicals, minimum amount of wear or damage to the surface and minimum amount energy used, therefore requires in-depth knowledge in many areas. The contaminants, the metal parts, the cleaning chemicals, the potential chemical reactions involved, the cleaning technology and the resulting waste need to be understood. There may be several types of contaminants or layers of contamination, each with its own composition and characteristics[20]. At least part of this knowledge is often outside the core competence of the company that need the part cleaned.

In order to supply an optimum process, it is therefore paramount that the supplier understands the customer's requirements, e.g., what the acceptable/desired results of the process must be.

4.1.5 Case studies reviewed

Five case studies of cleaning of metal parts were analysed. The case studies involved the suppliers SAFECHEM, CSC Jäklechemie, Dr Badawi Chemical Works, Qaisa and Polikem. The users were companies from the automotive and the aerospace industries and one aluminium products producer. The cases were from Serbia, UK, Germany, Egypt, Costa Rica and Colombia. The case studies are very briefly presented below, by describing the companies involved, the drivers for implementing the ChL business model and the responsibilities, which each part has. More data on the cases can be found in individual case studies already published, as referenced here.

[20] For example, when considering steel parts, contamination can cause e.g. adhesion failures of components, unsatisfactory appearances, corrosion, electrical contact problems etc. (see, e.g. Mustonen, O. (2011))

CASE 1: SAFECHEM + several users

Chemical manufacturer acts as supplier and service provider + several types of users

SAFECHEM *is a service and solutions provider for the surface cleaning industry. The company offers tailored solutions for customers in various industries like for example in the aerospace, automotive and high precision industry as well as in electronics. The company has 7500 customers via distributors and it is owned by Dow chemical company*[21].

SAFECHEM has shifted to ChL with several of their customers[22]*, including for example, FKL*[23]*, Henton Engineering*[24] *and Automobiltechnik Blau*[25]*.* ***FKL*** *is a Serbian automotive parts producer, a small user with one main site.* ***Henton Engineering*** *is a small user with one main site. Henton Engineering is located in the UK and manufactures components for the Aero Engine, Marine Engine and Satellite industries, and a member of the Nasmyth Group.* ***Automobiltechnik Blau*** *is a medium sized user, with two production sites in Europe. Automobiltechnik Blau is a manufacturer of re-fuelling systems and modules and a component supplier for the automotive industry.*

SAFECHEM has actively sought partners with whom it would be suitable to change to ChL. With new technology and machines, the consumption of chemicals is decreasing constantly. The business is more concentrated on focusing on the performance of the product now, and therefore it was logical to switch to relating the payment to performance.

CASE 2: CSC Jäklechemie and DHD[26]

Distributor acts as service provider + works with small user on one site, that in turn provide a service provider to many customers

CSC Jäklechemie *is a chemical supplier with 120 employees. CSC Jäklechemie works as a distributor for SAFECHEM. Customers that CSC Jäklechemie has worked with include* ***DHD****.*

DHD cleans metal parts for different customers. CSC Jäklechemie's role is to advice in the use of the machine used for the cleaning process and supply the solvents and stabilisers needed for cleaning. The supplier is in weekly contact with the user. The user has different types of cleaning problems all the time, and the supplier advices how the specific impurity should best be cleaned. The supplier analyses the solvent 2 times a year for each cleaning machine.

The driver for implementing ChL was to get a better connection with the customer and switch the focus to helping the customer. The information about the concept came from CSC Jäklechemie’s main supplier of solvents, SAFECHEM. CSC Jäklechemie searched actively for a suitable customer to establish their first ChL-project.

[21] See e.g. SAFECHEM (2015)
[22] UNIDO (2012)
[23] Satric, V. & Montémont, L. (2012)
[24] UNIDO database
[25] UNIDO database
[26] UNIDO database

CASE 3: Dr Badawi Chemical Work and General Motors[27]

SME private manufacture act as service provider + very large, multinational company (on one site)

Dr Badawi Chemical Work *is a SME chemical producer and supplier here acting as the service provider, highly specialised in chemicals used in metal finishing.* ***General Motors*** *is a multinational automotive manufacturer.*

In the ChL relationship, Dr Badawi Chemical Work (supplier) supplies to General Motors (user). The role of Dr Badawi Chemical Work include the service of cleaning with hydrocarbon solvent for a fixed fee per vehicle. The ChL contract defines specific responsibilities for the parties, with a shared responsibility for waste. Recycling of the waste is implemented at the Dr Badawi Chemical Work facilities and includes a target of using the waste for energy. As well as environmental and resource gains, the ChL model implemented a more efficient Life cycle based process where the solvent use was monitored and limited to the specific work (e.g. batch cleaning). Low cost measures targeting the efficiency of the process were also implemented, e.g. each shift painting specific colours in batches, minimising the need for cleaning. The implementation also included capacity building and raising the awareness of operational personnel.

The driver for implementing ChL was to achieve a reduction/elimination of waste, minimise use of raw materials and to create a foundation for a long-term business relationship based on shared liabilities and benefits.

CASE 4: QAISA and Extralum[28]

Chemical manufacturer acts as supplier and service provider + medium size user with three main production sites.

QAISA *is an SME producing speciality chemicals.* ***Extralum*** *manufactures, processes and markets products of glass and aluminium. In the ChL relationship, Extralum (user) uses a chemical product for degreasing aluminium profiles, which is supplied by QAISA (supplier).*

In this case, the companies developed a new product together. The user determined the requirements and the supplier developed a product that met the requirements. Joint tests were performed at the users production site until the desired end result was achieved.

The critical parameters in development were the degree of attack on the metal surface, easy dissolution in water, low sludge formation at the bottom of the tank, biodegradability, and above all variables, a cost / processed m2 equal or less than the once recorded the imported product.

The driver for introducing ChL was in this case taken by the user. The high import costs of the chemicals used for degreasing motivated Extralum to substitute these products for equivalents made in the country. Extralum also places an effort on achieving environmentally friendly production.

[27] See UNIDO (2013)
[28] Information from application for ChL award.

CASE 5: Polikem and Renault[29]

Distributor act as service provider + very large, multinational company (on one site)

Polikem *is a Colombian company that provides products and services to the metal, mechanics and plastics industries, with specific focus on the automotive industries.* ***Renault*** *is a multinational automotive manufacturer. In the ChL relationship, Polikem (supplier) is responsible for the anti-corrosion process for Renault Colombia automobiles (user), were the first step is cleaning the parts.*

Polikem is responsible for providing, managing and applying the chemical products used in the Renault Colombia (Sofasa) plant for anti-corrosion. Sofasa Renault is responsible for facilities and equipment maintenance and verifies compliance of the processes. Daily general verifications are performed on the production and supervision plans (customer specific requests) that are delivered and validated by them. Weekend maintenance and weekly meetings to guarantee the process' correct functioning and project proposals to improve the processes' performance are developed jointly. Approval tests for the surface treatment process are performed by Renault in France, Brazil and/or Argentina to test the surface treatment process and by external laboratories such as the Universidad Nacional de Colombia. The payment is charged per m2 of treated surface. A unique rate is charged for the whole process of anti-corrosion protection (degreasing+phosphate). The billing is defined by the cost of each treated cabin depending on each cabin's area by model.

The driver for implementing ChL was for Polikem the company vision, of leading the chemical products production and supply, and services, always committed to the protection of the environment.

Part of these five cases and their key parameters have been presented in the literature, in UNIDO's annual reports and in the Chemical leasing database, while part of the cases have been presented in applications in the newest round of applications for the Chemical Leasing award 2014. The unit of payments and KPIs used in these cases are summarised in Table 3.

The waste from the machine is handled separately, and hence the relevant environmental indicators of success relate to waste quality and quantity, energy use and chemical consumption. Financial indicators were set from total savings per year to more indirect measures of cost to the customer, e.g. electricity, waste costs, costs related to the machine.

The technical, safety, environmental and financial results the parties achieved with the ChL model are summarised in Table 4.

[29] Information from application for ChL award.

Table 3: Units of payments and KPIs used in the 5 cleaning of metal parts case studies

Variable	Examples
Unit of payment	• Currency per number of cleaned parts • Currency per cleaned surface area • Currency per vehicle produced • Currency per hours of operation of the equipment • Time based set-up • Monthly fee for work in three shifts seven days a week (two machines)
KPIs used / per case	• Solvent consumption (volume) • Life time of chemicals • Economic savings per year • Stability of cleaning quality • Performance of cleaning quality • Effect on surface • Employee safety (not specified) • Hazardous waste produced • Waste produced • Electricity or fuel consumption • Water consumption • Life time of machine • Spare parts consumption

Table 4: Results from switching to ChL in cleaning of metal parts

Variable	Examples
Technical results	• Stable level of quality achieved (formerly decreasing level of quality by time) (1 case) • More efficient cleaning process and concrete monitoring system
Safety results	• System for hazardous waste management (1 case) • Toxic fumes eliminated by chemical substitution • Employees not in contact with solvent due to closed system (1 case) • Awareness raised with operating personnel of chemical hazards
Environmental results	• Waste reduced by 94% per year • Waste reduced by 60% per year • Solvent waste reduced by more than 25 t/year • 20% more solvent waste collected • VOC emission reduction by 60% (100 ppm → 40 ppm)

Financial results and resource efficiency	• The use of cleaning chemicals reduced with 75%
	• Savings for customer (2 cases) 10-15%
	• Savings per cleaned item 33% and more
	• Energy consumption reduced by 50%
	• Fuel consumption reduced by 16% per year
	• Electricity savings
	• Water consumption reduced by 88%
	• Extended the lifespan of the chemicals in use
	• Use of spare parts reduced by 66%
	• Reduction in solvent consumption by
	  ○ 20 tonnes/ year (absolute level only reported)
	  ○ Ranges included: 10%; 8–10%; 23%; 71%; 75%
	  ○ perchloroethylene 83% = 25 t/year

Note that more details on the individual case study results are presented in previous literature. Whilst all the cases reviewed are examples of ChL, the actual units of payments, KPIs and hence contracts differ significantly. This indicates that there will be considerable difficulty in drawing general conclusions from the case studies. **Nevertheless, there is a generic trend that indicates that changing the business model to a result focused service will result in not only a reduction in chemical amount, but also in direct and indirect savings:**

- Two cases show direct savings for customer, whereas all cases indicate indirect savings on resources
- All cases indicated a reduction in chemical consumption, from 10-83%.
- Only two cases gave specifics on environmental results. In discussions with the other parties, it would appear that either the environmental performance baseline and/or the environmental KPIs were not established at the beginning of the project, whereby the change could not be measured.

4.1.6 How has ChL helped to achieve the results

Perhaps inevitably, switching to a closed system would lead to certain parameters improving. Over and above this, the case study results provide examples of decreasing chemical usage by substituting chemicals to ones that work better for the purpose and improving machine efficiencies.

The case study results indicate that introducing the service and result focused ChL business model contribute to optimisation in particular through the following mechanisms:

1. **Disconnection of payment from amount of chemicals → Reduces chemical volumes used.** Once payment is disconnected from the amount of chemicals, it will be in the interest of the chemicals provider to reduce the amount of chemicals and thereby reduce their costs. Reducing the chemicals in this case generally entails ensuring a closed loop system. A closed system makes it easier to control emissions to air, water and soil, which also has a direct beneficial effect on reducing emissions and discharges as well as reducing risk to people.
2. **Collaboration and knowledge pooling → Optimises the process.** The process requires a large amount of different types of knowledge (see 4.1.4 Optimising the cleaning process), neither buyer nor seller usually possesses all of it. Increased collaboration between the parties ensures the different aspects are considered at the same time and not as separate entities. When the business model is changed to providing a functional service, i.e. clean metal parts, the service user can focus on what the end result should be (this is what we need the process to produce and these impurities need to be removed). The service provider on the other hand focuses on how this could be achieved.
3. **Easily accessible knowledge → R&D directed towards optimising functionality.** When the required knowledge is easily accessible due to increased collaboration and the common incentive is to make the process more efficient, joint or supplier's R&D can be focused on making the cleaning more efficient.

4.2 Cleaning of vessels, bottles and pipes

4.2.1 Industry sectors

Cleaning of specific structures designed to hold liquid or materials, such as vessels, bottles and pipes, is needed in most processing industries either continuously or from time to time. Important industries with this requirement are, amongst others, the petrochemical, emerging biochemical, pharmaceutical and food industry. Vessels and pipes are an integrated part of the process infrastructure, and the cleaning of these a different prospect than cleaning metal parts. Bottle differ in many ways, but the cleaning is generally incorporated into the e.g. bottling process, and takes place in situ. The contaminants originate either from the process itself or from storage and/or transport of particular materials, which can vary from oil or chemicals to milk. The cleaning of the vessels, bottles and pipes may be part of a specific site maintenance program or because of for example batch problems, external contaminants or changes between products. In each case, the required degree of purity is related to the process.

4.2.2 The cleaning process and technology

Large vessels, pipes or pipelines can seldom be moved to a cleaning machine. Cleaning that takes place *in situ* place different requirements on the chemicals, application and technologies used. When compared with the cleaning of metal parts, a somewhat different palette of parameters therefore influence the cleaning process design. These are:

- Size, site and siting of the vessel/pipeline and potential pre-fitted equipment
- Contamination level
- Type and composition of the contamination
- Target level of cleanliness
- The extent of pre-cleaning and post-cleaning procedures that are included
- Potential for personnel exposure to hazardous chemicals and personal protective equipment requirements

The selection of chemicals and their concentration, application methods, measurement of process parameters and recycling systems determine the process efficiency, safety and environmental impacts. As with the cleaning of metal parts, the selection of appropriate chemicals and the sequence of their application therefore play an important role in the design of the cleaning process. As the cleaning process often is an integrated part of overall working processes, there is also a need to ensure that all cleaning agents are removed and the bottle, vessel or pipe is dry and ready to be used again within a set timeframe.

4.2.3 Optimising the cleaning process

Optimisation should be based on a joint understanding of the required degree of cleanliness and requirements for e.g. downtime. Once this frame is established, an in-depth understanding of the vessel/pipe or bottle material and the contaminants will allow optimisation of the process, the chemistry and the use of chemicals.

Cleaning efficiently, with optimum amount of chemicals, minimum amount of ware or damage to the surface and minimum amount energy used, requires in-depth knowledge in many areas. For efficient cleaning, the contaminants, the metal parts, the cleaning chemicals, the potential chemical reactions involved, the cleaning technology and the resulting waste need to be understood. As the vessels and pipes and bottles to be filled form an integrated part of the customer's overall manufacturing and packaging processes, the customer can provide significant understanding of the contaminant while the supplier has the knowledge of how to remove the contaminant.

For the customer, important considerations when deciding on which chemicals and which technology to use include at least the following aspects

- What will be the downtime, if any, for the process?
- What potential hazards will arise during the cleaning process, and can these affect the rest of the process detrimentally?
- How does the cleaning process and technology used fit in with potential discharge limits and what are the potential effects on the environment?
- How is risk to workers and environment controlled and minimised?

In order to answer these aspects, both the cleaning process and the technology used must be optimised.

4.2.4 Case studies reviewed

The review includes two main cases. Case 6 looks at one supplier case study with two different users and Case seven is another supplier case study with one user for ChL in the cleaning of vessels and bottles. The case studies involved the suppliers Ecolab and Diversey Eastern and Central Africa. The users were companies from the food and beverage industry. The cases were from Serbia, Croatia and Uganda. The case studies are shortly presented below, by describing the companies involved, the drivers for implementing the ChL business model and the responsibilities, which each part bears.

CASE 6A: Ecolab and Coca-Cola HBC Serbia

Chemical manufacturer act as service provider + very large, multinational company

Ecolab *is a multinational company providing hygiene, water and energy technologies and services.*

CCHBC Serbia *is part of Coca-Cola Hellenic Group, one of the largest bottlers of Coca-Cola Company's products in the world, and the biggest in Europe.*

The change towards ChL started out with trials in some applications. With the new agreement, joint co-operation between Ecolab and Coca-Cola HBC Serbia has been expanded to full cooperation under the ChL model. The agreement includes both cleaning of bottles and lubrication of conveyer belts. For the cleaning process, the seasonal changes and large variation in consumer behaviour, and thus demand for different drinks, was a main issue to address. In the case study the original unit of payment was changed from price/kg and cost/working hours to payment for the performed job as cost/litre of produced drink.

The main driver for implementing ChL is the increase of co-operation through minimizing the environmental footprint and contributing to local quality of life. Chemical leasing is in line with the issues that Ecolab prioritizes in their business: Water stewardship, Energy and climate protection, Packaging and recycling, Consumer health, People development, Supplier engagement, Benefiting communities and UN Global compact.

CASE 6B: Ecolab[30] and Unilever

Chemical manufacturer act as service provider + very large, multinational company

Unilever *in Costa Rica produces beans and products from these. Unilever is a multinational company that at the same time is multilocal due to a mixture of experience in meeting the needs of consumers throughout the world. Unilever has developed strong roots in each of the countries where it operates. It is one of the five largest companies in the industry of consumer products, with over $ 50 billion in sales and operations in more than 151 countries.*

Ecolab performed washing tests of tanks to optimize the process, which included the reduction of consumption, substitution of chemicals used, the change in dosages with respect to those used previously, recycling of water and modifications to the washing process. Within the project, Ecolab is responsible for technical assistance, training of Unilever staff and monitoring of programs implemented. Unilever pays for the service as per volume of cleaned tanks. The results and consumption indicators are quantified and monitored monthly.

The driver for implementing ChL was Unilever's vision to double the size of the business while halving its environmental impact through the Sustainable Living Plan, and the commitment to continuously improve the way they manage their environmental impact. To aid them in this, Unilever made a strategic alliance with the supplier Ecolab, as the company in the same way is highly committed to sustainability in business processes and products offered to customers.

[30] Information from application for ChL award 2014.

CASE 7: Diversey Eastern and Central Africa and Crown Beverages Limited.[31]

Chemical manufacturer act as service provider + medium size user with few sites, few processes

Diversey Eastern and Central Africa *is part of the multinational Sealed Air Corporation (former Diversey Inc), which provides commercial cleaning, sanitation and hygiene solutions.*

Crown Beverages Limited (CBL) *is the largest soft drink producing company in Uganda. In the ChL relationship Diversey (supplier) provides cleaning and lubrication services to CBL's returnable glass bottles plant.*

In this business model, the supplier supplies and manages chemicals, optimises chemical utilisation, gives solutions to hygiene challenges, offers consultancy in hygiene solutions and provides maintenance of the lubrication system. The supplier receives payment as Uganda shillings per litres of beverage produced.[32] *The supplier is also in charge of training the staff and supervising operations at the user's plant, whereas the service recipients provides the favourable environment for the service provider to execute the tasks. The responsibilities of the user include working hand in hand with the supplier, facilitating the service through providing office, storage facilities and conducive environment, ensuring that Key Performance Indicators are followed and available to the supplier, and verification of the incoming chemicals.*

The driver for ChL was that CBL was suffering from high operating costs at the returnable glass bottle plant for soft drinks, and CBL was looking for ways to lower these. Costs were made of costs for the chemicals used for bottle washing and for lubrication of the bottle conveyors. In addition to these direct costs there were other associated costs for treatment of the effluent.

Part of these cases and their key parameters have been presented in the literature, in UNIDO's annual reports and in the Chemical leasing database, while part of the cases have been presented in applications in the newest round of applications for the Chemical Leasing award 2014. The unit of payments and KPIs used are given in Table 5. The technical, safety, environmental and financial results the parties achieved with the ChL model are summarised in Table 6.

Table 5: Units of payments and KPIs used in cleaning of vessels, bottles and pipes case studies

Variable	Examples
Unit of payment	• Currency per litre of product produced • Currency per m3 of cleaned tank
KPIs used / per case	• Water consumption • Energy requirements • Chemicals consumption • Downtime • Waste produced

Table 6: Results from switching to ChL in cleaning of vessels, bottles and pipes

[31] Information from application for ChL award 2014.
[32] The Unit of payment is Uganda Shillings per Lt of beverage produced. The unit of payment was determined using a baseline volume of beverage of 9,000,000 Lts. In order to compansate for losses/gains associated with volume changes by either party, a cost escalator was developed. This works in such a way that for higher volumes compared to the baseline, a certain fraction of cost is deducted from the base pay rate and the reverse is true for lower volumes.

Variable	Examples
Technical results	• Decreased downtime • The user is now more interested and skilled in monitoring chemical consumption
Safety results	• Replacement of solid caustic mixing onsite, with liquid caustic, which is easier to handle hence improved safety for the workers
Environmental results	• Decrease in chemical waste due to decrease in chemicals consumption • Decrease in GHG emissions and uses of fossil resources due to decrease in internal transport and warehouse needs • Substitute chemicals are biodegradable
Financial results and resource efficiency	• The turnover went down 10%, while the profit was kept the same during the first year. After 2 years profits started increasing for both companies • Savings achieved, 20 000 USD/year • Large decrease in chemicals consumption. 30% decrease during first year. • Decrease in chemicals consumption, 60%. • Large decrease in internal transport and warehouse costs • Decrease in water consumption, 40% • Decrease in fuel consumption due to lower temperature, 65% • Personnel costs were decreased with 60%. • Decreased risk of stock damage while in storage, with optimized delivery

4.2.5 How has ChL helped to achieve the results

For the supplier, the use of ChL has led to a co-operation model that has put them on a different level to competitors, e.g. the supplier feels that they have become a partner who helps in developing the process rather than just "another supplier". In the beginning, Ecolab provided only one service to Coca-Cola, but today they are the sole supplier for all of Coca-Cola's cleaning operations. In applying the ChL model, only small investments were needed. The improvements were achieved by changing the process and raising employee awareness.

In case 6B of Ecolab and Unilever, the chemicals were substituted with much more expensive chemicals. However, as the process and consumption of chemicals was optimised, chemical usage could be decreased to a level where economic benefits of 20% savings were achieved, despite the higher price.

With increased collaboration, better planning of timed maintenance and cleaning operations is achievable. This has reduced downtime and related costs. Planned cleaning sequences and controlled amounts of the right cleaning agents are the key issues for reducing chemicals consumption in all cases. When the required knowledge is easily accessible due to increased collaboration between the three parties (providers of chemicals, providers of technology and users), R&D can focus on making the cleaning more efficient.

Results of ChL implementation in CBL have been tremendous that it prompted CBL to evaluate and adapt a similar concept to forklift operations. This has resulted into higher efficiencies in this area, and consequently large savings to both CBL and the service providers. Evaluations have also been finalised and implementation of the same concept in cooler maintenance is in final stages. Therefore, the fundamental business model behind ChL can be extended successfully to other areas than chemicals.

4.3 Industrial wastewater treatment

4.3.1 Industries

Wastewater treatment is required by all industrial activity that generate wastewater of such quality that the legislation/standards/ expectations of stakeholders require the wastewater to be cleaned prior to discharge into either sewers or water bodies. Wastewater treatment is therefore of major importance and broadly used in various industries either to recycle used water for further processing or to treat the wastewater to aforementioned required levels before discharges.

Note that ChL has also been applied in wastewater treatment done by (municipal) water & sewage companies, prior to discharges or use for drinking water. However, these cases were not included in this study, which has focused on industrial processes.

4.3.2 The cleaning process and technology

Treatment of wastewater in the industry is based on chemistry that focuses on separating different liquids, particles and dissolved components from water or water from a product stream. Chemically induced separation is used widely in different industries and the chemical processes include various stages such as coagulation, flocculation, precipitation, oxidation, ion exchange, neutralisation and stabilisation. The chemistry is applied in, through or with a variety of technological solutions, depending on the wastewater stream, the cleanliness requirements and the contaminants.

4.3.3 Optimising the treatment process

For the customer, the efficient separation of the contaminants from the wastewater, or the wastewater stream from the product stream, is paramount. Here the quality, the reliability of the results and ensuring minimisation of harmful discharges are highly relevant.

A review of the steel and iron industry wastewater indicated that the most common contaminants were[33] heavy metals**,** organic compounds, especially PAHs, oils and surfactants**,** cyanides, and fluorides

Wastewaters from the food industry give rise to the following primary issues of concern[34]:

- biochemical oxygen demand (BOD)
- total suspended solids (TSS)
- excessive nutrient loading, namely nitrogen and phosphorus compounds
- pathogenic organisms, which are a result of animal processing
- residual chlorine and pesticide levels

Untreated wastewater from cleaning operations in the chemical industry can be highly contaminated with substances that are dangerous to the environment, including solvents, petrochemicals, plastics and pharmaceuticals.

Hence each industry requires tailored processes, and any results of ChL within one industry is not necessarily transferrable to others. The treatment processes need to be designed based on the

[33] Biswas, J. (2013)
[34] UNIDO, Pollution from food processing factories and environmental protection available at http://www.unido.org/fileadmin/import/32129_25PollutionfromFoodProcessing.7.pdf (viewed 11.2.2014)

quality of the wastewater that need treatment, taking into account the type of contaminants, solid load and composition, BOD, health related contaminants, toxins and nutrients etc. [35].

Wastewater treatment systems can consist of primary, secondary and tertiary treatment, sometimes complemented by chlorine disinfection before final discharge[36]. Chemicals can be used as part of all of these treatment steps in various degrees. Parameters that influence the chemical use therefore include e.g.:

- the type of contaminants in the water that need to be removed;
- the loading rate of contaminants;
- the required purity; and
- the volume flow that has to be treated.

4.3.4 Case studies reviewed

Two very different case studies concerning wastewater treatment were included. The case studies involved the suppliers Nalco (now part of Ecolab) and Hidrotechnik. The users were companies from the oil industry and the ceramics industry. The cases were both from Colombia. The case studies are shortly presented below, by describing the companies involved, the drivers for implementing the Chl business model and the responsibilities which each part bears. Note Case 9 represents a case where chemicals where eliminated, and the term itself (Chemical Leasing) becomes partly misleading. Nevertheless, it is a particularly successful case of reducing chemical hazard to environment and people and as such, certainly meets the objectives of ChL.

CASE 8: Nalco (now Ecolab) and Ecopetrol

Chemical manufacturer acts as supplier and service provider + Large company with many sites and many processes

Nalco, now a part of Ecolab, is a global service company supplying the oil industry with specialist chemicals and services. ***Nalco was a distributor, which acted as a service provider in the ChL relationship****. Nalco has worked with Ecopetrol since 2008 on ChL projects.*

The case is presented in detail in the UNIDO annual report 2012, in several articles as well as the UNIDO annual report.

CASE 9: Hidroteknik and Corona-Colceramica

[35] see, for example, World Bank (2015)

[36] see, for example, World Bank (2015)

Technology provider acts as service provider + Very large, multinational company

Hidroteknik *is a wastewater treatment supplier that handles the wastewater treatment system of Corona's plant that manufactures ceramic tiles. They give support for the use of the system, service and maintenance of the system.*

Corona-Colceramica *is a part of Corona Group, which is* ***a multinational company*** *that manufactures and markets home improvement and construction products. Corona Group is involved in different business sectors, e.g. mining, ceramic manufacturing (sanitary ware, tiles, tableware, electrical insulators) and retail.*

This case is made rather special by the fact that the system de facto works without chemicals, using only c. 10 kg/year for cleaning the systems. The Corona-Colceramica-Hidrotechnik case is presented in Global Promotion and Implementation of Chemical Leasing Business Models in Industry.

The driver for implementing ChL was reaching the goal of zero discharge. The company had an earlier implementation of ChL at another plant and wished to try the model also in the wastewater treatment. The discharge fees set by the government were high and new methods were sought to decrease the amount of discharged wastewater.

Part of these cases and their key parameters have been presented in the literature, in UNIDO's annual reports and in the Chemical leasing database, while part of the cases have been presented in applications in the newest round of applications for the Chemical Leasing award 2014. The unit of payments and the KPIs used are given in Table 7. The technical, safety, environmental and financial results the parties achieved with the ChL model are summarised in Table 8..

Table 7: Units of payments and KPIs used in the industrial wastewater treatment case studies

Variable	Examples
Unit of payment	• Fixed monthly cost for maintenance. • USD per kilo barrels (Kbls) of oil with the specified quality.
KPIs used / per case	• m3 water discharged • costs of implementation • quality of water • cost of maintenance of equipment • Oil water content (% BS&W): A measure of the water content dissolved in and free water present in the oil stream. The operative range is between 0 and 0.8%. %BS&W is measured both in the oil for sale and at intermediate process points. • Water oil content (G&A): The operative range is between 0 and 3 ppm oil in water. G&A is measured at the end-of-pipe point of discharge. • Total Suspended Solid Content (SST): SST is measured at end-of-pipe point of discharge and the operative range is between 0 and 3 ppm.

Table 8: Results from switching to ChL in wastewater treatment

Variable	Examples
Technical results	• No sub-products in the chemicals production process due to the methodology used • Removal of 99% of the oil and suspended solids from the served waters although the legislation requires only 80%
Safety results	• Estimated reduction of 2–3% of health impacts on workers and chemical risk
Environmental results	• Zero discharge due to the recirculation of water treated • Reduction by about 18% of groundwater extraction (total 30,000 m3/year) = 5400 m3/year • potential: water savings of 30 000 m3/year • Reduced solids (waste) content of 20% • Reduction of chemical use up to 46% ○ Clarifier concentration in discharges 14 % ○ Clarifier concentration in waste 18 % ○ Reverse emulsion breaker concentration in discharges 44 % ○ Reverse emulsion breaker concentration in waste 44 %
Financial results and resource efficiency	• Permits for the discharge of wastewater no longer required • Cost reduction of the treatment process by almost 20% due to the recovery of the oil in pools, the prolongation of cleaning and the maintenance of the pools and cooling towers • Reduced consumption of the polymer • Reduction of the polymer residues in the stabilisation pools and the served waters • Adjustment of the yield of the equipment • Reduction of oil and grease in the cooling towers • Reduction of chemicals used up to 44% less • Reverse emulsion breaker concentration in waste 44 %

4.3.5 How has ChL helped to achieve the results

In the industrial wastewater treatment cases, the benefits seen with the change in business model also relate to the fact that it would mainly not have been possible to implement the new technology without knowhow from outside the using company. Overall, intensive collaboration was needed between the provider and user to exchange knowledge on the waste streams. The results from case 8 in particular indicate that extensive economic as well as environmental and health benefit are achievable, with considerable savings for the user, seen already three months after the implementation of the model.

Both cases showed considerable environmental and social benefits. In Case 9, it should be noted that whilst the case follows the ChL business model, with close co-operation and knowledge sharing between the partners, chemicals are practically eliminated and the case is therefore in that sense more about leasing the technology. This highlights the problem area associated with the terminology.

4.4 Service sector cleaning operations

4.4.1 Service sectors

Cleaning operations are important in many service sectors, especially in food and accommodation services, where the flow of customers is large and cleaning operations are needed in between every change of customer. Cleaning operations are even more important in the health sector services, such as hospitals, where the contaminants are concentrated and the customers vulnerable to infections.

In hotels, motels, hostels and other accommodation forms, chemicals are used in the cleaning of rooms and sanitary areas, in the washing of bed linen. In restaurants, chemicals are used for dishwashing and cleaning of surfaces. Hospitals are large users of chemical disinfectants. In Germany for example, around 6000 tons of disinfectants are consumed per year.[37]

4.4.2 The cleaning operation and technology

HSE[38] has listed several types of hazardous cleaning chemicals used in the hospitality industry. Many of these are hazardous because they are corrosive and can cause skin and eye burns if splashed onto the body. Some may cause breathing problems or may even produce harmful gases, if not used according to the supplier's advice. Hazardous cleaning chemical types include familiar chemical uses, e.g.:

- washing-up liquids
- dishwasher detergents and rinse aids
- drain-cleaning products
- oven cleaners
- disinfectants
- toilet cleaners
- bleach
- sanitisers
- descalers.

The disinfectants can be further divided into subcategories. In the hospital case included in this study, following disinfectant categories were recorded[39]:

- Ready-to-use surface cleaning agents
- Concentrated surface cleaning agents
- Skin and hand disinfection agents
- Automatically used disinfection agents for equipment
- Manually used disinfection agents for equipment
- Disinfecting cleaning agents

4.4.3 Optimising the cleaning process

In the service sector it is especially important to note that the requirements for cleaning results may vary considerably. For example, cleaning in hotels covers operations that aim at removing e.g. dust, stains and odours from various kinds of surfaces. However, cleaning in hospitals often focuses on disinfection of equipment and surfaces.

4.4.4 Case studies reviewed

Two case studies were reviewed for the service sector cleaning operations. The case studies involved the suppliers Ecolab and Schülke. The users were companies from the hospitality sector and the health sector. The cases were from Brazil and Germany. The case studies are shortly presented below, by describing the companies involved, the drivers for implementing the Chl business model and the responsibilities which each part bears.

[37] Ehold, V. (2014)
[38] Health and Safety Executive (2012)
[39] Schülke (2012)

CASE 10: Ecolab and Hotel Windsor Atlantica

Chemical manufacturer acts as supplier and service provider + Small user, one main process/one site

***Ecolab** is a multinational company that manufactures and supplies technology and chemicals. Ecolab is a partner to the **Hotel Windsor Atlantica,** Rio de Janeiro Brazil, in chemicals use, pollution prevention and sustainable solutions. The 5 star hotel is established in year 2010 and aims constantly at reducing the consumption of water, energy and chemicals, and the amount of wastes and pollution. Chemical leasing has been implemented and new solutions for waste are being evaluated as an opportunity to improve the ChL approach and cooperation with Ecolab.*

Chemical Leasing is applied to the cleaning of rooms, common areas, dishwashers and laundry services. Ecolab controls the chemicals´ storage and quantities consumed. ECOLAB ensures safe handling of chemicals and no direct exposure of chemicals to employees. The unit of payment is a service fee based on the number of occupied rooms per month.

The driver for implementing ChL was to minimise the use of chemicals in the hotel's operations. An additional driver was that Ecolab offered a smart billing method when the new hotel was started-up.

The partners are now working on minimizing packaging and transportation, as well as decreasing water usage. A future focus will definitely be on minimising water usage, as Brazil is suffering from fresh water availability and water prices are increasing.

CASE 11: German Hospital

Chemical manufacturer acts as supplier and service provider+ additional service providers and evaluators + Small user, one main process/one site

*The other service sector case covered is a German hospital case. The implementation of chemical leasing was performed as a pilot, to test the possibilities of the model for hospitals. It was a joint co-operation of **Schülke & Mayr GmbH,** OPAL Service GmbH, Klinikum Worms, Institut für Umweltmedizin und Krankenhaushygiene (IUK), Leuphana Universität Lüneburg and Deutsche Bundesstiftung Umwelt (DBU).*

***Schülke & Mayr GmbH** is a multinational chemicals manufacturer and solution provider of disinfectants, preservatives, biocides, hygiene products and system cleaners for medical hygiene and food, pharma, cosmetics and fluid industries. **OPAL Service GmbH** is a subsidiary of Schülke, providing consultancy services in the same fields. **Klinikum Worms** is the university hospital of the Johannes-Gutenbergh University, with about 26 000 patients.*

Schülke & Mayr GmbH ran the project and the provided the chemicals. OPAL Service GmbH worked as advisor and gave the required training to the personnel. The hospital where the tests were performed was Klinikum Worms. Evaluation was performed by the Institut für Umweltmedizin und Krankenhaushygiene (IUK) and Leuphana Universität Lüneburg (scientific evaluation of disinfectants) and Deutsche Bundesstiftung Umwelt (DBU) (Environmental part of the study).

The aim in the hospital case project was to show that an optimal combination of consultation and disinfectants can increase infection protection, reduce costs, ensures occupational safety and minimise environmental impacts.

Part of these cases and their key parameters have been presented in the literature, in UNIDO's annual reports and in the Chemical leasing database, while part of the cases have been presented in applications in the newest round of applications for the Chemical Leasing award 2014. The unit of payments and the KPIs used are given in Table 9. The technical, safety, environmental and financial results the parties achieved with the ChL model are summarised in

Table 10.

Table 9: Units of payments and KPIs used in cleaning operations in the service sector case studies

Variable	Examples
Unit of payment	• Currency per occupied room • Currency per area of cleaned and disinfected surface area of instruments
KPIs used / per case	• Use and cost of disinfectants • Environmental impacts (AOX/l of wastewater, tons of alcohol evaporated per year, kg waste per bed) • Use of antibiotics (doses of antibiotics per bed and year) • Hygiene level (share of samples with number of bacteria exceeding set limits) • Infection protection (share of post-operative wound infections of relevant operations) • Occupational safety (number of occupational accidents relating to the use of

	hazardous substances) • Knowledge level of personnel (duration of education)

Table 10: Results from using ChL in service sector cleaning operations

Variable	Examples
Technical results	• Chemicals are prepared in a device. The dosage of water and chemical is made automatically. • Reduction of chemical use regarding some types of chemicals and an increase for some other chemicals. ○ Consumption of disinfectants increased during the project by 18,5% (yearly total) ○ Use of surface disinfectants was reduced by 14,3% and 41,6% for concentrated and ready-to-use, respectively. ○ Use of disinfecting cleaning agents was reduced by 28,6% ○ Use of hand disinfectants was increased by 38% ○ Use of disinfectants for equipment increased by 28%
Safety results	• Use of concentrated chemicals more efficient with no direct contact with workers. • Less work accidents. • Improved hygiene.
Environmental results	• Reduced environmental impact through education to employees and less emissions
Financial results and resource efficiency	• The leasing cost is lesser than the direct purchase for the hotel. The size of the hotel allows promoting a leasing with a lower price. • Budget planning is easier for both parties due to the unit of payment • Direct cost savings for hotel • No direct cost savings for hospital

4.4.5 How has ChL helped to achieve the results

In Case 10, the knowledge on how to reduce chemical use and ensure safe handling of chemicals came from the supplier. The unit of payment was, as is the ChL model, clearly decoupled from chemical. The unit of payment was, however, not coupled to the result or cleanliness, but to the service required.

The laundry process represented 96 % of the overall chemicals used, and was taken as the focus in this case study. The dosage of concentrated chemicals and water is done automatically to certain parameters. One party pays for the chemicals and the other party for the water. It is in the interest of both parties to find a combination that minimise the use of both water and chemicals. An important factor in achieving reductions was that the hotel was able to directly affect the laundry process, as it is performed at the hotel. A future business idea is to include small hotels in the laundry service, as they would not have the possibility to implement ChL on their own due to small amount of service needed.

In the case of chemical leasing implementation at the hospital, the main benefits seen were benefits that will lead to indirect cost savings. This was improved hygiene at the hospital, with the possible result of a lower occurrence of hospital acquired infections at the hospital. A surveillance program has been started with the purpose to follow if infections are decreasing and thereby resulting in indirect cost savings. Direct cost savings were not achieved as the use of some cleaning agents increased and the use of other cleaning agents and disinfectants decreased.

5 Potential for Chemical Leasing

This chapter discusses the potential for wider application of ChL in the industry and service cleaning operations under scrutiny. The discussion is based on the interviews carried out for the 11 case studies and include consideration of two scenarios created to illustrate the wider application potential of ChL in the operations in selected countries.

5.1 ChL and business potential for suppliers

All interviewed suppliers saw a considerable potential in using ChL more widely and none stated that the use of ChL would not be continued. There was no clear difference between the different types of suppliers here (e.g. manufacturer, distributor etc.). It should however be noted that in order for a distributor to be able to offer ChL, there is generally a need to ensure that the working relationship with the manufacturer is good, and that the manufacturer is willing to support the business model through e.g. research.

Suppliers of ChL for cleaning of metal part gave particularly good reviews. This is a stand-alone process, which can be undertaken either at the customers premises or elsewhere. It is not integrated into the using industry’s own processes in the same way as for example a pipeline is an integrated part of a process system. As soon as the ChL moves into areas which are an integral part of the customer’s own processes or operations, it becomes more complex to optimise, with potentially many different aspects that must be taken into account over and above the desired outcome of the cleaning process. Accordingly, there may be a large proportion of work required in the beginning, both by the suppliers but also by the users. This requires a larger investment of time into developing specific ChL applications for such integrated processes, and hence it is perhaps not so attractive from e.g. a fast sales aspect. On the other hand, once a supplier becomes integrated into the customer’s processes, the sales process becomes based on trust and can often cover longer contract terms, allowing the supplier to plan long term.

The work done in particular by SAFECHEM with ChL has established good references and clear examples of profitable cases for cleaning of metal parts. These practical examples of success was also the main reason for CSC Jäklechemie’s decision to try the model, as they saw evidence of being able to achieve a better connection with the customer. Even so, the early sales process was much more time consuming and demanding than when selling a traditional, off-the shelf standard solution. Here the existing case studies and publications on these are of paramount importance, as these provide evidence of benefits.

Potentials for widening ChL both to new customers and for helping existing ChL customers to use the model more widely within their different sites and different processes were seen as existing opportunities that need to be realised. Where very harmful chemicals are concerned, suppliers’ knowledge can bring much benefit and reduce risk. ChL was seen as an opportunity in this field, specifically where legislation such as the EU REACH legislation strongly encourages towards risk reduction and substitution of very harmful chemicals.

Successful example of building ChL partnerships with existing customers

All current cases have been built from existing business relationships. In order to price the ChL correctly, the first step has been to calculate what the current usage of chemicals is, the cost of these and then make this equal to the ChL fee/ service fee should be per month. This way the cost/income is kept the same in the beginning, which allows work towards increased benefits such as decreased energy consumption, waste treatment costs, downtime costs and costs for service of equipment, which can be proven to the customer from their own data.

Quite naturally, extending the concept to other products is easier once the first product has been developed and the more ChL becomes known, the easier it is to introduce to new customers. At the same time, it is essential to tailor the business model to the product assortment, and make it “your own”. Selling the ChL model to the user requires specific resources within the company offering ChL based products, applications or solutions, and the business model requires step-by-step development to fit in with what the company offers. Once this is done, the company does however have “*a new, different product to sell*”. Extending supply of ChL products to something distributors can offer their customers - and supporting your distributors in this – then becomes a mean of enabling the distributors to achieve more sales, and consequently the manufacturer can increase their sales.

The profitability of ChL contracts appear mixed, and in particular the following points should be noted:

1. Financial results are not always immediately gained and the timescale can vary. For example, in one case a decrease in turnover was seen for the first two years, whilst the profit staid the same. After that the profits started to increase. In other cases, the supplier has not seen changes in profits (up or down), whereas in others, financial gains are seen after as little as 3 months.
2. Direct savings in terms of lesser chemical material used and hence potential for higher profits was often offset by more time spent on the service elements. This does, in turn, increase the number of man-hours used and hence employment. Notably, the time spent on service elements decreased over time in at least some of the cases. It should also be born in mind that the ChL business model has not been in use long enough in most companies to give reliable, statistical measures over time. However, the service element appear to be at its highest in the beginning.
3. Whilst no suppliers reported a loss of profitability, there is both variation in results, differences in reporting and all regarded profits a business secrets.
4. Cases reviewed indicated that a clear gain from ChL was in terms of customer loyalty and long term opportunities as well as not having to enter into tendering processes on an e.g. annual basis.

Hence it is not possible to put absolute numbers on the business potential from the supplier’s side. However, for companies whose business strategy aims towards maintaining and broadening their customer base and providing a different, service orientated product assortment, ChL opens new doors and appears to provide considerable potential for becoming a trusted long-term partner rather than a straightforward supplier. Profit margins at least over the long term have the potential to increase, although this does require initial investment in personnel and product development, and the gains can sometimes be difficult to see immediately.

5.2 Business potential for ChL users

5.2.1 Savings potential for new and existing ChL users

By switching to ChL, the case study customers reviewed have saved from anything from 10% upwards. Not all cases report direct savings, and in some cases the way the customer costs/savings are measured is not wholly transparent. Nevertheless, the results indicate a considerable savings potential. Indirect savings reported separately include savings in permit costs, transport and warehouse costs, waste management, energy consumption and spare parts. In order for a potential user to evaluate the savings potential, the existing baseline is of prime importance. Hence no sweeping generalisations can be made, sufficient to say that there is potential for savings.

5.2.2 Replication potential for existing ChL users

The potential for any particular customer to increase the benefit from ChL could in its simplest form, be estimated through how many times ChL is used and can be used. For example, a company with ten wastewater streams to clean could replicate a successful ChL project in all ten waste streams. A company doing metal part cleaning in twenty countries could use the same supplier and same technology in all twenty. This type of maximisation of the benefits is not yet the norm. Whilst there are cases where successful ChL projects have been extended to encompass also other processes within the same company, particularly with the same supplier, the drive to introduce ChL more widely within the company does not yet appear widespread. In other words, despite the success of individual ChL applications in e.g. one country, the use of ChL has not spread. This may be due to the fact that ChL is still not seen as an alternative product to buy because it performs well, but perhaps still as a concept that fits only certain situations and require a large amount of tailoring. The knowledge of the benefits and ease of use once in place need to move upwards and wider in the user organisation before a more routine use of ChL in e.g. tendering is achieved. This type of information flow does not appear to be very well developed yet, although exceptions exist.

The cases analysed indicate that a key element for success is a relationship between supplier and chemical user that goes beyond the norm. Firstly, the relationship has to be based on trust, i.e. the chemical user must be willing to take the supplier into a closer relationship and share problems and past experiences openly. Secondly, the customer must have a willingness to forge a long term partnership with the supplier. This second requirement may be a stumbling block for many companies, where the purchasing is based on ensuring as competitive an environment as possible and annual or more frequent calls for tenders.

As ChL success also require personal trust between buyer and seller, ChL appears to be somewhat difficult a concept to “sell” to other people inside the customer organisation. In order to increase the chance of widening the use of CHL within the customer organisation, suppliers working successfully with customers have therefore packaged their ChL concepts as trademarked products, and put emphasis on making it as easy for the customer as possible to broaden ChL use.

5.2.3 Customer size and business potential

When looking at customers from a company size point of view, some very tentative differences can be recognised. Note that these do not apply to all SMEs or large companies, but rather provide a very generalised view:

- SMEs may have lower in-house knowledge/understanding of the usage of the particular chemicals when the chemical functionality is not part of the company's core process. Acquiring use of the supplier's expertise of functionality optimisation through ChL may therefore be particularly attractive.
- Smaller companies often have less complex purchasing criteria or rigid purchasing IT systems, and can therefore relatively easily implement different units of payment basis.
- If the potential ChL contract is of low overall value, it should be noted that particularly early stages of ChL require frequent meetings and discussions. The expense of the time required may become too expensive for the customer. For the supplier, this may also be the case, especially if they do not have the potential to repeat the type of contract easily with many other users.
- In large companies, the need for know-how may not be as large as they may have considerable in-house chemical expertise. On the other hand, large companies often outsource non-core process knowledge and the need for expertise outside core processes may be considerable.
- For large companies, the ratings of environmental and health performance through verifiable third party audits etc. are often important and more and more frequently measured. Specific criteria for purchasing may be in place that assess these impacts. Environmental arguments may therefore in some cases weigh heavily in the decision making process on purchasing.
- Large companies often have strict purchasing criteria and complex IT- systems for payments, which may require implementation of changes in order to accommodate ChL payments based on KPI performance rather than volume. This may lead to a barrier for ChL. Once the change has been instigated, however, there should be a largish potential for wider use of ChL also for other processes in such companies.

5.2.4 Core process or freestanding task

When looking at the overall different customer segments, one can identify two key issues to consider when estimating the potential for a particular customer to adopt a ChL contract. These are a) the degree of how integrated the task, application or process is with the customers' core and other processes; and b) how high the customer's know-how of the chemical functionality and methods to optimise it is. These are of course not dependent on each other, but for illustrative purposes, the overall trend of relative complexity of ChL introduction has been plotted in Figure 2. It serves as an indication of the willingness of the customer to be "persuaded" to try ChL in any particular application. Further issues to take into account include e.g. the customer company purchasing policy criteria, willingness to try something new and willingness to enter into long-term partnerships.

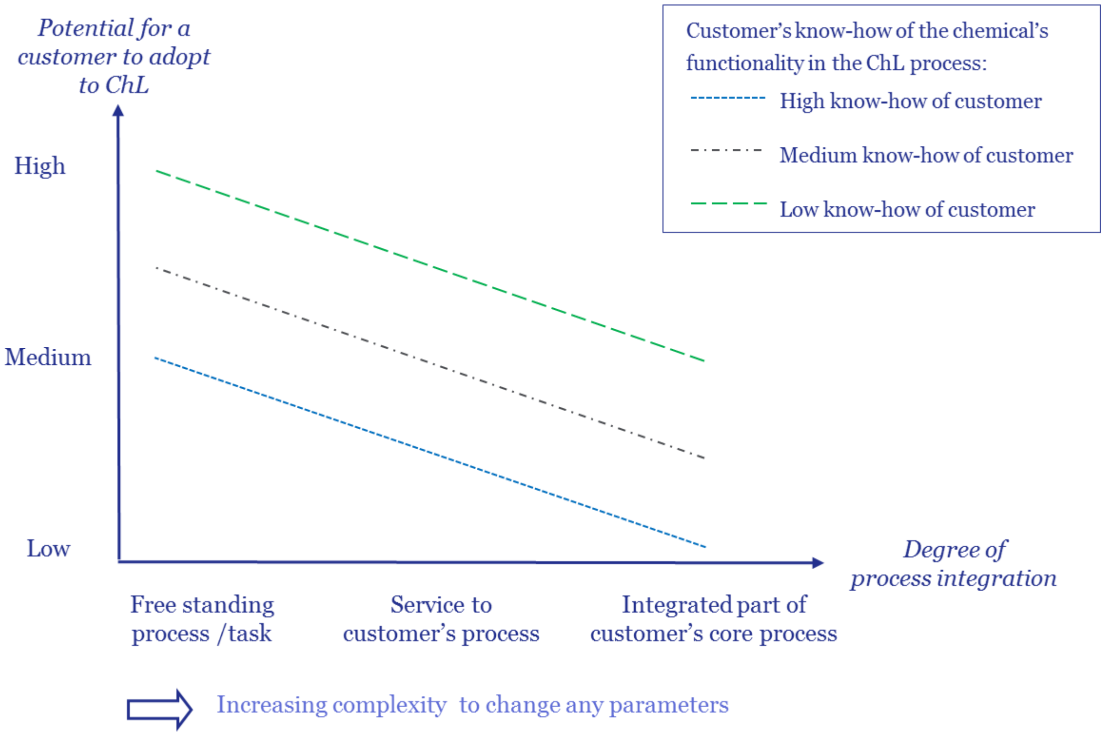

Figure 2: Potential for ChL against customer know-how and how integrated the ChL application is to the customers process

6 Identified requirements for wider adoption of Chemical Leasing

The results from the case studies clearly indicate that there are measurable benefits from ChL application in all four types of cleaning processes. This Chapter discusses the necessary conditions and potential obligations for wider adoption of ChL based on the study findings. First the challenges identified with mainstreaming are presented, followed by a discussion of the suitability of ChL for the industry and service cleaning operations included in the study.

6.1 Challenges with mainstreaming ChL

There is a general transition towards more service-orientated concepts within the chemical industry, as in many other sectors. It could be said that ChL is but one of the concepts that this trend puts forward. As one supplier noted: *"It is really important to find the problem that the customer has and to then build the business model around that".*

A significant obstacle to a more mainstream use of ChL is the, perhaps perceived, complexity associated with switching to ChL. This can in turn be related to the following conditions identified for successful ChL: Experience, ability to demonstrate value, trust and willingness to try something new.

Experience: ChL is a business model, and as such intended to give the supplier a business advantage and provide a way to win new customers. The interviews indicate that this is the case when the supplier has a good working knowledge of ChL and quantifiable references from existing customers. When neither party have prior experience of ChL, lengthy and complex discussions with the other party as well as ChL experts such as NCPCs tend to be required. Whether ChL is a suitable concept to promote for new customer-supplier relationships is therefore not always clear-cut.

Ability to demonstrate value: In some of the cases, the switch to ChL has been accompanied by a plethora of new things, including tangible things such as new technology, new processes and new people. The overall value of the ChL business model can become lost unless it is clearly measured and quantified from the beginning. This requirement is easy to forget when day-to-day business concentrates on practical issues. This may act as a hampering effect on future ChL ventures. In order to ensure a ChL trial is extended beyond the trial stage, it is therefore necessary to be able to demonstrate the value of ChL. This ability to demonstrate value also applies to writing up marketing material and cases, where quantification of benefits based on real cases will be valuable. This requires real case quantification of benefits, which may not be easy to achieve.

Trust and willingness to try something new: The results indicate that it is, perhaps inevitably, easier to implement ChL when the customer and supplier already have a business relationship that includes mutual trust. Trust is a strength in existing ChL relationships, but when trying to open new business:

- Any new supplier must be convinced enough about the ChL potential, with either a specific customer or a specific customer segment, for them to take the step to develop named solutions or trademarked products based on ChL.
- If the customer is not convinced the product or solution a particular supplier offers is what they need, or does not trust the supplier, the supplier will not make a sale.

Development of trust is not achieved overnight, and the reliance on something intangible combined with a fear of the unknown can therefore dampen the enthusiasm and willingness of the supplier to try selling ChL, especially to new customers. There may also be opposition to ChL internally within a chemical supplier new to ChL, as the concept may be alien to e.g. the sales people without a strong training internally, and for example. linking performance measurement appropriately to ChL generated profits, not chemical volumes. A more traditionally priced service may therefore be needed as an alternative, perhaps with options of how this can be, in the future, developed into ChL once mutual trust is established.

When the target is to mainstream the business model to more suppliers, the above indicates that there are certain challenges in increasing the ChL supplier number. It is, however, not only the case of having more companies selling ChL, but about mainstreaming the ChL concept to become "business as usual" to customers. Here some suppliers have succeeded, whereas others have a some way to go still. In relation to, in particular existing ChL suppliers mainstreaming ChL, the following challenges were identified:

1. **Same customer, more sites:** ChL will not become a mainstream way of doing business for any customer without sufficiently high-level management buy-in, based on understanding the benefit potential. For large multinational companies, an effort to spread the word of the benefits from e.g. one country to another may not be easy, as often purchasing may be done independently for each site.
2. **Same customer, more processes:** It requires considerable buy-in from a customer for the management to make a decision actively look for processes where ChL could be adopted. This can be difficult for a supplier to drive, as their interest will be limited to the processes they have products for. Encouraging and driving chemical users to take an active role in identifying new processes as well as enticing new suppliers to bid with ChL products rather than conventional services therefore remains a task for e.g. UNIDO or the NCPCs.

3. **Same process, more customers:** As ChL at least in the beginning necessitates close working relationships with the customer, there is a higher requirement for effort with new customers. In some cases the customer has convinced the supplier to try out the model. In these instances, the role of the customer has been driving, and the supplier has had to adapt to the model. In this case, it may be more difficult for the supplier to envisage the use of ChL with other customers, and the widening of ChL to become an established product could be delayed or not happen at all.

SAFECHEM, an established and long-term provider of ChL solutions has overcome the difficulties of convincing the customer to use ChL by packaging ChL into specific trademarked products with service elements. This allows the discussion to focus on the product and the benefits rather than introducing a new theoretical concept.

Successful example of going beyond just including service in the package

When including service in the package provided to the customer, the consumption of solvent was reduced from 160 kg to 15 kg and waste generation was reduced from 150 kg to 5 kg. When the business model was changed to chemical leasing, the use of solvent was reduced further. The process then required only 4 kg of solvent and emission to air were 1 kg and 3 kg of waste was generated.

Specific **practical difficulties** with ChL that may become obstacles for either the customer or the supplier are:

- According to some interviewees, chemical Leasing was not seen as a good name to use for the type of service. The chemical need to change ownership when handed over to the user, e.g. including legal reasons related to risk. This may lead to unnecessary complications in the negotiation process. Here naming the product specifically allows this problem to be avoided.
- Definition of the unit of payment is complex, and require considerable thought from both parties in order to avoid excessive work for tracking the results. Some cases have therefore moved from KPI based units of payments to service rates based on for example machine working hours. These are however revised and assessed periodically to ensure that they are up to date and correspond to the KPI.
- Definition of KPIs are crucial to the success, but often complex and difficult to set. Here examples of successful KPIs for each process would be valuable.
- Setting up billing and invoicing may be problematic, and require the customers ERP systems to be set up differently (e.g. to follow KPIs, not volumes). The case studies showed that this may be an obstacle specifically for large customers.
-

6.2 ChL suitability for industrial cleaning of metal parts

In optimisation of cleaning of metal parts, chemical use optimisation goes hand in hand with technological efficiency. ChL provides a concrete framework for working towards optimum processes in this case. Many of the identified changes may, however, be at least in part be attributable to a change to a more efficient technological solution, e.g. the actual machinery used for the cleaning has a considerable impact on the results. The use of a particular machine and the advantages thereof cannot be solely seen as benefits achievable from ChL. On the other hand, the change of payment basis allows technologies to enter that normally would be too expensive. Furthermore, suppliers noted that as new closed loop technology enters the market, the consumption of chemicals is constantly decreasing and building businesses on margins is becoming difficult for the supplier. Hence, the performance, i.e. the cleanliness results, of the product is becoming the most important sales argument. Therefore, it is logical for the supplier to convince customer to switch to a contract where payment is based on performance rather than chemical amounts.

ChL is highly suitable to cleaning of metal parts as the process is stand-alone and results are relatively easily quantifiable and measurable. It is also a process often outside the core competence of the customer. The potential to repeat the contract for other processes is not direct, but there are many companies in different industries that require cleaning of metal parts. Whilst the overall volume of chemicals used per process per annum is relatively small, the chemicals may often be harmful. The combination of many potential customers with a reduction in harmful chemicals make ChL highly relevant for reduction of the overall chemical footprint, as well as other negative environmental impacts, from cleaning metal parts.

6.3 ChL suitability for industrial cleaning of vessels, bottles and pipes

In the cleaning of vessels, bottles and pipes, where the process must be stopped during the cleaning operation, minimising the downtime is of paramount importance. The business relationship therefore requires flexibility, seamless co-operation and much knowledge about the customer's process and schedule. ChL can provide a concept for managing the relationship and building close, long-term relationships that allow building such in-depth understanding of customer needs.

ChL is suitable for industrial cleaning of vessels, bottles and pipes as the process is outside the core competence of the customers. The added value from ChL contracts are closely linked to the ease of mind for the customer that the provider takes responsibility of the process. At the same time, this may lead to an unwillingness by suppliers to provide ChL, if downtime costs are linked to the provider in any way. Hence care must be taken in the formulation of ChL contracts to ensure reasonable liability.

6.4 ChL suitability for industrial wastewater treatment processes

Wastewater and water separation from e.g. process streams is a continuous process that should be monitored, controlled, analysed and optimised on a continuous basis. At the same time, the process may be integrated into the customer's other processes, and analysis and understanding of potential knock-on effects from treatment onto other processes must be achieved. Increased collaboration such as is experienced in ChL will provide a platform for facilitating cooperation and discussions on e.g. changes in the process that may require changes in the treatment. When the required knowledge for optimisation is easily accessible due to increased collaboration, R&D can be focused on making the treatment process more efficient. R&D can here be extended to include e.g. testing on dosage optimisation against specific variable contamination levels etc. For example, in several cases the R&D is done together and interviewees commented that neither one could have developed the processes on their own.

The interviewed companies saw potential for expanding within their own company, but also for spreading the ideas to other production processes. It was also acknowledged that the fines for discharging wastewater were rising and legislation becoming tougher. As long as the costs for treatment are higher than the fines, many companies choose to continue to discharge wastewater and pay the fines.

ChL is highly suitable for the treatment of wastewater and process water streams, but requires a very close and continuous collaboration between parties. The threshold for entering into a ChL agreement may be high, as the customer may be unwilling to relinquish responsibility for an integrated process. On the other hand, the use of chemicals in wastewater and process water treatment can be relatively high, there are many different industries that require this type of service, and the potential for reducing negative environmental impacts is therefore considerable.

6.5 ChL suitability for service sector

Companies in the service sector may either handle part of their cleaning operations, such as laundry, dishwashing and cleaning of areas by themselves or outsource it partly or fully. When outsourcing, the companies will pay for the service, but at the same time accept the costs the service provider takes. For the service provider, lowering of chemical usage is of interest, but more difficult to optimize and control cleaning schedules when the co-operation is between the user and supplier is low. When the cleaning operations are handled alone, there is neither time nor knowledge to optimize the process.

The hotel included in the case study saw significant suitability for ChL in their business. The largest savings occurred from laundry cleaning. The amount of laundry needs to be large enough for ChL to be economical for the supplier. For smaller hotels, ChL could be interesting if a joint ChL relationship could be built, where one supplier works with many smaller hotels with a coordinated and centralized laundry.

Implementation of ChL at the hospital showed many benefits. The suitability of ChL for the health sector was discussed at the European Forum Alpbach, Health Symposium. The issue of clinical hygiene in medical care is a highly complex issue. Successful implementation of ChL in health care requires an organization, which is mature and ready regarding its structure, its internal processes and its results, and not all hospitals are modern enterprises. **The conclusion was that some hospitals are ready and the vision that ChL might be a suitable model for improvements of hygiene, sustainable and resource efficient processes is realistic and highly desirable.**

7 Potential of Chemical Leasing to contribute to more sustainable industries and a reduced global chemical footprint

In this Chapter, the potential for reduction of the global chemical use through ChL is briefly discussed.

7.1 Production and use of chemicals

Chemicals production in EU in total has increased in the last 20 years by 60%. According to the 2013 Cefic European Facts & Figures, the European chemical industry produces 20 per cent of the world's chemicals, employs 1.2 million workers and contributes €558 billion to the EU economy.[40] Of the industrial uses, one can mention that the Food and beverage industry uses 2.6%, Machinery and equipment 2.8%, Automotive 4.3% of chemicals produced. Specific values for chemicals used for cleaning operations in the specific sectors are not reported.

Data on volumes per chemical is available for certain chemicals, such as

- Sulphates of barium or aluminium: 0.9 Mt/year in EU 27 (used in e.g. Wastewater treatment)
- Chlorides (excluding ammonium chloride): 4,7 Mt/year in EU 27 (Wastewater treatment)
- Trichloroethylene; tetrachloroethylene (perchloroethylene) 0,16 Mt/ year in EU 27 (used as solvent)

However, all of the relevant chemicals can be used for several other purposes than cleaning, and an estimation of how much of chemical produced is used for cleaning purposes was not found[41]. The largest users are the dry cleaning industry (80-85%) and textile mills, vapour degreasing and metal cleaning operations, and makers of rubber coatings also use PERC. It can be added to aerosol formulations, solvent soaps, printing inks, adhesives, sealants, polishes, lubricants, and silicones. Hence it is not possible to relate reductions in one use to overall environmental impacts within the limits of this study. The same dilemma also applies to e.g. solvents, alkali, acids, and stabilizers. Whilst data on specific chemicals can be found, data on for which purpose the chemicals are used is not available.

7.2 Scenario analyses: Potential savings from wider application of ChL

In the absence of sufficient statistical data on usage, the two scenarios described earlier are presented as examples.

Scenario 1

The environmental impacts from the production of the selected cleaning agents are listed in Table 11. If all four and five star hotels in the top 12 tourist destinations in Brazil were able to achieve 50% of the savings that the hotel in the case study reported the total impacts in Brazil would be 0,5 million kg emissions of CO2 equivalents prevented per year, a decreased water footprint of 0,3 million m3 per year and a reduction of the eutrophication potential with 400 kg per year.

Table 11 The environmental impacts avoidable from chemicals used at hotels in Brazil.

Cleaning agent	CO2 eq. from chemicals used at hotel (kg/year/room)	CO2 eq. from chemicals used at hotels (kg/year)	Water footprint from chemicals used at hotel (WSI m3/year/room)	Water footprint from chemicals used at hotels (WSI m3/year)	Freshwater eutrophication from chemicals used at hotel (kg P eq/year/room)	Freshwater eutrophication from chemicals used at hotels (kg P eq/year)
Dishwashing total	2,9	49664	0,1	2012	0,002	37

[40] Cefic (2014)
[41] Databases included in search e.g. Eurostat, PRODCOM, Cefic

Laundry total	25,2	428349	20,3	344621	0,021	354
Total	28,1	478013	20,4	346633	0,023	391

Scenario 2

The world production was 65 million cars in 2013. The environmental impacts from the production of the selected cleaning agents are listed in Table 12. If all car manufacturers in the world were able to achieve similar savings, the global impacts would be 5,1 million kg emissions of CO2 equivalents prevented per year, a decreased water footprint of 13 million m3 per year and a reduction of the eutrophication potential with 2000 kg per year.

The scenario calculations serve only as examples, and cannot be taken as a statistical truth as both scenarios are based on the savings reported from only one case study respectively. Other companies could be using either less or more resources, thus resulting in different saving potentials, and no information has been collected on average consumption in the specific cleaning operations.

Table 12 The environmental impacts avoidable from savings in chemicals use in the selected operation in the total global production of cars.

Trade mark of the cleaning agent	CO2 eq. from chemicals used at car manufacturing plant (kg/car)	CO2 eq. from chemicals used at all car manu-facturing plants in the world (kg/year)	Water footprint from chemicals used at car manufacturing plant (WSI m3/car)	Water footprint from chemicals used at all car manu-facturing plants in the world (WSI m3/year)	Freshwater eutrophication from chemicals used at car manufacturing plant (kg P eq/car)	Freshwater eutrophication from chemicals used at all car manu-facturing plants in the world (kg P eq /year)
Ridosol 1580	0,006	116869	0,002	35812	0,000001	23
P3 Ridoline 7163 CF/5	0,031	4964048	0,086	13734508	0,000013	2031
Total	**0,037**	**5080917**	**0,088**	**13770321**	**0,000014**	**2054**

7.3 Impact of supplier and user type on the application potential of ChL

In the case studies analysed, different types of users and suppliers could be identified. The different types of user involvement were *service at isolated process*, *service to customer's process*, *service integrated into customer's process.*

An example of service to an isolated process is cleaning of metal parts, for example in car industry or aviation industry. The parts are cleaned elsewhere or at the facility, but not in the production process. The supplier cleaning the parts needs knowledge on the dirt formed from the user, but provides the knowledge of how to clean that specific type of dirt. Another example is the cleaning operation: laundry in the hotel case.

An example of service to customer's process is cleaning of bottles and pipes, for example food and beverage industry. The parts cannot be removed and cleaned elsewhere, but must be cleaned in the production process. Downtime needs to be considered, and when the cleaning procedures can be done to minimize problems for the production. Other examples are the cleaning operations in the hotel case: cleaning rooms, dish washing at restaurant, swimming pool.

An example of service integrated into customer's process is Industrial wastewater treatment, for example industries that need to treat their waste water at site. The continuous process needs to be monitored and in-situ analysis done. Variations in production need to be accounted for and indications of problems need to be detected in time.

The types of suppliers identified were *Global chemical manufacturer acts as a supplier and service provider, Local distributor acts as supplier and service provider* and *Small specialist's company acts as a service provider and supplier, manufacturing or sourcing technology and chemicals separately.*

For customers (users) all levels of supplier involvement, from operations isolated from process to operations that are fully integrated into the customer's process, have potential for economic and environmental savings. The initiation phase becomes more difficult when the involvement is deeper, but seen from a longer perspective; planning and organization will be much easier when everything has been settled. Specifically for suppliers, the amounts, in quantitative and monetary terms, need to be sufficiently large, to make the effort of getting to know the customer's process worthwhile. Small customers are the ones most in need of help from outside since they have no extra time to spare. Larger suppliers, such as chemicals manufacturers or local distributors could find these users interesting if services could be either combined or duplicated to several similar. The case examples tend to form a pattern of either large user and small supplier or small user and large supplier. In the cases where it is large user and large supplier, the participating division is small. From an environmental point of view, reaching the large users is still the most effective, both because of the effect from the amount of chemicals and from the possibilities of spreading the idea of chemical leasing.

The following table provides a summary on the application potential of ChL in various permutations of the user-suppliers as identified and analysed in this study. It must be noted that the application potential of the model may depend on the type and size of the participating companies. Also the limited number of companies involved in the case study may impact the results.

Table 13 Summary on application potential in various permutations of the user-suppliers

USERS /Suppliers	**Customer potential**	**Supplier potential**		
		Global chemical manufacturer acts as supplier and service provider	**Local Distributor acts as service provider**	**Small specialist company act as service provider, sourcing chemicals and machinery separately**
Service to an isolated process (for example cleaning of parts in separate machine before parts enter customers process)	Can include low hanging fruits such as moving to closed systems and improvements from these Easy to perform outside the core process. Requires specification, set up and monitoring, but little else.	Easy to duplicate and make into **trademarked products** Potential to widen use to more existing customers and to widen customer basis	Considerable potential if manufacturer has specific products and sales material to support it. Potential dependent on support from trademarked products.	Considerable potential to stand out as offering something extra, but this requires large service element that is tailored to customer Requires dedication and can be difficult to do without close connections with technology supplier
Service to customers process (For example cleaning of vessels integrated into the customers core infrastructure)	Supplier must have an understanding of how the cleaning affects the core processes. Once technical and commercial objectives are agreed on, there is considerable potential for direct and indirect savings and HSE benefits with right supplier and right ChL contract.	Can be duplicated within a specific industry and modified to other industries. Considerable potential for ChL or other service orientated products.	Considerable potential to stand out as offering something extra. If combined with trademarked products, potential increases	Considerable potential to stand out as offering something extra. May be difficult to stretch the suppliers resources to many customers
Integrated into customers process (For example cleaning product stream whilst working within the core processes)	Set up may take time and require several trials. Considerable potential for savings both directly and indirectly. Considerable potential for environmental benefits in terms of chemical discharges, waste streams and emissions.	Can be duplicated within a specific industry and modified to other industries. Requires dedicated sales/Support team with good contacts to the customer. Not directly duplicable in detail but overall concept can be duplicated. There is a potentially large potential for ChL or other service orientated products to a specific industry.	Considerable potential to stand out as offering something extra.	Require in-depth knowledge of customer's processes and potential for developing very close integration into customer's processes. Potential to develop close relationship with selected key customers – little potential to sell to many customers as this would stretch knowledge resources too thin

8 Conclusions and recommendations

ChL appears to have considerable potential for savings as well as other benefits. Whilst ChL is currently not used widely, mainstreaming of the model could lead to even considerable reductions in overall chemical usage within a specific application. Wider adoption of ChL within each of the studied operations could therefore contribute to Cleaner and Resource Efficient Production (RECP) on a global scale.

In order to make it easy for potential customers to evaluate whether switching to ChL is a good idea, tools that allow for the calculation of savings potential would be of use. These should be neither too complex nor too rigid, but rather act as a guidance to how such potential can be assessed.

The existence of a potential to achieve benefits does not mean that such opportunities will be automatically realised whenever parties engage in a ChL contract. There are several obstacles to a more widespread adoption of ChL, including terminology, legal obstacles mainly concerning liability, rigid purchasing policies and often simply a reluctance to change. The perhaps most difficult one to overcome is the need to change the mind-set of new users in order to create a demand for the business model, as it currently appears to be difficult to widen the application of ChL within an organisation where use of the model indicate good results.

The essential issue is payment by result. Policy needs to support this as it is an investment for the supplier. It requires increased payment for service. Raising fees and taxes on waste and chemical usage could drive the market towards service oriented concepts, where business is made on knowledge and not on mass production margins. As this is dependent on the political will and overall legal framework in any one country, it is indeed a long-term prospect.

If part of the strategy for mainstreaming ChL is based on enticing more suppliers to offer ChL to customers, the focus should be on supporting suppliers new to ChL to achieve a first pilot with an existing customer and that the first pilot is a good experience. Entering into a pilot without clear ideas about what the potential ChL solution or product will be is likely to lead to a waste of time and effort on both sides. Hence there is a continued need for supporting companies that take the first steps into ChL, both to try it and then to be successful in the piloting.

If a target of reducing the global chemical footprint and other environmental impacts through ChL is seen as desirable for e.g. UNIDO, much more emphasis on marketing the model to users is needed. Specifically, users in a high enough position within their organisations that they can induce a change in the corporate purchasing behaviour must be reached, and the potential for benefits. To help achieve this, the following recommendations are presented:

1. Create a market pull and make it easy for potential users to grasp ChL

A. Target top management in large user companies to create more pull

B. Understand the psychological barriers towards changing business models/purchasing policy and use the insight to create a more business driven awareness campaign

C. Provide a set of tools and material that allow company top management to do a quick assessments for financial and sustainability potential

D. Provide an easily accessible library of case studies that are both comparable and max 1 page long, with focus on the business as well as environmental and health benefits in addition to more complete case studies giving technical and process details
E. Provide tools and examples of how to take ChL into purchasing (e.g. how to remove IT obstacles, especially for companies using software to run purchasing)

2. Support chemical companies in offering ChL

A. Support smaller specialist chemical companies through concrete examples such as how to present the model in proposals and to customers
B. Provide tools and support for turning ChL from a concept into a suite of products, that have a clear marketing message
C. Encourage the use of trade names for ChL products and a move away from the term “leasing”

3. Make the available guidance and examples easy and accessible

A. If mainstreaming is to be achieved, there is a need to simplify the complex and very broad set of instructions and guidance available today
B. Provide more market-orientated and less technical guidance also, where focus is on a step by step vision of how users and suppliers can gain. This type of material should have much less focus on the ins and outs of the business model/contract concept, which can be in separate “technical manuals”

4. Link to current trends in concepts and terminology

A. Link chemical leasing business model more firmly to the global drive for e.g. circular economy concepts and reducing sustainability risk
B. Incorporate and make use of the notion of reduced chemical footprint, providing tools and visual means of presenting the achievements
C. Embed the Chemical Leasing Programme in the UNIDOs Inclusive Sustainable Industrial Development Programme

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Appendix 1: Building the scenarios

Scenario 1 – Cleaning operations in Brazilian hotels

The scenario is built on the ChL data obtained from the case study on the Brazilian Hotel Windsor Atlantica and the ChL supplier Ecolab, described in Chapter 4 (Case 10).

Hotel Windsor Atlantica is a large 5 star hotel situated in Rio de Janeiro. The type of hotel is important for approximating the number of hotels that could possibly achieve similar savings. The hotel amenities include 4 restaurants, 2 swimming pools, a conference centre with 30 meeting rooms + banquette facilities, 545 hotel rooms (accommodation capacity for approx. 545 x 1.5 persons) and a laundry service (with the laundry situated inside the hotel).

The cleaning agents included in the environmental impact analysis are three types of detergents used in laundry and one dish machine detergent. Together these account for 96% of all cleaning agents used at the hotel. The cleaning agents and their active compounds used are listed in Table 14. The hotel reported a total decrease in chemicals consumption of 70%.[42]

As ChL was implemented at the same time as the hotel started its operation, the consumption could not be compared to previous years. Instead the hotel chose to compare its consumption to that of a hotel with similar functions, but much smaller with only nine rooms. Hence, the possible effect resulting from economics of scale makes the comparison difficult. The scenario is therefore calculated for a case where 50% of the reported savings could be achieved.

Table 14 Cleaning agents selected for the Brazilian hotel scenario

Type of cleaning agent	Trade mark of the cleaning agent	Composition
Chlorinated dish machine detergent	Solid Power Plus	Sodium hydroxide 35% Triphosphoric acid, Pentasodium Salt 19% Sodium Carbonate 20- 50% Water
Inhibits scale formation and controls water hardness and yellowing from iron	Eco-Star Builder 2000	Sodium Hydroxide 48% Water
Chlorine cleaner for washing clothes and linens	Eco-Star Destainer	Sodium Hypochlorite 9,5%
Neutraliser used in washing textiles	Eco-Star Antichlor	Sodium bisulfite/sodium hydrogen sulfite 20-50%

[42] In the calculation of the savings, it is assumed that the values reported at the comparison hotel are for non-concentrated detergents, while the values for the case hotel are for concentrated detergents. Concentrated detergents contain 20-45% ingredients (water content 55-80%), while non-concentrated detergents contain 5-20% ingredients (water content 80-95%). All laundry detergents used at the case hotel contain 52-91% water. The average dry matter is 34% (water content 66%). Since the type of detergent is unknown in the comparative case, the values reported are assumed to be non-concentrated detergents, with a solid content of 5-20%. The calculations are performed under the assumption that the hotel uses diluted detergents of 10% solid content. The values are recalculated to match the amount it would have been if the solution was a concentrated detergent.

The environmental impacts from the production of the selected cleaning agents are listed in Table 15 and hazards related to use of chemicals are listed in

Table 16. The former table shows the impacts with respect to the indicators greenhouse gas emissions, water footprint and eutrophication potential and the latter the health, safety and environmental properties of the chemicals. As a result of decreased chemicals production and resources thus saved and emissions thus decreased, the hotel prevented 11 000 kg emissions of CO2 equivalents per year, decreased the water footprint with 8 000 m3 per year and reduced the eutrophication potential with 9 kg per year.

Table 15 Environmental impacts from the production of cleaning agents in scenario 1 and the savings achieved at the hotel.

Trade mark of the cleaning agent	CO2 eq. (kg/kg)	CO2 eq. from chemicals used at hotel (kg/year)	Water footprint (WSI m3/kg)	Water footprint from chemicals used at hotel (WSI m3/year)	Freshwater eutrophication (kg P eq/ kg)	Freshwater eutrophication from chemicals used at hotel (kg P eq/year)
Solid Power Plus	2,25	1115	0,09	45	0,0017	1
Eco-Star Builder 2000	1,05	4820	0,02	87	0,0010	5
Eco-Star Destainer	0,56	2558	0,01	40	0,0005	2
Eco-Star Antichlor	0,49	2235	1,66	7607	0,0002	1
Total		**10727**		**7779**		**9**

Table 16 Hazards related to the use of cleaning agents in scenario 1

Trade mark of the cleaning agent	Environmental properties	Health properties	Safety properties
Solid Power Plus	No environmental hazards reported	Severely irritating to eyes Severely irritating to skin Harmful if swallowed.	May be corrosive to metals
Eco-Star Builder 2000	No environmental hazards reported	Corrosive to eyes. Corrosive to the skin. Corrosive to the respiratory system. Causes burns to mouth, throat and stomach. May be harmful if swallowed.	May be corrosive to metals
Eco-Star Destainer	No environmental hazards reported	Causes serious eye damage Causes severe skin burns and eye damage	No safety hazards reported
Eco-Star Antichlor	No environmental hazards reported	Harmful if swallowed	No safety hazards reported

The second step was to arrive at an approximation of the number of hotels in Brazil, where ChL could be applicable and similar savings could be achieved. The extrapolation to the country level was based on hotel statistics obtained from the survey *Lodging Industry in Numbers Brazil 2014, by JLL*[43] and general search engines for hotels[44].

Due to the lack of information on hotel amenities where complete hotel statistics were reported, the scenario[45] was chosen as all 4 and 5 star hotels with swimming pool, restaurant and meeting room in Brazil’s top 12 destinations, found by the search engine. This meant that the scenario encompasses 100 hotels and 17 000 rooms. [46]

There are uncertainties in the data, which forms the basis for the scenario and these should be noted:

- ChL data on savings at the case hotel is not calculated based on before and after, but from the difference between usage at one hotel, which does not implement ChL and one hotel, which does.
- The amount of similar hotels in Brazil and the number of rooms available have been approximated by combining data from several sources. The search engine displayed that 8% of all hotels in the top 12 destinations in Brazil are 4 and 5 star hotels with similar amenities as the hotel in the case study. When compared to the survey by JLL, 40% of all hotels and condo hotels could be found via the search engine.
- Amenities provided by the hotels vary from hotel to hotel and thus the usage of chemicals. Thus it is only an assumption that similar savings could be achieved.

The first scenario thus illustrates the environmental impact would be if 100 (approximately 13% of all) 4 and 5 star hotels in Brazil would implement ChL in their laundry and dishwashing operations and achieve similar savings.

[43] JLL (2014)
[44] TripAdvisor (2014)
[45] **Scenario 1:** 4&5star hotels in top 12 destinations: 100 hotels, 170 rooms/hotel. All 5 and 4 star hotels with swimming pool, restaurant and meeting room in Brazil'z top 12 destinations and listed in tripadvisor: 92 hotels. Weighted room average of international brand hotels and national brand hotels: 167 rooms/hotel. Results in 17000 rooms.

[46] The possible savings achieved are calculated from the hotel Windsor Atlantica, where the occupation is 70% in average. No data has been collected on the occupation in average at all the hotels, whereby the same 70%, although this is very high, is assumed.

Scenario 2 - Cleaning of metals parts for automotive industry in Columbia

The second scenario is based on the case study of the car manufacturer Renault and chemicals supplier Polikem in Colombia (Case 5). Cleaning chemicals are used prior to corrosion prevention to remove grease from the surfaces of the chassis parts. With the introduction of a chemical leasing relationship between the supplier and the customer, the usage of cleaning chemicals has gone down with 75 %.

The cleaning chemicals used for the degreasing operation can be seen in Table 17. All chemicals are included in the scenario.

Table 17 Cleaning agents used in the anti-corrosion step of car manufacturing

Type of cleaning agent	Trade mark of the cleaning agent	Composition
Degreaser in cleansing step	Ridosol 1580	Terpene EO/PO block copolymer / Ethoxyl-propoxyl-terpene / methyloxirane polymer with oxirane 20% Dodecanol, ethoxylated, propoxylated 15% Fatty alcohol ethoxylate C13 ethoxylated / Polyethylene glycol monoalkyl ether 10% Water 55%
Tensoactive in cleansing step	P3 Ridoline 7163 CF/5	Potassium hydroxide 40% Water 60%

The environmental impacts from the production of the selected cleaning agents are listed in Table 18 and hazards related to use of chemicals are listed in Table 19. The former table shows the impacts with respect to the indicators greenhouse gas emissions, water footprint and eutrophication potential and the latter the health, safety and environmental properties of the chemicals. In total the car manufacturing plant prevented 220 kg emissions of CO2 equivalents per year, decreased the water footprint with 1 400 m3 per year and reduced the eutrophication potential with 0,2 kg per year, although the treated surface area had a threefold increase. In addition, water consumption was decreased at the plant by 3000 m3, resulting in a reduction of chemicals used at the wastewater treatment of 1000 kg. Although important effects, these were not included in the scenario as the scenario only described the impacts from the reduction of surface cleaning chemicals.

Table 18 Environmental impacts from the production of cleaning agents used in scenario 2 and the savings achieved per car at the manufacturing plant.

Trade mark of the cleaning agent	CO2 eq. (kg/kg)	CO2 eq. from chemicals used at car manufacturing plant (kg/car)	Water footprint (WSI m3/kg)	Water footprint from chemicals used at car manufacturing plant (WSI m3/car)	Freshwater eutrophication (kg P eq/ kg)	Freshwater eutrophication from chemicals used at car manufacturing plant (kg P eq/car)
Ridosol 1580	1,08	0,002	0,33	0,0006	0,0002	0,000000
P3 Ridoline 7163 CF/5	0,90	0,076	2,50	0,2113	0,0004	0,000031
Total		**0,078**		**0,2119**		**0,000032**

Table 19 Hazards related to the use of cleaning agents in scenario 2 [47]

Trade mark of the cleaning agent	Environmental properties	Health properties	Safety properties
Ridosol 1580	Harmful to aquatic organisms, may cause long-term adverse effects in the aquatic environment	Harmful if swallowed Risk of serious damage to eyes	No safety hazards reported
P3 Ridoline 7163 CF/5	No environmental hazards reported	Harmful if swallowed Causes severe skin burns and eye damage	No safety hazards reported

The other basis of the scenario is an approximation of the number of cars manufactured where it could be applicable. The total world production of passenger cars was used as basis for forming the scenario.[48] In the case study the consumption per surface area is reported. The surface area varies depending on car type and the average value of 3.2 m^2/car, reported from the factory, is used in the calculations.

[47] HSE properties for Ridosol are based on risks phrases stated in suppliers MSDS. For Ridoline information was searched from multiple suppliers MSDS as the classification in suppliers MSDS was not based on EU or GHS classification.
[48] Statista (2015)