REPORTS OF THE FINNISH ENVIRONMENT INSTITUTE 18 | 2015

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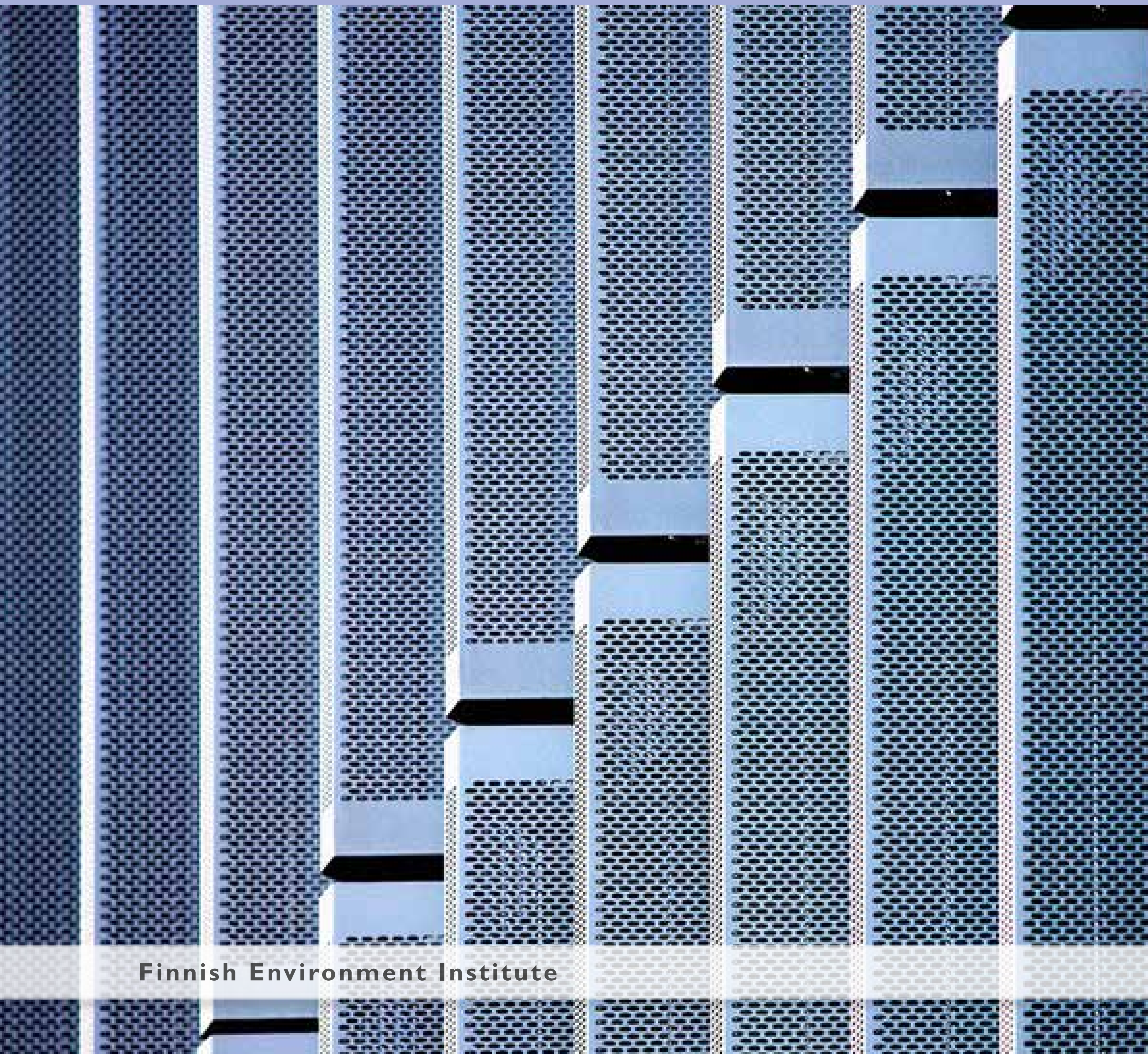

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PREFACE

How to make life cycle assessment (LCA) more affordable? How to minimize product environmental impacts through ecodesign? These were they key questions asked in the strategic development project of SYKE: “Towards sustainable economic systems – key methods and tools, lessons learnt and future outlooks (ToFu)”.

One of the possible answers could be a newly developed concept which we call *the LCA clinic*. The concept is described in this report and its practical testing in real world is discussed. The authors of the report would like to thank all the participants of the LCA clinic trials.

CONTENTS

1 Introduction

1.1 Background

Within the past decade life cycle assessment (LCA) has become one of the main tools for quantifying environmental sustainability (Finnveden et al. 2009). It provides a framework that makes it possible to widen the scope and to take into account the full “triple bottom line” of ecological, social and economic sustainability. Such scope is currently being rapidly developed (Guinée et al. 2011) and, moreover, some concepts go even beyond that (Gaasbeek & Meijer 2013). One of the main benefits of using LCA is the simultaneous consideration of several environmental impact categories across the whole supply chain of a product or a service. This ideally leads to avoiding problem shifting from one part of the life cycle to another, or the minimization of one impact with the unintended consequence of increasing another (Finnveden et al. 2009).

In Finland, LCA has been mainly used by the larger companies, which are striving to be environmental forerunners (Antikainen & Seppälä 2012). However, according to a survey on Finnish companies (Österlund 2010), most of them considered environmental issues as a part of product design and 70% had specified targets for the environmental quality issues of their products. In order to reach the targets most companies relied on key environmental performance indicators or on simplified lifecycle thinking tools, such as carbon footprinting. However, with the reference to the already mentioned *problem shifting*, without quantifying multiple environmental performance indicators it is difficult to improve overall sustainability. This is where LCA offers an added value. Therefore, why is it that the method is not more widely applied by manufacturing and service businesses even though the societal benefits have been recognized for years?

Similar question has been raised by Horn (2014) when she asked “How can life cycle tools be applied to private sector sustainability (climate) strategies?” and “Are these tools effective?” Her research is based on a hypothesis that LCA is a valuable method, but it is expensive, time demanding and results are not always easy to interpret and communicate. The resulting costs are such that only the larger companies can afford undertaking it. However, in Finland, 93% of all companies consist of less than 10 employees (Statistics Finland 2012) which are classified by the European Union as *micro* enterprises (EC 2003). Therefore, for most Finnish companies, it is not possible to perform an in-house environmental assessment, or to outsource such a service.

Currently the use of LCA for product design is facing a paradox. In order to be effective, LCA should be conducted at the earliest stage possible – to test the conceptual designs. Some large enterprises have developed their in-house processes to do so, e.g. Nestlé (Curran 2012, p. 175). At the same time, an accurate LCA costs so much, that it is applied to products which are already in large scale manufacturing. If the costs and time requirements of LCA were reduced, without losing too much of the accuracy, the method could be used in the early stages of product design by many more companies. That would be practical, because product development commonly follows an exponential cost-of-change-curve. Making changes to the conceptual design require only minutes, changes in preliminary planning may require hours, detailed planning changes require days and changing the manufacturing process can take months. Such a rule of thumb (Figure 1) has also been found to be reasonably accurate for traditional software products (Boehm 1981). As a consequence, software developers have designed ways to test products at their earliest stages and making small testable units before constructing a full scale product. Can LCA method be streamlined to better fit its purpose and expectations of companies?

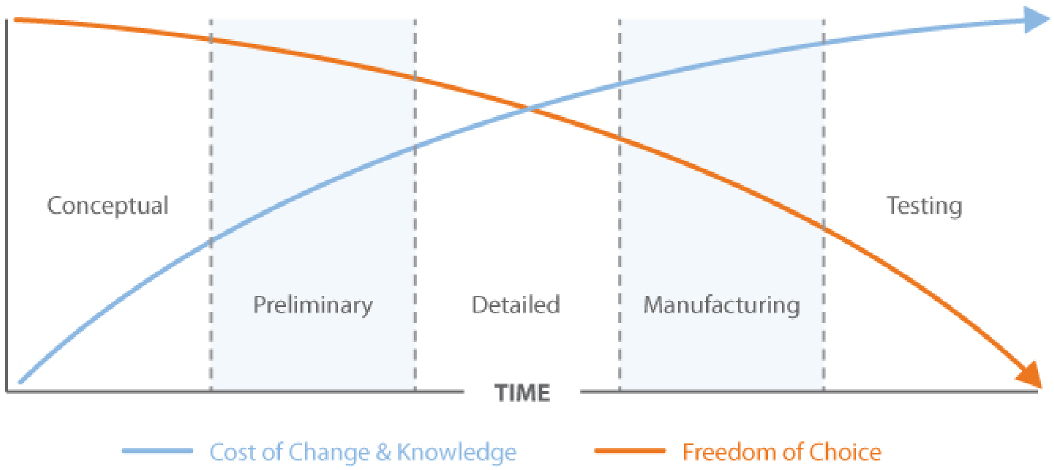

Figure 1. As the design proceeds from conceptual to manufacturing, the opportunities for changing the product decrease rapidly as the costs increase (Enfinio 2014).

The idea of streamlining LCA is not new, it has been discussed already in the 1990s (Curran & Young 1996) and it receives attention still today (e.g. LCA2go FP7 project[1]). Over the years the main challenges in streamlining LCA have remained the same: to maintain a consistent system boundary and to cover all environmentally relevant inputs (e.g. raw materials, energy) and outputs (e.g. air emissions).

The focus of our research presented in this report was on finding and testing ways how to speed up the process of LCA implementation, streamlining it, and at the same assuring that the holistic approach is maintained. The main research questions in this study were:

- Is it possible to consistently perform an LCA within a very limited timeframe, without losing the benefits of looking at all relevant impact categories?
- What tools and methods should be developed in order to carry out, and successfully manage, such study?

The approach of *learning-by-doing* was applied and the idea of a quick LCA was tested in a series of trials with existing companies. The aim of the feasibility study (hereafter also referred to as *clinics trials*) was to learn if such an assessment is of an interest in small and medium enterprises (SMEs) and start-ups (here after also referred to as *companies*). Such target group is very well justified by the fact that in Finland approximately 30 000 new companies of all sizes are started every year (Statistics Finland, 2014). Moreover, many of them are start-ups with high ambition of scaling up their business.

Another aim of the clinics trials was to test how to advise the companies in product development (ecodesign) and how to help them to identify the potential environmental benefits that their products could have when being used/consumed (so called *environmental handprints*).

[1] http://www.lca2go.eu/

2 Materials and methods

We call the approach presented in this report the *LCA clinic*. Essentially, it represents an attempt to perform a multiple impact category, cradle-to-grave LCA in a short period of time (0.5-1 day on site, 0.5-1 day in office). LCA clinics methodology follows the traditional LCA framework defined in the ISO standards (ISO 2006): Goal and scope definition; Life cycle inventory; Life cycle impact assessment and Interpretation. The *Goal and scope* definition step is carried out prior to each clinic through a questionnaire filled by a company representative. In the beginning of the clinic day, the goals are reviewed and decisions are made on the appropriate system boundaries and the functional unit of the product system. The *inventory phase* is prepared by the company representatives before the LCA clinic session and is based on the guidance of the practitioners. The inventory is further elaborated during the clinic. The *impact assessment* is performed on-site based on the data collected beforehand and the results are *interpreted* together with the representatives. An ecodesign brainstorming sessions is integrated within the interpretation phase. An LCA clinic should be performed by at least two LCA practitioners to better divide the tasks.

2.1 Protocol of LCA clinic

In order to achieve the expected time and cost efficiency, each step of a clinic must be well planned and the practitioners must be guided on how to perform it. A standardised protocol used in chemical labs served us as example and we created an *LCA clinic protocol*. It is presented in Appendix I. The overall flow for the clinic process is guided by the protocol and can be described as follows:

1. *Meeting with company representatives*. Meeting with the chief executive officer (CEO) or the chief operating officer (COO) is preferable in the case of a small/family company or a start-up. In larger SMEs a suitable person to discuss with is a production manager, logistics manager, process designer or environmental officer.

2. *Process flowchart*. After the initial discussion in which the basic concept of LCA is described and where company's objectives and expectations are discussed, a process flowchart is drawn. The flowchart represents production of the product/service manufactured by the company and supplied to the market. This step is done in compliance with the ILCD Handbook guidance for identifying system boundaries for attributional LCAs (ILCD 2010).

3. *Data collection*. It is essential that the company representatives prepare for the clinic in advance by collecting the bill-of-materials (BOM) and/or other data concerning the production of their product. The data is discussed and ideally all known values are collected in the flowchart. The use and end-of-life (EOL) phases shall be discussed as well, especially in case of products which will likely cause high environmental footprint during those phases.

4. *Modelling*. While one member of the team draws the flowchart on a white board, the other one models it in the computer (either in spreadsheet software such as MS Excel or in dedicated LCA software such as OpenLCA, SimaPro or other). The modelling continues after the flowchart has been approved by the company representatives. The next step is finding relevant life cycle inventory (LCI) data from existing databases, such as the ecoinvent[2] or the ELCD[3]. The company representatives are not required to be present during this stage of the clinic.

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[2] www.ecoinvent.ch

[3] http://eplca.jrc.ec.europa.eu/ELCD3/

5. *Results and discussion*. At the end of the day one, the initial results and conclusions are communicated to the company representatives. If necessary, minor adjustments are done to the model immediately. More substantial adjustments can be implemented in the day two or after the clinic on the day one. Possible ecodesign options are also discussed at the end of the session.

6. *Report*. In the day two, the LCA clinics team produces a short report and emails it to the company. A feedback on whether the clinic had an influence on the way how the company operates, or not, is collected.

2.2 LCA clinic trials

In SMEs and start-ups, the management is commonly well acquainted with the whole production process. Therefore, if the company owners/managers are present for the whole duration of the clinic, they can make reliable estimates on production input flows, or check them directly. They are also a good source for product development ideas and can rapidly assess whether a development idea would work in practice, or not. These benefits of the LCA clinic method can be lost in larger companies, where supply chain management, research and development and product manufacturing are often located in separate departments.

Table 1. The LCA clinic trials participants, their business sector and the size of the company.

	Sector	Size
Company 1	IT	micro-enterprise
Company 2	bioenergy	start-up
Company 3	paper hygiene products	SME
Company 4	IT, energy	start-up

In order to select the companies for the trial, we contacted start-ups through different start-up networks. The main approach was to contact the organizers of Startup Sauna[4], Aalto Center for Entrepreneurship[5] and Peloton Club[6] to identify potential companies for the experiment. A brief description of the clinic, the benefits of LCA and the time requirements were provided to the network managers with a request to pass them to start-ups. The clinic was offered free of charge. The main purpose of the clinic and main requirements were summarised on a flyer which was distributed in the networks (Figure 2). The Table 1 contains a list of the companies participating the clinic trials.

[4] http://startupsauna.com/

[5] http://ace.aalto.fi/

[6] http://www.pelotonclub.me/


Life Cycle Clinic
for start-ups and SMEs

SYKE

Streamlined sustainability assessment of your product or service FREE OF CHARGE

What is it?
Life Cycle Clinic is an attempt to bring environmental life cycle assessment to start-ups. It is a trial project of the Finnish Environment Institute SYKE.

How can you benefit?
You will get a free streamlined sustainability assessment of your product (or service). You will get to know your product and its supply chain from a different than business perspective and will gain a competitive advantage. How?

We will provide you with a map of the main potential sustainability issues of your product and its supply chain (so called *footprints*). We will discuss with you results of a streamlined sustainability assessment and explore how your product could be improved through eco-design. Also, we will like to try to find ways how your product could reduce emissions elsewhere (so called *handprints*).

Your participation will involve:
- About **4 hours** of time for the clinic and **1 hour** for the follow up.
- Writing down you expectation from the clinic. We would like to learn about your motivations and plans for utilisation of the outcomes?
- Writing down a brief description of your business model (can be a link to website with where the information can be found). Indicate an optimistic market forecast for your product.
- Writing down a short description of the functionality of the product which is subject to the clinic. How is the product useful for the final customer?
- Collecting the *Bill of materials (BOM)* for your product or and/or a *flowchart* of the production process (value chain).

What will we do?
- Provide you with our expertise in environmental life cycle assessment, free of charge.
- Sketch a product supply chain (cradle-to-gate/grave) in LCA software.
- Calculate an initial sustainability assessment of your product.
- Discuss eco-design options for improving your product and minimising impacts.
- Discuss handprinting possibilities of your product.

Interested?
The offer is valid until the end of the year 2013. Do not miss your chance and contact us already today at jachym.judl@ymparisto.fi.

Figure 2. A campaign flyer advertising the LCA clinics trial to potentially interested companies and start-ups.

The aim was not only to analyse, but to advise the companies on how they could change their product (ecodesign) and how they could identify the potential environmental benefits that their products could have when being used/consumed. This *environmental handprinting* approach has been found to be useful in motivating companies and individuals (Goleman 2012), so the approach was tested by attempting to quantify the scale of benefits from using the product. These benefits were however discussed separately from the footprint results, in order to focus also on options to mitigate the footprint.

3. Outcomes from LCA clinics test cases

3.1 Implementation of LCA clinics is possible

In order to identify the bottlenecks we initially shortened the duration of a typical LCA from several months to just four hours. After the first trial we extended the clinic to one whole working day. Later the concept evolved into a longer procedure with a short company visit followed by deskwork and a discussion of key findings. In its final form, the clinic took less than two working days of the researchers, including reporting, and less than a day from the company. Therefore it can be concluded that one working day is sufficient to make an initial LCA, which can be used to highlight hotspots and focus further research. In all trial cases, the actual clinic work lasted about 4-5 hours. In some cases we did a longer reporting stage, which took a full day. In most cases, the reporting was done in less than three hours.

The aim of the LCA clinic trial was to see how much useful insight could be acquired during a short, but intensive, session, when using only readily available information. Under such constrained conditions the main challenges, which an LCA practitioner must undertake, were recognised:

- To clearly explain basics of LCA to the stakeholders in half an hour.
- To convince the stakeholders that the time reserved for the clinic is sufficient, and that the results will be useful.
- Swift understanding of the product system and definition of the system boundary and the functional unit.[7]
- Processing the provided inventory data; searching for additional data; not confusing units of measurements.
- Finding the balance between a simplification of an LCA model and an in-depth modelling (e.g. to enable sensitivity analysis).
- Performing sensitivity analysis of any kind (e.g. through scenarios modelling).
- Making sense of the results; communicating the results to the stakeholder.

Each clinic was somewhat unique and the outcomes and the lessons learned are discussed separately in the following sections. It must be noted that findings of any LCA study is a subject to uncertainties (from parameters, model structure and especially system boundaries). In order to take those into account, we performed a scenarios analysis in some of the trials. However, developing and testing an approach of how to tackle uncertainties in LCA clinics should be on the agenda of future research.

CASE 1. A TELECOMMUNICATIONS SOFTWARE PRODUCT

The first case was about a software product, which has a novel way of transferring data from databases to the final user. The functional unit chosen for the study was *access to 2 GB of data, for example through blog reading*. The system boundary and product flows were sketched following the ILCD guidelines (Figure 3). Prior to the clinic the company had mainly focused on shortening the data processing time. One aspect of this is to conserve energy at server farms.

As a result of the clinic, the data centres were identified as the hotspot of the product system. They caused about 50% of the carbon footprint, followed by the manufacture of the smartphone (20%) and data transfer through the mobile network (8%). Based on this, it was advised, that further product development should focus on minimizing data transfer through the internet. The energy consumption at the

[7] A studied product or service is produced and consumed within a product system, defined by a boundary. Functional unit describes the primary function provided by the product system.

processing stage was significantly lower than that of the data centres needed to transfer and store the data.

The company was already working with reducing the amount of data transferred, so advice was given to look for ways to relocate data to data centres with the lowest carbon footprint per kWh of electricity. As smartphone manufacture was found to be a significant cause of carbon footprint and metal depletion, it was advised to ensure that the software would run also on older devices in order to support their extended lifetime.

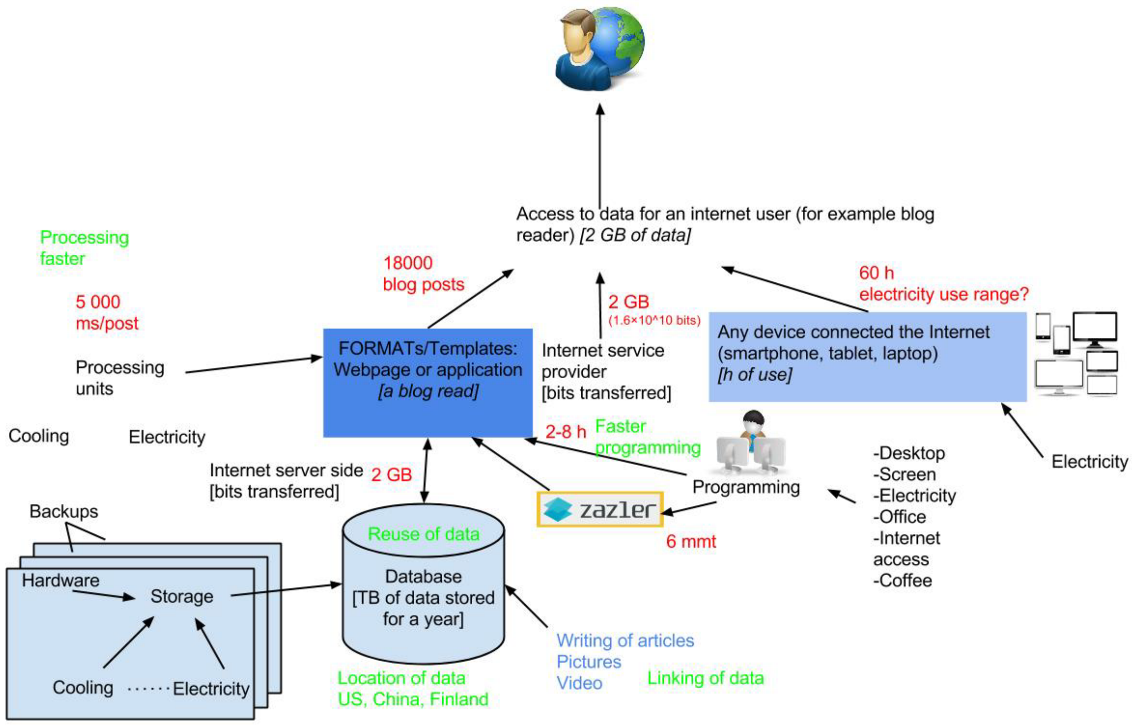

Figure 3. A product flowchart drawn as a shared *Google Drive* document (original unmodified figure used in the LCA clinic). The red numbers are estimates of product flows. The green text represents options for improving the environmental aspects of the product.

CASE 2. A BIOENERGY PROCESS TECHNOLOGY

The second case was about a technological process of biomass utilisation as a fuel. At the time of the clinic the technology was at a pilot scale. The functional unit was *MJ of fuel energy, at power plant*.

Initially, the company concentrated on improving energy efficiency of the process but was interested of its entire life cycle. After the first iteration results, it become apparent that transport of raw material plays an important role in several impact categories (climate impacts, fossil depletion, particulate matter formation and acidification). Thus, several scenarios were developed where the location of the fuel plant was either closer to the source of the raw material, or closer to the customer (the power plant).

One of the main results was that climate impacts (carbon footprint) is not the dominant impact. Instead, land use and eutrophication were higher on the priority list, which is typical for biomass-based products.

Although climate impacts of the technology are not so high in this particular case, they are the driving force in implementing biomass fuels to replace hard coal and thus are of a high interest. General conclusion and advice given to the company was to avoid long distance truck transport (i.e. in the range of hundreds of kilometres) and to locate the fuel plant on the sea shore to facilitate ship transport. The

Figure 4 shows how different logistics arrangements influence the climate impacts of the analysed technology, compared to hard coal and wood pellets.

The source of the wood material should come from sustainably managed woodland which is not a net emitter of CO_2 emissions.

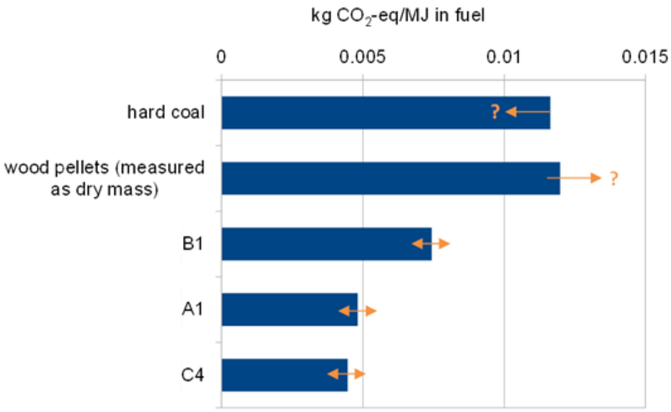

Figure 4. Example of results comparison for different logistics scenarios A1, B and C4 (original unmodified figure).

CASE 3. A PERSONAL HYGIENE PRODUCT

The third case was a disposable consumer product, consisting mainly of wood based materials and plastics. The company had been participating in environmental management and product ecolabelling. However, the company was interested in the potential of application of LCA on their whole value chain, which can show the importance of on-site emissions (Scope 1: All direct greenhouse gas (GHG) emissions, such as emissions from facilities operated by the company or its fleet[8]) versus those originating from the supply chain (Scope 3: Other indirect emissions, such as the extraction and production of purchased materials and fuels, or other outsourced activities.). The company had already shifted to purchasing electricity from renewable sources from the grid (Scope 2: Indirect GHG emissions from consumption of purchased electricity, heat or steam.). The company was considering switching the materials of their product to biodegradable and bio-based, but they were not sure about what kind of the effects that would have.

The clinic proceeded by mapping the supply chain and raw material composition of the product. The company representatives had the data readily available. Proxies were used for transport instead of actual route mapping (i.e. about 400 km of transport).

Based on the results (Figure 5), the most critical environmental impact category to consider was land use change, followed by eutrophication, marine ecotoxicity and human toxicity. Land use change was caused by the wood based raw materials, some of which originated from natural woodlands. Most of the eutrophying emissions were from electricity production (nitrous oxide and long term mining emissions). The human toxic emissions were linked to electricity needed for manufacturing the raw materials for the product and the chlorine emissions of pulp manufacturing. Overall, reducing the amount of non-renewable raw materials and one additive in particular would reduce most of the environmental impacts considerably.

[8] Methodology of the Greenhouse Gas Protocol (2004); commonly used in carbon footprint reporting. Scope 1 represents company's direct emissions, while higher scopes represent emissions from purchased inputs, such as energy, materials or services.

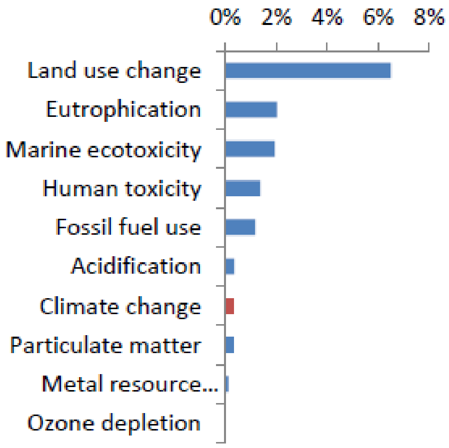

Figure 5. An example of presenting the normalised results (original unmodified figure).

The company had earlier focused on reducing climate impacts. Considering this, four scenarios were studied (Figure 6). In the first scenario, no improvements on the production process were made. The second scenario had current actions implemented (green electricity and chlorine free pulp). The third scenario targeted at replacing some, and the fourth at replacing most, of the non-renewable materials with maize based polylactide and starch.

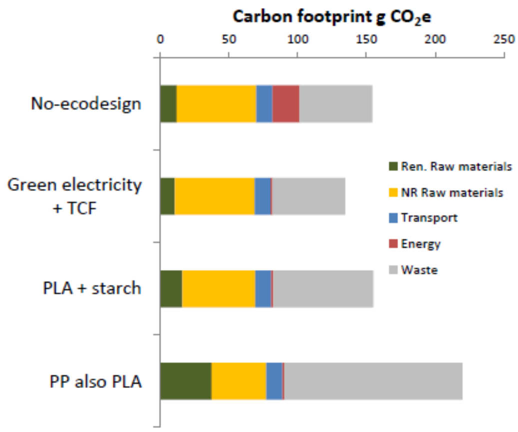

Figure 6. Example of results presentation for scenarios comparison.

Based on the results, the currently implemented ecodesign activities had already reduced the carbon footprint of the product, but had not targeted the main contributors (non-renewable raw materials and consumer waste processing). Switching to bio-based materials would in fact worsen the situation. This would be caused both by a larger upstream energy consumption from manufacturing the biomaterials and more methane emissions from landfilling the product. If the product would be converted to energy after use, the situation might change, but this scenario was not assessed.

CASE 4. A SMART TEMPERATURE CONTROL SYSTEM FOR APARTMENT BUILDINGS

The fourth case was a smart house temperature control system built out from simple electronic elements, which communicate with each other wirelessly over low energy enOcean standard. The system is controlled by a central micro-computer Raspberry Pi (Figure 7).

The idea of the product (in a prototype phase at the time of the clinic) is that it would replace control valves of heating batteries by automated valves and a thermostat. The functional unit was defined as *a single installation of the control system in an apartment house of four apartments and its operation over the period of ten years*.

For the clinic's purposes the company prepared a list of components. However, the material composition of the components had to be estimated.

Based on the analysis, the product would seem to have the highest relative impacts for human toxicity, marine ecotoxicity, freshwater eutrophication and freshwater ecotoxicity, followed by land transformation and metal depletion. In all these cases, however, the overall impact level is fairly low compared to the life cycle environmental impacts caused by an average European. (The results are calculated for 10 years of operation for four apartments.) Overall, the impacts are similar to building a single laptop.

As the product was in a prototype stage, no empirical data referring to its use phase were available. However, the product could save heating energy if it was used as intended. If the heating energy saving potential were about 10% of a residential building, currently in category G (241 kWh/m^2), it would save approximately 5 800 kWh of district heat annually.

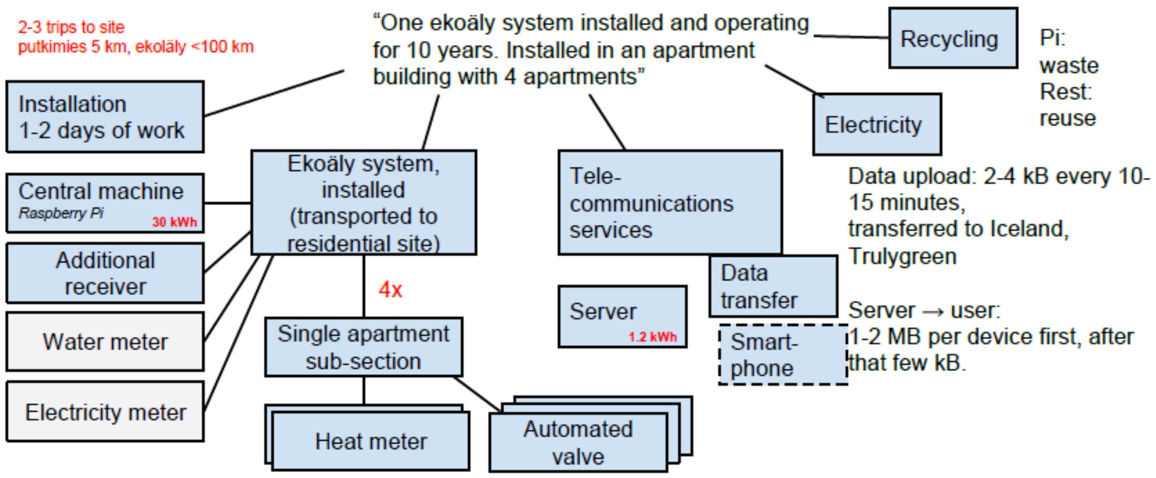

Figure 7. System flowchart for the smart house temperature control system (original unmodified figure).

3.2 Challenge to involve start-ups in clinics

Our initial expectation was that there would be a great demand by start-up companies for a clinic process, which is time-efficient and gives insights into their product. We also assumed that start-ups would be easy to contact and that the companies would be interested in innovations and sustainability.

However, out of all the companies contacted through different networks, only four took part in a clinic. In addition some companies were interested, but could not participate for various reasons. Considering that dozens of start-ups and micro enterprises are represented by the networks, the success rate was moderate to low.

One reason for the low participation rate could be that environmental sustainability is not on the top of the priority list for most start-up companies. Starting up a company with limited capital and an uncertain market represents a considerable economic risk. Additionally, a product ecodesign clinic might be too early in the life cycle of the start-up. A start-up is usually just developing their idea into a product.

Therefore material choices and supply chains might change rapidly, reducing the interest in participating in a LCA clinic session.

In order to make it easier to implement ecodesign in the start-ups, *checklists* might be easier to use than attending a clinic. A similar approach was taken by the American Institute of Architects 25 years ago, in 1989. An EPA supported project *Environmental Resource Guide* provided architects and engineers with guidance on e.g. what materials to choose from environmental point of view. The Guide was used to perform streamlined LCAs and to develop so called *application reports* which contained information on potential impacts of use of particular materials. Combination of both led to wider spreading of life cycle thinking and streamlined LCA (Curran 2012, p. 319-320). This type of concept could be applied also to start-ups, but the advice would have to be tuned for each industry.

It might be that bigger companies participate in LCAs, in order to better market their products (i.e. through ecolabels, or certifications). This allows companies to differentiate from competitors and achieve market segmentation. If a start-up is focusing on a completely novel idea, they have no need for market segmentation and therefore little need for certification.

We did not ask the start-ups which did not participate, why they did not. Some reasons might include:

- not interested about sustainability;
- not enough time for this right now;
- not sure if understood the purpose of the clinic;
- unsure if the free and fast clinic would be of any real use (poor quality, not professional).

This would need to be confirmed by contacting the start-up entrepreneurs through questionnaires or interviews.

3.3 Satisfaction of the involved companies

Although the companies which participated in the trials were on their way to eventually carry out an LCA, their attitudes at the beginning of the clinic differed. Two of the companies were sceptical and the other two were positive and excited. The sceptics were larger companies, both from processing industries. The enthusiastic companies were software start-ups.

The reasons why the companies were likely to carry out an LCA were as follows: The Company 1 was rapidly developing its product and was wondering what the changes mean for sustainability (as it has recently been highlighted in the popular media in connection to the electronics industry). The Company 2 was mandated to employ life cycle thinking by its investor while the Company 3 was using environmental information in marketing and was involved in environmental product quality improvement. The Company 4 was genuinely interested in sustainability issues, and the whole product was labelled as “eco”. Therefore it was important to quantify and confirm the real eco-benefits of the product.

The initial attitude of each company might have been influenced by the industrial sector it operates in. The process industry is quite static and capital intensive. It is not easy to change processes once investments have been made. On the other hand, software companies can often redesign a whole product quite rapidly, so a threshold for changing the product is smaller.

Despite the initial doubts, or excitement, all four companies gave a very positive feedback towards the concept of LCA clinics right after the trial at the end of the day one. This has proven us that with the right attitude, and by involving the stakeholders in the process, they leave the clinic positively charged.

A summary of the motivations and attitudes of the participating companies before and after the clinic is presented in the Table 2.

Table 2. Motivation and attitudes of the participating companies before and after the clinic.

	Why participated?	Attitude before clinic?	Feedback right after clinic	After 6 months
Company 1	Increasing awareness of product footprint. To advise users on responsible use of the product.	Positive and full of expectations.	Positive. The company got concrete advice on reducing its impacts and planned to implement them.	Positive. Felt that the clinic improved capabilities to do ecodesign and prioritize. Also felt it difficult to communicate results to other company members.
Company 2	Required to take life cycle impacts into account by the main funder.	Sceptical, but interested.	Positively surprised, did not expect to get so much from the clinic. Not sure how to utilise the recommendations.	Clinic helped to assemble thoughts, but the product was still under prototyping and many of the application alternatives and production processes were not finalized.
Company 3	Previously hired a private consultant to reduce carbon footprint of consumed electricity (Scope 2). Interested in comparison. To get a better understanding of LCA.	Interested in LCA, wanted to change materials to bio-based, but were a bit sceptical about that.	Positive, but needed to discuss the outcomes internally. Before the clinic the company thought that electricity consumption is the main hotspot, and concentrated their efforts on greening its supply. The contribution of raw material supply to the overall impacts was not previously investigated. The results were surprising.	Based on the LCA clinic, the company took concrete actions in order to replace those raw materials which cause the highest impacts in the value chain. The company gave a very positive feedback.
Company 4	Thought that the concept of clinics is cool. Have a lot of open questions about product design. Interested if the product's use actually results in net environmental benefits, or not.	Positive, curious and excited.	Positive and full of ideas on how to make the product better. Interested in using the clinic's results in marketing and communication. Relieved that there would be net environmental benefits when using the product.	Felt that the clinic improved capability for ecodesign and highlighted important sustainability hotspots for product development. Felt that a more concrete description of data needs would be given before clinic. (Had assembled extra information.)

3.4 High handprint as important as low footprint

All the tested companies had also a potential for reducing impacts outside their own product system (Table 3). For some of the products, this was their main purpose. For example, the bioenergy technology was developed to replace hard coal and the house temperature control was designed to save heating energy. For the two other products, the main potential for an ecological handprint was in affecting other similar products.

Most of the companies were motivated by the idea that their products could result in net reduction of their environmental impacts. For the Company 4, for example, the clinic provided a proof that although its product is made of electronics, production of which is energy intensive, it can help the consumer to save more heating energy than it needs for its production.

Table 3 Potential handprints of the analysed products.

	Product	Handprint
Company 1	A telecommunications software	Potential to reduce data traffic across different platforms. If the technology was widely implemented the energy saving could be substantial.
Company 2	Novel bioenergy application	Emissions much lower than those of wood pellets or hard coal. Therefore the implementation of the technology would result in emission savings of companies or municipalities
Company 3	A personal hygiene product	A single additive contributed vastly to carbon footprint of the product because it is energy intensive to manufacture. Finding a viable and more environmentally friendly substitute could generate additional business for the company while reducing environmental impacts of other products. The company had done some trials on the matter, but had not realized the significance of the potential emission saving before.
Company 4	House temperature control system	The only one product for which the emission saving potential could be quantified. Based on the results it would seem, that the system would save approximately 50 times the carbon emissions caused by the manufacture and operation of the components.

3.5 Relativity of the low costs

The performed series of LCA clinics was offered to the companies free of charge as a part of a strategic development project of SYKE: “Towards sustainable economic systems – key methods and tools, lessons learnt and future outlooks (ToFu)”. However in practice, a clinic would cost, based on the required time (between 10-40 hours of work time), approximately 600-2500 € + VAT (expert’s hourly rate 60 €/h). While the cost is much less than of the typical full LCA costs, especially the higher end of the range might be limiting to start-up companies. Nevertheless, the costs of the LCA clinic can be justified considering that already participation in a clinic, and its outcomes, can be used to increase the visibility of the company.

3.6 Increased visibility

Based on the feedback received from the companies it is evident that visibility is a very important motivation for participation in the clinics. One of the participants mentioned that even small companies are typically prepared to invest large amounts of money into making their product visible, for example on currently popular social media. Thus, it would be beneficial to make the reports, or their executive summaries, available online. By this, the participants would get a public announcement of the performed clinic which they could share with their networks for low or no costs.

A repository of the reports could be created to a unique life cycle thinking blog which could be operated by SYKE in connection to other projects in this field. Featuring the companies which participated in an LCA clinic on such a website would serve as a desirable PR, justifying the already reasonable cost of the clinic.

3.7 Bottlenecks and areas to improve the concept

Before discussing potential improvements of the clinic concept, it is useful to discuss, whether the clinic could be replaced with a simple checklist. AT&T performed in the early 90s a test on streamlined LCA

(Curran & Young 1996). It was based on a sustainability matrix in which environmental concerns in each life cycle stage of a product were estimated in quantitative terms, but based purely on educated guesses. The company reported that when several independent assessors evaluated the same product, the overall rating did not differ more than 15% (Fitzpatrick 2006). In case of LCA clinics, the results might be more prone to variations as the scope of each clinic pretty much depends on the practitioner's choices. Especially the choice of a proper system boundary for each case study is not a trivial matter. Therefore, the use of a sustainability matrix with pre-defined categories might not be applicable in particular cases. It is also difficult to follow the raw material supply chain far enough without access to LCA databases. Therefore important issues in primary production (mining, agriculture, forestry) might be overlooked if the company "stops short" in broadening the life cycle from cradle to grave. Therefore the main benefit of the clinic is assisting in having a consistent system boundary and quantitatively identifying the sustainability hotspots.

During the process of running the first clinics, ideas for streamlining work and definite bottlenecks have been identified. Overcoming these would improve efficiency and quality even further:

- Despite following the *laboratory protocol*, each clinic was unique with regards to methods, questions and workflow. A higher standardisation would reduce the number of steps when a practitioner has to make a subjective decision.
- Checklists. The more decisions the practitioner has to make, the more time a clinic will require. And if difficult decisions have to be made rapidly, the risk of mistakes increases, lowering the quality and repeatability of the clinic. Carefully written set of checklists (Table 4) could help to keep the practitioner focused on the analysed case without diverting his attention elsewhere. These checklists could further streamline and standardise the modelling work.
- Interpretation of results. Given the limited time it is extremely difficult to interpret the results in an understandable and meaningful way. Finding ways how to discuss as much of results as possible while showing as little data as possible would be of a great benefit. Too many figures confuse even an expert, not to mention a non-expert. LCA gives tools for normalizing, finding the key hotspots, but choosing the details for discussion is always a subjective choice. Practical and easy-to-understand guidance on relevance thresholds would make this decision easier (i.e. if the impact is less than X, don't worry about it).
- Handprinting and ecodesign. In order to provide useful handprinting ideas it is important to be familiar with the type of the analysed product/service. Internal discussions between practitioners on that matter would improve our abilities there, as would discussion with industry experts or product designers. Potentially this would result in an "ecodesign cookbook" for solving different kinds of situations.

Table 4. Proposed checklists which could be used within an LCA clinic to streamline and standardize the process.

Type of checklist	Content
General	Following the protocol of an LCA clinic, this checklist should guide the practitioner step-by-step through it. It should specify the required time for each step within the clinic.
Interview	A decision tree which includes a list of important elements of each production system which have to be discussed (i.e. "Is input material supplied in bulk – yes or no. If it is, then remember to include…").
Modelling	A list of frequently used unit processes (e.g. typical steps in production plastic components) and guidance on how to treat certain more common, but challenging, situations during modelling (e.g. empty runs in transport, waste management, allocation).

In addition to the bottlenecks associated with the practical work, there are bottlenecks in marketing the concept of clinics to companies, as well as in implementing the results of LCA in practical product design. It would seem that the marketing bottleneck is quite critical, as only a small fraction of the companies contacted wanted to participate. This could also indicate that the companies are not aware of the benefits of life cycle thinking.

4 Conclusions

The study sought to find solutions for a product design life cycle problem. Most of the critical design choices are made at the first stages of product design, but at that stage, resources for design are usually small. When resources for ecodesign come available, the product is already mostly designed. In order to guide early design, the advice should be low-cost and rapid. The current tools of LCA do not meet this goal.

The main aim of the study was to test, if the standard LCA process could be shortened to a timeframe, which would make it affordable for smaller companies and start-ups. Based on the experiences from a series of trials, the study was a success. The key issues in a product life cycle could be identified with 10-40 hours of research work, of which 8 hours were spent with the company involved. This resulted in an affordable LCA for ecodesign purposes and the recommendations were well received and useful to companies.

The short time frame put a considerable pressure on the LCA analyst to make consistent decisions on allocation, system boundaries and the use of background data. Each company had a unique product, requiring customized work on the LCA. This series of clinics relied on the experience of the analysts from previous LCAs, but standardization would make the process faster and more reliable. This could be achieved through checklists and decision flowcharts for repeatable processes (e.g. recycling, transportation, retail trade).

The study also highlighted some non-technical bottlenecks for applying LCA in start-up ecodesign. First of all, very few of the companies contacted were willing to participate in a free half-day clinic. This would indicate that marketing of the benefits of life cycle thinking could improve participation. Some of the participated companies also discussed difficulties in communicating the results to company staff, who were not involved in the process. Therefore tools for communicating the results in an indirect way should be developed. The current way of communication relies on expert knowledge and discussion. Without a background in environmental issues the results are still difficult to interpret.

The short trials were able to highlight some issues for further study. Especially the repeatability and standardization of the process should be further studied, as should be the ways for communicating the results to the company decision makers.

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The LCA Clinic Protocol

Life Cycle Clinic for start-ups

SYKE

Case ______________________________

1. What are your (start up's) expectations for this session?

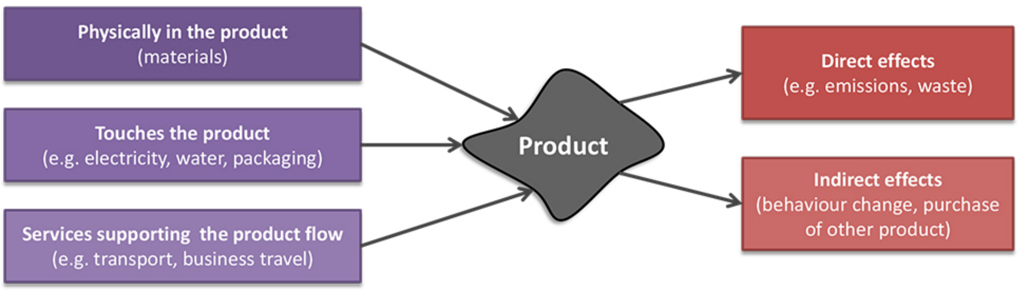
Footprinting

2. "Functional unit:" *What kind of a service does your product provide to the user? Who are the users? How would you measure the benefit to the user?*

3. What market are you aiming at? *If all goes extremely well, how big would this technology be? How fast?*

4. System boundary: *What is needed to provide the service for the user?*

→ What does it physically include?
→ What touches it?
→ What services are needed?
→ Are there any indirect effects?
→ Does your product/service replace or reduce anything what the customer already has?



5. Hotspot identification:
* connect the relevant flows to ecoinvent + other sources (for example data transfer UPR)
* estimate the magnitude of the flows
* characterize and normalize using ReCiPe Hierarchical

→ Discuss results: which environmental impact categories are the most significant, what is causing them in the product system?

6. Discuss benchmarking: Choose a reference product for comparison.
E.g. Smartphone, beer, laptop, car driving, one year of social media, transport of goods via truck and boat. Compared to the reference, where is the product doing well and where not so well.

1

Life Cycle Clinic for start-ups

SYKE

Handprinting

7. Ecodesign: How could we reduce the footprint?

8. How could this product **reduce the footprint** of the user and others?

9. Are there any **rebound risks?** How could those be avoided?

2

APPENDIX 2

In the Appendix 2 we present two sample reports of the LCA clinic. The reports are in the original form, as delivered to the participating companies.

Life Cycle Clinic for start-ups and SMEs

Case *XYZ*

1. What are your (start up's) expectations for this session?

Not any concrete expectations. Curious if it is possible to come up with meaningful results in four hours. A little bit sceptical.

Footprinting

2. "Functional unit:" *What kind of a service does your product provide to the user? Who are the users? How would you measure the benefit to the user?*

Our *XYZ* technology provides pulverised biomass used in coal-fired power plants and also in forest industry in pulp mills as a replacement for heavy fuel oil in lime kilns (i.e. "carbon neutral" fuel).

The functional unit was defined as ***1 MJ of energy, in XYZ fuel, at consumer***

3. What market are you aiming at? *If all goes extremely well, how big would this technology be? How fast?*

At the beginning Finnish market, but global expansion is possible. One option is to sell the *XYZ technology* and other option is to sell the *fuel*.

4. System boundary: *What is needed to provide the service for the user?*

→ What does it physically include?
A wc[redacted]dryer.

→ What touches it?
Electricity, heat

→ What services are needed?
Truck and ship transport

→ Are there any indirect effects?
Reallocation of market shares of solid biofuels production. Competing technologies are torrefication, pellet production and wood gasification.

→ Does your product/service replace or reduce anything what the customer already has?
Yes, the technology replaces coal as a fuel in CHP plants. Also it replaces heavy fuel oil in lime kilns in pulp mills. Additionally, competing technologies are *torrefication*, *pellet production* and *wood gasification*.

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Life Cycle Clinic for start-ups and SMEs

Case *XYZ*

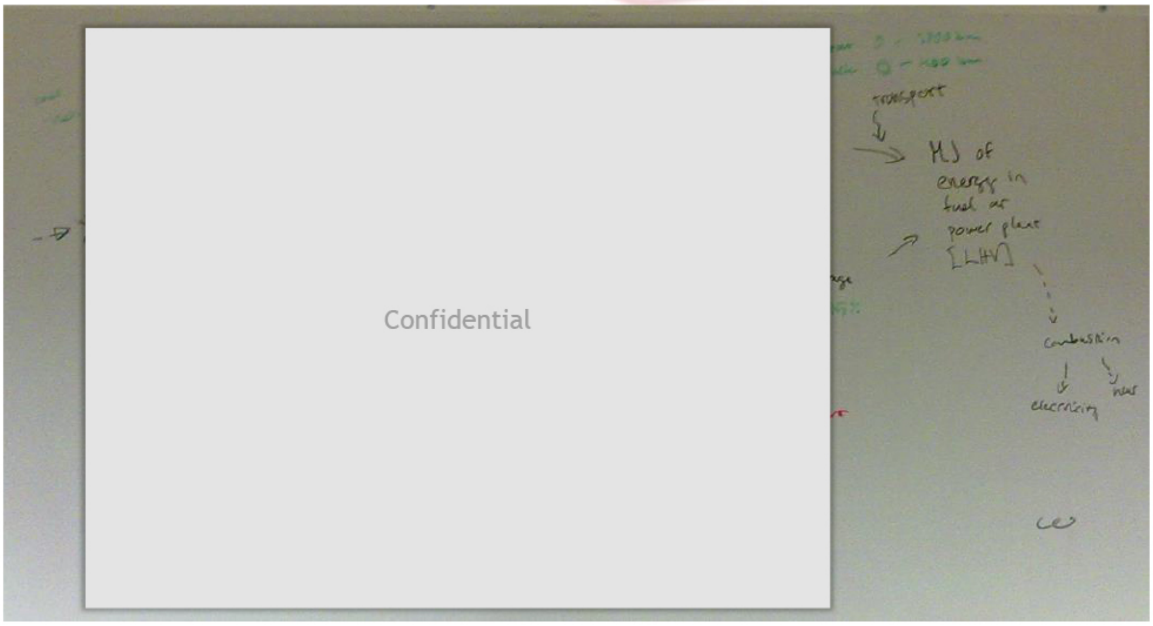


Figure 1 Process flowchart of the *XYZ* manufacturing and distribution process.

The product system was modelled in the openLCA software tool and background life cycle inventory data from the ecoinvent v2.2 database were used to illustrate e.g. electricity and heat production, transport and physical structures of the *XYZ* plant.

Environmental impacts were calculated by using the ReCiPe life cycle impacts assessment method, hierarchist perspective. Characterised midpoint impacts (absolute numbers) were normalised to average European impacts (relative numbers). Normalised results make it possible to compare all impact categories and to see how significantly the analysed product system contributes to each of them in the context of Europe.

After performing a preliminary impact assessment calculation for a default scenario, we defined the following three scenarios (A, B and C; see Figure 2). *Scenario A* represents a situation when the *XYZ* plant is located closer to the source of the raw material but farther from the end consumer (a CHP plant). In the Scenario B the *XYZ* plant is located somewhere in between and in the Scenario C it is located closer to the end consumer. For each of the scenarios we defined several possible options of distribution routes (Table 1).

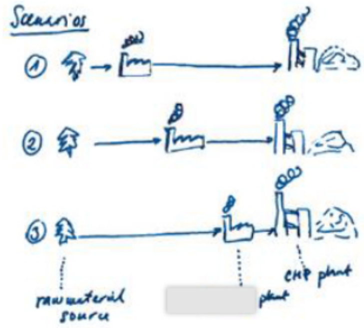


Figure 2 Scenarios illustration.

Table 1 Distances and types of transport for raw material and final product transport. Summary of scenarios and different transportation options within them.

		raw material transport			final product transport		
	Option	distance (km)	type of transport	note	distance (km)	type of transport	note
Scenario A	1	50	road	plant located close to the source	300	sea	Helsinki-St. Petersburg, Russia
	2				600	sea	Helsinki-Klaipeda, Lithuania
	3				800	sea	Helsinki-Gdansk, Poland
	4				1100	sea	Helsinki-Lübeck, Germany
Scenario B	1	300	road	plant located halfway between the source and the customer	300	road	
	2				600	sea	Helsinki-Klaipeda, Lithuania
Scenario C	1	300	road	plant located close to the customer	0		plant located at the port
	2	500	road		0		
	3	800	road		0		
	4	300	sea	St. Petersburg-Helsinki	0		
	5	19000	sea	Prince Rupert, Canada-Rotterdam, Netherlands-Helsinki	0		

2

5. Hotspot identification:

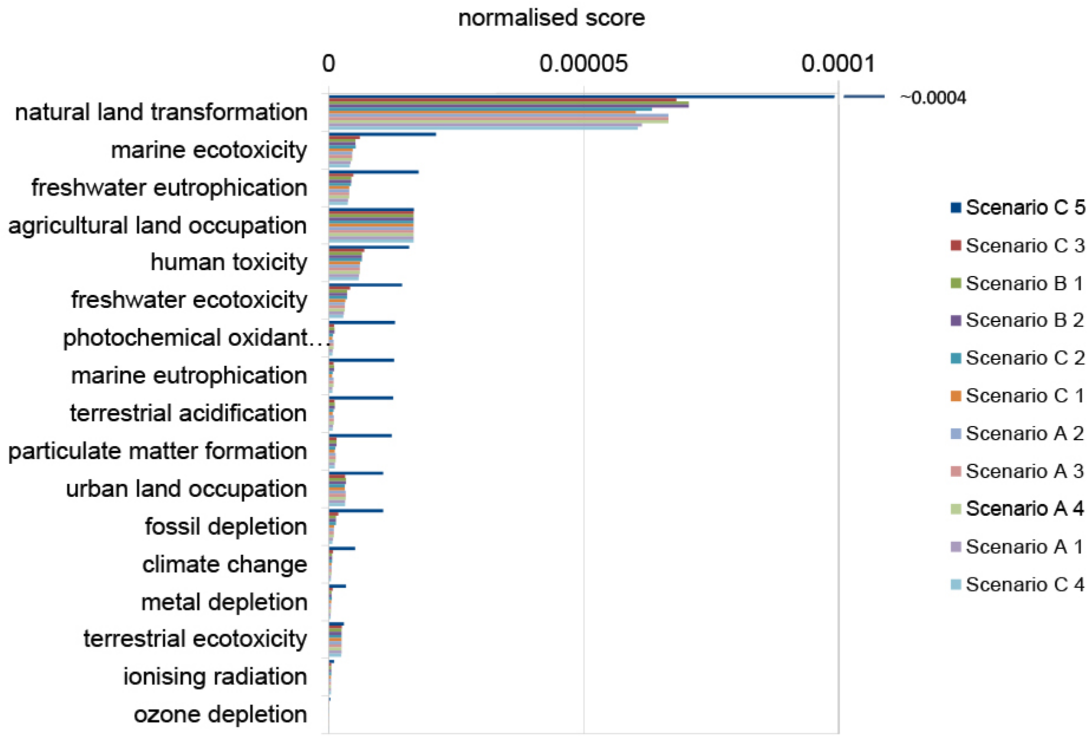


Figure 3 Normalised results for all defined scenarios.

Normalised results indicate dominance of land use-related impact categories: natural land transformation and agricultural land occupation (Figure 3). The reason for land use impacts is used of roundwood in production of wood chips used as the raw material for *XYZ*, as well as in heat production used in the flash dryer (Figure 4A).

An exception is the *Scenario C 5* (scenario where wood chips are imported from Canada by ship via Rotterdam straight to Helsinki where they are burned in a CHP plant) (Figure 4B). The extreme land use impacts are due to a modelling assumption. In the model we used *barge tanker transport* because a container ship did not seem to be a good option for bulk transport. But it turned out that barge transport causes land use impacts because barges sail long *river canals*. Naturally, there are no canals (except Panama) on the way from Canada to Finland.

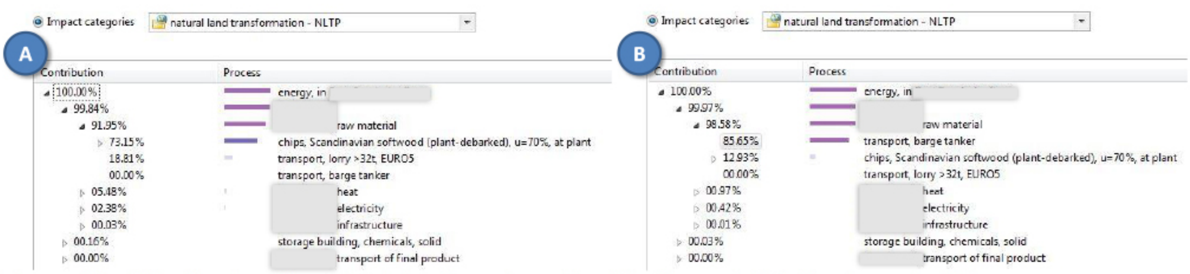


Figure 4 Contribution tree for natural land transformation (A = Scenario C 3, B = Scenario C 5).

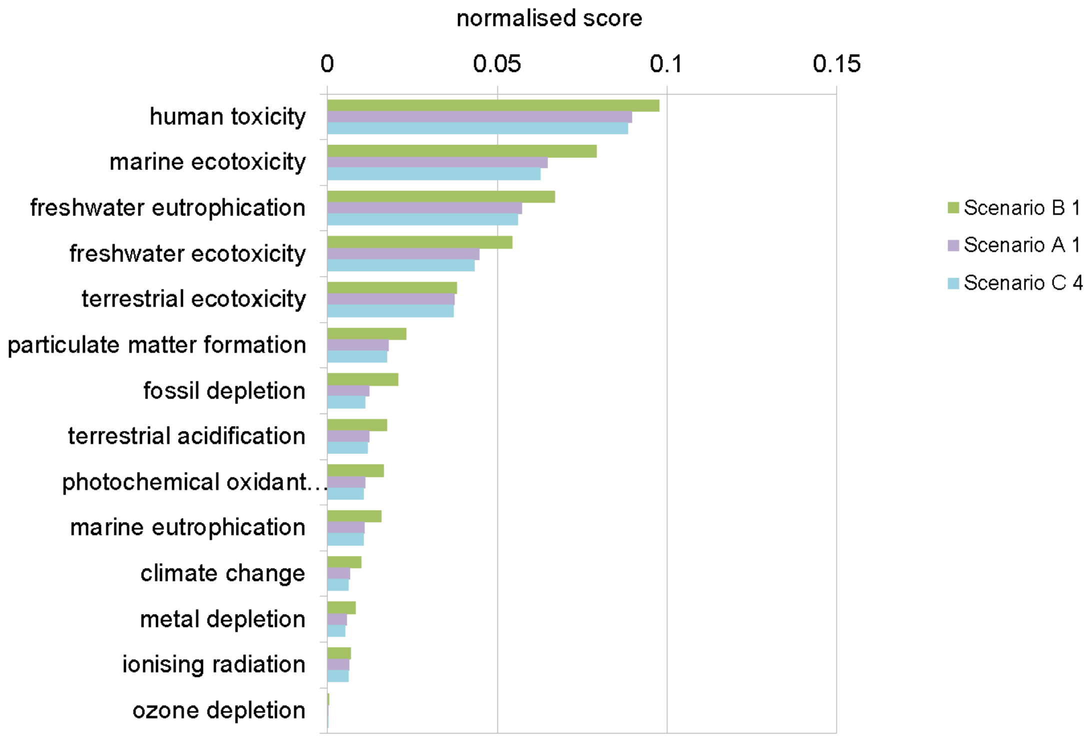


Figure 5 Normalised results for the three selected scenarios, one transport option per each (excluded land use impacts).

(Eco)toxic impacts are significant after excluding land use impacts from the list of normalized results (Figure 5). However, the way how these impact categories are modelled is complicated and the results may be even misleading. Instead we present contribution trees for *freshwater eutrophication* (Figure 6), *particulate matter formation, fossil depletion, terrestrial acidification and climate change* (Figure 7 *A-D*).

Freshwater eutrophication is caused by production of electricity which is used in wood defibrer and by truck transport. The other four impact categories are caused by the same activities, just in reversed order (due to longer truck transport).

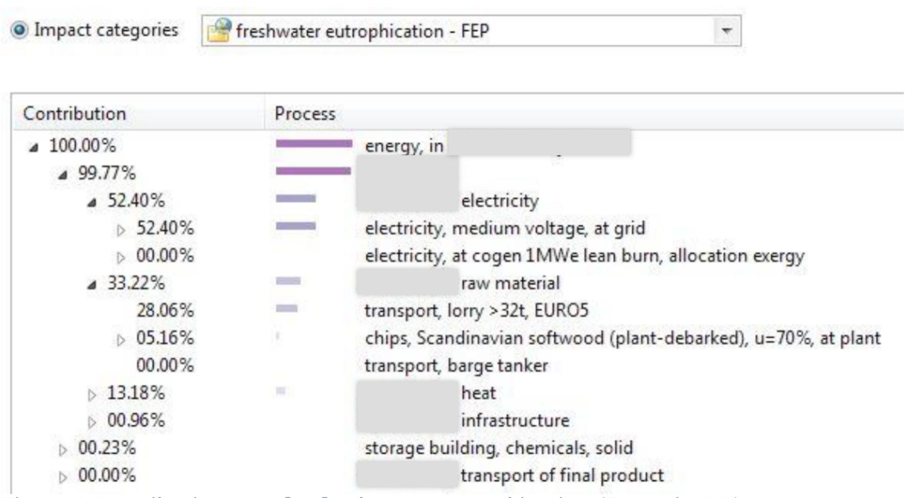


Figure 6 Contribution tree for freshwater eutrophication (Scenario C 3).

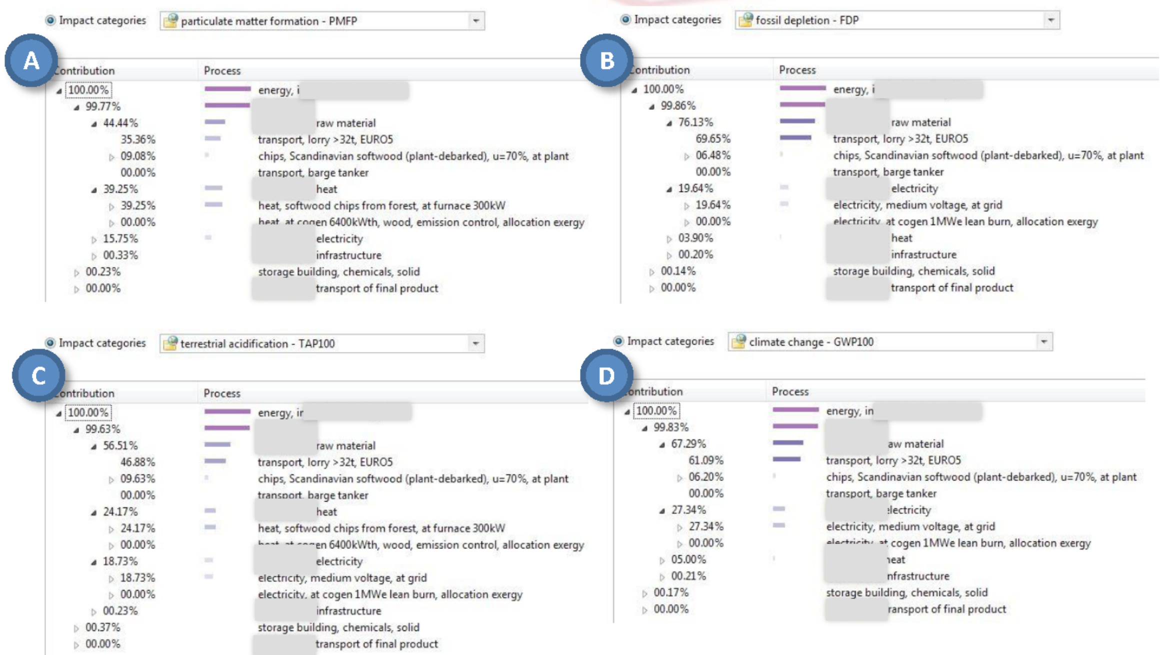


Figure 7 Contribution tree for particulate matter formation, fossil depletion, terrestrial acidification and climate change (Scenario C 3)

Although the normalised results suggest that *climate change* (*carbon footprint*) is not that important impact category for the analysed product system, it deserves attention. The driving force behind development of the *XYZ* technology is reduction of fossil carbon emissions by replacing fossil fuels with biofuels.

Based on our model, the results would indicate that importing Canadian wood chips and producing *XYZ* fuel at the site of a CHP plant in Helsinki is not a viable option (Figure 8). On the other hand, importing wood chips from St. Petersburg could be the best alternative when looking at carbon footprint.

Interesting finding is that locating *XYZ* plant on the sea shore, sourcing raw material near to the plant and exporting fuel to Baltic countries, Poland, Russia and Germany could also make sense.

All scenarios where longer truck transport is considered (in general 300 km and more), on the other hand, should be avoided.

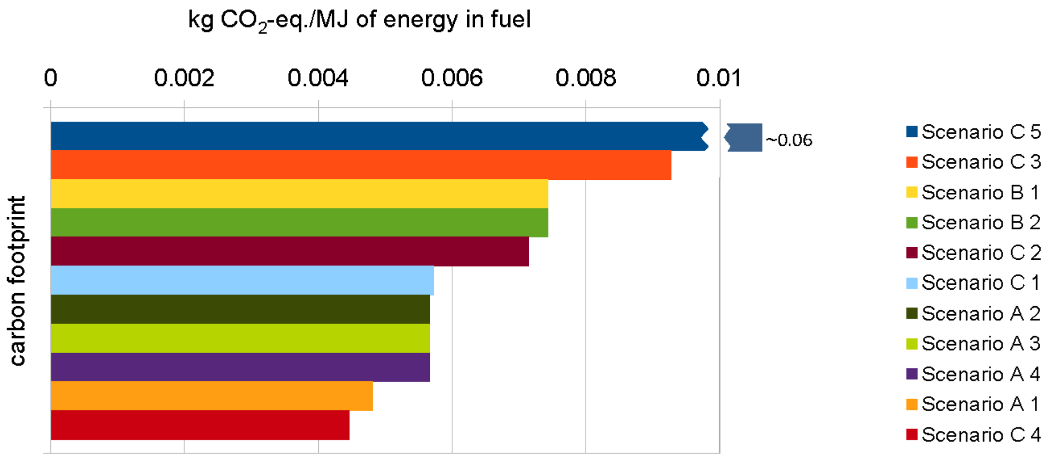


Figure 8 Climate impacts for all scenarios and options.

6. Benchmarking:
A comparable product to *XYZ* would be wood pellets. *XYZ* could also be used to substitute hard coal. Below is a benchmark comparison of production carbon footprints of the three fuels.

As the **benchmark** we defined primary energy supplied by one ton of *XYZ*: 15100 MJ.

Assumptions:
- Energy density of wood pellets is roughly 18 MJ/kg [1]
- Energy density of hard coal (anthracite) is roughly 30 MJ/kg [2]
- Distance of wood pellets transport from plant to the consumer is assumed to be 90 km (as in ecoinvent v3).
- Transport of coal to the market is 500 km by train

The Figure 9 shows that carbon footprint of wood pellets production is likely the highest of the three compared fuels, per supplied MJ of primary energy. However, it must be noted that carbon footprints of wood pellet production and *XYZ* very much depend on the moisture content of the raw material, as well as on the type of heat used to dry the wet matter. Thus the actual impacts will vary.

Also, the footprint of wood pellets in the figure below was calculated per 1 MJ of energy in wood pellets, measured as *dry mass*. Moisture content in wood pellets is said to be typically around 10%. Thus the footprint would be higher for wood pellets if moisture content was taken into account.

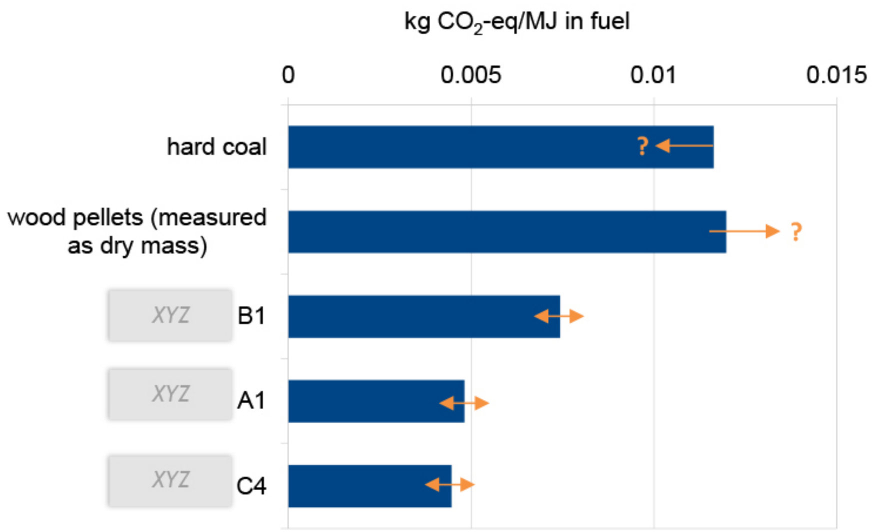


Figure 9 Carbon footprint of fuel production, per 1 MJ of primary energy supplied by respective fuel.

When benchmarking the production of fuel it is important to remember that burning hard coal produces fossil CO_2 emissions while burning wood-based fuels produces biogenic CO_2 emissions which are considered to have no effect on climate change.

[1] http://en.wikipedia.org/wiki/Pellet_fuel (Accessed: 12.12.2013)
[2] http://en.wikipedia.org/wiki/Anthracite (Accessed: 12.12.2013)

Handprinting

7. Ecodesign: How could we reduce the footprint?

It may be concluded that *XYZ* fuel could be a very good alternative fuel to both coal and wood pellets.

In order to assure that attention must be paid to the ***source of raw material*** and its ***moisture content***. The higher the moisture content, the higher the energy requirements for drying the material. Ideally, energy used in drying and defibring should be ***low-carbon energy***. From this point of view an ideal location of a *XYZ* plant would be next to a CHP plant which utilises *XYZ* fuel.

Also, as the scenarios indicate, it is important where to locate *XYZ* plant and where the final consumption occurs. It cannot be clearly said if it is better to locate to plant closer to the raw materials source or closer to the place of final consumption. What matters more is the distance and type of transport. ***In general, long distance truck transport in all stages of the XYZ supply chain should be avoided***.

Not only the transport distance is important, but also how well the fuel will be ***compressed*** on trucks/ships [3].

8. How could this product **reduce the footprint** of the user and others?

XYZ fuel is a fuel with carbon neutral direct emission from combustion. Replacing fossil fuels like coal, especially in large scale CHP plants, could significantly reduce greenhouse gas emissions.

It must be stated again, though, that the source of wood raw material matters. If it comes from free standing forest (this might be the case e.g. in Russia) which is not sustainably managed, emitted CO_2 emissions should not be considered as carbon neutral. Utilisation of wood waste, and logging residues is a better option.

9. Are there any **rebound risks?** How could those be avoided?

As indicated by in our calculation, even if the raw material is sustainably sourced but is imported from the other side of the world, the negative impacts might outbalance the positive ones.

[3] Density of bulk wood pellets is said to be around 0.6-0.7 t/m^3.

Case Ekoäly

LCA by Tuomas Mattila and Jáchym Judl

1. What are the company's expectations for this session?

It would be interesting to know if the Ekoäly automation system actually results in net environmental benefits. The product includes quite a bit of electronics, which has it's own footprint, but could that be offset by the energy savings. The aim of the company is not just to be cool or green, but actually be more ecological.

Footprinting

2. "Functional unit:" *What kind of a service does your product provide to the user? Who are the users? How would you measure the benefit to the user?*

The product is a set of house automation devices installed to a single apartment building. For example it could be a set of four apartments in two floors. Each apartment would have "smart" control valves in the radiators and temperature monitors in rooms. These would then be connected wirelessly to a central computer, which the inhabitants can access via internet to change settings. The data is stored on a cloud service in Iceland ("Truly Green").

The user is therefore the inhabitant of an apartment, but the customer would be a housing company ("taloyhtiö"). Building managers could use the product to compare buildings and to highlight potential energy savings.

Although the functional unit of the product would be to save heating energy and increase living comfort, these are hard to quantify. Therefore the results in this clinic are presented per a single house installation of Ekoäly automation systems. It was assumed that the product would be operated for 10 years.

3. What market are you aiming at? *If all goes extremely well, how big would this technology be? How fast?*

If all goes well, this product could be installed in 50 housing companies in five years. If each housing company would have 10 apartments, this would be 500 apartments and approximately 1500 smart-valves. It is unlikely that the demand would require additional infrastructure from the supply chain manufacturers.

4. System boundary: *What is needed to provide the service for the user?*
The Figure *XY* represents the analysed product system.

- What does it physically include?

The Ekoäly system is controlled by a *central machine*, which is a Raspberry Pi micro-computer. It communicates via enOcean wireless protocol with a *heat meter*, a wall-mounted box installed in an apartment, which controls the room air temperature. Each radiator in an apartment is fitted with an *automated valve*. The automated valve would ideally be an self-energy-harvesting valve operating with energy harvested from the hot water in the heating system. It communicates via the same enOcean wireless standard with the heat meter and central unit. An additional receiver might be needed in some cases.

1

- What touches it?

Finnish grid electricity mix is needed to power the central unit, additional receiver and for data transfer (mobile base stations).
Icelandic electricity is needed to power green data centers in Iceland.

Packaging of the components (cut-off).

- What services are needed?

Telecommunication services are needed in order to transfer data between the Ekoäly system and an internet-enabled device used for retrieving the data (e.g. a smartphone).

Servers are needed for hosting the Ekoäly database.

Installation of the device including transport to the site. Transport of components from country of manufacture (cut-off).

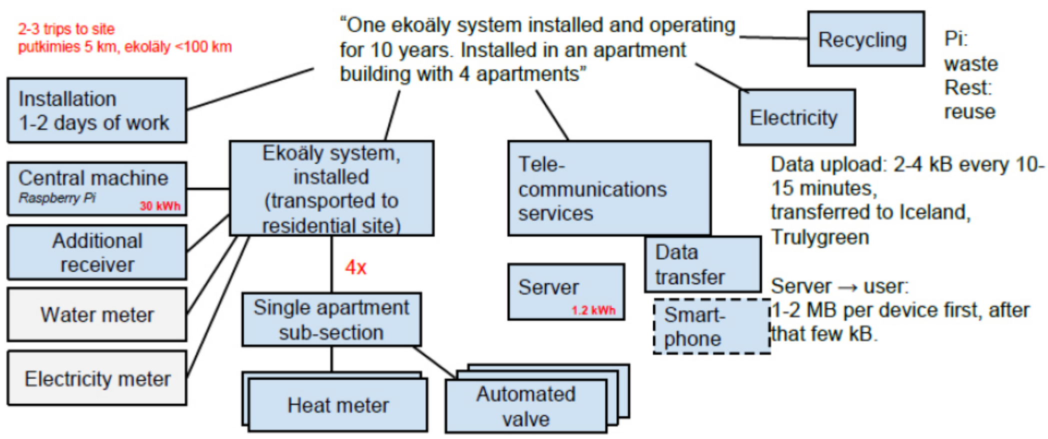
- Are there any indirect effects?

Data transfer increases with higher frequency of accessing the database. However, the system is coded so that the data packages would be small.

- Does your product/service replace or reduce anything what the customer already has?

Yes, the system replaces existing radiator valves, as well as thermostats. But it is expected that housing companies would fit Ekoäly only when replacement of existing valves must be done anyway. Therefore in theory no products would be replaced.

The product ideally decreases consumer's heat consumption. In some cases it might, however, increase it due to easy remote settings.



For the installation, it was assumed that the distances would be 105 km in total, with a passenger car. It would include both the plumbing and the hardware installations.
For electricity consumption of data transfer a electricity consumption of 0,00042 kWh/MB was used based on previous research.

For the central computer, it was assumed that it would consist of 35 g of printed wiring board (similarly equipped than for a laptop), 5 g of additional processors and memory ICs, 10 g of ABS plastic covering and an 10 g unspecified active electronic component (USB stick antenna). At end of life it was assumed that the central machine (Raspberry Pi) would be discarded as waste, but the other components would be reused. This contributed to 55 grams of electronics waste.

For the heat meters (thermometers), they were operated by photovoltaics (50 cm2) and a small backup battery (5 g NiMH). For the other components it was assumed that they would be represented by 10 g of printed wiring board and 15 g of ABS plastic.
The automated valve was modeled as a mixture of electric motor (50 g), brass parts (100 g), battery (40 g), rubber (2 g), printed wiring board (10 g) and a ABS cover (20 g). In addition the valve had a thermoelectric generator which was modeled as a mixture of graphite (5 g) and transistors (5 g). (The thermoelectric generator is based on semiconductors and a graphite heat conductor, so the assumption is probably not too erroneous.)

Cutoff: packaging and transport of components was not included in the analysis.

5. Hotspot identification:

After modeling the LCA system, the following results were obtained for the different impact categories. The results are normalized by dividing them with the impacts caused by an average European citizen. This gives an indication, which impact categories are the most significant for this product, when compared to the overall level of emissions in the society.

Based on the analysis, the product would seem to have the highest relative impacts for human toxicity, marine ecotoxicity, freshwater eutrophication and freshwater ecotoxicity, followed by and transformation and metal depletion. In all these cases however, the overall impact level is fairly low, with impacts less than an average European’s consumption. (The results are calculated for 10 years of operation for four apartments.) Overall, the impacts are very much similar to building a single laptop.

Category	Unit	Result	Normalization	Ratio
human toxicity	kg 1,4-DCB-Eq	553,49	592,36	93 %
marine ecotoxicity	kg 1,4-DCB-Eq	7,24	8,50	85 %
freshwater eutrophication	kg P-Eq	0,35	0,41	85 %
freshwater ecotoxicity	kg 1,4-DCB-Eq	7,02	10,88	65 %
natural land transformation	m2	0,04	0,16	24 %
metal depletion	kg Fe-Eq	152,33	713,30	21 %
fossil depletion	kg oil-Eq	63,54	1 556,09	4 %
terrestrial acidification	kg SO2-Eq	1,33	34,37	4 %
particulate matter formation	kg PM10-Eq	0,50	14,90	3 %
ionising radiation	kg U235-Eq	152,36	6 260,01	2 %
marine eutrophication	kg N-Eq	0,24	10,12	2 %
climate change	kg CO2-Eq	241,37	11 215,12	2 %
terrestrial ecotoxicity	kg 1,4-DCB-Eq	0,17	8,20	2 %
photochemical oxidant formation	kg NMVOC	0,74	53,15	1 %
urban land occupation	m2a	3,59	406,79	1 %
ozone depletion	kg CFC-11-Eq	0,00	0,02	0 %
agricultural land occupation	m2a	14,10	4 517,92	0 %
water depletion	m3	2,69		

Contribution analysis was used to identify which parts of the product system cause the most of each impact category. The results are presented in the following table. In all impact categories the printed wiring boards were in the top 3 of impact sources. Electricity use in Finland was also a significant hotspot and was mainly caused by the central machine (300 kWh/a). Brass parts and the transistor for the valve thermoelectric generator were significant for some impact categories. Passenger transport of installation was significant mainly for climate impacts and fossil fuel depletion.

		Installation: passenger transport	Valve: electric motor	Valve: brass, at plant	Valve: casting, brass	Valve & heat meter: battery, NiMH	Valve: transistor	Valve: graphite	Valve: synthetic rubber	Valve, meter, Pi: printed wiring board	Pi: IC processor	Pi: IC memory	ABS cover	Pi: USB stick	heat meter: photovoltaic cell	Pi: recycling	Data transfer: electricity, in FINLAND	server: electricity, hydropower
agricultural land occupation	m2a	0,1	0,0	0,1	0,0	0,2	0,2	0,0	0,0	1,0	0,1	0,0	0,0	0,1	0,2	0,0	12,1	0,0
climate change	kg CO2-Eq	16,7	1,9	2,9	0,1	9,5	8,7	0,1	0,1	62,7	5,1	2,5	1,6	7,4	6,5	0,0	115,5	0,1
fossil depletion	kg oil-Eq	5,9	0,6	0,9	0,0	2,3	2,5	0,1	0,0	17,0	1,3	0,7	0,8	2,0	2,1	0,0	27,3	0,0
freshwater ecotoxicity	kg 1,4-DCB-Eq	0,1	0,1	1,0	0,0	0,4	0,2	0,0	0,0	3,9	0,4	0,1	0,0	0,5	0,1	0,0	0,3	0,0
freshwater eutrophication	kg P-Eq	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,2	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
human toxicity	kg 1,4-DCB-Eq	3,0	7,3	100,0	0,2	17,2	12,2	0,1	0,0	301,2	33,7	5,0	0,0	40,4	5,0	0,0	28,1	0,0
ionising radiation	kg U235-Eq	3,8	0,4	0,8	0,0	2,4	5,6	0,0	0,0	30,4	2,1	1,5	0,0	3,4	2,8	0,0	99,0	0,0
marine ecotoxicity	kg 1,4-DCB-Eq	0,1	0,1	1,2	0,0	0,4	0,2	0,0	0,0	3,8	0,4	0,1	0,0	0,5	0,1	0,0	0,4	0,0
marine eutrophication	kg N-Eq	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,1	0,0	0,0	0,0	0,0	0,0	0,0	0,1	0,0
metal depletion	kg Fe-Eq	1,1	3,3	28,6	0,0	3,9	47,1	0,0	0,0	54,8	4,9	0,6	0,0	6,6	0,4	0,0	1,1	0,0
natural land transformation	m2	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
ozone depletion	kg CFC-11-Eq	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
particulate matter formation	kg PM10-Eq	0,0	0,0	0,0	0,0	0,1	0,0	0,0	0,0	0,1	0,0	0,0	0,0	0,0	0,0	0,0	0,2	0,0
photochemical oxidant forma	kg NMVOC	0,1	0,0	0,0	0,0	0,1	0,1	0,0	0,0	0,2	0,0	0,0	0,0	0,0	0,0	0,0	0,2	0,0
terrestrial acidification	kg SO2-Eq	0,0	0,0	0,1	0,0	0,3	0,1	0,0	0,0	0,4	0,0	0,0	0,0	0,0	0,0	0,0	0,3	0,0
terrestrial ecotoxicity	kg 1,4-DCB-Eq	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,1	0,0
urban land occupation	m2a	0,7	0,0	0,2	0,0	0,1	0,1	0,0	0,0	1,6	0,2	0,0	0,0	0,2	0,0	0,0	0,6	0,0
water depletion	m3	0,1	0,0	0,1	0,0	0,2	0,1	0,0	0,0	1,0	0,1	0,0	0,0	0,1	0,1	0,0	1,0	0,0

6. Discuss benchmarking: Choose a reference product for comparison.

If the product is compared to manufacturing a laptop, the results are very similar, especially for carbon footprint and the toxicities.

Handprinting

7. Ecodesign: How could we reduce the footprint?

By reducing the amount of printed wiring boards. Mainly in the valves, since there are the most of those. At this stage this is not a possible option, since Ekoäly is not big enough a purchaser to influence the valve manufacturers. What can be done is to avoid using extra stations (Raspberry Pi:s) for transferring data inside large buildings, preferably antennas should be used instead.

Usually in products such as these, data transfer is a hotspot, but in this case the data transfer has already been minimized to a level where it is not a significant emission source. Also the servers are located in a good geographical location.

As a large part of the impacts are from producing Finnish electricity to power the system, recommending the housing companies to shift to certified green electricity would reduce that impact.

8. How could this product **reduce the footprint** of the user and others?

This product could save heating energy if it was used as intended. If the heating energy saving potential were about 10% of a residential building, currently in category G (241 kWh/m2) x 240 m2 x 10% = 5784 kWh of district heat.

If this is compared to the emissions of producing district heat by combined heat and power, (emission factor 217 kg CO_2e/MWh, (Motiva, 2013.)), the emission saving is approximately 1 260 kg CO_2e/year. Since the carbon footprint of the product was calculated for 10 years, the emission saving would be approximately 13 tons, while the carbon footprint would be 241 kg CO_2e. Therefore the product could save over 50 times the emissions it causes. Therefore an energy saving of only 0,2% would be necessary to offset the carbon emissions caused by the manufacture and operation of the product. If the electricity used by the product would be climate neutral, this would improve the ratio even further.

9. Are there any **rebound risks?** How could those be avoided?

People who feel cold can use the tools to overheat the apartment. (Program could have setpoint limits.) Program could monitor what is happening and encourage people to reduce energy consumption. Paper flyer giving guidance on energy saving and usage of the tool.

Do not overmanufacture the product, so you don't end up with a huge amount of unsold electronics. Improve usability, so the product will actually be used.

DOCUMENTATION PAGE

Publisher	Finnish Environment Institute (SYKE)			*Date* June 2015
Author(s)	Jáchym Judl, Tuomas Mattila, Kaisa Manninen and Riina Antikainen			
Title of publication	**Life cycle assessment and ecodesign in a day - Lessons learned from a series of LCA clinics for start-ups and small and medium enterprises (SMEs)**			
Publication series and number	Reports of the Finnish Environment Institute 18/2015			
Parts of publication/ other project publications	The publication is available only on the internet: www.syke.fi/publications | helda.helsinki.fi/syke			
Abstract	In recent years, life cycle assessment (LCA) has become one of the main tools for quantify-ing environmental sustainability of products and services. The main advantage of LCA is that several environmental impacts are assessed simultaneously over the entire life cycle of a product or a service, across its whole value chain. Its holistic nature makes LCA a laborious and expensive method, less accessible to start-ups and small and medium enterprises (SMEs). However, as most of Finnish companies are of those sizes there is a clear need for a more simple, yet robust, solution. To tackle the challenge, we have developed a concept called the LCA clinic. Our idea is to streamline LCA and make it affordable for SMEs and start-ups. In this report we present the conceptual idea and illustrate its application on a series of trials with real companies. The outcomes of the LCA clinic trials show that it is applicable in practice. Moreover, they provide a valuable feedback for further development of the concept. The trials also proved that LCA clinics have a potential to stimulate life cycle thinking (LCT) in the participating companies.			
Keywords	small and medium enterprise, start-up, life cycle assessment, life cycle thinking, ecodesign, product development, sustainable development			
Financier/ commissioner				
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Printing place and year				

KUVAILULEHTI

Julkaisija	Suomen ympäristökeskus (SYKE)			*Julkaisuaika* Kesäkuu 2015
Tekijä(t)	Jáchym Judl, Tuomas Mattila, Kaisa Manninen ja Riina Antikainen			
Julkaisun nimi	**Elinkaariarviointi ja ekosuunnittelu päivässä - Opittua ja kokemuksia kasvu- sekä PK-yrityksille tehdyistä LCA-klinikoista**			
Julkaisusarjan nimi ja numero	Suomen ympäristökeskuksen raportteja 18/2015			
Julkaisun osat/ muut saman projektin tuottamat julkaisut	Julkaisu on saatavana ainoastaan internetistä: www.syke.fi/julkaisut | helda.helsinki.fi/syke			
Tiivistelmä	Elinkaariarvioinnista (LCA) on tullut viime vuosina yksi tärkeimmistä työkaluista arvioitaessa tuotteiden ja palveluiden kestävyyttä ympäristön kannalta. LCA:n etu on, että sillä voidaan arvioida samaan aikaan useita ympäristövaikutuksia koko tuotteen tai palvelun arvoketjussa. LCA:n kokonaisvaltainen luonne tekee siitä kuitenkin raskaan ja kalliin menetelmän erityisesti startup-yrityksille sekä pienille ja keskisuurille yrityksille. Suomen yrityksistä suurin osa lukeutuu näihin kokoluokkiin, ja on selvää että kokonaisvaltaisen LCA:n tilalle tarvitaan yksinkertaisempi, mutta kuitenkin luotettava ratkaisu. Ratkaistaksemme ongelman, kehitimme LCA-klinikka konseptin, jonka ajatuksena on suoraviivaistaa LCA:ta ja tehdä se mahdolliseksi pienemmille yrityksille. Tässä raportissa esitämme LCA-klinikan käsitteenä ja havainnollistamme sen toimintaa yrityskokeiluilla. Yrityskokeilujen perusteella LCA-klinikka toimii konseptina myös käytännössä. Lisäksi kokeiluista saatiin arvokasta palautetta konseptin edelleen kehittämiseksi. Kokeilut myös osoittivat, että klinikoiden avulla osallistuvien yritysten elinkaariajattelua voidaan lisätä.			
Asiasanat	pienet ja keskisuuret yritykset, kasvuyritykset, elinkaarianalyysi, elinkaariajattelu, ekosuunnittelu, tuotekehitys, kestävä kehitys			
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Julkaisun kustantaja	Suomen ympäristökeskus (SYKE), syke.fi PL 140, 00251, Helsinki Puh. 0295 251 000			
Painopaikka ja -aika				

PRESENTATIONSBLAD

Utgivare	Finlands miljöcentral (SYKE)		*Datum* Juni 2015
Författare	Jáchym Judl, Tuomas Mattila, Kaisa Manninen och Riina Antikainen		
Publikationens titel	**Livscykelanalys och ecodesign under en dag – Lärdomar från en serie LCA kliniker för tillväxts- och små och medelstora företag**		
Publikationsserie och nummer	Finlands miljöcentrals rapporter 18/2015		
Publikationens delar/ andra publikationer inom samma projekt	Publikationen finns tillgänglig bara på internet: www.syke.fi/publikationer | helda.helsinki.fi/syke		
Sammandrag	Livscykelanalys (LCA) ha kommit att bli ett av de viktigaste verktygen för att mäta miljö-mässig hållbarhet av produkter och tjänster Bland de största fördelarna med LCA är att man med den här metoden simultant kan analysera flera miljöpåverkningar under produktens eller tjänstens hela livscykel och över hela utbudskedjan. LCA metodens holistiska natur gör ändå att den blir tungrodd och dyr och inte så tillgäng-lig för start-ups och små och medelstora företag (SMEs). Eftersom största delen av de finländska företagen är små eller medelstora så existerar det ett klart behov för en enklare men ändå robust lösning. För att tackla den här utmaningen så har vi utvecklat ett koncept som vi kallar LCA klinik. Vår ide är att finslipa LCA och göra den möjligare för SMEs och startup företag. I den här rapporten presenterar vi den konceptuella idén och illustrerar applikationen med en serie försök med riktigta företag. På basen av företagsförsöken med LCA klinik metoden visar vi att den här metoden är möjlig att applicera i praktiken. Dessutom så ger företagsförsöken värdefull feedback med tanke på en vidareutveckling av det här konceptet. Försöken visar också att LCA klinik metoden ger potential till att stimulera livscykeltänkande i de deltagande företagen.		
Nyckelord	små och medelstora företag, startupföretag, livscykelanalys, livscykeltänkande, hållbar design, produktutveckling, hållbar utveckling		
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