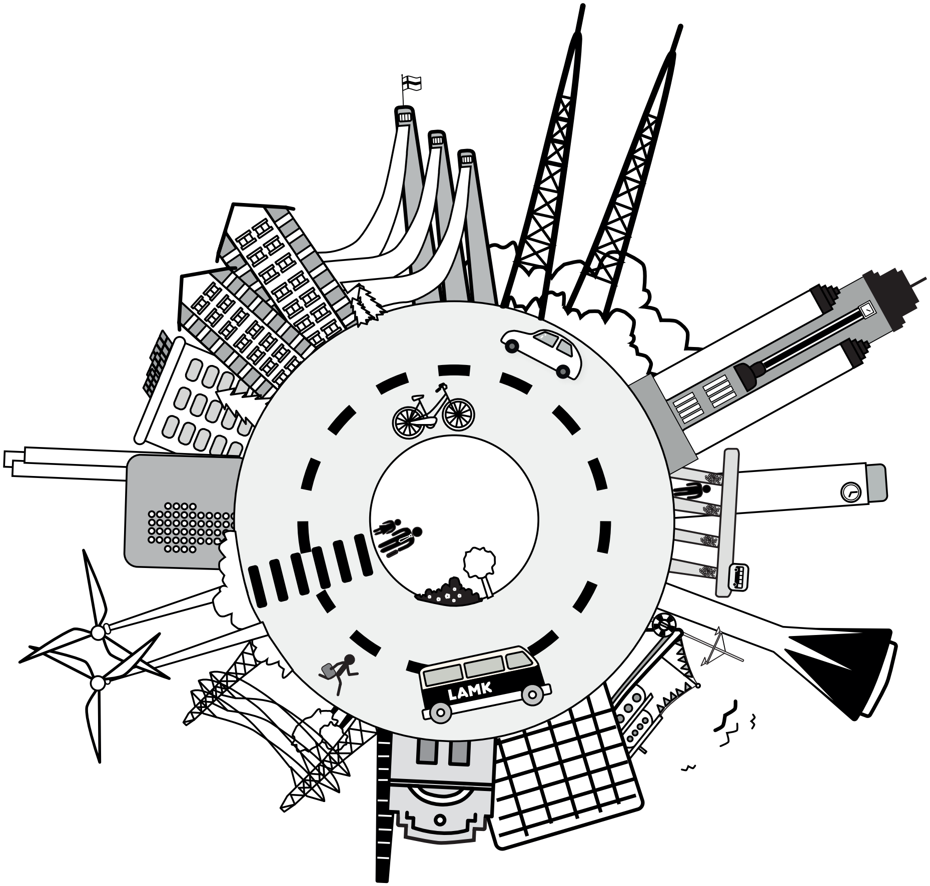
Material Efficiency | Energy Efficiency | Sustainable Urban Environment



Kirsti Cura (ed.)

Lahti Cleantech Annual Review 2016

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Lahti Cleantech Annual Review **2016**

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Kati Manskinen

Foreword

Figure 1. Circular economy actions on macro, meso and micro levels. (Susanna Vanhamäki, Kati Manskinen)

This publication is the third Lahti Cleantech Annual Review, where the latest interesting research, development and innovation activities in the context of cleantech are presented by the experts from Lahti University of Applied Sciences (Lahti UAS) and their partners. The Lahti region is an internationally known forerunner in the cleantech business and a cluster of environmental expertise. A strong regional and international network supports us to develop new technologies, methods, services and ecosystems which promote the sustainable use of resources.

The EU adopted the circular economy package at the end of year 2015 and pointed out that business and consumers are the key in driving the transition to a stronger circular economy, where resources are used in a more sustainable way (COM 2015). Furthermore, according to the EU's circular economy package (2015), local, regional and national authorities as well as the EU are enabling this transition. Therefore, in order to promote circular economy, a holistic approach is required and actions on macro, meso and micro levels need to be implemented (Ghisellini et al. 2016; Christensen and Hauggaard-Nielsen 2015), as described in Figure 1.

In September 2016, the Finnish Innovation Fund Sitra published one of the world's first national circular economy roadmaps, which shows the steps to sustainable success in Finland (Sitra 2016). Meanwhile, Lahti UAS together with local stakeholders started to develop a regional circular economy model of Päijät-Häme and a roadmap towards it in a project called Kiertoliike, which is funded by the European Regional Development Fund. The project includes modelling of material flows in the region, as well as developing some consumer centered business opportunities and piloting new circular economy demonstrations. In their article in this review, Ms. Maarit Virtanen from Lahti UAS and Dr. Sauli Eerola from Muovipoli Ltd. present a Circular Economy Library, which is one of the new interesting demonstrations of the Kiertoliike project.

The concept of circular economy traditionally distinguishes material flows into biological and technical materials. In the Lahti region, the biological streams such as material flows from the food industry and agriculture are well known and utilized effectively in local ecosystems. In their article, our highly appreciated partners Dr. Ville Uusitalo et al. from Lappeenranta University of Technology (LUT) expand our knowledge related to sustainable use of regional biological streams through important key indicators.

In practice, technical and biological materials are often mixed and they may also contain some harmful elements and substances. Hence, in order to optimize the cascading of materials, a profound understanding of the various materials and their properties is needed. Mr. Reijo Heikkinen from Lahti UAS describes in his article some utilization opportunities for recycled materials and the significance of material properties in recycling. The importance of material identification in order to promote material efficiency is also shown in the article by his colleagues Dr. Kirsti Cura and Dr. Lea Heikinheimo who present the IR spectroscopy results of textile sorting for Finland's waste textiles.

Besides the environmental expertise of the region, the development of sustainability at Lahti UAS is also supported by cooperation with design and business experts. When moving towards a more circular-economy way of living, design is one of the main promotors. In this review, the significance of design is well presented in two articles; the first article by Ms. Katerina Medkova and Mr. Brett Fifield gives an extensive overview of design aspects in the circular economy, while the second article by Ms. Noora Nylander describes the importance of user experience in packaging design.

Lahti UAS builds international partnership networks in order to support new businesses and the region's SMEs (Lahti Growth Model, 2016). In year 2016, the project called ERREC brought us lots of experiences about intercultural cooperation between partners from ITMO University, (Russia), NOvSU University (Russia), University of Gävle (Sweden) and Aalto University (Finland). An article by Ms. Päivi Kärnä and other key persons from the ERREC project presents the various activities which were carried out during the project together with students. Research, development and innovation projects bring new knowledge for students but also important contacts. The Nordic Innovation Accelerator (NIA) offered students of Lahti UAS and LUT an opportunity, for the first time, to join the Green Campus Open Night and to listen to world-class speakers in October 2016. In her article, Ms. Nina Harjula from NIA presents their cleantech activities and the themes of The Cleantech Venture Day 2016.

I wish to express my sincere thanks to all authors who published their latest interesting projects in this review. I am very pleased that many of our partners had a chance to share their professional knowledge and experience in this review. I also warmly thank the editor of this review Dr. Kirsti Cura, and Ms. Maija Varala for correcting the English language of the articles. Finally, I wish for all of you that this review gives new insights and inspiration into your journey of sustainability.

Lahti, 27 November, 2016

Dr. Kati Manskinen
RDI Director
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Reijo Heikkinen

Possible Applications for Potential Recycled Materials

Recycled materials

Every material can be recycled in some way. It depends greatly on the material's family how this is done in the most efficient way. After all it is just certain atoms and molecules that we need for our processes, and it does not make much difference where those carbon and hydrogen atoms come from. Whether it is crude oil, biomass, or old plastic parts, modern chemical processes can utilize these atoms. Some materials can be recycled as raw material with little or no chemical or physical altering of the material. This is the most efficient way to recycle. For example thermoplastics are reprocessable if they are just separated and cleaned from foreign materials and ground into suitable grain size (Fig. 1). In most cases it would not even cause any harm if some plastics are mixed with each other. That makes separation easier and faster. When the chemical and physical properties of polymer chains are compatible, they will mix together easily. The physical properties of the mixtures are in the middle of each component's individual properties. Some plastics also show a little degradation during recycling, and it can be taken into account easily. It is also possible to add necessary additives to ensure the quality of secondary materials. That is why thermoplastic polymers are easy and one of the most commonly recycled materials, along with metals.

Metals were the first materials to be recycled and even today they are the most commonly recycled materials. Most aluminium today is recycled. Recycling of metals is a very energy efficient way to use materials. It takes about 10 times more energy to make pure metals from ores than melt and reprocess recycled stock. Physical properties do not change in the case of pure metals like aluminium and electrical copper. Some heavily alloyed metals, like steel, need some virgin material feed for achieving some special alloys. There is a small burn lost, but it is negligible.

Figure 1. If plastic is collected in a proper way and it is clean, recycling will be very easy. These containers are all same polyethylene grade and pure, ready-to-use material with very little effort. (photo Reijo Heikkinen)

Glass is also easily recycled. It will not change chemically during the recycling process, even if it is heated for long periods at a high temperature. Glass is a very stable material with practically no loss by burning. Glass can also be easily separated by different colours.

Paper has been recycled for a long time. Cellulose fibre is a very durable biomaterial, which will show no or very little degradation after use. Paper fibers can be processed with very simple processes since they are already pure cellulose without lignin and resins. That makes paper recycling desirable compared to processes which make cellulose fibre from wood.

Other material families are more complicated to recycle. They usually need much more processing before they are ready to be used as raw material. Among these more difficult materials, wood is one of the easiest. Wood has more uniform mechanical properties than plastics, but it is more difficult to recycle, because it usually needs to be ground into particles. Since wood is a relatively soft material, it can be chipped easily. These particles can be used to make particleboard or other similar products. Some bigger blocks of wood can be used by themselves by carpenters and artisans, but the volume of that kind of production is small. One possible way to recycle wood is to use its cellulose and lignin as feed for many chemical processes.

Concrete is a more difficult material for recycling. The most common application for recycled concrete is as landfill. Basically, concrete is calcium carbonate, aluminium silicate with alcaline metals and gipsum. These are natural minerals, which can be naturally found in the earth. Because of the large portion of calcium carbonate, which is actually limestone, concrete will dissolve slowly in acid soil. As soon as concrete hardens, it will change chemically, so it is not possible to be used as cement. Concrete can be recycled in a cement factory by burning it in a cement kiln as a portion of raw material. That is the only method to regain its hydraulicity.

There are a lot of materials which are recycled. Electronic waste is a valuable source of precious metals. Car catalyzers also contain valuable materials. Even common household waste is a valuable source for different materials. Today less than 10 % of household waste ends up in landfills.

Recyclable materials that are not commonly known

As mentioned earlier, every material is somehow recyclable. When studying the cost effectiveness of recycling, the most important aspect is usually the volume of the material flow. Many processes are basically simple, but in order to be done effectively they need large reactors and a steady flow of materials. In many cases this is not possible due to the small amount of material available. However, it is cost-effective to develop simple processes for a small-industry scale. For example waste vegetable oil can be converted to car fuel quite easily with small-scale facilities. It seems that carbon will be an important recycled material in the future. All organic materials contain mostly carbon. When more and more of our energy can be made without the carbon cycle, we have plenty of carbon available in organic materials. The most important thing is that we do not have to release it into the atmosphere. More and more of traditional oil-based materials are made from biobased materials. Cellulose from wood and some other plants is a commonly used biomass. There are many other non-useful plants that can be used for that, like straws, foliage, chaffs, peat, lawn, brushwood, etc. (Fig. 2) There is a rising industry around carbon dioxide economy. Right now it is under development and relatively unknown.

Possible application for some recycled materials

It is possible to combine different materials together if these materials are difficult to use by themselves. In many cases thermoplastic polymers can be used as a matrix for many different materials which are fibres or particles. The resulting composite has different properties which depend on some interaction between the matrix and filler or reinforcement. The greatest effect comes from the matrix/filler ratio, filler size and fibre size and aspect ratio, wetting and coupling between components and the physical properties of each component. Usually the ratio between matrix and fillers varies between 10 % to 70 % of filler by volume. With thermoplastics, it seems that the biggest challenge will be poor coupling between matrix and filler.

By using thermoplastic matrix all kinds of composites are quite simple to make. In our laboratory, many different composites are made and processed. We have used polyethylene, polypropylene, polystyrene, polycarbonate, ABS and PET and cornstarch-based polymers as matrices. As fillers we have used cotton, peat, wood particles, cellulose fibres, nanocellulose, PET- and elasthane-fibre, minerals and glass-, aramide- and carbonfibre. Because of the thermoplastic nature of these composites they are mouldable, extrudable and 3D-printable.

Figure 2. Common biomass. This brushwood is normally burned or composted. Anyhow, a lot of valuable carbon is released into the atmosphere. (photo Reijo Heikkinen)

These composites can be made in large factories or in situ of the production or source of the materials. It seems that the combiner-extruder for mixing these materials is relatively simple.

Some precautions to take into account

Most hazards from recycled materials are the result of mainly two reasons. These reasons have a common root – the material is not what we think it is or it is contaminated in some way.

1 The material is not what we think it is

In the recycling process there can be some leaking into the flow of pure material. For example agricultural plastics are usually very pure grades of certain plastics. Also recycling is well organized for this kind of materials. Separation and characterization are not needed, because we are certain about the material we have. However, there is a big risk involved. If contamination happens, it could ruin the process and can be expensive to recover. If we want to make products with lighter coloured plastics, it is most undesirable if there is even a very small amount of black or dark plastic. Black pigments are very strong, ruining the whole production. The effect of black pigments is based on the excessive amount of carbon black. Just for colouring, only a small amount of black pigment is needed. Usually plastic contains 10 to 100 times more of black pigment. This excessive amount is needed for ultraviolet protection. Since carbon black is cheap, it is commonly used for UV protection for black plastic materials.

The situation is much more difficult, if we have to separate different plastics from mixtures of general waste. Whether this is economically wise depends on the price of the materials. Anyway, there is a risk that the material we have is not exactly correct and pure.

2 Materials can contain harmful substances

Many materials can absorb other materials that are chemically compatible. Many materials act like a sponge, absorbing substances from the surrounding space. These substances can cause a chemical or biological risk for the processor or the end user of the product. Some polymers can contain several percent of additives that are useful but they can also absorb considerable amounts of unknown chemicals over a long period of exposure. Wood can absorb 10 percent or more chemicals such as oils and other liquids, which are difficult to remove by drying. Metals and glass do not have such problems. These are quite dense and nonporous materials and processing temperatures are so high that other molecules will be removed during melting.

When plastics are heated for processing, they will degrade through certain processes. These processes will consume stabilizers and antioxidants and form chemical residues. Chain scission will change physical properties, and oxidation forms fetid chemicals by carbonyl derivatives like ketones, aldehydes and carboxylic acid.

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Maarit Virtanen and Sauli Eerola

Circular Material Library as a Tool for Promoting Industrial Symbiosis in the Päijät-Häme Region

The Circular Material Library, which is being constructed as a part of the Kiertoliike project, aims at providing information on new materials for product designers to support companies' move towards circular economy. The library provides information on the properties, usage and also availability of recycled materials. The library consists of a digital database and a physical library with material samples and prototypes.

Circular Economy and Industrial Symbiosis

Circular economy requires re-thinking and re-designing of products and services, which means that companies need to build competencies in circular design to enable product reuse, recycling and cascading. The choice of materials is an essential issue in product development. In addition, the European Union aims at developing markets for secondary materials, as they still account for a small proportion of materials used. New materials need to be integrated into existing value chains to ensure their wide use, but this requires that product designers have adequate information on the properties of recycled materials. One question is also the availability of materials.

Industrial symbiosis can be defined as an association between two or more companies, in which the wastes or by-products of one become the raw materials for another. Industrial symbiosis can help companies in reducing raw material and waste costs, earning revenue from by-products, creating environmental benefits and opening new business opportunities. Industrial symbiosis is one way of moving towards the system-wide change of circular economy by bringing together different companies looking for new solutions.

There are already some examples of industrial symbiosis in Päijät-Häme. These include the cluster of companies around the Kujala Waste Treatment Centre of Päijät-Häme Waste Disposal Ltd. The industrial symbiosis includes, for instance, a biogas facility that produces compost for seed beds and biogas that is reprocessed into transport fuel. Scrap metal brought to the waste treatment centre is processed by two recycling companies. Also crushed concrete products are manufactured from concrete waste for use in earthwork. Another interesting example of activities is the collection and treatment of used roofing felt. The used felt is processed and then used in asphalt.

Industrial symbiosis is promoted nationally by the Finnish Industrial Symbiosis System (FISS). Motiva coordinates the FISS model, while regional organisers work directly with companies promoting cooperation. Workshops are a central tool in activating companies, collecting resource data and identifying symbiosis possibilities. There have also been workshops organized in Päijät-Häme. The challenge is, however, how to get especially smaller companies involved. The companies can lack time to get involved and also may not realise the possibilities of symbiosis. Companies would need easily available information on recycled materials, and here the Circular Material Library could be of help.

Recycled Material Use at Companies: Case Plastics Industry

The aim of the Circular Material Library is to promote the use of recycled materials based on industrial symbiosis. The use of recycled materials is hindered by the lack of information in the product design phase. The direct benefits of using recycled materials can be relatively small compared to their "time-to-market" costs and risks. The reduction of the time it takes to reach the market and a wider use of recycled materials requires their adoption in existing value chains for products that already have markets. The Circular Material Library assists in transferring information to the product design phase at companies, as well as to students, product and material manufacturers, and designers. The material information is especially relevant in innovation related to product development processes.

Päijät-Häme has a significant plastics industry and also machine and component manufacturers that use polymers, and semi-finished plastic products and components.

Figure 1. Wood material samples. (photo Oona Rouhiainen)

Plastics form a large part of the industrial materials in the region. In the waste and recycling sector plastics consist of, for example, construction and demolition waste, packaging, energy and mixed waste, electronic waste and car demolition waste. Plastics and particularly thermoplastics are promising materials in terms of industrial symbiosis, because pure side streams and fractions can be utilized in commonly used plastic production processes (injection moulding and extrusion). In addition, many companies in the region use extrusion in their production, which means that both product and side stream quantities are considerable.

Extrusion is used for producing, for instance, plastic films, pipes and profiles. Plastic companies do not always utilize plastic side streams themselves. The reasons for this include the lack of processing techniques, the prohibitions on the use of recycled materials (for instance, in food packaging), and the technical challenges of using composite materials (for instance, multi-layer films). Often companies producing side streams of small quantities lack economic incentive to seek users for them. In this case, the side streams are directed to waste and recycling companies for use as energy or material. However, there are also small actors who could utilize even small amounts of materials. Accordingly, it is possible to use recycled materials in the plastics industry maintaining the value of materials instead of “downcycling”. This means replacing a part of products’ virgin materials with recycled materials made available by industrial symbiosis.

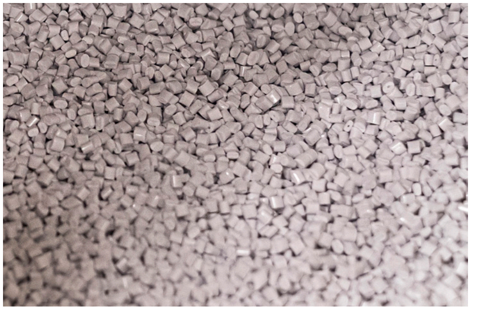

Figure 2. Recycled plastics.
(photo Oona Rouhiainen)

The Circular Material Library

Several material libraries already exist around the world with good experiences on how a library and related experts can help product designers at companies and universities. For example, Material Connexion has seven full-service libraries around the world, in addition to satellite libraries, educational libraries and an online database with over 8 000 materials. Several universities also have material libraries mainly for the use of architect and design students.

The Circular Material Library in Lahti differs from the existing libraries in that it primarily aims at promoting industrial symbiosis in the region, and covers only recycled materials. Special attention is paid to issues hindering symbiosis, such as inadequate information on material quality, quantity, availability and characteristics. The material samples represent available industrial side streams that can be a basis for production, instead of single waste or leftover lots.

The Circular Material Library is being developed by Muovipoli Ltd and Lahti University of Applied Sciences. At Lahti UAS, the library is constructed through a multidisciplinary approach. The Institute of Design provides the design of both the physical library and the visual appearance of the digital library. The Faculty of Technology Information Technology students create the digital database and the implementation of the visual appearance, while Process and Materials Technology students collect material samples, analyse them and help to create the material specifications. The Faculty of Business students benchmark and examine business models for running a material library.

Muovipoli Ltd was established in 1999 as a development company of plastics industries in Finland offering R&D, expert and testing services. Its 25 stockholders include industrial companies, universities and development organizations. Muovipoli is responsible for the realisation of the circular material library, including its structure and functions. Muovipoli defines the materials which will be taken into the library. The main material groups will be plastics, wood, composites and fibres. For example, availability, properties, amounts, quality, usability, locations and logistics will be inspected in the selection process of library materials. The samples are collected and analysed together with Lahti UAS.

Figure 3. Equipment at Muovipoli Ltd. (photo Oona Rouhiainen)

Special attention is paid to the Circular Material Library's design and usability. While most material libraries are permanent structures, the circular material library is a mobile "pop-up" unit that can easily be used by product designers, but also to promote new materials and industrial symbiosis at different events or companies. The digital library enables the search and comparison of different materials based on their characteristics. The main users of the library are companies, students, industrial designers, product designers and material specialists, who can promote the adoption of new materials in product design.

Kiertoliike - Päijät-Häme Region Circular Economy Model and New Business Opportunities project is implemented in 2016-2018 with support from the European Regional Development Fund. Lahti University of Applied Sciences coordinates the project carried out with Muovipoli Ltd, Lahti.

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Kirsti Cura and Lea Heikinheimo

Identifying textile fibres in discarded textiles – Case Patina

Use of textiles in the world

The global consumption of textiles is in constant increase, due to world population growth, urbanisation and higher standards of living. The textile industry is one of the most polluting industries in the world. This is due to the high consumption of water in cotton production and the use of fossil fuels for producing man-made fibres. Therefore, textile waste is linked with heavy climate effects. In addition, single use of garments has become a fashion trend, which in turn increases the consumption of consumer textiles. In 2014, the production of cotton and polyester was 65 million tonnes and it is expected to be 90 tonnes by 2020. It has been estimated that the use of cotton is going to decrease and the use of synthetic fibres will increase. The decrease of cotton use can be seen particularly in developed countries. In any case, the global demand for fibres is increasing. The demand for polyester accounts for the largest share, and polyester producers are looking for other fibres for replacement. In addition, the production of man-made cellulosic fibres has considerably increased during the past decade. Limiting the production of synthetic fibres comes from demands of using less fossil resources and hence leads to a demand for sustainable fibres. In the Nordic countries, the consumption of textiles grew considerably prior to the economic crisis in 2008; for example, in Sweden new textile purchases grew by 40% and in Denmark by 36% in the 2000's. In 2012, every Finn produced about 13 kg of waste textiles. These numbers refer to domestic textiles.

However, a great part of the textiles is used as interior textiles and technical textiles. Technical textiles refer to such material that is mainly used for its technical properties and superior performance. It is estimated that the use of technical textiles will continue to grow and will take the global fibre demand to 30.71 million tons by the end of 2018.

The global fibre consumption was 96 million tonnes in 2015. The share of the different fibre types was as follows:

- oil-based fibres 62%
- cellulosic and protein-based fibres 38%, including cotton's 25% share
- wood-based cellulose fibres 6%
- other natural fibres 1.5%
- wool 1.2%

The estimated average shares of the consumption of textile fibres in the Nordic countries are cotton (57%), polyester (34%), wool (4%), and others (5%).

The status of textile recycling and reuse in Finland

The ban on organic waste at landfills – which category textile waste belongs to – came into effect in Finland on January 1st 2016. Currently, a major part of waste textiles goes to incineration, which does not fulfill the requirements of the waste hierarchy in the Waste Act. There are numerous projects ongoing in Finland to get more information on collecting, sorting and reuse of discarded textiles. Among these, chemical dissolving treatment of cellulose to spin modified cellulose is one of the most interesting development paths. This process requires well identified and clean cellulosic fibre materials.

Regarding Finland, there is very little information on the material composition and shares of the fibres of the discarded textiles. It is challenging to try to find reliable statistic data on the amount of textiles and textile waste in Finland. In the national statistics of Finland, textile waste is not treated as a separate stream of waste, but it belongs to municipal waste. In some parts of Finland, such as in Lahti, discarded textiles can be sorted to energy waste. There is no official information available on discarded textiles from domestic households nor private and public establishments. As a part of the TEXJÄTE project in 2013-2014, the Finnish Centre of Consumer Research estimated textile streams in Finland using Foreign Trade Statistics by Finnish Customs, and Statistics of Industrial Output by Statistics Finland, and treated them using the method developed by Tojo et al. The estimates and results showed that 77% of discarded textiles ended up to waste and 23% to charity. About 20% of the textiles that went to charity got back to consumers, about 50% was exported and 20% went to waste. A study by Käppi et al. in the Poistaripaja project showed that out of 23 000 kg of discarded textiles, 35% was reused, 55% was recycled and only 10% was incinerated. For the recycled stream (i.e. 55% of the mentioned 23 000 kg), material identifying was carried out using the naked eye. In this 12 650 kg of textiles, 60% was cotton, 35% was polyester and 5% was acryl, wool and fleece (which is also polyester).

In a report by Schmidt et al., it was estimated that out of 71 000 tonnes of annual use of textiles in Finland, 25 000 tonnes got separately collected. From this lot, 3 300 tonnes went to incineration and/or landfill, 6 200 tonnes got exported, 7 000 tonnes was reused in Finland and 8 500 tonnes was recycled. Out of 46 000 tonnes of not separately collected textiles, 40 000 tonnes ended up in municipal waste and then to incineration and landfill. It is interesting that accumulation and material loss was estimated to be 6 000 tonnes. This estimate is from 2010, and it can be assumed that the landfill ban will change the situation.

A study of discarded textiles in Patina

Experimental

The aim of this study was to get quantified information on discarded textile streams at the recycling centre Patina in Lahti. Patina is a part of Lahden Työn Paikka Ltd, which is a non-profit company owned by the City of Lahti. Identifying of textile fibres was carried out using the naked eye, reading the textile care instruction labels which were attached to the pieces of clothes, and using FTIR (Fourier Transfer Infra Red) spectroscopy.

Collection of discarded textiles was carried out between January 8 and February 5, 2016. At Patina, consumers can bring textiles, furniture, kitchenware, electronic devices, etc. at the recycling centre. The collection point is outside the building. People are supposed to inform the staff of Patina when they leave items. However, this is not always the case and therefore the staff has to sort dirty, worn- out, mouldy, and in other ways non-usable materials out of the recycling stream. This causes extra cost to Patina.

During the above mentioned period of time, all the incoming textile was weighed and reported by the members of the staff. Employees sorted the textiles depending on their quality and cleanness for sale as they are, for storage or for waste. The main reasons for textile items going to waste were that they were dirty, worn out or out of fashion. Underwear and swimming costumes went to waste as well. In addition, unsold textile items go to waste after some time. Pillows, duvets, towels, carpets, etc. were separately weighed and donated further to local animal rescue centres. Patina does not export any textiles to developing countries as many charity organisations do.

Textiles labelled “waste” were weighed and re-sorted. Using textile care instruction labels, textile fibres of the items were identified to two categories: 1) single fibre textiles and 2) mixed fibre textiles. Those textile items that could not be identified manually were sent to FTIR analysis at Lahti University of Applied Sciences, Laboratory of Materials Technology. Different fibres can be identified based on the library of the known textiles. The example spectra of cotton (green), wool (red) and polyester (blue) can be seen in Figure 2. Cotton shows typical peaks at 1100 cm-1 (C-O stretch, alcohol) and a wide peak at 3300 cm-1 (OH stretch, free and bonded). Wool shows typical peaks at 1510 cm-1

Figure 1. Students are sorting discarded textiles. (photo Ida Borén)

(N-H deform, secondary amine), 1620 cm-1 (N-H deform, primary amine) and 3200 cm-1 (OH stretch, free). Polyester shows typical peaks at 1700 cm-1 (C=O stretch, ester) and 730 cm-1 (C-H aromatic). The OPUS Spectrum Libraries, which are used in the Laboratory of Materials Technology, confirmed these samples to be cotton, wool and polyester, respectively. As a conclusion, cotton, wool and polyester textiles can be identified and separated using FTIR spectroscopy.

Results

The discarded textile stream consisted of coats, jackets, children's clothes, underwear, knitwear, hats, scarves, etc. The stream did not contain upholstery textiles such as curtains and table cloths because those were sorted to items to be donated. Bags and shoes were also separated. A part of the waste stream was very dirty.

During the three weeks, Patina received 892 kg of discarded textiles. The amount of textiles (duvets, carpets) donated to reuse was

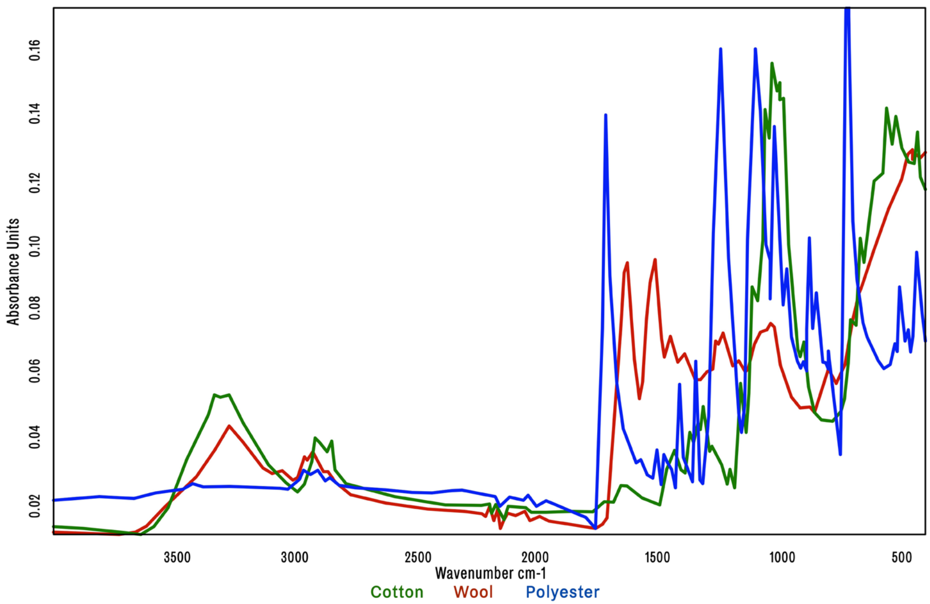

Figure 2. FTIR spectra of cotton, wool and polyester. (edited by Oona Rouhiainen)

117 kg. A total of 118 kg went to waste. Out of this, 73kg was from incoming discarded textiles and a further 45 kg from shoes, bags and some carpets that were not feasible for Patina's further use. After sorting and identifying, 238 kg of textiles were found to be suitable for further recycling. Based on these numbers, 419 kg went for sale as they were.

The composition of the 238 kg of discarded textiles that was brought to Patina and was further sorted and identified as suitable for recycling during the three-week study was as follows: 51% was mixed fibres, 33% was cotton, 9% was polyester and 7% was wool, acryl, polyamide and silk (Fig. 4).

Discussion

According to our knowledge, this was the first time IR spectroscopy was used to identify the composition of discarded textile streams in Finland. This study obviously represents a very small amount of Finland's waste textiles. The only study this result could be compared to was the one with Käppi et al. That study was carried out using the naked eye only, and perhaps it is the reason why their study did not show any mixed fibres as it was not possible to identify them. Both in our study and Käppi's study, wool is missing. This is because wool is relatively easy to identify and sort manually. It is also a valuable and wanted textile stream for reuse and recycling.

Table 1. Percentages of different textile fibres in the study at Patina and by Käppi et al.

Type of textile fibre	Patina (%)	Study by Kämppi et al. (%)
mixed fibres	51	N/A (not identified)
cotton	33	60
polyester	9	35
others	7	5

It is worthwhile noticing that the amount of cotton is very high compared to the global stream of textiles. This is good news for developers of a chemical recycling process for cotton and other cellulose-based fibres as they can expect to receive raw material without problems. Identification of discarded textile fibres still needs further development, especially for an industrial scale. FTIR is not suitable for industrial applications because of too long measurement time. Lahti UAS has recently purchased an analyzer based on near IR technology (NIR) and built an experimental unit set up for it. Experimental trials will be started during late 2016.

According to Patina's staff, the textile stream was normal during the studied three weeks. High seasons are Christmas and New Year, spring and autumn. They would like consumers to pay more attention to what kind of textiles they bring to the recycling centre. It would be more beneficial for every party if textiles to be discarded were clean and reusable. In Lahti, the correct sorting destination for dirty, worn-out and non-usable textiles is energy waste. It is very important to communicate and guide consumers about how to recycle textiles and what happens to recycled and reused textiles.

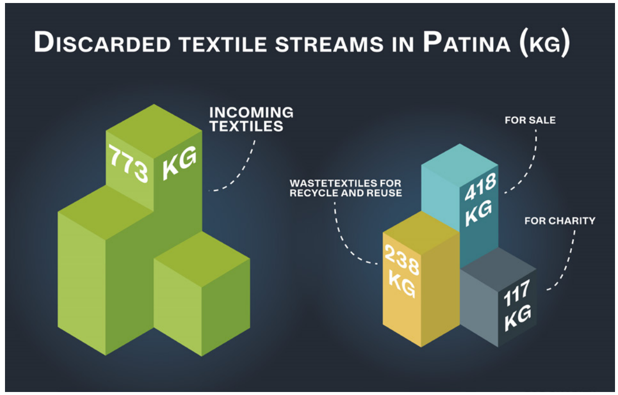

Figure 3. Discarded textile streams in Patina. (edited by Oona Rouhiainen)

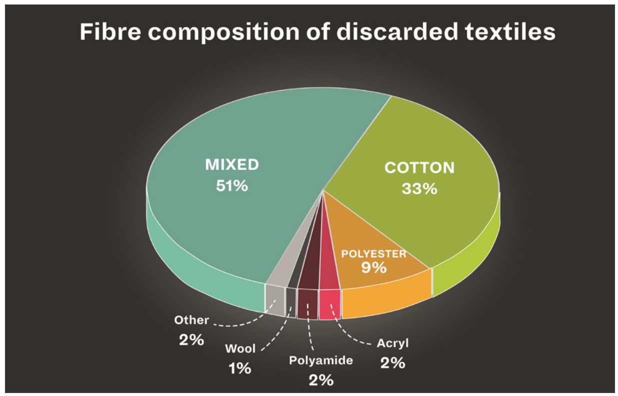

Figure 4. Fibre composition of discarded textiles. (edited by Oona Rouhiainen)

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Nina Harjula

The fast track for cleantech enterprises to reach the world

The **Nordic Innovation Accelerator (NIA)** service for cleantech enterprises is one of a kind. Among the beneficiaries are large global innovative companies, up-and-coming innovative cleantech companies and investors looking for sound investments for their capital.

The NIA online service is more than a standard website. It is a platform on which large companies can submit **an open challenge** to find new, innovative solutions to their existing problems. Thanks to NIA, the challenge is visible in all the Nordic countries and Estonia. Companies in the participating countries can use the NIA fast lane directly at the push of a button and offer their own solutions to the challenge. In addition, small businesses can use the platform free of charge to introduce their own expertise, while connecting with their new partners.

For capital investors, NIA also provides the opportunity to seek out suitable investments, such as small growing enterprises that have already worked in cooperation with a large company.

The Managing Director of Nordic Innovation Accelerator Ltd, Nina Harjula, is excited about the expansion of the service into all of the Nordic countries and Estonia.

”The network of Finnish cleantech companies is a relatively small player in the world and it is difficult to reach global corporations as clients. Aside from the Finnish partner network, NIA is now also working with Swedish Cleantech, Danish CLEAN, Norwegian OREEC and Startup Estonia. These main partners run their own networks in their respective countries. These networks have over six thousand growing innovative clean technology companies.”

NIA provides a powerful set of tools for each user group. It is also a unique pan-Nordic platform, which is being developed with determination and allows companies to network in order to help them develop cooperation. Nina Harjula says that the NIA service has the potential to reach over 6,000 clean-tech businesses in the Nordic countries and Estonia.

Process Genius Oy from Joensuu is one of the companies that has utilised NIA's fast lane. ”We were chosen as one of Fortum's partners last year. Our company creates virtual interfaces, and this cooperation has had a revolutionary impact on the development of our company,” says Managing Director Jani Akkila.

The concept of NIA has already produced good results and operations will be expanded.

”We are negotiating with new partners around the world and the aim is that, by next year, we will plan to have similar self-service platforms operational and companies will be communicating with each other across the continents. Therefore, for example a challenge opened in China would simultaneously be visible on every service platform. The first

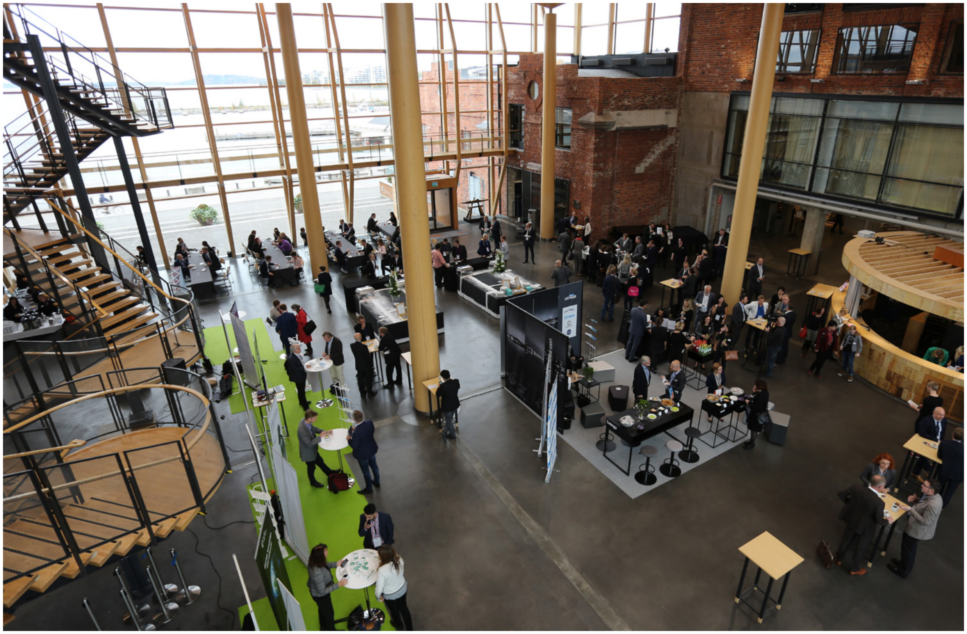

Figure 1. The venue of Cleantech Venture Day is the wooden Sibelius Hall in Lahti. Every year, the event is attended by a significant number of international private equity investors. The 190 companies that have previously pitched at the event have received more than EUR 400 million in funding. (photo Jani Wallenius)

collaboration platform will be launched with Switzerland in November 2016." Harjula explains the new enormous growth potential for small businesses that are being provided by NIA.

Cleantech Venture Day 2016

The Cleantech Venture Day, which was held in early October this year, helps private equity investors and growing businesses come together. This was the eleventh such venture capital event and is one of the most important and most popular in Europe.

The compactness and efficiency of the event guarantees that it will pique the interest of investors.

"The investors know that they will meet screened companies from Finland, other Nordic countries and the Baltic countries that are offering new approaches," says Nina Harjula, Managing Director of Nordic Innovation Accelerator Oy.

The themes for this year were digitalization and blockchain technology. The first ever Green Campus Open Night brought together our higher education partners Lappeenranta University of Technology and Lahti University of Applied Sciences and offered students an opportunity to listen to world-class speakers and topics during the evening.

Nordic Innovation Accelerator is an Open Innovation platform. NIA's services include the Corporate Venture Program and the Cleantech Venture Day event.

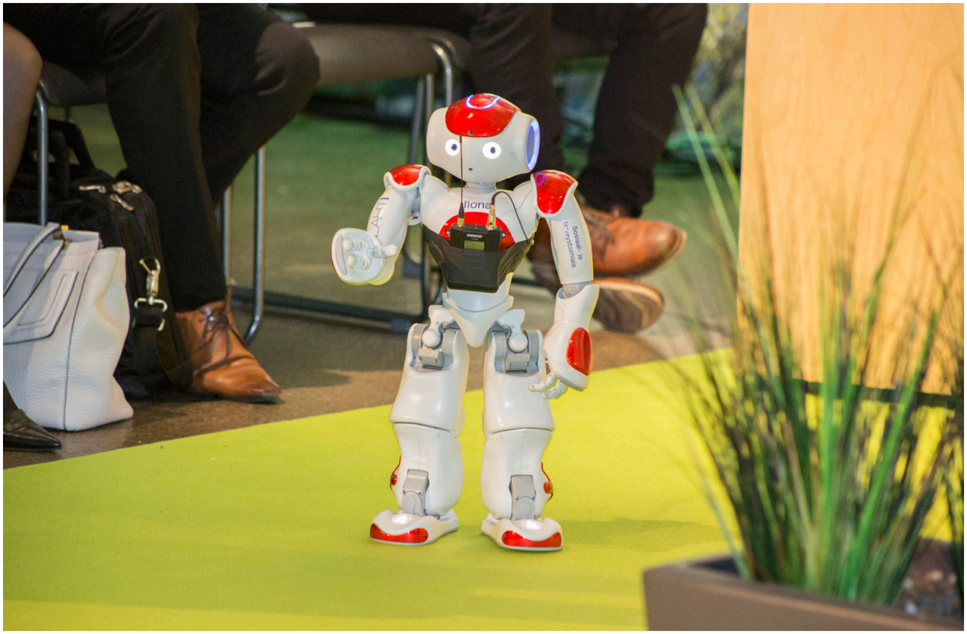

Figure 2. For the first time in Cleantech Venture Day's history, a robot gave part of the opening speech. Working with the Ilona robot was made possible by the collaboration of the City of Lahti, Lahti UAS and LUT. (photo Jani Wallenius)

NIA offers companies the opportunity to showcase their innovations on an international forum and a way of helping corporations find new solutions. Twitter: @CleantechDay @ NIAccelerator

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Katerina Medkova and Brett Fifield

Circular Design - Design for Circular Economy

Background

Economic growth, in our linear economy, is measured by gross domestic product, in other words the growth in throughput or the value of products and services produced. This pattern creates the consumer society, which assumes an abundance of resources and shapes behaviour around accumulation of stuff. This accumulation of stuff is manifested in three forms: non-reparability, functional obsolescence and the power of marketing. As societies attempt to mirror the lifestyles advertised in media, they fuel the unsustainable demand for new and improved products.

The linear-structure design focuses on the product itself and how it is packed. The cheap and readily available resources and a hunger to produce and sell more and more products have made manufacturers as well as consumers blind to what happens with the products after they break down or become obsolete. Sometimes, planned obsolescence has been built in, even for products that could have lasted longer, in order to make space for brand new ones.

Traditionally, design has not considered product impact during its birth and use, and what happens when it is not in use anymore and thrown away. Products were not designed to last, allowing for new models to fulfil the needs and temptations of consumers. The emphasis was laid on product aesthetics and attractiveness, and brand promotion by applying smart marketing. As a result, our consumer society has been actively seduced by new and better goods and services, leading to massive resource consumption and waste.

Pervasive seduction marketing and even cultural norms compel us to buy more and more products that we do not really need. When the product breaks down, it is either financially not viable to repair it, or it is simply non-reparable. Innovation and technology development make us buy new models, as it is almost impossible to upgrade a product. As a result, huge quantities of goods end up in landfills, creating detrimental environmental consequences with enormous loss of materials, energy, water and labour embedded in them. As Sophie Thomas, a director of Circular Economy in RSA, stated, ‘We are convinced that waste is a design flaw.’

Having more ‘sustainable’ products, partially made of recycled materials, or being more energy-efficient than their previous versions, is not enough. For instance, Bakker et al. (2014) indicates that even though the energy consumption of the products studied (laptops and refrigerators) has been reduced considerably, their life cycle has been counterbalanced and, therefore, the overall environmental impact is negative.

Circular Design

Design in the circular economy is complex and requires a transformation in thinking, to shift 'from the current product-centric focus towards a more system-based design approach'. Circular design searches for a way to deliver a product or a service that is functional and made of optimum materials to deliver the best performance while minimizing its negative impact along the whole life cycle.

Circular design challenges a generation of products and materials in a way that minimizes the use of primary raw materials. As the name implies, the focus of circular design is on curtailing the value loss embedded in these products and materials, by keeping them circulating in closed loops. These loops, such as reuse, repair, remanufacture, refurbishment or recycling, extend the product's life cycle and improve resource productivity. At the end of the life, inspired by nature, a product, its part, or a material will become a resource within or even outside of the original application. Components could be reclaimed for remanufacturing. Materials can continue their life through recycling. The circular economy applies a combination of these strategies with a preference to the activities closer to the user or consumer, in other words, as in the inner loops of the diagram in Figure 3.

The key lies in how a product or a material is designed and how different aspects and requirements are balanced. The design phase influences the product's life and the ease of its reprocessing. Designers have the opportunity to consider the durability, compatibility, modularity or multi-tasking functions of the designed products. However, this does not rest solely on designers' shoulders.

Both circular design and sustainable design focus on environmental, economic and social aspects. However, they differ significantly in how the goals are attained. The latter puts a product, value preservation, and its eco-impact on the planet into the central role. On the other hand, circular design commences with the optimization of the resources' economic potential through new business models. At the same time, emphasis is on resource restoration and quality of life.

New Business Models

A project called The Products That Last, led by the Industrial Design Engineering Faculty of the Delft University of Technology, focused on discovering new business opportunities, models, and design strategies for the circular economy.

"Every new product development effort should be coupled with the development of a business model which defines its "go to market" and "capturing value" strategies." The Products That Last project names five business model strategies to help businesses and designers in a thinking shift towards a circular economy.

There are five business models for long-lasting products. The (1) classic long-life model focuses on the sale of high-quality long-life products. The (2) hybrid model combines durable products, designed to be easily disassembled, with short-life and fast-cycling, repeatedly sold consumables. The (3) gap-exploiter model uses the leftover value in products or components that are still functional, broken or discarded and resells repaired or refurbished products, components or services. The (4) access model provides access to a product rather than its ownership. The (5) performance model provides product performance rather than the product itself. Products are designed for easy maintenance, durability, and long life. The last two models listed above provide capability and services to a user without physical ownership.

Similarly, Bocken et al. (2016) discuss six potential business models for a circular economy: (1) access and performance; (2) extending product value through life extension strategies, which is similar to the gap-exploiter model; (3) classic long life; an extra model, (4) encouraging sufficiency through principles, for instance, products' durability, upgradability, and non-consumerist approach to sales; (5) extending resource value, which is also similar to the gap-exploiter model; and (6) industrial symbiosis, a process-oriented solution, which uses residual output to become a feedstock for other processes.

Strategies for Circular Product Design

Based on the Products That Last research, six strategies for Circular Product Design were identified (Fig. 1), indicating an impact on product integrity. The aim of these strategies is to counter obsolescence and keep a product as close as possible to its original purpose.

1. Design for Product Attachment and Trust, sometimes called 'design for emotional durability', is regarded as the most challenging strategy. It aims at responding to an emotional obsolescence by creating long lasting products that people will love and trust.

2. Design for Product Durability creates products resistant to wear and tear, in other words, physically durable products. Here, the material choice is crucial in overcoming functional obsolescence.

3. Design for Standardization and Compatibility fights against systemic obsolescence by designing product parts and interfaces suitable for other products and aims at multi-functionality and modularity.

4. Design for Ease of Maintenance and Repair counters functional obsolescence by ease of maintenance to keep a product in working condition, and non-challenging reparability and replacement of broken parts to extend the end of the life.

5. Design for Upgradability and Adaptability avoids systemic obsolescence by maintaining product usability for a long time by upgrading its value and performance, and at the same time, by adaptation and modification towards the changing needs of a user.

6. Design for Disassembly and Reassembly also avoids systemic obsolescence by designing products and their parts to be eventually easily separated and reassembled. This strategy has a big impact on component and material reuse and remanufacturing.

In addition, Bocken et al. (2016, 310) propose Design for Reliability, which relates to products designed with a high prospect of no-failure operation through a certain time if the manufacturer's use and maintenance instructions are observed. Also, Design to Dematerialize, reducing the amount of materials required but still sustaining the core functionality, should be taken into account. Dematerialization also means inventing brand new solutions with no or less material required.

SIX DESIGN STRATEGIES FOR LONGER LASTING PRODUCTS

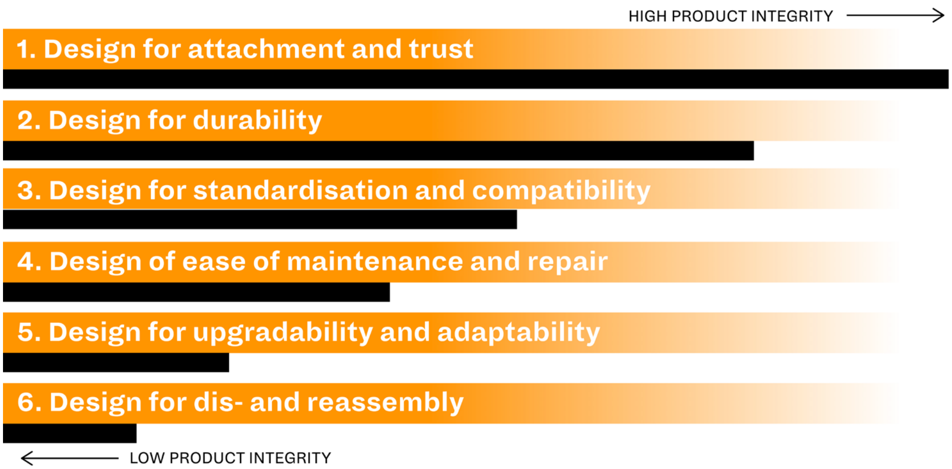

Figure 1. Six Design Strategies for Longer Lasting Products. (Circular Economy 2015)

Practical Examples

Clocks are available everywhere, for instance in our smartphones or computers, and still we wear watches on our wrists. Classic watches are typical examples of design for attachment and trust. They are of high quality and last long (Design for Durability) and thanks to a stylish classic look can be inherited from generation to generation. Miele, a manufacturer of high-end domestic appliances, is well known for its long lasting and durable products. Both of the design strategies are also reflected in a product called My Paper Bag, made of ecological tanned leather with a wooden bottom in a Fair Trade workshop in India. The bag has a classic look, is durable and the leather appearance becomes even more attractive over the years. The same could be applied to the original Swiss army knives from Victorinox or cast iron pots and pans from le Creuset. The Gaggia Classic home-use espresso machine has not changed its design since the 70's. It is durable, high-quality and offers online guides for maintenance, repair and upgrade.

Bugaboo Cameleon is a high-quality multifunctional baby carriage adaptable to every age (from newborns to toddlers) and the type of surface it is used on (Design for Upgradability and Adaptability). It is durable and long lasting (at least 15 years - Design for Durability). Bugaboo Cameleon is easily adjustable and transformable. Different colours and many accessories are available (Design for Product Attachment and Trust).

A combination of all the above-mentioned design strategies is applied in Google's project Ara. It is a customized, modular mobile phone with swappable parts: a high-resolution camera, a louder speaker or a better battery (Design for Attachment and Trust, Durability, Standardization and Compatibility, Ease of Maintenance and Repair, and for Dis- and Reassembly). During the designing stage, a free space for new functions and applications that do not yet exist is reserved to overcome systemic obsolescence (Design for Adaptability and Upgradability).

All the above-mentioned examples represent the classic long-life business model.

The Reef NWS sustainable sandals are made from non-toxic materials and glues with minimum material use in mind (Attachment and Trust). The smart puzzle-like cut enables to minimize the waste to less than 1% and allows the production of seven more pairs of shoes per yard of fabric. For instance, the stitching, logo, threads and upper-liner are made of 100% recycled water bottles (PET). The footbed contains 51% post-industrial recycled ethylene vinyl acetate (EVA), whereas the common producers' standard is only 31% EVA. The smart design of the sole mould reduces waste by 20%. Also, Freitag bags and accessories are made from used products and materials, such as truck tarps, car seat belts, air bags and bicycle inner tubes. This makes their products unique (Attachment and Trust) and durable due to tear resistant and waterproof materials. Both cases give used material a new life in a different product and thus represent the gap-exploiter model.

gDiapers combine long lasting breathable gPants together with short-lifespan disposable inserts, representing the hybrid business model. These 75% cellulose-based inserts are flushable and compostable (only the wet ones) and Cradle to Cradle Certified™ Silver (Attachment and Trust).

Sandwichbike' s bicycles consist of a durable frame made from four weather-coated plywood plates (PEFC certified) and aluminium cylinders that squeeze the other necessary components into a sandwich-like structure. The eco-friendly and eye-catching product is delivered in a flat cardboard box and easily assembled by the customer (Product Attachment and Trust, Product Dis- & Reassembly). All necessary tools are included. In addition, the different parts of the bike can be interchanged across different models (Product Standardization & Compatibility).

Examples of the access model could be public bicycles, online access to accommodation (Airbnb), cars (Zipcar, Greenwheels, Car2Go), or movies (Netflix) and music (Spotify). The representatives of the performance model are, for instance, Phillips selling lighting service via their Pay per Lux system, Michelin selling kilometres, not tyres, and Rolls Royce's leasing programme for aircraft engines.

Tools and Methodology for Designers

Circular economy emphasizes the importance of cooperation and collaboration across various fields; producers, suppliers, remanufacturers, logistic and recovery managers, users/ consumers, academia, scholars, policy makers, and researchers and developers. Especially in the design phase, active communication between designers, material experts and engineers, environmentalists and economists, and end users is essential for innovative circular design decisions.

RSA (2013, 2014) created a tool for designers, the Circular Network Diagram (Fig. 2), in which they mapped different stakeholders engaged during a product's life cycle that should be involved in the dialogue on changing design towards circularity. The Circular Network Diagram divides these players into segments of a circle, which emphasizes the equality and importance of all stakeholders' collective views and insights. These general segments are: consumers and users, design, academics and education, investors, policy makers, resource management, material experts, manufacturers, and finally brands and companies. The segments are then split into more detailed sub-segments.

Most of the current solutions predominantly focus on "end-of-pipe" solutions, such as recycling, which more accurately might be referred to as downcycling and major loss of embedded value. The resource challenge should not be approached from the end. Instead, we have to start at the beginning of the life cycle of the product, component or material, before it is physically born, during the design phase. Also, Hatcher et al. (2011) recognize that the product's impacts and costs during its lifespan and during reprocessing at the end of life are determined during the design stage.

To reiterate the earlier findings, 'Product design is the starting point of the resource challenge' for creating a sustainable and systematic approach to reconfigure our resource dependency while supporting well-being and economic growth.

According to The Great Recovery research, conducted by the Royal Society for the Encouragement of Arts, Manufacturers and Commerce (RSA), four models can be distinguished for circular design: design for longevity, design for leasing or service, design for re-use in manufacture, and design for material recovery. The circular economy

Figure 2. The Circular Network Diagram. (RSA 2014)

principles are expressed in the Four Design Models diagram in Figure 3, where the loops closer to the user are the most powerful. Also, the model enables designers to understand who possesses the key knowledge in all four loops.

Design for Longevity promotes long-life and reliable products that can be easily dismantled for upgrade or repair by the user. Security seals or glued components should be avoided in order to avoid possible warranty loss or component breakage. Open-source manuals, reasonably priced spare parts, and services should be available.

This all leads to a relationship development with the user and his quality association with a product that lasts and thus brings an emotional value to the consumer to use it longer or pass it on to somebody else rather than simply dump it.

Not everything should be designed for longevity. There is a wide spectrum of products with a different length of life cycle: short, medium and long. A very short life cycle should be predetermined for food packaging and it should be biodegradable or easily recycled. A medium long life cycle can be seen in electronics, which can be easily repaired and upgraded to extend the life cycle. And finally, products meant for a long life cycle, such as pots and pans, furniture, and jewelry should be durable not only physically but stylistically as well.

Design for Leasing/Service changes product ownership into a product as a service business model. As the product and, therefore, the material ownership stays with the producer or manufacturer, the designed products are durable and long lasting in order to maximize efficiency. The value in the product is therefore kept within the system. Product as a service can provide more users with high-tech products and higher specifications of design, which would normally be out of reach for them.

Another way could be selling an outcome. An example of this is ProjectBox, a package of quality professional tools, materials, and detailed instructions on how to complete a required job. Purchasing cheap, one-time-used tools can be avoided, and time and resources are saved. When the job is done, the ProjectBox is collected, together with the waste and unused materials.

Design for Re-use in Manufacture aims at the return of old products or their components back to manufacturers for replacing faulty or obsolete parts, to be subsequently resold. These products are designed for longevity and easy disassembly on a manufacturing scale, in order not to waste the value embedded. The key enablers are reverse supply chain management and supporting legislation.

According to Bakker et al. (2014), it is essential for designers to attain a deep knowledge of ‘how the product and its parts wear and tear, and of how to decide which parts should last, and which should be replaced, and when’ if the product is expected to be refurbished several times during its life cycle. Many aspects ought to be considered: the functionality, appearance, and costs.

Easy non-destructive and quick disassembly can be attained, for instance, by placing a small pellet next to a snap-fit joint. Using a vacuum, the pellets expand and open the snap fits, and thus disassembly of a product with high-quality material reprocessing and recovery is possible.

Despite the significant economic, environmental and employment benefits, remanufacturing continues to be undervalued and under-recognised, reveals the recent Remanufacturing Market Study (2015), sponsored under Horizon 2020. In Europe, knowledge transfer across industrial sectors is missing, both for remanufacturing and recycling.

Design for Material Recovery recaptures materials and products to be reprocessed and recycled into new materials. This involves components that cannot be repaired or upgraded but also fast-flowing products and materials such as packaging.

Using single rather than complex materials and avoiding toxic materials increases recyclability. Also, developing accreditation systems for secondary materials will boost the confidence of the designers, manufacturers and consumers.

The below-mentioned tool (Fig. 3) serves only as a guideline for designers, as no one-fits-all solution for designing circular products exists. Different life extension and repurposing strategies are needed for different product characteristics, such as resource intensity, life expectancy or technological and style maturity, and business limitations, such as legislation or market dynamics.

Various methods, indicators, and tools can guide the designers or companies in their decisions. So far, these measurements have indicated only specific business drivers or were designed for linear operations. According to the Circularity Indicators Project (2015) of the Ellen MacArthur Foundation (EMF), no circular economy metrics exist. A complex methodology providing the systems thinking still needs to be developed.

Life Cycle Assessment (LCA) and Cradle to Cradle (C2C) only partly indicate circularity and exclude material criticality, as seen in Figure 4. The LCA tool evaluates environmental aspects and impacts of a product or a service during its entire life cycle. C2C is a framework of biological and technical nutrient cycling and it aims at eco-effective, waste-free production.

In 2015, Circularity Indicators (CI) methodology and a web-based tool were developed by EMF, together with Granta Design, and co-funded by the European Union, to measure a company's "linear to circular" transition progress. The CI tool only deals with technical cycles and non-renewable materials. The focus is on the material flow restoration level of products or companies. Circular Indicators are particularly intended for product designers to guide their decision making, and can serve internal and external company reporting, procurement and investment purposes as well.

Circular Indicators consist of the main Material Circularity Indicator (MCI) and optional complementary indicators for additional insights: complementary risk indicators (material price variation, material supply chain risks, material scarcity and toxicity) and complementary impact indicators (energy usage, economic benefits, or CO2 emissions). The results obtained from the MCI range between zero and one; low values show linear flows and the maximum value of one represents fully circular flow. The LCA and MCI could be combined as many of their input data are identical.

The success of circular design or circular economy in general depends on transforming the whole system and redesigning our thinking and, ultimately, the collecting and return systems. The same importance should be paid to establishing of infrastructure for various

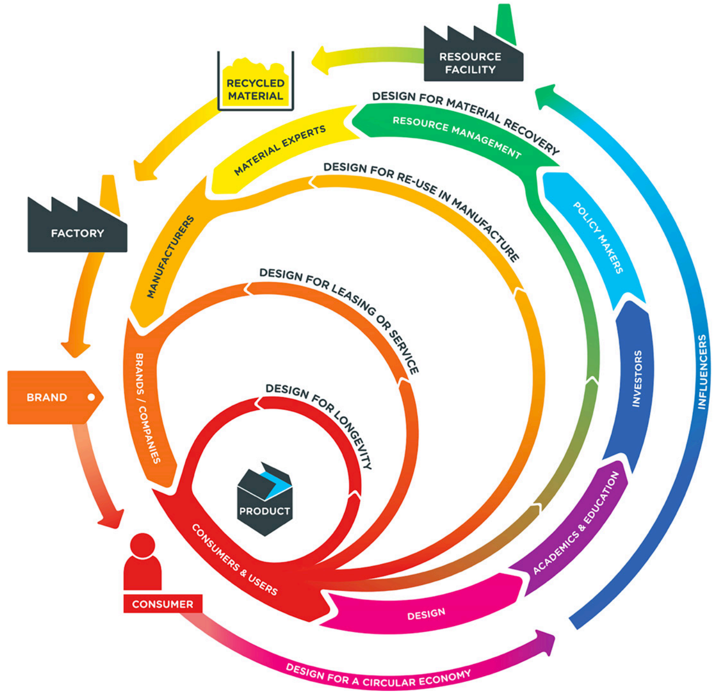

Figure 3. The Four Design Models. (The Great Recovery 2013)

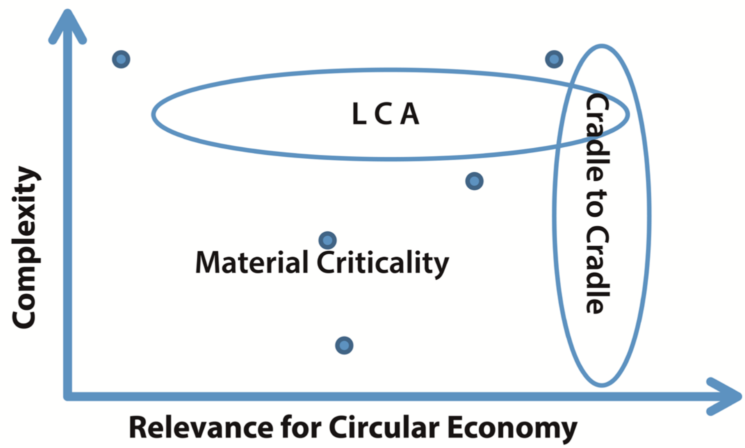

Figure 4. Stakeholder Perception of Existing Indicators (Circularity Indicators 2016)

rejuvenating processes (repair, rebuild, recycle, etc.), and the exchange of information and knowledge via active dialogue between various stakeholders to spark innovation. By creating ongoing and circulating material and information flows, a product, a component or a material will get to the right and most value-saving player in the system at the time, in order to extend product life or give it a second or multiple life cycles. Changes in technology, products and markets are dynamic, and so should be the circular design strategies, policies, and processes.

Education

The shift towards a circular economy is associated with a change in our attitudes, mindsets, perceptions and behaviour. It requires a change in the way of thinking and acting, going towards sharing and collaborating. Educational institutions are responsible for implementing circular economy principles into their curricula and developing the required new skills and competencies. Based on the RSA (2014) study, action-based learning is recommended, including teardown workshops and various supply chain site visits.

Cross-disciplinary education can be beneficial as it encourages people to see world views from a different angle. At the same time, it helps people understand complexity and systems thinking. Multi-disciplinary education not only broadens designers' knowledge of other fields, it also offers them an opportunity to practice communication and problem-solving strategies with non-design students. This will be essential when dealing with colleagues and clients from different backgrounds in the future.

New competencies, knowledge and working methods for core areas of functional circular design need to be developed. According to the EMF, these areas include "material selection, standardized components, designed-to-last products, design for easy end-of-life sorting, separation or reuse of products and materials, and design-for-manufacturing criteria that take into account possible useful applications of by-products and wastes".

Circular Economy Design Concept

Based on the literature research, a Circular Economy Design Concept is depicted in Figure 5. Circular economy design is the engine of the circular economy. The vehicle for changes is Redesign. Redesign occurs by focusing on the four lines of discussions (Systems Thinking, Awareness, Mental Shift, and Communication) around the four elements (Circular Design Strategies, New Business Models, Cross-disciplinary Intelligence, and System Conditions).

The three dimensions of People, Planet, and Profit both drive and are driven by circular design and influence the redesign processes in the circular economy. In Figure 5, the overall mutual impact of circular economy design on the three dimensions of People, Planet and Profit is emphasized by the bidirectional drivers. Also, these three dimensions are symbiotic, because changing one dimension has a direct impact on the other two dimensions. Not only does the circular design have an impact on the social, environmental and economic aspects of the circular economy, but People, Planet and Profit influence the design at the same time. Continuous redesigning enhances the understanding and appreciation of the four elements.

The first element, Circular Design Strategies (1), consists of various life-extension strategies. It aims at designing long-lasting and durable products that are easily maintained and repairable, upgradable on a modular basis, and standardized. It ensures easy dis- and reassembly, and product structure adaptability.

New Business Models (2) are closely bound to Circular Design Strategies. These models focus on long lasting products offered as services or sharing platforms, enabling a product access or performance, rather than its ownership. As the focus of the main producers and manufacturers is not on volume anymore, additional revenues are generated from additional services offered along the entire product life cycle to counteract the drops. The aim of the new business models is to retain products, components, or materials of the highest utility and value. It includes easy maintenance, cost-effective repair, refurbishment, and remanufacturing. Additionally, reselling and remarketing of used products are included, as the first user is not meant to be the last one. The re-commerce and value recapturing activities require a functional take-back system and reverse logistics. The supply chain is no more one-way only, but it includes both directions: to the market and from the market.

Systems Thinking is vital for the circular economy concept. As Joël de Rosnay proposed in 1979, the world should not be looked at through a microscope, to see all the details, nor through a telescope, to see the distance, but through a new tool, a macroscope. The macroscope is a symbolic tool made of various methods and techniques that diminishes details but observes the big picture and magnifies what links things together. "The roles are reversed: it is no longer the biologist who observes a living cell through a microscope; it is the cell itself that observes in the macroscope the organism that shelters it." In order to think in systems, Cross-disciplinary Intelligence (3) is necessary. As the name implies, the intelligence comes from various sectors, industries, and players, and can be obtained through cooperation, collaboration and new partnerships. Furthermore, it involves mapping and evaluation of various aspects: social, environmental, economical, cultural, emotional, physical, and technological. Looking at the systems holistically is a prerequisite for a functional circular design and economy.

The fourth element, System Conditions (4), empowers an environment that supports circular economy. Just to name a few, sector-specific legislation, incentives, mandatory and voluntary programs, financial instruments to spur technological innovation and R&D, functional infrastructure, and information and material flows encourage the adoption of circular business models. Policy measures can raise consumers' and producers' awareness of circular economy practices and products and advocate the importance of repairability and durability. Development of corresponding assessment tools and methods, and quality standards, helps the transition towards a circular economy. Moreover, new skills and expertise are needed for these new ways of thinking, working, valuing, and new lifestyles. As the circular economy is a dynamic and developing concept, circular design reflects this evolution by continuous redesigning and system innovation. For that, a constructive debate and information sharing amongst relevant stakeholders must be facilitated. Also, the circular economy drivers, reasons, benefits, and challenges need to be communicated, in order to raise the awareness and importance of this topic. Only then can a mental shift and attitude change take place.

Conclusions

Design for a circular economy combines leveraging of the four main elements (Circular Design Strategies, New Business Models, Cross-disciplinary Intelligence, and System Conditions) with the four lines of discussion. By focusing on redesigning processes, the lines of discussion reflect the reprioritization of our choices. Circular design thinking is not a marketing buzzword. Circular design takes into consideration People, Planet and Profit, and is embedded as a core strategy for businesses and consumers.

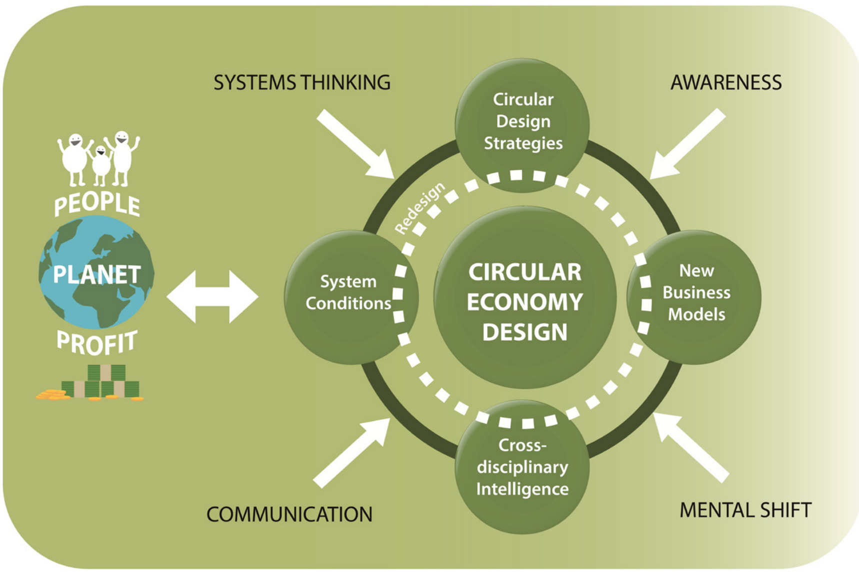

Figure 5. Circular Economy Design Concept.

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Noora Nylander

User Experience Design as Sustainable Design Strategy

Thinking of objects as services for the user

Service design is a process where the customer entering the service can face it through many phases and touch points that are relevant to the service. Packaging is an object but it can provide service type of experience to the user. Packaging provides multiple contact points which are happening between the customer, or the user, and the product itself. It communicates, provides user convenience and transports as well as protects. Packaging has been said to be a silent salesman. Naturally, this is true since it communicates the brand message, and good packaging design sells. However, packaging design for user experience can provide even larger benefit to the brands. Sinne (2015) describes that the usual business claim is to provide" the world's best customer service" when in reality the business is aiming to be "the world's best service". On the other hand, instead of those claims, the customer's goal is to be "the world's best customer". The era of social media is changing the communication between customers and brands a lot. Before, it was important to create for example brand loyalty but now it is important to create a dialogue between customers and brands. Davis & Bigornia (2015) describe how the brand enthusiastic millenial generation feels about loyalty towards brands. They are more and more willing to have a dialogue with the brands e.g. through social media. This means they provide information about themselves freely, but they want brands to listen to them. Otherwise they will go for something else.

Figure 1 shows an example from Bali. It shows wasted worshipping packaging in a ditch. This is a good example how user behavior affects sustainable issues. For ages, people in Bali have been making these kinds of packaging out of plant-based materials. After the daily use they are thrown away into nature. This would not be a problem with a biodergrable material like plant leaves but nowadays people are also behaving this way with for example plastics. In Bali the packaging waste now ends up

Figure 1. Wasted worshipping packaging in Bali. (photo Noora Nylander)

everywhere, creating an environmental problem. Materials and technology do not match people's traditional and intuitive behavior. Thus, we face two kinds of user experience situations from the sustainable angle: firstly, how to encourage the right kind of sustainable behavior, by educating and taking care that people intuitively behave in the correct way on their own terms. Secondly, how to create a better dialogue and involvement between users and products, to encourage sustainable user behavior.

Designing for and with users

One important driver in design thinking is user-centered thinking, which means that we are putting customers – here users – in the center of the design process and consider their segmentation, life style, needs and wishes to provide information to start the design process. We observe users' life as it is and even try to co-design with users to find their input. Good design can intuitively lead into better user behavior and this way provide natural and pleasant user experience.

In autumn 2016 packaging design students did their user-centered design project for elderly people and children. The task was to design a cookie and vitamin package for the focus group and keep the users in the focus of the design process. The user testing phase shows what the intuitive reactions of the users are towards the design. In the system level we are designing for example cookie packaging. However, an elderly gentleman says: ”Who wants to go dancing?” about the accordion-shaped packaging. ” I could use this for a mouse carrier bag”, says a school kid about the packaging. This user feedback shows how the objects we design start to live their own life with the users and their personality, and we as designers can use this observation data to create a bridge to provide more sustainable user experience. Thus, we should hold on to these moments and use them to change the objects.

Designing scenarios for the future

Bon Bon, a packaging concept by Roberta Parmose and Xinue Du (2016), is an example of a sustainable design project. It shows how important it is to define the user problem and its relation to sustainability very well. In this project the students tackle the single household user problem. From the user convenience point of view, a monodose packaging of pasta sauce would be a better option by providing variation and minimazing food waste. Additionally, students reflect on the process of preparing and heating the food, to create convenience. On the other hand, the monodose packaging means many times more material layers and this is not a very sustainable solution in the system level. The question here is again how to provide user convenience and, at the same time, systemwise sustainable solutions. In the course assignment the students start to tackle the problem by using new edible and biodegrable packaging materials and creating their concept around them. Figure 4 shows the final user scenario. However, to get this result, students needed to conduct several user tests and to quick prototype their idea several times. Initially, the idea seemed very complex but in the end it became simpler both from the user and the system point of view. This is the aim of quick user testing in a design thinking process.

Figure 2. Testing with users. (photo Törnqvist)

Figure 3. The accordion packaging concept. (photo Törnqvist)

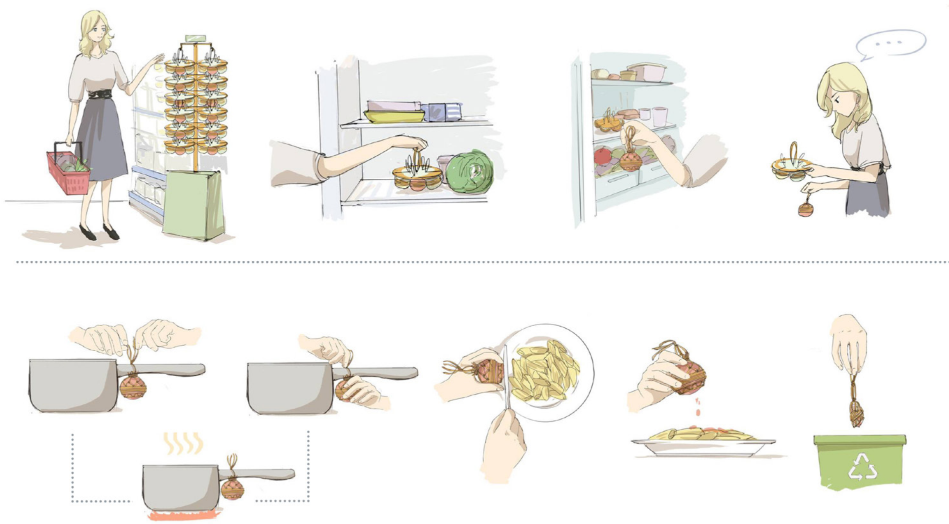

Figure 4. The user scenario for Bon Bon packaging concept. (Parmose and Du)

This is how students describe the concept (Fig. 4 and 5):

”Bon Bon is a fresh cooked sauce product packaged for singles. We decided to create a product targeted at singles as consumers of cooked sauce. The existing packaging does not satisfy their needs. In fact, since they live alone and cook by themselves, it is hard for them to finish big boxes of sauce with the same taste within a few days, as you should do with the existing cooked sauces. Therefore, we wanted to focus on this issue, to improve their lives, allow them to save time and energy in cooking, create a healthy lifestyle and meet the goal of being environmentally friendly as well.

The design concept of Bon Bon is to simplify the way of cooking pasta. In this package design, you can see five different sauces stored in small balls with a straw net, and tied together in a carton board holder. While cooking pasta, you do not need to use another heating pot or pan for the sauce, just choose the ball you prefer, hang the ball on the handle of the pot you use to cook pasta, and the sauce will warm up with the surrounding heat of the pot. Then, you take the ball and use a knife to cut it from the bottom, and the hot sauce can be squeezed out.

Our package changes the normal way of storing sauce: we use small balls with a one-meal amount stored in individual packages. This idea solves the problem that singles have: to eat up all the sauce inside the boxes or bottles after opening them. Five individual packages also give the chance to choose a different taste each time. For eco-friendly consideration, we chose to use for the sauce balls a new edible material like Wikipearls, which are soft and squeezable. That kind of material could conceptually tolerate the heating temperature without melting, with the appearance of a transparent shell. This material would also be organic, bio-degradable and zero polluting. For the outside of the balls, we chose straw string to make the net-shape package. The straw net can hold the balls inside and with the braided handle, the straw net is flexible to adjust the handle of the package, so it can be fixed to different sizes of pots and can be quite easy to hang beside the pot as well. The straw is heatproof, so after heating with the pot, the users can easily take it off the handle and squeeze out the ball inside the net without hurting their fingers. All sauce balls are kept together with a carton board holder. This round-shape sheet has instructions on how to use the product and all the information on it, so it is clear to see and easy to understand. On top of the whole package, all the straw handles are held together by a piece of paper with a logo and barcode on either side. After finishing the sauce inside the ball, singles can just throw everything in the organic waste, because everything is biodegrable."

Creating better sustainable behavior?

From the user-centered point of view, packaging design aims to create a good experience between the user and the product. Sustainable design, however, also involves many aspects of system thinking. This is the object level of the design. By starting from creating user experience, not just designing objects, we can create a better link between users and systems. While doing that, we can also create better sustainable behavior. Without user participation, the sustainable objects cannot reach their goals and become sustainable user behavior as well.

Figure 5. The Bon Bon packaging concept. (Parmose and Du)

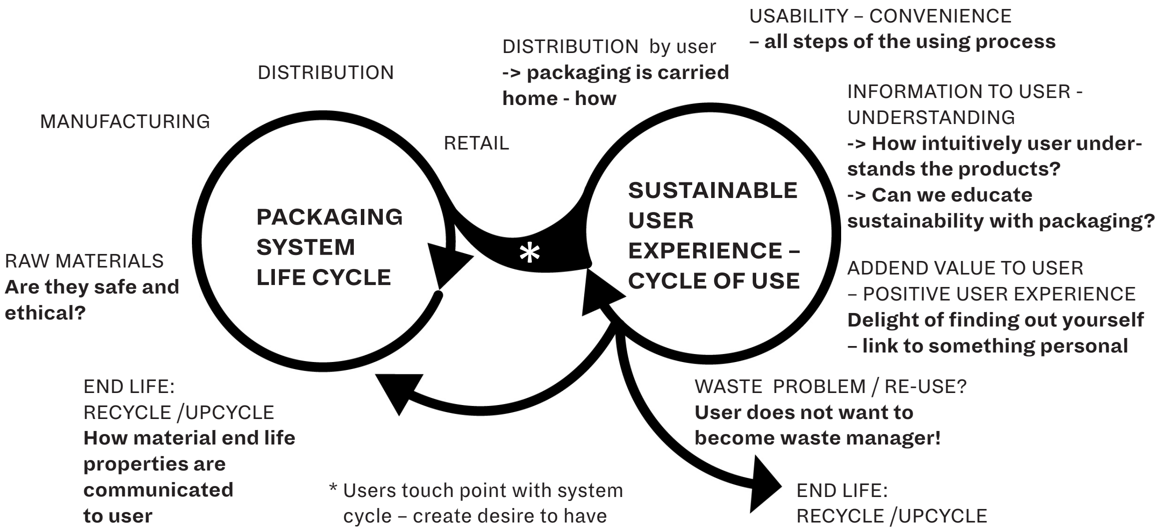

Figure 6. Sustainable packaging design: connection between systems and user experience. (Noora Nylander)

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Sustainability analysis of the agricultural and food systems in the Lahti Region Global situation and challenges in agricultural and food (agri-food) production

It is estimated that approximately 40% of the Earth's surface area is harnessed for food production. With the increasing population, there is a pressure to increase food production in the forthcoming years. According to Nelleman et al. (2009), the demand for food will continue to grow as a result of population growth (expected to be 9.6 billion by 2050), increased incomes, and growing consumption of meat. In the past, the world's agricultural and food (agri-food) production increased thanks to higher-yielding crop varieties, extensive use of irrigation and fertilizers, and expansion of arable lands, but now there are new challenges facing food security: the carrying capacity of ecosystems, resource scarcity, and climate change.

One of our greatest present and future challenges is finding out how to provide food to our increasing population. However, this challenge is no more about our ability to produce more but about our ability to do it in a sustainable manner. Thus, the sustainability of our ecosystem services has become a crucial factor in the production of agri-food commodities, because our current systems of food production and consumption are putting enormous pressure to our declining ecosystems. The current agri-food production has various environmental impacts such as eutrophication from excessive fertilization, contamination caused by pesticides, and climate change. It also contributes to land-use change, biodiversity loss, and excessive use of freshwater. Additionally, current inefficiencies in agri-food production, energy use and food products management are causing food loss or waste, which is about 30 -50% of the food intended for human consumption. Furthermore, the 30 million tons of fish needed to sustain the growth in aquaculture correspond to the amount of fish discarded at sea nowadays. As a possible consequence, an estimated 5-25 % of the world's agri-food production may be lost by 2050 due to climate change, land degradation, and water scarcity, which could lead to additional uncertainty in our food security. Other challenges relate to social and economic sustainability of the global agri-food systems, such as economic efficiency (i.e. cost of food economy against the losses and waste), social responsibility (i.e. quality of life of the people working in the sector), growing inequalities in the access to sufficient nutritious food and related health impacts, growing dependence on trade, financial volatility in the agri-food market, and governance (i.e. decision and policy making).

These global trends and challenges are, to a great extent, reflected in the condition of the agri-food systems in Finland, although manifested in different levels, forms and indicators. Food manufacturing (the food and beverage, grocery, meat and fish, and fresh produce industries) and agriculture (farming enterprises) are the main sectors of the food production chain in Finland. Despite the good economic performance demonstrated by the Finnish agri-food industry, factors related to environmental and governance aspects have generated concerns among the stakeholders of the Finnish agri-food industry. These aspects include the environmental impacts such as eutrophication, contamination, and inefficiency losses. A good example to highlight this concern is the city of Lahti, located in the Päijat-Häme Region. In Lahti, the food industry is making a significant contribution to the Finnish economy, but it is also generating large quantities of waste and side-flows, as well as consuming large amounts of fertilizers, energy, and even water. The agri-food sector is the main source of pollution, generating large amounts of sediment and chemical flows and therefore causing eutrophication in the local water systems such as Lake Vesijärvi.

Sustainability analysis is one of the main tasks of the ongoing REISKA project, dealing with resource efficiency in Lahti, and funded by the European Regional Development Fund and Päijät-Hämeen liitto. REISKA specifically focuses on the economic and environmental performance of Lahti's agri-food systems and analyzes the performance of selected sectors in terms of eco-efficiency and sustainability in general. In the big picture, this research identifies practices and technologies that can support the transition towards circular economy. Therefore, the research presents an opportunity to put forward the challenges faced by the agri-food sector and to mobilize stakeholders to ensure their active role in delivering sustainable food and nutrition security.

Agri-food systems in the Lahti region

Figure 1 presents a contingent model of the agri-food systems in the Lahti region. The model streamlines the primary sources of agri-food products, which are mainly agriculture (cereals, grains and field crops), animal husbandry, vegetable production, and other production systems (fisheries). With a life-cycle perspective, the model simplifies the flows

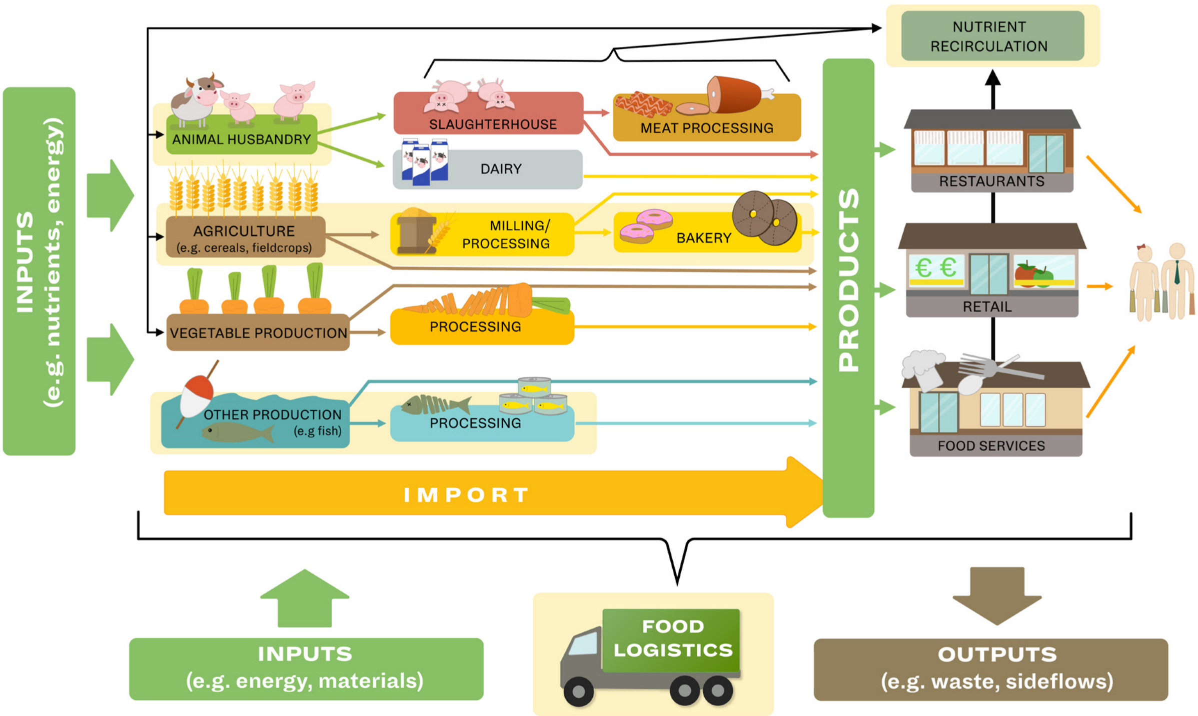

Figure 1. Agri-food systems in the Lahti region.

of inputs and outputs to and from the various processes. Hinging on the concept of circular economy, the model emphasizes the input-output flows, waste streams and side-flows as well as nutrient recirculation within the system.

Based on this contingent model, the different sub-systems and processes are currently being studied using case study methods. The case methods include life cycle assessment (LCA), literature review, and expert interviews, which are used depending on the applicability of the method for each case. In addition, the latest sustainability-related criteria, legislation and scientific discussions are taken into account. Since the main actors in the different sub-systems are small and medium enterprises (SMEs), farmers and producers, the research is carried out by recognizing them as the key actors in different stages of agri-food production. Their cases are analyzed to find out the strengths and weaknesses in their operations and to suggest some improvement measures for a more sustainable production. Importantly, since each sub-system or process is rather complex, the research project is primarily focused on the analysis of the main production streams wherein different aspects of sustainability (i.e. wastes, biodiversity, nutrient cycling, food delivery system) are being studied and analyzed accordingly. The research project is currently ongoing, with focus on different aspects of sustainability presented as follows:

Closing nutrient loops by producing biofertilizers via the biogas process

Organic materials such as biowaste or side-flows from agri-food production processes can be used as feedstock in the anaerobic biogas production process. The main product of the digestion process is methane gas for energy use but the process also produces digestate, which contains the nutrients of the feedstock. Digestate can be utilized in cultivation processes, replacing chemical and mineral fertilizers. Our research shows that digestate nutrients have a significantly lower carbon footprint than mineral and chemical fertilizers. Therefore, in addition to closing nutrient loops and reducing eutrophication, the utilization of biowaste for biogas production helps to prevent climate change.

Protecting biodiversity by organic sheep production

Sheep are common on Finnish farms. They typically graze in the fields and are eventually used for meat (mutton) production. Unfortunately, the greenhouse gas emissions of sheep production are relatively high. While utilizing sheep is important for protecting biodiversity, because grazing protects biotypes, the cost level on biodiversity-conscious sheep farms is higher than on traditional sheep farms with no biodiversity orientation. In order to achieve economic vitality, biodiversity-oriented sheep farms need to pay attention to green marketing. Biodiversity-conscious farms should target their marketing at green consumers. Green consumers are a small segment, but they are willing to pay more for products (e.g. meat, milk, and wool) from sheep that reflect their values.

Future food delivery systems

One approach in ensuring a food system's sustainability is to pay more attention to the logistics and the possibilities of new technologies and digitalization. Grocery shopping in the Internet may enable multiple sustainability benefits, such as lower emissions caused by delivery transport, less food waste, and better planned grocery shopping. When people are increasingly buying groceries online, the need for buildings and stocking decreases. Buildings tie natural resources and consume energy. Therefore, having a smaller number of grocery buildings, and locating storage buildings more efficiently create sustainability benefits for the whole food chain. More straightforward logistics from the producer to the customer also ensures the freshness of the groceries, which consequently helps to decrease the amount of food waste in households.

Removing nutrients and producing food using local fish

When nutrients have already ended up in the water systems, it is challenging and expensive to remove them. One way to remove nutrients is by fishing non-predator fish, such as roach fish. Eutrophication increases the amount of algae and zooplankton, which leads to a rapid growth of the roach population. Roach is an edible fish but rarely served in meals in Finland. However, there are signs of a growing interest towards its utilization as food. Replacing imported fish by roach could potentially reduce greenhouse gas emissions and could help prevent eutrophication in lakes. At the moment, the challenges are related to the development of business and a market for roach fish.

Evaluating the sustainability of crop (oat) production

When thinking about the sustainability of crop production, one opportunity is to find positive environmental aspects instead of simply focusing on the emissions of the production. One certain benefit in producing oats in Finland is related to the use of water. Oat production requires a lot of water, but the water resources of Finland are not diminished by oat production. Finland's water resources are abundant while such resources can be scarce in countries with warm or tropical climates. While many of the sustainability threats are global, agricultural use of water also causes many local problems, such as eutrophication, desertification or losing local income from fisheries. Consequently, if oats are produced in Finland instead of producing it in regions with scarce water resources, the sustainability consequences could go further than just measuring the emissions of oat production. With a global perspective, the sustainability benefits of oat production in Finland also include many social aspects, in addition to saving the scarce water resources of countries with warmer climates.

Preliminary conclusion

So far, the research has produced a preliminary list of key indicators of sustainability in the agri-food system, for a better understanding of a system where possible improvements, technological development, and policy interferences can be promoted. These indicators are: material flow, nutrients flow (the main cause of eutrophication) and recovery, bio-wastes, biodiversity maintenance, food delivery logistics, compensatory emission, and water-use offset. The performance of SMEs, farmers and food producers (i.e. manufacturers) with respect to these identified indicators will then be used in determining the efficiency and the level of sustainability of the different sub-systems. As the research continues, it is expected to show the big picture of the agri-food systems and industry in the Lahti region and the respective eco-efficiencies of the various sub-systems. Additionally, the research has presented and opened the door of different stakeholders in pursuit of agri-food sustainability, thereby starting the mobilization of the stakeholders to ensure their active role in delivering sustainable food and nutrition security. In addition, when different sustainability aspects are understood, there can be new business opportunities, or the business of existing companies can be improved.

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Learning sustainability in an intercultural way – Case ERREC

The European Union has set the EU 2020 targets to reduce the amount of greenhouse gas emissions by the year 2020 from the reference level of 1990. One of the main objectives of sustainable development in Russia is reducing pollution and the resource and energy intensity of products and services. The long-term goals of the "green" growth requires implementation of environmentally sound, resource saving and innovative technologies.

Sustainability issues are important in every country as we hear news of problems caused by climate change and depletion of natural resources and environmental contamination every day. The Earth Overshoot day is taking place earlier every year and this year it happened already on the 8th of August. It is evident that sustainability and resource efficiency are topics which require us all to develop. This article will tell how a group of universities from Finland, Russia and Sweden learned about sustainability from each other.

Introduction

During the year 2016, Lahti University of Applied Sciences coordinated the ERREC - Environmental Responsibility and Resource Efficiency of Companies project, which aims at starting and strengthening the cooperation between Finnish, Russian and Swedish universities around the topic of environmental sustainability of companies. The activities of the project included two workshops with companies, an intensive week, guest lectures and project meetings.

The partners were interested to join the project because of the opportunity to learn from each other and develop cooperation with their neighboring countries. The partners of the project are Lahti University of Applied Sciences (Finland), ITMO University (Russia), NOvSU University (Russia), University of Gävle (Sweden) and Aalto University (Finland). Each partner has its own education and research profile. This provides a fruitful starting point for the cooperation that is important for the countries around the Baltic Sea.

Background ideas of education and its arrangements

The challenge to overcome global problems caused by unsustainable human activities requires new collaborative approaches to education and learning. Moving from lectures to more participatory and activating education, where students get opportunities to interact not only within the academia but also with companies and where they broaden their perspectives out of their disciplinary, requires changes in education. Blended learning is a new pedagogical approach which consists of a variety of educational methods. It has been noticed that traditional classroom lectures often do not promote students' learning as efficiently as practical project work and learning tasks do. In blended learning contact lectures and meetings are typically connected with virtual learning and e-platforms, also including the use of different tools of social media. The idea of "flipped classroom" means that traditional lectures can for example be listened to at home and contact meetings are reserved for group work within projects.

The pressure to use time and resources more efficiently in education also brings new viewpoints to the educational methods. More independence and activity are needed from the students to proceed with their studies successfully. The role of the teacher has turned into a facilitator of the studies, being primarily responsible for the arrangements and communication. Getting the students motivated and committed to the tasks given to them remains a challenge.

The most relevant competence that students need in the future is to understand the complexities of the concept "sustainability" and to convert the knowledge of education for sustainable development (ESD) into systemic, anticipatory and critical thinking and actions. These skills are a necessity since future professionals will be working globally with companies to whom sustainability is an increasingly important issue on their agenda. Universities cannot only offer teaching on sustainability through fragmentary, single courses, but need to integrate and institutionalize sustainability into all activities. In addition, we need education on sustainable development and for sustainable development in society.

Working life cooperation in partner universities

During the project it was mutually found out that the universities are doing different kinds of cooperation with the working life, but also with the same kinds of elements. Lahti University of Applied Sciences offers education concerning resource efficiency, renewable energies and urban planning in its Bachelor programme in Energy and Environmental Engineering and in the Master programme in Urban Sustainability (in English). One of the recent focuses of the research, development and innovation work is circular economy and industrial symbiosis systems in the Lahti region. Cooperation with the private and public sectors is based on legislative duties and has traditionally been implemented as working- life-based projects with enterprises and municipalities. The cooperation is usually carried out as students' project work, thesis work, and apprenticeships. Experience shows that the most detailed information and opinions are shared when representatives of enterprises are communicating with teachers and students at the same time. General discussions in separate meetings, like "working life forums" or quality meetings arranged on a yearly basis, also provide a communication channel between the university and the enterprises.

ITMO University is one of the 100 top universities of Russia and is currently working on sustainable city development projects, with the focus on the implementation of environmental innovations in public and private companies. ITMO has also a long academic tradition in the food production industry of Russia. ITMO concentrates on resource and energy efficiency analysis, LCA and LCC as well as environmental management and economics and cleaner production on the spot. Among the important tasks of ITMO University is to provide scientific support for the Russian industry's transformation towards lowering material and energy intensity and implementation of the best available techniques (BAT). BATs implementation requires not only technical means but should also be complemented by new business models, and their special characteristics have been considered within the ERREC project. The importance of implementing the new business models in Russian companies is also confirmed by the last edition of the ISO 14001 international standard, according to which environmental performance and social aspects are to be manageable within the life cycle of products and services.

The University of Gävle (HiG) has sustainable development in its vision, mission and strategy for education and research and also works with them in practice in many ways. The University provides experience in environmental management and sustainable development and their implementation in higher education and other organizations. The knowledge related to the project also deals with resource efficiency, waste management, LCA and energy systems. HiG is cooperating with companies by integrating paid training periods in the curriculum, in a form called "Co-op", for example. Completing a degree through Co-op means conducting Bachelor level studies in four years instead of three years and obtaining valuable working experience along with the studies.

The Yaroslav-the-Wise Novgorod State University (NovSU), its Institute of Agriculture and Natural Resources and specifically the Department of Environment and Natural Resources focus on the decrease of environmental impacts of agricultural and industrial manufacturing and food processing technologies. Teachers, students and graduates of the Department of Environment and Natural Resources participate in regional programs on sustainable development and management of household and industrial waste. Experts of the department regularly teach engineers and workers of private enterprises on ecological safety and environmental protection.

At Aalto University sustainability is an integral part of all activities and the aim is to integrate responsibility and sustainability as a cross-sectional theme to all teaching. Aalto is one of the founder universities of the Nordic Sustainable Campus Network (NSCN), including 42 Nordic higher education institutions (HEI). Aalto's School of Engineering (ENG) has always had close relationships to industry, not least to its aim of educating experts for industry. Most of the Master's thesis are done for companies, and joint research projects as well as lectures given by company representatives provide additional means of collaboration. Environmental engineering at Aalto ENG deals with issues related to circular economy, resource efficiency and sustainability appraisal, the focus being on waste management and remediation of contaminated environment. The procedures and methods to measure and monitor sustainability and risk analysis are the key research themes, along with the optimization of logistics through digitalization and incorporation of sustainability in teaching of environmental engineering.

Experiences from the ERREC year

The ERREC project has brought the university partners and their students together several times during year 2016. The activities in the project can be divided into four parts: project meetings, guest lectures, two workshops with companies, and an intensive week.

The meetings started from the University of Gävle, Sweden, in March, followed by a workshop in Lahti, Finland, in May, an intensive week in St. Petersburg, Russia, in October 2016 and ending with the last meeting in Espoo, Finland, in the end of November. The first project meeting was used as a starting point, where details of the project were defined and preparation of the future activities was initiated. The following meetings supported the implementation of the project and its goals. The meetings were meant for the project staff and helped the partners in coordination and getting to know each other.

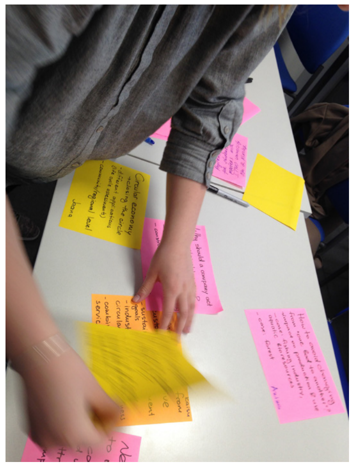
The guest lectures took place along with the meetings. The idea of the guest lectures was for the visiting partner representatives to give lectures on on-going courses of the host institution. When the project started it was evident that many issues could prevent the courses coinciding with the lectures, so the lectures were recorded using a web conference program, with the intention to use the recordings in blended learning carried out by the partners.

Figure 1. Olga Sergienko from ITMO University holding her guest lecture to students of Lahti University of Applied Sciences in May 2016. (photo Ksenia Donchenko)

For the first workshop organized in Lahti, students from partner universities were invited to participate and prepare a pre-assignment dealing with the company perspective to sustainability. Master's students from Gävle, Lahti and St Petersburg also had presentations dealing with different challenges in environmental issues, for example harmful materials and their reusability or recycling. The workshop was arranged as a side event of the "Smart Cities in Smart Regions" conference, which took place in Lahti at the same time. Local enterprises were invited to participate in the workshop.

The second workshop was organized as a part of the intensive week hosted by ITMO University in St Petersburg. Students from Lahti, Aalto, Gävle and Velikyi Novgorod participated in this event. The workshop attracted more company representatives, invited by ITMO, than the one organized in Lahti. The workshop concentrated on possible means to improve the companies' resource efficiency in production. Within the short time for cooperation, the processes and products were introduced and their environmental impacts were discussed with representatives of local enterprises "Coca Cola HBC Eurasia", "Passazhiravtotrans" company (municipal bus transportation), JSC "Nordena" (food additives) and "Baltika" Brewery.

To serve the purpose of a company-oriented approach, the students had been given a pre-assignment before the intensive week that addressed the resource-efficiency issues in the specific industry of the participating Russian companies. During the intensive week, the students presented their results

Figures 2 and 3. Enthusiastic discussions and ideas in the workshop at Lahti in May 2016. (photos Päivi Kärnä, Ksenia Donchenko)

Figure 4. The workshop in St. Petersburg involved company representatives as well as students from all the partner universities. (photo ITMO University)

of the pre-assignment tasks and formed multicultural groups that developed ideas for increasing resource-efficiency in these specific companies.

The intensive week also included several guest lectures given by the representatives of the partner universities and a one-day visit to Velikyi Novgorod. This visit was hosted by NOvSU, whose representatives also gave some presentations of the topics that are in the focus at their university. The rich cultural life of St. Petersburg was also introduced to the visitors by the host from ITMO university.

Figures 5 and 6. The one-day visit to Velikyi Novgorod hosted by NOvSU included lectures as well as a cultural program. (photos Lauri Luukkonen and Maija Vilpanen)

Results

The year 2016 has brought lots of experiences about intercultural cooperation within the coalition of ERREC partners. The topics of the lectures given along with project meetings have highlighted the resource efficiency subjects that are important for the partners and the education they offer at their institutions. It has been encouraging to find out that the feeling about the common interests and goals has been shared by all partners.

Intensive periods have also shown that intercultural cooperation with students and local enterprises is important. Shorter exchange periods, such as intensive weeks, provide several students with a possibility of learning in a multinational and –cultural environment and cultural experiences. The intensive weeks in general have had an important role in encouraging the students to join also long-term exchange activities lasting more than three months. The workshop in St. Petersburg already led into inquiries of student trainees in the participating companies.

Figure 7. The intensive week proved to bring new knowledge and ideas to all participants. (photo ITMO University)

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The third Lahti Cleantech Annual Review includes eight articles written by Lahti University of Applied Sciences's experts from the Faculty of Technology and Institute of Design, and Lahti UAS partners from Nordic Innovation Accelerator, Muovipoli Ltd. and Lappeenranta University of Technology. The aim of the review is to present the latest interesting research and development projects in the field of cleantech.
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