# Lahti Circular Economy Annual Review 2019

Anni Orola (ed.)

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# **Lahti Circular Economy** Annual Review **2019**

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## Kati Manskinen

# Foreword

This review presents the latest interesting research, development and innovation activities in the context of Circular Economy written by experts from Lahti University of Applied Sciences (LAMK) and their partners. Lahti UAS is developing innovations and incentives that enable the transition towards a carbon neutral society. The aim of our university is to create new technologies and digital solutions as well as systemic approaches and resource efficient methods that promote the sustainable circulation of materials.

The circular economy is promoted through European and national level policies. However, the regions play an essential role when practical cases of circular economy are implemented in real-word systems. The circular economy was chosen to be one of the three spearheads in the revised Päijät-Häme regional development strategy and programme 2018–2021 (Päijät-Häme Regional Council, 2017). The region is especially well-known for bio-based circular economy with several recognized transferable good practices such as a co-operation model of the grain cluster or bio-based industrial symbiosis of Labio Ltd (Interreg Europe, 2019). In order to further strengthen the bio-based circular economy in the region, a Bio-based Circular Economy Action Plan was drawn up in 2018. The first article of this review, written by Ms. Katerina Medkova, Ms. Susanna Vanhamäki and Ms. Johanna Snell, describes the concrete actions stimulating regional bio-based circular economy.

When talking about the circular economy, the significance of digitalization is often highlighted. Digitalization can boost the sustainable circulation of material, e.g. by providing accurate information on the availability, location and condition of products (Antikainen et al., 2018). The article written by Ms. Anne-Marie Tuomala presents how industrial smart system platforms enable the transition towards circular economy and UN's 17 Sustainability Development Goals. The digitalization also plays a major role in the article of Dr. Ari Serkola, Mr. Karri Miettinen and Mr. Aleksi Kinnunen, who present a new mobile cloud service called "Digimaa", for the purchase of soil and recycled materials. Furthermore, the article written by Dr. Sami Luste, Ms. Katerina Medkova and Mr. Tapio Kilponen share the experiences of the utilization of the Six Sigma tool with wastewater treatment plant data. These actions were performed in a partly EU-funded (Interreg Baltic Sea region) Interactive Water Management (IWAMA) project. In the same project, one of sub targets was to develop a game for developing the competence of the wastewater treatment operators. The game was designed and implemented by students from LAMK, and in his article Mr. Matti Welin describes the interesting game developing project from the perspective of the professor.

Resource efficiency is in the core of circular economy. The article written by Mr. Kimmo Heponiemi presents a new tool for material flow cost accounting, which was developed for the needs of SMEs. Moreover, the importance of resource efficiency together with high quality education is pointed out by Dr. Lea Heikinheimo and Ms. Erika Tapaninen, who in their article introduce co-created study methods for international students around the Baltic Sea. The international partnership networks offer our students a chance to expand their knowledge in an intercultural environment. LAMK's new master's program MUrCS (Master in Urban Climate and Sustainability) has opened new possibilities for international co-operation. Two MUrCS program students, Mr. Oliver Carlo and Mr. Mahmudul Chowdhury, joined a co-operation project where the City of Lahti strengthens co-operation with the City of Kyoto and the Kyoto prefecture in the field of environmental expertise, education and circular economy. In their interesting article, the students, together with Dr. Eeva Aarrevaara and Dr. Silja Kostia, describe their experiences of Finnish-Japanese collaboration.

I warmly thank all authors who made it possible to publish this review once again. I express my sincere thanks to all authors who published their latest results in the review. I am very glad that many of you had a chance to share your interesting results here. I express my gratitude to the editor of the review Ms. Anni Orola and to Ms. Maija Varala for correcting the English language of the articles. I hope that this review gives you some new insights and further ideas in the transition towards circular economy society.

Lahti, 10 November, 2019
**Dr. Kati Manskinen**
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**Katerina Medkova, Susanna Vanhamäki, Johanna Snell**

# Bio-based Circular Economy Action Plan Sets the Future Steps in Päijät-Häme

In bio-based circular economy, biological resources are used and managed sustainably, and economic, social and ecological values of products and nutrients are maintained for as long as possible. This article presents how bio-based circular economy is developed through a bottom-up action plan in the Päijät-Häme region.

**Figure 1. Bio-based circular economy offers solutions towards more sustainable future (Photo by Mac Mullins from Pexels).**

## Policy Background - EU, National and Regional Level

The European Commission (EC) strongly supports circular economy and bioeconomy. In 2015, the first circular economy package consisted of an EU circular economy Action Plan and proposals for waste legislation revision, was published by the EC. A new circular economy package including the revised Waste and Packaging Directives to be implemented by all Member States by June 2020 at the latest, was published in 2018. Also, the EU's Bioeconomy Strategy was updated in 2018, to meet current environmental, social and economic challenges. In Finland, The Finnish Road Map to a Circular Economy 2016-2025 was published in 2016.

It was the world's first national circular economy roadmap, which described actions for Finland to become a pioneer in the circular economy. In 2019, an update of the roadmap, Finland's Road Map to The Circular Economy 2.0 ensued. Furthermore, in 2014, the Finnish Bioeconomy Strategy was issued with a vision of sustainable solutions for bioeconomy to be the basis of Finland's well-being and competitiveness.

At the end of 2017, the Päijät-Häme Regional Development Strategy and Plan for 2018–2021 was approved, defining the region's three smart specialization spearheads: (1) circular economy, (2) design, and (3) sports and experiences. Moreover, the strategy recognizes the importance of circularity and bioeconomy for the rural vitality of the region. (Päijät-Hämeen liitto 2017)

In 2017, the strategy's circular economy objectives and actions were further clarified in the Päijät-Häme Roadmap Towards Circular Economy. With the vision of Päijät-Häme to be a successful, resource-efficient region by 2030 in mind, five themes were specified in the road-map: (1) sustainable business from the bio circular economy; (2) new consumption models and business opportunities; (3) closed loops of technical streams; (4) moving towards energy self-sufficiency; and (5) piloting and demonstrating innovative solutions. In 2018, the regional circular economy roadmap was updated. As a central part of the update, the bio-based circular economy actions were listed: making a bio-based circular economy action plan, developing separate collection and composting of bio-waste, closing nutrient cycles, and new innovations in bioproducts and bioenergy.

In order to strengthen the bio-based circular economy in the Päijät-Häme region, Finland, a Bio-based Circular Economy Action Plan was drawn up in 2018 in cooperation with regional stakeholders of the Päijät-Häme Circular Economy Cooperation Group. The Group comprises of representatives of regional public authorities, academia, and business.

## BIOREGIO Lays Cornerstone for Action Plan

BIOREGIO, an Interreg Europe funded project (2017-2021), aims to boost regional bio-based circular economy through a transfer of expertise about best available technologies and cooperation models. During the project, bio-based circular economy Good Practices have been identified in the project's regions in Finland, Spain, Slovakia, Greece, Romania, and France. Selected inspiring Good Practices were/will then be utilized in defining actions in the regional action plans. BIOREGIO also strives for improving effectiveness of structural funds by adjusting its management and strategic focus on the bio-based circular economy development, and new bio circular economy projects funding.

Päijät-Häme Regional Council steered the Action Plan drafting and together with Lahti University of Applied Sciences (LAMK) participated in the writing process. Both LAMK and the Council are BIOREGIO project partners and LAMK acts as a lead partner. The Päijät-Häme Bio-based Circular Economy Action Plan is issued in Finnish and English.


**Figure 2. The Action Plan defines four concrete actions towards bio-based circular economy in the Päijät-Häme region.**

The Action Plan was approved and signed by the Regional Director, Laura Leppänen in May 2019. The Päijät-Häme Bio-based Circular Economy Action Plan's implementation will be followed up by the Päijät-Häme Circular Economy Cooperation Group and the BIOREGIO project. At the same time, the group is committed to update the earlier-mentioned Päijät-Häme Roadmap Towards Circular Economy.

## Concrete Actions to Boost Bio-based Circular Economy

The Action Plan outlines four concrete actions stimulating regional bio-based circular economy. Those actions will be implemented mainly during 2019-2020 and will be financed primarily through the Sustainable Growth and Jobs 2014-2020 – Finnish Structural Fund programme.

**Action 1. Promoting a sustainable bio-based circular economy and enhancing nutrient cycles.** Establishing agricultural, biochar, and wastewater sludge pilot projects. The themes include the following: 1) Development of the circularity of wastewater sludge and biowaste side streams from biogas processes to new products. 2) Promotion of biogas side streams and biobased circular economy in agricultural nutrient cycles. 3) Willow cultivation for biochar and experimentation of pyrolysis along with life cycle assessment of the mentioned processes. 4) Creation of a platform for regional nutrient trading.

**Action 2. Pilot projects for biowaste collection and recovery**

The action focuses on promoting a separate collection of biowaste in residential areas with single-family homes. It includes testing different options (shared bins, regional collection, composting and co-composting), as well as conducting life-cycle assessment. Also, raising awareness of residents to reduce the amount of biowaste through a user-oriented approach is in focus.

**Action 3. Promoting the use of bio-products and bioenergy**

Together with companies, industrial symbiosis and opportunities for developing bio-based products e.g. bioplastics are promoted. The action comprises the development of piloting and testing environments for bio-based materials, e.g. pyrolysis and digestion, and exploring novel small-scale bioenergy solutions. Moreover, industrial symbiosis e.g. in order to close $CO_2$ cycles, and development of new products from bio-based side-streams are promoted. Also, the regional Climate Change Mitigation Roadmap is drafted in the region.

**Action 4. Päijät-Häme as an international reference area for circular economy**

The last action concludes the other three as it underlines the strategic development of the circular economy on the regional level. It includes dissemination of new solutions and good practices in the region, as well as internationally, and strengthening the expertise of circular economy in cooperation with universities and companies.

## Conclusions

The Bio-based Circular Economy Action Plan is a good example of how projects, as BIOREGIO, may provide concrete actions towards more sustainable future, and enhance cooperation in the region and between the regions, to benefit citizens, public and private sectors alike. Furthermore, research and development projects are capable to implement strategical goals.

The development process of the Action Plan has emphasized that cooperation between different sectors and levels is a necessity when results are sought after, and a systemic approach is needed in a way towards sustainable transition. We have reached the point were visions need to be met, and strategies must become reality. Regarding bio-based circular economy, the Action Plan will serve as a regional tool for the follow-up process during the coming years.

This article reflects the authors' views; the Interreg Europe programme authorities are not liable for any use that may be made of the information contained therein.

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Anne-Marie Tuomala

# Industry 4.0 and the Circular Economy Shake Hands without Forgetting Sustainability

Industry 4.0 refers to economy on a smart platform, and it is also regarded as the 4th industrial revolution. The timing of this industrial era is estimated to be in years 2006-2030. Finland does not have a national Industry 4.0 development program or strategy. In our country it has been decided - at least for the time being - to work through the separate technology programs, circular economy (CE) strategy and roadmaps, 5G strategy, and artificial intelligence (AI) development program.

Industry 4.0 changes how we perceive our environment, how we shape our environment, how we communicate with our environment and how we and our environment move from one place to another. When we enter the stage where smart system platforms are in use in different industries (smart energy, smart health, smart agriculture, smart factory, smart logistics etc.), the integration of the circular economy becomes possible. Then we will have Systems of Systems (SoS), where the circular economy has a new operational environment. The SoS of Industry 4.0 and the circular economy increase information flow and opportunities in general and enable to create more resource efficiency. This concerns energy and innovations, products and services, data and information, as well as collaboration and learning.

When observing whether the combination of Industry 4.0. and the CE is sustainable and whether they together generate more sustainable business and a more sustainable society, we can, for instance, apply and benchmark practices of international institutions and other countries. The United Nations (UN) has followed the data volume development since the 1980s and emphasizes that the volume of data in the world is increasing exponentially: 90% of the data in the world has been created in the last two years, and it is anticipated to increase by 40% annually (UN 2013).

Continually generated large amounts of digital data has been put under the umbrella term Big Data. The UN’s 17 Sustainability Development Goals (SDGs) are known worldwide and applied in all spheres of society and organizations. The following table is applied from the UN’s report “How data science and analytics can contribute to sustainable development”. For each SDG there is an example of how Big Data can contribute to it.

Industry 4.0 helps to highlight new possibilities of the CE and sustainability: Reference Architectural Model Industrie (RAMI) is seen as one of them (Dahmen & Roßmann 2018; Müller et al. 2018). This three-dimensional model was presented in 2015 at the Hannover Messe. The

**Table 1. The United Nations, Big Data for Development and Humanitarian Action (UN 2019).**

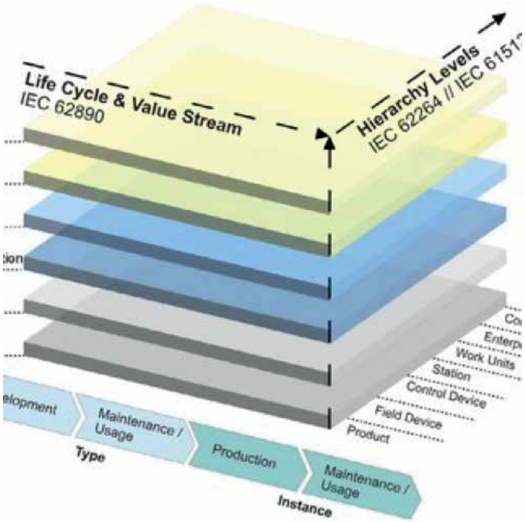
| | SDG | Big Data contribution example |
|---|---|---|
| 1. | No poverty | Spending patterns on mobile phone services can provide proxy indicators of income levels |
| 2. | Zero hunger | Crowdsourcing or tracking of food prices listed online can help monitor food security in near real-time |
| 3. | Good health and well-being | Mapping the movement of mobile phone users |
| 4. | Quality education | Citizen reporting can reveal reasons for student drop-out rates |
| 5. | Gender equality | Analysis of financial transactions can reveal the spending patterns and different impacts of economic shocks on men and women |
| 6. | Clean water and sanitation | Sensors connected to water pumps can track access to clean water |
| 7. | Affordable and clean energy | Smart metering allows utility companies to increase or restrict the flow of electricity, gas or water to reduce waste and ensure adequate supply at peak periods |
| 8. | Decent work and economic growth | Patterns in global postal traffic can provide indicators, such as economic growth, remittances, trade and GDP |
| 9. | Industry, Innovation and Infrastructure | Data from GPS devices can be used for traffic control and improve public transport |
| 10. | Reduced inequality | Speech-to-text analytics on local radio content can reveal discrimination concerns and support policy response |
| 11. | Sustainable cities and communities | Satellite remote sensing can track encroachment on public land and spaces such as parks and forests |

| | SDG | Big Data contribution example |
|---|---|---|
| 12 | Responsible consumption and production | Online search patterns or e-commerce transactions can reveal the pace of transition to energy efficient products |
| 13. | Climate action | Combining satellite imagery, crowd-source witness accounts and open data can help track deforestation |
| 14. | Life below water | Maritime vessel tracking data can reveal illegal, unregulated and unreported fishing activities |
| 15. | Life on land | Social media monitoring can support disaster management with real-time information on victim location, effects and strength of forest fires or haze |
| 16. | Peace, justice and strong institutions | Sentiment analysis of social media can reveal public opinion on effective governance, public service delivery or human rights |
| 17. | Partnerships for the goals | Partnerships to enable the combining of statistics, mobile and internet data can provide a better and real-time understanding of today's hyper-connected world |

model enables to combine business, value chains and systems. The model consists of elements and IT components in a layer and life cycle model (Schweichhart 2019). From the CE point of view, the new concepts in the administration shell of the model are 1) assets, 2) communication standard and 3) types and instances in the value chain. In this context, assets refer to "from sensors to company" activities, including products, devices and systems. Types and instances provide safe identification.

In addition, the development of the CE provides other possibilities for sustainability development. The Five Biosphere Rules, which form a biomimicry-inspired management framework for circular economy initiatives, are applicable in all spheres of the CE or Industry 4.0. This management framework, developed by Gregory Unruh, will bring more sustainability to manufacturing and business operations in general. The framework applies the laws of nature as a guide for efficient and innovative business operations. Instead of a linear value chain, the approach is to manage a cyclical value chain (Unruh 2010; Unruh 2019). Figure 1 introduces introduces the rules of the model.

The first rule, 'Materials Parsimony', aims at minimizing the types of materials used in products with a focus on materials that are life-friendly and economically recyclable. The second rule, 'Value Cycle', guides to recover and reincarnate materials from end-of-use goods into



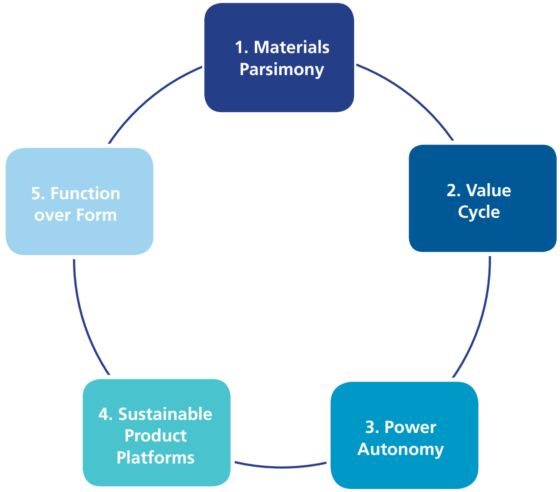




**Figure 1. Reference Architectural Model Industrie 4.0 (Industrie 4.0 2019).**

**Figure 2. The five principles that constitute the Biosphere Rules (Unruh 2019).**

new value-added products (Henrich et al. 2012). 'Power Autonomy' is to maximize the power autonomy of products and processes so they can function on renewable energy. 'Sustainable Product Platforms' are targeted to leverage value cycles as product platforms for profitable scale, scope, and knowledge economies. 'Function over Form' means meeting of customers' functional needs in ways that sustain the value cycle (Unruh 2019.).

To conclude, sustainability is seen as one of the Industry 4.0 and CE drivers (Stock et al., 2018). There have also been discussions in the academic world about whether Industry 4.0 and the CE are the last chance for truly sustainable production. The UN sees big data for sustainable development as an enabler of the evidence-based decision-making and measurement of the progress on the SDGs (UN, 2013). This seems to be a very realistic approach. It is a big challenge to develop the CE for Industry 4.0 (Stein Knudsen & Kaivo-oja 2018), as well as to develop Industry 4.0 for the CE, but, fortunately, management frameworks and models are being developed (Jabbour et al. 2017). In the higher educational institutions, the development should be followed and regarded as part of the educational programs.

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# Digimaa Application for the Purchase of Soil and Recycled Materials

## Ordering and Delivery of Soil

The Digimaa project has developed a mobile cloud service for the purchase of soil and recycled materials (ERDF 2017-19). The aim was to create a modern order-delivery service for earthworks constructors which can be used by companies in road, street, field and industrial construction. In the Digimaa service, the earthworks contractor sends an order with a mobile device to the soil manufacturer, who delivers the material to the building site. Drivers receive driving assignments including information on the collection and delivery sites, and site managers acknowledge receipt of the delivery of materials. All this creates a digital delivery note, which can be forwarded to invoicing, payroll and other tracking of material.

## Project Partners

The Digimaa demonstration was executed by the Aalto University Department of Water and Environmental Engineering in cooperation with the Lahti University of Applied Sciences Faculty of Technology and earthworks constructors. In terms of the division of labour between the research institutes, Aalto University was responsible for the planning of the background system and its data model (BackEnd), and Lahti University of Applied Sciences designed and implemented the mobile user interface prototype (FrontEnd). The application designers programmed the service according to the requirements, and integrated the background system into the user interface. This resulted in the demonstration described below.

## Execution

The project was divided into tasks, the most important of which were identifying the requirement attributes of the Digimaa service, developing and programming the background system (BackEnd) and creating and programming the user interface model (FrontEnd). The project adhered to the following procedures:

The general business of soil transfer and the role of companies in earthworks acquisition and supply chains were surveyed. In the supply chain, the following types of roles were identified: the client placing an order for soil, the supplier, the transportation coordinator, the driver and the recipient / person who ordered the soil, and the orders and deliveries made by these roles.

The project team designed a general model for the order and delivery of soil, and the key service tasks. The companies demonstrated which tasks the information system should perform, and which information is available for performing these tasks. The team investigated how to forward information on orders and deliveries of soil from one company to another, and from one employee to another.

The researchers organised consultations on the different versions with companies. In the consultations, the users commented on the service features and their specifications. Based on the feedback, additional features were added to the application. The integration of additional features into the data model and user interface created challenges for easy access to the service.

The data model's design was based on defining the actors' roles, their communication and messaging processes, and the necessary data. The data model specified the main sections of the service, the data they use, and the data relationships in the supply chains. The data model was built to allow for new features and information to be added to the model in the future.

## Programming the User Interface

The application was implemented as a scalable cloud service in the REST architectural style where the user interface communicates with the back-end system through an encrypted https protocol (Lahoti 2019). Initially, an API interface was designed for the model that defines which services are provided by the back-end system and what information is transmitted in service calls. In addition, agreements were made on the principles of data transfer, such as encryption. It was then possible to develop both parts autonomously and independently of each other. By using the REST model, the architecture of the system is simplified, which also makes the functional authentication and testing easier. With this implementation, the responsibilities of LAMK and Aalto University in the development of the application were divided into the creation of a modern background system and a user interface.

Secure communication is based on the open JSON Web Token (JWT) standard (RFC7519). The standard defines a compact and secure way of exchanging information between two operators using the JSON format. The recipient can trust the origin and accuracy of the messages, as the messages are digitally signed. (Auth0 2019)

The user interface follows Google's Material Design code, one of the most popular guidelines in the digital world (Bose 2019). Google's Material Design includes a set of rules, guidelines, components and best practices that should be used to design the UI for web services and applications (Google 2019a). A prototype of the user interface (UI mock-up) was first implemented using Adobe's XD UI/UX design tool. It was then used in consultations relating to the different versions to gather user experiences before programming the UI. The iterative nature of the design is illustrated by the fact that several different versions of the user interface prototype had to be developed during the project. In addition, the user interface prototype was translated into both English and Spanish.

The user interface itself is a component-based web service implemented within the Angular software framework (Angular 2019). The appearance is responsive and the components of the Angular Material Library were utilised either as such, or in a modified form. Responsiveness means that the position, size and relationships of the user interface elements adapt to the screen size of the device in use, so that the elements look smooth and the user interface is easy to operate (Google 2019b). From the outside, the user interface looks like a so-called 'single-page' application. The pages are not fully downloaded during the start-up phase, but the user interface and the back-end system exchange data in the background, using Ajax technology. The software was packaged into a web service using the WebPack tool.

Applications for mobile technologies (Android 75% and iOS 21%) were implemented using a hybrid application, a shared source code. Hybrid applications refer to applications that look like native applications from the outside, but have been implemented following the principles of a single source code (Mendix 2019). In hybrid applications, an embedded web view is created in the user interface of the mobile application. A traditional web page is uploaded into this view, which means that, from the perspective of software development, this form of application development refers to the development of a web service, eliminating the need for specialised iOS

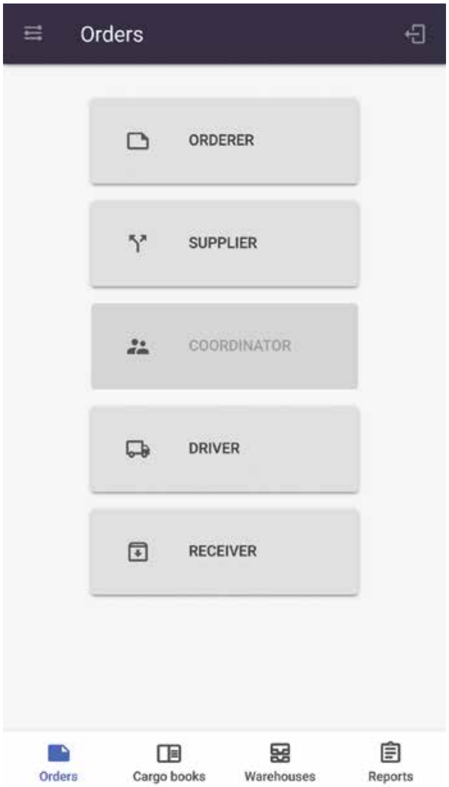


**Figure 1. Main menu screen.**

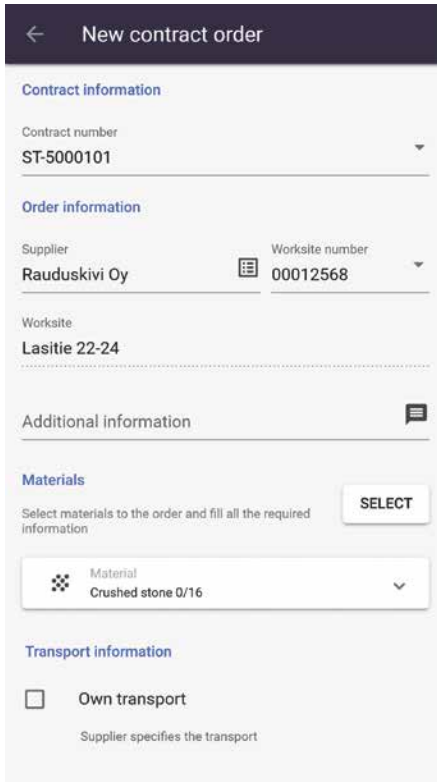


**Figure 2. Placing a new order.**

or Android expertise. Digimaa's mobile application was executed as a hybrid application using the Cordova software framework. Cordova also offers an interface to mobile device sensors and resources. Therefore, if necessary, the application can be uploaded to an app store (Google Play or Apple's App Store). Another advantage of hybrid applications is that the application's functionality can be changed without having to upload a new version of the application to the app store.

The application's access rights have been implemented in a role-based manner (RBAC). Role-based access means that the users can only access the information that is necessary for carrying out their task. This ensures that the supply chain only allows the company to see its own information, and each company distributes role-based access rights to the employees selected for the task.

## UI Template

Earthworks contractors play one or more roles in the supply chain. This is why the Digimaa application is also designed to be role-based. The service is based on roles such as the buyer of soil or recycled material, supplier, transportation coordinator, driver and recipient. The earthworks constructor, soil supplier or transport company may also use the service with their own employees. In the following figure the main menu screen is represented.

In the supply chain, companies supplement orders with their own data, and the software documents the information in the delivery note. In addition, almost all transportation of soil, stone aggregates and recycled material is recorded as location data, where the collection and delivery sites can be identified on the map. The delivery notes generate reports that can be forwarded to invoicing and payroll.

## Placing Orders

The orders concern the acquisition of soil, stone aggregates and recycled material, as well as transportation. The earthworks constructor, such as a contractor, selects the soil supplier and type of material when completing the order (see Figure 2). The client ordering the material enters the amount in tonnes, and the place and desired time of delivery. The order is forwarded in real time to the supplier, who can be employed by the same company or another one. The earthworks constructor can also book transportation services from other haulage companies.

## Organizing Deliveries

The supplier manufactures or supplies soil, stone aggregates or recycled materials, and organises transportation to the construction site (see Figure 3). The supplier opens the notice and either accepts or declines the order. The idea is that the supplier reacts promptly to the order request, and takes responsibility for the supply of soil and organising of transport. The client receives feedback on the processing of the order.

The suppliers of soil can forward the message to the transport department of their organisation, or to a subcontracting haulage company. The supplier records the address of the collection point, and, if necessary, supplements the transportation request with more detailed instructions. The materials supplier forwards the transportation order to the transportation coordinator or directly to the drivers.

## Soil Transportations

The transportation coordinators' task is to arrange deliveries and select drivers. Transportation coordinators have access to drivers in their own company, as well as drivers of the cooperating subcontractors. The transportation coordinators select the drivers and inform them about the task to be accomplished.

The drivers receive information on the materials to be transported (see Figure 4). The drivers may agree amongst themselves about more detailed schedules within the time frame of the delivery. The drivers register the collection and delivery information in the system and report the working hours spent on the transportation of materials, waiting times and breaks.

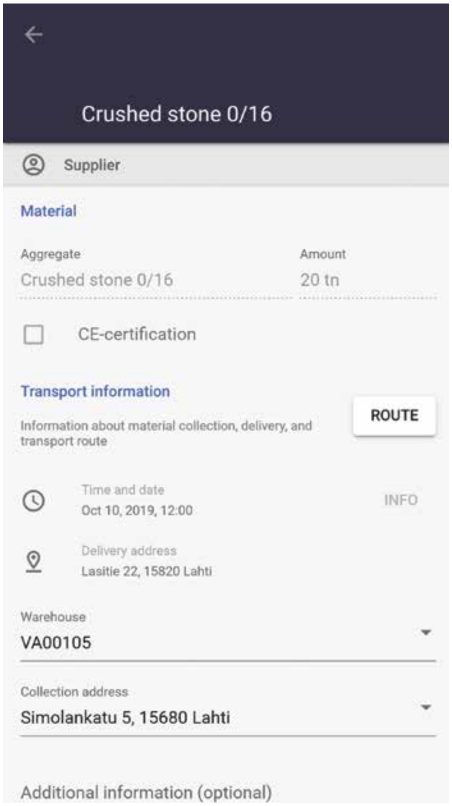


**Figure 3. Defining delivery.**

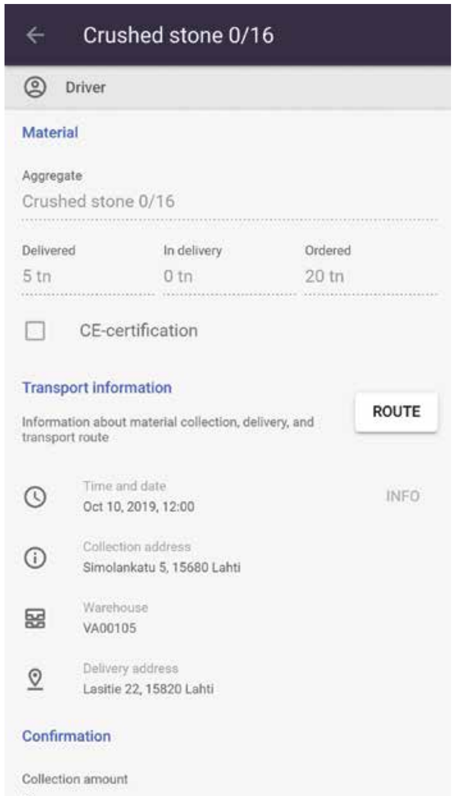


**Figure 4. Transportation details.**

## Recipient's Receipt of Acceptance

The recipients of soil and stone aggregates, such as construction managers or similar, can follow the transportation activities either on the construction site or in an office. The recipients will be informed on the deliveries and acceptance of material, including the collection and delivery stamps. Construction managers accept the loads either one at a time, or all at once (see Figure 5).

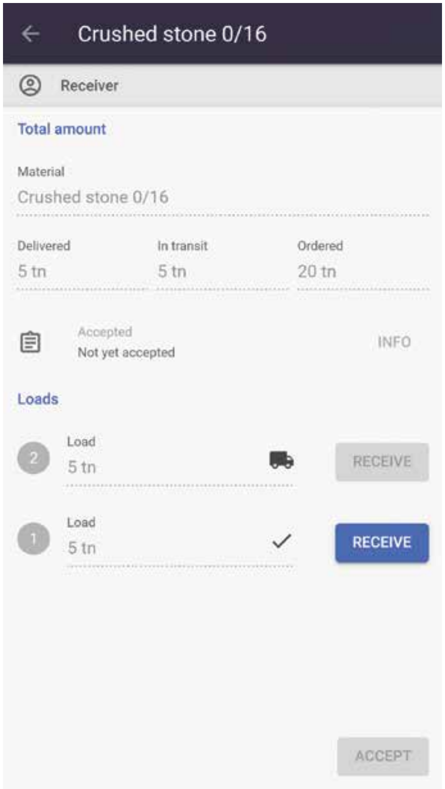


**Figure 5. Receiving loads.**

## Delivery Information Included in the Delivery Notes

The order and delivery information is saved in the system and organised into delivery notes. The delivery notes contain all the information required as supporting documents during deliveries, in reports and when monitoring material transfer (see Figure 6). The delivery notes can be forwarded in CSV or PDF format into invoicing, payroll or reports.

## The Advantages of the Digimaa Service

The Digimaa application forwards the orders of soil, stone aggregates and recycled material effortlessly to the entire supply chain. The service speeds up and systematises orders from one company or employee to another. The service makes the logistics and documentation of earthworks construction more efficient, facilitates the deliveries of soil, reduces transportation costs and creates location data for the monitoring of recycled materials.

Earthworks constructors can monitor the orders and their processing in real time. The system shows the earthworks constructors a real-time mass balance: how much has been ordered and how much has been delivered to each construction site. The earthworks constructors receive delivery notes as a receipt of each order that has been delivered.

The suppliers of soil and recycled material can receive the assignment effortlessly without phone calls or e-mails, and acknowledge receipt of the assignment. The suppliers simply delegate the order with additional information to the transportation coordinator and to delivery.

The digital assignments make the transportation company's administration and invoicing duties easier. Drivers are relieved from the need to record documents. The drivers only press the collection and delivery buttons related to orders of material transfer. The service helps drivers optimise their transport routes and reduce transport costs. In addition, drivers can use the service to transport various consignments by directing the delivery notes to different contracts.

The Digimaa service provides a method for documenting the location data of recycled material. The service is suited for monitoring the recycling of solid materials, such as crushed concrete, ash from power plants, and car tyres. The documented delivery notes display the ordered and delivered recycled materials, and their volume and location.  Information in the delivery notes can later be refined into supporting documents and indicator data for invoicing, payroll and environmental reporting.

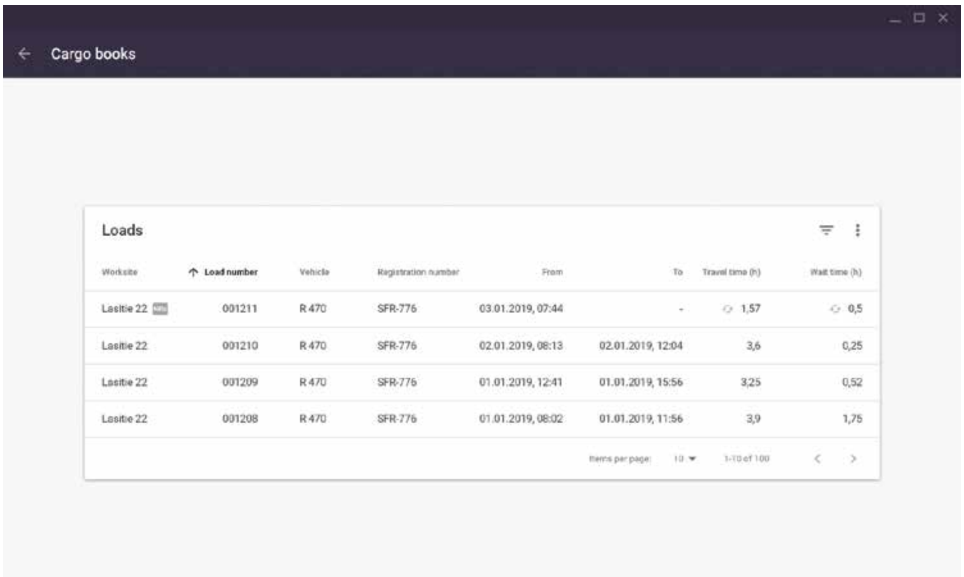


**Figure 6. Reporting view.**

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# Experiences of the Utilization of the Six Sigma Tool with the Wastewater Treatment Plant (WWTP) Data

**Six Sigma is a set of techniques for process improvement based on the number analysis. The original aim was to conduct a preliminary study on Six Sigma as a capacity development tool for wastewater treatment plant (WWTP) operators. An effective co-operation model between universities and WWTPs was tested with examples of the opportunities that the Six Sigma analysis may offer for developing the maintenance and monitoring of WWTP processes. The actions were performed in a partly EU-funded (Interreg Baltic Sea region) Interactive Water Management (IWAMA) project as a part of a survey of capacity development tools.**

The present article describes the way Six Sigma was used to enhance the local WWT network and the main observations from the Six Sigma results. The ultimate aim was to identify such dependencies that may help WWTPs to develop their monitoring facilities, for example what kind of new data is required to acquire more detailed information from the processes. Six Sigma was not selected as one of the actual capacity development tools produced during the IWAMA project, but hopefully the present article gives some idea of the possibilities it may provide.

Two activated sludge WWTPs were studied. The WWTPs are located near to each other, both with a population equivalent (PE) of 100 000 inhabitants. WWTP 1 is operating outdoors, while WWTP 2 is in a cave. The data from the year 2016 included the following WWTP quantities:

- Incoming wastewater and treated water flows ($m^3$)
- Temperature from incoming water and from aeration phase(°C)
- pH from incoming water, pre-clarification and post-clarification stage
- Biological Oxygen Demand (BOD) from incoming wastewater, pre-clarification and leaving water (mg/l)

- Nitrogen (N) from incoming wastewater, pre-clarification and from treated water (mg/l)
- Phosphorus (P) from incoming wastewater, pre-clarification and from treated water (mg/l)
- Suspended solids (SS) from incoming water, pre-clarification and from treated water (mg/l)
- Return sludge to aeration tank ($m^3/h$)
- Sludge flow rate to the digestion and the biogas flow rate from the digestor ($m^3/h$)
- Overall energy consumption (kWh)

It is notable that some measurements, such as BOD, N, P and SS measurement, were laboratory measurements that were performed on a weekly basis.

## Working Method with the WWTP Data

In order to learn, develop and innovate, we need to identify new questions. If we continuously deal with the same questions, we probably also get the same answers unless there is something which will break, disrupt and challenge the current state. The following chapter presents the method and reasons for working in such assemply of actors than presented in Figure 1.

The Venn diagram above illustrates the concept being tested. The concept consists of three elements: process data, scientific theory and practical knowledge.

- The process data is a data base, for example an Excel file, which contains fairly long-term data about the process under review. The data includes both data on process factors and data on process outputs.
- The scientific theory covers the laws of natural sciences, the tested and verified models, algorithms and equations as well as the natural limitations and obstacles of the process.
- The third element is the practice. It includes the practical methods, everyday standard procedures, the working guides and the tacit information.

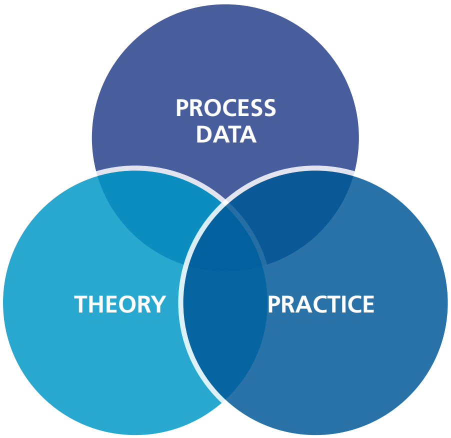


**Figure 1. The Six Sigma data analysis WWTP was achieved as a co-operation between WWTP operators, university experts from the fields of the data analysis and water management.**

The iterative testing environment is formed by an adequate number of "sprints", which repeat the following six phases (Image 2):

- Phase 1: to set-up the problem or challenge
- Phase 2: to ensure the know-how
- Phase 3: to gather the data
- Phase 4: to carry out the data analysis
- Phase 5: to review the data analysis in order to identify contradictions, deviations/peculiarities
- Phase 6: to identify the new questions, problems or challenges

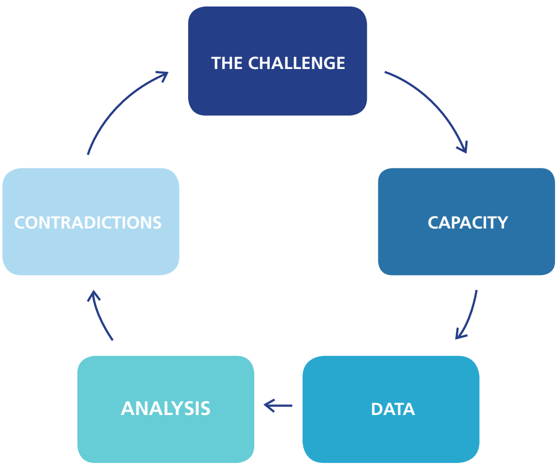


**Figure 2. The iterative test cycle of the six steps.**

The team consists of people who can convey and share knowledge about the scientific theory, and practical and empirical experience about the process. The third element of the team is a person who can generate new fact-based information on the process data.

Traditionally, scientific research has been based on reliable data and verified tests. So, there is no novelty here. The process staff utilizes the process data constantly in order to manage and adjust the process. There is then no novelty here, either. However, what is thrilling is the combination of all three elements, as well as the persistent aim to find contradictions when the process is reviewed from three different angles. This kind of iteration around the data-based phenomena may help the universities and WWTPs to upgrade their co-operation based on the observations from the practice.

The gap between theory and practice hampers the co-operation opportunities between the WWTPs and universities. Improving local co-operation and knowledge exchange between the WWTPs and universities has been one of the development objectives of the European Institute of Innovation and Technology (EIT), the European University Association (EUA), and the research & development framework programs of the European Union (e.g. FP7, H2020). The same phenomenon was also apparent during the IWAMA project. According to the IWAMA surveys for the WWTPs (n=78), the co-operation of WWTPs and universities (also universities of applied sciences) in the Baltic Sea region is the lowest, when compared to the co-operation between the WWTPs and other stakeholders, such as consultancies, associations, other WWTPs and vocational academies (Luste & Medkova, 2019). This type of co-operation would seem very natural especially for universities of applied sciences.

The cause and effect diagram (Figure 3) presents the starting point to the research. It shows the supposed factors that may have an effect on the energy consumption at a WWTP.

To be able to confirm the hypothesis right or wrong, the process data is collected, cleaned and analysed. The data is historical data. It was collected day by day and the collection period was one year, i.e. 365 days. The data covered two WWTPs, which are partly similar, but there are also clear differences. The main parameters that were paid attention to were the dependencies relating drivers from the operation environment (temperature, rainfalls and storm waters, increased wastewater flows in the summer) and the energy efficiency of the plants.

The data was transferred from the Excel sheet to the Minitab application. Minitab is statistical software, which is used in process improvement activities.

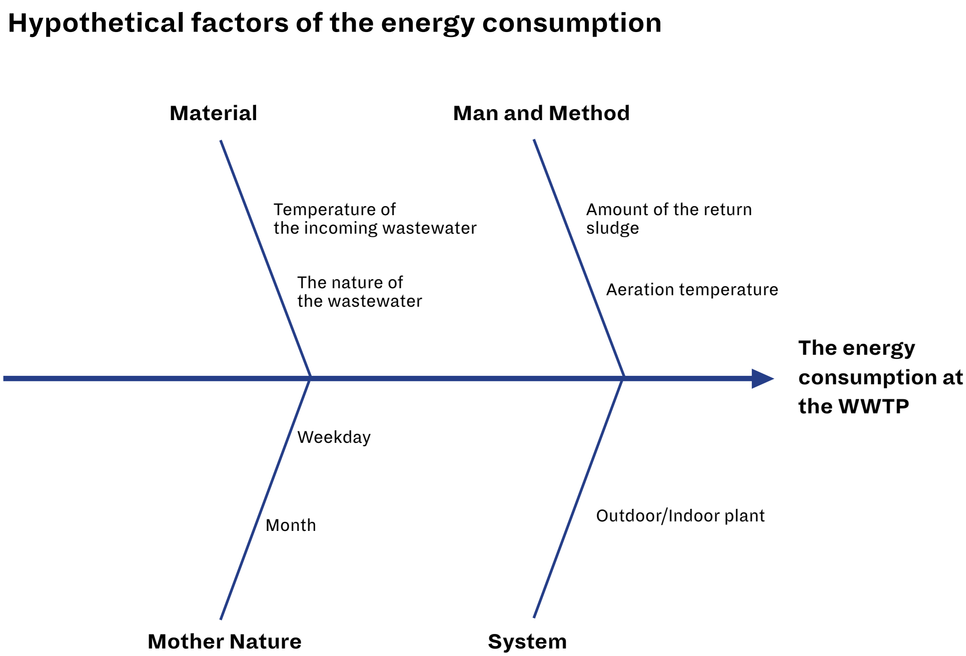


**Figure 3: Cause and effect diagram at sewage treatment plant.**

## Example of an Energy Efficiency Survey by Six Sigma

Below is a short example based on the amount of return sludge, which is compared to the energy consumption (kWh), the amount of incoming wastewater per day (m³) and the ratio of the energy consumption and the incoming wastewater (kWh/m³). The return sludge from the post-clarification stage back to the aeration phase of the WWTP process is one of the key management processes in activated sludge type of WWTPs. It is connected to the organics and nitrogen removal as well as energy efficiency. It is also connected to the two key indicators of the process: sludge age and sludge load.

Figure 4 reveals that WWTP 2 uses more energy than WWTP 1. Figure 4 also shows that WWTP 1 is managed differently from WWTP 2.

When the return sludge and incoming wastewater are plotted into the scatterplot in Figure 5, the curves look very different. WWTP 1 seems to operate in a linear way: when the incoming water volume increases, the return sludge increases accordingly. Instead, WWTP 2 is different. The upper limit of return sludge is about 3000 m³/day. According to the discussions with WWTP operators, the return sludge is limited by the sludge settlement characteristics in post-clarification. WWTP 2 is receiving such industrial wastewaters the content of which (e.g. filamentous bacteria, yeasts) may affect the sedimentation characteristics of sewage sludge (Parmar et al. 2001).

In Figure 6, the Y axis refers to the ratio of energy consumption and incoming wastewater per day. The X axis refers to the amount of return sludge per day. This image also tells the same fact that WWTP 2 requires more energy to process the wastewater than WWTP 1 as well as that the processes are carried out in different ways.

The image also shows this linearity quite clearly: when the amount of return sludge increases, the energy efficiency improves. We can see that WWTP 1 (~1.5 m³ of treated water/ kWh of electricity) treats its water more efficiently than WWTP 2 (~1.1 m³ of treated water/ kWh of electricity). There are many possible reasons for the lower energy consumption. One of them is that the indoor WWTP 2 requires a very large

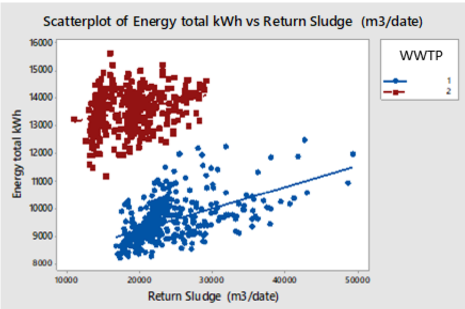


**Figure 4: The correlation between return sludge and kWh.**

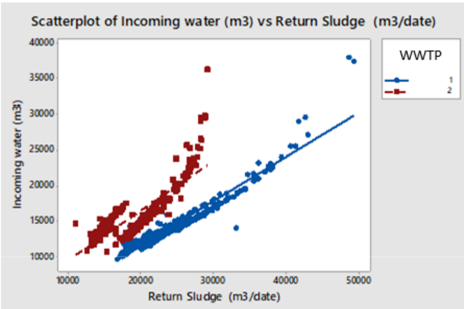


**Figure 5: The correlation between return sludge and incoming water (m³).**

ventilation system, since it is underground, so this could account for a large portion of the energy usage. The energy consumption of the indoor WWTP is stable throughout the year whereas in WWTP 1 the energy consumption is lower during colder temperatures (data not shown). A colder temperature usually means longer sludge age but also relatively decreased aeration need, and therefore oxygen is dissolved more easily. For example, when the water temperature rises from 10 ºC to 25 ºC, aeration need increases by over 30 %. This also has a big effect on the energy consumption of the process.

The purpose of return sludge is to enhance the bacteria population working with organics and nitrogen removal, when the organic load (i.e. amount of incoming wastewater) increases. However, as shown in Figure 7, the amount of return sludge does not have an effect on the removal efficiency of the organics (Chemical Oxygen Demand; COD) in WWTP 1.

An increased amount of return sludge increases the sludge age but decreases the sludge load (kg COD/kg MLLS d). A longer sludge age usually means a higher-quality end product due to the longer treatment period. The sludge age needs to be lengthened, for example, when the decreasing temperature is slowing down the bacteria. This may partly explain the differences between the outdoor (WWTP 1) and indoor (WWTP 2) facilities.

Besides the temperature, also the rainfalls affect the energy consumption of the WWTP, due to the increased amount of the incoming wastewater volume (Figure 8). The amount of influent is rising at certain regular times during the year, but also after heavy rains or during snow melting seasons. From the energy efficiency point of view, it would be more efficient to regulate the process according to the incoming concentration of the organics than the volume of the incoming wastewater. This would also have an indirect effect on the energy efficiency, through the improved biogas yields via the increased amount of excess sludge removed from the process to the digesting reactors.

The other monitoring need identified (data not shown) was the methane production from the WWTP sludge reactors. At the moment, only the volume of biogas (containing mainly methane

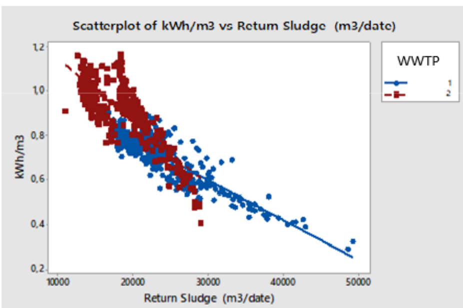


**Figure 6: The correlation between return sludge and kWh/m³.**

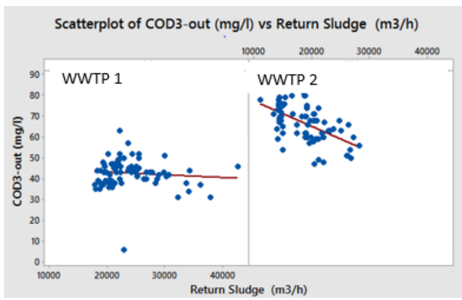


**Figure 7: The correlation between return sludge and COD concentration in the treated water.**

and carbon dioxide) is measured. The inhibition of the most sensitive digestion bacteria, methanogens, may take place due to the incoming inhibitors, such as too high or low pH (varying from 5.0 to 8.3 ), too strong concentration of degradation intermediates (e.g. volatile fatty acids, ammonia) and industrial wastewaters (e.g. detergents, chemicals, yeasts). Moreover, the data from the incoming industrial wastewaters as well as integrated weather information would enhance the predictability of resource efficient systemic level process management.

## Conclusion

- A lot of data from different parts of the process is needed, as well as “silent knowhow” expertise, for example concerning the measurement points and working practices.
- Through the data-based iteration process it is possible to identify (especially) the factors relating to monitoring needs and the development of the data collection system toward more energy efficiency, as well as to increase the predictability perspectives for more systematic process management.
- Iterative working around the questions rising from the data is a highly fruitful way to increase the practice-driven co-operation between the WWTPs and universities. This is also an efficient way for the students to get involved in the process by getting a good overall picture of the WWTP activities.

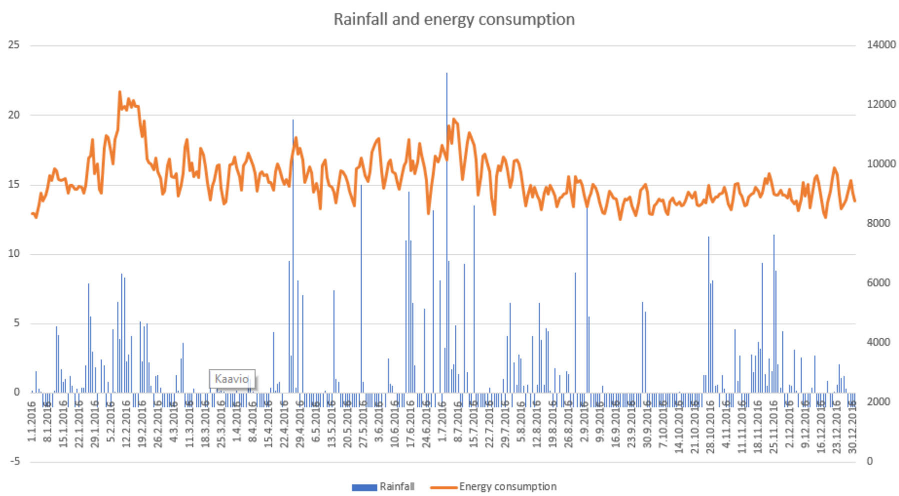


**Figure 8. WWTP 1 and energy consumption’s relation to the rainfalls in 2016.**

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# Learning by playing – case WWTP game

## General

Serious games are an expanding field of game development used in simulations and other immersive, interactive experiences developed for various fields of industrys (Suvak 2014).

Serious games have numerous definitions, but the aspect that is common to definitions is 'a game designed for a primary purpose other than pure entertainment' (Growth Engineering 2016). Serious games can be used for various purposes like education, training, health care, and marketing (Oksanen 2014).

The IWAMA project, started in spring 2016, was a joint project with north European universities and industry, funded by the European Union (European Regional Development Fund) (IWAMA 2019a). The aim of the project was to improve wastewater management by developing the competence of the wastewater treatment operators. The main focus area was the Baltic Sea Region. By implementing pilot investments, the energy efficiency and sludge handling were also improved (IWAMA 2019b). One sub-project towards the goal was the 'Day at the WWTP' game designed and implemented by students from Lahti University of Applied Sciences.

## Game Project

The IWAMA game project started in fall 2017 and it was integrated into workshop courses of ICT students at the Faculty of Technology. The initial project group consisted of seven third-year students of media technology and software engineering. Technical specifications of a wastewater treatment plant and biological formulas were defined by the environmental engineering experts involved in the project. Circular economy professionals and the fresh ICT point of view produced the idea of a 'Day at the treatment plant' game. The game idea consists of a series of mini games dealing with daily operations at a modern wastewater treatment plant. By using small mini games, it is possible to give an overview of the whole process and then focus more deeply on different areas of the treatment process for learning purposes.

## Development Tool Unity

At the start of the game project, development tools had to be chosen. In this case, teachers and the project group decided to use the Unity Game Development Platform developed by Unity Technologies, a tool which is used on a majority of the game development courses and was thus familiar to students. Unity is one of the leading game development platforms on the market (Dillet 2018). It supports both 2D and 3D designs, has an impressive real-time rendering machine and an advanced Nvidia PhysX physics engine for real-time physics operations (Unity 2019a). Unity integrates seamlessly to other 3D design tools such as 3D Max and Blender. Unity is also a cross-platform game engine that supports over 20 different platforms including iOS, Android, Mac, Linux, WebGL and various game consoles and smart TVs. This means that once the game has been developed, it can be deployed to, i.e. played on, all supported platforms. The Unity graphical editor is available on Windows and Mac computers.

## Graphical Design

In the beginning of the project, in parallel with the game concept design, game graphic design started. The aim was to design the look and feel of the game and characters used. A consistent look and feel works as an umbrella to tie all the mini games together: consistency is one of the molecules of the Design DNA (Nikolov 2017). Artefacts of the graphical design, like the character, colors, fonts, textures among others, were imported to Unity. Building the plant environment, character movement and animation was a big part of that development. The following figure presents the character used in the game. On the left side is the character without any safety equipment and on the right side is the character wearing a helmet and a safety vest.

Especially the development of character animation took a long time, but had to be done carefully, because the same clips were re-used in all different mini games. Animation in Unity is built around Animation Clips: A Game Object must have an Animator component and that Animator component should have an Animator Controller assigned to it. The Animator Controller asset must have at least one Animation Clip assigned (Unity 2019b). Animations like standing, walking, turning, and exiting from the scene were developed during the spring 2018 semester. At the end of spring semester 2018, the character animations and movement were fully implemented.

**Figure 1. Character without and with safety equipment**

## Game Development

Unity games are based on scenes. A scene can be thought of as a level of a game. A scene has all the game objects in a hierarchy tree. To be able to perform unique operations in the game, game objects can have script components attached to them. A script is a piece of program code written in the c#-language, which is executed during the game play. Scripts usually handle the user actions such as mouse clicks and keyboard input.

In the beginning of the project it was clear that a WWTP game should be built around different scenes. The first scene, the landing page, was used to give general information about the game, select the UI language, and key in a username. The logos of the financing institutions can also be seen on the front page.

The first mini game “Find safety equipment” was designed to remind the player that safety comes first, even in a simulated environment. The control room has a couple of wardrobes for safety shoes, a rack for a vest and a badge, and a helmet on the desk. To be able to proceed, the user must wear a helmet, a badge, a safety vest and safety boots. When all the required items have been collected, the next level, Puzzle, which tests the user’s knowledge of wastewater management, becomes available.

The game was designed so that the user can play the game without a manual. The items in the background, like control room monitors or doors, are used to get additional information and proceed to the next level. If the player needs extra information, there are proximity activated info buttons. In the following figure, an activated info window gives instructions for how to proceed.

The second mini game, Puzzle, tests the user’s general knowledge about the treatment process. Actually, it has two parts in it. In the first one the user has to put the different phases of the process in the correct order. The following figure presents the phases of the process.


**Figure 3. Front page of the game.**


**Figure 4. Activated information window.**

The second part tests the user's ability to understand the operation principles of different phases of the treatment process. A description is revealed by pressing a piece in the lower part of the screen: the user should drag the selected piece over the correct phase. In the following figure, the aeration description has been dragged over the aeration phase and the rest of the pieces of the puzzle are still unfinished.

After the second mini game, the user re-enters the control room. This time the door on the far right becomes accessible, a green glow surrounds the door and the door's locking panel is green instead of red.

The next scene is a kind of lobby to the next two mini games. A lobby in game terms is a place where people hang around before they go into a specific room to play. At this scene the user finds a set of claims behind the info marks. The claims are either true or false. The game records the correct replies to be displayed at the game session summary in the end. The claim is removed from the scene after it has been played. In this scene the user is able to walk around the treatment plant. Behind the doors are the mini games: Pumping and Screening, and Aeration.

The Pumping and Screening mini game is a typical speed game: the user has one minute to remove the solid particles from the wastewater flow by clicking the particles with the mouse. As the time goes by, the flow speed increases, and removing the dirty particles becomes more challenging. The user's ability to remove solid particles is graded using a four-step scale from poor to excellent. After the time is up, the user returns to the treatment plant.

The next game is Aeration and its aim is to adjust the process according to given instructions using water flow, temperature, dissolved oxygen and the amount of active biomass. This is a five-phase task, and the first task is to decrease the sludge age to 3-4 days. Next, the player should decrease sludge production by 10 percent. The third task is to adjust the process because of increased water flow. After that the player is instructed to adjust the process accord-

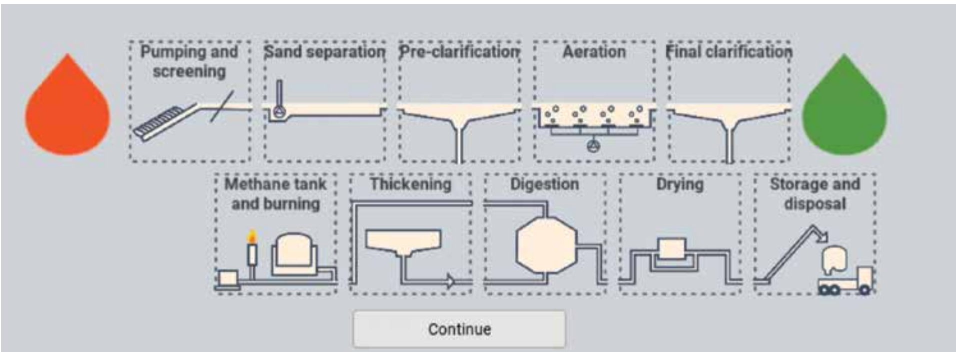


**Figure 5. Process phases.**

ing to a decreased temperature and finally the player should clean the water by reducing the amount of organic material and nitrogen in the water. These tasks simulate conditions found at a real treatment plant: e.g. increased incoming flow due to summer rains or a sudden temperature decrease in the incoming flow due to cold weather conditions. The Aeration game evaluation is based on individual task completion as well as energy efficiency and the amount of hints needed to complete the tasks.

After the Aeration game the player enters another lobby filled with a second set of claims. This lobby has an entrance to the Clarification mini game, where the player should control water influent, activated sludge return percentage and the lime amount, to finally produce clean water. In the following figure the Clarification mini game is presented.

After Clarification all the mini games have been played and it is time to view the summary. Statistics of the game can be seen in the figure 8. By pressing the Submit score and exit button, user statistics is sent to the back end and saved to the database.

As seen on the landing page, the player can select the game's UI language from a list of languages. Altogether, the game has six language options: English, Russian, Estonian, German, Latvian and Finnish. From the implementation

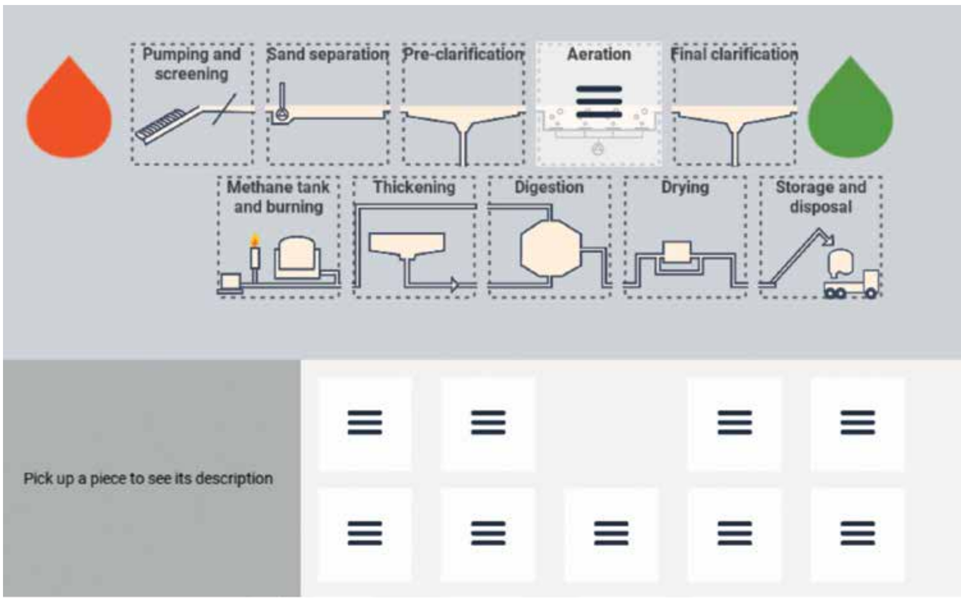


**Figure 6. Description connected to phases.**

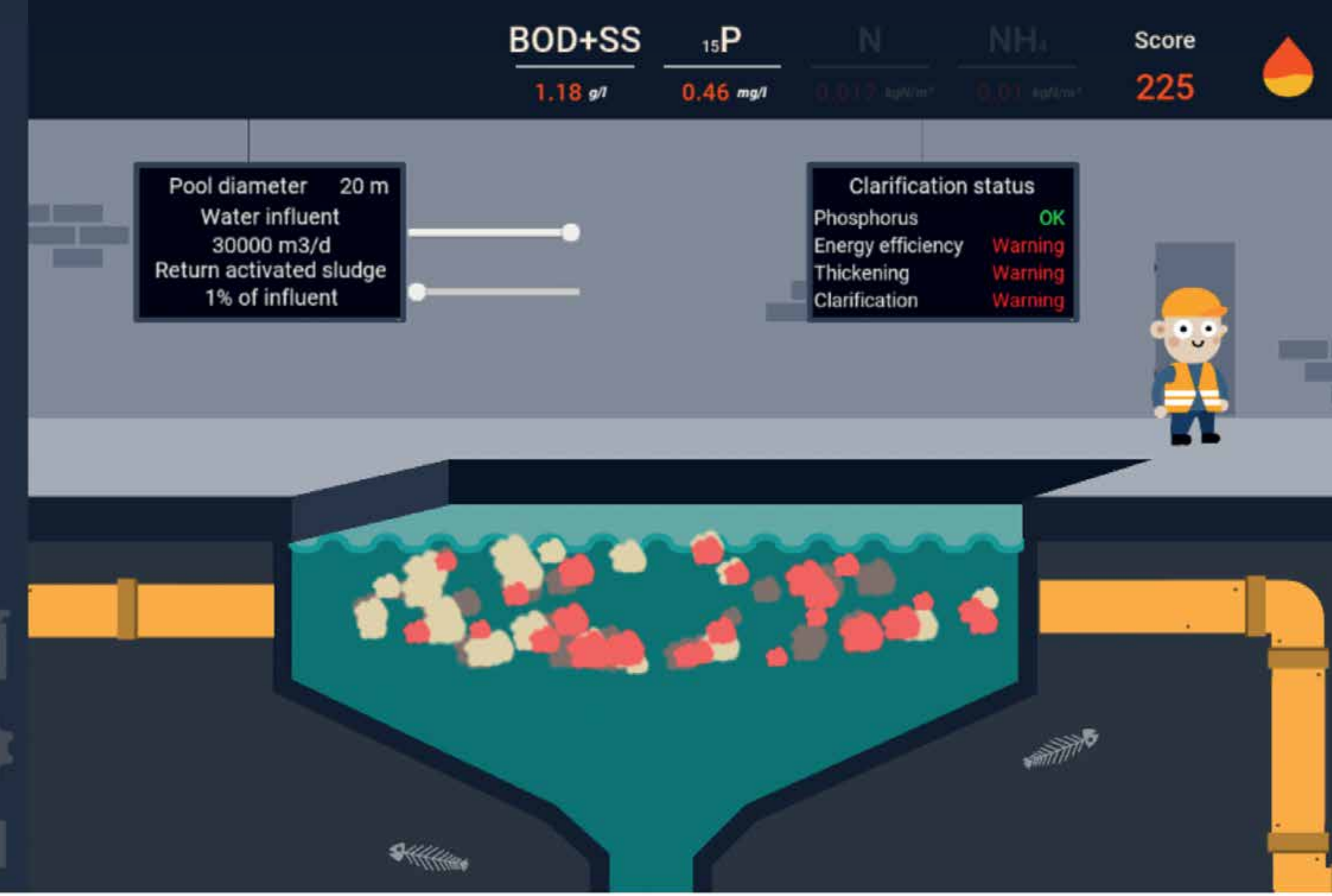


**Figure 7. Clarification.**

point of view, an Excel spreadsheet was filled with one sheet per language. This translation file was then packed as a part of the Unity assets and a script at the start of the game reads the correct sheet according to the user's preference.

The workshop courses with the student group ended in the spring 2018. After that the development mainly concentrated on coding. One student from the original group decided to participate in this project as internship. Final code changes were made during the spring semester 2019 after all the translations were ready. Building and packing of the Web-ready product took place in June 2019. The game was published in the IWAMA web server (http://wwtpgame.iwama.eu/) and a link to the game is available on the IWAMA www pages.

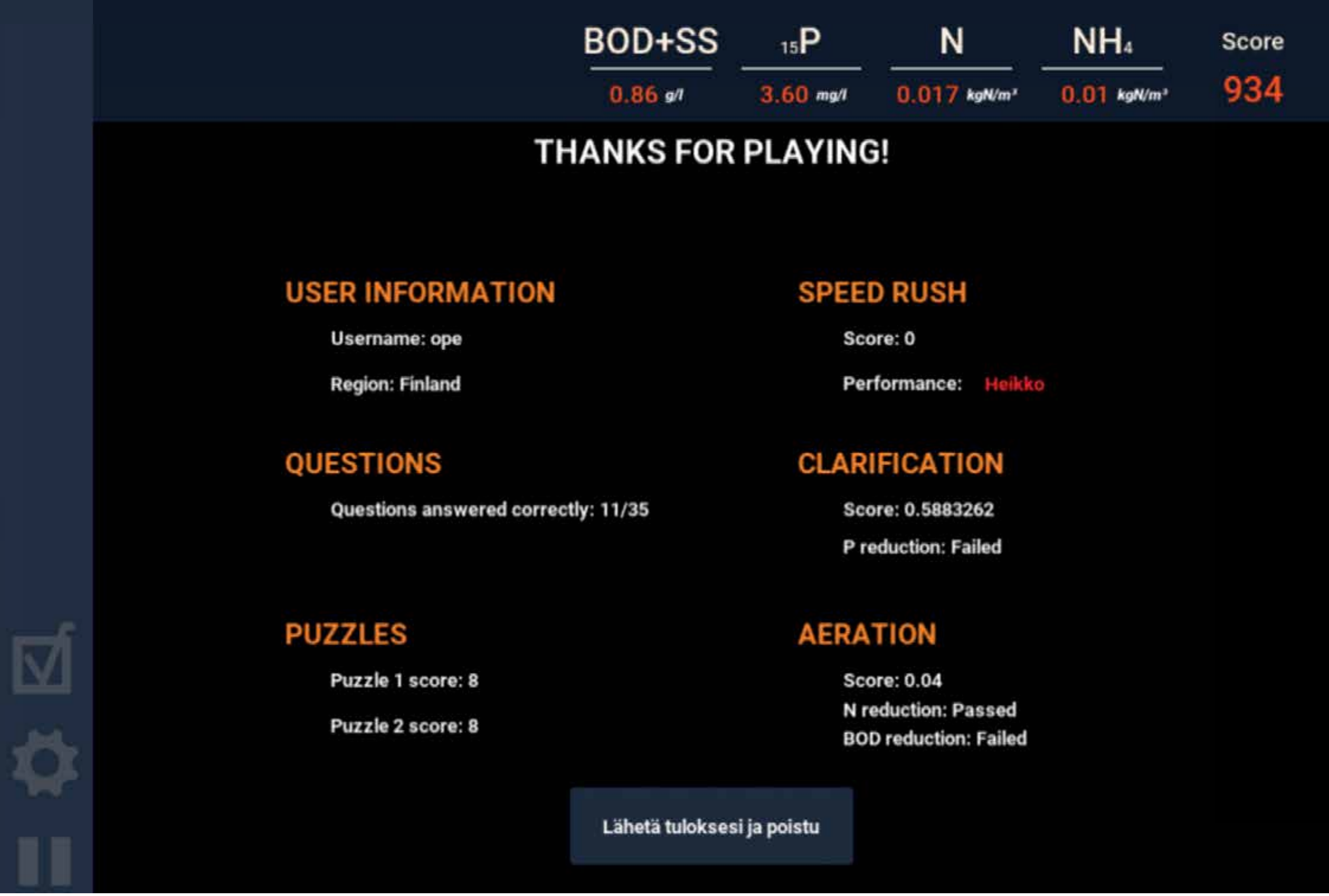


**Figure 8. Game statistics.**

## Conclusion

From the ICT point of view, this two-and-a-half-year project was a ‘textbook example’ of integration of a ‘real customer’ project with ICT studies and workshop courses. In the beginning, more students were involved with different areas of game design and development. As the project proceeded, only one student was responsible for delivering the product to the customer. Another successful issue in this project was the interdisciplinary aspect and skills needed: to be able to develop a successful game like this, professionals from environmental technology, graphic design and software engineering were needed.

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Kimmo Heponiemi

# Material flow cost accounting – a tool for better material efficiency

## Global state

We all have heard about IPCC reports and other research that had told us how we have been going to the wrong direction for quite a long time when it comes to sustainable way of living. The same kind of carefree consumption of non-renewable raw materials and energy has been going on also in many industries.

The industrial sector produced over one third of the global greenhouse gas emissions in 2010 (IPCC 2014). Industry-related greenhouse gas emissions have been increasing since that and it is estimated that the demand for material extraction and processing will be doubled in the next 35 years (Alwood et al. 2013). The environmental impacts of material production and processing are rapidly becoming critical (Allwood et al. 2010). Global stocks of non-renewable raw materials, like oil and ore, are dwindling. Our planet's supply of those non-renewable raw materials will eventually be exhausted to the point that their cost exceeds their utility (Allwood et al. 2011). Declining concentration of ore increases the energy intensity of utilizing the ore and increases greenhouse gas emissions (Allwood et al. 2013). Though some concerns about the scarcity of raw

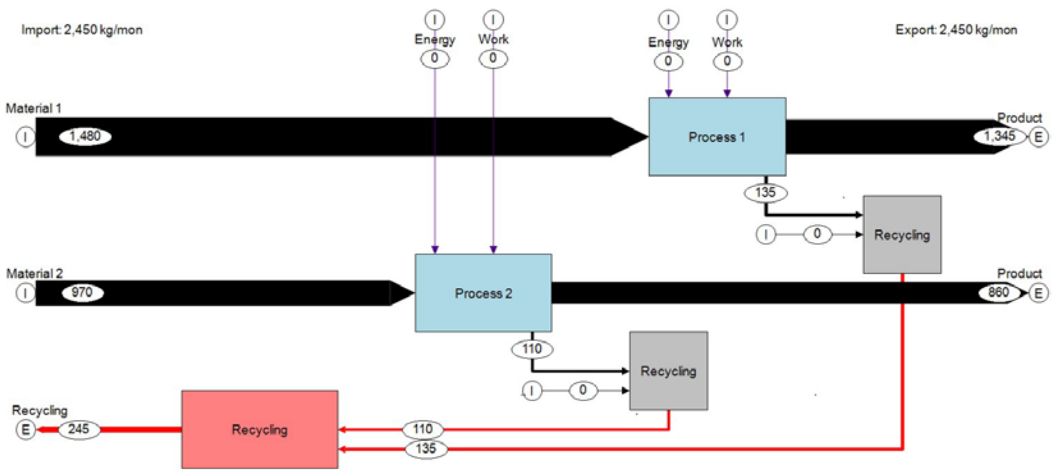


**Figure 1. Example of a MFCA mass flow chart.**

materials has risen to prominence and material efficiency has been seen as an important and promising practice to mitigate greenhouse gas emissions, it has received only a little attention to date (IPCC 2014). It is therefore clear that more attention should be paid to material efficiency.

## What is Material Efficiency?

So, what does material efficiency actually mean? Simply said, material efficiency means delivering services with less material (IPCC 2014), or in other words, providing material services with less material production and processing (Allwood et al. 2010). Using less material in production processes also requires less energy. Using less material and energy are both good things globally to the climate and locally to the environment. Material efficiency was a normal practice before the industrial revolution, because of the high value of raw materials and energy (Allwood et al. 2010). However, during the last 150 years, as the cost of energy and materials decreased, they began to be used as they would never run out.

Material costs make up about 60 – 70% of the total costs of the manufacturing industry, while energy costs are usually less than five percent of companies' total costs (Laatikainen & Sahla 2017). However, less attention is paid to material issues than energy issues. One of the key reasons for this is the diversity of practices in the production methods (Allwood et al 2010). The large variety of process methods and technologies makes the assessment process more complex (Tanaka 2008). Diversity creates uncertainty, lack of comparability, incompleteness, and lack of high-quality data available, and makes the reliable assessment of mitigation potential on a global or local scale very difficult. (Allwood et al. 2010).

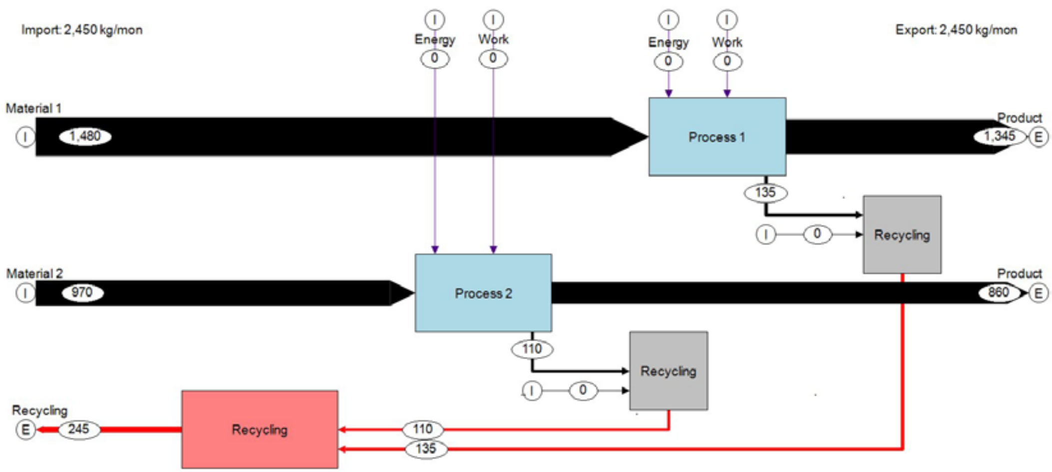


**Figure 2. Example of a MFCA money flow chart.**

## Material Flow Cost Accounting

One tool to address material issues and manage material flows is material flow cost accounting (MFCA). The MFCA model was developed in Germany, but it is popular in Japan (iPoint-systems gmbh 2019). By making an MFCA audit, a company can track its material side streams, calculate the price tag for those side streams and find ways to improve material efficiency (Figure 1). The MFCA process usually takes several months from the first meeting to the final report. MFCA also monitors energy and labor costs and allocates those costs to products and material losses. The company's responsibility in the audit process is to dig up the necessary numerical values of the production process and the consultant's job is to analyze these numbers and create a visual presentation of material flows and costs in the process.

In the sMARTTA project, implemented by LAMK, an updated version of the MFCA audit model has been developed. sMARTTA's version of the MFCA audit model aims to be lighter, more flexible and more suitable for SME's. This MFCA audit model is being piloted in the Päijät-Häme region between summer 2019 and autumn 2020. Companies have been very interested in the model. In the first round of piloting there are companies from many different sectors of industry, including the plastic, metal, furniture and food industry. The large variety of different industries is a very good thing at this stage of the developing process, because this is how it is possible to gain more experience and a wider perspective about the possibilities and limitations of the model. The updated MFCA model will be available for public use when the project ends at the end of 2020.

## Benefits of MFCA to the Company

The audit model suits a wide variety of companies, large or small, and in many fields. MFCA will help to optimize production processes and improve material efficiency in many ways. By using MFCA it is possible to find out the hidden streams in the production that carry money away from the business. It is estimated that the value of these hidden streams could be 3 -5 % of the company's turnover (Motiva 2017). The result of the MFCA audit process is practical suggestions for improving material efficiency and it can be used to support decision-making (Hyrslova et al. 2010).

The MFCA audit process calculates the price tag to the side streams of the production (Figure 2). This helps the company focus the actions on those points in production where the price tag is the highest. The audit process also points out the bottle necks of the production.

Some other benefits to the companies are that the audit process activates the personnel to pay attention to the material efficiency issues and commits the personnel to the principles of continuous improvement. The audit process also digs out so called silent wisdom in the company. Good practices, which may only be located in an employee's head, are documented and shared with other employees. The findings of the audit process can also be used as a part of the environmental marketing.

## Companies are Slowly Waking up

To this day, we have been more or less neglecting material efficiency issues. However, the increasing prices of the raw materials and the costs of utilizing them force us to pay attention to a more efficient use of materials. Quite often promoting material efficiency can be done without large investments by developing operating methods, by better monitoring and by more efficient production planning.

In the sMARTTA project, it has been encouraging to note that as the knowledge about material efficiency issues has been growing and the benefits have become tangible, companies are eager to get involved in improving material efficiency. Slowly, companies are starting to wake up to material efficiency and see its potential. By conducting a material flow cost accounting audit process it is possible to make the hidden waste flows visible and tackle them. The fact is that every single kilogram of raw material that has been purchased and does not reach the final product has cost money to the company.

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# International Studies in Resource Efficiency and Circular Economy around the Baltic Sea

One of the main objectives in the project Crea-RE ”Creating aligned studies in Resource Efficiency” is to implement joint innovative cooperation between companies and providers of higher vocational education and training, to ensure better matching work opportunities in sustainable business. As a part of the theme of resource efficiency and circular economy, case studies have been organized in Latvia, Sweden and Finland.

A total of almost 50 students from Latvia, Sweden, Finland and Russia have participated in these case studies, four different cases in each country. Students from those countries carried out their studies in groups to investigate possibilities for enhancing resource efficiency and circular economy in different industries.  Case-study courses were held in Riga, Latvia (University of Latvia UL) in the autumn of 2018; in Gävle, Sweden (University of Gävle HIG) in the spring of 2019; and in Lahti, Finland (Lahti University of Applied Sciences LAMK) in the autumn of 2019. In the spring of 2020, the final case-study course will be organized in St. Petersburg, Russia (ITMO University).

## Learning in International Groups

The idea of case-study courses is to bring together students and staff from different nationalities and knowledge to help companies with resource efficiency and circular economy issues. This increases the multicultural competence and understanding in students and in companies. In the Crea-RE project, some students have worked in an international group for the first time. Some challenges have been identified during case-study courses in every country, but this was expected. Mari Sagulin (2005) mentioned in her Master’s thesis that it is challenging to work in a foreign language with people from different cultures and working habits. This is one of the most important reasons why such courses are needed. Teamwork is one of the most important skills in working life. With this kind of international courses, students who do not have the opportunity to become an exchange student still have an opportunity to improve their language and international teamworking skills.

## Intensive Week in Lahti

The third case-study course, i.e. intensive study week, was held in Lahti, Finland in the first week of October 2019. A selected group of students was particularly international as the students had nine different nationalities due to exchange students of LAMK and HIG. The week included interesting lectures dealing with digital monitoring of traffic emissions, examples of sharing economy, textile sorting technologies, and industrial symbiosis. The students also visited furniture company ISKU and had a possibility to attend "Responsible Plastics – International Seminar for Students".

In the previous intensive weeks, we have had some challenges in getting specific tasks for the student group or getting feedback on the students' reports from the companies. This time, special attention was paid to the selection of companies and only those that had previously been co-operative were selected. The companies were:

**Purkupiha**

Purkupiha is one of Finland's largest demolition companies for buildings and industrial plants (Purkupiha 2019). To assist Purkupiha to evaluate export opportunities for their products, students are collecting examples of construction companies and power plants from each student's home country. Due to the multicultural background of the student group, the collected information is expected to be valuable to the company.

**Envirate**

Envirate is a startup company that has created a platform for completely new environmental big data, which produces valuable information for individuals, businesses, and policymakers. The solution is built on well-established, existing technologies: a smartphone app, cloud computing for web hosting, big data collection, and AI for data analysis. The app is easy to use: data is collected based on using natural human senses (look, hear and breathe) via the users' smartphone. (Envirate 2019) One of the tasks that Envirate gave the students was to find new ideas how the citizens, companies or institutions would like to utilize Envirate data.


**Figure 1. Students became familiar with the sorting of construction waste (picture by Erika Tapaninen).**

**Lounais-Suomen Jätehuolto Oy**

Lounais-Suomen Jätehuolto Oy is a forerunner among the Finnish waste management companies to collect and process textile waste. They are building a new pilot-scale textile sorting and processing plant in the Turku area. Today, globally about 85% of clothes end up in a landfill or are incinerated. (Lounais-Suomen Jätehuolto 2019)

The company gave students the task to find out how the consumer textile waste is collected in their home country. How is it is treated further (sorting/ incineration/ landfill)? What kind of interesting textile reusing or recycling opportunities and solutions are there in their country (big or small companies, municipalities, education, art)?

**Päijät-Häme Waste Management Ltd.**

The students' visit to the waste management centre of Päijät-Häme Waste Management Ltd (PHJ) was included in the program because the area is a significant example of industrial symbiosis in Finland. The area covers 70 hectares, and in the area 200,000 tons of waste is sorted each year (PHJ 2019). The students' task was again to find good examples of industrial symbiosis from their own countries and even to design new possible symbiosis. This learning method increases students' inventiveness.

## Towards the EU Targets

The Crea-RE project's content is backed up by EU directives and climate targets. For example, the waste directive (2018/851) and EU's 2050 long-term strategy (COM(2018) 773 final) for climate neutral economy are steering operations in a more environmentally friendly direction.

By sharing good examples in circular economy between students and teachers from different countries, the Crea-RE project is trying

**Figure 2. Sakari Autio (right) led the company visit around the Kujala Waste Management Centre of Päijät-Häme Waste Management Ltd (picture by Erika Tapaninen).**

to make its share to prevent climate change. Good examples are shared with companies in four different countries and students are sharing their new knowledge further. The feedback from the students on the study visits has been very positive.

The Crea-RE project is funded by the Interreg Central Baltic Programme and it is implemented in 2018-2020. The Russian partner is participating in the project (Crea-RE-RU) with funding from the Swedish Institute. (Crea-RE 2019)

The authors would like to express their gratitude to the Interreg Central Baltic Programme for the funding of the project "Crea-RE Creating aligned studies in Resource Efficiency".

Also, we would like to thank the partners and all the participants of the Crea-RE project who helped with organizing the case studies.

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# Exploring Japanese Cooperation Opportunities

Lahti region aims to strengthen co-operation with the city of Kyoto and the Kyoto prefecture. The targets of the development work are to promote opportunities for local companies to enter the Asian market and to introduce regional environmental expertise, education and circular economy implementations. Ongoing successful collaboration between universities, companies, cities and municipalities as well as regional development companies are a good basis towards achieving these targets.

Cooperation had started in 2016, with mutual visits in Lahti region and in Tokyo and Kyoto regions in Japan. Since 2018 it has been organized under HYPE project, coordinated by Ladec Ltd while City of Lahti and LAMK act as project partners. HYPE stands for "Wellbeing and clean environment – Japan-Finland cooperation platform for Asian markets". The nomination of Lahti as the European Green Capital 2021 strengthened the reputation of Lahti as environmental forerunner. United Nations Sustainable Development Goals goals are also well recognized in Kyoto, due to Kyoto Protocol which was signed in 1998 and came into force in 2005 including the mechanism of emissions trade.

LAMK's new master's program MUrCS (Master in Urban Climate and Sustainability) has opened new possibilities for international co-operation. LAMK has signed a Memorandum of Understanding (MoU) with Ryukoku University in Kyoto as a result of mutual visits and negotiations. Also, the last visit to Kyoto in the beginning of October 2019 contained meetings with Ryukoku University representatives and discussions of further cooperation opportunities. During this visit the mayor of Lahti, Pekka Timonen, signed cooperation agreements with the city of Kyoto and with Kyoto prefecture.

## Development in Urbanization and Universities

Finland and Japan share two important challenges: low birth rate causing declining age groups and decreasing rural population when people are moving to urban areas because of better career opportunities. The population of Kyoto prefecture surrounding the city of Kyoto is 2,6 million while the growing city of Kyoto has app. 1,5 million inhabitants. Majority of the cities in Kyoto prefecture are by size between 50 000 and 100 000 inhabitants. In the light of these facts Päijät-Häme region has many similar challenges with Kyoto prefecture. Both Japan and Finland are high technology countries and have developed new business opportunities based on clean technology. The challenge is to find new business opportunities in rural areas where agriculture is the main source of livelihood.  Although the needs for urban areas are primarily in discussions in the project, there are possibilities to enhance rural development with new technologies as well.

According to Eddy Van Drom the Japanese universities have faced several transition periods since the Japanese society started to open up to the surrounding world after 1868, called as the Meiji period (1868-1912). In 1868 Japan started a rapid modernization including education. The following major renovation took place after the war, in 1947, when Fundamental Law of Education (FLE) replaced earlier regulations. The importance of academic research for industrial implications was emphasized and there were attempts to strengthen the relationship between academics and industries to restore the Japanese economy. However, this idea faced also strong resistance, due to the thinking that the role of the universities was to educate leaders to the industries. In 1980´s the critical attitudes towards post-war education system became stronger and the Prime Minister founded a committee to develop new solutions to the situation. The committee, named as AHC (Ad-Hoc Council), suggested actions of liberalization and privatization. They also suggested the principle of lifelong education. In 1990 a Lifelong Learning Promotion Law was passed, and in 2006 the Fundamental Law of Education was amended to include articles enhancing the importance of the community and lifelong education as well as traditional values.

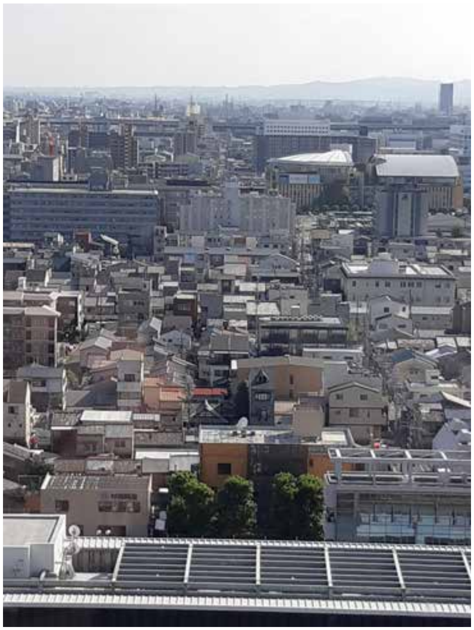

**Figure 1. View to the densely built Kyoto (photo by Eeva Aarrevaara).**

Ryukoku University started a special extension center (REC) in 1994, which had a role of providing support to small-scale industries for example by renting laboratories to them and provide academic expertise. Professor Yoshio Kawamura was one of the key figures from Ryukoku University in proposing this action. He has visited Finland/ Lahti, and also met with the HYPE team on several occasions. He still works as a senior advisor to the REC of Ryukoku University. According to him, the extension of the university should become the third social function in higher education together with the classical research and education.

In July 2019, two international Master students from the MUrCS program got the opportunity to participate in a JICA training arranged by Ryokoku University – primarily for representatives of local authorities in developing Asian, African, Middle East and South American countries. The lectures and excursions of the program demonstrated good examples of working life development in cooperation with universities and their institutions. The main aim of JICA training program was to enhance local government administration through participatory local development. This was demonstrated by several different lectures, project presentations and site visits. In the following chapter one project from JICA training is presented.

## Kameoka City – Carbon Minus Project

Kameoka city is one of the moderate size cities in Kyoto prefecture with the population about 90,000 inhabitants. The city has an abundance of biomass resources. This enabled the region to create a system wherein $CO_2$ reduction was possible, while at the same time improving regional development. The Carbon Minus project enabled private companies to contribute towards environmental conservation by funding forest management practices, which bought them $CO_2$ reduction credits.

For instance, dead trees have a lot of stored carbon, which get released in the atmosphere if allowed to decompose on its own. But by converting them to biochar, they are then stored below the ground in agricultural areas to facilitate the growth of fruits, vegetables and other agricultural products. The food produced with the help of biochar was then labelled as 'COOL VEGE' (where 'COOL' also stands for the reduction in carbon emissions created due to this process). The 'COOL VEGE' products were then marketed and sold accordingly in supermarkets.

The entire process created a sustainable social system, wherein collaboration with private industries, banks and other stakeholders led

**Figure 2. JICA training participants in a site visit (photo by Mahmudul Chowdhury).**

to the improvement in local communities. The good forest management practices, followed by the creation of biochar which was then used to create this 'COOL VEGE' branded agricultural product, all of which helped revitalize the local agricultural economy. Similar collaborative efforts that help revitalize the local economy of a region may be key investment opportunities.

Landowners are responsible for the naturally grown abundant bamboo plantations in their own property. This requires regular maintenance, which can be costly. To avoid such maintenance costs, landowners provide these plantations, which are used as the resource material for making biochar.

## Conclusions and Next Steps

Although there are a lot of similarities between Finnish and Japanese societies, collaboration has also provided a cultural learning path to Japanese working culture and university context. Finnish people are very task oriented, while in Japanese culture it is important first to create a mutual relationship and establish organizational structures. Hierarchy in Finland is generally low while the situation is quite opposite in Japan. In practice, this has manifested into questions concerning what kind of agreements are needed or even accepted. One challenge in student exchange is language barrier: in Japan there are only a limited number of university courses avail-

**Figure 2. JICA training participants in a site visit (photo by Mahmudul Chowdhury).**

able in English which means that the exchange studies are either a special project, a field work or a thesis project. Naturally, the same challenge concerns possible Japanese students entering Finnish universities.

Finland and Japan are celebrating one century of diplomatic relationship and the new free trade agreement between Japan and European Union has increased interest in developing mutual relationships in different fields of society. Cooperation with the Finnish Embassy in Japan and representatives of Business Finland has been essential for networking with enterprises, administrations and universities in Japan. Based on the earlier experiences the project team will develop further relationships and common understanding with Japanese stakeholders in the field of businesses and higher education. The nomination of City of Lahti as the European Green Capital 2021 will support these aims by providing a year full of events available for international professionals and students. Olympic games in 2020 and Metsä Pavilion in the site of the Finnish Embassy in Japan, Tokyo, are opportunities for Finnish companies, regions and universities to create new networks next autumn.

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The theme of this publication is circular economy solutions, which is one of the four focus areas at Lahti University of Applied Sciences (LAMK). This publication contains eight articles written by experts and students from Lahti University of Applied Sciences, Aalto University, Regional Council of Päijät-Häme and Lahti Aqua Oy. The aim of this review is to present the latest interesting research and development projects in the field of circular economy.

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