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Business cases development in public-private partnership within three pillar green focuses

Output from Cata3Pult project

gnf

Disclaimer

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Abbreviations and concepts

CDW	Construct and Demolition Waste
CE	Circular economy
CFC	Carbon footprint calculation
DBD	Dielectric Barrier Discharge
DCV/VAV	Demand Controlled Ventilation/Variable Air Volume
DH	District Heating
EaaS	Energy-as-a-Service
EKJH	South Karelian waste management organization
ESCO	Energy Saving Contract/Company
FS	Feasibility study
GAD	Gliding Arch Discharge
GD	GoogleDrive
GHG	Greenhouse gases
GNF	Green Net Finland
GSHP	Ground Source Heat Pump
HPOA	House Property Owners Association
HR	Heat Recovery
HSY	Helsinki regional environmental services
LCC	Life Cycle Costs
LETI University	St. Petersburg Electrotechnical University
LLC Kosmos	Limited Liability Company Kosmos
Metropolia UAS	Metropolia University of Applied Science
MW	microwave discharge
NTP	Non-thermal plasma reactors
PPP	Public-Private Partnership
PVC	Polyvinyl chloride
SDG17	17 United Nation's Sustainable Development Goals
SEFRCBC	South-East Finland - Russia Cross-Border Collaboration
SGM	Smart and green mobility
SPb	St. Petersburg
SPb MWR 3.0	St. Petersburg Market Watch Report - volume 3.0

Table of content

Abbreviations and concepts 2

Table of content 3

Introduction 5

What was Cata3Pult focus? 5

What do we mean by Business Case? 7

How do we organise the development work? 8

How do we define the public-private partnership PPP? 10

About structure of this publication 11

1 Eco- and energy efficiency 12

1.1 Ground source heating - feasibility study for ITMO HIGHPARK and Juzhniy Satellite City in St. Petersburg 13

1.2 Feasibility study on energy efficiency and advanced business models 17

1.3 Comparative Analyses of adopted energy efficiency PPP models for buildings 20

1.4 Learning from: simulations results from HUKATON-project 20

1.5 Study case of implemented modernisation of heating system in typical block of flats in St. Petersburg 23

1.6 Calculations of carbon footprint of heating and electricity systems of buildings 25

1.7 Learning from: Indoor air quality-as-a-service 27

1.8 Learning from: ESCO experience from St. Petersburg 28

2 Smart and green mobility - SGM 29

2.1 Biogas as fossil free fuel 30

2.2 Hydrogen solutions 30

2.3 Electrical vehicles 31

2.3 Shared use of e-vehicles the city of Lappeenranta 31

3 Circular economy 32

3.1 Biogas production and treatment of organic-/food-/biowaste 34

3.2 Textile reuse and up-/recycling 38

3.3 Learning from: Re-use and recycling in construction 40

3.4 Recycling concrete or geopolymer 43

3.5 Plastic/polymer waste recycling 47

4 Student innovation projects **51**
4.1 “LETI Live Glossary” project 51
4.2 Student innovation projects of LETI 52
4.3 Recycling of coffee waste project of Metropolia 52
4.4 Renewable Hydrogen project of Metropolia 54
4.5 Fucus Vesiculosus project of Metropolia 55
4.6 Plasma reactors (VTT) project of Metropolia 56
4.7 Future Outlook of Carbon Neutral Chemical Industry (St1) project of Metropolia 57

5 Individual support to businesses with wider intent **60**
5.1 Demand-controlled ventilation - case Enterprise # A 60
5.2 Urban farming solution - case Enterprise # B 62

6 Collaboration & communication group of SEFR CBC projects **63**

7 Conclusions and recommendations **64**

8 References **66**
8.1 Presentations of the Cata3Pult Expert Groups 66
8.2 Other references 67

Attachment: List of Figures (1 - 33) **68**

Introduction

The overall objective of the Cata3Pult project is to contribute to **economic and environmental development**, to enhance regional business competitiveness through cross-border public-private collaboration, and to **catalyse green solutions development** by attracting businesses to invest, locate, and operate in the programme area.

Cata3Pult name comes from: catalysing, 3 clusters in 3 regions, 3P - public-private partnership, 3 substance focus areas. Three project partners of Cata3Pult are managing organisations of three regional cleantech clusters:

- City of Lappeenranta (lead partner) and **Greenreality Network**
- "St. Petersburg Home Property Owners Association" (HPOA) and **International Consortium "St. Petersburg Cleantech Cluster for Urban Environment"** (SPb cleantech cluster)
- Association **Green Net Finland** (GNF) with the same name of member-network

What was Cata3Pult focus?

Cata3Pult project was focused on **urban environment**, which we see composed of three green pillars or three different **environmental business focuses,** which are**:**

1. Eco- and energy-efficiency (EEF)
2. Smart and green mobility (SGM)
3. Circular economy (CE)

Geographical focus of the Cata3Pult in St. Petersburg was Kolpino and Pushkin districts and in Finland South-East Finland.

As one set of activities, Cata3Pult project organised a work of the Finnish-St. Petersburg Expert Groups, whose **economic context is to develop at least six (6) Business Cases**. To make a structure for this work, there was also planned output of the Operational Model of Expert Groups and Business Cases Development .

Environmental context of the Cata3Pult is defined as following:

1. Reducing GHG/CO2-emissions by the private housing stock and public buildings of St. Petersburg and Lappeenranta by reducing the consumption of natural resources for lighting and heating, as well as improving the efficiency of solid communal waste management.
2. Reducing the environmental load from transport both in St. Petersburg and in Southeast Finland.
3. Reducing the consumption of primary natural materials by putting into practice the principles of a Circular Economy.

To create joint understanding and connect our contribution to bigger goals, we integrated our business cases objectives and environmental context into UN Sustainable Development Goals (SDG17). In Cata3Pult project business cases development work belongs to the following goals: SDG7 - affordable and clean energy, SDG11 - sustainable cities and communities, SDG12 - responsible consumption and production and SDG13 - climate action. The focuses and interconnections are visualised in **Cata3Pult development framework**. (Figure 1).

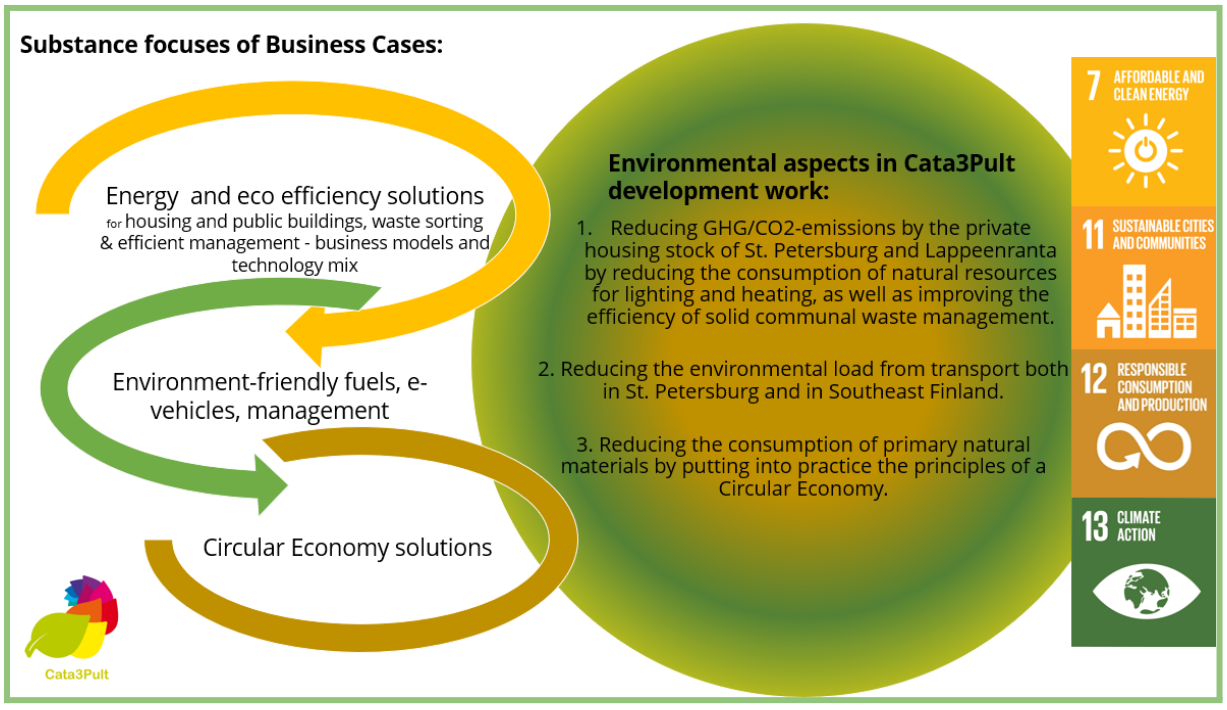


Figure 1. Cata3Pult development framework

This publication opens and describes the implementation story of Business Cases development work of Cata3Pult during the period of time June 2019 - November 2022. Overall framework of activities was not restricted to the three Expert Groups meetings. It included also such categories of activities as:

- Feasibility Studies (further - FS) of selected business cases (overall four FS:s, (Chapters 1.1, 1.2, 1.3 and 3.1)
- Learnings from existing results from previous projects with direct involvement of Cata3Pult experts (Chapter 1.4 and 3.3)
- Student Innovation Projects (Chapter 4)
- B2B and one-to-one meetings organised and supported by cluster business experts (Chapter 5)
- open events (organised and participated by Cata3Pult) such as educational webinars/seminars and get to know in practice- visits
- visibility & communication activities such as online mini-glossary/communication support tool, publications, website news and social media posts

What do we mean by Business Case?

In the Cata3Pult project we define the Business Case as a part of the development process in the so-called *Business Matrix* (Figure 2). On top of this are sales and business leads, which we see as enterprises' internal activities and are out of the scope of the Cata3Pult project. Instead, our scope is the development context in the business matrix and particularly Business Cases -part. This part in the business matrix still has quite a big volume of uncertainty. The Cata3Pult project attempted to bring to discussions uncertain matters.

The **Business Case means conceptualization around one substance focus aimed to support enterprises' evaluations of business potential, business decision and business development.**

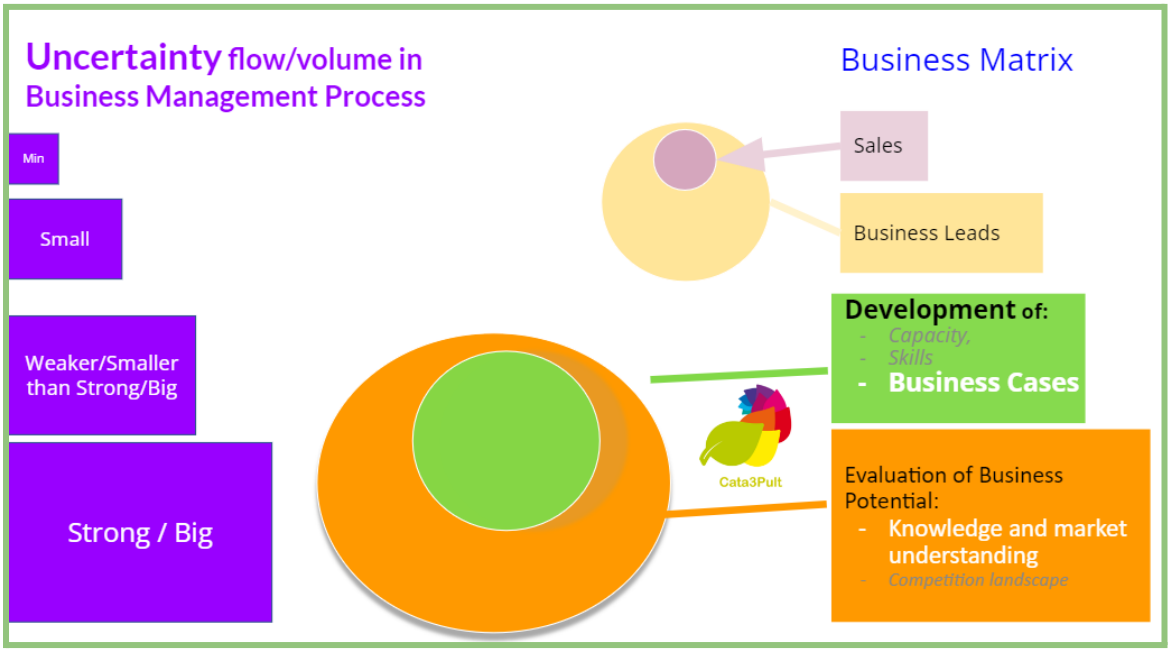


Figure 2. Business Cases of Cata3Pult in Business Matrix and uncertainty flow.

How do we organise the development work?

We started implementing activities of Cata3Pult in June 2019. It took about half a year to organise our work as a structured and dynamic process and to form first Business Cases. In the beginning we observed differences in understanding or not-understanding words and concepts brought onboard. Interactions during study visits of SPb experts to Lappeenranta and Helsinki area in the beginning of September 2019 probably was a key event of evidencing those observations. We attempted to do something to tackle this challenge. GNF proposed the idea to develop a so-called online communication supporting tool. The idea was not only to support communication within Cata3Pult project team and external experts, but also to help other cross-border collaborations. We discussed this idea on Cata3Pult meeting with participation also team from BBC1 project in SPb in mid September 2019. One of the Cata3Pult partners - KOSMOS LLC - brought onboard an already existing dictionary. If we go back to the idea, then there is also a certain logic behind it, that ***Good Business Starts with Good Communication***. We

organised work in such a way, that when we observed miss- or not-understanding of some words/terms/names during interactions, then we entered this item into the spreadsheet. There was also a so-called validation process of those items. We asked experts involved and also a wider audience to comment on existing items. After receiving comments we revised those and updated the content. So, we integrated into our Business Cases development process development of the mini-glossary/online communication support tool, which is Google Spreadsheet Cata3Pult mini-glossary.

The development of the Business Cases organised in the Cata3Pult as a process covering mentioned above categories of activities (Figure 3). In addition to the Cata3Pult project events, project experts also followed relevant ongoing changes and trends and participated in the international events organised by other projects/organisations green business and cluster collaboration. The Cata3Pult Business Cases are presented in general member and board meetings of the three regional clusters of the partnership - Green Net Finland GNF), Greenreality Network Lappeenranta and SPbCleantech Cluster. In addition to cluster meetings, information about Cata3Pult is shared via newsletters of each cluster.

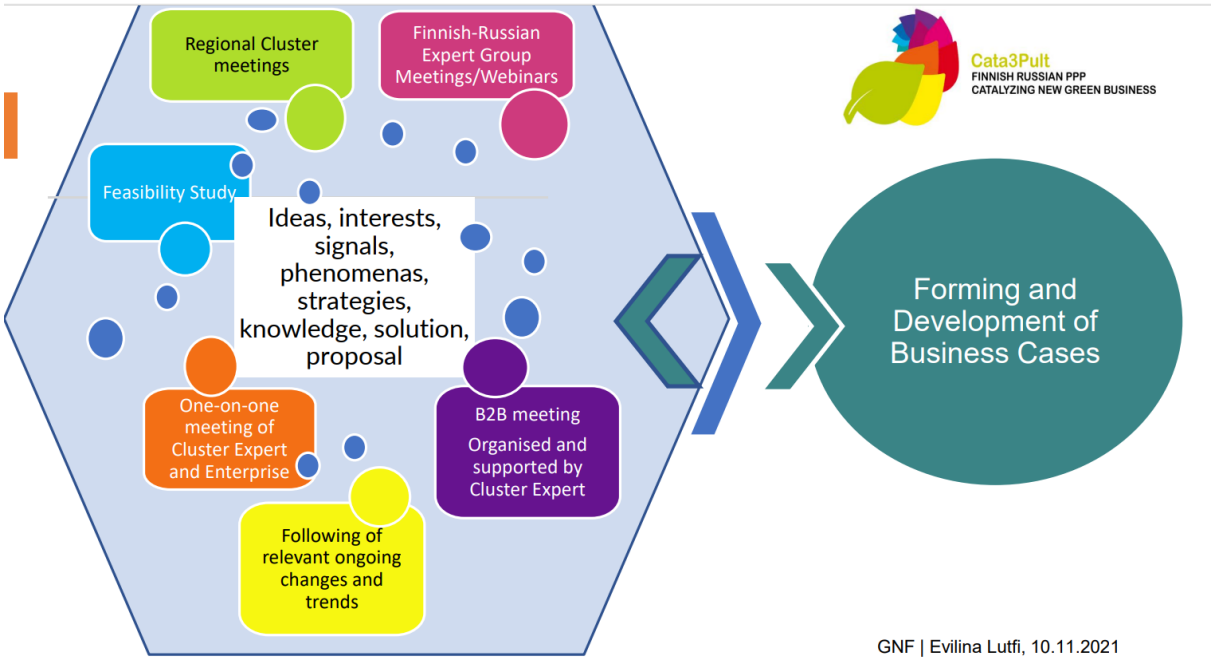


Figure 3. Process of Forming and Development of Business Cases in Cata3Pult.

How do we define the public-private partnership PPP?

Public-private partnership PPP definitions vary. In the Cata3Pult project we define ***partnership*** as collaboration between so-called "triple-helix clusters" or collaboration in "meta-cluster" or "cluster of three regional clusters". In business administration language this collaboration/partnership/meta-cluster is some sort of weak mash-up/co-branding. In the Cata3Pult project implementation phase collective activities focused on predefined project objectives and targeted outputs. One of the results was forming a new meta-cluster of 3 clusters called *Green Net Alliance*, which means not-fixed, not-obligated-to-something, free-to-join-or-leave-initiative without forming any kind of legal/juridical entity, but showing good-intent-to-collaborate.

To make distinction between **public and private** organisations/entities we followed SEFRCBC programme's indicators reporting principles. Under the definition of **public** are authorities (local, regional and state level), subordinating organisations (enterprises) of local public authorities (for example, State Unitary Enterprises/SUEs of St.Petersburg under relevant committee), public research & education sector in term of business-oriented project development (for example UNIDO information center of SPbSTI (TU) - Saint Petersburg State Technological Institute (Technological University)). Under the definition of ***private*** are SMEs LLCs, non-formal education enterprises. In certain cases the division between public and private is not clear. For example, is Finnish UAS enterprise or public organisation? The form of legal entity is LLC/enterprise, but UAS:s owned by municipalities/public, public projects e.g. EU INTERREG:s in UAS:s are part of enterprise/business activities/not-government-financed. So, what is the defining factor - public/municipal ownership or limited liability company legal entity? Figure 4 illustrates the PPP context of Cata3Pult.

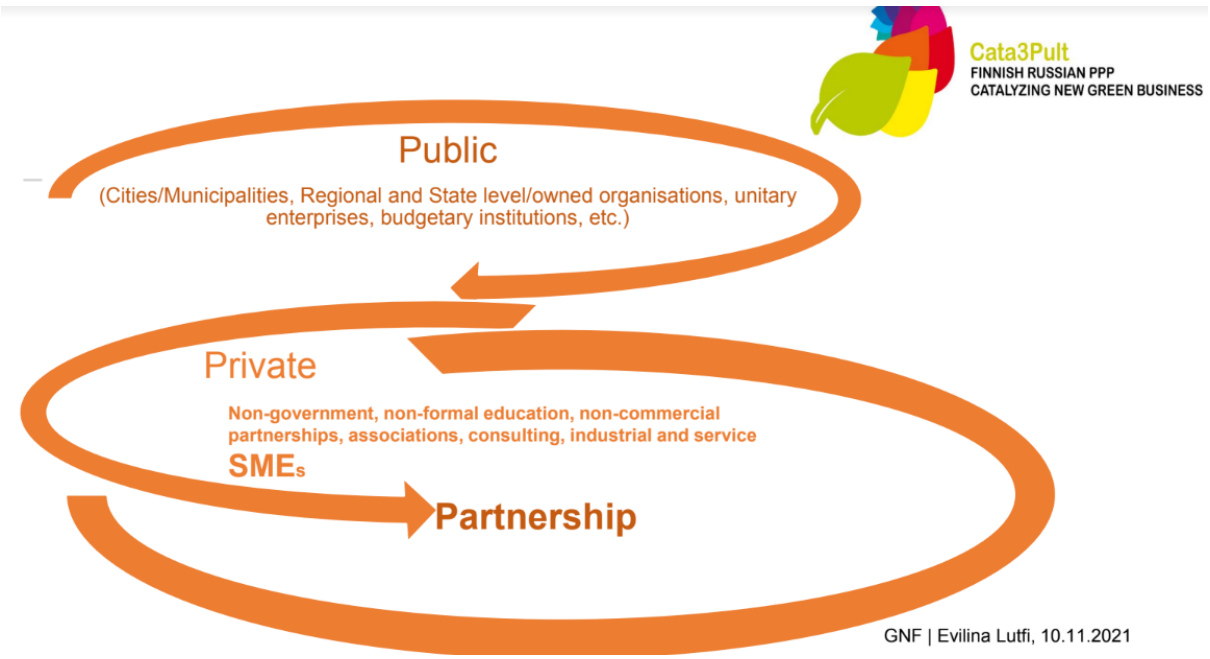


Figure 4. Illustration of public-private partnership in Cata3Pult

In addition, Cata3Pult project is initiated and coordinated work of collaboration & communication with four other SEFRCBC projects related to environmental and ecology matters (Chapter 6).
Since March 2022, the development work has continued within Finnish partners only, including writing of this output publication.

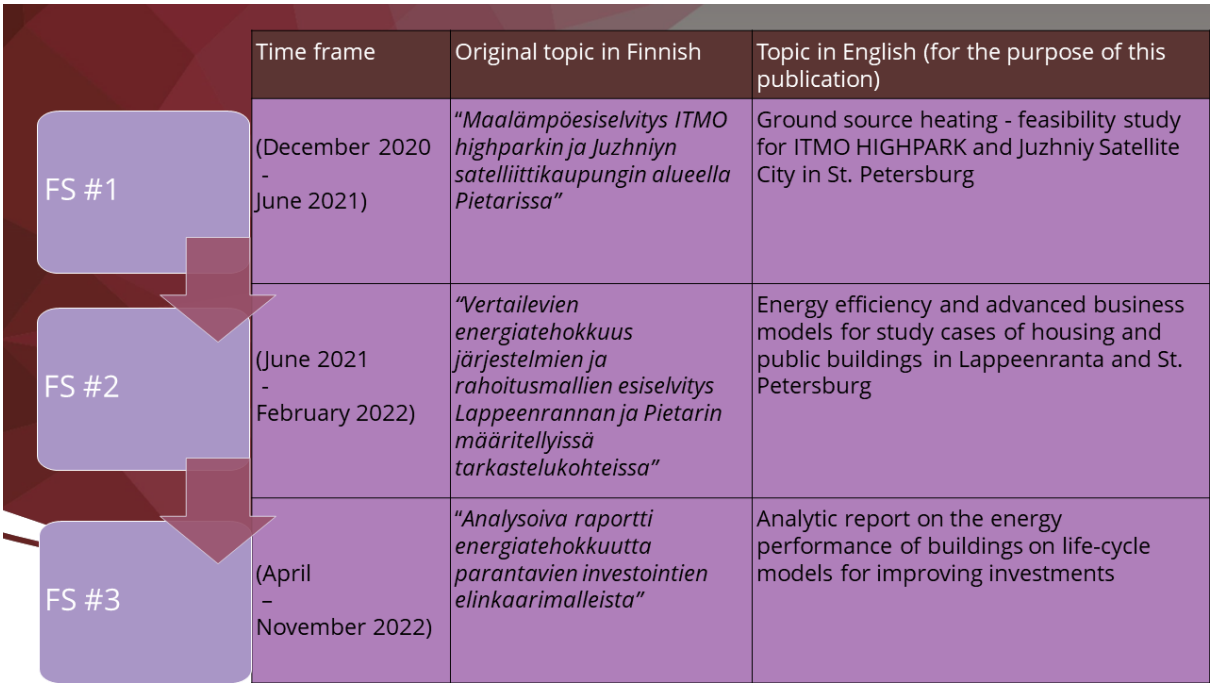
About structure of this publication

The body part of this report-publication has six Chapters. First three chapters are in line with the substance focuses of Cata3Pult project already presented in Introduction Chapter. Chapter 4 is dedicated to Student Innovation Projects and Chapter 5 is about direct support to individual enterprises. In Chapter 6 we describe collaboration and communication with other relevant SEFRCBC projects. In Chapter 7 we present conclusions and recommendations. In Chapter 8 References we listed presentations and reports utilised as the sources of information for content of this publication.

1 Eco- and energy efficiency

Starting point and argumentation for selection of energy efficiency of residential and public buildings as one of the focuses in Cata3Pult project was premises that, the share of heating energy in housing costs is quite high in Finland and St. Petersburg due to their Nordic location. Dominating amount of residential building stock in both regions needs refurbishment. By modernisation of heating systems remarkable savings of energy could be achieved and as result also GHGs emissions. However, energy saving investments are quite expensive. New financial models of financing are interesting for all regions. First public ESCO cases were started to implement around 2010 onwards in Finland (Vantaa among the first municipalities) and St. Petersburg 2013 first cases started by one of Cata3Pult project partners HPOA (Chapter 1.8.). There is still a lot of developing needed in ESCO and other energy saving contract model e.g. EPC or leasing contract. In such so-called Energy-as-a-Service (further - EaaS) models customers pay for an energy service without having to make any upfront capital investment.

The Cata3Pult project organised numerous activities related to the eco- and energy-efficiency (further - EEF) topic, part of which are described in this report. Cata3Pult project topics for discussions in Expert Group meetings as well as topics of/for feasibility studies were defined in proceeding with activities and discussions with companies and representatives of the cities. Overall three feasibility studies (FS #1 - #3) under the EEF focus were procured by the Cata3Pult (City of Lappeenranta) (Figure 5). The reports are originally in Finnish. In this publication the main highlights of the results are presented.



	Time frame	Original topic in Finnish	Topic in English (for the purpose of this publication)
FS #1	(December 2020 - June 2021)	*"Maalämpöesiselvitys ITMO highparkin ja Juzhniyn satelliittikaupungin alueella Pietarissa"*	Ground source heating - feasibility study for ITMO HIGHPARK and Juzhniy Satellite City in St. Petersburg
FS #2	(June 2021 - February 2022)	*"Vertailevien energiatehokkuus järjestelmien ja rahoitusmallien esiselvitys Lappeenrannan ja Pietarin määritellyissä tarkastelukohteissa"*	Energy efficiency and advanced business models for study cases of housing and public buildings in Lappeenranta and St. Petersburg
FS #3	(April – November 2022)	*"Analysoiva raportti energiatehokkuutta parantavien investointien elinkaarimalleista"*	Analytic report on the energy performance of buildings on life-cycle models for improving investments

Figure 5. Feasibility studies of Cata3Pult project in the focus area of eco- and energy-efficiency.

Potential of ventilation and heat recuperation was widely discussed via different Cata3Pult events and in social media channels. Also ground-source heating potential was one of the subjects of interest. Advanced business models were studied in the FS #2 and FS #3. Results of the FS #2 were presented on the EEC expert group webinar in February 2022. Results of the FS #3 planned to be presented during the final event.

1.1 Ground source heating - feasibility study for ITMO HIGHPARK and Juzhniy Satellite City in St. Petersburg

FS #1 was implemented by Sweco Talotekniikka LLc. The first part of the study includes a description of the geological structure of the study area (see Figure 6).

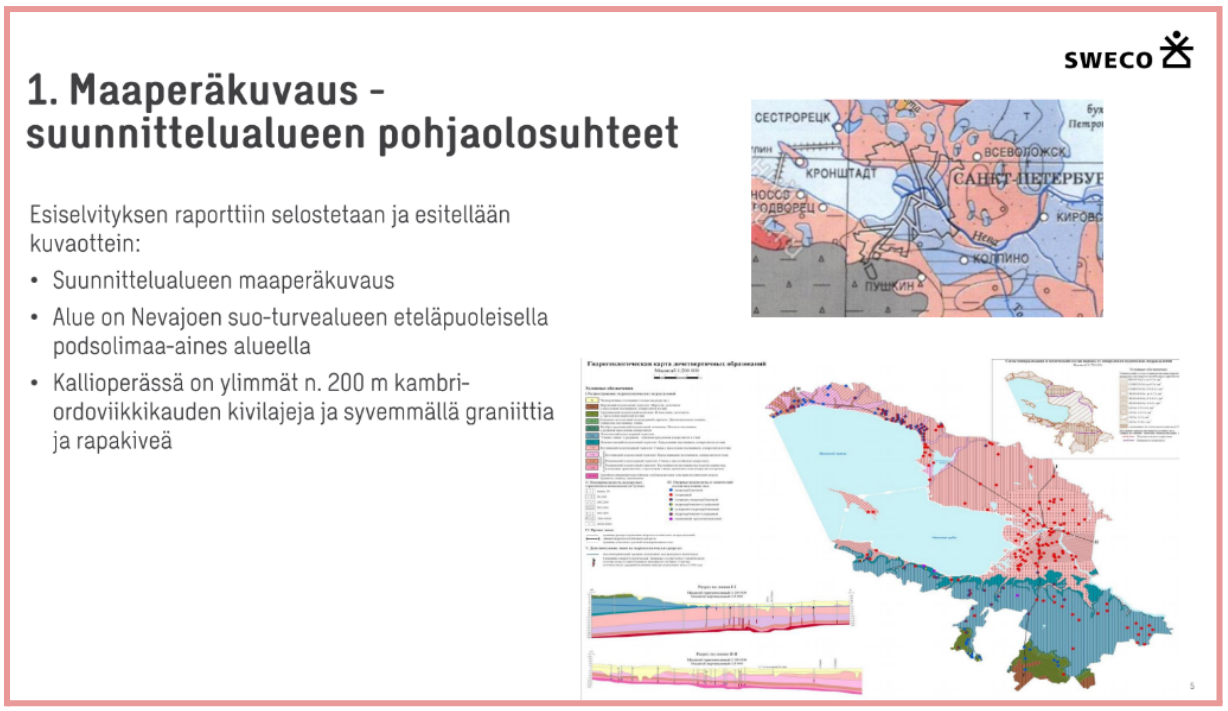


Figure 6. Screenshot on geological description of the study case area from SWECO presentation in Expert Group on 2.9.2021 (FS #1).

In the report is also described the General Plan of St. Petersburg, more detailed Land Plan (in Finnish *Asemakaava)* of the study case area with estimation of construction plans for Juzhniy Satellite City *(Figure 7).*

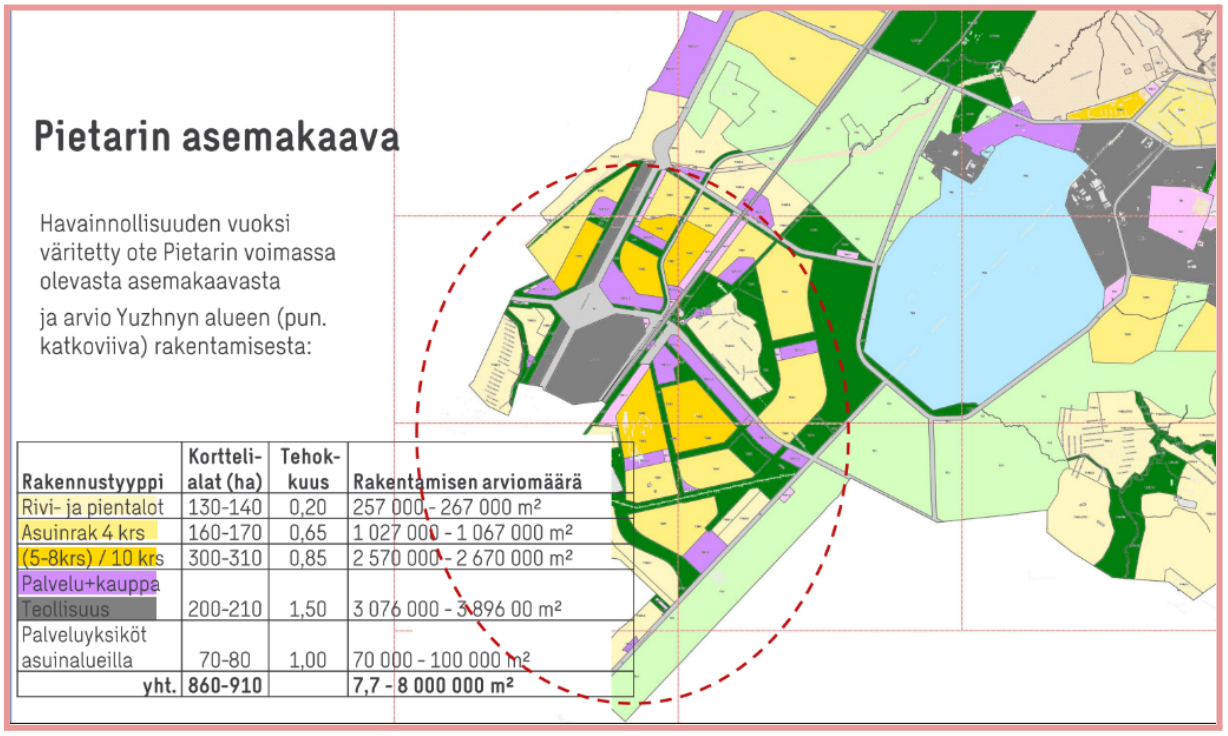


Figure 7. Land Plan of St. Petersburg with estimation of Yuzhniy area construction (FS #1).

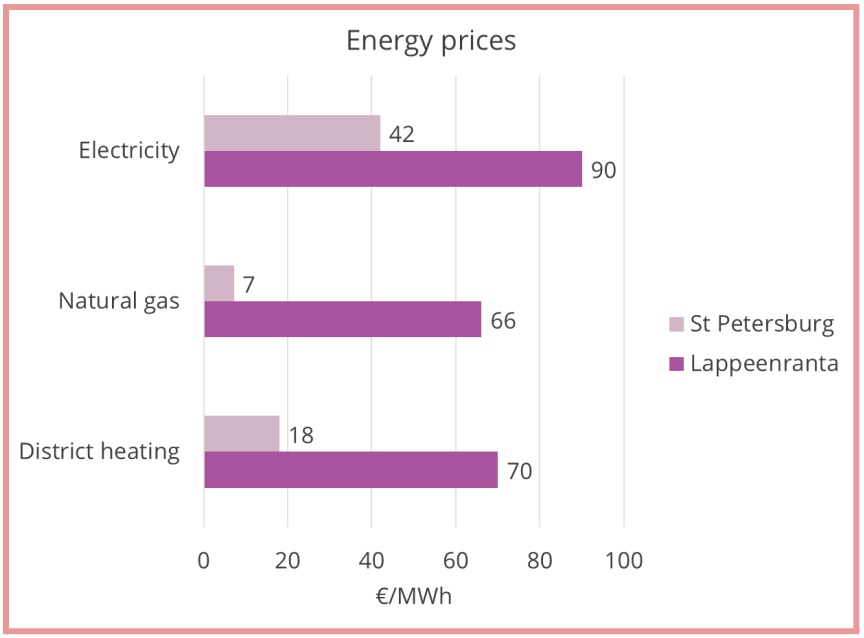
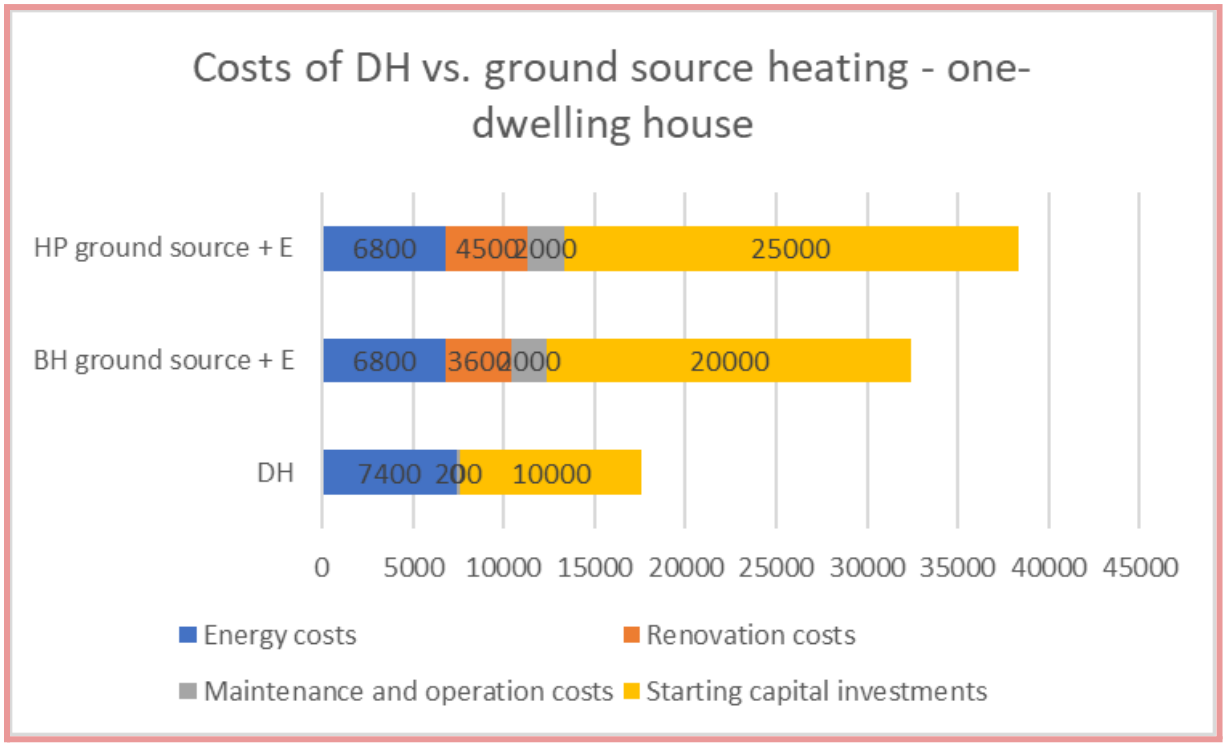


Figure 8. Energy prices in St. Petersburg and Lappeenranta used in LCC analysis of FS #1 and FS #2

Conclusions of the feasibility study FS #1:

- Costs of district heating (DH) for end users in St. Petersburg is very cheap in comparison to Finland (Figure 8)
- DH in St. Petersburg is appr. ⅔ cheaper than electricity (in Finland DH this relation is appr. ⅛)
- By ground source heating (GSHP) in St.Petersburg can achieve 6€/MWh savings in comparison to DH (in Finland - 44€/MWh)
- Capital investments into GSHP system are about 10 times more expensive in comparison to DH (Figure 9)



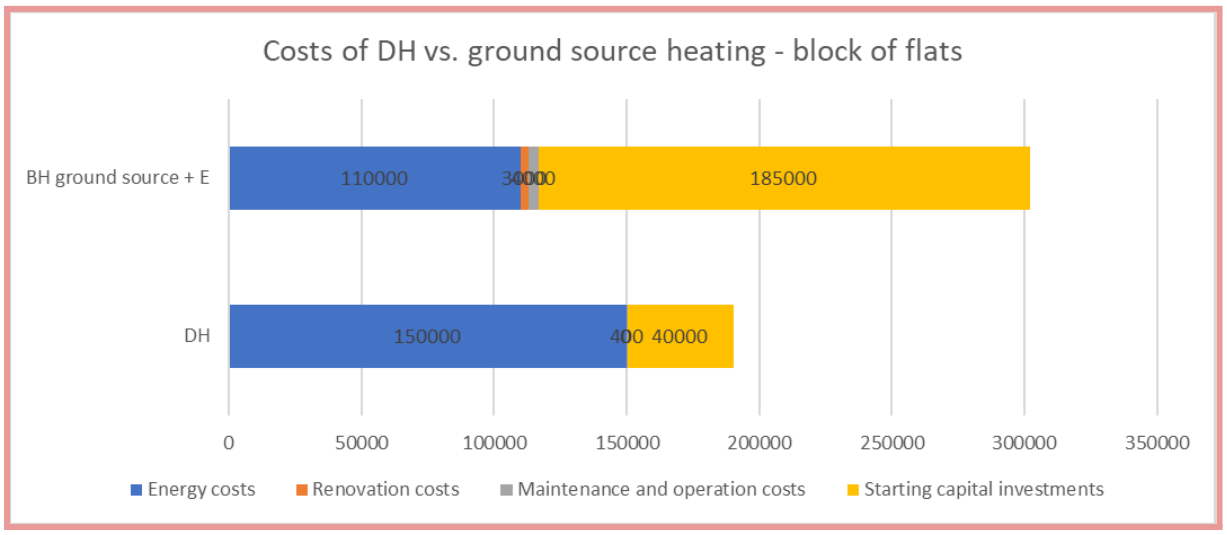


Figure 9. Life cycle costs (LCC) of heating energy - district heating (DH) vs. ground source heat pumps (GSHP) for one-dwelling house and block of flats (FS #1)

The main conclusion of the feasibility study is that the ground source heating system (GSHP) is not paying back itself in St.Petersburg. And this might be the main reason why Finnish companies are not interested in implementing GSHP projects to St.Petersburg.

1.2 Feasibility study on energy efficiency and advanced business models

We started with definitions and selections of study cases. Two categories of buildings - residential buildings and daycare centres (kindergartens) - were selected by the Cata3Pult expert team for this study. It was attempted to find as similar buildings under the same category as possible to make results of calculations more comparable. House Property Owners Association (HPOA) in St. Petersburg provided needed energy consumption data and technical info about the apartment building. LOAS (*Lappeenrannan opiskelijasunnot*) provided information about Lappeenranta's study building.

Four case study buildings in Lappeenranta and St. Petersburg in two groups in FS #2:

1. Residential buildings built after year 2000
2. Daycare centres (kindergartens) built before year 2000

Life cycle costs (further - LCC) analysis made for four energy efficiency improvements:

1. Constant air volume vs. variable air volume (VAV) or demand controlled ventilation (DCV)
2. Heat recovery (further - HR) from return/exhaust air
3. Geothermal/ground source and solar heating
4. Solar electricity/PV

The LCC of the systems were calculated over a period of 30 years. Starting energy prices for Finland/Lappeenranta and St. Petersburg were fixed (Figure 8).

For Lappeenranta cases:

- interest rate of 3% and an annual increase in energy prices of 2%.
- the price of electricity was fixed at 90€ / MWh
- the price of district heating 66€ (residential building) and 70€ (kindergarten) / MWh.

For St. Petersburg cases:

- interest rate of 3% and an annual increase in energy prices of 2%.
- the price of electricity was fixed at 42€ / MWh
- the price of district heating 18€ / MWh.

Results of the FS #2 were presented at the EEF Expert Group meeting in February 2022. To summarise those:

- In Lappeenranta, the price of energy is higher than in St. Petersburg. It makes energy efficiency measures more profitable.
- The most profitable measure is to change the ventilation to the variable ventilation (VAV), which is an almost profitable measure even in St. Petersburg (Figure 10).
- The second best measures in Lappeenranta are geothermal heat (GSHP) and an exhaust air heat pump (EAHP). Solar energy is the least profitable measure.
- In St. Petersburg, heat pumps and solar energy are not profitable even with a significant increase in energy prices.

[years]	Lappeenranta					St.Petersburg				
	VAV/ DCV	HR	**GSHP**	Solar PV	Solar heat	**VAV/ DCV**	HR	GSHP	Solar PV	Solar heat
Basic payback	**2**	18	**10**	18	23	**14**	-	64	37	80
Discounted payback time	**2**	25	**12**	25	37	**15**	-	-	80	-
Tradiotional financing model	**3**	31	**14**	50	31	**18**	-	-	-	-
Leasing model	**3**	62	**20**	100	61	**32**	-	-	-	-
ESCO model	**4**	57	**22**	80	47	**30**	-	-	-	-

Figure 10. Payback times of energy efficiency improvement in study cases of residential apartment buildings in Lappeenranta and St. Petersburg (FS #2)

Comparison of different investment financing models included traditional, ESCO and Leasing. The payback period was used as a comparison of financing methods.

Traditional. The customer invests in the implementation of the energy efficiency investment and arranges the financing itself. Payback time for investment is measured.

ESCO ”Energy Service Company”. The service provider invests in the energy efficiency measure, arranges the financing and is responsible for the operation of the system. And the investment is paid with the savings. Length of the contract period is measured.

Leasing. The investment is paid with the savings generated. The financing is unsecured and the customer does not invest in the energy efficiency measure. Length of the contract period is measured.

According to SWECO, the comparison of financing models is difficult as it depends a lot on the customer, which is the most cost-effective way to implement the measure. Especially in the ESCO model, estimating costs is very difficult because service contracts are entirely company-, operation- and financing-specific. In comparison, the traditional model is the most profitable. This is due to the assumption that the customer will be able to arrange affordable financing for itself and will be responsible for the operation of the system.

ESCO and leasing models do not succeed in comparison (Figure 10). This is because in the ESCO model, the service provider arranges the financing and is responsible for achieving the energy savings target. In the leasing model, the procurement is made with external financing with a high interest rate. Those factors affect profitability negatively.

ESCO and Leasing models are easy and safe options for improving energy efficiency, but costs for services are high and reduce profitability.

1.3 Comparative Analyses of adopted energy efficiency PPP models for buildings

As study case buildings for this work were kept the same buildings in Lappeenranta as in FS #2. As a background for the FS #3 was the *EPC toolbox* developed in the previous project with participation of the City of Lappeenranta. This *EPC toolbox* was presented on the Cata3Pult Expert Group webinar in November 2020. The toolbox is available: https://www.effect4buildings.se/toolbox/ ; Accessed on 4.11.2022

The report was purchased from *Rakennusfysiikka Vahanen* for development of public-private-partnership models (ESCO, other energy management as a service models). In the report selection of contract models based on a Guide Financial tools and instruments for energy efficiency in buildings made by Effect4Buildings -project (Interreg) adopted to target cases kindergarten and residential apartment building in Lappeenranta. The report includes basic description of contract models and operational models of energy efficiency investments which can be developed further and evaluate their viability.

The company visited target cases and mapped the current situation. Based on information from the visit, consumption of energy and cost of production of energy and improvement of energy efficiency and greenhouse gas emissions were assessed in alternative scenarios. Life cycle assessment calculations were made for 25 years operational age.

1.4 Learning from: simulations results from HUKATON-project

As one of the cases presented and discussed at the Cata3Pult expert group webinar were the results of implemented heat energy simulations for typical blocks of flats in Helsinki. These simulations were implemented by Aalto University and coordinated by GNF ERDF project HUKATON.

The heat recovery (HR) systems studied in HUKATON (for typical block of flats constructed before 2000:s, non-insulated envelope):

System 1 is the reference as such, exhaust ventilation without heat recovery (HR).

System 2 underwent air ventilation renovation and installed mechanical inlet-outlet ventilation with heat recovery.

System 3 is otherwise the same, but the ventilation flow was reduced if the apartments were empty. (*This is so called demand controlled ventilation - DCV*).

Systems 4 to 8 have original exhaust ventilation, but are equipped with an exhaust air heat pump and / or sewage HR. In these systems, HR is connected in series with district heating (DH) so that first the waste heat is preheated to the cold hot water and the heating circuit water, after which the flows are reheated with district heating to the desired setpoint. However, most district heating companies do not allow series connection of waste heat, but require parallel connection because they want to minimize the temperature of the DH return flow. Cases 4 B, 6 B and 8 B represent these cases.

To summarise HUKATON simulations results (see Figure 11A and 11B):

A. Energy consumption (DH and electricity, [kWh/year]) and CO2 emissions [t-CO2/year]

The greatest effect was obtained in case, which was used with both ventilation and wastewater HR heat pumps, with DH and waste heat connected in series. Consumption of district heating decreased 70% and CO2 emissions 50%. With a parallel version of the same system DH consumption decreased by 56% and CO2 emissions by 37%.

B. System life cycle costs (LCC) and CO2 emissions

The life cycle costs (LCC) of the systems were calculated over a period of 30 years, using an interest rate of 3% and an annual increase in energy prices of 2%.
The price of electricity was fixed at 122.5 € / MWh. The price of DH varied from 37 € / MWh in summer to 73.6 € / MWh in winter.

Switching to mechanical inlet-outlet ventilation was more expensive than the original system in terms of LCC, but demand controlled ventilation (DCV)
taking advantage of the costs decreased to the level of the comparison case.
Clear cost savings were achieved by utilising the exhaust air heat pump (EAHP) and waste heat from the wastewater (WWHP): the costs of waste heat in series - € 1,280,000, case 8 (vs. € 1,500,000 in parallel, case 8 B.). Savings LCC for the reference case were: 20% in series connection vs. 6% in parallel connection. EAHP alone generated 13% savings in series connection vs. 8% savings in parallel connection.

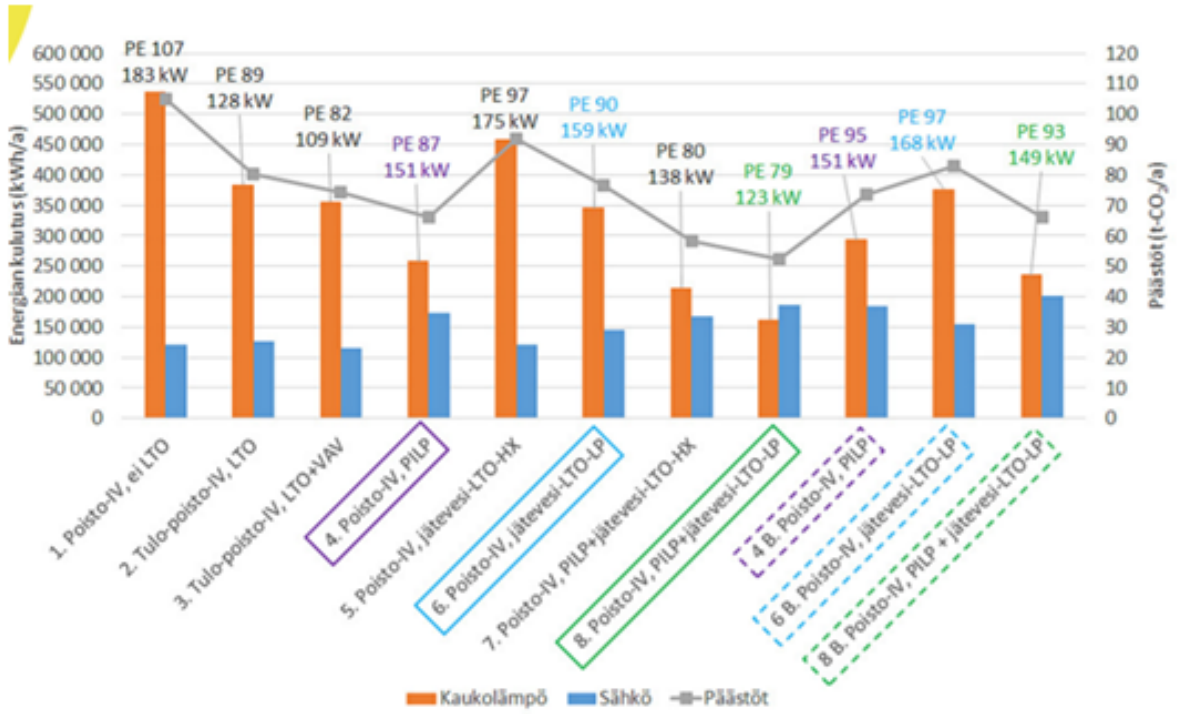


Figure 11A. Energy consumption and C02 emissions in HUKATON simulations (lessons learned case)

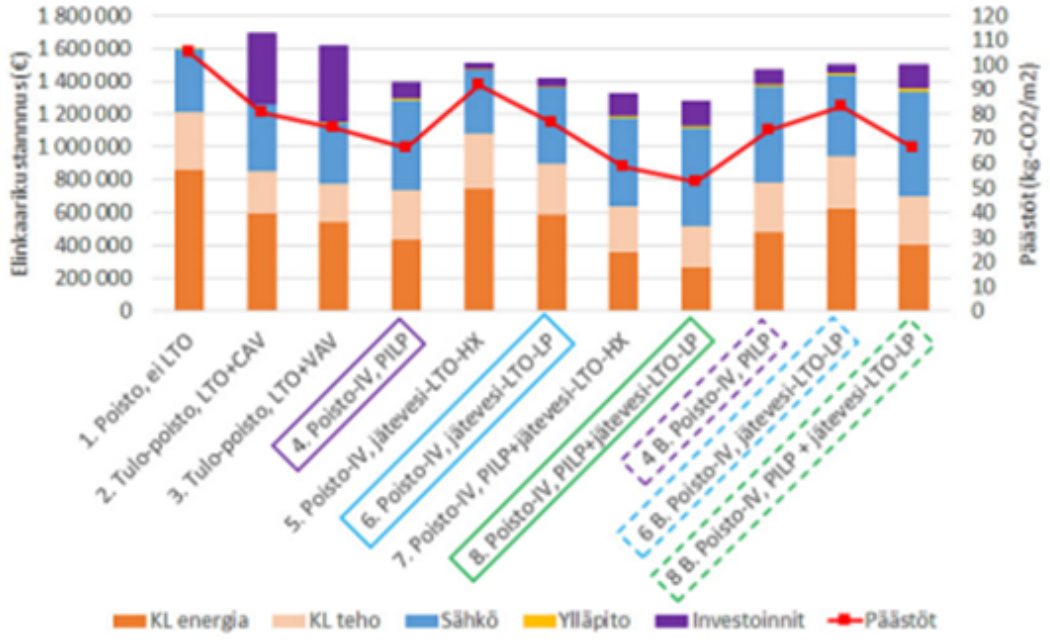


Figure 11B. LCC and CO2 emissions in HUKATON simulations (lessons learned case)

1.5 Study case of implemented modernisation of heating system in typical block of flats in St. Petersburg

Study case **block of flats of 137 type** located in the Kolpino district of St. Petersburg. The building is located in the so-called “energy efficient quarter” area of an umbrella project leaded by the St. Petersburg Homeowners Association (HPOA). This study case in a wider context of residential building stock of St. Petersburg is described in previous output of Cata3Pult project (Figure 12).

These type of buildings are selected as a study case for the Cata3Pult not only based on the scaling potential, but also on the fact that these type of buildings are appreciated and are not on the list of "potential demolitions". The first series of energy efficiency measures have already been implemented in a block of flats of the same type. It has been done only in small scale, but some ideas of how to approach this task can be extracted from this experience. Existing understanding of resources consumption (incl. energy and water) and technical characteristics of buildings.

62

Picture 2. Photo of the building of 137.11.2 modification in St. Petersburg.
Source: http://domavspb.narod.ru/. Author: unknown.

Figure 12. Screenshot "type of building for case study" in SPb MWR 3.0.
p.62 of publication Market Watch (vol. 3.0) - St. Petersburg region (Russia) urban cleantech sector. Available in open access:
https://gnf.fi/wp-content/uploads/2020/05/St.-Petersburg-region-urban-cleantech-market-watch-vol.-3.0.pdf

Bringing to this publication some business potential related highlights, such as composition of communal costs in this study case building (Figure 13).

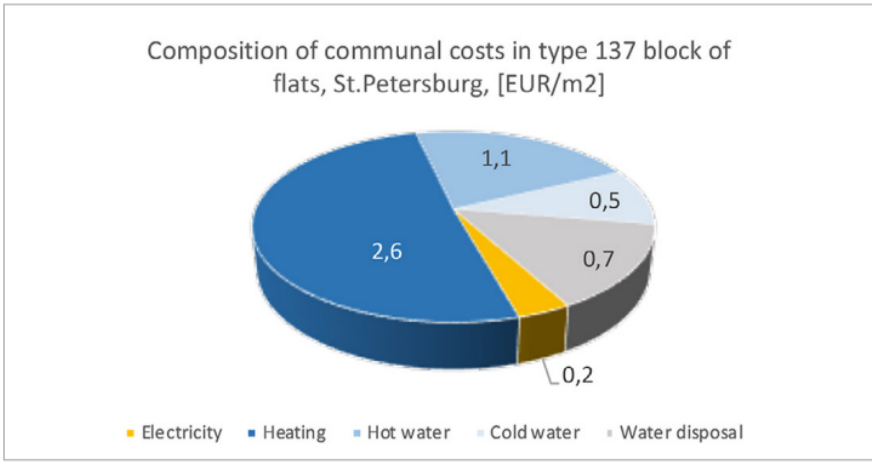


Figure 26. Composition and nominal amount in EUR/m² of communal costs in the study case.

Figure13. *Screenshot "composition and nominal amount of communal costs in the study case - figure 26" from SPb MWR 3.0.*

Modernisation of the heating system in the study case included installation of a property-specific heating distribution system and heat insulation of indoor pipes. The project was implemented in 2015. Investment payback time was under 5 years. Savings in heating energy consumption (measured in percentages) varied from month-to-month and year-to-year (Figure14).

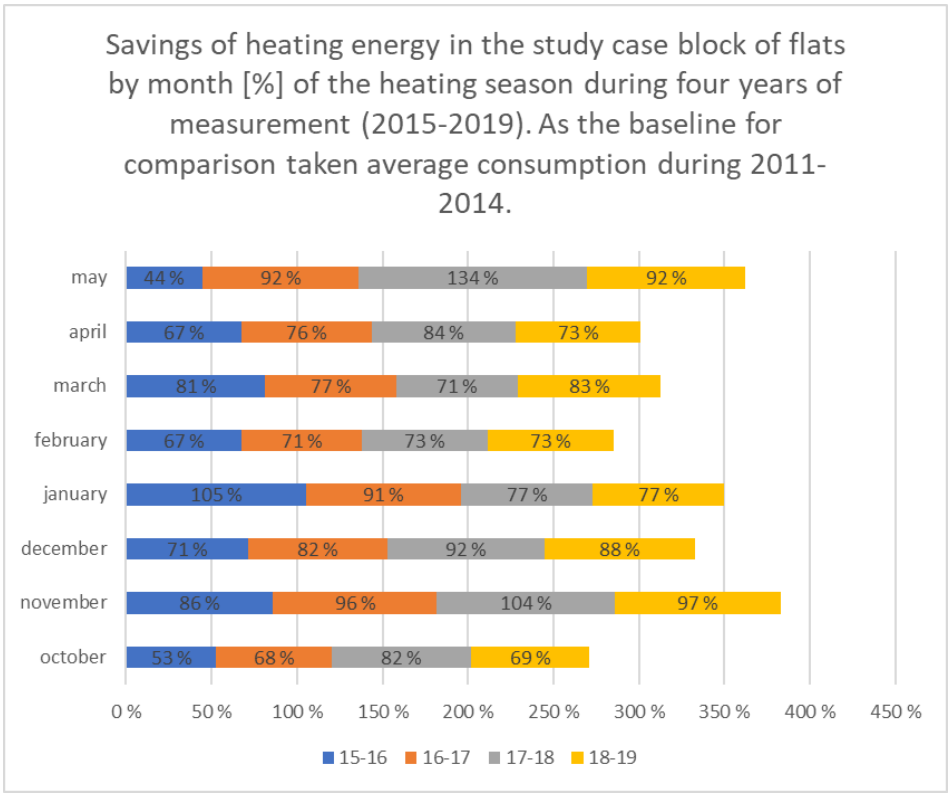


Figure 14. Savings of heating energy [%] during one heating season [years 2015-2019] in the study case block of flats in St. Petersburg

1.6 Calculations of carbon footprint of heating and electricity systems of buildings

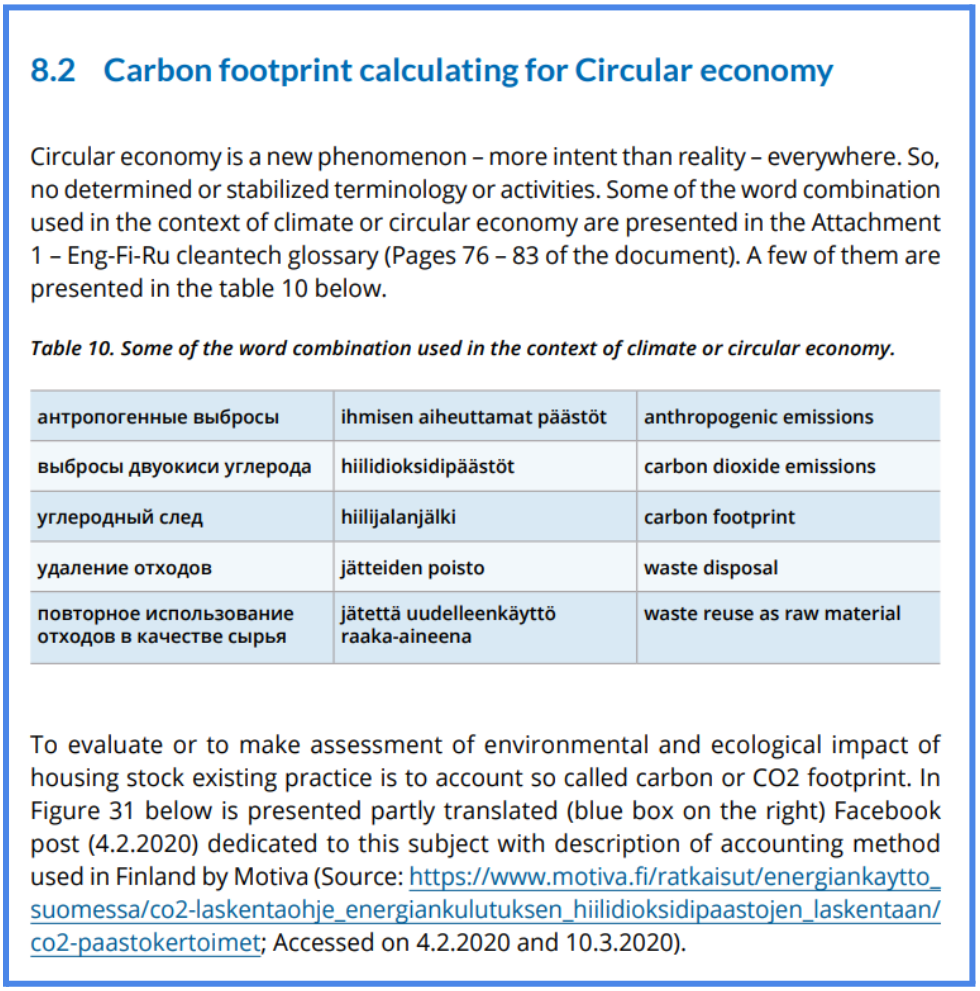
In the EU and Finland different calculation methods are under development for carbon footprint calculation (further - CFC). Public authorities and organisations are developing their own tools. Also private companies developing their own commercial versions of assessment. St. Petersburg City is also interested in developing its own tools.

Due to such wide interest to the topic, Cata3Pult project catched it for development.

We started with Cata3Pult expert group meeting in December 2019 in Metropolia UAS to which we also invited external experts to present their tools.

Then our St. Petersburg partner KOSMOS LLC conducted a study “Energy savings and the carbon footprint of buildings of different types and ages - a study from St. Petersburg” during December 2019 - March 2020. We also prepared presentations of examples of calculation methods and discussed those on our March 2020 Expert Group (links in References Chapter 7).

We also implemented a set of communication activities via social media related to this topic. Carbon footprint calculating for Circular economy was one of the Chapters of the SPb MWR 3.0 (Figure 15). Calculating carbon footprint differently is applicable for all 3 substance topics of Cata3Pult.



8.2 Carbon footprint calculating for Circular economy

Circular economy is a new phenomenon – more intent than reality – everywhere. So, no determined or stabilized terminology or activities. Some of the word combination used in the context of climate or circular economy are presented in the Attachment 1 – Eng-Fi-Ru cleantech glossary (Pages 76 – 83 of the document). A few of them are presented in the table 10 below.

Table 10. Some of the word combination used in the context of climate or circular economy.

антропогенные выбросы	ihmisen aiheuttamat päästöt	anthropogenic emissions
выбросы двуокиси углерода	hiilidioksidipäästöt	carbon dioxide emissions
углеродный след	hiilijalanjälki	carbon footprint
удаление отходов	jätteiden poisto	waste disposal
повторное использование отходов в качестве сырья	jätettä uudelleenkäyttö raaka-aineena	waste reuse as raw material

To evaluate or to make assessment of environmental and ecological impact of housing stock existing practice is to account so called carbon or CO2 footprint. In Figure 31 below is presented partly translated (blue box on the right) Facebook post (4.2.2020) dedicated to this subject with description of accounting method used in Finland by Motiva (Source: https://www.motiva.fi/ratkaisut/energiankaytto_suomessa/co2-laskentaohje_energiankulutuksen_hiilidioksidipaastojen_laskentaan/co2-paastokertoimet; Accessed on 4.2.2020 and 10.3.2020).

Figure 15. Screenshot “Carbon footprint calculating for Circular economy - p.72” from SPb MWR 3.0

1.7 Learning from: Indoor air quality-as-a-service

Inspiration to add this chapter has roots from Future Spaces project final event from of August 2022. Indoor air quality **(IAQ)-as-a-service business model development** and its part on **capability analysis** seeing a very interesting approach (see Figure 16).

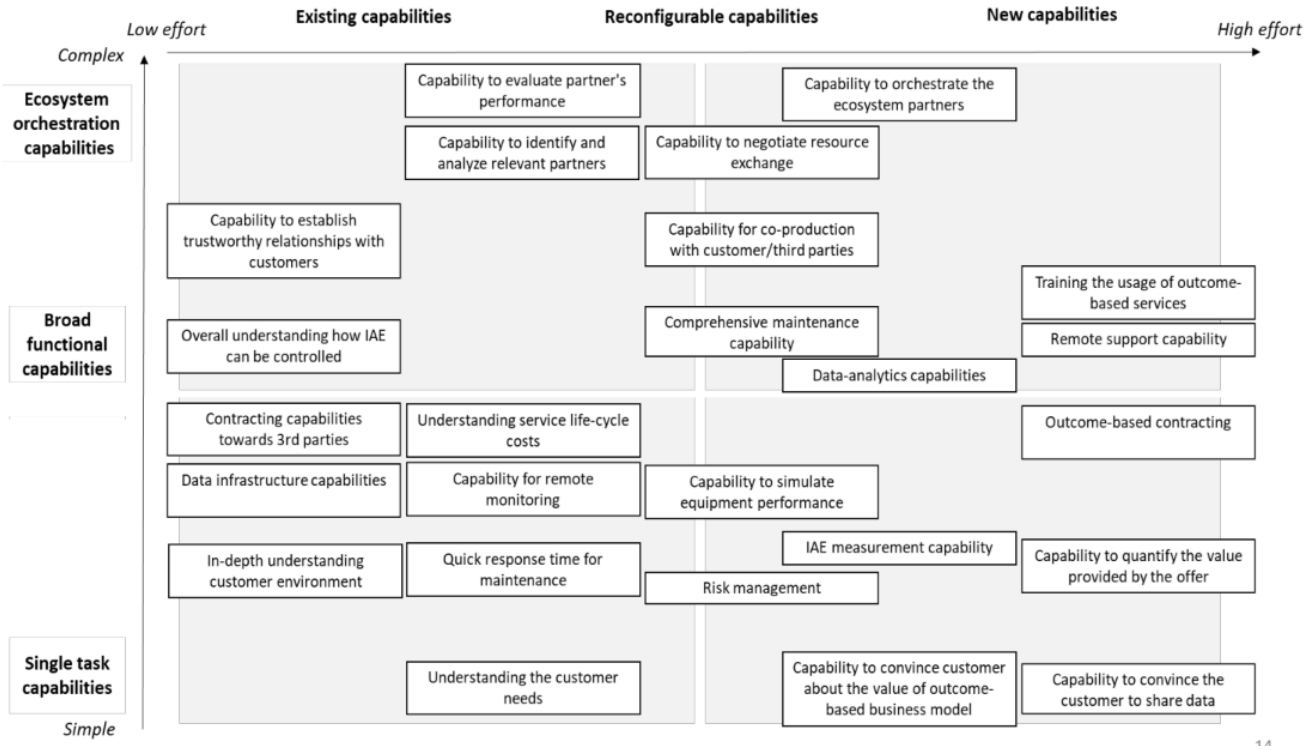


Figure 16. Capability analysis in (IAQ)-as-a-service business model development. Dr. Karan, 2022 (lessons learned case).

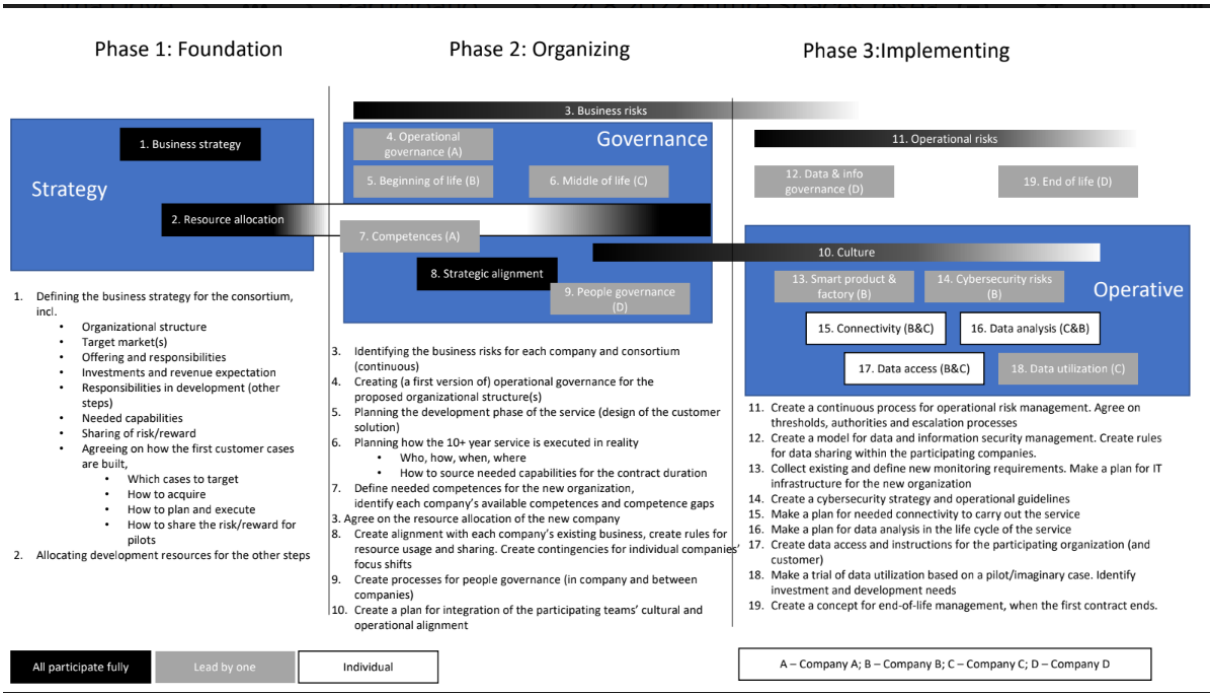


Figure 17. Roadmap in IAQ-as-a-service business model development. Dr. Karan, 2022. (lessons learned case)

It was interesting to notice that quite solid attention in the IAQ-as-a-service business model development was dedicated to energy efficiency. This borned thought that presented capability analysis and roadmap could be utilised by businesses operating in the energy efficiency and air quality improvement area.

1.8 Learning from: ESCO experience from St. Petersburg

"ESCO" in St. Petersburg is an *energy service contract.* One of the partners of Cata3Pult - HPOA - is the first organisation to our knowledge, which started to work on so-called *typical ESCO-contracts* back in 2013. Idea to establish SPb cleantech cluster initiated based on ESCO development for residential/housing stock. HPOA became a so-called management organisation of SPb cleantech cluster (the cluster does not have a juridical entity). Two types of ESCO-contracts are developed and implemented:

1. On modernisation of lighting equipment in the block of flats of SPb to LED with motion sensors.
2. On modernisation of heating engineering systems in block of flats of SPb (energy saving results of this modernisation project presented in Chapter 1.5 and in previous output of Cata3Pult project - SPb MWR3.0)

To proceed with ESCO-contracts of the second type (heating system) HPOA and Norwegian company Nordic Commodities established joint company “FIRST SPb ESCO” in 2014 and implemented their first (and last) joint project. The idea behind the establishment and implementation of ESCO-contracts is to attract non-public investments and provide business opportunities to enterprises, which are members of the SPb cleantech cluster.

2 Smart and green mobility - SGM

GHG emissions of transportation in Finland is about 26% of total emissions and on road transportation and logistics enterprises remarkably increase negative environmental impact. In addition to environmental impact, high fuel expenditures have a negative impact on the economy of the businesses. Cutting down emission in mobility includes both technical and social solutions. Public means of control like politics and regulations are affecting behaviour of people and businesses. Reducing usage of cars in short distances and preferring walking and cycling, electric skateboards and bikes. In Finland renewable fuel generation has started recently, new biogas plants for example and hydrogen and methane fuels are in the developing process. Production of biogas has started in Kukkuroinmäki, Lappeenranta in 2021, biogas is available in 5 fuel stations in South Karelia. In St. Petersburg and Russia this is still a new matter but has evoked quite a lot of interest.

Cata3Pult organised expert webinars on Smart, green mobility and logistics smart with several topics such as parking systems, smart apps for promoting individual mobility (city of Lahti), bus services of St. Petersburg, cycling possibilities in cross-border area, local train services. Such topics, which got deeper interest during discussions are formed as business cases for further development (Chapters 2.1 - 2.4). Solutions are divided between biogas and hydrogen fuels, electrical vehicles and shared use.

2.1 Biogas as fossil free fuel

Cata3Pult organised activities related to this topic, such as biogas production for vehicle fuels. The topic was presented and discussed on the circular economy expert group webinar organised in collaboration with BBC1 project/Miksei Mikkeli in March 2021 (Chapter 3.1.). Biogas buses operate in Mikkeli and in Lappeenranta. Biogas as fuel for mobility and logistics is one of the objects utilising products of digestion, which combines the production with circular economy.

Biogas is primarily (over 60%) methane (CH4) and carbon dioxide (CO2). Chemically it resembles fossil natural gas. Biogas methane content is high and impurities low so it can be effectively upgraded to a renewable biofuel. The Kukkuroinmäki biogas plant in Lappeenranta produces biogas from organic waste such as household food waste and municipal wastewater sludge. The upgraded biomethane is truly a completely renewable, domestic and emission-free alternative to imported fossil fuels.

2.2 Hydrogen solutions

Development of hydrogen economics, technology, business and know-how in the region of South Karelia has started within the city of Lappeenranta and Greenreality Network. Aurelia Turbines is a member of the national hydrogen network BotH2nia and the company is one of leaders to promote hydrogen economics. In March 2022 LUT University published a research report called South East Finland Hydrogen Valley. The study characterised the regional opportunities relating to the hydrogen economy in eastern and south-eastern Finland.The study region covers South and North Karelia, Kymenlaakso and parts of the Eastern Uusimaa (Loviisa, Porvoo). The study revealed that the region has significant renewable electricity production potential, and ample amounts of bio-based carbon dioxide – both of which are crucial ingredients for developing new PtX products. There are some obstacles to overcome like radars related to border surveillance have so far limited the permitting of wind power in the region and the existing electricity transmission grid is also not sufficient to permit the full-scale utilisation of the local solar and wind potential. Solving these challenges would enable

large investments, bringing new industrial activities to the area, increasing the energy self-sufficiency of Finland and improving the electricity grid balance significantly. The local actors like municipalities, companies, universities, research organisations have organised to address these challenges in future projects.

2.3 Electrical vehicles

Cata3Pult smart and green mobility expert group (SGM) participated in organising the outdoor event for promoting electrical mobility *"Vauhtia vihreästä sähköstä - kohti kestävää liikennettä"*. The event was organised in cooperation with *CANEMURE project (EU LIFE program)* in Lappeenranta Harbour market place in May 2022. In the event the companies provided electric cars, bikes and scooters for free testing and introduced features of the vehicles to the people.

Electricity is environmental fuel, if its source is renewable. Electricity was cheap until 2022, but the infrastructure of charging stations is still quite limited. Within SGM expert group expertise for charging was presented in the webinar and events by the project. In development of electric vehicles batteries are problematic in ecological sense because they include rare minerals. Not only limitations in natural resources but also environmental effects of mining companies are remarkable. The development of electric vehicles relates to large global issues.

2.3 Shared use of e-vehicles the city of Lappeenranta

Shared use of e- cars has been available in the city of Lappeenranta since 2017. It started simultaneously with a project and an experiment. For shared cars there have been big expectations in the city's mobility and as its usage will enlarge, it is expected to reduce owning cars. In the beginning the city made a contract of four e-cars service. The provider was Herz and charging stations for them were built in the city hall parking hall.

During working hours the cars are in use for city workers and other times freely available for citizens to rent.
Shared car service is supplementary for public transportation and it is suitable for dense urban structure. But also longer distance shared e-cars are a good choice, you don't need to have an own car, there are no emissions and the limitation is the range of the battery.

Usage of e-car in the city organisation has been popular and successful. In the end of March 2021 Hertz finished their service of shared e-cars in the city of Lappeenranta due to the Korona pandemic. Soon after that, in June 2021 the city made a contract with Omago, which provides one e-car for similar usage to the personnel of the city as Herz did before.

With marketing activities and by setting its own example the city wants to make shared carpooling known and thus influence the change in people's moving habits.

City of Lappeenranta has city bikes for rent from about April to November every year. They are normal bikes. In the electric vehicle event at the end of May 2022 for the first time e-bikes and scooters were introduced for test driving in Lappeenranta. Since then there are also electric bikes and scooters available for rent. The city has made agreements with companies renting e-bikes and scooters.

3 Circular economy

Work in the Cata3Pult project under topic of circular economy (further - CE) started from the beginning of the project in June 2019 by participation into WCEF2019 in Helsinki. A lot of discussions are held in term of finding relevant and interest concrete themes for development work. Our first finding was that measurement of environmental impact and municipal waste management could be the first two topics. Starting meeting of Cata3Pult Expert Group on Circular Economy was held in Metropolia UAS in December 2019. (Figure 18).

Figure 18. Photo from the starting meeting of the circular economy expert group in Metropolia UAS in December 2019.

Distinction between mentioned above in Chapter 1.6 carbon footprint or CO2 emissions calculation (further CFC) and environmental impact or life-cycle assessment (LCA) is that the LCA is a wider concept. **LCA** topic was presented and discussed at one of the expert group meetings in October 2021. Such topics, which got deeper interest during discussions are formed as business cases for further development (Chapters 3.1 - 3.5). Cases are divided based on waste fractions/flows between biogas production and treatment of organic-/food-/biowaste, textile re-use and up-/recycling, re-use of concrete, recycling concrete and plastic/polymer waste recycling.

The Cata3Pult project found several companies from St. Petersburg, which are interested in circular economy topics, such as LLC "Center for Environmental Services" Dokservice ", Spetstrans" Avtopark No. 6 ", LLC" Plastics Processing Plant named after "Komsomolskaya Pravda", LLC "RASEM", JSC "Autopark No.1" Spetstrans ", LLC" Improvement ", LLC" SPETSPEREVOZCHIK ", LLC" Management company "ECOTECHNOPARK".

3.1 Biogas production and treatment of organic-/food-/biowaste

Starting point and argument for selection of treatment of organic/food/biowaste as one of business cases for development work in Cata3Pult was the premise that food and agriculture industries and farmers as well as households produce a lot of biowaste. In case biowaste is part of mixed waste it has a negative health impact in terms of odour and attracting risk animals like rats. In addition, it disturbs the process of energy recovery. In agriculture, not processed bio digestion influences loss of nutrients. Biogas production via anaerobic digestion has several positive impacts, such as creation of revenues from sales of energy (electricity/heating) and fuel as well as returning nutrients to farmers via by-product from digestion process. In this way farmers can save on purchasing fertilisers. Using self-made fertilisers saves natural resources for example producing extracted minerals. Phosphorus is for example depleting natural resources.

Cata3Pult project has implemented a lot of activities related to this topic. As a starting event for this work could be seen preparing and holding Expert Group webinar in March 2021. Figure 19 presents a framework for discussions and development within this topic.

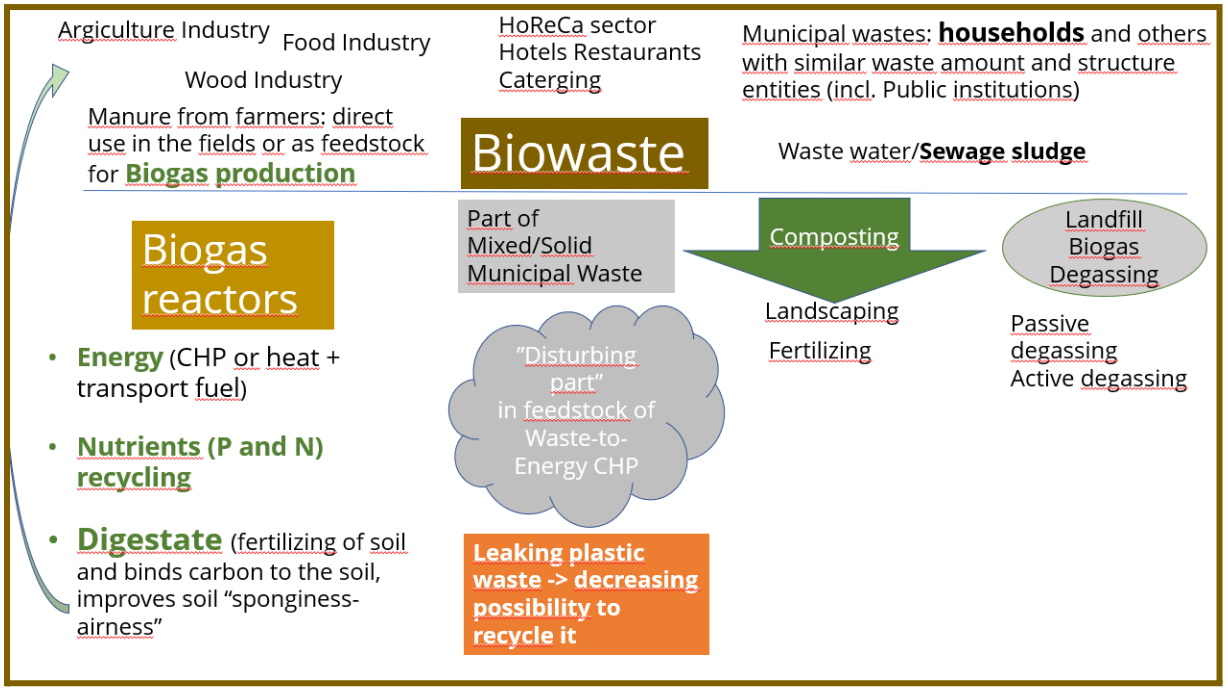


Figure 19. Framework for discussions and development within Biogas production and treatment of biowaste, expert group webinar in March 2021.

We organised this webinar in collaboration with BBC1 project and invited also external experts. Among the presentations are South Karelian municipal waste management organisation's (EKJH) Kukkuroinmäki biogas plant – fuel from local waste, Helsinki Metropolitan area - HSY biogas and composting plants, Blue Economy Mikkeli Water Hub, Biogas refinery of Biohauki Oy, Pascier process of Nanopar Oy and degassing station of polygon "Novy Svet-ECO". Student's project on biogas production from sawdust of Metropolia UAS. As one of the conclusions of the webinar was that by the same terms **"biogas production"** we understand different matters. For example, in Finland we mean by this term processing of separately collected bio-/organic waste in reactors by anaerobic digestion with the main final product of raw gas. In SPb case was presented the degassing process, which means collection of landfill or waste polygon gas.

Another event - teaching webinar on waste management - was organised in May 2021. SPb polygon "Novy Svet Eco" presented their data with biogas production from own landfill (also representatives of the Technical University and its UNIDO center presented

their developments on the prospects for processing woodworking industry waste and plant biomass into 2D nanocarbon graphene-like materials for various practical applications). There is a degassing station at the Novy Svet-ECO test site; it is planned to involve this enterprise in cooperation in this direction.

Another conclusion presented at the end of webinar is that in Mikkeli case of Biohauki Oy we have a good example of real **public-private partnership (PPP)**, when local farmers (or private sector) and local energy company owned by municipality (or public enterprise) co-own biogas generation plant. Benefit from such partnership has as economic as environmental positive impacts. Organic waste of local farmers instead of being expenditure and environmental load became revenue and formed as a direct decrease of air and water emissions as indirect positive environmental impact.
By-product from the digestion process is good raw material for "green" fertiliser, could replace mineral fertilisers produced by extracting of virgin natural resources.

Cata3Pult also organised a webinar dedicated to food waste treatment in August 2021. Idea for this webinar was initiated by GAIA LLC, which is interested in Finnish market (see presentations in Cata3Pult GD folder). As a result of this webinar, Cata3Pult partner KOSMOS LLC supported the company with environmental assessment of their technology. Later pilot project on treatment of kitchen waste in ITMO university cantine were implemented. And according to KOSMOS LLC, GAIA established some kind of activities in Finland afterwards.

Cata3Pult internal expert group was inspired since March 2021 webinar to see how new biogas plant of EKJH in Kukkoroinmäki is operating. And also to see HSY's biogas treatment facilities. In spring 2022 we get a chance to organise get to know in practice visits to those in collaboration with Cool4City project (Chapter 6). We collected highlights from those to blog post #1 and blog post #2 (in Finnish), which are available on GNF's website.

Development work under this topic included also **feasibility study - FS #4.** This FS#4 was implemented by Nanopar LLC. Prior to the FS #4 the company presented its own solutions on the Expert Group webinar in March 2021 (see Figure 20).

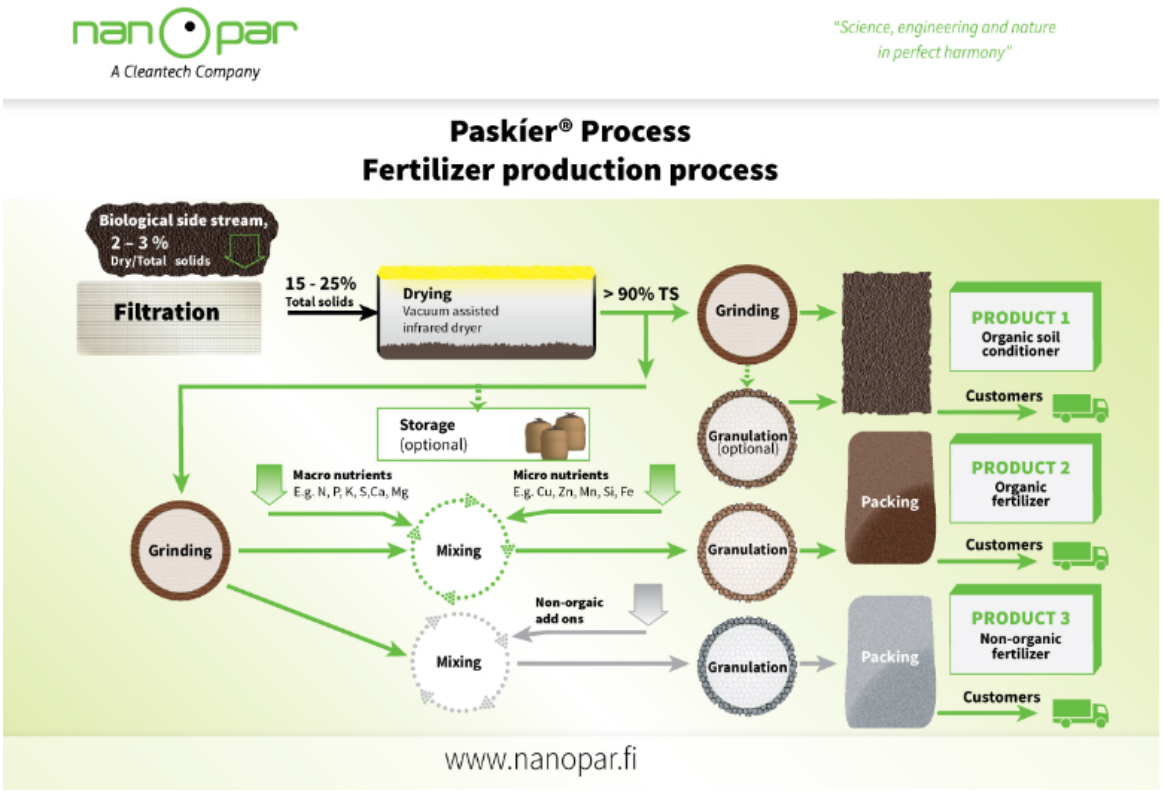


Figure 20. Screenshot of Paskier fertilizer production process from Nanopar's presentation, expert group webinar in March 2021.

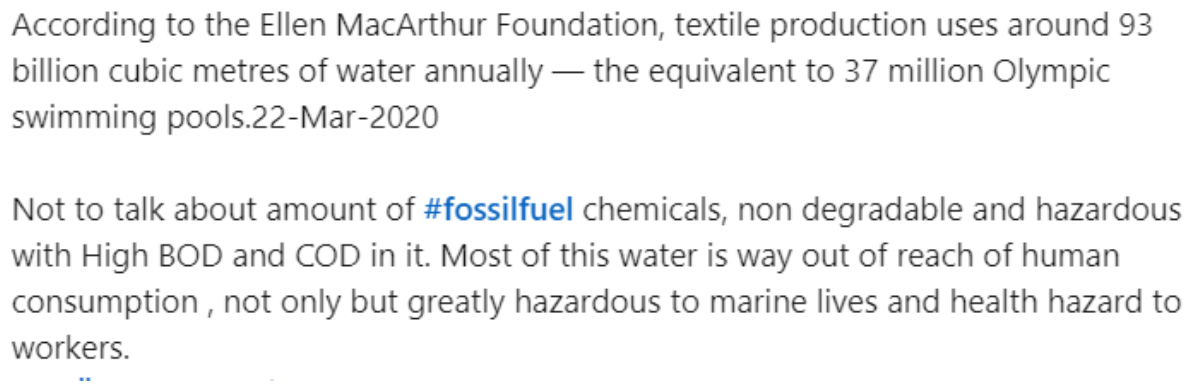
Feasibility study FS #4 **Preliminary study on the applicability of innovative thermal methods of wastewater treatment plant sludge for the removal of harmful substances and phosphorus recovery, taking into account the energy economy** (Original name in Finnish: *Esiselvitys jätevesipuhdistamolietteiden innovatiivisten termisten menetelmien soveltuvuudesta haitta-aineiden poistoon sekä fosforin talteenottoon energiatalous huomioiden)*

In the FS #4 *Nanopar* described a detailed infra-red drying system for WasteWater Treatment Plant (WWTP) sludge and estimated its applicability and future potential. Conclusions of the study was, that even without heat recovery, mid-wave infrared radiation and vacuum achieve water evaporation efficiencies that are impossible to

achieve with conventional drying technologies. In ore concentrates with no moisture inside the crystal, an evaporation power of 4–5 liters/kWh is achieved. In WWTP sludge, the average evaporation power is 2–2.5 liters of water / 1 kWh. However, it must be stated that the high cost of electricity does not make WWTP sludge drying profitable, taking into account the average sludge transportation and gate fees.

By producing dried sludge as recycled fertilizers, the situation changes and the payback period for the investment is 2–4 years.

3.2 Textile reuse and up-/recycling



Textile separate collection will become mandatory in Finland in 2023 (and in EU in 2025) bringing business opportunities for material recovery or recycling. However, according to priorities of waste treatment to principles of circular economy, the higher priority of utilizing the material is reusing goods/products for the same purpose or upcycling it. Recycling option following those. Due to this matter, we decided to focus on reuse and up-cycling phases before textile will become waste. After textile disposal is put to the waste bin, possibilities to utilise into higher priorities is not possible. Higher priorities can provide more possibilities for enterprising.

Cata3Pult organised a few activities related to this topic. We started with gathering background information and writing an overview on the state-of-the-art textile business in Finnish context (in Finnish). The overview work was done starting from March 2021 in terms of preparation to moderating discussions. The overview is available in Finnish in Cata3Pult's GD folder. The next step was Expert Group webinar in the end of April 2021.

We organised it in collaboration with another SEFRCBC project - LALAPETE (see Chapter 6). Materials from this webinar are available in Cata3Pult's GD folder. Figure 21 is showing one of the introduction slides of the webinar.

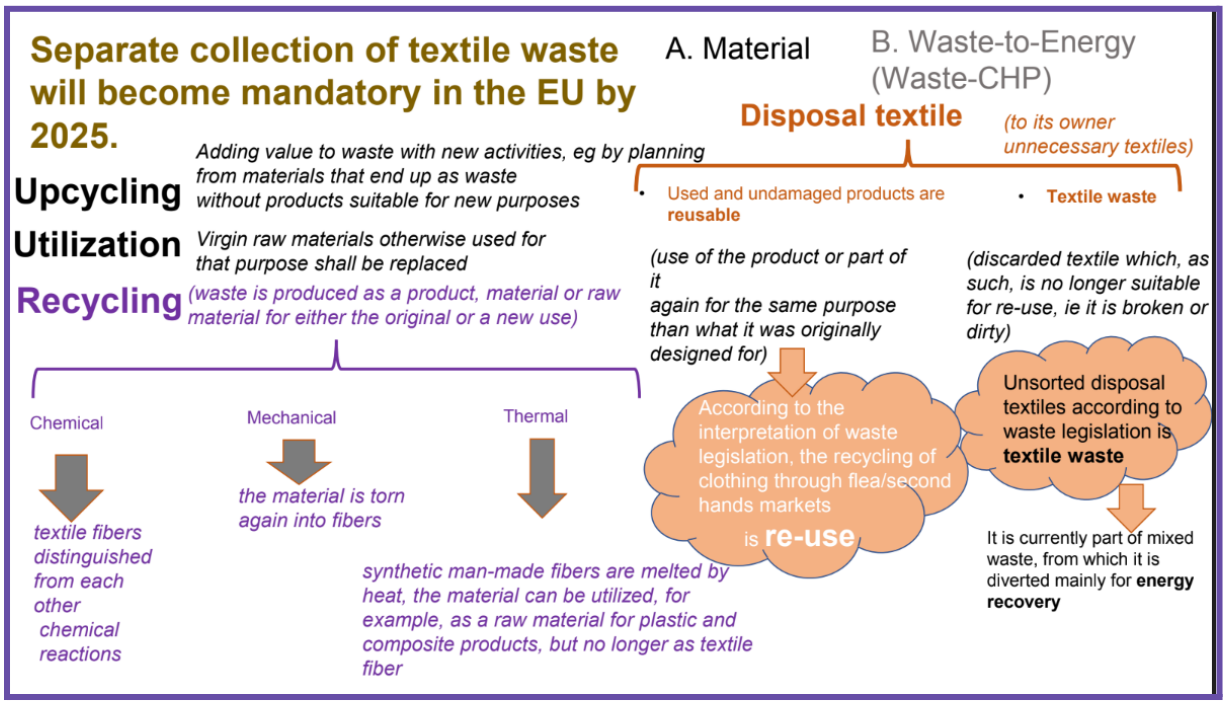


Figure 21. Extract from introduction presentation on Textile, expert group webinar in April 2021.

Interesting outcome from the Cata3Pult webinar was that new B2B collaboration between "99recycle"and FabRevizion started after it.

We also implemented supportive communication activities related to this topic, posts in FB: Finrusrecycling - Finnish Waste Management system. Textile topic also was discussed on another webinar in August 2021 - organic waste treatment in the Hotel, Restaurant and Catering - HoReCa sector (see more about this webinar in Chapter 3.1) One of the points of view discussed was e.g. hotel sector's premium quality disposal textiles and their utilising for sewing occupational clothes for e.g. restaurant and catering sector. This kind of up-cycling within the HoReCa sector is very interesting.

Textiles also contain a substantial amount of plastics. The first EU textile strategy was published in March 2022, and the regional collection of textile waste will be

launched in Finland at the beginning of 2023. The first textile waste recycling plant started up in late 2021. Further in Chapter 3.5 we present plastic-related content and a new Plastics Roadmap for Finland.

3.3 Learning from: Re-use and recycling in construction

(Written by Ilkka Aaltio)

Construction and demolition waste (CDW) accounts for more than a third of the total amount of waste generated in Europe according to the EC. Therefore, even a small increase of the re-use of the materials and parts from demolished buildings has a huge impact in increasing the degree of recycling and decreasing waste. Today scientists and countries have widely realised that we significantly overuse the raw material resources available globally. Increasing the re-use rate of all construction materials of demolished buildings to 70% and decreasing the GHG emissions of new buildings have recently become important drivers for increasing the re-use and recycling in the EU. According to a study (Rakhshan et al., 2020) the major drivers for the re-use of construction would be cost of components, energy and decrease of the GHG (Figure 22). Interestingly, cost is also shown as nr. 1 barrier in this Figure. This indicates the importance of investments and costs in the construction and demolition sector. Even if re-use sounds to be a very promising way for constructing buildings in the future, the re-use and recycling in construction is practically a complex process, to which numerous factors affect. It is dependent on the present construction and demolition processes, legislation, designs, market and service providers, available goods and materials, information governance and documentation, tax/cost incentives, procurement terms and so on. However, it is good to remember that even over 100 years ago, re-use of log-house-parts was commonly used and frequently entire log-houses were deconstructed and reconstructed. This demonstrates to us that it can be done in the future and it should be done more often.

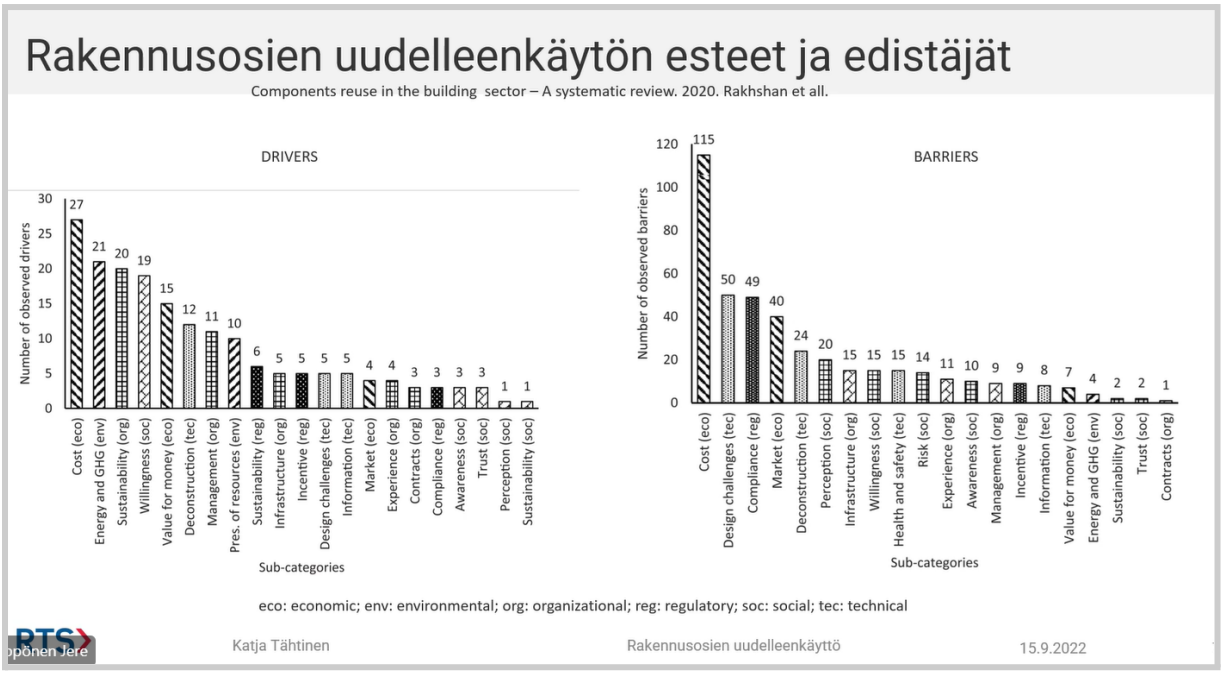


Figure 22. Major drivers and barriers for the re-use of construction materials (Rakshan et al., 2020; from a presentation of Katja Tähtinen RTS 15.9.2022).

In Finland it has been found that major barriers for re-use are the lack of market demand of used parts and materials, lack of acceptability (e.g CE-verification mark missing) and the conservative attitude in the construction sector (ref: HYPPY-hankkeen loppuraportti, GNF, 2022). In Finland the current situation is that a part of the CDW materials are frequently directed to re-use but the authorities (e.g., FIN Ministry of Environment), progressive research organisations and some environmentally responsible companies have realised the potential of increasing the re-use and recycling and started development action towards it.

According to (M. Raimovaara, 2021, Hämeenlinnan asunnot, asukaslehti 1/2021, pp.12-13) a significant number of buildings are found to be at inconvenient locations and end up demolished. In many cases, earlier built buildings, which have been adequate then, have later become inappropriate because of their type, dimensions, structural or other properties. There is often a need to replace them with a different and more suitable type of building, due to the long term changes in e.g. our society, built environment, and technology. Such inappropriate buildings are not any more meeting

the needs of users and often they are in poor condition. Significant investments would be needed for fixing them and doing so might not be economically possible. Thus they are to be demolished. This is a JOINT STATUS for the whole programme region. Interests are identified widely both in public buildings (schools, swimming pools, ice-halls, etc.) and in privately owned housing/block of flats/apartment buildings as well as in commercially used buildings.

The Cata3Pult project organised numerous events related to this topic, such as expert group webinars in August 2020 and in September 2020. Also there was organised a webinar together with the HYPPY project (ERDF) in November 2021.

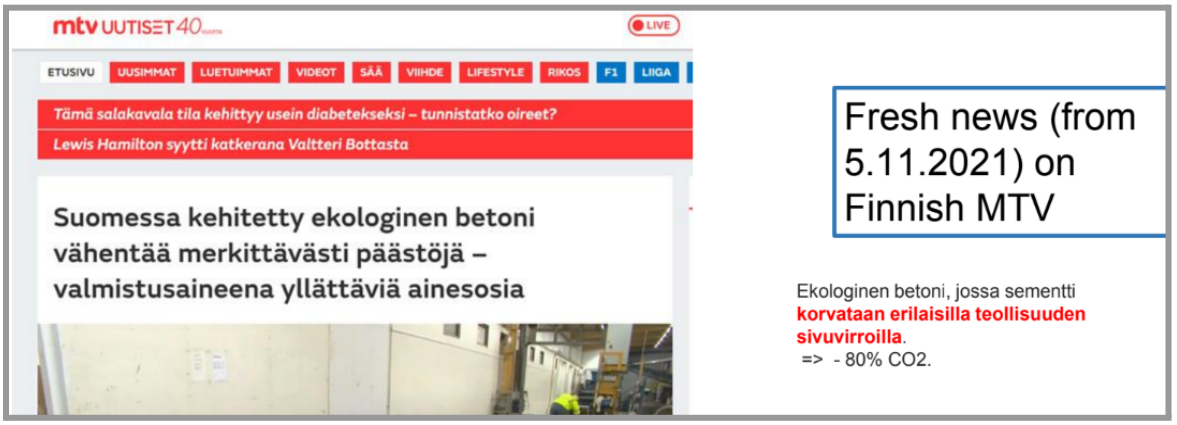
HYPPY-ERDF-project (full original name in Finnish is *Rakennusosat ja materiaalit kiertoon - kokeiluilla uutta liiketoimintaa (HYPPY))* was implemented in 2019-2022 in Finland. The project implemented several pilots, where various ways and working models for implementing re-use of parts of buildings were studied. Focus was in public (municipal) buildings. In the project it was found that in Finland a systematic and generally applicable way for the re-use of parts of buildings does not exist. The currently used construction processes are based almost entirely on the use of new construction products or parts and virgin materials, instead of enabling re-use in practice. A comprehensive report of this lack of systematic procedures, together with carefully considered suggestions for development, has been recently made by the Purater project in Finland. Despite the current situation some innovative companies have developed a business based on the re-use of parts of buildings. E.g. Purkupiha Oy in Finland has been providing services and products to customers in need of demolition or construction of industrial buildings. Several steel frame industrial halls have been de-constructed, carefully documented and their parts re-used at a new construction site. The company has used experienced designers and professionals and developed a specific process. This process and proper documentation and supervision has enabled the re-use resulting in a safe and healthy building which has been acceptable by authorities. Due to the current legislative and administrative framework in Finland the

re-use has been implemented by a case-by-case operation of designers and the local authorities responsible for the permission process for construction.

3.4 Recycling concrete or geopolymer

By **recycling concrete** we mean in this publication material with desirable concrete characteristics produced from industrial side streams and incineration slag from waste-to-energy plants. Recycling -context comes from a matter of using waste from one process as a raw material for another and replacement of virgin material by recycled one. It is also used the terms **geopolymer or ecological concrete as a synonym for recycling concrete.** We do not use term recycled by the purpose to avoid possible confusion with concrete which e.g. was crushed or treated in another way and then used again - in another cycle or object.

Cata3Pult project work on this topic was implemented by discussing on Expert Group webinar in November 2021 (Figure 23).



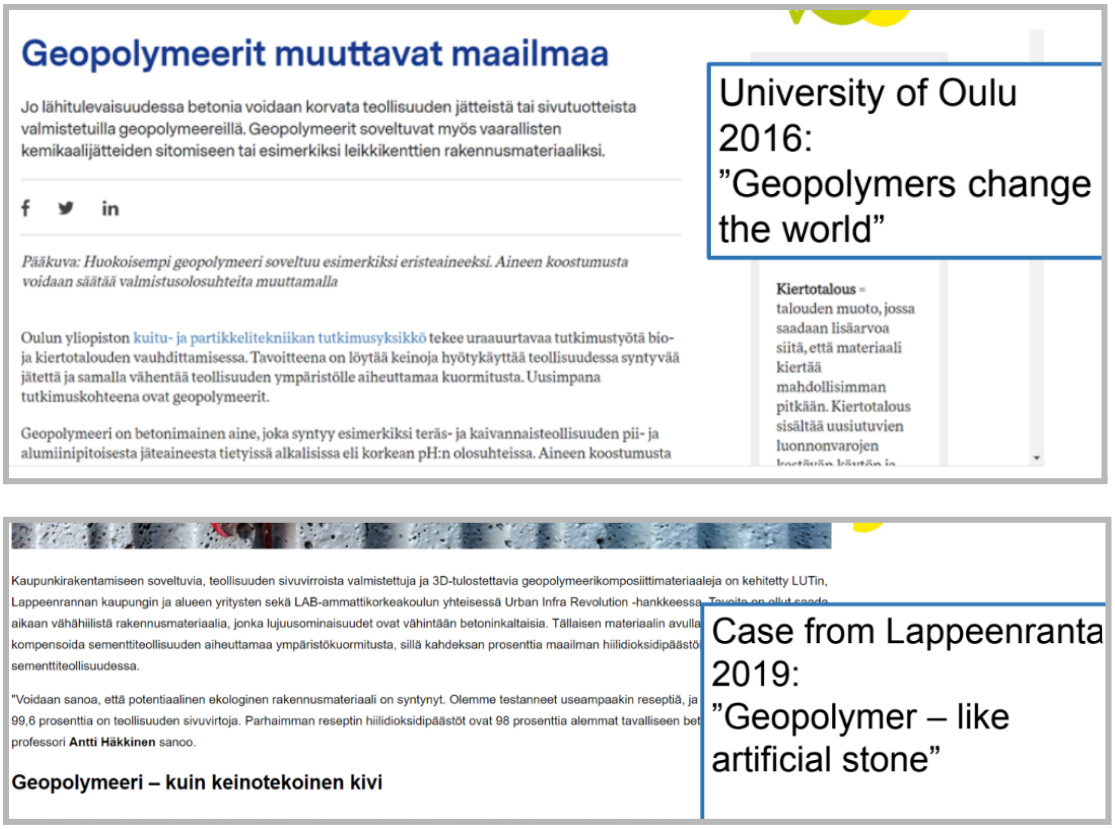


Figure 23. About geopolymers from the introduction presentation, expert group webinar in November 2021.

We were invited to the Cata3Pult Expert Group enterprise *Renotech*, which was involved in pilot activities in another CEFRCBC -project - Cool4City. In more detail about the pilot and results are presented in the Cool4City project final publication *Household waste management in the Helsinki Metropolitan Area and Mikkeli Region – operational models, practicalities and pilots,* which is available on GNF's website. Figure 24 presents concrete proportioning as well cements and binders used in pilot production.

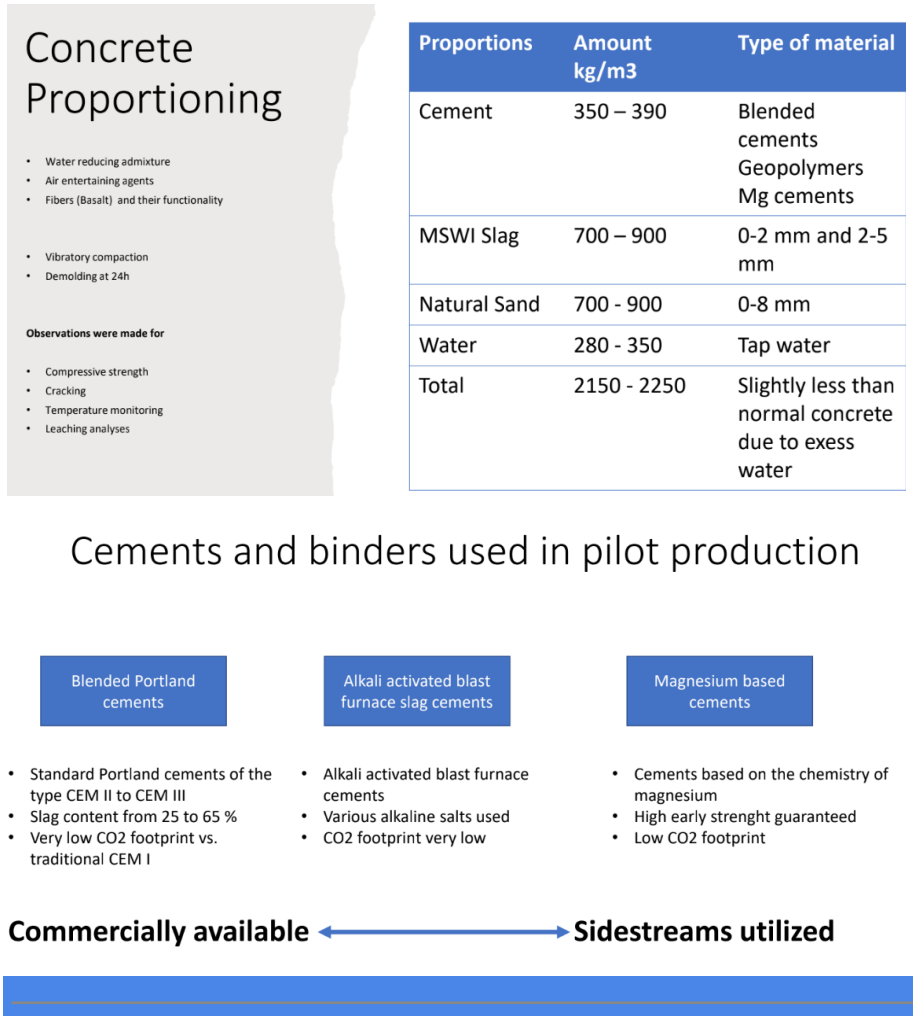


Figure 24. Extracts from Renotech's presentation, expert group in November 2021.

In the frames of Urban infra revolution project The City of Lappeenranta implemented noise protection wall installation in Pontus, Lappeenranta. The 100 m long noise wall is made of geopolymer composite partly 3D printed and partly casted. It protects school and kindergarten from railway noise. The geopolymer composite was made of industrial side streams from mining. Different recipes of geopolymer composition (Figure 25) were developed and tested by enterprise *Apila Group*.

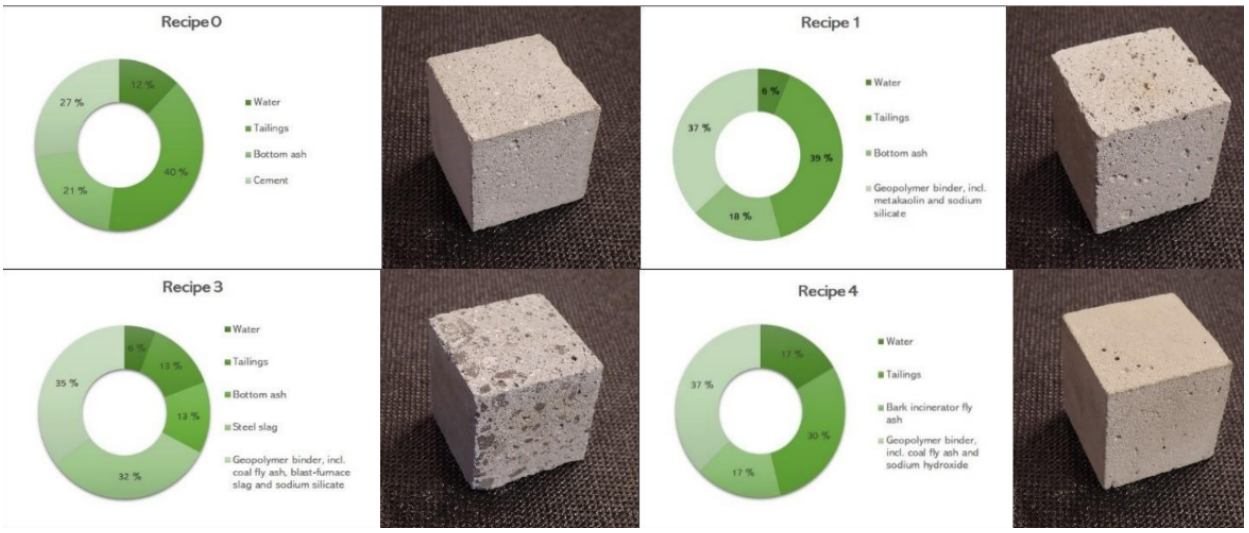


Figure 25. Extract from the City of Lappeenranta presentation on recipes of geopolymer composition, expert group webinar in November 2021

Presented above recipes could be interesting and useful for other enterprises having processing of similar mixes of materials as a part of their business.

3.5 Plastic/polymer waste recycling

Plastic recycling is selected as one of the cases in the Cata3Pult, because this type of waste includes a lot of different types of plastics, which circularity's success depends partly on the quality of the separate collection. Processing of the waste is another factor. Our work under this topic started at the end of 2021 by gathering background information and designing a programme for the Cata3Pult Expert Group webinar, which was organised at the end of January 2022 (Figure 26).

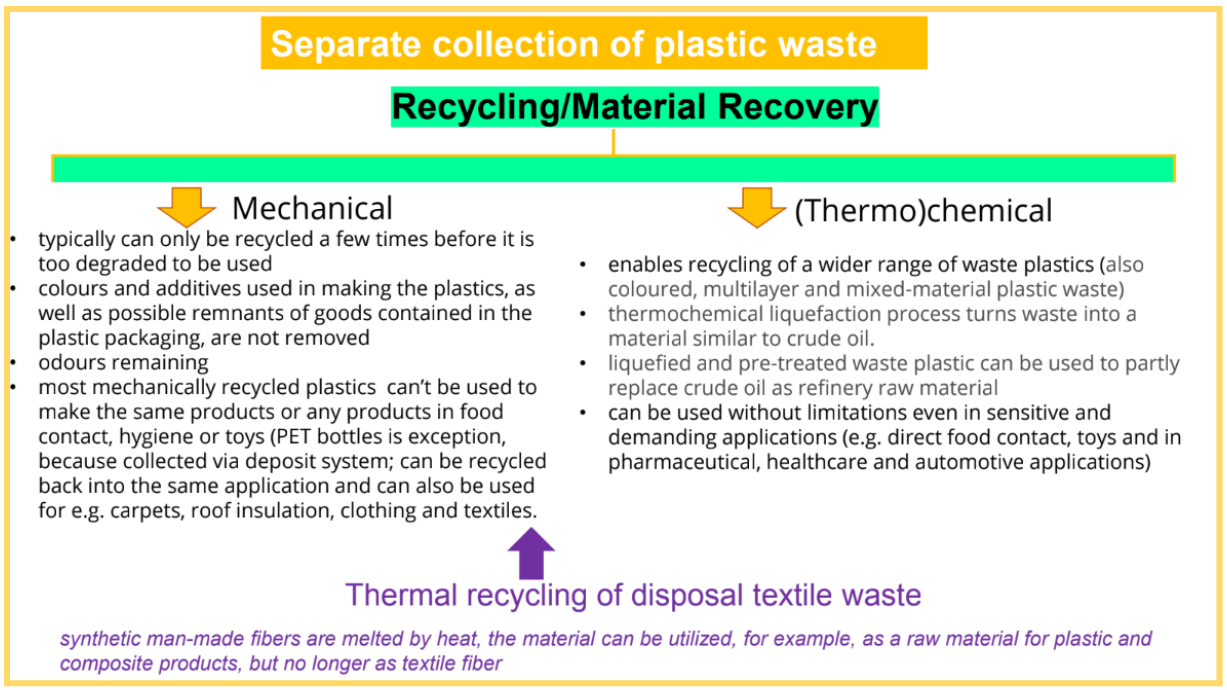


Figure 26. Extract from introduction presentation on Plastic, expert group webinar in January 2022.

It is good to notice that plastic and textile topics are related to each other, when/if we are talking about synthetic textile fibers. In economic terms of plastic waste recycling there is a big difference between types of plastics. As an example, in Figure 27 it is presented that styrofoam and PVC are not accepted in HSY Sortti Stations as Plastic waste, which price is 10 € per cubic metre. But they should be sorted into Combustible Mixed waste, which price is 26,5 € per cubic metre.

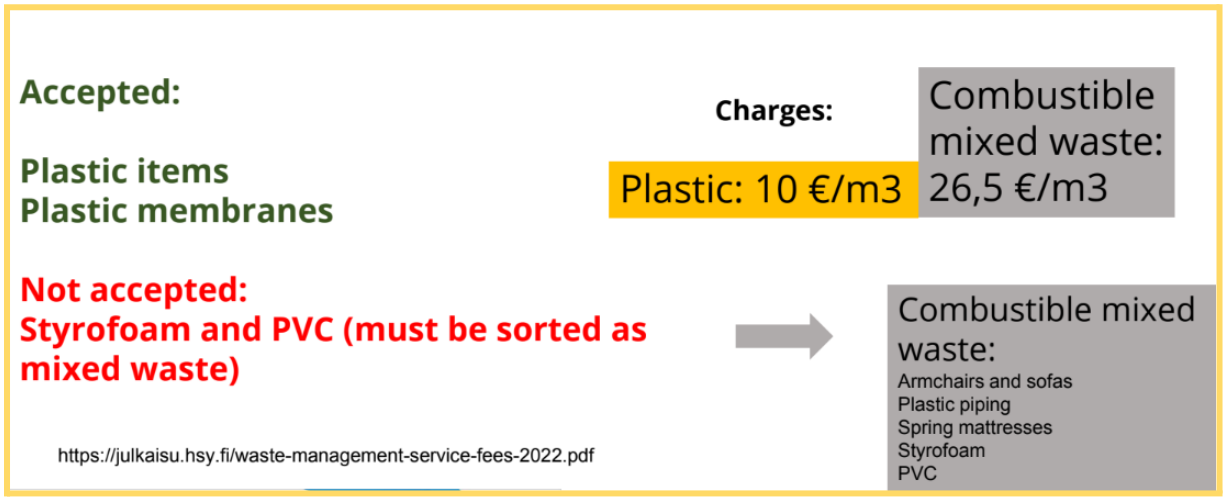


Figure 27. Acceptance matters and pricing of different plastic waste in HSY Sortti Stations.

As one of examples of so called semi-public-private collaboration could be mentioned SME Wimao and it's collaboration with regional municipal waste management organisation South Karelia Waste Management (origin name in Finnish *Etelä-Karjalan Jätehuolto Oy - EKJH*) and state-owned Fortum corporation. Wimao originated from South Karelia enterprise - SME. They have plastic waste treatment facilities on a land plot of EKJH and on Fortum's site in Riihimäki.

In EKJH sorting stations, styrox and other plastics are guided to be sorted to *Energy waste*. There is no such container as Plastic (at least was not in May 2022, when Cata3Pult project team was on a get to know in practice visit in Kukkoroinmäki).
To compare, in HSY Sortti Station in Ruskeasanta (in Vantaa, Helsinki Metropolitan area) there is a separate Plastic -container (see Figure 28). Common for both cases is that PVC (Polyvinyl Chloride) and plastic foam (*vaahtomuovi*) are not allowed to be sorted in those.

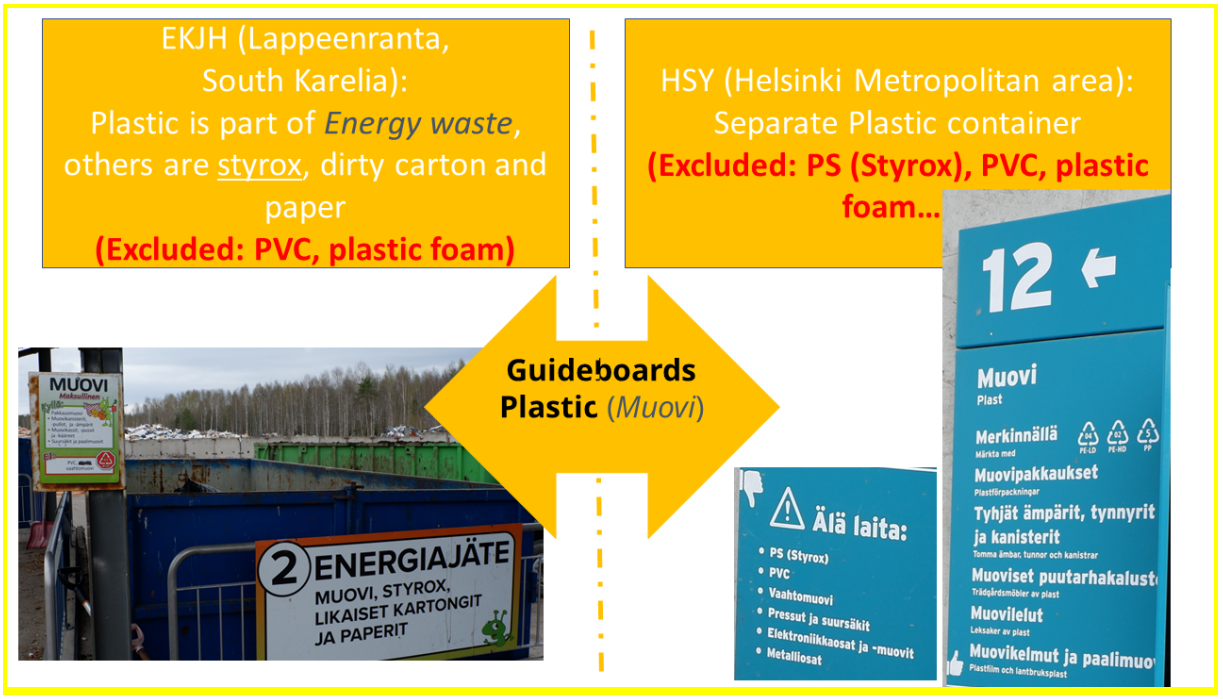


Figure 28. Examples of guideboards for Plastic waste sorting in HSY and EKJH sorting stations.

Cata3Pult also organised waste management seminars in October 2020 and in May 2021, which dealt with waste legislation and Finnish roadmap for plastic was presented.

The Ministry of the Environment launched a process to update the Plastics Roadmap in late 2021. Regarding further measures, special attention was focused on the viability of the value chains of the circular plastics economy and related development needs. The goal of the Plastics Roadmap is to reduce littering and other environmental damage caused by plastics, avoid the unnecessary consumption and improve the recycling of plastics and replace conventional fossil-based plastics with other materials and solutions. Figure 29 presents a summary of the Plastics Roadmap [Muovitiekartta-2.0-EN, 2022].

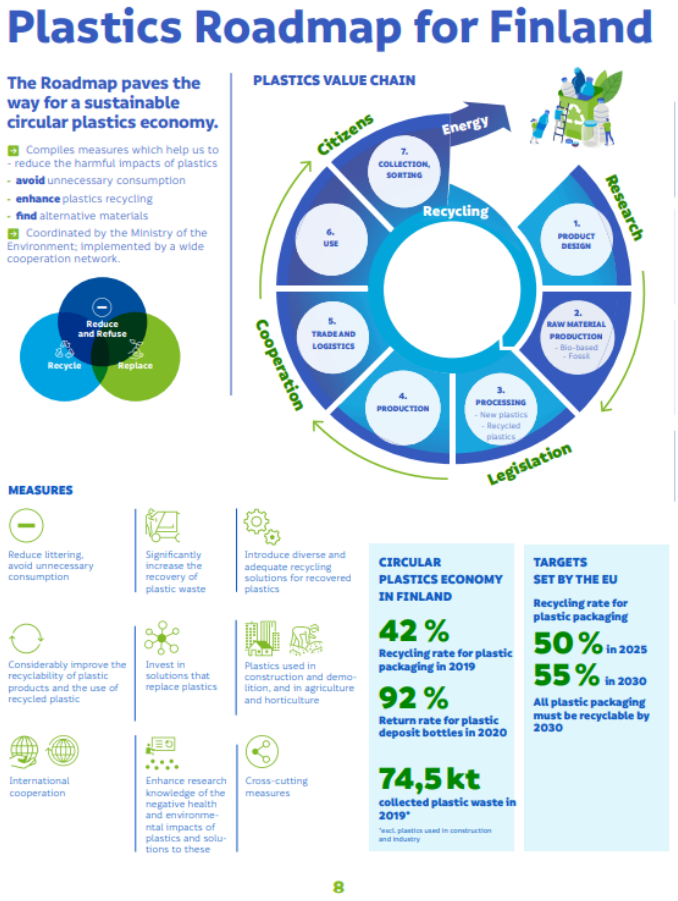


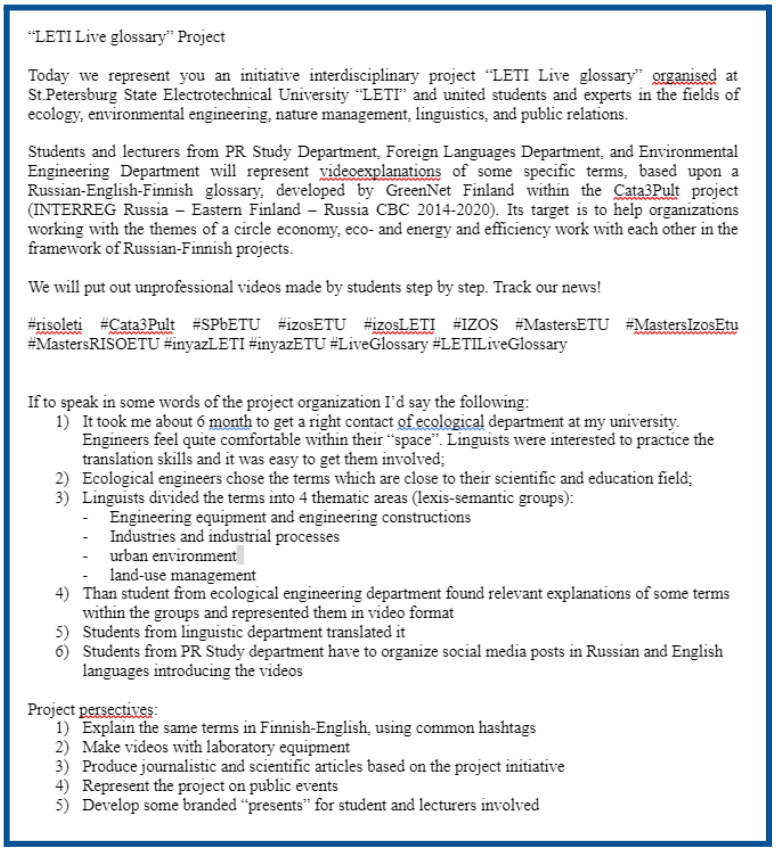
Figure 29. Screenshot of infographic of Plastics Roadmap for Finland.

4 Student innovation projects

Cata3Pult project also worked on development of student innovation projects, which have connection to business opportunities. Discussions between Metropolia UAS and LETI University about possible joint projects were initiated already since the kick-off meeting organised in the beginning of June 2019.

4.1 "LETI Live Glossary" project

First idea was to implement a video project with explanations of cleantech terms in English, Finnish and Russian. Thoughts behind this idea were that there are no established permanent definitions and this unclearness forming a barrier for successful collaboration. How can students and teachers implement joint projects, if they simply do not have a common understanding of what they are talking about?
Writing of LETI expert about the project as such is presented in Figure 30.



"LETI Live glossary" Project

Today we represent you an initiative interdisciplinary project "LETI Live glossary" organised at St.Petersburg State Electrotechnical University "LETI" and united students and experts in the fields of ecology, environmental engineering, nature management, linguistics, and public relations.

Students and lecturers from PR Study Department, Foreign Languages Department, and Environmental Engineering Department will represent videoexplanations of some specific terms, based upon a Russian-English-Finnish glossary, developed by GreenNet Finland within the Cata3Pult project (INTERREG Russia – Eastern Finland – Russia CBC 2014-2020). Its target is to help organizations working with the themes of a circle economy, eco- and energy and efficiency work with each other in the framework of Russian-Finnish projects.

We will put out unprofessional videos made by students step by step. Track our news!

#risoleti #Cata3Pult #SPbETU #izosETU #izosLETI #IZOS #MastersETU #MastersIzosEtu #MastersRISOETU #inyazLETI #inyazETU #LiveGlossary #LETILiveGlossary

If to speak in some words of the project organization I'd say the following:

1) It took me about 6 month to get a right contact of ecological department at my university. Engineers feel quite comfortable within their "space". Linguists were interested to practice the translation skills and it was easy to get them involved;
2) Ecological engineers chose the terms which are close to their scientific and education field;
3) Linguists divided the terms into 4 thematic areas (lexis-semantic groups):
   - Engineering equipment and engineering constructions
   - Industries and industrial processes
   - urban environment
   - land-use management
4) Than student from ecological engineering department found relevant explanations of some terms within the groups and represented them in video format
5) Students from linguistic department translated it
6) Students from PR Study department have to organize social media posts in Russian and English languages introducing the videos

Project persectives:

1) Explain the same terms in Finnish-English, using common hashtags
2) Make videos with laboratory equipment
3) Produce journalistic and scientific articles based on the project initiative
4) Represent the project on public events
5) Develop some branded "presents" for student and lecturers involved

Figure 30. Screenshot of presentation of "LETI Live glossary" Project. Author: Larisa Sharakhina, July 2020.

4.2 Student innovation projects of LETI

LETI University is implemented student projects and organised a series of webinars on presenting those. Presentations could be found in Cata3Pult GD folder (Figure 31).

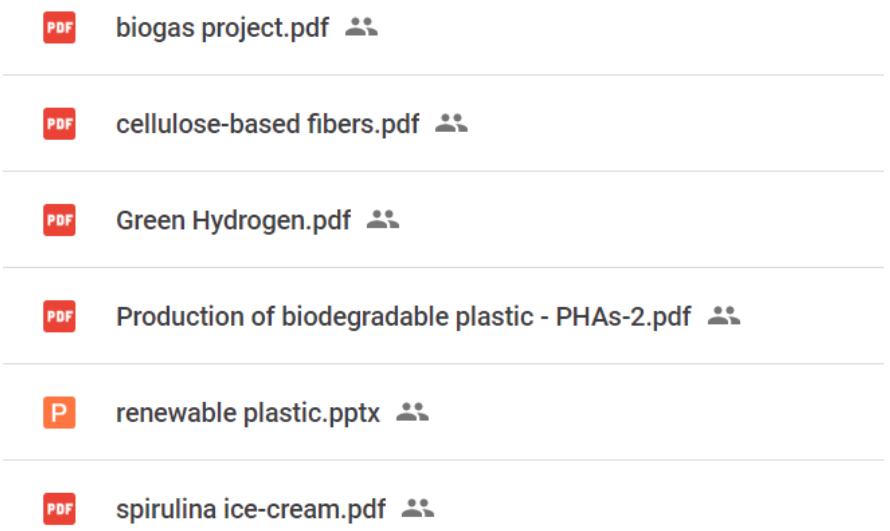


Figure 31. Screenshot of student innovation projects folder in Cata3Pult GD.

Chapters 4.1-4.3 are written by Metropolia. Descriptions in Chapters 4.1-4.3 written by participants to the student innovation projects, which were implemented during the second year of the project June 2020 - December 2021. Instructors of those were Cata3Pult project team members Timo Seuranen and Carola Fortelius-Sarèn.

4.3 Recycling of coffee waste project of Metropolia

The topic of the project was utilization of coffee grounds. The goal was to make survey about current circulation of coffee grounds and to find new uses for it. Objective was to go through information about coffee, its circulation and to make report about used coffee grounds as firewood, palm oil -like oil and fertiliser. Utilization of coffee grounds was also tested in oyster mushroom farming.

Coffee shops generate a lot of used coffee grounds and it usually end up in trash. The proportion of drunk coffee is very small compared to coffee beans biomass. Thus, used coffee grounds are potential reusable resources. Many people and companies have been inspired to create new solutions for coffee grounds because of the low amount of waste that gets into further processing. Used coffee grounds are rich in nutrients and that inspired us to use it in oyster mushroom farming. In recent years, usage of coffee grounds in commercial mushroom farming has grown rapidly.

In this project we made written reports of three different potential uses for used coffee grounds and focused more on oyster mushroom farming of which we studied also in practice. Microbe- and preservation tests were made for the coffee grounds. Also, temperature and relative humidity were measured on the farm. The tests were made to achieve optimal growing conditions for oyster mushrooms.

Relative humidity stayed high inside of the farm and the temperature didn’t fluctuate. 25 mm growth hole was optimal for the mushrooms. 18 mm and smaller growth holes caused mushrooms to grow smaller and deformed. Freezing wasn’t suitable for preservation. From the preservation test, it can be concluded that the amount of microbes increases exponentially after four days. The microbes could not be fully identified, but one mold specimen was believed to be part of Penicillium -genus due to its characteristics.

Oyster mushroom farm worked as expected, but it should be further optimized. To reach optimal growth, the farm needs to be moisturized more often or decrease the time in between addition of fresh coffee grounds. Preservation of growth mixture requires further studies. Additionally, possible spoilage microbes should be further analyzed.

4.4 Renewable Hydrogen project of Metropolia

The purpose of the project is to get acquainted with various modern processes and ways of producing renewable hydrogen. When we talk about renewable or green hydrogen, it means hydrogen that has been produced using only renewable raw materials and energy sources such as solar and wind power.

Four different methods were selected for the project:

- biomass gasification,
- water electrolysis,
- solid oxide technology and
- photosynthesis.

These four processes were examined in more detail in this report.

A market study was also carried out for each process, the purpose of which was to map the profitability of the process, the location of a potential production plant and the required capacity. In addition, the market study examined the costs associated with the use, production,import and export of raw materials and materials, as well as possible challenges, and to find a solution to the problems.

The five most important characteristics were selected for the processes, on the basis of which the processes were scored on a scale of 1 to 4, so that the best received four points and the worst one. In addition, the properties had their own coefficient

depending on how important the property was to the process. Properties were chosen; Price, quality, investment, technological maturity and raw materials.

4.5 Fucus Vesiculosus project of Metropolia

The topic of the product development project was the utilization of Fucus vesiculosus as food. The aim of the project was to develop a product from a new and so far, little utilized raw material, and to find out its manufacturing process. In the project was developed a fermented algae sauce from domestic F. vesiculosus.

The method of the work was a theory-based report. The work progressed from the selection of the main raw material to the assessment of its health effects and use. From the preparation of the sauce, the raw materials and processes needed for fermentation and preparation were studied, as well as, in the case of algae, also cultivation and collection. In addition, the regulatory aspects of production and the market were assessed. Experts were also contacted, both on the legislative side and on education.

The suitability of F. vesiculosus as a raw material was evaluated by investigating available studies on its nutritional values.

Nothing can be said for sure about the functionality of the final product, as the work could not be carried out in practice. However, several sources were found in the literature to support the successful implementation of algae sauce. F. vesiculosus contains a lot of glutamic acid and is successfully grown in the Baltic Sea. Many sources also indicated that it is possible to ferment algae. The help of the experts was a great benefit, as the information received from them contributed to the achievement of the goal of the work.

The production of algae sauce would be easy to carry out on a larger industrial scale, as it follows the traditional soy sauce production process with its simple ingredients. The

experts confirmed that it would be possible to implement algae sauce entirely with domestic production and from Finnish raw materials.

4.6 Plasma reactors (VTT) project of Metropolia

This Innovation project was commissioned by VTT. Non-thermal plasma reactors (NTP) are inadequate when compared to conventional reactors. The lack of suitable catalysts and useful scale-up factors make NTP reactors impractical. However, the demand for green and more efficient reactors is increasing rapidly.

The purpose of this project was to gather information about NTP reactors from literature and examine possible solutions for their upscaling. The project provides information about the basic theory of NTP reactors, their conversion and energy efficiency, and the issues regarding their up-scaling.

This report focuses on the three most common NTP techniques: dielectric barrier discharge (DBD), gliding arch discharge (GAD) and microwave discharge (MW).

From an economic point of view, NTP does not require rare earth minerals and emits zero carbon dioxide when powered by green energy. The promise of good energy efficiency makes NTP reactors a feasible alternative to conventional reactors in the long run.

Although there are some practical NTP reactors in industrial production, the results indicate that more research is needed before upscaling can be sufficient. Each reactor type is suitable for different solutions, for example DBD can be installed in parallel with longer tubes and some suggestions for improving GAD were made. The project discovered some possibilities for up scaling. In addition, it is stated that GAD and DBD need catalysts to be practical when scaled. DBD must be packed in order to have high conversion and energy efficiency.

From an economical and sustainability point of view, most of the reactors are at a disadvantage. This is because the use of rare earth minerals and energy consumption

are costly parameters in reactor design. The solution is to find some new, more abundant minerals to replace the expensive ones. It cannot be pointed out enough that this is a critical make or break point, but which is not an issue for the plasma chemical conversion.

Another thing to mention is the use of renewable energy sources as power in the reactors. Some of the reactors could use direct renewable energy i.e., solar radiation. Indirect use means that it relies on electricity from the grid. What gives the former the advantage is skipping over the energy conversion step, which causes further losses through the chain of electricity. On the other hand, the reactors that use indirect energy sources can rely on other sources of renewable energy such hydro, wave, and tidal power.

Most of the new plasma technologies have excellent conversion and yield, but what separates the ones usable in the future is sustainability and flexibility. By flexibility meaning the use of a variety of energy sources and operating circumstances. Also, one parameter to keep in mind is solar-to-fuel efficiency. This measurement shows how well different technologies convert solar energy into chemical energy. Keeping in mind these parameters there is a lot of studying to do to determine the future of plasma reactors.

4.7 Future Outlook of Carbon Neutral Chemical Industry (St1) project of Metropolia

This project was done in collaboration with ST1 as they wanted a report of the future outlook for the chemical industry and what chemicals and materials are most promising in future. Chemical industry has a considerable crude oil feedstock and decrease in use of these fossil-based raw materials is desired. Plastic and methanol production still mostly consist of fossil-based feedstocks; this report focuses on production of bioplastics and bio-methanol. Additionally, this review introduces other environment friendly solutions such as mechanical and chemical recycling for plastics and new innovations.

There is no bioplastic that has more significant impact than others in the market. This makes it difficult to rank them based on their potential market impact. Many

fossil-based plastics can be replaced with bioplastics made of different kinds of renewable raw-materials. In this study, the top five ranking bioplastics are:

1. Bio-PE
2. PHA
3. Bio-PVC
4. Bio-PP
5. Starch-based-plastics

Bio-PE is number one as PE has the biggest market scale and converting all this to bio-PE would have the biggest impact on the market. Another positive side is that it can be produced from pulp production of tall oil residue streams, and this decreases its competition with other biomass feedstocks.

PHA is number two as it is one of the most promising bioplastics because it has the same properties as fossil-based plastics, and it is also biodegradable even in the oceans. However, today PHA production is relatively low due to its complex process. In addition, the raw materials needed for PHA are relatively more expensive than other bioplastic materials, which raises the price of PHA. Alternative and cheaper raw materials, such as vegetable and animal oils, are currently being sought, so research indicates that PHA production will increase in the future.

Number three is bio-PVC because it can be produced from non-food-chain biomass. Similarly, to PE, PVC has a large market to convert to bio-PVC and potentially increasing the bio-PVC market.

Based on the bio-PP low production scale and commercial market bio-PP is number four. Bio-PP still made the list because it has potential to increase the production scale and commercial value will most likely increase based on the research.

Starch-based-plastics have excellent cost-competitive market value and are due to this the last mention on the list. It also has good physical properties for a bioplastic.

Another chosen industrial category for bio-based feedstocks was bio-methanol and the future seems promising for it. Cost-competitiveness is still not on the level of fossil-based methanol, but the predictions show potential for rising commercial status if the right regulatory measures are put in place.

Even though changing fossil-based feedstocks in petrochemical production is a viable way to decrease emissions, it only accounts for around 7% of total crude oil usage. Bigger concern for i.e., plastics is the waste in the environment and consumers have a big impact on this. Consumers should focus more on avoiding unnecessary consumption and concentrate on sustainable products. Efficient recycling should also be promoted, and consumer choices have a significant impact on the market. As the demand for bio-based products rises the transition to carbon neutrality will become easier.

ST1 press release 18.8.2021: St1 to construct a biogas upgrading and liquefaction refinery in Sweden

Energy company St1 has made an investment decision to construct a biogas upgrading and liquefaction refinery in Sobacken, Borås. A prerequisite for the biorefinery investment decision is the long-term off-take contract to buy raw biogas, which St1 has signed with Borås Energi och Miljö. With the agreement, also the two public gas filling stations of Borås Energi and Miljö in Åhaga and Hulta will be transferred to St1. St1 will continue expanding its biogas filling network in the Nordics to distribute this new liquid biogas production.

St1 will start the construction work in the autumn and the biorefinery is expected to commence its operations at the end of 2023

ST1 press release 4.10.2022: St1 is planning a synthetic methanol pilot plant in Lappeenranta, Finland

The energy company St1 is planning the first synthetic methanol plant in Finland next to the Finnsementti factory at the Ihalainen industrial site in Lappeenranta. The Ministry of

Economic Affairs and Employment has granted a funding of EUR 35.4 million to St1's Power-to-Methanol Lappeenranta project, which aims to produce renewable synthetic methanol to replace fossil fuels used in maritime and road transport. St1's goal in the commercial-scale pilot project is to develop a replicable and scalable synthetic methanol production concept.

5 Individual support to businesses with wider intent

In this Chapter we will describe activities we provided for and with individual Finnish enterprises. Two support cases will be opened in so-called generalised way, which means that we describe those by *Enterprise # A* and *Enterprise # B* without mentioning names of the enterprises, but by substance focus. Our intent is to deliver possible insights for development of business activities for other enterprises with similar focuses.

This Cata3Pult work started in March 2020, same time with the Covid2019 and for example in the Chapter 5.1 presented business representative made presentation in Finnish and Cata3Pult Expert supported in communication / translation. We see that this kind of work is also developing companies' capability to work in international markets because they learn how to communicate about companies' solutions in English. But in another case Chapter 5.2, there was another case where not original Finnish entrepreneur was supported by Cata3Pult Experts in developing marketing material in Finnish.

5.1 Demand-controlled ventilation - case *Enterprise # A*

Prior to start descriptions of supporting activities, let's take a look on some examples of definitions of **demand-controlled ventilation (DCV):**

- is a feedback control method to maintain indoor air quality that automatically adjusts the ventilation rate provided to a space in response to changes in conditions such as occupant number or indoor pollutant concentration. The control strategy is mainly intended to reduce the energy use by heating, cooling, and ventilation systems compared to buildings that use open-loop controls with constant ventilation rates https://en.wikipedia.org/wiki/Demand_controlled_ventilation

- solutions that manually or automatically regulate airflow to meet the exact need at a given time https://www.swegon.com/knowledge-hub/technical-guides/we-explain-demand-controlled-ventilation/
- looks at the demand for ventilation using sensors and supplies the outside air as needed https://www.rasmech.com/blog/demand-control-ventilation-for-dummies/
- is an intelligent ventilation system that adjusts the airflow and indoor climate parameters based on the needs of each separate room in the building, https://www.lindab.com/product/ventilation-systems/demand-controlled-ventilation/

This supported by Cata3Pult business case is interesting because of so-called synergic cross-regional support. An enterprise is located in the Mikkeli region. Before it came as the case in Cata3Pult project, it was supported by another project - BBC1, which lead partner is from Mikkeli (see about our collaboration in Chapter 6). The same enterprise was then also a member of Greenreality network - cluster operated by the City of Lappeenranta (lead partner of Cata3Pult project). Later, during proceeding with Cata3Pult project, the same enterprise also joined to GNF network/cluster as a member (note: GNF is located in the Helsinki).

Starting point for supporting activities of this enterprise, let's name it *enterprise # A*, was its interest in the SPb market. However it did not have contacts there and also no resources to conduct discussions with potential clients in SPb either in other countries meaning no english speaking representative. As a pre-support or background information: one of the activities of the Cata3Pult was to develop a concept *"From traditional industrial zone to new demonstration zone for green solutions in Kolpino St.Petersburg"*. We started this work in the beginning of the project by visiting this site in September 2019. In December 2019 we started planning a joint Cata3Pult+BBC1 event as a part of Ecology of Big City 2020 expo in SPb. This *enterprise A* was one of the engaged enterprises (then from the BBC1 project side only). Everything was ready for the event at the end of March 2022, but then became covid-2019 into the picture. So, we started to adjust our activities for a new virtual reality.

During spring 2020, our SPb partner HPOA developed the mentioned above concept (english version of the report is available in Cata3Pult GD folder. One of the residents in this zone was TYREMAN GROUP, which started to develop ecosystem around this zone in another (BSR Interreg) project. Just at the moment of starting of Cata3Pult TYREMAN started to think about new building of show-room for eco- and energy-efficiency solutions within this zone. It was planned to visit this zone in connection with participation in the Ecology of Big City 2020 expo at the end of March. At this moment a design of the show-room was ready and inviting of companies was started. So, we saw that there could be a good match between developer (TYREMAN) and our enterprise # A. We organised a B2B meeting at the end of April 2020 as soon as we managed to learn to work in a new "MS Teams/ZOOM/virtual-only" reality. At the end of the discussion it was concluded that presented by enterprise A solution sounds reasonable for the developer and its relatively short payback time and investment amount is acceptable. Enterprise A and the developer agreed to meet in Autumn 2020 to see the site and also discuss other potential sites for taking into use the proposed solution.

Residential buildings, e.g. blocks of flats, and also public facilities are identified as suitable objects for taking into use this technology. So, we included this type of energy-efficiency improvement solution into Cata3Pult feasibility studies - FS #2 and FS #3. (see Chapters 1.2 and 1.3). We believe that enterprise A and probably also other companies with a similar solution will benefit from Cata3Pult project outputs in terms of having neutral/third-party assessments on feasibility of demand-controlled ventilation.

5.2 Urban farming solution - case *Enterprise # B*

For the purpose of this publication, we defined **urban farming solution** as a set of equipment and ground-mix for farming is a small land plot or floor areas within urban agglomerations. Micro-enterprise from South Karelia, let's call it *enterprise # B*, approached Cata3Pult project cluster experts with ideas on a new recipe of a ground-mix and also container. This enterprise asked for help with creation of

marketing materials for its package/solution. We also discussed environmental and health matters related to the ground-mix.
Then the enterprise was also supported by providing the opportunity to advertise the solution at a Community Garden event and seminar organised in collaboration of LALAPETE and Cata3Pult projects in Lappeenranta in May 2022.

6 Collaboration & communication group of SEFR CBC projects

Work of this group was initiated and coordinated by GNF. In addition to the Cata3Pult project, also BBC1, Cool4City, LALAPETE and CroBBodIT -projects were contributing to this work.

The main objective of this group was information exchange and collaboration on events, publications and visibility & communication activities. An idea behind this group was that all five projects have in focus waste management and transition toward circular economy and they are approaching the same target groups. So, it is seeing natural and efficient to have such cross-projects' communication. We collected outputs from discussions on our meetings into newsletters. Overall eight (8) meetings were kept during the period of time March 2021 - January 2022 and newsletters published on GNF's website in open access. Since March 2022, collaboration was continued within Finnish partners of four projects. Joint final event was organised at the end of November, with a logo with the names of the collaborating projects presented in Figure 32.

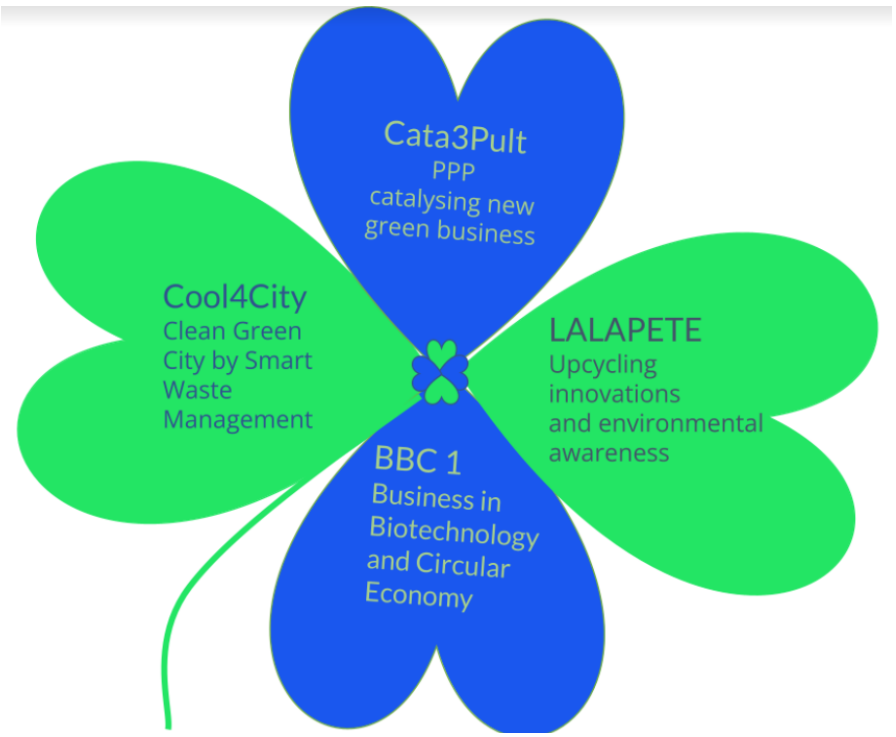


Figure 32. Logo for the final event of four collaborating SEFRCBC projects - Cata3Pult, BBC1, Cool4City, LALAPETE.

7 Conclusions and recommendations

This publication is sharing our understanding of the urban environment as a whole and interconnections between energy, mobility and consumption and industrial aspects. Cata3Pult project developed model for cross-regional collaboration of cluster organisations for development of generalised business cases by systematic and dynamic process with learning by developing approach. We structured business cases around three substance topics related to green solutions for the urban environment. Public-private partnership was in the focus. Work in practice was organised via the concept of the expert groups formed around each substance focus area of the urban environment followed by relevant feasibility studies, if a business case under development attracted interest of relevant stakeholders. These expert groups were diverse in public-private context as well as in geographical context. To get a more comprehensive view, we established a communication and collaboration group with

other relevant projects within the same financing programme. In parallel to the expert groups we established collaboration on student innovation projects. Inspirations for the topics usually originated from discussions within the expert groups. We, as cluster organisations experts, also catched signals from our cluster members and our extended networks, other relevant projects and initiatives, gathered information, utilised in our development work and shared it via a wide range of communication and visibility channels.

To act in real-life and as “economy” circular processes in industrial manufacturing, municipal waste management, services, consumers/households' lives should be smooth and systematic. Demand side in the circular economy neeAnds “raw materials” flows, which are predictable, enough volume and consistent quality. One-time or time-to-time items with an uncertain composition and flowing timeframe are hallmarks of recycling, but not circular economy yet.

Electrification of traffic, bio gas and hydrogen - combinations of fossil free fuels are important in cutting down emissions. Infrastructure is needed for all and they are different. Building and maintaining overlapping systems could bring not so positive impact. Compatibility of different systems is important. Power-to-X solutions bring renewable fuels and in a bigger picture change all energy systems.

In the report *Comparative analysis of life cycle model of energy efficiency investments* new models of energy efficiency agreements were tested. Some of them are already used in Finland in construction projects, and it seems that in future they would be mainstreamed based on the experiences and lessons learnt in the energy efficiency in the project.

Strong variations in energy prices globally, climate change, natural resources, political, ecological and economic crises are driving forces for this development. For successful and positive development public-private collaboration is needed.

We invite readers of this publication to share it! Our intent is to maximise efficiency of using public financing and enhance understanding of already achieved outcomes.

8 References

8.1 Presentations of the Cata3Pult Expert Groups

Content of this report is partly based on expert presentations on meetings organised by the Cata3Pult project or on collaborative meetings with other projects (e.g. BBC1, LALAPETE, HYPPY). Agendas of all meetings and presentations are collected in a Google Drive folder of Green Net Finland ***Cata3Pult Expert Groups materials for Synergic Business Cases report***. To make a search for a presentation more convenient, we allocated those in separate sub-folders, whose names are identical with the names of the Chapters of this report (see Figure 33 below). And names of the presentations .pdf files are started with the date of the meeting.

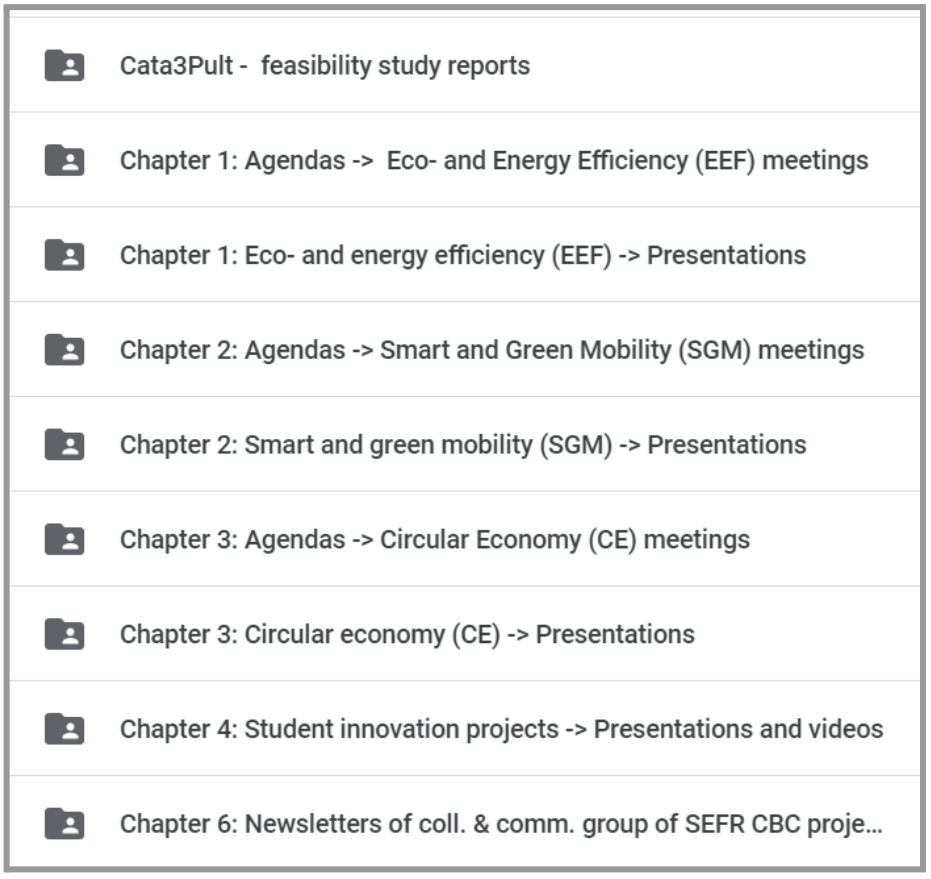


Figure 33. Sreenshot of Google Drive folder Cata3Pult Expert Groups materials for Synergic Business Cases report.

List of presentations of the Chapters 1-3 with links to the pdf- versions of the presentations are collected into the separate Google Sheets under each sub-folder:

Chapter 1 - list of presentations

Chapter 2 - list of presentations

Chapter 3 - list of presentations.

In addition, full list of presentations on the Cata3Pult expert group meetings is presented in the separate Google Sheet in the main folder.

8.2 Other references

https://research.tuni.fi/buildingphysics/research-projects/future-spaces/ ; Accessed on 14.9.2022

https://environment.ec.europa.eu/topics/waste-and-recycling/construction-and-demolition-waste_en accessed on 21.10.2022

GNF, 2022, Hyppy-hankkeen loppuraportti https://gnf.fi/wp-content/uploads/2022/05/Rakennusosat_ja_materiaalit_kiertoon_HYPPY_Loppuraportti_2022.pdf

Attachment: List of Figures (1 - 33)

1	Cata3Pult Development Framework
2	Business Cases of Cata3Pult in Business Matrix and uncertainty flow
3	Process of Forming and Development of Business Cases in Cata3Pult
4	Illustration of public-private partnership in Cata3Pult
5	Feasibility studies of Cata3Pult project in the focus area of eco- and energy-efficiency.
6	Screenshot on geological description of the study case area in FS #1
7	Land Plan of St. Petersburg with estimation of Yuzhniy area construction (FS #1)
8	Energy prices in St. Petersburg and Lappeenranta used in LCC analysis of FS #1 and FS #2
9	Life cycle costs (LCC) of heating energy - district heating (DH) vs. ground source heat pumps (GSHP) for one-dwelling house and block of flats (FS #1)
10	Payback times of energy efficiency improvement in study cases of residential apartment buildings in Lappeenranta and St. Petersburg (FS #2)
11 A	Energy consumption and C02 emissions in HUKATON simulations (lessons learned case)
11 B	LCC and CO2 emissions in HUKATON simulations (lessons learned case)
12	Screenshot “type of building for case study - p.62” from SPb MWR 3.0 publication
13	Screenshot “composition and nominal amount of communal costs in the study case - figure 26” from SPb MWR 3.0.
14	Savings of heating energy [%] during one heating season [years 2015-2019] in the study case block of flats in St. Petersburg
15	Screenshot “Carbon footprint calculating for Circular economy - p.72” from SPb MWR 3.0
16	Capability analysis in (IAQ)-as-a-service business model development. Dr. Karan, 2022c
17	Roadmap in IAQ-as-a-service business model development. Dr. Karan, 2022 (lessons learned case)
18	Photo from the starting meeting of the circular economy expert group in Metropolia UAS in December 2019.
19	Framework for discussions and development within Biogas production and treatment of biowaste, expert group webinar in March 2021.
20	Screenshot of Paskier fertilizer production process from Nanopar’s presentation, expert group webinar in March 2021.
21	Extract from introduction presentation on Textile, expert group webinar in April 2021
22	Major drivers and barriers for the re-use of construction materials (Rakshan et al., 2020; from a presentation of Katja Tähtinen RTS 15.9.2022).
23	About geopolymers from the introduction presentation, expert group webinar in November 2021.
24	Extracts from Renotech's presentation, expert group in November 2021
25	Extract from the City of Lappeenranta presentation on recipes of geopolymer composition, expert group webinar in November 2021

26	Extract from introduction presentation on Plastic, expert group webinar in January 2022
27	Acceptance matters and pricing of different plastic waste in HSY Sortti Stations.
28	Examples of guideboards for Plastic waste sorting in HSY and EKJH sorting stations
29	Screenshot of infographic of Plastics Roadmap for Finland
30	Screenshot of presentation of “LETI Live glossary” Project. Author: Larisa Sharakhina, July 2020
31	Screenshot of LETI university student innovation projects folder in Cata3Pult GD.
32	Logo for the final event of four collaborating SEFRCBC projects - Cata3Pult, BBC1, Cool4City, LALAPETE.
33	Screenshot of Google Drive folder Cata3Pult Expert Groups materials for Synergic Business Cases report.