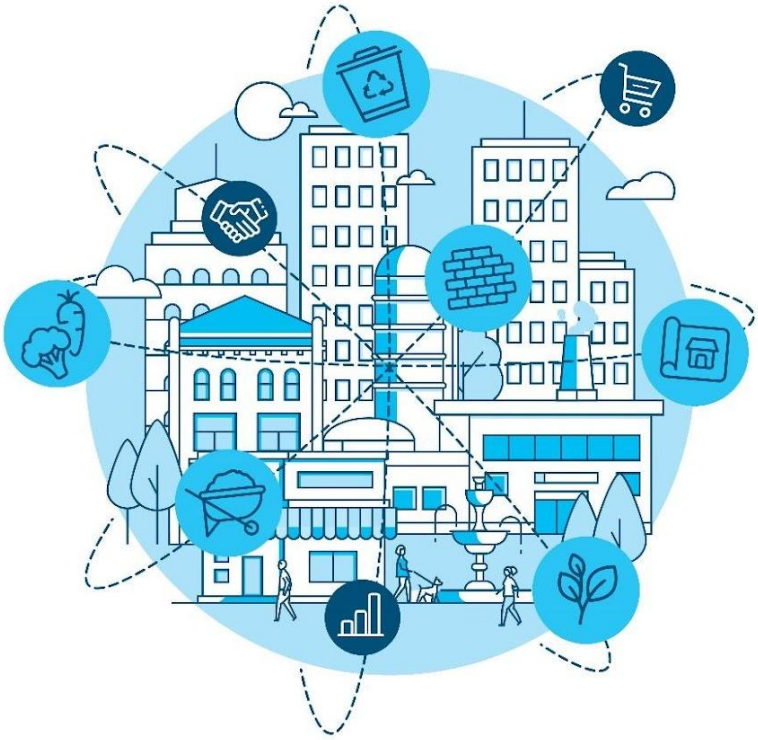
CIRCULAR CDW IN MIKKELI

Demonstration Report

Mikkeli, Finland



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Abstract	Mikkeli's demonstration involved the demolition of two public buildings: Pankalampi Health Care Centre and Tuukkala hospital. This report describes demonstration activities, results and lessons learned.
Keywords	Demolition, Circular Economy, Construction and Demolition Waste, Reuse, Recycling, Pre-demolition audit
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Contents

1. Executive summary 7
2. City context 10
3. Implementation 11
   3.1 Introduction 11
   3.2 Procurement activities 14
      3.2.1 Introduction 14
      3.2.2 Land use plans of demo sites and new construction plans 14
      3.2.3 Legislative requirements related to the circular economy 15
      3.2.4 Preparation phase of the tender 15
      3.2.5 Market dialogue in demo projects 16
      3.2.6 Circular economy objectives in tender planning 16
      3.2.7 Outcome of the tender 17
   3.3 Screening of the buildings 17
      3.3.1 Pre-demolition audits 18
      3.3.2 3D drone scan and flow-tracking 19
      3.3.3 Environmental health and safety check 20
   3.4 Selective demolition procedure 22
      3.4.1 Testing selective demolition guidelines 22
      3.4.2 Light dismantling 23
      3.4.3 Decontamination and indoor demolition 24
      3.4.4 Heavy demolition 26
      3.4.5 Assessing source separation 29
   3.5 Carbon footprint of selected waste management options 32
   3.6 Integration of the recovered materials data into the databank and digital marketplace 34
      3.6.1 Databank 34

3.6.2 Digital marketplace for reusable items 35
3.7 Stakeholder engagement 36
3.8 Planning and decision-making guidelines 37
3.9 Business case development activities 38
3.10 Evaluation activities 40
4. Results 41
4.1 Summary of results 41
4.1.1. Introduction 41
4.1.2 Interventions related to city strategies 41
4.1.3 Interventions related to permitting procedures 42
4.1.4 Interventions related to procurement 43
4.1.5 Interventions related to knowhow development 43
4.1.6 Results of environmental and health monitoring 43
4.2 Impacts 44
4.3 Economic Analysis 49
4.3.1 Economic assessment of demonstration 49
4.3.2 Business cases 51
5. Conclusions 53
5.1 Lessons learned 53
5.1.1. Lessons learned from the decision-making process 53
5.1.2. Lessons learned from business case studies 54
5.1.3. Stakeholder engagement 55
5.1.4. Procurement 55
5.1.5. Organisational changes 56
5.1.6. Data collection and monitoring 57
5.2 Future perspectives 59
5.3 Assessment of replicability/recommendations 59
6. References 61
7. Annexes 64
Annex 1. Business case A 64
Annex 2. Business Case B 78
Annex 3. Impacts of demonstration action: Circular demolition of 2 buildings 86

Annex 4. Impacts of city-wide application of tool A: Planning & Decision-Making Guidelines 91
Annex 5. Impacts of city-wide application of tool B: Business Cases 96
Annex 6. Baseline situation in CDW management 100
Annex 7. Monitoring results of waste fractions from demo-sites 103
Annex 8. Items recovered for reuse by Mikkeli Activity Centre 107

List of figures

Figure 1. View of Mikkeli harbour bay (photo Manu Eloaho) 10
Figure 2. Overview of Pankalampi health centre. (photo Esa Hannus, Xamk) 12
Figure 3. Tuukkala Hospital. (photo Esa Hannus, Xamk)....13
Figure 4 Volume calculation from a material pile based on drone imaging and 3D modelling (figure Juha Vihavainen)....19
Figure 5. Real-time dust monitoring with DustTrak Aerosol Monitor during the internal demolition phase in Pankalampi demolition site (left), dust deposition collectors (middle) and water sampling (right) in Pankalampi demolition site (photos Juha Vihavainen). 21
Figure 6. Examples of reusable items that were discarded as waste (photos Raimo Lilja)....23
Figure 7. Indoor demolition (photo Raimo Lilja) 25
Figure 8. Waste from indoor demolition (photos Raimo Lilja)....25
Figure 9. Asbestos waste at Tuukkala site (photo Raimo Lilja) 26
Figure 10. Pulverizer at work (photo Raimo Lilja) 27
Figure 11. Separate demolition of brick facade (photo Raimo Lilja) 28
Figure 12. Source separated untreated wood (photo Raimo Lilja) 30
Figure 13. Example of mixed demolition waste (photo Raimo Lilja) 31
Figure 14. Phases of selective demolition (Lauritzen 2022)....64
Figure 15. Components and outputs of the pre-demolition audits (figure Raimo Lilja and Jenina Luotolampi) 74
Figure 16. Visualization of the pre-demolition process and the roles of different actors (figure Raimo Lilja and Jenina Luotolampi)....75
Figure 17. Distribution of Metsäsairila Ltd. construction and demolition waste by type of waste in 2019 102

List of tables

Table 1. Impacts of demonstration action: Circular demolition of 2 buildings. 45
Table 2. Impact of city-wide application of tool A: Planning & Decision-Making Guidelines. .47
Table 3. Impact of city-wide application of tool B: Business Cases. 48
Table 4. The cost of Pankalampi demolition works 50
Table 5. The cost of Tuukkala demolition works 51

Table 6. Evaluation of Metsäsairila Ltd. recycling rate in 2019.....101
Table 7 Estimated and actual waste amounts from Pankalampi case. Total floor area of the building 9855 m^2.....103
Table 8. Estimated and actual waste amounts from the Pankalampi dental clinic building. Total floor area of the building 1416 m^2. 104
Table 9 Estimated and actual amount of waste from Tuukkala Hospital. Total floor area of the building 5350 m^2.....105

List of Acronyms

Acronym	Meaning
CCA	Copper, Chromium, Arsene = wood preservative
CDW	Construction and Demolition Waste
CE	Circular Economy
DMC	Domestic Material Consumption
DMP	Domestic Material Production
DOC	Dissolved Organic Carbon
EOL-RR	end-of-life
EQS	Environmental and Quality Systems
ESEDU	Southern Savo Vocational School
EU	European Union
GDP	Gross National Product
GHG	Greenhouse gases
Haz Mat	Hazardous Materials
HVAC	Heating, Ventilation and Air Conditioning
ICLEI	ICLEI – Local Governments for Sustainability, a global network
KEINO	Finnish program for promoting low carbon procurement
LCA	Life-cycle Analysis
MERN	MongoDB, Express, React, Node
MoE	Ministry for the Environment (of Finland)
NGO	Non-governmental Organisation
NRI	Norland Research Institute
OIP	Optimised Implementation Plan (for CityLoops)
ORP	Oxidation Reduction Potential
PAH	Polycyclic Aromatic Hydrocarbons
PCB	Poly Chlorinated Biphenyls
POP	Persistent Organic Pollutants
SME	Small and Medium sized Enterprises
SRF	Solid Recovered Fuel
TOC	Total Organic Carbon
UAS	Unmanned Aircraft System
UTK	Uutta työtä kiertotaloudesta = new work from circular economy
VOC	Volatile Organic Compounds
Xamk	South-Eastern Finland University of Applied Sciences

1. Executive summary

Introduction

The Mikkeli demo case consisted of two phases:

1) case studies of the demolition of two public buildings: the Pankalampi Health Care Centre and the Tuukkala hospital and
2) action research of the decision-making processes and policy interventions related to systemic changes needed in the setting of circular economy policies, planning, market engagement, procurement, contracting, permitting and enforcement of public owned demolition projects and waste management and reuse of building parts and wastes.

New approaches and instruments

The following new CityLoops instruments and approaches were applied in the demonstration cases:

- digital marketplace for buying or selling reusable building parts or materials
- 3D modelling to track onsite CDW flows
- Databank for Recovered Construction Materials
- Monitoring environmental and health effects of demolition as well as hazardous materials and contamination of buildings
- the CityLoops guide for pre-demolition audits was co-developed in parallel with the demo cases, using the Finnish pre-demolition audit guide as a model. The guide was tested by commissioning a pre-demolition audit of a part of the Pankalampi case
- the CityLoops guide for selective demolition was co-developed in parallel with the demo cases
- Lifecycle CO_2 calculators for concrete, soil and mixed CDW developed by Roskilde Municipality were tested in Mikkeli demonstrations to compare waste management options

Results

Circular economy was recognized as an important element in the Climate Program for Mikkeli City. A separate section on “Recycling of materials in construction” was included in the program.

Mikkeli has set a target in its City Strategy that states that by 2025 25 % of relevant tenders issued by Mikkeli should include criteria related to sustainable development and circular economy. The monitoring and reporting system for the implementation of this outcome is under preparation.

The current procurement practice prevents the demolition contractor from offering recycling services of its own: the only acceptable option is to deliver all demolition waste to the city owned waste company. Miksei CityLoops team has pointed out that an alternative approach is an open call for tenders for a long-term contract of managing specific CDW streams.

As a result of the CityLoops project, a new procurement guide has been drawn up to promote the circular economy in demolition projects. The guide proposes new qualitative requirements, benchmarks, or contractual incentives. Even reversed tendering could be used in demolition contracts: there the price is fixed, and awarding would be based on the quality of circular solutions proposed by the tenderers.

Occupational hygiene measurements at demonstration sites Pankalampi and Tuukkala showed that, as expected, the dust particle concentrations were high during the internal demolition phase. The concentrations of PAH and VOC compounds were not at a harmful level. The workers were well protected from dust at both demonstration sites. The dust emission due to demolition work could be seen in the dry matter and ash content of the deposition samples collected in demolition sites.

The impact of the demolition work was clearly visible in the storm water samples taken from the Pankalampi demolition site compared to the situation before the demolition work began. The concentrations of suspended solids and most of substances decreased soon after demolition phase, but concentrations of some substances were still elevated a year after demolition.

Selective demolition was implemented well in the demonstration projects and the sorting rate in the demonstration sites was over 99 %. The city-level recycling rate of CDW increased by 11 % from 2019 to 2021. At the same time incineration rate decreased 11 % and landfilling rate 1 %. However, there is lot or yearly variation in recycling, incineration and landfilling rates depending on total amounts and types of demolition projects and CDW. Now most of CDW materials are utilized in the Metsäsairila sorting and recycling centre area in earthworks. New local procedures and companies on circular economy are needed to increase the upcycling of materials.

In the planning phase of the project, the aim was that 5% of the materials would be reused on the demonstration sites. This goal was not achieved because there were no new building plans for the demonstration sites where the materials could have been reused.

In the planning phase of the project, there was also goal that cost effectiveness in the demolition of buildings would increase 10% compared to baseline values. This outcome was only partially reached. Total demolition costs were 30% lower than baseline, but there may be also other reasons for the decrease in costs than increased circularity (like type of the building, number of floors). The average waste costs were not decreased.

Summary of lessons learned

Procurement practices focusing only on lowest price cannot be used to promote CE. At the same time using in-house waste management as the only model can be seen as conflicting with the business promotion goals set in the Growth Strategy of Mikkeli.

In parallel with the CityLoops project Mikkeli has now adopted circular economy in its Climate Program and its City Strategy. The policy goals need to be translated into institutional change and adopted as new practices in all relevant departments.

Reuse of building parts cannot be promoted without a pre-demolition audit. The soft stripping procedure must be formalized with clear roles and duties for each participant. At least the soft stripping phase must be executed promptly after the last user of the premises has moved out. Soft stripping and organizing the reuse of items should occur before moisture and vandalism ruins the items.

Organisational change and changes in procurement practices must start from the strategic level. The policy level actors must set clearly defined circularity goals and indicators to monitor the implementation. This work has now started in Mikkeli with significant contribution from the CityLoops project.

Better coordination is needed between environmental authorities and building permit authorities and the units implementing public procurement. The minimum requirements on a case-by-case basis could be defined in the demolition permit or in the tender documents or both.

Land use planning, which in Mikkeli is lagging the demolition boom should be engaged so that the mass balance of digging soil and using of natural and recycled aggregates or building parts could be coordinated with infrastructure planning and operations.

CityLoops Mikkeli team proposes that the Mikkeli City Consortium would adopt a practice that a pre-demolition audit is performed for all demolition cases exceeding 250 m^2. In addition, the City Consortium organizations should consider creating a “pipeline” of future demolition cases within 5-10 years scope by creating a database of basic data of the material masses and reusable construction parts.

Drone monitoring and 3D modelling could be developed to aid the flow of building parts and recyclable waste to be used in a parallel building site. Using a drone can also be a useful tool during the pre-demolition audit before the demolition work begins. Drone imaging can be used in the planning of the demolition work. The overall progress of the demolition work can be monitored using a drone.

Replicability and recommendations

The systemic transformation in a city organisation requires time. It needs ambitious leadership decisions to initiate the change and to set realistic step-by-step goals and measurable

indicators. It requires back and forth processes to engage the substance experts in the process of setting the goals.

Public-private partnership must be forged through the procurement activities to identify new ways of planning and implementing construction projects and linking demolition to new uses of demolition materials and building parts.

Circular economy is a necessity and an important part of climate action and sustainable development. Adopting circular practices may cause extra costs in the development phase, but neglecting such changes constitutes a major risk of losing vitality and a positive image as a city and failing to promote the competitiveness of local businesses.

2. City context

Mikkeli is a city of 53 000 inhabitants, and it is the capital city of the South-Savo Region. The population has been stagnant or slightly declining since 1980 (Tilastokeskus 2018). The municipality is very popular as a summer house location, hosting more than 10 000 summer houses (Tilastokeskus 2020). The municipality covers an area of 3230 km^2 including 680 km^2 of waterways. The population density is 20,5 inhabitants per km^2. The urban centre is not very dense, and the vast rural area is sparsely populated, and housing is mainly wood-based single houses.

Figure 1. View of Mikkeli harbour bay (photo Manu Eloaho)

The GDP per capita of the region is the second lowest of all regions in Finland. Agriculture and forestry are important in the region. Employment is mostly based on services with a low percentage of industrial jobs and high percentage of jobs in the public services (e.g., education).

Characteristics of specific waste stream covered by the report

The volume of demolition works was estimated in the project by collecting data of demolition permit applications in 2018, 2019 and up to July 2020. The number of projects with a floor area exceeding 250 m^2 was 32 with a total floor area 48 277 m^2. 107 projects were below 250 m^2, with a total of 6197 m^2. It is generally known that in rural areas buildings may be demolished without applying for a demolition permit.

Of the 32 large demolition projects ten were owned by the municipality itself and the remaining 22 were owned by the state, the municipal social housing company, the church or by private sector.

Most of the demolition waste is managed by the municipal owned waste company Metsäsairila Ltd. In 2019 the company received 30409 tons of construction and demolition waste (CDW). 62,5 % of this was concrete waste, 13,8 % was wood waste, 5,3 % was source separated brick waste and the rest was divided between more than 10 waste fractions.

Relevant strategies, action plans, or targets

At the start of the project Mikkeli did not have any relevant strategies or targets related to Circular Economy or climate action.

3. Implementation

3.1 Introduction

The Mikkeli demo case consisted of two phases:

1) case studies of the demolition of two public buildings: the Pankalampi Health Care Centre and the Tuukkala hospital
2) action research of the decision-making processes and policy interventions related to systemic changes needed in the setting of circular economy policies, planning, market engagement, procurement, contracting, permitting and enforcement of public owned demolition projects and waste management and reuse of building parts and wastes

Pankalampi health centre

The site consisted of three separate buildings: a health centre (A), a dental clinic (B) and a garage / storage room (C) (Figure 2). The health centre consists of an old part (A1, built in 1976) and an extension part (A2, built in 1992). The dental clinic (B) was built in 1979. The garage / storage building (C) was built in 1992.

Figure 2. Overview of Pankalampi health centre. (photo Esa Hannus, Xamk)

During the history of use, the buildings were renovated and repaired, and the surface materials of the premises were renewed. The floor areas of the buildings were as follows:

A. main building:	8399 m²
B. dental clinic:	1416 m²
C. garage / storage:	40 m²
In total	9855 m²

Tuukkala hospital

The old part (A) of Tuukkala Hospital (Figure 3) was built in 1960 and the new part (B) in the 1970s. The buildings were vacant since 2010.

Building A was 5-storey, of which the ground floor was partly underground. Construction B was a 4-storey building. The buildings had a reinforced concrete structure, the exterior walls were covered with brick. During the history of use, the buildings were renovated and repaired, and the surface materials of the premises were renewed. The total floor area of the two buildings was 5350 m².

Figure 3. Tuukkala Hospital. (photo Esa Hannus, Xamk).

The demolition process of Pankalampi Health Centre and Tuukkala hospital was managed by the Building Services Department of Mikkeli Municipality, which was not directly part of the CityLoops project. The role of the CityLoops team of MikseiMikkeli and Xamk was to observe and document the workflow, and to identify opportunities and obstacles in transforming the process towards increased circularity.

The demonstration included the testing and co-developing selected CityLoops tools/instruments and draft guidelines. The key findings of these testing activities are reported below and in separate annexes.

Parallel to the demonstration process the CityLoops team was engaged in the promotion of business cases related to upcycling of demolition materials. These business cases were applied to the demonstration cases only to a very limited degree. However, the potential of the selected business cases was studied, and they are included in this report.

Based on findings from the demonstration cases, the CityLoops team was engaged in dialogue with the City administration and other stakeholder groups and strived for systemic changes in the decision-making processes to promote circularity.

Finally, the evaluation of the impacts of the project interventions was conducted following the evaluation plan and the reporting format jointly developed with all CityLoops partners.

3.2 Procurement activities

3.2.1 Introduction

The procurement activities included the procurement of demolition contracts for Tuukkala Hospital and Pankalampi Health Centre. Mikkeli's Building Services were responsible for the procurement. The demolition of Tuukkala Hospital and Pankalampi Health Centre were tendered as separate contracts, but contractors could also present their offer as a package for both. The demolition contracts included the demolition work of buildings including their foundations. The demolition contracts also included demolition of structures, equipment, technical systems and surface structures in the yard area.

The role of the CityLoops-team was to comment on the procurement documents and to make proposals regarding the incorporation of circularity issues in the procurement process.

The digital marketplace was procured by Miksei Ltd. The offer request was published in public procurement database in June 2020. Social responsibility reports were required as eligibility requirements in the procurement. Sustainability reference in the procurement criteria was awarded with 10 % of the total amount of points at maximum. References of previous solutions for circular economy was assessed with max 35 % of total points.

Miksei received two tenders, and Metatavu Oy was selected to deliver the digital marketplace program.

3.2.2 Land use plans of demo sites and new construction plans

The Pankalampi Health Centre is in the Mikkeli town plan area, which is bordered on the east by the Pankalampi recreation area, on the north by a cemetery and on the west by a residential area, a service building and a commercial building. The town plan dates from 1975. The property is allocated for the hospitals and other social buildings (plan area Y, i.e., public buildings). The town plan for the area of the health centre was scheduled to be completed during 2022. The future of the area is planned by means of a partner planning plan, i.e., with one or more construction companies. A design competition has been considered to identify partners and operating models. According to initial plans, the area will become a small-house-dominated area.

Tuukkala Hospital is part of the Moisio-Kyyhkylä partial master plan area. The plan was prepared in 2014. There is no town plan for this area. The hospital belongs to the service and workplace area in the zoned part. To the north of it is a gas station, to the east is a “study area with interests in recreational activities and land use” and a field of great (historic) value. To the

south is a service housing unit. The city has no new usage plans for the property so far. The options are either residential construction or a commercial building.

As there were no new construction plans for the property at either demo site, it was not possible to plan the re-use of building parts or recycling crushed concrete or excavated soil on the demolition sites. All demolition materials had to be removed from the site and the trenches levelled and filled with soil from the site in accordance with the owner's demolition program.

3.2.3 Legislative requirements related to the circular economy

The statutory requirements and other national control measures set out in the Finnish Land Use and Construction Act and the Waste Act can be summarized as follows:

- The owner of the demolition project must apply for a demolition permit and submit an estimate of the types of waste generated and a plan for their waste management.
- The project owner must ensure that the project is planned and implemented in such a way that usable objects and substances are recovered and reused, and that the operation generates as little and as harmless construction and demolition waste as possible.
- The holder of construction and demolition waste must organize separate collection for the 11 types of waste listed in the Waste Decree and they must be recovered to the highest possible quality in accordance with the waste hierarchy
- For shipments of construction and demolition waste, a waste transfer document must be generated for each load and, on request, submitted to the authority
- A nationwide target of 70% has been set for the recycling of construction and demolition waste.

3.2.4 Preparation phase of the tender

The CityLoops project had the opportunity to influence the preparation of the tender at stakeholder meetings from August to December 2020. The call for tenders was launched in December 2020.

As a baseline study, the CityLoops team reviewed the documents of some earlier demolition procurement projects carried out in the city of Mikkeli earlier and, for comparison, also selected procurements carried out in some other cities. The aim was to identify methods for the city to promote the principles of the circular economy in its projects. Based on the analysis, it can be stated that the initial situation in the city's procurement practice before the demo projects was as follows:

- the minimum requirements are the contractor's references for the implementation of similar demolition projects and proof of the fulfilment of the contractor's obligations under the statutory obligations (social security etc.)
- the lowest contract price is the only selection criterion. Quality criteria related to waste sorting and circular economy, for example, have not been used in any of the city's demolition projects
- A policy has been agreed with Metsäsairila Ltd, the municipal waste company, according to which *all waste generated in all demolition contracts awarded by the city will be delivered to the municipal waste centre*. The *contractor is allowed to use the in-house waste fee for each waste type, which is considerably lower than the commercial list price.* A flat-rate rebate is paid for scrap metal.
- Waste charges for contaminated waste, contaminated soil or hazardous waste identified in the pollutant inventory are determined based on the results of the analysis. The consultant hired by the city oversees the unloading and separate collection of the contaminated waste, takes samples and commissions the analyses of hazardous substances and the consultant prepares the shipment documents for delivery to the waste centre.
- Contaminated or hazardous waste that was not detected in the Hazardous Material (Haz Mat) inventory will be delivered to the waste centre at the expense of the customer. Thus, the contractor has no interest in not reporting suspected hazardous waste. If hazardous waste is generated due to the contractor's material handling method (i.e., hazardous waste is mixed with non-hazardous waste), the contractor is responsible for it at his own expense.

3.2.5 Market dialogue in demo projects

Of the two demolition projects selected for the demonstrations, the city's Building Services organized a market dialogue on 27 August 2020 together with Miksei Ltd. The event was announced on the public procurement announcement platform. The event was attended by representatives of two demolition companies and one representative of a consultant. Some companies participated remotely. Contractors were mainly satisfied with Mikkeli's practice of requiring the delivery of all demolition waste to Metsäsairila Ltd. Some contractors informed that they would be able to process concrete waste beyond just coarse crushing to a piece size of less than 150 mm. Contractors could provide crushing either at the demolition site or at Metsäsairila. When crushed on site, the concrete could be delivered directly to the new site (subject to legal conditions). One contractor complained that the compensation for scrap metal (same price per kilo for all types of scrap) did not encourage more accurate sorting of different types of scrap.

3.2.6 Circular economy objectives in tender planning

The following content in the tender documents and the demolition process was created directly through the interaction between the CityLoops project, the city, and the waste company:

- The tender document required that demolition work be carried out as selective demolition, with the different types of waste being separated primarily at the source.
- The contractor was required to present a waste management plan as part of the demolition plan. The request referred to the eight types of waste to be collected separately listed in the Waste Decree and required that the deviation from this sorting be justified.
- The contractor is required to provide a summary of the waste generated. In the past, this has been required, but only as a formality. No *ex-post* assessment of the report has been carried out.
- It was recorded in the contract program that the persons nominated by the CityLoops project will perform seepage water sampling at the construction site, personal occupational hygiene measurements during the manual dismantling phase and environmental measurements, drone monitoring and other demolition work documentation during the dismantling phase. The implementation of these measures is the responsibility of the CityLoops project.

The tender did not include quality criteria that would have promoted the circular economy and related innovations. One of the project's proposals was to include minimum requirements for soft stripping and indoor demolition or quality scores for source separation of wastes but these were not included because there was fear that it could increase the total costs or that the verification of quality criteria could be challenging. For example, the number of types of waste to be collected separately as a quality criterion could only be verified at the end of the contract. The actual recycling rate, on the other hand, cannot be decided by the contractor, as all wastes are delivered to the city's waste management company.

Based on lessons learned from the demolition cases, a useful discussion took place, which later led to the preparation of a procurement guide for demolition projects for future demolition projects.

3.2.7 Outcome of the tender

Six bids were received for demolition of each of the two cases and six bidders offered the demolition of both sites. Ahosen Palvelut Ltd. from Jyväskylä was awarded the contract for Pankalampi and Terra Infra Ltd. from Kouvola won the tender for Tuukkala.

3.3 Screening of the buildings

Before and during the demolition of the demonstration buildings, screening procedures were carried out to find out the recycling and reuse possibilities of the demolition materials, to test 3D drone modelling to track material flows, and to monitor the health and environmental effects of the demolition.

3.3.1 Pre-demolition audits

A pre-demolition audit is an important part of planning a demolition project. The purpose is to assess the types and quantities of wastes, harmful substances, and the potential for the reuse of demolition materials and to suggest a material management plan accordingly. The pre-demolition audit is typically divided in two parts: 1) an audit of asbestos and other hazardous materials and 2) inventory on reusable and recyclable materials.

In case of Mikkeli demonstrations, City of Mikkeli commissioned an audit of asbestos and other hazardous materials from a pre-selected external consultant (Ramboll Finland Ltd) for both demonstration premises as a standard practice. As a requirement for applying for a demolition permit, the City used its own staff to provide the building permit authority with a notification of demolition wastes, where the amount of each waste fraction was estimated.

In the CityLoops demonstration, the main focus was on the inventory part of reusable materials which is a voluntary practice in Finland. Xamk ordered a pre-demolition audit for the Pankalampi dental clinic building as part of the CityLoops project. The inventory was made by Ramboll Finland according to Finnish Ministry of Environment Guide (Wahlström et al. 2019). The audit report was included in tendering documents of the procurement of demolition contractors. In addition, Xamk students made a detailed inventory of the reusable furniture, HVAC equipment etc. of the dental clinic building, on the request of the Mikkeli Activity Centre.

CITYLOOPS GUIDE FOR PRE-DEMOLITION AUDIT

This procedure explains how a pre-demolition inventory and material audit can be conducted to identify building components and materials with reuse or recycling potential. CityLoops Mikkeli team participated in the co-development of the CityLoops pre-demolition audit guide in co-operation with the Capital Region of Denmark (see box below). The Finnish Ministry of Environment Guide on Pre-demolition Audits (Wahlström et al. 2019) was translated in English and used as basis for CityLoops guide. The experiences from Mikkeli demonstration were utilized in the CityLoops guide for pre-demolition audit. Furthermore, the pre-demolition audit report of the Pankalampi dental clinic building (Eskelinen 2020) was translated into English for the use of other demonstration and replication cities. Practical experiences from implementing pre-demolitions audits were gathered by interviewing Finnish consultants and other projects.

Lessons learned

The pre-demolition audit guide is an important tool that is suitable for replication in all demolition sites. Reuse of building parts cannot be promoted without a pre-demolition audit. Effective implementation still requires more experience. The pre-demolition audit should be done well in advance of the demolition and in cooperation with various stakeholders, so that the recycling of reusable materials can be connected to the design processes.

<Link to instrument>

Microsoft Word - CityLoops_Pre-Demolition Guide_Final draft 15.3

3.3.2 3D drone scan and flow-tracking

Drone monitoring was carried out by Xamk at the Tuukkala and Pankalampi demolition sites during 2021. The imaging was performed mainly 1-2 times a week during demolition phase, (in Tuukkala demolition site 10 times and in Pankalampi 24 times). In addition, monitoring continued in 2022 at the Pellosniemi replication site (10 times), where four apartment buildings owned by Mikalo Ltd rental housing company were demolished. The aim of the drone monitoring was to demonstrate mainly CDW volume calculations using 3D modelling tool (Figure 4). The methods and results are explained in more detail in a separate report (Vihavainen et al. 2023a)

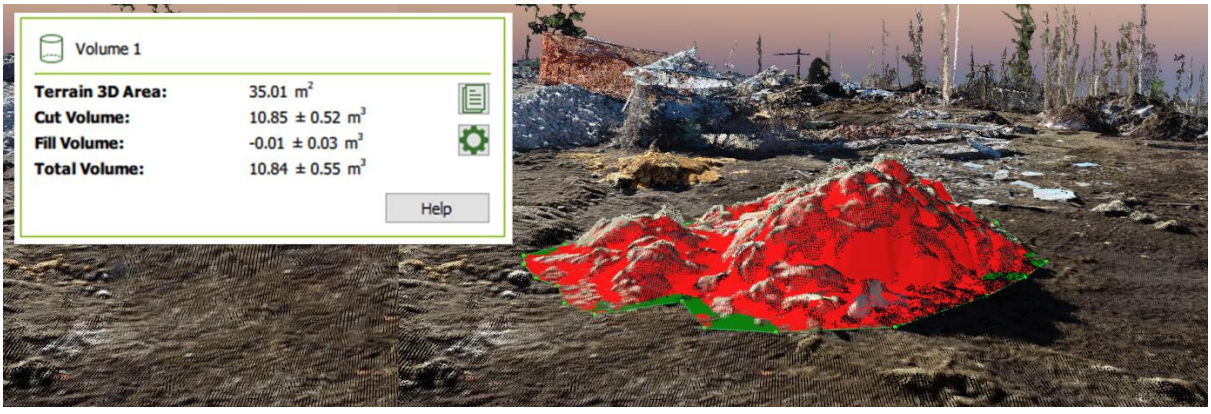

Figure 4 Volume calculation from a material pile based on drone imaging and 3D modelling (figure Juha Vihavainen).

3D MODELLING TO TRACK ONSITE CDW FLOWS

The 3D modelling tool for tracking the flows of on-site CDW is an operations model in which a camera drone and a photogrammetry software are used for modelling and

monitoring demolition sites in 3D. The tool uses commercially available software and equipment: Pix4DMapper software and DJI Phantom 4 drone. Volumetric measurements of material piles performed with 3D tool were compared to traditional tachymeter technique. The project also explored the suitability of a multispectral camera for material identification.
Lessons learned The use of 3D modelling tool to monitor demolition waste flows can be a cost-effective alternative in evaluating the amounts of material flows on-site when compared to traditional methods, e.g. tachymeter. Method can also produce useful data e.g., for the pre-demolition audit and planning of the demolition work. Volumetric measurements based on 3D imaging could be a useful tool for contractors, building owners, consultants, and designers especially in the future, when the reuse of building parts and materials are expected to increase. Multispectral camera used by Xamk (Micasense RedEdge-MX) was not able to recognize different CDW materials. However, camera techniques should be further investigated for automatic material recognition.
<Link to instrument> 3D TOOL FOR FLOW-TRACKING CDW (cityloops.eu)

3.3.3 Environmental health and safety check

In addition to increasing the circular economy, the demolition of buildings has many other environmental and health aspects that must be taken into account in sustainable and responsible demolition work. For example, stormwater from demolition sites can cause a significant load of solid matter and harmful substances into receiving water bodies but when the CityLoops project started, there was only little national research data on the topic in Finland. Recently, more attention has been paid to the management of stormwater in construction and demolition sites in Finland. Bigger cities have created guidelines for monitoring and managing construction site water, and there have been national discussions about the needs for e.g., legislative changes. Furthermore, workers and residents of the surrounding area can be exposed to dust and harmful substances during the demolition work. As part of the Mikkeli demonstration action, Xamk monitored environmental and health risks during the demolition phase of the Pankalampi Health Centre and Tuukkala Hospital.

The occupational hygiene measurements were made during the internal demolition phase. The amount of total respirable dust, the concentration of PAH compounds bound to particles, and the VOC concentrations were measured from sampling points located inside the buildings and with personal meters from two workers at the demolition site. Real-time dust monitoring with

DustTrak Aerosol Monitor was used to measure the total mass of particles in five different particle size classes based on light scattering (Figure 5). The samples were analysed in the accredited laboratory of the Institute of Occupational Health.

Figure 5. Real-time dust monitoring with DustTrak Aerosol Monitor during the internal demolition phase in Pankalampi demolition site (left), dust deposition collectors (middle) and water sampling (right) in Pankalampi demolition site (photos Juha Vihavainen).

The dust deposition from the demolition work was monitored by collecting samples in the yard area of the demolition sites in Pankalampi and Tuukkala (Figure 5). Dry matter and ash content as well as elements (As, Cd, Cr, Cu, Hg, Ni, Pb and Zn) were analysed from the samples in an accredited laboratory (Eurofins Ltd). In addition, fine particle content in outdoor air was monitored with a DustTrak meter.

Water samples were taken from three stormwater wells around the Pankalampi demolition site (Figure 5). A blank sample was taken before the demolition work. Other samples were taken during the demolition work in May and July 2021 and after the demolition work in November 2021 and June 2022. The metal content, sulphate, total nitrogen, total phosphorus, DOC (dissolved organic carbon), TOC (total organic carbon), fluoride and chloride concentrations were analysed in an accredited laboratory (ALS Finland). In addition, field measurements were made with a YSI ProDSS water quality probe, which measured water temperature, electrical conductivity, pH, ORP (Oxidation Reduction Potential), dissolved oxygen and turbidity. Solid matter content was analysed at Xamk's environmental laboratory.

In Tuukkala, vanadium was found in bricks in the inventory of hazardous materials carried out by Ramboll Ltd. By the CityLoops project, more material samples were taken from the bricks. Samples were taken separately from masonry mortar, joint mortar for vertical and horizontal joints, and bricks. Heavy metal concentrations were analysed from the samples in an accredited laboratory (ALS Finland Oy). The elemental concentrations were also analyzed in Xamk's environmental laboratory using the X-ray fluorescence method (Niton XL3 950 GOLDD- analyzer).

Material samples were also taken in Pellosniemi replication site. Concrete and brick samples were analyzed in an accredited laboratory (ALS Finland Oy) for heavy metal concentrations,

PAH and PCB compounds, as well as certain POP and VOC compounds. The elemental concentrations were analyzed with Niton XL3 950 GOLDD- analyzer in Xamk's environmental laboratory.

The methods and results of all environmental and health measurements are explained in more detail in the separate report (Vihavainen et al. 2023b).

3.4 Selective demolition procedure

3.4.1 Testing selective demolition guidelines

CITYLOOPS GUIDE FOR SELECTIVE DEMOLITION

This procedure explains how a selective demolition can be conducted to select and preserve value of building components and materials with reuse or recycling potential, following a series of chronological steps to dismount components or materials without damaging them. It can be applied when planning demolition projects, with sufficient time and coordination among actors, such that selective demolition be required in the procurement of a demolition contractor. The selective demolition procedure guide gives recommendations to manage material removal and treatment. The guide was developed by Capital Region of Denmark.

Selective demolition was a requirement in the tender for demolishing Mikkeli's demonstration buildings. The implementation of the selective demolition by contractor was compared to the procedure described in the CityLoops guide and comments were given on the guide based on experiences from Mikkeli´s demonstrations.

Lessons learned

In the case of Mikkeli's demonstrations, the demolition work was performed very well in accordance with the CityLoops selective demolition guidelines. Different waste fractions were sorted and at both demonstration sites, the amount of mixed CDW was minimal, as the legislation and waste prices guided sorting. However, it was found that there is some variation in the implementation of selective demolition between different contractors and demolition sites. The waste fractions that must be sorted at source should be stated in the demolition contract and compliance should be monitored during the implementation.

In Mikkeli, soft stripping was developed as one of CityLoops' business cases, in which the removal of materials for reuse could be further increased.

The selective demolition guide can be easily replicated in all demolition projects in different cities to give information on selective demolition procedure and help to plan demolition process.
<Link to instrument> CITYLOOPS GUIDE FOR SELECTIVE DEMOLITION

3.4.2 Light dismantling

Soft stripping is defined in the CityLoops guide as removing of all loose items such as furniture, carpets and garbage to facilitate free access to possibly contaminated installations and structures. Stripping refers to the dismantling of non-bearing installations, electrical installations, heating installations, doors and windows, sanitation equipment etc.

In Finland the term “light dismantling” (*kevytpurku* in Finnish) has been proposed. The purpose of this concept is to focus on the movable items and easily dismantled items with the intention to reuse these. Light dismantling is often accomplished by the building owner or other stakeholders than the actual demolition contractor. It is understood as a separate step from indoor demolition.

Pankalampi case

The city recovered a fire escape from the site, which was delivered for installation in the city's new day care centre. The city also sold the health station's backup power plant for reuse. The city had already taken advantage of the site, e.g., shower curtain rods, storage rail systems and plumbing fixtures for in-house renovations.

Through the CityLoops project, a small number of windows were handed over to two individuals. The main contractor removed the windows intact without any additional responsibility.

A list of furniture and demolition parts dismantled and sold by the Mikkeli Activity Centre is provided in Annex 8 to this report.

Figure 6 shows examples of items that were discarded as mixed waste, although they could have been prepared for reuse.

Figure 6. Examples of reusable items that were discarded as waste (photos Raimo Lilja)

Buildings A and C of the health centre were not audited for reuse potential, so no list of items was obtained. Shortly before the demolition contract the premises had been provided to the law enforcement authorities for urban combat training using paint guns - as a result part of the furniture in the training area was not suitable for re-use.

Tuukkala case

Tuukkala Hospital had been vacant for more than ten years before the demolition phase. Pigeons had nested in the upper floors and contaminated them with faeces.

Copper pipes had been broken into and stolen in the basement, and the asbestos insulation around the heating pipes and in the enclosure had been torn down. Asbestos dust had spread to the basement.

For these reasons, no furniture or fixed furniture could be recovered for reuse.

In coordination with CityLoops and with the permission of the city, a few granite slabs were recovered from the yard by the South-Savo Vocational College´s circular economy project and delivered for use in the construction of the park in Mikkelipuisto. The project also recovered the oak planks used in the roofs of the balconies and in the building's doorway. They were used in various wood products, for example to make a tabletop and cutting boards at ESEDU.

3.4.3 Decontamination and indoor demolition

Pankalampi case

The demolition worksite was established on March 22, 2021, and the work began immediately. The site was surrounded by a fence.

CityLoops Miksei team observed the demolition work visually on nine field visits during the demolition process which lasted from March 2021 till end of July 2021. Photos and video clips were taken, and workers and supervisors were interviewed on site. In addition, separate interviews were conducted with the contractor, the municipal waste company, and Building Services staff.

The demolition work followed the normal working procedures of the contractor. These practices were very well in accordance with the CityLoops selective demolition guidelines. The asbestos demolition sub-contractor isolated the asbestos-contaminated premises, removing asbestos-containing insulation, wind protection boards and asbestos-fibre cement boards.

After this, the main contractor's two stripping groups were set up for internal demolition, one in the dental clinic and the other at the health centre at the same time. The internal demolition teams dismantled the HVAC equipment, furniture, interior doors, partitions, the main part of the HVAC piping, internal insulation, etc. The windows were also removed and crushed before the heavy demolition. (Figures 7-8)

Figure 7. Indoor demolition (photo Raimo Lilja)

Figure 8. Waste from indoor demolition (photos Raimo Lilja)

Impregnated timber was revealed from around the windows. This was collected with non-impregnated wood and separated centrally at the Metsäsairila recycling centre.

Tuukkala case

The main contractor was Terra Infra Oy from Kouvola.

Asbestos removal was performed by the subcontractor Timanttiporaus Kaukonen Ltd. Discharge of contaminants was carried out in accordance with the safety plan for asbestos work. The supervisor commissioned by the Building Services inspected the performance of the work.

Figure 9. Asbestos waste at Tuukkala site (photo Raimo Lilja)

The indoors demolition began with the removal of furniture, fluorescent tubes, etc. The furniture in the building, the light partitions and the internal roofs were removed manually and mechanically, and the demolition waste was collected separately in waste containers. Working groups consisted of 2-4 men, a small (2 tn) excavator and skid steer loader. A stripping machine was used for removing floor laminate.

Hauling openings were made at logistically appropriate locations in the building walls. Sorting was done partly inside the building and during the loading phase outside the building. Demolition waste was sorted directly into containers.

Copper pipes were source separated but they were delivered as mixed metal, as the compensation for scrap metal at Metsäsairila Ltd. was the same for all types of scrap.

3.4.4 Heavy demolition

Pankalampi case

After pre-demolition work and asbestos demolition work, the excavators were used to carry out the heavier demolition of the bulk of the buildings. Machine demolition work was done as selective demolition. Demolition was done by beam spacing / construction type at a time and the resulting demolition materials were sorted directly in the waste containers, except for brick and concrete waste, which was collected in piles on the ground. If necessary, a manual worker was used in addition to the machine for sorting. The company used its own containers for transport to the waste centre.

The wood and brick structures were dismantled with a demolition grapple, the concrete structures were broken up with a pulveriser (Figure 10) and the largest reinforcement bars were removed from the concrete. Pure concrete was pulverized to a size of <500 mm and contaminated concrete to a size of <150 mm. An impact hammer was used to dismantle thick and strong concrete structures (e.g., civil shelters).

Figure 10. Pulverizer at work (photo Raimo Lilja)

In addition to the buildings, the asphalt pavement, district heating pipes, the electrical systems in the yard, etc. were dismantled during the machine demolition phase.

Tuukkala case

2-3 crawler excavators size range 28–50 tn were used with accessories: sorting grapple, pulverizing scissors, pick hammer, buckets. The transport of concrete waste was handled by Savon Kuljetus Ltd. Other waste was transported by Mikkelin Romu Ltd.

Demolition work was performed as selective demolition. The excavator demolished the building from the end and used the concrete waste piles to reach higher floors.

In collaboration with the CityLoops project and the UTK project, a few dozen perforated bricks were re-covered from the entrance façade for possible later re-use testing.

The contractor decided - on the recommendation of CityLoops team - to separately recover the bricks demolished from the façade due to the elevated vanadium content found in the bricks (Figure 11).

Figure 11. Separate demolition of brick facade (photo Raimo Lilja)

Mixing the brick waste with concrete could have prevented the later use of the aggregate in earthworks. The project owner did not require this separation of brick and concrete waste. The contractor had obtained the results of a solubility test on aggregate samples of bricks: the test result confirms that the vanadium content exceeds the limits (6 mg/kg) in the Decree on the use of waste in earthworks. Therefore, the bricks were taken to Metsäsairila as slightly contaminated waste. However, based on analyses later conducted by Metsäsairila, the brick waste did meet the conditions for landfill eligibility.

A significant finding was that separate dismantling of the brick facade with an excavator into a separate pile did not cause significant additional work. Some of the bricks were damaged, but a large part remained intact and could be recovered.

After the building was demolished to the basement level, the basement floor and foundations were demolished.

3.4.5 Assessing source separation

Pankalampi case

In this case the waste quantities were verified from two sources: the internal waste report of the contractor and the automatic weighing system of Metsäsairila Ltd. The latter is more reliable, but the former reflects the contractor´s source separation practices and interpretations

of classifying the waste. The differences between the two points out some possibilities of improving source separation and using economic policy instruments.

Comparing the verified quantities with estimates, the estimate provided by the contractor for concrete waste was only about 10% of the actual. The contractor's estimate was only 13% of the client's own estimate. It is not known whether the contractor used an incorrect estimate in their budget calculation. This example illustrates that waste statement in the preparation of a demolition project is only a formality and the data is not actually used in the preparation of the project.

The amount of concrete that was defined as slightly contaminated concrete was more than 20 times higher than that estimated by the contractor. This suggests that the Haz Mat survey did not provide sufficient assistance to the contractor to make a proper cost assessment. The amount of contaminated concrete was 13.5% of the total amount of concrete waste.

The waste estimate carried out by the consultant used by the Building Services was reasonably close to the actual figures for most waste types. However, the estimate for wood waste was less than 10% of the actual quantity and the amount of gypsum waste and roofing felt waste was also underestimated.

The contractor sorted the wood waste at the site into treated (painted wood, etc.) and untreated wood waste. This was evident from the contractor's own waste monitoring and visual observations by CityLoops team. At Metsäsairila, the waste fee for both types of wood waste is the same, so they are classified and recorded in the same category. At Metsäsairila, clean wood (Figure 12) is not treated different from surface treated (painted) wood, because all wood waste is crushed into energy recovery. In this case, sorting work on site was futile.

Figure 12. Source separated untreated wood (photo Raimo Lilja)

The contractor's own classification and reporting differed from Metsäsairila's classification in several other respects. This caused differences in the amounts of waste reported by the contractor and the waste company. This can lead to disputes over billing.

Metsäsairila's waste report included a notification that in four waste loads chemically preserved wood (copper-chromium-arsene, CCA) was found among the wood waste. It has a multiple waste charge compared to normal wood waste. Metsäsairila informed CityLoops that the chemically preserved wood was sorted afterwards in the sorting hall.

It would be advisable to calculate and report the amount of waste per floor area, because then it would be easier to notice deviations from the typical amount of specific waste (kg / floor-m2) by comparing it with similar demolition projects.

A pre-demolition audit of the dental clinic was prepared in accordance with the guide of Finnish Ministry of Environment (Wahlström et al. 2019). The results show that the quantities of waste predicted by the consultant in the pre-demolition audit were very close to the verified quantities. The difference was high only for the scrap metal (estimated at 216%) and for insulation mineral wool. Apparently, a significant part of the wool has been mixed with concrete. Unsorted construction waste (Figure 13) was generated about 10 times more than forecast in the survey, but still accounted for only 0.4% of the total waste.

Figure 13. Example of mixed demolition waste (photo Raimo Lilja)

The purpose of the pre-demolition audit is to indicate the types of waste that can and should be sorted separately. At this site, brick and ceramic waste or glass waste was not sorted separately. They were mixed with concrete waste.

Of the eight waste fractions listed in the Waste Decree of 2012 (eleven fractions in the renewed Decree 2021), the following *were not* delivered separately: glass waste, plastic waste, wastepaper and cardboard

Plastic waste was sorted separately but delivered as “energy waste” for energy recovery. The fragments of the window glass were likely to end up as a contaminant in a load of wood waste or scrap metal or crushed concrete. Separate recovery of glass waste cannot be considered realistic, as it is not possible to separate the glass from the window frames. In principle, windows could be re-used if such an operator was available. Separate sorting of wastepaper and cardboard waste may make sense on a construction site, but not on a demolition site.

Tuukkala case

According to the waste report submitted by Metsäsairila Ltd to the city after the contract, the following amounts of waste were generated from the demolition:

A total of 9,019 tonnes of waste was generated, of which more than 8,000 tonnes (90%) was concrete and brick waste. Other separately collected waste fractions were wood waste, scrap metal, asphalt waste. In addition, bitumen-contaminated concrete waste, slightly contaminated brick waste and heavily contaminated brick waste were sorted. 58.26 tonnes or 0.65% of miscellaneous construction waste was generated. In other words, more than 99% was sorted into separately collected waste fractions.

Of the eight waste fractions listed in the Waste Decree of 2012, the following were not delivered separately: gypsum-based waste, glass waste, plastic waste, wastepaper and cardboard.

The windows were not dismantled intact, but the glass was crushed during removal and can be assumed to have ended up in the concrete. According to the contractor's estimate, approximately 10 t of glass waste was generated at the site. It was unclear from the waste report where the insulation wool (estimated amount of 40 t), gypsum board (estimated amount of 10 t) and energy waste (estimated amount of 40 t) had ended up. According to the contractor, fewer gypsum boards were found than expected. Some mineral wool was included in sheet metal scrap loads because thermally insulated piping was not manually handled to separate the wool.

The contractor's waste estimate predicted that nine different types of construction waste in excess of 10 tonnes will be generated at the site*. In practice, only four types of waste listed in the Waste Decree were collected separately at the site*. In addition, asphalt waste and contaminated concrete and brick were sorted separately. This example raises the question of whether the sorting was complying with the Waste Decree and the procurement contract requirements.

The estimate of the amount of concrete and brick waste presented in the contractor's waste report proved to be very accurate. If all the mineral wool and glass estimated has entered the concrete, this means about 0.6% of impurities in the concrete waste, which cannot be considered particularly significant. Some impurities can increase the generation of harmful dust

during crushing and use. Preventing this dust emission risk can be considered as one of the advantages of a separate stripping phase.

Contaminated concrete (with bitumen content) and bricks accounted for about 2.8% of the total amount of concrete and brick waste, which can be considered quite a small fraction. This suggests that the concrete structures with contaminants have been well identified and separated at the site. The amount of asbestos in the contractor's waste plan was estimated at 10 tons. The actual amount was 18 tons. Impregnated wood was identified in the structures of the window frames. It was not delivered to Metsäsairila as a separate load. According to the information received from Metsäsairila Ltd, the impregnated wood has been recovered from the wood loads in the sorting hall.

3.5 Carbon footprint of selected waste management options

The CO_2 calculator developed by Roskilde Municipality was tested on Mikkeli demonstrations. Realized or estimated amounts of different CDW fractions from demolished sites Pankalampi Health Care Centre and Tuukkala Hospital were used as input values for calculator. In the case of Mikkeli's demonstrations, the CO_2 calculator could not be used in the planning phase of the demolition, because the demolition of the buildings had already begun when the calculators were developed and available. However, the calculator was tested afterwards and the emissions in different circular scenarios were hypothetically calculated. The tool includes three separate calculators: 1) CO_2 calculator for Demolition and Renovation Sites, 2) CO_2 calculator for concrete and 3) CO_2 calculator for soil transport. All of these were tested on Mikkeli demonstrations.

Concrete was the largest waste fraction in Mikkeli´s demolition sites, and the CDW calculator showed well that the reuse of concrete elements has by far the greatest emission saving potential. CO_2 calculator for concrete showed that in Mikkeli, recycling concrete as aggregate in the production of new concrete does not necessary save emissions because the transport distance for virgin aggregate is typically short in Finland and recycling of crushed concrete does not save emissions from the manufacturing of cement, which has the greatest effect on the carbon footprint of concrete. However, recycling concrete save the use of virgin stone material. CO_2 calculator for soil transport was used to estimate the hypothetical emission saving potential if the concrete had been utilized on earthworks on demonstration sites. The results showed that by using crushed concrete in earthworks on site, it is possible to save transport emissions and virgin aggregates, but the savings are small compared to the reuse of concrete as elements. The calculations and results have been described in more detail in a separate report (Malk 2023).

LIFECYCLE CO_2 CALCULATORS FOR CONCRETE, SOIL AND MIXED CDW
Roskilde Municipality has developed CO_2 calculators for Demolition and Renovation Sites to calculate the lifecycle CO_2e impact of concrete, soil, or mixed CDW. The tool includes three separate calculators: 1) CO_2 calculator for Demolition and Renovation Sites, 2) CO_2 calculator for concrete and 3) CO_2 calculator for soil transport. The calculators can be used in planning processes for building demolition and renovation projects to aid in decision making and in procurements, with lower emissions as an award criterion. The tool supports the reduction of CDW and soil waste, as well as the associated carbon emissions, by allowing comparison of possible actions for informed decision-making.
Lessons learned All three calculators illustrated well the emission saving potential of different recycling and reuse scenarios and they were very simple and easy to use. The calculators can be used in decision making process when planning construction and demolition projects or when looking for ways to achieve cities climate goals in construction sector. The tool has great potential for scalability and replicability because the use of the calculators does not require lot of resources or expertise. If possible, the CDW calculator could be adjusted so that input values could be given in different units and that local conditions (like distances to recycling facilities) could be taken into account.
<Link to instrument> CityLoops_Tool_factsheet_Lifecycle_CO2_calculator.pdf CO_2 calculator for concrete: CO2-Beregner

3.6 Integration of the recovered materials data into the databank and digital marketplace

3.6.1 Databank

The data bank was designed by Xamk to store demolition site data gathered from drone monitoring. Developing the databank and testing it for Mikkeli demonstrations is described in more detail in a separate report (Hämäläinen 2023).

DATABANK

The data bank was designed by Xamk to store demolition site data gathered from drone monitoring. It was developed using the MERN stack. The data bank is designed to handle three layers of data: demolition sites, material lots, and materials. Site data was classified based on the Finnish Ministry of the Environment's guidelines (Wahlström et al. 2019) along with some minor changes. Material lots contain data such as the lot id, volume, and weight. Materials contain a category, reusability grade, a description, and file attachments.

Lessons learned

Balancing the amount of detail and ease of data entry suited our needs for the pilot sites but ended up creating some challenges when considering compatibility with other systems such as the marketplace. Originally there were plans to have the option to transfer material lots from the data bank to the marketplace automatically but having to enter the same amount of information for each material in the data bank as the marketplace wasn't feasible.

The CityLoops databank has been tested in Mikkeli, but it has not been used on a larger scale. During the implementation of the CityLoops project, it was noticed that there is a need for a more advanced system. In a spin-off project of CityLoops, Miksei Ltd. and Xamk have developed a pre-demolition audit reporting software program to be used to report and archive audit findings. Lessons learned from the development of the CityLoops database were used in the creation of the pre-demolition audit software.

<Link to instrument>

https://cityloops.eu/fileadmin/user_upload/Materials/Factsheet_tools/Factsheet_Databank_and_Digital_marketplace_Mikkeli.pdf

3.6.2 Digital marketplace for reusable items

INSTRUMENT NAME

The Digital marketplace (DMP) was developed by Miksei Mikkeli in close collaboration with the Mikkeli stakeholders and users of the DMP. The programming work was executed by an SME Metatavu Oy.

The DMP holds information about volume, price and general quality of several construction material categories. It is working as a web platform to facilitate the exchange of materials between the seller and buyer of the reused material. In the marketplace, currently available materials are listed as ads, with the opportunity for entities or households seeking such materials to search for them or solicit what they need.

In the demolition phase, the target users were the local waste management company Metsäsairila Ltd and the local non-governmental organisation Mikkeli Activity Center. Metsäsairila sells demolition materials, like crushed concrete, while Mikkeli Activity Center sells building parts, such as taps and sinks, and different equipment and furniture

dismantled or taken from the demonstration object buildings on location and in digital marketplace.

Finally, the marketplace efforts were integrated with another similar national initiative in Finland (https://materiaalitori.fi), and efforts were made to increase awareness of the marketplace to encourage its use by other entities who demolish buildings or possess surplus building parts and materials.

Lessons learned

Miksei has found out that it has been challenging for the sellers and buyers to know about, and also for the circulation operators to start using the marketplace, despite being involved in the development of it. The marketplace was used in the demonstration phase to enhance the reuse and recycling of the materials, but for now its effectiveness in doing that has been quite low. To develop more flexibility and bring new ideas to the demolition process and the value chains, Miksei uses social media and organises workshops and meetings with potential sellers that could be useful. We expect to get more material offers in the marketplace before the end of the CityLoops project from the planned demolitions, but also understand additional effort will be required to find many more users for the platform after the demonstration phase.

Since the start of the CityLoops project, many digital marketplaces for the construction and demolition materials have been established in Finland, and now there are marketplaces available for public organizations and households as well. For example the biggest marketplace, tori.fi, has continuously over 100 ads of dismantled bricks for sale, and dozens ads of dismantled windows, doors and timber. Besides Tori, there are other marketplaces, based on auction principles, and Facebook groups, which sell recycled construction materials and building parts.

The conclusion is that commercial marketplaces are wide-spread and well-known for the public in Finland, and they manage nowadays a lot of reusable material and building parts. The success of the ads in the commercial DMPs is not known, though, and there still is a place for a dedicated solutions targeted to companies and public organisations, at least locally.

The publication of DMPs and other digital solutions require vast amount of marketing and communication to the stakeholders, which requires resources dedicated to the marketing and communication. The stakeholders must also be willing to implement the circular upcycling operation model, so that more items and building parts are to be reused.

www.kiertoon.fi

3.7 Stakeholder engagement

First the stakeholders were contacted, and simultaneously the stakeholder engagement plan was compiled in joint coordination with the CityLoops project personnel of Miksei and Xamk and personnel from NRI.

Altogether ca. 30 stakeholder meetings have been arranged in Mikkeli during the demonstration phase of the project. We have organized 5 workshops for the decision makers, procurement personnel and other professionals of the construction- and demolition sector in Mikkeli. Also participants from other regions of Finland have participated in the workshops and webinars between December 2020 – May 2022. These workshops included the participation of relevant procurement staff to a procurement workshop, where better circularity was assessed in the coming construction- and demolition projects.

24 stakeholder meetings were held with the project personnel and stakeholders from the city of Mikkeli and Metsäsairila Ltd in 2020-2021 to reach circularity targets of the project and to generally develop the upcycling in the waste management processes in construction and demolition.

Main stakeholders in the project implementation were:

- Mikkeli city building services and procurement services in practical management of the demolition cases
- City Board and leading civil servants in strategic issues
- Terra Infra Ltd. and Ahosen Palvelut Ltd. as demolition contractors
- Ramboll Ltd. as consultant for the pre-demolition audit services
- City owned waste company Metsäsairila Ltd. in receiving and managing demolition wastes
- private companies participating in market engagement and business case activities
- local and regional environment authority in permitting and supervision
- ESEDU vocational school in reuse experiments
- Mikkeli Activity Center (Mikkelin Toimintakeskus ry) in reuse activities

3.8 Planning and decision-making guidelines

INSTRUMENT NAME
Roskilde University, a CityLoops participant, developed a framework and a methodology for promoting systemic changes in the municipal decision-making process related to construction and demolition with the aim of promoting circularity. The tool consists of two parts:

1. A framework to map key decisions across the phases of demolition and construction, addressing the planning gap between demolition and construction projects. a. Indicate when decisions should be taken, which stakeholders should be involved, and what knowledge inputs are needed during different stages of the process. b. Address how relevant CityLoops-tools can be incorporated in the planning process supporting decision-making.

2. A workshop method addressing organisational change in operationalisation of circular planning and decision-making targeting three levels: i) strategy, ii) operations and iii) capacity building.

In Mikkeli the methodology was used internally in the CityLoops project team, but the city administration was not engaged in this work, because language barriers were considered to have negative effect on the internalization of the goals. Instead, a set of workshops and strategy formulation activities was tailored to the specific needs of Mikkeli and managed by the Miksei Ltd. team with backup from the Roskilde expert.

Lessons learned

The framework and the circular framing of the demolition process and linking it to new construction was eye opening to the Mikkeli CityLoops team. The importance of first ensuring a strategical view of Circular Economy and incorporating this view into the City strategy was recognized. Before that, systemic changes in the procurement process would not be achieved. The different administrative units must have a common goal in facilitating circular thinking. This thinking must traverse city planning, real estate management, permitting procedures, environmental regulation, procurement, municipal waste management and business promotion activities.

There are strong barriers against changing the practice of using qualitative circular criteria in procurement of construction and demolition services. On the other hand, circular businesses are recognized to have potential for employment.

Using the Miro group working tool was found useful when working with expert technical staff, but in approaching political decision makers more conventional interaction tools may be practical.

<Link to instrument>

3.9 Business case development activities

The Mikkeli CityLoops OIP set the following expected outcomes for the business case activities:

"To explore the potential business case for scaling up circular CDW management practices, Miksei Mikkeli and XAMK are holding innovation workshops (in the form of virtual meetings due to covid-19) with stakeholders including the City of Mikkeli, local waste management company and the operational centre responsible for public equipment at least once per month during the preparation and implementation phase of the demonstrations.

One focus on business cases is to collect and analyse data in order to calculate a feasible, scalable model based on experience in the demonstrations. This involves active efforts from Miksei Mikkeli to encourage users (both supply and demand) of the digital material marketplace and find buyers for the salvaged building parts and equipment."

In practice the business cases suitable for the market conditions were gradually selected through interaction with the CityLoops work package leaders, companies, other CE projects and other stakeholders and the findings from the demonstration cases. Finally, the following business cases were selected:

- Case A. Soft stripping and reuse operator services & Separate indoor selective demolition (stripping) services
- Case B. Upcycling of concrete waste to concrete production

The main activities conducted by CityLoops were:

Reuse audits and soft stripping

- drafting an agreement between the Mikkeli Activity Centre and Mikkeli Building Services for formalising the practice of allowing the Activity Centre to remove reusable furniture and other easily dismantled items before the demolition phase and sell them at their second-hand shop
- setting up the digital marketplace and offering it free of charge to the Activity Centre to advertise the recovered items
- contacting private services offering reuse audit service and reuse operations on a commission principle
- commissioning a student intern to conduct interviews of stakeholders regarding the feasibility of item reuse
- commissioning a consultant to conduct a pre-demolition audit in the Pankalampi dental clinic to demonstrate an example of a reuse audit
- promoting cooperation between the municipal social housing company Mikalo and Activity Centre for soft stripping of a demolition case (address: Nuottakatu 4a)
- several workshops with national and local participants on the challenges and solutions for promoting reuse.

Local indoor demolition and decontamination services

- two market engagement meetings were held to discuss about the possibility of separate contracting of these services
- study of local businesses offering asbestos removal services
- presenting the business case to the Mikkeli Building services and Mikalo Ltd. and achieving their commitment in principle to test the separate tendering of such services in a suitable future case
- studies related to the quality and gaps in decontamination studies and separation of contaminated waste from non-contaminated
- pointing out the development needs related to source separation and decontamination studies to the environmental authorities
- several webinars and workshops where the business cases were presented and discussed with stakeholders, national and local and disseminated in an article in Finnish.

Upcycling of concrete waste:

- experiences from Denmark were reviewed and summarised in a report in Finnish and distributed to Finnish stakeholders in several workshops and directly
- three concrete production companies were contacted, and the business case was introduced to them
- a bachelor's thesis was commissioned by MikseiMikkeli from a student in Xamk and a pilot test was conducted in cooperation with Suutarinen Group and SEMTU Ltd (Maukonen 2022)
- the findings from the pilot project were disseminated to other research groups in Xamk and presented in several workshops.
- a life-cycle assessment calculation was conducted using the CityLoops LCA-tool for calculating the carbon footprint of recycled aggregate use and comparing it with standard concrete.

The business case reports of these selected cases are presented in Annexes 1 and 2.

Other business case activities

Upcycling wood waste from construction and demolition was identified as a business option, because currently all wood waste goes to energy recovery and no formal recovery for reuse is practiced. This business case idea was studied more in a spin-off project.

The reuse of bricks was identified as an option based on experiences from Denmark. Teams interview was conducted with the managing director of Gamle Mursten, the leading company

in providing used and certified bricks to constructors. Information was shared with Finnish companies and other circular CDW projects. The concept was marketed to local stakeholders in market engagement events, webinars and workshops in Mikkeli and on-line. The demolition contractor at Tuukkala site demonstrated that separation of brick waste from concrete waste is rather easy. However, the demolition of brick masonry without damaging the bricks was not demonstrated in commercial scale. So far, actors in the Mikkeli region interested in piloting the feasibility of brick reuse have not been found.

The contractor at Tuukkala site has developed business models that enable it to recycle ceramic waste and bitumen roofing waste (Terra Kierrätys 2022). These recycling options were not realized in the Tuukkala case, but the contact facilitated potential cooperation with Metsäsairila in the future.

3.10 Evaluation activities

The objective of the CityLoops evaluation work is to ensure a comprehensive evaluation framework is established for all demonstration actions to assess their impact on sustainability and to assess the progress towards a more Circular Economy (CE).

Evaluation plan was prepared in co-operation with NRI and ICLEI according to the CityLoops Deliverable 6.1 Circular City Indicator Set (Vangelsten et al. 2021). Expected outcomes were phrased and indicators were selected to be in accordance with city-specific goals given in the Grant Agreement of the CityLoops –project. Final version of the evaluation plan was submitted in February 2022 (Deliverable 6.2, Evaluation Plan: CDW and Biowaste sectors, Mikkeli).

Baseline for the evaluation is typically data from year 2019. Main data sources were statistics of the waste management company Metsäsairila Ltd and authorities of the City of Mikkeli. Information on previous demolitions projects from Mikkeli were collected from demolition permit applications in 2018, 2019 and up to July 2020. Interim evaluation data was collected by the end of July 2022 and the final evaluation data by the end of May 2023 according to the evaluation plan.

4. Results

4.1 Summary of results

4.1.1. Introduction

The results from the Mikkeli CityLoops project are only to a small extent derived directly from the demonstration cases, because relatively little changes could be achieved in the decision-making practices of Mikkeli municipality. But the demolition of the demonstration cases acted as a platform for action research and for testing various environmental and circular tools.

A major result of the demonstration was the identification of systemic changes needed to move from demolition to a circular life cycle for municipality owned buildings. The following is a summary of CityLoops interventions to promote such changes.

4.1.2 Interventions related to city strategies

Miksei CityLoops team took actively part in the preparation of the City Strategy 2022-2023 and the Municipal Climate Program. Circular CDW management was recognized as an important element in the Climate Program and CityLoops was acknowledged as a project that contributes to the roadmap for implementing this program and to the monitoring of progress.

On the proposal of the CityLoops project, in October 2020, the city government authorized the mayor to sign the Declaration on Circular Economy Cities proposed by ICLEI. In it, the city commits itself to setting circular economy targets, integrating a circular economy perspective into decision-making, promoting the circular economy in procurement, and reporting on progress to the ICLEI (Network of Local Governments for Sustainability).

The CityLoops project has participated in the preparation of the City of Mikkeli's climate program by providing comments on the draft to the Environmental Services Unit preparing the program. A separate section on “Recycling of materials in construction” was included in the program.

In parallel with the CityLoops demonstration, the city council has approved an overall strategy for the years 2022-2025 (Mikkelin kaupunki 2021a). One of the focus areas in this strategy is Circular Economy, with the following three lines of action: a) The municipality is committed to include circular economy issues in all vocational education curricula. b) 25 % of public tenders related to CDW and biowaste should include requirements promoting sustainable development, Circular Economy and climate issues.

The city council has approved a climate program for Mikkeli in 2021 (Mikkelin kaupunki 2021b). The main goals related to CE are:

- the commitment to reuse or recycle excavated soil and demolition materials
- to promote business models based on public-private partnerships

Based on this overall strategy two implementation programs were prepared. Blue Economy and Green Economy were selected as two of Mikkeli's main business promotion sectors or platforms (Mikkelin kaupunki 2022a). Blue Economy refers to circular economy in the water treatment sector. The content of the Green Economy concept is under discussion, but it may be interpreted as Circular Economy or Resource Efficiency.

The CityLoops-project has strengthened the knowhow and the human resource base in CE issues within Miksei Ltd. This was institutionalized in 2022 by establishing a permanent Sustainable Development Team in Miksei. Miksei Ltd. was assigned with the role of coordinating activities related to the Green Economy platform in the Service Agreement 2022-2023 with the City (Mikkelin kaupunki 2022b).

The Environmental Services for the Mikkeli region is the local environmental authority, responsible for compliance monitoring and promoting climate policy. Together with the city administration it produces annually a document named Environmental Statement. In 2022 a new chapter was included in this statement: Promotion of Circular Economy. Under this chapter goals and new procedures are proposed to increase circularity in infrastructure projects, green area management and management of contaminated soil. Some suggestions made by the CityLoops-team are included in this document (Mikkelin kaupunki 2023a).

4.1.3 Interventions related to permitting procedures

The findings from the baseline studies of demolition procedures and from the demonstration cases pointed out that there are several gaps in the coordination and monitoring of the process:

There is too much variation in the contents of the Haz Mat audits. The scope of the audit in projects managed by the Building Services is broad and the process of sampling and analysing the demolition wastes covers asbestos, PCB, PAH-substances, and heavy metals. However, in many projects managed by other municipal actors or non-municipal actors only asbestos has been mapped out. There is a significant risk of neglecting occupational risks or hazardous waste regulations in such cases.

The waste Decree states that 11 types of demolitions wastes should be source separated in principle. The procedure for case-by-case assessment should be developed in interaction between authorities and the demolition actors.

These proposals were sent to the regional and local environmental authority for consideration and discussed in a meeting. The proposals were presented in a workshop of waste management stakeholders of three Eastern Finland regions in April 2023.

4.1.4 Interventions related to procurement

Experience from demo projects has shown that there is a need for development in Mikkeli's tendering practices so that procurement can promote circular economy goals and innovations. Currently, the only benchmark for tendering is the cheapest price. The requirements in the waste legislation are recorded as the minimum requirements for the demolition program. By demanding that all demolition waste must be delivered to the city's waste company, building services wants to ensure that no waste ends up in an inappropriate location. Also, the cost of CDW management is cheaper when using the in-house fees.

As a direct result of the CityLoops project, new procurement guidelines have been drawn up to promote the circular economy in demolition projects (Mikkeli Development Company Miksei 2021). The guide proposes new qualitative requirements, benchmarks or contractual incentives to promote CE. The procurement instructions are binding on the city's own organization. The CityLoops project also proposes to adopt it in the city's subsidiaries.

The guidelines document the necessary steps to be taken in the procurement process. It does not specify what qualitative criteria or detailed minimum requirements must be used in each individual case, but it lists examples of such criteria.

The comments from the building services stated that the quality criteria must be measurable and comparable between tenders. It was considered problematic to verify that a particular building component or material has been reused or otherwise utilized as promised by the contractor.

4.1.5 Interventions related to knowhow development

Altogether five workshops and seminars/webinars have been organized by the CityLoops Mikkeli Team for the decision makers, procurement personnel and other professionals of the construction- and demolition sector in Mikkeli. In the workshops the participants developed ideas and solutions for better upcycling of building parts and materials. These workshops also included two procurement workshops, with participation of relevant procurement staff. Ca. 30 stakeholder meetings have been arranged in Mikkeli during the demonstration phase of the project, to highlight the importance of upcycling of construction and demolition materials.

4.1.6 Results of environmental and health monitoring

Occupational hygiene measurements at demonstration sites Pankalampi and Tuukkala showed that, as expected, the dust particle concentrations were high during the internal demolition phase. The concentration of total respiratory dust clearly exceeded the reference values, but the concentrations of PAH and VOC compounds were not at a harmful level. The workers were well protected from dust and the protective equipment met the requirements of the occupational health and safety legislation.

The dust emission due to demolition work could be seen in the dry matter and ash content of the deposition samples collected in demolition sites. The metal concentrations were low, except for zinc, which may come from demolition materials. The spread of dust from the demolition site to the surrounding areas was well managed at both sites. Water spraying was used as a dust binding method during demolition works.

The impact of the demolition work was clearly visible in the storm water samples taken from the Pankalampi demolition site compared to the situation before the demolition work began. The concentrations of suspended solids, nutrients, and elements (such as calcium from concrete), as well as electrical conductivity, were elevated in the samples taken from the demolition site's stormwater well during the demolition work. Concentration of suspended solids decreased soon after demolition work, but concentrations of some substances (e.g., magnesium, sulphate, chloride) were still elevated a year after demolition and also in the discharge pipe leading to the nearby pond. Normal seasonal variation can contribute to the results. Organic contaminants were not analyzed from the samples. There was no local treatment for stormwaters on the demolition site, but waters were directly led into the city's stormwater network.

4.2 Impacts

The impacts of the project activities have been measured by the expected outcomes and indicators given in the city's CDW Evaluation Plan (D6.2.). Indicators shows that during the demonstrations, stakeholder cooperation has been close, and several new local and national stakeholder partnerships have been created.

The project has promoted the procurement processes related to demolition. Five new circular economy-promoting measures or requirements were included to the procurement process of demonstration cases. More circular requirements like quality criteria were proposed but not yet implemented. Based on lessons learned from the demolition cases, a useful discussion took place, which later led to the preparation of a procurement guide for future demolition projects.

New tools promoting the circular economy were developed and tested in demonstration sites. Mikkeli participated in the development of the pre-demolition audit guide and the selective demolition guide. The pre-demolition audit was tested during the project for the first time in Mikkeli and valuable experience was gained from the tool. 3D drone modelling was tested in demonstration sites to track material flows. The LCA tool developed by Roskilde Municipality was tested in the Mikkeli demonstrations and it allowed to quickly compare the emission saving potential of recycling and reuse of materials. A databank and a digital marketplace were established for archiving data and marketing reusable materials.

Selective demolition was implemented well in the demonstration projects and the sorting rate in the demonstration sites was over 99%. City-level recycling rate of CDW in city-owned waste management company Metsäsairila Ltd has varied between 64-85% between years 2020-

2022 compared to baseline value 74 % in year 2019. There is lot of yearly variation in recycling, incineration and landfilling rates depending on total amounts and types of demolition projects and CDW (especially concrete waste) in the city. Now most of CDW materials are utilized in the Metsäsairila sorting and recycling centre area in earthworks. New local procedures and companies on circular economy are needed to improve upcycling of materials.

In the planning phase of the project, the aim was that 5% of the materials would be reused on the demonstration sites. This goal was not achieved because there were no new building plans for the demonstration sites where the materials could have been reused.

Some items (e.g., fire stairs, HVAC equipment, furniture, few windows) were reused elsewhere and manual dismantling of bricks for reuse was demonstrated on a small scale. Recommendations have been drawn up based on the experiences from demonstrations that could increase reuse of demolition materials in the city's demolition projects in future.

In the planning phase of the project, there was also goal that cost effectiveness in the demolition of buildings would increase 10% compared to baseline values. This outcome was only partly reached. Total demolition costs were 30% lower than baseline, but there may be also other reasons for the decrease in costs than increased circularity (like type of the building, number of floors). The average waste costs were not decreased.

As a result of the project, two new business models have been identified: Separate light demolition or stripping service and recycling concrete aggregate into concrete production.

One of the most significant impacts of the project is the impact on city-wide planning and decision-making processes and the inclusion of the circular economy in the city's strategy and climate program. There has been progress in the strategic level on circular economy but putting the goals into practice still requires work. As a result of CityLoops, attitudes and operating culture have changed, which is reflected in the planning of future activities of the city.

All indicators, including the baseline value and the final result, are presented in the annexes 3-5. The expected outcomes and their interim review are summarized in the tables 1-3). Intermediate-stage results of the demo actions have previously been discussed in the CityLoops Interim Evaluation Report (D6.3). Final, updated results will be presented in the CityLoops Final Evaluation Report (D6.4).

Table 1. Impacts of demonstration action: Circular demolition of 2 buildings.

Planned outcome	Final outcome review
1: By the end of the project, several new local stakeholder partnerships and procedures with authorities and waste management and construction companies established related to demo actions (3	Outcome exceeded. A broad range of stakeholder outreach activities were carried out in accordance with the plan.

stakeholder groups, 30 participating workshops/events/round tables, interviews, meetings, workshops)	
2: By the end of the project, the skills and knowledge of the citizens and companies in CDW sector (both in Mikkeli and national level) have increased as a result of several new/innovative/strengthened stakeholder engagement tools/procedures related to demo actions (webinars, press releases, media articles, newsletter, replication, national meetings)	Outcome reached. A broad range of stake-holder outreach activities were carried out in accordance with the plan.
3. The circular economy has been taken into account in the procurement process for demo projects and the tender includes circular economy requirements.	Outcome reached. In the demolition project of demonstration action, circularity criteria were included for the first time.
4. New planning instrument/tools have been tested in the City of Mikkeli for decision making and monitoring of demonstration projects. Identifying procurement tool for special characteristics in a tender has been updated based on the demo projects.	Outcome reached. For the demolition project Mikkeli used several tools not previously employed in the city, including the CityLoops LCA tool developed by Roskilde and various screening tools (e.g., pre-demolition audit, 3D modelling based on drone monitoring, monitoring of environmental and health effects).
5. At the end of the demonstration action, 5% of materials are retained and reused on demonstration sites.	Outcome not reached. The building materials were not reused on the demolition site because no new building was going to be built on the site.
6. Selective demolition has been used in demonstration cases. Over 95% of CDW is sorted onsite for recycling and material or energy recovery.	Outcome reached. Nearly all the CDW was sorted onsite, however, this was common practice in Mikkeli already before CityLoops.
7. Digital marketplace for secondary materials established and in use.	Outcome reached. A digital marketplace has been established and is in use.
8. By the end of the demo action, a 10% increase in the cost effectiveness in the demolition of buildings (demolition, transport	The target for increased cost effectiveness has been partially reached. The average waste costs have not decreased. Demolition

and treatment of CDW) compared to the baseline values for similar demolition projects	costs were 30 % lower than the average cost per floor area in the baseline situation. However, there may be other reasons for the decrease in costs than increased circularity, e.g., type of building, number of floors.
9. At the end of the demonstration action several items (materials/equipment) have been prepared for reuse	Outcome reached. A number of items have been prepared for re-use. The available data do not give a clear picture of how the quantity and quality of items compare to normal practice in demolition projects in Mikkeli.

Table 2. Impact of city-wide application of tool A: Planning & Decision-Making Guidelines.

Planned outcome	Final outcome review
1: 100% of the procurement of demolition projects include the new guidelines for screening and selective demolition, making these an essential part of the procurement processes within the City of Mikkeli.	Outcome partly reached. Procurement guidelines have been produced and approved by the city but not yet tested in the demolition projects. There have been only two demolitions in Mikkeli since the demolition described in demonstration action. The buildings were in very poor condition, and circularity upcycling requirements were not used in the procurement process. However, there are planned demolition projects in the near future, where CityLoops procurement guide and new operating models will be tested.
2: The City of Mikkeli is well known as "Circular Economy City" and operates according to the CE closed loops principles. Circular economy is incorporated in new strategic objectives.	Outcome nearly reached. Mikkeli is already well-known circular economy city as a result of several events and planned innovative demonstrations in CityLoops spin-off projects. There has been very good progress in the strategic level on circular economy but putting the goals into practice still requires work. Progress in circularity is now monitored by annual evaluation by the city. As a result of CityLoops, attitudes and operating culture have changed, which is

	reflected in the planning of future activities of the city.
3: At the end of the project, use of CDW (especially crushed concrete) to replace virgin construction materials (soil) has increased as a result of new guidelines in planning and decision making. 5% reduction in consumption of virgin construction materials within the city of Mikkeli.	The target has not been reached. The consumption of virgin materials in a city such as Mikkeli depends on many factors outside the control of CityLoops. It is difficult to isolate the impact of the CityLoops guidelines. The goal in the new climate strategy of the city is that all soil masses and demolition materials that can be reused and/or recycled will be utilized.
4: By the end of the project, 5% reduction in the emissions of CO_2 related to extraction, processing and transportation (incl. logistics) of construction materials (replacement of virgin soil material with crushed concrete).	Outcome partly reached. There is yearly variation in saved emissions because the total amount of crushed concrete available to replace virgin material in Mikkeli varies from year to year and depends on many factors outside of the control of CityLoops. Since material recycling in construction has been incorporated in Mikkeli's official climate policy, one may expect a long-term impact in the direction of the expected outcome.

Table 3. Impact of city-wide application of tool B: Business Cases.

Planned outcome	Final outcome review
1: New products, service concepts and business models relating to the reuse/recycling and upcycling of the specific material flows established, leading to new business opportunities.	Two business cases have been developed (soft stripping and recycling demolition aggregate for concrete production) but not yet implemented. The business cases have a theoretical potential, but they are still unproven at this point. The business cases (e.g., soft stripping service) are planned to be tested in demolition project in the near future.
2: At the end of the project, the project activities are a component of creating a greener environment and providing a more sustainable economy in the city of Mikkeli (new jobs: 20 – all external).	Outcome reached. CityLoops has indirectly contributed to job growth at Metsäsairila Ltd and Mikkeli Activity Center.

3. At the end of the project, the recycling rate of CDW is close to 75% (CDW prepared for recycling and other material recovery, including backfilling) (95% if energy recovery included). 10% increase in recycling rate and 40% increase in upcycled amount of CDW as compared to baseline statistics from year 2019.	The outcome reached in 2021 but not in 2022. There is lot of yearly variation in recycling rate depending on the total amount of demolition projects and CDW (especially concrete waste) in the city. The recycling rate is higher in years, when there is more concrete waste which is utilized in earthworks (mainly in Metsäsairila area). New local procedures and companies on circular economy are still needed to improve upcycling of materials.
4. At the end of the project, 5% reduction in the amount of CDW landfilled or incinerated as compared to the baseline statistics from year 2019.	The outcome reached in 2021 but not in 2022. However, the rates are sensitive to external factors including the level of construction/demolition activity in the city.

4.3 Economic Analysis

4.3.1 Economic assessment of demonstration

Pankalampi case

The contract price for the Pankalampi site was € 378,000, or € 38 / m^2.

The waste charges accounted for a total of € 82,703 of the contract costs, calculated at the city's contract prices, and including the compensation received for scrap metal. The corresponding income can be recorded for the city-owned waste company, Metsäsairila Ltd. The income is generated from the gate fees for waste, but the company also receives sales revenue from some types of waste (scrap metal and wood waste for energy).

Waste management costs accounted for about 22 % of the contract amount or about € 8 per square meter. In addition, the contractor had to pay the cost of transporting the waste. The cost of waste management was reduced by the fact that the contractor used their own waste containers, so no rental costs were incurred.

Slightly contaminated concrete and brick accounted for 13.5 % of the total amount of concrete and brick waste. About 28 % of total waste fees can be allocated to contaminated concrete and brick waste.

The breakdown costs for the city were by type as follows (Table 4):

Table 4. The cost of Pankalampi demolition works

TYPE OF COST	€	%
demolition contract	391680	93,0 %
expert services	21632	5,1 %
control, permits	1521	0,4 %
other service	6 381	1,5 %
IN TOTAL	421 214	100,0 %

Most of the expert services consisted of the inventory of hazardous materials and monitoring of the demolition of structures containing hazardous materials. In addition, a nature survey was commissioned. Part of the site supervision was purchased as an external service. Other services included clearing of trees and disconnection of electricity, water and wastewater connections.

Xamk commissioned the inventory of reusable and recyclable materials part of the pre-demolition audit for dental clinic building of the Pankalampi health center. The audit was performed by Ramboll Finland Ltd as part of the CityLoops demonstration. The cost of the audit was about € 4600 (VAT 0 %).

Tuukkala case

The contract price for Tuukkala was € 278,000, or € 52 per floor area. Waste fees paid to Metsäsairila Ltd. totalled € 35 667, taking into account the compensation received for scrap metal of € 80 / t. Waste charges accounted for 13 % of the contract amount. This was somewhat lower than the typical percentage of the baseline cases (the average of the seven Mikkeli sites was 14 % and the median 17 %).

The in-house waste fees offered by the City of Mikkeli and Metsäsairila Oy to demolition contractors is a significant cost factor. At this site, using the Metsäsairila Ltd. commercial list price, the share of waste fees would have been more than € 160,000 and the share of the contract price would have risen to 58% of the total contract price.

Contaminated concrete and brick at this demo site accounted for only 2.8 % of the total amount of concrete and brick waste.

The demolition costs for the city were broken down by type of cost as follows (Table 5):

Table 5. The cost of Tuukkala demolition works

TYPE OF COST	€	%
Demolition contract	297 590	92,7 %
Expert services	19 959	6,2 %
Supervision, permits	560	0,2 %
Other services	2 815	0,9 %
IN TOTAL	320 924	100,0 %

In addition to the original contract amount, the demolition contractor's charge included additional work agreed upon. Most expert services consisted of pollutant mapping and monitoring of pollutant release. Part of the site supervision was purchased as an external service. Other services included clearing of trees and disconnection of electricity, water and sewer connections.

4.3.2 Business cases

Soft stripping and internal demolition as separate service

The business case for separate soft stripping, internal demolition and reuse operator services in presented in annex 1.

The sales of furniture and easily removable construction items has so far been a very occasional and small-scale activity in Mikkeli. At the Pankalampi demo site, the Activity Centre took a small number of products from the Pankalampi dental clinic for sale. In this case the gig was economically feasible for the Activity Centre because they could take the items for free, and they could choose only those items that were considered easy to sell. They had no further obligations towards the Municipality, for example reporting or cleaning of debris.

The critical question regarding the role of Mikkeli Activity Centre is whether it should be the only actor for soft stripping phase in city owned demolition projects. The experience in Pankalampi demonstration case showed that they have only limited capacity to conduct the work in due time. They don’t have the network for conducting business to business activities. The workforce is continuously changing. Their monopoly, informally provided by the city administration may obstruct the creation of commercial business and permanent jobs.

Risain Ltd (Kierrätysoperaattori Risain Oy 2022). is an example of a new business concept. The company calls itself “recycling operator”. The business logic is based on two elements:

1) the company conducts a pre-demolition audit of reusable items with a fixed fee. The audit provides a full report to be used in corporate responsibility reporting, including list of reusable items, their classification, estimated market value and carbon footprint of logistics. The company is specialized in reuse, so the audit is probably more realistic and cost efficient than when using an engineering office.

2) the company provides turn-key services for finding buyers and organizing the dismantling and logistics, including the procurement of waste management services. The reusable items are photographed and announced in digital marketplaces. Risain collects the income from sales and shares the net profit with the client sharing the profit with an agreed percentage. Risain can also arrange a pop-up auction on site if requested by the customer.

This model has the potential of maximizing reuse, because the reuse auditor earns most of her/his profits from selling of the items. Also, this model minimizes logistic costs because all items are sold on-site without need for temporary storage.

The market engagement events in Mikkeli indicated that small and medium sized companies that operate mainly in refurbishing of buildings are potential candidates for separate stripping contracts. Another group of such candidates are asbestos demolishing companies. They could expand their work from asbestos clean-up to all aspects of stripping and selective indoor demolishing. Part of their profit could come from the sales of dismantled HVAC equipment or other items for reuse or recycling.

Recycling of concrete aggregate to concrete production

The business case for upcycling demolition concrete to substitute natural aggregates in producing new concrete is presented in annex 2.

The Bachelor thesis by Sara Maukonen (Maukonen 2022) demonstrated that 100 % of the coarse aggregate in the concrete mix formula can be substituted by recycled aggregate (4…32 mm). The compressive strength of the test blocks was reduced by 21…28 % when using recycled aggregate. Extra water had to be added and mixing was conducted in two stages to overcome the increased water absorption capacity of the material.

The share of fine aggregates (0…4 mm) was 43 % which is in line with Danish experiences. This fraction was not used because the Finnish concrete standard does not approve this option. Technical research is needed to assess the recycling options for this fine dust. It has a high water-absorption capacity and a considerable concentration of alkali metals and sulphates. It can absorb carbon dioxide and it has hardening capacity in earthworks.

The concrete industry has shown interest in this upcycling concept, but in the current situation the economic feasibility is not considered be attractive. Adopting circular criteria in tendering demolition projects and by allowing delivery of concrete waste for recycling also to other recipients than the municipal waste company is the key to changing the balance in favour of recycled aggregates. The gate fee for receiving the waste is usually part of the recycling business concept.

There is some potential for such business in Mikkeli, but the turnover potential is not more than 200 000 – 380 000 €/a. The business would be most attractive to a company that is engaged in demolition and construction services and in addition operates a concrete production plant.

5. Conclusions

5.1 Lessons learned

5.1.1. Lessons learned from the decision-making process

The main challenge is the current procurement practice where price is the only tendering criteria and there is limited experience in the procurement units in setting qualitative criteria.

It is required in the procurement of city-owned demolition projects, that all CDW must be delivered to municipal waste management company. The in-house waste fee is only 30 % of the corresponding market price. This practice was designed to prevent dumping of waste in illegal places, but on the other hand it has prevented contractors from offering innovative recycling options or from using its contact network to find reuse or upcycling options.

Now, Mikkeli has set a target in its City Strategy that states that by 2025 25 % of relevant tenders issued by Mikkeli should include criteria related to sustainable development and circular economy. The monitoring and reporting system for the implementation of this outcome is under preparation. Changes in the procurement practice requires a culture of piloting new procurement alternatives.

Miksei Ltd. has raised the issue that in-house monopoly in CDW management may conflict with the business promotion goals set by the City Council. CityLoops team has pointed out that an alternative approach is an open call for tenders for a long-term contract of managing specific CDW streams from city-owned construction or demolition projects.

For the first time, the City Strategy and the Climate Program set targets for circular economy in demolition projects and in the procurement process. Until now these goals have not been translated into systemic changes in practice.

Green Economy is selected as one of the main components of the Mikkeli Strategic Plan. The main goal is to promote the establishment of new companies in the EcoSairila Business Park area, where also the municipal waste company Metsäsairila Ltd. is located.

The roles between Metsäsairila, the Activity Centre and private companies need to be clarified in implementing the City Strategy. CityLoops Mikkeli team has provided proposals for such coordination.

The findings from the demo cases have verified that the major demolition contractors are quite committed to selective demolition principles. They are already practicing a separate indoor

stripping phase. Source separation of wastes is conducted with the aim of optimizing the costs of source separation, transport, and waste management costs. The companies are developing their capacity in upcycling wastes and in on-site management of demolition wastes, such as producing recycled aggregate on site.

Most of the main contractors working in demolition are from outside the Mikkeli region. There are local sub-contractors working in the asbestos removal and internal demolition business. Some of them showed interest in separate contracting of internal demolition. It is not clear what is the level of environmental management in these smaller companies.

5.1.2. Lessons learned from business case studies

CityLoops Mikkeli team proposes that the Mikkeli City Consortium would adopt a practice that a pre-demolition audit is performed for all demolition cases exceeding 250 m^2. In addition, the City Consortium organizations should consider creating a “pipeline” of future demolition cases within 5-10 years scope by creating a database of basic data of the material masses and reusable construction parts.

CityLoops Mikkeli team has contributed to developing a CityLoops guide for pre-demolition audits and selective demolition. In a spin-off project of CityLoops Miksei Ltd and Xamk have developed a pre-demolition audit reporting software program to be used in the recording and reporting of the audit findings. The use of these guidelines and the use of the reporting software can be replicated by any European city.

At least the soft stripping phase must be executed promptly after the last user of the premises has moved out. Soft stripping and organizing the reuse of items should occur before moisture and vandalism ruins the items. In Mikkeli it is common that city owned building can stand empty for years, even more than 10 years, because there is low pressure for new construction in Mikkeli. This means that also the materials that could be recycled or reused from the stripping phase will probably be ruined.

The benefit of a separate stripping contract is that the timeframe for the work could be more flexible and would allow on-site sales of items. Income from the reuse sales could be used as an incentive to the indoors demolition contractors. The stripping phase does not need a demolition permit, which reduces the bureaucracy and time. The separate contracting would benefit local companies. After the stripping phase there would be less risk for vandalism. The tendering for heavy demolition would be more transparent because it would be clearer to the contractor what materials will have to be transported and managed.

The concept of separating the soft stripping, indoor demolition and heavy demolition contracts can be replicated by any city, taking into consideration the optimal timeline for each phase and available tenderers.

The demolition procedure must be formalized with clear roles and duties for each participant. There are too many actors in the soft stripping phase and their rights and obligations have been improvised case by case.

At the initiative of the CityLoops project, a written agreement on re-use was drafted in March 2021 between the Municipal Premises Centre and the Mikkeli Activity Centre (the NGO). A process description was drafted as an annex to this agreement. Up till now (March 2023) the agreement is still not signed by the parties. An important part of the proposed agreement is the obligation of the Activity Centre to conduct and report an inventory of all potential items that could be recovered in the soft stripping phase. This would fulfil the missing (voluntary) part of the pre-demolition audit that Mikkeli administration has not yet adopted. Alternatively, this service could be procured from a private reuse operator, as described in the business case in annex 1.

5.1.3. Stakeholder engagement

The stakeholders that took part in the CityLoops activities in the beginning were the Building Services unit, the municipal waste company and the Activity Centre. It soon became clear that the Building Services were not willing to radically change their procurement policy which mainly was concerned about minimizing cost but also wanted to avoid risks associated with unprofessional demolition contractors.

Important stakeholders that were not involved in the planning of the project are the land use planning department, Naistinki Ltd., the municipal company managing municipal real estate related to business premises, Mikalo Ltd. the social and student housing company, the infrastructure department etc. In the replication phase of the project some interaction with these has started.

The main lesson learned was that radical changes in municipal practices take a long time and they must be backed up with strategic decisions taken by political leaders and the leading civil servants. At the time when Mikkeli CityLoops project was planned such decisions and ambition were lacking. They only started developing parallel to the demonstration actions.

CityLoops team was active in market engagement with the private companies that could have a role in the circular demolition. The potential for such business promotion in a city of 50 000 inhabitants is not big and the market engagement activities attracted only a few local companies.

5.1.4. Procurement

The main challenge was that the CityLoops managers Miksei Ltd. and Xamk are not decision makers in the Mikkeli procurement processes. Miksei provides advice to the procurement units and supports the market engagement events, but the final decisions are taken by the Building Services staff. In the planning phase of the CityLoops project the Building Services agreed on providing the CityLoops team access to information regarding the two upcoming demolition projects. The discussion on the technical changes in the procurement practices started too late for new approaches to be incorporated in the procurement process.

Proposals were made to include qualitative criteria in the procurement document. Some amendments to the standard procurement template were made but the Building Services did not want to use other criteria than the price. Also, the procurement unit was not willing to procure a pre-demolition audit due to additional costs and lack of experience. CityLoops team procured an audit for one of the Pankalampi buildings, but the findings did not have much impact on the procurement.

The main lesson learned was that the organisational change must start from the strategic level. The policy level must set clearly defined circularity goals and indicators to monitor the implementation. This work has now started in Mikkeli with significant contribution from the CityLoops project. The replication phase of the project will include activities for supporting the realization of the circular goals in all the units of the Municipal Consortium and for ensuring the reporting of progress.

The best practice changes that have been suggested by the CityLoops team include:

1. Adding minimum requirements in the tender documents regarding the source separation of wastes: Specify, based on the pre-demolition audit, which waste types must be collected separately on site. Guidance in interpreting the Waste Decree concerning source separation is needed. Also, economic incentives could be considered to facilitate source separation and upcycling to higher levels than the minimum requirement. A bonus system could be used for this.
2. Quality control of hazardous material audits needs to be improved so that all relevant hazardous materials will be taken into consideration, not only asbestos, also in the demolition projects of other organisations than city-owned demolition sites. Hazardous material audits should be reported so that the contractors can base their waste cost estimate on reliable mass calculations.
3. Procurement units should consider separate tendering for soft stripping services and indoor demolition contracts to facilitate participation of local SMEs and to include criteria for promoting reuse.
4. Fixed price procurement with circularity being the main selecting criteria should be considered in selected cases to promote innovative contractors. The average cost of demolition per floor area is already quite well established so this type of contracting does not constitute a major risk for cost increase.

5.1.5. Organisational changes

Better coordination is needed between environmental authorities and building permit authorities and the units implementing public procurement. The minimum requirements on a case-by-case basis should be defined in the demolition permit or in the tender documents or both.

After the needed policy decisions, the procurement policy should be reasonably uniform across the entire Mikkeli Consortium, which means the City administration and all the city owned companies. Instead of each working in their own “silo” the units should participate in implementing the common goals regarding sustainability and climate issues.

The municipal waste company has currently a monopoly for receiving demolition waste from city owned premises. This can be counterproductive when at the same time the business policy of Mikkeli emphasizes Green Economy or Circular Economy as one of the spearheads of its business promotion policy.

5.1.6. Data collection and monitoring

The activities of CityLoops Mikkeli have almost totally focused on the demolition process. During the project we have understood that the value chain must have linkage with new construction or renovation. There is much bigger business potential in new, flexible construction and developing circular products and materials for construction, compared to demolition waste management. Also, the sustainable maintenance of existing buildings, maximizing the beneficial use of space, and recognizing buildings as material banks offer possibilities for new services and linkages.

Land use planning, which in Mikkeli is lagging the demolition boom should be engaged so that the mass balance of digging soil and using of natural and recycled aggregates or building parts could be coordinated with infrastructure planning and operations.

The demonstration cases pointed out the development needs in the data management of construction and demolition materials and waste information related to municipal or industrial wastes. Estimates for demolition wastes are often collected two or three times during the process, but this information is not stored digitally, and it is rarely reviewed and used in decision making. The mandatory trip-ticket for transporting CDW is currently not useful at all in accumulating useful data of waste flows, because it is not digitalized following a universal system and is not yet linked to a database that allows automatic calculations. A databank for digital archiving of material data was tested in the project and software for reporting pre-demolition audit was developed in the spin-off project. However, data management still needs to be developed. High expectations are staked on the new Construction Act and the obligation to report CDW into a new governmental database, which will have linkages to digital marketplaces.

There is much variation in collecting data on hazardous materials and this has also a significant impact on the cost of demolition waste management.

The practices in data collection of building items that could be reused is at a very modest level. The driver in this theme is the demand for second hand products or secondary materials in construction. There is an urgent need for active reuse operators who could conduct the

inventory of reusable items, find users for these items, and manage the pop-up sales and soft stripping activities.

The efforts of MoE in developing the national procedures for approval of reused materials and building parts are promising. The end-of-waste decree for concrete waste will promote upcycling of concrete aggregate.

The use of 3D modelling tool to monitor demolition waste flows can be a cost-effective alternative in evaluating the amounts of material flows when compared to traditional methods, e.g. tachymeter. In the case of Mikkeli demonstrations, all the CDW materials were transported to Metsäsairila sorting and recycling centre area where material flows as masses were detected at weighting station. However, in many cases material volumes instead of masses are more useful for planning the reuse of materials.

When the CDW materials are reused on-site or transported to other construction site for re-use, using a drone and 3D modelling tool is relatively fast and accurate method to estimate the amounts of materials. Aerial imaging and 3D modelling of the building before the start of the demolition work produce useful data e.g., for the pre-demolition audit and planning of the demolition work. Volumetric measurements based on 3D imaging could be a useful tool for contractors, building owners, consultants, and designers especially in the future, when the reuse of building parts and materials are expected to increase.

Some contractors already use drones to document and monitor the progress of the demolition site. Aerial photos and videos provide a very comprehensive and clear picture on the progress of the demolition work. 3D modelling could provide valuable data for planning and documentation with relatively little additional investment and efforts.

Multispectral camera used by Xamk was not able to recognize different CDW materials. The reflectance of different materials (e.g. concrete) cannot be identified efficiently with the wavelengths available in Micasense RedEdge-MX- multispectral camera. Identification of the materials would probably be possible with a hyperspectral sensor, which would enable obtaining much more detailed reflectivity data from the materials. However, manual data processing is laborious and expensive. Possible solution for material identification could be an automated solution that combines hyperspectral data and machine vision.

The challenges for using drones are the ever-tightening legislation on UAS operations, as well as the cost of photogrammetry software and a drone. However, the costs are not huge. In the CityLoops Mikkeli demonstration, the cost of drone and software were around 5700 €. The user must have expertise in flying drones and 3D modelling or the work must be ordered from an external expert.

Occupational safety and health and environmental protection play an important role during demolition work. Eye and hearing protection, helmet and safety shoes must be used in demolition sites. In dusty work tasks, protective clothing and a sufficiently effective respirator must also be used. In Pankalampi demonstration site, a mini excavator was used during internal demolition: The air emissions caused by the diesel engine must also be taken into account in the workers' protective equipment. To find out the necessary protection features, a

risk assessment must be carried out before starting the demolition work. A decision is then made about the necessary protective measures based on the risks. At the demo sites, the workers were well protected from dust and the protective equipment met the requirements of occupational safety legislation. The spread of dust from the demolition site to the surrounding areas was well managed at both sites.

Attention should be paid to the quality of storm water, especially in the vicinity of vulnerable water bodies. Environmental Quality Standards (EQS) in accordance with Water Framework Directive were momentarily exceeded at the Pankalampi demolition site during the demolition phase for various parameters. The effects of a single construction or demolition site may be temporary but the summary effect of several sites can be significant in receiving water bodies. The contamination could be reduced by filters that can be installed in stormwater wells for water treatment.

5.2 Future perspectives

The lessons learned from the demonstration cases will be incorporated into new practices in the procurement of demolition work throughout the Mikkeli Consortium. The driver for this is the requirement for using sustainability criteria in relevant procurement cases, as stated in the City Strategy and the goals in the Climate Program.

After CityLoops -project Miksei Ltd. and Xamk are planning to start a new circular project with the Mikkeli social housing company Mikalo Ltd. This project would demonstrate the reuse of dismantled concrete elements on the same site. Also, Mikkeli is preparing a multiyear project for the coordination of circular business promotion and drafting a CE roadmap for the municipal consortium.

Mikkeli Building Services unit has applied funding from the MoE program for low carbon construction (Mikkelin kaupunki 2023b). The project aims at transforming an industrial site (slaughterhouse area) into a housing area. The land use and infrastructure planning process will be used as a pilot for promoting circular infrastructure construction. A digital system will be adopted and tested to manage soil and recycled aggregates on site. The procurement of the demolition process will be conducted as a demonstration of circular procurement. The areal planning of the new housing area will be integrated with the planning of the demolition and soil mass balance. A soil bank will be established to allow temporary storage of excavated soil and recycled aggregate on site. Innovative procurement procedures will be used to link demolition with earthworks contracting.

The municipal real estate strategy of the Mikkeli Consortium should be reviewed to identify the potential of improving the energy and material efficiency of the use of current buildings, to assess the potential of changing the purpose of the building, moving buildings to other locations, or reusing building parts.

The infrastructure building activities should be reviewed to incorporate mass balance activities and to promote the use of recycled aggregates to replace natural aggregates.

5.3 Assessment of replicability/recommendations

City specific transformation process to incorporate circularity into decision making

The systemic transformation in a city organisation requires time. It needs ambitious leadership decisions to initiate the change and to set realistic step-by-step goals and measurable indicators. It requires back and forth processes to engage the substance experts in the process of setting the goals.

Public-private partnership must be forged through the procurement activities to identify new ways of planning and implementing construction projects and linking demolition to new uses of demolition materials and building parts.

Conflicts of interest of different sections of the City Consortium must be deliberated. Common goals and leadership are needed to settle such disputes.

Circular economy is a necessity and an important part of climate action and sustainable development. Adopting circular practices may cause extra costs in the development phase, but neglecting such changes constitutes a major risk of losing vitality and a positive image as a city and failing to promote the competitiveness of local businesses.

Many tools developed or tested in CityLoops in Mikkeli can be easily replicated in other cities. For example, drone imaging and 3D modeling is a useful technology to track CDW flows especially in pre-demolition audit phase and when planning the utilization of materials on site or at another construction site. We also recommend paying attention to the monitoring and management of stormwater at construction and demolition sites to prevent load of solid matter and harmful substances to receiving waters.

CityLoops pre-demolition audit guide and the selective demolition guide are useful tools for replication, although good practices are constantly developing as more experiences are gained. The LCA tool developed by Roskilde municipality is a good tool for the preliminary evaluation of the CO_2 emission effects of reuse and recycling of CDW materials, which cities can use e.g., when planning how to achieve the climate goals of construction sector. The tool was already replicated in Mikkeli and was found to be easy to use and eye-opening, so its use can be recommended to other cities as well.

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7. Annexes

Annex 1. Business case A

Business case A: Soft stripping and internal demolition as separate service

1. Introduction

Selective demolition is described in the CityLoops Guide for selective demolition as a systematic work method for maximizing the quantity of demolition materials delivered for reuse and high-quality recycling (Figure 14). Soft stripping is the first step of selective demolition and covers the removal of movables, easily dismantled indoor fixtures such as storage structures, HEPAC-installations. Stripping or indoor demolition is the mostly manual demolition phase of removing all or most non-bearing indoor structures.

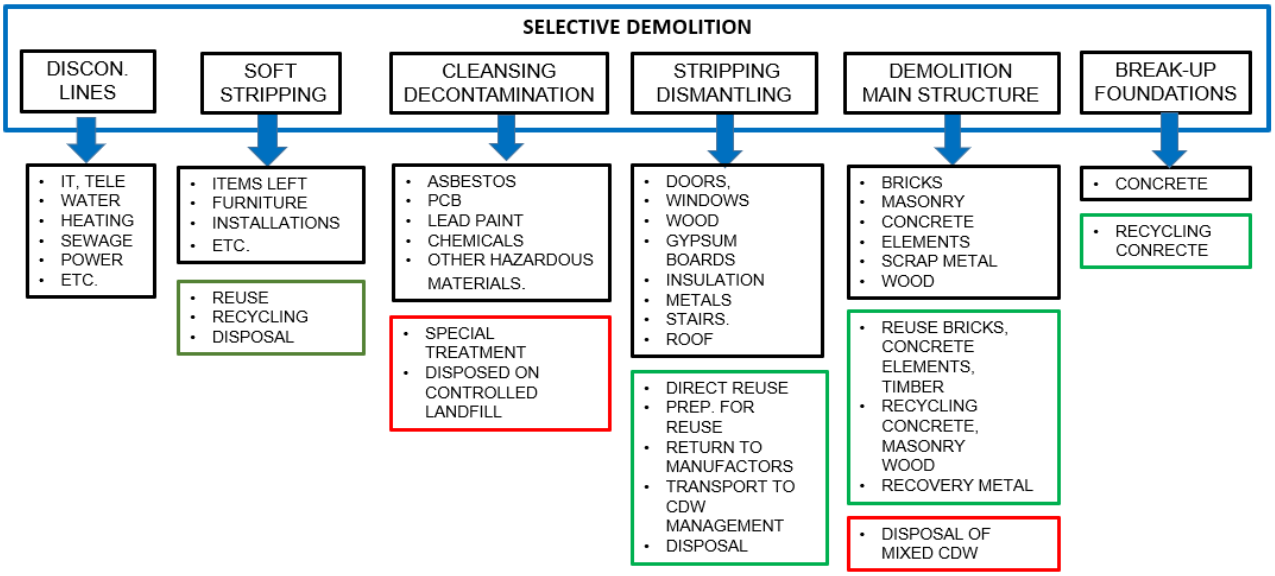

Figure 14. Phases of selective demolition (Lauritzen 2022)

This business case studies the opportunities and obstacles for developing these soft stripping and actual stripping phases as a commercial service in the context of Mikkeli municipality. The concepts presented here emerged from the qualitative research of the demonstration case of demolishing the city owned Pankalampi Health Centre in 2021. The new business options were not applied in the demonstration, but they have been the subject of various interactions with relevant potential beneficiaries.

2. National market conditions

Interest in stripping and reuse of demolition items is growing because of growing waste management costs and because of strategic goals and policy instruments promoting Circular Economy. In practice the scope and value of reused items has mainly been coincidental and poorly documented. Reuse of furniture or demolition items by the owner or latest user of the building have been random and are not based on systematic planning and partnerships.

The market for used furniture or used building items is mainly relying on the semi-informal and informal sector: flea markets, second-hand shops and coincidental offering of second-hand products to customers by the renovation or construction contractors or HEPAC-contractors. Some decades ago, there used to be retail shops that specialized in second-hand construction items[1]. On the other hand, informal trade through digital marketplaces from consumer to consumer or to small businesses is growing. Lately, also some demolition companies have opened their own digital sales of used building items[2].

There are a few small retail shops specialized on second-hand construction materials. The best known company is Metsänkylän Navetta https://www.metsankylannavetta.fi/. It focuses on building parts for renovation of old wooden country houses. A chain of companies called "Building Farmacy" operates in at least four locations in Finland. They sell also new construction items for traditional construction. A similar small business Vanhoo Ossoo operated in Southern Savo, but the owner has closed this business and has concentrated in renovation design work[3].

Reuse of products and prevention of waste is in theory higher in the waste hierarchy according to the Waste Framework Directive and the Finnish Waste Act. The Waste Decree 978/2021 25 § states that the building owner is obliged to plan and execute the demolition so that reusable construction items and materials are recovered and reused and demolition waste is minimized. CDW must be source separated into 11 fractions or more. Source separated waste must be managed to maximize reuse and recycling as material. These articles are not enforced in practice in issuing the demolition permits or through ex post enforcement actions.

The main obstacles for reuse are the cost of careful manual dismantling, renovation of the dismantled part, storage costs and slow turnover of the storage[4]. On the demand side, the use of old building parts is very rarely considered in new construction. There are many barriers related to quality guarantees, standard and energy requirements, uniformity and style. As one business representative put it in a CityLoops workshop: "To design a house based on what second-hand building parts are available, would be like the tail wagging the dog".

[1] interview of informant G, small scale demolition contractor, in market engagement event 22.6.2022 arranged by Miksei.
[2] Purkupiha Ltd. http://www.purkutori.fi/; Terra Kierrätys Ltd. https://terrakierratys.fi/
[3] Interview of informant F, owner of a second-hand shop for building items, interview 10.05.2021
[4] interview of informant E, owner of log construction and renovation business 21.4.2021

The potential for reuse of building parts is mainly in the renovation sector and in the do-it-yourself construction that takes place in the thousands of summer house premises in Finland.

Many buildings in Finland are demolished due to indoor air quality problems (verified or suspected mold spore contamination). The fear of liability issues has prevented the release of furniture or dismantled parts for use[5].

A soft policy instrument for promoting reuse is the pre-demolition audit concept that the Ministry for the Environment (MoE) is advocating. MoE has published a set of guides for conducting a pre-demolition audit (Wahlström et al. 2019). The auditing of hazardous materials is obligatory and the estimate of quantities of waste fractions is a prerequisite for obtaining a demolition permit. The inventory of reusable items is voluntary. Preparing a full pre-demolition audit is promoted by MoE through a Green Deal (Voluntary Agreement) with major premise owner organizations.

MoE has commissioned a study of the possibilities for overcoming the barriers of using second-hand construction materials. The study shows that precast concrete, brick, steel and unprocessed sawn timber do not contain particularly problematic raw materials based on the existing information, therefore their reuse may be possible from a safety or health point of view. There is however significant challenge currently for the reuse of dismantled construction products due to the ambiguity of the qualification procedures. In the short term, clarification of existing regulations and development of official interpretations can clarify the situation and streamline product approval processes for reusable construction products. In the long run, the reform of the EU Construction Products Regulation should establish principles for the product approval and validation of reusable building components. In addition, it must be accepted that reusable building components may also be used for purposes other than their original use. This creates room for innovation and is therefore encouraged (Zhu et. al 2022).

3. Business case description

The OIP of CityLoops Mikkeli sets the following targets:

- *holding innovation workshops (in the form of virtual meetings due to covid-19) with stakeholders including the City of Mikkeli, local waste management company and the operational centre responsible for public equipment at least once per month during the preparation and implementation phase of the demonstrations.*
- *One focus on business cases is to collect and analyse data in order to calculate a feasible, scalable model based on experience in the demonstrations. This involves active efforts from Miksei Mikkeli to encourage users (both supply and demand) of the digital material marketplace and find buyers for the salvaged building parts and equipment.*

A pre-demolition audit was commissioned by CityLoops-project for the Dental Clinic, a separate building that was part of the Pankalampi Health Centre demonstration site. The audit

[5] e.g. CityLoops workshop 11.3.2020. Working group 2. report

was conducted by Ramboll Finland, Mikkeli Unit. In addition, a group of XAMK students conducted an inventory of reusable items within the Dental Clinic, in cooperation with Mikkeli Activity Centre (Mikkelin Toimintakeskus ry). Some recovered items were advertised using the digital marketplace www.kiertoon.fi developed as one of the CityLoops tools.

The soft stripping and stripping works in Pankalampi and Tuukkala demonstration sites were conducted by the demolition contractors, correspondingly Ahosen Palvelut Ltd. and Terra Infra Ltd. The indoor demolition was conducted according to their normal practices. No specific targets were set by the procurer, except for a reference to the source separation requirements in the waste regulations.

The concept, barriers and opportunities for establishing business cases related to stripping and reuse of construction items has been discussed in the following CityLoops workshops and webinars:

- Market engagement event regarding demonstration sites 27.8.2020
- From demolition to circular economy 9.12.2020
- Reuse of Building Parts 11.3.2021
- Planning and Procurement 31.8.2021
- Planning and Decision Making 24.9.2021
- Knowhow Needs and Challenges 18.2.2022
- Joint workshop with Circuit-project 23.5.2022
- Procurement workshop for Demolition and Construction 29.4.2022
- Market engagement event with potential contractors 22.6.2022

In addition, several demolition contractors and other actors in the field have been interviewed one-to-one. As a summary of these findings the following business options have been identified:

1) Soft stripping and organizing reuse of dismantled parts
2) Stripping and upcycling as a separate demolition service

4. Business case characteristics

4.1. Soft stripping and organizing reuse of dismantled parts

Soft stripping generates the following types of items with potential for reuse:

- usable furniture (movable or easily dismantled)
- other equipment left by the last user of the premises: office equipment, equipment specific to the type of building (school, health care, workshop etc.).

- easily dismantled HEPAC items such as sinks, taps, sanitary ware, air conditioning equipment, heating equipment, radiators, lamps (indoor/outdoor)
- unusable items often consist of many different materials and are classified as mixed demolition waste.

Economic aspects and benefits

The business income consists of the following elements:

- fees for the dismantling and cleanup of the premises
- income from the sales of recovered items

The expenditures consist of the following elements:

- low-skill manual labor cost for dismantling items and logistics, basic checking and cleaning of items
- protective clothing and masks, hand tools
- vehicles for logistics, drivers
- warm and dry temporary storage
- waste management cost for items that could not be sold
- medium skilled supervisor for conducting the audit for reusable items, supervising staff, ensuring work safety, interaction with building owner
- medium skilled staff for quality control and eventual maintenance of sellable technical equipment
- sales staff for pricing of items, organizing sale (pop-up sale, digital marketplaces, permanent second-hand shops, business to business sales)
- advertising costs of sales.

The sale of furniture and easily removable construction items is so far a very occasional and small-scale activity. At the Pankalampi demo site, the Activity Centre took a small number of products from the Pankalampi dental clinic for sale. The estimated market value of these was 3700 € and the work input was estimated at 90 person-hours. 70 % of the sales value was allocated to a mechanical garage door. With a typical salary and social care cost of a low skilled construction worker the staff cost would be about 1560 €. Estimated other costs listed above could bring the total cost to 2500 €. In this case the gig was economically feasible for the Activity Centre, because they could take the items for free, and they could choose only those items that were considered easy to sell. They had no further obligations towards the Municipality, for example reporting or cleaning of debris.

A significant amount of furniture remained unused due to lack of time, human resources, and lack of storage space. No inventory was made in the main building of the health centre. In Tuukkala, all furniture was broken or spoiled due to vandalism.

Cities that have municipal recycling centres or partnerships with third sector recycling centres report some success stories of soft stripping operations, for example open house events where soft stripping items have been sold to private consumers. These events have been framed rather as circular awareness activities rather than business activities[6]. In Mikkeli a similar pop-up auction day was held at Urpola school in 2021 (Mikkelin Toimintakeskus 2021). The Mikkeli Activity Centre provided 4 workers and two drivers. Examples of items sold were 400 chairs, cloths racks, cupboards, musical instruments, tables, books, teaching equipment etc. The buyers were private citizens, especially alumni of the school. The income from the auction was 6500 €, so the event was profitable for the Activity Centre, because they received all items for free.

The critical question regarding the role of Mikkeli Activity Centre is whether it should be given the monopoly for soft stripping phase in city owned demolition projects. The experience in Pankalampi demonstration case showed that they have very limited capacity to conduct the work in due time. They don't have the network for conducting business to business activities. The workforce is continuously changing. The monopoly, informally provided by the city administration may obstruct the creation of commercial business and permanent jobs.

Risain Ltd. is an example of a new business concept. The company calls itself "recycling operator". The business logic is based on two elements[7]:

1) the company conducts a pre-demolition audit of reusable items with a fixed fee. The audit provides a full report to be used in corporate responsibility reporting, including list of reusable items, their classification, estimated market value and carbon footprint of logistics. The company is specialized in reuse, so the audit is probably more realistic and cost efficient than when using an engineering office. In one example case the fee for this reuse audit was 9000 €.
2) the company provides turn-key services for finding buyers and organizing the dismantling and logistics, including the procurement of waste management services. The reusable items are photographed and announced in digital marketplaces. Risain collects the income from sales and shares the net profit with the client sharing the profit with an agreed percentage. Risain can also arrange a pop-up auction on site if requested by the customer.

[6] Personal communication with HSY (Environmental Services of Helsinki Metropolitan area) and Espoo City
[7] Sirpa Rivinoja, Risain Ltd. director, interview 7.6.2022

This model has the potential of maximizing reuse, because the reuse auditor earns most of her/his profits from selling of the items. Also, this model minimizes logistic costs because all items are sold on-site without need for temporary storage.

Risain is offering these services to municipalities and businesses (e.g. retail chain) in demolition cases, in cases of moving to new locations and cases of refurbishing existing premises. Risain Ltd is in partnership with Purkupiha Ltd. one of the biggest demolition contractors in Finland.

The outcomes of CityLoops business case activities have so far been:

- development and publishing of a digital marketplace for used building items
- demonstrating models and reporting schemes for reuse audits
- proposal for an agreement with Mikkeli Activity Center regarding soft stripping
- promoting cooperation between Mikkeli Social Housing company (Mikalo Ltd.) and Mikkeli Activity Center
- interaction with Mikkeli Consortium companies in circular procurement issues and market engagement.

Social aspects and benefits

Mikkeli Activity Centre (Mikkelin Toimintakeskus ry) is an NGO that was established in 1991 to activate unemployed people and help them to acquire counselling, education and work experience to promote their path to permanent jobs. Mikkeli Municipality has outsourced this work to the Activity Centre and pays annually more than 1 M€ for these services. To provide work experience to their unemployed customers Activity Centre is operating recycling centres, second-hand shops and repair workshops. In 2022 130-150 people were working in these activities with 100 % salary subsidy from the labour administration. The salary subsidy generally applies only for 6 months, after that the people must be rotated. The number of such workers associated with circular economy was about 70 in 2019, including permanently employed supervisors. In addition, Mikkeli Activity Centre is providing rehabilitation activities to about 500 people, who have health and social issues that currently prevent them from entering the labour market.

According to Activity Centre, EU regulations are threatening the continuity of this model because it does not allow subsidies to distort competition with commercial businesses. 100 000 € turnover is planned to be defined as the lower limit of commercial repair and reuse, after which the subsidy restrictions would be applied. If the drafted Finnish regulations enter into force, the Activity Centre could only employ 4-5 people per year in total compared to the current 130-150 (Ranta 2022). However, if the salary subsidy is smaller than 100 % the regulation of market distortion is more lenient.

Informant A is project manager in the municipal employment demonstration in Mikkeli. In the demonstration project the labour services are transferred from national authorities to the local level. The informant pointed out that that in the long run circular construction cannot be implemented with government subsidies. The activities must bear the reasonable salary costs. Subsidies should only be used in demonstrating new concepts. He supports the CityLoops proposal of procuring the stripping phase separately from total demolition. This would make possible the participation of local smaller companies that could then recruit unemployed people locally. Partial salary subsidy can be used in the start-up phase by companies to reduce the risk of employing new staff. In his opinion, the role of the Activity Centre is not to provide such permanently needed workforce – such services should be provided by businesses. The role of the Activity Centre is to provide a transition period for unemployed people to train and rehabilitate them to be ready to enter the free labour market.

Soft stripping activities and the related maintenance and repair of recovered items for sale fit well into this concept of employing low-skill workers. Mikkeli Activity Centre could support unemployed people to enter the permanent labor market by providing training with support from the Mikkeli Municipality. This requires partnership with the local or national level contractors.

Environmental aspects and benefits

The main environmental benefit of a systematic reuse audit and a separate soft stripping service is the potential increase of reuse of building items and the associated prevention of waste and the saved carbon and material footprint of producing an equivalent product.

Cultural aspects and benefits

As pointed out in the case of Urpola School pop-up auction, the inhabitants value items from the past decades and have the interest to reuse rustic furniture and other items which have cultural and personal significance for them.

4.2. Separate stripping service as business

The market engagement events in Mikkeli indicated that small and medium sized companies that operate mainly in refurbishing of buildings are potential candidates for separate stripping contracts. Another group of such candidates are asbestos demolishing companies. They could expand their work from asbestos cleanup to all aspects of stripping and selective indoor demolishing.

Economical aspects and benefits

Company B is a local demolishing contractor that has a license for asbestos removal from buildings. 40 % of the turnover (about 1 M€) comes from asbestos work, 40 % from other types of stripping work and 20 % from diamond cutting and drilling. The business is usually based

on sub-contracting. The company participated as subcontractor for asbestos removal in the Tuukkala demonstration case.

Informant C, the owner of Company B assessed that combining asbestos removal with stripping work could reduce the total cost of demolishing. In the current practice, where asbestos removal is provided by a sub-contractor, but the remaining stripping work is conducted by the main contractor, the scheduling of the work is not as fluent as it would be if the asbestos contractor could shuffle between asbestos removal and normal stripping[8]. Offering small contractors the possibility of separate contracting for stripping work could also reduce total costs, because of increased competition with big total demolition companies.

The duplication of costs of fencing, when dividing the contract into separate stripping contract and heavy demolition contract can be avoided, according to the interviewee. The stripping contractor can transfer the rental of the fencing and construction site barrack to the next contractor (assuming that there is little delay between the phases).

The company has 11 staff, five of them have a certificate to conduct asbestos removal. It is difficult to recruit asbestos workers that have the appropriate attitude required in this hazardous work. The company has used Estonian workers when needed. Unfortunately, the company was sold in 2021 to a company located in another city and the company is no longer operating in Mikkeli.

Company C is a local demolition contractor with a turnover of 1…2 M€ and 19 workers. 50 % of the turnover comes from diamond drilling and asbestos removal work, the remaining from other demolition work. The company is licensed to do asbestos audits and it has several authorized asbestos removal workers. It has adequate equipment for indoor demolition work but not heavy demolition. It also provides waste transport services. Informant C, the owner of the company considered subcontracting to total demolition companies as unfeasible. They provide too little time for the indoor demolition. Asbestos removal must be conducted before indoor demolition. Partitions, doors and windows cannot be removed before asbestos work, because the working space must be insulated, and negative pressure induced. The informant is for separate tendering of indoor demolition. This would lower the price of heavy demolition and the total cost would probably be lower. Indoor demolition does not require considerable costs for fencing. Demolition materials can be discharged from windows without removing the window. The company does not consider the reuse of building parts.

Company D is a construction company located in the Mikkeli region. The business consists of construction, renovation and earthworks. It has experience of stripping work as part of renovation. It expressed interest in separate contracting of stripping services. The challenges for reuse are related to the short timeframe allocated for the stripping phase, storage costs of items that are not immediately sold, overstatement of the risks linked to indoor air quality and approval procedures required for building materials[9].

[8] Informant C, interview 20.4.2021.
[9] Informant D in the market engagement event. 22.6.2022

The separate procurement of stripping works would probably benefit local businesses, because of cost savings compared to nationally operating companies that must bring workers from other locations with associated cost of lodging and per diem. In cases of subcontracting the stripping work by the main contractor there will be added cost to the customer from the margin taken by the main contractor.

Social aspects and benefits

Contracting local businesses for the stripping phase as alternative to total demolition would benefit local employment and the increased experience of local skilled workers specialized in demolition work. The stripping work would probably not provide permanent work alone, but it would be a new source of income for companies in the construction and renovation field. Socially this would be better than recruiting temporary migrant workers from e.g. Estonia. Work safety is probably better when using permanent staff than temporary staff.

Local businesses could form partnerships with the Activity Centre and offer opportunities for permanent employment to the customers of the Activity Centre. They could also find synergy with the local Vocational school by recruiting students, student entrepreneurs and newly graduated people.

Environmental aspects and benefits

Engaging local enterprises in soft stripping and stripping contracts could have environmental benefits in promoting reuse of building items. Building a local network of buyers would reduce transport costs and would enable on-site sales.

Building parts that have cultural and historical value to Mikkeli inhabitants would more probably find buyers locally than nationally.

5. Business case impact indicator calculations

Indicator 22 in the CityLoops evaluation plan sets the goal of introducing eco-innovations: New products, service concepts and business models relating to the reuse/recycling and upcycling of the specific material flows established, leading to new business opportunities.

Indicator 23 monitors the quantitative impacts of each eco-innovation in monetary terms.

In this Mikkeli business case A two eco-innovations have been studied: one is the soft stripping and reuse operation business and the other is the indoor demolition or stripping phase where the soft stripping operations can be included or excluded.

In this report the soft stripping business is selected as the basis of the impact indicator.

The soft stripping business can be roughly assessed using the example of the dental clinic in the Pankalampi demonstration case. The turnover that Mikkeli Activity Centre calculated was 3746 €. The floor area of the dental clinic was 1416 m2, so the realized selling value was 2,65 €/m2. During 2018-2021 the Municipality has typically demolished about 10000 m2 of municipal public buildings per year. The demolition projects managed under Mikalo (municipal rental housing company) and Naistinki (manager of city owned business premises) or other city owned companies are not included in the estimate.

If the dental clinic case is used as a benchmark, the value of reusable soft stripping items from city owned buildings would be about 30000 € per year. Based on observations from the demo site the potential would have been much more, but due to constraints in time, human resources, and lacking sales channels the potential was not realized. The pre-demolition audit only covered the dental clinic.

The impact indicator 23 is tentatively given the value 30 000 €. There is potential for much more.

The total sales of reusable items in the New Life shop of Mikkeli Activity Centre were 423926€ in 2021 (Mikkelin Toimintakeskus 2022). Most of the income obviously came from sales of furniture, used household items and household appliances donated by private citizens. Compared to these sales the share of items that could be recovered from to-be-demolished municipal buildings would be 7 %. Most of the recovered items are currently furniture, not actual building parts such as water fixtures.

6. Lessons learned and replication opportunities

Reuse cannot be promoted without pre-demolition audit

The process and roles of demolition actors are proposed by the Mikkeli CityLoops team is depicted in figures 15 and 16.

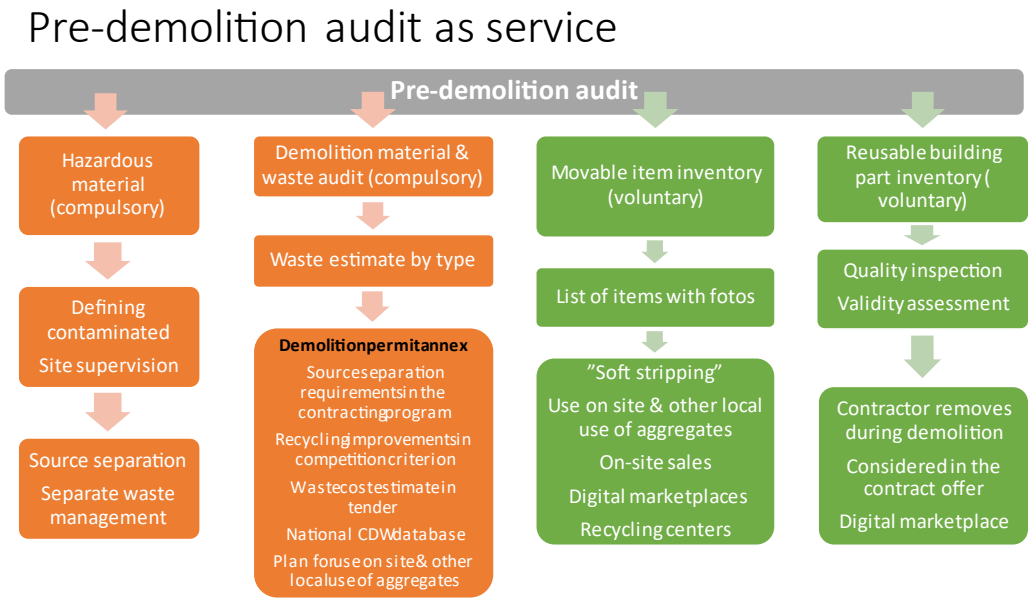

Figure 15. Components and outputs of the pre-demolition audits (figure Raimo Lilja and Jenina Luotolampi)

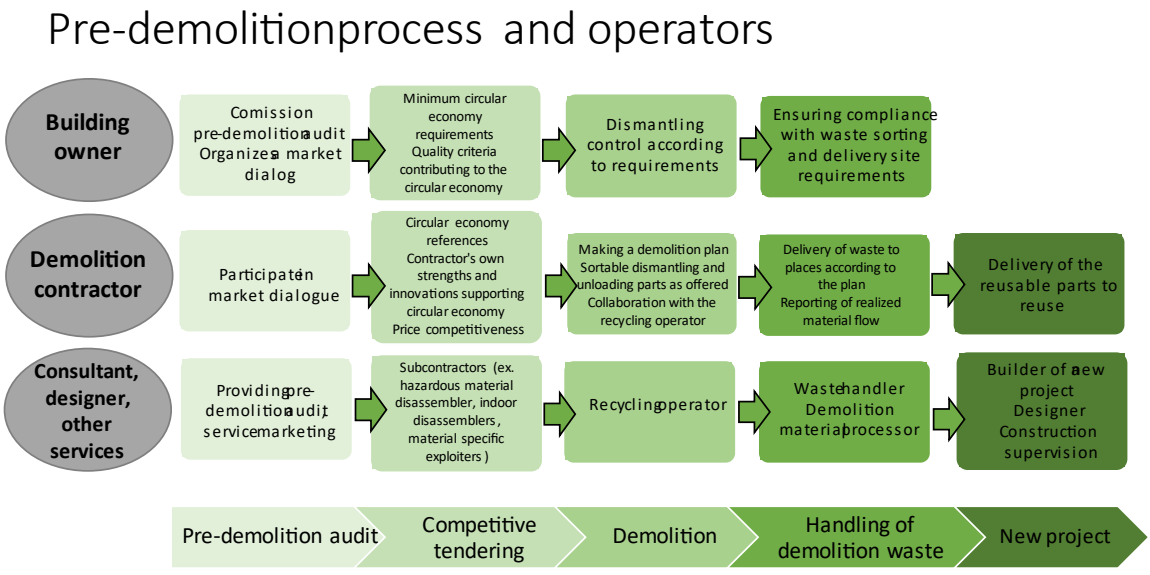

Figure 16. Visualization of the pre-demolition process and the roles of different actors (figure Raimo Lilja and Jenina Luotolampi)

CityLoops Mikkeli team proposes that the Mikkeli City Consortium would adopt a practice that a pre-demolition audit is performed for all demolition cases exceeding 250 m2. In addition, the City Consortium organizations should consider creating a “pipeline” of future demolition cases

within 5-10 years scope by creating a database of basic data of the material masses and reusable construction parts.

CityLoops Mikkeli team has contributed to developing a CityLoops guide for pre-demolition audits and selective demolition. The use of these guidelines and the use of the pre-demolition audit reporting software can be replicated by any European city.

Appropriate timing of soft stripping and stripping

At least the soft stripping phase must be executed promptly after the last user of the premises has moved out. Soft stripping and organizing the reuse of items should occur before moisture and vandalism ruins the items.

In Mikkeli it is common that city owned building can stand empty for years, even more than 10 years, because there is low pressure for new construction in Mikkeli. This means that also the materials that could be recycled or reused from the stripping phase will probably be ruined.

The benefit of a separate stripping contract is that the timeframe for the work could be more relaxed and would allow on-site sales of items and temporary storage of dismantled parts.

After the stripping phase there would be less risk for vandalism. The tendering for heavy demolition would be more transparent because it would be clearer to the contractor what materials will have to be transported and managed.

The stripping phase does not need a demolition permit, which reduces the bureaucracy and time. The separate contracting would benefit local companies.

The concept of separating the soft stripping, indoor demolition and heavy demolition contracts can be replicated by any city, taking into considerations the optimal timeline for each phase and available tenderers.

Clear definition of roles and duties

The demolition procedure must be formalized with clear roles and duties for each participant. For example, in the Urpola case the headmaster of the school was expecting that the income from the pop-up auction would be accounted for the Education Department. The Activity Centre was allowed to start the soft stripping operation only five days before the demolition contractor started the demolition work.

There are too many actors in the soft stripping phase and their rights and obligations are improvised case by case. The last users of the premises leave behind their property, for example confidential archives, hazardous wastes or valuable equipment that end up being

managed by the demolition contractor. The municipal construction department may or may not use some selected building parts, such as fire escape stairs in new construction. The Activity Centre and the Vocational school teachers scavenge for selected items. Private households ask for windows or other items and sometimes end up in the restricted area where the demolition is already on-going. Hazardous situations have occurred where for example the electricity has not been switched off as expected[10].

At the initiative of the CityLoops project, a written agreement on re-use was drafted in March 2021 between the Municipal Premises Centre and the Mikkeli Activity Centre (the NGO). A process description was drafted as an annex to this agreement. Up till now (July 2022) the agreement is still not signed by the parties. An important part of the proposed agreement is the obligation of the Activity Centre to conduct and report an inventory of all potential items that could be recovered in the soft stripping phase. This would fulfil the missing (voluntary) part of the pre-demolition audit that Mikkeli administration has not yet adopted.

Another option is to outsource the reuse audit and reuse operations to a private operator as outlined in the business concept above.

Creating demand for reuse and recycling through procurement criteria

Waste legislation sets general targets and requirements for waste prevention, waste hierarchy and source separation of CDW. These are not reflected in demolition permits, because the building permit authority is not an expert in waste management and the environmental authority rarely involved in individual demolition or construction permits and is mainly involved in regulating waste management companies.

This emphasises the role of the public procurement units. Public procurement should set ambitious targets for promoting circular economy. The minimum requirements should clearly define what is the minimum level of source separation, based on the estimate of waste generation by type in the pre-demolition audit. Measurable recycling rates could be used as qualitative criteria in tendering or ex post verified and higher than minimum recycling rates could be awarded with bonuses.

Setting minimum targets for reuse in procurement is difficult because the market price and demand for reusable items is so item specific. It may be practical to separate soft stripping and reuse of easily dismantled items from the demolition tendering.

Second, all major demolition tenders should set qualitative criteria that encourage reuse and upcycling and innovative solutions. In Mikkeli the demonstration of such criteria was not possible, because of the in-house position given to the Municipal Waste Company (Metsäsairila Ltd), virtually requiring the contractor to deliver all the demolition material to the

[10] interviews with informants representing Mikkeli Activity Centre and Vocational School (ESEDU)

Company. Reuse and upcycling of CDW are not part of the business strategy of Metsäsairila Ltd.

This practice in in conflict with the City Climate Program goal that the “City will promote and execute circular economy and will establish an operation model based on cooperation between the municipality and companies.”

The Mikkeli Activity Centre has been informally given a similar in-house position, even though it is an NGO, not a part of Mikkeli administration. It has the preferential right to soft stripping, but in practice it does not have the human resources and business contacts to organize systematic reuse audits and sales. Such an in-house position should be questioned and new partnerships with private sector reuse operators should be demonstrated.

The issue of hazardous material assessment is essential to guarantee work safety and safety of the reused items. Asbestos waste management is well organised in city owned demolition sites, but the procurement of hazardous material audits needs to be improved in other organizations and chemicals other than asbestos are often neglected.

The Mikkeli CityLoops team was not successful in incorporating circular criteria in the procurement process in the demonstration cases, because there was not enough time and enough political ambition to change the standard procedures. Other cities may replicate the proposed actions, but they must be implemented in the unique context of each organization and country.

Annex 2. Business Case B

Business case B. Reuse of concrete aggregate in concrete production

Introduction

About 20000 tons of concrete demolition waste is received at the municipal waste centre in Mikkeli, operated by the municipal waste company Metsäsairila Ltd. It is currently crushed by a contractor and used in maintaining the landfill roads and other earthworks on the premises. This can be classified as down-cycling of the concrete waste because it could have higher value recycling possibilities. On the other hand, without access to this material Metsäsairila would have to buy natural aggregates for landfill maintenance.

Occasionally the crushed concrete has been used for road construction. In 2019 5800 tons of recycled aggregate was used by Mikkeli in building the access road to the waste centre. The process was conducted following the Government Decree 843/2017 (Valtioneuvosto 2017). In 2020 134 tons of recycled aggregate was used by Metsäsairila Ltd. in constructing a rural waste transfer station in Rämälä. In 2021-2022 no such recycling activities were conducted by Mikkeli municipality[11].

Inspired by several demonstration actions in Denmark and information exchange within CityLoops project, the CityLoops team in Mikkeli decided to study the feasibility of recycling concrete aggregate into the production of new concrete to replace natural aggregates. As part of these studies a Bachelor thesis was commissioned from Ms. Sara Maukonen from XAMK University of Applied Sciences (Maukonen 2022). The thesis was conducted between February and August 2022.

National market conditions

Finland differs from Denmark and most Central European countries, having an abundance of natural aggregate resources. The market price of natural gravel or rock gravel in Finland is low because of good availability of high-quality granite rock and natural gravel in esker formations in Finland. There is an abundance of such resources in the Mikkeli region. The transport distances of sand and gravel is short on average.

The consumption of natural aggregates is high in Finland because of the vast geographical area, long distances and the demanding winter conditions that burden the maintenance of roads. The per capita consumption of these resources was 15,5 tons. The total consumption was about 85 million tons in 2013. About two thirds of the consumption is crushed from rock,

[11] Pekka Kammonen, infrastructure director, Mikkeli Municipality. e-mail 16.8.2022

the remaining third comes from eskers or the sea bottom. New roads are designed to utilize the rock formations along the road line.

Eskers and rock formations are valuable landscapes and 8 % of endangered species in Finland live in these ecological niches. Natural aggregate consumption is regulated by a permitting procedure. Esker formations are protected because of their importance in groundwater formation and as biotopes.

Recycled aggregates currently cover 2-3 % of the total consumption of aggregates (Suomen ympäristökeskus 2015).

Using a natural resource tax to promote the use of recycled aggregates to substitute natural aggregates is proposed now and then in policy discussions. This has not been politically acceptable so far, because it would mostly be paid by the taxpayers, as road construction is mostly funded with public budget.

Other national policy instruments that affect the market conditions are waste regulations and waste taxes. Waste legislation obliges actors to source separate demolition wastes and to separate contaminated wastes from non-contaminated materials. A national waste tax 70 €/t is charged if demolition waste is deposited on a landfill. Recycling has been promoted by defining the quality criteria for recycled aggregates in earthworks. Following these criteria, the need to obtain an environmental permit for such recycling is revoked.

As the newest development a government decree was issued that sets the criteria for defining the end-of-waste status for concrete waste (Valtioneuvosto 2022). Following these criteria, the producer of the recycled aggregate can obtain a CE-certificate. This also means that the use of recycled aggregate in the production of new concrete is possible without obtaining an environmental permit for this recycling.

There are still obstacles for large scale use of recycled aggregates in concrete production. Another challenge for higher utilisation of concrete aggregate is that currently the standard SFS-EN 206 (2014) recommends that a maximum of 50 % of the total aggregate should be replaced by recycled aggregates in the lowest exposure class X0. In the rest of the classes, the recommended proportions get progressively smaller. The standard should ideally be updated to accept the use of recycled aggregate with a 100 % replacement ratio as has been done in Denmark. In the Finnish standards, there is no provision for utilizing the fine fractions of crushed concrete.

Business case description

The business case aims at promoting the upcycling option of using demolition concrete waste as the raw material for producing CE-certified recycled aggregate to be used in the production of new concrete for construction.

The value chain includes the selective demolition of concrete structures by source separation of bricks, ceramic material, and mineral wool waste from concrete. Concrete structures contaminated with asbestos, PCB, bitumen, or heavy metal paints need to be identified in the

pre-demolition audit and demolished selectively to avoid mixing with non-contaminated concrete. Concrete blocks are crushed < 500 mm with demolition equipment to remove iron bars.

Instead of delivering the concrete waste to the municipal waste company, it will be delivered to a sub-contracted concrete plant for crushing and sieving. The coarse fraction (4…32 mm) will be analyzed and tested according to the quality requirements of the End-of-waste decree. The fine fraction (0…4 mm) could be used for earthworks or possibly in the future also as recycled aggregate. This is pending on updating of the national or EN standards.

Alternatively, in some cases the concrete waste could be crushed at the demolition site and stored in silos to be used in production of new concrete with mobile mixers in construction at the same site or in the close vicinity. This, however, is more challenging in terms of quality assurance and timing.

Due to the higher water absorption capacity of recycled aggregate the concrete formula needs to be adjusted by using plasticizers or other additives and tailoring the mixing program to achieve optimum plasticity, compressive strength, and resistance to damage by freezing.

Economic aspects and benefits

Economic aspects in the value chain

In the Pankalampi demonstration case, waste fees accounted for about 22% of the demolition contract amount and about € 8 per square meter. In addition, the contractor had to pay the cost of transporting the waste. The cost of waste management was reduced by the fact that they contracted and used their own waste containers, so no rental costs were incurred.

In the Tuukkala case, waste charges accounted for 13% of the contract amount. This was somewhat lower than the typical per-centage of the initial situation (the average of the seven Mikkeli sites was 14% and the median 17%). The cost of transport by the sub-contractor was confidential information.

The waste costs would have been about double if it was not arranged in the procurement conditions that the subcontractors could use the in-house waste fees that are applied in city owned demolition projects. The pre-condition for using these in-house fees is that all wastes must be delivered to the municipal waste company.

This in-house arrangement means that circular aspects cannot be used as procurement criteria in municipal demolition tenders. Presently the contractor cannot offer the delivery of concrete waste to a earthworks project or a concrete plant for recycling. From the point of view of circular economy goals this practice needs to be revised.

From the point of view of Metsäsairila Ltd. the monopoly for waste management of city owned demolition projects means a steady flow of income. 20 000 tons of concrete waste generates 100 000 € of income with the in-house fee level and 300 000 €/a if normal list fees are used.

For the municipality this in-house practice means lower demolition contract prices due to lower waste fees. On the negative side, there is less opportunity for circular business in the municipality for the private sector. In principle the municipal waste company could process the waste into CE-certified recycled aggregate and sell it to the concrete industry. If this is the role of a municipal waste company can be challenged. The Waste Act and the Procurement Act has set a limit of 10 % of turnover to municipal waste companies for providing market-based services (Jätelaki 646/2011 § 145a §).

For the concrete industry the use of recycled aggregate would most probably not be cheaper than using natural aggregates in the current market situation. However, for a company that offers both demolition services and owns a concrete plant, this offers a major competitive advantage as it will avoid the waste fees completely. For other demolition contractors a framework agreement with a concrete plant can also be beneficial. The concrete plant could charge a gate fee for receiving concrete waste, as long as the fee is lower than the shadow price at the waste centre.

Some customers may be reluctant to use recycled concrete due to risk aversion, but other customers would consider such “green concrete” as a significant demonstration of corporate responsibility and environmental competitiveness. It can be expected that such green criteria will be adopted in public procurement also in Finland. This would mean a major competitive advantage for a concrete plant using recycled aggregates.

The concrete plant must factor in the costs of crushing, sieving and storage of the recycled aggregate or alternatively it must buy the certified aggregate from an intermediate contractor. This process is more costly than the process for natural aggregate because the fine dust from cement paste is more difficult to screen and causes lumping when moist.

The concrete company has some extra costs in using recycled aggregate because of tailoring of the mix formula, perhaps some additives and quality control costs. These are apparently not major costs after the initial testing process. Concrete plants that develop their procedures to receive recycled aggregate from demolition can easily extend this procedure to residual concrete from their own production or possibly from other regional producers.

In the long run the cost of natural aggregates is expected to rise because of conservation actions and possibly also if an environmental tax on the use of natural aggregates or “mining tax” is enacted.

Evaluation indicators for the business case

Indicator 22 in the CityLoops evaluation plan sets the goal of introducing eco-innovations: New products, service concepts and business models relating to the reuse/recycling and upcycling of the specific material flows established, leading to new business opportunities.

Indicator 23 monitors the quantitative impacts of each eco-innovation in monetary terms.

In this Mikkeli business case the substitution of the coarse natural aggregate fraction in cement production with recycled aggregate from demolition waste is assessed.

The municipal waste company Metsäsairila Ltd. received 19536 tons of concrete waste. The concrete waste is allowed to contain brick waste or ceramic waste if it does not exceed 30 % (Valtioneuvosto 2017). Contaminated concrete and brick waste is source separated and not included in this figure.

When concrete waste is crushed to 0…32 mm size, the share of fine material (0…4 mm) is about 40 % (Maukonen 2022, Kobenhavns commune 2020). This cannot be used in producing new concrete because of restrictions in Finnish concrete standards (Suomen standardisoimisliitto 2008) and technical disadvantages. The coarse fraction of recycled aggregate (4…32 mm) can be used to substitute natural aggregates. The quantity of concrete waste at Metsäsairila Ltd. could generate 11722 tons (60 %) of such material after sieving off the fine dust.

Company internet websites quote prices ranging from 20 €/m3 to 36 €/m3. Assuming a bulk density of 1400 kg/m3 (Netrauta 2022) this translates to 15…16 €/ton (VAT 0 %). Large scale users could purchase gravel with 7…8 €/ton[12]. Using a conservative estimate 8 €/ton, t*he market value of the available quantity of recycled aggregate could be about 94000 € per year.*

As a hypothetical example, Company T has a concrete factory about 50 km from Mikkeli. Their production capacity is 25000 m3 of concrete mix and 17000 m3 of concrete elements. Assuming a bulk density of 2400 kg/m3 for concrete the capacity in tons would be 60000 t/a. A typical Portland cement concrete mix consists of 27 % cement, 9 % fine aggregates, 52 % coarse aggregates and 12 % water (Rintala et. al. 2021). The consumption of coarse aggregate at the plant would be 31200 tons. 38 % of this consumption could be covered with recycled aggregate, if all the waste at Metsäsairila would be available for recycling. In addition, the company could recycle its concrete production waste to increase its aggregate recycling rate even higher. Presently the company has an environmental permit for crushing 10 000 tons of concrete waste annually. This waste arises from the production waste of the concrete manufacturing plants and from demolition work that another company of the same consortium is performing (Mikkelin seudun ympäristölautakunta 2011).

In addition to the value of the recycled aggregate the business value of recycling aggregate consists of the savings in transport and savings in waste fees. Transport of gravel costs 2-3 €/t, assuming a modest transport distance 30 km, which is typical in Mikkeli. Some digital marketplaces offer transport for 11 €/ton. The transport cost of 11700 tons of natural aggregate would be between 25000 € to 130000 €. Assuming a best case where demolition waste can be crushed and screened on-site and then used on-site for casting of new concrete structures, the saving potential would be correspondingly 25000-130000 €. However, this is generally not realistic. In most cases the concrete waste would have to be crushed centrally at the concrete plant or waste treatment facility. The transport distances would be in the same range as the transport distance for natural aggregates. *Transport savings would have to be calculated case by case, that's why these savings are not included in the evaluation indicator.*

[12] Pekka Kammonen, infrastructure director, Mikkeli Municipality, e-mail 18.8.2022

The waste fee for concrete waste is 5 €/t if it arrives crushed with maximum 500 mm block size. The fee is 13 €/t for larger blocks of concrete (Metsäsairila 2020). These fees apply for demolition waste from city owned demolition projects. The Metsäsairila fees for other contractors than city projects are 15 €/t and 30 €/t correspondingly (Metsäsairila 2022). This latter set of fees means that the demolition contractor can save 15 €/t by delivering the waste for reuse at the concrete plant instead of the municipal waste company. The saving potential is 293040 €/a, if anyway the waste must be crushed < 500 mm during demolition. This saving potential is smaller if it calculated with the in-house waste fee. The in-house practice is dubious because the waste owner is no longer the municipality: the contractor is the waste owner according to the tender documents.

For the evaluation indicator estimate the market value of the concrete aggregate and the saving of waste fees can be summed up. This gives us about 386 000 € per year.

Note: the waste tax for waste deposited at a landfill is currently 70 €/ton. This tax is paid by the landfill owner and naturally it will influence the waste fee charged from the waste deliverer. For concrete waste this tax is currently avoided because all concrete waste is crushed at Metsäsairila waste center and used in the landfilling operations and road construction at site. It must be crushed below 150 mm to be excluded from tax (Jäteverolaki 2010). The cost of crushing is covered with the waste fee.

Social aspects and benefits

Social aspects are not very significant in this business case. Some employment impacts can emerge from the processing of recycled aggregates in the concrete industry but that is balanced by reduced employment needs in the municipal waste company.

Environmental aspects and benefits

Based on a study by Kikuchi and Kuroda (2011, 123) the CO2 uptake of crushed recycled aggregate increases significantly the smaller the particle size is. The study mentions that alternately wetting and drying the aggregate also increases the CO2 uptake. Based on a survey presented in the study, the CO2 uptake of one ton of crusher-run concrete aggregate of size 0–40 mm is 11 kg (Kikuchi & Kuroda 2011). This negative carbon footprint should be incorporated in LCA calculations in principle. But if the CO2 uptake is the same in landfill disposal or earthworks than in upcycling then this aspect can be disregarded.

The biggest impact on the carbon footprint of concrete lifecycle comes from the manufacturing of cement. 1,5 tons of limestone is required to produce 1 ton of cement clinker and 530 kg of CO2 is released in the process. In addition, CO2 is generated from energy consumption of 4500…5000 MJ per ton of clinker. The current footprint of the energy consumption is 300 kg CO2/ton of clinker which means a total of 830 kg CO2/ton (Betoniteollisuus 2022). If the quantity of cement in the concrete formula can be reduced, this would have a major impact on the footprint.

In the Copenhagen demo case, the cement content of the formula using recycled aggregate was 10…15 % lower than in standard C35/45 classified concrete. Fly ash was used in both the reference concrete and the recycled concrete. However, the recycled concrete formula was optimised (optimizing details were not disclosed) to reduce cement use, but the reference concrete was not optimized to the specific case. Standard cements must be applicable for various usages, so they usually have a broader margin of safety. Anyhow, the study concluded that using recycled aggregate does not require an increase in the cement input (Lauritzen advising & Pelocon 2020).

The biggest effect on the carbon footprint in the Copenhagen demonstration was the energy required for quarrying the natural aggregate and transporting it. A 75 % saving in CO2 footprint was reported. This hardly can be applicable to Finland where natural granite aggregates are usually available quite near the consumption site.

Ramboll has estimated that in Finland the carbon footprint of stone quarrying is 2,76 kg CO2 per ton of quarried stone (Ramboll 2019). Recycling a corresponding quantity of concrete waste could reduce carbon emissions with an equivalent amount of CO2, if 100 % of the waste derived aggregate could be recycled. If only the 60 % of concrete waste generates aggregate that can be recycled the emission reduction potential in the Mikkeli case would be 32 t CO2 per year.

The crushing of concrete waste is estimated to have a zero impact, because crushing is anyway required as part of the demolition and waste management option. The carbon footprint of sieving is not known, but it is roughly the same for natural and recycled aggregate. However, the recycled aggregate cannot be properly sieved if it very wet or frozen, so it will need to be stored appropriately.

Transport of aggregates with trucks generate about 0,1 kg CO2 per km per ton. This will have to be calculated case by case depending on the transport.

A calculation of CO2-impacts of substituting 100 % of the coarse natural aggregate with recycled aggregate was conducted using the LCA-calculator that was produced in CityLoops project (Xamk 2022). In the case of Mikkeli demonstrations, the CO2 saving potential of recycling concrete as aggregate for production of new concrete was negative meaning that recycling does not save emissions but even increases them when compared to conventional concrete. In Mikkeli, as in Finland general, the distance of transporting virgin stone and sand from gravel pit to concrete facture is very short and even shorter than the distance of transporting concrete waste from demolition sites to concrete facture. Also, the distance to the landfill area is shorter than to the concrete factory. Therefore, the transport emissions are higher for demolished concrete than for virgin stone. Recycling of crushed concrete does not save emissions of cement, which has the greatest effect on the carbon footprint of concrete. However, recycling of crushed concrete in production of new concrete save virgin soil materials.

Indirect environmental aspects arise from the decreased pressure on using natural aggregates. The availability of easily accessible natural rock is limited in the long term. Reduction of annual consumption of natural aggregates will reduce its harmful effects on the conservation and recreational value of the potential excavation sites.

Using of recycled aggregates can in the long run reduce traffic of the transport of aggregates. In some cases, the increased crushing of concrete waste on-site can add to the noise and dust immission on neighboring residential areas.

Lessons learned and replication opportunities

The Bachelor thesis by Sara Maukonen (Maukonen 2022) demonstrated that 100 % of the coarse aggregate in the concrete mix formula can be substituted by recycled aggregate (4…32 mm). The compressive strength of the test blocks was reduced by 21…28 % when using recycled aggregate. Extra water had to be added and mixing was conducted in two stages to overcome the increased water absorption capacity of the material.

The share of fine aggregates (0…4 mm) was 43 % which is in line with Danish experiences. This fraction was not used because the Finnish concrete standard does not recognize this option. The standards should be revised to promote circular economy. Technical research is needed to assess the recycling options for this fine dust. It has a high water-absorption capacity and a considerable concentration of alkali metals and sulphates.

The concrete industry has shown much interest in the concept, but in the current situation the economic feasibility is not considered be attractive. Adopting circular criteria in tendering demolition projects is the key to changing the balance in favour of recycled aggregates. The monopoly of the municipal waste company and the low gate fees in receiving demolition waste from city owned projects constrains the business opportunities. The gate fee for receiving the waste is usually part of the recycling business concept.

Upcycling concrete waste is already a dominant concept in some Central European countries and Denmark is leading the way to the same in the Nordic countries. There is some potential for such business in Mikkeli, but the turnover potential is not more than 200 000 – 380 000 €/a. The business would be most attractive to a company that is engaged in demolition and construction services and owns a concrete plant.

The business case is applicable to any city area that generates at least 20 000 tons of concrete waste annually and has the will to promote circular procurement in demolition and construction contracts.

Annex 3. Impacts of demonstration action: Circular demolition of 2 buildings

This section summarizes the impacts of demonstration action - circular demolition of 2 buildings - achieved by Mikkeli as measured by the expected outcomes and indicators given in the city's CDW Evaluation Plan (D6.2). Intermediate-stage results of the demo actions have previously been discussed in the CityLoops Interim Evaluation Report (D6.3). Final, updated results will be presented in the CityLoops Final Evaluation Report (D6.4).

Planned outcome 1: By the end of the project, several new local stakeholder partnerships and procedures with authorities and waste management and construction companies established related to demo actions (3 stakeholder groups, 30 participating workshops/events/round tables, interviews, meetings, workshops)

Indicator	Baseline result	Final result
Indicator 6. Circularity-related stakeholder activities	0 (Only stakeholder activities during the project are measured)	1. Waste and demolition group: 20 meetings, 6 people involved (number of members in the group). 2. Construction and business cases: 31 interviews, 42 people involved. 3. Additional stakeholders: 25 meetings/workshops/marketing dialogues etc., 158 people involved.
Outcome review: • Outcome exceeded.		

Planned outcome 2: By the end of the project, the skills and knowledge of the citizens and companies in CDW sector (both in Mikkeli and national level) have increased as a result of several new/innovative/strengthened stakeholder engagement tools/procedures related to demo actions (webinars, press releases, media articles, newsletter, replication, national meetings)

Indicator	Baseline result	Final result
Indicator 11. Communication measures on circular	Baseline 0 (only activities during the project are measured)	• Webinars/seminars: 3 (201 people reached) • National dissemination workshops: 5 (187 people reached)

transformations and waste prevention		• CityLoops presentations in other webinars/events: 12 (774 people reached) • Press releases 3 (150 people reached) • Media articles: 17 (689 000 people reached) • Web articles / publications: 5 (10 071 people reached) • Newsletters: 1 (100 people reached) • Replication meetings: 17 (66 people reached) • National networking meeting: 28 (286 people reached) • Webpages: 3 (1 677 people reached) • Exhibitions/events 3 (1 315 people reached) • Social media: 10 posts (9 981 people reached)
Outcome review: • *Outcome reached. Furthermore, final webinar & workshop for regional and national stakeholders will be held in 6.9.2023. Final publication with articles presenting CityLoops results to Finnish audience will be published by the end of the project.*		

Planned outcome 3: The circular economy has been taken into account in the procurement process for demo projects and the tender includes circular economy requirements.

Indicator	Baseline result	Final result
Indicator 12. Circularity requirements in procurement beyond existing levels	0 (No circular requirements in procurements related to demolition projects. The lowest contract price is the only selection criterion. However, contract prices for waste fractions favor sorting.)	5 (1. Marketing dialogue was organised before tendering to enhance circularity, 2. selective demolition was required, 3. minimum number of sorted waste fractions was required, 4. waste management plan was required, 5. summary report on CDW management was required)

Indicator 15. Procurement with circularity requirements beyond existing levels: Impact	0 (No circular requirements in procurements related to demolition projects.)	Demolition of 2 buildings: Tuukkala hospital 278000 € and Pankalampi health centre 378000 €.
Outcome review: • *Outcome reached.*		

Planned outcome 4: New planning instrument/tools have been tested in the City of Mikkeli for decision making and monitoring of demonstration projects. Identifying procurement tool for special characteristics in a tender has been updated based on the demo projects.

Indicator	Baseline result	Final result
Indicator 21. New planning instruments/tools for improved circularity: Qualitative description	- Life-cycle assessment for demolition and renovated sites has not been conducted before the CityLoops project. - Amount of demolition waste fractions are assessed (purkujäteilmoitus) for demolition permit. Identification of hazardous materials is made at each demolition site. Identification of recyclable and reusable materials has not been made before the CityLoops project. Environmental and health effects are not monitored at demolition sites before the CityLoops project. - Amount of waste flows is recorded in the weigth station of Metsäsairila Ltd. 3D modelling has not been used before CityLoops project.	- LCA tool developed by Roskilde Municipality in the CityLoops-project have been tested on Mikkeli demonstrations. - New screening procedures and tools for selective demolition have been used: Guide produced by Finnish Ministry of Environment for pre-demolition audit was tested. CityLoops guide for pre-demolition audit and selective demolition was developed in interaction with the Mikkeli demonstration. Environmental and health effects were monitored. - 3D modelling has been tested for tracking the flows of CDW on demonstration sites.
Indicator 22. New planning instruments/tools for improved	0 (Only qualitative data for baseline is available)	- # of projects where the tools were used: 2 (Pankalampi health centre and Tuukkala hospital)

circularity: Impact		- Total mass of materials (CDW) that the tools have been impacted on per year: Pankalampi 14646 t, Tuukkala 9019 t - # of drone flights: 24 (Pankalampi), 9 (Tuukkala)
Outcome review: ● *Outcome reached.*		

Planned outcome 5: At the end of the demonstration action, 5% of materials are retained and reused on demonstration sites.

Indicator	Baseline result	Final result
Indicator 27. Increased share of materials retained and reused on demonstration sites	0 %. No materials retained or reused on site, data from previous demolition projects 2018- July 2020.	0 %. Materials were not retained or reused at demonstration sites. However, the areas were landscaped with soil produced on site (amounts not known).
Outcome review: ● *Outcome not reached. There were no new building plans in the demolition sites.*		

Planned outcome 6: Selective demolition has been used in demonstration cases. Over 95% of CDW is sorted onsite for recycling and material or energy recovery.

Indicator	Baseline result	Final result
Indicator 28. Volume onsite sorting (improved source separation)	98 % (Typical sorting rate on the demolition sites of the City of Mikkeli and private sector in Mikkeli, data 2018 - July 2020.)	Over 99 %.
Outcome review: ● *Outcome reached.*		

Planned outcome 7: Digital marketplace for secondary materials established and in use.

Indicator	Baseline result	Final result
Indicator 30. New digital material databank/marketplace: Qualitative description	Demolition materials are marketed by Mikkeli Activity Center in their store and tori.fi. In a few cases, sales days at the site.	Digital marketplace (www.kiertoon.fi) established in January 2021 and in use. Databank established and tested.
Indicator 31. New digital material databank/marketplace: Impact	0 (Only qualitative data for baseline available)	32 items/ advertisements in digital marketplace as of May 17, 2023. Estimated total amount of items: 50.
Outcome review: • *Outcome reached.*		

Planned outcome 8: By the end of the demo action, a 10% increase in the cost effectiveness in the demolition of buildings (demolition, transport and treatment of CDW) compared to the baseline values for similar demolition projects

Indicator	Baseline result	Final result
Indicator 32. Reduced costs due to improved circularity	Demolition costs 45-91 €/m^2 (floor area, average 64 €/m^2), of which waste costs 16-22 %.	Tuukkala: demolition costs 52 €/m^2 (floor area) of which waste costs 13 %. Pankalampi: demolition costs 38 €/m^2 (floor area) of which waste costs 22 %.
Outcome review: • Outcome partly reached. Total demolition costs are 30 % lower than baseline but average waste costs have not decreased.		

Planned outcome 9: At the end of the demonstration action several items (materials/equipment) have been prepared for reuse

Indicator	Baseline result	Final result
Indicator 49. Quantity of material subjected to reuse	Baseline 0 (only activities during the project are measured).	- 56 items (or type of items) sold for reuse by Toimintakeskus (e.g. HVAC equipment, furniture)

	Data from earlier demolition projects in Mikkeli is not available; reused materials have not been registered.	- 5 items (or type of items) reused by City of Mikkeli (e.g. fire stairs, back-up power equipment) - few windows - The reuse of small amount of bricks, granite tiles and oak board were demonstrated.
Outcome review: • *Outcome reached.*		

Annex 4. Impacts of city-wide application of tool A: Planning & Decision-Making Guidelines

This section summarizes the impacts of city-wide application of tool A – Planning & Decision-Making Guidelines - achieved by Mikkeli as measured by the expected outcomes and indicators given in the city's CDW Evaluation Plan (D6.2). Intermediate-stage results of the demo actions have previously been discussed in the CityLoops Interim Evaluation Report (D6.3). Final, updated results will be presented in the CityLoops Final Evaluation Report (D6.4).

Planned outcome 1: 100% of the procurement of demolition projects include the new guidelines for screening and selective demolition, making these an essential part of the procurement processes within the City of Mikkeli.

Indicator	Baseline result	Final result
Indicator 12. Circularity requirements in procurement beyond existing levels	0 (No circulaty requirements in procurements related to demolition projects.)	0 (The city has had only two demolition sites after the CityLoops demo sites. These buildings were in very poor condition, and circularity upcycling requirements were not used in the procurement process. Some circularity requirements were included (e.g., sorting). CityLoops' procurement guide will be tested in the demolition site of the city-owned housing company Mikalo Ltd in the spin-off project of CityLoops: there is ongoing procurement in which upcycling criteria will be demanded. In addition, the
15. Procurement with circularity requirements beyond existing levels: Impact	0 (No circulaty requirements in procurements related to demolition projects.)	

		new operating models will be tested in the city´s upcoming demolition site.)
21. New planning instruments/tools for improved circularity: Qualitative description	There are no guidelines for circular procurements in Mikkeli. Some statutory requirements related to the circular economy in Land Use and Building Act and the Waste Act exist. In 2018, the City Government approved a general rule for procurements where also environmental impacts are mentioned. No circular economy program or “roadmap” has been prepared for the City of Mikkeli.	Procurement guidelines for circular demolition in the city of Mikkeli have been produced. Procurement workshop was organised in November 2022 and the guide has been presented in the city's management groups. CityLoops' procurement guide was officially approved by the city in April 2023. Procedures resulting from task 2.4 "Co-development of planning and decision making guidelines" have been applied in workshops in Mikkeli. Promotion of circular economy and CE business in Mikkeli have been supported by politicians. Pre-demolition audit software/databank (developed in CityLoops´ spin off project) will help planning and decision making in the future.
22. New planning instruments/tools for improved circularity: Impact	0 (Only qualitative data for baseline available)	1 guideline produced and approved by the city (procurement guidelines for circular economy in demolition projects)
Outcome review: ● *Outcome partly reached. Procurement guidelines have been produced and approved by the City but not yet tested in the demolition projects.*		

Planned outcome 2: The City of Mikkeli is well known as "Circular Economy City" and operates according to the CE closed loops principles. Circular economy is incorporated in new strategic objectives.

Indicator	Baseline result	Final result
Indicator 19. Progress towards circular city strategy objectives (city level)	Resource efficiency (bio- and recycling economy) mentioned in the Mikkeli city strategy 2018-2021. No implementation plan. No binding guidelines, eg. for procurement.	4 (ambitition nearly reached) Mikkeli signed the The European Circular Cities Declaration in October 2020. Material recycling in construction (objectives, actions and indicators) has been included in Mikkeli's climate program due to the influence of the CityLoops project. Mikkeli city has started to publish an annual environmental statement document which has a special section on the promotion of circular economy of CDW. Environmental Services for Mikkeli Region together with Mikkeli city have started to publish annual follow-up reports of the Mikkeli Climate Program including data of circular economy indicators. Annual evaluation has started to influence the decision-making processes, because the city organisation feels the pressure to demonstrate annual progress. A chain of circular economy events was arranged in the spring of 2023 in Mikkeli region and will be repeated annually. The intention is to increase public awareness on circular economy and circular businesses. Mikkeli is presented in many national circular economy events and e.g., demonstration in the reuse of concrete elements in the CityLoops spin-off project is still very new in Finland.
Outcome review: ● *Outcome nearly reached. There has been very good progress in the strategic level on circular economy but putting the goals into practice still requires work. As a result of CityLoops, attitudes and operating culture have changed, which is reflected in the planning of future activities of the city. Mikkeli is now a well-known circular economy city as a result of many events and innovative demonstrations in spin-off projects.*		

Planned outcome 3: At the end of the project, use of CDW (especially crushed concrete) to replace virgin construction materials (soil) has increased as a result of new guidelines in planning and decision making. 5% reduction in consumption of virgin construction materials within the city of Mikkeli.

Indicator	Baseline result	Intermediate result
Indicator 35. Domestic material consumption (DMC) of virgin materials	Average consumption of virgin soil material in the infrastructure services of the City of Mikkeli: ≈16 750 t Materials used e.g., in green areas and sport areas or street maintenance are not included to the calculation.	Consumption of virgin soil material in the infrastructure services: • 2020-2021: no change to baseline (estimated data) • 2022: 21 625 t
Outcome review: • *Outcome not reached (consumption of virgin soil materials has not decreased). The use of crushed concrete e.g., by infrastructure service of the city to replace virgin soil/stone materials has not increased as much as expected. This is mainly because the city has a large amount of extra virgin stone material available because a large cave was recently excavated in the rock for a new wastewater treatment plant. Crushed concrete has been used to replace virgin soil materials especially in the field and road structures in the Metsäsairila waste management area.* • *The goal in the new climate strategy of the city is that all soil masses and demolition materials that can be reused and/or recycled will be utilized. Currently all soil masses from street construction are stored in the area of old wastewater treatment plant and will be utilized in the reconstruction of the area.*		

Planned outcome 4: By the end of the project, 5% reduction in the emissions of CO_2 related to extraction, processing and transportation (incl. logistics) of construction materials (replacement of virgin soil material with crushed concrete).

Indicator	Baseline result	Final result
Indicator 85. GHG emissions per year (demo level)	Saved CO_2 emission pr. year when using crushed concrete instead of virgin soil material: • 2019: 185 938 kg CO_2e (virgin aggregates replaced in total 26	Saved CO_2 emission pr. year when using crushed concrete instead of virgin soil material: • 2021: 400 482 kg CO_2e (virgin aggregates re-placed in total 57 212 t by Metsäsairila Ltd. No use of

	563 t by Metsäsairila Ltd and Infrastructure services) Emission of crushed rock 0,007 kg CO2e/kg (https://co2data.fi/). No emissions were calculated for crushed concrete, as it was assumed to be produced from a demolition site that would have been demolished in any case (Ramboll 2019. Ahosen Palvelut Oy – Betonimurskeen päästöselvitys).	crushed concrete by infrastructure services.) • 2022: 104 782 kg CO_2e (virgin aggregates re-placed in total 14 969 t by Metsäsairila Ltd. No use of crushed concrete by infrastructure services.) • Crushed asphalt from Mikkeli is utilized by Peab Asphalt to produce new asphalt, but the amounts are not known.
Outcome review: • *Outcome only partially reached. Emission savings increased 115 % in 2021 but decreased 44 % in 2022 compared to baseline. All crushed concrete has been used in the development of the Metsäsairila waste management area. The yearly variation in saved emissions is due to the variation in the amount of crushed concrete.*		

Annex 5. Impacts of city-wide application of tool B: Business Cases

This section summarizes the impacts of city-wide application of tool B – Business Cases - achieved by Mikkeli as measured by the expected outcomes and indicators given in the city's CDW Evaluation Plan (D6.2). Intermediate-stage results of the demo actions have previously been discussed in the CityLoops Interim Evaluation Report (D6.3). Final, updated results will be presented in the CityLoops Final Evaluation Report (D6.4).

Planned outcome 1: New products, service concepts and business models relating to the reuse/recycling and upcycling of the specific material flows established, leading to new business opportunities.

Indicator	Baseline result	Final result
Indicator 23. Eco-innovation: Qualitative description	Metsäsairila Ltd is a waste management company owned by the City of Mikkeli, whose basic task is to arrange statutory waste management services. All the CDW from the demolition sites of the City of Mikkeli are delivered to Metsäsairila. Mikkeli Activity Centre's main activities are recycling-related services and products, as well as coaching services related to employment and rehabilitation. The operations centre receives recycled materials (including materials from demolition sites) based on donations. The economic significance of the reuse of demolition materials is negligible.	Two business cases established by CityLoops: 1. Soft stripping service, 2. Recycling demolition aggregate to concrete production. In addition, the exchange of information from other countries to Finland has been promoted regarding other business cases: local reuse of wood waste, bricks, and logs.
Indicator 24. Eco-innovation: Impact	0 (Quantitative data not available)	1. The value of reusable soft stripping items from city owned buildings is about 30000 € per year. There is potential for much more. Theoretical potential has been calculated

		based on Pankalampi dental clinic demonstration case: realized selling value 2,65 €/m^2. During 2018-2021 the City of Mikkeli has typically demolished about 10000 m^2 of municipal public buildings per year. 2. Recycling demolition aggregate to concrete production: Estimated monetary value (theoretical potential) 386 000 € per year.
Outcome review: ● *Outcome reached (new business models established). The business case on soft stripping service is now considered to be piloted in the demolition case of a Moisio hospital building in Mikkeli. The business case on circular soil management and recycled aggregate use is now taken into consideration in two demolition and land use planning projects, the old Slaughterhouse and the old sewage treatment plant. In addition, the business case on reuse of concrete elements is included in a CityLoops spin-off project with Mikalo Ltd. municipal housing company.*		

Planned outcome 2: At the end of the project, the project activities are a component of creating a greener environment and providing a more sustainable economy in the city of Mikkeli (new jobs: 20 – all external).

Indicator	Baseline result	Final result
Indicator 33. CE-based employment (city level)	92 (22 employees in Metsäsairila Ltd in 2019 and 70 CE-based employees in Mikkeli Activity Centre in 2019).	126 (26 employees in Metsäsairila Ltd in 2021-2022 and 100 CE-based employees in Mikkeli Activity Centre in 2021, 2022 data not available due to change of data system). In addition, data of the following companies from year 2022 (baseline data not available): Mikkelin Romu: 7 employees Otavan Metalli: 7 employees Puijon Romu Ltd. is planning to establish operations in EcoSairila industrial park. It

		will recycle metal scrap and construction wood waste. (No jobs yet.)
Outcome review: • *Outcome reached (≈34 new CE-based jobs)*		

Planned outcome 3. At the end of the project, the recycling rate of CDW is close to 75% (CDW prepared for recycling and other material recovery, including backfilling) (95% if energy recovery included). 10% increase in recycling rate and 40% increase in upcycled amount of CDW as compared to baseline statistics from year 2019.

Indicator	Baseline result	Final result
Indicator 55. EOL-RR (End of Life Recycling Rate) (city level)	2019: 74 % (Source: statistics from Metsäsairila Ltd)	2020: 64 % 2021: 85 % 2022: 68 % (Source: Statistics from Metsäsairila, Ltd.)
Outcome review: • *Outcome reached in year 2021 but not in 2022. There is lot of yearly variation in recycling rate depending on the total amount of demolition projects and CDW (especially concrete waste) in the city. In 2022, the total amount of CDW and concrete waste was low (total CDW only 35 % from the amount of 2021). The recycling rate is higher in years, when there is more concrete waste which is utilized in soil construction.*		

Planned outcome 4. At the end of the project, 5% reduction in the amount of CDW landfilled or incinerated as compared to the baseline statistics from year 2019.

Indicator	Baseline result	Final result
Indicator 59. Incineration rate (city level)	20 % (Source: Statistics from Metsäsairila, Ltd.)	2020: 24 % 2021: 9 % 2022: 19 %
61. Landfilling rate (city level)	7 %	2020: 12 % 2021: 6 %

	(Source: Statistics from Metsäsairila, Ltd.)	2022: 12 %
Outcome review: • *Outcome reached in 2021 but not in 2022. There is lot or yearly variation in incineration and landfilling rates depending on total amounts and types of demolition projects and CDW in the city. (Data source: Metsäsairila Ltd)*		

Annex 6. Baseline situation in CDW management

Based on the in-house arrangement of demolition waste from city owned premises, all waste from the demonstration cases was delivered to Metsäsairila Ltd. Each truck load was weighed, automatically reported, and classified according to the waste types defined in the municipal company´s price list. The waste generated from the demonstration cases can be tracked to the waste centre, but the final recycling rate cannot be tracked to the level of individual demolition projects. The recycling efficiency can be assumed to follow the average treatment procedures of CDW in this municipal waste company:

Concrete and brick waste was crushed by a mobile crusher into aggregate and used on-site in landfill road constructions. All wood waste was crushed to produce low-grade renewable fuel. Mixed organic waste (cardboard, plastic, organic insulation) was treated as “energy waste” and crushed to produce solid recovered fuel (SRF) for waste incinerators.

Mineral wool insulation, gypsum board and asbestos were not utilized. Roofing felt, glass and porcelain were crushed for use in landfill road substructures. It is not clear whether this can be interpreted as recycling, backfill or landfill.

Miscellaneous construction waste is directed to a sorting hall in Metsäsairila, where the waste is sorted into transport containers of up to 20 different types of waste with the help of an excavator with a grab. In 2019, 2545 tonnes of miscellaneous construction waste entered the sorting hall, or 8.1% of the total amount of construction waste. It was sorted and the recovered waste fractions obtained are included in the recovery figures above.

In 2020, approximately 33% of all material entering the sorting hall was rejected as landfilling material. Assuming that the share of construction waste is the same, this would correspond to 840 tonnes in 2019.

Taking into account the reject from the sorting hall, the distribution of waste types looks as follows (Table 6, Figure 17):

Table 6. Evaluation of Metsäsairila Ltd. recycling rate in 2019

	AMOUNT (t)	%
Recovery as material		
Concrete	19536	62,4
Bricks	1657	5,3
Mildly contaminated concrete and bricks	57	0,2
Metals	920	2,9
Roofing felt	594	1,9
Glass	271	0,9
TOTAL (material recovery)	*23035*	*73,6*
Recovery as energy		
Wood/timber	4306	13,8
Energy waste	1537	4,9
Chemically reserved wood	346	1,1
TOTAL (energy recovery)	*6189*	*19,8*
Final disposal		
Reject from manual sorting of CDW	840	2,7
Insulation wool	596	1,9
Asbestos	376	1,2
Gypsum	269	0,9
TOTAL (final disposal)	*2081*	*6,6*
TOTAL	31305	100

The recycling rate is 73.6%, energy recovery was 19.8% and final disposal was 6.6%.

Asphalt waste and soil waste are often generated from demolition sites. These are not included as construction and demolition waste in Metsäsairila's statistics.

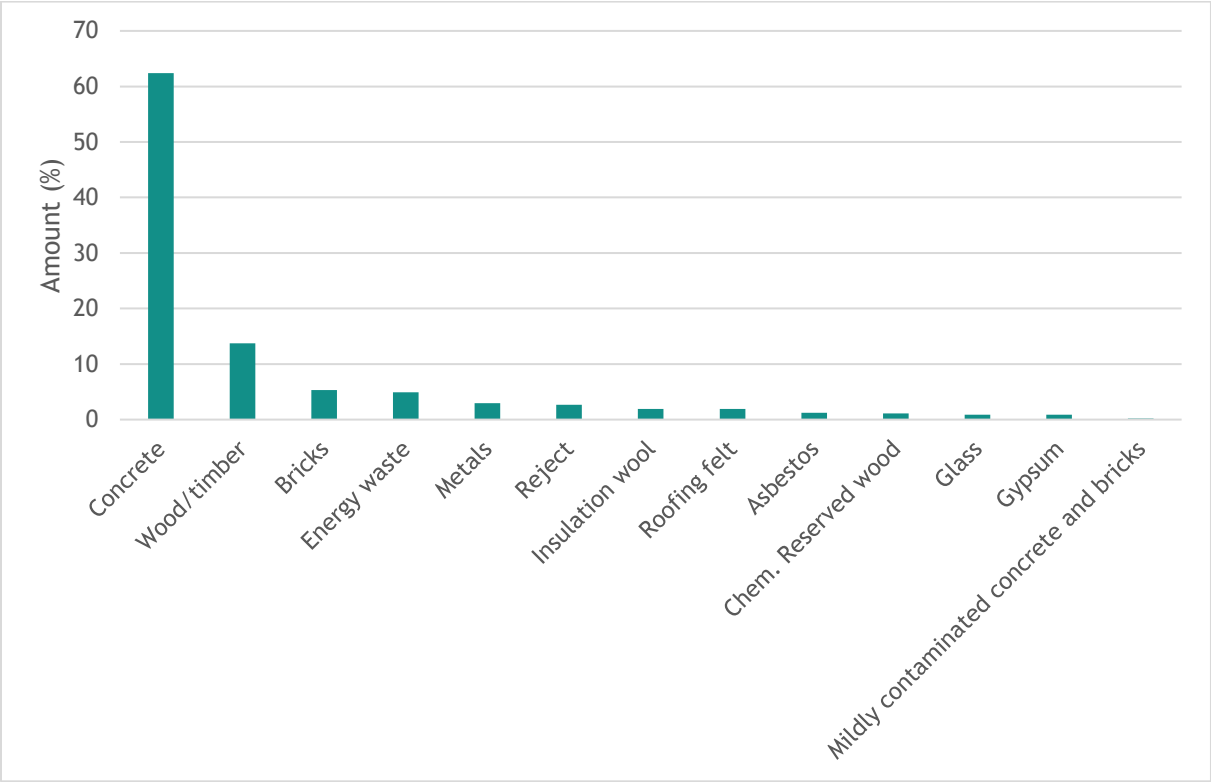

Figure 17. Distribution of Metsäsairila Ltd. construction and demolition waste by type of waste in 2019

Concrete and brick waste is received either separately or in the same load. Brick has a slightly cheaper waste fee than concrete waste, so the contractor may decide to sort it separately. After accumulating enough waste, Metsäsairila's contract supplier crushes the waste materials with a mobile crusher. The aggregate is stored pending suitable construction use.

Most of the recycled aggregate has been used in Metsäsairila's own earth works. The city of Mikkeli used about 6,000 tonnes of MARA-compliant[13] recycled aggregate on the access road to the waste center in 2019, and in 2020 Metsäsairila Ltd. used 134 tonnes at the Rämälä waste transfer station. Large quantities of recycled aggregate have been used within the waste facility premises. In 2020, there were 20,000 tons of crushed concrete and brick waste in stock. At the end of 2021, the stock had been used up, for example for the construction of a large processing field. Slightly contaminated bricks and concrete can also be used for construction or backfill in Metsäsairila's own area.

[13] MARA-compliant refers to the decree 843/2017 about the conditions for using recycled aggregate in earthworks without the need to apply for an environmental permit.

Annex 7. Monitoring results of waste fractions from demo-sites

Table 7 Estimated and actual waste amounts from Pankalampi case. Total floor area of the building 9855 m^2.

CDW FRACTION	REPORTED BY CONTRACTOR (t)	REPORTED BY WASTE COMPANY (t)	WASTE AMOUNT PER FLOOR AREA ($kg/fl\text{-}m^2$)
Concrete, tile, ceramic waste	11695	10875	1103
large cement blocks < 1 m	723		0
Mildly contaminated concrete	80	1696	172
Highly contaminated concrete		2	0
Gipsum waste	91	91	9
Wood waste	183	194	20
• Wood with surface coating	82		0
• Untreated wood (no paint, color etc.)	10		0
• Other wood waste	81		0
Wood waste from garden	9	0	0
Wood stems, contains soil		3	0
Metal scrap, mixed type	325	346	35
Glass waste	0		0
Plastic waste	0		0
Paper and cardboard waste	0		0
Soil waste			0
Asphalt waste	1141	1141	116
Bituminous roofing waste	134	149	15
Organic waste for energy recovery ("energy-waste"	4	20	2
Unsorted CDW	106	90	9
CDW for final disposal	1		0
Insulation wool	28	32	3

Asbestos waste	3		0
Chemically preserved wood (Hazardous waste)	2	4	0
Other hazardous waste	0		0
TOTAL	**14697**	**14642**	**1486**
Unsorted CDW	106	90	
Source separation efficiency	99,28 %	99,38 %	

Table 8. Estimated and actual waste amounts from the Pankalampi dental clinic building.[14] Total floor area of the building 1416 m^2.

CDW FRACTION	CONCULTANT ESTIMATE (t)	REPORTED BY WASTE COMPANY (t)	WASTE AMOUNT PER FLOOR AREA (kg/fl-m^2)	ESTIMATE % OF REPORTED
Concrete	1861	1972	1393	106 %
Bricks	220	0		
Ceramic waste	8			
Mildly contaminated concrete		360	4	0 %
Gypsum	8	6	5	125 %
Wood	42	51	36	82 %
• painted etc.	15			
• not painted	27			
Metal scrap	127	59	41	216 %
Glass	18	0	0	
Plastic	15,5	0	0	
Paper and cardboard		0	0	
Soil		0	0	
Asphalt	365	457	323	80 %

[14] these quantities are included in the overall quantities of Pankalampi case

Bituminous roofing waste	11	16	11	70 %
Energy waste		2	1	0 %
Unsorted CDW	1	12	8	8 %
Insulation wool	50	6	4	890 %
Asbestos		0	0	
Chemically preserved wood		2	1	0 %
Other hazardous waste		0	0	
TOTAL	**2727**	**2943**	**2078**	**93 %**
Unsorted CDW		12		
Source separation efficiency		99,60 %		
Efficiency when excluding asphalt		99,52 %		

Table 9 Estimated and actual amount of waste from Tuukkala Hospital. Total floor area of the building 5350 m^2.

CDW FRACTION	CONCULTANT ESTIMATE (t)	REPORTED BY WASTE COMPANY (t)	WASTE AMOUNT PER FLOOR AREA (kg/fl-m^2)
Concrete, brick and ceramic	8000	8085	1511
Gypsum	10	0	
Wood	150	102	19
Wood waste from garden		1	
Metal scrap, mixed	50	209	39

Glass	10	0	
Plastic		0	
Paper and carboard		0	
Soil		0	
Asphalt		308	
Bituminous roofing waste		0	
Energy waste	40	0	
Unsorted CDW		58	11
Insulation wool	40	0	
Asbestos	10	18	
Mildly contaminated concrete		0	
Mildly contaminated concrete < 150 mm	400	136	
Mildly contaminated bricks		75	
Contaminated bricks		26	
Chemically preserved wood	10	0	
Other hazardous waste	0,05	0	
TOTAL	**8720**	**9019**	**1686**
Unsorted CDW		58,26 %	
Source separation efficiency		99,35 %	

Annex 8. Items recovered for reuse by Mikkeli Activity Centre

Floor	Number	Product	The need for dismantling	Price estimate
1.	7	Tap several	Yes	50,00 €
	28	Sink 12 pcs	Yes	100,00 €
	32	Target light	No	2,00 €
	29-34	Fujitsu Air-source heat pump	Yes	50,00 €
	37	Trolley board	No	2,00 €
	30	Electric radiator	No	10,00 €
	31	Stainless steel table cover	Yes	10,00 €
	18	Coat rack 2 pcs	No	5,00 €
	35	Dishwasher	Yes	50,00 €
2.	1	Stand	No	2,00 €
	15	Conference table	No	50,00 €
	27	Stainless steel railings	Yes	30,00 €
	15	6 x Conference chairs	No	120,00 €
	10	Sheet metal box	No	2,00 €
	14	Containers	No	10,00 €
	18	Coat rack	No	5,00 €
	16	Electric radiator	No	10,00 €
	6	Lower cabinet	No	5,00 €
	19	Wall coat rack	Yes	5,00 €
	8	Curtains in a box	No	10,00 €
	21	Mirror cabinet	Yes	5,00 €
	20	Bidee hose	Yes	5,00 €
	26	Sink for handicaps	Yes	20,00 €
	23	Paper stand	No	2,00 €
	5	Mirror	No	5,00 €
	24	Office chair	No	10,00 €
	25	Table fans	No	5,00 €
	11	Toolboxes	No	5,00 €
	22	Overhead projector	No	10,00 €
	2	Dining table	No	10,00 €
	2	Dining chairs x 6	No	20,00 €
	13	Fridge	No	50,00 €
	35	Bosch dishwasher	Yes	100,00 €
	12	Coat rack	No	5,00 €
	9	Shredder	No	50,00 €
Basement	37	Stainless steel sink 2 pcs	Yes	30,00 €
	45	Stainless steel sink with tap	Yes	30,00 €
	46	Metal box	No	15,00 €
	49	Metal cabinet	No	15,00 €
	42	Metal shelf	Yes	20,00 €
	50	Light with shaft	No	10,00 €
	39	Wood box	No	5,00 €
	40	Protective masks	No	5,00 €
	38	Overhead projector	No	10,00 €
	41	Stool	No	2,00 €
	43	Light bulbs and luminaires	No	50,00 €
	48	Electrical supplies	No	50,00 €
	47	Toolboxes	No	15,00 €
	44	Shop stool	No	5,00 €
The yard	51	Heating posts 10 pcs	Yes	100,00 €
	52	Heat pump	Yes	50,00 €
	53	Ashtray	No	2,00 €
	54	Signpost	Yes	2,00 €
Miscellaneous		Electrical equipment	Yes	
		Luminaires, sauna heater	Yes	
		Lift-up doors	Yes	2 500,00 €
TOTAL				3 746,00 €

CITYLOOPS

CityLoops is an EU-funded project focusing on construction and demolition waste (CDW), including soil, and organic waste (OW), where seven European cities are piloting solutions to be more circular.

Høje-Taastrup and Roskilde (Denmark), Mikkeli (Finland), Apeldoorn (the Netherlands), Bodø (Norway), Porto (Portugal) and Seville (Spain) are the seven cities implementing a series of demonstration actions on CDW and soil, and OW, and developing and testing over 30 new tools and processes.

Alongside these, a sector-wide circularity assessment and an urban circularity assessment are to be carried out in each of the cities. The former, to optimise the demonstration activities, whereas the latter to enable cities to effectively integrate circularity into planning and decision making. Another two key aspects of CityLoops are stakeholder engagement and circular procurement.

CityLoops started in October 2019 and will run until September 2023.

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