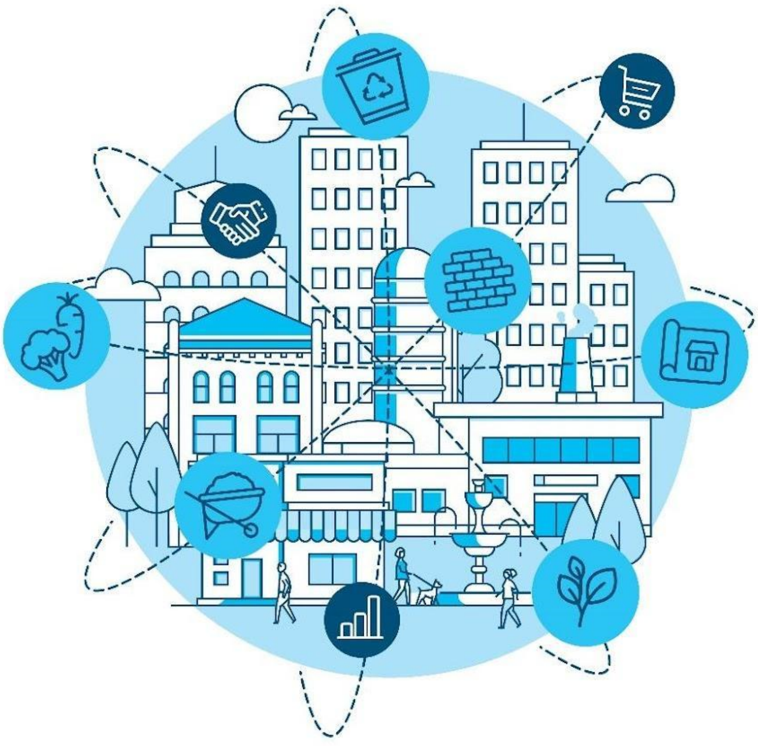
CIRCULAR CDW in Roskilde

Demonstration Report

Municipality of Roskilde



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Contents

1. Executive summary

The transition towards a circular build environment requires new approaches to construction, demolition and urban development. In the EU 2020 project CityLoops, the municipality of Roskilde, have developed procedures, methods, instruments and generated knowledge to promote a circular transition, through a series of demonstration projects. These activities was based in the urban development area Musicon, a transformation of an old concrete factory and former waste deposit. The area contains a series of production halls and the development of the area focuses on preserving the industrial aesthetic as well as the existing buildings, to be a hub for creativity, music and cultural activities.

The demonstration projects concern the 1) transformation of some secondary buildings, 2) construction of two Car Parks and 3) circular soil management in the area.

Activity 1 Transformation of Hall 11 & 12

Hall 11 and 12 are secondary buildings situated in the demonstration area. Hall 11 will be partly demolished and materials from the demolition incorporated into other construction projects. Hall 12 is preserved and renovated keeping its current function as a skaterpark. Some of the high quality aggregates such as steel structures are dismantled and preserved. Hall 12 will be connected to one of the car parks.

To secure the quality of the materials, the following actions was applied:

- A pre-demolition audit and selective demolition was performed to preserve and document the materials.
- A material passport afterwards documented the quality of materials and possible application.
- A virtual material bank was developed using Building Information Modelling (BIM) for information on regulations, quantities, material types, etc.
- Life cycle assessment (LCA) on selected materials was performed to support decision making by revealing the carbon emissions impacts of different handling options.

Activity 2 a multi-storey Car Park "Indfaldet"

Based on experiences from minor construction projects, the Car Park Indfaldet was developed as flagship to apply circular actions in a larger commercial projects. Thus, circular tender criterion was included to engage market dialog focussing on recycling of materials, design for disassembly, multifunctionality, and reduced CO2 emissions. When preparatory digging for the car park was initiated, a large amount of concrete obstacles was discovered, originating from concrete production activities from the past. The concrete was stored and crushed on site, to be integrated in the construction of the car park as filling under the foundation and as aggregate in the new concrete.

Activity 2 b Car Park "Pulsen"

The second multi-storey car park will be built as a steel structure. Besides using recycled concrete aggregate in the foundation, application of reused hollowcore concrete elements, is furthermore tested moving up the waste hierarchy. As this requires a very different risk assessment method, involving close cooperation between advisor, contractor and building authority. Moreover, a physical material bank on the ground floor will be created and a roofed passageway between the car park and hall 12 will connect the projects.

To secure the quality of the materials, the following actions was applied:

- A Sustainability plan was developed for the projects and quality criteria was formulated to secure circular decision-making in procurement.
- A Design for disassembly manual was created and demountable joints applied to preserve materials for future use.
- An LCA was performed to document environmental benefits of reuse and recycling.
- Multifunctionality involving local stakeholders provided the car park higher value to the community and more efficient use of m2.
- Reuse and recycling of materials reduced CO2 emissions and consumption of virgin resources.

Activity 3 Circular soil management

To secure circular soil management, thus minimising excavation and transportation of soil by using excess soil locally, a series of instruments were tested in Roskilde. To support planning and decision-making in the Hall 11/12 area, LCA calculations were performed to assess the CO2 impact of minimising excavation and transport of soil. Moreover, barriers in reusing soil were uncovered by interviewing authorities, clients, advisors and contractors with experience in projects involving circular soil management.

At the strategic level activities supporting the development of a circular soil strategy was conducted. Feeding into such strategy a framework for circular soil handling was tested, and a prediction of potential generation of soil to be excavated in the coming years was performed.

1.2 New approaches/instruments

To support the promotion of circular construction, demolition and urban development, a series of methods, instruments and tools was developed and tested in the demonstration projects. In Roskilde the following were developed and/or tested:

Procedure for CDW to obtain a Material Passport

The procedure consists of first, an environmental and resource screening to identify materials or elements for reuse and recycling. The information is typed into an Excel sheet, which forms the Material Passport. Information includes procedures for handling and application a structural assessment of the materials and recommendations for application. If the materials are planned for reuse or recycling, information about location of storage and expected future use (time, place and building) is also included. If this is the case, the elements or materials will be added to the tendering of the selective demolition.

When the demolition is completed, the elements and materials are assessed for further tests required for reuse/recycling based on a colour coding. Green means they are fit for direct reuse/recycling, yellow means they need further testing, red means they should not be reused/recycled. The local construction authority can then authorize use of the materials in a new construction if they fulfil the requirements for application.

Lifecycle CO2 calculator for construction materials

Lifecycle CO2 calculator - soil

Based on an LCA methodology, the tool calculates the CO2 impact of excavating and moving soil from a site. In the demonstration phase, the methodology has been applied in planned soil movements in Musicon, including the demolition and reconstruction works of hall 11/12, and is also considered in the procurement process for the demolition works, to encourage site soil balance.

Lifecycle CO2 calculator - Concrete

The tool calculates the lifecycle CO2 impact of using and demolishing concrete. The tool was used in the pre-demolition screening of Hall 11/12 to encourage preservation and recycling of concrete. The tool will also be applied to other projects in the Musicon area.

Lifecycle CO2 calculator - CDW

Building on the CO2 calculators for soil and concrete, the calculator for CDW, was expanded to 11 fractions and developed to specifically support planning and decision in the demolition process, on whether to keep and refurbish, deeply renovate, or demolish a building by comparing a multi-material composite calculation taking into account the pre-demolition state, and post-demolition state of the CDW. The tool has been tested at Hall 11/12 and the methodology will be applied in other projects in Musicon.

Pre-demolition audit guide

This guide helps to prepare selective demolition and covers both the environmental audit focusing on identification of hazardous materials, and the circular audit focusing on elements for reuse and materials for recycling. It has been developed based on the Finnish guidelines in cooperation with Mikkeli, Apeldoorn, Høje-Taastrup and Capital Region Denmark.

Selective demolition guide

This guide explains how a selective demolition can be conducted to select and preserve the value of building components and materials with reuse and recycling potential. It has been developed based on experiences in Denmark, Austria and Belgium.

Framework for circular soil management

Roskilde is incorporating a circular soil strategy in urban development strategies as well as real estate management strategies. A builder’s guidance has been developed as the project planning went on for the demonstration project at the parking house area in Musicon. In the process the builder’s guidance has been designed to address each identified barrier. For tendering, prices and CO2 calculations have been lifted to the same strategic decision level in order to highlight the economic potential of circular soil management in the future. The effect of the circular soil strategy has been evaluated on project level by comparing predicted soil volumes with soil volumes which has proved to be suitable for use inside the project area. Current builder´s guidance concentrates on the description of the procedure regarding necessary steps in the initial work prior to the project planning, and simultaneously with the construction process.

The framework is applied to identify levers, plans, procedures or tools promoting circular soil management in Roskilde Municipality to support the development of a circular soil strategy. Key actions are identified at the strategic, tactic and operational level including main actors to be involved, thus supporting the alignment of strategies, plans and operational procedures. The effect of the circular soil strategy will be evaluated on an annual basis by comparing predicted soil volumes with soil volumes actually produced in corresponding years.

Instrument for predicting future excavated soil production

Roskilde has used this tool to predict annual volumes of future excavated soil within a period of 12 years (2020-2031). It will be evaluated by comparing predicted soil volumes with annual soil volumes reported. Drawing on data from planned future construction works, the prediction is based on a “business as usual” scenario, considering a situation where municipal planning and construction activities are performed without paying special attention to excavation and production of excavated soil, to mobilise planning efforts to avoid soil excavation, contamination and movement – creating both economic and CO2 savings.

2. City context

Roskilde municipality is located in the eastern part of Region Zealand covering an area of 212 km2. It is the most inhabited municipality in the region with 89,001 inhabitants in 2021 and is characterised by a steady increase in population, namely by 2.67% from 2017-2021. The population in Roskilde is largely represented by higher education - more than twice as much as in the rest of the Region Zealand. Roskilde University attracts a number of new citizens every year and a portion of those stay in the municipality when they start working. This is balanced by a growing portion of elders in the population, since the number of deaths is decreasing.

The municipality is characterised by a mixed land use. Agriculture and nature fill up a significant part of the landscape. Low rise dwelling areas also dominate the land use. In 2021, there will be a special focus on changed land use, nature conservation and increased biodiversity on municipal land, cooperation on afforestation, further development of the nature areas close to the city, and improved access to nature.

The construction industry plays a key role as the second largest industry in the municipality and contributes to the economic activity overall. The construction industry accounts for 13% of the total industry. The construction sector of Roskilde is characterised by many small to medium sized companies in the construction sector. Most are associated with raw material production and typical craftsmanship.

The demonstration area in Roskilde is Musicon, a 200,000 m2 former concrete factory and gravel pit, located in the middle of Roskilde's south city between the city centre and the Festival/Animal Show Square, which Roskilde Municipality (RK) bought in 2003. Beginning in 2008 the ambition was to create a new neighbourhood with no grand masterplan. Instead the area is developed through a series of projects in collaboration between citizens, developers, architects, cultural institutions, local businesses and the municipality, also focussing on refurbishment of existing buildings and reuse and recycling of structures, construction materials and soil to be applied in new constructions.

Musicon today contains a modern dance theatre, artist workshops, skate hall, Denmark's Rock Museum “Ragnarock”, the newly opened Folk High School “Roskilde Festival Højskole”, the award-winning Rabalderparken, which combines rainwater collection and recreation and more. When Musicon is fully developed, the aim is for the district to contain 1,000 homes and 1,000 workplaces.

In 2018, Roskilde Municipality adopted an ambitious property strategy with a focus on sustainability. The success criterion for sustainability in the municipality's property portfolio must not only be measured by whether new projects become sustainability certified, but equally by whether the municipality's construction projects relate to the basic sustainability parameters a) environmental sustainability (e.g., energy efficiency, resource consumption, minimise environmental and climate impacts), b) economic sustainability (e.g., minimising operating costs, higher rental prices, total cost of ownership) and c) social sustainability (e.g., increased well-being, better indoor climate, flexibility, accessibility, safety). The following properties action plan 2021-2022 prescribes that all construction projects must, in the planning phase, uncover the sustainability potential through to be founded in a sustainability plan.

3. Implementation

3.1 Implementation Activities

3.1.1 Hall 11/12

Introduction

Hall 11 is a secondary building situated in the demonstration area. It will be partly demolished and materials from the demolition will be incorporated into other construction projects. The function of hall 12 was and will remain a skate hall. Beams and pillars and the main steel structure of hall 12 will be preserved - therein lies the greatest savings in materials and CO2. The building will get a new roof, new façade and new interior. Hall 12 will be connected with a new multi-storey car park by a roof spanning 12 x 45 metres.

The buildings had a pre-demolition screening and selective demolition will take place, keeping reusable elements in storage for reuse in new buildings and creating material passports documenting their quality and possible use. A virtual material bank will be created through design for disassembly using Building Information Modelling (BIM) for information on regulations, quantities, material types, etc. LCA on selected materials will aid in decision making by revealing the carbon emissions impacts of different handling options. Roskilde will also try to implement circular soil strategies in the project by minimising soil movement and facilitating reuse on site.

Transformation of Hall 12

Hall 12 is preserved and renovated keeping its current function as a skaterpark. Some of the high quality aggregates such as steel structures are dismantled and preserved. Hall 12 will be connected to one of the car parks.

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Lifecycle CO2 calculator for construction materials

Lifecycle CO2 calculator - soil

The tool calculates the CO2 impact of excavating and moving soil from a site. In the demonstration phase, the methodology has been applied to planned soil movements in Musicon, including related to the demolition and reconstruction works of hall 11/12, and is also considered in the procurement/ bidding process for the demolition works, to encourage site soil balance.

Lifecycle CO2 calculator - Concrete

The tool calculates the lifecycle CO2 impact of using and demolishing concrete. This tool will be used in the Hall 11/12 pre-demolition screening to make decisions about the demolition and recycling of concrete. The tool will also be applied to other projects in the Musicon area.

Lifecycle CO2 calculator - CDW

The LCA tool for CDW (11 fractions) will serve as a planning and decision making tool, specifically for the demolition process, helping you to make different decisions on whether to keep and refurbish, deeply renovate, or demolish a building by comparing a multi-material composite calculation. It will take into account the pre-demolition state, and post-demolition state of the CDW. The tool has been tested at Hall 11/12 and the methodology will be applied in other projects in Musicon.

CO2 calculator for soil

ROSKILDE MUNICIPALITY ROSKILDE FOREVER

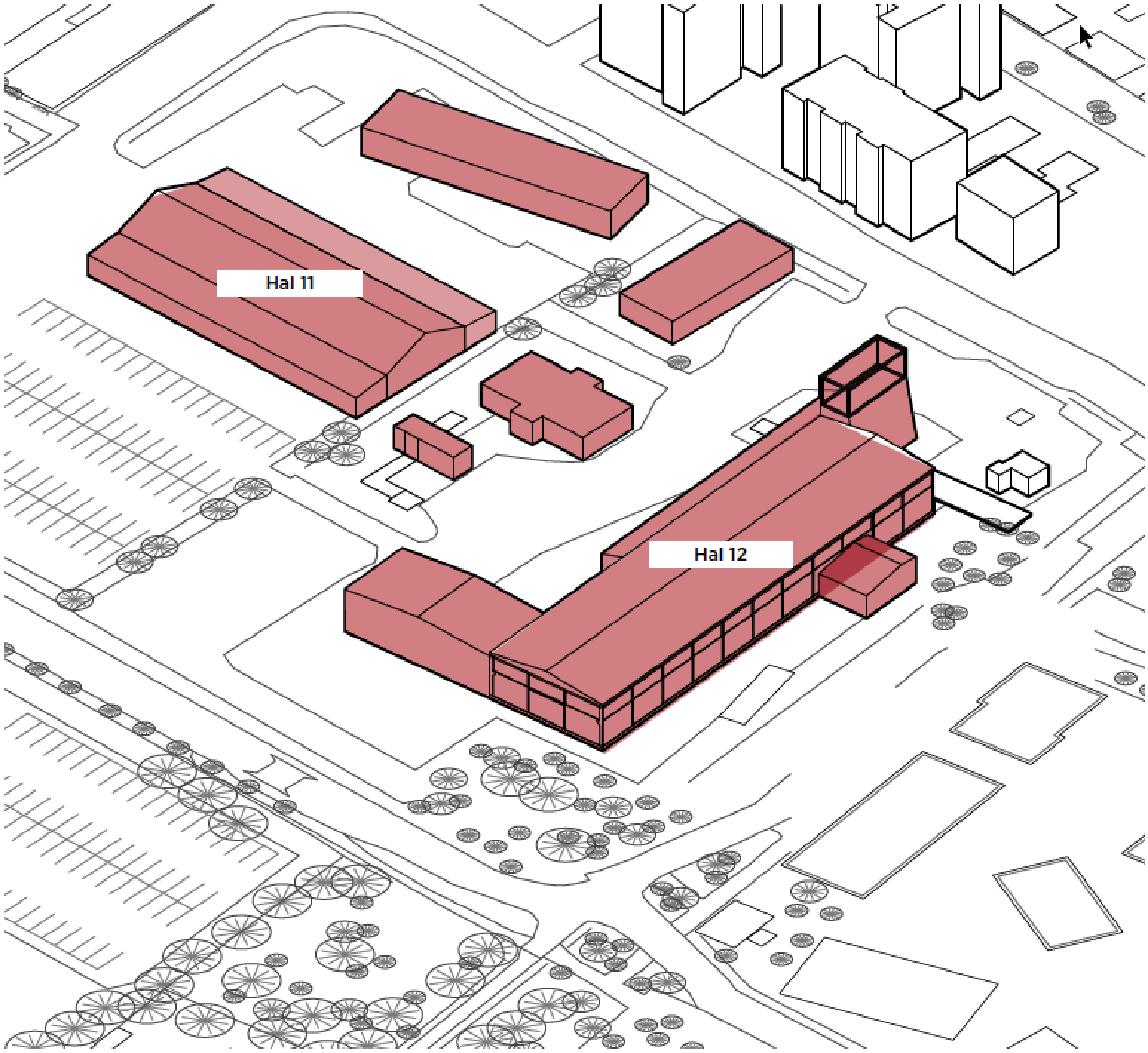
Comments	LCI	
Cells marked in light blue, should be filled. All distances are calculated from site where soil is excavated.	Distance to end deposite, km	25
	Distance to local reuse, km	3
	Amount of soil, tons	9000
	Reuse percentage	100
	Use of wheel loader, hours	25
	Use of dumper, hours	25
CO2-emissions soil transport per tonne kilometre	Soil transport, kg CO2/tonkm	0,081
CO2-emissions crushing per tonne material, diesel crusher	Wheel loader, kg CO2/hour	25,68
CO2-emissions local transport	Dumper, kg CO2/hour	37,54
CO2-emissions full trailer combination, two way transport	Transport of loader and dumper kg CO2	135,13
	Kg CO2e per liter diesel	2,65

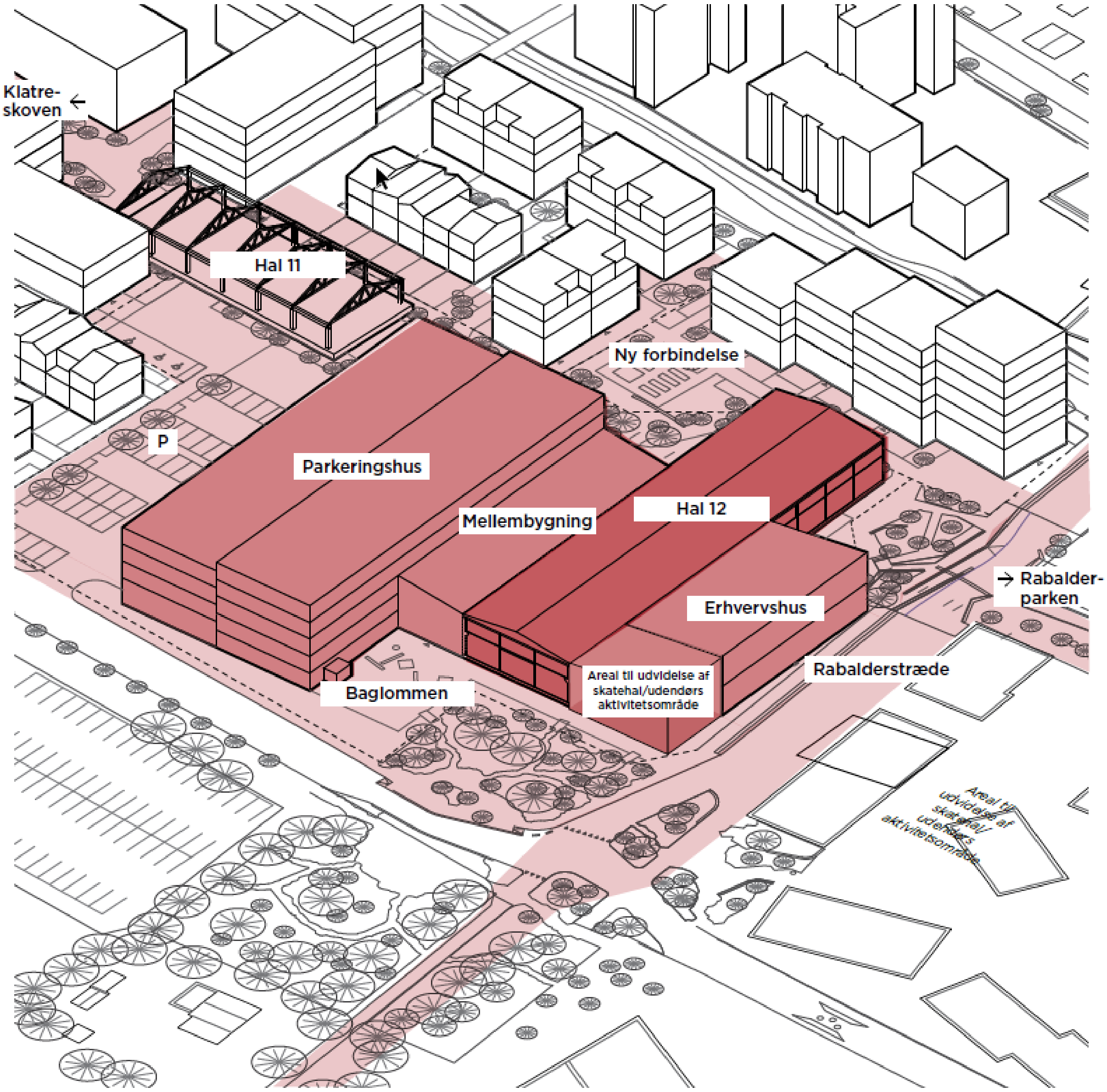
CO_2 saving potential		
Soil transport	**Project CO2 saving**	**reference**
Transport to end deposite, kg CO2		18.293
Transport to site for reuse, kg CO2	2.195	
Use of wheel loader	642	
Use of dumper	939	
Transport wheel loader and dumper	135	
Kg CO_2	**14.382**	**Reference**

Partial demolition of Hall 11 and 12

Hall 11 is a secondary building situated in the demonstration area. It will be partly demolished and materials from the demolition will be incorporated into other construction projects. The function of hall 12 was and will remain a skate hall. Beams and pillars and the main steel structure of hall 12 will be preserved - therein lies the greatest savings in materials and CO2. The building will get a new roof, new façade and new interior. Hall 12 will be connected with a new multi-storey car park by a roof spanning 12 x 45 meters.

The buildings had a pre-demolition screening and selective demolition will take place, keeping reusable elements in storage for reuse in new buildings and creating material passports documenting their quality and possible use. A virtual material bank will be created through design for disassembly using Building Information Modelling (BIM) for information on regulations, quantities, material types, etc. LCA on selected materials will aid in decision making by revealing the carbon emissions impacts of different handling options. Roskilde will also try to implement circular soil strategies in the project by minimising soil movement and facilitating reuse on site.


Hal 11
Hal 12


Klatre-
skoven
Hal 11
Ny forbindelse
P
Parkeringshus
Mellembygning
Hal 12
Erhvervshus
Rabalder-
parken
Rabalderstræde
Areal til udvidelse af
skatehal/udendørs
aktivitetsområde
Baglommen

The transformation of Hall 12 should be carried out with respect and sensitivity towards the building's existing qualities and unique ambiance. These are characterised by:

- Graphic compositions
- Space for interpretation
- Uncompromising expressiveness

The goal is to preserve and enhance these characteristics during the transformation process, ensuring that the essence and atmosphere of Hall 12 are maintained. The graphic compositions within the space, along with the freedom for individual interpretation, contribute to its distinctiveness.

Graphic Compositions

The existing Hall 12 is a rational and simplistic structure with strong concrete pillars and beams, and long bands of windows above closed facades. The closed nature of the facades and the high-set windows give the hall a secretive and intriguingly dim appearance, which are qualities that are desired to be preserved in selected parts of the future skatepark, while the building as a whole opens up to the surroundings.

The large, uniform ceiling unifies the space and features visible concrete panels that, in contrast to the robust beams, appear elegant. The overall composition of large, simple surfaces and continuous lines holds exciting contrasts and graphic qualities that should be carried into the future skatepark - and should also be refined in the integration between new and old building elements.

Space for Interpretation

When the former concrete production facility shut down around the turn of the millennium, the factory buildings were not only emptied of content and activity but also of meaning. For skateboarders, the functionally empty hall became a space for interpretation, free from predetermined programs, with an inspiring invitation for new and creative interpretations. In Hall 12 today, one can observe rational, beautiful, and humorous encounters between the industrial remnants and the new functionality and expression.

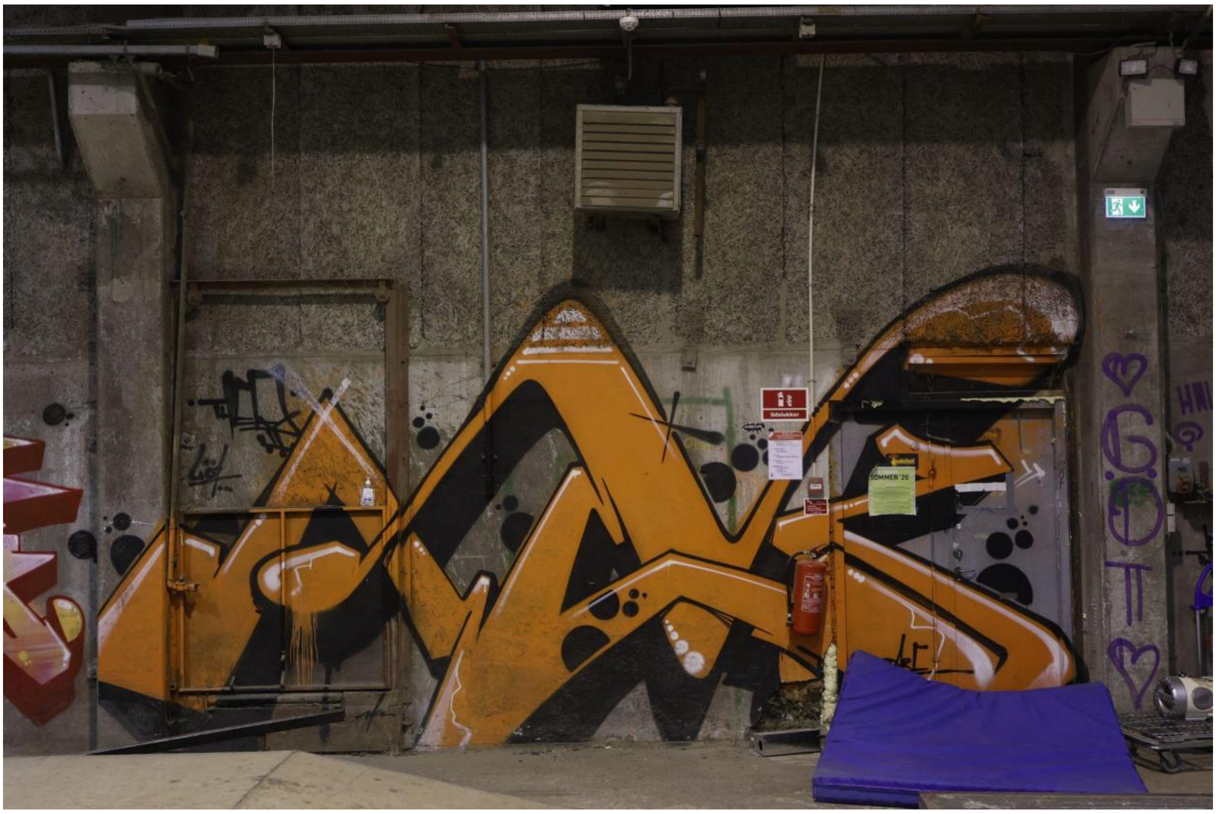
Some of the industrial remnants should also be preserved to serve as reminders of the history and ignite curiosity.

Expressiveness through circularity

In addition to preserving the hall's industrial identity and raw environment, the transformation is also crucial for the project's sustainability, as the direct reuse of the building's structures will result in a significant reduction of greenhouse gas emissions compared to using new materials. Building preservation will therefore be complemented by the reuse of building components and materials. With this circular focus, the sustainability and aesthetics of the building begin to intertwine and become interdependent.

This circular approach aligns well with the municipality's overall work on sustainability in Musicon. Broadly speaking, the urban development of Musicon is a massive transformation project that upcycles a polluted former concrete factory, gravel pit, and landfill into a new dense and mixed-use neighbourhood. The development of the area incorporates a range of overarching and holistic sustainability principles that are put into practice and implemented throughout the area in specific construction and infrastructure projects.

Reusing the former industrial buildings and preserving traces of the industry as part of the area's identity and aesthetic expression has been a central aspect of Musicon's development. Roskilde Municipality has therefore gained previous experience in preserving structural building elements as character-defining elements in new construction and creating an entirely new aesthetic expression through a playful and unconventional use of recycled building materials.



Materials and Materiality

Prior to the renovation and expansion of Hall 12, a side building, a tower, and a canopy will be demolished, releasing construction materials that can be reused in the skatepark and thus recycled locally. The reusable materials have been carefully catalogued, allowing them to be gently extracted during the demolition and temporarily stored.

The renovation of Hall 12 provides an opportunity for a creative design process, where unconventional solutions can be explored, and surprising and playful aesthetic expressions can be created. The specific potentials for reuse will be investigated collaboratively with the involved design-build teams during an extended bidding phase.

In this work, emphasis will be placed on:

Creative use of recycled materials that contribute to the development of a new, resource-appreciating aesthetic.

Efforts to incorporate reuse in load-bearing structures.

Minimisation of construction waste through preservation or local reuse of materials that are extracted.

Drawings and photos on the opposite page illustrate the materials that will be released for reuse during the preceding demolition and where they may potentially be reused in the construction. Recycled materials from outside sources, such as windows discarded due to low insulation capacity, can also be added to the project.

In addition to recycled materials, a significant portion of the skatepark's materiality is expected to consist of plywood panels used for the floor, walls, and ramps. This will create a warm and soft backdrop in the hall, contrasting beautifully with the visible concrete structures. The plywood also provides acoustic dampening and serves as a good canvas for graffiti murals, which are expected to contribute to the atmosphere and architecture with vibrant colours and designs.

Furthermore, the skatepark will be enriched with architectural and artistic quality through the design of seating stairs/bleachers as prominent, sculptural, and inviting space-defining furniture, as well as the integration of a permanent artwork.

Screening procedure and selective demolition

Hall 11/12 has been screened for material inventory by Golder using the CityLoops Pre-demolition audit guidelines. The selective demolition procedure will be applied according with the CityLoops Selective demolition guide to three buildings in the hall 11/12 area at Musicon, to identify and keep materials with potential for reuse.

The procedure was expanded to involve more key actors in the value chain. This meant in the case of pre demolition screening of Hal12 Special environmental consultants, architect, demolisher, contractor and representatives from the municipality were present at an initial planning meeting and later on at a physical inspection on site. At the physical inspection everybody was asked to keep an open mind and listen to others' experience and ideas. This kind of process demands very clear communication from the building client, in this case the municipality. If the purpose and frame for the work is not clear, many will not know how to act in the process. Basically it is a creative process and it was evident that the architect was familiar with the idea, but the environmental consultant on the other hand needed a bit more time and words before they were comfortable with the process.

We spend time talking about the process together in advance, so everybody grew to trust each other. This element of trust is key to understanding the procedure, since we will not be able to do anything, if elements like responsibility and risk are not kept open until later in the process.

Everybody was encouraged to flag any elements of risk they were aware of at any time in the process. This meant that everybody felt secure to bring up risk elements, since it was our common responsibility to solve it. This again led to very fruitful discussions and creative problem solving in the process. As an example a certain building element would be discussed, e.g. a fire door. The different members of the screening group would each have their own focus. The environmental consultant was worried about hazardous substances in the paint and sealant. The contractor focused on dismantling the doorframe from the wall. The construction client focused on the value of the door opposed to a new door, and the architect loved the graffiti on the door. So the procedure would start by determining the possible future use of the door. If the architect could see any use of it, the construction client would be asked whether he saw any use of the door. If it passed this initial test, the contractor was asked whether he could take down the door without ruining it for future use and without spending too many hours doing so. If the door still was interesting for reuse, the environmental consultant would be asked to test the door according to the agreed future use. scenario.

The experience in Roskilde has shown the importance of involving all key actors in the early stages in order to minimise risk building.

Resource mapping

When a building is to be demolished or renovated, the developer is responsible for identifying and reporting any waste that may be classified as hazardous to the municipality. This is done through an environmental screening, which involves taking samples of the building components and materials involved in the construction project. It is through this screening that environmentally harmful substances are identified.

Before demolition or renovation, the building owner can conduct a more detailed examination of the building to map the available resources. This mapping provides a detailed overview of the materials suitable for reuse, recycling, and material recovery.

The buildings have been screened by Golder (a contracted consultant) using the CityLoops pre-demolition audit guidelines along with the local procedure for pre-demolition in Roskilde. It was essential for the usability of resource mapping that it was carried out in the initial phase of the project in conjunction with or as an extension of an environmental survey of the building. The information about hazardous substances from the environmental survey was an important parameter for assessing whether the available materials could be considered resources or if they needed to be managed and disposed of as contaminated or hazardous waste. Together, these mappings formed the basis for subsequent planning and description of the demolition process.

Based on the resource mapping, the building owner could demand the extraction of demolition materials for reuse, recycling, or other forms of material recovery. For all materials that were removed from the building, sufficient information had to be provided to assess their circular potential.

'End of Waste' criteria for materials intended for recycling or other forms of recovery

Depending on whether the demolition material is intended for reuse, recycling, or recovery, there are different requirements for documenting its location, condition, environmental impact, etc. To achieve maximum transparency and flexibility, it is advisable to collect the same information for all materials intended for circular processes. This ensures that demolition materials can move from one category to another without requiring additional documentation in the regulatory process.

In Section 6 of the EU Waste Framework Directive (DIRECTIVE 2008/98/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL), a series of conditions are listed that must be met for waste that has undergone a recycling operation or another recovery operation to be considered as ceasing to be waste. These are referred to as the 'End of Waste' criteria:

(a) the substance or object is commonly used for specific purposes;

(b) a market or demand exists for such a substance or object;

(c) the substance or object fulfils the technical requirements for the specific purposes and meets the existing legislation and standards applicable to products; and

(d) the use of the substance or object will not lead to overall adverse environmental or human health impacts.

In other words, the above criteria needed to be addressed for demolition materials to cease being waste and be incorporated into new construction.

Requirements for reuse materials: "Reuse" referred to the reuse of products or components for the same purpose for which they were designed. An example of reusing construction materials from demolition projects was using bricks from masonry or entire floorboards that originated from the demolition of existing buildings and were reused in new construction as part of the masonry or flooring.

Construction materials from demolition projects that could be used for reuse were not considered waste and therefore did not need to be managed according to waste regulations. This meant that construction materials from demolition projects could be handled and freely sold by anyone, and it was not the responsibility of a municipal authority to grant permission for the handling of these materials.

Step-by-step procedure: In Roskilde Municipality, we aim to follow this procedure for all circular demolition of municipal buildings:

1. During the mandatory environmental screening, the circular potential of the demolition materials is assessed through a resource mapping, and the building owner decides to what extent materials should be extracted for reuse or other forms of recovery during demolition.
2. The 'End of Waste' criteria are assessed for all materials with circular potential.
3. A material passport is created and pre-filled for all materials with circular potential. The material passport accompanies the material throughout the entire process. The material passport should contain at least the following information: a) Location of the building from which the material is extracted. b) Information about where the material will be stored until the time of reuse or recycling. c) Description of the material, including its dimensions and quantity. d) Test results from mandatory environmental screening and possibly resource mapping, including an assessment of the material's condition/durability. e) Assessment of the fulfilment of the 'End of Waste' criteria, including the expected future use and anticipated time of use. f) Photographic documentation of the demolition material.
4. Prior to demolition, a dialogue is conducted with the waste authority to provide an overview of which materials are expected to be reused, recycled, or disposed of.
5. Before demolition, the contractor applies for permission to dispose of materials deemed as construction waste.
6. Environmental inspections are conducted during the demolition process to ensure proper treatment of the demolition materials.
7. At the conclusion of the demolition, the information in all material passports is updated.

8. Prior to the reuse of materials, either the producing contractor/building owner or the receiving contractor/building owner applies for 'End of Waste' approval.
9. If materials intended for reuse are no longer desired, the material owner must apply to the waste authority, by the expected time of reuse stated in the material passport, for either permission to dispose of the material or permission for 'End of Waste' if the material is intended for recycling.
10. In case the reuse of materials is delayed or changes compared to the expectations stated in the material passport, the material owner must inform the waste authority about the revised use or schedule for the material, prior to reuse or by the anticipated time of use stated in the material passport.
11. Upon completion of incorporating reused, recycled, or otherwise recovered materials, the information in the relevant material passports is updated.

LCA on selected materials have been performed as well. Selective demolition will take place between March – August 2023, keeping the main structure intact. Concrete recovered from the demolition will be crushed for recycling into new concrete in the construction of the new multi-story car park.

This procedure was repeated for all relevant materials and ended up on a list with information on the materials location, future use scenario, need for further testing, number, etc. This list later on transforms into material passport.

Construction material passport, databank and digital market place

A material passport will be created for selected materials from the demolished buildings. A virtual material bank is sketched and will be used for hall 11/12 - both for materials going out from the selective demolition and in construction of the new renovated hall. The first version consists of an Excel sheet for each material, describing its lifespan, what kind of testing it has to go through, and where it could end up in future uses.

The virtual material passport and databank are merged in one database. The circular procurement strategy includes use of the virtual material bank to source and supply secondary construction materials. The data is extracted from BIM models and kept in a database.

GOLDER MEMBER OF WSP

Musicon, Hal 12 området: Materialepas

Materiale-kategori	Materiale	Lokalitet (Hal nr)	Reg nr.	Nærmere placering	Antal	Dimension	Foto	Miljøforhold: (A) Særlige arb.miljøkrav ved håndtering (skæring i materialet - afrensning af maling) (B) Særlige miljøkrav ved bortskaffelse som affald (C) Særlige krav ved genanvendelse og indbygning mht. indeklima (se *Miljøforhold* ark for nærmere beskrivelser)	Holdbarhed/ stand	Mulighed for/ metode til adskillelse	Potentiale (skriv bogstav) Genbrug lokalt (A) Genanvendelse lokalt (B) Genbrug / genanvendelse andetsteds (C) Bortskaffes (D)
Døre - træ/metal	Dobbelt trædør Venstre ud Venstre-gående	H12	**H12.H.5**	Hal 12 - nordlig ende - streetskate område. Udgang i vestlig facade	1	210 x 88 cm		Prøvetaget. Miljøforhold i maling: **A1** **B1** **C1**	God stand	Karmskruer skrues ud og døren inkl. karm tages forsigtigt ud. Dør opbevares fastmonteret i karm. Skruer og propper gemmes. Håndtag og greb afmonteres og opbevares sammen med døren. Døren stilles lodret på palle, med skråstivere monteret (som ved nye døre). Opbevares tørt og indendørs.	A Kan genbruges i ny hal 12
Døre - træ/metal	Dobbelt trædør Venstre ud Venstre-gående	H12	**H12.H.6**	Hal 12 - nordlig ende - streetskate område. Udgang mod silo i nordlig gavl	1	210 x 195 cm		Prøvetaget. Miljøforhold i maling: **A2** **B2** **C2 (PCB)**	God stand	Karmskruer skrues ud og døren inkl. karm tages forsigtigt ud. Dør opbevares fastmonteret i karm. Skruer og propper gemmes. Håndtag og greb afmonteres og opbevares sammen med døren. Døren stilles lodret på palle, med skråstivere monteret (som ved nye døre). Opbevares tørt og indendørs.	A - B Kan bruges til konstruktion i skure. Kan alternativt bruges indendørs hvis maling afrenses.
Døre - træ/metal	Dobbelt ståldør Venstre ud Venstre-gående	H12	**H12.H.7**	Hal 12 - nordlig ende - streetskate område. Udgang i vestlig facade	1	210 x 150 cm		Prøvetaget. Miljøforhold i maling: **A2** **B2** **C2 (metaller) (gennemsnitskoncentration)** **C2 (PCB)**	God stand	Karmskruer skrues ud og døren inkl. karm tages forsigtigt ud. Dør opbevares fastmonteret i karm. Skruer og propper gemmes. Håndtag og greb afmonteres og opbevares sammen med døren. Døren stilles lodret på palle, med skråstivere monteret (som ved nye døre). Opbevares tørt og indendørs.	A - B Kan bruges til konstruktion i skure. Kan alternativt bruges indendørs hvis maling afrenses.

Roskilde asks for the BIM in the tendering process for each building to be built at Musicon, toensure such documentation is available for the future. Contractors need to provide a Revit/BIM model level of detail of each building with amounts/ types of materials.

The tender of the demolition was prepared by the same consultant that participated in the screening and they were asked to procure a tender with the demand of taking all materials listed in the positive list out and preparing them for reuse. Therefore, the material passport list was part of the tendering material.

Gule felter: Kvalitetsikres af nedrivere forud for udbud
Grønne felter: Udfyldes af nedriver efter udtagning

Hal 12 - sidebygning (3)

Materiale	OPLYSNINGER TIL BRUG FOR UDTAGNING										OPLYSNINGER TIL BRUG FOR GENBRUG					
	Placering og omfang				Tilstand		Håndtering				Dokumentation efter udtagning *(udfyldes af nedriver)*					
	Bygning	Nærmere placering	Foto	Mængde/ antal/ dimensioner	Miljøforhold *(se ark om miljøforhold)*	Genbrugs-potentiale	Udfaldskrav/ ønsket kvalitet efter udtagning	Metode til adskillelse	Metode til pakning	Placering	Nummerering	Foto efter udtagning	Holdbarhed/ stand	Mængde/ antal	Dimensioner	Pakning
Træplader/krydsfiner.	H12, side	Nedre del af væg		Ca. 70 m²	Ingen, synes ubehandlet	Stabiliserende element i skurtag, interim eller skateramper	Hele plader	Skrues fra hinanden	Lægges på strøer	Indendørs lager, Hal 11, Pulsen 7						
Mursten, akustik-/hulsten, stående	H12, side	Indermure		Ca. 100 m²	Uden grafitti: Ingen, synes ubehandlet Miljøforhold i maling (grafitti): A2 B2 C2 (PCB)	Facadeparti i skatehal-passage	Flest mulige hele rene sten	Mursten nedrives nænsomt så stående mursten kan adskilles fra bagvedliggende mursten.	Mursten med grafitti udsorteres til deponi, og rene mursten samles i bunke og overdækkes med pressening.	Nærlager 1a ved Rabalderstræde 30						
Mursten, akustik-/hulsten, liggende	H12, side	Indermure		Ca. 200 m²	Ingen, synes ubehandlet	Skillevæg eller teknikkerne i skatehal	Kvadratiske skiver á ca. 142 x 142 cm. 	Udskæres i kvardratiske felter á ca. 142 x 142 cm. Min antal: 45 felter	Stilles lodret på paller. Tværstivere monteres på skrå (som ved nye vinduer) ved fastgørelse i palle og i felter/skiver. Overdækkes	Indendørs lager, Hal 11, Pulsen 7						
Armaturer, lystofrør + LED	H12, side	Ophængt under loft		14 stk lysstofrør + 6 stk LED	Ingen, kan umiddelbart anvendes uden behandling	Lysarmaturer i skatehal eller facadebeklædning i affaldsskure	Hele armaturer i bedst mulig stand	Demonteres forsigtigt. Ledning klippes i størst mulige længde.	Lægges forsigtigt på paller og strøer og overdækkes.	Indendørs lager, Hal 11, Pulsen 7						

This was a very ambitious goal and therefore it was important to communicate this to the bidding demolishers. Early market dialogue was carried out in collaboration with the environmental consultant and involved three well respected demolishers, who agreed on participating in the tender.

The three demolishers were given parts of the tendering material in advance for commenting and it was adjusted according to their remarks. This is a very efficient way of communicating complex assignments in advance and it is allowed under the public procurement act, as long as the fundamental information regarding time, prize and award criteria are not revealed.

Demands and award criteria

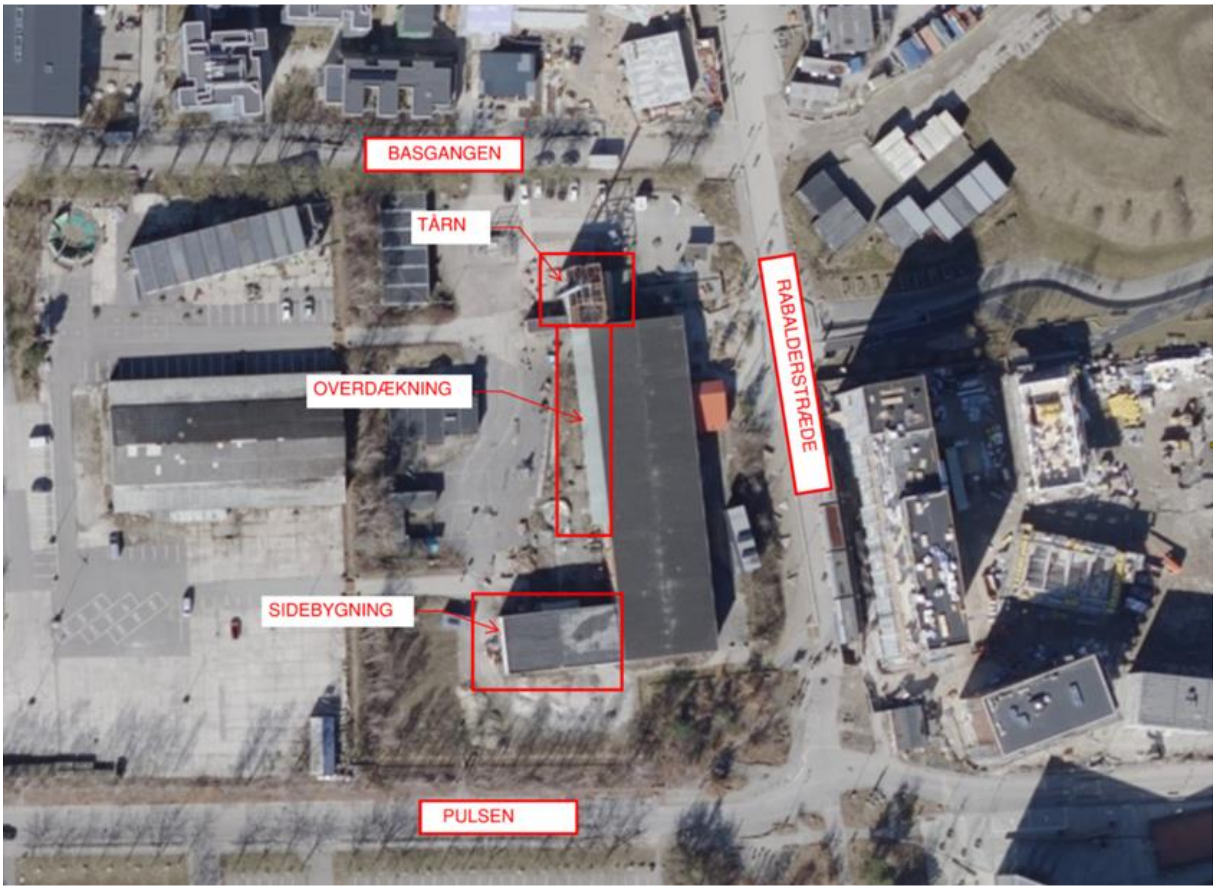
The balance between demands and award criteria is crucial when communicating your ambitions and prioritisation as a construction client. Demands are equal for all bidders and therefore perceived as a barrier more than an opportunity to excel.

Award criteria on the other hand are answered differently by each contractor/bidder and therefore allows for more specific solutions. The specific solution chosen by the contractor comes with an ownership and responsibility.

Overview of the tender

Roskilde Municipality aims to develop and explore possibilities for extracting construction materials from demolitions and remediation for future reuse and recycling. The current tender should be seen as part of that ambition.

The project includes environmental remediation and demolition of 2 buildings, the southern annex building and the northern tower, in the Musicon area, located in immediate proximity to Musicon Hall 12, (Figure 1).



The buildings are to be demolished prior to the renovation of the skate hall in Hall 12, as well as the expansion of the new Hall 12 neighbourhood.

Furthermore, the demolition of the covering from the northern tower along Hall 12, as well as the demolition and filling of the existing pit, which is currently covered with metal trapezoid cladding panels.

Requirements for offers and award criteria

The following criteria, in the specified order and weighting, apply to the conclusion of the agreement:

Price: Weighting 40%

Quality: Weighting 60%

Quality criteria should include two elements:

Resource utilisation and methods:

A brief description (approximately 2 pages) is required of the Contractor's specific proposed solutions for how they will address the following critical tasks as part of the demolition:

Ensuring that documentation and labelling of materials extracted for reuse are done systematically, allowing for easy identification of the materials.

How the Contractor will address challenges related to dismantling the steel structure in the tower using a crane, specifically regarding detachment/cutting from underlying materials.

How the Contractor will safely remove metal trapezoid panels from roof surfaces and areas above the pit in the most secure manner.

Furthermore, a brief description is requested of the risks the contractor identifies regarding the tendered task, with a focus onthe UK Achitects Registration Board, ARB Appendix 5: Resource Mapping of Materials for the Client's Reuse. This should cover outcome requirements, extraction methods, and packaging methods, with particular emphasis on:

How brick sections from the annex building will be extracted in the described size without causing damage during dismantling, packaging, and transportation.

How concrete elements from the roof deck over the original part of the annex building can be removed/extracted in full length without damage.

Please note that the translation provided may need to be adapted to fit the specific requirements and terminology of the target document.

Communication and Key Personnel:

A brief description (approximately 1 page) is required of how the Contractor will ensure good communication and collaboration with the Client and other involved parties, including the users of Hall 12, throughout the different phases of the project.

Furthermore, a description is requested of the proposed organisation and key personnel who will be involved in the project, including their experience with similar tasks (approximately 1 page, including relevant CVs).

When evaluating this criterion, the Client will consider:

The Contractor's proposal on how to ensure that the demolition is carried out as a collaboration between the Contractor, the Client, their consultants, and the users of Hall 12, including:

- Ongoing dialogue and collaboration to find gentle solutions to unforeseen problems.
- Prompt communication regarding unforeseen risks and issues with the proposed solutions.
- The relevant experience of the key personnel with similar demolition work.

Early Market Dialogue

Before the tender was sent out, an early market dialogue was conducted amongst three demolishers. They were asked to participate in onsite meetings and prior to the meeting they had access to a preliminary version of the tendering material. The material did not include timetable, award criteria, and price conditions which were translated to the fundamental elements of the tender.

The fundamental elements should be understood in relation to the fundamental principles of equal treatment and transparency. A change is considered a change in fundamental elements if it can impact the participation of potential applicants or tenderers in the specific procurement procedure or distort competition among applicants or tenderers.

In other words, any modification that affects the fundamental elements of a procurement procedure and has the potential to influence the participation of interested parties or create an unfair advantage for certain applicants or tenderers, would be classified as a change in fundamental elements. It is crucial to ensure that such changes are carefully managed to uphold the principles of equal treatment and transparency in the procurement process.

Early market dialogue is a very efficient way of getting feedback from the market before the tender is sent out. Often the balance between the contracting authorities' expectations and the economic operator's capacity does not meet each other. E.g. if the contracting authority doesn´t have sufficient knowledge about market conditions and/or the practical conditions of the job. Early market dialogue gives both parties a chance of eliminating the worst misunderstandings and reaching a balance between need and capacity.

However, it is crucial to have a good understanding of the rules described in the Danish Public Procurement Act No. 1564 of 15 December 2015 (Udbudsloven). Most important is to focus on equal treatment and transparency at all times. The law says:

§ 2

A contracting authority shall comply with the principles of equal treatment, transparency, and proportionality in public procurement in accordance with Sections II-IV.

Paragraph 2. A public tender must not be designed with the purpose of excluding it from the scope of this law or artificially restricting competition. Competition is considered artificially restricted if the tender is designed with the intention of unjustifiably favouring a single or certain economic operator or placing them at a disadvantage.

§ 39

Prior to initiating a procurement procedure, a contracting authority may conduct market surveys in order to shape the tender and inform economic operators about the contracting authority's procurement plans and requirements. In this context, the contracting authority may engage in dialogue and receive advice from economic operators. The advice can be used in the planning and implementation of the procurement, provided that it does not violate the principles outlined in § 2.

Paragraph 2. If an economic operator or a company associated with an economic operator has provided advice to a contracting authority in connection with a market survey or has otherwise advised or been involved in the preparation of the procurement procedure, the contracting authority must take appropriate measures to prevent distortion of competition due to the involvement of that particular economic operator in the tender. At a minimum, the contracting authority must:

Ensure, to the extent possible, that relevant information exchanged during the economic operator's involvement in the procurement procedure is included in the tender documentation, and

Set the deadlines for the submission of applications and bids in a way that offsets any time advantage that an economic operator may have gained through involvement in the preparation of the tender, including through dialogue and advice received from economic operators.

Paragraph 3. If the contracting authority cannot ensure compliance with the principle of equal treatment through less intrusive measures, the contracting authority must exclude the respective applicant or tenderer in accordance with § 136, no. 2.

In the early market dialogue contractors were asked to participate in an onsite meeting, where they had the chance to express concerns regarding the bidding material, processes or time. Consultants in charge of the tendering process, were asked to compile the comments. The following is a condensed version of this.

Focus points for preliminary dialogue regarding demolition, remediation, and resource utilization of the Side Building and Tower at Hall 12 - Musicon:

During the preliminary dialogue with three contractors, the following focus points were discussed. Below is an overview of the different focus points and the input from the contractors:

Contractor's design for the removal of decking elements above the Side Building:

- It is initially not problematic for the contractors to design the removal of concrete elements in the roof decking.
- Access routes will be established via scaffolding towers for the removal of roofing membrane and for the positioning of elements for the crane. Additionally, the work area will be secured (with handrails or fall protection).
- There is disagreement regarding whether the elements span the entire width of the building (12 m) or only half the width (6 m).
- There are no guarantees, but it is assessed that the majority of elements can be removed without breaking.
- The elements will be removed by an excavator "loosening" the elements, which will then be lifted down to the ground by a crane.

Cutting of brick squares in the Side Building:

- Horizontal bricks can be cut and placed on pallets, with two pieces per pallet.
- Vertical bricks (acoustic wall on the southern side of the central wall) cannot be cut into squares without significant waste. The stones can possibly be carefully removed and cleaned to separate individual bricks (they are fragile because they stand on their edges in a single layer, allowing the mortar to be removed).

Removal of steel structures and wooden framework in the walls of the Side Building:

- Cutting the steel and wood into the longest possible lengths is not a problem.
- If the steel is removed with an excavator, there is a risk that it may resemble a "crumpled summer hat" when it reaches the ground.

The contractor's design for the dismantling of the steel tower structure and the covering over the pit and chimney:

- It is initially not problematic for the contractors to design the dismantling of the tower structure in two parts, as well as the covering over the pit and chimney.

- A 100-ton mobile crane is planned for the dismantling of all the parts.
- The description of backfilling the pit with stabilising gravel and concrete rubble should be improved.

Interim closures of the southeast and north facades (streetskate) using recycled materials from the Side Building:

- It is possible to primarily use recycled materials for interim closures, but there may be certain parts that need to be purchased new.

Cutting of brick squares on the ground floor in the Tower:

There is significant waste associated with cutting brick squares on the ground floor of the Tower due to:

- Limited space for cutting.
- Risk involved in hoisting the squares out of the building before moving the steel structure.
- High risk of PCB contamination in the bricks in the transformer room, which would damage the stones during cleaning (it is also unclear how deeply the PCB has penetrated the stones).
- Plaster and moisture on the stones in the boiler room adjacent to the transformer room.

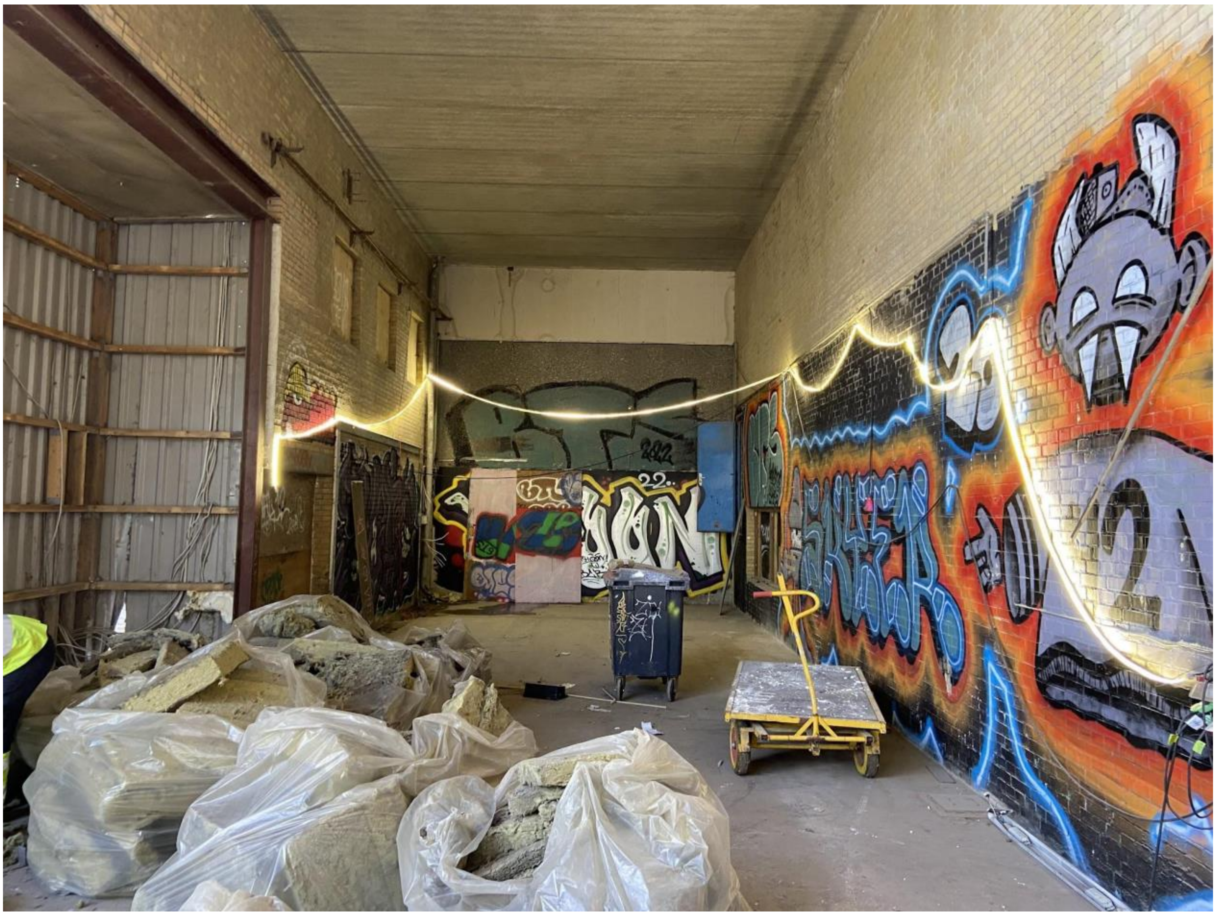
Bill of quantities:

It would be appropriate to include unit prices in the bill of quantities for:

- Demolition work - hourly rate.
- 30-ton excavator including operator - daily rate including mobilization and removal.
- 100-ton crane including operator - daily rate including mobilization and removal.
- Additionally, there should be an item in the bill of quantities for the removal of vegetation, old ramps, fences, etc., in the corner between the Side Building and Hall 12, as well as along the covering.

Timeline:

- Two months for the task is somewhat tight to ensure a smooth process. This includes the removal of recycled materials, optimal cutting of bricks in the Side Building, and minimizing disruption to the users of the hall. Three months would be more appropriate.
- However, it would be advantageous to commence the project before the summer vacation (July) to ensure it is underway before people go on holiday.




SØNDERGAARD

Tabel 2: Beskrivelse af bygninger

Sidebygning	
 	Adresse: Rabalderstræde 30 Brug: Oprindeligt betonvarefabrik, nu lager Opførelsesår: 1972 og tilbygning i 1990 Bebygget areal: 300 m^2 Etageareal: 300 m^2 Bærende konstruktion, oprindelig bygning og midtervæg: Tegl Bærende konstruktion, tilbygning: Stålkonstruktion med træskelet og krydsfiner Tagkonstruktion, oprindelig bygning: Betonelementer med tagpap Tagkonstruktion, tilbygning: Stålbjælker og trækonstruktion med tagpap. Indretning: 2 rum adskilt af teglvæg. Maskingrav i sydlig del.

Implementation of circular actions in Roskilde Municipality

In 2021 a group of employees from various administrative areas formed a multidisciplinary sustainability group in order to collaborate on sustainability-related issues. The group's purpose was to promote a holistic approach to sustainability and facilitate collaboration across different fields within the organisation. By involving employees with diverse expertise and perspectives, the group can achieve a broader and more nuanced understanding of sustainability issues and develop interdisciplinary solutions.

The group's members can come from different departments, such as environmental, urban planning, transportation, energy, social affairs, etc. Each employee contributes their knowledge and experience within their specific area and collaborates to identify and implement sustainable initiatives and policies across the organisation.

The multidisciplinary approach also enables better coordination of resources, efforts, and projects as the group shares information, exchanges ideas, and identifies synergies between different administrative areas. This contributes to a more efficient and cohesive approach to sustainability throughout the organisation.

Most important was that the group wasn't embedded in any already existing formal structures in the municipality, leading to a more fluent exchange of information and more efficient decision making.

One of the first interest areas of the group was to agree upon a procedure for handling CDW and soil within the authority network of the municipality. When planning for a circular building process it is rarely sufficient to focus on one or two areas at the same time. Often it is necessary to implement many elements into the planning, e.g. procurement, practical selection of materials, demolition, selection of advisors, etc. But often the internal municipality process is neglected. This meant that we chose to focus on the internal procedures in relation to the external processes. This means that external partners are helped in understanding the formal procedures within the municipality structure as well as the municipality is matured in its handling of requests internally.

This procedure has now been tested in a couple of cases and is being ratified by the different departments in the municipality.

Roskilde’s procedure for CDW to obtain a Material Passport

One of the most important aspects of absorbing reused and recycled CDW into new constructions is the need for data associated with the specific material. Early in the transition towards circular economy, Roskilde Municipality identified the need of a simple data vehicle that could ensure that data is kept and accessible throughout the procedure. This data vehicle can best be described as a material passport.

One of the oftenoverlooked functions of such a material passport is the need for delivering information to the different authorities, so the necessary permits can be given. Therefore information in the material passport is targeted towards three different authorities, namely the:

- Environmental Authority.
- Waste Disposal Authority.

- Building Authority.

By law certain procedures are mandatory. Before demolition of a donor building, an environmental screening delivers data for the demolition permit. This environmental screening can be expanded to an combined environmental and resource screening to identify materials or elements for reuse/recycling. If this is the case, the elements or materials will be added to the tendering of the selective demolition.

When the demolition is completed, the elements and materials are checked to see if they are fit for further tests of their suitability for reuse/recycling. The following color codes are used for the materials: Green means they are fit for direct reuse/recycling, yellow means they need further testing, red means they should not be reused/recycled.

The information is written in an Excel sheet, which forms the Material Passport. Information includes whether special care should be taken when handling or using the materials, as well as an assessment of the structural usability and recommendations on purposes for reuse/recycling. Together with pictures, tags and analysis results this constitutes the Material Passport. If the materials are destined for reuse/recycling in a new project, information about location of storage and expected future use (time, place and building) is also included.

The local building authority can then authorize use of the materials in a new construction if they fulfil the requirements of the intended use. [Source: Procedure Roskildemodellen, figure below]

PROCEDURE

Forudsætning for anvendelsen af materialepas er at det indgår i "Roskildemodellen", der er en procedure, hvor byggeaffald tages ud af affaldshierakiet og indgår som bygherreleverance under nogle bestemte omstændigheder.

"Roskildemodellen" består af fem faser:

1

Bygherre eller dennes repræsentant vurderer på baggrund af miljørapport/er, hvorvidt der er byggematerialer fra den kommende nedrivning, der har potentiale til genanvendelse/ genindbygning i fremtidigt byggeri.
Hvis det er tilfældet, bliver det tilføjet som et udbudskrav til selektiv nedrivning, hvor nedriver får udfaldskrav til renhed af de pågældende materialer.

2

Når nedrivningen er overstået, bliver de nedtagne materialer kontrolleret i forhold til udbudskrav. Hvis de overholder de beskrevne krav, kan de testes yderligere for egnethed til genanvendelse. Det er typisk en specialrådgiver, der tester på foranledning af bygherre.

3

Når testresultaterne er kendte, kan bygherre vurdere, hvorvidt de nedtagne materialer er af en type, der:
A) kan genanvendes direkte uden yderligere undersøgelser
B) skal undersøges yderligere, før man kan vurdere egnetheden til genanvendelse
C) kategoriseres som byggeaffald og forlader materialestrømmen, fordi de fordi de er uegnede til genanvendelse.

4

Resultatet bliver derefter skrevet ned i et lokalt materialepas, der følger materialet videre i processen. I materialepasset kan man aflæse, om materialet er godkendt til genanvendelse eller yderligere undersøgelse, og man kan indskrive særlige begrænsninger for anvendelse af de materialer, der skal undersøges. Udover miljøforhold er der også anført byggeteknisk egnethed og begrænsning i materialepasset, der sammen med billede, mærkning og analyseresultater udgør en samlet dokumentation for materialet.

5

Den lokale byggemyndighed godkender genindbygning af materialer med medfølgende materialepas, hvis dokumentationen er fyldestgørende i forhold til det, materialet ønskes brugt til.

Resource mapping

When a building is to be demolished or renovated, the developer is responsible for identifying and reporting any waste that may be classified as hazardous to the municipality. This is done through an environmental screening, which involves taking samples of the building components and materials involved in the construction project. It is through this screening that environmentally harmful substances are identified.

Before demolition or renovation, the building owner can conduct a more detailed examination of the building to map the available resources. This mapping provides a detailed overview of the materials suitable for reuse, recycling, and material recovery.

It is essential for the usability of resource mapping that it is carried out in the initial phase of the project in conjunction with or as an extension of an environmental survey of the building. The information about hazardous substances from the environmental survey is an important parameter for assessing whether the available materials can be considered resources or if they need to be managed and disposed of as contaminated or hazardous waste. Together, these mappings form the basis for subsequent planning and description of the demolition process.

Based on the resource mapping, the building owner can demand the extraction of demolition materials for reuse, recycling, or other forms of material recovery. For all materials removed from a building, sufficient information must be provided to assess their circular potential.

During the procurement period of the demolition of Hal 12, all relevant people will have access to the database and the construction material passport has been part of the tender for the demolition.

Roskilde asks for the BIM in the tendering process for each building to be built at Musicon, to ensure such documentation is available for the future. Contractors need to provide a Revit/BIM model level of detail of each building with amounts/ types of materials.

3.1.2 Car park 1 “Indfaldet”

Introduction

Construction of Car Park Indfaldet was finished in mid-2021. When the building authority started digging in preparation for the car park, we discovered a large number of concrete obstacles in the ground stemming from the site’s concrete production function in the past. The concrete unearthed was kept on site and crushed into a mixed fraction. The mixed fraction was used for material layers below the construction, replacing virgin gravel. Other concrete recovered from the digging was cleaned and crushed, to be mixed on site and used as aggregate in new concrete. This has made a very positive business case.

A criterion in the tender for the new car park was that the developer foresee design for disassembly, including scenarios for future recycling. Consequently, a report was delivered by the contracted developer (MT Højgaard). They created the multi-storey car park with a steel skeleton, premade components assembled by bolts and a minimal use of concrete. They made calculations on CO2 for future reuse/ recycling and have documented the benefits on future use of materials from the car park. The local Parkour club is to finish/ furnish their area of the Car Park Indfaldet with materials from the material bank at Musicon.

Early Planning and local plan

In early 2017 it was politically decided to develop an area located near the eastborder of Musicon in Roskilde. The area under the name “Indfaldet” was planned in Local Plan 660 for Roskilde.

The purpose of the local plan is to secure the framework for a new quarter at Musicon with a total of 46,000 floor meters divided into mixed residential types, office businesses and public-oriented functions. Part of the local plan was the parking facility “Indfaldet” with approx. 240 parking spaces to serve approx. a quarter of the entire district. The parking facility includes one multi-storey parking garage and parking on the ground.

The local plan stated, it was desired that new developments at Musicon build on the area's identity as an innovative urban area with experimental construction and clear industrial traces. It is therefore part of the purpose of the local plan that new buildings have an experimental and characterful expression.

The illustration plan shows the overall layout of "Indfaldet".

Planning

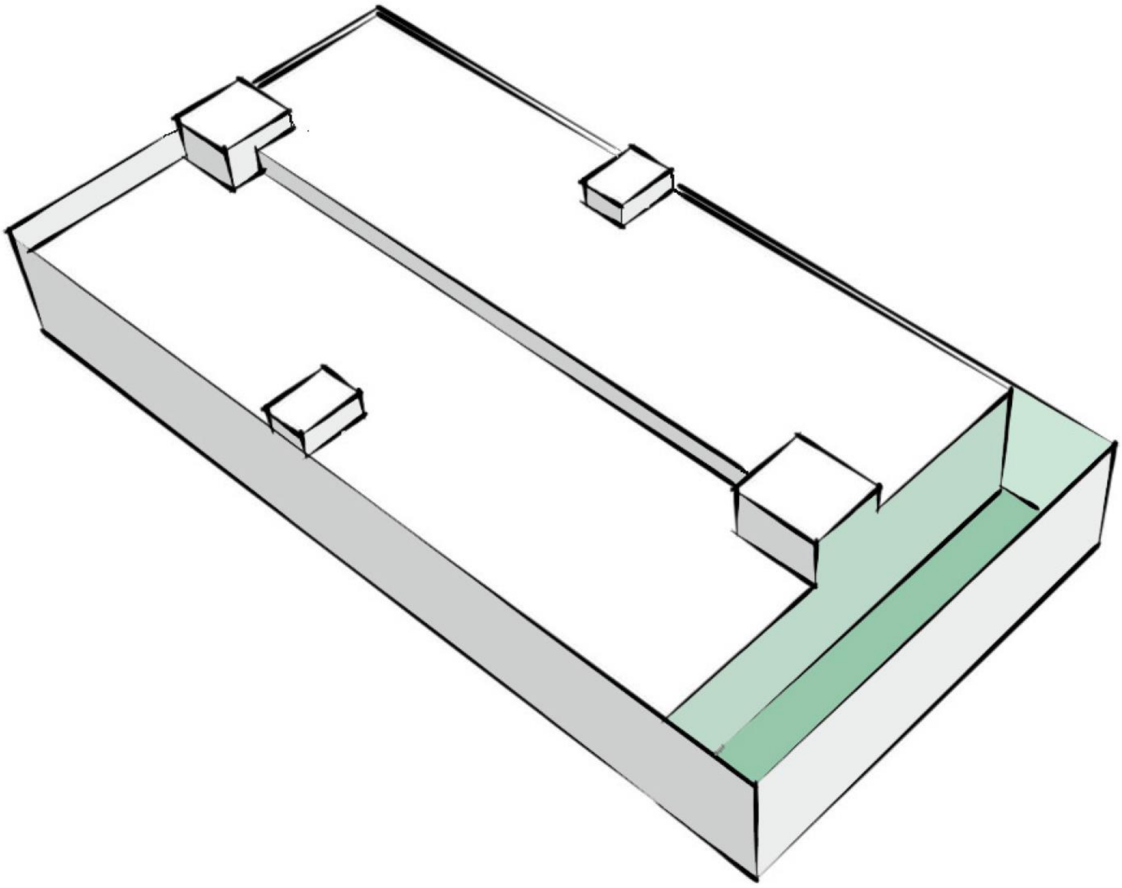
After approval of the local plan 660 in August 2018, planning of the Multi-storey Car Park “Indfaldet” was handed over to the building department in the municipality, where practical planning of the Car Park started in late 2018.

Musicon already offered a great variety of activities for especially young people, but most of these activities were placed in outdoor facilities. Therefore it was decided in the steering group of the car park, that the house should hold possibilities for other activities than parking. This decision was underlined by the fact that other car parks in the municipality had suffered a great deal of unwanted activities, especially at night. The hope was that inviting other activities into the car park would create a sense of ownership in the house, that again would be translated into caretaking of the place.

As a starting point, a traditional car park with 2 floors above ground was desired, as well as parking on the roof with space for around 250 parking spaces. To the south, an area for activities other than parking was desired. This area is referred to as "Indskydelsen" in this program. The "Indskydelsen" can be understood as an area that is inserted between the main structure of the car park and the facade to the south. This area allows alternative functions to be envisaged at the southern end of the house.

In illustration 01, the “Indskydelsen" is marked in light green. Roof elements above the deposit are not shown in the illustration.

Illustration 01



The planning for car park “Indfaldet” was started by gathering all available information on previous soil surveying in the area. As part of the strategy for Musicon environmental testing had already been carried out and the results showed that large amounts of soil contamination could be expected in the area of the car park. Therefore the environmental department in the municipality was contacted and the need for further surveying was established. As part of the environmental documentation for the car park an approval according to the regulations of §8 in the national soil pollution act.

According to § 8 of the Soil Pollution Act, the developer must apply for a § 8 permit when excavation and construction work is carried out on most mapped plots. The permit is called an §8 permit, as the provision is in §8 of the Soil Pollution Act. The application for the §8 permit is sent to the municipality where the activities are carried out, where the application must contain as much concrete information as possible about the upcoming project.

This information would normally be handed over to a turnkey or general contractor, who then would apply for necessary permits (amongst those §8), as part of the building procedures. However in the case of the car park, the preliminary testing of the soil already has shown a high amount of different complexities. E.g. there had been shown high levels of gas in the underground due to old deposits of organic landfill. The presence of underground gas would trigger special measures to prevent ignition of trapped pockets of gas underneath the building.

But most significantly there had been discovered a large number of concrete obstacles in the ground stemming from the site's concrete production function in the past.

Procurement strategy

Both the presence of underground gas and concrete obstacles would lead to a high risk for the contractor, since he would be locked to a fixed timetable in his contract with the municipality. This risk he would need to cash in in his offer to the municipality. The conclusion was straight forward. If the municipality could apply and receive a §8 approval in advance of the tender, a big risk would be lifted from the tender to the builder and thereby ensure a better price. This practice has later led to a new procurement strategy in the building department where three elements are always contemplated in advance of deciding where a risk shall be placed in a building process, namely risk, responsibility and consequences. This procurement strategy will be folded out under "Circular procurement strategy".

It was decided to carry out the tender as a turnkey contract. According to The Public Procurement Act No. 1564 of 15 December 2015, the contracting authority can set the price or costs to ensure that competition is carried out based on qualitative criteria only. When deciding to carry out a competition based on qualitative criteria only, it gives the contracting authority an advantage in communicating the wishes for the building more effectively, compared to competition, where price is the main focus. This is because when carrying out a competition you have to balance demands and incentives in the tender. Demands typically come in the form of very specific descriptions for function or materials. But demands will often be interpreted by the market as minimum requirements and the overall quality of the building can be lowered. Incentives on the other hand come in the form of award criteria, where the award criteria will be interpreted as the main interest of the building authority, and thereby will receive more attention by the bidders.

The balance between demands and award criteria is crucial when communicating your ambitions and prioritisation as building authority. Demands are equal for all bidders, whereas award criteria are answered differently by each contractor/bidder and the specific solution chosen by the contractor subsequently comes with ownership and responsibility.

Underlining the wish to focus on quality and not price, it was decided to carry out the tender as a competitive procedure with negotiation according to The Public Procurement Act Section 61 -66. A competitive procedure with negotiation means that the contractors will be participating in bilateral negotiations with the building authority after handing in a preliminary offer.

Tender

An advisor was hired for the continued planning and surveying in relation to obtaining a §8 permission in advance of the tender. The advisor laid out a timetable for the tender in close collaboration with the building authority.

- The process started in October 2019 where all applications for attending the bidding, should be handed in.
- In late November an information meeting was held with all interested contractors. In the meeting the overall scheme for the bidding process was presented.
- In early January 2020, there was a deadline for presenting questions before the negotiations started.
- By mid January 2020 preliminary offers should be handed in and in late January the negotiation meetings would start.
- By the end of February the final offer should be handed in and mid March the contractors who handed in offers would be informed of the result. By law a stand still period follows the communication of the winner, this stand still period would end in late March 2020.
- By early April it would be expected to have a contract with the winning contractor. Immediately after signing the contract the contractors' planning could start.

After creating the tender time schedule, work on the remaining part of the bidding materials was started. A number of very central documents was created, amongst those was the technical programme, where all demands for function and materials are listed. An architectural programme where all the aesthetic demands were listed along with the description of the wanted place, atmosphere and relation to the future users. A sustainable strategy, listing all objectives for sustainability.

Overall, the construction must provide the best conditions for Car Park Indfaldet to fulfil its purpose and at the same time contribute to sustainable development locally. This is expressed in the following focus areas:

● We wanted a building where conscious, sustainable choices have been made within all aspects. Life cycle calculations must be thought into the project both in relation to maintenance and operating economic solutions as well as in aesthetic considerations. The building must be robust and durable with the focus that good architecture creates satisfied users and lasts further. This is documented i.a. through an account of the total economy, which submitted in connection with offers, total economic assessments in connection with change projects, and preparation of a total economic calculation in connection with the delivery.

● A building with a low environmental impact was desired. Therefore, life cycle assessments had to be considered in the project both in relation to the choice of materials and the design of solutions as well as in aesthetic considerations. This should be documented i.a. through an account of life cycle assessments with a focus on CO_2, which is submitted in connection with offers and preparation of life cycle calculation in connection with main project.

● With its local roots and voluntary efforts, the house is a socially sustainable project with accessibility for everyone and space for the community. The interior design of the house must support this function with the possibility of variation in use.

The layout is crucial for a building's functionality and flexibility different uses. These factors play a decisive role in the building's performance
spatial and architectural quality and will also be reflected in the building's
value stability. Functionality and flexibility also affect user satisfaction with the building.

A flexible building that can be changed over time is desired. The addition of P-hus mod south must be able to change its use to the greatest extent possible and be used for several purposes. As well as being too prepared for 100% conversion to electric cars.

● In order to best promote the recycling of valuable materials in the waste shell
it is taken into account that the building parts can be easily separated and sorted. It is done best if the actual separation and sorting is thought of already in the design phase, and materials and components are mounted independently of each other as far as possible. On in the same way, removed components and materials must be treated with a view to
to ensure recycling of the highest possible quality, i.e. with the least possible environmental impact and best use of resources in the recycling process.

● Recycled concrete must be used in connection with in situ casting of new ones concrete constructions with low environmental class.

Handling risk and securing soil balance in tender and procurement strategy

As part of the tender two rounds of negotiations were held. In the negotiations the topic of the concrete in the ground was taken up and the contractors had to describe how they would overcome the possible obstacles they would meet in the ground. Normal procedure for the contractor would be to stop the work and wait until an agreement of removing the obstacles was achieved. This normally is a risk that falls upon the building authority, since the contractor does not have any possibility to evaluate the costs before the actual amount is known. Each of the bidders were asked to describe what they would do in advance and how they would handle the situation in the building process.

The winning contractor described that they would reinforce the tips of the pile foundation and that they would dig trenches 1 metre deep in order to guide the piles better. Secondly they described that, if obstacles were met, they would contact the building authority and the problems would be observed and solved in partnership.

A criterion in the tender for the new car park was that the developer implemented design for disassembly, including scenarios for future recycling. Consequently, a report was delivered by the contractor (MT Højgaard). They created the multi-storey car park with a steel skeleton, premade components assembled by bolts and a minimal use of concrete.

One of the main objectives in the procurement of the multi-story car park was to maintain as much soil as possible on site. Through our participation in City Loops we have established that the CO2 associated with moving soil is considerable, and therefore the savings potential when keeping soil on site is also considerable.

For this reason, we had a large incentive to address the issue in the procurement strategy. We knew in advance from the technical investigation of the site that there was a high risk of concrete waste in the ground on site. The contractor was therefore in the tender obligated to work with an optimal soil balance. The procurement process was therefore the single most enabling factor in maintaining the incentive to keep working for a soil balance and circular solutions.

Dialogue with the contractor and risk assessment in the construction process

In the early dialogue with the chosen contractor, the risks were discussed and a reasonable process for what the contractor should do was agreed upon, the moment he encountered any obstructions in the digging process. The contractor was to immediately stop and

together with the municipality project manager regarding the obstruction. Then he was to present an excavation price for whatever amount they had found. (The unit price was agreed upon in advance, in the tender list.)
By having this very close dialogue with the contractor, it was possible to keep the price of the excavation to a minimum.

A normal procedure would have been that the contractor excavated the concrete waste, got it transported away and deposited, and brought new virgin soil and gravel to fill up the remaining pocket. This would also result in time delay, CO2 expenses on the increased transport and not least, an increased price for the builder.

In this case, instead of the above-described normal procedure, the contractor was to contact the builder, agree on excavation, and place the excavated concrete waste just outside the plot. The contractor would then continue with his normal tasks, while the project manager of the builder ordered a crushing contractor to crush and sort the dug-out materials into three fractions. Fine, coarse and mixed aggregates.

When this was complete, the contractor immediately rebuilt these aggregates into the site project. The fine and coarse aggregate was incorporated into new concrete in the ground level floors, and the mixed aggregate was used as bottom protection gravel.

The contractor was obligated to do this, as the tender stipulated that he was responsible for keeping soil balance. The complexities and costs associated with the excavated concrete were turned into a benefit for all involved parties. The original period of the project was not altered, as all crushing and rebuilding was kept within this timeframe. The obstacles were found and rebuilt into the site within approximately two months.

In the procurement process, we were very much aware of how the burden of risk lies in the process. Sometimes the price for the contractor to bear certain risks is disproportionately high.

The task for the builder is therefore to assess where the elements of risk are naturally handled with greatest benefit for sustainability and price. In this project, the builder undertook detailed investigations of the site in advance so the risks were uncovered and the information was available in the tender.

In addition, the responsibility for handling any obstacles remained with the builder, in this case the handling and crushing of the concrete. Having removed this risk from the contractor, and the price agreed upon in advance, the costs associated with this operation was reduced to the price for excavation of any found waste. The contractor's time flow was uninterrupted, he could get rid of the obstacle immediately, and regain the finished product (foundation gravel ready to rebuild) just as easily from the depot next to the building site.

By assuming the risk for obstacles and the task of handling the concrete obstacle, and by requiring the bidders to define the practical procedures in advance, the builder was able to solve the situation with the highest focus on a circular solution, as well as keeping the price lowest possible.

They made calculations on CO2 for future reuse/ recycling and have documented the benefits on future use of materials from the car park. The local Parkour club is to finish/ furnish their area of the Car Park 1 with materials from the material bank at Musicon.

The crushing itself took place onsite, when all the dugout obstacles were ready outside the building fence. In total an amount of 1087 tonnes of concrete waste materials were placed outside the fence.

As mentioned earlier we knew in advance from the technical investigation of the site that there was a high risk of concrete waste in the ground on site. The whole area of Musicon used be the factory ground of the concrete manufacturer "Unicon" in Roskilde and the concrete waste was placed in the ground from the time when the area functioned as waste pit for the concrete leftovers. The quality of the materials was very diverse, since most of the concrete waste was fail casts and surplus material from the casting of concrete elements in the past.

Therefore we asked a specialised advisor to visually inspect the dugout materials prior to crushing, in order to determine the potential for using crushed materials in recycled concrete. There were two main conclusions from the inspection. Firstly there was a high degree of humus contamination in the dugout materials, and secondly a percentage of the dugout materials stemmed from low strength materials such as concrete pipes and pavers. This led to the conclusion that the dugout materials should be sorted prior to cruising into two selections. One selection of bigger pieces of high strength concrete suitable for aggregates in recycled concrete and a selection of the dugout materials that could be crushed to a mixed aggregate for foundation works.

The selection was carried out by the same contractor who was responsible for the crushing itself.

The neighbours were informed about the crushing in advance in an information meeting, held by the contractor on site. The meeting was part of the contractor's obligations to communicate activities to local actors in Musicon in order to prevent unnecessary conflicts due to lack of knowledge of the ongoing activities. In other projects it has shown fruitful to communicate activities, which could give rise to worries, very directly and openly.

After the initial selection of materials, crushing started on site. The crushing itself was carried out by a specialised local company, who had all necessary machinery and materials. For the crushing a track-mounted impact crusher was used (Kleemann Mobirex MR 130 Z) with an attached screener.

The crushing of a total of 1087 tonnes of concrete was carried out over a span of 6 hours. After the crushing the crushed material was screened into three different fractions: 0-16mm, 16-32mm and a mixed fraction.

Knusningsrapport - uge 47

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Dato	Start	Stop	Eff. knusn.	Rep.	Opstk. bånd	Materiale	Sold	Ton type	Ton
Mandag 16/11-2020			0,00	0,00	Nej				0,000
Tirsdag 17/11-2020			0,00	0,00	Nej				0,000
Onsdag 18/11-2020	10:30	17:00	2,50	4,00	Nej	Beton	40 mm	0-32	390,000
Torsdag 19/11-2020	06:00	14:00	5,00	3,00	Nej	Beton	40 mm	0-32	555,780
Torsdag 19/11-2020			0,00	0,00	Nej	Beton	20 mm	0-16	140,940
Fredag 20/11-2020			0,00	0,00	Nej				0,000
Lørdag 21/11-2020			0,00	0,00	Nej				0,000
Søndag 22/11-2020			0,00	0,00	Nej				0,000
I alt:			**7,50**	**7,00**					**1086,720**

When the crushing was finished the contractor was informed that he could pick up the mixed crushed fraction for foundation works and only the fine and coarse fractions were left. The use of the mixed fraction is standard procedure and the quality of the mixed fraction is equivalent or better compared to standard stabilised gravel. Procedure described in EN 13285:2018 Unbound mixtures - specifications were followed. The European Standard specifies requirements for unbound mixtures used for construction and maintenance of roads, airfields and other trafficked areas and applies to unbound mixtures of natural, manufactured and recycled aggregates with an upper sieve size (D) from 5,6 mm to 90 mm and lower sieve size (d) = 0 at the point of delivery.

During the progress of the building we discussed how to reintegrate the two fractions. It was decided to use them in the concrete floors in the lower part of the building, since demands for strength in this type of construction are low and the consequences of a possible failure are very small. The standard build up of floor constructions on ground is levelling the ground placing insulation plates of expanded polystyrene (EPS), placing reinforcement net and pouring concrete mixture onto the insulation and reinforcement. This means that the load bearing capacity of the surface is directly connected to the ground and a smaller failure in the concrete will not have any significant consequence for the strength of the concrete deck itself.

As part of the preparation the two crushed fractions were tested for particle density and water absorption by the special technical consultant according to EN 1097-6.(Tests for mechanical and physical properties of aggregates - Part 6: Determination of particle density and water absorption)

PELCON

Korndensitet og vandabsorption (DS/EN 1097-6)

Udført af: SGP Sagsnr. 21-043a

Prøve-ID	Densitet, tilsyneladende [Mg/m³]	Densitet, VOT [Mg/m³]	Densitet, tør [Mg/m³]	Absorption [%]
1	2,61	2,41	2,29	5,3

Modifikation af metode: Prøven er ikke sigtet på hhv. 4 mm og 31,5 mm-sigte og er vandmættet i >24 timer.

Based on the tests and using earlier developed guidelines for mixing concrete using recycled aggregates. Parts of the guideline is described later in this document and is a more general guideline for mixing concrete using recycled aggregates.

The municipality asked a local contractor who has specialised in on site mixing of concrete, to assist us in the process. On the day of the mixing the contractor came with a mobile mixing plant that was already loaded with cement and water. The building contractor then helped with loading the two crushed fractions onto the mobile mixing plant. The mixing followed specific mixings recipes given by the special consultant.

When the mixture was ready it was poured onto the insulation and reinforcement and levelled by hand.

NOTE Guidance on the effects of alkali-silica reactivity, is given in annex G.

5.8 A1 Classification of the constituents of coarse recycled aggregates

The proportions of constituent materials in coarse recycled aggregate shall be determined in accordance with prEN 933-11 and shall be declared in accordance with the relevant categories specified in Table 20.

Table 20 — Categories for constituents of coarse recycled aggregates

Constituent	Content Percentage by mass	Category
Rc	≥ 90	Rc_{90}
	≥ 80	Rc_{80}
	≥ 70	Rc_{70}
	≥ 50	Rc_{50}
	< 50	$Rc_{Declared}$
	No requirement	Rc_{NR}
Rc + Ru	≥ 95	Rcu_{95}
	≥ 90	Rcu_{90}
	≥ 70	Rcu_{70}
	≥ 50	Rcu_{50}
	< 50	$Rcu_{Declared}$
	No requirement	Rcu_{NR}
Rb	≤ 10	Rb_{10-}
	≤ 30	Rb_{30-}
	≤ 50	Rb_{50-}
	> 50	$Rb_{Declared}$
	No requirement	Rb_{NR}
Ra	≤ 1	Ra_{1-}
	≤ 5	Ra_{5-}
	≤ 10	Ra_{10-}
X + Rg	≤ 0,5	$XRg_{0,5-}$
	≤ 1	XRg_{1-}
	≤ 2	XRg_{2-}
	Content cm^3/Kg	
FL	≤ 0,2 [a]	$FL_{0,2-}$
	≤ 2	FL_{2-}
	≤ 5	FL_{5-}

[a] The ≤ 0,2 category is intended only for special applications requiring high quality surface finish.

In the following you can read a chronological review of all the processes associated with production of recycled concrete. Each process is described as concrete and simple as possible. The description is valid as a general guideline for handling, crushing and mixing recycled aggregates and is not a special for “Indfaldet”. For the specific process that took place at “Indfaldet” see above.

Concrete flow

Control and monitoring

The production of recycled concrete involves several crucial processes such as crushing, welding, and pile building. These processes require specialized skills and abilities. It is crucial to have experienced individuals who are specifically knowledgeable in this field to manage and supervise the work, rather than relying solely on those with experience in general industrial concrete production. There are numerous potential issues that can arise and must be avoided. Even a small error, such as using an incorrect substrate or operating a soldering plant on contaminated soil, or a brief 10-minute mistake in handling with a front loader, can result in the destruction of an entire production of recycled aggregate.

The crushing of 1,000 tons of concrete can be completed in just half a day, and the subsequent welding process takes approximately the same amount of time. Therefore, the time required for monitoring and overseeing the process is relatively limited.

Examination of concrete before demolition

Prior to demolition, it is important to conduct a thorough examination of the concrete structure to assess its condition and identify any damages. Simultaneously, it is advisable to separate the concrete into different structural parts. Following this, the concrete quality is assessed through the process of drilling cores, examining their quality, and determining the potential for recycling.

It is crucial to also consider the environmental conditions during the demolition phase. This includes effectively managing dust and noise in compliance with the environmental regulations and guidelines stipulated in the relevant municipality's environmental activity order. Further information on contamination studies of the concrete to be demolished can be found in the "Investigation of waste types" section.

New edition of DS/EN 206 DK NA (Concrete - Specification, performance, production and conformity)

As of January 1, 2021, a new edition of DS/EN 206 DK has been implemented, which has implications for the utilization of recycled aggregate in concrete. According to this edition, provided that specific requirements are met, the following is now permissible:

It is now allowed to replace 100% of both fine and coarse aggregate with recycled aggregate.

Recycled concrete can be used in all exposure classes.

From January 1, 2021, a dispensation from the municipality is no longer required. Recycled aggregates that meet the requirements can be used interchangeably with traditional aggregates.

The key requirements for recycled aggregates are outlined in DS/EN 206 DK NA:2020, section E.3.3, as follows:

These requirements pertain to recycled aggregate, as well as crushed process aggregates used by a group of concrete manufacturers in quantities exceeding 5% of the total aggregate quantity, as mentioned in point E.3.2.

Recycled aggregate must originate from concrete structures. Aggregates from concrete products such as pipes, well materials, concrete products, paving stones, aerated concrete, lightweight clinker blocks, and plaster and mortar from masonry constructions should not be used in the production of recycled concrete. However, concrete with cement and aggregates that meet this standard may be used. In case of any uncertainty, it must be documented that the concrete is composed as structural concrete.

Aggregates for recycled concrete

Crushed concrete serves as an excellent aggregate material for the production of new concrete, provided that the material is deemed "healthy," well-documented, declared (in accordance with DS/EN 12620), and meets the applicable requirements for recycled aggregates as per DS/EN 206 DK NA. Once the desired maximum stone size (Dmax) has been established, taking into account the specific use of the concrete, such as reinforcement and cover layer requirements, the crushing and soldering processes can commence. Piles of recycled material, consisting of sand (0-4 mm) and stone (traditional fractions or a wider range, e.g., 4-25 mm), can then be built up.

Once these bunkers are ready and the documentation is in order, the recycled material can be utilized in concrete production in the same manner as natural aggregates. This means that it can be incorporated into concrete mixes according to the desired specifications and requirements.

Crushing

The concrete is typically crushed using either a cone crusher or a jaw crusher. The desired size for the crushed material is usually 0-32 mm, as this categorizes it as stable gravel KVII according to DS401 standards. It is essential to ensure that the operator responsible for the process is knowledgeable in handling crushed materials intended for reuse.

Some operators prefer to combine the crushing and soldering processes in a single operation using a crushing plant with separate soldering capabilities. However, most operators choose to perform the soldering process separately, as it provides flexibility in disposing of certain parts of the crushed material, such as using them as road fill or for similar purposes. This approach allows for greater versatility in utilizing the crushed material effectively.

Soldering

The soldering process for the crushed concrete can be done on two separate sieve sizes: 6 mm and 28 mm. In the experimental project at Musicon, the 1,000 tons of crushed concrete

(0-32 mm) were divided into three piles: 0-4 mm, 4-25 mm, and 25-32 mm. However, the pile with 25-32 mm sand was not used in the concrete production at Musicon.

After soldering, representative samples need to be taken from the piles intended for concrete production (specifically, the stacks of 0-4 mm and 4-25 mm). These samples are used for a comprehensive aggregate analysis in accordance with DS/EN 12620 standards. It is important to conduct density and absorption determinations using a modified method (refer to Appendix 2 of the standard), while other tests for recycled aggregate can be carried out as specified in DS/EN 12620.

Experience has shown that new concrete with recycled aggregate often exhibits improved properties in fresh concrete, attributed to better grain shape and lower density. When crushing concrete, the aggregate material naturally divides into stone fractions that can be directly used in new concrete, eliminating the need for additional soldering. Consequently, a single silo for stone aggregate is sufficient for subsequent concrete production.

Recycled aggregate has a higher absorption rate than natural materials due to the presence of cement paste. Finer crushed concrete contains fewer natural stones among the grains, resulting in higher porosity and absorption. As a result, crushed concrete takes a significantly longer time to become saturated with water, often taking days, compared to natural materials. If the recycled aggregate (crushed concrete) is not saturated with water, it will absorb moisture from the concrete during mixing. This can significantly reduce the workability of the concrete immediately after mixing, leading to potential issues with casting and durability.

In Denmark, where autumn weather brings abundant rain, the material piles typically become waterlogged naturally. However, during dry periods (especially in summer), it may be necessary to water the piles, for example, using a garden sprinkler. Just like in any concrete production, the free moisture content in the aggregates should be determined before commencing the concrete production process.

In the case of mixing recycled concrete in "Indfaldet," the contractor neglected to measure the amount of water in the stored aggregates. Consequently, lumps of dry material formed during mixing and had to be manually removed.

It is important to note that crushed concrete requires a significantly longer drying time than natural aggregate to accurately determine the moisture content.

Mobile mixing plants

Normal/small mobile mixing plants have a smaller production capacity compared to factory-made concrete, which is why precast concrete typically holds the exclusive right for large castings. However, for productions below 25 m3 of concrete per hour, normal/small mobile mixing plants can effectively handle the task, provided there is sufficient space on the construction site and the work can be carried out without causing disturbance to neighbouring areas in terms of dust and noise.

Operating a mobile mixing plant requires the involvement of a minimum of three personnel:

- A certified and experienced mixing master who oversees the concrete mixing process and ensures the proper blending of materials.
- A person operating an excavator/front loader for continuous filling of the open material silos, ensuring a steady supply of materials.
- A concrete laboratory technician responsible for testing the fresh concrete, including measuring set dimensions, air content, and temperature. This technician also performs casting and molding of items for pressure testing.

These three individuals collaborate to ensure the smooth operation of the mobile mixing plant, maintaining quality control and meeting the necessary standards for the produced concrete.

Handling of concrete on mobile mixing plants

Overall, there is no difference between factory concrete and concrete produced on a mobile mixing plant. Also on a mobile mixing plant, the concrete delivery must of course be adapted to the casting technique and speed, so that the contractor's expectations and the production capacity match. In connection with handling the concrete, however, there are a number of conditions that are different:

- The concrete is produced and delivered in small loads – typically 1m3.
- The emptying height under the mixer requires the use of a flat crane bucket without stocking and emptying device — in other words, the low crane bucket must be tipped when emptying.
- Driving via belt directly into a traditional crane bucket is not recommended for concrete with a high set point, because the concrete risks demixing.
- The concrete in the low crane bucket must be driven and lifted by a separate vehicle – eg front loader/Manitou.
- The flat crane bucket can fill the concrete directly the pump when casting high walls.
- Use of two crane buckets (one flat and one traditional with stocking) makes it easy to fill the concrete in the form with moulding of moderately low walls.
- Using two crane buckets (one flat and one traditional) does the concrete is easy to place when pouring floors and all-terrain tires.

Receipt optimization and mobile mixing plant

To ensure the desired properties of concrete, including workability, strength, and durability, a suitable concrete recipe must be determined for all concrete production, including recycled concrete. This process involves a combination of experience, laboratory testing, casting of standardized specimens, and verification of strength and durability properties.

Since concrete requires at least 28 days to fully develop strength, casting of test specimens begins well in advance, typically at least 1 ½ months before the concrete is to be produced. This allows for sufficient time to assess the strength and durability characteristics of the concrete.

Setting up and calibrating a mobile concrete mixing plant typically takes at least half a day, and the process of transferring and running in a concrete recipe requires a similar amount of time. During this preliminary work, it is common to produce 3-6 m^3 of concrete that cannot be included in the actual production. This excess concrete must either be disposed of or used as filler, if suitable opportunities arise.

These measures are essential to ensure that the concrete produced meets the required specifications and performs as expected in terms of its properties and durability.

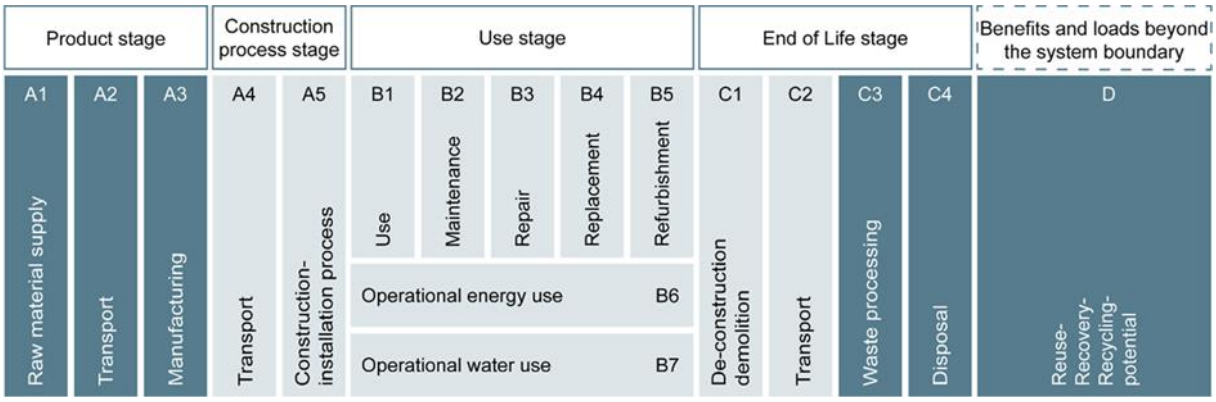
LCA calculations on recycled materials and design for disassembly

The trial project at Musicon has been joined by an online CO2 - calculator that can help you set figure on the potential CO2 -saving that is connected with your specific project. This means you can look on your own project's potential to save CO2 - instead
to look at average figures for discharge. Tool for calculating possible CO2 - saving
Before you can use the calculator to assess the environmental benefits of recycling concrete on a given construction project, you must obtain a number of information and data. You must, among other things, be able to put numbers on that amount of crushed concrete that is available – or can be expected to be available – and you must also know the distances
for gravel pit, site for landfill, recycling site and name of concrete supplier. Once these data are in place, you can use the online CO2 - calculator to calculate the amount of CO2 - emissions that you can save the environment for, if you choose to reuse concrete on your construction project. The calculator is based on the three recycling levels, A, B and C, described earlier, and compares the three recycling levels with use of traditional mobile concrete for in situ casting as reference value for CO2 - the discharge. During the development of CO2 - we have focused on the calculator on providing a sufficiently uniform data basis for the two different processes (in situ casting with recycled aggregate material vs. the more traditional process with allocated concrete production and transport to construction site for in situ casting with new concrete). The concrete recipe (the content of cement and aggregates) has therefore also been the same in both processes. Since it is a tool for calculating CO2 - the savings potential, takes CO2 - the calculator does not height for theentire life cycle of each of the two processes, but concentrates only on the elements that differentiate the two processes. It is therefore important to emphasise that that CO2
- the calculator does not replace the need to make LCA calculations with dedicated tools, such as LCA build. LCAbyg is the market standard for LCA calculations in DK and can be downloaded for free at https://www.lcabyg.dk/ The calculator's prerequisites
It is a basic prerequisite for CO2 - the calculator that it not only uses generic data from various sources, but to an equal extent is based on project-specific data such as the distance to the landfill and the amount of crushed concrete. This means that the comparison between
recycled concrete and mobile concrete - and their respective CO2 -discharge – is not static and therefore can never be seen as a general recommendation. So it is only when you
allows the project-specific data to be included in the calculation, that you can use the result to assess whether recycling is the right solution.

Embodied carbon can be contemplated the same way. When new products are introduced to a building, the materials come with a carbon “price”, which is the amount of carbon associated with the production, transport and handling of the building materials. This means, if we extend the idea, that a material bank not only will help minimise the need of new materials from primary sources (virgin materials), but it is also a way of maintaining embodied carbon in the materials and thereby avoiding emissions outside the system.

The effect of maintaining embodied carbon in a closed material loop is seen throughout the different life cycle stages. The life cycle stages are divided into several main groups according to EN 15804 and 15978, which are the European standards for Life Cycle Assessments (LCA) in the built environment.

The principles of LCA and circular economy are based on the same basic principles of circularity and therefore allow us to overlay the LCA methodology on circular economy in general.



This means that the carbon saving potential in circular economy is not isolated to the production process itself. There is also a carbon saving potential in the construction stages and in the end of life stages. Take, for example, wood as construction material. When timber grows in the forest it accumulates carbon and embeds it in the biomass. The accumulated carbon remains in the wood until it is released again at the end of life stage, therefore extending the lifespan of the product will prevent the carbon from being released to the atmosphere. Embodied carbon can be contemplated the same way. When new products are introduced to a building, the materials come with a carbon "price", which is the amount of carbon associated with the production, transport and handling of the building materials. This means, if we extend the idea, that a material bank not only will help minimize the need of new materials from primary sources (virgin materials), but it is also a way of maintaining embodied carbon in the materials and thereby avoiding emissions outside the system.

The effect of maintaining embodied carbon in a closed material loop is seen throughout the different life cycle stages. The life cycle stages are divided into several main groups according to EN 15804 and 15978, which are the European standards for Life Cycle Assessments (LCA) in the built environment.

The principles of LCA and circular economy are based on the same basic principles of circularity and therefore allow us to overlay the LCA methodology on circular economy in general.

The carbon saving potential in circular economy is not isolated to the production process itself. There is also a carbon saving potential in the construction stages and in the end of life stages. Take, for example, wood as construction material. When timber grows in the forest it accumulates carbon and embeds it in the biomass. The accumulated carbon remains in the wood until it is released again at the end of life stage, therefore extending the lifespan of the product will prevent the carbon from being released to the atmosphere Roskilde Municipality has developed three CO2 calculators for early decision making. This means that the calculators are meant to help choose the right solution for a circular project based upon the potential CO_2 savings involved in the process.

Basically the use of the calculators is associated with early planning and procurement. The CO_2 soil calculator has shown value in procurement, since the simple calculator allows contractors to compete on lowest possible CO_2 emissions. Using a common calculator in the tender complies with the regulations according to Public Procurement Act 1565 in regards to transparency and equality.

CO2 calculator Concrete

The main purpose of the CO_2 calculator is to provide primarily public developers with a tool for a qualified assessment of the CO_2 savings potential associated with a specific quantity of recycled concrete. Link to calculator. The CO_2 calculator is based on three recycling classes: A, B, and C, which are described in the document "Recycling of Concrete - from manual effort to permanent change in practice." These three recycling classes are compared to the use of traditional mobile concrete for in situ casting as a reference value for CO_2 emissions.

The CO_2 calculator is built on a range of consumption data derived from various databases, reported consumption figures from contractors, and environmental product declarations. The purpose of these consumption data is to provide an overall overview of the CO_2 emissions associated with different processes in the handling and processing of recycled concrete. A standard mobile concrete, strength class C30/37, has been chosen as the reference value. In addition to this, the efficiency of crushing and sorting at the processing site plays a significant role, as well as the transportation distances in the various scenarios.

When considering the different processes associated with concrete recycling, many of them are identical to those associated with traditional mobile concrete production in factories. These processes account for the majority of the total CO_2 emissions associated with both methods of concrete processing. However, this does not exclude the possibility of considering the processes that differentiate the two methods and assessing which method results in the least climate impact in terms of CO_2 equivalents.

The results from Musicon showed that the main CO_2 saving potential is associated with the need of driving. A high percentage of the CO_2 was used on the new cement needed for mixing the recycled concrete. Therefore, it was decided to focus on a simple calculation for driving materials from a to b. The reason why CO_2 calculation of recycled concrete is still valuable is due to the high amount of concrete being produced. In addition to the saving potential of driving less with the aggregates, there is also a saving potential of optimising the mixing recipe. Many times the recipe of the concrete mixture can be adjusted to fit local conditions and the quality of the aggregates. This saving potential can amount to 12% whereas the saving potential associated with minimising driving typically amounts to between 1 and 5 %.

The saved amount of CO_2 in recycling concrete on Indfaldet was almost exclusively associated with saved transport of soil/concrete from the site and transport of new aggregates to the site. The calculated saving from in situ moulding 50m2 concrete was 0,4 tons CO_2.

The calculator's prerequisites

It is a basic prerequisite for CO2 - the calculator that not only uses generic data from various sources, but to an equal extent is based on project-specific data such as the distance to the landfill and the amount of crushed concrete. This means that the comparison between recycled concrete and mobile concrete - and their respective CO2 -discharge – is not static and therefore can never be seen as a general recommendation. So it is only when you allows the project-specific data to be included in the calculation, that you can use the result to assess whether recycling is the right solution.

CO2 calculator Soil

As mentioned above it was decided to develop a dedicated CO2 calculator for soil, that only focused on driving and handling soil (and all other materials). The calculator simply calculates the CO2 associated with driving a given amount of soil or other materials, based upon standard EU values for CO2 emissions tonnes/kilometre.

CO_2 calculator for soil transport

ROSKILDE KOMMUNE

Comments	LCI	
Cells marked in blue, should be filled. All distances are calculated from site where soil is excavated. Cells marked in yellow cover on site handling of soil.	Distance to end deposite, km	0
	Distance to local reuse, km	0
	Amount of soil, tons	0
	Reuse percentage	0
	Use of wheel loader, hours	0
	Use of dumper, hours	0
CO2-emissions soil transport per tonne kilometre	Soil transport, kg CO2/tonkm	0,081
CO2-emissions crushing per tonne material, diesel crusher	Wheel loader, kg CO2/hour	25,68
CO2-emissions local transport	Dumper, kg CO2/hour	37,54
CO2-emissions full trailer combination, two way transport	Transport of loader and dumper kg CO2	135,13
	Kg CO2e per liter diesel	2,65

CO_2 saving potential		
Soil transport	**Project CO2 saving**	**reference**
Transport to end deposite, kg CO2		0
Transport to site for reuse, kg CO2	0	
Use of wheel loader	0	
Use of dumper	0	
Transport wheel loader and dumper	135	
Kg CO_2	**-135**	Reference

The calculator is Excel based and only demands filling out four values before getting a result:

1) Distance to end deposits, km. (Distance from excavation to standard end deposits. Standard end location for soil if nothing else is planned.)
2) Distance to local reuse, km. (Distance from excavation to site of local reuse. When on site or nearby reuse location, leave value as "0".)
3) Amount of soil, tons.
4) Reuse percentage. (Percentage of the soil that will be reused on site.)

In addition to the four main values, you can also add values for estimated amount of wheel loader and dumper hours necessary for local reuse. Only hours that are extra compared to standard handling, e.g. not for loading trucks.

Emission factors are taken from Lipasto, Energistyrelsen and consumption data from manufacturers of the crushing machinery.

Processes	Emissionsfactors	Source/comments
Transport, kg CO2/tonkm	0,081	LIPASTO, Earth moving lorry, Gross vehicle mass 32t, pay load capacity 19t, 75 % Highway driving and 25% urban driving, 2016 average LIPASTO 0% returnload
Transport crusher and screener kg CO2	135,13	LIPASTO, Full trailer combination Gross vehicle mass 76t, pay load capacity 51t, 9 axles. 75% Highway driving and 25% urban driving. Distance 4*25km.
Parameters for machinery		
CO2 per liter diesel	2,64	Energistyrelsen
kg CO2 per kWh	0,85	Kleemann
Efficiency [tonne per hour]	100	Informed by MIS
Weight [tons/m3 beton]	2,4	Epd
Engine capacity screener [kW]	95	McCloskey
CO2 emmision dumper [kg/hour]	37,54	LIPASTO
CO2 emmision wheel loader [kg/hour]	25,68	LIPASTO
Parameters for transport		
Earth moving lorry, highway driving [kg CO2/tkm]	0,04	LIPASTO
Earth moving lorry, urban driving [kg CO2/tkm]	0,073	LIPASTO
Earth moving lorry returload, highway driving [kg CO2/	0,558	LIPASTO
Earth moving lorry, returload urban driving [kg CO2/km	0,838	LIPASTO
Earth moving lorry, payload [ton]	19	LIPASTO
Full trailer combination (76t), highway [kg CO2/km]	1,43	LIPASTO
Full trailer combination (76t), urban driving [kg CO2/km	2,55	LIPASTO
Full trailer combination (76t), highway [kg CO2/km] Re	0,87	LIPASTO
Full trailer combination (76t), urban driving [kg CO2/km	1,36	LIPASTO
Percentage of highway driving (75%)	0,75	Average
Percentage of urban driving (25%)	0,25	Average
Total transport distance for machinery used on site [kr	100	Average

The calculator does not replace the need to make LCA calculations with dedicated tools, such as LCA build. LCAbyg is the market standard for LCA calculations in DK and can be downloaded for free at https://www.lcabyg.dk/

CO2 calculator CDW

In addition to the soil calculator a generic CDW calculator was developed. The CDW calculator is based upon more generic estimates of CO2 saving potential associated with recycling and reusing building materials and soil.

Construction and demolition waste

When a building owner has to decide whether to demolish a building and how to treat the waste, several deciding parameters are typically taken into account. One of these should be the overall effect the actions will have on the environment. The present calculator is meant as a step in that decision making process. The first steps would typically be to carry out a Pre-demolition audit. A Pre-demolition audit will deliver most of the necessary number for this calculator, e.g. amounts of different building waste fractions. The remaining numbers relate mainly to soil movements and can either be estimated or retrieved from soil screening procedures.

The core function of the calculator is to combine site specific information with generic information on Global Warming Potential (GWP) from the processes. This means that only very few numbers are needed in order to get a result that will help in the decision making process. The result from the calculator therefore is focused on showing the CO2 saving potential depending on the chosen actions, where the baseline is replacing a given building fraction with new building components and disposing the waste without any circular actions. In order to keep the calculation simple and operational only three different actions are allowed. This makes the calculator very operational, however if more precise calculations are needed, further calculations should be carried out. Within CityLoops more detailed calculators have been made for specific use for soil and concrete.

A total of 11 different material fractions are included in the calculator. Each material fraction can be calculated by only adding two types of information, this means the calculator is very quick and simple to use. In the following each material fraction will be briefly described.

1. Sand/Gravel
Sand and Gravel from a demolition and renovation can in most cases be reused on site unless it is contaminated with environmental hazardous substances. The saving potential is measured against driving the sand/gravel to end deposits. Therefore the information for this fraction is the amount i tons and the distance to deposit. The calculation is based on a reference emission of CO2 from the transport itself, combined with a smaller amount of fuel for handling. In this calculation recycling is not an option. If more accurate calculations are needed please use the dedicated CO2 calculator for soil.

2. Soil
Like sand and gravel, soil can be reused on site unless it is contaminated with environmental hazardous substances. The saving potential is measured against driving the soil to end deposits. Therefore the information for this fraction is the amount i tons and the distance to deposit. The calculation is based on a reference emission of CO2 from the transport itself, combined with a smaller amount of fuel for handling. In this calculation recycling is not an option. If more accurate calculations are needed please use the dedicated CO2 calculator for soil.

3. Concrete
Concrete is a very CO2 heavy building material, mainly because of the cement added to the concrete. This also is the case when old concrete is crushed and used as aggregate in new concrete (Recycling). The big saving potential is associated with reuse of concrete elements, preferably on site. The information needed for this calculation is the amount in m3 and what kind of circular action is carried out. Reference value in "No circular action" is the embedded emissions associated with the production of one m3 new conventional concrete. If more accurate calculations are needed please refer to the dedicated CO2 calculator for concrete.

4. Bricks
Bricks from buildings before 1950 normally are able to be recycled and reused. The scenario where bricks are cleaned and reused either locally or in another building is referred to as recycling in this calculation. The "reuse" action is referring to the situation where parts of a brick wall are cut into smaller pieces and are reused on site. The reason for the low saving potential for reuse, is the high amount of transport needed for this action. Reference value is one m2 of conventional bricks.

5. Glass/windows

Reusing windows has great potential from both a climatic as well as an architectural point of view. When replacing or tearing down windows, there will most often be intact double-glazed windows with a certain remaining life, as well as window frames and frames with continued good durability. Windows however is a mixed building material and therefore the "Reuse" action is the only relevant for this fraction. Reference value is the production of one m2 new conventional window.

6. Gypsum
Gypsum is a more delicate building material and therefore the "reuse" action is not relevant for gypsum. Recycling however is commonly used in the production of new gypsum. Reference value is one m2 of conventional new gypsum. The reason for the small saving potential is that recycling already is used in the reference material from the Okobaudat database.

7. Steel
Recycling of load-bearing steel profiles has a great potential if it has been considered already in the design phase so that the profile can be dismantled. Steel structures found in halls and industrial buildings are constructed with bolted joints and are therefore ideal for reuse, as they are easy to disassemble and reassemble in a new building. Recycling is also a valid action since there is a long tradition for melting and recycling steel in new profiles. Reference value is the production of one kg conventional steel profile.

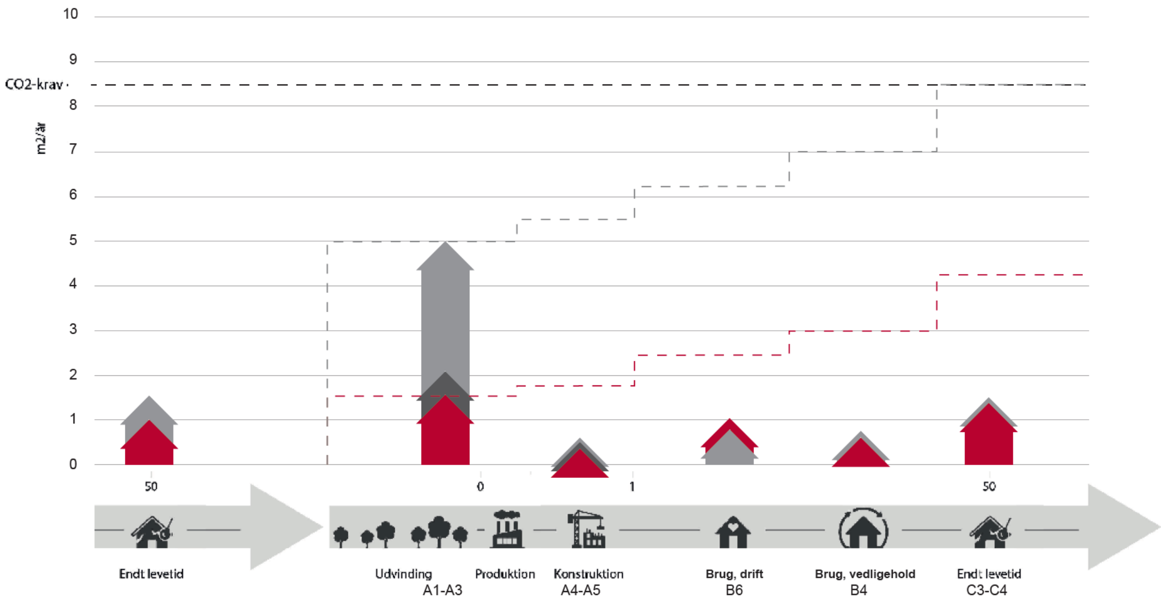
8. Aluminium
Recycling of aluminium sheets has great potential, as the sheets are made of aluminium which has great resistance to wind and weather. The plates are also easy to disassemble, as they are usually mounted with screws. When disassembled, the plates are sorted and cleaned, after which they can be transported on pallets to a new destination, where they can again be mounted with screws. Likewise recycling aluminium is a valid action, since it often is seen in modern production in high numbers. Reference value is the production of one m2 conventional 1mm aluminium plate.

9. Bitumen/roofing
Roofing felt consists primarily of a mixture of bitumen, plastic materials, reinforcement and filler. Traditionally, bitumen from roofing felt was deposited, but in recent times bitumen has been recycled in asphalt production and to a lesser extent as a secondary product in new roofing felt. In the production of new roofing felt, secondary bitumen from roofing felt waste can replace parts of virgin bitumen. Direct reuse of roofing felt however is not an action in this scenario, since it is not commonly used. Reference value is the production of one m2 conventional roofing felt.

10. Insulation
Traditionally insulation materials are neither reused or recycled, but lately certain insulation manufacturers have been gathering used insulation material and adding it to the conventional production. This is the circular action referred to in this calculator. The reference value is the production of one m3 of conventional mineral wool.

11. Timber
Most often, wood is collected at large recycling plants, where it is sorted according to quality and impurities. The wood that is mapped as being clean is recycled as secondary raw materials

for the production of new chipboard. This recycling process however is quite energy intensive, which can be read in the negative saving potential for recycling. Reuse on the other hand is very energy efficient and when possible a very valid circular action. The reference value is the production of one m3 of conventional wood.



Before you can use the calculator to assess the environmental benefits of recycling concrete on a given construction project, you must obtain a number of information and data. You must be able to put numbers on e.g. the amount of crushed concrete that is available – or can be expected to be available – and you must also know the distances for gravel pit, site for landfill, recycling site and name of concrete supplier.

Once these data are in place, you can use the online CO2 - calculator to calculate the amount of CO2 - emissions that you can save the environment for, if you choose to reuse concrete on your construction project. The calculator is based on the three recycling levels, and compares the three recycling levels with use of traditional mobile concrete for in situ casting as reference value for CO2 - the discharge

Concrete is a very CO2 heavy building material, mainly because of the cement added to the concrete. This also is the case when old concrete is crushed and used as aggregate in new concrete (Recycling). The big saving potential is associated with reuse of concrete elements, preferably on site. The information needed for this calculation is the amount in m3 and what kind of circular action is carried out. Reference value in "No circular action" is the embedded emissions associated with the production of one m3 new conventional concrete. If more accurate calculations are needed please refer to the dedicated CO_2e calculator for concrete.

The calculated CO2 saving associated with recycling concrete on Indfaldet was rather low due to the fact that the concrete was recycled and not reused. The saved CO2 amount was 0,5 tons.

3.1.3 Circular soil management

process and in the later contracts. Early C02 calculations of possible savings have actively been used at a strategic level along with the economical calculations.

This have lead to the recognition of a few simple ways to break down barriers, which the builder should follow in order to successfully obtain circular soil management:

- Initiate early geotechnical and environmental investigations on the location.
- Use the obtained knowledge from the investigations to conduct early CO2 calculations on the material streams.
- Use actively the early CO2 calculations along with the economical calculations in the tender process in order to support soil balance in the project.
- Continually focus on handheld and close project management.
- Close communication and cooperation between authorities, builder, consulting engineer, contractors.

- If possible keep the same consultant for a bigger project area or secure a forced transfer of knowledge. To secure circular soil management, thus minimising excavation and transportation of soil by using excess soil locally, a series of instruments were tested in Roskilde. The soil management instruments were developed along with the demonstration cases, keeping focus on creating a dynamic process for circular soil management at city level in order to keep excavation of soil to a minimum and use excess soil locally, instead of driving it further away.
- In the test area Musicon, soil is treated like any other waste stream: it is kept separate and kept track of. The LCA calculations proving the environmental impact of excavation and moving of masses are used as arguments for planning and decision making to keep soil in the ground or use it on-site. In the Hall 11/12 area, the plan is to keep soil on-site.
- In 2020-2021 initial environmental investigations were conducted on the Musicon area covering Hall 11/12. The geotechnical and environmental parameters for the soil were measured and mapped in order to combine and use data in the planning process along with mapping of the other waste/material streams in the project area.
- To support planning and decision-making LCA calculations were performed to assess the CO2 impact of minimising excavation and transportation of soil. Moreover, barriers in reusing soil was uncovered by interviewing authorities, clients, advisors and contractors with experience in projects involving circular soil management.
- After determination of the planning process further investigations involving a tighter net of environmental analyses have been completed in order to qualify the amount and quality of soil to be handled in the specific areas for the different developers. Furthermore geotechnical boreholes have been used to qualify the necessary foundation. The parallel mapping of the amount of soil and concrete have led to more detailed designation of temporary crushing and storing facilities within the project area. For instance the soil streams for the area planned for the future parking house has been further investigated for content of oil, heavy metals and methane gas in close cooperation with the developer, the consulting engineer and the environmental authorities since the area is polluted. This has led to isolation of 90% of the soil which are only slightly polluted and thereby can be reused in the project area. Approximately 9000 tons of crushed concrete and soil will be reused in the project area with the new parking house. From the total project area, which involve the parking house and several future housing projects in the area by hall 11/12 area a total of 860 tons of heavily polluted soil are planned to be removed and transported to an approved recipient.
- CO_2 calculations have been conducted and focus on soil balance has been kept as an overall goal for the project. At this stage a CO2 saving from reuse of soil at approximately 22 tons CO2 can be calculated for the parking house.
- The initial geotechnical and environmental investigations have proved to be especially important since the results have been used to facilitate soil balance inside the project area both in the planning.

The demonstration area of Hal 11/12

In the test area Musicon, soil is treated like any other waste stream: it is kept separate and kept track of. The LCA calculations proving the environmental impact of excavation and moving of masses are used as arguments for planning and decision making to keep soil in the ground or use it on-site. In the Hall 11/12 area, the plan is to keep soil on-site.

In 2020-2021 initial investigations were conducted on the Musicon area covering Hall 11/12. The geotechnical and environmental parameters for the soil were measured and mapped in order to combine and use data in the planning process along with mapping of the other waste/material streams in the project area. After determination of the planning process further investigations have been completed in order to qualify the amount and quality of soil to be handled in the specific areas for the different developers. For instance the soil streams for an area planned for a future parking house has been further investigated in close cooperation with the developer, the consulting engineer and the environmental authorities since the area is polluted. CO2 calculations have been conducted and focus on soil balance has been kept as an overall goal for the project.

In connection with the project, it is expected to excavate approximately 4,800 m3 of soil from the area and remove approximately 670 m3 of pavement, concrete, and foundations.

It is planned to reuse suitable clean and slightly contaminated soil excavated from the area under the upcoming parking garage and in the drainage project on the remaining part of Hal 12, property number 9k.

For the construction of the parking garage, intermediate building, and parking area outside the building, an estimated 5,070 m3 of backfilling is required. The drainage project is expected to be able to accommodate approximately 1,000 m3 of soil from the parking garage. Similarly, it is expected that approximately 1,800 m3 of crushed concrete from existing pavements can be incorporated into the future subbase construction under the parking garage, of which approximately 670 m3 comes from pavements within the parking garage.

In the initial pre-classification, 420 m3 of contaminated soil was identified, which needs to be disposed of from the site. This corresponds to 10% of the total pre-classified amount of soil. Assuming a similar distribution in the upcoming supplementary pre-classification, it is estimated that 480 m3 of contaminated soil should be removed from the site. Similarly, it is expected that up to 4,320 m3 of clean and slightly contaminated soil can be reused under the parking garage and in the drainage project.

Based on the estimated excavation quantities and backfilling capacity, a soil balance has been prepared for soil and crushed concrete from the parking garage project and the surrounding drainage project, see Table 7-1.

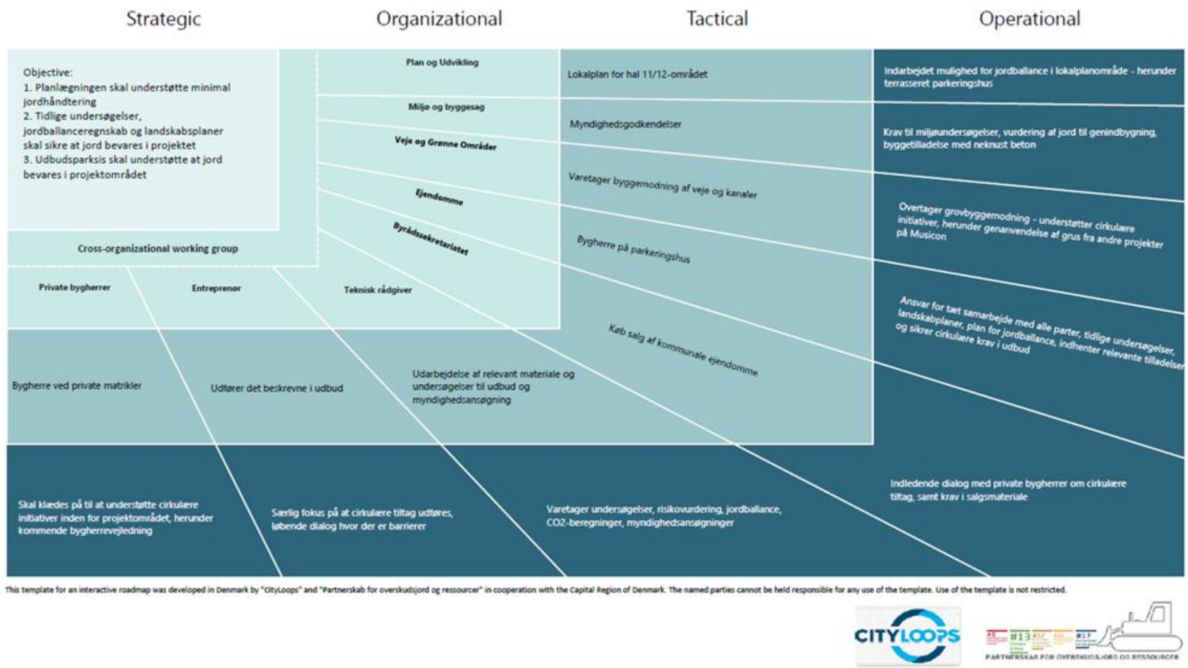
Tabel 7-1: Jordbalance fra de forventede afgravnings og genindbygnings mængder fa P-huset og omkringliggende afvandingsprojekt

	Jord m^3	Knust Beton m^3	Totale mængder m^3
Afgravning fra P-husprojekt	-4.800	-670	-5.470
Afgravning udenfor P-husprojekt	0*	-1.130	-1.130
Genanvend under P-husprojekt	3.270	1.800	5.070
Genanvendt i afvandingsprojektet	1.050	0	1.050
Bortkørsel til jordmodtager	480	0	480
Jordbalance	**0**	**0**	**0**

*Afgravning af jord ifm. afvandingsprojektet ikke estimeret men antages genindbygget i projektet

Roadmap for soil management

The roadmap has proved to be useful on an initial stage in any given project involving possible soil excavation. The roadmap was useful on project level to secure an overall designation on all the involved authorities, advisers, builders, developers and so on. An initial roadmap for the project involving Musicon hal 11/12 project area is shown below.



Interviews identifying barriers

Roskilde has in cooperation with RUC, HTK og CK performed a series of interviews with stakeholders about the barriers to implementing a great degree of soil reuse on site. Barriers to soil reuse have shown to be lack of initial investigations regarding pollution and geotechnical soil parameters. Cooperation between the consulting engineer and the authorities have proved to be essential for optimizing soil reuse and at the same time secure people and the environment. It is important to commit the developer to keep focus on the potential for reuse by presenting CO2 calculations for soil handling along with calculations for handling the other material streams on the building site. Finally, retention of knowledge and ongoing focus on the goal for circular soil reuse has shown to be improved by keeping the same consulting engineer and keeping an ongoing inclusion of the environmental authorities and the developer. The results are currently used in the applicable estate management strategies conducted by Roskilde Community.

Instrument for predicting future excavated soil production

Roskilde has used this tool to predict annual volumes of future excavated soil within a period of 12 years (2020-2031). It will be evaluated by comparing predicted soil volumes with annual soil volumes reported. The prediction is based on a "business as usual" scenario, considering a situation where municipal planning and construction activities are performed without paying special attention to excavation and production of excavated soil. It is based on historical analysis and knowledge of major construction projects that will take place in the future. Link to the Danish report on making the prognosis for Roskilde: https://3.basecamp.com/4291695/buckets/14002130/uploads/6107579338

YEAR	TON
2020	150.000
2021	250.000
2022	200.000
2023	250.000
2024	200.000
2025	300.000
2026	300.000
2027	200.000
2028	150.000
2029	100.000
2030	100.000
2031	100.000
Total	2.3 mio. ton

Table 1- prognosis for amounts of excess soil from construction and infrastructure projects in Roskilde Kommune

Roskilde has evaluated the tool by comparing predicted soil volumes with annual soil volumes notified and reported in the registration system Flytjord.dk. Registration of soil transportation notified to the Municipality of Roskilde in 2022 amounts to 1.7 mio. tons of soil and it is estimated that approximately 1.2 mio. tons of soil have actually been loaded on trucks and transported to a reception facility in or outside the Municipality of Roskilde. This amounts to a calculated CO_2 load from soil transportation at 3400 ton CO_2.The registration system Flytjord.dk has a built-in uncertainty since not all soil transportation must be notified and the amount of soil actually transported is not always reported. Independent of this uncertainty it is clear that the evaluation showed that the soil prognosis underestimated the amount of soil transported from locations in Roskilde municipality. Possible sources of errors in Roskilde are that a major part of the building activities in Roskilde are conducted on areas that were already developed several years ago. Since the prognosis focuses on new development areas this is not included. Furthermore big amounts of soil are transported between the approved soil handling sites, and this also leads to an underestimation of the transported soil amounts in Roskilde.

In the CityLoops demonstration phase, the prognosis has been used to explore what can be done on an overall view. If a certain development area potentially can generate big amounts of soil, then it can be useful to mobilise planning efforts to avoid soil excavation and transportation outside the project area – creating both economic and CO2 savings.

The results indicate that the tool underestimated the annual amount of soil handled in Roskilde. However the cases on Musicon have shown a big potential for minimising soil handling by incorporating local reuse of soil on the project site.

Framework for circular soil management

Roskilde is currently in progress with incorporating the results of a circular soil strategy in urban development strategies as well as real estate management strategies. It will be a set of levers, procedures or tools that are developed as they go according to how to address each identified barrier. The overall bearing mark is to rank soil management in order to promote soil handling linked with the CO2 load. The soil stream hierarchy is outlined in the following picture.

NB Slide 3 indsættes uden tekst her+ i "den anden rapport".

For tendering, prices are needed to be able to calculate more accurately the economic potential of circular soil management in the future. The effect of the circular soil strategy will be evaluated on an annual basis by comparing predicted soil volumes (tool 4) with soil volumes actually produced in corresponding years.

Current project status concentrates on the description of the procedure regarding necessary steps in the initial work prior to the project planning, and simultaneously with the construction process.

The introduced barriers have been designated and incorporated in Roskilde's work with a new builders guide, which address how these barriers can be pinpointed and minimised in order to advance circular soil management. A final draft of Builders guide will be introduced ultimo 2023.

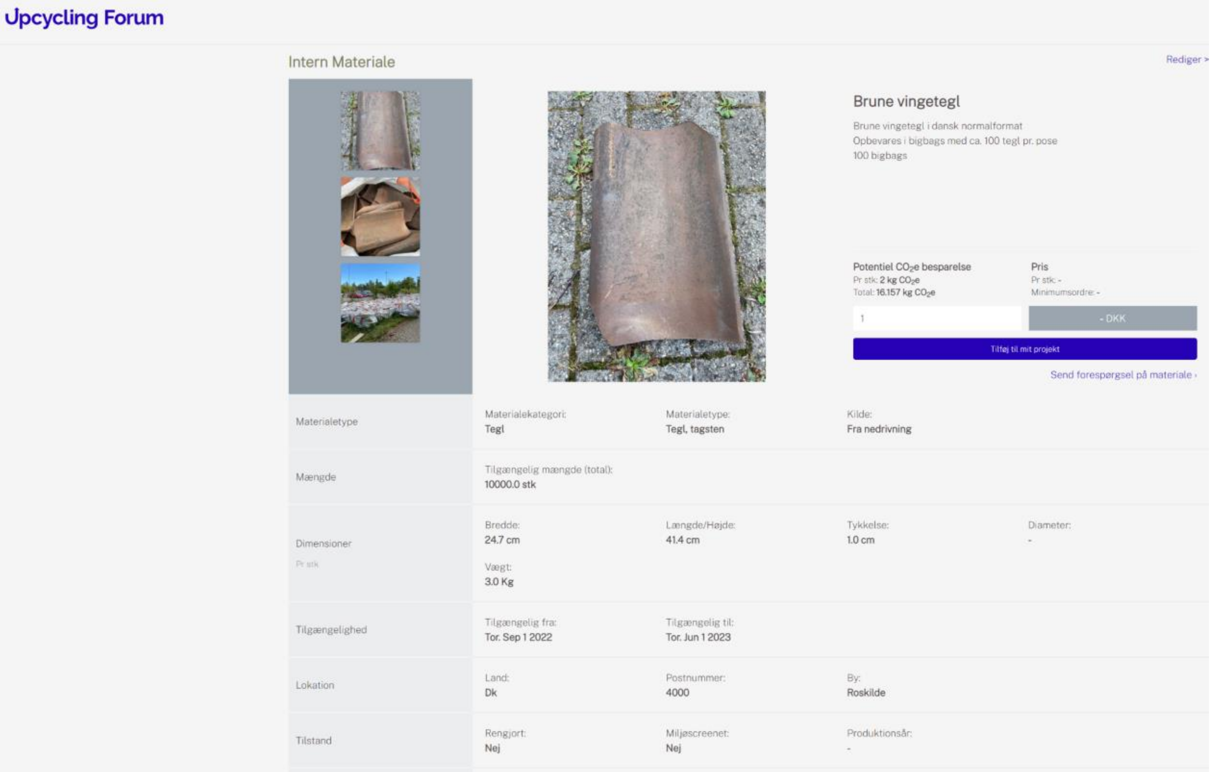
Material Bank

Local access to reused and recycled building materials are central elements in achieving the transition to circular constructions. In order for the municipality to have a study supply of circular building materials, it was decided to establish three collaborative efforts to facilitate the circulation of the municipality's own building materials.

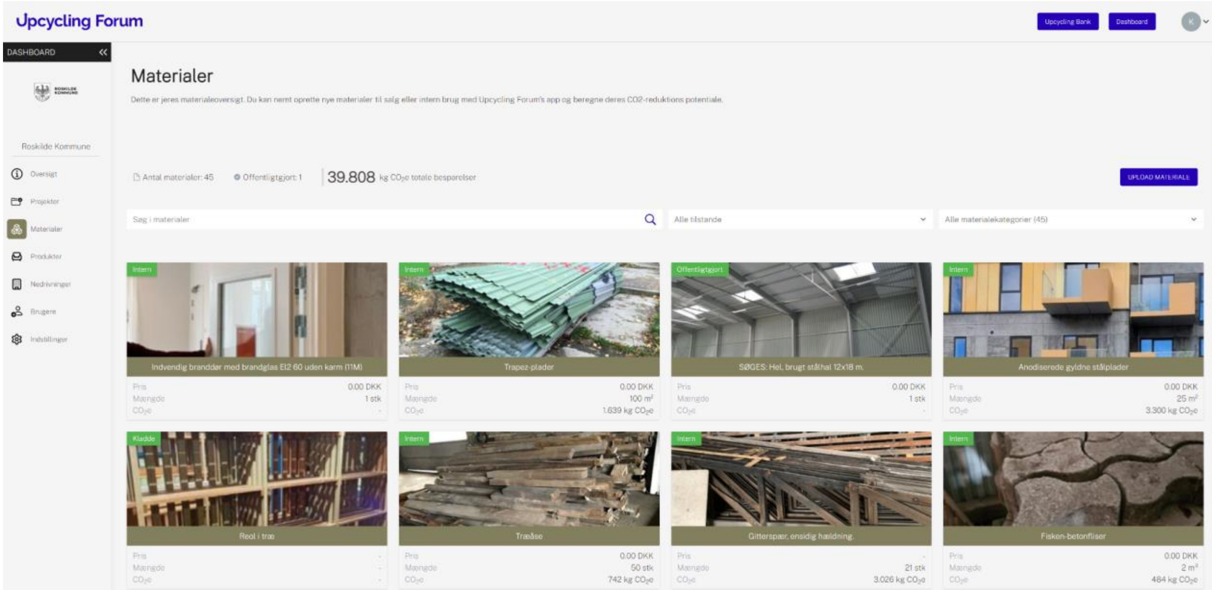
In order to be able to work with direct reuse in more and larger projects and thus ensure continued good development within circular construction, the requirement to obtain sufficiently good used building materials is increasing. The administration will therefore ensure access to recycled materials by facilitating the circulation of primarily the municipality's own excess and used building materials and thus service the municipality's own constructions and demolitions. This is done through three collaborative efforts:

a) Virtual material bank

A virtual material bank with an online platform that conveys both available and requested building materials. The virtual material bank is based on a commercial online platform that is already used in the municipality. The platform was adapted to the municipality's needs so that it can contain additional information about the materials' environmental and technical specifications/properties/conditions.



Basically the virtual material bank is a database, where all circular building materials are listed. Each material is registered with basic information regarding Origin, present location, environmental testing, future use and description of the material regarding size, weight and type. The virtual material bank allows the municipality to exchange information regarding available material with advisors and contractors, in order for them to suggest solutions using the available materials in the municipality. In time it will be possible to exchange materials with other municipalities and to sell circular construction materials on normal commercial terms.



Beside the commercial platform "Upcycling Forum" the municipality is registering its existing buildings in a database, where information is stored in both 3d BIM files as well as in attached files containing information such as environmental product declarations etc. This is especially important for buildings that were constructed as "design for disassembly". The building model contains information on all relevant materials used in the building, their expected lifespan, the amount of the material and instructions on how to take the material out of the building, without damaging the building.

The transformation of information from existing buildings has allowed us to cooperate more closely with the maintenance department and has created a common understanding of the potential in reusing building materials.

b) Physical material bank

A central, physical material bank, which is permanently located between the Holbæk motorway and Darupvej, and will function as the municipality's primary physical storage area for used building materials. The materials are managed and disseminated via the virtual material bank. In the long term, it is appropriate to upgrade the site with a smaller storage hall for materials that must be stored under roof. The space will replace a previous and temporary physical material bank that has operated in Hall 1 at Musicon since 2019, but will be closed at the end of 2023 in order to be transformed into a local district square for the benefit of surrounding housing.

c) Local pop-upterial bank

A local pop-up material bank at Skt. Hans, which will service the temporary need for local handling of used building materials and will be shut down again when the need ceases. The material bank is placed in an existing garage building and managed via the virtual material bank. Similar to this, it may also be relevant elsewhere to establish a temporary pop-up material bank.

The material bank aims to investigate the possibility of recycling materials locally and at the same time get the circular economy going. It turns out that the absolute greatest benefit, economically and environmentally, occurs if we are able to recycle building materials as high up in the waste hierarchy as possible and as locally as possible. So, if we can use building materials as close to the same function and design as originally, and preferably in the same place, we get the biggest benefit out of it.

If the concrete walls of an existing building can be reused directly in a new building in the same place, then that is the best we can do. It is the highest level in the hierarchy and the most local reuse, which is what we aim for. If we can reuse an entire wall disc elsewhere at Musicon, that's great. If we have to break it down and reuse it in a new concrete, that's still okay, but not as good.

If it is a question of rafters, we try to preserve them as whole rafters instead of dividing them into laths and beams. Because it may be that we can reuse them in their original form somewhere, and if there is a need for separation, we will do so afterwards. We look at recycling before recycling.

The waste hierarchy as guide

The waste hierarchy has shown to be a very efficient way to navigate in the early investigations. And this is reflected in the material banks. First priority is to keep materials on site in the building, this is the case in Hal 12, where almost all load bearing structures are maintained. The virtual material bank´s main purpose is to catalogue existing materials while still incorporated in buildings. This allows us for optimal planning and preservation of relevant building elements. Second priority is to extract building components in their original shape and reuse them directly in other buildings. This is where the physical material banks come into play. They absorb materials in the timespan from extraction to reuse.

The material bank operates practically by storing primarily reclaimed materials from demolition projects at Musicon, as well as materials from other buildings owned by the municipality. When there are projects that require the recycling of building materials, advisers and contractors participating in the bidding process have the opportunity to visit the material bank. They can physically inspect the available materials and select the specific ones they would like to incorporate into their projects. These material selections are then included in their bidding proposals, allowing for project planning to proceed accordingly, taking into account the chosen materials. In the future, there are plans to expand the material bank into a virtual platform that covers the entire district, providing remote access to a wider range of materials. The primary objective of the material bank is to promote sustainable practices in the construction industry by encouraging the reuse and recycling of building materials, ultimately reducing waste.

All buildings constructed in Musicon are included in the material bank. The municipality is actively registering and analysing these buildings to identify any environmentally harmful substances. This comprehensive catalogue of the existing building stock allows for effective future planning. By identifying buildings that may become obsolete in the next 5-10 years, the municipality can anticipate the release of materials such as concrete, which can be broken down and reused.

In addition to creating a material passport that indicates the presence of environmentally harmful substances in the materials and their appropriate usage contexts, the municipality also develops a Building Information Model (BIM). This BIM records the quantities of all materials used in the buildings and notes any potential challenges associated with them.

The screening process takes into account the presence of dangerous substances. This aspect is of great significance for risk calculations and management in new circular projects. By considering the potential risks associated with demolishing a building and reusing its materials in a nearby construction project, contractors must factor in these risks when submitting their bids. Consequently, this may lead to a higher price for the client. However, if the developer assumes these risks, it is possible to maintain a competitive price without compromising environmental safety.

In Roskilde Municipality, the construction process is divided into several sub-contracts, and an environmental screening of materials is conducted in advance, as required by legislation. This comprehensive screening ensures that the contractor does not face any specific risks in the demolition contract. Instead, their responsibility is to deliver materials for recycling rather than disposing of them in a landfill. Once the demolition contract is completed, the municipality receives the materials, which are then analysed to determine their potential for recycling. This valuable data empowers other contractors to confidently state, "I could use that!"

There are already notable examples of buildings where the material bank concept has been successfully applied. One such instance is the recently constructed car park in Musicon. Designed by Mangor & Nagel and built by MT Højgaard as the turnkey contractor, this project incorporated the principles of the material bank from its inception. During the construction process, specific requirements were set regarding the quantities of building materials, taking into account life cycle analyses and overall project economics. These requirements ensured efficient resource management and facilitated the inclusion of data into the virtual material bank for future projects.

Moreover, the car park project embraced the concept of "Design for Disassembly." This design approach allows for easy disassembly and the potential reuse of materials in the future, further enhancing the sustainability and circularity of the building. By implementing the material bank and prioritising sustainable design principles, the municipality showcased its commitment to reducing waste and promoting a more environmentally friendly approach to construction in Musicon.

Cooperation amongst municipalities

Several municipalities in Denmark are actively involved in the recycling of building materials. While many municipalities have strategies in place to reuse common items like wooden doors, the importance of assessing the environmental and financial feasibility becomes more pronounced as we delve deeper into the waste hierarchy. For instance, if we were to request a factory to collect concrete for crushing and repurposing it in new factory concrete, the immediate environmental advantage would be negated due to exorbitant transportation costs. Although there would be a gain in terms of raw materials, the overall advantage in relation to the life cycle analysis diminishes significantly if the transportation distance exceeds 50 km.

It is crucial to conduct a meticulous evaluation that weighs the environmental benefits against the associated costs at every step of the waste hierarchy. By making informed decisions regarding the recycling and reuse of building materials, municipalities can strike a balance between sustainability and economic considerations. Thankfully, this approach is being embraced by numerous municipalities across Denmark, contributing to the larger goal of creating a more resource-efficient and environmentally conscious construction sector.

While achieving a completely circular material economy is an ambitious goal, it is essential to maintain a realistic perspective. It is unlikely that we can entirely eliminate the need for new materials in certain contexts. However, it is worth noting that buildings incorporating reused building parts offer a unique aesthetic value. By blending old and new materials together, such as combining recycled building materials with "affordable" options like trapezoidal panels and plywood, an appealing visual harmony can be achieved. This approach not only enhances the environmental benefits but also creates captivating architectural compositions.

It is encouraging to see that numerous advisors have embraced this concept and are successfully implementing it in their projects. By striking a balance between recycled and new materials, they demonstrate the possibility of creating structures that are both visually striking and environmentally conscious. While a fully circular material economy may present challenges, the integration of sustainable design principles and the thoughtful use of recycled materials contribute significantly to the overall goal of fostering a more sustainable and aesthetically pleasing built environment.

4. Results

4.1 Summary

The results of the demonstration actions include generation of new knowledge in the organization on how to screen, document, tender, calculate and extract used building materials. The knowledge spans from very formal organizational knowledge building to very practical hands on experience. We have created new strategies in the municipality with goals for circular actions. And we have created manuals on how to do basic material extraction, and anything in between.

The results are already visible and have created awareness in both our own organization and in the local market.

4.2 Impacts

Impacts of demonstration action 1: Demolition of hall 11/12

Planned outcome	Indicator	Baseline result	Final result	Outcome review
Improved mapping of CDW and soil resources in Hall 11/12. The use of tools in the demo project is expected to have a significant impact on recycling and reuse of CDW and soil.	3/20. New tools for better mapping of resources and their location: Qualitative description and impact	No tools were used consistently before CityLoops. Reuse of soil was more coincidal and not very well structured. Unstructured and mostly coincidal attempts to encourage tomapping of resources	Pre-demolition audit has been developed and used in regards of CDW. The pre-demolition audit is now being promoted as a standard internally in the municipality as a standard procedure. This procedure is described in the DR. Soil in the whole area was calculated as a single resource in order to obtain soil balance.	

New working procedures for cooperation between planning, building and environmental departments and authorities in Roskilde Municipality as well as more user involvement leading to more and new potentials for circularity and sustainability.	10. Stakeholder contribution to improved circularity	The baseline is 0	Development of sustainability group in the municipality. All relevant departments are represented as well as representatives for relevant authorities. The group meets every 6 weeks with an agenda topics like practical obstacles, communication between departments and implementation of new procedures. The group took initiative and planned a workshop in Musicon with participation of managers and directors in the municipality, in the workshop new goals were agreed upon.	
New business models for the valorizations of CDW and soil developed and validated. The focus of the business models is on keeping methods, working procedures, and use of materials simple.	23. Eco-innovation: Qualitative description	The baseline is 0	A new risk handling procedure is being implemented that involves comprehensive risk analysis in the early planning stages before the tenders are send out. The risk handling procedure consist of three elements 1) **Isolation of risk.** Early in the planning process, risk elements are identified and it is assessed whether they can be separated from the primary construction activity. 2) **Early market dialogue.** Early dialogue ensures greater understanding of how risk is handled the most efficient way. 3) **Building phase.** Throughout the building period, close dialogue and transparency between actors is ensured. It is agreed how to react to changes in risk. Risk for the client is not the same as risk for the contractor or consultant.	

Materials (structures and soil) retained on demonstration sites. At project's end: 25% of the total mass of building is retained on site Soil: 5800 tons are retained on site	27. Increased share of materials retained and reused on demonstration sites	Only a small mass of materials has previously been retained on site. Aprox. 5%.	In the processes that has been carried out already, indication is that more than 75% of the building mass is retained on site. Tender for demolition of Hal 12 has demands for direct reuse of 25% of the remaining building materials. All suitable materials have been tested for reuse potential and hazardous components, this has resulted in a material list that can be communicated to contractors and advisors. The same list also functions as material passport internally in the municipality.	
Increased number of CE jobs locally, through migration of costs, including a significant budget going to local craftsmen.	33. CE-based employment	The baseline is 0	In all CE oriented projects traditional advisors have been spending minimum 20% of their time on CE activities. Special advisors have spent up to 100% of their time. Contractor on parking facility Indfaldet has spent 100 hours on CE related activities and demolisher of Hal 12 havel spent 50-75% of their time on CE activities.	
25% of CDW from demo site is prepared for reuse or high-value recycling	49/52. Quantity of material subjected to reuse or recycling	Only a small mass of materials has previously been reused/recycled.	Tender for demolition of the first part of Hal 12 has been send out and contains demand of more than 50% reuse or high-value recycling. This includes special operation activities which will investigate	

			possibilities of direct reuse of whole brick wall in pieces of 1,4mx1,4m.	
Reduced emissions of CO_2 related to extraction, processing, and transportation (incl. logistics) of construction (%). At project's end: CDW: 30% CO_2 emission reduction 11 tons of CO_2 savings from minimizing excavating and moving soil, by achieving soil balance in the project area instead of normal procedure	85. % of CO_2 pr. project in average.	Baseline is 12 kg/CO2/m2/pa.	Reduction of CO_2 is being calculated with CDW CO_2 calculator. Calculator focusses on saving potential in association with normal practice. Interim data suggests that the biggest savings are on preserving load carrying structures within Hal 12. Total saved CO_2 associated with CE decisions following the waste hierarchy principles (prevention, reuse, recycling) amounts to more than 110 tons.	

Impacts of demonstration action 2: Construction of car parks

Planned outcome	Indicator	Baseline result	Final result	Outcome review
Improved mapping of soil resources in the construction of parking garages. The use of tools in the demo project is expected to have a significant impact on recycling and reuse of soil and to minimize the CO_2 impact of the construction projects.	3/20. New tools for better mapping of resources and their location: Qualitative description and impact	No tools were used consistently before CityLoops. Reuse of soil was more coincidal and not very well structured. Unstructured and mostly coincidal attempts to encourage to mapping of resources	Advisors was instructed to carry out complete investigations on preserving soil on the whole Hal 11/12 area. Soil balance has been proven to be obtainable for all projects and first project to follow the plan for soil balance is car park 2 (Pulsen). Tender material demands soil balance. Car park 1 (Indfaldet obtained 100% soil balance due to	

			innovative reuse of concrete in the ground. Total amount of CO2 saved due to soil balance is more than 50 tons.	
New working procedures for cooperation between planning, building and environmental departments and authorities leading to more circularity. More user involvement leading to new potentials for circularity and sustainability through increased knowledge and social sustainability.	10. Stakeholder contribution to improved circularity	The baseline is 0	Establishing the sustainability group in the municipality has shown as a very strong platform for increased cooperation between planning, building and environmental departments, as well as authorities within the municipality. A CE procedure has been implemented, with very explicit descriptions on how to document and apply for CE actions.	
Changed tendering procedures, shifting emphasis from lowest cost to a fixed cost and quality in the award criteria.	12/15. Circularity requirements in procurement beyond existing levels	No circular requirements were implemented in the procurement procedures before CL.	Properties Strategy in Roskilde has been updated with requirements of circularity. Text in strategy: *Circular economy* *Circular economy and better resource utilization are playing an increasingly important role in construction. In the early decision-making process, it must be assessed how material consumption can be minimized through recycling and recycling of both buildings and building materials, including land.*	

			It is an objective to ensure that circular construction is profitable both environmentally and economically. Therefore, business cases must be prepared for various recycling projects. This will happen both internally and through participation as a demonstration municipality in development projects such as Hall 12, CityLoops and Circle Bank.	
New business models for reuse and valorisation of soil developed and validated with focus on soil balance for whole areas instead of individual plots.	23. Eco-innovation: Qualitative description	The baseline is 0	Business model has been described in car park Indfaldet where underground concrete elements were dug out and crushed and reused for foundation works under the car park. Around 100.000 Euros was saved during this operation.	
Soil retained on demonstration sites. Pulsen: 1500 m3 of soil is expected to be kept on site.	27. Increased share of materials retained and reused on demonstration sites	Only a small mass of materials has previously been retained on site. Aprox. 5%.	Advisors was instructed to carry out complete investigations on preserving soil on the whole Hal 11/12 area. Soil balance has been proven to be obtainable for all projects and first project to follow the plan for soil balance is car park 2 (Pulsen). Tender material demands soil balance. Car park 1 (Indfaldet obtained 100% soilbalance due to innovative reuse of concrete in the ground. Total amount of soil retained on site Pusen: 1250 m3.	

Reduced virgin gravel from multi-storey car park, Pulsen. The reduction is expected to amount to 1500 m3 of virgin gravel in comparison to normal procedure.	34. Reduced use of virgin materials	Replacement of dug out materials is normally 100%	Advisors was instructed to carry out complete investigations on preserving soil on the whole Hal 11/12 area. Soil balance has been proven to be obtainable for all projects and first project to follow the plan for soil balance is car park 2 (Pulsen). Tender material demands soil balance. Car park 1 (Indfaldet obtained 100% soil balance due to innovative reuse of concrete in the ground. Total amount of saved virgin gravel: 1250 m3.	
Soil is reused and large uniform fractions of CDW are reused/recycled, e.g. concrete and roof tiles.	49/52. Quantity of material subjected to reuse/recycling	Only a small mass of materials has previously been reused/recycled.	A total of 12.000 pieces of roof tiles are stored on site of Pulsen. The tiles are included in tender for car park Pulsen as a reward criterium.	
Reduced emissions of CO2 related to extraction, processing, and transportation (incl. logistics) of construction (%). Indfaldet: CO2 savings from keeping soil on site in multi-storey car park Indfaldet is expected to be 6.7 tons of CO2e. Future CO2 saving potential is 326 tons for building the parking garage as design for disassembly. Pulsen: Target CO2 savings from	85. GHG emissions per year		Indfaldet: CO2 savings from keeping soil on site in multi-storey car park Indfaldet was 6.7 tons of CO2e. Future CO2 saving potential is 326 tons for building the parking garage as design for disassembly. Pulsen: Target CO2 savings from keeping soil on site, has been upgradet to 50 tons tons of CO2e. 20 tons of CO2 are saved by reusing a total of 12.000 pices of rooftiles in car park Pulsen.	

keeping soil on site is 5-10 tons of CO_2e.				

Impacts of demonstration action 3: Circular soil management

Planned outcome	Indicator	Baseline result	Final result	Outcome review
Strategic approach to circular soil management in the municipality. It is expected that the tools will be scaled and integrated in normal procedure in Roskilde and that the project managers using the tools have	3. New tools for better mapping of resources and their location: Qualitative description	No tools were used before CityLoops. Reuse of soil was more coincidal and not very well structured	A builder's manual for circular soil management has been developed in the municipality. The manual focuses on keeping soil on site according to the waste hierarchy (Prevention, reuse, recycle)	

the adequate competence level to use the tools.				
			Property strategy has included demands on CE both traditional CDW and soil. Strategy has been politically decided. Budget agreement of 2022 included explicit focus on CE. Budget agreement was politically voted through by a significant majority.	

Impacts on city level

Planned outcome	Indicator	Baseline result	Final result	Outcome review

Internal and external CE-based collaboration platforms/networks established: - Internal: A new environmental group is formed in the municipality focusing on implementing CE in the strategy of the city. The expected outcome from this group/network is to strengthen stakeholder engagement and create a better dialogue between the different departments in the municipality. - External: Scaling the results from the demo projects to other municipalities.	9. New formal CE-based collaboration platforms/networks	The baseline is 0		
BIM Model will function as a digital material bank for new construction. In renovation projects, screenings will be used to map materials, and materials from the physical material bank will be a part of the digital databank.	30/31. New digital material databank/marketplace: Qualitative description and Impact	The baseline is 0	Municipality has a demand in tenders that contractor delivers BIM model with associated material amounts and lifespan of matrials. Municipality has contracted with software provider "Upcycling Forum" to facilitate digital material bank.	

4.3 Economic Analysis

4.3.1 Economic assessment of demonstration

4.3.2 Business case

Business case – Parking House "Indfaldet"

Recycling of demolished and crushed concrete

Multi-storey parking house in the Musicon Area in Roskilde

National market conditions

The circular economy in the Danish building sector is growing, and some influencing regulation is on its way. The national regulation concerns primarily material (waste) flows to increase the transparency of CDW flows (soil are regulated already) and includes among other resource mapping (added to the already applicable environmental mapping) and demolition plan both connected to selective demolition. The new national regulation is expected to be implemented during 2023.

One of the issues regarding growing the circular market for secondary materials and product is the lack of end-of-waste criteria, which for the moment is individually and locally handled by the municipalities without a clear national consensus. It seems that the authorities are waiting for two EU-related initiatives; common end-of-waste criteria and the revision of the construction product regulation as secondary products and materials are expected to be included in this regulation. In addition, CE and/or ETA regulation must be taken into consideration.

However, the market actors including demolition and waste handling companies, consultants and clients are innovating and experimenting on demonstration level to get useful experiences for the future market. Few companies have succeeded with a full value / block chain implementation of recycled CDW e.g., A:GAIN [Link] who upcycles e.g. fixtures as furniture, panels etc., NÆSTE (NEXT) [Link] who creates and deliver sheds made of recycled construction wood, STARK/GENTRÆ [Link] who recycles construction site wood and Fischer Lighting [Link] who collects lamps and light fixtures and upgraded them with new technology for B2B resale.

Some Danish contractors and concrete suppliers are also capable to handle crushed concrete and/or elements as reused material in new constructions including screening, sampling, testing, (perhaps) temporary storing and mixing into approved recipes. Furthermore, there are several companies who are capable of handling and reusing excavated soil, gravel, and sand for new, typically landscape purposes.

Handling of both excavated soil and CDW are generally liberalised in Denmark. Depots must be approved by the authorities which includes temporary depots at waste handling companies, but handling of waste for energy production (e.g., construction wood) are mainly driven by public owned facilities. The liberalisation of the last mentioned is however under negotiation for the moment.

There are no current plans for regulation of the circular market though it could speed up the adjustment process with e.g., taxes or other incentive stimulating elements. Politically it seems to be the attitude that the market should develop itself within consideration of access to resources and the prize development on both primary and secondary materials. However, there will be some obstructions regarding other aspects of sustainability as several analysis conclude that the number of demolished buildings should be decreased and that can affect the access to secondary resources.

The business case in a brief

The demonstration project, “Indfaldet”, is an above-ground, multi-storey parking house with 240 parking spaces made as a steel structure. The construction was started by the winning contractor in April 2020, and delivered to the client (Roskilde Municipality) in 2022.

Recycled concrete remains from demolished previously concrete production facility has partly compensated new gravel fills for bottom protection of the new parking house, and as aggregate in new concrete in the ground floor deck. Both reuse processes were handled on site by using mobile crushing and separation facilities. Essential for this local transformation of the concrete was a far distance from the site to other facilities as e.g., offices and residences regarding *space*, *noise*, and *dust*. In most similar cases it is necessary to take these aspects into consideration differently.


MIS
LIEBHERR

These pictures represent different actions and situations during the demolishing, crushing, separation and recycling process transforming local concrete remains into gravel fill and aggregate in new concrete.

Conclusion and lessons learned

The local circumstance according to space, noise, and dust on the site has without any doubt had substantially importance for the possibilities of handling and recycling the concrete remains locally, and the local handling has resulted in significant carbon and economical savings in this case. As mentioned above, it would often be necessary to consider these aspects differently as it depends on the local conditions.

Overall, the choice to crush concrete locally and re-integrate it during the construction has proven to be an ap-propriate solution in this case.

The contractor has been able to keep the construction site running continuously and has had access to crushed piles at the site. Delays consisted solely by excavating obstacles in the ground, the rest was managed as client delivery.

Roskilde Municipality has – as a developer - been able to minimise costs associated with obstacles. The additional costs have been associated with the excavation of obstacles and various measures in connection with the ramming of piles. These extra works had to be carried out anyway. On the other hand, almost **€ 53,000 excl. VAT** has been saved on demolition, loading and disposal of concrete residues, as well as delivery and installation of new gravel fill, and at the same time the business case has been profitable for all parties.

Risk management

Risks are often a blind mate in construction projects, especially when the projects are including non-conventional methods, materials etc. In the case, “Indfaldet”, risk management therefor has been included as a central aspect in the planning process of the project and how the business case was assessed and evaluated, and the following description represent lessons learned and recommendations for handling this topic.

As a starting point, any risk elements must be identified as early in the process as possible, and this is carried out by the client (or in collaboration with an adviser) in the form of a risk mapping, where responsibility, risk and consequence are described.

Based on the risk mapping, it is assessed whether there is an opportunity to neutralise risks and whether responsibility for risk management is placed by the right actor. It is often experienced that rigidly placed responsibilities inhibit the possibility of proactive solutions and neutralisation of risk elements. It is therefore crucial to maintain an open view of the nature of the individual risk and accept alternative placement of responsibility if it is advantageous for the solution of the problem – not least financially.

It adds value to the project if the identification and handling as well as the allocation of responsibility and risk between the actors takes place proactively, transparently, and according to commonly accepted rules of the game, and often an open dialogue about potential risks can help to minimise any consequences of a triggered risk.

It is the type of risk that determines how and whether it can be eliminated or reduced. Certain types of risk can be neutralised through the provision of more knowledge, e.g., sampling. This typically applies to risk that relates to a lack of knowledge about scope and consequence. If a risk of the presence of environmentally hazardous substances is identified at an early stage, it is always advantageous to investigate this, in-stead of passing on the risk to a consultant or contractor, as they necessarily capitalise risk in an offer situation.

As part of the risk mapping, an early market dialogue is carried out with key actors. The key actors in the value chain in circular construction are - at least in a transition period - typically looking differently at risks than in traditional construction. Therefore, there is obvious potential in placing responsibility for a given risk with the actor who has the potential to neutralise it. This way of thinking can advantageously be drawn into the tendering phase, where it is planned that bidders already in connection with tenders identify the risk elements that affect their responsibility and which they do not immediately have the opportunity to influence. This enables risk management to be dealt with already in connection with contract negotiations, and negative impacts on the bidder's business are minimized.

During the construction process, one may experience that new risk elements arise or known risk elements change in nature and must be handled differently. Therefore, in connection with offers, a process description must be included that explains how the risk that has arisen and/or changed risk is handled in the construction process itself - with respect for all parties involved.

Both a presentation of known risk elements and a description of the handling of emerging risk must be included in a proposal for a risk management plan when submitting an offer, so it can be included in the bidder's as well as the client's or procurer's business case estimation.

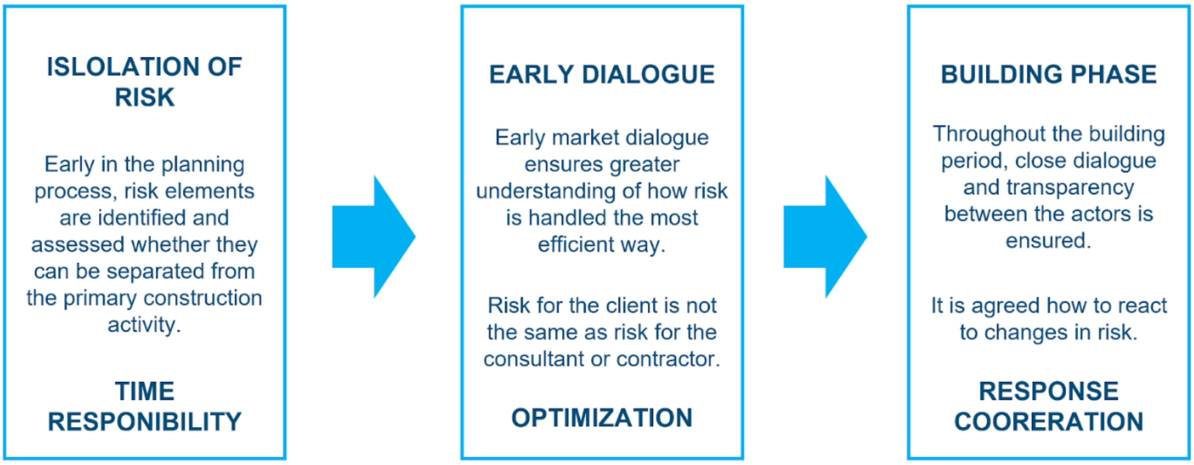


Fig. 1: Isolation of potential risks in the early phase and managing risks in close and transparent dialogue between the involved actors in the process will have a positive effect on any business case[3].

The business case in facts and details

Tender process

A total contracting was offered as a *tender with negotiation* in accordance with the Public Procurement Act (Law nr. 1564 of 15.12.2015). The award criterion was the economically most advantageous offer with the best ratio between price and quality, where competition is based solely on quality. The Parking House

The total budget included all deliveries were tendered for a total of € 4,6 million, excl. VAT.

The contractor was selected based of the following allocation model:

- Architecture 50%
- Functionality 40%

[3] Kellermann, K., Roskilde Kommune (2022)

- Process 10%

Among the criteria with a focus on circular economy in operation can be mentioned:

- Construction solutions with the highest reduction of materials as possible, including load-bearing structures, coatings, and installations.
- Material with a high degree of recyclability
- Considerations regarding cleaning and operation clearly included in the design of the house.
- Considerations regarding total energy included as a parameter in the choice of materials.

In addition, demands were made in the tender material for recycling and circular economy e.g., reinstatement of crushed concrete and soil balance on the overall project.

Construction process

Even before the construction work started, the municipality (client) was aware that there could be obstacles in the ground, as the site is an old production facility for Unicon. For this reason, stricter requirements for notification of obstacles in the ground for the contractor were added. In addition, the geotechnical report prescribed pile foundations.

After approx. 2 months of work, obstacles in the ground were warned. Obstructions were inspected jointly by the involved actors and assessed to be mainly large, connected pieces of concrete.

A solution was decided jointly, namely that reinforced concrete piles should be rammed and trenches should be dug for approx. 1 meter depth to ensure fewer obstacles in the upper soil layers. In addition, foundation beams had to be excavated along the house in three lines.

This led to the excavation of a large amount of concrete mixed with soil, which was placed in an intermediate depot immediately outside the construction site.

From here, the normal procedure would be to obtain offers for the removal and disposal of concrete. This would both be costly and lead to large CO_2 emissions in connection with driving the material. In addition, a large part of the excavated concrete and soil would have to be replaced by new gravel materials for filling around piles and foundations, as well as bottom protection. Again, this would be associated with costs and CO_2 emissions.

It was therefore decided to handle the excavated concrete remains on site by crushing. A crushing plant was set up as a client supply and concrete residues were sorted into materials immediately suitable for re-incorporation into new concrete and that which had been mixed with soil. Pure concrete was crushed into 0-32 mm fraction, which was subsequently sorted into 0-4 mm and 4-22 mm fraction via soldering. This material amounted to approx. 100 tons. The remaining approx. 1000 tons material was crushed to 0-32 mm stable.

The general contractor now had the opportunity to pick up 0-32 mm stable immediately outside the construction site fence and re-integrate it directly as bottom protection etc. This ensured a good working process without delays.

If you consider the costs associated with the two scenarios described above, namely the scenario where the concrete remains are driven away and replaced by new gravel and the scenario where the concrete remains are crushed and rebuilt, the rebuilding of crushed material is associated with lower costs.

In the offer list, the price is for the cost of excavation, transport and disposal of class 2/3 soil/gravel incl. deposit fee indicated. In addition, delivery, and installation of new gravel fill as well. Finally, the price for breaking up, loading and disposal of concrete residues in a thickness of 20 cm has been supplemented subsequently by the general contractor.

Based on the prices for the excavated concrete remains (1.100 tons), the following calculation can be made:

Drive-away scenario	
Demolition, loading and disposal of concrete residues	1,100 tons at € 33 per ton
Delivery and installation of new gravel fill	1,000 tons at € 25 per ton
In total	€ 61,700 excl. VAT
Scenario with re-integrating	
Installation and crushing of concrete residues incl. sold	€ 9,000 excl. VAT
Rebuilding of broken 0-32 mm stable	Included in contract offer
In total	€ 9,000 excl. VAT

The two scenarios have in common the excavation and handling of concrete remains. This was clarified as extra work offered at a fixed price.

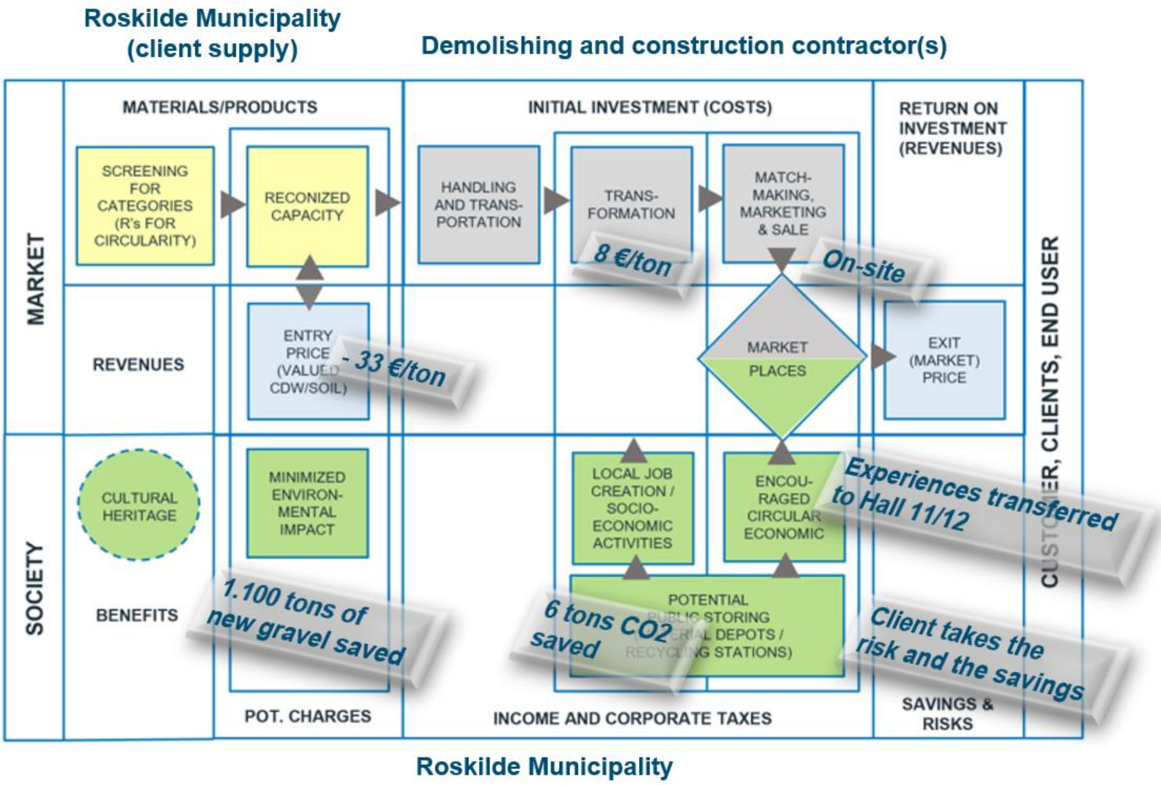


Fig. 2: The CityLoops developed business model used for overviewing and evaluation of the business case[4].

[4] https://bygherreforeningen.dk/download/13/filarkiv/51142/cityloops_circular_construction_business_case_model_final-1.pdf

5. Conclusions

5.1 Lessons learned

5.1.1 Stakeholder engagement

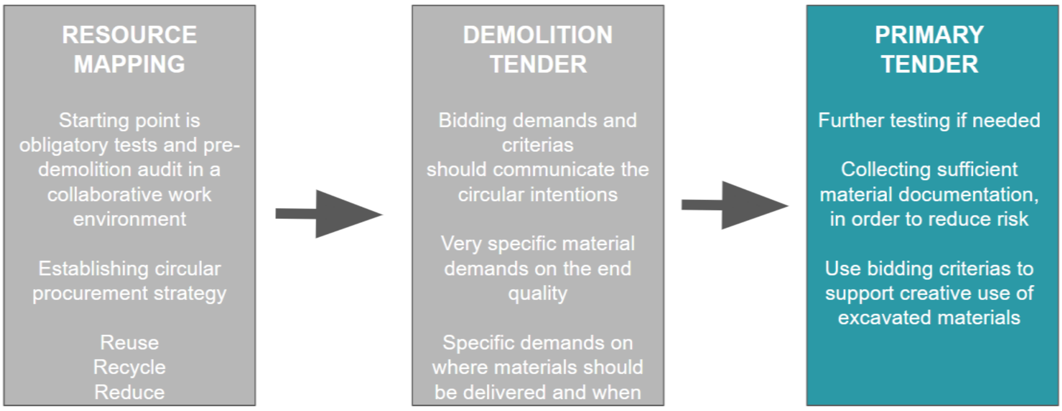
Provide an assessment of the effectiveness of the involvement of internal and external stakeholders in the demonstration actions, and what lessons can be learned from this - were the appropriate stakeholders involved, at the correct stage in the demonstration action? What worked/what didn't? What would you do differently next time?

5.1.2 Procurement

Working with recycling and reuse can be associated with several practical challenges. This is because the recycled and/or reused building materials will not always be thoroughly tested, and because several of the construction processes that are linked to building with these products and materials, are still relatively new.

The early collaboration is particularly important in construction projects that begin with an environmental and resource mapping of a building ready for demolition, because this gives the parties the opportunity to identify together the places where recycling and/or recycling of materials is possible. The contractor's knowledge is an important contribution to the advisor's work in the very early phases and in screening the environmental and esource mapping. The detailing process around material use, construction technical conditions and technical assessments of a material's qualitative nature and thus future use can have an impact on how the material is used in relation to planning, detailing architectural and technical aspects. Based on interdisciplinary discussions in the project, a common knowledge base and a common process are created regarding the development of prototypes of the selected recycled and/or recycled materials. When knowledge about the use of materials is brought to the table, the demolisher can prioritise selective removal of a building and its building parts, which must be brought to recycling or recycling. Parallel to the subsequent planning in accordance with Danish work description standard YBL 18, it will be advantageous to initiate a further one product qualification and development in collaboration with relevant manufacturers and contractors.

3 STEPS OF CIRCULAR PROCUREMENT



It is recommended that, prior to the circular tender, the client sets objectives for which circular principles the client wants to work with in the current construction. The objectives for circular principles can be drawn up in collaboration with the sustainability management.

As an example, the client can set concrete targets for CO2 savings, targets for use of circular principles such as design for separation or the degree of use of recycled or recycled materials in the building when it is finished. The National Strategy for Sustainable Construction can advantageously be used as a baseline when targets for CO2 impact are to be set. The objectives for circular principles must be transparent for all parties in the construction, including builder, contractors, consultants and ultimately the end users. The objectives can be linked to incentive schemes to motivate the advisers and the contractor.

In connection with the client having to set targets for, for example, recycled or recycling of materials, a calculation of any CO2 savings (LCA calculations) could support the decision-making process. In order to identify all aspects of such a saving, and because in the industry does not yet have LCA calculations for many recycled or recycled materials, will it be necessary to bring more expertise across the value chain into play in order to enlighten everyone prerequisites for the recycling of the material. The circular principles and requirements should be laid down already at the conclusion of the contract.

In the circular turnkey contract, the objectives for circular principles in construction are set by the client in collaboration with the sustainability management prior to holding the turnkey contract tender.

The key to innovation in a building with circular principles assumes that the client can have an open and trusting dialogue with the contractor and advisers. The dialogue is the prerequisite for that the circular principles in construction are as much as possible assessed from both an environmental point of view and architectural value, costs, quality, etc. The framework for innovation and the challenges involved should therefore already be discussed at the negotiation meetings, where the parties should articulate the special conditions that require dialogue and openness.

The negotiation topics below are an expression of the issues where law is particularly affected by the circular principles. Dialogue about the themes creates transparency about what can be created in particular insecurity on the part of both the client, contractor and advisers.

Negotiation meetings can be structured in many different ways depending on the purpose of the negotiations and which resources are used. Since the negotiations are part of the evaluation of the offers, the client can advantageously divide the negotiation meetings so that they follow the award criteria in the tender conditions. This makes it easier for the client to give constructive feedback during the dialogue, just as it is easier for the tenderer to adjust his offer on the basis of the negotiations and the client's feedback.

5.2 Future perspectives

Roskilde Municipality will utilise, further develop, and upscale the demonstration actions in CityLoops in the following ways:

Utilisation: Roskilde Municipality will actively incorporate the demonstrated actions into their own urban planning and development processes. They will integrate the innovative solutions and approaches showcased in CityLoops into their strategies and policies to improve resource efficiency, waste management, and sustainability within the municipality. This will involve implementing the demonstrated actions in specific projects and initiatives across different sectors, such as construction, waste management, and transportation.

Further Development: The municipality will engage in ongoing research, monitoring, and evaluation to further develop the demonstrated actions. They will collaborate with relevant stakeholders, including research institutions, businesses, and community organisations, to gather insights and feedback. Through this collaboration, they will identify opportunities for improvement, refine the actions, and adapt them to the specific needs and context of Roskilde. This may involve testing new technologies, optimising processes, or exploring innovative partnerships.

Upscaling: Building on the successful demonstration actions, Roskilde Municipality will seek to upscale these initiatives to achieve broader impact. They will explore strategies for replicating and expanding the demonstrated actions across different neighborhoods or areas within the municipality. This may include engaging with local communities, businesses, and residents to promote awareness and participation in circular economy practices. The municipality will also actively share their experiences, lessons learned, and best practices with other municipalities and stakeholders, both regionally and nationally, to inspire and encourage the adoption of circular economy principles.

5.3 Assessment of replicability/recommendations

The overall approach taken within the circular demonstration actions in Roskilde Municipality has several key aspects that contribute to its replicability in other parts of Europe.

- Local Context and Collaboration: The success of the circular demonstration action in Roskilde is closely tied to the understanding of the local context and the collaboration between various stakeholders. To replicate the approach, it is crucial to assess the specific conditions and challenges of the target region. This includes factors such as waste management infrastructure, regulatory frameworks, available resources, and the willingness of local stakeholders to participate and support circular initiatives.

- Circular Economy Strategies and Policies: The circular demonstration action in Roskilde is underpinned by a strong commitment to circular economy principles, which are reflected in the municipality's strategies and policies. These include setting clear goals and targets for resource efficiency, waste reduction, and sustainable practices.

- Integrated Approach and Innovation: The circular demonstration action in Roskilde takes an integrated approach, addressing various sectors and value chains to maximise resource efficiency and minimise waste. It also emphasises innovation and the adoption of new technologies and practices to enable circular solutions.

- Knowledge Exchange and Learning: The circular demonstration action in Roskilde places importance on knowledge exchange and learning from other regions and stakeholders. This includes sharing best practices, participating in networks and initiatives, and actively seeking collaboration opportunities.

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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