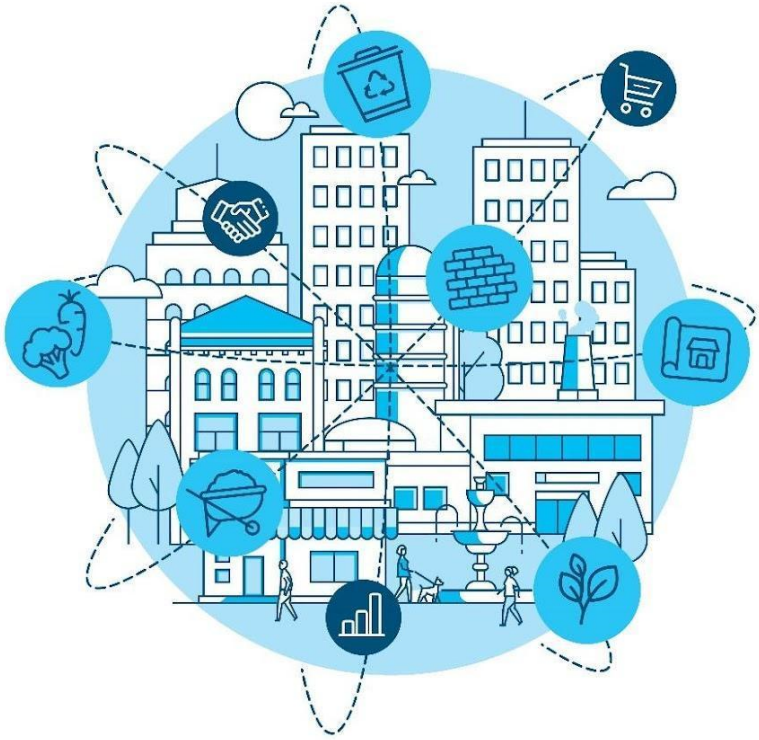
CIRCULAR CDW in Høje-Taastrup

Demonstration Report

Høje-Taastrup, Denmark



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Abstract	Parts of Taastrupgård were demolished, concrete from the demolition was recycled as aggregate in the concrete foundation of the nearby new city hall construction. Soil from the new city hall area was reused in Taastrupgård prior to development of the area where the demolition took place. Circular criteria were implemented in tendering material when selling old city hall for demolition. The project and criteria were however modified such that the building will be transformed instead of demolished.
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1. Executive summary

In Høje-Taastrup municipality, the entire geographical area was treated as the site for potential demonstration projects. This increased the possibilities for identifying potential matching material flows between demolition and construction projects as well as matching timelines, compared to if the demonstrations were limited to public projects. The CityLoops project was positioned administratively in the environment department rather than the properties department as in most of the other CityLoops municipalities, which meant that the demonstration managers functioned not as construction clients but as coordinators and environmental authorities. This opened the possibility to have a broader reach of influence but also diluted influence as the environmental department does not have the decision-making authority over the other stakeholders involved.

Thanks to the wide geographical scope, Høje-Taastrup had 5 demonstration cases spanning both private and public projects. The CityLoops project managers strived to act as matchmaker between the material flows in different projects and facilitate the establishing of partnerships between them. The demonstration projects were transformation of the old city hall grounds, demolition of Taastrupgård, construction of the new city hall, development of recycled sidewalk tiles, and circular soil management. Several of these demonstrations were strongly interlaced, with Taastrupgård providing the source concrete for the recycled foundation of the new city hall, and circular soil management taking place between these two projects as well.

Through these demonstration projects, several successes were achieved: circular criteria in the tendering material for the sale of the old city hall was achieved; over 1000 tons of concrete was successfully diverted from the demolition of Taastrupgård for use as recycled aggregate for the new city hall; circular opportunities were described in the tendering material of the new city hall - which resulted in a recycled concrete foundation being used; and over 30 tons of CO2 were saved through circular soil management. Many valuable lessons were also learned: that it is never too late to integrate circularity into a project (though earlier is better); that it is essential to establish partnerships with key stakeholders and identify key risks and who has responsibility for what; and on an organizational level witnessed a shift in mindset is possible in terms of sustainability and most notably in sustainable soil management. The most important takeaway from this project is, however, that the most sustainable building is one you do not need to build. If one can at all avoid having to demolish and build a new building, this is what one should strive for. Focus on optimizing use or converting the function of existing buildings before considering new building projects. The potential savings in raw materials and CO2 of avoided demolition is several orders of magnitude greater than the savings when recycling materials into new building projects.

Structural changes are needed to ensure that circularity is not left up to chance, and this is being addressed through the development of a municipal sustainability strategy and corresponding action plan. Meanwhile, it is still valuable to highlight the smaller victories along the way that pave the way for future legislation by demonstrating that circularity can succeed.

The CityLoops project managers in Høje-Taastrup believe that any EU city could replicate these projects if they manage to identify key, willing stakeholders.

2. City context

Høje-Taastrup Municipality (HTK) is located west of Copenhagen and is one of the largest municipalities within the capital region. The municipality covers an area of 78 km2. About 55.000[1] residents live in Høje-Taastrup, and the population is increasing. In terms of infrastructure Høje-Taastrup is situated centrally with good access to highways, and regional as well as local trains. Høje-Taastrup Municipality has two main urban areas: Taastrup/Høje-Taastrup and Hedehusene/Fløng. These areas are densely populated with extensive road networks. Høje-Taastrup Municipality is one of the capital region's greenest municipalities. Two-thirds of the area consists of forest, meadows, fields and lakes including a number of protected areas.

Høje-Taastrup is undergoing urban development primarily in two larger areas but also in other parts of the municipality. Therefore, a lot of construction is taking place.

In total around 27,000 people commute to Høje-Taastrup to work every day from other municipalities. Several of the companies located in the municipality have grown in recent years. In addition, several companies have moved to the municipality resulting in approximately 9,000 new local jobs in recent years.

The CityLoops project managers work in the environmental department of Høje-Taastrup municipality and therefore normally function as environmental authorities, specifically regarding demolition waste and soil. However, in the context of CityLoops the project managers functioned as coordinators more so than authorities and did not have the role of construction client as was the case in other CityLoops municipalities. The demonstration actions of Høje-Taastrup focus both on including circular practices in public construction projects, as well as on influencing construction and demolition projects for buildings and sites not owned by the municipality. Projects in the whole geographical area of the municipality were considered. The projects were at different stages of planning and execution at the start of CityLoops. This enabled the CityLoops project managers to see what impact the municipality can have by getting involved at various phases of each project and to develop and test planning and decision-making frameworks through these cases.

In Høje-Taastrup Municipality the transition towards a more circular construction sector is supported by a climate plan, a development strategy, and a procurement strategy - and will be further strengthened in the sustainability strategy and corresponding action plan that are currently in development and will be adopted at the end of 2023. The sustainability strategy will be developed by the CityLoops demonstration managers in collaboration with the internal sustainability group they established. Through cooperating with colleagues in many different departments during the CityLoops demonstration actions, the CityLoops demonstration managers realized there are many colleagues interested in sustainability who do not work

[1] December 2022

directly with it; and many initiatives in the municipality that relate to sustainability or could benefit from knowledge sharing in order to increase their sustainable potential. This group was therefore established in order to bridge the gap between departments through knowledge sharing and transdisciplinary cooperation. It includes at least one colleague from every municipal department.

3. Implementation of demonstration cases

Høje-Taastrup's demonstration cases are all related to the current urban development taking place in the municipality. The demonstration cases are to certain degrees related to each other. Concrete from the demolition of Taastrupgård was used as recycled aggregate in the foundation of the new city hall – and considered as aggregate for the recycled sidewalk tile. The demolition of the old city hall is dependent on the final construction of the new city hall. Sustainable soil management is an important factor in all urban development, including the development of the old city hall area and the construction of the new city hall.

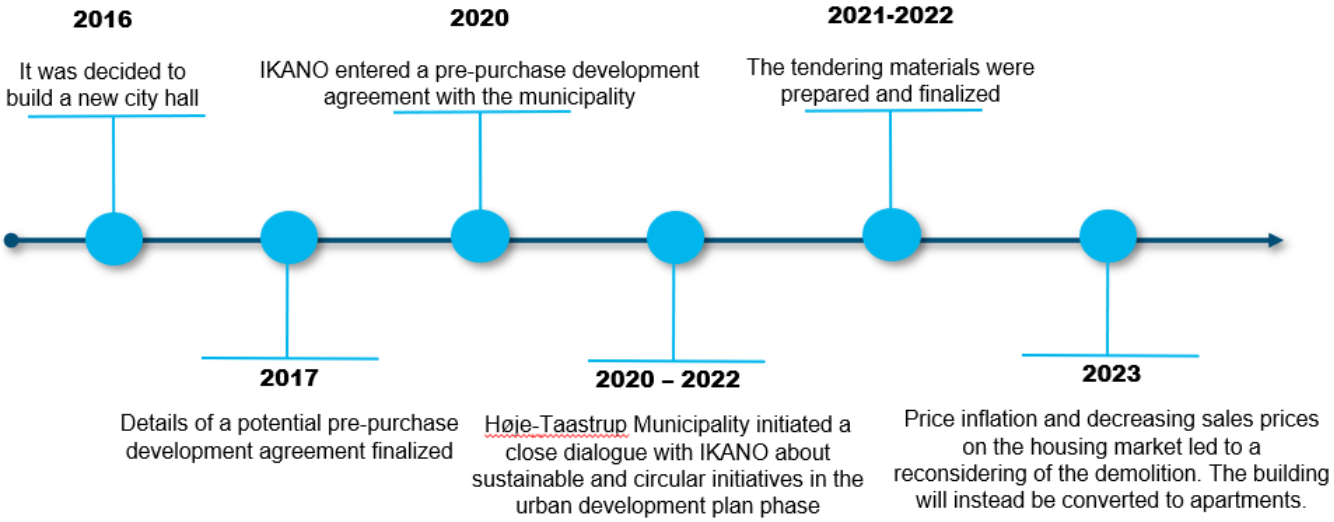
3.1 Transformation of old city hall grounds

In 2016 it was decided that Høje-Taastrup would build a new city hall due to the need for extensive renovations in the existing city hall. It was furthermore decided that the municipality would sell the old city hall, and that the area would be developed into a residential area resembling the nearby old village of Høje-Taastrup. The old city hall and surrounding property would therefore be sold for demolition.

Høje-Taastrup municipality owned the property and was therefore responsible for selling it. The CityLoops project managers sought the opportunity to impose circular conditions in the tender about how the demolition should take place and how soil should be handled. The aim was to impose criteria ensuring that as much building material as possible should be reused, if possible, on-site, and as much soil as possible should be kept on-site.

According to the original plan, the demolition was planned to start in 2023. During the demolition process, the CityLoops project managers would be in close dialogue with the developer and the demolition contractor as well as potential buyers of the materials from the demolition. The reusable materials would be incorporated into new buildings or crushed on-site and used as filler. Some materials could also be used in other (yet unidentified) building projects off-site. Soil would be, as much as possible, either prevented from being dug up or reused on site. However, the high quality of the foundation and load-bearing structures of the building as well as price inflation and decreasing housing prices led the developer to reconsider demolition, and they are now working towards adaptive reuse for (part of) the old city hall as apartments. Soft-stripping and partial demolition will still take place, but not within the CityLoops timeline.

Timeline for demonstration action 1: Selling the old city hall



3.1.1 Planning and decision-making process

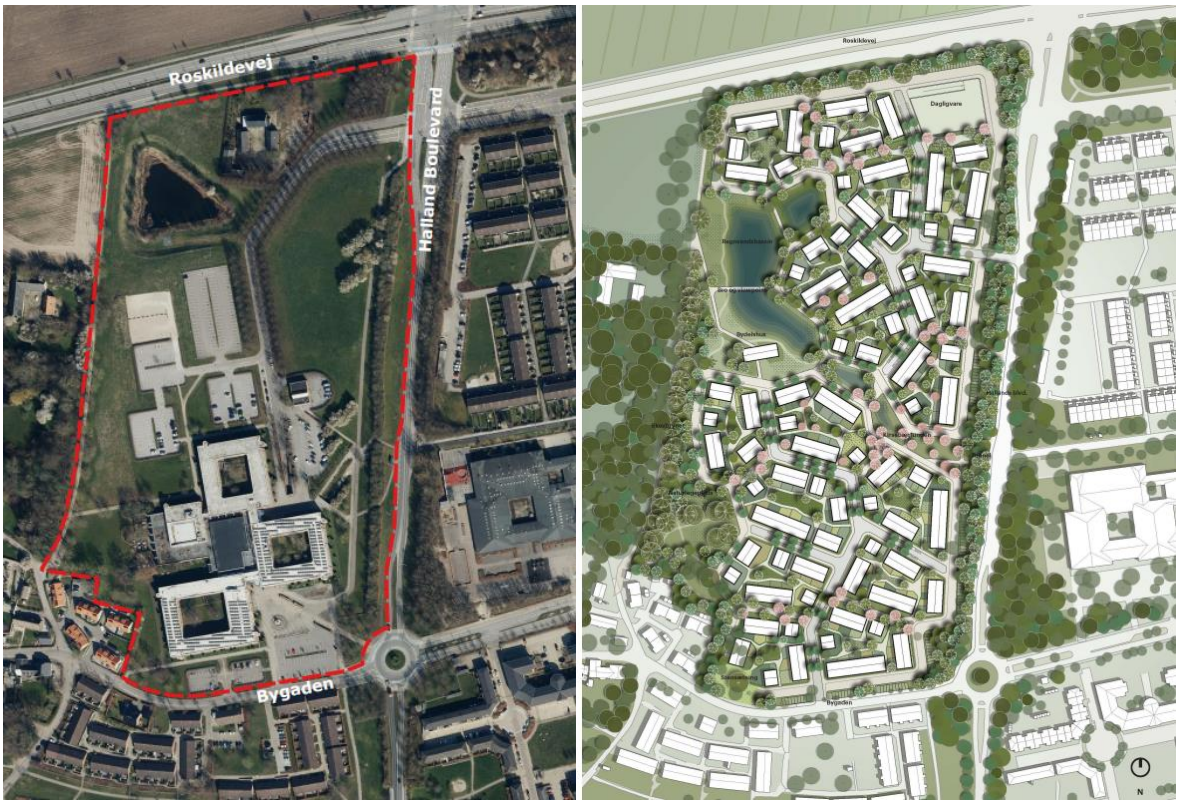
Pre-purchase development agreement

Danish procurement law allows private companies to participate in the planning of the development of urban areas under special circumstances. Hoping to secure such an agreement, in 2017 (pre-CityLoops) the municipality outlined the parameters of an agreement for developers to consider. IKANO approached the municipality hoping to make a pre-purchase development agreement with the urban development department based on this outline. An agreement was signed in 2020, and this allowed IKANO to influence how the property would be developed after the sale of the grounds. The city hall had to be sold on the open market, but the pre-purchase development agreement ensured that IKANO had the advantage of the opportunity to re-bid with a new price if another developer outbid IKANO. Particulars of the agreement were finalized before CityLoops and needed to be respected. This limited somewhat the scope of influence CityLoops could have as nothing could be changed in the project without IKANOs agreement.

Urban development plan

IKANO made a proposal for urban development of the area (including maps, sketches, materials, infrastructure, parking etc.) which constituted the basis for a formal urban development plan which was prepared by the urban planners in the municipality. The draft urban development plan for the area was in public hearing, after which the final development plan was rectified by the City Council. The final urban development plan is public: Lokalplan 2.05.3

The CityLoops project managers in cooperation with the development department initiated a close dialogue with IKANO about sustainable and circular initiatives in this phase. IKANO showed a great interest in circular and sustainable initiatives.



Existing city hall and map from the urban development plan showing the suggested locations of buildings, roads, green areas, parking etc.

3.1.2 Procurement: Tendering material for sale of grounds

The tendering material was prepared in 2020 and 2021 and finalized in early 2022. The urban development department in collaboration with the legal department were in charge of preparing the tendering material. The CityLoops project managers contributed sustainability and circularity criteria to the tender.

Formulation of circularity criteria

Circular requirements were formulated over the course of extensive dialogue with IKANO and the urban development department, and finally with help from consultant Niels Trap from TRE who has extensive experience with circular requirements in tendering. The criteria were limited by a combination of what legally can be required in public tendering (according to the Danish municipal power of attorney and fair competition), by political mandate to prioritize earnings from the sale over sustainability, as well as by the pre-purchase development agreement, which had to be complied with. It was not possible to make any major divergences from the agreement, as IKANO had the right to refuse any extra criteria that was not outlined in the agreement. The fact that this agreement was finalized pre-CityLoops meant that it did not

necessarily favour circular initiatives. Luckily, IKANO was open to most sustainability initiatives since sustainability is an important part of IKANO's company policy. Specific sustainability criteria were used where possible in the tendering materials under the limitations of the development plan. For instance, the initial urban development plan left no room for keeping some of the building as it is and reconstructing it into residential buildings.

The environmental department listed several other sustainability criteria (beyond CityLoops) as visions or intentions e.g., biodiversity in urban green areas, solar panels on the roofs, and excess heat from the grocery store to be rerouted to the district heating system. If IKANO did not win the bid for purchasing the property, the municipality's focus on sustainability would thus still be evident based on these criteria.

Circularity criteria in tender

The included requirements for demolition and recycling were (translated from Danish):

"*Høje-Taastrup municipality participates in the EU-supported Horizon2020 project CityLoops, and the demolition of the old city hall is included as a demonstration project within circular construction. The goal is that as much building material as possible must be recycled/reused, and as much soil as possible must be kept on site. The municipality therefore requires that demolition of the existing city hall abides by selective demolition and circular criteria upon selling the existing city hall:*

- *The buyer is obligated to abide by the requirements in appendix X when demolishing the parts of existing buildings which will not be used in conjunction with the development of the grounds. Appendix X describes requirements and documentation requirements in relation to:*
    - *Resource mapping/ pre-demolition screening – based on the identification of resources and the preparation of a resource mapping report, selective demolition is carried out ensuring that min. 80 percent by weight of the uncontaminated materials from the demolition of the city hall must be reused, recycled or recovered.*
    - *Requirements for reuse and recycling of materials in connection with the construction of a new communal building in the area.*
    - *Requirements for sustainable soil management including preparing an estimate of soil flux in conjunction with the development."*

Selected relevant sections of Appendix X: Criteria for demolition of Høje-Taastrup city hall and subsequent development of the area" are listed here (translated from Danish):

Requirements for reuse and recycling of material in the construction of the communal building:

"The community building must be constructed as much as possible with recycled materials. At least 5 percent by weight of the total new construction or 10 different types of building

components/materials. The recycled components/materials can be either from the demolition of the city hall or from other suppliers.

At least 30 percent by weight of material used for the parking areas, paths and spaces around the new community building must be reused, recycled, or recovered material."

Requirements for sustainable soil management:

"The developer must prepare a plan for soil balance and estimation of soil flux for the development of the area. In conjunction with this, the developer must assess possibilities for limiting the amount of soil that is handled or removed from the area, for example based on knowledge of existing soil types in the area via geotechnical drilling as well as specific knowledge of future construction sites in the area.

The developer must assess the possibility of alternative foundation methods for buildings or roads/paths/parking areas such as lime stabilization to reduce the amount of soil that must be handled.

To support the sustainable soil management in the area CO2 calculations must be carried out using the CityLoops CO2 calculator."

3.1.3 Change of project

Due to market conditions as a result of increasing prices and discrepancies with the utilities company about a rainwater pond, IKANO has temporarily paused the development of the area.

IKANO is considering changing the whole project into transforming the existing buildings into housing instead of demolishing them. However, this will require a new urban plan, and therefore postpone the project significantly.

The CityLoops project managers have drafted a revised version of the circular criteria which come into effect if IKANO goes forward with the plan to leave the majority of existing structures standing. The updated criteria specify that structures do not need to be demolished, but the components that are still demolished or stripped still need to be demolished selectively with maximum direct recycling. It also specifies that structures that remain standing will be counted as 100% recycled.

At the time of publishing, the details of the project have not been finalized. The exact degree to which the building will be transformed rather than demolished has yet to be determined, as it will be based on the intersection of constantly changing market factors and the project budget.

3.1.4 Adaptive reuse vs demolition

Upon measuring the avoided CO2-emissions that would result from leaving the city hall building standing and converting it to housing rather than demolishing, it becomes very clear that this trumps all other circular initiatives that are based on recycling demolition waste by several orders of magnitude. A conservative estimate results in 2000 tons of CO2-savings (in comparison, recycling concrete for the foundation of the new city hall resulted in 6.6 tons of CO2-savings). In addition, a rough estimate reveals a potential savings of more than 20.000 tons of raw materials.

This must therefore be emphasized as a first priority – both to others planning on doing circular building projects and internally within the municipality: If you can avoid demolishing and instead maintain and renovate the buildings you have, that is what you should do. Part of the reason the initiative to demolish the old city hall and build a new one even started was that the old city hall had not been well-maintained. This meant that the cumulative damage to the building due to things like leaky roofs made potential renovation seem like an insurmountable task. If you maintain the buildings you have, use them to their fullest potential, and renovate if you need them for another use, this will give the greatest natural resource and CO2-savings rather than building a new building (even if it is made of recycled materials).

3.1.5 Pre-demolition screening & selective demolition

A preliminary pre-demolition screening and resource mapping has taken place. The mapping outlines the different material types in the building and their potential uses, including how the material must be taken down or demolished depending on the planned reuse. For instance, direct reuse involves careful disassembly, while materials that will be transformed in the recycling process can be handled less delicately.

The demolition or stripping of the building has not yet taken place.

3.1.6 Soil management

Preparations

The CityLoops project managers are in close dialogue with IKANO regarding soil balance and opportunities for reusing soil on site as well as local re-use off site. IKANO and their consultant (WSP) are working to identify local off-site reuse locations. WSP will create a log documenting effort to reuse as much soil as possible.

Additional geotechnical drillings were performed with extra focus on reuse potential of the soil.

Most probably the greatest challenge will be reuse of topsoil, since there is a general surplus of topsoil on the market as a result of urban development areas on former agricultural areas generating large amounts of excess topsoil. Initial soil accountancy shows a surplus of approximately 60-70 000 m^3 of topsoil on the city hall grounds.

IKANO's schedule is being adjusted due to market conditions challenging the project finances (increasing prices). Therefore, focus is currently on the parts of the grounds that do not currently contain buildings and therefore would not require demolition. A clarification about the schedule for the remaining areas is expected soon.

An advantage of the delays is that IKANO had more time to engage in market dialogue regarding circular potential.

It is likely that the potential change in project to adaptive reuse rather than demolition will result in the generation of less excess topsoil, as fewer new areas will need to be dug up. Seeing as the project details are not yet finalized, no results can yet be presented for comparative soil balance prognoses.

3.1.7 Reflections on collaboration

The pre-purchase development agreement resulted in a very fruitful collaboration with the possible developer – with a practical and targeted vision of how the area could be developed. Pre-purchase development agreements are in general quite common in Denmark.

At an early stage, while the details of the pre-purchase development agreement were still being outlined (pre-CityLoops), one of the future CityLoops project managers, working in the environmental department, approached the urban development department to discuss the opportunities for including sustainability criteria when selling the old city hall. At the time, economic interests and perceived costs of sustainability initiatives dissuaded the urban development department from integrating any specific sustainability initiatives into the material. The pre-purchase development agreement was thus entered without specific sustainability criteria, but rather a recognition of intent towards sustainability. In the years since, there has been a change in focus such that sustainability has been a higher priority. When the idea of implementing circularity was brought up again in conjunction with more detailed planning of the tendering material for selling the grounds of the old city hall, the idea was embraced. The CityLoops project manager offered help formulating the criteria for the tendering material, and furthermore offered assistance from an experienced consultant. The collaboration and understanding between the urban development department, the urban planning department and the CityLoops project managers in the environmental department was a great advantage. The collaboration helped break down barriers between possible municipal silos.

While focus within the organization has shifted towards a higher prioritization and focus on sustainability, it is still largely left to chance on a case-by-case basis whether or not the people involved consider it or are given specific mandate to prioritize it. In order to ensure that

circularity criteria are implemented in future similar cases/projects, a more structured approach must be established. This would involve, among other things, a requirement that sustainability is considered at specific checkpoints in a project. This approach will be suggested in the future citywide sustainability strategy and action plan which the CityLoops project managers in the environmental department are in charge of, in cooperation with the internal sustainability group.

3.1.8 Lessons learned

The process described above led to the following lessons learned:

- The CO2 and raw material savings from adaptive reuse of a building instead of demolishing it and constructing a new building far exceeds the potential savings from recycling building materials or other circular initiatives and should therefore be prioritized in future projects.
- The collaboration and understanding between the urban development department, the urban planners and the CityLoops project managers in the environmental department was a great advantage. The collaboration helped break down barriers between possible municipal silos.
- A fruitful pre-purchase collaboration is a great support in identifying possible circular actions. Future pre-purchase development agreements should include sustainability and circularity criteria, rather than leaving this for later in the process when the development partner can potentially refuse such initiatives or when previous agreements which are financially or legally difficult to modify can present barriers to circular initiatives.
- It is possible to successfully implement circularity criteria in the tendering of a building for demolition.
- A structured approach is required if sustainability criteria in the sale of municipal property is to become standard practice. Such an approach would involve sustainability being considered at specific checkpoints in a project. This approach will be suggested in the upcoming municipal sustainability strategy and action plan.
- IKANO has provided the feedback that the selective demolition tool developed through CityLoops is too long and heavy to read. The Danish standards for demolition already include a high degree of sorting, so for the consulting engineers reading the demolition guide it seemed merely to be a description of standard practice.

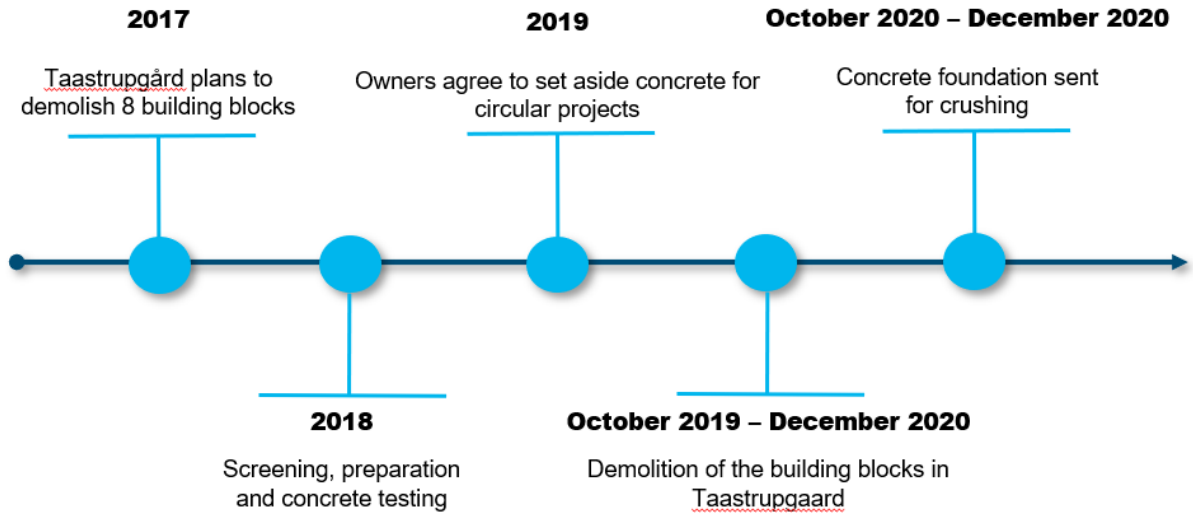
3.2 Demolition of Taastrupgård

This demonstration case is the demolition of Taastrupgård. Taastrupgård was built in the beginning of the 1970's with approximately 1.000 housing units. Over the years, Taastrupgård has developed into a social housing area with several challenges. As a part of municipal as well as national action plans to overcome challenges in certain social housing areas it was decided that 8 apartment blocks in Taastrupgård were to be demolished to make room for a new school, day-care facilities and a cultural centre within the area.

Taastrupgård was mainly built of concrete, thus the demolition would generate a large amount of concrete with a potential for recycling. The focus of the demonstration case was therefore to find potential building projects in which to recycle the concrete or use it locally as filler.

Taastrupgård

Timeline for demonstration action 3: Demolition of Taastrupgård



3.2.1 Dialogue with stakeholders

Before CityLoops, one of the CityLoops project managers in Høje-Taastrup participated in an EU Interreg project, Cleantech TIPP. In this project the municipality had dialogue with KAB, which is the social housing company that runs Taastrupgård, regarding reuse of material from demolition of apartment blocks in Taastrupgård. As an outcome of this project, the quality of concrete in Taastrupgård was tested.

The tests revealed that the concrete from the foundation of Taastrupgård apartment blocks was of such a great quality and enough of it was not contaminated with PCB or other harmful substances, that those parts would be suitable for reuse as aggregate in production of new concrete. Pelcon, a concrete specialist, tested the concrete and recommended use of either 20 % recycled aggregate or 100 % recycled aggregate (which at the time would have required a special dispensation - the revised concrete standard, DS/EN DK NA which came into effect in 2021 makes this no longer necessary) and developed a recipe for use of concrete from Taastrupgård as aggregate. The demolition was to generate approximately 25 000 tons of concrete.

KAB was open to the idea of the concrete being recycled and after extensive dialogue with the CityLoops project manager, ended up including an option in the tender which involved the uncontaminated concrete being transported to a location determined by the municipality, and received at no cost (the savings for future construction companies purchasing this aggregate and the reduced transport distance was meant to cover the cost). Eventually, KAB opted not to use this option and instead made a separate agreement regarding the concrete. In this agreement, KAB agreed to earmark 10 000 tons of clean concrete from the demolition of the apartment blocks to recycling projects facilitated by us.

3.2.2 Concrete flow - demolition with separate collection of recoverable concrete

The demolition contractor, Søndergaard Nedrivning demolished the apartment blocks. KAB encouraged reuse of concrete in the contracting process. Søndergaard agreed to deliver the earmarked concrete from the demolition to other projects.

Both KAB and Søndergaard saved money through the concrete recovery, since the projects that received the concrete received it for free.

Approximately 2000 tons of the 10000 earmarked tons of concrete were transported to Norrecco and crushed for use as aggregate. This resulted in 1088 tons of aggregate (a portion of the concrete ends up being pulverized in the crushing process and cannot be used as aggregate, hence the reduction of mass of concrete when transforming it into aggregate). It is crucial that the concrete is uncontaminated - both chemically but also with other waste

materials (soil, pipes, insulation, etc.) in order to produce a high-quality aggregate when crushing it. Initially, the first few truckloads (approximately 100 tons) contained too much soil and foreign material, so Norrecco ended up having to do extra sorting, extracting usable concrete blocks from the pile. In order to remedy this situation and avoid receiving more concrete mixed with soil and other waste, Norrecco requested that Søndergaard deliver larger chunks of demolished concrete (1 m x 2 m blocks instead of the typical 40 cm x 40 cm pieces) in order to reduce the quantity of soil and mud and ease the drying of the wet materials and sorting process for Norrecco. Once the concrete was crushed and sieved, it was delivered to Unicon (concrete mixing company) to be blended into concrete ready for pouring into the city hall foundation.

Unicon was very satisfied with the cooperation and dialogue but considered the relatively small quantity of the recycled material as a challenge due to the space it occupies in their silos. In the future, Unicon would prefer to receive larger quantities of recycled materials. Recycled aggregate has to be managed separately, which makes it more difficult to manage in small quantities compared to the required effort.

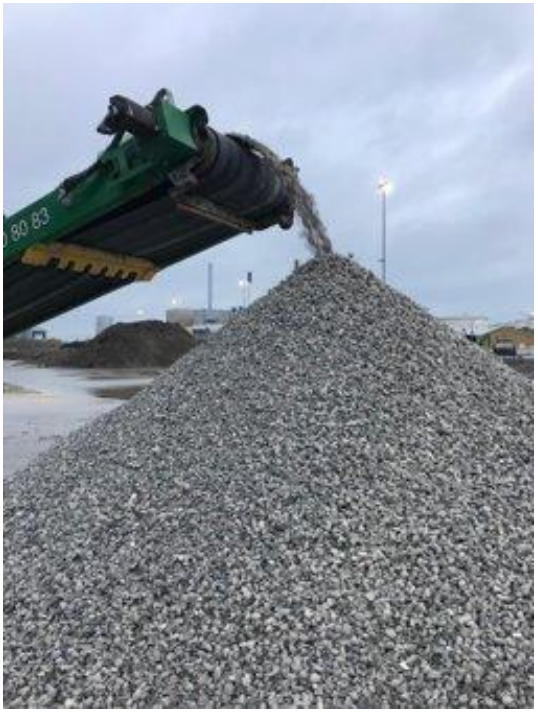
Some more of the concrete from the demolition was used in road stabilization locally – 6000 tons (4000 tons on the Taastrupgård site and 2000 tons in Høje-Taastrup C (the development area around the new City Hall)). The concrete that was used as filler on-site in Taastrupgård was crushed at RGS Nordic (a waste management/treatment company). The CityLoops project managers suggested that the concrete be crushed on-site in Taastrupgård and, as environmental authorities, were also willing to grant the required permissions with terms about noise restrictions and other disturbances. However, KAB decided against crushing on site due to the risk of annoyances like noise and dust for the residents of Taastrupgård.

The concrete that was used as filler in Høje-Taastrup C was crushed on-site at Høje-Taastrup C, resulting in substantial transport savings.

Demolition of Taastrupgård

3.2.3. Lessons learned

- It was possible to recover approximately 10.000 t concrete for local recycling (2.000 t recycled aggregates and 6.000 t recovered materials). This saved money (see business case section) and CO2 emissions.
- Local crushing of concrete for the city hall foundation would have saved more CO2-emission from transportation but this was not possible in this case.
- Reduction of transport distance and CO2-emissions by on-site mixing of the concrete instead of using prefab concrete should be required. However, the project did not include this opportunity. Future projects could consider integrating this into their planning.
- It was a problem to keep the demolished concrete free from soil, mud, and other materials. To facilitate the drying and cleaning process, Norrecco required bigger sizes (1 – 2 m) than the normal size (0,3 – 0,4 m).

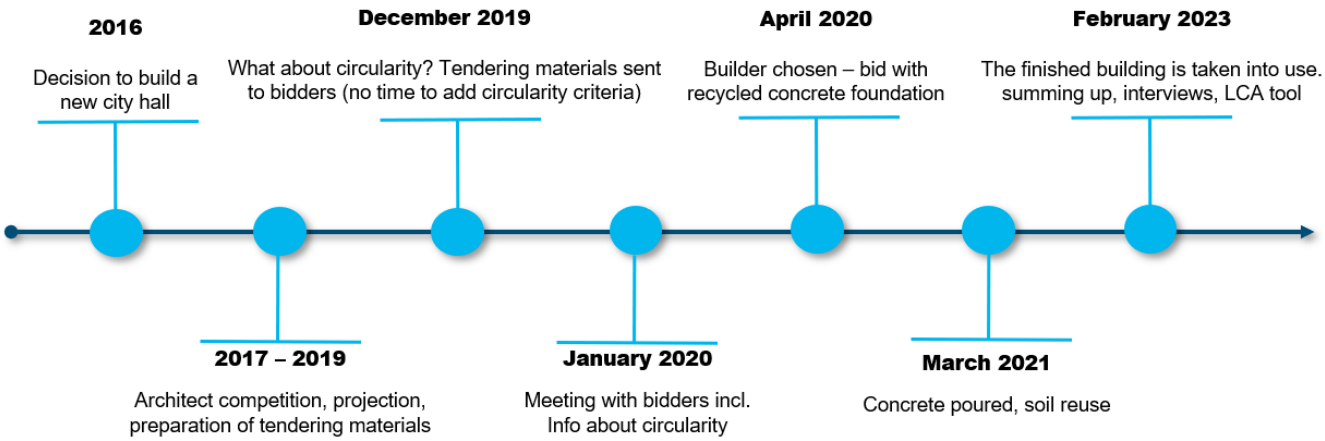


Transformation – crushed concrete for aggregate

3.3 Construction of the new city hall

In 2016 it was decided that Høje-Taastrup would build a new city hall due to the need for extensive renovations in the existing city hall. The new city hall would be located in the planned urban development area Høje-Taastrup C (HTC) as a way of kickstarting its development. At the same time, a part of the Taastrupgård neighbourhood was earmarked to be demolished. The CityLoops project managers saw the opportunity to use material from the demolition in the construction of the new city hall. Therefore, the focus of this demonstration action was to recycle material from the demolition of Taastrupgård into the construction of the new city hall.

Timeline for demonstration action 2: New city hall



3.3.1 Planning and decision-making process

The municipal department of properties and internal service (CEIS) was in charge of the construction of the new city hall.

The architectural design competition took place in 2018. The winning design was chosen at the end of 2018. It was decided by the steering group that the city hall would aim for DGNB Gold certification.

There was no obligatory procedure at that time that would lead a dialogue to take place between the properties department and the environmental department regarding the project or the tendering process and as such the environmental department did not have any influence over the decision-making process. In 2018 there was however a short meeting between the properties department, the manager of the environmental department and the climate department where environmental issues were discussed. There was however no formal structure or mandate upon which various environmental initiatives could be considered and the meeting therefore did not result in any concrete changes to the project. There were no further collaborations between these departments at that stage of planning.

Soon, the plan to DGNB-certify was discarded due to economic considerations. In response to this decision, the CityLoops project managers as well as others in the environmental department and the internal sustainability group maximized pressure on the steering group of the new city hall. In mid-2019, the steering group returned to the initial plan in favour of DGNB certification. The environmental department was at the time not informed about the considerations that led to opting for DGNB certification in the end but have since been told that it was a result of the pressure put on the steering group.

The decision to go ahead with DGNB certification opened the door to new initiatives being considered in the city hall project. Selected employees (among others, one of the CityLoops project managers; the head of the environmental department; and the climate department) were invited in autumn 2019 to brainstorm about how potential initiatives could be implemented to obtain additional DGNB points. The CityLoops demonstration manager pointed out that the municipality had access to concrete from Taastrupgård (see section 3.2 above), which could be used as recycled aggregate. This opened the door for dialogue, and the project manager from the properties department was open to hear about the possibility of using recycled materials.

The decision to go through with DGNB certification came relatively soon before the tendering material was to be published, so there was very little time to integrate potential changes into the material. Just a few days before the material was published, the CityLoops demonstration manager was invited to a steering group meeting to pitch the idea of integrating recycled materials, specifically recycled concrete, into the construction. The initiative was welcomed by the steering group, on the condition that it would not be more expensive. Due to the timing, no specific criteria or requirements were added to the tendering material regarding recycled materials. Instead, information was added about Høje-Taastrup's involvement in CityLoops and intention to promote circular economy.

3.3.2 Procurement: Tendering process for construction of new city hall

At the very last moment circular suggestions/options (but no requirements) were added to the tendering material. They were as follows (translated from Danish):

"Høje-Taastrup Municipality is involved in the project CityLoops, which is a Horizon 2020 project, with the aim of promoting circular economy within construction projects. The project must contribute to future-proofing the construction market to be able to meet the increasing demand for recycled materials in buildings.

In connection with the construction of the city hall, the municipality requests that reusable/recyclable materials are used wherever possible. We have a particular focus on the

use of recycled concrete since we have access to a large amount of concrete waste from a local demolition, Taastrupgård (up to approx. 25,000 tons).

The concrete has been tested to assess the recycling potential. It is determined to be well suited for use as aggregate in new concrete or in new tiles.

Approximately 2000 tons of concrete are set aside for use as aggregate in tiles in the new neighbourhood Høje-Taastrup C. The same type of recycled tile may be used on the city hall grounds.

In addition, the floor in the atrium of the city hall could also be made of concrete with recycled aggregates from the local demolition project. Recycled concrete may also be used for elements such as benches etc. on outdoor areas.

If the contractor sees opportunities for the inclusion of additional recycled elements such as panels of recycled wood, the municipality can, if necessary, help the contractor to identify a local source for these materials.

The municipality's involvement in the CityLoops project means that we, among other things, can contribute by offering access to advice regarding any special measures when using recycled concrete, preparation of the concrete recipe for recycled concrete, coordination assistance in connection with securing access to the concrete from the demolition, etc. The concrete will be stored within approx. 10 km from the construction site and as a rule are stored in pieces of up to 50 cm"

At a meeting in the beginning of January 2020, the 5 pre-qualified bidding contractors were informed that initiatives including recycled materials would be positively considered in conjunction with other bidding criteria, and that the municipality had access to concrete from the demolition in Taastrupgård. However, at the same time, the tendering material contained stipulations that could potentially block the use of recycled materials: namely, that well-tested materials should be used.

The contractor that ended up having the winning bid had investigated the possibility of using the recycled concrete in their construction and ended up proposing using recycled concrete in the foundation of the new city hall as a part of their offer.

3.3.3 Concrete flow

Crushed concrete from demolition of 8 housing blocks transformed to recycled aggregate concrete (100%) in concrete foundation of new city hall, Høje Taastrup, 2021. CityLoops HTK demo-project 2.

The winning contractor CASA contacted the concrete expert Pelcon and the waste management company receiving the concrete for crushing (Norrecco) to discuss the opportunities for using recycled concrete and concluded that the recycled concrete would be suitable for aggregate in the foundation of the new city hall.

In addition to the direct effect on the circular economy the case would be a great story to tell in a transferred meaning – the municipality standing on a solid foundation of recycled material from a social housing area in which the municipality made a great effort to develop.

The steering group were worried about the aesthetics of the building if the concrete were to be used as a visible floor in the atrium - if it didn't turn out right, it would be the first thing visitors would see. In addition, it did not suit the architect's design suggestions for the floor, so this idea was abandoned.

With extensive testing and coordinating between parties, a concrete foundation with 100 % recycled aggregate was poured at the beginning of 2021.

The donor concrete from Taastrupgård (see section 3.2 above) was crushed by Norrecco and received a CE-certification as the first recycled concrete aggregate certified under the new Danish standard which permits the use of up to 100% recycled aggregate in concrete, which came into effect in January 2021. In order to certify the aggregate, Norrecco needed to document their procedure for producing recycled aggregates and document that it lives up to the two standards for aggregates: DS/EN 12620 and DS/EN 206 DK NA. Tests are conducted on each batch of aggregate to ensure it has the necessary quality. The certifying body conducts audits to ensure that the aggregate and producer live up to these criteria.

Once crushed, the aggregate was temporarily stored until it was time for it to be mixed into concrete and transported to the construction site for pouring (the aggregate is combined with sand, cement and water to be prepared for pouring).

Administratively, the process met some obstacles due to the risk aversiveness of the contractor's consulting engineer. The consulting engineer called for several rounds of extra tests on the concrete, despite extensive existing documentation on its quality. This caused several delays and there was a risk that they would not accept the use of the recycled concrete. In the end, the concrete specialist Pelcon ended up taking responsibility for the quality of the concrete by writing a statement saying that the concrete had the required quality. Pelcon was sufficiently confident in the concrete to agree to this, despite it implicitly meaning that they took on the risk, as it was the only way forward to succeed with the initiative. Another factor that sufficiently subdued the advisor's risk aversiveness was the fact that Norrecco opted to get the aggregate CE-certified as part of their investment in product development in offering recycled aggregate as a product.

The resources saved were 1088 tons of concrete diverted from the waste stream or 27 truckloads. The raw materials would have otherwise been extracted from the seafloor north of Poland or from a quarry in southern Sweden. The recycled aggregates in the new concrete saved approximately 6,6 tons CO2, which result from reduced transport distance (approximately 25 km in total rather than 100 km total). The CO2 savings are greater when concrete is reused intact, because even with recycled aggregates you have to add carbon-intensive cement to get new concrete. See detailed calculations in section 4.2 Impacts.

Pouring of concrete foundation with 100 % recycled aggregate, photos: Unicon

3.3.4. Other flows

Wood

Wood from offcuts/ industrial processes (extra cuttings, excess materials that were unused) has been used as facade panels around the new city hall. This was not a part of the specific demonstration project delineated in the CityLoops regime, but a bonus that came with the momentum of the increased awareness of closing the loop of material flows.

Furniture

The municipal sustainability group got involved in the city hall furnishing team to lobby for as much direct reuse of furniture from the old city hall as possible. This initiative was further supported by the current supply chain issues and inflation as a result of the war in Ukraine, since furniture producers were not able to live up to supply chain demands. It was however decided by the municipal board of directors that the bulk of the furniture in the new city hall would be new. It was estimated that approximately 10 % of the furniture in the new city hall is reused from the old city hall. Other municipal departments such as schools, day-cares, nursing homes etc. as well as associations for sports and leisure were invited to pick up furniture for reuse before the building was finally stripped and the remaining furniture was disposed of.

New city hall with outside wooden panels from offcuts (ground level and roof terrace)

3.3.5 Local reuse of excavated soil

Concurrently with the construction of the new city hall the department of properties took over the area in Taastrupgård where eight apartment blocks were demolished to build a new school. In order to modulate the terrain in the area after demolition, a large amount of soil was needed. The project manager for construction of the school and the project manager for the construction of the new city hall realized that the timing would be almost perfect for reusing excess soil from the city hall construction at the area in Taastrupgård where the school was to be built. Therefore, they contacted the CityLoops project manager who is also an authority on soil in the environmental department in order to clarify if there were any legal or other barriers to reusing the soil locally. Since the soil was uncontaminated and geotechnically suitable for the purpose of modulating the terrain, there were no concerns or barriers for reusing the soil.

However, it turned out that the soil had to be stored intermediately for a couple of weeks, which the CityLoops project manager helped find a suitable area for.

Approximately 9.000 tons of soil from the construction of the new city hall was reused in Taastrupgård. CO2 calculations revealed that almost 30 tons of CO2 were saved from transporting the soil a shorter distance.

3.3.6 Lessons learned

The key lesson learned is that successful recycling of concrete and use of 100% recycled stone aggregates in new concrete for the foundation of the new city hall was possible.

Natural resource and CO2 savings

Approximately 9.000 tons or 257 truckloads of soil from the construction of the new city hall was reused in Taastrupgård. The CityLoops CO2-calculator shows CO2 savings as a result of the reduced transport distance are almost 30 tons.

1088 tons or 27 truckloads of raw materials were saved by using recycled aggregates, also resulting in CO2 savings of about 6,6 tons due to the reduced transport distance. The raw materials would have otherwise been extracted from the seafloor north of Poland or from a quarry in southern Sweden. The CO2 savings for recycling concrete are exclusively from reduced transport distance, as the concrete pouring process is the same as with standard concrete, involving carbon-intensive cement. Direct reuse of concrete slabs (not possible with a foundation) therefore saves substantially more CO2 and should be considered in future projects.

CO2 and material savings calculations could easily be applied predictively and should be considered being used in future projects – construction as well as demolition – in the tendering

process. Truckloads of soil/concrete savings are easy to communicate and understand as way of illustrating savings potential.

Stakeholder engagement

The use of recycled concrete as aggregate in the foundation of the new city hall was a result of a great collaboration between the department of properties, The CityLoops project manager in the municipal environmental department, CASA, KAB, Norrecco, Søndergaard Nedrivning, Unicon and Pelcon.

Interviews with stakeholders were performed upon completion of the project resulting in a Q&A pamphlet (translated from Danish). See Appendix A.

Organizational factors

As a construction client the municipality has now built some capacity in reusing materials in construction. However, no procedure currently exists in the municipal operations to ensure that necessary parties coordinate their efforts to ensure circularity and sustainability are considered. In order to ensure that reuse of material is considered in future municipal constructions it will be included as a strategy in the future citywide sustainability strategy and action plan which the CityLoops project managers are in charge of.

Project planning

Early incorporation of sustainable initiatives into the project planning process is favourable, but this demonstration action showed that it is never too late. A last-minute, minor addition to the tendering material opened the possibility for using recycled concrete and emphasized the focus on sustainability, and this change was pivotal for incentivizing the contractors to consider recycled materials.

Legal factors

Modulus of elasticity is a measure of concrete's elasticity. Eurocode 2 for design of concrete structures refers to this elasticity based on measurements from the 1960s, when standard concrete typically contained a higher proportion of aggregates, which gives a lower elasticity. Modern concrete of a given strength therefore does not correspond to the values for elasticity referred to in Eurocode 2. However, current regulations state that if needed, modulus of elasticity should be measured in recycled concrete. This creates a problem because the modulus of elasticity for recycled concrete – like modern concrete – does not correspond to the values listed in Eurocode 2 – but usually the discrepancy goes unnoticed as it is normally not measured. Given the allowance to measure elasticity in recycled concrete, the city hall

contractor's consulting engineer opted to request this. The results showed the expected discrepancy from Eurocode 2. In order to compensate for the discrepancy, the consulting engineer called for additional reinforcing bars (steel inside concrete). From a technical perspective, these extra reinforcing bars were unnecessary as the information that led to this recommendation is outdated.

In order to attempt to address this problem of outdated knowledge and practice, Pelcon (concrete expert and consultant on this project) is lobbying to change the practices surrounding measures of elasticity so that they more closely reflect real-world requirements. Changing these practices would contribute to reducing barriers for the use of recycled concrete, which currently faces extra testing and scrutiny.

Norrecco worked to get the recycled aggregate CE-certified, which helped in the approval process of the concrete. The fact that the aggregate material was certified and thoroughly documented contributed to its being accepted by the consulting engineer.

Risk and responsibility

A very important lesson learned is to assess who has the responsibility for the quality of the material and thereby who will take the risk at an early stage. Risks must be identified and communicated about as early as possible. In this case the final decision regarding responsibility for risk was done at a very late stage which almost obstructed the whole initiative.

Concrete standards and quality are complex and depending on the required function of the concrete, the relevant quality parameters can vary substantially. In future projects it would be helpful to clearly outline which parameters are relevant and at what quality levels. This would avoid the problems encountered regarding module of elasticity: it is not a relevant parameter in a foundation, but is relevant in long, narrow structures such as columns.

DGNB as incentive for circular soil handling

The DGNB criteria with regards to soil played an important role and was an incentive for local reuse. Most DGNB points are given for reuse on site, though some points are also given for keeping soil within a certain distance from the site. The intermediate storage of soil was done to account for discrepancy in timing in order to secure local reuse and thereby get DGNB points.

3.4 Recycled sidewalk tile

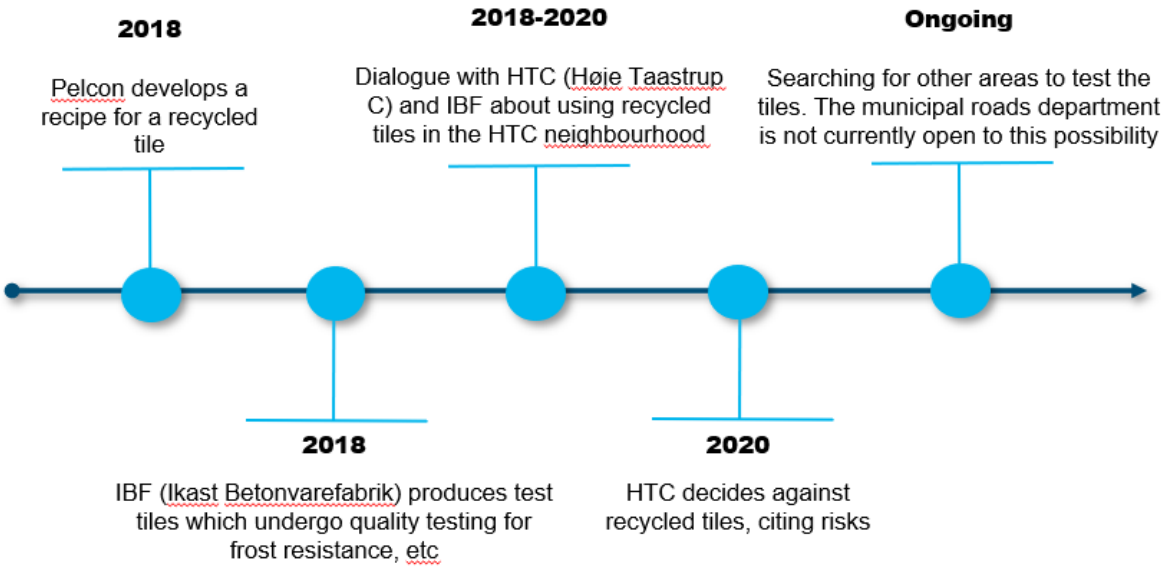
The fourth demonstration action was an attempt to use recycled sidewalk tiles. In Denmark the production of tiles is responsible for emitting 260 thousand tons of CO2 per year, the third largest emission of CO2 related to the use of concrete[2]. At the same time, it is an element where there are not the same kinds of risk related to recycling or reusing it as other concrete elements. This makes it a relatively easy place to start recycling concrete.

CityLoops commissioned Pelcon (concrete experts) to develop a recipe for sidewalk tiles produced with recycled concrete.

The aim of the demonstration action was for Høje-Taastrup municipality to identify an appropriate test area to try the tiles, followed by evaluations after the first winter period and after five years (beyond CityLoops). Based on the first evaluation the municipality would ideally initiate using the tiles in other areas, and eventually in the whole municipality.

The concrete factory Ikast Betonvarefabrik (IBF) showed interest in developing and producing a sidewalk tile with 30% recycled concrete from excess concrete from their own production.

Timeline for demonstration action 4: Recycled sidewalk tile



3.4.1 Negotiations with tile factory

IBF is interested in producing sidewalk tiles from recycled concrete, since they see a market potential for recycled tiles. They agreed to produce tiles for tests and showed great interest in

[2] Dansk beton, 2019. Bæredygtig beton initiativ Roadmap mod 2030: Halvering af CO2-udledningen fra betonbyggeri

testing tiles in a specific area, if we could locate one along with a buyer. IBF already has a test site in western Denmark where recycled tiles are being used in a municipality. The tiles are however still so relatively new that little data exists on their durability.

The tiles would be produced locally on IBF's site in Hedehusene.

3.4.2 Finding a test area for the tiles

In 2018, the company behind the urban development in Høje-Taastrup C showed interest in using the tiles to pave the roads and sidewalks in the upcoming neighbourhood. Test tiles were made and subject to frost and strength tests but in 2020, the urban development company decided against using them, citing risks. The development company was concerned that the recycled tiles would not have the same quality and durability as other tiles despite positive test results. Considering that it was a new product, IBF would not attach the same product guarantee that normally follows a delivery. This resulted in a situation where neither party was comfortable taking on the risk involved in the purchase of recycled tiles and bearing the financial responsibility of replacing tiles that may break over time.

The municipality consulted with an external lawyer on the possibility of taking on the risk in order to meet the resistance for a private company to test the tile on their sidewalks. However, the external lawyer concluded that a municipality is not allowed to take such a risk for a private company as it would be considered a special advantage.

The opportunity for having the sidewalk tiles laid in the new city hall area was also looked into. The city hall developers were open to this idea, but the landscaping plan involved 5 different types of tiles, each with very few square metres (approx. 50-100 m2). This would make it logistically very complicated for IBF to produce, as it is a time-consuming process to change the tile moulds, so it is economically much more advantageous to produce large batches. Since the tiles were in such small quantities, it would be too expensive to produce them.

Opportunities for other developers, owners etc. to test the tiles were sought. KAB showed interest in having recycled sidewalk tiles on their properties. The municipal urban development department developed a design manual for an area connected to Taastrupgård (Kulturstrøget) and the idea of the recycled sidewalk tile was presented to them. As of 2023, Kulturstrøget plans to use tiles from IBF containing 15% recycled factory excess from their own production. Another option currently being considered for Kulturstrøget is direct reuse of concrete slabs as pavement.

The recipe for the recycled tile and contacts to IBF have been shared with potential interested developers, owners etc.; however, the decision to use the tiles by these parties is beyond the control of the municipal CityLoops project managers.

Despite acceptable technology, the Høje-Taastrup municipality and the producer of tiles have not yet found a solution on risk-taking. IBF is very keen on testing recycled sidewalk tiles since

they see a future market potential and would like to upscale the production. It is an interesting outcome and experience that an actual product is available for testing.

The CityLoops project managers will continue pushing for having a test area laid with recycled sidewalk tiles by suggesting the possibility to future developers and continued dialogue with the roads department about the opportunity.

3.4.3 Perspective

IBF produces a sidewalk tile with excess production aggregate substituting virgin materials. The aggregate is crushed excess concrete from their own production. In 2022, they used 47000 tons excess production aggregate in their tiles as well as 1000 tons recycled aggregate. The CityLoops project managers do not have data on what percentage of total aggregates this corresponds to. IBF is still very interested in real-life testing of sidewalk tiles with recycled aggregate from outside projects. They are also involved in projects testing and developing cement with less CO2 emissions, using alternative materials, for instance clay instead of limestone (FutureCEM) and other similar projects.

As part of the upscaling effort in CityLoops, Gate21 is also working on gathering a shared demand from many developers for recycled and reused concrete tiles through an ongoing market dialogue for example with IBF. The experience from the market dialogue so far is that there is a great interest from many developers to reuse concrete tiles in projects, but there is still a need to develop solutions for it to be economically feasible in larger projects. For example, there is a need to develop machines that mechanically can lay reused tiles that may vary in size or other parameters, which do not exist today. And there is a need to solve logistical challenges. The ambition in the ongoing market dialogue is that a common demand from many developers will help accelerate the creation of the needed solutions.

Furthermore, general information, education and training of all actors in the value chain of recycling concrete tiles is necessary.

3.4.3 Lessons learned

- Address risk: Even though the risk seems small it can halt the implementation of circular solutions like the use of pavement tiles with recycled concrete.
- There is a market for recycled pavement tiles and reused pavement tiles.
- New technology would help make direct reuse of tiles more economically feasible.

3.5 Circular soil management

The focus of this action is on establishing circular soil management at the city level in order to keep excavation of soil to a minimum and use excess soil locally, thereby reducing handling and transport of soil. Reduced transport of soil will lead to reduced CO2 emissions, increased traffic safety, less wear and tear of roads, reduced particle pollution and less traffic in general.

An instrument for predicting how much soil will be produced at city level was developed and tested. Barriers to reusing soil have been uncovered by interviewing stakeholders. A roadmap for identifying municipal roles and ways of improving circular soil management was developed.

Høje-Taastrup contributed the guidelines for sustainable soil management and assessment of soil reuse potential of excavated soil. In addition, the CO2 calculator was used to illustrate the significant effects that more circular soil management has on emissions.

The overall objectives for circular soil management order of priority are:

1. Reduce excavation during construction projects – leading to a reduction in the amount of excess soil generated
2. Strive for soil balance in projects/urban planning - maximize reuse on site
3. Reuse soil at local sites/projects

3.5.1 Soil instruments

These soil instruments have been developed and simultaneously tested in the demonstration actions in Høje-Taastrup:

- *Soil prognosis: Instrument for prediction of soil production* INSTRUMENT FOR PREDICTING EXCAVATED SOIL PRODUCTION RELATED TO URBAN DEVELOPMENT (cityloops.eu)
- *Roadmap for soil management* ROADMAP - English - final ver7 19062023.xlsm (live.com)
- *Guidelines for sustainable soil management and assessment of reuse potential of excavated soils* Guidelines for Sustainable Soil Management and Assessment of Soil Reuse Potential of Excavated Soils (cityloops.eu)

3.5.2 Prediction of future excess soil

A prognosis to predict annual expected excavated soil in Høje-Taastrup for 12 years (2020-2031) was carried out. The predictions were based on a business-as-usual scenario,

considering a situation where municipal planning and construction activities are performed without paying special attention to reducing the amounts of excavated and excess soil. The prognosis is based on historical analysis and knowledge of upcoming major construction projects that will take place in the future.

Data for the prognosis was collected by the urban planning team and the soil team within the municipality.

NIRAS synthesized the relevant data and carried out the analysis.

YEAR	TON
2020	300.000
2021	250.000
2022	900.000
2023	450.000
2024	200.000
2025	250.000
2026	400.000
2027	250.000
2028	250.000
2029	250.000
2030	90.000
2031	90.000
Total	3.7 million. tons

Table 1- Prognosis for expected excess soil from construction and infrastructure projects in Høje-Taastrup municipality

3.5.3 Identification of barriers to circular soil handling

A series of stakeholders in the market were interviewed about barriers for on-site soil reuse and circular soil handling. Stakeholders included construction clients, contractors and developers.

Main barriers identified were:

- urban development plans usually lack physical space for local reuse of soil or temporary storage.
- traditional tendering processes leaves no time or room for new solutions for local reuse of soil.

3.5.4 Example of application of instruments

FB Gruppen, a private developer, is developing a large area for an expected 3000 residents in the eastern part of the urban development area Nærheden in Hedehusene. FB Gruppen performed an early soil calculation in order to be able to plan for reducing amounts of excess soil when developing the area. FB Gruppen saw the benefits for reusing soil, from an economic and sustainability perspective.

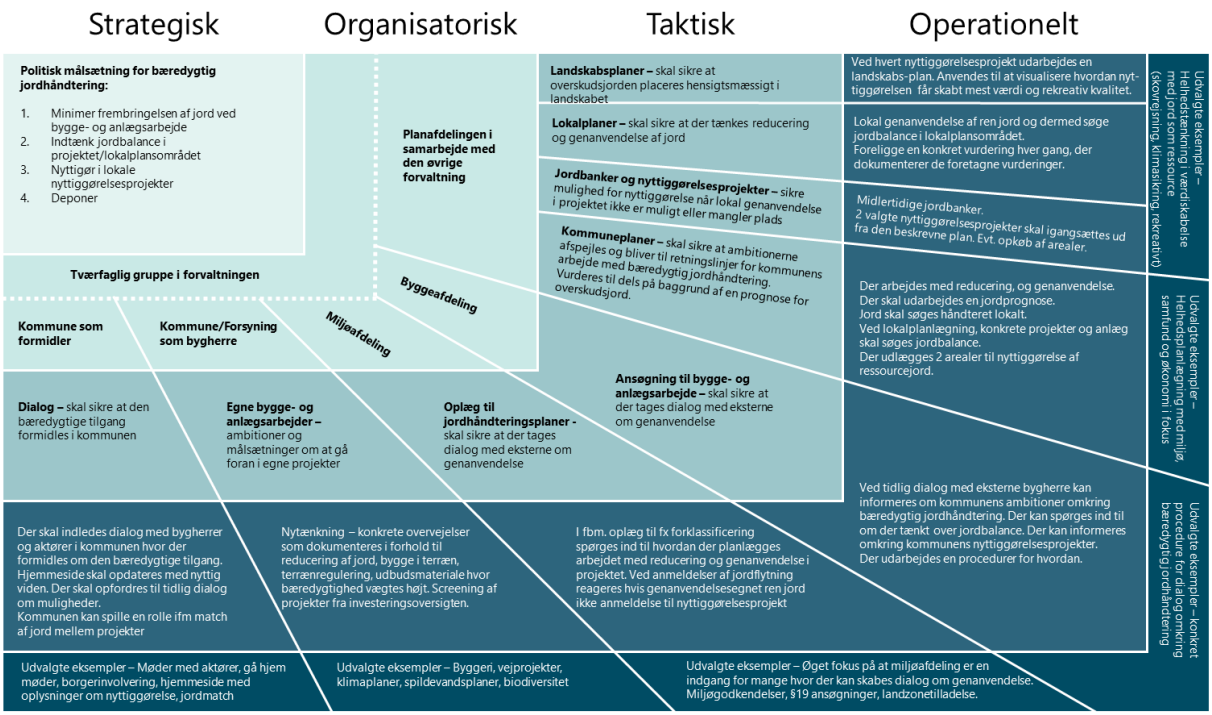
The soil calculation is based on planned future terrain elevation, location of future buildings, expected excavation depths etc. In addition, geotechnical drillings were performed in order to estimate the reuse potential of the identified soil types around the area. Furthermore, FB Gruppen performed lime stabilization under future parking areas thus avoiding the need to dig up soil in order to stabilize the ground with filler, further reducing the amounts of excess soil. The soil is reused on site as much as possible to adjust and model the terrain prior to construction.

According to the calculation, more than 90 % of what would have been excess soil is being kept on site in FB Gruppen's area. The estimated amount of excess soil saved is more than 700.000 tons saving an estimated more than 1.000 tons of CO2 – and of course a substantial amount of money depending on market prices for soil deposit and transport.

3.5.5 Roadmap for soil management

The collaborative learning network for circular soil management was set up by the capital region of Denmark in cooperation with Gate21 and consultant NIRAS. A roadmap was developed as a diagram to provide an overview of the strategically anchored effect that a municipality has on soil management. The roadmap illustrates the different roles that a municipal organization has on soil management - land owner, construction client, urban

planning and development, authorities etc. Tactical and operational opportunities are identified in relation to each organizational role to identify where the potential for improvement is in the specific organization.



General road map for circular soil management in Denmark.

In Høje-Taastrup the roadmap is a dynamic document and thus, there is no final version of it. Outputs from CityLoops workshops and experiences are continuously put into the roadmap. The sustainability strategy and action plan will also further develop the roadmap and set the strategic goal.

3.5.6 Circular soil handling – a part of the sustainability strategy

The municipal sustainability strategy, which is under development contains 8 overall themes, one of which is material resources, including the overall objectives for circular soil management. An action plan will be connected to the sustainability strategy.

The experiences and tools from circular soil management in CityLoops as well as outputs from CityLoops workshop supports and feeds directly into the sustainability strategy and action plan at different levels:

- The prognosis illustrates and emphasizes the need for circular soil management and can furthermore be used in the action plan on a project level.

- Examples of circular soil management illustrate how circular soil management can be performed and serves as inspiration
- The guidelines for circular soil management are used directly in the action plan
- The roadmap clearly identifies at which levels the municipality has influence on soil management and which municipal department should be responsible for each action related to the strategy.

3.5.3 Lessons learned

Soil prognosis

- Increased awareness of masses of soil being produced and transported in general. Especially if the amounts are converted into truckloads of soil (estimated 35 tons of soil per truck), it becomes very clear that soil is an important parameter to consider – not solely as a result of CO2 emissions, but also in terms of traffic safety and volume, road wear and tear, noise impact, etc.
- Early awareness of the expected amount of excess soil at certain development areas. Being able to pinpoint the expected amounts of excess soil at an early stage often is advantageous, since the developer can take this information into account in the planning stage of the project, thereby increasing the opportunities to try to reduce amounts of excess soil being dug up and reusing as much as possible on site.
- Possibility of measuring impact when circular soil handling is prioritized in new development areas. The actual amounts of soil can easily be compared to the prognosis and a simple calculation will reveal how much soil is being kept on site. The CO2 calculator will easily reveal the CO2 emissions saved.
- Experience from development projects taking place since 2020 revealed that the amounts of excess soil on already developed areas being transformed is underestimated in the prognosis. This feedback was given back to NIRAS, who in future similar prognosis will adjust the calculations and estimates.
- Urban development plans are regularly being adjusted and changed. Therefore, it is recommended that the prognosis be updated for example every 4 years to maintain a realistic prognosis that is as useful as possible.

Circular soil handling

- Awareness about the importance of and possibilities around circular soil handling is an important pre-requisite for initiatives. In the circular soil handling between the new city hall and Taastrupgård (see section 3.3.5), the two project managers in charge of each of these projects knew of these possibilities as a result of CityLoops initiatives and

opted to aim for that. Had they not known it was a possibility, they would have continued with business as usual

- DGNB criteria are a great incentive for reusing soil, since most points are given for reuse on site, though some points are also given for keeping soil within a certain distance from the site.
- Furthermore, in the urban planning process it is very important to designate an available nearby storage place - as otherwise the soil will be transported off site.
- In addition, tendering is an important factor. If the tendering leaves no opportunity for reusing soil, the soil will be handled as usual, thus being transported off site.
- It is crucial to consider soil management at early stages in every project if soil circularity is to be increased. If it is considered as an afterthought, often the project is planned in such a way that the soil is dug or used in the wrong order to be able to use what is already on site. Simply taking soil into account enables it to be factored into the planning.

4. Results

4.1 Summary

The demonstration actions have contributed to a better understanding and prioritization of sustainability and circular economy within the municipal organization. This has also happened in conjunction with an overall better understanding of these concepts in society at large. At the beginning of this project, “sustainability” was considered synonymous with CO2-reduction and circular economy was an unfamiliar concept. There is now a greater understanding that sustainability is so much more than CO2: resource use, for instance, is also an essential parameter to consider if you want to improve sustainability.

The greater prioritization of sustainability in the organization is noticeable for instance with the fact that the sustainability group has gained approval and traction and is now heading a municipal sustainability strategy which will help guide future projects and management in the municipality.

The demonstration actions themselves have had an impact both in terms of raw material savings and CO2 savings. The CityLoops project managers will continue to encourage circular practices in municipal projects, now equipped with experience and lessons learned from CityLoops.

The detailed results and impacts are outlined below.

4.2 Impacts

4.2.1 Raw material and CO2 savings

Concrete aggregate

The main goal of recycling concrete for the city hall foundation was avoiding raw material extraction. However, using the recycled aggregate still resulted in approximately 6.63 tons CO2 savings due to reduced transport distance. The concrete was transported approximately 25 km to Norrecco to be crushed. It would have been transported this approximate distance for crushing even if it were not to be recycled as aggregate. This transport distance is therefore not factored into the total distance. It was then transported to neighbouring Unicon, and then 25 km to the construction site. Normally, aggregate would be extracted from a quarry in southern Sweden or from the ocean floor north of Poland, estimated to have CO2 emissions in both cases approximately equivalent to 100 km based on information from Unicon. The savings were calculated using the CityLoops CO2 calculator for soil as this calculation is based

on transport distances. With 25 km transport of 1088 tons (approximately 27 truckloads) from the source rather than 100 km, 6.63 tons of CO2 were saved, and approximately 2025 km avoided truck transport. Local crushing of concrete for the city hall foundation would have saved more CO2 but in this case logistical barriers prevented this. It would have furthermore required on-site mixing of the concrete, which the project did not include. Future projects could consider integrating this into their planning.

The resource savings were considerable. 1088 tons or 27 truckloads of concrete aggregate was used instead of raw material from these gravel pits or sea floor.

These calculations were not used in decision making in this case, rather done afterwards for reporting and reflection.

Concrete filler

The 2000 tons (50 truckloads) of crushed concrete from Taastrupgård used locally in Høje-Taastrup C as filler also resulted in CO2 savings. It is estimated that standard recycled filler would have come from approximately 25 km away instead of 3 km away, saving 1100 km of truck transport. Using the CO2 calculator for soil this amounts to a saving of approximately 4.06 tons CO2.

For the 4000 tons crushed concrete from Taastrupgård used on site to stabilize the ground in conjunction with construction of the new cultural centre in Taastrupgård, there is a net 0 CO2 saving in terms of the transport of the materials. As KAB did not want to crush the concrete on site, it was transported to a standard waste treatment plant for concrete, where it was crushed and returned to the site (not necessarily 1:1 the same concrete - concrete from other sites was likely also used). Thus, this is the same process as if the crushed concrete filler had been purchased as a good instead of just transported back and forth.

Soil

Approximately 9000 tons of soil from the construction of the new city hall was reused in Taastrupgård. CO2 calculations revealed that almost 30 tons of CO2 was saved from transporting the soil a shorter distance. This corresponds to 257 truckloads avoiding 5667 km of driving.

Totals

In total Høje-Taastrup's participation in CityLoops has resulted in raw material savings of 1088 tons of granite and approximately 40.7 tons of CO2 savings. 8792 km of truck transport was also avoided, as well as the subsequently avoided particulate pollution, road wear and tear, noise pollution, reduced traffic, etc.

Impacts of demonstration action 1: Demolition of old City Hall

Expected outcome	Indicator	Baseline value	Final value
The use of CityLoops tools (selective demolition, pre-demolition screening, LCA for soil and concrete and soil tools) are a part of tendering material and improve the mapping of materials for future use	3. New tools for better mapping of resources and their location: Qualitative description	No tools were used consistently before CityLoops. Reuse of soil was more coincidental and not very well structured. Unstructured and mostly coincidental attempts to encourage mapping of resources.	Change in project - the city hall will most likely not be demolished and instead it will be converted into apartments. The circularity criteria presented in the tendering material were modified to correspond to this new project - parts of the building will still be demolished, so resource mapping and selective demolition is still relevant, and we will still require that the materials added contain re-used materials. There is likely to be much less soil dug up than with the original project, but we still require a calculation of soil balance and assessment of re-use potential and of alternative foundation methods in the areas that will be developed. Similar procedure with circular requirements to be suggested as action point in sustainability strategy. We will also emphasize examining the potential of existing buildings to fulfil needs rather than demolishing and rebuilding.
Increased stakeholder dialogue leading to more circularity in tendering material	10. Stakeholder contribution to improved circularity	Zero. No systematic attempts at stakeholder dialogue.	The close dialogue with the developer helped cement the initiatives and kept the door open for more dialogue about additional initiatives. In the pre-tendering phase, there were certain criteria that the developer encouraged us to make stricter because they knew they could live up to those standards while they also thought it would be more challenging for competitors to live up to.
Improved practice of including sustainability and circularity considerations in urban development plans and tendering criteria when selling municipal property	12. Circularity requirements in procurement beyond existing levels	No circularity requirements in procurement before CityLoops. No structured attempts to improve circularity and sustainability in urban development plans before CityLoops.	Sustainability strategy still under development. The dialogue about sustainability and circularity is however much more present in the organisation. So, while specific guidelines are not yet enforced, in practice they are taken into consideration (if not implemented) in tendering materials.
Out of 18,000 tons of soil, 80% is kept on site (15,000 tons)	27. Increased share of materials retained and reused on demonstration sites	Zero (only activities during the project are measured)	Project heavily delayed due to new plan to renovate and transform the existing building instead of demolishing it. The amount of soil to be moved is therefore heavily diminished, but due to the delays the exact amount is unknown. The amount of other materials retained or reused on site will also heavily increase due to the plan to transform rather than demolish.

Expected outcome	Indicator	Baseline value	Final value
Reduced consumption of virgin resources, by using recycled materials instead	34. Reduced use of virgin materials	Zero (only activities during the project are measured)	The sum of virgin materials needed for this project is significantly reduced due to the change in project from a demolition to a transformation. The majority of the heavy structures will remain (and therefore not require any new virgin materials to construct) while criteria on recycled materials will be in place for the light structures that will be installed.
30 tons of CO2e savings from soil kept on site. In addition, a reduction of CO2 is expected due to a more circular handling of other CDW.	85. GHG emissions per year	Zero (only activities during the project are measured)	No data currently exists due to project delay, but savings are expected to far exceed those initially forecasted due to the change in project from demolition to transformation.

Impacts of demonstration actions 2 and 3: New City Hall and Taastrupgård

Expected outcome	Indicator	Baseline value	Final value
Increased stakeholder dialogue, leading to more circularity in relation to CDW and soil reuse and recycling	10. Stakeholder contribution to improved circularity	Zero. No systematic attempts at stakeholder dialogue have been recorded.	A number of stakeholders were included in order to improve circularity - municipal department of properties, social housing company, demolition contractor, consultants, waste company, concrete company, turnkey contractor etc. Most stakeholders involved in the project contributed enthusiastically in order to succeed.
Improved practice of including sustainability and circularity considerations in the procurement process	12. Circularity requirements in procurement beyond existing levels	No circularity or sustainability requirements in procurement before CityLoops.	The sustainability strategy which is currently under development will include sustainability and circularity considerations for procurement processes. The strategy is not yet complete. However, the procurement department is working independently to become more sustainable and circular.
New business models for reuse, recycling, and valorisation of CDW and soil developed and validated	23. Eco-innovation: Qualitative description	Zero (only activities during the project are measured)	Business case model developed by DACC based on data from demonstration actions. Emphasis is put on the different parameters that can be valued in a circular building situation, many of which are hard to quantify such as cultural value. These different factors all contribute to the overall evaluation of whether or not a particular initiative is deemed to be worth pursuing.
Use of virgin resources (gravel) reduced by 1,088 tons	34. Reduced use of virgin materials	1088 tons of virgin gravel would have been used in concrete if business as usual	1088 tons of virgin gravel would have been used as concrete aggregate if business as usual. Instead, concrete from the demolition of Taastrupgård was used for the 100% recycled aggregate foundation of the city hall.

Expected outcome	Indicator	Baseline value	Final value
The recoverable materials have been incorporated into new buildings or crushed on-site and used as filler. Some materials may also be used in other (as yet unidentified) building projects off-site: - recycling of 8,000 tons of concrete into filler in other projects - recycling of 1,088 tons (high-value recycling) of concrete aggregate for the city hall foundation	52. Quantity of material subjected to recycling	Concrete has been recycled primarily as filler before CityLoops, primarily in the department of infrastructure (for roads etc.). However, we do not have the quantities. CityLoops will hopefully increase awareness and focus on using materials and keeping its quality.	1088 tons reused as concrete aggregate in foundation of new city hall. The rest used as filler in Taastrupgaard and Høje-Taastrup C.
CO2 savings from reduced transport of soil and high-value recycling of concrete: 9,000 tons of soil transported 3km instead of 25km, 15 tons of CO2e saved CO2 savings from recycling 8,000 tons of concrete into filler in other projects. 4,000 tons are transported 3 km and 4,000 tons are transported 46 km. CO2 savings from recycling 2,000 tons into 1,088 tons of concrete aggregate for the city hall foundation. Transport of concrete aggregate is halved, to approximately 50 km total. CO2 savings 6.6 tons	85. GHG emissions per year	Baseline is zero at the demonstration level.	Soil: 30 tons of CO2e saved (15 in each end). 2000 tons of concrete transported 3 km between building sites instead of 25 km from a supplier to use as filler saved 3.75 tons of CO2e. Use of virgin materials was saved which has indirect CO2 saving effects, in addition to 6.6 tons of CO2e savings from reduced transport distance.

Impacts of demonstration actions 4: Recycled sidewalk tile

Expected outcome	Indicator	Baseline value	Final value
Increased awareness of using recycled tiles in projects (scaling potential)	10. Stakeholder contribution to improved circularity	Zero (only activities during the project are measured)	Several municipal departments and other organizations within the municipality have expressed interest in using recycled concrete tiles after hearing about it through this project. There is in general a

Expected outcome	Indicator	Baseline value	Final value
			greater awareness of the possibility of using recycled materials in various projects.
Reduced use of virgin material due to the use of recycled concrete aggregate	34. Reduced use of virgin materials	Zero (only activities during the project are measured)	Private actors have begun to incorporate recycled tiles into their plans for paving new areas after hearing about it through this project. As this is not controlled by the municipality, we do not have access to exact numbers.
Pilot project: 30% recycled concrete used in tiles	52. Quantity of material subjected to recycling	Zero (only activities during the project are measured)	Test tiles have been made out of 100% recycled concrete, and production of tiles with 15% recycled concrete is incorporated into the standard product catalogue for the local tile factory in Høje-Taastrup.
CO2 savings from 100m sidewalk with tiles made from 30% recycled concrete	85. GHG emissions per square meter	Zero (only activities during the project are measured)	Municipal test area not yet identified but private actors have begun to incorporate recycled tiles into their plans after hearing about it through this project. As this is not controlled by the municipality, we do not have access to the exact numbers.

Impacts of demonstration action 5: Circular soil management

Expected outcome	Indicator	Baseline value	Final value
More local reuse of soil as a result of the implementation of CityLoops soil tools and LCA tool in soil management (25% reduction of what the prognosis predicts from 2020-2023)	3. New tools for better mapping of resources and their location: Qualitative description	No tools were used before CityLoops. Reuse of soil was more coincidental and not very well structured.	Soil prognosis used to raise awareness on how much soil will be excavated and transported from a specific site if circular soil management is not being taken into consideration at an early stage. Increased number of developers carry out soil calculation at early stage of development in order to reduce and save amounts of soil being transported. A specific site has predicted a 90% reduction in soil excavation or transport due to early planning and soil prognosis, with the help of the tools and encouragement from this project.
Increased involvement of planning department and developers has led to more awareness and earlier consideration of soil reuse potential	10. Stakeholder contribution to improved circularity	Zero (only activities during the project are measured)	Urban planners and developers are more aware of the importance of taking circular soil management into consideration at an early stage when planning and developing an area. Circular soil management is mentioned in the latest overall municipal frame for urban planning. In addition, circular soil management is considered to be included in the overall development strategy for Høje-Taastrup which is in progress.
New business models for reuse and valorisation of soil developed and validated	23. Eco-innovation: Qualitative description	Zero (only activities during the project are measured)	Business case has been developed by DACC.

Expected outcome	Indicator	Baseline value	Final value
General increase in reuse of soil on construction sites	27. Increased share of materials retained and reused on demonstration sites	Zero (only activities during the project are measured)	A precise number is not available, but the actual registered amounts are smaller than what the prognosis shows. However, market conditions likely contributed to less construction and thus, less excess soil. An evaluation of the soil prognosis reveals that there is a need for regular update of the prognosis in order to keep it relevant. A regular update is suggested to urban planning department as part of the evaluation of the overall municipal frame for planning and the overall development strategy which is in progress.
CO2 savings from less excess soil transported	85. GHG emissions per year	Zero (only activities during the project are measured)	A precise number is not available, but the actual registered amounts are smaller than what the prognosis shows – see indicator 27 above.

Impacts on city level

Expected outcome	Indicator	Baseline value	Final value
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 of the results from the demo projects to other municipalities and private projects within the municipality	9. New formal CE-based collaboration platforms/networks	Zero (only activities during the project are measured)	Internal sustainability group established. 20-25 employees from across the organization. External: Collaborative learning network: Partnership for excess soil and resource. Joining declarations of intent of more circular construction in the municipality as a property owner.
Raised awareness of circular practices across the administration and amongst local citizens and businesses. The internal	19. Progress towards circular city strategy objectives	No circular strategy before CityLoops. Unstructured circular actions in specific departments. To a high	Awareness of circular economy and circular practices has been raised across the administration. For instance, the procurement department targets circularity and sustainability. Sustainability strategy and evaluation of climate action plan also faces circular

Expected outcome	Indicator	Baseline value	Final value
sustainability group will make a roadmap for an action-oriented strategy for sustainability in the entire municipality.		degree very employee dependent.	economy to a larger extend than earlier. The sustainability group was established and approved by the municipal board of directors. Politicians and private developers are more focused on sustainability and circular economy.

4.3 Economic Analysis

4.3.1 Economic assessment of demonstration

The economic impacts varied between the different stakeholders involved in the demonstrations.

For the flow of concrete between Taastrupgård and the new city hall, there were savings for the demolition client (owner of Taastrupgård) and for the demolisher. There was potentially a small profit for the demolition client's advisor due to extra hours advising. For the construction client of the city hall (Høje-Taastrup municipality) and the contractor, the project was price-neutral. Costs were incurred by Norrecco (the waste processing facility which crushed the concrete) and Unicon (the concrete mixing facility), but both parties considered these investments in product development. Costs were incurred related to extra testing of the concrete, and these were absorbed by CityLoops. Outside of a CityLoops context, the parties would need to agree where these costs would lie, but it is also clear that these costs will be less over time - as we gain experience with recycled concrete, the requirements for extra testing will diminish. Furthermore, if raw material prices increase, the relative cost of recycled materials when testing is considered would be less. For more information on the experiences of the involved stakeholders, see Appendix A.

4.3.2 Business case

A business case analysis was developed based on the available information from the demonstration projects of the new city hall and Taastrupgård. A lot of the specifics from the companies involved were considered confidential, so much of it is based on market estimates. See Appendix B for the details of the business case

5. Overall lessons learned

5.1 Summary and recommendations

The specific lessons learned have been described under each demonstration action. Looking at the demonstration actions all together, certain themes stand out.

- Adaptive reuse of buildings compared to demolition and new construction gives by far the biggest resource and CO2-savings, as illustrated by in the demonstration action concerning the Old City Hall.
- As the first step in any building- or urban development-related decision-making process, a careful audit of the existing building mass should be carried out with the goal of identifying the potential to use existing building mass for the desired new function. For example, by taking currently under-used spaces into use. Maintenance of existing buildings should also be prioritized in order to avoid wear and tear that over time could necessitate major renovation or demolition. Converting buildings in order to fulfil other functions is also favourable to demolishing and building a new building. The plans surrounding the old and new city halls illustrate the importance of these steps.
- Plan for sustainability and circularity right from the start of any project - or as early as possible if a project has already started. While it is easiest to implement circular actions when planned as early as possible, it is never too late – as illustrated in the last-minute change to allow for recycled concrete in the new City Hall, despite the fact that the planning process had been going on for years already. The last-minute change was pivotal for incentivizing the contractors to consider recycled materials.
- Aim for a high ambition level in actions and tenders. The market is ready to respond if there is a demand. Plans can always be adjusted but starting with a high level of ambition contributes to setting the intention. The tender for the sale of the old city hall showed the importance of this.
- At the same time, celebrate the small successes - Rome wasn't built in a day. Being inspired by the small successes can give traction to the bigger initiatives.
- Involve all relevant stakeholders/departments/parties in the value chain to ensure meaningful cooperation.
- Identify key decision-makers to ensure that the project in question can actually commit to sustainable initiatives.
- Assess key risks and how to address them, as well as which party is legally responsible for these risks. Confirm that they are willing to take on the risk, ease this process by identifying how to mitigate risk and how to remedy the situation if the problem occurs. This was a key challenge with regards to implementing the recycled sidewalk tile.
- Lobby for political change and action in favour of sustainability, both within the municipality and at higher political levels - regionally, nationally or on an EU-level,

depending on which political body is responsible for the change in question. This helps make it a standard rather than an exception to operate sustainably.

- Until regulations or laws are established regarding circularity, the success of initiatives is highly dependent on individuals who are dedicated to the initiative. Strong cooperation and partnerships are therefore important in early projects.
- Municipalities should ensure ambitious sustainability goals are included in pre-purchase development agreements, urban plans, urban development plans, etc.
- There are many different departments in a municipality that can potentially contribute to working towards circular construction. The most obvious role is that of construction client, but city planners, the urban development department, the procurement and the environmental department can all influence the process. In Høje-Taastrup' s case, the CityLoops demonstration managers work in the environmental department. Normally this department does not have a direct involvement in municipal construction projects, and the demonstration managers acted therefore more as coordinators between the various actors in the value chain. This role is important in such pilot projects as the demonstration actions tested during CityLoops, but hopefully will be less necessary as more actors gain more experience with circular building projects.

5.2 Assessment of replicability

The demonstration projects carried out in Høje-Taastrup could potentially be replicated in other medium-sized EU cities, if there is willingness to create opportunities for circular initiatives in all stages of decision-making. See section 5.1 Summary and recommendations for inspiration on how to get started.

5.3 Organizational changes - planning and decision-making

The CityLoops project gave interesting insight into how planning and decision-making has taken place in the municipality, and how it should take place in the future. A common thread in the demonstration actions is that until now there has been no formal structure in place to ensure circularity or sustainability in most municipal operations, and the success was due to identifying and taking advantage of windows of opportunity as well as cooperation with passionate and willing colleagues. The high level of chance involved in this model does not make it a very robust system for ensuring circularity. In the municipal organization there wasn't any obligation to ensure circularity either, among the various roles the municipality plays in building and development projects: there is not yet a specific political mandate or internal policies which require that circularity or sustainability should be taken into account. There is

also no procedure that ensures that the relevant departments consult one another to ensure a common vision for sustainability. It became clear that specific structures need to be in place to ensure that sustainability and circularity are taken into consideration. This directly support the need for a sustainability strategy and corresponding action plan, which are currently being developed by the CityLoops project managers with support from the internal sustainability group.

In addition, the sustainability group raises awareness of circular economy across the organization. The group works as an inspiration forum where members share relevant experiences or projects with each other, support each other's projects with interdisciplinary knowledge and information, and bring inspiration back to their own departments. The group consists of employees from across the organization - who are all passionate about sustainability and interested in moving the municipality in a more sustainable direction.

Høje-Taastrup participated in developing the CityLoops planning and decision-making methodology. In the co-development process, a framework was used to map key actions in the different phases of the demonstration projects. This exercise facilitated a reflection process on learning from the projects, hence fostering a formalizing of circular procedures for future projects.

In the future, stakeholder mapping can be used prior to projects instead of retrospectively. A workshop concept to promote organizational change helped facilitate a joint space for reflection, to discuss strategic and operational actions to promote circular construction, demolition, and urban development. The concept is described in the Replication Package "Planning and Decision Making" (www.CityLoops.eu)

The experiences from the demonstration actions have furthermore contributed to an increased focus on circular procurement in general in Høje-Taastrup. For instance, Høje-Taastrup is a part of "partnership for green public procurement" (POGI) where ambitious procurement goals are set for a number of different goods and services.

CityLoops has contributed to clarifying that the municipal organization have several roles to play in relation to circular construction depending on the specific project. It is important to identify roles and accordingly, different approaches to exploit the opportunities for influence on circular economy. Municipalities can influence circular construction through their role as a construction client, city planners, waste management authorities, road authorities, purchasers, urban development and through political mandate and publicity.

In general, CityLoops experiences have increased the awareness about circular economy and sustainability across the organization.

5.2 Future perspectives

The demonstration actions are largely complete - at least the phases which took place during the CityLoops timeframe. The tools and instruments developed provide a template that can be used in future tendering - both for construction and demolition. The CityLoops project managers as well as the sustainability group also continue to work towards organizational and political change that will solidify the status of sustainable initiatives as essential components of any project.

Appendix A: Interviews with the partners behind the recycled concrete loop of the new City Hall

Taastrupgaard

Interview with Claus Bjørton – Project manager, KAB

Claus Bjørton is business manager of the housing and administration company AKB, Taastrup (KAB) and project manager for the transformation of Taastrupgaard.

Have you worked with circular construction before?

No, but I have worked on demolitions where the crushed concrete was recycled as filler under roads and as aggregate. It is more interesting for the residents that the concrete is reused more visibly and concretely, rather than being used as filler, which is more abstract.

What were the economics of recycling concrete from your standpoint?

The crushed concrete has no value for Taastrupgaard. It is a financial burden because we have to pay to get rid of it. It was therefore financially advantageous for us that Høje-Taastrup Municipality received the concrete. I think we saved about a million DKK.

How did you prepare the tendering materials for the demolition of Taastrupgaard?

No one had imagined how much concrete was in a residential building from the 70s in Vestegnen (the suburbs west of Copenhagen) — it is a lot. We prepared a tender where the price weighted 50 percent. The other two sub-criteria that had to be factored in were CSR and the process for the residents, because the demolition took place in a residential area. This meant that you did not necessarily win the bid, even if you had the lowest price.

What challenges did you experience?

The way the world and the value chain are right now, you need to have a 1:1 donor and recipient who enter into an agreement. It has been good to have the municipality involved in the project — it provides reassurance in the handling of the concrete. I do not think that such a project can take place between two private parties yet. With the risk we face, certain questions have come up like: "What if, for example, the municipality no longer needs the concrete — then what do we do? Who is responsible for transporting it from the building site?" It is important to make clear agreements, as we have had in this project.

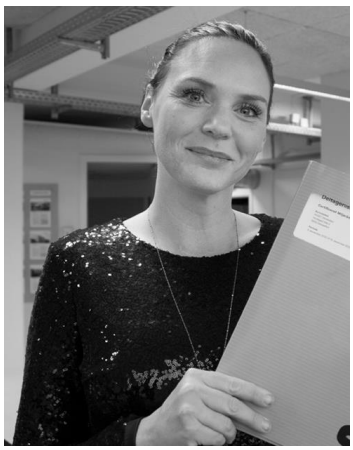
Was it more difficult to work with recycling concrete rather than status quo?

No, it has not presented major challenges. It would have given greater challenges to send it to a waste management facility. We got a really good success story out of it – the whole project was characterized by good dialogue. All parties put in the effort to make things happen.

Who bears the biggest responsibility to incorporate recycling into construction projects?

All parties involved in a construction have a certain responsibility. Circular construction can seem complicated and daunting — which is why the authorities also bear a big responsibility. Broadly speaking, you could say that society has a shared responsibility

Interview with Helene Gaarn – former environmental advisor, Wissenberg



Helene Gaarn is a former environmental advisor for Wissenberg, specializing in demolition and remediation of building materials.

What challenges did you experience?

Early in the process, they began to examine the quality of the concrete. The environmental assessment showed that the construction in Taastrupgaard had a very high concentration of PCBs, which meant that parts of the building had to be disposed of as hazardous waste, because we couldn't remediate it. Therefore, it was mostly the in-situ constructions that could be used for the city hall project because they were not contaminated. The surfaces still had to be remediated, but there were no major problems with contamination seeping into the concrete. A quarter of the concrete could be directly recycled. The remaining concrete was cleaned and sent to a demolition waste processing facility where it can be used as road fill.

In terms of reuse, there are challenges with finding market opportunities and with the division of responsibilities. Who takes responsibility for a light fixture that has been installed, and then taken down? There aren't many market opportunities, and there are also costs related to storing them. That's why they chose to have a flea market where they sold the parts of the building that you wouldn't otherwise reuse, for example refrigerators. The earnings went to social initiatives in the neighbourhood.

What were the economics of recycling concrete from your standpoint?

Our customer is the housing association, so we work for their best interests. It is a public housing association, which means that you cannot have ambitions that make the project more expensive without extra funding, because the extra cost will land on the residents' shoulders. Our task was therefore to ensure that the project remained price neutral. The price you normally pay for a ton of concrete to be transported away from the building site, is around 100 DKK + transport. It could therefore not be more expensive than that for the municipality to take it over.

Who bears the biggest responsibility to incorporate recycling into construction projects?

The decision will ultimately lie with the construction client, but the consultant must inform about the possibilities. As things are right now, there are plenty of opportunities to get funding to try something out. In all construction cases we need to get a resource coordinator on, who goes in and decides what has value to recycle. It also requires someone who is passionate about it. Projects can quickly get lost in financial and practical considerations. So, you need to have someone who wants to recycle and will push through.

What recommendations do you have for those considering circular building?

I think it's really good to think creatively, but you also have to consider early on how to manage the environmentally hazardous materials, and the risk involved in recycling materials. The environmentally hazardous materials can put the brakes on what you end up using. But recycling is the way forward, so we just have to get started.

Demolisher

Interview with Mads Søndergaard – Director, Søndergaard Demolition

Mads Søndergaard is the director of Søndergaard Demolition. He is the third generation in the family business and has been project manager on the demolition of Taastrupgaard.

Have you worked with circular construction before?

Yes, I have worked on recycling and reuse pilot projects before. Waste is a resource - that's something relatively new. When my father was younger, you mixed everything together dumped it in the landfill. Now we are better at sorting because that is regulated by fees. It provides an economic incentive to sort. The Taastrupgaard project is about stimulating the market to find better solutions.

What were the economics of recycling concrete from your standpoint?

The balance sheet pretty much evened out. We are constantly finding new methods that make the process more efficient and thus more competitive. We view the Taastrupgaard-case as an investment in strengthening our knowledge on more skilful demolitions. After Taastrupgaard, we are working on a new big project. Now we can actually charge money for the concrete because it can be used as aggregate. This is the first time that's happened in my career. Concrete is now seen as a resource and as a raw material with a value like gravel and sand. It is interesting and it changes things in the market.

What challenges did you experience?

When you recycle materials, you need lots of time and planning. There were not so many challenges in the Taastrupgaard case, as it was a big project with lots of space on the site. It therefore didn't take more time. The main challenge comes with smaller projects with less space to manage the different fractions. There is less flexibility with smaller projects, which can therefore be a challenge.

Who bears the biggest responsibility to incorporate recycling into construction projects?

If you want it to happen quickly, you need political regulation in the form of requirements. There needs to be penalties for not living up to the requirements and rewards for meeting them. It has to be expensive to not care about the environment. Transport and CO_2 emissions on construction sites must be reduced through, for example, electric and battery-powered machines instead of diesel-powered machines. In tenders, you can't just go for the lowest common denominator. Sustainability also needs to be weighted in tenders, with for example 40 percent price and 60 percent sustainability. Quality affects durability.

What recommendations do you have for those considering circular building?

Go for the low-hanging fruit first. Start by working with the heavy fractions - better that, than giving up and nothing happens. The municipality had a vision. That made a big difference. The early tests that the municipality carried out of the quality of the concrete was an important prerequisite for this to be possible. There was also a lot of dialogue between parties, which was good because otherwise the project could quickly run aground. Sustainability needs to be factored in as early as possible. Be a market driver yourself. You won't develop if you don't to try to do things differently.

Demolition waste processing facility

Interview with Jette Bjerre Hansen – Sustainability Manager, Norrecco

Jette Bjerre Hansen is responsible for sustainability at Norrecco. Among other things, she handles the development of new reprocessing technologies and processes for documentation of quality, such as certification of aggregates.

What was the process with the concrete aggregate like for you?

The updated version of the standard for the production and use of concrete in Denmark opened up to using 100 percent coarse aggregate as replacement for new raw materials. It also became possible to use recycled aggregate in all exposure classes. In the city hall project, 100 percent recycled stone aggregates were used in an exposure class corresponding to moderate environmental exposure. For the city hall project, we received a certification which enabled us to CE certify the coarse aggregate. Previously, you would have to apply for an exemption in order to use 100 percent recycled stone aggregate in that exposure class.

What challenges did you experience?

Today, only approximately 50 percent of the crushed concrete can be used as recycled stone aggregate. The remaining 50 percent is made up of the fine fraction of 0-4 mm. We are working on building up sufficient experience in recycling this part of the concrete. We also need to address how we distribute the risk between parties. At one point we faced a high risk in terms of our role in the project. The contractor's advisor was close to not approving the recycled aggregate for the city hall project. None of us had discussed what would happen if the aggregate was not approved for the project in question —who had the responsibility and the risk then?

What were the economics of recycling concrete from your standpoint?

Financially, it still costs more for us to produce recycled aggregate for new concrete. For us, however, we still gained valuable experience. We hope to soon upscale our production, and I'm sure that that will bring down costs. We expect to produce much more recycled aggregate in the future for new concrete, as quality raw materials will become scarcer. It is important that recycled materials be perceived as valuable resources, equal to others on the market — then they will be able to be sold for use in the production of building materials on an equal footing with natural raw materials.

Who bears the biggest responsibility to incorporate recycling into construction projects?

It is a good idea to use high-quality concrete for high value products. It is sustainable raw material management to maintain quality for as long as possible. Everyone has a responsibility — we just have different responsibilities for pushing the agenda. The construction client must be willing to demand recycled building materials. It will create a demand and thus a market.

What recommendations do you have for those considering circular building?

Develop strong partnerships. It is important that you work with someone you can talk to and trust. Then you work together to make it succeed. Make sure you have clear and precise agreements. It has been fun and inspiring to work with circular construction. It is immensely satisfying when you see it succeed in the end.

Concrete Producer

Interview with Ib Bælum Jensen – Technology Manager, Unicon

Ib Bælum Jensen is head of technology at Unicon, who were responsible for the concrete production for the city hall.

Have you worked with circular construction before?

Yes, Sydhavn's Recycling Station. The common factor in the two projects is that the entire value chain is included. It is an advantage to have the entire value chain involved from the start, because you can lean on each other better and talk about things early on. Everything went much faster like that.

There is often a tendency for everyone to only talk about CO_2, but there are actually 25 different parameters that matter when talking about sustainability. Sand and stone are becoming scarce resources. Recycling saves money on transport and removes the disadvantage of having to secure new materials of varying quality.

What challenges did you experience?

It was high quality concrete we worked with. The durability is therefore just as good as normal concrete. It can be difficult to find enough space for many tons of recycled concrete because it needs to be kept in production silos. In that period, we can't sell the concrete types that were previously kept in the silos.

Quite extensive documentation is needed to be able to use recycled concrete. We support that, but it means that it takes a little extra time. Currently, it can affect the unit price enormously for smaller projects, but in the case of larger projects it can be well worth it. Today we talk a lot about donor concrete — projects want to use their own recycled concrete. In the future, it should not matter where the recycled concrete comes from. You have to be able to call and order it just like any other building material. Technically speaking, recycled concrete absorbs more water than normal concrete because there are lumps of mortar in it. When the concrete is delivered, it must be fluid so that it is easy to process and move, but this can be solved with a little extra water.

What were the economics of recycling concrete from your standpoint?

We sold the concrete on roughly the same market terms as normal concrete, so it cost us a little bit. We want to continue working with recycled concrete and gain experience with it. Product development is therefore the most important thing for us right now.

Were there any legal challenges?

No, everything worked extremely well. Now we have even more experience, so later we may not have to take as many tests. There is no greater risk in this type of product than in anything else. We are already working on the next project, which is similar in size.

What recommendations do you have for those considering circular building?

Prepare yourself early on and have lots of coordinating meetings where everyone is together. Get sustainability described and demanded in the tendering material from the beginning. I hope the next project will be 10 times bigger – that would be exciting.

Contractor

Interview with Michael Eldor Birk – Project manager, Casa

Michael Eldor Birk is project manager at Casa on the city hall project.

What challenges did you experience?

In general, the recycled concrete does not differ much from normal concrete. The idea is that there should be as few differences as possible. However, you do have to be a little careful with the water-cement ratio, in terms of how fluid the concrete becomes. Recycled concrete absorbs more water than new concrete, so you need to be mindful of how much extra water to add. When the concrete was transported from the plant to the construction site, it absorbed some water which made it less liquid than what we normally use. The water cement ratios varied slightly from load to load, and it can be a bit challenging relation to casting and vibrating.

Normally, you can call up the concrete manufacturer and order an extra truck of concrete if you calculated incorrectly. You cannot do that with recycled concrete. They only mix exactly the amount you order. This is why we hope that recycled concrete becomes an off the shelf item with a standardized crushing process. This would mean that all recycled concrete can be mixed together regardless of where it comes from. This will come as demand increases.

There were a few challenges with respect to whether the concrete was too elastic. Getting the test concrete approved ended up being very last-minute. But with some extra testing of the curing process of the concrete, we managed to get it through.

What were the economics of recycling concrete from your standpoint?

We choose to look at it in such a way that it makes no financial difference to use recycled concrete as opposed to new concrete. There is some extra consulting and extra tests that make it a little more expensive, but in the long run it won't matter if it is recycled or not.

Were there any challenges in terms of the building standards?

No, it was okay. It was an okay process for the parties, and the standards have become more user-friendly. It is always difficult to be among the first to use the standard, but we found a way to make it work. The approval process will be easier in the future because we now have agreed on what is needed for the concrete to be approved.

Who bears the biggest responsibility to incorporate recycling into construction projects?

In general, the greatest responsibility lies with the construction client. They must drive the demand and be part of giving it good publicity. The construction client must put recycling as a requirement in the tendering material, so that everyone bids on equal terms.

What recommendations do you have for those considering circular building?

The main takeaway from here is that it's not that bad. It can be done. Yes, there were some challenges along the way, but it wasn't so bad. Just do it, it's not as daunting as it might sound. If everyone does it, it becomes easier, and it'll be the new normal.

The New City Hall

Interview with Erika Yates – Environmental consultant

Erika Yates is an environmental consultant in Høje-Taastrup Municipality and is the demonstration manager for the CityLoops project responsible for construction waste.

Have you worked with circular construction before?

Yes, I have previously been involved in a Cleantech TIPP project with a focus on circular economy, where different things had to be matched and connected. I learned that it was important to reach out and coordinate between the projects to find possible matches as different contractors and demolishers do not necessarily coordinate. Initially people were resistant to broach the subject because it is easier to just do what you usually do. Many thought it was complicated, but it worked out in the end: we had Taastrupgaard with lots of materials, so we hired Pelcon to analyse the concrete quality to see if you could use it for something. It turned out that it was perfect to use for recycled concrete.

How did you make the tender material for the city hall?

We didn't have time to add specific requirements for recycled concrete into the tendering material, as it came quite late in the process. A few days before the tender was sent out, I was invited to a steering-group meeting for the city hall project, where I pitched the idea of recycling the concrete from Taastrupgaard into the construction. The tendering documents ended up stating that the client favours sustainability and the use of recycled materials. At first, I hoped that the concrete would be used for the floor. I took a sample of recycled concrete with me to a meeting with the architects, and they were excited about it. Casa ended up bidding on the project — with the entire foundation made of recycled concrete, on Pelcon's recommendation. It went from a thin little floor to a whole foundation. It was fantastic.

What challenges did you experience?

There was no financial difference for the construction client in using recycled concrete compared to new concrete. One challenge was to ensure clarity and consensus about the precise documentation all parties required, and about who in the end is responsible for the quality of the concrete.

Who bears the biggest responsibility to incorporate recycling into construction projects?

The biggest responsibility lies with the construction client and the contractor. The construction client has to demand recycling, and the contractor has to be able to deliver it. If more contractors offer recycled materials, it's more likely that construction clients will demand it. The more construction clients demand recycled materials, the more projects' contractors can bid on. The supply and demand will go hand in hand.

What recommendations do you have for those considering circular building?

Take recycling into consideration as early in the project as possible — the earlier, the better. Make specific requirements in the tendering material that are as precise as possible. It's all about good cooperation and partnerships and starting with the low-hanging fruit. At the same time, we also found out it's never too late!

Interview with Jim Holme Højfeldt - Project Manager, Høje-Taastrup Municipality

Jim Holme Højfeldt is project manager on the city hall project in Høje-Taastrup Municipality. He is part of the facilities team in the municipality's properties department.

Have you worked with circular construction before?

This is the first circular construction project I have been involved in. There wasn't anything about sustainability and circular economy included in the tender before Erika Yates came in and suggested it. Recycling the concrete from Taastrupgaard also made for a really good story. It's a good story, being able to point at a column and say that it is recycled concrete from the Taastrupgaard social housing. The timing and the materials fit, so it made sense to use the concrete in the city hall. Høje-Taastrup Municipality also wants to brand itself on sustainability and responsibility. Recycled concrete fits in well as the foundation of our city hall.

We couldn't write the recycled concrete in as a requirement in the project, as it came too late in the process. We wrote that the construction client considered it an advantage if bidders focused on sustainability and recycled concrete.

The city hall was also going to be DGNB certified, but recycled concrete does not give that many points towards the certification. However, it results in a strong documentation of the process, which ensures high quality. In DGNB there are also requirements for soil balance. The soil that was dug up on the city hall grounds was therefore transported to Taastrupgaard, where the concrete came from. This led to a close collaboration between the projects.

What differences were there in working with recycled concrete compared to new concrete?

There wasn't a big difference. When it's finished, it looks the same. The difference is just in the approvals — there are a little more audits and a little more meetings when working with recycled concrete rather than new concrete. It was the most controlled concrete I have ever used. You have to start early with all the documentation. Because it was one of the first times that such a large quantity of recycled concrete was being used, it took a little longer. Next time it will go faster.

What were the economics of recycling concrete from your standpoint?

If we had managed to get recycling written in as a requirement the tendering material, it could have given us a price advantage because then it would have been subject to competition in the bidding process. Recycled concrete is not cheaper than new concrete. It's about the same price, but when the demand increases, the price will fall. In conjunction with resource scarcity, it will become more difficult to get new materials. Then at some point it will become cheaper to recycle.

What recommendations do you have for those considering circular building?

The sooner you can get recycling into the tendering material, the better. The collaboration was fantastic. Everyone wanted it and wanted it to succeed. Good cooperation and partnerships are important**.**

Appendix B: Business cases – Høje-Taastrup

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 compagnies have succeeded with a full value / block chain

implementation of upcycled 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.

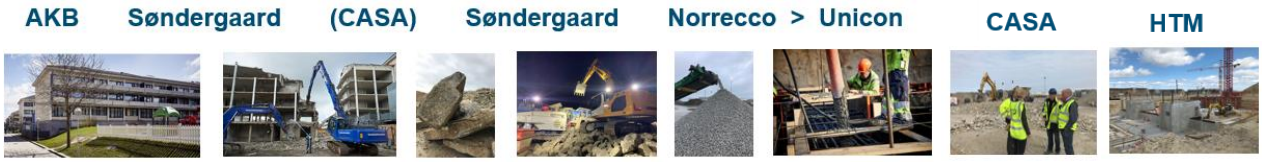
Some Danish contractors and concrete suppliers are also capable to handle crushed concrete and/or elements as reused material in new constructions including screening, sampling, testing, (perhaps) temporary storing and mixing into approved recipes. Furthermore, there are several companies who are capable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

Handling of both excavated soil and CDW are generally liberalized 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 liberalization 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 developed itself within consideration of access to resources and the prize development on both primary and secondary materials. However, there will be some obstructions regarding another aspects of sustainability as several analysis concludes that the number of demolished buildings should be decreased and that can affect the access to secondary resources.

Business case #1 - New City Hall (reuse of crushed concrete)

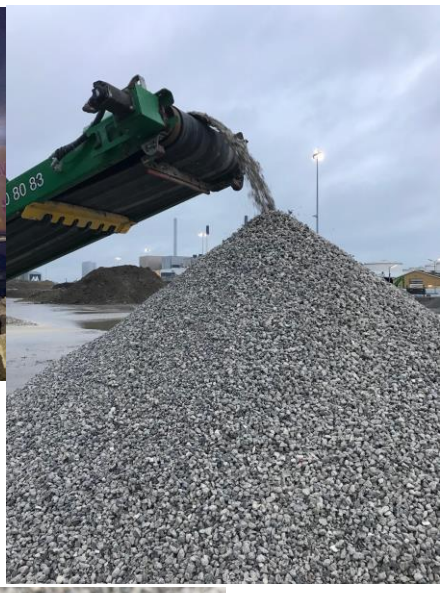
The business case #1 in a brief



The value chain – involved actors.

- 1.100 tons demolished concrete has been 100 pct. reused as aggregate in the foundation of the new City Hall. The rest of the building was made of prefabricated, new concrete from a long distant producer.
- In the calculation, the environmental consultant (Wissenberg) estimated approx. 15 € excl. tax per ton including disposal and transport (approx. 25 km) as the actual savings.
- The demolition company (Søndergaard) has sold (handed over) the demolished concrete to the CDW deposit and handling company (Norrecco) for the price of 0 €.

- The handling and production cost of recycled aggregate has roughly been around (net) 25 € excl. tax per ton, and the final (exit) price (from Unicon) is estimated to 200 € excl. tax per ton. The market price for new concrete to foundation including production, test and transport is estimated to 200-250 € per ton.
- As the aggregate in the foundation concrete has been 100 pct. recycled aggregate, it is possible to compare between the used concrete with recycled aggregate with new concrete with virgin aggregates. The concrete supplier (Unicon) states that the exit/market price of recycled aggregate has been a bit higher than the new aggregate, but not higher than the difference could be absorbed in the overhead.
- The contractor (CASA) who bought the concrete with recycled aggregates states that the added cost compared to new concrete primarily is caused by more testing and consultancy (by Pelcon). This cost has partly paid by the CityLoops project.
- The client and future owner of the City Hall has paid same price as if it has been used 100 pct. new concrete.



These pictures represent different actions and situations during the demolishing, crushing, separation and recycling process transforming demolished concrete into aggregate in new concrete for the foundation of the new townhall.

Business case #2 - Taastrupgaard (reuse of excavated soil)

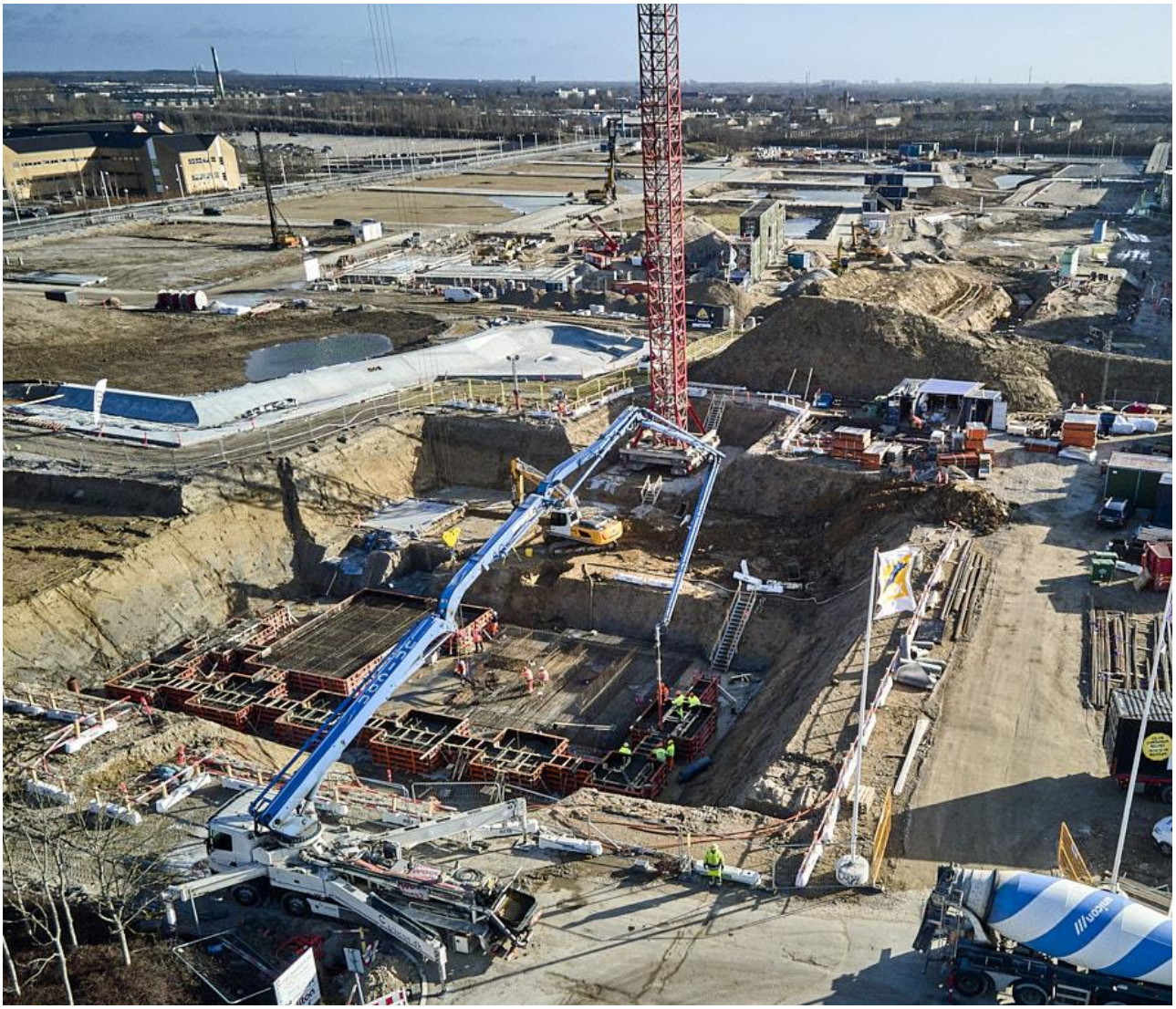
The business #2 in a brief

There has been moved 9.000 ton of uncontaminated soil from the excavation of the cellar and foundation at the new City Hall to the landscape around the children's and cultural house in Taastrupgaard.

The soil had to be intermediated landfilled (close to the City Hall site for two weeks before Taastrupgaard was ready for receiving the soil on site.

The distance between the two sites / locations is approx. 3 km. The estimated alternative was depositing the soil at land recipients around 25 km away from the City Hall site (based on average distance deposits).

In the same way excavated soil to the Tastrupgaard site was expected coming from as least 25 km away if the new City Hall has not been built.



The construction site at the new City Hall I Høje-Taastrup from where excavated soil was transported 3 km away and reused under a football field (see next page)

The excavated soil from the construction of the new City Hall I Høje-Taastrup is reused under this football field 3 km away.

Lessons learned and replication opportunities

The two cases descripted above are directly connected and has given the municipality as client to opportunity to optimize them both, even if it has not been the same carrying out companies who were involved.

The evaluation of the project as a whole and the business cases in particular shows,

- that stakeholder engagement and willingness to collaborate among the involved stakeholders is a necessary precondition in an immature circular market where everybody must make their own considerations on a low level of experiences – one part in the value chain can block the process as it was happening in an early phase of the demonstration project, where recycling of crushed concrete into new sidewalk tiles were given up,
- that “time is money” and time line matching with material deliverance is often essential - in this particular cases it was not possible to store and handle the concrete on site and avoiding preliminary storing of the soil, but the costs related to temporary moving machinery away from the area for a while and transportation of the material over only short

distances was affordable, and the client got the demolished concrete or excavated soil for free,

- that establishing clean fractions in one transaction are essential – every transaction or separation in-creases the costs and effects the final price, and finally,
- that potential risks must be identified up front to connect risk and responsibilities between the involved stakeholders unambiguous – insecurity about the responsibility increases the prices to cover potential losses.

Based on the preconditions and experiences above the two cases are immediately replicable. Unfortunately, it has not been possible to explore the commercial part of the two business cases in Høje-Taastrup because of some reluctance to share financial data for competitive reasons.

Therefore, the conclusion of the financial success in both cases is primarily related to the fact that the costs of recycling and re-use of concrete and soil in these cases has not been higher – compared to the market price of new concrete and virgin materials for the same purposes – but gives a market advantage in terms of being able to offer a more sustainable product.

The business case #1 in facts and details

Revenues	**€ per ton**
Entry price (AKB > Søndergaard)*	0
Handling and transport to handling to Norrecco (crushing on-site was not an option)	15
Handling, testing, production and storing of recycled aggregate at Norreco (agreed price)	25
Production, testing and deliverance of concrete with partly recycled concrete from Unicon	200
Market price - New concrete for foundation with virgin aggregates	250

**) Demolition costs are not included in the calculation as it was meant to be done anyway.*

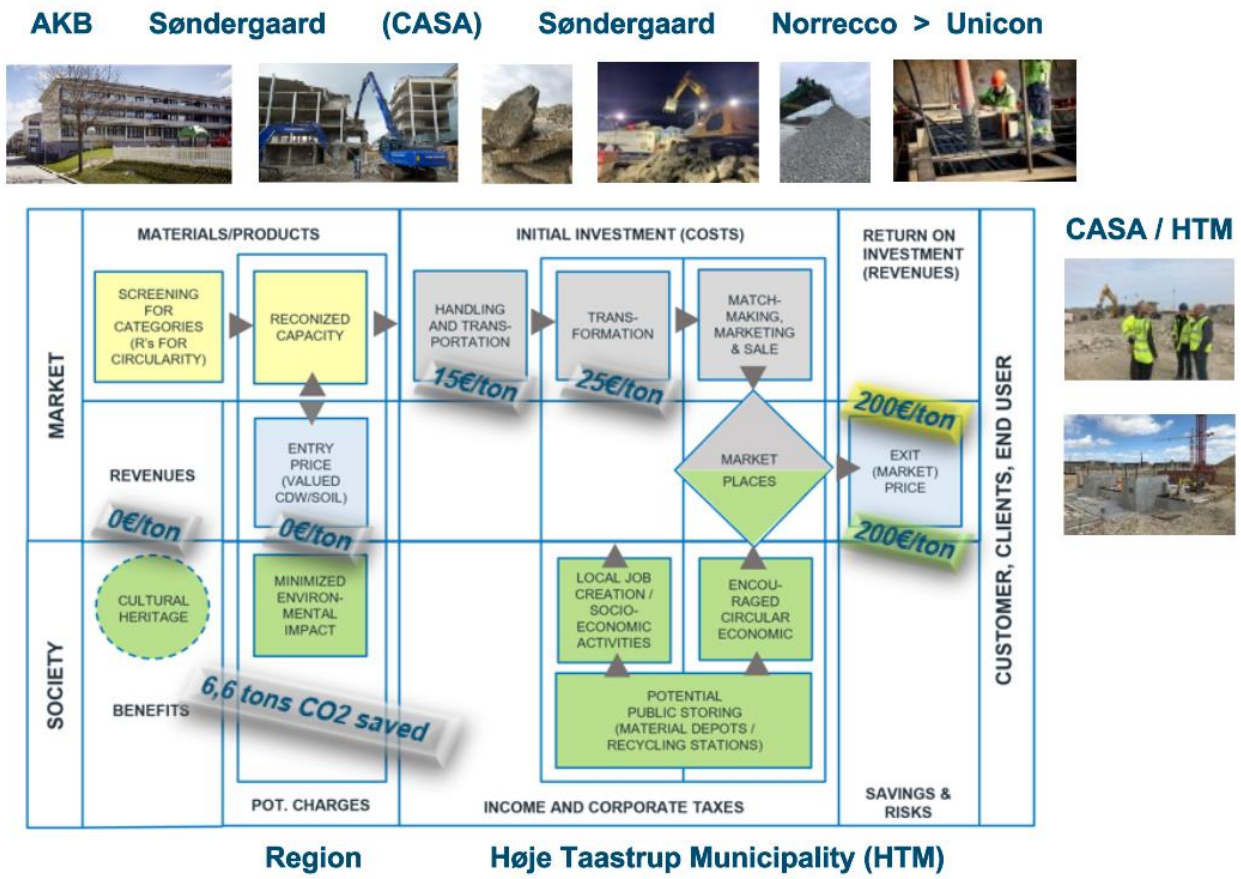


Fig. 1: Model used for overviewing and evaluation of the business case[3].

Benefits

- Less use of virgin raw material as aggregate / recycling locally in the municipality / region
- Utilization of recycled concrete in higher value than road fill
- 6,6 tons of carbon has been saved by less transport
- Material storage has been limited to two months (Norreco)
- Demonstration effect and experiences has been achieved (Mayor of Architecture 2022)
- Increased attention on circular economy – locally and broader during conferences, Market readiness, inspiration etc.

The business case #2 in facts and details

- 9,000 ton of uncontaminated soil from the excavation of the cellar and foundation at the new City Hall have been moved to the landscape around the children's and cultural house in Taastrupgård.

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

- The soil had to be intermediated landfilled (close to the City Hall site in two weeks before Taastrupgård was ready for receiving the soil on site.
- The distance between the two sites / locations is approx. 3 km. The estimated alternative was depositing the soil at land recipients around 25 km away from the City Hall site (based on actual open deposits).
- In the same way excavated soil to the Taastrupgård site was expected coming from as least 25 km away if the new City Hall has not been built.
- So, 9,000 ton of soil has been transported 3 km instead of (2x25) = 50 km. In addition, there has been a number of dumper truck hours at the intermediate landfill.

The amount of CO2 emission is calculated as:

Comments		
Cells marked in light blue, should be filled. All distances are calculated from site where soil is excavated.	Distance to end deposite, km	50
	Distance to local reuse, km	3
	Amount of soil, tons	9000
	Reuse percentage	100
	Use of wheel loader, hours	15
	Use of heavy dumper, hours	15
CO2-emissions soil transport per tonne kilometre	Soil transport, kg CO2/tonkm	0,081
CO2-emissions crushing per tonne material, diesel	Wheel loader, kg CO2/hour	25,68
CO2-emissions screening per tonne material, diesel	Dumper, kg CO2/hour	37,54
CO2-emissions full trailer combination, two way transport	Transport of loader and dumper kg CO2	135,13

CO_2 saving potential		
Soil transport	**Project CO2 spend**	**Reference**
Transport to end deposite, kg CO2	0	36.586
Transport to site for reuse, kg CO2	2.195	
Use of wheel loader	385	
Use of heavy dumper	563	
Transport of loader and dumper	135	
Sum	3.279	36.586

Kg CO_2 saving potential total	33.308

The price for transport and disposal of excavated soil is estimated to be between 15-25 € per ton excl. taxes (the exact price in this specific case is unknown), the price per hour for a wheel loader / a dumper is estimated at 500 € incl. driver, and for the moment a tax price of 100 € per ton CO2 is negotiated in the industry.

The calculation can be presented as:

Conventional handling

Entry price: 0€

Transport and disposal of the soil in deposit in 25 km distance (20 x 9,000) = 180,000 €

CO2 tax (100 x 36,6) =3,600 €

Total: 183,300 €

Recycling of the soil

Entry price: 0 €

Intermediate landfill and transport of the soil in 3 km distance (3 x 9,000) = 27,000 €

Wheel loader and dumper (30 hours x 500) = 15,000 €

Saved CO2 tax (100 x 3,3) = -330 €

Total: 41,670 €

Difference in favour of the client conventional vs circular handling: 138,630 €

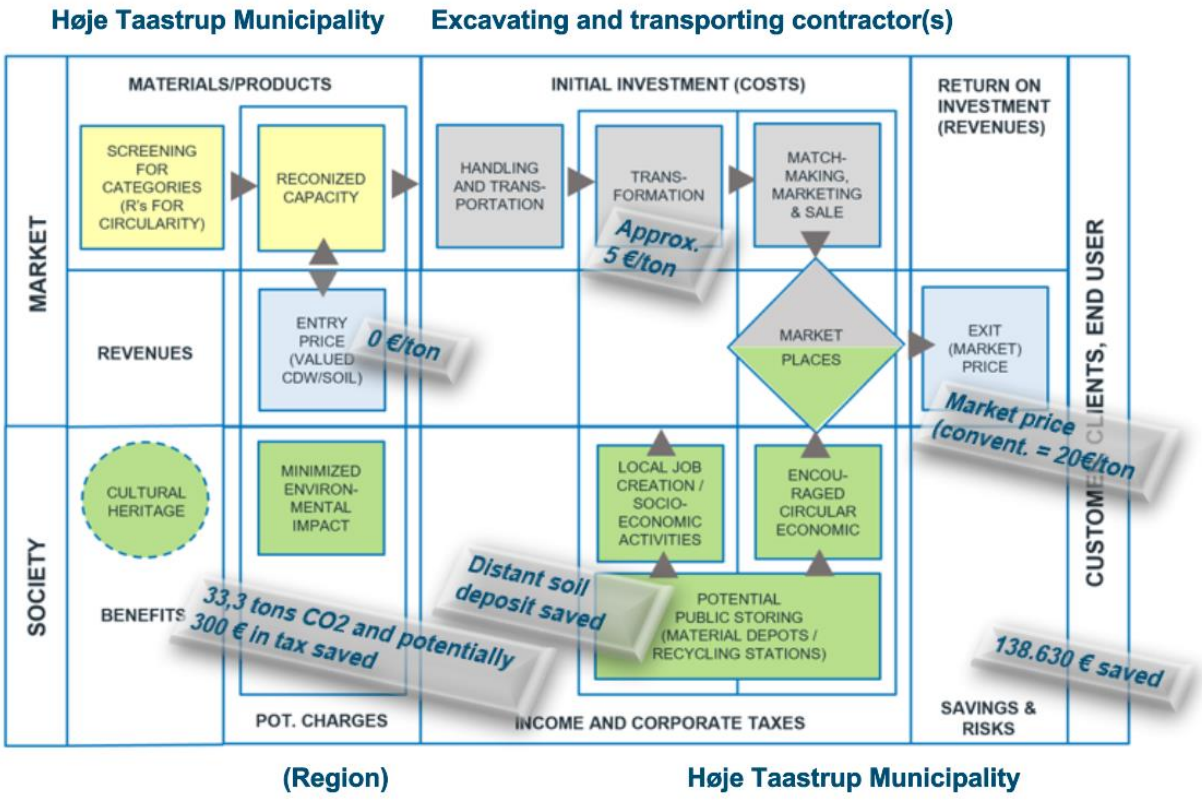


Fig. 2: Model used for overviewing and evaluation of the business case[4].

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

CITYLOOPS

CityLoops is an EU-funded project focusing on construction and demolition waste (CDW), including soil, and bio-waste, 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 bio-waste, 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.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 821033.