Iceland Liechtenstein Norway grants

(De)construct for Circular Economy

(Des)construir para a Economia Circular

WP 1 – Baseline situation analysis and follow-up

Activity 1.2 – Data collection about best practices and constraints

Final report

Operador do Programa:

REPÚBLICA PORTUGUESA
AMBIENTE E AÇÃO CLIMÁTICA

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1. Introduction

The main objective of the project **(De)construct for Circular Economy [in Portuguese: (Des)construir para a Economia Circular]** is to promote a regional strategy for the reuse of building products and components as well as the recycling of construction and demolition waste (CDW), thus reducing the environmental impact of the construction sector and promoting its circularity.

The development of a regional strategy for the promotion and reuse of construction and demolition waste is based on knowledge of the territory, the type and size of population centers and the characterization of the waste produced.

The objective of this WP is to characterize the current state of the construction sector in terms of the management of the CDW, identifying good practices, constraints and characterizing the dynamics of the construction sector. This work will serve to support subsequent WP's that aim to develop a global strategy for the management of CDW in the region.

In this WP it is intended to answer the following item:

- Data collection about best practices and constraints.

2. Data Collection work criteria

2.1. Main considerations

This chapter presents the data collections about best practices on the recovery and reuse of CDW's. The examples presented were identified by the different project partners.

2.2. Data collection

In order to collect the information necessary for the development of the project's work, we designed a survey, Annex I, entitled “Data collection protocol about best practices for the reuse of construction and demolition waste”, aims to identify good practices that already exist on the ground and to identify constraints on the use of CDWs. This survey is aimed at different actors in the construction sector (AEC), public or private, whose presence on the ground is relevant to the study being developed. In general, it is intended to obtain an answer to the following questions:

- Best practices and constraints about construction materials reuse;

- Best practices and constraints about construction CDW recovery.

For the preparation of these surveys, work meetings were held by video conference. The surveys were posted online so that stakeholders could respond without any kind of constraint.

It also needs to be emphasized that a lot of new investments have been initiated or are procured (FredrikSelmers vei 5, Sofienberg skole), as the circular economy in construction industry is high on a Norwegian agenda, but at the moment insufficient information is available to present project experiences.

The criteria, set by IDN (Norway) to select the best practices cases were:

- The project includes in construction materials reuse and/or recovery;

- The project has been realized in Scandinavia with at least 50 % of the cases coming from Norway;

- The project is completed or ongoing (at least one year);

- The project has a completed LCA analysis available or is run in accordance with the future built[1] methodology for circular buildings.

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[1] *FutureBuilt is a Norwegian program started in 2010. The program is governed by a broad partnership consisting of Oslo, Bærum, Asker and Drammen municipalities, the Housing Bank, Enova, the Ministry of the Environment, Directorate for Building Quality, Transnova, Green Building Alliance and the National Association of Norwegian Architects. The program developed the criteria for model projects, which will significantly contribute to reducucing greenhouse gas emissions for the buildings in a life cycle perspective, both in the construction phase and in operation. www.futurbuilt.no.*

3. Survey results and analysis

3.1. Main considerations

Five of the participating countries responded to surveys about good practice:

- Romania – tree answers;

- Finland – one answer;

- Czech Republic – fourteen answers;

- Norway – five answers;

- Denmark – one answer.

Based on the information collected, it was decided to divide the good practices into three typologies:

- Waste recovery / collection systems;

- Reuse (saving natural resources);

- Materials made with waste.

3.2. Waste recovery / collection systems

3.2.1. Management system for CDW in Medias City, county of Sibiu

Promoter: Sibiu Environmental Protection Agency - a Norvegian financed project.
Localization: Medias, Sibiu County, Romania.

Intervention area: The efficient management of CDW through sorting, reuse and recycling and reduction of CDW landfill. New facilities for CDW receiving and processing, including the necessary equipment (crusher, sorter, excavator with pickaxe and scissors/sprayer, containers).

Classification of the CDW: Concrete, bricks, tiles and ceramic materials.
Volume of CDW: 4295 ton, representing the highest CDW processed quantity in 2013.
Preparation processes for the CDW: Sorting and crushing.

Project goal
To reduce the CDW landfill.
To implement a pilot project to demonstrate CDW reuse and recycling.
To reduce the environmental impact of CDW in the project area.

Project description
Between 2009 - 2011, the Sibiu Environmental Protection Agency, in partnership with the Norwegian Association of local and regional development, implemented the project "Partnership for a waste reduction and sustainable development in Region 7 Centre". Mediaş Municipality, as partner of the project, received financial support for the implementation of a pilot project, having as main objective the efficient management of construction and demolition waste. Thus, the Municipality of Mediaş was the first city in Sibiu County to have the necessary infrastructure to collect and process the construction and demolition waste.
A guideline of best practices in the management of C&DW has released in 2011 as part an integrated waste management project in Center Region (NUTS 2) between regional and local Norwegian and Romanian authorities. Throughout this project, Mediaş city has implemented a recycling and recovery center dedicated to C&DW fraction. Individuals or economic agents may require a special container for C&DW fraction. The waste operator transports the container to the recycling and recovery facility or the C&DW generated are brought by each generator. The C&DW are sorted via a mechanical process resulting in new materials for reuse in the construction sector. In 2016, this facility collected and processed 4278.5 t of C&DW and it received 394 orders for waste collection services.

Other materials used
Excavated material (soil, sand, gravel, clay, rocks).
CDW from road construction (bitumen, tar, paving, sand, gravel, crushed rocks).
Materials from the construction or demolition of buildings (ground, cement, tiles, bricks, concrete, plaster, wood, metals, glass).
Materials from construction sites (wood, plastic, paper, cardboard, metals, cables, lacquering and painting solutions).

Support equipment
Mobile installation for CDW crushing and sorting.

Used methodologies

The C&DW are screened at the weighing system in order to record the waste fractions, which are accepted for crushing plant:

- The owner requires the construction/deconstruction permit;
- The owner requires a waste collection permit from the sanitation company;
- Before starting the construction/demolition works, the owner provides a financial deposit to guarantee the good management of CDW;
- The owner is required to submit a CDW management plan to the responsible department of the municipality and to sort the waste properly during the works;
- The sanitation company provides containers, collect and transport the CDW to the recycling center;
- The administrator of the center is responsible for receiving, crushing, sorting and recovery of CDW as raw material for construction;
- The municipality verifies the compliance with the procedures for management and recycling waste and refunds the guarantee deposit based on evidence of CDW plan fulfilment.

Benefits

The CDW is managed properly and is not illegally abandoned
The significant CDW landfill reduction
Meeting of the CDW legal targets for recycling
The recycled material is used in construction works
The reduction of environmental impact

Difficulties

Difficulties in the application of the procedure, the owners are not always willing to assume the cost of CDW management and provide the deposit.
Some types of CDW (ceramics, insulation materials, bricks) difficult to reuse or recycle.
A clear business case out of CDW recovery could not be demonstrated, the availability of a clear market for the final end-application is necessary to be identified.

Opportunities

Civic amenity sites represent a great potential in terms of collected quantities, but generally collect products of lesser quality, compared to other, more secured collection points. To overcome this shortcoming, it is recommended to:

- Train the staff to better identify re-usable products and direct them to the re-use section of the CAS;
- Better inform the users of the possibility of re-use;
- The handling and storing should be done with care: items should be stored in closed areas protected from rain and scavenging.

The described project was a pilot demonstration of the good CDW management; nevertheless, in order to prove its efficiency the site should be extended and developed and the investments in technology shall continue. Moreover, the activities and products of the center shall be connected with the market needs.

3.2.2. LIFE10 ENV/RO/727 Recovery of construction and demolition waste from Buzău County – pilot project for CDW reuse and recycling [1]

Promoter: Buzău County Council and SC Natura Management SRL.
Localization: Buzău County, Romania.

Figure 1 - CDW SC Domenii Prest Serv Srl Buzău CDW recovery site.

Intervention area: CDW waste recycling pilot station, a public – private partnership established under the Life project LIFE10 ENV/RO/000727 "Recovery of construction and demolition waste in Buzău county/VAL-C & D", It provides a critical pilot research area related to C&DW management activities at Buzău County level. There is a pilot station for mechanical treatment (crushing) and, where appropriate, gravimetric sorting of C&DW which has a maximum treatment capacity of 40,000 t/year, respectively 20 t/hour. [2]

Classification of the CDW: Concrete, bricks, tiles and ceramic materials.

Volume of CDW: Disposal of 1977 tones CDW waste illegally deposited on the territory of Buzău county.

Preparation processes for the CDW: Baseline analysis, comparative LCA of CDW, land identification; Carrying out the SF and obtaining the necessary approvals and agreements for the SF phase (including the SF agreement); Contracting the technical project realization service (PT); Carrying out the PT and obtaining the necessary approvals and agreements for the PT phase; Supply of backhoe and angle grinder; Carrying out the public procurement procedure of the pilot station part II (landscaping, installation, commissioning and personal training); Contracting the site management; Running the pilot plant for CDW recovery.

Project goal
The project aims to develop an efficient construction and demolition waste management system in Buzău County, which can be extended and implemented at national level.; creating a coherent decision system by clarifying the responsibilities of all factors involved in the CDW waste management system at county level; establishing a procedure for end of life waste status for materials resulting from the treatment of CDW waste; promoting the recovery of suitable CDW waste; fulfilling the legal objectives regarding the recovery of CDW waste at the level of Buzău county, including by recovering the illegally deposited CDW waste.

Project description
The project is a public-private partnership that aims to promote sound management of C&DW fraction. In order to encourage the recycling and recovery operations, this facility charges a fee (50 RON, 1 EUR = 4.7 RON) for the use of weighing system not per ton of C&DW disposed of.
In 2015, this facility processed 1200 t of C&DW and all resulted building materials were sold while in 2016, 1500 t C&DW were processed of which 280 were sold - photo gallery in [2].
The central element of the project is the construction of a pilot plant for mechanical treatment of waste from construction and demolition, respectively those in the category of concrete, bricks, tiles and ceramic materials. The installation was intended to contribute to the proper management of CDW and is also an investment that generates new jobs. The geographical area of application of the project covered the administrative area of Buzau County, Romania, however, the problems identified and the ways to solve them, proposed by the project, are applicable in several areas of the EU.

Other materials used
The interactive web application associated with the pilot installation, which is the first exchange platform of construction and demolition waste and materials resulting from their treatment.

Support equipment
Recovery system for construction and demolition waste in Buzău County (mechanical treatment plant for inert CDW waste - Pilot Project), including illegally stored waste in this category.
- The wastes are disposed into a temporary storage area;
- The recyclables are sorted (wood, paper, and cardboard, metals, glass, plastics, tiles, etc.);
- Cutting beams and other large reinforced concrete elements;
- Primary crushing with the jaw crusher;
- Magnetic separation of metals;
- The pick secondary crushing;
- Manual selection of wood, plastic, paper, and cables;
- Sieving by particle size fractions;
- Granulometric classification (0/10 mm, 10/30 mm, >30 mm);
- Removal of the tiny particles by filtration, washing;

Used methodologies
Methodology regarding the "End of Life" waste status for materials resulting from the treatment of inert construction and demolition waste - class 17 01.

Benefits
CDW waste treatment, through the financing provided by the project, the waste coming from the illegal landfills, so that they will be eliminated from the administrative territory of Buzău county.

Difficulties

Currently, in Romania, there are not enough facilities for treatment, recovery or recycling of CDW waste. There are only a few economic operators or public authorities (County Councils and City Halls) that recover / recycle these types of waste and operate crushers (mobile or fixed), transforming concrete and bricks into materials that can be used later.

Opportunities

Comparative analysis of the benefits and losses (for the environment and the community) caused by the exploitation of mineral aggregates, on the one.

3.2.3. C&DW Management Activities in Neamt County—A Regional Case Study

Promoter: Public Authority.
Localization: Piatra Neamt, Romania.

Intervention area: Fixed crushing plant.

Classification of the CDW: Concrete, bricks, tiles and ceramic materials.
Volume of CDW: Capacity of 15,000 t/year**.** The average of C&DW processed is 1300 t/year under 10% of plant capacity (8.6%)
Preparation processes for the CDW: Collection, weighing, crushing, using as layer and filling material on the waste landfill.

Project goal
Provide solutions for the CDW in the region.

Project description
This facility is located in the proximity of the composting plant and sanitary landfill avoiding supplemental transportation costs. Crushed waste, resulting from the plant, has been primarily used as the coating material (drainage layer) of the old landfill (during the rehabilitation process) then as a covering material for the first cell of the sanitary landfill (closed in 2010).
In 2015, about 3670 t of coating material was used for cell No. 2 within the sanitary landfill area. This fact suggests that this crushing plant could expand the geographical coverage area across the Neamt County. Piatra Neamt city has two separate collection centers located in Maratei and Darmanesti districts where C&DW fraction is collected in special containers (included bulky items).

Other materials used
Concrete, asphalt.

Support equipment
Crushing machines.

Benefits
Savings of primary materials (rock, gravel), Cheaper solution.

Difficulties
The final material is not properly valorized.

Opportunities
After the hall lifetime, the material can be recycled and used again.

3.3. Reuse (saving natural resources)

3.3.1. Construction and demolition waste recycling for processing concrete, asphalt and other types of demolition debris

Promoter: Mesto Outotec.
Localization: Helsinki, Finland.

Classification of the CDW: Soil (including soil excavated from contaminated sites), rocks and dredging mud.
Volume of CDW: Approximately 20,000 metric tons of concrete from demolished buildings had been piled up in an industrial area. 3,000 metric tons in a 12-hour shift. Annual recycling volume is approximately 50,000 tons and quarrying 100,000 tons.

Preparation processes for the CDW: All the necessary equipment is prepared and moved to the CDW sites where the process of recycling is going to take place. In an optimal case this waste is processed near the demolition site, making the discarded matter a continuous stream of raw materials for new roads, buildings, bridges and urban landscape.

Project goal
Reducing the waste that is resulted from CDW.
Recovering as much materials as possible, Transform the CDW in new products, CDW becomes construction materials or energy production.

Project description
Waste is processed near the demolition site, making the discarded matter a continuous stream of raw materials for new roads, buildings, bridges and urban landscape. Recovering as much materials as possible also is a benefit. Oftentimes, heavy and bulky waste is expensive to dump in landfills or store in stockpiles. The larger the proportion of materials reused, the greater are the savings in waste management costs.

Other materials used
Another good application for recycled material is the use of crushed concrete as riprap dust and erosion control.

Support equipment
Metso Outotec equipment offering for construction and demolition waste recycling consists of crushers, shredders, screens and conveyors.

Used methodologies
From waste to energy. Waste reduction.

Benefits
Profitability (make use of material that would otherwise be waste).
Easy to move (mobile and portable equipment plus simple to move around or relocate whenever needed).

Difficulties

Old asphalt is often a difficult material to be recycled due to its two main ingredients, bitumen and aggregates.

The recycle of CDW can be costly most of the times.

Opportunities

Less transportation needs and dumping costs.

High dependability (robust and field-proven technologies).

Environment and safety (less raw materials required).

3.3.2. Reconstruction of Stramberska Street

Promoter: City of Koprivnice (Kopřivnice).
Localization: City of Koprivnice, Czech Republic.

Figure 2 – Reuse of construction products (Source: David Macháček).

Intervention area: Reuse of construction products.

Classification of the CDW: Concrete, bricks, tiles and ceramic materials.

Volume of CDW: Not provided.

Preparation processes for the CDW: Cleaning, sorting.

Project goal
Reduction of a road surface noise.

Project description
The City of Koprivnice decided to replace original cobblestones (granite cubes) with asphalt surface in order to reduce noise from traffic. Most of the cubes were used back in the construction in a form of surface for adjacent spaces, parking places and bus stops (bus bays). Further they were used in other construction activities of the city while the small remaining part was sold.

Other materials used
Granite cubes.

Support equipment
Cleaning equipment.

Benefits
Savings of primary materials, Waste disposal fully avoided, Lower costs.

3.3.3. Construction of an industrial hall

Promoter: AZS 98 (construction company).
Localization: Czech Republic.

Figure 3 - Underlying layer of a construction (Source: Katalog soutěže Přeměna odpadů na zdroje, 2018).

Intervention area: Underlying layer of a construction.

Classification of the CDW: Concrete, bricks, tiles and ceramic materials.

Volume of CDW: Not provided.

Preparation processes for the CDW: Crushing.

Project goal
Improvement of the load-bearing capacity of the underlying layer for the construction of the hall.

Project description
When building an industrial hall, the construction company AZS 98 used 100% recycled crushed concrete – as substitute for natural rock/gravel – to improve the load-bearing capacity of the underlying layer (made of clay).
Achieved load-bearing capacity of the new construction layer was 90 MPa, which is proof that recycled aggregate can fully replace natural aggregate and can be used even in demanding conditions.
Similarly, the company implemented a project where natural rock/gravel was substituted by recycled crushed asphalt.

Other materials used
Concrete, asphalt.

Support equipment
Crushing machines.

Benefits
Savings of primary materials (rock, gravel), Cheaper solution.

Difficulties
High quality separation is necessary.

Opportunities
After the hall lifetime, the material can be recycled and used again.

3.3.4. Building of facilities for sport activities

Promoter: Municipality of Karlovice.
Localization: Municipality of Karlovice, Czech Republic.

Figure 4 - Use of demolition materials (Katalog soutěže Přeměna odpadů na zdroje, 2018).

Intervention area: Use of demolition materials.

Classification of the CDW: Concrete, bricks, tiles and ceramic materials.

Volume of CDW: Not provided.

Preparation processes for the CDW: Crushing.

Project goal
Use of demolition materials for building of facilities for sport activities.

Project description
The recycled material was obtained from construction debris (CDW mixture) from a demolished building, which had been damaged by floods. It was used to build sport facilities for various groups of citizens (e.g. MTB park) as well as for construction (reinforcement) of a trail along the river, connecting two parts of the village.

Other materials used
Mixture of CDW from demolition.

Support equipment
Demolition machines, crushing machines.

Benefits
Savings of primary materials, Minimization of disposed waste.

Opportunities

Social dimension – the facilities are used for leisure activities of the citizens, tourists and other visitors of the village.

3.3.5. Panattoni Park Ostrov North

Promoter: Panattoni Europe.
Localization: City of Ostrov, Czech Republic.

Figure 5 - Revitalization of a brownfield [3].

Intervention area: Revitalization of a brownfield.

Classification of the CDW: Concrete, bricks, tiles and ceramic materials.
Volume of CDW: 103 000 tons of recycled CDW.
Preparation processes for the CDW: Demolition, sorting, crushing.

Project goal
Revitalization of a brownfield.

Project description
During the revitalization of the brownfield at the site of the closed manufacturing factory, 98.7% of utilisable demolition waste was recycled directly on the site. It consisted of concrete, brick and asphalt debrises, while 96.7% of this recycled material was reused directly on site as part of new construction, mainly in the underlying layers of the building. A record of a total utilization of 103 thousand tons of secondary raw materials was achieved.

Other materials used
Concrete, bricks, asphalt.

Support equipment
Demolition machines, sorting machines, crushing machines.

Benefits
Savings of primary materials, Recycling of a vast majority of demolition waste.

Difficulties
Huge amount of demolition waste had to be treated on-site.

Opportunities

Reduction of traffic. Use of recycled demolition waste prevented a journey of 10 300 lorries that would have to transport primary materials.

3.3.6. Building of facilities for sport activities

Promoter: City of Zabreh (Zábřeh).
Localization: City of Zabreh, Czech Republic.

Figure 6 - Building of facilities for sport activities [4].

Intervention area: Reuse of CDW.

Classification of the CDW: Concrete, bricks, tiles and ceramic materials.
Volume of CDW: Not provided.
Preparation processes for the CDW: Sorting, crushing.

Project goal
Use of CDW for building of facilities for sport activities.

Project description
The City of Zabreh (through its fully owned municipal company) operates a large drop-off centre equipped with sorting and crushing equipment as well as a composting plant. The CDW recycled in the drop-off centre is used in construction activities of the city. It always needs to be prepared to fit specific characteristics (e.g. composition, size, etc.) required for particular construction. An example of a construction activity, in which only recycled materials were used, is a construction of a new BMX park built at the area of former illegal dumpsite.

Other materials used
Mixture of CDW, soil.

Support equipment
Sorting machines, crushing machines.

Benefits
Savings of primary materials, Low-cost solution.

Difficulties
Preparation of the site (illegal dumpsite).

Opportunities

The BMX Park was built at the area of former illegal dumpsite, which had previously been cleaned by a group of volunteers who had initiated the idea of the BMX park. It's a great example of a brownfield rehabilitation and citizens engagement at the same time.

3.3.7. Revitalization of the village square, local roads and preparation of a zone for family houses

Promoter: Municipality of Neumer (Neuměř).
Localization: Municipality of Neumer, Czech Republic.

Figure 7 - Neuměř village - revitalization of the village square, local roads and preparation of a zone for family houses [5].

Intervention area: Use of demolition waste.

Classification of the CDW: Concrete, bricks, tiles and ceramic materials.
Volume of CDW: Not provided.
Preparation processes for the CDW: Demolition, separation of materials, crushing.

Project goal
Maximize the use of demolition waste from old farm building.

Project description
In the centre of the village, there was a dilapidated building of a former farm with severely disturbed statics. The municipality decided to demolish it and temporarily deposit all construction debris. They were later recycled and used in the project of revitalization of the village square and local roads and preparation of a zone for new family houses.

Other materials used
CDW mixture (concrete, bricks, plaster), wood.

Support equipment
Demolition machines, sorting machines, crushing machines.

Benefits

Savings of primary materials, Minimization of waste disposal.

Difficulties

Time consuming and demanding process of waste separation, Necessity to have enough space for CDW temporary deposit.

3.3.8. Construction of a new depository

Promoter: Eastern Bohemia Museum in Pardubice.
Localization: City of Pardubice, Czech Republic.

Figure 8 - Depository, Eastern Bohemia Museum in Pardubice.

Intervention area: Low-energy building.

Classification of the CDW: Concrete, bricks, tiles, tiles and ceramic materials.
Volume of CDW: 1 000 tons.
Preparation processes for the CDW: Sorting, crushing.

Project goal
Construction of a building respecting sustainability principles.

Project description
When constructing a new depository, the Eastern Bohemia Museum in Pardubice decided to construct a "sustainable building" with low energy consumption and use of sustainable materials. Recycled concrete from another demolished building (former canteen of a school) was used as an underlying layer. It was poured in 800 mm thickness under the whole building in order to increase the load-bearing capacity of the foundation slab. In total, 1 000 tons of recycled material was used.

Other materials used
Concrete, unfired bricks, clay plastering.

Support equipment
Sorting and crushing machines.

Benefits
Savings of primary materials, financial savings.

Opportunities

The whole building was constructed as a low-energy building with the maximal use of sustainable materials. Besides recycled concrete, they were for example unfired bricks and clay plastering.

3.3.9. Construction of highway D4

Promoter: SKANSKA.
Localization: Czech Republic.

Figure 9 - Underlying layer of D4 [6].

Intervention area: Underlying layer of a road.

Classification of the CDW: Soil (including soil excavated from contaminated sites), rocks and dredging mud.
Volume of CDW: 490 000 tons.
Preparation processes for the CDW: Sorting, crushing.

Project goal
Finding a source of rocks close to the construction site.

Project description
When constructing a new part (5km) of the highway D4, SKANSKA was looking for a suitable source of aggregate to be used as an underlying layer under the road, which would be situated close to the construction site. Finally, the material (rocks) from nearby old mining heaps was used, which showed to have great mechanical characteristics. In total, 490 thousand tons of waste material were used.

Other materials used
Rocks.

Support equipment
Mobile sorting and crushing equipment.

Benefits
Obtaining aggregates with excellent mechanical properties, Minimization of costs.

Opportunities
Contribution to the removal of old environmental burdens after mining.

3.3.10. Milicovsky haj (Milicov Grove)

Promoter: SKANSKA.
Localization: Prague, Czech Republic.

Figure 10 - Reuse of concrete waste.

Intervention area: Reuse of concrete waste.

Classification of the CDW: Concrete, bricks, tiles, tiles and ceramic materials.
Volume of CDW: 67 tons of concrete, 12 tons of asphalt.
Preparation processes for the CDW: Crushing.

Project goal
Reuse of materials (waste) from demolition in a new construction.

Project description
During the implementation of a development project on construction of a new quarter of residential houses, SKANSKA crushed and reused 67 tons of concrete waste from the original demolished buildings and 12 tons of asphalt from local roads. The material was reused as a basis for the foundations of newly built roads and apartment buildings. Moreover, the excavated soil from the land was used in landscaping as backfill material, which significantly reduced the amount of waste disposed of in a landfill.

Other materials used
Concrete, asphalt, excavated soil.

Support equipment
Crushing machines.

Benefits
Reduction of primary materials used, Reduction of the amount of landfilled waste.

3.3.11. Powerhouse Kjørbo – rehabilitation of 30-years old office building.

Promoter: Developer: Entra Eiendom AS; General contractor: Skanska Norge AS; Architect: Snøhetta AS; Project management: Aase Byggadministrasjon AS; Consulting engineers: Skanksa Norway (energy, building physics, environment, daylight), Asplan Viak (acoustics, plumbing, electrical, construction technology, fire), Itech (lighting); BREEAM-NOR auditor: Multiconsult; BREEAM-NOR AP: Skanska Norway; Tenant: Asplan Viak.
Localization: Sandivka, Bærum, Norway [7], [8], [9], [10], [11], [12].

Figure 11 - Powerhouse Kjørbo, street view [13].

Intervention area: Resue-Recovery-Powerhouse (buildings that have a positive energy consumption over the lifetime).

Classification of the CDW: windows, steel reinforcement.

Volume of CDW: In the project more than 90% of waste from construction phase is recycled and / or reused.
Reused were: Windows from old façade (Each of the glass plates reused had a dimension of 210 x85 x0,8 cm, the facades from both blocks have been reused with approx. 25% lost); All reinforcement steel and concrete.
Common to all the blocks was that the facade glass was reused for office fronts the cell offices. These were made of dark, tempered glass, so they could not be resized resulted in all cell offices having taller and wider doors than standard.
The concrete decks, supporting structure and stair treads were also reused in all the blocks.

Preparation processes for the CDW: Baseline analysis mapping of the building materials (CDW) in a building before rehabilitation; Co-operation with many industrial actors all the way from the start (series of workshops, ideas, theories and experiences have been exchanged between participants from a broad range of professions (with high degree of mutual learning and trust).
The process related to the glass reuse was roughly as follows:
1. Disassembly of the windows and glass - put on pallets.
2. Driven to wash - put on pallets
3. Drive to Stange - quality control (then delivered to the glass factory from Kjørbo, there was 25% los) and mounting in frames.
Reuse of tempered glass requires special planning, as tempered glass cannot be adjusted for new use, therefore the design had to be adapted.

All other materials used in the Project had to meet the highest possible environmental standards, with the lowest possible embodied energy:
- Burned wood for façade cladding;
- Labeling materials or materials with low polluting according to EN 15251;
- All product categories listed in BREEAM have been tested against and documented to meet the relevant standards Volatile Organic Compound (VOC) emissions;
- Declarations according to ISO 14025/EN -NS15804) have been procured for at least 10 different building products used to a large extent.

Figure 12 - Preparation for the installation of the partitions (left), office interior made of tempered glass (right) [9].

Project goal
The vision in this Project to develop and realize buildings that have a positive energy consumption over the lifetime, with reuse of building materials (concrete and windows as the most relevant drivers)

Project description
Project period: 2012 – 2014.
Powerhouse Kjørbo is a converted office building, from 80ties, located in Sandvika, Oslo, Norway. It consists of two blocks of a total of 5,000m^2. Enova supported the project with 15,9MNOK, which covered 50% investment in the solar roof. It must be emphasized that reuse on the construction waste was just one of (but very relevant) the measures to achieve the energy standards. Each of the two planned rehabilitated buildings is approx. 2600 square meters, on three and four floors - as well as a basement, and was built in 1980. Today, the buildings have an energy consumption of around 250kWh per square meter per year. The project has obtained following environmental standards: BREEAM Outstanding, Passivhusstandard (NS3700/3701), Plusshus.
Environmental measures in the building:
- Reuse of building materials;
- Solar panel roof delivering 200,000kWh annually, or 41kWh / m2 annually;
- Energy wells drilled in the rock can supply the buildings with free cooling in the summer, and act as an energy source for the buildings' heat pump systems in the winter;
- One of the heat pumps is also used to heat hot tap water;
- The ventilation solutions combine high-efficiency heat recovery, extremely low pressure drop and efficient, demand-controlled ventilation in a way that minimizes the need for ventilation ducts, dampers and associated automation for control;
- The need for electricity for lighting has been reduced through efficient utilization of daylight and the use of energy-efficient lighting systems, controlled as needed;

- Walls, ceilings and windows are planned with very good tightness and insulation;
- Exterior sun protection and interior solutions, such as exposure of concrete in the tires, contribute to reduced cooling needs in summer.

Other materials used: standard building process, no specific information available

Support equipment: standard building process, no specific information available

Used methodologies
- LCA for the baseline analysis
- Interactive cooperation with many stakeholders. Workshops.
- Materials mapping.

Benefits
CDW - By reusing glass plates from existing facade as office fronts, greenhouse gas emissions were reduced by over 80% per m^2 partition compared to new (0.06 kg CO_2 equivalents/kg) The cost of this solution was similar to what they had become produced based on new materials.

Difficulties
The project was demanding and implemented with the great success, but there were two dimensions of challenges:
1. Integration or cooperation between stakeholders (client, architect and other consultants, and eventually users) from early on in the design process.
2. In achieving high energy/ environmental ambitions, the implementation of integrated architectural solutions or passive qualities are prioritized before active systems.

Opportunities
The building was renovated within commercial market conditions (The rent is higher than for a similar office building with an average energy standard. However, when the reduced energy costs are included, the total cost for the tenant is at the same level as for a standard office building.)
The project was a first Norwegian commercial building with a BREEAM outstanding standard and opened the way for similar projects (two Powerhouses has been completed by now in Trondheim)

3.3.12. Kristian Augusts gate 23 Tullinløkka, Oslo. Rehabilitation and renovation of the office building (KA23) in accordance with the circular principles

Promoter: Client: Höegh Eiendom; Architect: Arcasa arkitekter AS; Original architect Bjercke & Eliassen; Project management (PL): Stig A. Nilsson; Environmental consultant: Multiconsult AS; Main contractor Seltor AS; Construction management: KPP AS;
Localization: Tullinløkka, Oslo, Norway [14], [15], [16].

Photo 1. KA23, Tullinløkka, Oslo, Street View [15].

Area of intervention: Reuse of CDW / Recovery / Transformation.

Classification of the CDW: glass, ceiling tiles, wooden wall panels, bricks, equipment.

Volume of the CDW: 50 percent of materials and building parts during rehabilitation process. As the result of environmental mapping following amounts where identified: 165m^2 ceiling tiles and 130lm wall duct given to Entra (Kristian August 13 project); 8147kg for external reuse given to Bruktrom (glass field, interior walls and kitchen); 325tons of bricks sent to Østfold grass for reuse as drainage mass
Internal reuse: Oak pillars from Indekshuse; Residual tile from Bergersen Tile. Taken over from KA 13 the project to KA 23; Glass; Wood.
Some good examples of this in KA 23 are the brick, which was too porous to be used in the project, this is now crushed and used as drainage mass for green roofs.

Preparation processes for the CDW: The process applied by Höegh Eiendom is summarized in the following way:
1. Reuse mapping: For internal purposes; For external purposes; Not possible for reuse.
2. Disassembly: Marking of the materials; Contacting networks/markets for reuse of CDW; Organization of the inspections, disassembly and transport.
3. Usability: Design for reuse; Describing for further experiences.
4. Documentation: FDV* documents for all materials; Instructions for disassembly; Other good example of KA23 is brick which was too porous to be used in the project, this is now crushed and used as drainage mass for green roofs.

Project goal

The ultimate goal for the investment was connected with the achievement of the high energy standard (BREEAM in-use be certified as «Excellent» or better) reuse of the materials has been just the incentive to achieve the energy and climate goal.

Project description

Project period: 2020 – 2022

Kristian Augusts gate 23 (KA 23) was built in 1950 and was originally the headquarters of the Norwegian Employers' Association. The office building is located on Tullinløkka in Oslo and was acquired by Höegh Eiendom in the autumn of 2019 (8736 m^2 of usage space) The building was designed by the architects Bjercke & Eliassen and the facade is protected in accordance with the Planning and Building Act. The building is built in steel and concrete, with Solvågstein as facade panels and original teak windows. Inside, the entire eighth floor as well as some corner offices are original with characteristic teak and marble walls. The building is in the final realization phase (will be fully open in 2022). Enova supported the project with 2 459 969 NOK.

Project type: Reuse / Rehabilitation / Transformation. Model program: FutureBuilt.

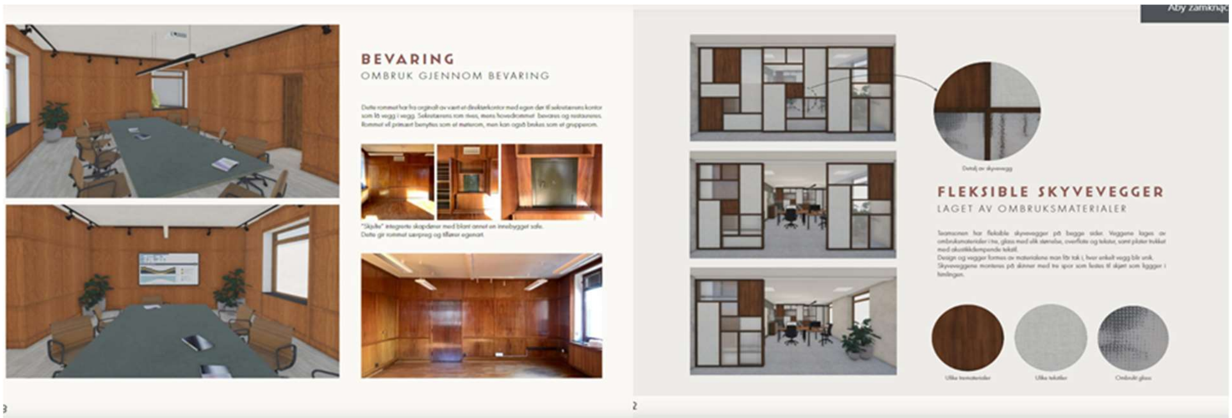

Figure 13 - Visualization of the reuse solutions (wooden panels and glass) for office interior [17].

Other materials used:

The aim in the Project was to retain foundations, load-bearing structures, exterior walls, frames, decks, load-bearing systems, stairwells, lifts, parts of interior walls and some technical equipment.

Methodologies adopted

Baseline analysis to model scenarios (re-use and upgrading of existing building components).

The LCA methodology, powered by OneClickLCA (software adapted for the building and construction industry) was also used.

Special consideration to FDV and detailed disassembly instructions for the various components that are reusable.

Interior design focused on usability and changeability for the future use. (ex. the project proposes flexible solutions with open and area-efficient plans, the radiators will be places under each window for any future adaptations).

Benefits

Two main environmental benefits can be expressed as 70% lower of CO2 emissions than a reference building and reduction with 1100 –1500ton CO_2.

In addition, there are several green solutions adapting the building for the city needs as bicycle-friendly infrastructure, car sharing scheme available and green roofs, safeguard biological diversity in central Oslo, manage surface water, recreation site for users of the building.

Difficulties

The building conservation status made difficult to further optimize energy consumption.

Opportunities

The project is one of the investments in Oslo, proving potential of reuse of building material for the energy efficiency. At the same time, it is designed with the modern design standards making the place even more attractive for the tenants.

3.3.13. Gjenbrukshuset - a pilot project in Trondheim

Promoter: Client: Trondheim Eiendom; Architect: HSØ Arkitektkontor; Contractors: Stavne Work and competence (demolition work, material processing, training), AS Trebetong, AS Vindusrestaurering.
Localization: Trondheim, Norway [18], [19].

Figure 14 - Recycyled house in Trondheim (on the right) [19].

Classification of the CDW: wood, glass, bricks, steel, technical porcelain
Volume of the CDW:
Wood 24,400kg; Brick 27,500 kg; Glass 224kg; Technical porcelain 152kg; Steel 62kg.
That gives: About. 85% of construction and cladding is made of recycled and re-dimensioned wood; All interior doors; About. 50% of the kitchen fittings; All roof tiles and brick walls; 16 of 24 windows; Toilets and sinks.

Preparation processes for the CDW: Baseline analysis; Identification of the demolition sites available in Trondheim municipality; Mapping of the available building materials, disassembly and storage; Acquiring building materials: Wood from Rye skole (bygd i 1898), Lerkendal stadion, St. Olavs Hospital, Ikea; Brick from TMV på Nedre Elvehavn; Rooftiles from St. Olavs Hospital; Doors and technical porcerail from Lerkendal stadion; Windows St. Olavs Hospital; Kitchenfittings from St. Olavs Hospital; Testing and quality assessment; Redimensioning of the building elements; Rehabilitation of windows and doors.

Project's goal
The objective of the project was to investigate technical, environmental and economic aspects of reuse in modern housing construction, at the same time as stimulating the establishment of a recycling center.

Project description
Trondheim municipality has built two seemingly "similar" four-person homes on Tiller in Trondheim; one, however, is built with a large proportion of recycled material while the other is built in the usual way. Both houses follow current housing bank standard and is financed by the municipality and the Housing Bank. The project was initiated in collaboration with Stavne Farm through the Interreg II project "Border Blasting". Both houses have two two-room apartments of 60.9 m2, and two three-room apartments of 74.7 m2, which shall be leased to financially disadvantaged households in the municipality. The house is built of wood in two floors without basements.
Total project costs for both four-person homes with eight apartments were approx. 11 million. This amounts to approx. 18,000 kroner pr. m^2, which corresponds to comparable housing projects and includes the

additional cost of approx. 2% related to the completion of the experimental construction with reuse. The coverage of the extraordinary project cost can be seen as a direct municipal contribution of 70% and a state contribution of 30% to the implementation of the pilot project.
The extraordinary project costs have no effect on the rent. The Housing Bank provided housing subsidies of NOK 3.3 million, construction loans of NOK 7.7 million and NOK 250,000 for environmental analyzes, documentation and information. Project period – 1997-2000. LCA available.

Other materials used
Concrete 82,380kg; Mineral wool 24,843kg; Foam plastic 428kg; Plastic foil 104kg; Chipboard / plywood 15,628kg; Plaster 7,631kg; Cardboard 30kg; Asphalt board 509kg; Steel for reinforcement and nails 1,229kg; New wood 4,696kg; New glass 112kg.

Support equipment
As in standard building process, no specific information available.

Used methodologies
Baseline analysis – mapping the possible demolition projects in the Trodheim area.
Collection and processing by the municipal work training center Stavne Gård.
Reminiscing of wood to current standards.
Cleaning of other building materials.
Testing of the collected materials at Sør-Trøndelag University College, Department of Construction and environment who were also advisors about material quality, reuse and evaluation.
Renovation of the windows by indusrestaurering AS.
LCA analysis and evaluation.

Benefits
An environmental comparison of Gjenbrukshuset and Nybygget in the construction phase, shows that the construction of Gjenbrukshuset provides significant environmental benefits for all investigated environmental aspects in the LCA analysis.
Compared with Nybygget, the construction of Gjenbrukshuset leads to reduced total energy consumption equivalent to two years of energy consumption in a household. In the same way, Gjenbrukshuset reduces potential greenhouse effect with in excess of 3 years of car use and the potential for acidification with over 30 years of car use (assuming 15,000km/year).The difference in environmental costs for the two houses in the construction phase is NOK 11,400.

Difficulties
The most challenging issues, pointed by the Trondheim Municipality at the time when project was completed (1999) were:
- Quality testing and resizing of the used woods were resource-intensive;
- Design, acquisition and building process was assed to be too resource-intensive for the municipality apply in on the large scale;
- Construction timber, doors, windows are less suitable for professional (residential) construction on a larger scale.

Opportunities
The project proven environmental benefits, but at that time Municipality of Trondheim dropped larger scale projects with the recycled and reused materials. What needs to be emphasized is that the project was

completed more than 20 years ago when the circular economy was not so high on the agenda. As Tronheim is a home to Zero Emission Neighborhood Research Center from 2000 numerous initiatives were taken.

3.3.14. Resource Rows by Lengedager, Denmark

Promoter: Developer: NREP A/S; Contractor: Arkitektgruppen; Architect: Lendager ARC; Upcycle material supplier: Lendager UP; Consulting engineer: MOE.

Localization: Copenhagen, Denmark [20], [21].

Figure 15 - Resource rows, Kopenhagen, streetview [20].

Intervention area

Reuse-Recycle-New construction.

Classification of the CDW: brick (façade and stones), wood
Volume of the CDW: Brick wall – 459tons waste saved; 2,914m^2 brick facade have been used in the Resource Rows. Here, approximately half of them is placed at the row house facades facing the street; 300tons of wood waste.

Preparation processes for the CDW: It is important to emphasize that circularity and resource savings is the fundament of the project, so the architectural office (Lengedager Architects) and specialized upcycling company – Lengedager Up had a leading role in identification and acquiring of the materials:
- Design of the building;
- Identification of the construction sites available and establishing cooperation with another players (Carlsberg, Cøpenhagen Byen and the Cøpenhagen Underground, Diensen);
- Cut brick facade from two facades in two former brewing houses in Carlsbergbyen (Stødpuden and the Matrix Building) and two schools in Aarhus;
- Experimenting with new acquisition techniques (the strong cement mortar from 1960ties was a challenge);
- Preparation of the facade modules, consisting of (cut brick elements (55%), recycled bricks (22,5%) and waste (22,5%) from Gamle Mursten is used;
- Cutting the elements of 1 m2 were from old facades: Packed and protected with the use of pallets and a wooden structure; Transport to upcycling company;
- Installation in steel frames to form facade modules that were fixed to a composite concrete/timber superstructure. Each module consists of between six to nine modules, which results in the result is a patchwork of different colors and slightly uneven depth.

Figure 16 - Steps in preparation of the facade module (cutting from existing building, transport to the site, installation in steel frame) [22].

Project's goal

The projects inspired by the Lengedager Group, which is focusing at the sustainable architecture was to demonstrate large environmental savings by only changing parts of the building components, in the manner that is visually attractive and follows contemporary design.

Project description

Project period 2015-2019.

The project called Resource Rows is a new residential building that was built in Ørestad Syd, a new development area in Copenhagen. It consists of 29 row houses and 63 apartments made of upcycled building materials (upcycle brick facade, the offcut wooden facades, offcut wooden floors, offcut wooden terrace, upcycle roof top houses). The project has been completed in 2019, at the total investment costs of EUR 38.3 million.

Out of the 205tons of materials per row, approximately 18tons or 9% are upcycled materials. The volume of upcycle materials seems not to be significant, due to the amounts calculated in tons which makes the many upcycle wooden materials disappear in more dense conventional materials such as concrete. In total, 463 tons of waste was saved in the investment.

Brick: The most distinguishing resource is the brick- which was mainly acquired as the result of collaboration with the Carlsberg breweries and development company Carlsberg Byen, but also from the Lengedager Up activities. Taken from demolitions of the brewery, abandoned houses and schools the bricks were cut and formatted in into new façade modules, as described above.

Wood: All floors are made from off-cuts and waste from Dineson, the high-spec flooring company – timber that would otherwise have been incinerated. It is worth to mention that this collaboration does not retrain to this specific project – Lengedager has established a company specialized in the upcycling and standardized product portfolio is offered[2].

For the externally used wood (façades, terraces, floors and balconies), it was acquired from expansion for Copenhagen's expanding Metro, where wood was used in the transportation and construction of concrete tunnel elements for the new underground. The Resource Rows project got of 300tons (of 900tons of larch wood) before it was delivered for burning.

[2] https://offcutfloor.com/UP/wp-content/uploads/2020/01/UP-Produktkatalog_udgave4.pdf

Glass: Glass for the shared roof gardens also is coming from demolition projects across the country. As a final element a huge concrete double T beam deck taken from an industrial building and used to form a bridge between the two sides of the block.
Project also used a number of sustainable building solution as: An old Japanese technique (yakisugi) on the exterior wood, charring the surface with fire to impregnate it – making it fireproof and resistant to fungus and insects (and fire too) completely without using any chemicals; Roof greenhouses made from upcycled windows and glass, where residents can cultivate a green roof, with the potential space for growing up to 4 tons of fruit and vegetables a year; Rainwater is collected to help irrigate the green roof and to flush toilets.

Other materials used: as in standard building process – brick, concrete, wood, glass, steel.

Support equipment: steel frames to install the cut-off facade elements, no other specific information available.

Used methodologies:
The investment was an experiment so a number of solutions where investigated and prototyped (especially reg. upcycling of the bricks, which is described in the upper sections).
As for proving the environmental effect, the LCA modelling, using the database Ecoinvent 3.4 in the open software OpenLCA version 1.8.

Benefits
Compared to benchmark, Resource Rows has saved in total 20 tonnes CO2eq, or 29%.
CO2 savings ranged between 5-8% for concrete, 38% for brick walls, 44-88% for wood products and 87% for windows.
At building level the LCA indicated reduction of embodied carbon of 12% for Resource Rows. . At building level the learnings are less clear because several confounding factors and unrelated design decisions impact the aggregate building level CO2 footprint.
CO2 savings from the operation of the building (48% from 4.0kg to 2.1kg CO_2-eq/m^2 per year).

Difficulties
No existing concept for reusing the brick modules. The challenge was that the abandoned old buildings were made from brick façades with cement mortar and not from lime mortar anymore. Due to its stronger composition recovery of the bricks is usable shape was more difficult.

Opportunities
The project was initiated to demonstrate environmental and costs benefits of upcycling building materials on the large scale. The results confirmed that the investment costs are not higher comparing to the reference building with the great potential for CO_2 savings.
The apartment block was delivered for the same price per square meter as the equivalent block built traditionally. And although flat rentals were slowing in Copenhagen even before the Covid-19 pandemic, properties in Resource Rows were the fastest let. The project's low carbon credentials provided the catalyst to help client Nordic Real Estate Partners (NREP) differentiate itself from the competition.
The project also investigated a number of optimized scenarios for reusing brick, wood and glass which will be used in the future projects.

3.3.15. Kristian Augusts gate 13–renovation of eight-story building.

Promoter: Developer: Entra ASA; Main contractor: Haandverkerne; Architect: Mad AS, Asplan Viak AS, AS Scenario Interiørarkitekter; Project management: Insenti AS; Counselors: Rambøll AS, Norconsult AS, Heiberg & Tveter, Fokus rådgiving AS, Brekke & Strand Akustikk AS, Asplan Viak (ombruksrådgiver), Spaces (leietager), Scenario (interiørarkitekt for leietager); Environmental consultant: Asplan Viak AS.
Location: Tullinløkka, Oslo municipality, Norway [23], [24], [25].

Figure 17 - KA13 Roof view [24].

Intervention area: Reuse / Rehabilitation.

Classification of the CDW: glass and windows, wood, bricks, doors, steel.
Volume of the CDW: Façade glass: 2 pcs. facade field in glass (total approx. 25m^2) has been acquired from Dronning Eufemias gate 8; glass door (5.7m^2) acquired from profits at Saga Aluminum; Windows (acquired via Resirqel); 28 pcs. windows from Turbinveien 15, mounted on floors 5, 6, 7 and 8; 2 pcs. windows from Nordregate 20-22, mounted on the 1st and 2nd floor.
Façade covering: Fiber cement boards: 55m^2 have been obtained from St. Olav hospital; Steni plates: Some of the Stone Plates are used and come from a residential complex in Trondheim. Procurement, transport and cutting of the plates was done at Steni. The rest of the boards are surplus materials from the Steni factory's warehouse(450m^2); Metal plates: The metal plates come from Oppsal nursing home which was to be demolished(185m^2).
Office glass: Delivery of office fronts from CreoNordic includes 80m^2 reused glass + 25 reused doors.
Interior doors: Existing doors in KA13: 17 pcs. of the existing doors in KA13 have been reused. 7 + 4 (all bucket doors + 4 doors on the 6th floor) are kept in their original position. The rest of the doors have been moved to new walls. Doors on the 6th floor are only green soap washed. The rest of the reused doors have been cleaned and surface treated.
Floor: About 600 m^2 concrete; 8 m^2 Bolon coating from residual storage at Berg Studio is placed in internal stairs etc.
Ceilings: About 600 m^2 Cellulose spray, based on recycled paper, Amphitheater: About 250ch handrails from railings in Tøyenbadet; About 15m^2 ceiling with pillars from sauna in Tøyenbadet.

Railing: Lattices from Tøyenbadet: 38pcs. fields with gratings from Tøyenbadet (KID) have been reused / converted into railings; Railings in glass from St Olavsplass 5: 11 pcs. used glass panels from railings in St Olavsplass 5 (corresponding to approx. 24.5m^2 glass) is used in new railings.

Preparation processes for the CDW:

- Identification of the reusable building materials available internally in Entra premises and within the cooperation network;
- Ideation workshops with different stakeholders (Entra in collaboration with Futurebuilt);
- Design of the building;
- Planning of the logistics (NB! decisions have been made in several rounds when procuring used materials, and in some cases reuse has led to changes in the design);
- Acquiring of the materials: Disassembly, transport and storage (NB! The reusable materials have had different needs for intermediate storage, processing therefore requiring complicated logistic process);
- Testing;
- Transport to construction site.

Material Category	Total crowd reused	Obtained from	Necessary processing
Steel beams and - columns	45,089kg	Eastern Norway area	Kapping, sandblasting and priming
Hole cover in concrete	96tons	Government Quarter, R4	Kapping, testing
Cooling baffles	138pcs	Queen Euphemias gate 8 (DEG8)	Cleaning by pressure blowing
Ceiling tiles	1660m^2	Four nearby projects in Oslo	Possible manual adaptation by capping

Project's goal:

The standing goal of the project on Kristian Augusts gate 13 is to achieve re-use on the largest scale possible, minimum 50% of all materials shall be reused, therefore achieve a large reduction in greenhouse gas emissions from materials.

Project description:

Project period: 2018 – 2020.

From the existing building stock, various building parts and materials are reused locally in the project, such as doors, radiators, wood and fixtures. This is internal reuse within Entra's organization. In addition, the load-bearing system from the existing building is retained. This is not directly referred to as reuse as it is not moved, but it contributes to increased service life of the materials and high resource utilization

Kristian Augusts gate 13 is an office building from 1950s in the Tullin quarter undergoing a complex rehabilitation process. The building is part of a larger development of an entire quarter with active passages with art, culture, restaurants and cafes:

- Total building area is 4.297 square meters;
- Existing building is 2.734 square meters;
- Basement is 708 square meters;
- Extension is 855 square meters.

Even the concrete slabs and supporting structures in the office building are sourced from buildings undergoing demolition. Reuse of these structures represents major challenges to be worked around for the architects, engineers and building contractors working on the project. In addition, a special focus is given to further circularity of the construction elements (for example, bolting steel, proper mortar for brick walls, removable partitions, good traceability of documentation, etc., to enable further reuse).
The project achieved BREEAM Very Good environmental standard, and it is a model FuturBuilt building.

Used methodologies
To calculate environmental effect the LCA approach was taken, however with the limitations. Environmental analyzes for re-use is a relatively new field, and methodology for this is not well established therefore been a topic of discussion along the way- The system boundaries in standard LCA do not fully correspond to the system boundaries used in e.g. environmental declarations for products (EPDs). (ex. Dismantling of an element and transport in connection with waste treatment is counted in an EPD as part of the waste phase of the product). EPD was used to track the materials in the project.
BIM Modelling to simulate different solutions in the building.

Benefits
More than 70% CO_2 savings q. for the total material composition in the building.
Total saving of 186tons of CO_2-eq with steel as the greater contribution (97%) (At the same time, it also entails large extra expenses compared to the use of new steel) windows 92%.
Cooling baffles provide both savings of CO_2-eq. (95%) and costs.

Difficulties
Reuse of windows: finding used windows with dimensions that exactly match existing window openings in a rehab project is difficult. Windows of older date can be challenging to reuse, both due to requirements for U-value and due to environmental toxins used in the period approx. 1965-1989 and a requiring multifactor analysis has to be performed (U-value and energy calculations, daylight requirements, environmental impacts during production, possible health / environmentally hazardous content).
Office fronts: It is demanding to find office fronts with the right dimensions and sound requirements. Also, only laminated glass can be cut (not tempered).

Opportunities
Steel is practical for disassembly because it is less prone to damage during handling, and costs related to recertification can become affordable over time.
It is easier to get material recycling and reuse as parts of new products than direct reuse, as there are good solutions for recycling today. The key factor for both reuse and recycling is related to volume for it to be efficient enough.

3.3.16. Ruseløkka school – rehabilitation of old building.

Promoter: Developer: Undervisningsbygg Oslo KF; Main contractor: veidekke ASA; Architect: Gasa A/S, Arkitektkontoret; Project management: Undervisningsbygg Oslo KF, Veidekke AS;
Counselors: Bjørnstad Prosjektering AS, Union Consult AS, SIVILINGENIØR SV BOLKESJØ ANS, Roar Jørgensen AS, Multiconsult AS; Environmental consultant: Asplan Viak.
Location: Oslo municipality, Norway [26], [27], [28].

Figure 18 - Building overview [26].

Intervention area: Recovery / Reuse / Passive house.
The building is constructed in steel and concrete, with a requirement for low carbon concrete and recycled steel. The project serves as a pilot project through the use of 2nd generation low carbon concrete. Materials and building components from the existing building were stored for reuse in the new building. 4,500 bricks were mined from the old school building and are used as interior walls in the main entrance hall. Granite steps from the old staircase are upcycled as benches outside. The old doors were disassembled and stored for reuse in other projects. The aim has been to gain experience with material recycling and reuse which can be applied in other projects.

Classification of the CDW: bricks, stone, doors, ventilation pipes, wood.

Volume of the CDW: 4,500 bricks were mined from the old school building and are used as interior walls in the main entrance hall; Granite steps were used in the outdoor areas as benches. The doors were disassembled for reuse (28 pieces); Reuse of brick façade (demolition at Nøklevann school); Ventilation ducts were disassembled at Etterstad school to be used as roofing on a communal house at Fornebu; Wooden girders and beams; Floor covering.

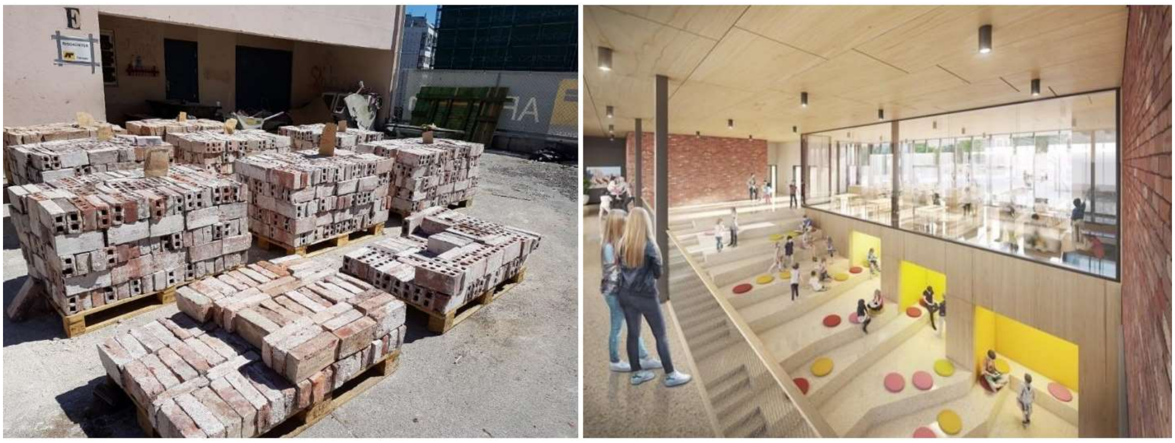

Figure 19 - Reuse of the bricks in Ruseløkka school [26].

Project's goal

The school has set high energy ambitions and aims to be a near net zero energy building. It is a pilot project for the use of 2nd generation concrete and for circular measures. As part of the project, materials from the original building will be reused in the new school building

Project description

Project period: 2016 - 2021

The New Ruseløkka school consists of a new primary and lower secondary school for 690 pupils. The existing school building was demolished and new Ruseløkka school was built on the same site with the high energy ambitions. The school also offers several special classrooms such as a large dance studio and a multi-purpose room for cultural activities both in and after school hours. Ruseløkka school is a pilot project for the use of 2nd generation concrete and for circular measures. As part of the project, materials from the original building will be reused in the new school building. 4,500 bricks, wooden beams and granite blocks from the interior staircase was stored for reuse. In order to simplify future reuse of the old bricks, lime mortar will be used in interior brickwork. Ruseløkka is also a fossil fuel free building site. Sunken games area (20cm deep) planted areas and a green roof on part of the building enable open, natural surface water management. The terrain is shaped to lead the water away from the school facade and towards the planted area and the playground. To achieve the energy targets (near net zero energy), 320m^2 of integrated photovoltaics have been mounted in the façade.

There will also be some 370m^2 of photovoltaics placed on a green roof to investigate whether this combination can contribute to a more efficient energy production (roof and façade 75,000kWh/year). The project also tests photovoltaics in the asphalt as a new innovative method for energy production. The school aims to achieve the energy label dark green A and a Passive house standard (NS3700/3701). The school is also included as a FutureBuilt model building.

Used methodologies

Futurebuilt model building. Passive house standard (NS3700 / 3701). Research and investigation for lime mortar.

Benefits

Increasing the energy efficiency of the building and achieving the A green label. Full LCA was not performed yet as the building is not completed.

Difficulties

The mortar in the brick facade was not firm enough to be reused tile panels in new facade so new options had to be investigated. The present requirement for mortar are higher, also it is not possible to mix lime mortar with the new one. A lot of research and investigation had to be done, so it is necessary to include it in the process and as early as possible.

Opportunities

Reusing old cabinets and interior elements (With new doors, plastered surface and new hinges, screws and bolts the look as new at 70% cost reduction). New façade is fully designed for re-use (with special track of documentation etc). Use of popular sale platforms for selling the materials demounted from existing building. The school is one of the first school buildings undergoing such a complex rehabilitation, with different user profile and therefore safety requirements that most of on the newly accomplished projects of office buildings circular renovation. The project is to be completed by 2021, so when finalized it will be possible to discover many relevant findings for education buildings, made available by Education Department in the Oslo Municipality.

3.4. Materials made with waste

3.4.1. On-site recycling of road surface

Promoter: Not indicated.
Localization: Czech Republic.

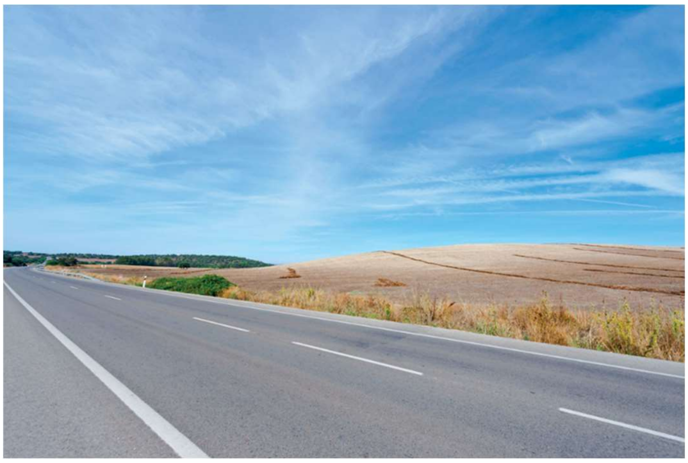

Figure 20 - On-site recycling of road surface[29].

Intervention area: On-site recycling of road surface.

Classification of the CDW: Bituminous mixtures, tar and tar products.
Volume of CDW: 4 km of a road.
Preparation processes for the CDW: Milling, thermal processing.

Project goal
Reconstruction of a road using on-site recycling method.

Project description
Four kilometers of a road in a concerned municipality was reconstructed using a hot in-place recycling technology. The milling machine disconnects the existing construction layer, the resulting mixture is improved with the necessary materials and placed back on the road. In the process, both the asphalt layer and the underlying layer are recycled on-site without the need to remove, transport and dispose of them. Old base layers become a secondary raw material for immediate use directly in road repairs.

Other materials used
Asphalt, underlying layer of a road (soil, rocks).

Support equipment
Milling machine.

Used methodologies
Hot in-place recycling.

Benefits

Waste-free process/technology, Replacement of primary materials, Lower costs, Faster reconstruction.

3.4.2. Reconstruction of highway D2

Promoter: SKANSKA.
Localization: Czech Republic.

Figure 21 - Reconstructing a 12 km long part of the highway D2, SKANSKA [30]

Intervention area: Road surface.

Classification of the CDW: Concrete, bricks, tiles and ceramic materials.
Volume of CDW: 50.000tons of concrete.
Preparation processes for the CDW: Crushing, sorting, milling, manufacturing of new concrete.

Project goal
Use of recycled materials in reconstruction of a highway.

Project description
When reconstructing a 12km long part of the highway D2, SKANSKA was able to recycle and return back the demolished cement-concrete cover of the highway. In a nearby deposit site, they crushed and sorted almost 50 000 tons of demolished concrete. Most of the material was then used in the mobile concrete mixing plant for the production of more than 17 000 m^3 of new concrete. It was then laid down in the bottom layer of the cement-concrete cover of the reconstructed road.

Other materials used
Concrete.

Support equipment
Sorting machines, crushing machines, milling machines, mobile concrete mixing plant.

Benefits
Saving of primary resources, Minimization of landfilled waste, Reduction of dust, noise and exhalation generated during the transport of aggregates.

Difficulties

Necessity to build a mobile concrete mixing plant.

Opportunities

The concrete waste was used to produce a new concrete for the main body of the road, instead of being simply crushed and used as an underlying layer (downcycling).

3.4.3. Certuv Vrsek (Čertův Vršek)

Promoter: SKANSKA.
Localization: Prague, Czech Republic.

Figure 22 - Rezidence Čertův vršek [31].

Intervention area: Use of recycled materials.

Classification of the CDW: Concrete, bricks, tiles and ceramic materials.
Volume of CDW: 960 tons of concrete waste (600 m^3 of new concrete produced).
Preparation processes for the CDW: Complete reprocessing of concrete waste to new concrete.

Project goal
Use of "rebetong" recycled concrete in a building construction.

Project description
SKANSKA, together with a company ERC-TECH, has developed and patented the technology for production of recycled concrete (so called "rebetong" – reconcrete). This new product meets all criteria of concrete standards but instead of natural aggregate, it uses 100% construction debris. 1600kg of concrete waste/debris is needed to produce 1m^3 of "rebetong". As a pilot project, 600 m3 of "rebetong" (made of 960tons of construction debris) was used as a bottom layer in a construction of residential project Certuv Vrsek.

Other materials used
Concrete.

Support equipment
Complete reprocessing technology.

Used methodologies
Patented technology "rebetong".

Benefits
Full substitution of primary material with waste material, Reduction of transport, CO_2 reduction.

Difficulties

Technical standards.

Opportunities

In a further step, “rebetong” is going to be applied not only as a bottom layer, but as a material for construction of both load-bearing and partition walls.

3.4.4. Cukrkandl parcour playground

Promoter: SKANSKA.
Localization: Prague, Czech Republic.

Figure 23 - Using recycled concrete [32].

Intervention area: Use of recycled materials.

Classification of the CDW: Concrete, bricks, tiles and ceramic materials.
Volume of CDW: Not provided.
Preparation processes for the CDW: Complete reprocessing of concrete waste to new concrete.

Project goal
Use of “rebetong” recycled concrete blocks.

Project description
SKANSKA, together with a company ERC-TECH, has developed and patented the technology for production of recycled concrete (so called “rebetong” – reconcrete). This new product meets all criteria of concrete standards but instead of natural aggregate, it uses 100% construction debris. 1 600 kg of concrete waste/debris is needed to produce 1 m3 of “rebetong”. Besides ‘raw’ concrete, prefabricated building blocks can be produced. As a pilot project, these blocks were used to develop a parcour playground in Prague.

Other materials used
Concrete.

Support equipment
Complete reprocessing technology, casting.

Used methodologies
Patented technology “rebetong”.

Benefits
Full substitution of primary material with waste material, Reduction of transport, CO_2 reduction.

Difficulties

Technical standards.

3.4.5. Ecoschool Masovice

Promoter: Municipality of Masovice (Mašovice), company CIUR.
Localization: Municipality of Masovice, Czech Republic.

Figure 24 – Ekoskola [33].

Intervention area: Thermal insulation.

Classification of the CDW: Insulation and building materials containing asbestos.
Volume of CDW: 395m^3 of insulation material.
Preparation processes for the CDW: Paper recycling and processing, Blowing-in of insulation.

Project goal
Thermal insulation of school and kindergarten buildings.

Project description
As a part of reconstruction of school and kindergarten buildings in the municipality of Masovice, a thermal insulation of ceilings, attic horizontal structures as well as vertical structures was carried out. The insulation material used was a unique blown-in insulation made from recycled paper produced by a company CIUR. (There are several case study applications of this insulation material in schools as well as many other types of buildings. The one presented is just an example.)

Support equipment
Blowing-in mobile machine.

Used methodologies
Blowing-in of insulation.

Benefits
Product made from waste material, Waste-free technology (no remains/cuttings of a material), High fire resistance.

4. Conclusions

The proposed survey had a low turnout. None of the municipalities of *Baixo Alentejo* presented elements relating to good practices. The best practices collected are mostly related to the collection and reuse of CDW:

- Waste recovery / collection systems – two answers;

- Reuse (saving natural resources) – 15 answers;

- Materials made with waste – five answers.

The good practices presented in this document can be a good support for the establishment of a strategy to integrate the CWD in the construction process, making it more circular, reducing the use of natural resources.

References

[1] F. C. Mihai, "Construction and demolition waste in romania: The route from illegal dumping to building materials," *Sustain.*, vol. 11, no. 11, 2019.

[2] "Domenii Prest Serv." [Online]. Available: http://www.domeniiprestserv.ro/despre-noi.html. [Accessed: 13-Aug-2021].

[3] "Panattoni Europe." [Online]. Available: http://www.panattonieurope.com/cz/zeme/ceska-republika-slovensko/tiskove-stredisko/zpravy/demolice-komina-symbolicky-zahajila-vystavbu-panat/. [Accessed: 13-Aug-2021].

[4] "Recyklace v praxi – výstavba BMX dráhy Zábřeh." [Online]. Available: https://druhotnasurovina.cz/vyherci-2019/. [Accessed: 13-Aug-2021].

[5] "Catalog_of_competition_MPO_Stranslation-of-waste-to-resources," 2017.

[6] "Construction of the D4 motorway Skalka u Příbrami - SKANSKA." [Online]. Available: https://www.youtube.com/watch?v=fPYaLKPuevM. [Accessed: 13-Aug-2021].

[7] I. Andresen, M. K. Wiik, S. M. Fufa, and A. Gustavsen, "The Norwegian ZEB definition and lessons learnt from nine pilot zero emission building projects," *IOP Conf. Ser. Earth Environ. Sci.*, vol. 352, no. 1, 2019.

[8] Å. L. Sørensen *et al.*, *Pilot Building Powerhouse Kjørbo. As Built Report*. 2017.

[9] "Avfall som del av verdikjeden." [Online]. Available: https://docplayer.me/151295943-Avfall-som-del-av-verdikjeden-anne-sigrid-nordby.html. [Accessed: 17-Aug-2021].

[10] "Utvendig glass." [Online]. Available: https://issuu.com/sportmedia/docs/g_f_01_2013_full/37. [Accessed: 17-Aug-2021].

[11] "Bruker byggeavfall fra skole til produksjon av sponplater." [Online]. Available: https://www.hent.no/2021/03/26/bruker-byggeavfall-fra-skole-til-produksjon-av-sponplater/. [Accessed: 17-Aug-2021].

[12] "Reduksjon, gjenbruk og resirkulering." [Online]. Available: https://www.if.no/om-if/barekraft/reduksjon-gjenbruk-og-resirkulering. [Accessed: 17-Aug-2021].

[13] "Powerhouse Kjørbo." [Online]. Available: https://www.bygg.no/powerhouse-kjorbo/1186020!/?image=0. [Accessed: 17-Aug-2021].

[14] "Byggfakta." [Online]. Available: https://nyheter.byggfakta.no/skal-gjenbruke-50-prosent-162183/nyhet.html. [Accessed: 17-Aug-2021].

[15] "Futurebuilt." [Online]. Available: https://www.futurebuilt.no/Forbildeprosjekter#!/Forbildeprosjekter/Kristian-Augusts-gate-23. [Accessed: 17-Aug-2021].

[16] "Kunsten å bygge sirkulært." [Online]. Available: https://www.arkitektnytt.no/nyheter/kunsten-a-bygge-sirkulaert. [Accessed: 17-Aug-2021].

[17] "Rehabilitering av kontorlokaler med sirkulære prinsipper." [Online]. Available:

https://issuu.com/ninnipetrin/docs/6262_presentasjonsmappe_a3. [Accessed: 17-Aug-2021].

[18] I. S. Modahl and H. L. Raadal, *Evaluering av miljø- og ressursforhold ved bygging av Gjenbrukshus i Trondheim*, no. November. 2003.

[19] "FAKTAARK: Gjenbrukshuset i Trondheim." [Online]. Available: https://www.trondheim.kommune.no/gjenbrukshuset/. [Accessed: 17-Aug-2021].

[20] "Old into new: recycled bricks form facade of copenhagen housing project." [Online]. Available: https://www.architectsjournal.co.uk/buildings/old-into-new-recycled-bricks-form-facade-of-copenhagen-housing-project. [Accessed: 17-Aug-2021].

[21] "Lendager." [Online]. Available: https://lendager.com/nyheder/the-resource-rows-2/. [Accessed: 17-Aug-2021].

[22] "Why this Danish city is rebuilding itself out of recycled rubble." [Online]. Available: https://www.weforum.org/agenda/2018/03/copenhagen-denmark-rebuilding-recycled-rubble/. [Accessed: 17-Aug-2021].

[23] "Erfaringsrapport fra sirkulærprosjektet KA13." [Online]. Available: https://insenti.no/erfaringsrapport-fra-sirkulaerprosjektet-ka13/. [Accessed: 17-Aug-2021].

[24] "Kristian August gate 13." [Online]. Available: https://www.futurebuilt.no/Forbildeprosjekter#!/Forbildeprosjekter/Kristian-August-gate-13. [Accessed: 17-Aug-2021].

[25] "Rapport om KA13." [Online]. Available: https://entra.no/news-and-media/rapport-om-ka13/2114. [Accessed: 17-Aug-2021].

[26] B. Motzke, "Sirkulære løsninger på Ruseløkka skole."

[27] "Ruseloekka-skole." [Online]. Available: https://www.futurebuilt.no/Forbildeprosjekter#!/Forbildeprosjekter/Ruseloekka-skole. [Accessed: 17-Aug-2021].

[28] "Ruseløkka skole." [Online]. Available: https://ruselokka.osloskolen.no/nyhetsarkiv/ruselokka-skole---et-forbildeprosjekt-i-futurebuilt/. [Accessed: 17-Aug-2021].

[29] "Road reconstruction - cold recycling." [Online]. Available: https://www.asb-portal.cz/stavebnictvi/inzenyrske-stavby/doprava/rekonstrukce-vozovek-recyklace-za-studena. [Accessed: 13-Aug-2021].

[30] "auto-mania.cz." [Online]. Available: https://auto-mania.cz/zrekonstruovana-cast-dalnice-d2-u-brna-se-zitra-otevre-ridicum/. [Accessed: 13-Aug-2021].

[31] "Rezidence Čertův vršek." [Online]. Available: https://reality.skanska.cz/prodej-bytu-praha-8-liben. [Accessed: 13-Aug-2021].

[32] "Reality Skanska." [Online]. Available: https://reality.skanska.cz/blog/skanska-zacala-pouzivat-recyklovany-beton. [Accessed: 13-Aug-2021].

[33] "EkoSkola." [Online]. Available: https://www.skolaadelka.cz/ekoskola/. [Accessed: 13-Aug-2021].

ANNEX I - Data collection protocol about best practices for the reuse of construction and demolition waste

Data collection protocol on good practices for reusing construction and demolition waste
Name of the person responsible for completing the form
Email
Project identification
Project designation
Promoter
Localization
Intervention area
Reused CDW's characterization
Classification of the CDW
Volume (global value and / or per element or m3)
Preparation processes for the CDW
Other materials used
Project charaterization
Project goal
Project description
Support equipment
Used methodologies
Considering the project in a global way, indicate:
Benefits
Difficulties
Opportunities