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Super Circular Estate Project
Journal nr 2
Project led by the Municipality of Kerkrade

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1. Executive summery

In 2015, the world agreed to limit global warming to less than 2ºC by 2100, and make best efforts to limit warming to 1.5ºC. Since then many national governments as well as global players are making efforts to achieve this goal and reduce carbon emissions.
Concern over climate change and high CO2 emissions related to linear material streams has led to policies that stimulate circulate approach to material use through its whole life cycle and put a price on carbon emissions using either a market-based emissions trading system ("cap and trade") or a carbon tax, both of which can affect the operating cost. A well-known example of carbon pricing is the European Union cap-and-trade system .

Super Circular Estate project aims to contribute to a sustainable, low carbon, resource efficient economy by testing circular deconstruction and construction building techniques.

Construction industry is one of the key stakeholders in the transition towards carbon neutral industrial processes since it is responsible for 40% of CO2 emissions in the EU. This is primarily related to the destructive demolition of buildings which results in waste streams (40% of waste in EU is Building related) and energy used to demolition of buildings, extract new materials and produce new building elements/products.

The Super Circular Estate (SCE) project is addressing this challenge and takes a proactive approach. SCE team is undergoing deconstruction of the existing 10 story housing block and using 75% -100% of its material to construct three, and later potentially, sixteen houses in the same neighborhood.

This UIA project in Kerkrade demonstrates potentials of circular buildings by creating a material bank from existing housing block built in the 1960's, studying their potential future applications and reusing its materials through new construction. SCE consortium is meeting different challenges on this road of explorations.

Many challenges with respect to the differences between circular and conventional building process have been addressed by consortium members in zoom-in movie from January 2019. (UIA 2019) https://www.youtube.com/watch?v=azLRMLTlOMw. Key challenges mentioned by the design and engineering team are changing roles of participating partners through the development process, shifting responsibilities, shifting user's perception and acceptance of reused materials, changing costs and financial models, development of new building methods, registration of materials and their potential future value. Although the project is facing big challenges it has already illustrated the potential of new circular approach to the transformation of existing buildings. As such SCE has already drawn attention of the Dutch Government and its ministers, National Universities and research institutions, and has won well recognised Dutch Building Prise 2019.(Figure 1)

Figure 1: left visit of Dutch Minister of Interior/ second Deputy Prime Minister of the Netherlands to the SCE, middle: one of many SCE presentations to the students and professionals, right: Dutch

Building Prise 2019 award ceremony (first prise to SCE in the category building materials and systems)

This second expert's journal elaborates on the steps that have been taken in order to meet above mentioned challenges during last six months of work on building permit documentation. Firstly, it will address the selection of materials to be reused in the new construction, secondly journal will elaborate design of new houses which is now in building preparation stage, and finally initial financial and environmental impacts of the designed solutions will be discussed.

2. Super Circular Estate material bank for the new construction

2.1 Inventory of Material Bank

Super Circular Estate consortium has done detailed investigation of the exiting 10-story high 100-appartment housing block that will be deconstructed in order to create a material bank for the construction of three new houses and in the later stage 12 more apartments. In order to create an overview of available materials to be harvested for the new construction, deconstruction company Dusseldorp has created a material database creating material cods in order to track and trace materials during deconstruction and construction phase. Material database consist also of quantities and weight of materials as well as their embodied energy and embodied CO2 (Table 1). Besides the specification of material composition of exiting building block and their quantities, deconstruction company has also specified materials according to their reuse options (together with structural engineer and contractor), and have sorted materials into three categories form category 1 easy to recover to category 3 difficult to recover. During the investigation of the reuse potential of individual building parts and materials from the existing building block it became evident that different materials can be reused on different levels of building decomposition. For example, (1) some parts of the building can be cut out as 3D units and directly reused in new construction, or (2) window frames can be upgraded and reused on component level after refurbishment. After being recovered, window frames will be refurbished by extracting asbestos from the frame and reinforcing the frame with new piece of wood. This would create a functional frame which can be reused again and again. (3) Concrete and brick parts can be reformed by crunching them into smaller stones which will be re-arranged into a façade module (4) Finally, concrete parts of the building can be crashed to a small piece (to the aggregate level) and can be used to produce new concrete, while cement from the old concrete can be reactivated using new methods for recycled concreate production without adding new cement. This makes reuse on material level possible. Each of these reuse options have recovery time and cost constrains as well as CO2 emissions attached to them. The impacts of different reuse options are subject to research and evaluation during this project.

	A	B	D	E	F	G	H	I	J	M	N
1	Code S1432016462TM S1432026462TM S1432036462TM S1432046462TM S1433016462TM	material copper, 12 mm copper 10 mm steel (88,9 x 3,25mm) copper, 10mm PVC 110 mm	quantity m1 (,44kg/m1) m1 m1, 6,81kg/m1 m per woning,10 m1	quantity (kg) 1104,4 1900,08 190,68 378 1075,84	source inventory Dussel inventory Breme inventory Breme calculation Michi inventory Dussel	ee/kg (MJ) 42 42 19,8 57 67,5	source ICE 2011 ICE 2011 ICE 2011 ICE 2011 ICE 2011	CO2/kg (kg) 2,6 2,6 1,37 3,65 2,56	source ICE 2011 ICE 2011 ICE 2011 ICE 2001 ICE 2011	ee total (MJ) 46.384,80 79.803,36 3.775,46 21.546,00 72.619,20	CO2 total (kg) 2.871,44 4.940,21 261,23 1.379,70 2.754,15
2	S1433026462TM S2000016462TM	PVC, 110 mm concrete RC32/40	m1, 1.64kg/m1 m3	1558 1192770	inventory Breme inventory Dussel	67,5 1,03	ICE 2011 ICE 2011	2,56 0,153	ICE 2011 ICE 2011	105.165,00 1.228.553,10	3.988,48 182.493,81
3	S2000026462TM S2127016462TM	steel steel	kg	18270 140194	inventory Dussel verwerkt per ond	17,4	ICE 2011	1,31	ICE 2011	317.898,00	23.933,70
4	S2127026462TM S2133016462TM	steel per m3 concrete RC32/40	m3	504985	inventory Dussel	1,03	ICE 2011	0,153	ICE 2011	520.134,55	77.262,71
5	S2133026462TM S23516462TM	steel laminated veneer timber 18 mm, 1	m2	77385 7740	inventory Dussel inventory Dussel	17,4 9,5	ICE 2011 ICE 2011	1,31 0,63	ICE 2011 ICE 2011	1.346.499,00 73.530,00	101.374,35 4.876,20
6	S3000016462TM S3000026462TM	asbestos kit stainless steel	m1 (50 ml/m1); (pieces (250 gr/pi	16,6075 107,75	inventory Breme inventory Breme	7,4 56,7	ICE 2011 ICE 2011	6,15	ICE 2011	122,9 6.109,43	0 662,66
7	S3000036462TM S3000046462TM	stainless steel aluminium	pieces (250 gr/pi pieces (2kg/piec	122 352	inventory Breme inventory Breme	56,7 155	ICE 2011 ICE 2011	6,15 8,24	ICE 2011 ICE 2011	6.917,40 54.560,00	750,3 2.900,48
8	S3000056462TM S3000066462TM	mastic sealant stainless steel	m1 (50ml/m1);(0 pieces (250 gr/pi	19 75	inventory Breme inventory Breme	131 56,7	ICE 2011 ICE 2011	6,15	ICE 2011	2.489,00 4.252,50	0 461,25
9	S3000076462TM S3000086462TM	asbestos plates 5 mm asbestos plates	m2 (12.1kg/m2 N m2 (12.1 kg/m2	171323,9 9292,8	inventory Breme inventory Breme	7,4 7,4	ICE 2011 ICE 2011	1,561983471 1,561983471	NIBE (houtvezel NIBE (houtvezel	1.267.796,86 68.766,72	267.605,10 14.515,20
10	S3000096462TM S3000106462TM	single pane glazing (10 kg/m2) mastic sealant	m2 m1 (50ml/m1);0.	2020 14	inventory Breme inventory Breme	15 131	ICE 2011 ICE 2011	0,86	ICE 2011	30.300,00 1.834,00	1.737,20 0
11	S3032016462TM S3032026462TM	sawn softwood (pine) (70x45 mm) sawn softwood (pine) (4,8 m1 per	m1 = 39.4 m3 (4 pieces (7.4 m3)(	18124 3404	inventory Dussel inventory Dussel	7,4 7,4	ICE 2011 ICE 2011	0,58 0,58	ICE 2011 ICE 2011	134.117,60 25.189,60	10.511,92 1.974,32
12	S3033016462TM S3033026462TM S30446462TM S3062016462TM S3062026462TM S3062036462TM S3063016462TM	sawn hardwood meranti 4,8m1 pe aluminium 20 kg aluminium 18 mm meranti hardwood wooden steel, 2 mm plaatstaal 2x2 m steel, 5 mm 1x2 m stainless steel wood stomp, hardboard met hong	pieces (5.3 m3)(pieces piece (640 kg/m3 pieces (16kg/m2 pieces (40kg/m2 pieces (500 gr/pi pieces, 10.5 gk/p	2438 2000 25,92 2496 400 7,5 10899	inventory Dussel inventory Dussel inventory Breme inventory Dussel inventory Dussel inventory Breme inventory Breme	10,4 155 10,4 25,1 25,1 56,7 7,4	ICE 2011 ICE 2011 ICE 2011 ICE 2011 ICE 2011 ICE 2011 ICE 2011 (sawn	0,86 8,24 0,86 1,55 1,55 6,15 4,39047619	ICE 2011 ICE 2011 ICE 2011 ICE 2011 ICE 2011 ICE 2011 NIBE	25.355,20 310.000,00 269,57 62.649,60 10.040,00 425,25 80.652,60	2.096,68 16.480,00 22,29 3.868,80 620 46,13 47.851,80
13	S3063026462TM S3231016462TM	stainless steel hinges concrete RC32/40	pieces (250 gr/pi m3	757,75 58564,55	inventory Breme inventory Dussel	56,7 1,03	ICE 2011 ICE 2011	6,15 0,153	ICE 2011 ICE 2011	42.964,43 60.321,49	3.326,88 8.960,38
14	S3231026462TM S32376462TM	steel steel HEB 140, lengte 1,8 m, gew	897,05 pieces	897,05 270	inventory Dussel inventory Dussel	17,4 20,1	ICE 2011 ICE 2011	1,31 1,37	ICE 2011 ICE 2011	15.608,67 5.427,00	1.175,14 369,9
15	S3251016462TM S3251026462TM	sawn softwood pine (120x40mm) aluminium bars, 5 mm, 12.5 cm in	m1 (.134 m3)(46 m2 (8m1/m2); .0	61,64 165,2	inventory Dussel inventory Dussel	7,4 154	ICE 2011 ICE 2011	0,58 8,16	ICE 2011 ICE 2011	456,14 25.440,80	35,75 1.348,03

Insert Table 1: Track and trace data base representing harvested materials form the 10story building produced by deconstruction company (Dusseldorp 2019)

Based on the material database system produced by deconstruction company Dusseldorp (Table 1) the research team at the University of Applied Science ZUYD has calculated embedded energy and Carbon emissions related to the harvested materials. According to this study, the existing (10 story high) apartment block consists of 2.3E03 GJ embodied energy and 2.9E03 tons of embodied CO2. (Table 2) (M.Ritzen at all. 2019). This has been used as a baseline for the embodied energy and CO2 impact analyses of the new designs.

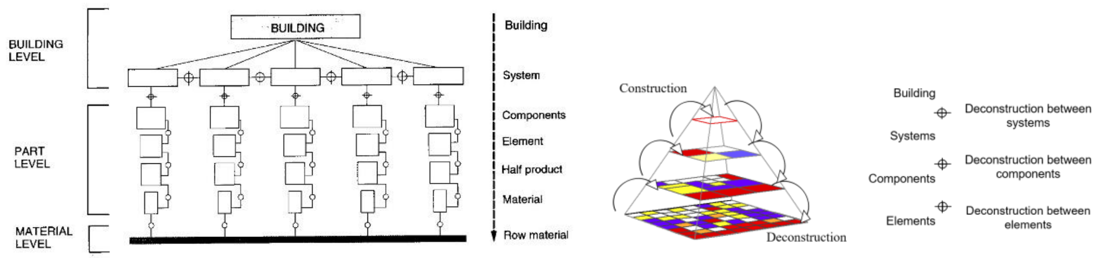
MATERIAL	**QUANTITY (TON)**	**EMBODIED ENERGY (GJ)**	**EMBODIED CO2 (TON)**	**SHADOW COSTS (€)**
Aluminium	1.03E+01	1.59E+03	8.45E+01	2.11E+03
Asbestos	1.81E+02	1.34E+03	2.82E+02	7.05E+03
Diferent	1.78E+01	2.97E+02	6.23E+00	1.56E+02
Ceramique	4.40E+01	5.50E+02	3.41E+01	8.52E+02
Concrete	1.30E+04	1.33E+04	1.97E+03	4.93E+04
Copper	7.45E+00	1.52E+02	9.81E+00	2.45E+02
Glass	1.75E+01	4.26E+02	2.56E+01	6.40E+02
Masonry	6.38E+01	1.92E+02	1.47E+01	3.67E+02
Plastics	1.24E+01	1.00E+03	3.50E+01	8.74E+02
Steel	3.26E+02	3.79E+03	3.00E+02	7.50E+03
Natural Stone	6.05E+01	5.12E+00	2.96E-01	7.40E+00
Timber	7.15E+01	6.64E+02	1.00E+02	2.50E+03
TOTAL	**1.38E+04**	**2.33E+04**	**2.87E+03**	**7.16E+04**

Insert table 2: overview of harvested materials and their embedded energy and embodied CO2 including shadow costs based on 25€/ton CO2 (M.Ritzen at all. 2019)

2.2 Hierarchy of Levels of Deconstruction

Circular buildings recognize four mayor levels of technical/physical decomposition:

1. Building level represents the arrangement of systems/units representing one or more mayor building functions (load bearing construction, enclosure, partitioning, servicing), that can be deconstructed for reuse.
2. Product level (this can be a system or component level), equals to cluster of parts or prefabricated modules that can be deconstructed for reuse
3. Element level stands for individual elements as steel beams or concrete slabs that can be deconstructed and reused.
4. Material level represents extraction of material for recycling purposes. (Figure 2)



Insert Figure 2: Levels of Material decomposition (Durmisevic 2006)

First three levels of building decomposition are associated with disassembly and have potential for high value recovery of building parts. The last, material level of building decomposition is associated with destructive demolition. This means that part of the building cannot be directly reused or refurbished and that the only reuse option is recycling.

The hierarchy of building composition goes from high level (building level) to low level (material level). Reuse of building materials which can be achieved on higher level of building decomposition by disassembly would have lower CO2 emissions and costs, since the processes of extracting materials, processing materials into half elements and elements that can be installed into a building would be bypassed. Their reuse options are direct reuse, reuse by reparation, reuse by refurbishment or mechanical re-forming. Contrary to that recycling materials means that there is much more energy and CO2 emissions associated with recycling process and all fabrication steps that follow. This also counts for the deconstruction techniques on building or product level which are not associated with disassembly (mechanical process of recovering materials without using substantial force)(BAMB 2019)

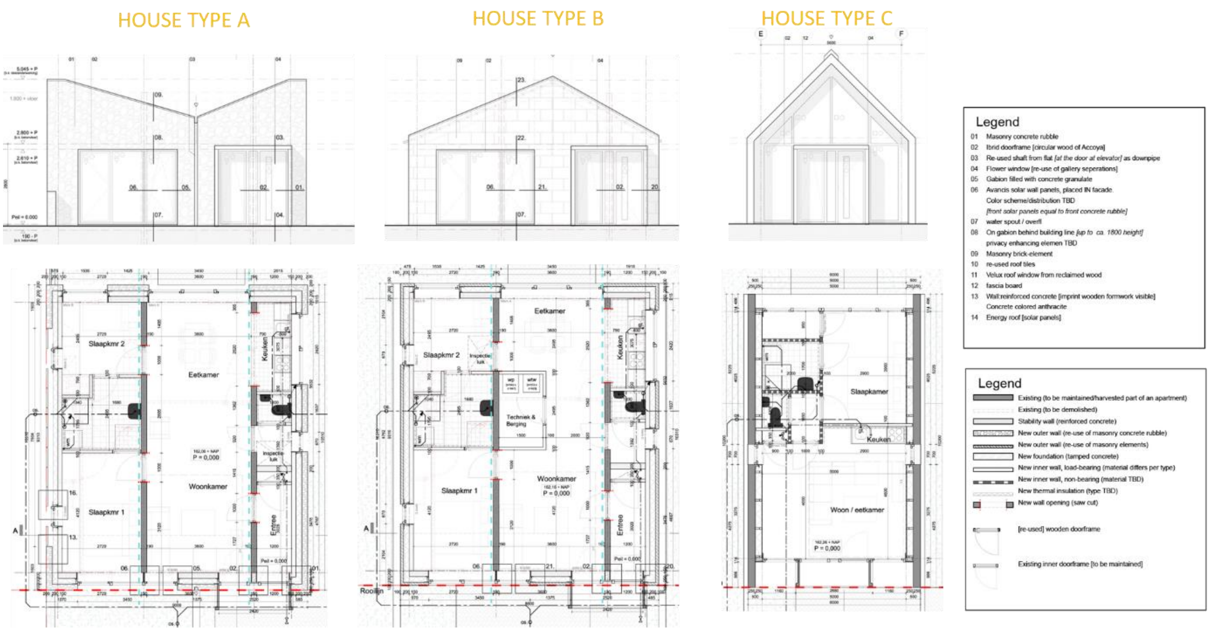
10-story housing block of SCE project has been deconstructed on building, product and material level partly by disassembly, partly by cutting or by destructive demolition. (Figure 2) This provides solid base for analyses of reuse benefits on different levels of building decomposition, considering the method of industrial housing construction in The Netherlands in the late 1960's. Preliminary environmental and economic impact of reuse within SCE project will be discussed in chapter 4. Figure 3a and 3b illustrate four levels of material recovery for reuse in three new houses of SCE. Figure 3b presents the process of reusing recycled aggregate (which has been recovered from the neighbouring building block) in the production of concrete and its instalment into the fundaments of SCE houses.

Insert Figure 3a: Examples of harvested materials from the 10-story housing block (on building, product and material level) to be used in new construction (Dusseldorp 2019)

Insert Figure 3b: use of recycled aggregate from the existing neighbouring block for the construction of the fundaments and ground floor slab (reuse on material level/lowest level of building decomposition)

3 Design of new houses with reusable materials

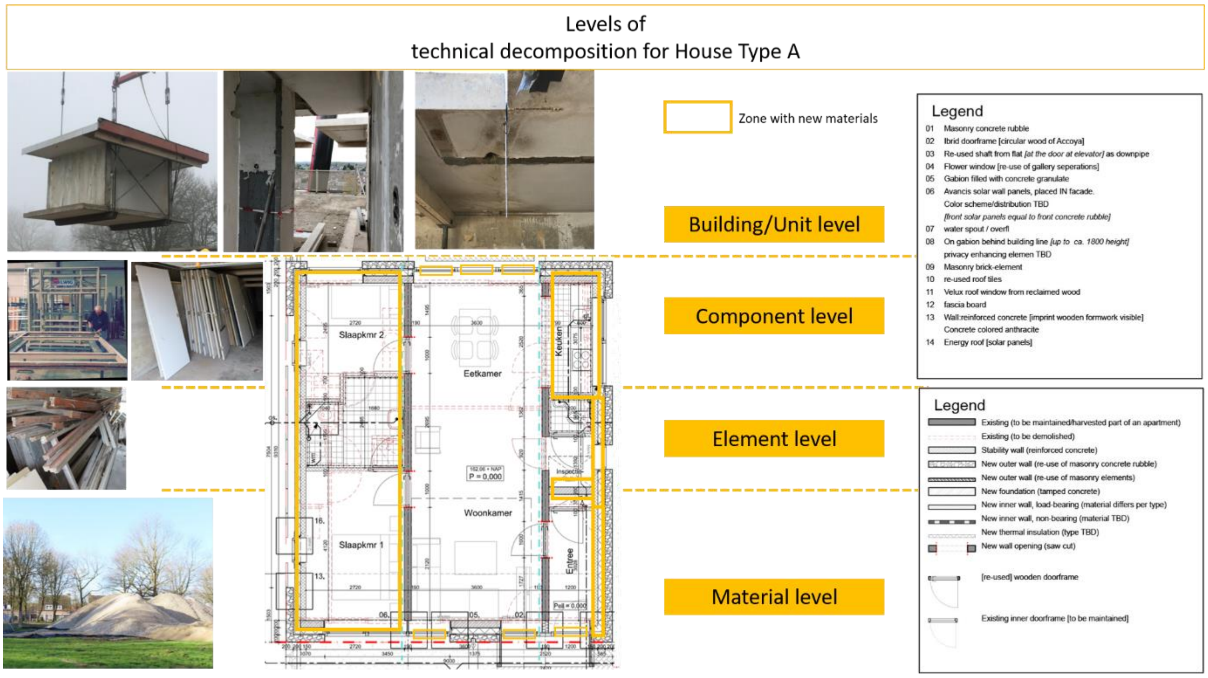
Architectural office “SeC Architecten” initially designed four new houses. Houses types A, B, and C were designed with the aim to use at least 70% of harvested products and materials form the 10-story building. Figure 4



Insert Figure 4: Three types of houses designed by Bart Creugers from SeC Architecten

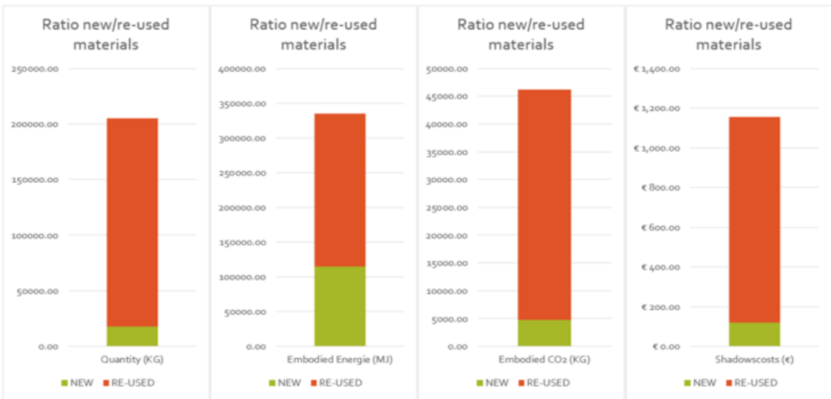
Fourth house type D has been designed with focus on bio-based design aiming to use locally produced bio-based materials. Construction costs of type D house has been estimated to be two times more expensive than the other three types. After cost analyses made by the housing cooperation HEEMwonen for all four experimental housing types, it become evident that the total construction costs substantially exceeded the available budget. Since housing type D was not in the line with the core ambition of the experiment of SCE project, being to explore potential of exiting building materials in new construction, SCE consortium decided to focus on testing the new techniques and circular construction methods of types A, B and C (Figure 4) and to exclude type D from this experiment.

Houses Type A (74m2) and Type B (74m2) are two bedroom houses and Houses Type (C) 54 m2 is one bedroom house. Houses will be built with 3D modules, concrete façade elements, doors, window frames, partitioning walls as well as re-formed cocreate as façade finishing and recycled concrete, all directly recovered from the 10-story building. Figure 5 illustrates house Type A and parts of the floorplan that will be constructed with reused materials and the parts of the floorplan that will be constructed with new materials. (Figure 5)



Insert Figure 5: Housing Type A and overview of recovered material to be used in construction

According to the study done by the University of Applied Science Zuyd (Zuyd) approximately 90% of materials used for Type A have been reused from the 10-story building and only 10% of materials are new materials.(Figure 6) (M.Ritzen at all. 2019) This ratio of new and reused material also reflects a ratio of the CO2 emissions that have been reused. When looking at the embodied energy 65% is embodied in reused materials and 35% is used for production of new materials as illustrated in figure 5.



Insert figure 6: Impacts and benefits related to the ratio between use of new and reused materials for the construction of house type A (M.Ritzen at all. 2019)

As mentioned in previous text, building products and materials that will be used for the construction of the three house types will be recovered on different levels of building decomposition and different deconstruction techniques will be applied. According to recently finalised EU H2020 BAMB project and its Reuse Potential Tool, Reuse potential is directly related to disassembly potential of building elements. Disassembly/reuse potential measures the effort needed to disassemble building parts without damaging the part itself and surrounding parts. The higher reuse potential the lower environmental and economic impacts. (Durmisevic 2019, BAMB 2020 Reversible Building Design

Protocol) Considering such definition which incorporates existing state of the art deconstruction methods, 3D unites recovered by cutting off concrete floor slabs would have lower reuse potential. High efforts needed to recover 3D units are associated with high costs and CO2 emissions.
This has been seen during environmental impact assessment of recovering concrete elements form 10-story building. “To re-use this element, about 18 MJ per m_1 cutting is needed, resulting in a total of approximately 1.5E02 MJ energy needed for removing the element. Having in mind the first pilot, it can be derived that removing the tunnel shaped concrete elements from existing housing block is rather complex, labour intensive (and thus expensive) and requires a considerable amount of energy to complete.”(M.Ritzen at all, 2019)

The perception of reuse potential of such recovery technique may change in the future due to the technological advancement and further development of CO2 tax policies on global and national level.

During the construction of three houses as a part of the SCE experiment different reuse options of concrete elements will be tested and evaluated. These tests will provide batter insides into potential and benefits of different deconstructing technics as well as different levels of building decomposition. This will help to support decision making when evaluating benefits of different reuse options in future.

3.1 Preliminary construction cost calculations

Insert Figure 7: House type A -first left, House type C -first right (SeC Architectecten 2019)

The contractor Jongen Bouw made preliminary cost calculations for the construction of three houses after receiving the building permit. At the moment, the costs related to the cutting off the tunnel shaped concrete elements in a form of 3D modules is not known (will be provided by the deconstruction company Dusseldorp) and has not been integrated into the cost calculations. There are also many assumptions that have been built into the cost estimate simply because the contractor does not know how much time and effort will go into the refurbishment of the existing building parts, but also how much tie and effort will go into the construction with existing elements and materials. The real costs will be known only after the full completion of the construction. Preliminary cost estimations have been made for house type A and house type C. House type A and B have similar footprint. (Figure 7)

<u>Type A : Total +/- 74m²</u>
Total costs exclusive VAT and recovery of exiting materials €214.392,-

Construction costs +/- €2.897,-/m² excluding VAT

<u>Type C: Total +/- 54m²</u>
Total costs exclusive VAT and recovery of exiting materials €176.908,-
Construction costs +/- €3.276,-/m² excluding VAT

3.2 Reference buildings

In order to understand financial impact of the experiment construction costs of two reference buildings developed by the same housing cooperation have been presented by the housing corporation HEEMwonen. (Figures 8)

Reference project 1	Reference project 2

CIty Landgraaf +/- 85m² Designed 2015 Constructed 2017 Construction costs €110.000 including VAT Construction costs +/- €1.294 / m² including VAT (Martijn Segers, 2019)	Haesenplein - 8 100m² (6x) – 115m²(2x) Designed 2016 Constructed 2018 (Construction costs per house €125.000,- incl. VAT Construction costs +/- 1.259 /m² including VAT (Martijn Segers, 2019)

Insert Figure 8: Left reference building 1, 85m2 constructed in 2017, right reference building 2, 100m² (6x) – 115m²(2x), constructed in 2018

4 CO2/Shadow costs within Super Circular Estate project

4.1 Carbon tax background

Concern over climate change has led to policies that put a price on carbon emissions using either a market-based emissions trading system (“cap and trade”) or a carbon tax, both of which can affect the operating cost. A well-known example of carbon pricing is the European Union cap-and-trade system.

A draft law for the Dutch carbon floor price was recently published, raising the carbon price to 43 euros by 2030. (Overheid, 2018) Once the draft law is adopted, the Netherlands would be the second country, following the UK’s example, to implement a minimum price on carbon pollution.

Although carbon prices have tripled under the EU’s Emissions Trading System (EU ETS), the current levels (€18[US$21]/tCO2) are still far below the prices that leading economists say are required to

meet the Paris climate goals (US$40-80 by 2020).
https://carbonmarketwatch.org/2018/08/21/netherlands-fits-its-new-price-floor/
The evolving policy environment creates uncertainty around the price for carbon, especially over the long lifetime of business operations. Shadow carbon pricing addresses this uncertainty by introducing a hypothetical price, or shadow price, as an input to the financial analysis.
In the Climate Change Action Plan, the World Bank committed to support the achievement of global climate change goals.
The High-Level Commission on Carbon Prices, led by Joseph Stiglitz and Nicholas Stern, concluded based on an extensive review that a range of US$40-80 per ton of CO_2e in 2020, rising to US$50-100 per ton of CO_2e by 2030, is consistent with achieving the core objective of the Paris Agreement of keeping temperature rise below 2 degrees, provided a supportive policy environment is in place. (High-Level Commission, 2017)

"Given that the High-Level Commission report does not prescribe any specific carbon price values beyond 2030, the low and high values on carbon prices are extrapolated from 2030 to 2050 using the same growth rate of 2.25% per year that is implicit between the 2020 and 2030, leading to values of US$78 and $156 by 2050. This is seen by World Bank experts on carbon pricing as conservative assumption reflecting a very optimistic forecast of early mitigation action and rapid cost decline of low-carbon technologies. "(World Bank 2017)

4.2 Shadow/ carbon costs in SCE project

According to the preliminary estimations made by Zuyd, based on the calculations of House Type A, embodied energy of this house type is 3.35E02 GJ while embodied carbon is 46,2 ton CO_2 out of which 41,2 ton CO_2 is related to reused CO_2 (thanks to reuse of exiting material) and 5 ton CO_2 is related to use of the materials. Based on proposed carbon pricing of Dutch Government of 43€/ton CO_2, shadow costs would be €1,986, -. If maximum World Bank pricing per ton of CO_2 by 2030 would be applied (150€/ton CO_2) than the shadow costs would be €6.930, -

If reuse of carbon within SCE project would be calculated as financial benefit, according to the potential carbon pricing development, the gap between construction costs of conventional house presented by Housing corporation HeemWonen and initial estimation of construction cost of House Type A (calculated by contractor Jongen Bouw) would still remain significantly high at +/- €1.500,-/ m².
This indicates that significant improvements of deconstruction technique are needed, but at the same time this emphasise the importance of adopting new design and construction strategies for new/ future circular buildings, a design strategy that will enable easy disassembly of building parts after their initial use. This will be important aspect to be considered during assembly of recovered products /materials into new SCE houses, and whether their structures will be configured with future reuse in mind. Ultimately the way materials and elements are assembled together will determent the value of the material bank in the future and future reuse potential and market value of building products.

5 Lessons Learned and future challenges

Figure 9: high value recovery of 3D unit to be used in new SCE house

In order to reach the goal, set up by the Super Circular Estate consortium and contribute to a sustainable, low carbon, resource efficient economy by creating high-quality and affordable housing based on breakthrough innovative material, the consortium is facing many challenges on a way.

Next development stage of the Super Circular Estate project will continue addressing many of these challenges. Lessons learned and challenges ahead are specified bellow:

- Prior to the Building Permit procedure, it was necessary to have consultations with Dutch Minister for Environment and discuss the nature of the experiment and potential exceptions with respect to the building procedure. This was related to the fact that technical and spatial characteristics of the building built in the 1970's does not comply to the Dutch building regulations today. It has been agreed that for the SCE experiment the new construction of three houses does not have to comply with building regulations for new construction, but for the regulations applied to reconstruction. Based on these consultations the municipality of Kerkrade has set up the protocol for the building permit procedure with relevant stakeholders and the building permit has been issued in February 2019.

- Due to the experimental character of the project, building permit documentation does not contain all necessary information that a regular project documentation should have, because of many unknowns. It has been agreed to finalise the documentation at the end of the realisation of the project.

- Besides different approach to regulations, demolition and construction process will also be different from conventional projects. Both demolition and construction will be happening simultaneously, and demolisher will in an interactive manner supply the building contractor with building materials. The demolisher will become the main supplier of building materials. The time and process needed to recover materials and hand them over to the contractor, in form and shape that is suitable for construction works, will be subject to future monitoring and explorations.

- In order to make preliminary cost calculations of construction, the contractor had to make many estimations which can be validated only during construction of three houses.

- Design of the three houses was preliminary focused on creating functional and comfortable housing while using existing materials. Lot of effort has been put into understanding the quality of the existing materials and structures and their potential applications in new construction. Considering the fact that circular building design and construction is about design for multiple use scenarios of materials and not for one use option, the reuse potential of materials that will be assembled in new houses will be looked at in order to investigate their potential for third life (Xth life). This would increase the total life cycle value of the materials and products.

- SCE as experimental project has many unknowns and one of them is also the time needed to finalise the physical construction. Partners who are involved with monitoring of their products and systems in operational stage will make efforts to develop monitoring strategy with the contractor and housing corporation during next developing stage.

- Considering the initial findings with respect to the financial and environmental costs and benefits related to the recovery of materials from the buildings that were not designed to be recovered and reused, as well as development of carbon pricing, there is an indication that if future buildings are designed in a way that will enable quick non-destructive disassembly of building products (eliminating complex processes on the deconstruction site) than the future circular buildings will have high potential to directly benefit from reused materials and carbon pricing.

CHALLENGES	LEVEL	OBSERVATIONS
1.Leadership for implementation		
	Low	SCE project continues to have strong coherent leadership. Leadership of SCE process is about continually stimulating partners to be innovative and to investigate options which are beyond the work as usual.
2.Public procurement		
	Low	Important procurement issues have been addressed already. Considering that approach and objectives of SCE have never been addressed or tested before, there is no established market and knowledge that can provide tailored solutions for the SCE project. A call for open innovation and collaboration has been put to the market in order to establish a pull of companies which are committed to innovation.

3.Integrated cross-departmental working

	Low	Urban authority managed to mobilise different departments which have created a strong commitment and understanding within organisation. This has resulted into relatively smooth building permit procedure without delays.

4.Adopting a participative approach

	Low	High levels of participation evident across stakeholder groups.

5. Monitoring and evaluation

	Medium	Monitoring and evaluation process of technical aspects is going on smoothly. This has been priority during the building permit procedure. Stapes have been made to define KPI for social circularity. Partners will finalise strategy for measuring the social impacts during the next project phase. The issue has been raised about the timing of finalisation of buildings and the time needed for monitoring during the operational stage. This has been seen as a challenge that will be addressed during next developing stages.

6. Communicating with target beneficiaries

	Low	The project communication team has consistent communication strategy around objectives and potentials behind the project. The progress and activities of the project have been promoted on the social media, websites, newspaper. This has created a positive image of the project. The project partners are organising frequent tour and presentation to the groups of professionals coming to the SCE site from all the Netherlands and Euregion. At the same time partners have been presenting the project on scientific conference and national events.

7. Upscaling

	High	The challenge related to the financial sustainability, broad applicability and high adoption level of the technology and tools being developed remains high . The project partners are focused on development of three types of houses now and assessment of their financial and environmental impacts. During realisation stage many issues related to the process and technological innovation will be tackled prior to investigating potential for the broader implementation of the technology and upscaling.

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