Circular approach for neighbourhood renovation

Construction material passports and databanks

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Abstract	What are the circular possibilities for materials and products available in the Griffiersveld pilot and how can this information be presented? Interviews with stakeholders have led to a list of requirements for the material passports and what information they should include. Existing and experimental material passports have been collected and analysed to see whether they meet the requirements. The construction materials on site are identified and circular possibilities of these materials are listed. Finally an advice is given for the municipality of Apeldoorn for a circular renovation approach.
Keywords	Material passport, circularity, stakeholders
License	

Contents

1. Introduction

Municipalities are becoming more aware of their environmental footprint. The construction and renovation of public spaces come with the transport and processing of large volumes of concrete, clay bricks and asphalt. We are in the transition towards a circular economy.

In the CityLoops project we propose the following composite definition for the circular economy, drawing on the work of different academics in the field (Bosch, 2015; Geissdoerfer et al., 2017; Kirchherr et al., 2017; Murray et al., 2017; Naustdalslid, 2014; Ness and Xing, 2017; Thomas and Birat, 2013; Van Buren et al., 2016):

The Circular Economy is a regenerative system in which resource input, waste and emissions are minimised by slowing, closing, and narrowing material loops. This can be achieved by cooperative approaches, reuse, adaptation, resource stewardship, stock management, sharing, and other new business models that foster longevity, renewability, refurbishment, capacity sharing, dematerialisation and recycling and are induced by multi-stakeholder and multi-sectoral collaboration with the ultimate aim to increase resilience and maximize ecosystem functioning and human well-being.

In order to facilitate renovation of public spaces in the Circular Economy (circular renovation), information about the construction materials on site is needed. The problem is that little information is available about the road construction materials on site.

The H2020 Cityloops project aims to develop a circular approach for neighbourhood renovation. The neighbourhood Griffiersveld in the city of Apeldoorn was chosen as a pilot location for circular renovation. This research aims to find out what information is needed from the materials on site in Griffiersveld. This in order to make a decision what to do with these materials, for example: leave them as they are, enhance, reuse or recycle them. Secondly, a suggestion is provided on how to store these data. At the start of this research the assumption is made that material passports would be useful for this.

The scope of the project is the public space located between the private properties at each side of the road. Relatively small elements, like street furniture and elements in the underground, e.g. soil and pipes, will not be part of this particular research project.

The structure of this report follows the research approach used. Interviews with stakeholders have led to a list of requirements for the material passports and what information needs to be included. Existing and experimental material passports were collected and analysed to see whether they can meet the requirements. The construction materials on site were identified and circular possibilities for these materials, in terms of lifetime extension, reuse and recycling, for these materials have been listed. Finally, an advice is given to the municipality of Apeldoorn for a circular renovation approach. The findings from this pilot and the exploration of the use of a material passport can contribute to a circular approach for renovating other neighbourhoods, also outside the municipality of Apeldoorn.

2. Research setup

This research aims to answer the main research question:

What are the circular possibilities for materials and products available in the Griffiersveld area?

It is necessary to find out what information about the materials is needed, in order to decide what their circular possibilities are. Secondly, a suggestion is provided on how to present this information, in order to enhance decision making. Therefore, the following research questions were defined:

1. Who are the stakeholders in the renovation process?
2. What information do the stakeholders need for circular renovation decision making?
3. How can this material information be presented?
4. What material information is already available?
5. What are examples of circular renovation in road construction?

To answer these research questions, the following steps were executed:

Step1: List of Requirements

The first step was to find out who are the stakeholders in the renovation process and what their requirements for a material passport are. To do so, the management and maintenance department from the municipality of Apeldoorn was interviewed. The renovation process is explained and stakeholders within the renovation process were contacted and interviewed following a Questionnaire (Appendix A).The interviews were conducted by video calls (TEAMS) or by phone and were recorded when permitted. Notes have been made during the interviews and afterwards. In total, eight people were interviewed. An overview of their function and years of work experience is provided here:

- project manager construction demolition waste, 18 years;
- subsidy advisor, 16 years;
- management and maintenance roads and civil engineering works, 19 years;
- director of engineering, 14 years;
- R&D manager road contractor, 20 years;
- environment specialist road contractor, 10 years;
- team manager and road inspection, 20 years;
- project mentor (‘begeleider’ in Dutch) circularity and product development recycling, 8 years.

Their answers were clustered and used to answer the following research questions:

1. Who are the stakeholders in the renovation process?

2. What information do the stakeholders need for circular renovation decision making?

The result is an overview of stakeholders in the renovation process and a list of requirements for a material passport.

Step2: Inventory databases

The second step was to find out how required information can be stored and presented. By desk research and a literature study, available material passports and databases were identified. Articles and webpages about material passports, sustainability measurement and circularity measurement were read, supplemented by suggestions from the respondents.

3. How can this material information be presented?

The result is an overview of material passports which (partly) meet the requirements from the stakeholders.

Step3: Inventory material and products on site

In order to know what information is already known, an inventory of the materials and products on site is made. This is done by a student group, together with an employee who is responsible for the "grey part" of the entire district of De Maten, where Griffiersveld is part of.

4. What material information is already available?

The result is a table with available material information from the pilot location.

Step 4: Inventory circular possibilities

In this step an inventory is made of circular possibilities for materials and products in the Griffiersveld area. Circular possibilities are suggestions on what to do with materials on site, according to a circular cascading.

This is done by literature research, best practices found via web search and analysing the interviews.

5. What are examples of circular renovation in road construction?

The result is an overview of circular possibilities for materials and products on site at the Griffiersveld.

Step 5: Create a circular approach for neighbourhood renovation

The data from the previous steps is combined into a proposal for a circular neighbourhood renovation approach. Recommendations are made in how to proceed. This shows what the circular possibilities for materials and products available in the Griffiersveld area are. In addition, guidelines are given for circular renovation in general.

3. List of requirements

To develop an approach for circular renovation of neighborhoods with the use of a material passport, information is needed from who are involved in the renovation process. Therefore an interview has been prepared with a questionnaire. The first part is about the current situation of renovation, the second about the ideal situation of renovation in with a view to circularity. The questionnaire can be found in Appendix A.

First, the municipality of Apeldoorn is interviewed because they are the client. In order to get to know their demands for the material passport, a questionnaire is prepared. Via the project manager of the municipality, other users within and outside the municipality have been identified: management and maintenance (roads and works of art, landscaping, traffic regulation installations, sewage systems), the engineering department, contractors and road inspectors. Also material suppliers and waste management/recyclers are questioned.

Stakeholders renovation process

Stakeholders in the renovation process, and therefore users of the material passport according to the respondents include:

- management and maintenance departments of municipalities or Public space or real estate and land departments at municipalities;
- neighborhood directors (in Dutch “wijkregisseur”);
- engineering departments of municipalities or external engineering agencies;
- contractors;
- road inspectors;
- data specialists;
- recycling companies.

Note: inhabitants are also stakeholders but out of the scope of this research.

List of requirements

The respondents were asked how a material passport would look ideally and what it would be able to do. Based on the interviews, requirements for the material passport are clustered and filtered:

Costs

1. the economic viability to reuse materials is expressed in money;
2. the costs of the material passport (labor intensity, system costs). It must be manageable in terms of administrative workload;

Definitions

3. it offers criteria and definitions for circularity;
4. generally agreed (data driven) life spans, 'now basically free to fill in a life span;

Organization

5. It combines / connects revitalizing and maintenance;
6. most to all data is accessible in one application;
7. preferably combined with GBI software (Maintenance system from Antea Group used by the municipality of Apeldoorn, not used as material passport at the time), https://gbibeheersysteem.nl/ (25-11-2020)
8. forms an uniform system (data stored for structured output).
9. level of detail to know what to do with it after use, the company that is going to harvest the materials, should have sufficient information to estimate the value and is able, and knows where and how, to use it again.

Decision making based on:

10. flexibility regarding future developments is a pre (think 40-50 years ahead);
11. environmental data: uses LCA data (for instance Environmental Costs Indicator) MKI for comparison;
12. transport is taken into account (preference for local);
13. data driven decision making;
14. the passport uses rule of thumbs, which are practice based, instead of complex (theoretical) calculation models;
15. inspection and maintenance history of the materials on site (ideally inspect more often when end of life approaches in order to repair at the right moment);

Material specific:

16. for concrete bricks: pressure test data is needed to know the quality of the material;
17. for concrete bricks: top layer or solid stone. Solid stones can be reused by turning them around. For top layer stones this is not the case, since the base is of less material quality.
18. for asphalt: construction, layer thickness, bearing capacity, tar (yes or no) (Drill core data) is needed;

Generic:

19. includes a bill of materials (BOM) with quantities, material composition, and location (GIS) of the materials on site;
20. includes technical lifetime expectancy of materials on site;

21. includes ‘end of life options’ of the materials. The information needed differs per material stream. (f.e. Asphalt, processing conditions are relevant, for clay clinkers not);
22. Come up with a front runner approach (koploper aanpak https://www.magazinesrijkswaterstaat.nl/ 12-3-2021) to reward circular innovation. Nowadays projects are often too little in time and size in order to make real steps in the transition.

In short the material passport must include information on what material is located where, maintenance history, the expected lifespan and end of life possibilities together with (eco)costs. Next to this it must not become too much of an administration burden.

Besides the functional aspects of a material passport, financial costs were mentioned. Specifically the way renovation and construction is organized in a project structure at the time. It’s hard for contractors to compete with innovations and new ways of working, when asked to do so for the lowest price possible. In case of asphalt, an asphalt production facility produces for example 200.000 ton (interview road contractor) of asphalt annually. Such a facility cannot be altered for one renovation or construction project, because of the limited amount of asphalt needed and the fact the price per kg will be rising. From the contractor perspective there is a need for a commonly approach in how to deal with road construction and maintenance.

For checking whether existing material databases or circularity methods are applicable for the municipality, a top 5 list of requirements has been made:

The material passport:

1) includes a bill of materials (BOM) with quantities, material composition, and location (GIS) of the materials on site;
2) includes inspection and maintenance history of the materials on site (ideally inspect more often when end of life approaches in order to repair at the right moment);
3) includes technical lifetime expectancy of materials on site;
4) includes ‘end of life options’ of the materials. The information needed differs per material stream. (f.e. Asphalt, processing conditions are relevant, for clay clinkers not);
5) forms an uniform system (data stored for structured output).

4. Inventory material passports and databases

After the requirements for a material passport were collected, this section provides an overview of material databases . There are many material passports, databases and methods available or currently being developed. This underlines the importance and demand for a material passport in a circular economy, or in any case information about the materials.

The material passports were found by literature- and desk research or were mentioned during the interviews. Search terms used on the internet were: “materialenpaspoort” and “material passport”. This inventory gives a short description, additional information can be found via the links and in in the Appendix. The following databases were identified:

Material passports

- **BREEAM** stands for Building Research Establishment Environmental Assessment Method and is the certification method for a sustainable built environment. With this method, projects (buildings and areas) can be assessed on integral sustainability. Part of the assessment is the inventory of materials. (https://www.breeam.nl 14-10-2020)
- **Circularity passport®** is a passport based on Cradle to Cradle from EPEA. This combines material information with a score on circularity. (https://epea.com 14-10-2020)
- **Cirdax** is a material management system developed by Reuse Materials. A material passport is part of this system. (https://www.cirdax.com/ 14-10-2020)
- **Grondstoffenpaspoort** is a material passport developed by Dutch network operators for their suppliers. (https://www.enexisgroep.nl 14-10-2020)
- **Madaster** is a cadastre for materials. (https://www.madaster.com 14-10-2020)
- **Materials Passport Platform** is a prototype materials passport from the Building as material banks (BAMB 2020) project. (https://www.bamb2020.eu 14-10-2020)
- **Obsurv** is municipality management software from SWECO. The module ‘overige objecten’ is used as a material passport. https://obsurv.nl/ (25-2-2021)

Besides material passports, there is also looked into material information databases, used material marketplaces and methods for assessing circularity. An overview is given in Appendix B.

The material passports from this inventory are assessed using the top five requirements in Table 1. Basically, material passports share the same objective, namely quantifying and qualifying the materials on site. However, they differ in the level of detail and number of aspects taken into account. There are services which are supervised by consultancy agencies, such as BREEAM, EPEA and Madaster. Advantage is that the results are comparable with other users of the system, the municipality will be supported and information can be exchanged and

compared. The downfall are the costs and the need for an extra system / platform which need to be integrated in the existing organization and infrastructure.

Table 1 An overview of material passports and requirements

	Bill of materials	Inspection and maintenance history	Expected lifespan	End of life possibilities	Structured data	Comments
Material passports						
BREEAM	x	?	?	?	x	Suitable for area level. Integral approach (also health and wellbeing, energy). Too broad?
Circularity Passport®	x			x	x	Product configuration, disassembly steps and recycling potential.
Cirdax	x	x	x	x	x	CO_2 calculator, material inventory app
Grondstoffen paspoort	x			x	x	Dedicated to telecom suppliers
Madaster	x	?	x	x	x	Payment required to add or extract information.
Materials Passport platform prototype	x			x	x	material safety datasheet (MSDS), environmental product declaration (EPD) and technical datasheets can be added.
Obsurv	x	x	?	?	x	Developed by municipalities
x = meets requirement ? = unknown						

There is not a standard yet, but it's possible to learn from the available passports and circularity assessing tools. Material passports exist which are designed by the users themselves, such as the Grondstoffenpaspoort from the Dutch Network operators and the passport in the Obsurv software from SWECO. It's advised to "start and learn in the process" (Huitema, et al. (2017) "*Bouwmaterialen hoogwaardig hergebruiken* [podcast]).

4.1. Selected material passports

Three material passports are highlighted below, since they cover most aspects from the list of requirements as shown in Table 1. This makes them usable for the Griffiersveld pilot.

1. CIRDAX, besides this one is still in development based on the current demand.
2. Circularity passport from EPEA, it contains dismantling possibilities and EPEA is the leading agency on Cradle to Cradle, the basic of the circular economy.
3. OBSURV material passport, already used by a municipality and integrated in the management and maintenance software.

In the next chapter they are described more in detail and in Section 7 an advice is given about the usability for the municipality of Apeldoorn.

4.1.1. Cirdax

Cirdax contains multiple tools, from which a material passport is one. The material passport includes amongst others: quantity, quality, dimensions, colour, recyclability and disassembly options. It is developed by Re Use Materials: https://www.reusematerials.nl (25-11-2020). An overview of the tools is shown in Figure *1*. There is an inventory app, the inventory of materials can be outsourced to Cirdax as well. Other useful aspects are the CO_2 balance calculator, material marketplace, management and maintenance and lifecycle manager. There will be overlap with the already existing organisation of management and maintenance in the municipality.

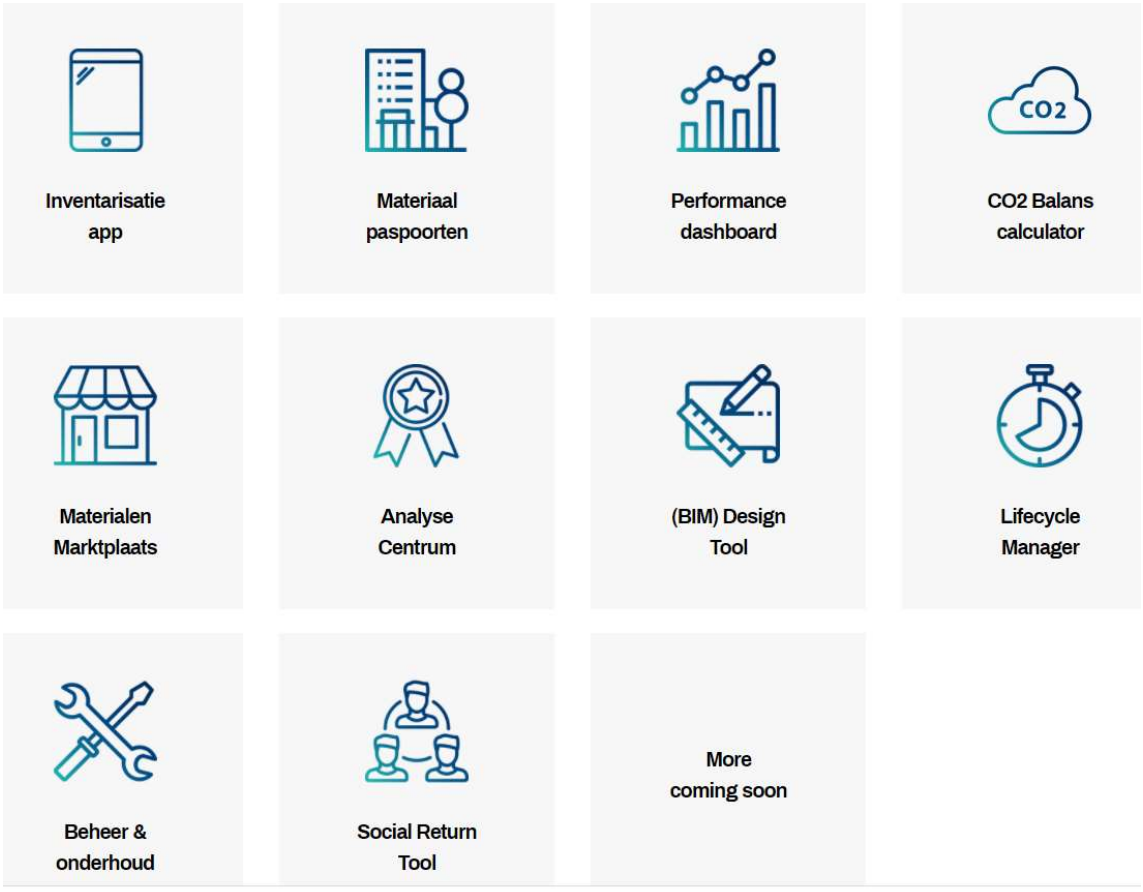


Figure 1 An overview of tools in Cirdax (https://www.cirdax.com 25-11-2020)

4.1.2. Circularity passport from EPEA

EPEA has developed circularity passports on product, building and area level. Since EPEA GmbH was founded in 1987 in Hamburg by Prof. Michael Braungart, it has developed into an international innovation partner for environmentally friendly products, processes, buildings and urban districts (https://epea.com 10-3-2021).

The building circularity passport contains an estimated financial value on the total of materials and has a circularity index in percentages. It includes the number of evaluated components, materials, products and the total floor area in m^2 and total mass in kg. The circularity is based on six circularity values as shown in Figure 2.

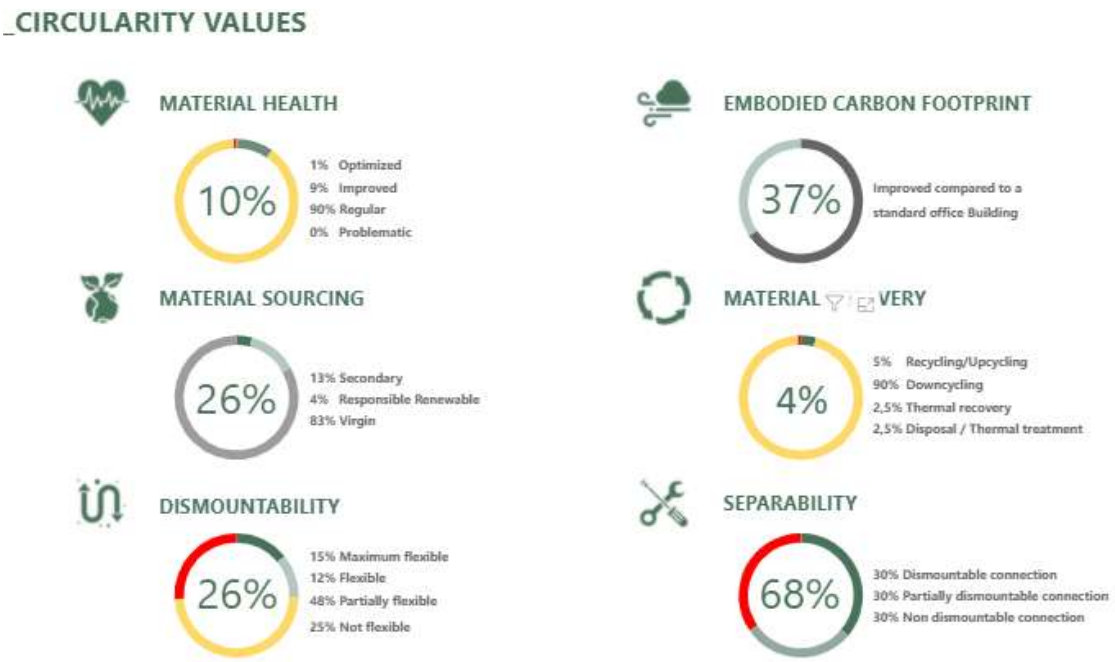


Figure 2 Circularity values from Building Circularity passport® (https://epea.com/nl/onze-diensten/gebouwen)

Material health, and therefore toxicity, are important to add. Dismountability refers to if components can be dismounted and reused as a whole. Separability is the possibility to separate materials in a mono material stream. Material recovery reflects on if mono-stream materials can be recycled and to what extent.

4.1.3. Obsurv material passport

This material passport is a pilot project from Sweco (architectural and engineering office, developer of Obsurv management system) in cooperation with municipalities from Rotterdam, Tilburg and Zwolle. Starting point was the maintenance and management department of the municipality, since most information on the public space is stored and managed there. They used the module 'other objects' to add material information to the roads in their existing system.

It now includes, location, dimensions, type of asphalt top layer, the number of layers and their thickness. The date of production is added and the name of the contractor.

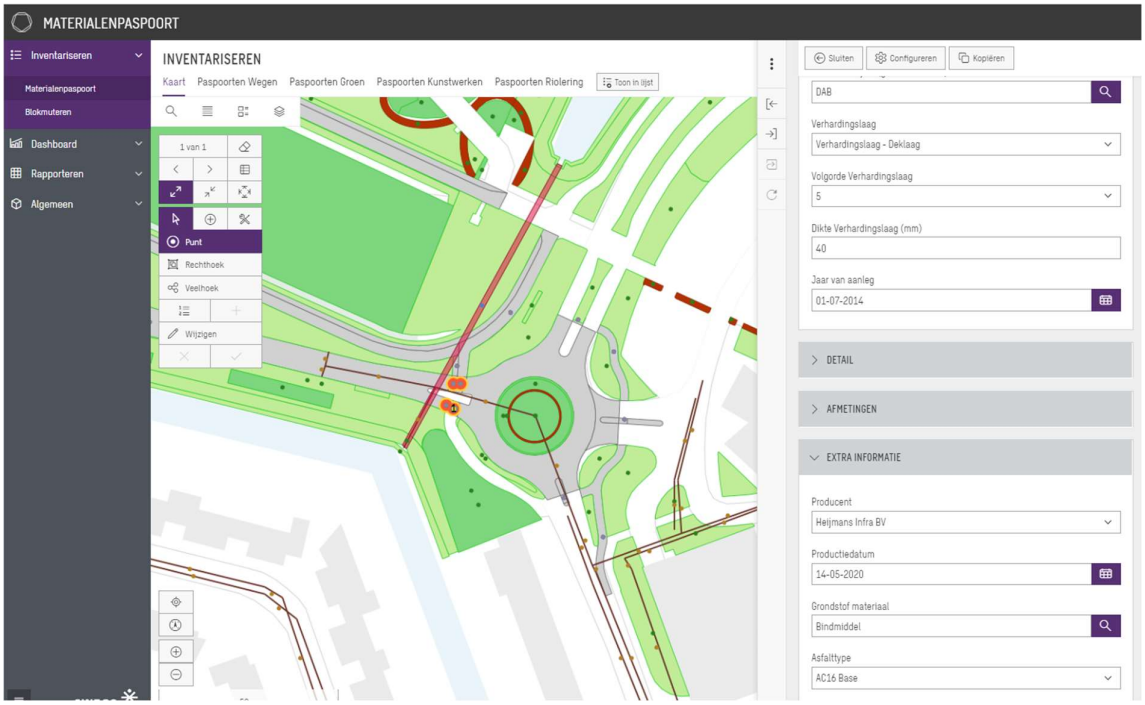


Figure 3 Screenhot materials passport in 'overige objecten' module (https://obsurv.nl/ 9-3-2021)

5. Inventory of onsite materials and products

As stated in the introduction (Section 1), the pilot location for a circular renovation is the Griffiersveld area in the city of Apeldoorn. In Figure 4 this area is marked with a red dot.

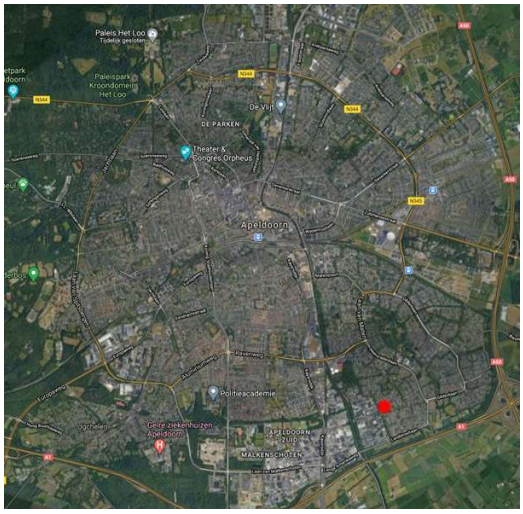


Figure 4 City of Apeldoorn, red dot is the location of the Griffiersveld area (Google Maps)

The scope of this project is public space. Therefore, an inventory was made of the products available to the public in Griffiersveld by a group of students during their Smart Solutions Semester (Poutainen, Willoughby & Otten, 2020). This is a multidisciplinary research semester at Saxion University of Applied Sciences.

In general there is a pavement, street furniture and pipes infrastructure (gas, electric, drain, water) underneath ground level, and there is the public green with trees. Street furniture and below ground infrastructure are out of the scope of this research.

The Griffiersveld area was constructed around 1977 and most horizontal surfaces (4540 m^2 in total) consist of concrete: 3690 m^2 of pavement using concrete tiles and 850 m^2 of pavement made of concrete bricks. The concrete bricks have the following dimensions: 105 mm x 210 mm x 80 mm. The concrete tiles are 300 mm x 300 mm x 65 mm. Concrete tiles come is a variety in thickness ranging from 40 – 80mm. (https://www.morssinkhof-groep.nl , 10-3-2021). The higher the traffic pressure, the thicker the tile.

For parking spaces there is some variation in colour, for instance by marking parking lots and repairs done with bricks coloured differently. There are also some ‘specialities’, like the one with P for parking.

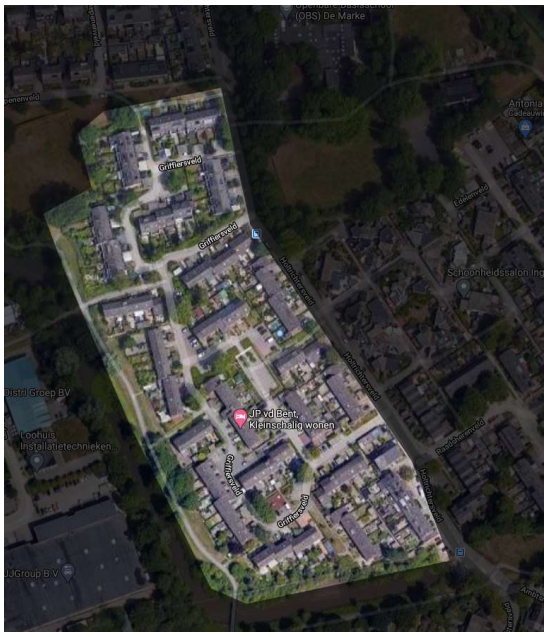


Figure 5 Griffiersveld area highlighted (Google Maps)

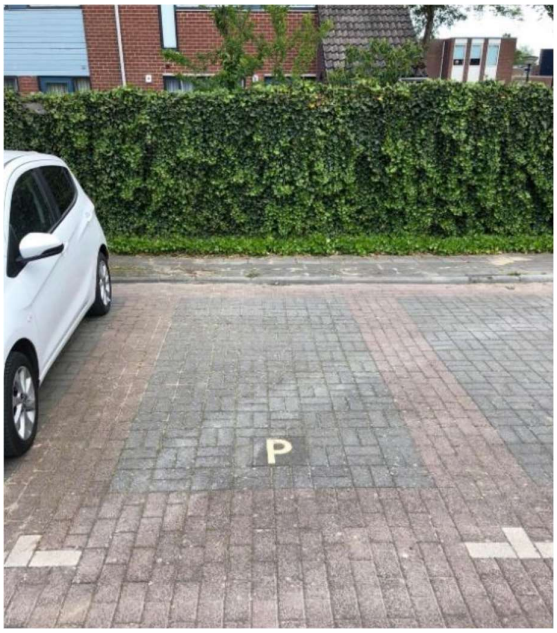


Figure 6 'special' stones in terms of colour or print

Figure 7 Concrete elements as border separation (Google streetview)

Next to the concrete material there is an asphalt bicycle path in the Griffiersveld area. The asphalt area is approximately 128 m^2 with a density on average of 2500 kg/m^3 (Poutainen, Willoughby, Otten, 2020). All in all there are concrete tiles, concrete bricks and some asphalt. Furthermore there is green, and some specials like the border separations, the P sign tiles and the repairs made with newer stones.

More detailed information about the materials on site is lacking at this time. For the concrete bricks and tiles it is important to know whether they are top layered or solid products. To gain information on the quality of the concrete, a pressure test is advised (interview project mentor recycling company). For the specific composition of the asphalt, drill core research needs to be performed.

6. Inventory circular opportunities

There are several possibilities for products to fit in a circular economy. Out of the interviews and articles read, several circular possibilities have been found for the (product)materials in the public space. Firstly, general guidelines will be provided. Secondly, per material category in road construction (concrete, asphalt and baked clay) specific circular possibilities are listed.

6.1. General guidelines

As a general guideline there is the waste hierarchy, named 'Ladder of Lansink' as shown in Figure 8. It can be stated that the highest level within this scheme, preventing using new resources and therefore preventing of having waste in the first place, is the most circular. The lowest level is the dumping of waste.

Figure 8 'Ladder of Lansink' (http://www.recycling.nl/ladder-van-lansink.html, 10-3-2021)

A more comprehensive model is the so called Butterfly diagram (Figure 9) from the Ellen MacArthur foundation (https://www.ellenmacarthurfoundation.org 10-3-2021), based on the Cradle to Cradle principle waste equals food (https://epea.com 10-3-2021). It shows a biological material loop (left, green side) and a technical material loop (right, blue). In the loops on the right side, the levels of 'Ladder of Lansink' can be seen: prevention by longer use and maintenance, reuse by redistribute, refurbish as an extra level, and recycle. At the bottom of the diagram incineration with energy recovery and landfill can be found. The left side shows the biological loop with biodegrading and composting.

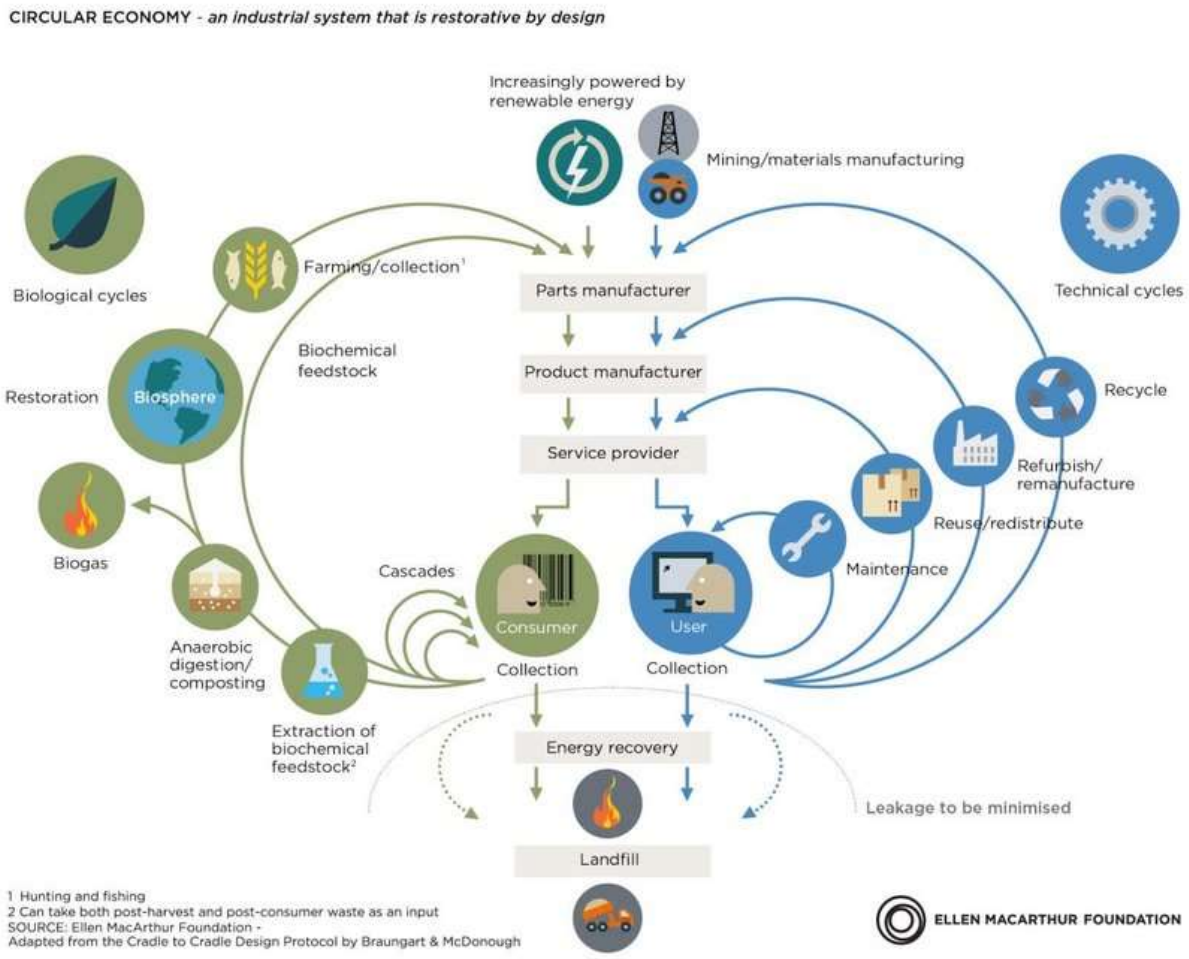


Figure 9 'Butterfly diagram' from the Ellen MacArthur Foundation (https://kenniskaarten.hetgroenebrein.nl , 10-3-2021)

Then there is the 10R model (Cramer, 2014) in Figure 10, which is a more detailed version of the Ladder of Lansink. Again, the higher in this model, the more circular the chosen solution is. The rule of thumb is: more circularity = les use off resources and less environmental impact.

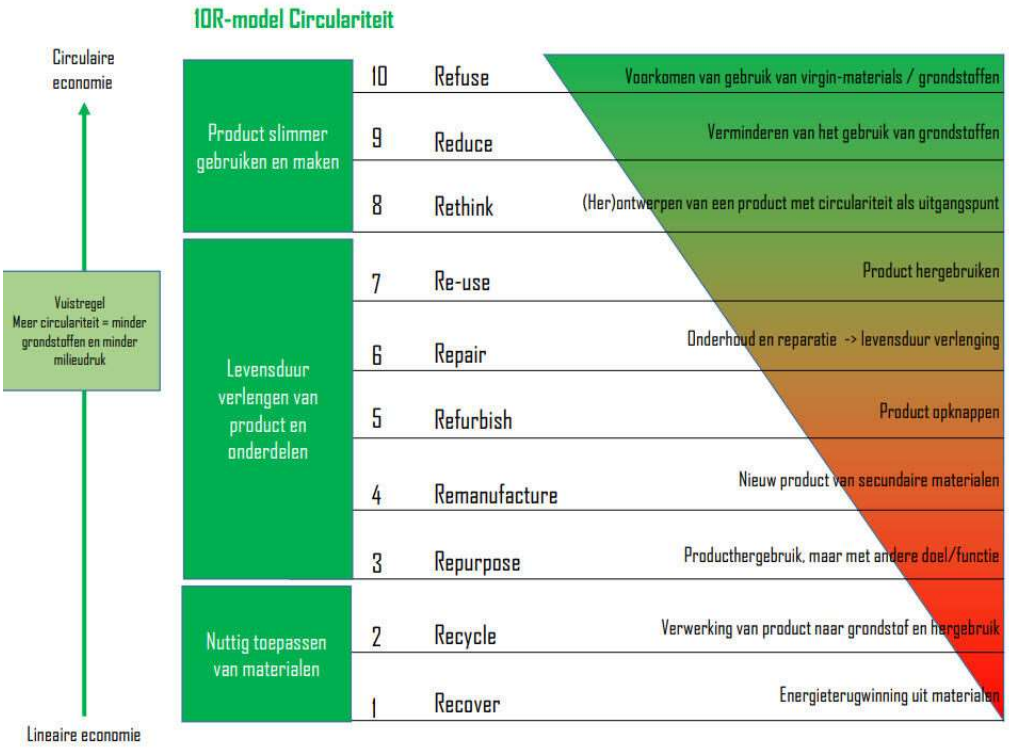


Figure 10 10R-model from Cramer - Utrecht Sustainability Institute (https://platformcb23.nl (25-2-2021))

Supplementary to the 10R model, the Material Circularity Indicator (MCI) from the Ellen MacArthur Foundation (as shown in Figure 11) is a tool for quantifying circularity. This substantiates the 10R model. If products, in this case paving products, are reused instead of recycled, products score higher in terms of circularity. It is basically a mass balance, in which life time extension, reusing and recycling are valued in this order. A screenshot of the tool input is shown in Figure 12. The input is divided into the feedstock and (expected) destination after use and the (expected) lifespan. An outcome of 1 is fully circular, an outcome of 0,1 is completely linear and an outcome of <0,1 is near linear since the product will have less utility than an industry average product.

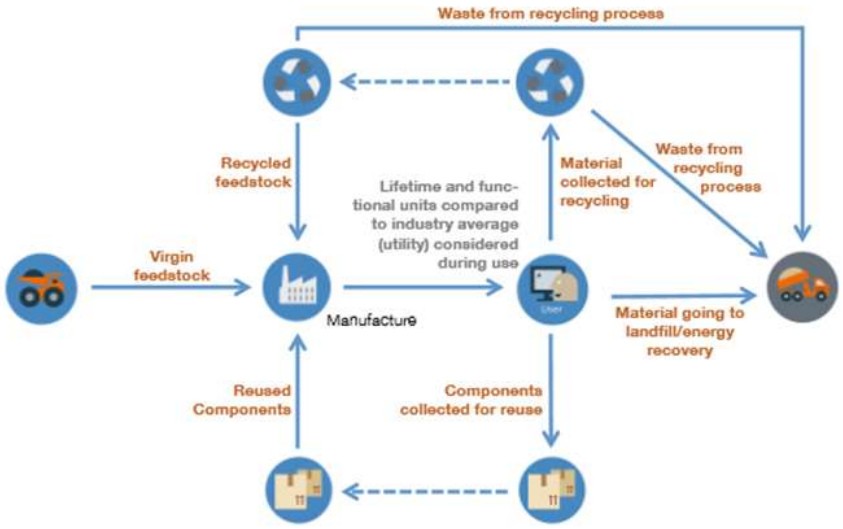


Figure 11 Material Circularity Indicator (MCI) Ellen MacArthur Foundation, (https://www.thinkstep-anz.com, 10-3-2021)

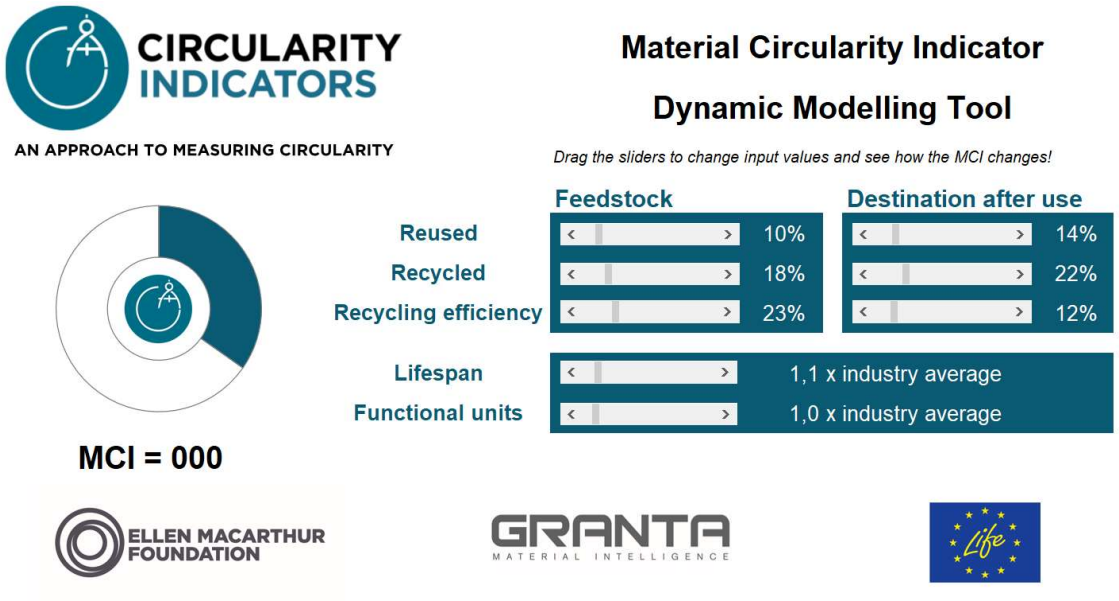


Figure 12 Material Circularity Indicator Dynamic Modelling Tool (Tuppen, 2014) (screenshot from Circularity-Indicators_MCI-Product-Level-Dynamic-Modelling-Tool_May2015)

The MCI 'simplifies' the levels of circularity to Reduce, Reuse, Recycle and Waste (Energy Recover). The NEN-EN 15804 "Sustainability of construction works - Environmental product declarations - Core rules for the product category of construction products" standard (https://www.nen.nl/, 30-3-2021) uses an input and output indicator. The input indicator is the use of secondary materials (kg) and output indicator components for re-use (kg) and materials for recycling (kg).

For buildings (BAMB project) the circular potentials for re-use are categorized in a more detailed manner (https://vimeo.com/23890974114-10-2020). Translated to the road construction the levels of circularity are:

- Re-installable for same use in the same road/location
- Reused “as is” in another product
- Extracted & reused in other road/location
- Extracted and refurbished or remanufactured, then reused
- Designed for recycling
- Designed for composting

The cascading of circular options differs in the level of detail. In general the cascading: refuse, reuse, refurbish, recycle might already suffice in practice. If a more detailed cascading is preferred, the following circular cascading is advised:

1. Refuse (do not intervene, extend lifetime)
    a. Clean
2. Partially renovate
    a. Redo bad street work
    b. Repair asphalt
3. Reuse
    a. On site (same road)
    b. Nearby road
    c. On site different function
    d. Nearby different function
4. Refurbish (for instance new top layer)
5. Recycle
    a. Material onsite, same application
    b. Nearby material, same application
    c. Different application
6. Recover (by products from waste incineration plants)

Ideally, besides the amount of reused and recycled material, many more aspects such as financial costs, CO_2 footprint, energy consumption, water usage, toxicity, acidification, maintenance, construction time and transport are taken into account to make a considered decision. When more insight in the environmental aspects of multiple options is requested, a quick scan Life Cycle Analysis (quick scan LCA) is advised. Since MKI (‘Environmental cost indicator’), the environmental impact expressed in Euro’s / societal costs, is used more and more in construction (https://www.pianoo.nl 10-3-2021) it is advised to use MKI as well.

6.2. Circular options road construction

In this section circular options per material category (casted concrete, asphalt and elements (baked clay and concrete) are described, structured by Reduce, Reuse, Recycle, Recover. Casted concrete and baked clay is not onsite in the Griffiersveld area, but included for a better overview of the most commonly used road construction materials.

Since there is no data available for all the presented options, no quick scan Lifecycle Analysis (LCA's) are performed. In general the reused material have zero environmental impact in an LCA, besides the impact of the effort it takes to extract and transport them. As a rule of thumb, this environmental impact is less than the production of new materials.

6.2.1. Casted concrete slabs and roads

In this section circular possibilities for casted concrete slabs and roads are made. These are not known in the Griffiersveld area, but are present in the municipality of Apeldoorn.

Reduce

- Maximize the lifespan (on average 40 years) by replacing the road not too soon, based on inspection reports (interview);
- For new projects: look into geopolymer concrete or cementless concrete (https://bioclearearth.nl/, https://beton-lab.com (25-2-2021).

Reuse

- Reuse sawed road parts as:
  - Benches
  - Wells for water storage
  - Borders
  - Planters
  - Root barriers

Recycle

- Make new concrete with a percentage recycled concrete granulate from previous cycling roads. Same application. (example from out the Municipality Apeldoorn) https://www.ajansenbv.com (25-2-2021)
- Make new concrete with recycled concrete material out of other applications to replace new sand and gravel (20% of total) > Schagen Infra and concrete supplier Bruil (example in Municipality Apeldoorn) https://www.circonl.nl (25-2-2021)
- SilensTONE, a top layer stone with reclaimed concrete material in the base, with an additional sound reduction benefit. https://www.dehamer.nl (25-2-2021)

6.2.2. Asphalt roads

Asphalt is a layered product. There is a variety in top layers: ZOAB, DAB, SMA and DGD. So the type of asphalt, and the thickness of the layers is important to know. If this information is not known, drill core measurements can be made. When the contractor who made the road is known, information about the composition of the asphalt can be received from them. Note that this is a risk when the information was not well documented. Due to legislation it is not allowed to reuse asphalt with tar in it. If so, this needs to be thermally cleaned form tar before processing it in a road again (recover).

There are calculation methods for Environmental costs for road constructions, the 'Milieuprestatie Gebouwen en GWW-werken'. Since they can be interpreted in several ways, additional rules are added: Product Category Rules (PCR) Asphalt with NEN-EN 15804 as a base https://www.asfaltblij.nl/ (25-2-2021).

Reduce

- Extend the lifetime by replacing the road not too soon (repair first). On average an asphalt road last 15-20 years (depending on traffic pressure and weather conditions)
- Repair the asphalt:
  - American road patch http://www.americanroadpatch.com/ (25-2-2021)
  - Gerhard Herbers road repair: https://www.gerhard-herbers-gmbh.de/ (25-2-2021)
- Apply 'self-healing' asphalt which reduces maintenance in the future. Note, can this be recycled end of life? (https://www.self-healingmaterials.com 21-03-2021)

Reuse

Leave the asphalt as is and make a new top layer from plastic fibers reinforced concrete on it. By adding fibers the concrete layer thickness is reduced from 20 mm to 12 mm. https://www.circonl.nl(25-2-2021)

Note 1, can this be recycled end of life? The will be mixture on the interface of asphalt with concrete where they attach.

Note 2, can the concrete and plastic be separated once again?

Recycle

- It's possible to recycle, but there is little data available yet on the life span of the recycled layers out in the field. Use reclaimed asphalt (RA) only when contractor has his processes under control and preferably uses ASPARI. (interview contractor)
- Ecofalt: asphalt with construction demolition waste and processed at low temperature.

Recover

Check whether there is tar in it, so called TAG (Tar Asphalt Granulate). If so, thermal recycling is an option. (https://www.ajansenbv.com/ (25-2-2021)

6.2.3. Elements

This section describes the options for elements (bricks, tiles) made out of baked clay or concrete.

- **Baked clay elements** *(note these are not onsite at the Griffiersveld area at the time)*

Reuse

- Partial renovation: leave the technical good parts, for instance parking spaces, as is;

Baked clay elements have a very long lifespan comparing to asphalt and concrete. The lifespan on average is 135 year (95 - 190 year, examples of 250 year). This makes them very suitable to reuse, therefore 80-90% is reused (https://www.vandersanden.com/ and https://www.knb-keramiek.nl/ , 25-2-2021)

Their value increases over time because of the aged/nostalgic aesthetics. There is a trade in used stones. (Interview recycler and http://project.stonebase.nl/ 25-2-2021)

Recycle and Recover

Small or broken elements are crushed for underlayers of street work. This is considered as downcycling since this is not the function it is intended to fulfill.

- **Concrete elements**

Important is to determine whether the elements have a top layer or are solid (Dutch: ‘door en door’). Solid concrete elements can be turned upside down for reuse, top layer stones cannot since the underlay is of less quality concrete.

Reuse

- Renew the street with the same stones (clean or turn). It is advise to use a fishbone pattern, since this pattern is extra strong comparing to a brickwork pattern, which reduces the chance on repairments needed. The lack of stones, since some of them might be broken) can be covered by increasing the space between the tiles. Additional benefit is the dewatering: the water has more space to infiltrate in the soil. The space in between can be filled with slow growing succulents.
- Traffic pressure can be used as a criteria for the quality of (reused) stones. Since parking spaces endure less traffic, stones with less quality can be used for parking spaces. The possible difference in color and appearance in comparison to the street emphasize the different functions. Other applications for reusing stones with a low expected lifespan are silage pavement and temporary/emergency paving.

- Reuse on site with a different function: border, planter or foundation. An example of the municipality of Rotterdam is based on three pillars: Technical quality, practicality and aesthetic permissibility https://www.cirkelstad.nl/ (25-2-2021)

Recycle

- Use recycled concrete in the production of new top layer elements. C2C silver certified concrete clinkers (top layer) Exclunatura Basic with recycled content https://excluton.nl/ (25-2-2021).
- Tiles with 76% recycled content: https://studiowae.nl/ (25-2-2021). This can be used if a new look is wished. Note: transport distances not taken into account yet.
- Dualton concrete elements: minimal 15% recycled content (ash or recycled concrete). With CO_2 bonding olivine https://www.morssinkhof-groep.nl/ (25-2-2021).
- Other applications for concrete granulates: aggregate for asphalt, temporary road surfacing, water buffering, drainage, dikes construction, street sand (the finer fraction). https://webdog.brbs.nl/ (25-2-2021)
- Parking space with herbs and dewatering https://www.morssinkhof-gww-beton.nl/ (25-2-2021).
- Quality requirements for concrete (2R): In general, max 5% contamination. (by weight, or volume) BRL 2506.

Recover

- Example of tiles with recycled waste in it https://www.renewi.com (25-2-2021).

7. Material passport

In this section the structure for a material passport is suggested. As stated in Section 3, the top five requirements for a material passport are:

1. Includes bill of materials (BOM) with quantities, material composition, and location (GIS) of the materials on site.

Since the location of products in the public space is already well documented in the GBI system with GIS (geographic information system), it's advised to extend these products with material information (Table 2 and

- Table 3). For concrete elements and asphalt paving different information is required.

2. Includes inspection and maintenance history of the materials on site (ideally inspect more often when end of life approaches in order to repair at the right moment)
   - Add visual inspection reports and measurements to the GBI system.
   - Identify similar locations in terms of materials and traffic pressure to create practice based data on life span.
3. Includes technical lifetime expectancy of materials on site
   - Production date
   - Life time expectancy from manufacturer, adjusted with information from the field (rule of thumb) and inspection and maintenance history
   - The difference of the above and the current date is the expected lifespan.
4. Includes 'End of life options' of the materials. The information needed differs per material stream. (f.e. Asphalt, processing conditions are relevant, for clay clinkers not)
   - To keep the number of possibilities manageable, it's suggested to use a 3R (refuse, reuse, recycle) or a 5R model (Refuse, reuse, remanufacture, recycle, recover). To review renovation options it's advised to analyze with MCI and MKI (incl. transport).
5. Uniform system (data stored for structured output)
   - The what is more important than the how. Most important is to use the same definitions.

In essence the information needed is what lies were, what's the expected life span and what can be done with it end of life. If recycling or remanufacturing is needed, a pressure test and drill core test will provide the needed information for the recycler and producer.

Basic information could be stored as in the following tables, 2 and 3. The data is an example.

Table 2 General information elements

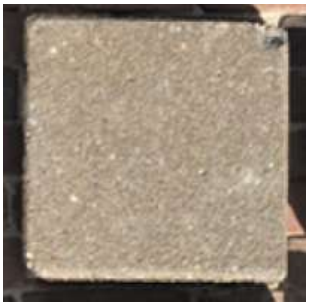
TILE	TILE (V2)	BRICK
		
Dimensions: 300 x 300 x 65 mm	Dimensions: 300 x 300 x 65 mm	Dimensions: 105 x 210 x 80 mm
Material: concrete (solid)	Material: concrete (solid)	Material: concrete (top layer)
Colour: grey	Colour: grey + P (white)	Colour: pink
Area: 3690 m2	Area:	Area: 850 m2
Location: 52.18877892446144, 5.994409573507057	Location: 52.18877892446144, 5.994409573507057	Location: 52.18877892446144, 5.994409573507057
% damaged:	% damaged:	% damaged:
Weight: (ton)	Weight: (ton)	Weight: (ton)
Amount (aprox): 41.000	Amount (aprox): 10	Amount (aprox):
Theoretical life span: 30 years	Theoretical life span: 40 years	Theoretical life span: 25 years
Years in use: 43	Years in use: 20	Years in use: 43
Expected life span: -13!	Expected lifespan: 20	Expected lifespan: -18!
Contractor:	Contractor:	Contractor:
Material supplier: unknown	Material supplier: unknown	Materials supplier: unknown
Pressure test data (link)	Pressure test data (link)	Pressure test data (link)

Table 3 General information asphalt

ASPHALT

Material: asphalt
Area: 128 m2
Top layer type:
Layer thickness:
Bearing capacity:
Construction:
Weight: (ton)
Contains Tar? Yes / No
Drill core (pdf)
Theoretical life span:
Years in use:
Production date:
Contractor:

It is advised to pay attention to the difference in between the theoretical lifespan and the amount of years the materials are actual in use. Lessons can be learned from the lifespan out in the field and the expected or theoretical life span can be modified accordingly.

Figure 13 shows a visualization to compare end of life options. The blue beam is the current life cycle the material is in. The colored beams are possible circular options for a new lifecycle. They contain MKI and MCI data for comparison.

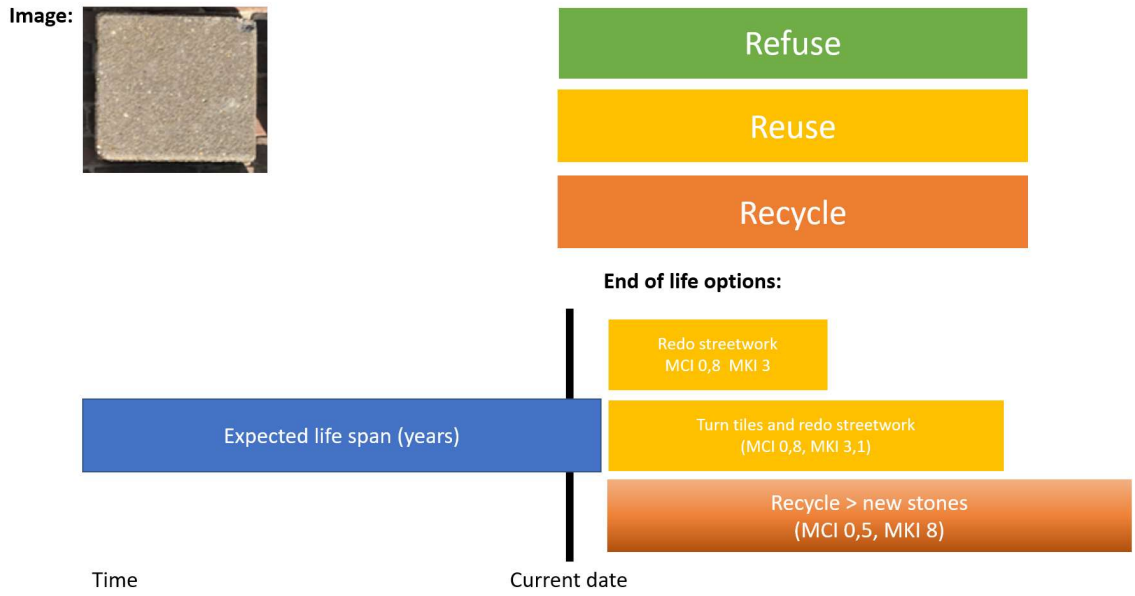


Figure 13 Visualization end of life options for comparison

8. Discussion

Definition and scope of circularity

The definition of circularity might differ per individual. It's practical to join a commonly used one like the definition form the Dutch CB'23 (Circular Building'23), translated into English: *Develop, use and reuse of buildings, areas and infrastructure, without the unnecessary exhausting of natural resources, polluting the living environment and affecting ecosystems. Construct in a way which is economical responsible and contributes to the wellbeing of human and animal. Here and there, now and later* (https://platformcb23.nl, 25-2-2021). However, this one differs from the definition used in this project as stated in the introduction.

Biological loop

The biological material loop is part of the Ellen MacArthur Foundation butterfly diagram and the Cradle to Cradle principle. Since stone like materials are often used in public space, the focus is on the technological material loop. It might be interesting to look into alternatives for cement, clay and asphalt, in biobased and or compostable materials.

Level of detail

As stated in Section 6 there is a variety in the level of detail of circularity cascades. Since the amount of subassemblies and functions is limited in road construction materials and products comparing to for instance the installation technique, it is assumed that a relatively high level circularity model will be sufficient. Of course, local and same function are preferable, but this should be visible in MKI values.

When more detail is preferred it's advised to look into the guidelines provided by the circular manufacturing industry from Holland, based on three circular data categories: raw material usage, environmental impact, and maintaining of value, each with their own KPI's https://circulairemaakindustrie.nl/ (12-3-2021).

Level of detail MKI

Since the MKI is a single score indicator (euro's) it is easy to compare several renovation options in terms of impact. However this might oversimplify the choice. For instance what if option A has low toxicity but high water usage and vice versa for option B. Based on what level of detail, decisions want to be made? Low environmental footprint and a high level of circularity are not always directly connected.

Visibility of circularity

A wish from clients might be that they are able to see that it's circular (interview recycler). For instance in the case of a brick wall: no discarding of the cement and redo the bricklaying, but use a sawn out element which is reused as part of a new bricklaying wall.

Opportunity: use the difference in colors in between new and reused stones (with a pattern, or random) to emphasize they are reused.

Another way to do this is to put textual or visual information on the street. For instance with a template and a high pressure cleaner.

Emphasize the renovation to inform and involve the inhabitants, for instance water management can be emphasized by https://rainaway.nl/ (12-3-2021). Additional check from what material they are made. It might be interesting to use recycled material from the Griffiersveld area for the production of rainaway stones.

Question for the municipality: do you and or inhabitants like to see it's a circular renovation?

Approach

The refuse step is in renovation not possible besides postponing renovation, since refusing is more relevant in the design stage. There is already a given situation with materials on site. One might wonder should the new design be leading, or are possibilities of reuse of the materials on site leading?

A suggestion is to use the properties of the materials where they come best to serve. Distinguish for example between parking space -where sideways movement is often, but traffic intensity low- and roads where mainly straight traffic is going on.

Make different functions / places in the road with different materials.

It's possible to make a road maximum circular with minimal lifespan and vice versa. The challenge is to find trustworthy information on the lifespan in order to make useful comparisons.

9. Conclusion

What are the circular possibilities for materials and products available in the Griffiersveld pilot, and how can this information be presented?

In essence there are four main circular possibilities for these materials: 1) reject/refuse (lifetime extension), 2) reuse (on site or on a different location), 3) recycle and 4) recover. It is advised to use this cascading. If additional material is needed for the renovation, use as much as possible secondary and renewable materials and a minimum use of virgin and non-renewable materials. Policy should be made to guarantee this. The material circularity indicator (MCI) is advised to use to make the above measurable.

Since the scope of this research is renovation, there is already a given situation with products and materials on site. In the case of renovation, the most circular way in terms of environmental impact, is not intervening at all and thus leave it as is (lifetime extension). At some point in time neighborhoods need to revitalize (i.e. change in parking capacity, water management and green) and a wish for change in aesthetics.

Therefore, an inventory is made in what materials are in the Griffiersveld area at the time. There are mainly concrete elements (4540 m^2) and an area of approximately 128 m^2 asphalt.

Suggestions for circular renovation per material and level of circularity are made, in terms of life time extension, reusability and recycling. Root barriers are advised to place if not there already in order to prevent root damage in the future.

For the concrete bricks and tiles, first step is to find out whether the bricks and tiles are top layer or solid products. When solid, clean and or turn and reuse is the most circular way to go. For recycling a pressure test should be performed in order to know the quality of the concrete.

About the asphalt bicycle lane: first step is to find out whether or not there is tar in the asphalt. The structure of the asphalt and the type of top layer should be documented. If this is not known, drill core research needs to be performed. The bearing capacity indicates the expected life span. Based on the collected information a decision can be made whether it can stay as is, needs repairs or recycled.

For the presenting of this information, a list of requirements is made for a material passport based on interviews with stakeholders. Seven material passports were identified and in the base they have the same structure. They should contain material information, life time expectancy and end of life possibilities. Starting point is to gather the information provided in Tables 2 and 3. As stated in Section 7, what information need to be stored is more critical than how / with what type or brand of material passport. It is advised to enrich the maintenance and management software that is used in a municipality. Since the municipality of Apeldoorn already uses GBI management software, it is advised to enrich this software with the information above. Integration in the currently used software is also done by the municipalities of Tilburg, Rotterdam and Zwolle in their Obsurv software.

10. Recommendations

Municipality organization

- Since there will be different views on circularity it is suggested to make a common language on circularity based on platform CB'23 and the NEN-EN 15804 standard.
- Make policy on circularity so it becomes part of day to day work. The policy should include to apply the circularity cascading, and if additional material is needed start with looking for reused or recycled materials (see the used material and product market places in Appendix B, page 62). There is a shift from a new build market to a replace and repairment market. This means a lot of material will come available when replaced, so called urban mining. It is recommended to demand for used materials, so the market will grow and organisation and investment will follow.
- Check whether the municipality maintenance and management software can be enriched with material information. For the municipality of Apeldoorn this software is GBI from Antea. Check whether this has layered possibilities to add the suggested information of the materials.
- Intensify the collaboration between the revitalization and maintenance department, to combine activities and reduces costs. Consider to combine the budget for revitalization and maintenance.

Partnerships

- Contact Sweco and the municipalities of Tilburg, Rotterdam and Zwolle about their experiences with the material passport project in Obsurv software.
- Cooperate with partners who are already experienced in circularity and have a drive to contribute to this. Dusseldorp, Insert, VBI, BAM and Heijmans for instance.
- Join with "buyer group duurzame wegverharding" for a critical mass and to get away from project based and small volume circular renovation. https://www.pianoo.nl/ (25-2-2021).
- Join with asfaltnu to check the quality of recycled asphalt. https://www.asfaltnu.nl/ (25-2-2021).
- For the LCA part, it might be interesting to join Ecochain since they work with a 'live LCA' where data is linked to the actual situation. https://ecochain.com/ (25-2-2021).
- Interview with recyclers and manufacturers of tarmac or stones, like MBI, STRUIK, for the state of the art in recycling and use of recycled content in new products.
- Partnership with companies who use PIM and ASPARI in order to combine processing and lifespan data out of the field.

Required information

- Involve roadworkers since they are a crucial link in the renovation process. Their experience should be used in order to get lifespan information form the field, linked to the used underlayer, paving materials and patterns.
- Costs estimation should be added (in terms of labor etc.), but costs should not be leading in the decision making.
- Contact the contractor if known, since they should have information (datasheets) about the used materials on site.
- Cooperate with the PIM ((Pavement Information Modelling) model for maintenance and new projects, since material information is in there already, namely on asphalt. Explore whether PIM and GBI can be connected.
- Make the inventory of materials on site less labour intensive > automation (digital scanning, drones).

General

- Use elements paving preferably, since these are best to repair and open up for maintenance to infrastructure underneath the road. Based on MKI calculations, baked clay elements have a low impact due to their long lifespan. Therefore it is advised to use (used ones) these in areas where the traffic and sound norms allows. The recycling possibilities for baked clay after use are only downcycling at the time.
- Then there are some principles to take into account, which are advised to use in the way of a checklist. When a neighborhood is renovated it's advised to combine other building activities, such as water management, heat stress measures, infrastructure like construction of optical fiber connections. In the case of (tree)roots nearby roads, it's advised to place root barriers in order to prevent damage in the future. By combining construction activities, the importunity is high but reduced to a limited amount of time. Also the amount of resources and future repairments will be reduced.

Checklist for circular renovation:

- Combine with nearby construction activities;
- Take change of weight vehicles (trucks, electrical cars), parking need and traffic pressure, into account when choosing the (reused) paving material;
- Integrate climate adaption measurers, like decouple rain water (remark: no car washing on the street) and heat stress measures (more green, tiles with less heat absorption) to get wind into the cities;
- Combine with maintenance below ground level (gas, fresh water, electric, sewer);
- Combine with new infrastructure (f.i. glass fiber);
- Place root barriers near planting to prevent damage to street work;
- Enhance biodiversity.

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Appendix A: Questionnaire

The following questionnaire is used. Some questions have been altered slightly per user in order to get the information needed.

“Ask permission to record”

What’s is your function?

Current situation:

How does a renovation work nowadays? Who are involved?

What questions about sustainability and circularity do you get? From who?

How do you answer these?

Based on what information do you or your team make a decision? (f.i. costs, environmental impact, aesthetics, support base)

Ideal situation:

Based on what is discussed, describe the ideal situation for a renovation. (circular!)

What kind of tradeoffs do you want to make?

What other options are considered (besides a material passport)

Who (what functions) are going to use the passport (inside and outside the municipality)

How do you see the material passport?

What do you want to achieve with it?

How does the material passport look like ideally? What should it be able to do?

On what devices should the passport be used?

Do you have questions or remarks?

Appendix B: Databases and models

ASPARI (research group for asphalt construction)

ASPARI is a collaboration from Ballast Nedam, BAM, Boskalis, Dura Vermeer, Heijmans, Strukton, Roelofs, KWS, TWW and van Gelder. Goal of the collaboration is to improve the process quality for paving, by collecting data during the pavement and analyse this data.

The table shows wat is measured and how.

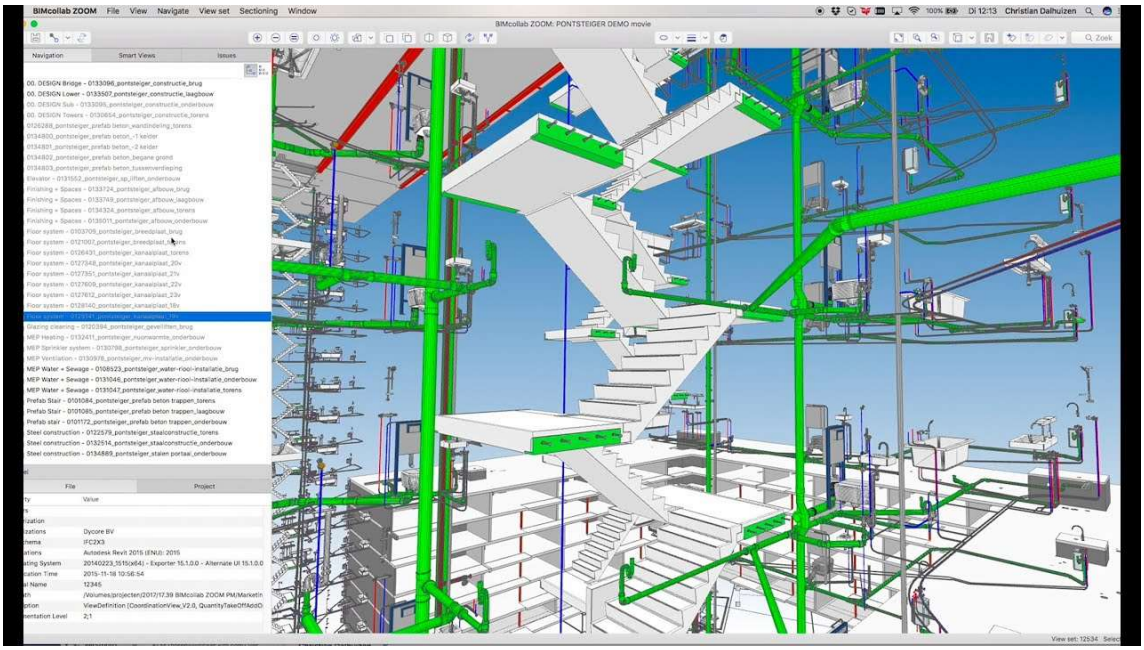
Task	Instrument	Method	Measurement accuracy & frequency
Monitor weather conditions	Weather station (vintage pro)	Weather station set up next to the construction site to log local conditions	Ambient temperature, wind speed, relative humidity, solar radiation data logged at 5-minute intervals
Measure asphalt surface temperature behind screed	Linescanner (Raytek)	Laser linescanner mounted on the back of the HMA asphalt paver.	captures HMA surface temperature at 1-second intervals behind the paver screed
Measure surface temperature cooling rate	2 handheld infrared cameras (Flir & Fluke)	Cameras on tripods at fixed positions approx. 100m apart	Images taken manually every 30 seconds
Measure in-asphalt temperature cooling rate	2 channel digital thermometer (by contractor)	Thermo-coupler placed in the middle of asphalt layer	Temperature logged automatically every 30 seconds
Monitor movements of all asphalt paving machinery	5 GPS receivers (Trimble)	Base station set up on site & GPS receivers mounted on HMA machinery	Differential GPS accuracy of < 10 centimetres, Data logged at 1-second intervals
Measure asphalt density	Nuclear density gauge (by contractor)	Density measured after every roller pass at fixed temperature logging positions	Preferably on spot of cooling measurement after each roller pass, and afterwards
Record noteworthy incidents on site	Memo recorders (Sony)	Record incidents as they occur	Incident log; observations

https://www.aspari.nl/methodology (25-11-2020)

The measurements are specific for the processing of the asphalt and do not contain information about the composition of the asphalt. Nevertheless this information can be useful in order to predict the life expectancy, together with information on the traffic pressure.

BIM (Building Information Modelling)

BIM is basically a digital twin of a planned or existing building. This is used for asset management and early error detection in the design for planned buildings. Furthermore it can be used for management and maintenance of the building. Information on product / component level can be stored in the BIM and even interdependence of components. (software: Revit, Navisworks)



Example of a BIM model interface with plumbing pipes information https://www.bimcollab.com/ (25-11-2020)

Keep use of your own sytems and communicate via an open standard. https://www.bouwinformatieraad.nl/p/52/Wat-is-BIM (video)

BREEAM (material passport for buildings)

BREEAM stands for Building Research Establishment Environmental Assessment Method and is the certification method for a sustainable built environment. With this method, projects can be assessed on integral sustainability. (https://www.breeam.nl/english-9 25-11-2020)

BREEAM scores a building on 10 categories (9 + innovation?). It's possible to assess on: New buildings and renovation, In Use buildings and on area level.

https://www.breeam.nl/upload/files/Downloads/Engels/BREEAM-NL%20Area%20Development%20-%20ENG.pdf

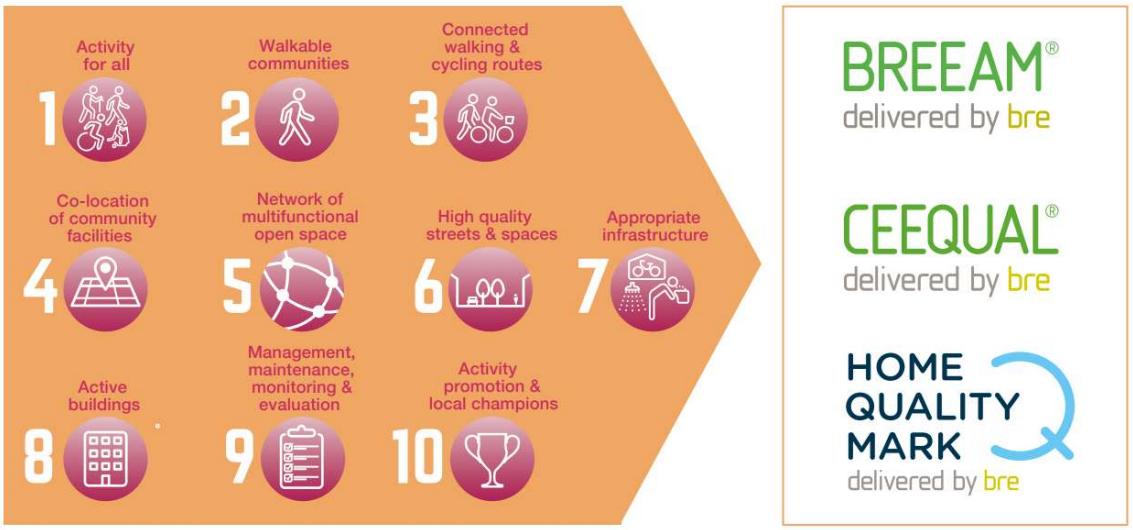
BREEAM: keurmerk voor duurzame gebiedsontwikkeling.

https://www.breeam.nl/sites/breeam.nl/files/bijlagen/BREEAM-NL%20Gebied%202018%20v1.0%20NL_1.pdf

Material passport or raw materials passport contributes (as evidence) to the quality mark.

https://www.breeam.com/discover/technical-standards/breeam-in-use/ (25-11-2020)

Quickscan on area level.



https://www.breeam.com/wp-content/uploads/sites/3/2019/12/BREEAM_ActiveDesign-V8-06-12-19-002.pdf (25-11-2020)

https://gebied.assessmenttool.nl/quickscan/create (25-11-2020)

Circularity passport (passport from Cradle to Cradle / EPEA)

The Cradle to Cradle (C2C) philosophy is waste equals food. EPEA is the organisation who is responsible for the C2C certificates. EPEA is now a part of Drees & Sommer.

In the H2020 BAMB (buildings as material banks) project they combined the C2C and BREEAM certificate into a Circularity Passport. Material passports in combination with reversible building design.

Product Circularity Passport® by EPEA

Today, downcycling is standard practice when recycling materials. Products are often not developed to be disassembled and recovered. The exchange of information, particularly with regards to product composition and disassembly steps and between stakeholders, is insufficient. Product Circularity Passports® are a Cradle to Cradle® instrument to accelerate the implementation of a Circular Economy. By closing information gaps, Product Circularity Passports® ensure transparency and pave the way for the introduction of circular products.

https://epea.com/nl/onze-diensten (25-11-2020) (is offered as a service).

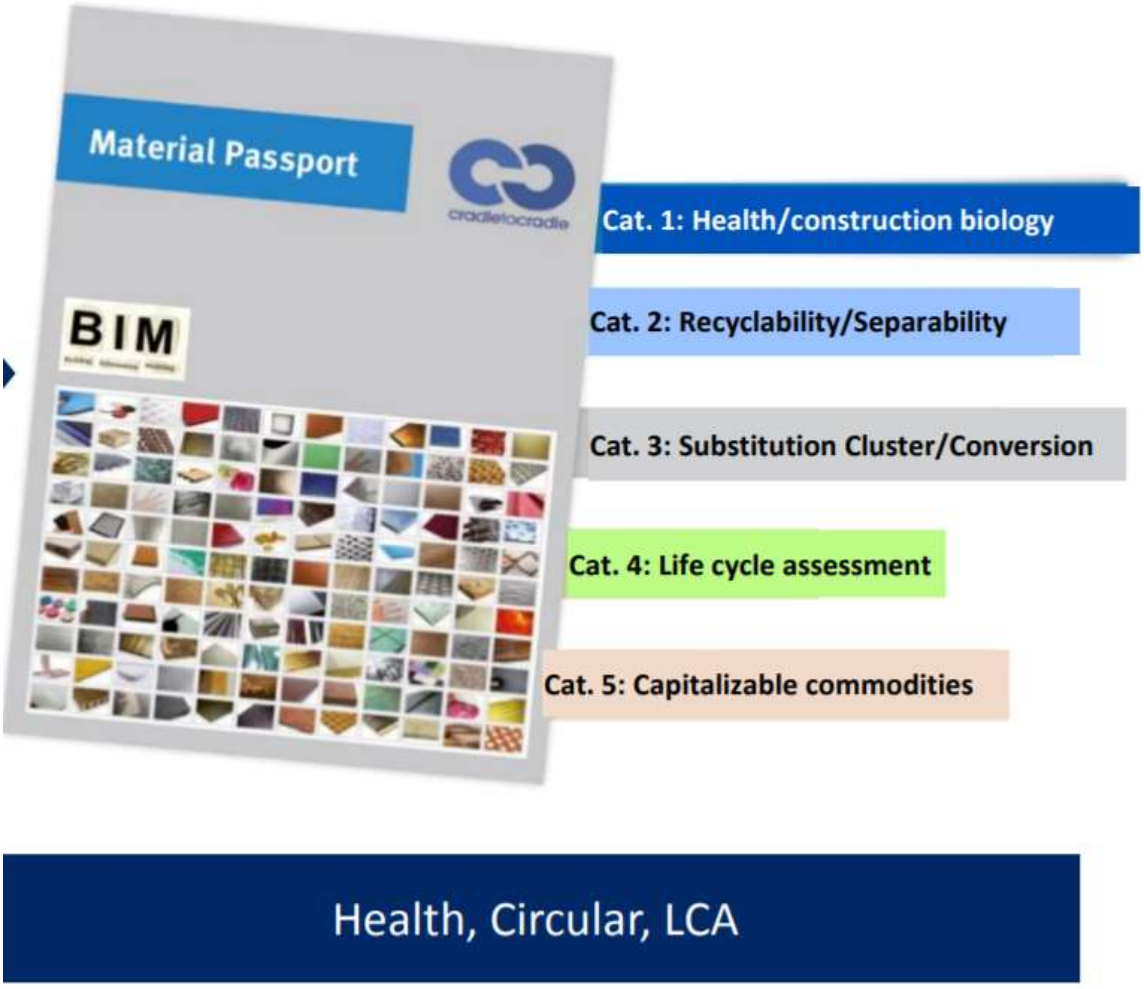
https://www.dreso.nl/nl-NL/diensten/smart-infrastructure/ (25-11-2020)

https://epea.com/nl/en/services/cities-infrastructure (25-11-2020)

C2C i.c.w. BIM

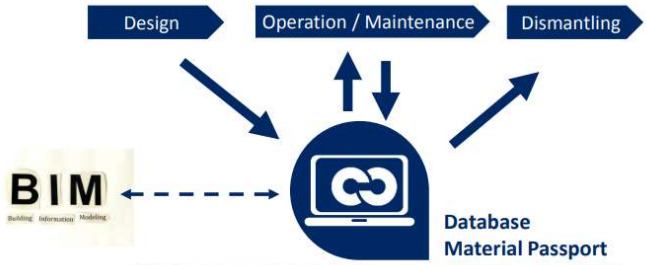
Following images are screenshots from:

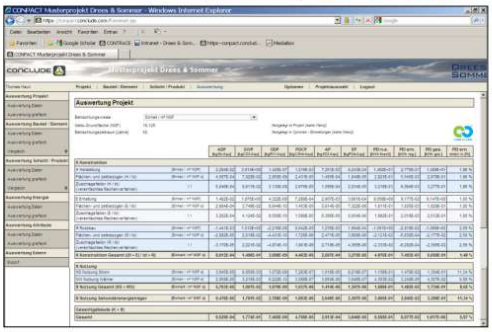
https://ondernemingen.bnpparibasfortis.be/docs/default-source/campaign_doc/innovation_plane_presentation_ltfc_michaelmoradiellos.pdf?sfvrsn=2 (25-11-2020)



Material Passport for buildings

Consistent use of material-specific information





Material Passport

Extended digital construction elements catalogue with material information

cradle to cradle

For all construction materials used

- Building-ecological material declaration
- Material composition
- Mounting situation
- Separability proof
- Recycling concept
- Commodity stock

For the building:

- Modular and substitution concepts
- Disassembly structure

LATERAL THINKING FACTORY

DREES & SOMMER

10 Drees & Sommer | Cradle to Cradle

Bauteilkatalog

Objekt: **6406 Neubau Zeche Zollverein_Ökobaudat 2013_EnEV_2**

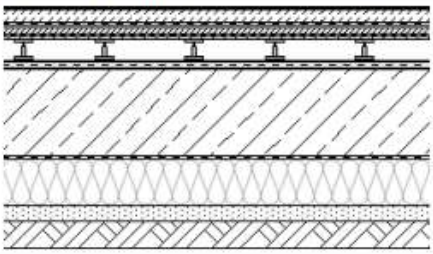
Bauteil: **Boden gegen Erdreich, EG (DGNB Platin)**

Stand: **09.08.2016**

ADVANCED BUILDING TECHNOLOGIES DS-PLAN

Nr.: **002B**

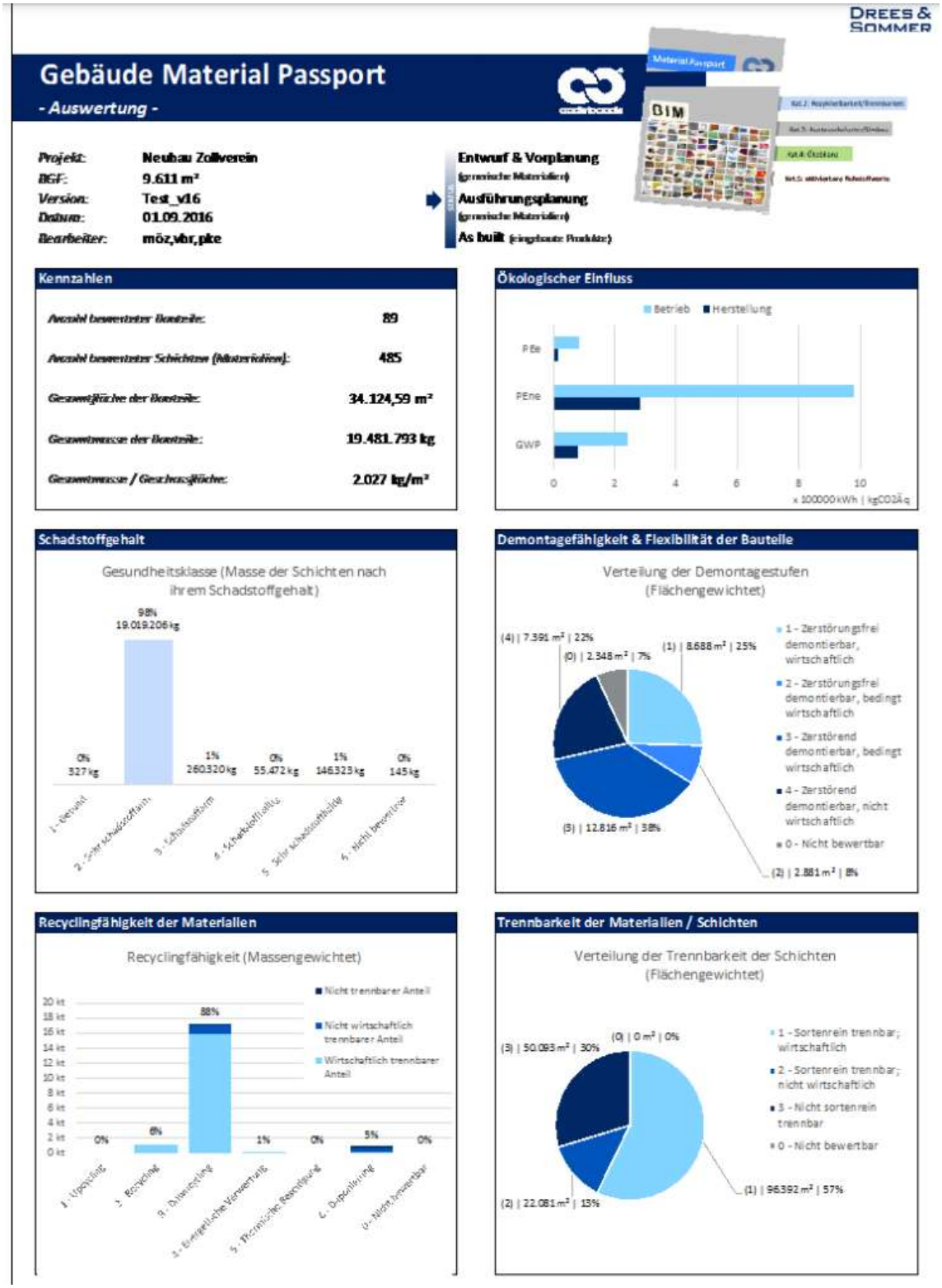
Nr.	Schichtaufbau (von oben nach unten bzw. von innen nach außen)	Dichte ρ [kg/m³]	Dicke d [mm]	λ [W/mK]	s / λ [m²K/W]
1	Textiler Bodenbelag, Mix	200	10	0,06	0,167
2	Calciumsulfatestrich auf Trennlage mit der Bezeichnung DIN 18560-CA-(F)-F3	2100	35	1,2	0,029
3	PE-Folie, 1-lagig als Trennschicht, Dicke d = 0,2 mm	970	0,2		
4	Hohlraumboden- Bodenplatten (40 mm) bestehend aus hochverdichteter Calciumsulfatplatte, Stütze aus verzinktem Stahl, stufenlos höhenverstellbar durch Gewinde, nicht brennbar- Fugen- und Stützenkleber; Bettung des Stützfußes im Stützenkleber, Boden gegen Erdreich	546	155		
5	Dampf- und Windsperre aus Vacufol-Folie, Dicke 0,14 mm, Stöße 200 mm überdeckt, mit Alukaschiertem SK-Band, b = 100 mm luftdicht verklebt	1130	0,14		
6	Stahlbeton-Bodenplatte aus wasserundurchlässigem Beton (weiße Wanne) nach DIN EN 1992-1-1	2473,7	300	2,3	0,13
7	PE-Folie, 1-lagig als Trennschicht, Dicke d = 0,2 mm	970	0,2		
8	Wärmedämmung aus extrudierten Polystyrol-Hartschaumplatten (XPS) nach DIN EN 13164, mit Stufenfalz, dicht gestoßen verlegt, Anwendungstyp nach DIN 4108-10, Boden gegen Erdreich	32	140	0,04	3,5
9	Sauberkeitsschicht	2365	80	1,4	0,057
10	Erdreich	3500	(1)		
11	nur LCA [Gutschrift für Schotter aus Bauschuttaufbereitung Beton]	2365	(380)		
12	nur LCA [EoL inkl. Recyclingpotenzial (Modul C3+D) von Stahlprofilen] Recyclingpotenzial der Stahlstützen des Hohlraumbodens, 2 % von 190 mm -> 3,8 mm Stahlprofil	7800	(3,8)		
13	nur LCA [Recyclingpotentail (Modul D) von PS in MVA]	32	(140)	0,04	3,5
	Gesamt:	**Σ**	**720,54**	**Σ**	**7,383**
Wärmeübergangswiderstände $R_{si/se}$ [m²K/W]		**R_{si}**		**R_{se}**	
Wärmedurchlasswiderstände R [m²K/W]		**R_{erf}>=**		**R_{vorh}**	7,38
Wärmedurchgangskoeffizient nach DIN 4108 U [W/m²K]		**U_{erf}<=**		**U_{vorh}**	



Zu Nr.	Bemerkung
	sämtliche Angaben gelten nur in Verbindung mit den "Vorbemerkungen zum Bauteilkatalog"

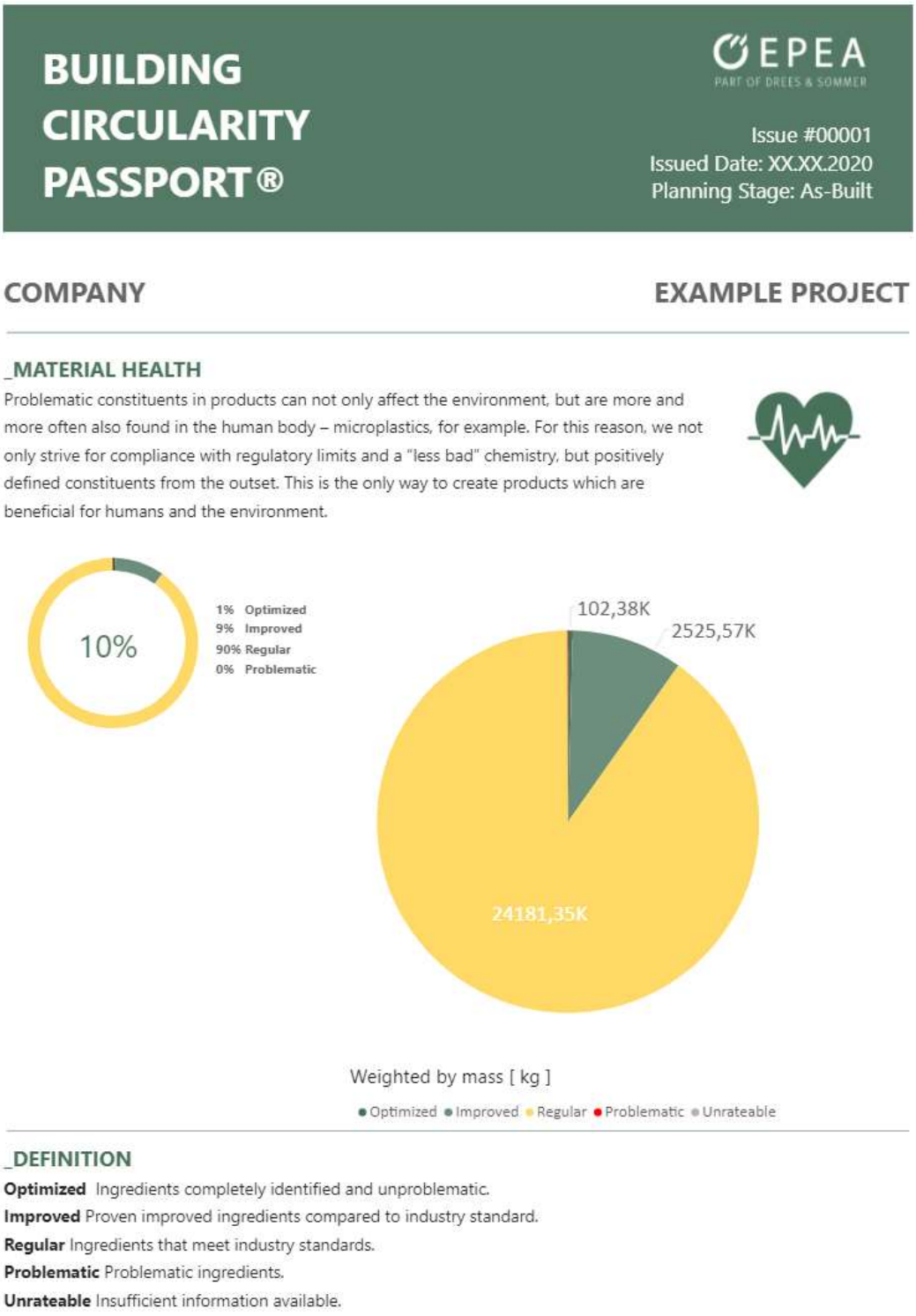
DS-Plan GmbH Obere Waldplätze 11 70569 Stuttgart

DS plan now a part of Drees & Sommer



Building Circularity Passport EPEA

Following images are screenshots made from https://epea.com/nl/onze-diensten/gebouwen (25-11-2020)



BUILDING CIRCULARITY PASSPORT®

EPEA
PART OF DREES & SOMMER

Issue #00001
Issued Date: XX.XX.2020
Planning Stage: As-Built

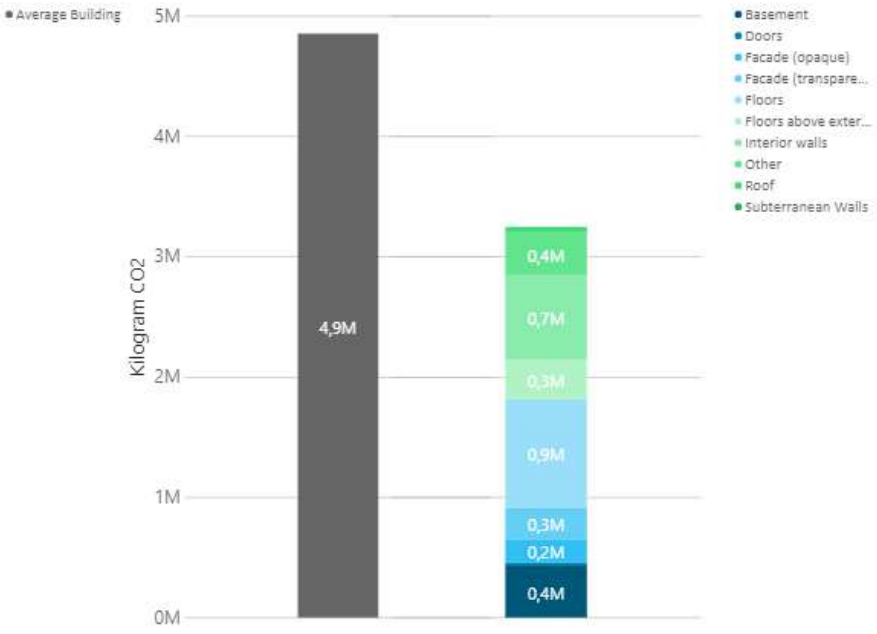
COMPANY

EXAMPLE PROJECT

_EMBODIED CARBON

With a reliable climate protection strategy for your building, you will gain new qualities in this changing world. You reduce future risks, increase property values and know that the climate protection measures you choose are targeted and effectively reduce the CO2 emissions of your building.The CO2 footprint compared to a standard office buildings is shown.

Improved compared to a standard office Building



_DEFINITION

To be able to make a comparison, the amount of CO2 is compared to a standard office building. The benchmark is 9.4 kg CO2/m²a (0%) and has been determined by the DGNB. The goal is to achieve 100%. Then the building would be CO2 neutral.

BUILDING CIRCULARITY PASSPORT®

EPEA
PART OF DREES & SOMMER

Issue #00001
Issued Date: XX.XX.2020
Planning Stage: As-Built

COMPANY

EXAMPLE PROJECT

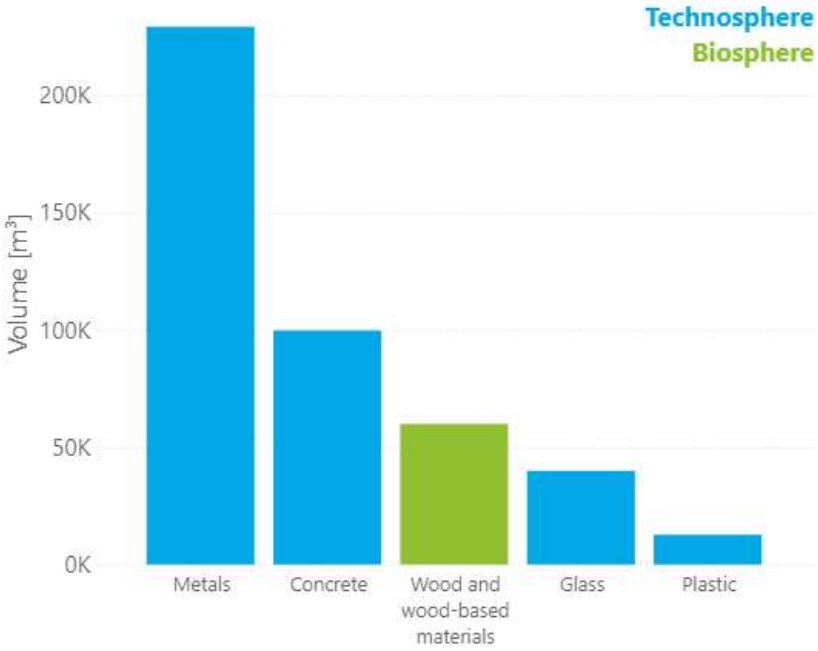
_MATERIAL SOURCING

To establish a circular economy in the built environment the use of virgin non-renewable material must be minimized. It is important to know how much of the materials used in the building have what kind of origin as the extraction of virgin materials generally has a negative impact on the environment. A circular building is mostly built out of materials that come from secondary or renewable sources.

13% Secondary

4% Responsible Renewable

83% Virgin



_DEFINITION

Secondary material Products consisting of secondary material.

Sustainable Renewable Material Products made from renewable materials with certified sustainable cultivation.

Virgin Unused raw material that has never been subjected to any processing other than for its production.

BUILDING CIRCULARITY PASSPORT®

EPEA
PART OF DREES & SOMMER

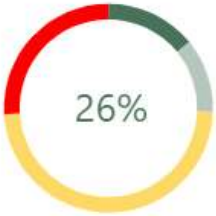
Issue #00001
Issued Date: XX.XX.2020
Planning Stage: As-Built

COMPANY

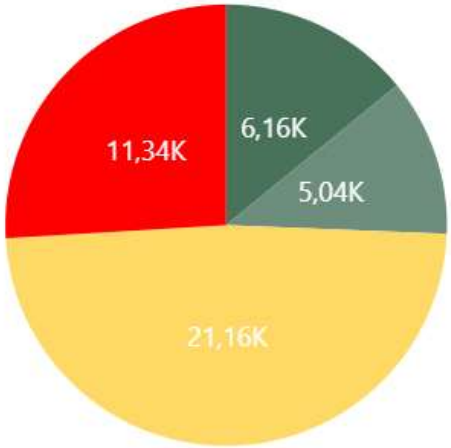
EXAMPLE PROJECT

_ DISMOUNTABILITY

At the level of the assemblies (functional units), non-destructive dismantling should be aimed for where it is economically feasible. The aim is to increase the flexibility of the building through the simple exchangeability or adaptability of individual functional units, which is planned from the outset. Added values are a higher third-party usability, simpler conversion and thus a longer total useful life.



15% Maximum flexible
12% Flexible
48% Partially flexible
25% Not flexible



Weighted by area [m²]

● Maximum flexible ● Flexible ● Partially flexible ● Not flexible ● Unrateable

_DEFINITION

Maximum flexible Functional units can be separated from each other. The entire element can be completely removed and theoretically reused.

Flexible Functional units can all be separated from each other.

Partially flexible Functional units can be partially separated from each other.

Not flexible Functional units cannot be separated from each other.

Unrateable Insufficient information available.

BUILDING CIRCULARITY PASSPORT®

EPEA
PART OF DREES & SOMMER

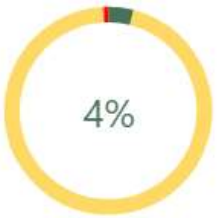
Issue #00001
Issued Date: XX.XX.2020
Planning Stage: As-Built

COMPANY

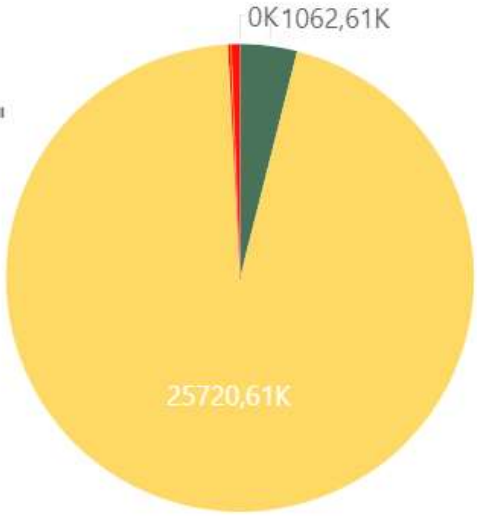
EXAMPLE PROJECT

_ MATERIAL RECOVERY (POTENTIAL)

The objective of the Circular Economy powered by Cradle to Cradle® is to ensure that the resources used can serve as starting materials for new, pollutant-free products after they have been used. This allows them to circulate continuously in product cycles - instead of "downcycling", the aim is to enable "upcycling" of products.



4 % Recycling/Upcycling
95% Downcycling
0,5% Energetic utilization
0,5% Thermal removal/ Landfill



Weighted by mass [kg]

● Upcycling ● Recycling ● Downcycling ● Energetic utilization ● Thermal removal ● Landfill ● Unrateable

_DEFINITION

Recycling/Upcycling The material is recycled without significant loss of quality and can therefore substitute a primary raw material of at least the same material quality.

Downcycling Through material recycling, the material experiences a considerable loss of material quality.

Energetic utilization Using waste as a substitute fuel.

Thermal removal/Landfill Material is burned without any energetic benefit or disposed of in a landfill.

Unrateable Insufficient information available.

BUILDING CIRCULARITY PASSPORT®

EPEA
PART OF DREES & SOMMER

Issue #00001
Issued Date: XX.XX.2020
Planning Stage: As-Built

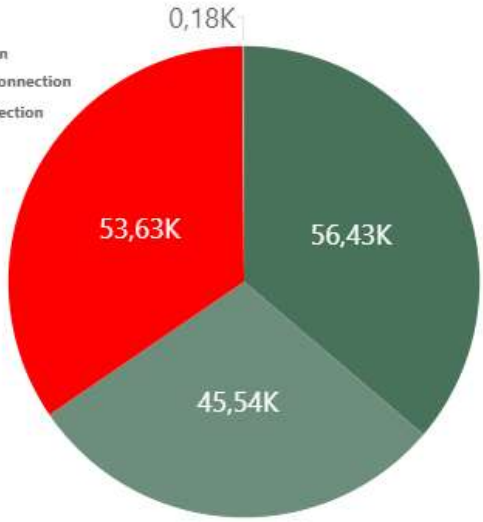
COMPANY

EXAMPLE PROJECT

_ SEPERABILITY

The aim is to be able to dismantle all constructions into single materials. For this purpose detachable joining techniques are to be used. The use of composite components should be avoided in favour of separable component assemblies. On the other hand, steel-concrete composites, metal-glass composites and constructions that can be completely recycled biologically are unproblematic, because they are compatible for recycling.

36% Dismountable connection
30% Partially dismountable connection
34% Non dismountable connection



Weighted by area [m²]

● Dismountable connection ● Partially dismountable connection ● Non dismountable connection ● Unrateabl

_DEFINITION

Dismountable connection Directly accessible, visible and exposed, element is not damaged by dismantling.
Partially dismountable connection Conditionally accessible, surrounding layers/components must be laboriously removed to extract the material.
Non dismountable connection Connections are not dimountable with considerable effort.
Unrateable Insufficient information available.

Cirdax (material management system used by Reuse Materials)

Different tools, from which a material passport is one. Some are still in development. Developed by Re Use Materials: https://www.reusematerials.nl/over-ons/ (25-11-2020)

Marcel Claessens: “Materialen inventarisator”

https://www.cirdax.com/#__tools (25-11-2020)

Excess Materials Exchange (EME) (marketplace for excess materials)

Makes use of a raw material passport, with overlap in the Cirdax content, although toxicity is added. Gives insight in composition, origin, toxicity and detachability of materials or products. https://excessmaterialsexchange.com/nl/ (25-11-2020)

GBI (database from Antea used by municipalities, not used as material passport at the time)

According to this video of the Antea Group https://www.youtube.com/watch?v=H-lkD_436vE&feature=youtu.be&ab_channel=AnteaGroupNederland (25-11-2020) they can cope with circularity information in their management system.

Grondstoffenpaspoort (example from Liander)

Format for a raw material passport developed in collaboration with Dutch Network operators. Raw material passport which Liander asked to fill by their suppliers.

https://www.enexisgroep.nl/nieuws/grondstoffenpaspoort/ (25-11-2020)

https://www.enexisgroep.nl/media/2621/grondstoffenpaspoort_enexis-netbeheer_012020.pdf (25-11-2020)

GRANTA EduPack 2020 (Architecture Universe)

This software is developed for material selection in engineering and contains therefore detailed material properties information.

Sandstone

Datasheet view: All Architecture | Show/Hide | Find Similar

Durability					
Water (fresh)		Excellent			
Water (salt)		Excellent			
Weak acids		Acceptable			
Strong acids		Acceptable			
Weak alkalis		Excellent			
Strong alkalis		Acceptable			
Organic solvents		Excellent			
UV radiation (sunlight)		Excellent			
Wear resistance		Limited use			
Industrial atmosphere		Acceptable			
Rural atmosphere		Excellent			
Marine atmosphere		Acceptable			
Primary material production: energy and CO2					
Embodied energy, primary production		0,952	-	1,05	MJ/kg
CO2 footprint, primary production		0,0571	-	0,063	kg/kg
Water Usage		* 3,23	-	3,57	l/kg
Material processing: energy					
Grinding energy (per unit wt removed)		* 7,34	-	8,11	MJ/kg
Material processing: CO2 footprint					
Grinding CO2 (per unit wt removed)		* 0,551	-	0,608	kg/kg
Material recycling: energy, CO2 and recycle fraction					
Recycle		✗			
Recycle fraction in current supply		1,34	-	1,48	%
Downcycle		✓			
Combust for energy recovery		✗			
Landfill		✓			
Biodegrade		✗			
A renewable resource?		✗			

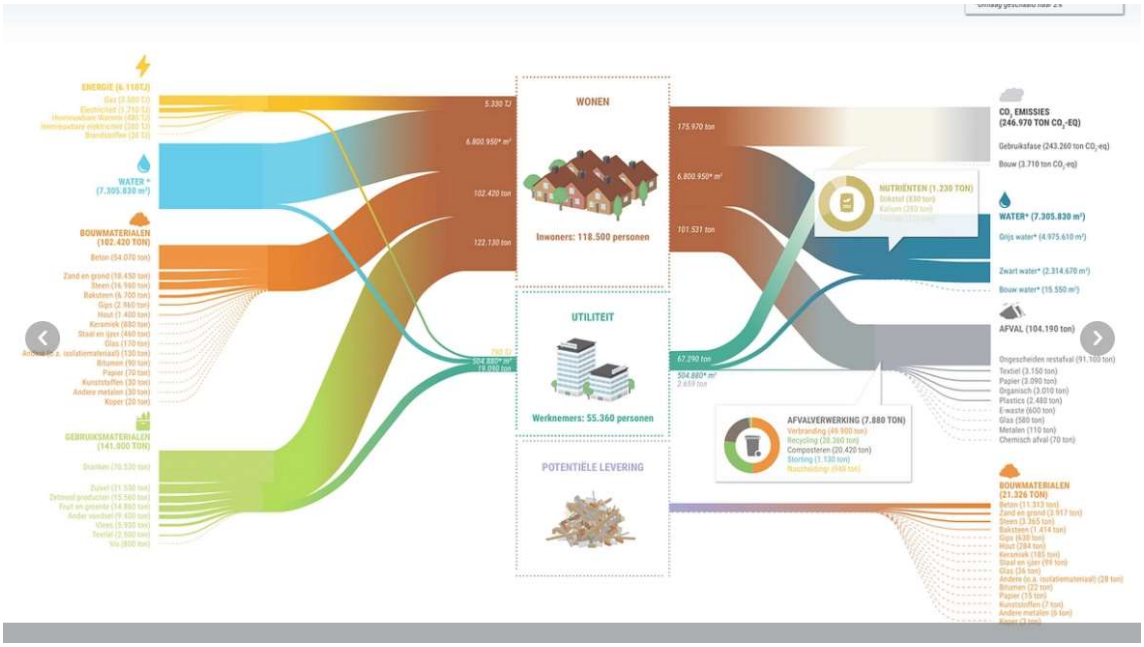
Figure 14 example of sustainability material information from Sandstone in GRANTA Edupack 2020

Greenworks is a label for ranking building materials https://www.greenworksacademy.nl/ (25-11-2020)

Also takes comfort into account:

Visualise material flows

Screenshot from: https://www.metabolic.nl/projects/dordrecht-circulair/ (25-11-2020)



Madaster (Cadastre for materials)

MATERIAL PASSPORT

A material passport is a compact but detailed view of your building information as registered on the Madaster platform. Like a regular passport, it gives identity to your building and all its separate materials, components and products included. The quality of the underlying data that forms the basis of a material passport largely determines the quality and completeness of the materials passport. The richer the underlying data, the more detailed a materials passport will be.

A material passport is a PDF document that is added to your building dossier each time it is generated and can, subsequently, be printed or downloaded. The passport can be generated periodically, as many times as required.

CIRCULARITY TAB

Gain insight in the circular value of your building. The Madaster Circularity Indicator is based on the Ellen MacArthur Foundation Material Circularity Indicator. Depending on the user input, it scores a building between 0-100%. A completely circular building in Madaster, receiving a score of 100%, is built with reused materials, has a more than average lifespan and can, eventually, be completely dismantled. In close cooperation with various experts we constantly enhance the Madaster Circularity Indicator.

Besides an overall indication on building level, Madaster also indicates the level of circularity per phase of the building (construction, use & end of life) and for each of the separate building layers.

Material passport is part of the platform, as well as a circularity tab. https://www.madaster.com/en/our-offer-2/Madaster-Platform (25-11-2020)

Example for infrastructure project (https://www.madaster.com/en/newsroom-2/press-releases/kws-schiphol-trade-park-materialpassport 25-2-2021)

Greenstar (buildings Australia) https://new.gbca.org.au/rate/green-star/ (25-11-2020)

ISCA (infrastructure sustainability council of Australia) https://www.isca.org.au/ (25-11-2020)

Thinkstep Australia (Now GABI Ica software?) Gabi contains MCI calculator tool.

https://www.youtube.com/watch?v=gljrdd4T3tA&ab_channel=thinkstep-anz (25-11-2020)

“Quantify Circular Economy for Materials and Infrastructure Projects”

NL Greenlabel is linked to Sustainable Development Goals (SDGs), sustainability and circularity of products and materials included (https://www.nlgebiedslabel.nl/indicatoren/ 25-11-2020)

CB’23 Guideline circular construction - Leidraad Circulair bouwen

Initiative from the construction to get to a common language with definitions about circularity. https://platformcb23.nl/ (25-11-2020)

Materials Passport Platform (Prototype) (SeAmk Newspaper, 2019) (p38) video with explanation: https://vimeo.com/238909741 (25-11-2020)

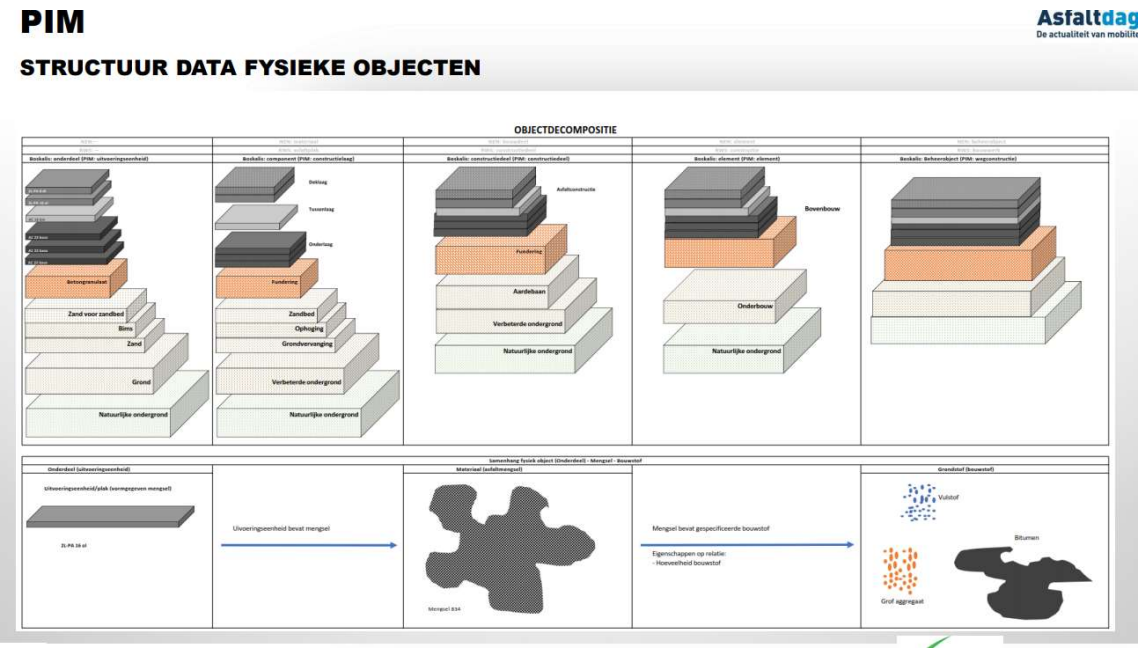
PIM (Pavement Information Modelling)

Implemented in 2019, information building for road constructions (focus on asphalt). Leads too standardization towards a BIM standard (PIM OTL) for roads.

Future steps are: further implementation and data collection and combine with i.e. traffic intensities, maintenance, etc.

EAPA symposium Paris, June 6 2019 Dr.ir.ing. Frank Bijleveld (Strukton Civiel / Ooms Producten)

https://www.asfaltblij.nl/media/2618/asfaltdag-2019-presentatie-pim.pdf (25-11-2020)



Standards

IMBOR (‘*informatiemodel beheer openbare ruimte’*): information model https://www.crow.nl/thema-s/management-openbare-ruimte/imbor/over-imbor (25-11-2020)

RAW (standard for civil engineering) Opportunity to incorporate circularity om this standard

MPG (Dutch: Milieu Prestatie Gebouwen, translated: environmental performance buildings)

MKI (Dutch: Milieu Kosten Indicator, translated: material costs indicator)

"Building as material banks" EU 2020 project. https://www.bamb2020.eu/topics/materials-passports/ (25-11-2020)

2.1. Physical Properties

2.2. Chemical Properties

2.3. Biological Properties

2.4. Material Health

2.5. Unique Product and System Identifiers

2.6. Design and Production

2.7. Transportation and Logistics

2.8. Construction – Identifying Material and Product Locations within Buildings

2.9. Use and Operate Phase

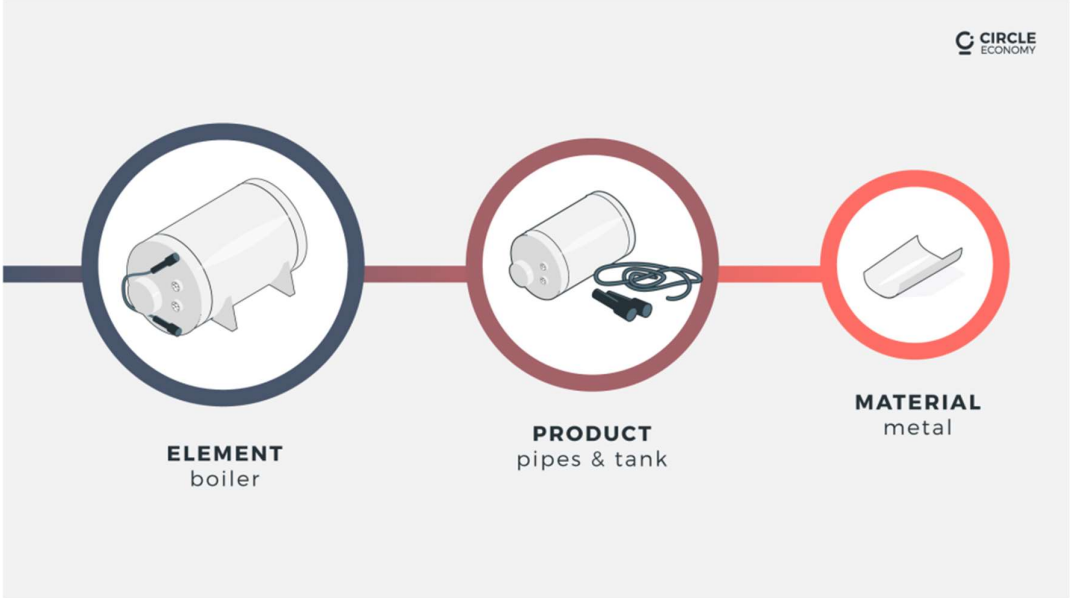
2.10. Disassembly and Reversibility

2.11. Reuse and Recycling

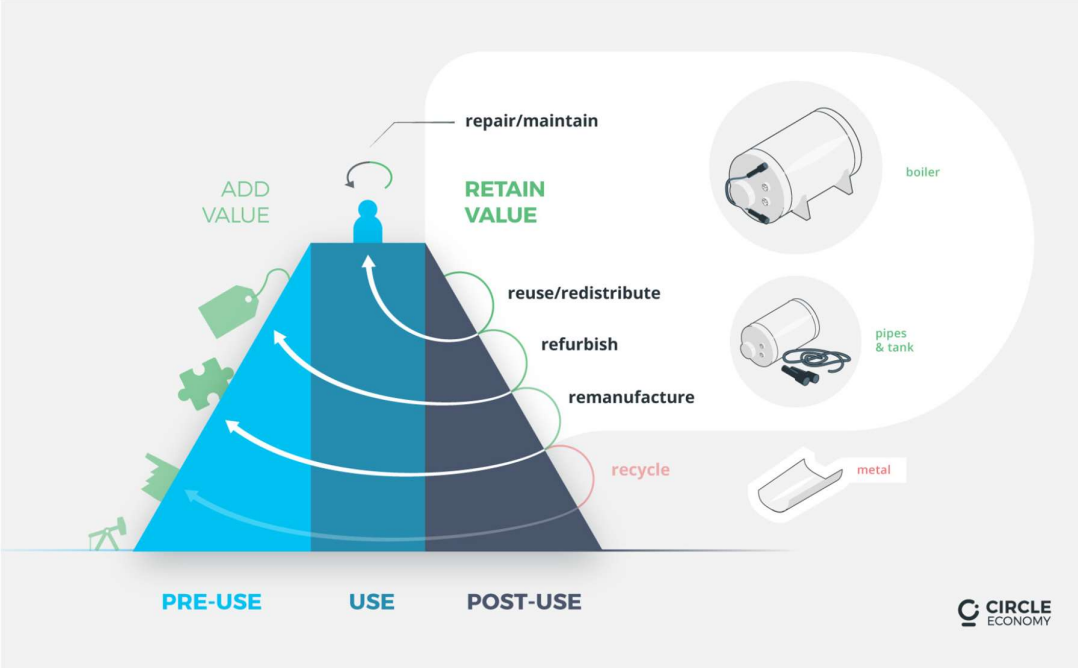
https://www.bamb2020.eu/wp-content/uploads/2019/02/BAMB_MaterialsPassports_BestPractice.pdf (25-11-2020)

In the report “Building Value, a pathway to circular construction finance’ from Circle economy and Nederland Circulair, they use the division of elements, products and material. This can be combined with the value hill and the 10R model.

https://www.duurzaambedrijfsleven.nl/circulaire-economie/30857/gebouwde-omgeving-circulaire-economie (25-11-2020)



(image from page 8)



(image from page9)

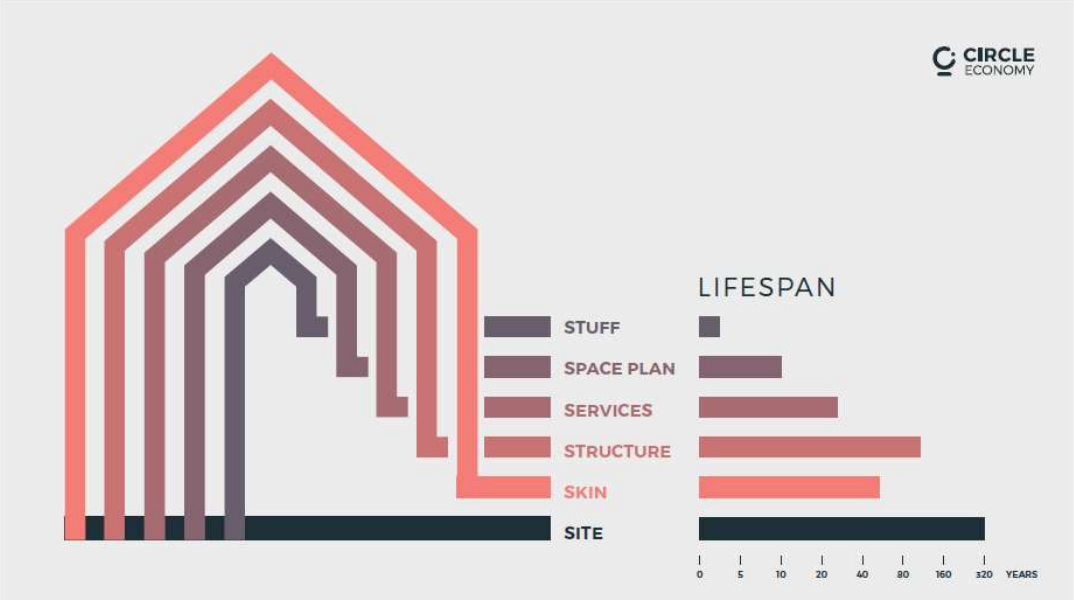
report: https://www.duurzaambedrijfsleven.nl/download/building-value-a-pathway-to-circular-construction-finance.pdf

MKI concrete pavement: https://www.kiwa.com/nl/nl/service/brl-2312-betonstraatstenen/ https://www.kiwa.com/nl/nl/service/brl-2313-betontegels/

Programma van Informatie-Eisen materialenpaspoort Infra : adviesrapport https://puc.overheid.nl/rijkswaterstaat/doc/PUC_166676_31 (25-11-2020)

VBI, a producer of concrete flooring products, develops circular concrete products with greenscore certificates. This proofs the amount of secondary material. Furthermore they give design guidelines and re-assembly details to support design for reassembly and design for flexibility. https://www.cirkelstad.nl/wp2/wp-content/uploads/2019/09/Krant_DNWC19_v1.2_web.pdf (25-2-2021)

Figure 4: 6 building layers, adapted from Steward Brand (1995)



report “Building Value, a pathway to circular construction finance’ from Circle economy and Nederland Circulair (p10)

Material information databases

As inspiration for a material passport, existing GIS (geographic information system) have been looked into.

DINO loket (geo technical information)

Open source database with geotechnical soil information. For instance drill measurements. Possibility to enhance this with drill core measurements from roads. https://www.dinoloket.nl/

BRO loket (soil information)

Basic registration substrate. (Basisinformatie ondergrond). Opensoure database drilling research, geotechnical research, soil wall research, and probe research.

This information can be found in the dinoloket.

KernGIS (Rijkswaterstaat)

Asset management system of Rijkswaterstaat, which is a digital map with objects (points, lines or planes). To each object data can be linked.

https://www.geomaat.nl/producten/kerngis/

Used-material and products marketplaces

Since a circular economy is about slowing, closing, and narrowing material loops, materials have to be reused of recycled at some point in time. Therefore used-material and product marketplaces were looked into, in order to find out what material information is presented there.

- Excess Materials Exchange (EME) https://excessmaterialsexchange.com/nl/
- Gemeentewerf (marketplace, free of use for municipalities, provinces, regional water authorities, educational institutes and sport association. Companies can place paid advertisements) https://gemeentewerf.nl/
- Materialenmarktplaats (material marketplace) https://materialenmarktplaats.nl/
- Insert Material marketplace (linked to Insert for material inventory and Madaster) https://marktplaats.insert.nl/

Methods

- Blockchain (example https://www.circularise.com/)
- MPG (milieu prestatie gebouw, Environmental Performance Building) (GPR is software to make MPG calculations) https://www.rvo.nl/onderwerpen/duurzaam-ondernemen/gebouwen/wetten-en-regels/nieuwbouw/milieuprestatie-gebouwen
- GreenCalc+: calculation program for environmental costs of a building or neighboorhoud https://www.ensie.nl/duurzaam/greencalc
- EMVI (‘*economisch meest voordelige inschrijving’*): grant based on value (https://houseoftenders.nl/wat-is-emvi/)
- MVI (‘Maatschappelijk verantwoord inkopen’: criteria for social responsible buying) https://www.pianoo.nl/nl/themas/maatschappelijk-verantwoord-inkopen-duurzaam-inkopen/productgroepen-mvi-criteria-4 (10-3-2021) (https://www.mvicriteria.nl/nl/webtool#//45/3//nl(10-3-2021)
- RCC (Rapid Circular Contracting) https://www.kplusv.nl/rapid-circular-contracting/

- Circulytics is used for integral reporting on company level. https://www.ellenmacarthurfoundation.org/assets/downloads/Circulytics-2.0-Indicator-Table.pdf
- EPD (environmental product declaration) With an EPD, manufacturers report comparable, objective and third-party verified data that show the good, the bad and the evil about the environmental performance of their products and services. https://www.environdec.com/home (11-3-2021)
- PCR (product category rules) Product Category Rules provide the rules, requirements, and guidelines for developing an EPD for a specific product category. https://www.environdec.com/product-category-rules-pcr (11-3-2021)
- Guidline materials passport https://circulairemaakindustrie.nl/app/uploads/2020/06/UPCM-leidraad-materialenpaspoort-v1.pdf
- Beelen (from demolition to urban mining) Urban Next https://www.cirkelstad.nl/beelen-next-experimenteert-met-materiaalpaspoorten-bij-sloop/

CITYLOOPS

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

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

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

CityLoops runs from October 2019 until September 2023.

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