CONTINUE MATERIAALCYCLUS:
MULTIFUNCIONAL BUILDING AT FAST SCHEVENINGEN

gebruiker

materialen

locatie

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Since the lectures at the start of the semester I wanted my focus/fascination on a topic related to sustainability. Some years before I had seen the VPRO documentary on tv and had read the book ‘Cradle to Cradle, Remaking the Way We Make Things’ by Braungart and McDonough. At the time it seemed like an interesting subject, but I never looked much further into the topic. What appealed most to me was the positive approach of ‘doing the right thing’ instead of minimizing ones impact on the world. My graduation looked like a good oppertunity to go deeper into C2C.

Cradle to cradle is a broad paradigm, to focus my project the topic therefor changed during my graduation into ‘continuous material cycle: a multifunctional building at FAST Scheveningen’.

The first part of this report is an outline of the graduation plan. The context of my project is given that explains where the project will be located and who the people are that will make the project their own. Next the objective of the graduation project is stated and how these objectives are planned to be reached.

In ‘Part 2: Concept’ the main idea of the building will be stated. This gives a frame for the material research given in part 3.

Part 4 is about the materials that were selected to go in with in the design. Part 5 ‘the design’ provides a description of the design; how the various material cycles are specified in the building, the calculations of the construction and climate. The report finishes with the reflection as handed in at the P4.
Part 1: Introduction
CONTEXT

SCHENENINGEN

The location given for the AE graduation studio is Scheveningen. Scheveningen is one of the most popular seaside places of the Netherlands and part of the municipality of The Hague. Er is a long, broad beach and long boulevard, a recent design by the architect Morales, and various attractions. On the beach there are many beachpavilijons and terraces. Scheveningen is a place where people go to relax, hold parties, meet, enjoy the sun, do watersports and walk through the dunes.

FAST SCHENENINGEN

The project is located on the terrain of F.A.S.T. Scheeningen. F.A.S.T. stands for Free Architecture Surf Terrain. It is a cultural platform next to the northern pier in Scheveningen where families, businesses, surfers, skaters, students, walkers, musicians and tourists meet. There is a beach hostel, camping and motor home, a bar, restaurant, art projects, a surf shop, surf lessons, board storage, unique meeting rooms, museum and theater Scheveningen (website FAST).

F.A.S.T. is an example of development in inbetween periods. It originated as a response to slowed down construction projects, a result of the financial crisis (website FAST). There is no clearly defined plan of what FAST should do, or how certain goals should be reached. Unexpected events are included in the plan and during the execution the terrain continues to develop.

afb.1: Scheveningen haven: location FAST
afb.2: main entrance FAST
PROJECT DEFINITION

PROBLEM FORMULATION

THE CURRENT SITUATION

The current state of the building industry is still based on a linear “take, make and dispose” model, also known as the ‘cradle-to-grave’ approach.

RAW MATERIAL → PRODUCT → WASTE

This model of the construction industry has an impact on some specific environmental problems:

- share in the landfill, mainly due to demolition waste
- depletion of natural resources
- the loss of fertile land due to urbanization
- large share in the emissions of greenhouse gases, mainly due to the combustion of fossil fuels for energy (both during the production of building products as for heating and electricity use in buildings)
- poor indoor air quality (sick building syndrome).

Some numbers: 35% of the national landfill comes from the building- and construction sector. Of this 40% consists of concrete, 25% of masonry, 25% asphalt, 10% remaining. (source slimbouwen en senternovem http://issuu.com/architecten-van-mourik/docs/levensduurzaamheid_totaal_web).

Although construction and demolition waste in the Netherlands is being recycled for about 98% since years (AFVALBRIEF STAATSSecretaris Atsma 2011), most of this is in the form of ‘downcycling’. Downcycling is a term popularized by William McDonough and Michael Braungart, authors of Cradle to Cradle: Remaking the Way We Make Things. Downcycling means the reuse of a product for alternative purposes or the recycling of material into lesser quality (Braungart & McDonough 2002). An example of this in the building industry is ‘betongranulaat’ which is currently mainly used as a foundation for roads. Next to downcycling, some of the waste ends up in landfills and incinerators as part of mixed flows. The expectation is that the amount of construction and demolition waste will increase in the coming years.

Furthermore any building today contains materials that are hazardous to our health. They range from materials that can be toxic with short-term or low-level exposure to those that can be toxic or carcinogenic years after exposure to those that are only irritants. Examples of this are PVC, Polyurethane, Volatile organic compounds (VOC’s). Some VOC’s have been associated with short-term acute sick building syndrome symptoms, as well as other longer-term chronic health effects, such as damage to the liver, kidney and nervous systems, and increased cancer risk (International Agency for Research on Cancer (IARC)).

high environmental impact of building materials

The environmental impact in the first decades of the lifespan of both homes and offices is for the most part determined by their materials (SEV 2004, Dobbelsteen 2004). This share of environmental costs of materials is greater than that of energy. After 20-30 years they are equal after that period the impact on the environment is mostly determined by the energy consumption. In the building materials, the loadbearing construction accounts for 60 to 70% of the environ-
mental impact (standard office). In office buildings, this high environmental impact is mainly due to the many transformations within the building. If materials are not handled with care, they can lead to a high environmental impact of the building.

**Wasting Nutrients**
The linear model fails to consider the high nutrient value of waste. Material recycling is essential for solving the increasing scarcity of raw materials on the world market. Worldwide consumption of raw materials is unsustainable at its current pace (Braungart 2010).

Prices of resources are increasing as they become more difficult and expensive to extract from the natural environment. Example copper that is now stolen from buildings, art etc.

We need to move away from this end of pipe paradigm to a situation where the cycles are closed. Despite many available technologies to effectively recycle materials, most products and buildings on the market are not designed for nutrient recovery.

**PROJECT OBJECTIVE**

The objective for my graduation project is to design a multifunctional centre on the FAST terrain in Scheveningen that after a short period of several years will be broken down and of which the building parts and materials are in a continuous material cycle. That means the project should be a construction constituting materials and building elements that can be recovered from the building and infinitely recycled through natural or industrial processes (Sassi 2008).

**RESEARCH QUESTION**

(How) is it possible to have the design of the building made from materials that are in a continuous material cycle?

**SUB-QUESTIONS**

1. Which are the design strategies to be followed for the building in Scheveningen in order for a continuous material cycle to be achieved?
2. Which materials and processes allow for continuous reuse of wastes, by-products and materials as technical or biological nutrients?
3. Which materials and processes are best used for the materialisation of the project in Scheveningen?
4. How can the lifespan of building materials be tailored to the lifespan and use of the building?

**METHOD**
The research question is dealt with from two directions as seen in the picture on the next page. On the one hand a preliminary, more general, research into the material cycle and possible materials is done, on the other hand the possible materials are looked at with the specific location, user and programme as a starting point.

**PRELIMINARY RESEARCH**
The theory shows that two aspects are important to a continuous material cycle: the material of the building elements itself and how that element is designed in
the building so it can be recovered. With the preliminary research an overview of materials is formed, dividing the various materials into main groups. The aspect of recovery from the building is looked into by analysing the principles of ‘design for disassembly’ and by some case studies of buildings made with these principles in mind.

SPECIFIC MATERIAL RESEARCH

Life cycle sustainability (Levensduurzaamheid) is the idea of taking the life cycle of a building as the main principle when thinking of sustainability (Van Mourik 0000) Optimizing the balance between the lifecycle of the building, components and materials can significantly reduce environmental impact by building materials. Materials with a longer lifespan used where that is actually necessary. And demountable components or materials with a short lifespan used if the service life of the building is short. Rapid changes require more flexibility in buildings. By reuse and recycling the environmental impact is reduced, as this prevents the use of new raw materials.

By investigating the external forces acting on a certain location, it can be determined what the life of a building can be, to which extent the building must be flexible and which functions the building should accommodate. With this a concept for the building is formed. With the concept of the building derived from the preliminary material research, starting points from the user and location, an idea of which building parts are needed in the building is formed.
life cycles of the building elements

When the concept for the building is established and thus the task is defined, a strategy and requirements for the materials is determined for each building part. With these elements the layers of a building as categorized by Brand is taken into account construction, access, skin, installations, dividing elements, furniture (Brand 1994)

» construction means the bearing walls, structural floors, columns, beams and trusses, foundation.
» access includes emergency staircases, stairways, elevators, corridors, galleries.
» The skin is formed by the wall and the roof.
» The installations consist of horizontal and vertical lines and cables, end-points (sockets, wifi connection, fan, etc.), appliances (heating, airconditioning, etc.) and the technical room.
» The dividing elements and the furniture are interior floors, walls, ceiling.

MATERIAL SELECTION

By selecting the right material to be applied for each element, efficient and effective use is made of the construction material. With selecting the materials the following in order of importance:

1. C2C certified products
2. Catalogus biobased bouwen
3. recommended materials from the Builddesk handreiking voor bouwen met Cradle to Cradle
4. NIBE basiswerk
5. other sources

MATERIAL EVALUATION

With selecting the materials per building element the following steps are taken.

6. What is the building element for?
7. What are the requirements?
8. evaluate the materials, more about these criteria in the next chapter
   › material health
   › reutilization
   › renewable energy use
   › water stewardship
   › social responsibility
9. Define the materials
10. Predict the material fates and identify hazards over the timeline of the product

use of lca

As can be read in the position paper ‘Usability of Life Cycle Assessment for Cradle to Cradle purposes’ (Bör et al. 2011) LCA is not a good tool to measure the extent to which a product is Cradle to Cradle, or how good it is for a continuous material cycle. LCA cannot measure the qualitative aspects of a C2C product. What it can do is add information to know what you have. This is how LCA studies are used in the material research part of this report.

THE DESIGN

After the materials the project will consist off are selected, the design is developed. The aspects construction and climate play an important role in this since
they are closely related to the chosen materials.

**BOUNDARY CONDITIONS**

This study examines the building materials, the lifespan and flexibility of certain building elements. These are all connected with the use by the handlers/users of the building and the environmental impact. The environmental impact of the building in this research is related to the building material and its cycle not by energy, which often is the initial thought when it comes to sustainability.

The “research” is focus on a specific building: the multi-use building on the FAST terrain in Scheveningen.

**DESIGN ASSUMPTIONS**

**LIFESPAN BUILDING**

When the location is very unstable, the building would be easy to disassemble. The service life of the location is indicative of the life of a building. Some sites are very dynamic and are within a few decades restructured (van Mourik 0000). In the project in Scheveningen all these considerations are present. The lifespan of for the project is set at about 10 years. The building is designed a flexible structure. It can be easily adapted to new needs and requirements, when the needs of the users for the building changes. It can also easily be demolished after his lifetime. This scenario is likely in places where a lot of momentum, a feature where flexibility is desirable and often changes occur, or for clients who only a short period may overlook.

**RESULT**

The result of the research is a design and an overview and evaluation of materials for the short/flexible scenario for the project on the FAST terrain in Scheveningen. The overview is used as a framework during the design process. Solutions for the scenarios and strategies are considered within environmental impact and use. It is a means to make the choice regarding of components during the design (where you can ask questions such as: How long will the construction take, how impermanent installation, etc. ..) related with the building itself (how long is the life of the building, to what extent it is flexible, etc. ..)

For the materials that were selected a more indepth study is done which is included in this report.
CRITERIA

MATERIAL REUTILIZATION

DEFINED APPROPRIATE CYCLE

Materials that have a continuous material cycle are defined as technical or biological nutrients that are recycled or renewable and are designed to be reclaimed in future life cycles.

According to the Cradle to Cradle paradigm definitions are given for the biological and technical nutrients. Hence, biological nutrients are “biodegradable materials (or the result of biodegradation processes) posing no immediate or eventual hazard to living systems that can be used for human purposes and be safely returned to the environment to feed biological processes”. A technical nutrient respectively is defined as “a material, frequently synthetic or mineral, that has the potential to remain safely in a closed-loop system of manufacture, recovery, and reuse (the technical metabolism), maintaining its highest value through many product life cycles”.


DEFINED RECOVERY PLAN

There is a strategy developed and implemented to close the loop on the product at the end of its useful life.

“For CLC to be relevant to the building industry, the timeframe within which the processes take place has to relate to human ability to plan the use and recovery of materials, as is the case in managed forestry.”


The key conditions which need to be met in order for a material to be considered as a Closed Cycle Material in relation to its recovery process, are as follows (Sassi, 2008):

» Infinitely through industrial or natural recovery.
» Without significant loss of material quality and mass.
» Within a limited time frame.
» Without uncontrolled or significant pollution emissions.

MATERIAL HEALTH

The following materials-substances states some of the current Red lists’ materials (of the frameworks mentioned above), which should be avoided during the building’s life cycle according to their high risk impacts on human and environmental health. (Cradle to Cradle Products Innovation Institute, 2011, http://c2ccertified.org/product_certification/program_details)

» Toxic heavy metals such as lead, mercury, hexavalent chrome, and cadmium
» Pigments, dyes, or other colorants
» Phthalates
» Halogenated organics

HUMAN HEALTH

Human health can be directly or indirectly affected on physiological and psycho-
logical level by the current built environment, its physical, chemical and biological characteristics (Sassi 2006). Related to building materials, chemical and biological disease agents can be identified, having physiological effects on human health such as allergies, respiratory problems or even carcinogenesis. These effects can also occur in a long term basis, according to the current amount of time and dose exposure.

The following is a list of the human health criteria used for substance evaluation by the C2CPII Cradle to Cradle® Design Protocol. The criteria are subdivided into Priority Criteria (most important from a toxicological and public perception perspective) and other Additional Criteria. Substances that do not pass the Priority criteria are automatically

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>PRIORITY</strong></td>
<td></td>
</tr>
<tr>
<td>Carcinogenicity</td>
<td>Potential to cause cancer</td>
</tr>
<tr>
<td>Endocrine Disruption</td>
<td>Potential to negatively effect hormone function and impact development</td>
</tr>
<tr>
<td>Mutagenicity</td>
<td>Potential to damage DNA</td>
</tr>
<tr>
<td>Teratogenicity</td>
<td>Potential to harm fetus</td>
</tr>
<tr>
<td>Reproductive Toxicity</td>
<td>Potential to negatively impact reproductive system</td>
</tr>
<tr>
<td><strong>ADDITIONAL</strong></td>
<td></td>
</tr>
<tr>
<td>Acute Toxicity</td>
<td>Potential to cause harm upon initial, short term exposure</td>
</tr>
<tr>
<td>Chronic Toxicity</td>
<td>Potential to cause harm upon repeated, long-term exposures</td>
</tr>
<tr>
<td>Irritation of Skin and Mucous</td>
<td>Potential to irritate eyes, skin, and respiratory system</td>
</tr>
<tr>
<td>Membranes</td>
<td></td>
</tr>
<tr>
<td>Sensitization</td>
<td>Potential to cause allergic reaction upon exposure to skin or airways</td>
</tr>
<tr>
<td>Other</td>
<td>Any additional characteristic (e.g., flammability, skin penetration potential,</td>
</tr>
<tr>
<td></td>
<td>etc.) relevant to the overall evaluation but not included in the previous cri-</td>
</tr>
<tr>
<td></td>
<td>terea</td>
</tr>
</tbody>
</table>
ENVIRONMENTAL HEALTH

Apart from materials’ impact on human health, they can also be considered in terms of environmental health. This impact can be seen in local-short term level and global-long term level. The first level is related to pollutive substances for the local ecosystem (soil, air, water) and the second level is related to environmental issues of a greater scale, such as materials depletion, global warming and so on.

The assessment of materials’ impact on environmental health is a highly complex research field, especially on global-long term level since all processes from the material extraction, manufacture, use, and finally its end of life phase need to be considered.

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fish Toxicity</td>
<td>Measure of the acute toxicity to fish (both saltwater and freshwater)</td>
</tr>
<tr>
<td>Daphnia Toxicity</td>
<td>Measure of the acute toxicity to Daphnia (invertebrate aquatic organisms)</td>
</tr>
<tr>
<td>Algae Toxicity</td>
<td>Measure of the acute toxicity to aquatic plants</td>
</tr>
<tr>
<td>Persistence/Biodegradation</td>
<td>Rate of degradation for a substance in the environment (air, soil, or water)</td>
</tr>
<tr>
<td>Bioaccumulation</td>
<td>Potential for a substance to accumulate in fatty tissue and magnify up the food chain</td>
</tr>
<tr>
<td>Climatic Relevance</td>
<td>Measure of the impact a substance has on the climate (e.g., ozone depletion, global warming, etc.)</td>
</tr>
<tr>
<td>Other</td>
<td>Any additional characteristic (e.g., soil organism toxicity, WGK water classification, etc.) relevant to the overall evaluation but not included in the previous criteria</td>
</tr>
</tbody>
</table>

The following is a list of the environmental health criteria used for substance evaluation by the C2CPII Cradle to Cradle® Design Protocol.

Figure 1.05: Key factors effecting environmental assessment of building materials
Curwell et al. 2002
ENERGY USAGE AND SOURCE

Renewable resources, including solar, wind, biomass and low-hydro projects. (http://c2ccertified.org/product_certification/program_details)

The goal of this category is to encourage manufacturers and their suppliers to manage their carbon emissions as efficiently and effectively as possible, while taking into account individual circumstances and assets available. Instead of minimizing the effects of inherently unsustainable activities, industry could be pursuing wholly sustainable goals, seeing carbon not as something negative and destructive, but as a resource. Cradle to Cradle® posits that an optimal carbon economy is one where energy is derived from current renewable energy sources, while other carbon emissions sources are returned to forests and soil.

The scope of the emissions measured in this category are initially contained to the facility assembling or manufacturing a product before it goes to the consumer (Scope 1 and 2 emissions under the Greenhouse Gas Protocol). More points are awarded as more of the carbon footprint is included.

EMBODIED ENERGY

The embodied energy is the energy consumed by all the processes required to produce a product. This includes the manufacturing energy for all the materials, sub components, and components as well as the energy to assemble all components into the finished product. Transportation energy is not included here.

WATER USAGE AND DISCHARGE

Water may appear to be a cheap, abundant and renewable resource, but in reality, just 3 percent of all water across the globe is usable. Unless an amount of clean water equal to what is withdrawn is returned to our aquifers, this resource cannot be considered truly renewable.

The goal of this category is to encourage manufacturers to move toward treating water as the valuable resource it is. By effectively managing water resources, manufacturers also reduce their business risk. These goals can be achieved by understanding water withdrawals, consumption, and healthier releases in a local context and innovating in the areas of improving conservation, quality and social equity.

The scope of the water stewardship measured in this category applies to the facility or facilities where a final product is manufactured, including any contracting facilities.

The following are resources that can be used as a guide:
World Business Council for Sustainable Development (www.wbcsd.org)
Hannover Principles: Design for Sustainability - Water (www.gemi.org/water/resources/hannover.htm)

At the Gold certification level, manufacturers are required to complete a water audit of their manufacturing process. This process is based on the Global Environmental Management Initiative resources. (www.gemi.org/water)

SOCIAL RESPONSIBILITY

Addresses fair labor practices, corporate and personal ethics (e.g., supplier relationships, competitive behavior, integrity), customer service, and local community. (http://dl.dropbox.com/u/83829123/Version%202.1/Social%20Responsi-
At a minimum, the following components of labor practices are evaluated using explicit criteria:

» Child labor
» Forced labor
» Health and safety
» Freedom of association and collective bargaining
» Discrimination
» Discipline/harassment
» Working hours
» Compensation

Suggested certification systems include, but are not limited to, the following:

» SA8000 (Social Accountability International) (www.cepaa.org)
» WRAP (Worldwide Responsible Apparel Production) (www.wrapapparel.org)
**CRADLE TO CRADLE CERTIFICATION™ CRITERIA**

<table>
<thead>
<tr>
<th>CRITERIA</th>
<th>Basic</th>
<th>Silver</th>
<th>Gold</th>
<th>Platinum</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1.0 Materials</strong></td>
<td></td>
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</tr>
<tr>
<td>All material ingredients identified (down to the 100 ppm level)</td>
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<td>•</td>
<td>•</td>
<td>•</td>
</tr>
<tr>
<td>Defined as biological or technical nutrient</td>
<td>•</td>
<td>•</td>
<td>•</td>
<td></td>
</tr>
<tr>
<td>All materials assessed based on their intended use and impact on Human/Environmental Health according to the following criteria:</td>
<td>•</td>
<td>•</td>
<td>•</td>
<td>•</td>
</tr>
<tr>
<td>Human Health: Carcinogenicity, Endocrine Disruption, Mutagenicity, Reproductive Toxicity,</td>
<td>•</td>
<td>•</td>
<td>•</td>
<td></td>
</tr>
<tr>
<td>Teratogenicity, Acute Toxicity, Chronic Toxicity, Irritation, Sensitization</td>
<td>•</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Environmental Health: Fish Toxicity, Algae Toxicity, Daphnia Toxicity, Persistence/Biodegradation, Bioaccumulation, Ozone Depletion/Climatic Relevance</td>
<td>•</td>
<td>•</td>
<td>•</td>
<td></td>
</tr>
<tr>
<td>Material Class Criteria: Content of Organohalogens, Content of Heavy Metals</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Strategy developed to optimize all remaining problematic ingredients/materials</td>
<td>•</td>
<td>•</td>
<td></td>
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</tr>
<tr>
<td>Product formulation optimized (i.e., all problematic inputs replaced/phased out)</td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No wood sourced from endangered forests</td>
<td>•</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>All wood is FSC certified</td>
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</tr>
<tr>
<td>Contains at least 50% GREEN assessed components by weight</td>
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<td></td>
</tr>
<tr>
<td><strong>2.0 Material Reutilization/Design for Environment</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Defined the appropriate cycle (i.e., Technical or Biological) for the product and developing a plan for product recovery and reutilization</td>
<td>•</td>
<td>•</td>
<td>•</td>
<td>•</td>
</tr>
<tr>
<td>Well defined plan (including scope and budget) for developing the logistics and recovery systems for this class of product</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Recovering, remanufacturing or recycling the product into new product of equal or higher value</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Product has been designed/manufactured for the technical or biological cycle and has a nutrient (re)utilization score &gt;= 50</td>
<td>•</td>
<td>•</td>
<td>•</td>
<td></td>
</tr>
<tr>
<td>Product has been designed/manufactured for the technical or biological cycle and has a nutrient (re)utilization score &gt;= 65</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Product has been designed/manufactured for the technical or biological cycle and has a nutrient (re)utilization score &gt;= 80</td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td><strong>3.0 Energy</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Characterized energy use and source(s) for product manufacture/assembly</td>
<td>•</td>
<td>•</td>
<td>•</td>
<td>•</td>
</tr>
<tr>
<td>Developed strategy for using current solar income for product manufacture/assembly</td>
<td></td>
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</tr>
<tr>
<td>Using 50% renewable energy for the manufacturing steps</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Using 50% renewable energy for entire product (including suppliers) and using 100% renewable energy for the manufacturing steps</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>4.0 Water</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Created or adopted water stewardship principles/guidelines</td>
<td>•</td>
<td>•</td>
<td>•</td>
<td></td>
</tr>
<tr>
<td>Characterized water flows associated with product manufacture</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Implemented water conservation measures</td>
<td>•</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Implemented innovative measures to improve quality of water discharges</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>5.0 Social Responsibility</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Publicly available corporate ethics and fair labor statement(s), adopted across entire company</td>
<td>•</td>
<td>•</td>
<td>•</td>
<td></td>
</tr>
<tr>
<td>Identified third party assessment system and begun to collect data for that, training for the employees</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Acceptable third party social responsibility assessment, accreditation, or certification for all manufacturers and adoption of social statements for the suppliers</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Part 2: Concept
STARTING POINTS

USER
The users of the project will be a large variety of people, ranging from families, businesses, surfers, skaters, students, walkers, musicians and tourists. The core users though can be described as alternative, active people that like to surf.

An ambition from the initiator of FAST is to have something new on the terrain every week something. Co-creation with others is a very important aspect in that.

From this a few starting points for the project can be derived:
• not a ‘finished’ building
• to anticipate the unforeseen with the project
• for the user to build on in the project to make it their own
• open/informal/beach atmosphere
• to have a connection with the open air and the rest of the terrain

LOCATION
The plot on the terrain that is chosen to base the project is located in the south-west side. In the current situation it is the least attractive area of the terrain, with containers on both sides of a path and a small messy place that serves as a camping place. The containers close off the terrain completely to the adjacent street and leave the passersby and boats that go to the harbor unknown of what is lying behind.

With the project the goals is to give the terrain a better image towards the street while being focused on what is happening on the terrain itself. For coming from the location. Another ambition is to make the terrain more visible from the beach to attract more people and extend route people take from the boulevard to the project.

CONCEPT
To accomodate the needs of the users the ‘programme’ is cut up in two parts: a fixed part which houses the ‘permanent’ functions and an open part where the users can add the functions that they find necessary themselves. The fixed part is designed as closed volumes while the open part is shaped as an open construction that can be filled in later to make partitions and an internal climate.

afb.7: location
vast
> natte cellen
> stijgpunten
> zalen
> technische ruimte
> energieopwekking

flexibel
> kantoren
> workshops
> slaapplekken
> ......

Patio’s
> accentueren contrast grancrete
> licht toetreding
> interactie tussen bouwlagen

flexibele indeling

Toren
> uitkijkpunt naar zee/strand
> tonen aan boulevard
> herkenningspunt/uithangbord

volumes
> zalen uitkomend op dakverdieping
> begane grond vrij voor andere functies
**MATERIAL REQUIREMENTS**

From the concept of the building requirements for the materials of the several parts can be derived:

<table>
<thead>
<tr>
<th>Volumes</th>
<th>Basis flexibel deel</th>
<th>flexibel deel &gt; maken ruimtes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gemakkelijk te maken</td>
<td>Gemakkelijk te maken</td>
<td>Gemakkelijk te gebruiken</td>
</tr>
<tr>
<td>constructief</td>
<td>constructief</td>
<td>Aanpasbaar - kan worden gevormd in elke gietbare vorm</td>
</tr>
<tr>
<td>robust</td>
<td>open constructie</td>
<td>Lichtgewicht, lage dichtheid</td>
</tr>
<tr>
<td>Biologische kringloop</td>
<td>Biologische kringloop</td>
<td>Goede geluidsisolatie</td>
</tr>
<tr>
<td>Vuurbestendig</td>
<td>Vuurbestendig</td>
<td>Biologische kringloop</td>
</tr>
<tr>
<td>vochtbestendig</td>
<td>vochtbestendig</td>
<td>Vuurbestendig</td>
</tr>
<tr>
<td>Bestendig tegen vriezen</td>
<td>Bestendig tegen vriezen</td>
<td>vochtbestendig</td>
</tr>
<tr>
<td>energiezuinig</td>
<td>robuust</td>
<td>Bestendig tegen vriezen</td>
</tr>
<tr>
<td>Termieten en schimmel bestendig</td>
<td>energiezuinig</td>
<td>energiezuinig</td>
</tr>
<tr>
<td></td>
<td>Termieten en schimmel bestendig</td>
<td>Termieten en schimmel bestendig</td>
</tr>
</tbody>
</table>

| Goede warmteisolatie in de zomer            | in de winter zijn ruimtes aangenaam            | Goede geluidsisolatie         |
|                                               |                                                 | Biologische kringloop         |
|                                               |                                                 | Vuurbestendig                 |
|                                               |                                                 | vochtbestendig                |
|                                               |                                                 | Bestendig tegen vriezen       |
|                                               |                                                 | energiezuinig                 |
|                                               |                                                 | Termieten en schimmel bestendig |
Part 3: Case studies
The aspects from the case studies are subdivided in the following categories: mens, energie, materiaal, natuur, profijt (see below). These categories come from the ‘handreiking voor het bouwen met cradle to cradle’ (Hoogers et al 2010).

### MENS
- lucht
- licht
- therm. comfort
- hygiene
- geluid
- flexibiliteit

### ENERGIE
- verwarming
- koeling
- elektriciteit
- lucht
- licht

### MATERIAAL
- drager
- schil
- systemen
- stuff

### NATUUR
- water
- flora/fauna
- omgeving

### PROFIJT

![categories case studie](image-url)
MENS
- flexibel / aan te passen gebouw met lange levensduur > grote overspanning
- mensvriendelijke werkplekken met maximale individuele beïnvloedingsmogelijkheden, een overvloed aan daglicht en uitzicht naar buiten. De keuze voor mogelijkheid tot individuele beïnvloeding leidde tot de integratie van hybride ventilatie. Een dergelijk ventilatiesysteem is ten dele mechanisch, en in dit geval CO2-gestuurd, in combinatie met natuurlijke toevoer via gevallen.

ENERGIE
- pv-panelen op dak, concentrator systems http://www.suncycle.nl/
- thermische zonnepanelen met bodemopslag van warmte en koude in de grond met een primeur voor hoge temp. opslag.
- hergebruik warmte uit bedrijfsprocessen
- plants on greenroof generate electricity: http://www.plant-e.com/

MATERIAAL
- prefab elementen
- extra gedetailleerde ruwbouw: hierdoor kit en schuim gebruik tergedrongen
- vaste luifels
- gebruik zoveel mogelijk C2C materialen
- geen giftige coatings, schuimen of verven
- Staal in plaats van aluminium
- Weinig gebruik van kunststoffen, kitten of schuimen
- Glas
- Niet chemisch verduurzaamd (Plato)hout en hout met FSC keur
- Beton met puingranulaat zonder kunststof toevoegingen en een laag gehalte portlandcement (dus meer hoogovencement)
- EPDM dakbedekking (gerecyclede autobanden)
- Veelal vlas, cellulose of schapenwol (rond luchtkanalen) als isolatiemateriaal
- Geen epoxy gietvloeren, maar gepolijste en milieuvriendelijk geimpregneerde betonvloeren. zodat optimale warmte- en koudeafgifte mogelijk is
- veel gebruik gemaakt van hout: wesem red cedar en plato hout voor niet constructieve delen, bekleding van gevels binnenwanden vlonders kozijnen en deuren
- Glas
- LED verlichting

De selectie van de materialen gebeurde hoofdzakelijk op basis van NIBE’s Basiswerk Duurzaam en Gezond Bouwen. niet een heel goede indicatie dat deze praktijkgids het ‘C2C-gehalte’ van bouwmaterialen weergeeft
lijst van gecertificeerde C2C-materialen niet geconsulteerd.

**NATUUR**

- vijver
- sterke verrijking van de aanwezige flora en fauna rond de gebouwen
- groot vegetatiedak, deels ingericht voor experimenten
- grondwallen ipv hek waarop planten groeien
- vlechtheg ipv hek
- in grondwal kelder ingegraven voor vleermuizen
- bijenhotel
- experimentele biologische zuivering van eigen afvalwater met fosforverwinning door algen
- helofytenfilter

**PROFİJT**

- recover nutrients from feces. recover nutrients with algae biogas, fosforus > toilets
- helofytenfilter
- algenkweek als meststof voor landbouw of grondstof voor bioplastics
VENLO CITY HALL

**project Stadskantoor te Venlo**
architect Hans Goverde
jaar 2009 -
functie: kantoren, overheid
13.500 m² vloeroppervlakte nieuwbouw stadskantoor
2.000 m² kantoornieuwbouw in het naastgelegen Nedinsco ondergebracht
circa 630 werkplekken (flexfactor 75%)
3 laags publieke parkeergarage met circa 400 parkeerplaatsen
11 verdiepingen
2.026 m² groene gevel
totale kosten: 46 miljoen
http://www.venloernieuwt.nl/stadskantoor

**MENS**
- uitgangspunt bij het ontwerp: De mens centraal Medewerkers en bezoekers moeten zich prettig voelen in het gebouw.
- Open, transparant Het stedekantoor moet zijn als de gemeentelijke organisatie: open, transparant, toegankelijk.
- Ondersteunend aan de dienstverlening van de gemeente Het stedekantoor moet het mogelijk maken dat de gemeente Venlo de best mogelijke dienstverlening kan bieden aan inwoners en bedrijven.

**ENERGIE**
- De kas, boven op het gebouw, zuivert de lucht en levert warmte voor het hele gebouw en voor de omliggende woningen
- De parkeergarage wordt gebruikt om de lucht in het gebouw vóór te verwarmen (in de winter) of te koelen (in de zomer).
- Daglicht wordt zo diep mogelijk het gebouw in gehaald, waardoor het gebruik van kunstlicht verminderd.
- Grootte en vorm van de vides zijn afgestemd op een zo natuurlijk mogelijke luchtstroom, waardoor minder gebruik hoeft te worden gemaakt van mechanische ventilatie.

**MATERIAAL**
- De constructie bestaat grotendeels uit hout.
- De inrichting is onafhankelijk van de constructie van het gebouw. Dat resulteert in een lange levensduur.
- Materialen zijn na de levensduur van het gebouw opnieuw te gebruiken.

**NATUUR**
- het gebouw zuivert de zwaar vervuilde lucht van de naastliggende weg en wordt gekoeld door de Maas en de onderliggende parkeergarage. Het gebouw zuivert de lucht van de weg en spoorlijn naast het gebouw door gebruik te maken van een grote groene gevel.
- Regenwater wordt opgevangen, gebruikt en door een plantenfilter gezuiverd voor het de Maas in stroomt.

**PROFJIT**
Daarbij wordt nu al rekening gehouden met toepassing van technieken die in de toekomst beschikbaar zullen komen. De cradle to cradle ambitie kan daardoor meegroeien naarmate er meer mogelijk wordt. Hoe langer het gebouw staat, hoe meer cradle to cradle het wordt.
KANTOORGEBOUW SEARCH

Datum definitief ontwerp 01-10-2006
Datum oplevering / realisatie 01-02-2008
Bruto vloeroppervlakte 1000 m² / Bruto inhoud 6450 m³
Netto vloeroppervlakte 900 m² / Netto inhoud 5580 m³
Projectarchitect: George Witteveen
Opdrachtgever: Search, Heeswijk-Dinther
Adres en Locatie
Petroleumhavenweg 8, 1041 AC Amsterdam
Programma
kantoor, opleiding, laboratorium
Constructeur
Raadschelders Bouwadvies, Spaarndam
Aannemer
Van Kessel Projectbouw, Rosmalen

**MENS**
- flexibel / aan te passen gebouw

**ENERGIE**
- overstek dak om zon en regen te weren.
- Buitenzonwering
- 's avonds wordt het gebouw afgesloten met schuifpanelen op het zuiden en harmonica panelen op het westen.
- vloerverwarming > daardoor weinig duurzame gevlingerde beton toegepast

**MATERIAAL**
- grote op maat geleverde elementen van een minimum aantal leveranciers.
- Demontabel
- gelamineerde vurenhouten kolommen en liggers. op maat aangeleverd en demontabel vastgezet met bouten en roeren en pen-gatverbindingen
- houten dak, verdiepingsvloeren en gesloten tussenwanden: KLH Massivholz zelfdragende platen.
- NOORD EN OOSTZIJDE: kruislingsverlijmde naaldhouten platen, 16cm dikke Pavatex isolatie, gevel en panelen afgewerkt met grof gezaagd western red cedar (geschilderd met antracietkleurige verf op lijnoliebasis)
- WESTZIJDE EN HELFT ZUIDZIJDE: gevelhoge drielaagse glaspanelen
- tussenwanden van geharde glasplaten op blokjes met bovenaan een vuren lat.
- gekit op de hoeken en verbinding met gangwand en raam

**NATUUR**
- vijver

**PROF.IJT**
BREATHING SPACE: EXPO-GEBOUW FLORIADE 2012

Onderzoeksproject Slimbouwen® meets Cradle-to-Cradle
Opdrachtgever: Venlo Greenpark, Venlo
Locatie: Floriadeterrein (Business park Venlo Greenpark) te Venlo
Ontwerp: WVTTK architecten
Ir. J. Henstra, Ir. J.J.M. van ’t Klooster, M. van der Wiel MArch
maart 2009
Supervisor: Prof. dr. ir. J.J.N. Lichtenberg
Oppervlakte: 24.400 m2 bvo kantoor- en exporuimte 400 parkeerplaatsen
Bouwkosten: € 28.914.000,-- ex. BTW, per m2 bvo € 1.185,-- ex. BTW
Partners: ABT, Velp - Stichting Slimbouwen, Eindhoven - TU/e, Eindhoven - Vitrivius Consultancy, Oss
Meer informatie: www.wvttkarchitecten.nl | www.slimbouwen.nl

MENS

• flexibel / aan te passen gebouw, casco en inbouw gescheiden, vrij indeelbare vloeren, flexibel gebouw dat kan krimpen en opzwellen, door wand tussenruimte
• De entree en gevelzones zijn de longen van de structuur. Hier zorgen bomen en planten voor de verse lucht en de juiste vochtigheid. Microzone als landschappelijke tussenruimte

ENERGIE

• lowtech oplossingen
• zon geoogst met een energiedak, PV-panels op het dak
• ventilatie door grondbuis aangevoerd in microzone. vervolgens individueel geregeld. creëren van een micro-klimaat tussen binnen en buiten dmv dubbele huidgevel
• mechanische en natuurlijke ventilatie
• buitenzonwering
• s Zomers vangen de koelwaterleidingen in het plafond de warme lucht deels af. Die wordt opgeslagen in de bodem en ’s nachts gedeeltelijk weggeventileerd.
• betonkernactivering + WKO
• pcm toegepast in gebouw

MATERIAAL

• scheiden van waardevolle casco en de vraaggerichte inbouw
• prefab onderdelen
• casco kan circuleren in de technosfeer, Het casco is in basis licht en compact
• glazen buitengevel en een houten binnenkozijn met draaiende delen
• leidingtechniek een duidelijke plaats te geven, Het separeren van leidingen in combinatie met bereikbaarheid (luiken, goten, etc.). De Slimline-vloer met een demontabele topvloer houdt de leidingen toegankelijk voor aanpassingen

NATUUR

• Het regenwater wordt opgevangen, gefilterd in de naastgelegen vijver en gebruikt voor toiletpoeling en beregening van het groen.
FORD ROUGE CENTER

Client: Ford Motor Company
architect: McDonough + partners
location: Dearborn, Michigan
Program: Manufacturing, administration, employee amenities
Area: 1,300,000 square feet
Status: Completed June 2003
Team: William McDonough + Partners, Design Architect, Arcadis Giffels, Architect of Record, Civil MEP and Structural Engineers, Walbridge Aldinger, Construction Manager

MENS
- Inside the plant, wood flooring reduces stress on workers’ feet and legs
- Light monitors and skylights ensure that work areas receive daylight.
- An innovative air delivery system reduces the need for duct work, and mezzanine-level walkways house team rooms, a cafeteria, and a dining room above the main work areas.

ENERGIE
- Solar energy

MATERIAAL
- Wood flooring

NATUUR
- Restores native habitat to the site
- The plant’s 10-acre vegetative roof—the largest installation of its kind in the United States—provides aesthetic and operational benefits that include restoration of native habitat, effective thermal and acoustic insulation, and improved air and water quality.

PROFJIT
- Green roof reduces maintenance costs
- Sunlight reduces amount of electrical lights
DESIGN FOR DISASSEMBLY

To have materials and building elements that can be recovered from the building and infinitely recycled through natural or industrial processes, they have to be able to be removed from the building and dismantled. This requires the building to be built so it can be deconstructed.

The Design for Disassembly (DfD) movement has developed various principles to reach this goal. Common DfD principles are (source: www.design4deconstruction.org):

**Use mechanical connections** – avoid composite connections such as select fittings and custom fasteners as well as adhesives and sealants for they are more difficult to remove and recover reclaimed materials without damaging. Mechanical fasteners and releasable adhesives allow for quick and clean material recovery, improved reusability, reduced toxicity and even reduced initial construction and deconstruction costs.

**Prefabricated and modular construction** – this allows for quick assemble and disassemble on-site as long as the connections are simplified and mechanical. Prefabrication of components and elements off-site improves the quality by consistent fabrication and protection from weathering.

**Standardize connection details and materials** – enhance assembly and disassembly process by specifying fewer connections and standardizing the connection type. Few connections reduce construction and deconstruction times. Specifying standard connection types increase the feasibility of the connection to be used elsewhere in the project. Tools required for fastening the connection ought to be standardized tools.

**Design with unit sizes and large spans** – Designing with material unit sizes greatly reduces the construction waste and construction times while increasing the future usefulness of the product. If there are no unit sizes specified (such as structural steel) design to cover large spans with standard dimensions. Covering long spans in construction reduces interior structural elements while having standard dimensions increases the potential of the elements to be used again.

**Minimize building components and materials** – Reduce the problem of multiple layering of materials by specifying components that have multiple physical properties. Choosing whole materials that are durable and that can have multiple functions will increase the life and use of that component while reducing the fabrication of poor quality products that only serve a single temporary use.

**Reduce building complexity** – buildings with complex structural elements such as pre-stressed and post tensioned beams, cantilevers and undercuts are more difficult to deconstruct and ought to be avoided. Simplify the constructability of the project and separation of materials. Easier construction means easier modification or deconstruction. This includes integration of multiple building services/systems which are entangled into one another.

**Separate building components and systems** – long-lived components must be separated from short-lived components in order to facilitate adaptation for future needs. Typically this means separation of the following building layers; site, structure, skin, building services, space planning, and mobile equipment. This also means that each layer must have proper accessibility, visually and physically, for ease of future modifications. Designing in such a manner will facilitate easier
collection process because materials can be removed one at a time.

**Design for flexibility and adaptability** – design to include an open bay design in which interior operations can adapt to future needs. This design can help improve constructability as well as reduce costs of the life of the building. Flexibility in meeting future code requirements ought to be considered as well. This includes; increased electrical demands, increased insulation demands, increased durability to withstand potential extreme climate changes, etc.

**Provide a detailed deconstruction plan** – create a list and specifications of building elements, components and materials used in the construction project. Include the expected service life, weight, and material recovery strategy. (Ex. direct reuse, product recovery management, or waste management) and recommended handling strategies. The deconstruction plan must also include a set of drawings which include key structural properties, location of wiring systems, details of connections and deconstruction strategies. Also in the deconstruction plan, a list materials that are hazardous to human health or require high levels of safety concerns.
XX OFFICE PROJECT, DELFT

• designed to last 20 years
• supposed to lay on steel pillars which could be easily taken out from the ground
• ground floor is separated from thermal insulation with thin foil so that the floor could be easily replaced and recycled in the future.
• first floor level wooden sandwich panels (600x500cm) are filled with a thick layer of sand in order to improve the acoustical separation between the floors.
• wood as the structural material
• The elements used to connect columns and beams are standard steel plates, pins and bolts. A few simple tools will be needed in order to loosen the connections while a small crane is needed for loading the materials on to a truck.
• The buildings envelope is made of glass façade. Triple pre-assembled glass segments (2x5m) which are placed in the wooden frame with screws.
• The wooden façade frames have been placed on the steel consoles which are attached to the main structure. This makes the façade independent from the main frame however because the upper side of the frame is screwed to the first floor panels,
• Each glass façade segment contains an integrated climate façade system.
• All horizontal ducts for air condition are made of cardboard and are attached to the T-profiles that are connected to the floor panels.

DELFTECH PARK, DELFT

• flexible building concept
• deconstructable double glass façade system, for the following reasons: energy performance, maintenance, employment fluctuations, multiple functioning, image and investment
• This system only requires two people in moving the main façades horizontally however if the façade needed to be moved vertically a crane would be needed as well as the removing of the outermost glass façade.
• ground floor can be changed from a parking as it is now to office, storage unit, or separate business. column spacing,
• A noticeably large open atrium is in the middle of the building and has been designed to add a floor without disruption of the plumbing and HVAC system. Interior walls are made out of temporary partitions so if the floorspace in a room needed to be modified
• building grid contains standard mechanical connections so deconstruction and reconstruction is more consistent and feasible.
• components were prefabricated
MARTINI HOSPITAL, DRONINGEN, NETHERLANDS

- departments are blurred with rooms in between them which can support both functions
- standardize dimension “building block” which can satisfy the demands of safety, natural daylight, structure, services and floor planning.
- extensions can be added onto the hung facade to gain extra floor area
- layouts based on 300mm grid
- only fixed elements are the services shafts
- elevations have been designed to allow for flexible wall positions
- modular partition walls, coupling services and furniture
- Points for electrical, medical gases and water are movable as well as cupboards and counters
- facade made of removable panels which can be changed to suite the functions it encloses
- great amount of prefabrication

STRAW BALE HOUSE, LONDON, UNITED KINGDOM

- low cost materials that were often originally intended for another use. structure composed of straw bales and sandbags
- The structures’ two stories are set on gabion columns, wire casings filled with concrete blocks retrieved from nearby demolition sites.
- other walls are timber framed, wrapped in a quilt like “cloth” made of silicone face fiber-glass with an insulating layer and as inner lining
- timber grained wall lined with a wall of woven polypropylene sacks filled with sand, cement and lime
Part 4: Material Research
<table>
<thead>
<tr>
<th>MATERIAL</th>
<th>START CYCLE</th>
<th>DESIGN OPTIONS</th>
<th>END CYCLE</th>
<th>SAMPLE</th>
</tr>
</thead>
<tbody>
<tr>
<td>MUSHROOM DERIVED MATERIAL</td>
<td>byproducts such as rice hulls, buckwheat hulls, oats, cotton seed hulls or cellulose sludge from paper mills mushroom</td>
<td>insulation Structural Insulating Panels building blocks acoustic tiles cast in molds easy to sculpt with, make blocks, mortar, plaster insulation</td>
<td>homecompostable</td>
<td></td>
</tr>
<tr>
<td>PAPERCRETE</td>
<td>re-pulped paper fiber Portland cement or clay and/or other soil added</td>
<td></td>
<td>with clay used: biodegradable</td>
<td></td>
</tr>
<tr>
<td>HEMPCRETE</td>
<td>hemp hurs (shives) and lime (possibly including natural hydraulic lime,sand, pozzolans or cement)</td>
<td>building blocks insulation must be used together with a frame of that supports the vertical load in build-</td>
<td>recycled in new hempcrete biodegradable (can be used as fertilizer after being demolished)</td>
<td></td>
</tr>
<tr>
<td>GRANCRETE</td>
<td>sand/soil, ash magnesium oxide, phosphate powder water</td>
<td>spray on</td>
<td>biodegradable crushed and mixed with soil fertilizer</td>
<td></td>
</tr>
<tr>
<td>TIMBERCRETE</td>
<td>timber waste products Sand binders (Cement binder such as Portland cement)</td>
<td>bricks blacks panels paving</td>
<td>cementbinder restricts biodegradability</td>
<td></td>
</tr>
<tr>
<td>RAMMED EARTH</td>
<td>earth (additives possible)</td>
<td>walls blocks flooring arcs</td>
<td>back in soil</td>
<td></td>
</tr>
<tr>
<td>DEMODÈ</td>
<td>textile waste starch-based binder</td>
<td>wall tiling in development, easily drilled, sawed, or bound to other materials</td>
<td>?</td>
<td></td>
</tr>
<tr>
<td>Zefo</td>
<td>plants and waste with high cellulose contents. hemp, flax, paper</td>
<td>molding replace conventional plastics and chipboard</td>
<td>biodegradable</td>
<td></td>
</tr>
<tr>
<td>Waste plastic structural material</td>
<td>waste plastic sand</td>
<td>moldable liquid product</td>
<td>?</td>
<td></td>
</tr>
<tr>
<td>Aggcrete</td>
<td>agricultural waste cement and or lime binder</td>
<td>blocks moldable</td>
<td>biodegradable</td>
<td></td>
</tr>
<tr>
<td>Baggerspecie (baggerslib)</td>
<td>baggerslib uit rivieren, sloten</td>
<td>bodem versterken opvullen</td>
<td>reinigen en verwerkt</td>
<td></td>
</tr>
<tr>
<td>Thermo Poly Rock</td>
<td>waste products Resin</td>
<td>moldable liquid product</td>
<td>?</td>
<td></td>
</tr>
</tbody>
</table>
CRETES

The materials I summarize under the name ‘cretes’ consist of natural fibres or waste material with a binder that try to approximate concrete in use and material characteristics.

PAPERCRETE

Papercrete is an experimental building material made of re-pulped paper fiber with Portland cement or clay/other soil added. Using Portland cements in the mix has several environmental drawbacks and is therefore not preferred in this project. With clay added to the paper the mix is also known as ‘fidobe’ or ‘padobe’. The dry ingredients are mixed with water to make a slurry.

The material is lightweight and easy to sculpt with, make blocks, use as a mortar, a plaster for walls, as floors, as wall insulation, as roofing insulation and various other applications. Papercrete is very cheap (Roberts 2008). The properties of the material vary considerably depending on the mix of ingredients.

Two downsides of papercrete have to do with water: the material takes a long time to dry and it absorbs water when it’s applied (Lacinski & Bergeron 2000). It will become moldy if it holds water for too long and might even deteriorate. Some experiments with papercrete without any cement added to the material have found problems with termites (Living in Paper 2007).

sources:

HEMPCRETE

Hempcrete is made out of hemp shives and lime (possibly including natural hydraulic lime, sand, pozzolans or cement). Together these form a bio-composite material that can be used to make buildings that have excellent thermal properties as well as offering healthy living and working environments.

Using hempcrete requires the construction of a load bearing timber frame. This is necessary because the material only has a typical compressive strength of 0.2 - 1.0 N/mm² (HLCPA 2006). Hemp and lime masonry construction provides a method of building which can provide thermal and acoustic insulation, thermal mass and storage but can also be used as the external skin of a building. It is
simple to construct, it can be to meet very many different requirements for walls, floors and roofs (Bevan & Woolley 2008). Hempcrete has the ability to lock up CO₂ where it is used, which makes it CO₂ negative.

Hemp grows very fast, from seed to four meters high in fourteen weeks, and is virtually disease resistant. It can be used in rotation with other crops and helps improve the soil. Furthermore, 100% of the plant is useful.

Properties:
- Hempcrete can be reused in new hempcrete and is biodegradable
- Low density
- High thermal insulation
- High thermal inertia
- Good vapour permeability
- Good flexibility
- Fire and pest resistant
- Can significantly reduce CO₂ emissions
- Inherently air-tight structures

In the Netherlands there is almost no experience with building with hemp. In France and the UK however there are several hundred buildings made with hempcrete. Point of attention is that getting the right mix for hempcrete is important as there has to be enough lime for it to set the thermal properties would be lost if it contained too much (or not enough hemp).

sources:
Woolley T., 2004, The role of low impact building materials in sustainable construction: The potential for hemp, Sustainable Building, Africa Conference, Stellenbosch, South Africa
http://www.lhoist.co.uk/tradical/hemp-lime.html
http://equalplanet.co.uk

GRANCRETE

Grancrete is a sprayable ceramic, developed at Argonne National Laboratory as an application of a magnesium oxide-based cement. Grancrete is made from an environmentally friendly mix of locally available chemicals (Wagh 2004). It consists of sand or sandy soil, ash, magnesium oxide and potassium phosphate, which is a biodegradable element in fertilizer. When the project is demolished, grancrete can be pulverized by crushing equipment and mixed with soil. The potassium phosphate then will actually revitalize the soil.
The Grancrete family of products solves tough problems due to unique characteristics:

- Strong: between 6,000 & 8,000 PSI
- Short curing time: ~15 to 20 minutes
- Non toxic
- Impervious to water, including salt water
- Fire resistant
- Does not expand or contract
- Long life span > 100 years
- Nontoxic to humans and the environment
- Can be sprayed, poured, troweled, or painted

Possible downside of the material is the ability to use it in a way that it is designed to be disassembled. The material is in its use comparable to concrete, which from case studies are unlikely to qualify as a material good for DfD (Sassi 2008).

sources:
http://www.grancrete.net/
http://www.rexresearch.com/wagh/wagh.htm#worldsci
http://www.world-science.net/othernews/050124_grancretefrm.htm
http://www.greenhomebuilding.com/QandA/manufactured/magnesiumoxide.htm

Paola Sassi (2008): Defining closed-loop material cycle construction, Building Research & Information

**afb.17:** Grancrete
TIMBERCRETE

Timbercrete is an Australian building product made from timber waste such as sawdust and or wood chip, unwashed sand and a small portion of portland cement binder (17% to 20%) that is typically added.

With Timbercrete you can construct with a single skin. Construction alternatives include blocks, pavers, veneer or double brick, and wall panels but the material can be moulded into a vast range of sizes, shapes and textures.

Timbercrete has an embodied energy of 1.6 MJ/kg (JOHNSTON 2006). Furthermore it has a very high load-bearing capacity, it is lightweight (density is 900 to 1000 kg/m$^3$). Walls made from the material have good sound and thermal insulating values. it has a Thermal mass of (Volumetric thermal capacitance) $= \text{MJ/m}^3\text{K}$, an R value of W/m.K 0.234, and low thermal drag (about Timbercrete).

From comments of users it can be found that a drawback from using Timbercrete are the special mortar requirements. Also Timbercrete and the mortar contain cement.

sources:

MUSHROOM MATERIAL

This material is made out of agricultural byproducts and mycelium, a fungal network of threadlike cells. It’s like the “roots” of mushrooms. The mycelium acts as a binder that. It forms a material that is fast growing, has an environmentally low-impact is 100 percent biodegradable and renewable, and is part of a healthy ecosystem.

The material is experimental and as a product is sold only as a material for packaging and thermal insulation. Other uses are currently in development. Ecovative, a material science company known for its innovative mycelium technology, is currently developing Structural Insulating Panels, and acoustical tiles made out of this material. Phillip Ross, an inventor/artist, has made several architectural structures and furniture pieces out of the mushroommaterial. He discovered that when dried,
it can be used to form a super-strong, water-, mold- and fire-resistant building material. And according to Bayer’s engineering tests, densely packed mycelium is strong enough to be used in place of wooden beams (Fisher 2010). In 2010 Phillip Ross patented several ways of making and building with the material (Ross 2010).

sources:
http://www.ecovativedesign.com/
http://www.greensulate.com/

AGGCRETE
This material uses common agricultural wastes such as crop stalks, chipped wood, or any other low density, commonly available lightweight material. Waste material is simply chopped (up to golf ball size or so), blended, and mixed with cement and/or lime. When cured and dried, it makes a very lightweight composite.

The properties of the material vary greatly depending on the waste material used and the ratio’s of the mix.

sources:
http://www.planetaryrenewal.org/ipr/structural.html

RAMMED EARTH
Buildings made from rammed earth are made simply by ramming the earth in between shuttering to form a wall. Rammed earth is both cheap and has low embodied energy, if earth from the site can be used. Rammed earth can be returned to the soil or reused in other building projects. Earth is available at most construction sites and therefore a very local material. However to get the right mix additional material (such as clay) may be required.

The compressive strength of rammed earth can be up to 4.3 MPa (Cassel & Robert 2001). This is less than that of concrete, but more than strong enough for use in domestic buildings.
Rammed earth is not particularly thermally efficient, but has high thermal mass which is beneficial in warmer summer months. The material contains no toxins or off gasses unhealthy substances. Walls made out of rammed earth are typically 30 to 35cm , with the density of the earth this makes them soundproof. They are also termite-resistant and fireproof. It can take as little as two to three days to
construct the walls for a 200 to 220 m\(^2\) (2,200 to 2,400 sq ft) house (Cassel & Robert 2001).

Downside in using this material is that rammed earth is a labour intensive process that requires some skill. Furthermore it has to be designed so the water and wind present in Scheveningen do not erode the structure a the point of failure.

sources:
http://equalplanet.co.uk/http:/equalplanet.co.uk/sustainability/building-materi-als/hello-world/

DEMODE

This new material uses natural and plastic waste and is held together with a biodegradable starch-based adhesive. After being sealed with greenwash it has a high structural strength according to Bernardita Pecas, who has designed various furniture pieces with the material.

Currently it is used as decorative interior wall cladding, design objects and accessories like furniture application. It is easy to work with (sawing, drilling, sanding, screwed, glued and attached to other materials, etc.).
A few properties of the material are known:

- Demode contributes to LEED certification, since it has a 36% pre-consumer recycled content, 40% rapidly renewable material content and 40% regional material.
- Acoustic properties: In study (sound absorption)
- Fire resistance: Self-extinguishing according to standard Of.85 NCh 1977. (IDIEM) UV resistance: Good resistance to moisture: Keep out of moist areas
- Weight: 5 Kgs approx. (10 mm module)

sources:
http://www.demode.cl/

ZELFO

Zeflo is a patented material developed by Zeflo Technology. The material is made for 100% of renewable or recycled cellulose fibres. Potential raw materials for the production of Zeflo include various plants and wastes with a high cellulose content (e.g., hemp, flax, waste paper).

In the production process the raw material is chopped and mixed with water. This results in a microfiberpulp, which is subsequently predried, cast or molded into a final shape and dried. The use of Zeflo-based materials provides the potential to up-cycle fibre-based waste, which can then be recycled into new products which, in turn, are recyclable and biodegradable.

Due to the possible variations in raw materials and in the production process, properties of Zeflo can be varied over a certain range. For example, values for density from 0.5 to 1.5 g/cm³, for tensile modulus from 1500 to 6550 MPa and for tensile strength from 7 to 55 MPa can be achieved. Thus, Zerfo is likely to compete with both conventional plastics and chipboard for certain applications.

Because of the cellulose based chemical nature of Zeflo, Zeflo materials absorb water which significantly reduces modulus and strength properties. Via the incorporation of internal water-proofing agents and/or surface sealants this drawback can be avoided. The Zeflo material has inherently good fire resistance.

sources:
http://www.zeflo-technology.com/zeflo-by-industry/
Renewable Resources, Molecular Crystals and Liquid Crystals Science and Technology. Section A. Molecular Crystals and Liquid Crystals

Thermo Poly Rock

Thermo Poly Rock is a structural composite material made from 100 percent recycled plastic. Affresol, the firm that invented Thermo Poly rock, mixes granulated plastic waste with a mineral/resin compound. The finished product pours like concrete and dries in 2½ hours and is produced for about 12 percent less than standard bricks or blocks. It has a carbon footprint much lower than that of composites made from plastics melted at high temperatures.

Some properties of Thermo Poly Rock (TRP) are:
- TPR stronger than concrete, the strongest version has a compressive strength ranging from 58 N/mm² to 82 N/mm²
- TPR has excellent thermal insulation characteristics;
- TPR is very durable (estimated at 80 years);
- TPR is water proof/fire retardant/not susceptible to insect infestation;
- TPR has a “Low Carbon Footprint”
- TPR has better flex and tensile characteristics than concrete.

In view of a continues material cycle, TRP scores low since the plastic and resin can only be downcycled after use.

sources:

Strawbale

Strawbales can be used in a structural and non-structural way. In the structural way the strawbales are stacked after which they are tensioned by a wooden frame. In the non-structural way the strawbales are only used as insulation alongside a wooden frame. Although these are the two main methods of building with strawbales there is much difference in execution. Each country has its own way of building, depending on local regulations and presence of material. Strawbale panels can also be prefabricated, so that entire walls can be placed in one go.
Straw bales are a by-product of agriculture. Therefore, it is plentiful and cheap. For demolition, no harmful substances, only easy to process or reusable materials remain.

- Straw is a 100% organic material.
- Straw is free of toxins.
- Energy required for extraction, processing and transport of straw is very low.
- Size: Width x Height x Length: approx 480 x 360 x 800 mm
- Weight: 15-20 kg per bale
- Very suitable for DIY
- Depending on the design it is possible to build quickly. The nature of the finishing and detailing determine the required amount of work and thus to a large extent the cost.
- Thermal insulation is excellent (Rc > 7 m²K/W).
- Acoustics are good (Rw 55 dBA).
- Plastered straw bales are excellent fire resistant (> B90).

During construction, the straw bales are not fire or water-resistant, which makes it tricky to build with in the Dutch climate. Also, the thickness of the walls, about 55 cm, must be taken into consideration in the design. How there is dealt with rainwater stays a point of attention when building with straw.

Sources:
http://www.strobouw.nl/

afb. 24: prefab straw panel
afb. 25: structural method
WOOD

Wood and woodproducts can be used as biological material for various building parts as a replacement of steel, concrete, flooring, inner walls and finishes (Fraanje & Van Kampen 1998). Which species of wood is used for which application can be found in the tables in the appendix (Van Dam & Oever 2012).

CERTIFICATION

According to the criteria of C2C, also used in this research, all wood must be certified (MBDC 2008). This means that wood must have either an FCS or PFEC certification. The FSC certification states ten principles that require the forest owner or manager to do the following:

<table>
<thead>
<tr>
<th>Principle</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1: Compliance with laws and FSC Principles</td>
<td>to comply with all laws, regulations, treaties, conventions and agreements, together with all FSC Principles and Criteria.</td>
</tr>
<tr>
<td>2: Tenure and use rights and responsibilities</td>
<td>to define, document and legally establish long-term tenure and use rights.</td>
</tr>
<tr>
<td>3: Indigenous peoples’ rights</td>
<td>to identify and uphold indigenous peoples’ rights of ownership and use of land and resources.</td>
</tr>
<tr>
<td>4: Community relations and worker’s rights</td>
<td>to maintain or enhance forest workers’ and local communities’ social and economic well-being.</td>
</tr>
<tr>
<td>5: Benefits from the forest</td>
<td>to maintain or enhance long term economic, social and environmental benefits from the forest.</td>
</tr>
<tr>
<td>6: Environmental impact</td>
<td>to maintain or restore the ecosystem, its biodiversity, resources and landscapes.</td>
</tr>
<tr>
<td>7: Management plan</td>
<td>to have a management plan, implemented, monitored and documented.</td>
</tr>
<tr>
<td>8: Monitoring and assessment</td>
<td>to demonstrate progress towards management objectives.</td>
</tr>
<tr>
<td>9: Maintenance of high conservation value forests</td>
<td>to maintain or enhance the attributes which define such forests.</td>
</tr>
<tr>
<td>10: Plantations</td>
<td>to plan and manage plantations in accordance with FSC Principles and Criteria.</td>
</tr>
</tbody>
</table>

(source: FSC website, https://ic.fsc.org/the-10-principles.103.htm)

WOOD PRESERVATION METHODS

modified wood

- Thermo Wood® and Plato® wood are softwood (spruce) products that by a thermal treatment are preserved and are therefore more versatile in use, including for outdoor applications such as cladding, fencing or barns. http://www.metsawood.com/products/thermowood/pages/default.aspx
  http://www.platowood.nl/
- Accoya® wood treats (needle) wood with acetic anhydride, which makes the material water-resistant and improves dimensional stability. Acylation of wood has the effect that the treated material no longer absorbs water and that the wood is not more recognized by wood-degrading micro-organisms. http://www.accoya.com/
- Waxwood® is an example of a water-repellent product on the basis of native wood where the wood is impregnated with wax at elevated temperature. The product is suitable for outdoor use. http://www.foreco.nl/waxedwood.html
- Coal tar was formerly used in shipbuilding. By means of pyrolysis of wood under oxygen-free conditions a reactive black coal tar oil (bio-oil) is obtained that can glue wood, make it hydrophobic and can be preserved.
- Impregnation of wood with renewable products such as pyrolysis oil, lignin
(residue from the paper production) and furan resins has an excellent wood-preservative effects, especially on cheaper and lighter wood such as poplar and willow or softwood.


RENEWABLE PLASTICS

Currently a lot of research is being done into bioplastics and bioresins. PLA and PHB are two of these plastics and can replace PP and PET plastics in many applications. PLA is made on the basis of natural sugars. It can be completely biodegraded, composted or used for feedstock for recycling. Biofoam by Sinbra Technology is a foamed product made of PLA and is Cradle to Cradle gold. It can be a replacement for EPS.

sources
http://www.greengran.com/
http://www.biofoam.nl/index.php
http://www.npsp.nl/page.asp?ID=14
http://en.european-bioplastics.org/
FOUNDATION

WOOD

Historically foundations were made of wood. In the Netherlands two types of wooden polefoundations were most commonly used: the Rotterdamse polefoundation and the Amsterdamse polefoundation (see afb10).

Point of attention with a wooden foundation is that they should always stay below groundwaterlevel, otherwise the wood will rot and lose its loadbearing capacity.

Wooden foundationpoles are stil up to this day. A ‘betonopzetter’ a concrete piece is nowadays placed on top of the wooden piles. The betonopzetter makes sure the pole stays below the groundwaterlevel to avoid polerot.

sources:
http://www.joostdevree.nl/shtmls/amsterdamse_methode.shtml

MAGNESIUMOXIDE CEMENTS

Usually Portland cement-based concrete provides the foundation for buildings. Cements based on magnesiumoxide have various benifits over portland cement.
For the use in foundations Ceratech’s Eccomax is an option,

SOURCE
Magnesium deposits exist in abundance in every corner of the earth and cover roughly 8% of the world’s surface. Phosphates are available from many sources ranging from phosphoric rock to animal wastes and fermented plants, which historically were used to “react” with various oxides to produce these environmentally friendly, non-toxic cements.

MATERIAL HEALTH
In comparison with portland cement MgO cements have no off-gassing or harmful fumes. Furthermore research at Argonne National Laboratories has shown that in buildings with MgO cements there were fewer instances of radiation sickness compared with other buildings in the area near Chernobyl.

MATERIAL REUTILIZATION
Some MgO based cements allows for the use of non-traditional aggregates such as crushed consumer or commercial glass in the mix, this is an advantage over portland cement. Also coal ash, a waste product from coal burning utilities, is added to the mix.

What is possible with the material when a project is demolished is not to be found in the various sources. Presumed is that the cement is crushed and used as aggregate.

RENEWABLE ENERGY AND CARBON MANAGEMENT

<table>
<thead>
<tr>
<th>CURRENT CEMENT PRODUCTION</th>
<th>MGO CEMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbonate feedstock: limestone is dug up and processed. Typically 400kg of CO₂ released from limestone per tonne of cement.</td>
<td>Non-carbonate feedstock (uses magnesium silicates) so no CO₂ from the raw material.</td>
</tr>
<tr>
<td>High temp process (1,450°C) requires fossil fuel. Typically 400kg of CO₂ created from fuel per tonne of cement.</td>
<td>Lower temperature process (700°C) can better utilise biomass fuel. 0-420kg CO₂ created per tonne of cement, depending on fuel mix used and choice of feedstock.</td>
</tr>
<tr>
<td>No absorption of CO₂ in cement production.</td>
<td>Cement composition includes a carbonate created during production process by absorbing CO₂. 30-100 kg CO₂ absorbed per tonne of cement.</td>
</tr>
<tr>
<td>Total typical emissions of +800kg CO₂/tn cement</td>
<td>Total typical emissions of -100kg to +320kg CO₂/tn cement</td>
</tr>
</tbody>
</table>

PROPERTIES
- superior in compressive (9,000 to 45,000 psi) and tensile strength (over 800 psi)
- superior in environmental integrity
- bind naturally and exceptionally well to all things cellulose in contrast
to portlandcement > no binders necessary. binders > restrict ability to breathe> binding in moisture and increasing the likelihood of mold damage  
  • moisture can breathe through  
  • Zero shrinkage  
  • long durability,  
  • fire, water/salt/acid resistance  
  • MgO cements are completely non-conductive of electricity unlike portlandcement (used for flooring for radar stations and hospital operating rooms)

sources:
http://www.greenhomebuilding.com/pdf/MgO-General.pdf
http://novacem.com/technology/novacem-technology/
http://www.ceratechinc.com/

CONSTRUCTION

I have looked into five different cases for the structure: the Nurholz system, wood construction, concrete construction, steel+concrete and steel+slimline.
afbeelding 26: milieukosten constructie source: (afstuderenzoek CT TUDelft)
Tool F., Ontwerptool voor de beoordeling van constructieve alternatieven op duurzaamheid, 2010
LCA
LCA data from NIBE for various construction methods.

STUDY ENVIRONMENTAL COSTS
A graduation study on the sustainability of structural alternatives in which also future developments are taken into account by F. Tool shows that when using standard materials (graph left) the concrete and slimline construction are the most sustainable. When using sustainable materials however a wooden construction is the most sustainable (graph right).

CONCRETE
COMPOSITION
The basis of concrete is sand, gravel, cement and water. The exact composition of concrete is different per case, due to the specific requirements per application: the mechanical properties, durability and handling properties additives are added to the mix (Cement en Betoncentrum 2010).

There is only one concrete additive that is C2C certified, this is Hycrete®. It has a Cradle to Cradle gold certificate and is an additive used to prevent corrosion and rust.
The concrete component cement can consist of three types of cement: Portland-cement, blast-furnace cement and Portland-fly ash cement. (VOBN 0000).

- Portland cement consists for the most part of portland clinker, gypsum, and further other additives. (VOBN 0000). Clinker or cinder lumps are formed by heating limestone, Bauxite, iron ore and sand to 1500°C. The production of clinker is very resource intensive. Producing one ton of clinker requires an energy input or Between 3000 and 6000MJ and approximately 1.6 tons of raw material.

- Blast-furnace cement is made from granulated blast furnace slag and is itself a recycled raw material, because the slag is produced during the steelmaking process and is a quality replacement of limestone. In addition to reducing the use of primary raw materials, the emission of CO2 is reduced because there is less need to be calcined limestone. Blast-furnace cement also possesses a high resistance to chloride penetration and is therefore suitable for durable use in concrete that is used in marine (sea) Environment (VOBN 0000).

- Portland fly ash cement consists of Portland cement to which fly ash has been added. Fly ash is recovered from the gases emitted by coal-fired power plants (VOBN 0000).

Allied Concrete is a concrete company in the USA that has its Concrete 3000psi, 3500psi, & 4000psi certified silver. What exactly is different in the composition of these products and other concrete company’s products is not clear.

**MATERIAL HEALTH**

Additions to concrete may include alkaline compounds (such as lime) that are corrosive to human tissue, small amounts of crystalline silica that are abrasive to skin and causes damage to lungs or small amounts of chromium that can cause allergic reactions. (State Compensation Insurance Fund 2010)

Superplasticizers contribute with approximately 0.4-10.4% of the total environmental impact of concrete, the least to the global warming potential (GWP) and the most to the photochemical ozone creation potential (POCP). The leakage of superplasticizers from concrete leads to a low risk for the environment and for humans. (Sjunnesson 2005) Because of chemical admixtures, concrete could conceivably offgas small quantities of formaldehydes and other chemicals into the indoor air. Unfortunately, it is difficult to find out from the manufacturers the actual chemicals in these admixtures. (Wilson)

Some aggregates that have been used in concrete production have turned out to be sources of radon gas (Wilson).

**REUSE**

Concrete rubble and brick rubble can be used as aggregate for new concrete en worden reststromen opgewaardeerd als nuttige grondstoffen door het toepassen van hoogovencement.

Industrial waste products, including blast furnace slag, cinders, and mill scale are sometimes substituted for some of the aggregate in concrete mixes. Also recycled concrete can be crushed into aggregate that can be reused in the concrete mix—though the irregular surface of aggregate so produced is less effective than
sand or crushed stone because it takes more cement slurry to fill all the nooks and crannies. In fact, using crushed concrete as an aggregate might be counterproductive by requiring extra cement—by far the most energy-intensive component of concrete. (Wilson)

**ENERGY USE**

<table>
<thead>
<tr>
<th>CONSTITUENTS</th>
<th>ENERGY (MJ/KG CEMENT)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coarse aggregate</td>
<td>0.028</td>
</tr>
<tr>
<td>Fine aggregate</td>
<td>0.028</td>
</tr>
<tr>
<td>Portland cement</td>
<td>0.735</td>
</tr>
<tr>
<td>Water</td>
<td>0.000</td>
</tr>
<tr>
<td>Manufacturing</td>
<td>0.102</td>
</tr>
<tr>
<td>Total</td>
<td>0.893</td>
</tr>
</tbody>
</table>

Most materials for concrete are acquired and manufactured locally which minimizes transportation energy (VOBN 2008).

If the energy is sustainably generated is unknown.

**WATER USE**

Water pollution associated with recycled aggregate operations can arise from the following causes (WRAP 2010):

Separation, screening and processing of waste material - Rain and dust suppressions sprays on waste will cause solids to be released into the drainage. In the case of recycled aggregates, the solids will principally be concrete dust, rock dust, sand, silt and clays;

Lime within the concrete dust may dissolve within the water to create an alkaline solution, but the pH is unlikely to be raised significantly due to the quantity of lime present.

Other sources of water pollution from recycled aggregate could come from its contamination in a previous use.

Processing of the aggregates to a finer grade may expose contaminants held within the material into the air, this in turn may enhance solubility into water.

If the water is treated and returned to nature in good or better quality is unknown.

**SOCIAL RESPONSIBILITY**

Worker conditions depend on the company used for the concrete construction.

The quarries for sand, gravel, limestone and clay (the raw material for the binder) in the Netherlands are sustainably redeveloped for use as water storage, river widening, nature, recreation and residential areas along the water (VOBN).
Approximately 5% of global carbon emissions are produced in the manufacture of cement.

Concrete reabsorbs most of the CO2 emitted by calcination during the time it serves its useful life, and shortly after it is demolished and crushed.

WOOD

The building industry prefers to hardwood (KAAN 2009). Hardwood has a long life and is highly fire resistant. Softwood, as used in the conventional way, can not compete with hardwood in that way. But hardwood also has its disadvantages. Hardwood grows much slower than softwood. And in Europe there is not enough timber available to meet the European demand. Therefore, many hardwood comes from South America or Asia. (KAAN 2009)

Wood, according to the cradle to cradle principle preferably needs to be left untreated as wood preservatives could lead to significant risks for humans, animals and environment (Geldermans 2009 p33).

ACCOYA

Accoya wood is better then Plato wood in the case of bending strength, this makes it more appropriate for construction purposes (GELDERMANS 2009).

Created via acetylated wood modification, using sustainably grown timber, the Accoya® process is non-toxic (ACCOYA 2012). The process creates a new durable, stable product, a 'treated timber' that has the good environmental credentials. Accoya can be used in windowframes, doors, decking, cladding and glulam structural beams.

REUSE

Wood is a material that can be reused multiple times and at the end of its product life it is biodegradable and it can be used as a bio-fuel (ACCOYA 2012).

ENERGY USE

Life cycle assessment studies show that wood requires substantially less energy to manufacture, transport, construct and maintain than other materials. Most notable is the significant volume of greenhouse gas emissions avoided by substituting low impact wood products for materials such as concrete, which are responsible for high amounts of CO2 emissions. (Forestry Climate Change Working Group)

The transport of large quantities of wood from South America or Asia over long distances does take a lot of energy and causes emissions of CO2 (KAAN 2009)

The treatment of wood in the Plato and Accoya process leads to an increase in energy use.

WATER USE

Compared to the alternatives like steel and concrete, wood buildings produce less air and water pollution, require less energy across their life cycle, and generate less CO2 emissions. (Forestry Climate Change Working Group)

SOCIAL RESPONSIBILITY

Most wood used in the Netherlands has an FSC certification. In the FSC certification categories are specified related to social responsibility. There are 10 Principles and 57 Criteria that address legal issues, indigenous rights, labor rights, multiple benefits, and environmental impacts surrounding forest management.
NURHOLZ
Nurholz is a recently developed solid wood construction system, made of untreated wood, with layers of wood bonded with wooden screws. The Nurholz system consists of wall, ceiling and roof elements. (Bouwpuur 2009). Thoma Holz100, the German equivalent, is the only construction Cradle to Cradle Gold certified.

Due to the rigid system and small spans this system is not suitable for my project.

LIGNATUR
LIGNATUR is a high-tech timber system. The floor and roof elements are fully composed of wooden pine slats. The floor and roof elements are particularly suitable when several building physical aspects in one element must come together as insulation, fire resistance, sound absorption, vibration and noise. Lignatur surface elements are suitable for projects with (lignatur):

- Ceilings and roofs in new and industrial building
- spans up to 9.0m and onwards
- fire resistance rating up to REI 90
- visible surfaces
- sound proofing specifications
- sound absorption specifications
- heat insulation requirements
- standard height: 120, 140, 160, 180, 200, 220, 240, 280, 320 mm
- standard width: 514 mm, 1000 mm
- maximum length: 16 m

The wood in Lignatur timber system is glued together. This may cause problems when returning in the biosphere at the end of its product life.

STEEL
Steel for constructions is preferably used untreated inside the building. In steel support structures for outdoor application galvanizing is discouraged. The zinc leaches out and is harmful to flora and fauna (Hoogers 2010). As an alternative the steel can be sprayed with aluminum. Separation of the aluminium at reprocessing has to get extra attention in that case. For mesh fence in outdoor applications steel can be powder coated to prevent leaching. (Hoogers 2010, p46)

COMPOSITION
The two main steel production routes and their related inputs are: Blast Furnace Process and Electric Arc Furnace Process (BOUWEN MET STAAL 2012)

In the Blast Furnace Process (BF) the steel is made from iron ore with coal. 20 to 30% scrap steel is added. During the process furnace slag are and gas is created. Some applications for the slag are paving and ballast in civil engineering. The gas is used for electricity generation. (BOUWEN MET STAAL 2010) On average, this route uses 1,400 kg of iron ore, 770 kg of coal, 150 kg of limestone, and 120 kg of recycled steel to produce a tonne of crude steel. (Worldsteel.org)

In the Electric Arc Furnace Process (EAF) 100% scrap steel is used: direct remelting of steel without the use of primary raw materials. Only oxygen and lime
are added to bind any impurities. Zinc-plated steel can also be processed in the electric arc furnace. The zinc is recovered and used in the production of new zinc. (BOUWEN MET STAAL 2010) On average, the recycled steel-EAF route uses 880 kg of recycled steel, 150 kg of coal and 43 kg or limestone to produce a tonne of crude steel (worldsteel.org).

REUSE

The cycle of steel is closed and steel is recycled and upcycled. A steel profile grade S235, is able to be remelted into the higher quality S460. The recycling of S235 to S460 takes as much energy as the recycling of S235 to S235. A S460 profile also possesses better properties, such as higher strength.

In principle, it is possible to produce all the steel as EAF. At present however, there is not yet sufficient scrap available in order to meet the demand for steel. Of all the steel used in Europe is on average 50% produced by EAF. This percentage varies by specific product. Structural steel, such as steel beams and pipes, which is on the dutch market is now produced for almost 100% by EAF. Elsewhere in Europe also there is a shift from Blast Furnace to Electric Arc Furnace, as more and more scrap returns to the steel industry.

ENERGY USE

The sector is a very large consumer of energy, and as such is a major contributor to greenhouse gas emissions. The production of primary steel is more energy intensive than the production of secondary steel due to the chemical energy required to reduce iron ore to iron using reducing agents (worldsteel.org factsheet energy). If the energy is sustainably generated is unknown.

applications of energy inputs in steel production. source: factsheet energy worldsteel.org

<table>
<thead>
<tr>
<th>ENERGY INPUT</th>
<th>APPLICATION AS ENERGY</th>
<th>APPLICATION AS ENERGY AND REDUCING AGENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coal</td>
<td>-</td>
<td>Coke production, BF pulverised coal injection, DRI production</td>
</tr>
<tr>
<td>Electricity</td>
<td>EAF, rolling mills and motors</td>
<td>-</td>
</tr>
<tr>
<td>Natural gas</td>
<td>Furnaces</td>
<td>BF injection, DRI production</td>
</tr>
<tr>
<td>Oil</td>
<td>Steam production</td>
<td>BF injection, DRI production</td>
</tr>
</tbody>
</table>

afb.13: Water Use By Operation, Gallons per Ton of Production
**SOCIAL RESPONSIBILITY**

Corus is a company located in the Netherlands where most dutch steel comes from. Due to toxic emissions people in the area have higher health risks and sensitive areas in the dunes are deteriorate by pollution and acidification. The Corus blast furnaces are the largest source of dioxins, cadmium, lead and mercury in the Netherlands. Also for fine particulate matter pollution Corus is a major source. The sinter containing an entirely outdated flue gas cleaning (Corus is the only one in Europe, this technique still applies) and is the largest source of fine dust Netherlands.


**SLIMLINE**

The basis of Slimline is a concrete layer (70mm thick) with integrated steel beams and optional tubing system for climate control. The basic module can be applied on both skeleton constructions and wall-bearing constructions. (Slimline)

![Slimline floorsystem, source: Slimline](image)

The ceiling plate is about 70 mm thick and is usually provided with pipes, the ceiling which can be cooled and heated, if desired. The thin plates cool or heat the space quickly.

Slimeline claims on its site that the materials can be reused after the floor is disassembled. The floor is light and thin, with that materials are reduced compared to other floorsystems. Furthermore Slimeline is a prefabricated system. Prefabrication reduces wastematerials on the site and in the factory.

**FLEXIBILITY**

One of the main features of the Slimline is the easy accessibility of pipelines and installations in the floor. In practice there is therefore almost no cross-over with horizontal pipes outside the shaft. Changing the interior space is thus considerably simplified. The application of the SlimLine floor increases the flexibility of the building, and thus has a positive effect on the durability of the building.

**CASES**

The Slimline floorsystem is used in multiple buildings in Park 20/20 and in the Breathing Space, office- and expobuilding on the Venlo Floriade.
CONCLUSION
From the data it is concluded that a wooden construction is the best choice.
### INSULATION

<table>
<thead>
<tr>
<th>MATERIAALSOORT</th>
<th>HERWINBARE GRONDSTOF</th>
<th>RESTSTOF</th>
<th>MATERIEEL</th>
<th>RESTSTOF</th>
<th>MEUBELEN</th>
<th>DIGITALE VERVAARDIGD</th>
<th>VOCHTREGULERING</th>
<th>TRIAS ECOLOGICA</th>
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<tr>
<td>Hennep</td>
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<td>Houvezel</td>
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<td>+</td>
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<td>+</td>
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<td>+/-</td>
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<tr>
<td>Polyester-aluminium</td>
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<td>x</td>
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<td>Polyfaseen</td>
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<td>+</td>
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<td>+</td>
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<td>Schelpen</td>
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<td>-</td>
<td>+</td>
<td></td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>Steenwol muur</td>
<td>x</td>
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<td>-</td>
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<td>+</td>
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<td>x</td>
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<td>Steenwol vloer</td>
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<td>-</td>
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<td>Vlaswol</td>
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<td>x</td>
<td>+</td>
<td>+</td>
<td>+</td>
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<td>x</td>
<td>x</td>
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</table>

**Table: Material properties related to environmental and health aspects of different insulation materials.**

<table>
<thead>
<tr>
<th>MATERIAALSOORT</th>
<th>VIBE-KLASSE (HELLEND DAK)</th>
<th>VIBRAAL-WAARDERHD 90 (R, W/M²K)</th>
<th>WARMTE-OPSLAGCAPACITEIT C (J/KGK)</th>
<th>VOLUMEMASSA VAN EEN MATERIAAL (KG/M³) VAGELS EN NGS</th>
<th>DIFFUSE-WEERSTANDSGETAL Ψ</th>
<th>MINIMALE DIKTE DAKISOLATIE LAGE-ENERGIEWONING (CM) (MET EEN U-WAARDE VAN 0,3 W/M²K)</th>
<th>MINIMALE DIKTE HSB-MUURISOLATIE LAGE-ENERGIEWONING (CM) (MET EEN U-WAARDE VAN 0,3 W/M²K)</th>
<th>MINIMALE DIKTE DAK/MUURISOLATIE PASSIEFHUIS (CM) (MET EEN U-WAARDE VAN 0,15 W/M²K)</th>
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</thead>
<tbody>
<tr>
<td>vlas</td>
<td>1a</td>
<td>0,038</td>
<td>1550</td>
<td>20±30</td>
<td>1±2</td>
<td>17</td>
<td>11</td>
<td>24</td>
</tr>
<tr>
<td>hennep</td>
<td>0,040±0,042</td>
<td>2520</td>
<td>30±36</td>
<td>1±2</td>
<td>18</td>
<td>12</td>
<td>25</td>
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<tr>
<td>schapenwol</td>
<td>1a</td>
<td>0,035</td>
<td>1720</td>
<td>25±5</td>
<td>1±5</td>
<td>17</td>
<td>11</td>
<td>24</td>
</tr>
<tr>
<td>papierlolaken</td>
<td>2b</td>
<td>0,040</td>
<td>1940±250</td>
<td>30±40</td>
<td>1±2</td>
<td>18</td>
<td>12</td>
<td>25</td>
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<tr>
<td>houtvezel-zacht</td>
<td>0,038±0,040</td>
<td>2000±100</td>
<td>1×160</td>
<td>1±5</td>
<td>18</td>
<td>12</td>
<td>25</td>
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<tr>
<td>houtvezel-hard</td>
<td>0,045±0,055</td>
<td>2000±1200</td>
<td>230±270</td>
<td>5±4</td>
<td>24</td>
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<td>plumen</td>
<td>0,04</td>
<td>?</td>
<td>20±5</td>
<td>?</td>
<td>18</td>
<td>12</td>
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<tr>
<td>kurk</td>
<td>2b</td>
<td>0,038±0,040</td>
<td>1670</td>
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<td>25±30</td>
<td>18</td>
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<td>25</td>
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<td>perliet</td>
<td>0,051</td>
<td>900</td>
<td>135±165</td>
<td>5±5</td>
<td>23</td>
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**Table: Comparison insulating capacity bio-ecological insulation.**
Part 5: Material selection
<table>
<thead>
<tr>
<th>TOEPASSING</th>
<th>MATERIAAL</th>
<th>START</th>
<th>EIENDE</th>
<th>LEVENSDUUR</th>
<th>VOORBEELD</th>
</tr>
</thead>
<tbody>
<tr>
<td>funderingspalen</td>
<td>hout fcs keurmerk</td>
<td>vuren Verantwoord beheerde bossen</td>
<td>- biologisch afbreekbaar</td>
<td>75 jaar</td>
<td></td>
</tr>
<tr>
<td>prefab fundering</td>
<td>ceratech ekkumax™ cement</td>
<td>95% vliegas 5% rapidly renewable proprietary liquid activators</td>
<td>- gebruikt voor volgend gebouw op dezelfde plek - vermalen tot granulaat</td>
<td>oneindig</td>
<td></td>
</tr>
<tr>
<td>kolommen</td>
<td>accoya hout c2c goud</td>
<td>gecertificeerd hout grenen- of radiata pine</td>
<td>- herbruikbaar - verzaagd - biologisch afbreekbaar</td>
<td>50 jaar</td>
<td></td>
</tr>
<tr>
<td>liggers</td>
<td>accoya hout c2c goud</td>
<td>gecertificeerd hout grenen- of radiata pine</td>
<td>- herbruikbaar - verzaagd - biologisch afbreekbaar</td>
<td>50 jaar</td>
<td></td>
</tr>
<tr>
<td>plaatmateriaal</td>
<td>OSB platen beharste en geperste dunne houtnippers of schilvers sqalij en hars</td>
<td>- biologisch afbreekbaar</td>
<td>&lt;50jr</td>
<td></td>
<td></td>
</tr>
<tr>
<td>balken</td>
<td>accoya hout c2c goud</td>
<td>gecertificeerd hout grenen- of radiata pine</td>
<td>- herbruikbaar - verzaagd - biologisch afbreekbaar</td>
<td>50 jaar</td>
<td></td>
</tr>
<tr>
<td>isolatiemateriaal</td>
<td>hempcrete hennep hurs (scheven) kalk</td>
<td>- recycled in nieuw hempcrete - biologisch afbreekbaar - can be used as fertilizer after being demolished</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>vloerafwerking</td>
<td>hout fcs keurmerk grenen Verantwoord beheerde bossen</td>
<td>- biologisch afbreekbaar</td>
<td>10 jaar</td>
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<td>harde isolatie</td>
<td>pavatex houtvezelisolatie natuurlijke houtvezels, een restproduct van Zwitserse houtzagerijen verbonden met het houteigen bindmiddel lignine</td>
<td>- biologisch afbreekbaar</td>
<td>in droge condities onbeperkt</td>
<td></td>
<td></td>
</tr>
<tr>
<td>wand</td>
<td>hempcrete hennep hurs (scheven) kalk</td>
<td>- recycled in nieuw hempcrete - biologisch afbreekbaar - can be used as fertilizer after being demolished</td>
<td></td>
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</tr>
<tr>
<td>plaatmateriaal</td>
<td>OSB platen beharste en geperste dunne houtnippers of schilvers sqalij en hars</td>
<td>- biologisch afbreekbaar</td>
<td>&lt;50jr</td>
<td></td>
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<tr>
<td>isolatiemateriaal</td>
<td>hempcrete hennep hurs (scheven) kalk</td>
<td>- recycled in nieuw hempcrete - biologisch afbreekbaar - can be used as fertilizer after being demolished</td>
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<tr>
<td>harde isolatie</td>
<td>pavatex houtvezelisolatie natuurlijke houtvezels, een restproduct van Zwitserse houtzagerijen verbonden met het houteigen bindmiddel lignine</td>
<td>- biologisch afbreekbaar</td>
<td>in droge condities onbeperkt</td>
<td></td>
<td></td>
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<tr>
<td>waterkerende laag</td>
<td>derbipure plantaardige dakbaan derbipum cradle to cradle basic (zilver?) - plantaardige oliën en dennenhars - versterkt met een composiet glas/polyester - neutrale pH-coating - beschermfolie voor installatie</td>
<td>volledig recyclebaar tot nieuw derbipure membraan</td>
<td>30 jaar</td>
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<td>hout fcs keurmerk vuren Verantwoord beheerde bossen</td>
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<td>goot</td>
<td>hout fcs keurmerk vuren Verantwoord beheerde bossen</td>
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<tr>
<td>glas</td>
<td>glas zilverzand, soda, kalksteen, magnesiuncarbonaat toevoegingen: trachiet, fonseliet, vloeispaat, mangaan/Vlooi, basalt en glauberzout</td>
<td>recycled voor nieuw glas</td>
<td>20-30 jaar</td>
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<tr>
<td>deur</td>
<td>hout fcs keurmerk vuren Verantwoord beheerde bossen</td>
<td>- biologisch afbreekbaar</td>
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<tr>
<td>TOEPASSING</td>
<td>MATERIAAL</td>
<td>START</td>
<td>EINDE</td>
<td>LEVENSDUUR</td>
<td>VOORBEELD</td>
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<td>------------</td>
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<td>Verantwoord beheerde bossen</td>
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<td>glas</td>
<td>zilverzand, soda, kalksteen, magnesiumcarbonaat toevoegingen: tras, trachiet, fonoliet, vloerspaat, mangaan(N)oxide, basalt en glasvezel</td>
<td>recycled voor nieuw glas</td>
<td>20-30 jaar</td>
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<td>funderingspalen</td>
<td>vuren hout</td>
<td>Verantwoord beheerde bossen</td>
<td>- biologisch afbreekbaar</td>
<td>75 jaar</td>
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<tr>
<td>prefab-funderingsballen</td>
<td>ceratech ekkomax™ cement</td>
<td>95% vliegwas 5% rapidly renewable proprietary liquid activators</td>
<td>- gebruikt voor volgend gebouw op dezelfde plek - vermalen tot granulaat</td>
<td>oneindig</td>
<td></td>
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<tr>
<td>vloerspouw</td>
<td>biofoam cradle to cradle zilver</td>
<td>Poly-Lactid Acid (PLA) grondstof: alle fermenteerbare suikers &gt; maïszetmeel (VS), tapioca wortels, chips of zetmeel (vooral in Azië), suikerriet (rest vd wereld)</td>
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<td></td>
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<tr>
<td>vloerspouw</td>
<td>grancrete</td>
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<td>&gt;100 jaar</td>
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<tr>
<td>voorgeteelde daktegel</td>
<td>plastic</td>
<td>PHB niet-toxische samenstelling</td>
<td>biologisch afbreekbaar</td>
<td></td>
<td></td>
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<tr>
<td>filterende laag</td>
<td>vilt</td>
<td>samengeperst wol</td>
<td>biologisch afbreekbaar</td>
<td></td>
<td></td>
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<tr>
<td>Drainagelaag</td>
<td>geëxplodeerde kleikorrels</td>
<td>kalkarm klei met fijn verdeelde organische bestanddelen door verhitting uitgezet</td>
<td>biologisch afbreekbaar</td>
<td></td>
<td></td>
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<tr>
<td>waterkerende laag</td>
<td>derbigum plantaardige cradle to cradle basic (zilver?)</td>
<td>- plantaardige oliën en dennenhars - versterkt met een composiet glas/polyester - neutrale pH-coating - beschermfolie voor installatie</td>
<td>technische cyclus volledig recyclebaar tot nieuw derbi-pure membraam</td>
<td>30 jaar</td>
<td></td>
</tr>
<tr>
<td>Grindvangprofiel</td>
<td>staal</td>
<td>EAF: 100% schroot gebruikt</td>
<td>technische cyclus recyclebaar</td>
<td></td>
<td></td>
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<tr>
<td>steriele zone</td>
<td>grind</td>
<td>erosieproduct, ontstaan uit vast gesteente en wordt meestal door rivieren getransporteerd en afgezet, wingsbieden: Rijn en Maas</td>
<td>hergebruikt</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>wandopbouw</td>
<td>biofoam cradle to cradle zilver</td>
<td>Poly-Lactid Acid (PLA) grondstof: alle fermenteerbare suikers &gt; maïszetmeel (VS), tapioca wortels, chips of zetmeel (vooral in Azië), suikerriet (rest vd wereld)</td>
<td>biologisch afbreekbaar</td>
<td></td>
<td></td>
</tr>
<tr>
<td>wandopbouw</td>
<td>grancrete</td>
<td>zand/aarde, as magnesium oxide, phosphate poeder water</td>
<td>biologisch afbreekbaar</td>
<td>&gt;100 jaar</td>
<td></td>
</tr>
<tr>
<td>TOEPASSING</td>
<td>MATERIAAL</td>
<td>START</td>
<td>EINDE</td>
<td>LEVENSDUUR</td>
<td>VOORBEELD</td>
</tr>
<tr>
<td>-----------</td>
<td>-----------</td>
<td>-------</td>
<td>-------</td>
<td>------------</td>
<td>----------</td>
</tr>
<tr>
<td><strong>WAND- OEINLEN</strong></td>
<td>kozijnen</td>
<td>hout</td>
<td>vuren</td>
<td>Verantwoord beheerde bossen</td>
<td>- biologisch afbreekbaar</td>
</tr>
<tr>
<td></td>
<td>glas</td>
<td>glas</td>
<td>zilverzand, soda, kalksteen, magnesi-umcarbonaat toevoegingen: tras, trachiet, fonoliet, vloeispaat, mangaan(IV)oxide, basalt en glauzenzout</td>
<td>recycled voor nieuw glas</td>
<td>20-30 jaar</td>
</tr>
<tr>
<td></td>
<td>deur</td>
<td>hout</td>
<td>vuren</td>
<td>Verantwoord beheerde bossen</td>
<td>- biologisch afbreekbaar</td>
</tr>
<tr>
<td></td>
<td>trap</td>
<td>hout</td>
<td>vuren</td>
<td>Verantwoord beheerde bossen</td>
<td>- biologisch afbreekbaar</td>
</tr>
<tr>
<td><strong>TRAP</strong></td>
<td>zonnewinder</td>
<td>zonnewinder vacuumbuis</td>
<td>glazen buizen</td>
<td>absorberende laag aluminium</td>
<td></td>
</tr>
<tr>
<td></td>
<td>boilervat</td>
<td>boilervat</td>
<td>roestvrij staal</td>
<td>technische cyclus volledig recyclebaar</td>
<td></td>
</tr>
<tr>
<td></td>
<td>verwarmingsleidingen</td>
<td>PPR epdm leidingisolatie</td>
<td>epdm: basis is aardolie</td>
<td>epdm: downcycling (vb rubbertegels)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>LTV radiator</td>
<td>LTV radiatoren radson</td>
<td>metalen</td>
<td>technische cyclus volledig recyclebaar</td>
<td></td>
</tr>
<tr>
<td></td>
<td>bio pcm</td>
<td>bio-pcm</td>
<td>snel hernieuwbaar planteneextract&gt; vetzuren zoals plantaardige olie</td>
<td>technische cyclus herbruikbaar in nieuwe PV panelen of in nieuwe producten</td>
<td></td>
</tr>
<tr>
<td></td>
<td>pv panelen</td>
<td>pv panelen</td>
<td>silicium, aluminium (kader) en beschermend glas</td>
<td>technische cyclus herbruikbaar in nieuwe PV panelen of in nieuwe producten</td>
<td></td>
</tr>
<tr>
<td></td>
<td>elektra leidingen</td>
<td>halogeenvrije kabel (kan zonder buis gelegd worden) halogeenvrije leiding</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>stopcontact</td>
<td>PP mogelijk PHB, PLA?</td>
<td>aardolie</td>
<td>technische cyclus thermoplast&gt; downcycling</td>
<td></td>
</tr>
<tr>
<td></td>
<td>rioleningsbuis</td>
<td>gresbuis steinzeug-keramo</td>
<td>op milieuvriendelijke wijze ontgonnen klei</td>
<td>volledig gerecycled</td>
<td>lang</td>
</tr>
<tr>
<td></td>
<td>hemelwaterafvoer</td>
<td>PP mogelijk PHB, PLA?</td>
<td>aardolie</td>
<td>technische cyclus thermoplast&gt; downcycling</td>
<td></td>
</tr>
</tbody>
</table>
HEMPCRETE

HISTORIC PERSPECTIVE
The importance of hemp has declined rapidly since the late 19th century. It was a leader in everyday life and the economy and it had many uses, from clothing or bedding, to ropes and sails for the Navy through the oil light. However due to the competition from exotic and synthetic fibers, and finally the prohibition prohibiting the cultivation in the United States in 1960 which was followed by most Western countries, hemp had almost disappeared in our landscapes. Currently in countries as France and the UK industrial hemp is going through a renaissance and is stimulated by the government.

TECHNICAL PERFORMANCE

THERMAL
Hempcrete scores exceptionally well related to its thermal performance. Thermal performance is a combination of the thermal conductivity, thermal mass and thermal inertia. Hempcrete has a beneficial mix of thermal capacity and thermal inertia to provide excellent dampening. A 250mm Hempcrete wall reduces external temperature changes by 98% and shifts the peak with 15 hours (LIMETECHNOLOGY 2009).


<table>
<thead>
<tr>
<th></th>
<th>Insulator</th>
<th>Thermal capacity</th>
<th>Thermal inertia</th>
<th>Scoring</th>
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<tbody>
<tr>
<td>Mineral wool</td>
<td>High</td>
<td>Low</td>
<td>Low</td>
<td>5</td>
</tr>
<tr>
<td>EPS</td>
<td>High</td>
<td>Low</td>
<td>Low</td>
<td>5</td>
</tr>
<tr>
<td>PIR</td>
<td>High</td>
<td>Low</td>
<td>Low</td>
<td>5</td>
</tr>
<tr>
<td>AAC</td>
<td>Med</td>
<td>Med</td>
<td>Med</td>
<td>6</td>
</tr>
<tr>
<td>Hemcrete®</td>
<td>High</td>
<td>Med</td>
<td>High</td>
<td>8</td>
</tr>
<tr>
<td>Brick</td>
<td>Low</td>
<td>High</td>
<td>Med</td>
<td>6</td>
</tr>
<tr>
<td>Block</td>
<td>Low</td>
<td>High</td>
<td>Low</td>
<td>5</td>
</tr>
<tr>
<td>Concrete</td>
<td>Low</td>
<td>High</td>
<td>Low</td>
<td>5</td>
</tr>
</tbody>
</table>

HEMCRETE U VALUES

<table>
<thead>
<tr>
<th></th>
<th>Wall Thickness (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>200</td>
</tr>
<tr>
<td>Standard 275</td>
<td>0.300</td>
</tr>
<tr>
<td>Hi Strength 330</td>
<td>0.345</td>
</tr>
<tr>
<td>Insulation 220</td>
<td>0.250</td>
</tr>
</tbody>
</table>
ACOUSTICS

Testing carried out by the BRE on houses build with hempcrete in the UK showed that hemp lime construction met the acoustic requirements of the building regulations. Further ongoing research shows that Tradical® Hemcrete® has the ability to absorb up to 90% of air-born sound.

STRUCTURAL

Hemcrete has a typical compressive strength of around 1N/mm² and is therfor not normally used in load bearing applications. Although it may be possible to use thick Hemcrete walls (particularly when tamped into place) in load bearing a situa- tion for low-rise buildings, it is not recommended.

ENERGY PERFORMANCE:

The overall approach of building performance requires taking into account the different aspects of energy consumption are the two main energy-related construction and operation of the energy required for the production of materials (embodied energy).

Embodied energy: the production of hemp materials needs relatively few energy compared to most building materials. It is mainly due to the manufacturing pro- cess (eg oven treadmill for insulating complex) or additional materials (eg bind- ers for concrete and mortar) as well as transport. This energy consumption may decrease in the future by optimizing the manufacturing process and especially the limitation of transport caused by local product development.

ENVIRONMENTAL PERFORMANCE:

Hemp is an easily renewable annual crop with high yields, this is particularly true with regard to the use of renewable raw materials difficult. It should also be noted that, even if it does not appear in the analysis of the life cycle, the hemp does not require (or very little) input of insecticides, fungicides, herbicides. Lime production has significant impacts in quarrying and production.

Like all plants, growing hemp is accompanied by CO₂ consumption. It will be stored in the building material, at least during his lifetime and as long as a recycling material is sure what is generally relatively simple with this type of material. This allows to consider building with zero carbon footprint.

REUSE

Hemcrete requires little energy to make it reusable. Any material spilt or not used on a building site can be easily crumbled by hand and recycled into the next project. Cast Hemcrete can be cut out and reused for more casting.


HEALTH PERFORMANCE

Although, in the absence of test and established for standard building materials, there has been no thorough research on the health performance of hemp materi- als, many elements suggest that they have positive attitudes:

CHEMICAL POLLUTION (VOCS, FORMALDEHYDE ...)

The production of hemp requires no (or very little) of phytosanitary inputs (insecticides, fungicides, herbicides), the first transformation does not call for chemical processes and the manufacture of various materials avoids the use of material
presenting risks identified toxicity. This suggests that there is very little chance that hemp materials can affect the quality of the air inside the building negatively, since there is no known toxicity to the plant.

ORGANIC POLLUTION (DUST MITES, MOLD ...)
Where materials have been used in normal conditions - particularly in regard to humidity - there hasn’t been find any particular development of parasites on projects completed over twenty years, especially as physical factors (see below) are not conducive to development.

PHYSICAL FACTORS (TEMPERATURE, RELATIVE HUMIDITY ...)
Regarding the mortars and concretes hemp, users have found that they reach a satisfactory level of thermal comfort at relatively low ambient temperatures (17 or 18 °C, sometimes less), which is probably largely due to the regulation of humidity. These two factors - temperature and relative humidity of the air inhaled, have important influences on respiratory function.

ECONOMIC PERFORMANCE
Materials made from hemp have uses extremely varied and economic performance are also varied depending on the application: it would be simplistic to say that the hemp materials are “expensive” or “cheap. An analysis must take into account the overall cost including the use value, building operation, maintenance and, of course, the durability of the material.

ADAPTABILITY AND DIVERSITY OF HEMP SOLUTIONS
Hemp has many potential uses regarding construction and actual development are very diverse between complex insulating fiber and hemp mortars and concretes. By varying the mixes hempcrete has the ability for a variety of applications: insulation slabs, filling walls with insulation, prefabricated, roof insulation.

ISSUES, CHALLENGES AND SOLUTIONS
EXPERIENCE IN THE NETHERLANDS
In the Netherlands there are few cases where hempcrete is used. This can make implementation problematic. If we look over the borders into the UK or France this is different. In France limehemp construction is today common and has already been used in hundreds of new buildings. The UK has recently carried out research, both private and academic, in order to test the claimed benefits of lime-hemp and, after a few pilot projects, the new construction material is now available on the market for those interested (Ronchetti, 2007)

GUARANTEED QUALITY
To meet the demand in good conditions, building contractors should be able to use products that are reliable and recognized methods. They must also provide their clients with all the necessary and required terms of guaranteed insurance. In the Netherlands this is stil hard to accomplish. In France however the hemp construction industry has implemented a quality approach described in the Professional Rules of Running Structures in Concrete Hemp. This document is based on two pillars:

1. the proper functioning of materials, guaranteed by the suppliers
2. the quality of the work is guaranteed by companies implementing

Professional Guidelines for Performing Work Concrete Hemp is the first - and so
far the only point of reference for the use of hemp concrete.

GRANCRETE

HISTORIC PERSPECTIVE
Grancrete is a type of magnesium-oxide cement. Magnesium-oxide cements were used before the invention of portland cement, dating back to ancient times in Europe, India, and China, among other countries. The Great Wall of China and many of the stupas in India, still standing today, were all made with magnesium-based cements.

With the invention of portland cement, magnesium-oxide cements were cast aside. The successful manufacture and marketing of Portland cement occurred at a time when energy was cheap, sustainability not such an important topic, and health concerns of the public simply not an issue were. Now these aspects do become a point of concern magnesium-oxide cements come into play again.

TECHNICAL PERFORMANCE
Grancrete material has the following properties, for more data see the table on the next page.

- binds naturally and exceptionally well to all things cellulose in contrast to portland cement > no other binders necessary
- drillable
- sets under water
- Combustibility: Does not burn. Retards the flame when coated on combustible materials such as Styrofoam.
- Freeze Thaw Resistance
- Durability factor of 81 at 300 cycles
- TheRmal Conductivity: 0.53 w/m.k
- Shrinkage: None. < 1% expansion during setting.
- Weight: Density of 2.1 grams/cubic centimeters density can be varied by aggregate addition.
- Fracture Toughness: 0.6 - 0.7 Megapascals.
- Cold Weather Handling: 20°F—no special handling required

ENERGY PERFORMANCE
As previously said Grancrete is a ceramic cement compound blend of in-organic material consisting of magnesium oxide and potassium phosphate, recycled material (fly ash) and sand. The only product that requires energy is the magnesium oxide which requires a small amount of heating (Nabil & Beawy 2010). magnesium oxide/magnesium chloride cements require only 20%-40% of the energy required to produce Portland cement (Swanson 2010). This means that Grancrete has a very low carbon footprint.


## ASTM Data for Grancrete®

All tests performed by TEC Testing Services, 235 Buford Dr.
Lawrenceville, GA 30045

<table>
<thead>
<tr>
<th>ASTM Test</th>
<th>Protocol #</th>
<th>Grancrete®</th>
<th>Cement Comparables</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Compressive Strength (psi)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.5 hr</td>
<td></td>
<td>~2,500</td>
<td>Estimated</td>
</tr>
<tr>
<td>1 hr</td>
<td>ASTM C 109 - 05</td>
<td>5,000</td>
<td></td>
</tr>
<tr>
<td>3 hrs</td>
<td></td>
<td>6,540</td>
<td></td>
</tr>
<tr>
<td>24 hrs</td>
<td></td>
<td>6,260</td>
<td>1,800</td>
</tr>
<tr>
<td>7 days</td>
<td></td>
<td>6,310</td>
<td>2,800</td>
</tr>
<tr>
<td>28 days</td>
<td></td>
<td>6,880</td>
<td>3,200</td>
</tr>
<tr>
<td><strong>Flexural Strength (psi)</strong></td>
<td>ASTM C 78 - 02</td>
<td>325</td>
<td>400</td>
</tr>
<tr>
<td>7 days</td>
<td></td>
<td>455</td>
<td></td>
</tr>
<tr>
<td>28 days</td>
<td></td>
<td>1,300</td>
<td></td>
</tr>
<tr>
<td>28 days*</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Slant Bond Strength (psi)</strong></td>
<td>ASTM C 882 - 99</td>
<td>1,350</td>
<td></td>
</tr>
<tr>
<td>1 day</td>
<td></td>
<td>1,220</td>
<td></td>
</tr>
<tr>
<td>7 days</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Modulus of Elasticity (psi)</strong></td>
<td>ASTM C 469</td>
<td>1,615,000</td>
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<tr>
<td>28 days</td>
<td></td>
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<tr>
<td><strong>Coefficient of Thermal Expansion (1/°C)</strong></td>
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<td>8.9748E-06</td>
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<tr>
<td>28 days</td>
<td></td>
<td></td>
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</tr>
<tr>
<td><strong>Length Change (%)</strong></td>
<td>ASTM C 157 - 04</td>
<td>0.11%</td>
<td>0.07%</td>
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<tr>
<td>28 days (soak/dry)</td>
<td></td>
<td>-0.03%</td>
<td>-0.14%</td>
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<tr>
<td>56 days (soak/dry)</td>
<td></td>
<td></td>
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<tr>
<td><strong>Direct Tensile Strength (psi)</strong></td>
<td>ASTM C 190 - 85</td>
<td>285</td>
<td>180</td>
</tr>
<tr>
<td>Day 1</td>
<td></td>
<td>260</td>
<td></td>
</tr>
<tr>
<td>Day 7</td>
<td></td>
<td>270</td>
<td></td>
</tr>
<tr>
<td>Day 28</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>IRCI Pull-off Test (psi)</strong></td>
<td>IRCI 3739</td>
<td>205</td>
<td>Broke @ epoxy bond</td>
</tr>
<tr>
<td>Day 1</td>
<td></td>
<td>240</td>
<td></td>
</tr>
<tr>
<td>Day 7</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Day 14</td>
<td>No Data</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Day 28</td>
<td>No Data</td>
<td></td>
<td>Broke @ epoxy bond</td>
</tr>
<tr>
<td><strong>Water Absorption</strong></td>
<td>ASTM 642 - 97</td>
<td>TBD</td>
<td>17%</td>
</tr>
<tr>
<td>Day 7</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Day 28</td>
<td>&lt;1%</td>
<td></td>
<td>18%</td>
</tr>
<tr>
<td><strong>pH Resistance @ Day 28</strong></td>
<td>ASTM 1308 - 02</td>
<td>Significant scarring</td>
<td>Significant damage</td>
</tr>
<tr>
<td>pH = 0.25</td>
<td></td>
<td>No effect</td>
<td></td>
</tr>
<tr>
<td>pH = 3.0</td>
<td></td>
<td>No effect</td>
<td>Significant damage</td>
</tr>
<tr>
<td>pH = 5.0</td>
<td></td>
<td>No effect</td>
<td>Slight effect</td>
</tr>
<tr>
<td>pH = 10.0</td>
<td></td>
<td>No effect</td>
<td></td>
</tr>
</tbody>
</table>

TBD – To be determined
*
– Argonne Data
ENVIRONMENTAL PERFORMANCE
Magnesium-oxide production has negative impacts in quarrying and production. Grancrete contributes to the reduction of the landfill by using coal ash as one of its components. When crushed and mixed with the soil the potassium phosphate, an element in fertilizer, will actually revitalize the soil.

PRODUCTION PATHWAY
Magnesium deposits exist in abundance in every corner of the earth and cover roughly 8% of the world’s surface. Phosphates are available from many sources ranging from phosphoric rock to animal wastes and fermented plants, which historically were used to “react” with various oxides to produce these environmentally friendly, non-toxic cements. Ash is a waste product coming from coal burning utilities. The sand or earth used in Grancrete can be found everywhere.

REUSE
When the project is demolished, grancrete can be used as aggregate or pulverized by crushing equipment and mixed with soil. As previously stated the potassium phosphate will then actually revitalize the soil.

HEALTH PERFORMANCE
The material is nontoxic to humans and the environment. In contrast to portland cement, off-gassing or emission of harmful fumes does not occur with Grancrete. High temperatures used in the making of Portland cement make it extremely hydrophilic, causing some health problems to people standing on concrete floors for a longer period and mold growth. Grancrete is made with lower temperatures and therefore do not have these problems connected to it. Furthermore Grancrete, like other magnesium-based cements, does not conduct electricity which prevents fatigue.

ECONOMIC PERFORMANCE
The Grancrete is manufactured on site, there is very little overhead cost. Although Grancrete is developed as a key to quality low cost housing in India. Due to the properties of the Grancrete, it is possible to create very strong thin-shelled structures also using a variety of lightweight and inexpensive fibers. This means that there isn’t much material necessary when constructing. However the cost per pound of magnesium-oxide cements is more than conventional Portland cement. This continues to be problematic in the use of magnesium/phosphate cements. Recently studies have been successful in identifying large, worldwide sources of recyclable MgO’s that were produced as a by-product of the industrial revolution, and less-expensive process for producing the necessary phosphates are being developed needed for these innovative ceramic cements. The price for a bag of grancrete is about $33/bag, or $50/bag with shipping.

ISSUES, CHALLENGES, SOLUTIONS
A drawback of Grancrete is that there is little information available for the user. One of the problems found by users is that the excessively fast setting is difficult for continuous pours.

Possible downside of the material is the ability to use it in a way that it is designed
to be disassembled. The material is in its use comparable to concrete, which from case studies are unlikely to qualify as a material good for DfD (Sassi 2008).

Grancrete is often applied with a styrofoam core, that serves as the basis to spray the material on and as extra insulation. Styrofoam however has to be handled differently than Grancrete when the building is demolished. Styrofoam can be recycled in a technical cycle whereas Grancrete can be used as aggregate or bio-degraded. Separating the Grancrete from the styrofoam may pose to be difficult due to the binding properties of Grancrete. Therefor another system needs to be proposed.
Part 6: Design
GRANCRETE VOLUMES
From this material four fixed, solid volumes are made, which house the fixed functions as toilets/showers/large halls and watchtower. The strengths the material has are used and tested by making one high, one with a large span and one with an overhang. The water/salt resistance of the material is used in the toilet and showers and in dealing with the local conditions of the beach.

WOOD
Wood is used to construct two levels inbetween the volumes: a ground floor where rooms can be made and a public deck which gives access to the large rooms in the volumes and from which the terrain can be overlooked. This construction is prefab, has the same, commonly used, sizes and is designed to be disassembled.

HEMPCRETE FLEXIBLE WALLS
In the project hempcrete is used to make internal spaces in the wooden construction. This way the qualities of the material are used the best. From the material light blocks are made that can easily be stacked to make walls. The hempcrete walls can be broken down and constructed again or repoured into new blocks. Hempcrete is also used as insulation in the wooden floors.

*afb.27:* Layers of the design
-1,200 funderingspoer
-900 prefab fundering
3,600 Begane grond
4,500 dak hempcrete
8,400 verdieping
dak
14,408 uitkijk
18,000 dak toren
G6 Straatgevel 1:200
G7 Havengevel 1:200
G8 Zeegevel 1:200
G9 Terreingevel 1:200

elevations
CLIMATE DESIGN

ENERGY

GOAL
» passive measures: the orientation of the spaces in the plan
» recycling of warmth between the spaces and seasonal storage
» a part of the demand is provided by sustainable energy

KNOW WHAT YOU HAVE
climate
Scheveningen has a mild seacclimate with warm summers and mild winters. The maximum temperatures in the summer months amount to 21°C. In winter the maximum temperatures fluctuate around 5°C. Rainfall is evenly distributed over the whole year. See appendix .. for graphs.

sun & wind
As can be seen in the picture below there is a main winddirection over the year coming from the southwest. The wind in Schevenignen is strong.

underground
A quickscan has been done to investigate the potentials for heat and cold storage, see appendix. The underground at the projectlocation has a good potential for heat and cold storage. The payback time for this system is short: 4-8 years.

energy systems
For dwellings in Duindorp a seawater heating plant constructed (source: Plan- mer Scheveningen). This plant extracts heat from the seawater, which through a exchangesystem the homes are heated and provided with hot water. The new homes and facilities in the planning area Scheveningen Harbour will, wherever possible and in combination with the houses in Duindorp on in the planning area in the building to integrate large-scale seawater heating plant can be connected.

There is also an existing warmthnet with wastewarmth from the sewer running through the projectarea (source: energievisie Den Haag).

Afb. 30: Geothermie, In het masterplan Scheveningen is een warmtenet voorzien waar warmte wordt opgewekt met Geothermie.

Afb. 31: Energievisie Den Haag p44: Bestaande warmtenetten
ENERGY POTENTIALS

From the context in Scheveningen energy potentials for my project can be given:

» wind for natural ventilation
» sun for passive measures: orientation of spaces
» sun for active measures: pv and collector
» ground for heat and cold storage
CLIMATE CONCEPT

NATURAL VENTILATION + NIGHT VENTILATION

With the character of the project in mind there is chosen to apply natural ventilation in the project. There is ventilated through openings at the patio’s and an opening next to the entrance in the spaces. The wind direction is perpendicular to the facade most of the time.

Night ventilation is an interesting and inexpensive system for cooling and a variant of natural ventilation. During the night, the building is intensively ventilated with air of which the temperature is lower than the indoor temperature (outside temperature at least 3 °C < than outside). The room temperature will drop and the heat stored in the hempcrete walls is released.

HEATING BY SOLAR COLLECTOR (VACUUM TUBE)

To provide heat solar collectors are installed on the roof of the volumes. The solar collectors use heat pipes in vacuum tubes, making this much more efficient than normal flat plate collectors. By evaporation in a vacuum the tube generates heat for heating or hot water.
Three large storage tanks with water are placed in the technical room, one for domestic hot water (0.3 m$^3$) and heating (2 m$^3$). The third is a reserve tank for times when the power supply is too low. These tanks need to be insulated really well.

**HEATING WITH PELLET**

As a backup when the collectors still provide enough heat, a pellet boiler installed. This burn compressed sawdust (pellets), an environmentally friendly fuel with high efficiency and CO2 neutral.

**LOW TEMPERATURE RADIATOR**

For heating low temperature radiators are used in the design. These turn out to be the best choice with the flexible spaces of the project in mind.

attributes of low temperature radiators are:
- faster system than underfloor heating
- combination of convection and radiation
- possible to set different temperatures in different rooms
- manually set psychological effect
- long lifespan
- the metal parts are recyclable

**ELECTRICITY: PV PANELS**

The necessary electricity is generated by means of photovoltaic panels on the roof of the fixed parts of the building in the building. In a PV panel is direct and diffuse sunlight is converted into energy in the form of electricity.

**WATER**

Rainwater is buffered by a vegetation on the volumes then collected in a tank and used for toilet flushing.
SIMULATION IN ORCA

A simulation for the internal climate and energy use for heating/cooling is done in Orca, a calculation programme of the TUDelft.

**INPUT**

<table>
<thead>
<tr>
<th>vloer</th>
<th>dak</th>
<th>wand</th>
<th>vliesgevel</th>
</tr>
</thead>
<tbody>
<tr>
<td>houten vloer hempcrete isolatie</td>
<td>houten vloer hempcrete isolatie pavatex isolatie</td>
<td>200mm hempcrete wand</td>
<td>trippe glas</td>
</tr>
<tr>
<td>U-waarde: 0.2 W/m2K</td>
<td>U-waarde: 0.04 W/m2K</td>
<td>U-waarde: 0.3 W/m2K</td>
<td>U-waarde: 1.2 W/m2K</td>
</tr>
</tbody>
</table>
# Simplified Static Heating/Cooling Demand Calculation

Vereenvoudigde methode om de warmtebehoefte van een vertrek of gebouw te bepalen

<table>
<thead>
<tr>
<th>Steps</th>
<th>Results and characteristic numbers</th>
</tr>
</thead>
</table>

1. Choose a building, part of a building or a room which should be calculated

2. Calculate the net floor area

   - Length: 7.2 m
   - Width: 9.6 m

   Net floor area: 69 m²

3. Calculate the net volume (between floor and ceiling)

   - Average height between floor and ceiling: 3.3 m

   Net volume: 228 m³

4. Choose a design indoor and outdoor temperature

   - Indoor temperature: 20 °C
   - Outdoor temperature: -5 °C

5. Calculate transmission heat loss

   - Area closed parts building envelope: 209 m²
   - Average U-value closed parts building envelope: 0.18 W/m²K
   - Area transparent parts building envelope: 20 m²
   - Average U-value window building envelope: 1.2 W/m²K (triple glas)

   Transmission loss: 1540.5 W = 22 W/m²

6. Calculate ventilation heat loss

   - Air change rate: 2
   - Ventilation flow Q_{vent}: 0.127 m³/s
   - Heat recovery percentage (sensible heat) hrp: 0%
   - Infiltration rate: 0.2
   - Infiltration flow Q_{inf}: 0.013 m³/s
   - Volumic mass air: 1.3 kg/m³, specific heat capacity air c: 1.000 J/kgK

   Ventilation heat loss: 4530 W = 66 W/m²

7. Determine total heat demand

   Total heat demand: 6071 W = 88 W/m²

Exclusive:

- More heating capacity necessary due to cooled down building mass after a night, weekend or holiday: 5 - 20 W/m²
- More heating capacity necessary due to heat loss to the surrounding spaces
- Less heating capacity necessary due to Internal heat gains
- Less heating capacity necessary due to solar gains
Vereenvoudigde methode om de koudebehoefte van een vertrek of gebouw te bepalen

**Steps**

<table>
<thead>
<tr>
<th>Step</th>
<th>Description</th>
<th>Calculation</th>
<th>Results and characteristic numbers</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Choose a building, part of a building or a room which should be calculated</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Calculate the net floor area</td>
<td>length m</td>
<td>width m</td>
</tr>
<tr>
<td>3</td>
<td>Calculate the net volume (between floor and ceiling)</td>
<td>Average height between floor and ceiling</td>
<td>3.3 m</td>
</tr>
<tr>
<td>4</td>
<td>Choose a design indoor and outdoor temperature</td>
<td>$T_{binnen}$ = 26 °C</td>
<td>$T_{buiten}$ = 28 °C</td>
</tr>
<tr>
<td>5</td>
<td>Calculate external heat load</td>
<td>$A_{glass}$ = 4.68 m²</td>
<td>ZTA (g) = 0.3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$Q_{sun}$ = 259 W/m²</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>External heat load = $A_{glass} \times ZTA \times Q_{sun}$</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Determine internal heat load</td>
<td>Number of persons</td>
<td>1612</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Capacity lighting</td>
<td>15 W/m²</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Capacity computers</td>
<td>40 W/m²</td>
</tr>
<tr>
<td>7</td>
<td>Calculate ventilation cold loss</td>
<td>Air change rate $n$</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Ventilation flow $Q_{vent}$</td>
<td>0.385 m³/s</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Heat recovery percentage (sensible heat) hrp</td>
<td>0%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Infiltration rate $n$</td>
<td>0.2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Infiltration flow $Q_{inf}$</td>
<td>0.026 m³/s</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Volumic mass air $\rho$</td>
<td>1.3 kg/m³</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Specific heat capacity air $c$ = 1.000 J/kgK</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Ventilation cold loss = $(Q_{vent} \cdot (1- hrp) + Q_{inf}) \cdot \rho \cdot c \cdot (T_{outside} - T_{inside})$</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Without dehumidification</td>
<td>1,068 W</td>
</tr>
<tr>
<td></td>
<td></td>
<td>With dehumidification</td>
<td>5101 W</td>
</tr>
<tr>
<td></td>
<td></td>
<td>24°C, 50%RV inside; 28°C, 60%RV outside</td>
<td>36 W/m²</td>
</tr>
<tr>
<td>8</td>
<td>Determine total cold demand</td>
<td>Without dehumidification</td>
<td>138,091 W</td>
</tr>
<tr>
<td></td>
<td></td>
<td>With dehumidification</td>
<td>142,125 W</td>
</tr>
<tr>
<td></td>
<td></td>
<td>24°C, 50%RV inside; 28°C, 60%RV outside</td>
<td>1015 W/m²</td>
</tr>
</tbody>
</table>

Exclusive:
- More cooling capacity necessary due to cold loss by transmission via the building envelope
- More cooling capacity necessary due to cold loss to the surrounding spaces
- Less cooling capacity necessary by free cooling, such as night time ventilation with cooling down of the building mass, 20-30 W/m²
The placement of the collector module is very important in the office lineament that is to be expected. This placement will be expressed in terms of the angle of inclination of the panel, and the direction in which the "look".

In the figure below the average yield is shown in relation to optimal placement.
**INPUT**

Panel direction in degrees: 180 (south = 180)  
Slope of the panel in degrees: 40 (0 = horizontal)  
Weather type: NASA 10-year averages, averaged over the sunlight in: whole year  
Size storage tank: 200 liters  
Number of tubes: 60

**RESULT**

In the chart below you can see how much power will be absorbed during the day by the solar system. Note, this is averaged over all the days in the year.

» on average this means that:
   › the energy absorbed = 12.33 kWh per day
   › 12.33 kWh per day * 365 days = 4500.45 kWh per year
   › increase in boiler temperature = 53 °C per dag

» financially this means:*  
   › systemprice = 2690 Euro  
   › gas savings = 500 m³/year (335 Euro/year)  
   › paybacktime = 6.1 jaar

*This example is indicative and is based on the optimum use of the energy absorbed, a gas price of 0.67 Euro / m³ and an increase in the price by 15% per year.
ENERGY CALCULATION

» total square meters panel possible on roof volumes: 139m²

The amount of energy possible to produce on the roof of the volumes is taken as a starting point to calculate how many square meters of the programme can be realized in the building. For this the function with that demands the most, an office, is taken as the calculation value.

HEAT
• Totaal (zomer + winterperiode): 10183 +63 = 10246 kWh
• de opgenomen energie per zonnecollector = 4500.45 kWh per jaar
• (4500.45 kWh per jaar * (365 dagen * 24 uur) = 4500.45 * 8760 = 513.75 W)
• 10246 voor 140m² > 73 kWh/m²
• zonnecollector: 4500 kWh per jaar per 4.8m²
• nodig per m² kantoor: 0.08 m² zonnecollector

ELECTRICITY
• kengetal kantoor: 50 kWh/m²
  bron: Kengetallen overheidsbenchmark 2012 (data over 2011) (n=94),
  http://www.milieubarometer.nl/kantoor
• 1 m² pv: 100-150 kWh per jaar
• nodig per m² kantoor: 0.3 m² pv paneel

PROGRAMME
The ratio solarcollector/pv-panel to provide for an office function is about 1/4
With 139m² this means that 337.5 m² of office function can be placed in the project.
### Permanent belasting = G

<table>
<thead>
<tr>
<th>Dak</th>
<th>Derbisedum filterende laag</th>
<th>in polyester 150 g/m²</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>of in polypropyleen 120 g/m²</td>
</tr>
<tr>
<td></td>
<td>Eigen gesatureerd gewicht van de drainagelaag 4 cm grind 80 kg/m²</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Eigen gesatureerd gewicht van de DERBISEDUM® tegels 1 kg/m²</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>of EPS-platen: 40 kg/m²</td>
</tr>
</tbody>
</table>

| Wand      | grancrete 2.1 g/cm³ = 2100 kg/m³ > 20.6 kN/m³  |
|           | biofoam 40 kg/m³ > 0.4 kN/m³  |

| Vloer     | grancrete 2.1 g/cm³ = 2100 kg/m³ > 20.6 kN/m³  |
|           | biofoam 40 kg/m³ > 0.4 kN/m³  |

### Veranderlijke belasting = Q

<table>
<thead>
<tr>
<th>Dak</th>
<th>voor daken (bij globaal dimensioneren) p rep 1 kN/m²</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>( \psi ) factor voor de</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Vloer</td>
<td>stations, horeca, bijeenkomstgebouwen en tribunes p rep 5 kN/m²</td>
</tr>
<tr>
<td></td>
<td>( \psi ) 0.25</td>
</tr>
<tr>
<td></td>
<td>woon kantoren en scholen p rep 2.5 kN/m²</td>
</tr>
<tr>
<td></td>
<td>( \psi ) 0.5</td>
</tr>
</tbody>
</table>

### Windbelasting

<table>
<thead>
<tr>
<th>Gebied 2, onbebouwd</th>
<th>extreme waarde van de stuwdruk ( pw )</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>( h = 8 &gt; pw = 0.81 \times 10^3 \text{ kN/m}^2 )</td>
</tr>
<tr>
<td></td>
<td>( h = 18 &gt; pw = 1.07 \times 10^3 \text{ kN/m}^2 )</td>
</tr>
</tbody>
</table>

windbelasting \( \text{prep} = \text{pw} \cdot \sum c p e \)

<table>
<thead>
<tr>
<th>Volume 1</th>
<th>onderdruk maatgevend ( \text{prep} = 1.07 \times 1.1 = 1.177 \text{ kN/m}^2 )</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>bijbehorende windzuiging ( \text{prep} = 1.07 \times 0.1 = 0.107 \text{ kN/m}^2 )</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Volume 2, 3, 4</th>
<th>onderdruk maatgevend ( \text{prep} = 0.81 \times 1.1 = 0.891 \times 10^3 \text{ kN/m}^2 )</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>bijbehorende windzuiging ( \text{prep} = 0.81 \times 0.1 = 0.081 \times 10^3 \text{ kN/m}^2 )</td>
</tr>
</tbody>
</table>

### Belastingfactoren

veiligheidsklasse 3, veel mensen, veel schade

<table>
<thead>
<tr>
<th>BG = bruikbare grenstoestand</th>
<th>G en Q = alle belastingen ( 1 )</th>
</tr>
</thead>
<tbody>
<tr>
<td>UG = uiterste grenstoestand</td>
<td>( G ) = permanente belasting gunstig ( 0.9 )</td>
</tr>
<tr>
<td></td>
<td>( G ) = permanente belasting ongunstig ( 1.2 )</td>
</tr>
<tr>
<td></td>
<td>( Q ) = veranderlijke belasting ( 1.5 )</td>
</tr>
<tr>
<td></td>
<td>alleen ( G ) = permanente belasting ( 1.35 )</td>
</tr>
</tbody>
</table>
**STRUCTURAL DESIGN**

For three grancrete volumes the structure is calculated, all have different characteristics:

- the tower
- the overhang
- large span

**TOWER**

Mass building should be

\[
\gamma = \frac{3}{ab^2} = \frac{3}{10 \times 10^2} = 3 \times 10 = 30 \text{ kN/m}^2
\]

Weight building \( Q = \gamma \times b \times a \times h = 3 \times 10 \times 10^2 \times 17.5 = 525,000 \text{ kN} \)

\( Q_{sr} = 3785,25 \times 10 = 37852,5 \text{ kN} \)

\[
Q_{sr} = \frac{8EI}{I^2}
\]

\[
EI = 37852,5 \times \frac{17.5^2}{8} = 1449041,02 \text{ kNm}^2
\]

\[
E_{\text{grancrete}} = 1,11 \times 10^7 \text{ kNm}^2
\]

\[
I = \frac{1449041,02}{1,11 \times 10^7} = 0,103 \text{ m}^4
\]

\[
I = \frac{1}{12}bh^3 - \frac{1}{12}(b - 2t)(h - 2t)^3 = 0,103 \text{ m}^4
\]

\[
I = \frac{1}{12} \times 10 \times 5^3 - \frac{1}{12}(10 - 2t)(5 - 2t)^3 = 0,103 \text{ m}^4
\]

\( t = 0.75 \text{ mm} \)

\[
W = \frac{I}{h} = \frac{0,103}{10} = 0.04
\]

\[
M = \frac{1}{2}wh^2 = \frac{1}{2} \times 10 \times 10^2 \times 17.5 = 1802,28 \text{ kNm}
\]

\[
\sigma = \frac{M}{W} = \frac{1802,28}{0,04} = 45057,03 \text{ kN/m}^2 = 45 \frac{N}{\text{mm}^2}
\]

Grancrete: max compressive strength na 3 uur: 45.09 \( \frac{N}{\text{mm}^2} \)

for tensile strength reinforcement is necessary
OVERHANG AND LARGE SPAN VOLUMES

For the other two volumes an analyses in Autodesk Robot Structural Analysis is done. First for the overhang volume the center of gravity is shifted so no tension in the foundation occurs, see scheme below.

In the programme different thicknesses and sections for walls and floors are tried to get the stresses below the maximum stress of the grancrete material.
RESULTS

**overhang volume**

\[ \sigma_{xx} \text{ max } 0.65 \text{ N/mm}^2 > \text{wand sandwich profiel 60mm dik} \]

\[ \sigma_{yy} \text{ max } 1.83 \text{ N/mm}^2 > \text{wand sandwich profiel 60mm dik} \]

**large span volume**

doorbuiging max 1.3 mm > wand sandwich profiel 60mm dik

doorsbuiging max 12.2 mm
Part 7: Reflection
**RELATION THEME AND STUDIO**

In the studio Architectural Engineering the design is a result of research of a 'technological' subject. In this project the subject is the 'continuous material cycle'. This subject has both a technological part and an architectural part related to it. The technological part is connected to the design of pathways for materials/building components, the construction methods, and material choices. The theme was also the starting point for the development of a scenario for the 'architectural part': the choice of location, timeframe and users of the design. In the material cycle, the building is just an in-between phase. The same can be said about FAST village in Scheveningen, which is a temporary project on an empty construction site. Thereby, the limited timeframe of the building makes a scenario for reuse or recycle more plausible.

**RELATION METHOD STUDIO AND USED METHOD**

**METHOD USED**

The materials are researched from two directions: starting at the different layers of a building (skin, structure, services, space plan, mobile equipment) and with the material itself as a starting point. In the first a 'typical' building is in mind, materials that fit the criteria for a continuous material cycle are looked at that could replace the conventional building materials.

When starting from the material, first the distinction is made between the 'biological cycle' and the 'technological cycle' in which the materials need to return.

Materials were then divided into different categories. The aim here is to look for a material that performs the best on certain aspects. After that the possibilities to apply them in a building are looked at. Also there is taken into account how some materials can be improved in the future to better fit the criteria for a continuous cycle.

**ASPECTS**

The criteria to rate the different materials are:

- Cycle
  - biological or technical cycle
  - the source, use and end of life application of the material
  - possibilities in building method design for disassembly
- Health for humans and environment
- Energy: use and source
- Water management
Social responsibility

SOURCES
As a starting point for the search for materials the following sources are used:

» Catalogus biobased bouwmaterialen, Van Dam Van den Oever, Wageningen UR, Wageningen, 2012
» Handreiking voor het bouwen met C2C, Hoogers et al, Builddesk, Delft, 2010
» C2C certified products, http://www.c2ccertified.org, Cradle to Cradle Products Innovation Institute
» nibe Milieuclassificaties Bouwproducten, http://www.nibe.info, nibe

RELATION RESEARCH AND DESIGN
The research for the ‘technological part’ of the design is about the continuous material cycle. The research is divided into ‘design for disassembly’ and in a material research part. The result from the technological part of the research is an overview of materials that are good to use in the design, with the source and cycle of these known.

The research for the ‘architectural part’ of the design is about the location, user and programme. This is integrated into the design by making the building temporary, and for the user able to self-build and grow within the building. The informality, the location close to the beach and sea and the sense of community aimed for in the design is derived from the user of the building.

MATERIALS CHosen
Both parts of the research come together in the choice of the materials. Three main materials are selected out of which the project will be build: grancrete, hempcrete and wood. These materials fit a continuous material cycle, can be build with in cooperation with the users and use locally found ingredients.

grancrete
Grancrete is a sprayable ceramic that is stronger than concrete. It has a high compressive strength, high flexural strength, strong bonding strength, long durability and fire/water/salt/acid resistant. It is developed to be a cheap and efficient building material for the poor. Grancrete is manufactured right on site, so there is very little overhead cost. Also it has a fast cure rate, 15 to 20 minutes, which makes building with it quite fast.

Grancrete consists of sand or sandy soil, ash, magnesium oxide and potassium phosphate, which is a biodegradable element in fertilizer. When deconstructed, pulverized by crushing equipment and mixed with soil it will revitalize the soil.

From this material four fixed, solid volumes are made, which house the fixed functions as toilets/showers/large halls and watchtower. The strengths the material has are used and tested by making one high, one with a large span and one with an overhang. The water/salt resistancy of the material is used in the toilet and showers and in dealing with the local conditions of the beach.

wood
Wood is used to construct two levels in between the volumes: a ground floor where rooms can be made and a public deck which gives access to the large rooms in the volumes and from which the terrain can be overlooked. This construction is prefab, has the same, commonly used, sizes and is designed
Hempcrete is a combination of chopped hemp shiv and a binder comprising of natural hydraulic lime. Hempcrete can easily be poured or formed into blocks in a similar manner to concrete. It has low compressive strength, good thermal, acoustic and moisture regulating properties. Hempcrete is biodegradable and can be re-used, either as a building material or a soil amendment. In the project hempcrete is used to make internal spaces in the wooden construction. This way the qualities of the material are used the best. From the material light blocks are made that can easily be stacked to make walls. The hempcrete walls can be broken down and constructed again or repoured into new blocks. Hempcrete is also used as insulation in the wooden floors.

**RELATION PROJECT AND WIDER SOCIAL CONTEXT**

**THE CURRENT SITUATION OF MATERIAL USE**

The current state of the building industry is still based on a linear “take, make and dispose” model, also known as the ‘cradle-to-grave’ approach.

![RAW MATERIAL → PRODUCT → WASTE](image)

This model of the construction industry has an impact on some specific environmental problems:

- share in the landfill, mainly due to demolition waste
- depletion of natural resources
- the loss of fertile land due to urbanization
- large share in the emissions of greenhouse gases, mainly due to the combustion of fossil fuels for energy (both during the production of buildingproducts as for heating and electricity use in buildings)
- poor indoor air quality (sick building syndrome).

Some numbers: 35% of the national landfill comes from the building- and construction sector. Of this 40% consists of concrete, 25% of masonry, 25% asphalt, 10% remaining. (source slimbouwen en senternovem [source](http://issuu.com/architect-en-van-mourik/docs/levensduurzaamheid_totaal_web)).

Although construction and demolition waste in the Netherlands is being recycled for about 98% since years ([Afvalbrief staatssecretaris Atsma 2011](http://issuu.com/architect-en-van-mourik/docs/levensduurzaamheid_totaal_web)), most of this is in the form of ‘downcycling’. Downcycling is a term popularized by William McDonough and Michael Braungart, authors of Cradle to Cradle: Remaking the Way We Make Things. Downcycling is the reuse of a product for alternative purposes or the recycling of material into lesser quality (Braungart & McDonough 2002). An example of this is in the building industry is ‘betongranulaat’ which is currently mainly used as a foundation for roads. Next to downcycling, some of the waste ends up in landfills and incinerators as part of mixed flows. The expectation is that the amount of construction and demolition waste will increase in the coming years.

The linear model also fails to consider the high nutrient value of waste. Material recycling is essential for solving the increasing scarcity of raw materials on the world market. Worldwide consumption of raw materials is unsustainable at its current pace (Braungart 2010).
Furthermore any building today contains materials that are hazardous to our health. They range from materials that can be toxic with short-term or low-level exposure to those that can be toxic or carcinogenic years after exposure to those that are only irritants. Examples of this are PVC, Polyurethane, Volatile organic compounds (VOC’s). Some VOC’s have been associated with short-term acute sick building syndrome symptoms, as well as other longer-term chronic health effects, such as damage to the liver, kidney and nervous systems, and increased cancer risk (International Agency for Research on Cancer (IARC)).

We need to move away from this end of pipe paradigm to a situation where the cycles are closed. Despite many available technologies to effectively recycle materials, most products and buildings on the market are still not designed for nutrient recovery.
Appendix
LITERATURE AND GENERAL PRACTICAL PREFERENCE


Geldermans, S. 2009. masterthesis: Cradle to cradability: two material cycles and the challenges of closed-loop in construction, TUDelft


Sjunnesson, J. 2005. Life Cycle Assessment of Concrete. Lund University


Tool, F. 2010. (masterthesis CT TUDeft) Ontwerptool voor de beoordeling van constructieve alternatieven op duurzaamheid, Delft

Tulp, D. 2009. masterthesis: De mogelijkheden voor het Cradle to Cradle concept in de Nederlandse woningbouw. TUEindhoven


Bodemenergie kansrijk voor uw locatie

Projectinformatie

Locatie
X/Y-coördinaten: 77.697;457.130
Bouwvolume: 350 huizen
10 appartementen
10.000 m² bouwvoorzielingen

Kan en mag het?
- Bodem is zeer geschikt
- Wettelijk toegestaan
- Rekening houden met aandachtsgebieden: specifiek provinciaal beleid

Wat levert het op?
- Korte terugverdientijd van 4 - 8 jaar
- Energiebesparing tot 59%

Het vervolgtraject

Stap 1: Voer haalbaarheidsstudie uit voor go/no go besluit
Stap 2: Ontwerp eyetoom en vraag vergunningen aan

Disclaimer

Deze quickscan is bedoeld om op quickscan-niveau een indruk te krijgen van de kans voor de toepassing van open WKO-systemen op een bepaalde locatie. Indien met de toepasbaarheid interessante terugkoppelingen ontstaan, kan in de volgende fase een haalbaarheidsstudie uit worden gevoerd om de wettelijke mogelijkheden van WKO voor een locatie in kaart te brengen. De tool is niet geschikt voor vergunningen aanvragen, haalbaarheidsstudies of ontwerpen. Iedere initiatiefnemer zal aanvullend onderzoek moeten verrichten om de wettelijke, juridische en financiële geschiktheid voor bodemenergie op locatie te kunnen bepalen.
De belangrijkste voordelen en randvoorwaarden uitgewerkt

Kan het?

Bodemgrondsoorten

zeer geschikt

Grondwaterkwaliteit

goed beperkt

Mag het? - restrictiesgebieden

groen-wit-herbestemminggebieden

spatief provinciaal beleid

Mag het? - aandachtsgebieden

WKO-systemen

DNW-systemen

grondwaterontwikkelingen

verniezingen (ontwerp)

verniezingen ( puntlocalisatie)

nuur

aardkundige waarden

archeologie

spatief provinciaal beleid

specifiek provinciaal beleid van toepassing

omgevingsbelang niet aanwezig op locatie of in omgeving

omgevingsbelang aanwezig op locatie

omgevingsbelang aanwezig in omgeving

geen informatie beschikbaar

Milieuvordeel - wat levert het op?

Energiebesparing [%]: 59

CO2-ontsmettingsvoordeel [%]: 54

Financieel - wat levert het op?

Heerdeloos investering [k]: 1.126.000

Exploitatievoordeel [C/year]: 194.000

Terugrechting [ jaar]: 4 - 8

Financiële kantallen

Prijs CV-hotel huis [C/kBtu]: 3.500

Prijs CV-hotel collectief [C/kBtu]: 100

Prijs warmtepomp huis [C/kBtu]: 3.500

Prijs warmtepomp collectief [C/kW]: 230

Prijs koelmachine huis [C/kW]: 800

Prijs koelmachine collectief [C/kW]: 225

Elektriciteitsprijs [C/kW]: 0,16

Gasprijs [C/m³]: 9,67

Opname van subsidievoordeel [k]: 0

Inkomsten uit koeling [C/year]: 240

Financiële analyse

Omslagpunt WKO

Disclaimer

Deze nieuwbouwlocatie is bedoeld om op plus Cascade niveau een indruk te bieden van de kansen voor de toepassing van open WKO-systemen op een bepaalde locatie. Indien met de voorgestelde interessante terugroepringen belast word door de toepassing van een open WKO voor een locatie in kaart te brengen. De locatie is niet geschikt voor vergroeiingsoverlasten, houtaanpakbouw of eventueel studies. Individuele inlichtingen die aanvullend onderzoek moeten verschijnen om de werkelijke kanttekeningen, juridische en financiële mogelijkheden voor bodemenergie op locatie te kunnen bepalen.
### Tabel 2: Meest toegepaste houtsoorten in de bouw in Nederland (Houtinfo, 2012).

<table>
<thead>
<tr>
<th>Houtsoort</th>
<th>Wetenschappelijke naam</th>
<th>Duurzaamheidsklasse NEN</th>
<th>Dichtheid kg/m³</th>
<th>Toepassingen</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fijnspar (vuren)</td>
<td>Picea abies</td>
<td>4</td>
<td>460</td>
<td>kozijnen, puien, ramen, deuren, trappen vloeren, kasten, bekisting lijstwerk, triplex, spaanplaat</td>
</tr>
<tr>
<td>Grove den (grenen)</td>
<td>Pinus sylvestris</td>
<td>3/4</td>
<td>510</td>
<td>kozijnen, ramen, deuren, vloeren, binnen- en buiten betimmering, balkhout, triplex, houtwol, hekpalen</td>
</tr>
<tr>
<td>Lariks</td>
<td>Larix sp</td>
<td>3</td>
<td>590</td>
<td>dragende constructies, kozijnen, ramen, gevelbekleding, binnen betimmering, trappen, stutten, daksporen, afrastering</td>
</tr>
<tr>
<td>Western red cedar</td>
<td>Thuja plicata</td>
<td>2</td>
<td>350</td>
<td>Buitentoepassingen, palen, plankieren, shingles</td>
</tr>
<tr>
<td>Douglas</td>
<td>Pseudotsuga menziessii</td>
<td>3/4</td>
<td>530</td>
<td>Timmerhout, balken, planken, heipalen, multiplex</td>
</tr>
<tr>
<td>Berk</td>
<td>Betula sp</td>
<td>5</td>
<td>670</td>
<td>Fineer, multiplex</td>
</tr>
<tr>
<td>Beuk</td>
<td>Fagus sylvatica</td>
<td>5</td>
<td>680-720</td>
<td>Voor binnen toepassingen, meubels, dorpels, trappen, parket, gereedschap</td>
</tr>
<tr>
<td>Eik</td>
<td>Quercus robur</td>
<td>2</td>
<td>650-750</td>
<td>Constructiehout, houtskel frames, balken, parket, fineer</td>
</tr>
<tr>
<td>Kastanje (tamme)</td>
<td>Castanea sativa</td>
<td>2</td>
<td>590</td>
<td>hekwerk</td>
</tr>
<tr>
<td>Iep</td>
<td>Ulmus sp</td>
<td>4</td>
<td>550-600</td>
<td>Meubels,</td>
</tr>
<tr>
<td>Wilg</td>
<td>Salix sp</td>
<td>5</td>
<td>420</td>
<td>Vlechtwerk en afscheidingen, fineer</td>
</tr>
<tr>
<td>Robinia</td>
<td>Robinia pseudoacacia</td>
<td>1/2</td>
<td>350-450</td>
<td>Pallets, multiplex, papierpulp</td>
</tr>
<tr>
<td>Noten</td>
<td>Juglans regia</td>
<td>3</td>
<td>750-950</td>
<td>Meubels, vloeren, wanden, hekwerk</td>
</tr>
<tr>
<td>Eucalyptus</td>
<td>Eucalyptus sp</td>
<td>1/2</td>
<td>570-660</td>
<td>Meubels, vloeren, fineer</td>
</tr>
<tr>
<td>Esdoorn</td>
<td>Acer sp</td>
<td>5</td>
<td>755</td>
<td>constructie, trappen, hekken, leuningen, parket, tuinhout, plaatmateriaal (multiplex, houtvezelplaat)</td>
</tr>
<tr>
<td>Es</td>
<td>Fraxinus sp</td>
<td>5</td>
<td>540-710</td>
<td>Timmerhout, meubels, houtsnijwerk, gereedschap</td>
</tr>
</tbody>
</table>

*Meubels, fineer, schrijnwerk*
### Tabel 3. Overzicht van meest gangbare tropische hardhoutsoorten (Houtinfo, 2012).

<table>
<thead>
<tr>
<th>Houtsoort handelsnaam</th>
<th>Wetenschappelijke naam</th>
<th>Duurzaamheidsklasse NEN</th>
<th>Dichtheid kg/m³</th>
<th>Toepassingen (Herkomst)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acapou</td>
<td>Vouacapoua americana</td>
<td>1</td>
<td>880</td>
<td>(Midden &amp; Zuid Amerika)</td>
</tr>
<tr>
<td>Angelim de campigna</td>
<td>Aldina heterophylla</td>
<td>1</td>
<td></td>
<td>Buitentoe passing, vloenders en vloeren, zware meubels (Brazilië)</td>
</tr>
<tr>
<td>(Macucu de paca)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Angelim vermelho</td>
<td>Dinizia excelsa</td>
<td>1</td>
<td>1070</td>
<td>Buitentoe passing, vloenders en vloeren, trappen (Brazilië)</td>
</tr>
<tr>
<td>(Gurupa)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Azobé (Bonkole)</td>
<td>Lophira alata</td>
<td>1/2</td>
<td></td>
<td>Buitentoe passing, vloenders en vloeren, trappen, constructief en zware meubels (West Afrika)</td>
</tr>
<tr>
<td>Bangkirai (Meranti) #</td>
<td>Shorea spec.div.</td>
<td>1/2</td>
<td>500-600</td>
<td>Sterk constructief timmerhout voor buiten toepassingen en tuinmeubelen. (Zuidoost Azie)</td>
</tr>
<tr>
<td>Bilinga</td>
<td>Nauclea diderrichii</td>
<td>1</td>
<td></td>
<td>Buitentoe passing, hekwerk, beschoeing (W. Afrika)</td>
</tr>
<tr>
<td>Cumaru</td>
<td>Dipteryx odorata</td>
<td>1</td>
<td>910-1060</td>
<td>Vloeren, parket, (N. Zuid Amerika)</td>
</tr>
<tr>
<td>Ebben (Ebony) #</td>
<td>Diospyros sp</td>
<td>1</td>
<td>960-1120</td>
<td>Houtbewerking, snijwerk, meubels, muziekinstrumenten (India, Sri Lanka, West Afrika)</td>
</tr>
<tr>
<td>Favinha, Timbauba</td>
<td>Enterolobium schomburghi</td>
<td>1</td>
<td></td>
<td>Meubels, boten, vloerdelen, constructie hout, fineer (Brazilië)</td>
</tr>
<tr>
<td>Guariuba, Mururé</td>
<td>Clarisa racemosa</td>
<td>1</td>
<td>1160</td>
<td>Tuinmeubels, dekvoor en vloeren (Brazilië)</td>
</tr>
<tr>
<td>Ipé</td>
<td>Tabebuia sp</td>
<td>1</td>
<td>850-970</td>
<td>Meubels, vloerdelen (M en Z Amerika)</td>
</tr>
<tr>
<td>Itauba</td>
<td>Mezilaurus sp</td>
<td>1</td>
<td>960</td>
<td>Boten, vloeren (M Amerika tot ZO Brazilië),</td>
</tr>
<tr>
<td>Iroko</td>
<td>Milicia excelsa</td>
<td>1/2</td>
<td>655</td>
<td>(Afrikaans teak, bedreigde soort)</td>
</tr>
<tr>
<td>Jarrah</td>
<td>Eucalyptus marginata</td>
<td>1</td>
<td>860</td>
<td>Buitentoe passingen, vloeren, constructie hout, fineer (West Australië)</td>
</tr>
<tr>
<td>Jatoba</td>
<td>Hymenaea courbaril</td>
<td>1</td>
<td>710-820</td>
<td>Meubels, vloeren, parket decoratie, snijwerk, gereedschap (Caribben, Midden &amp; Zuid Amerika)</td>
</tr>
</tbody>
</table>

# Staan op IUCN rode lijst
<table>
<thead>
<tr>
<th>Houtsoort handelsnaam</th>
<th>Wetenschappelijke naam</th>
<th>Duurzaamheidsklasse NEN</th>
<th>Dichtheid kg/m³</th>
<th>Toepassingen (Herkomst)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Karri</td>
<td>Eucalyptus diversicolor</td>
<td>2</td>
<td>900</td>
<td>Vloeren en afdimmerwerk (Australië)</td>
</tr>
<tr>
<td>Louro gamela</td>
<td>Ocotea rubra</td>
<td>2</td>
<td>640-720</td>
<td>Meubels, dekloer en parket (Brazilië, Suriname, Guyana)</td>
</tr>
<tr>
<td>Louro preto (Imbuya)</td>
<td>Ocotea spec.div.</td>
<td>1</td>
<td>650</td>
<td>(Zuid Brazilië)</td>
</tr>
<tr>
<td>Mahonie (Sipo) #</td>
<td>Entandrophragma utile</td>
<td>2/3</td>
<td>650</td>
<td>Meubels, fineer (Afrika)</td>
</tr>
<tr>
<td>Massaranduba</td>
<td>Manilkara huberi M. bidentata</td>
<td></td>
<td>870-1050</td>
<td>Meubels en vloeren (Midden Amerika)</td>
</tr>
<tr>
<td>Merbau</td>
<td>Intsia bijuga</td>
<td>2</td>
<td>1050</td>
<td>Vloeren, deuren, kozijnen (Zuid Azië, Pacific)</td>
</tr>
<tr>
<td>Padoek (Narra, Amboyna)</td>
<td>Pterocarpus soyauxii Pterocarpus indica</td>
<td></td>
<td>740</td>
<td>Fineer, vloeren, meubels, draaierwerk (Centraal-West Afrika)</td>
</tr>
<tr>
<td>Piquia</td>
<td>Caryocar villosum</td>
<td>2</td>
<td>780</td>
<td>Kozijnen en constructiehout (Brazilië)</td>
</tr>
<tr>
<td>Purperhart</td>
<td>Peltozyne spec. div.</td>
<td>2/3</td>
<td>860</td>
<td>Meubels, fineer, parket (Midden &amp; Zuid Amerika)</td>
</tr>
<tr>
<td>Sucupira amarelo</td>
<td>Ferreinea spectabilis Bowdichia nitida Qualea paraenesis Ruizterania sp</td>
<td>2/3</td>
<td>980 1010 720</td>
<td>Meubels, fineer, vloeren, balkhout, shingles, constructiehout (Brazilië)</td>
</tr>
<tr>
<td>Mandloqueira</td>
<td>Andira parviflora</td>
<td>2</td>
<td>630-710</td>
<td>Constructiehout, deuren, kozijnen, trappen en gevelbekleding, meubels, fineer (M &amp; Z Amerika)</td>
</tr>
<tr>
<td>Sucupira vermelho</td>
<td>Tectona grandis</td>
<td>1</td>
<td>630-720</td>
<td>Meubels, vloeren, timmerhout (Zuidoost Azië, Afrika, Cariben)</td>
</tr>
<tr>
<td>Vitex</td>
<td>Vitex cofassus</td>
<td>1/2</td>
<td>700-800</td>
<td>Vloeren, constructiehout (Zuidoost Azië, Papua N Guinea)</td>
</tr>
<tr>
<td>Wenge #</td>
<td>Millettia laurentii</td>
<td>2</td>
<td>750</td>
<td>Vloeren, parket, hekwerk, draaierwerk, instrumenten (West-Centraal Afrika)</td>
</tr>
</tbody>
</table>

# Staan op IUCN rode lijst