RETHINKING THE UNWANTED

Exploring the possibilities of implementing waste materials in architectural design

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Research Paper "Rethinking the Unwanted"

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"we produce such an abundance of stuff that the time has arrived to experiment with what is there rather than try and create the new over and over again"
- Césare Peeren (Superuse, 2009)

I. FOREWORD

In line with present-day issues like reducing CO_2 emissions and the scarcity of resources, the reuse of materials is a relevant topic in modern society. Architecture, being one of the main consumers of materials, can play an interesting and relevant role in this field. This paper will elaborate on the possibilities of reusing local waste materials in architectural design and construction.

The research is set in the harbour area of Rotterdam. With the city swallowing up its former industrial areas, these zones will be undergoing major transformations in the coming decades. The aim of the research is to map the waste flows of the current industries of the Merwe-Vierhavens and provide generic solutions on how to incorporate these waste materials into the construction of new offices and dwellings for the area.
An example of a material found in abundance in the Merwe-Vierhavens is the oildrum. This packagingmaterial for transport of liquids overseas, arrives to the harbours by numbers of thousands a day. Being discarded after single use, the oildrums are an interesting and high quality material that is very suitable for reuse. Cutting it in different ways, it can be applied as construction or cladding material in architecture.

The fact that oildrums are to be found in any harbour worldwide adds to the relevancy of the solutions. The designpossibilities with for example oildrums are not only valuable for buildingprojects in the Merwe-Vierhavens but are generically applicable to any architectural project located near a harbour area. The results conducted in the research can thus be seen as a hands-on toolbox of innovative and generic designsolutions.

Implementing these solutions into architectural design however, demands from an architect to work in a different way. Materialchoice becomes the first step in the process and forms an immediate input in the design. The methodology described in this research can be read as a guideline for this material-driven designprocess.
It elaborates on how to map waste flows of a specific area and how to categorize the encountered materials into different scopes. Out of this information, a 'harvest map' is created, showing all the materials that can be found in the Merwe-Vierhavens, by which company they are discarded and their properties. The criteria on which to test those materials form the filter of the method, helping the architect to narrow his materialchoice down to a few most promising materials. Together with the four pillars of architectural potential, the criteria defined can be applied to any selection process of waste materials for architectural purposes.

Any architect willing to implement waste materials into his design can use this paper in two ways. The method for the material-driven designprocess can be followed in order to analyse a project location and investigate its waste-materials. The focus then lays on the use of locally available materials.
On the other hand, the toolbox of ready-to-use designsolutions with the four selected waste-materials, provides a direct input for certain buildingcomponents.

The higher purpose of this paper is to inform designers, architects and researchers about the possibilities that lay within the field of waste-materials and make them reconsider the traditional designprocess. There is still a long way to go before the implementation of waste materials will be able to compete with new buildingmaterials, but in this time of change it is already a valuable step to start rethinking the unwanted.

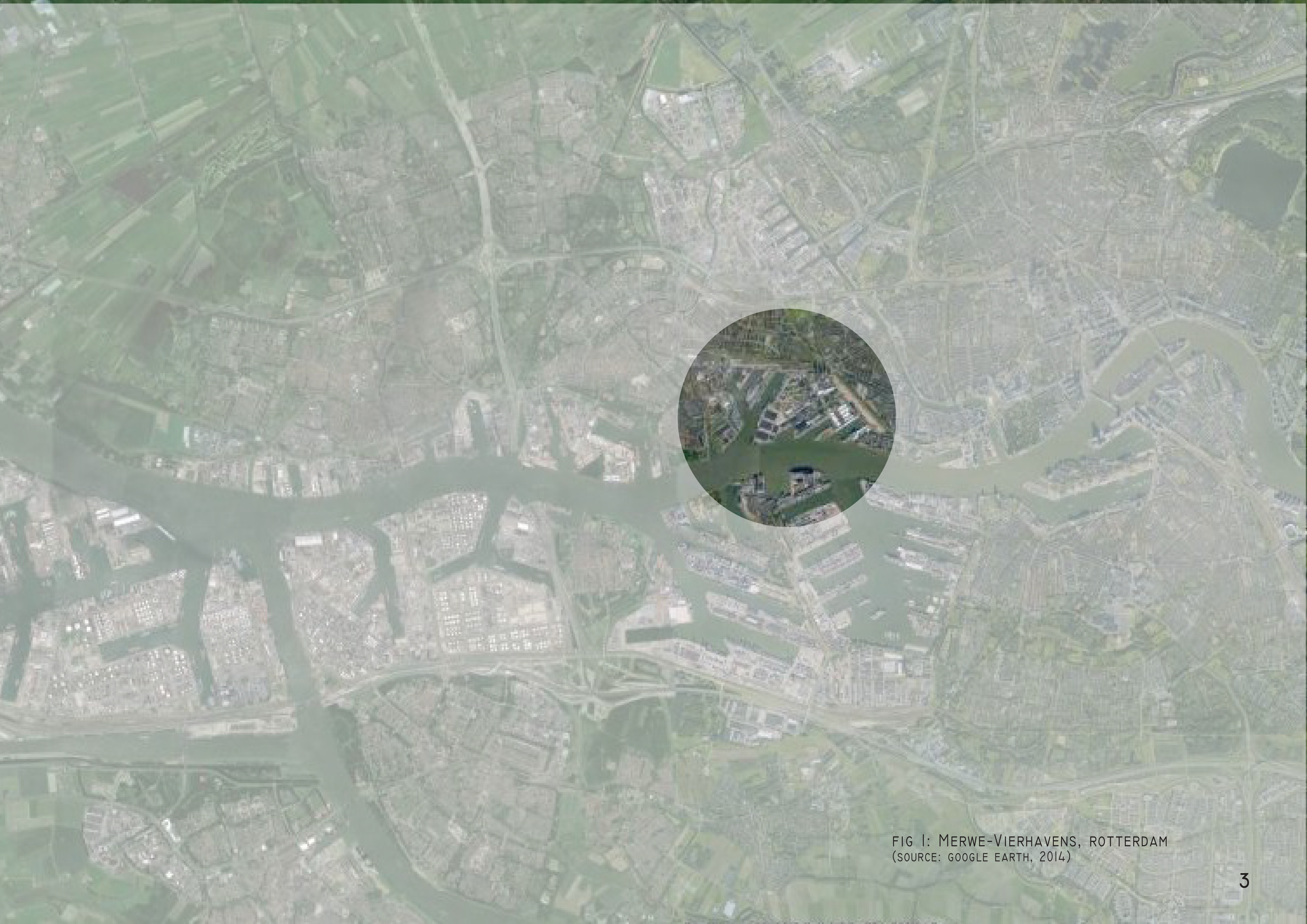


Fig 1: Merwe-Vierhavens, Rotterdam
(Source: Google Earth, 2014)

2. Introduction

Harbours in transition

Rotterdam, like many cities in Europe, is a growing city. Its population is increasing every year with approximately 10.000 new inhabitants who all need housing (Centrum Onderzoek en Statistiek, 2013). Allready the city is notably growing vertically, with new skycrapers being built everywhere. But densifying the population is not the only solution. The city is also pushing its borders outwards. Being a harbourcity, this means that the industrial harbours are slowly being swallowed by the growing metropolitan. Within the last few decades, harbour activity has been pushed more and more out of the city, towards the appointed area of the Maasvlakte. With the opening of the new Second Maasvlakte last year, even more pressure has fallen onto the industries to move outwards.

Looking at the map of Rotterdam, of all these harbours, the Merwe-Vierhavens are situated relatively close to the citycentre, with residential neighbourhoods surrounding it (fig.1). Yet the harbours are still in full operation as import- and export industries. The main activity is the import of fresh fruit - unloading them from ships into Ultra-Low Oxygen warehouses for further distribution - and condensed fruitjuices - which are imported in oildrums and transfered to liquidtanks - giving the harbours its nickname: the Fruit Harbours (fig.3).
The municipality wants this activity, with international companies like Fruit Logistics, HIWA and Continental Juice, to move to the Tweede Maasvlakte in order to create space for dwellings and offices (Straver, 2009).

This transition however is not something that can be realised in a whim; it is a process of slow change that will take up to at least 2040. Figure 2 shows this plan of transition as designed by DoepelStrijkers architecten together with Stadshavens Rotterdam (Programmabureau Stadshavens, 2011).
Nowadays small changes can already be noticed in the area. While harbouractivity has its focus on the waterfront, the ‘backgardens’ of the industry are slowly being taken over by new users. Like almost everywhere in city-development and regeneration of industrial zones, artists are the first

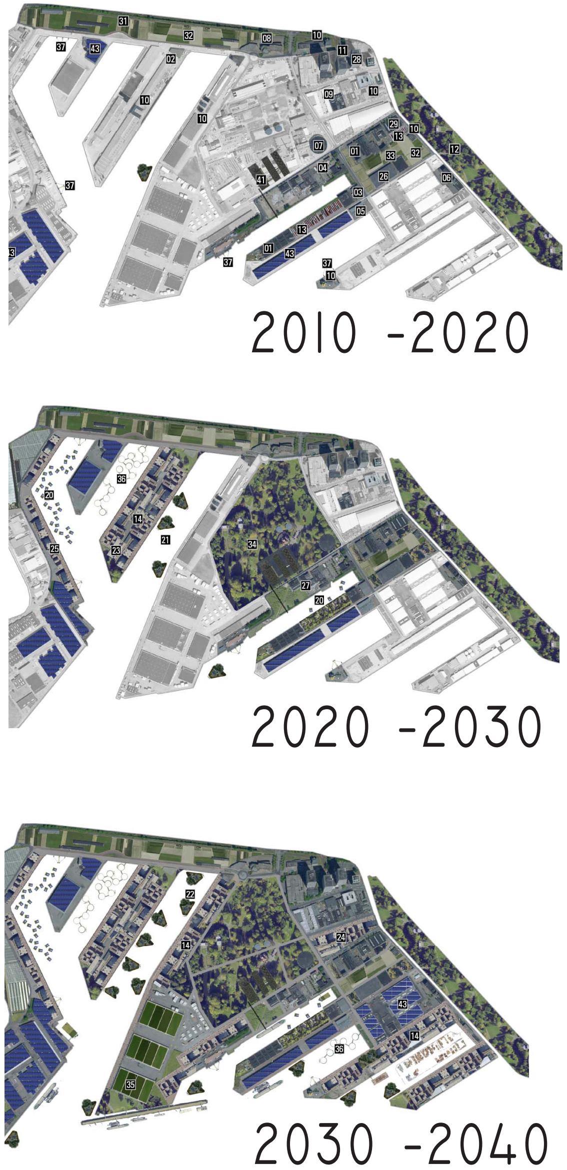


Fig 2: Merwe-Vierhavens in transition (source: "M4H, van Woestijn naar Goudmijn", J. Rotman, 2011)

FIG 3: MERWE-VIERHAVENS, ROTTERDAM

FIG 4: ATELIER VAN LIESHOUT, MERWE-VIERHAVENS

to be attracted to the place. They are the pioneers that settle in these raw and unfriendly zones because of low rents, abundance of space and limited regulations. The atelier of Joep van Lieshout coming to the area was an important step in this direction (fig 4).

Nowadays more and more companies and entrepreneurs, mostly in the creative industry - musicians, architects, designers etc - have settled in the Merwe-Vierhavens, adding to its new character. It is in all its aspects an area in transition. An area that is open to everyone, generating a strange but interesting mix between traditional industry (HIWA and others),big companies (E-on, Joulz, Gemeentewerken, etc.) and pioneering creative entrepreneurs.
All of it however has a temporary character. Transition literally means "passage or change from one stage to another" (dictionary.com, 2014). This future stage has been defined by the municipality: by 2040 the area is to be Rotterdams newest living- and working area. Industry will have to move away, buildings will be demolished, the ground will need to be sanitated but most of all, new building will have to be designed and built (fig.2).
According to area-development plans, there are 5500 dwellings and 352000m^2 of commercial real estate to be realised in the coming 25 years (Programmabureau Stadshavens, 2011). This means a huge buildingtask for architects and developers.

FUTURE

In the ´vision´ that Stadshavens Rotterdam have composed together with the municipality, the Merwe-Vierhavens are appointed as an area for "experimental development" and "sustainable dwellings". The MarconiFreeZone is adressed as a "playground for innovations" (Straver, 2009). This gives architects and builders the space and freedom to experiment with new ways of constructing buildings. Steel, bricks and concrete are no longer the only buildmaterials available. In this time, innovation should be something that brings us step by step closer to the essence of sustainability. This opportunity of a buildingtask in an area of experimental development can be seized to design buildings in an smart and innovative way.

If we look at the city of Rotterdam as if it were a metabolism, many different flows going in and out of the city can be distinguished (fig. 5). Jan Jongert

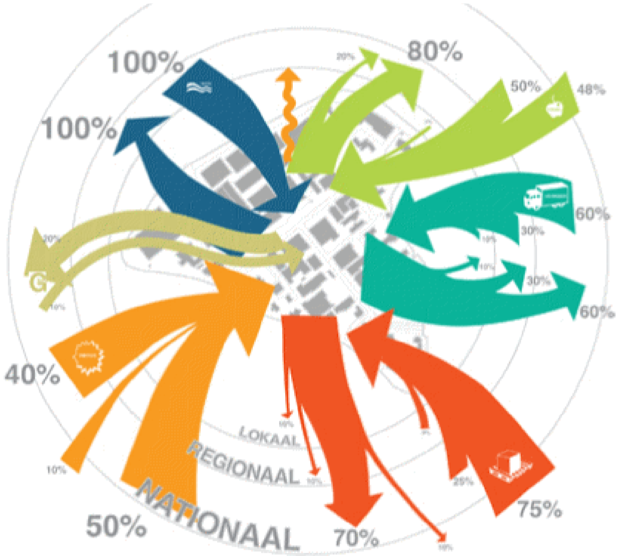


FIG 5: STUDY OF THE 'METABOLISM' OF GOUDSE POORT
(SOURCE: WWW.RECYCLICITY.ORG, 2014)

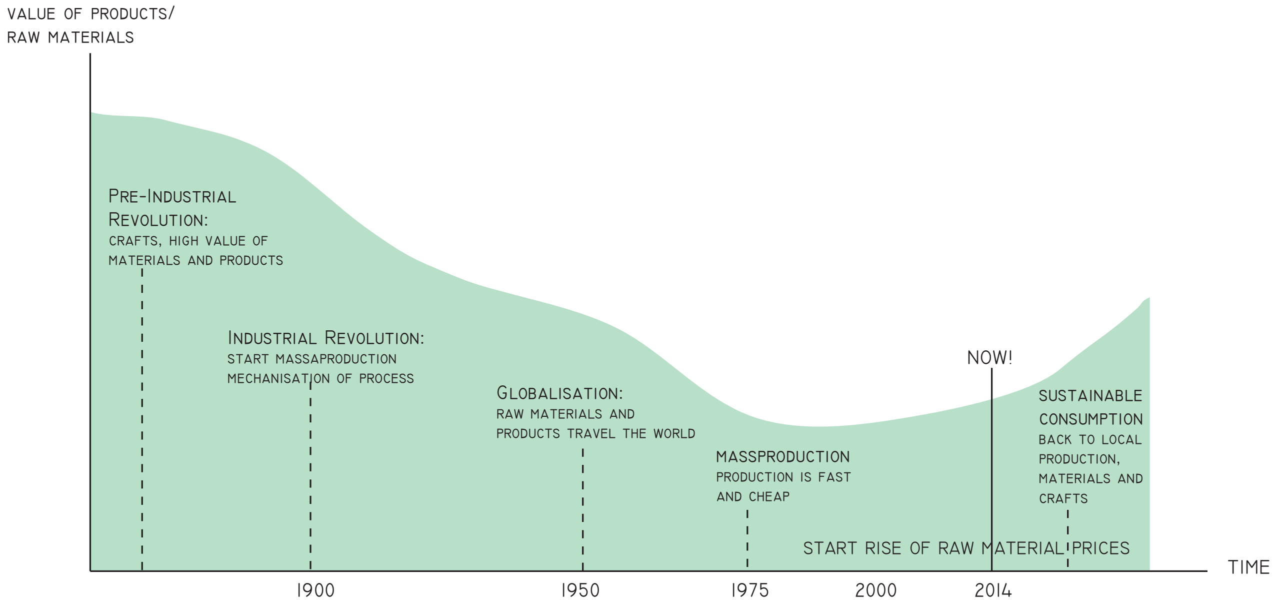


FIG 6: VALUE OF PRODUCTS AND MATERIALS OVER TIME
(OWN IMAGE, SOURCE: 'CITIES', A. DE VRIEZE, 2013)

defines 14 different flows varying from intangeble aspects like culture and knowledge to physical flows of energy and water (Jongert, 2014).
One of these flows is the import and export of materials; new materials going into the city for construction and waste materials being collected and transported out of the city. Looking at the principles of the circular economy, in which “material flows are designed to reenter the biosphere safely, and technical nutrients circulate at high quality without entering this biosphere” (McArthur, 2013), closing material cycles can be seen as one of the startingpoints of creating a healthy and sustainable city.

Reducing this excess of materialflows going in and out of a city can be reached by making more efficient use of what is already available and interconnecting flows. Waste materials can than become an alternative to importing new materials. This perspective on materialuse in architecture will be the guiding theme thoughout this research .

THE PROBLEM CALLED “WASTE”

“For every pound of garbage people generate, about seven pounds of waste are produced upstream, in the manufacturing process, before the product gets to the consumer “ - Dan Kupinksi (2013)

The western society can currenly be characterized as a “throw away society” in which the perception and value of materials is at one of its lowest points in history (fig. 6). Before the industrial revolution products were handcrafted and made only out of locally available materials. Then with the industrialisation of processes and globalization of international trade an era of mass-production came into being. The prices of raw-materials, transport and production dropped to a minimum (De Vrieze, 2013).
In this current situation of a consumer society, the economic system is focused on making products and getting them to peoples front door. But 99% of the stuff that is bought is thrown away within 6 months (P. Hawken, 1999). What happens to the objects after being thown away is rarely a subject of thought. What people don’t tend to realise however is that they dispose a whole load of valuable materials.

In a time where scarcity of resources is to be one of our main future topics (Van den Dobbelsteen, 2014), it is necessary to address waste from a different perspective. To see waste a a resource of raw materials. The European Union defines waste as "an object the holder discards, intends to discard or is required to discard" but as Duncan Baker-Brown states "Waste is just stuff in the wrong place".

In the Netherlands already 50% of our waste is being recycled. Glass for example is being collected seperately and melted into new glass. Paper and cardboard are being recycled into new paper. Steel is brought to the irondealer who sells it to the blasting furnaces (van den Vijver, 2014). But the remaining 50%, about 60 million tonnes per year, remains unsorted garbage, making the Netherlands the EU-country with the highest amount of wastage per capita (fig. 9).
Most of this unsorted garbage is sent straight to the incinerators, which the government built in answer to the problem of growing amounts of waste. Since the change in legislation on landfill in 2002 there are 12 incinerators in the Netherlands which burn the waste at temperatures of around 1000°C - the necessary minimum to be able to burn everything ranging from plastics to metals (Heijne, 2009). These ovens are amongst the cleanest installations worldwide, filtering pollution to a maximum and reclaiming heat and energy for the electricity network. The government therefore assigns this way of processing waste as 'usefull reuse'. Reality however is that the energy reclaimed is only a small percentage of our energy consumption, being only by-product of the primary intention of the ovens: burning our waste.
Since 2002, the government has invested a lot in the construction of these ovens. However, this was in a time of economic prosperity and with a vision on economic growth. With the crisis looming over the economy since 2009, the amount of wasteproduction has gone down, leading for the ovens to have a notable overcapacity. Ovens at such temperatures are hard to turn off, so currently waste is imported from the UK in order to keep the ovens running (de Vrieze, 2013). This constant need for waste is hardly in line with the governments' aim of reducing waste production. Considering the investments the authorities made in the ovens, it is however unlikely that this the noble policy of reducing waste can compete against the financial interests of keeping the ovens running.

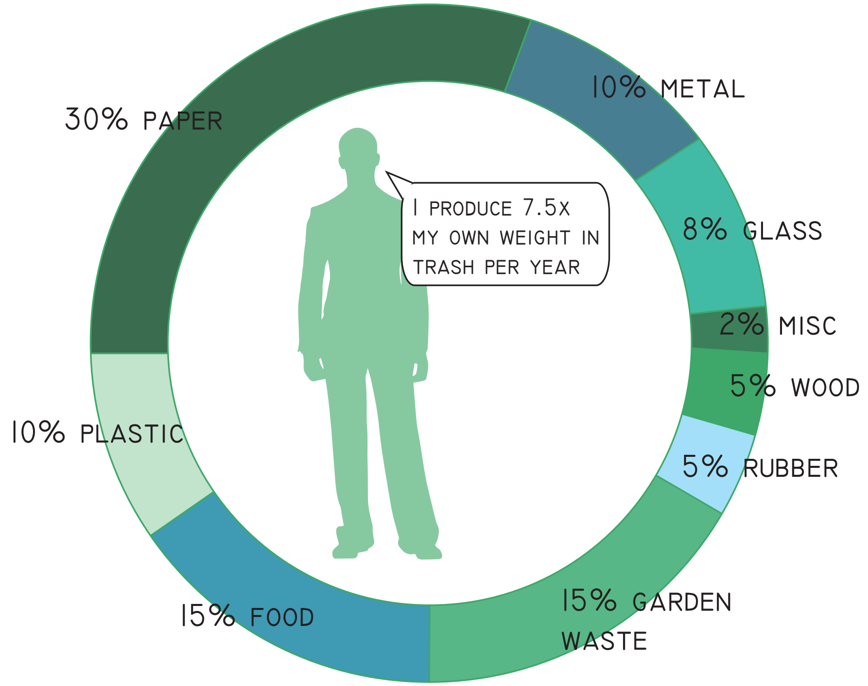


FIG 7: TYPES OF WASTE PRODUCES PER PERSON
(OWN IMAGE, SOURCE: NEDERLANDS AFVAL IN CIJFERS, 2011)

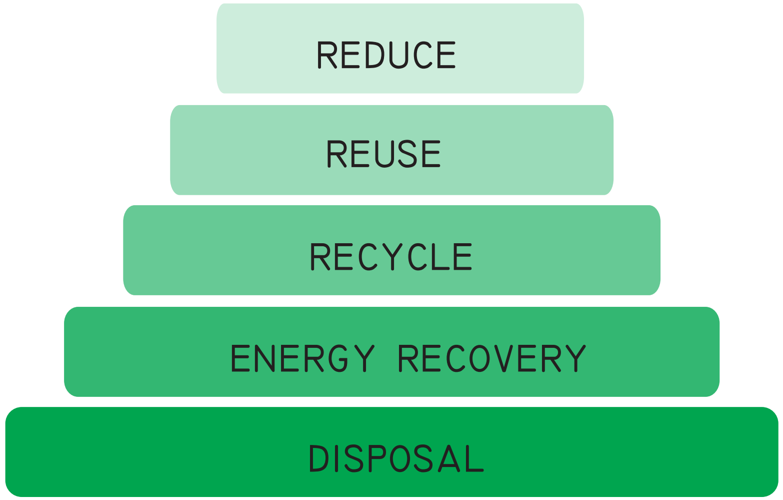


FIG 8: LADDER OF LANSINK
(OWN IMAGE,)

In 1979 the Dutch politician Ad Lansink tried to improve national waste-policy by introducing the Ladder van Lansink (fig. 8) - internationally known as the waste hierarchy. “Energy recovery” - a positive way to address incineration - is almost the lowest step and yet it is the solution the governments have decided to invest in most over the past decades. Recycling is a topic that has increasingly reaches the political agenda but the aspects of Reusing and Reducing - the highest on Lanskins’ Ladder - have not yet found their way into the habits of our current society (F. Boer, D. van Peijpe, 2009).

The building industry contributes to this problem by producing over 35% of all solid waste in the Netherlands (van den Dobbelsteen, 2014). A responsibility thus lays in the hands of architects to design buildings that are not only sustainable in their performance but also in their material-choice and waste-production.
A way of reducing the amounts of waste is by Reuse; Implementing discarted, wasted or second-hand materials into the design of new buildings.
This does not only reduce the need for new raw materials, but also approaches the projectlocation from a different way. The context of a building becomes its materialcatalogue, with the waste materials from the area as input for design.

This paper will look at the buildingtask there lays in the Merwe-Vierhavens and approach it through the eyes of Lansink, focussing on Reducing and Reusing, by closing materialcycles in a way that fits to the current challenge. The following chapters will elaborate on how to map material-flows and the possibilities of reusing specific waste materials in architectural design.

FIG 9: WASTAGE PER CAPITA IN EUROPE
(OWN IMAGE, SOURCE: 'VERLIES EN VERSPILLING',2011)

3. THEORETICAL FRAMEWORK

The main theme of this paper "architecture from waste materials". There are of course different ways to approach this subject and a variety of existing theories touch upon the theme. This chapter aims at drawing the boundaries of the research.
A description of history of reuse and its current developments is given, along with the definition of several approaches to the subject. By defining this 'body of knowledge', a statement can be made on what this research will add and the position is takes alongside other theories.
Outlining the specific scope of the research dives a bit deeper into the content, describing the focus of the study, along with some more general constraints that work as a guiding framework throughout the research.

STATE OF THE ART

Seeing opportunities for reuse of waste materials in architecture is not a new insight. Nowadays these solutions would be addressed as "sustainable" and "innovative" but reuse of materials is as ancient as architecture itself. Arthistorians refer to this tradition as "spolia", literally meaning 'the re-use of earlier building material or decorative sculpture on new monuments'. (Griffoen, 2012) The incentive could be pragmatic - using the available materials - but often also symbolic - as a way to celebrate triumph over another dynasty. The Romans for example reused 2nd century imperial reliefs depicting scenes of former emperors on the 3rd century Arch of Constantine in Rome (fig. 10). But also the Mosque of Cordoba, dating from 8th century A.D., was constructed using columns from nearby villa's (fig.11).

In modernday architecture, we hardly find examples of this sort of reuse of materials. One of the main reasons for that is the architect. Architects are used to choose their materialisation depending on their concept. The reuse of materials however implies a direct input for design and influences the concept and the process all along (van Hinten, Peeren & Jongert, 2009).

While most architects prefer to stick to the traditional designprocess, ordering materials from all over the world to match their concept, there are

FIG 10: ARCH OF CONSTANTINE, ROME, 3RD CENTURY A.D.

FIG 11: MOSQUE OF CORDOBA, 785 A.D., AN EXAMPLE OF SPOLIA

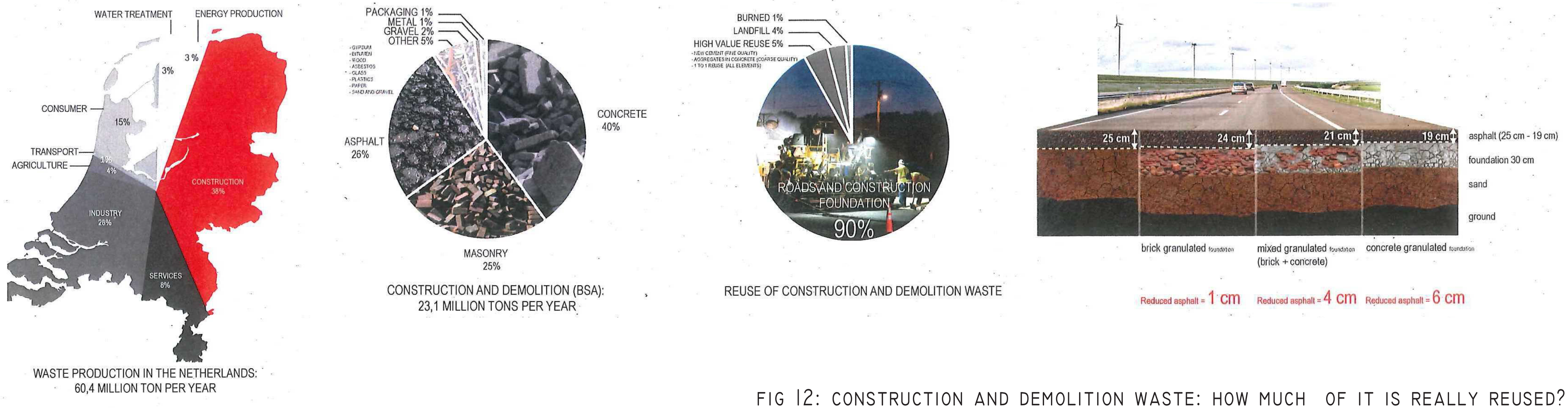


FIG 12: CONSTRUCTION AND DEMOLITION WASTE: HOW MUCH OF IT IS REALLY REUSED?
(SOURCE: CTD CAMPUS, STUDY BY THE URBANISTEN, ROTTERDAM, 2009)

some pioneering reseachers, architects and designers who are exploring the field of reuse of materials. Their ways of working with wasre materials within the field of architectute can be categorised in 3 approaches:

REUSING BUILDING MATERIALS

While architecture from waste materials recalls images of plastic-bottle-domes, building materials themselves are one of the main sources of waste. As can be seen in figure 12, 38% of solid waste comes from building sites while the building industry is also responible for the use of almost 50% of our raw materials (Van den Dobbelsteen, 2014). Several initiatives therefore promote the usage of second hand buildingmaterials in the design and construction of new buildings.

Rotor - an architecture studio in Brussels - is one of these institutions conducting research into wasteflows from the building industry. They have set up the online platform Opalis.be to fill the gap between professional dealers in secondhand materials and potential buyers. The aim is to inform architects and builders about the availability and possibility of incorporating reused building components in the design of a new building (Gielen, 2009). These components can vary from floorslabs to antique doors and from golden doorknobs to steel beams but what they have in common is a minimum amount of treatment that is needed before reinstallation. The system is not based on the recycling of materials but on the recovery and direct reuse of elements with maintenance of their intrensic qualities (Billiet, 2012).

In 2008, the UK-based initiave WRAP published the “Reclaimed building products guide”. Directed at the British market, it provides an overview of different types of materials from building sites, their specifications, costs and potential ways of reuse. Besides product-specific information, the guide shows calculations of the differences in envirnomental impact between reusing certain materials as oposed to using new materials (fig. 13), proving that the use of reclaimed steel for example reduces the environmental impact of a construction by 25 times (BioRegional, 2008). Reusing discarted building elements therefore not only prevents materials from becoming waste but also decreases the need for raw materials.
This realisation is raising more and more to the awareness of designers and

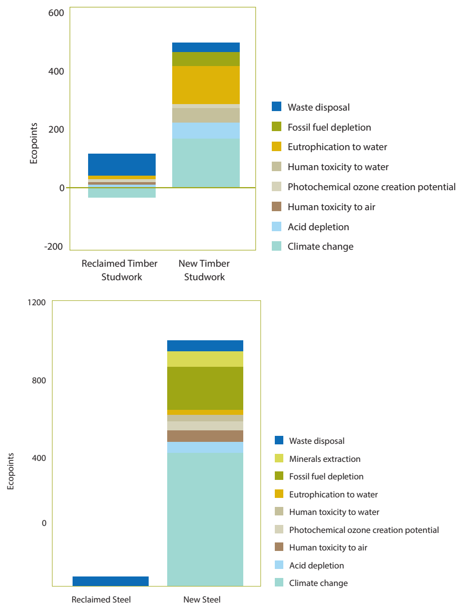


FIG 13: ENVIRONMENTAL IMPACT : RECLAIMED VS. NEW WOOD AND STEEL (SOURCE: WRAP, 2011)

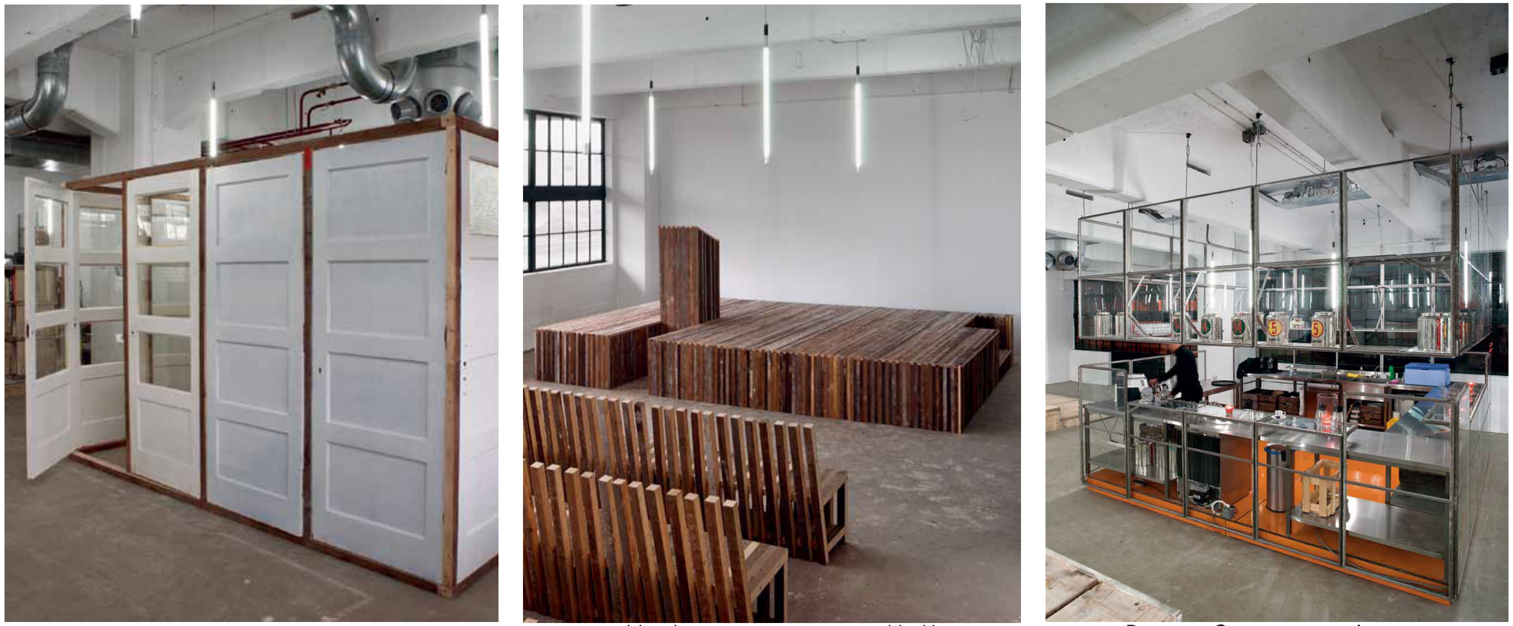


FIG 14: INTERIOR OF THE HAKA BUILDING BY DOEPELSTRIJKERS ARCHITECTEN (SOURCE: HAKA RECYCLE OFFICE - AN APPROACH FOR SUSTAINABLE INTERIORS, 2011)

in the last decades several projects have been realised that incorporate disposed building materials.
One of these projects is the interior of the HaKa office in Rotterdam by DoepelStrijkers architecten. Being in the area of the Merwe-Vierhavens and realised with local waste materials, this was an interesting case in light of this research. The design was a process of interaction between available materials from demolitionsites and requirements of the design brief which resulted in innovative solutions (Vos, 2014). Doors became walls, roofslats were used to build a podium and windows were turned into a counter (fig14)

What is striking about waste from buildingsites is that the demolition of buildings is something that we have only been doing since the 20th century (Billiet, 2012). Before the second world war, such a thing as a wrecking ball didn't exist. Buildings, if unwanted, were taken apart, leaving the elements almost intact. It is only since the 1960s that it has become common practice to bulldozer buildings down to the ground, crumbling everything to rubble.

According to a study by De Urbanisten (2009) 90% of this rubble consists of stone materials (bricks, asphalt and concrete). This material, as opposed to steel, has no value after demolition. Most of it is grinded even further and reused as baselayer under roads (fig. 12). The Dutch government labels this as "useful reuse" but this employment of stone material only saves up to a maximum of 20% of asphalt during roadconstruction (Boer, van Peijpe, 2009). It should thus rather be called 'downcycling'. Unfortunately, in currentday practice, it is the only alternative there is as oposed to the incinerators. Finding new solutions for implementing discarted materials, especially brick and concrete, from buildingsites on a large scale would thus be very relevant in the striving for reduction of waste.

CRADLE2CRADLE

Another approach to the problem of waste is the concept of Cradle to Cradle by Micheal Braungart and William McDonough. Their focus lies not necessarily on implementing reused materials in design, but on designing in such a way that materials are suitable for disassembly and reuse. It is a strategy that envisions a future economy in which materialflows are circular and not linear like our current economy. Idealy, waste as we know it, with

FIG 15: INTERIOR OF THE HAKA BUILDING BY DOEPELSTRIJKERS ARCHITECTEN
(SOURCE: HAKA RECYCLE OFFICE - AN APPROACH FOR SUSTAINABLE INTERIORS, 2011)

FIG 16: INTERIOR OF THE HAKA BUILDING BY DOEPELSTRIJKERS ARCHITECTEN
(SOURCE: HAKA RECYCLE OFFICE - AN APPROACH FOR SUSTAINABLE INTERIORS, 2011)

its negative connotation, would not exist anymore since every material would return in its biological or technical metabolism forever (Braungart, McDonough, 2002).
In the current building industry, people following the Cradle2Cradle concept envision materials that have a positive impact rather than 'not a bad one'. One way to do this is to make life-cycle assesments of the materials they use and calculate the procedures after the lifespan of the material. In practice this means that buildings need to be designed for disassembly with C2C-certified elements or materials that can either be given back to nature or be recycled/ upcycled without lowering its quality.
As oposed to the 'End of Pipe' solution, in which the lifespan of a product or material is prolonged, the Cradle2Cradle concept invisions design to be the solution for endless materialuse.

SUPERUSE
Formerly known as 2012Architects, Superuse Studios has been one of the first architectural studios to experiment with the reuse of materials - of all type, size and origin - in design. They define their way of reuse as "Superuse", which is "a way of creating architecture by shortcutting the flow of products and elements from their state of maximum added value to the stage at which value has either been dissipated or been broken down" (van Hinten, Peeren& J 2009). The materials, elements and products they use range from juice-packaging to windmill blades (fig. 15). Any material that has been discarted from its initial use is a valid material for reuse. Solutions are derived from the intrensic qualities of the materials and the potential they have within them. Carwindows have been turned into shelves, IBC-containers into toilets and washbins into facade-elements.
Superuse Studios has realised several projects in the Netherlands, amongst which Villa Welpeloo (fig.16). The construction for this private house was made out of a discarted steel textile-machine. For the facade, wooden planks from cable reels were used and panels from old caravans were used as insulation. This demonstrates how a modern house can be constructed out of materials that the initial user considered as waste.
The approach used in this projects is based on the conviction that architecture could contribute to saving transport, energy and raw materials by looking at what is available locally (Jongert, 2014).

ADDING TO THE BODY OF KNOWLEDGE

Taking into account all the approaches and studies mentioned above, this research will focus on defining more generic solutions to specific waste materials. It looks into waste materials that are commonly found in harbour areas and conducts possible ways to implement those in the design and construction of new architecture.
Unlike to Rotor and WRAP, this research will not only take waste materials from construction- and demolitionsites into account but include all types of waste materials that are to be found in the area.
It resembles therefore the methodology of Superuse Studios, but is different in its application of the knowledge. Where the method of 'superuse' is always directed at a specific project, this study aims at finding generic solution for projects that could be realised in any harbourarea worldwide.
The goal of the research is to find hands-on solutions for the currentday practice of the harbour. Being a sublime example of a linear economy, it would be unrealistic to incorporate Cradle to Cradle principles in conducting solutions for the harbourindustry. The focus of the research will lay more in prologing the life-span of current waste materials by giving them a new life as material for architecture.

SPECIFIC SCOPE OF RESEARCH

Most people consider "waste" to be the grey binbag that they put out on the streets now and then. This waste however only makes up 17% of the national wasteflow (Rijkswaterstaat, 2013). The industry make up for the other 83% of waste. This "waste" is different from household waste in that it is generated along a process of production, fabrication, packaging, storage and transportation. Often the materials are still of high quality, having been used only once of twice, and very suitable for reuse.
Most of this waste is generated simply out logistic processes. Oildrums that have been used for overseas transport for which it is more expensive to send them back empty for refill than to order new ones (HIWA, 2014). Beams of 5m from which 4 beamlengths of 1m02 are needed, leaving a piece of 92cm of waste everytime (Arend, 2012). Advertisementbanner for festivals that are outdated afterwards (Brighton, 2013). Or a stock of thousands of windshields for cars that are not in production anymore (Audi, 2004).

We can recognise different catagories within these industrial waste materials.

- PRODUCTION WASTE:	materials that are discarted after a productionprocess. Left-overs.
- DEAD STOCK:	materials that are in stock but will never be needed again or are abundant in number.
- PACKAGING:	materials that have been used to protect a product during transportation
- END OF LIFE:	materials that cannot serve their initial purpose anymore and are discarted by the user

It is this waste that is interesting in this research for repurposing waste materials in architecture. These materials that are still of fine quality, some of them never even used. Materials that have become the victim of our money-and-time driven economy in which efficiency seems to rule above sustainable material use.

CONSTRAINTS

OLD VS. NEW

Designing and building with waste materials requires a different mindset than with new materials. Architects are used to choosing the materials they want from a nicely ordered catalogue of products and elements, each of which comes with a garanty of quality and waranty on performance. With waste materials, this is hardly the case. Most flows of waste materials are not homogeneous and are hard to track back to the origins of the material.

As Rotor defined in one of their studies, there are many advantages to new materials as opposed to second hand materials. First of all, the certainty of properties (dimension, color, weight, etc.) that come with a new material. Secondly, the guaranty of availability in stock is also an important issue, as well as the possibility to order custom-made products. Furthermore, the reliability of the material is assured with new materials, whereas for waste materials this is hard to predict, making it unfavourable for a producent to carry responsibility for its safety (Billiet, 2012).
It is therefore understandable that new materials are prefered above the waste materials. However, it would be valuable if architects, as well as

constructors and producents, learn to work with those materials that are available in abundance and ready to use locally.

THE ECONOMY OF WASTE

When dealing with waste materials, there are several things one should take into account. Materials that have been discarted to become waste usually fall into a whole different economic catagory, regardless their quality.

Legislation on these materials is therefore an important issue. European law is strict on matters of waste and performs controls on their treatment. This also means that in many cases it is difficult to legaly obtain waste materials from the industry because law states that once discarted, the materials are owned by the company that takes care of their distruction, like van Gansewinkel (Van de Vijver, 2014). The Milieupark is another example of this. People can bring their sorted waste here and depose it in 22 different material containers, but once the material is in there, it becomes property of the municipality and can not be repurposed for anything else anymore.

Along with legislation comes the aspect of value of waste. Waste is a business with many stakeholders and behaves like any other branche of the economy. Most waste materials are worth nothing, but metals for example still have a value of 0.16€/kg (www.KH-metals.nl, 3.6.2014). On the other hand, companies have to pay a fee for every container they have picked up, so waste usually costs a company a lot of money. When researching on a specific material, its value or cost should always be taken into account

Furthermore, it is necessary to gain knowledge on the recycling procedures of the specific materials. Some materials, like glass and paper, can be recycled or even upcycled for new use. Other materials, like EPS, stone materials or composed materials are hard to recycle and would therefore be even more relevant for reuse since the incinerators are often the only other option.

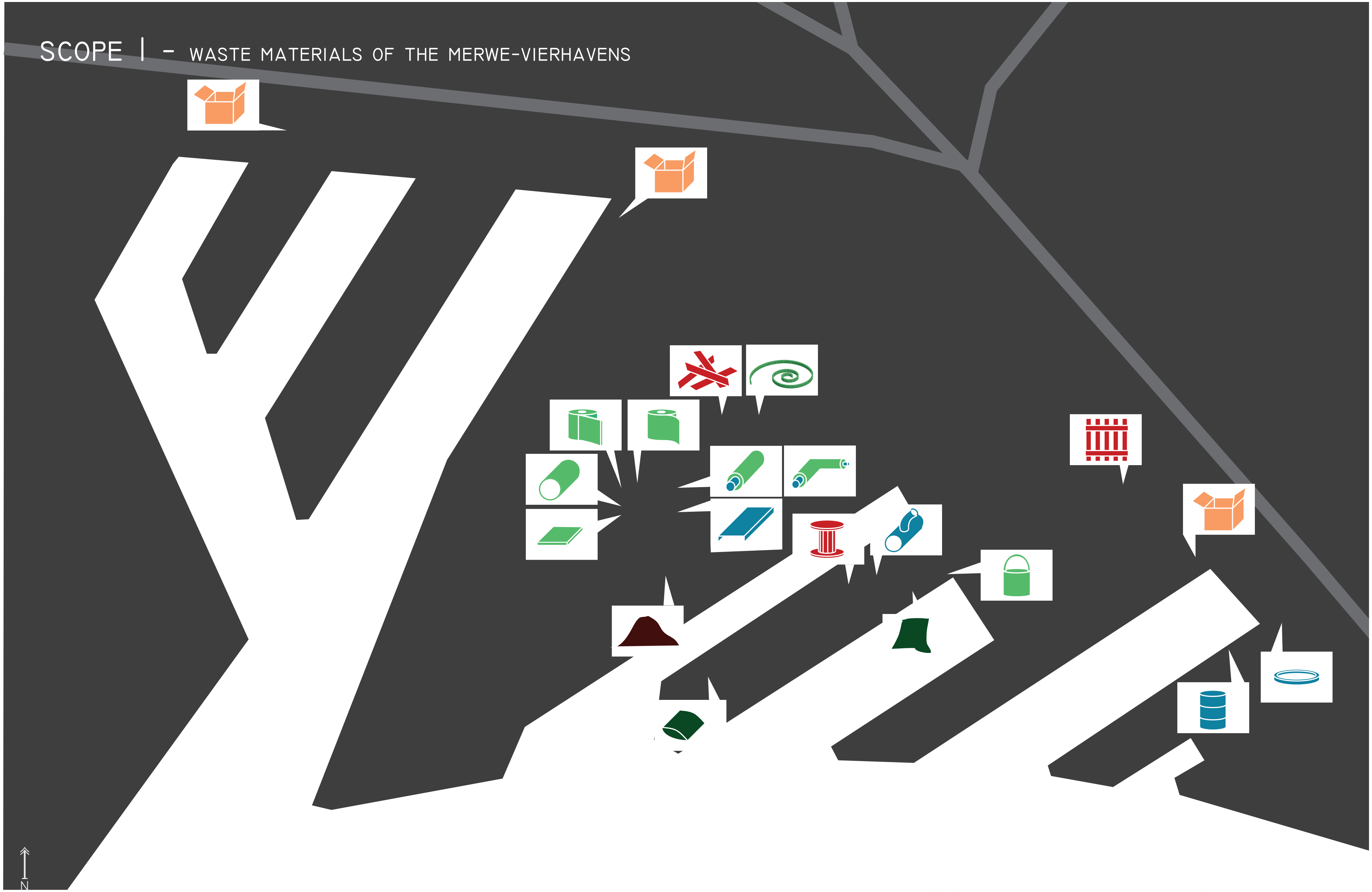


Fig 17: Harvest map of the Merwe-Vierhavens, scope I
(own image)

4. METHODOLOGY

Resulting from all that is stated above, the main research question can be defined as: *How can waste materials from the current industries of the Merwe-Vierhavens be used as a buildingmaterial for new architecture?*

Being limited to a specific location - the Merwe-Vierhavens - the goal of the research however aims at answering a much more generic question, namely: *How can waste-flows from harbour-related industries be implemented in the design and construction of local architecture?*
This much broader study is strongly related to the current trend of harbourareas being swallowed by growing cities and undergoing transformation. With the need for new sustainable dwellings and offices in these areas, the research aims at finding hands-on solutions for an alternative way of constructing this new architecture.

The method of this research will concentrate on the analysis of the Merwe-Vierhavens, the material-flows that it produces and the potential of these materials for architectural purpose. It will then zoom back out of this specific area and look at ways in which the materials found could play a role in the transition of harbourareas anywhere in the world and propose different solutions for their implementation in architectural design.

MAPPING THE AREA

The first step is to define which specific industries are located in the area of the Merwe-Vierhavens and which flows of waste materials they discart (fig. 18). Superuse studios calls this methodology, the 'harvest map' (van Hinten, Peeren & Jongert, 2009).
For the mapping of this area, the information was gathered from site visits, interviews with companies and architects and desktop research. The harvest map of the Merwe-Vierhaven (fig .17) shows, in icons, which materials can be found where. The map comes together with a list of materials (fig. 18). In this list, specifications of each material on its dimension, former use, origin and materialtype are assembled.
The materials are additionally colourlabelled according to their main

FIG 18: ANALYSIS OF THE INDUSTRIES OF THE MERWE-VIERHAVENS (OWN IMAGE)

material: metal, wood, stone, earth, plastic, textile, paper/cardboard or glass. This labelling can be used in the search for materials for specific functions.

The total list of materials and the additional harvest map can be found in the appendice (N° 1-3)

DEFINING DIFFERENT SCOPES

While mapping an area, one always stumbles upon uncertainties. Some materials are clearly discarted by the initial user, but other materials lay around without a clear purpose. Getting information on these waste materials from the exploiting company is not always easy. Especially bigger companies tend to be very cautious about giving insight into their waste-data.

The harvest map of the area can therefore be divided into 2 scopes:
- SCOPE 1: materials that are part of a (semi)constant flow of waste-materials, usually as a result of logistic processes of industries of the Merwe-Vierhavens.

MATERIALS // SCOPE I	SORT	DIMENSIONS	COMPANY	FORMER USE	COMMENT
CARDBOARD	PAPER/CARDBOARD	STANDARD TRANSPORTBOX: 1200 X 1000 X 800MM	ALL TRANSPORTS, HIWA, KANTOREN, VARIA	PACKAGING	AVAILABLE IN BIG AMOUNTS DUE T OFFICES
GALVANIZED STEEL SHEET	METAL	2000 X 400 X 40MM	JOULZ	CABLETRAY	ZINK MAKES WELDING DIFFICULT
PVC TUBE	PLASTICS	Ø 50 - 300MM LENGTH: 1 - 5M	JOULZ	PROTECTION OF CABLES UNDERGROUND	REJECTED WHEN EXPOSED TO TH SUN TOO LONG
PVC PROTECTION FOIL	PLASTICS	1M WIDE, 3MM THICK LENGTH: RADIUS OF REEL	JOULZ	UV PROTECTION OF CABLES ON REEL	COULD BE CUT OFF MORE CAREFUL
PVC TILES	PLASTICS	400 X 400 X 20MM	JOULZ	PROTECTION OF CABLES UNDERGROUND	
SLUDGE	EARTH	-	VAN DER VELDEN RIOLERINGSBEHEER ROTTERDAM BV	SLUDGE FROM SEWER	POLLUTED GROUND, NEEDS SANIT TION BEFORE USE
STEEL SEALING RING	METAL	Ø 600MM 3CM WIDE, 3MM THICK	HIWA	SEALING OF OILDRUM DURING TRANSPORT	CAN BE STACKED IN PATTERNS
OILDRUM	METAL	Ø 610MM HEIGTH: 888	HIWA E.A.	TRANSPORT OF CONDENSED FRUITJUICES	TO BE CLEANED WITH FREEZE-DR TECHNIQUE
BLANKETS + CUSHIONS	TEXTILE	VARIA	KLEDINEXPORT MEMOTEX	SECONDHAND, DISCARTED	CUSHIONS AND BLANKETS ARE THR OUT BECAUSE OF VOLUME
CABLEREEL	WOOD	Ø 600 - 2000MM HEIGTH: 500 - 1500MM	RENTALLOCATION KEILEWEG	STORAGE OF CABLES	WOODEN PLANKS IDEAL FOR REUS

FIG 19: (PART OF) MATERIAL LIST OF THE MERWE-VIERHAVENS, SCOPE I
(OWN IMAGE)

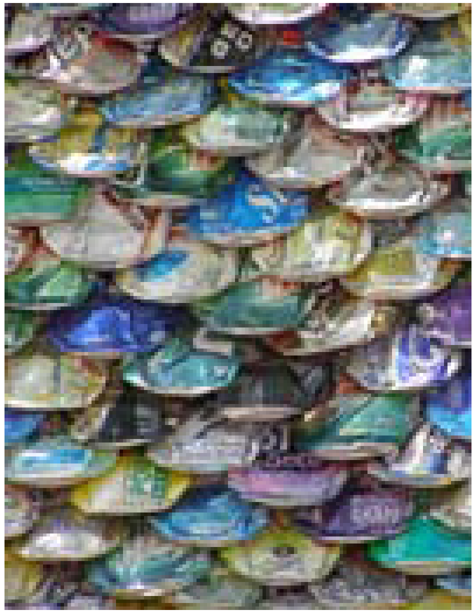


FIG 20: NOORDERPARK PAVILJOEN

FIG 21: BRIGHTON WASTE HOUSE

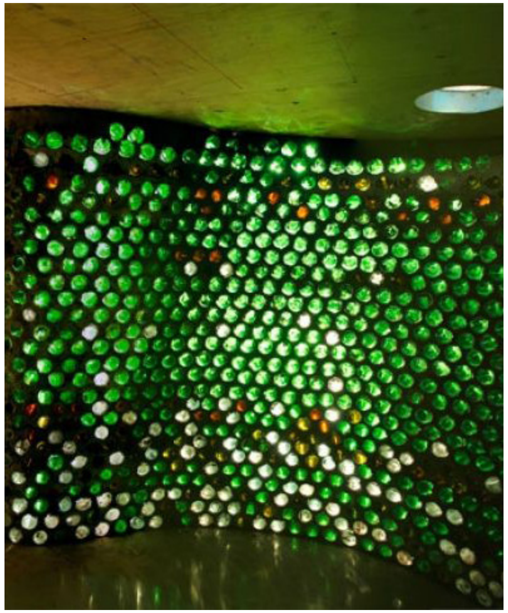


FIG 22: LIVING ROOM AND SEPARATION WALLOFICINA IN ROME, RAUMLABOR

- SCOPE 2: Materials that have been apperceived in the area of Merwe-Vierhavens but of which it is uncertain when or whether they can be discarted. This can be due to value, stockkeeping, assumptions or legislation

In addition to the analysis of the area and industries of the Merwe-Vierhavens, several complementary methods have been used to get a grip on the possibilities of designing with waste materials. The aim was to make use of knowledge there already is in the field instead of reinventing the wheel.

Casestudies

Besides Villa Welpeloo (Superuse Studios) and the Haka Office (DoepelStrijkers), several existing projects have been analyzed to understand the way that architects so far have succeeded in turning waste materials into architectural designs. A few examples:
- The Noorderpark Paviljoen by SLA Architecten in Amsterdam aims at transforming plastic householdwaste into slates for a facade (fig.20)
- The Brighton Wastehouse, a project by the Faculty of Arts, experiments with videotapes, wallpaper and old jeans as insulationmaterial. (fig.21)
- La Oficina in Rome, by the german Raumlabor, utilises oildrums as roofing and constructs seperationwalls out of glassbottles. (fig.22)
-The office of Denis Oudendijk and Jan Körbes, Refunc, has done several projects with cartyres as facade-system or interior elements.
Analyzing these projects on which materials have been applied and why, the way the materials have been treated or edited and their performance, has given insight into the different approaches of architects working with waste materials and the motivation of their materialchoice.

Literature

Desktop research on reusing waste materials and literature on various theories about reuse in architecture have provided knowledge on specific materials or possibilities.
“Some materials have the right proportions and qualities as they are, for creating a functional separation between interior space and sometimes harsh climatic conditions. Carpet tiles are a good example, although holes may need to be punched in some of them.” (p. 32, van Hinte, Peeren & Jongert, 2009)

But also the analysis and rating system of building components by Rotor (Gielen, 2009) and the research into properties of secondhand building materials by WRAP (BioRegional, 2008) have supplied valuable information on specific waste-flows.
The literature on waste-management and recycling procedures on the other hand, have provided interesting insights on which materials would be valuable for reuse since throwing them away either costs a lot or is very poluting. For example, 95% of the gypsum as well as insulationmaterial is currently dumped in landfills and 90% of the EPS is currently sent to incineration instead of being recycled (Tulp, 2009).

Interviews
Designing with waste materials is a very specific discipline within architecure. Not only is the designprocess significantly different but it also comes with a lot of technical complications and logistic struggle. It was valuable therefore to interview several architects and designers in the field on their experiences with waste materials. Not only to get grip on the pitfalls of the process but also to learn about new sources of waste materials and abundant material-flows. Chantal Vos from DoepelStrijkers, for example, pointed out that underlaymentplates are widely available and that clothing functions very well as sound insultaion (Vos, 2014). Studio Content addressed the overall abundancy of materials like big bags, advertisement panels and truck tarpaulins (van Ziel, 2014). And Superuse studios rose the awareness of production-waste such as diecutting sheets and misprints (Verhoeve, 2014).

From the information gathered through case studies, literature and interviews, an additional list was generated with materials that would be particulary interesting, valuable and relevant for reuse in architecture. This list was to be added to the existing two scopes of materials from the Merwe-Vierhavens as a broader third scope:

SCOPE 3: Waste materials that can be categorised as valuable for reuse. These materials are not specifically to be found in the area of Merwe-Vierhavens but are most likely to be available within a range of about 50km from the area (Peeren, 2009).

Lastly, there is of course an infinite list of new materials that could be, and will have to be, incorporated in an architectural design. This could, theoretically, be defined as scope 4, but it is not in the intention of the research to elaborate on those materials.

CHOOSING MATERIALS
Having a list of materials is not enough as a starting point for architectural design. One needs to be able to compare the materials on different aspects in order to decide which material is more interesting, valuable and relevant.

From the above mentioned researchmethods, a twofold method was conducted to rate the materials. On the one hand, they are submitted to general criteria that rate their relevance in respect to other materials. On the other hand the materials are valued on their intrensic qualities and the potential these create for implementation in architectural design.

CRITERIA
Harbour Specific:
In order to make a design that is generic for other harbour areas in transition, it is relevant to define how close the material is related to harbouractivity. Materials like oildrums for example are sure to be found in harbours all over the world, making it more interesing to conduct a generic solution for them.

Reuse Relevance:
As described in the theoretical framework, waste materials belong to a different economic and legislative system than new materials. In choosing a material for design, its value should be taken into account, as well as its current recycling procedures. A material that costs a company a lot to discart and is also poluting or unsuitable for recycling, would have a high relevance for implementation in architectural reuse.

Ready to Use:
Some materials need extensive cleaning, treatment or adaptation in order to be ready for reuse. It is prefered if materials can be implemented without much further action needed, making the process easier and more realistic.

Innovative:
Only a handfull of architectural projects have been realised out of waste-materials, but of them some materials are repeatedly implemented. Shipping containers are a good example. On one hand this means that quite some research has been conducted into the use of the material. On the other hand, it would be interesting to add something to the body of knowledge and research into a material that could mean an innovation in the buildingindustry.

POTENTIAL USAGE

Constructive Potential:
To which extend could the material be part of the construction of a building? Does it have load-bearing properties? Does it withstand bend?

Insulation Potential:
To which extend does the material insulate warmth, cold and sound? Could it be applied to improve the indoorquality of a building?

Facade Potential:
To which extend could the material be part of the cladding of a building? Is it UV proof? Waterproof? Airtight? Can it resist all weatherconditions?

Interior Potential
To which extend could the material be applied in interior decoration? Could it be a seperating element? Furniture? Or just decoration?

GENERIC APPLICATION OF THE METHOD

The methodology of research as stated above could be used for almost any architectural project that expresses a desire to implement waste materials in the design.
Its most appropriate application would be to use the method as input for new architecture in harbour areas, as an answer to the generic question of harbour transformations. Using the harvest map, material scopes, general criteria and architectural potential as defined above, one can come to selection of interesting and relevant waste materials that have the potential to act as building material for that specific project.

For each project, other waste materials will be available and in each design, the materials will take on another role in architecture. The overall goal of this method, however, is to provide a set of guidelines that will help architects to take the leap and start inventorising the possibilities of material that are readily available in the direct proximity of the site of the their project.

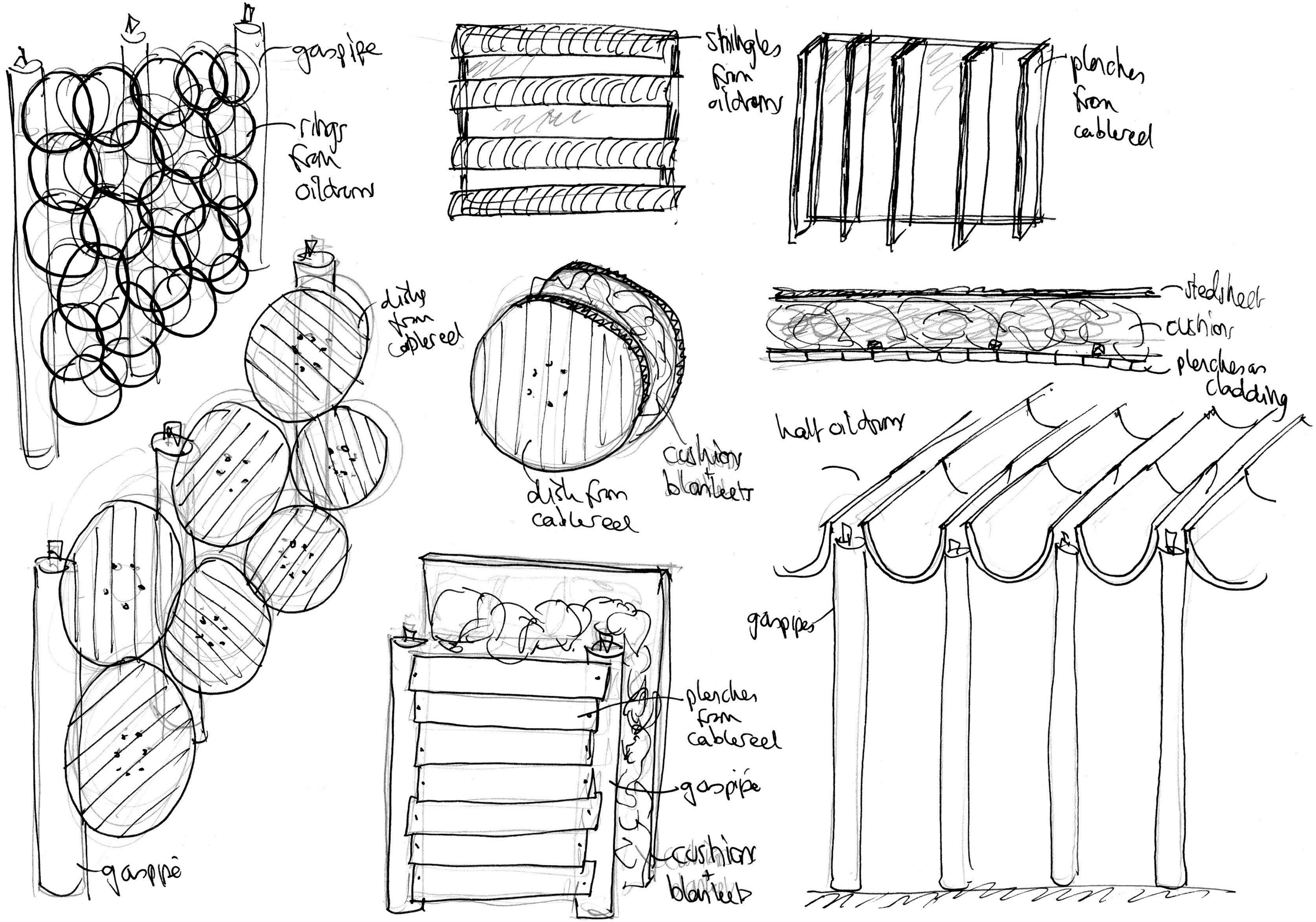


FIG 23: SKETCHES OF POSSIBLE DESIGNSOLUTIONS WITH THE SELECTED MATERIALS
(OWN IMAGE)

5. RESULTS

This chapter will elaborate on the outcome of the above described methodology for the specific case of the Merwe-Vierhavens. It will descibe the selection of materials and, more specifically, the way that those waste materials can be turned into building materials.

For each of the four chosen materials, some background information is provided, giving a clearer insight in the current use of the material and its properties. Furthermore, a dissection shows the different ways in which the material can be taken apart. Lastly, but most importantly, an overview is given of the possible implementations of the material in architectonical design.

These possible design solution - which have been conducted through brainstorming, case-studies and research - are not a define document. They are just a few of the many possibilities that lay hidden in the intrensic qualities of the material. The aim is not to present a catalogue of absolute and welldefined solution, but to make a first step into the direction of envisioning waste materials as an alternative to traditional building materials.

CHOICE OF MATERIALS

Each material from the list of available materials in the Merwe-Vierhavens (fig.19) has been rated on the 4 defined general criteria as well as on the 4 pillars defining its architectural potential, as described in the chapter above.
From this calculation, a selection of four materials was brought forward (see appedice N° 4-6). These materials each had a high total score, but also contain very different qualities from one another. This makes it interesting to look not only at solutions for the reuse of that one material, but to think of ways in which the materials could be combined and strengthen each other in use.

Of course, many other materials from the list have high potential to be used in architectonical design, but a final selection of only four materials makes it possible to dig a little bit deeper into the materials themselves.

The four selected materials (fig.24):

- Oildrums
- Gaspipes
- Cushions/blankets
- Cable Reels

Fig 24: The 4 selected materials: oildrums, gaspipes, blankets & cablereels

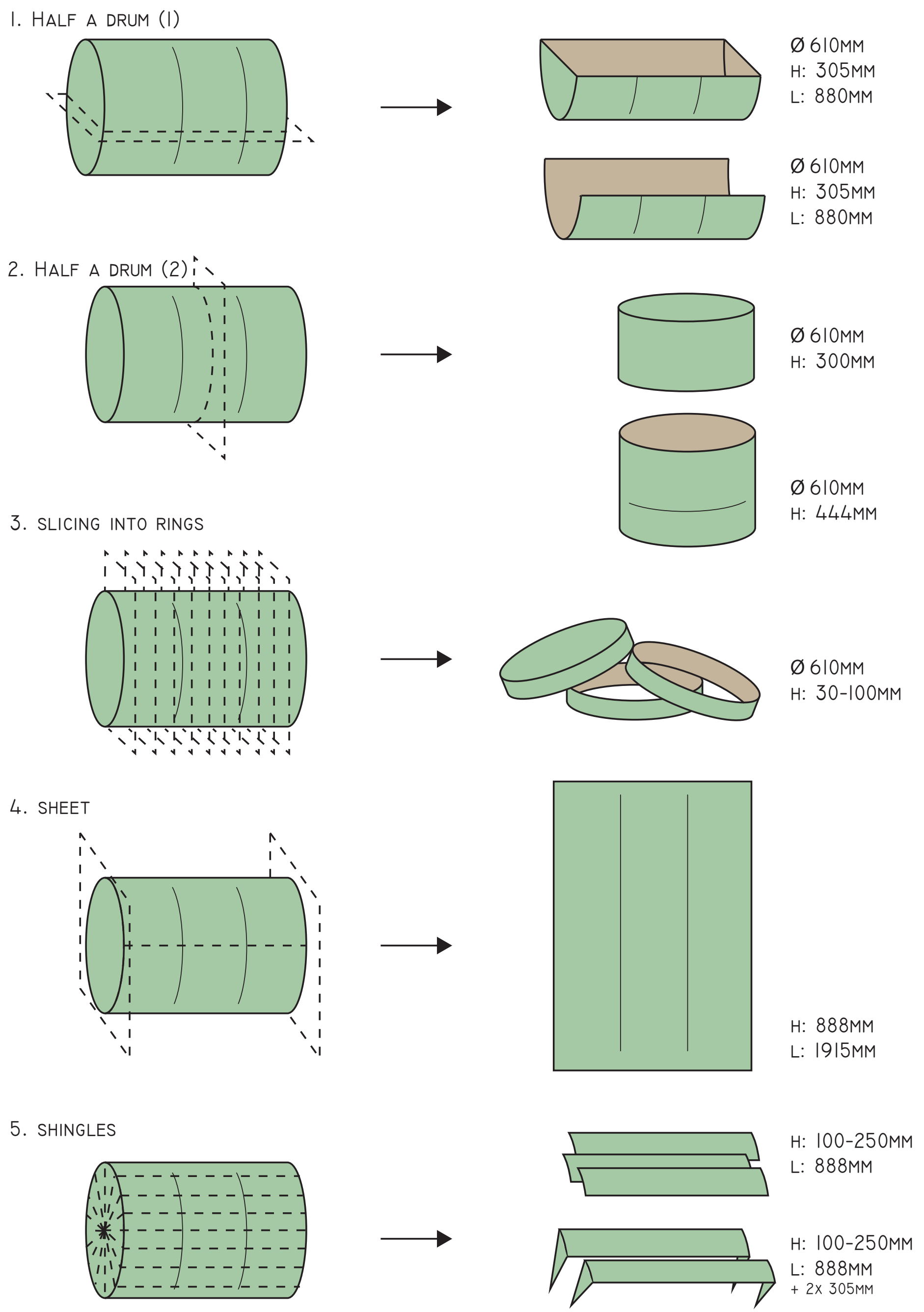


FIG 25: DIFFERENT WAYS OF DISSECTING THE OILDRUM
(OWN IMAGE)

OILDRUMS

Current practice

All over the world, oildrums are used to transport liquids overseas. As the name suggest, its most common use is for oil, giving name to the metric unit of oil: “barrel”, or 200litres. In the Merwe-Vierhavens, the oildrums are most commonly used for transport of condensed fruitjuice. Upon arrival, the drums are emptied and stacked. Most companies only use the drums once. Sending the empty drums back overseas for refilling turns out to be more expensive than buying new ones. This results in huge amounts of wasted drums, about 2000/week per company. The discarted drums are sold to a scrap-dealer. Sometimes they are compressed before transport, but most companies do not have a machine to do this.

Properties for reuse

Oildrums are made out of a thin sheet of steel. They are cilindric in form with a diametre of 61cm and a regular height of 88cm. The drum usually has 3 ribs to strengthen the cilinder. A steel ring with a clipping system is used to seal the drum during transport. When this ring is removed, the lid of the drum can be taken off.
Most companies don’t clean the drums after use. Collecting waste-drums for reuse thus means that the drums still contain some juice- or oilrests in them. The easiest way to clean the oildrums is done with the freeze-method. By bringing the oildrums into a room with extremely low temperatures, the remaining content will freeze and fall out. The drum is then ready for reuse.

Dissecting the oildrum

The oildrum can be taken apart in many different ways which all lead to different possibilities of use. (fig.25)

1. HALF A DRUM: cutting the drum overlength in order to create a halfpipe with or without sides
2. HALF A DRUM2: cutting the drum across creating a shortened drum. As tube or with lid as a bowl.
3. SLICING INTO RINGS: cutting the drum across many times, generating upto 60 hollow rings and 2 lids out of one drum

4. SHEETS:	taking out the lid and bottom, cutting the drum open overlength makes it possible to roll out the steelsheet as a flat slab of 191x88cm
5. SHINGLES:	cutting the drum like a pie, in 8 or more pieces, generating slightly curved strips of steel with or without the pointed flap from the lid

Possible architectural implementations

Discovering the possibilities of implementing these elements for architectural purposes (fig. 26)

> CONSTRUCTION:
- Filling the drums with sand (or cement) and stacking them like a column (1.)
- The drums can be compressed into bricks that can be stacked to form a loadbearing wall (2.)

> FACADE:
- Using half drums, they can be applied like rooftiles on the horizontal surface (4.) or facade elements on the vertical surface. (6.)
- Interlacing the rings of the oildrums to create a half transparant facade/curtain (5.)
- The shingels can be used as blinds in front of a window or as cladding (8.)
- Using the oildrum as sheets, they can be used as cladding . The sheets can also be punctured in order to play with daylight (7.)

> INTERIOR:
- Sheetmaterial, especially when punched with holes, can be also be applied in interior decoration (7.)
- tubular hollow drums can be a seperationwall (3.)
- All typed of furniture can be thought of based on oildrums without dissecting

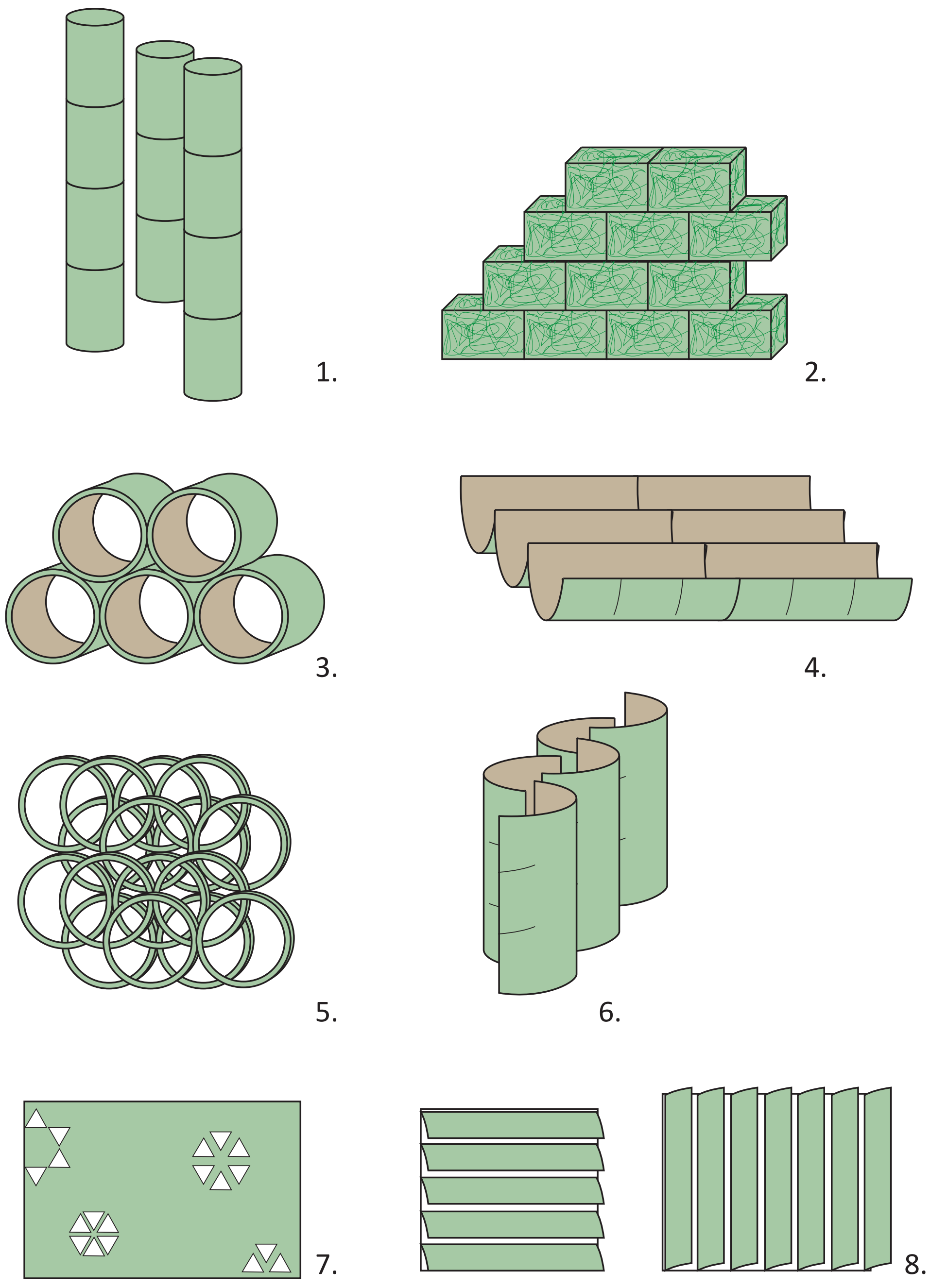


FIG 26: ARCHITECTURAL IMPLEMENTATIONS OF THE OILDRUM (OWN IMAGE)

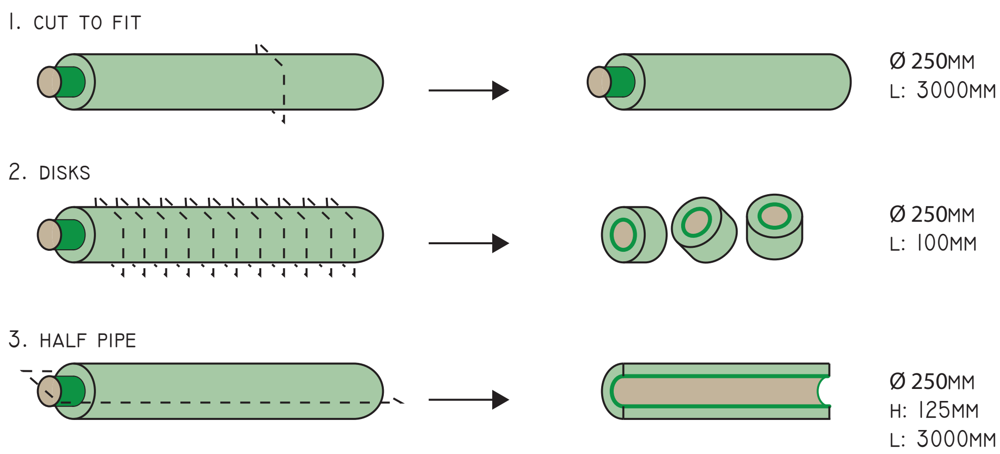


FIG 27: DIFFERENT WAYS OF DISSECTING THE GASPIPE
(OWN IMAGE)

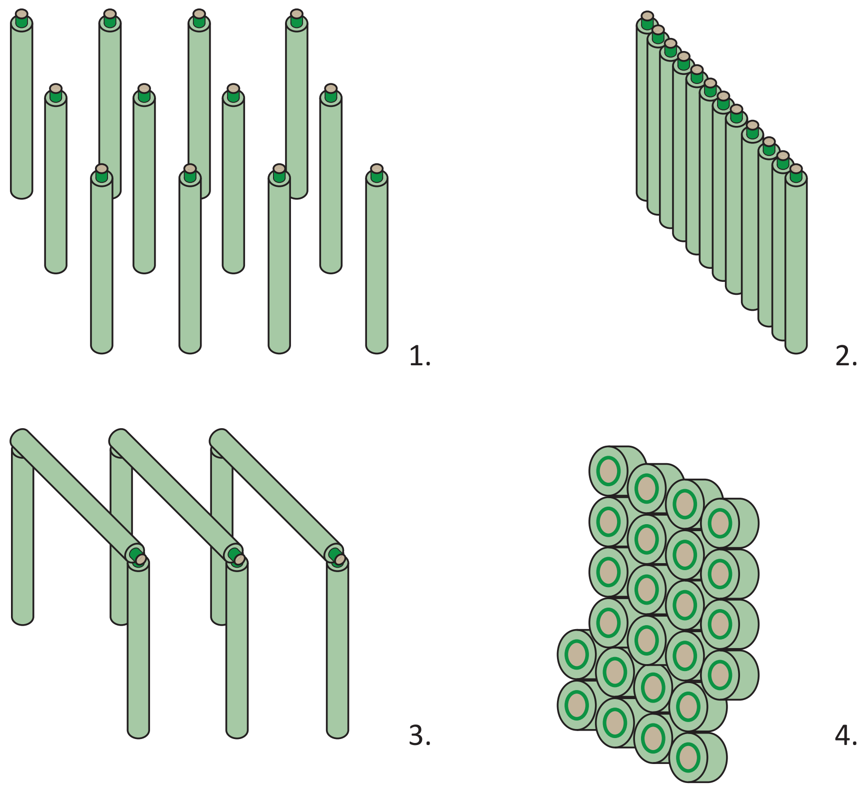


FIG 28: ARCHITECTURAL IMPLEMENTATIONS OF THE GASPIPE
(OWN IMAGE)

GASPIPES

Current practice

Joulz uses the gaspipes to lay and maintain the underground network of gastransportation throughout the Netherlands. They have the national storage for materials in the Merwe-Vierhavens,on a outside terrain. Here lays the whole stock of gaspipes and coupling heads out in the open, waiting for usage. When the pvc-coated gaspipes have been exposed to the sun for too long, the pvc slightly changes colour and the whole gaspipe is rejected for further use.
When discarted, the gaspipes cannot be thrown away easily. Besides their lenght and weight, the fact that it is a composition of 3 materials - steel, pur and pvc - makes it a costly process. The pipes have to be transported to Nijmegen where they are put through a shredder in order to seperate the materials. The steel can than be sold to a steel-dealer and the pur and plastic are thrown away.

Properties for reuse

The gaspipes that Joulz uses exist in a range of dimensions. The diameter can vary between 100-500mm and the length can be 5m upto 12m. The pipes are composed out of 3 materials. The inner core consists of a hollow steel pipe (4-8mm). This pipe is surrounded by an insulation layer of pur (5 - 15cm) which is protected by a layer of black pvc (8-18mm).
The gaspipes -if used at all - have been used for gastransportation, so there is little to be cleaned. The outer layer may be a bit damages or coloured because of its exposition to all weather conditions, but this doesn’t affect the materialproperties in any extreme way.

Dissecting the gaspipe

The gaspipes are a rather ready to use material. Taking apart the different layers would be a lot of work and would not add to its possibilities in reuse. The fact actually that it is a combination of all those materials, is what makes the gaspipe so interesting. Dissecting it in that sence of the word would thus not be sensible.

It is possible though to use the gaspipes in different lengts and ways of cutting without seperating the materials (fig. 27):

0. FULL LENGTH:	leaving the gaspipe the length that it is and looking for a way to implement it at full length
1. CUT TO FIT:	cutting it to the length that is needed in design
2. DISKS:	cutting the gaspipe in disks of max 100mm thick
3. HALFPIPE:	cutting the gaspipe overlength, leaving an open half pipe of variable length

Possible architectural implementations

The range of possibilities for implementing the gaspipes in different architectural purposes (fig. 28):

> CONSTRUCTION:	- The most obvious implementation of the gaspipe is to use it as a loadbearing column (1.) - the gaspipe can also be implemented as a beam to form a portal construction (3.)
> INSULATION:	- making a massive wall out of gaspipes gives the loadbearing wall insulation properties (2.)
> FACADE:	- cut into disks, the elements could be used as a semi-insulating semi-transparant cladding (4.)

CUSHIONS AND BLANKETS

Current practice

Memotex collects discarted clothing and other textile in the region of Rotterdam. They press the items into bales of 90x90cm before they ship them to Afghanistan. Cushions and blankets take up too much of a volume for too little revenue, so Memotex rather throws them away. Throwing them away means in this case, going straight to the incinerators.

Properties for reuse

The cushions and blankets are usually made out of cotton sheeting, stuffed with foam particles. Because of the air trapped inbetween the particles, they have a high insulation value (which is what they were intended for, insulating people at night).
When delivered to Memotex, they have already been discarded by the user. It might be that they are dirty after years of usage. The properties of the cushions and blankets however do not change.

Dissecting the cushions and blankets

Being soft and fluffy materials, taking them apart would be no added value. The best way to regard the cushions and blankets is thus to leave them intact. No diagram of dissection is therefore made for this material.

Possible architectural implementations

The cushions and blankets are quite straightforward in their potential usage; their main feature in insulation:

> INSULATION:	- The cushions and blankets are ideal as insulation material in wallcavities, lowered ceilings or flooring
> INTERIOR:	- wrapped around something, they can create a soft surface out of edges - The blankets could be used as carpet or sublayer in flooring

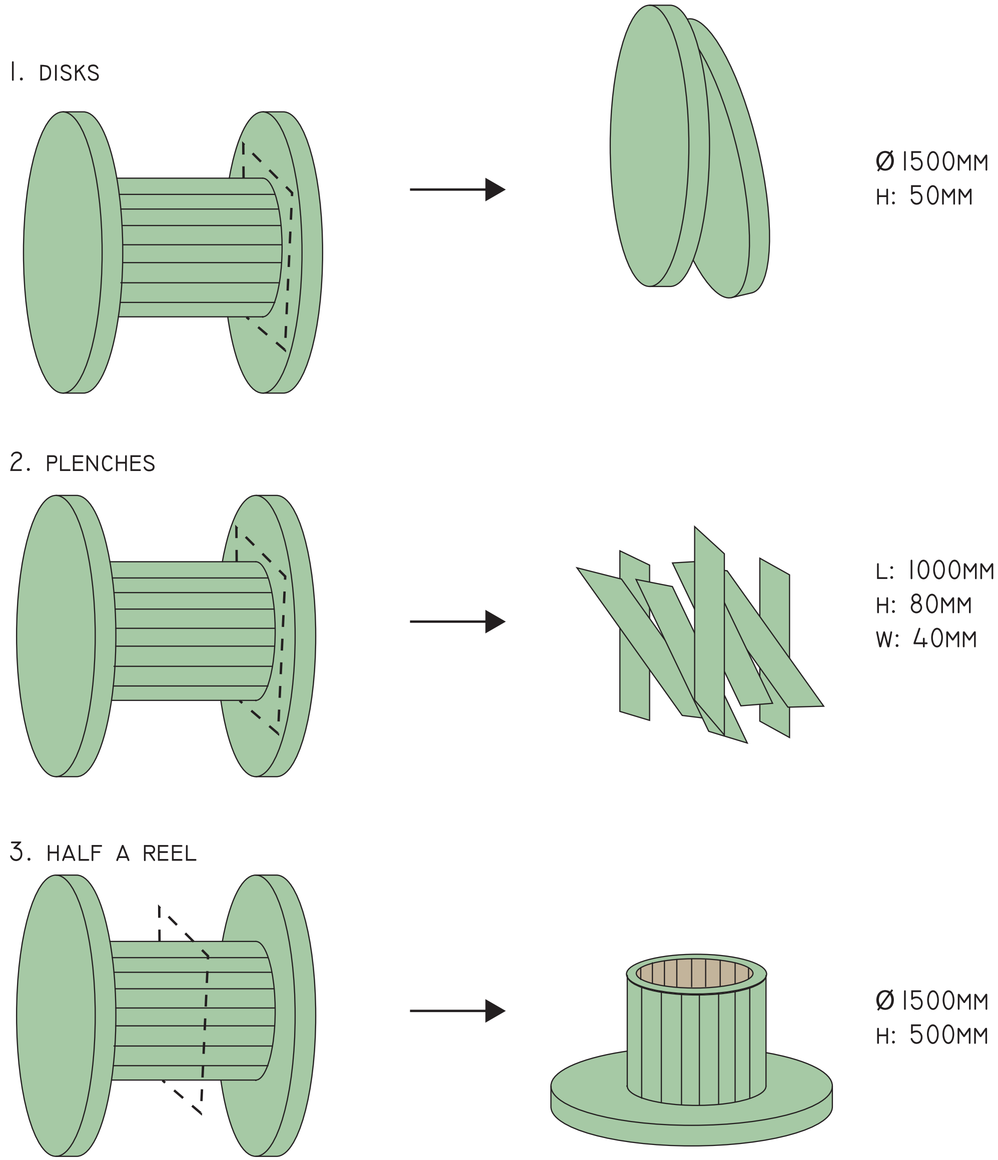


FIG 29: DIFFERENT WAYS OF DISSECTING THE CABLE REEL
(OWN IMAGE)

CABLE REELS

Current practice

Cable reels are used by all companies who work with cables. Joulz has them in many different sizes and diametres. The cables are wrapped around the reel for storage and transport. Sometimes a protecting pvc-foil is wrapped around it as UV-protection.
When a reel is worn out, broken or discarted it goes back to the company from which they are leased and are then thrown away. Most wood ends up as firewood while many of the parts might still be okay.

Properties for reuse

Cablereels van vary is size but the relation between height and diametre is mostly 150%. A standard reel of 1m height has a disksize with a diametre of 1,5m. The reels are made of whitewood which is strong and weatherresistant and thus excellent for reuse. The core is made of two steel profiles to which the plenches are attached. The plenches are seperate pieces so can be taken apart easily.
When a reel is discarted it might be damaged due to extensive use. Because the reel can be taken apart in seperate elements it is easy though to seperate the broken parts from the still good ones.

Dissecting the cable reels

The wooden cablereel can be taken apart in its elements (fig 29):

1. DISKS: the top and bottom are round wooden disks with a diameter of 1500mm
2. PLENCHES: the core of the reel consist of about 25 wooden plenches (40x80x1000mm) that are slightly bended. Since it is a dryfit connection, they are ideal for reuse.
3. HALF A REEL: Cutting the cable reel in two, creating a hollow bucket.

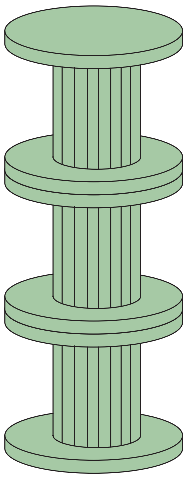
Possible architectural implementations

The reel can be applies in different ways:

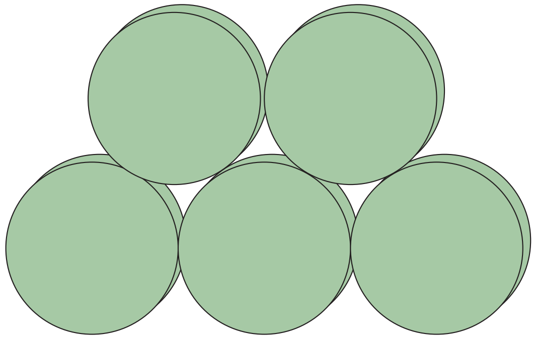
> FACADE: - The disks can de stacked in order to form big facade-elements (2.)
- The seperate plenches can be sorted in different ways

in order to be applied as windowframe or as cladding of a facade (3.)

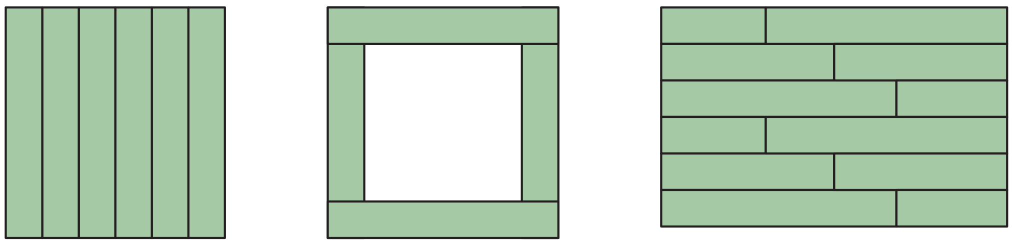
> INTERIOR: the cable reel as a whole can be used a an interior element in for example furniture. Stacking them can also be an alternative to an intior column (1.)



1.



2.



3.

FIG 30: ARCHITECTURAL IMPLEMENTATION OF THE CABLE REEL (OWN IMAGE)

6. DISCUSSION & CONCLUSION

Each person in the Netherlands produces approximately 550kg of waste per year (van Woerden, 2010). Sending all of this waste straight to the incinerators does not seem like the most sustainable solution anymore in a time where scarcity of resources, a healthy environment and reducing CO^2 emissions stand high on the political agenda. Changing this behaviour towards waste materials does not only mean that waste should be sorted more precisely but also implies taking on a different attitude towards waste itself. In the current western society, waste is regarded as something filthy and unwanted. But if we take a closer look at what is thrown away, waste is actually a valuable resource of raw materials. As was rightly formulated by Duncan Baker-Brown “Waste is just stuff in the wrong place”.

Giving these reclaimed raw materials a second life by implementing them in architectural design marks the scope of this research. The different case studies and interviews with architects demonstrate that this uncommon approach to architecture has many snags to it and still needs a lot of research, governmental backup and logistic organization to become a real competitor to traditional building practice. However, they also confirm a growing interest in this field amongst designers and researchers. In the Netherlands alone, several buildings have been realised with the inscentive of reusing waste-materials in its design and construction.

The bottleneck for most architects to implement waste materials in their design is the inversed design-process it requires with available materials as a driving force. The current day society however is increasingly valueing the use of locally produced materials as opposed to imported materials. Vernecular architecture is gaining in interest and buildings that are true to their location are appriciated. The implementation of locally reclaimed waste-materials therefore fits this architectural trend, forcing the architect to throughly research a projectlocation and reconsider using waste materials of fine quality that have been discarded by its initial users.

In its methodology, this research provides the architect with a guideline on how to approach such a locationstudy. The harvest map as a result of this study can be made for any projectlocation. Mapping the waste flows of a specific area however, is subject to many different sources of information. Getting to know what a company discards is not an easy task, mostly because the companies themselves do not know or don’t want to know how much waste they produce. For a harvest map to provide current and accurate information on material flows is thus not simple. Big companies like HIWA for example are not keen on giving insight in their waste-management. Other companies, like Joulz, were much more open to a new approach on waste materials but couldn’t provide the exact figures on their waste flows. While the municipality is expressing its desire for an innovative and sustainable harbour area (Straver, 2009), the current industries remain surprisingly traditional and stubborn in their access to information in waste materials. The research done for the Merwe-Vierhavens would thus need a lot more time and depth in order to get a full and total grip on all the waste flows that are discarded in the area.

Taking into account however that the Merwe-Vierhavens only cover an area of about 2 km^2, the amount of interesting and valuable waste-materials encountered was significant. With the addition of a few specifically relevant materials gathered through case studies, literature and interviews - the list of scope 3 - a total of 52 waste-materials have been listed. These lists, together with the harvest map, give an important insight into which materials circulate in an area like this. It is an eye-opener as well as a hands-on tool for generating innovative design possibilities.

For the four selected materials, these design possibilities have been developed into a toolbox of architectural elements. These ready-to-use solutions can be implemented in the design of buildings as single elements. Yet it becomes even more interesting if one starts to look at the combination between materials. In this research, each waste materials has been analyzed and treated separately. A next step would thus be to visualize how certain materialcombinations strengthen each other because the higher purpose of this paper is not to show how a gaspipe can be used as a column, but to address the possibility of constructing buildings out of waste materials. It lays in the future development of this research to take the generated solutions a step further and combine them into actual buildingconstructions. These constructionsolutions involving different materials would turn the generic materialresearch into a locationspecific solution.

Another recommendation for future use of the research in architectural projects would be to include the aspect of knowledge and craftmenship in the locationstudy of an area. For this research, the investigation of the Merwe-Vierhavens was merely focussed on waste-materials and not so much on how to work them. If one really wants to start building with oildrums however, it would be valuable to know for example if services or machines for welding, cutting, cleaning, pressing or sanding are available within proximity of the projectlocation. This investigation demands more profound research but it enables a project to fully run on local resources in materials as well as labour.

The conducted research on the flows of waste materials in the Merwe-Vierhavens and the possible designsolutions of specific materials as presented in the toolbox are a first step into the direction of making architects familiar with the concept and possibilities of waste materials in architecture. In the current building tradition, it would be naive to expect this material-driven designmethod to really take off. There is still a long way to go before designing with waste materials can really compete with a neatly ordered catalogue of new buildingmaterials. But as in most innovative solutions, there need to first be some pioneers that dare to take the leap.

The aim of this paper was therefore to outline a methodology that makes it easy and accessible for architects to start using waste-materials in their design-projects. And who knows that by 2030, when the dwellings and offices for the future Merwe-Vierhavens are really being designed, the implementation of waste materials will find its way into its architecture.

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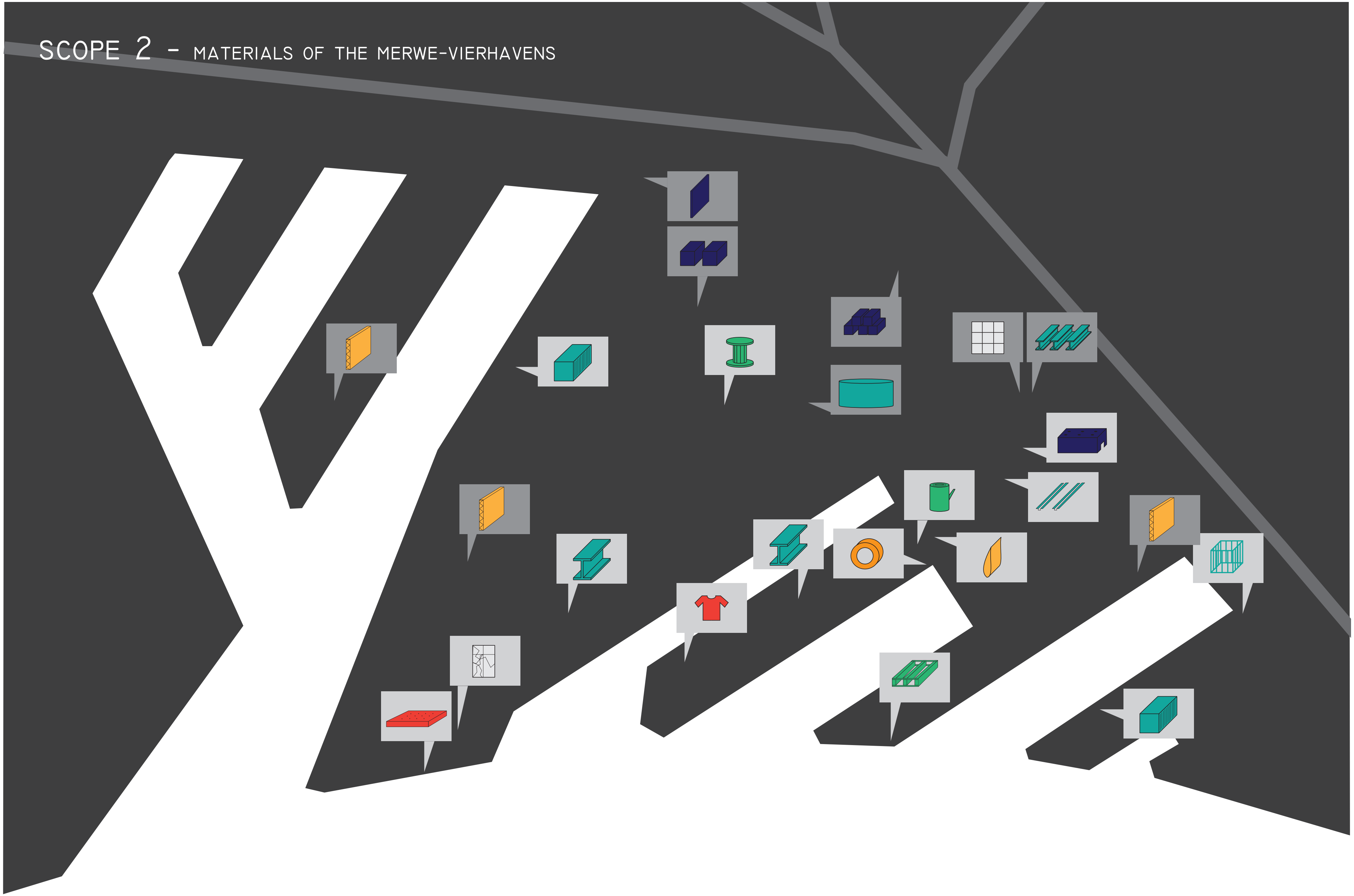
8. APPENDICES

MATERIALS // SCOPE I	SORT	DIMENSIONS	COMPANY	FORMER USE	COMMENT
CARDBOARD	PAPER/CARDBOARD	STANDARD TRANSPORTBOX: 1200 X 1000 X 800MM	ALL TRANSPORTS, HIWA, KANTOREN, VARIA	PACKAGING	AVAILABLE IN BIG AMOUNTS DUE TO OFFICES
GALVANIZED STEEL SHEET	METAL	2000 X 400 X 40MM	JOULZ	CABLETRAY	ZINK MAKES WELDING DIFFICULT
PVC TUBE	PLASTICS	Ø 50 - 300MM LENGTH: 1 - 5M	JOULZ	PROTECTION OF CABLES UNDERGROUND	REJECTED WHEN EXPOSED TO THE SUN TOO LONG
PVC PROTECTION FOIL	PLASTICS	1M WIDE, 3MM THICK LENGTH: RADIUS OF REEL	JOULZ	UV PROTECTION OF CABLES ON REEL	COULD BE CUT OFF MORE CAREFULLY
PVC TILES	PLASTICS	400 X 400 X 20MM	JOULZ	PROTECTION OF CABLES UNDERGROUND	
SLUDGE	EARTH	-	VAN DER VELDEN RIOLER-INGSBEHEER ROTTERDAM BV	SLUDGE FROM SEWER	POLLUTED GROUND, NEEDS SANITA-TION BEFORE USE
STEEL SEALING RING	METAL	Ø 600MM 3CM WIDE, 3MM THICK	HIWA	SEALING OF OILDRUM DURING TRANSPORT	CAN BE STACKED IN PATTERNS
OILDRUM	METAL	Ø 610MM HEIGTH: 888	HIWA E.A.	TRANSPORT OF CONDENSED FRUITJUICES	TO BE CLEANED WITH FREEZE-DRY TECHNIQUE
BLANKETS + CUSHIONS	TEXTILE	VARIA	KLEDINEXPORT MEMOTEX	SECONDHAND, DISCARTED	CUSHIONS AND BLANKETS ARE THROWN OUT BECAUSE OF VOLUME
CABLEREEL	WOOD	Ø 600 - 2000MM HEIGTH: 500 - 1500MM	RENTALLOCATION KEILEWEG	STORAGE OF CABLES	WOODEN PLANKS IDEAL FOR REUSE
PLASTIC BUCKET	PLASTICA	Ø 300MM HEIGTH: 400MM	KOEKELA	PACKAGING OF FLOUR	ONLY BEEN USED ONCE
GASPIPE	PLASTICS+METAL	Ø 50 - 300MM LENGTH: 4 - 12M	JOULZ	ISOLATED GASPIPE UNDERGROUND	INTERESTING COMBINATION OF 3 MATERIALS THAT CAN BEAR LOADS AND ISOLATE
PVC ON ROLL	PLASTICS	WIDTH: 40CM THICKNESS: 5MM	JOULZ	PROTECTIONLAYER UNDERGROUND	BECOMES WASTE-MATERIALS WHEN REMOVED FROM GROUND, OFTEN BROKEN
RESTWOOD	WOOD	VARIA	JOULZ	BROKEN PALLETS AND REELS	UNEVEN PARTS
WOODEN FENCE	WOOD	1750 X 1750MM	HIWA	FENCE OF TERRAIN	ABOUT 20< PIECES
CABLESLEEVES	PLASTICS	Ø 30 - 50MM LENGTH: 4M<	JOULZ	PROTECTION OF CABLES	LEFTOVER THAT STAY ON THE REELS
VENTILATION-SHAFTS	METAL	Ø 200 - 600MM LENGTH: 1.5 - 3M	RENTALLOCATION KEILEWEG	UNKNOWN	ONE BATCH OF A FEW PIECES
JUTEN BAGS	TEXTILE	VARIA	SANTAS COFFEE	TRANSPORT OF COFFEEBEANS	ONLY BEEN USED ONCE
COUPLING HEAD GASPIPE	PLASTICS+METAL	Ø 50 - 300MM ANGLES OF 30-18=45*	JOULZ	MAKING ANGLES UNDERGOUNDS WITH GASPIPES	

App I: Materiallist scope I

MATERIALS // SCOPE 2	SORT	DIMENSIONS	COMPANY	FORMER USE	COMMENT
PALLETS	WOOD	1200 x 800 x 140MM	HIWA, Citronas, All Transports e.a.	TRANSPORT	ARE OFTEN ONLY DISCARTED WHEN BROKEN
CABLE REEL	WOOD	Ø 600 - 2000MM HEIGTH: 500 - 1500MM	Joulz e.a.	TRANSPORT OF CABLES	IDEAL FOR REUSE DUE TO GOOD QUAL-ITY OF THE WOOD AND CONNECTIONS
PLASTIC OILDRUM	PLASTICS	Ø 604MM HEIGTH: 888	HIWA e.a.	TRANSPORT OF LIQUIDS	
MATRASSES	TEXTILE	2000 x 900 x 200MM 2000 x 1800 x 200MM	MILIEUPARK - GEMEENTE ROTTERDAM	PRIVATE	EVERYTHING THAT ENTERS THE MILIEU-PARK OFFICIALLY IS PROPERTY OF THE MUNICIPALITY. OPTION: PLACE CONTAINER
BROKEN FLOATGLASS	GLASS	VARIA (300-1200 x 300x2200MM)	MILIEUPARK - GEMEENTE ROTTERDAM	PRIVATE	EVERYTHING THAT ENTERS THE MILIEU-PARK OFFICIALLY IS PROPERTY OF THE MUNICIPALITY. OPTION: PLACE CONTAINER
STEEL BEAMS	METAL	VARIA (LENGTH: 3-6M)	VERHUUR/OPSLAGTERREIN	UNKNOWN	VALUE IS 0.16€/kg
STEEL CAGES	METAL	1000 x 1000 x 1000MM	HIWA, OPTICOOL	TRANSPORT OF OILDRUMS	THEY CAN BE FOLDED IN
TRAMRAIL	METAL	50 x 30 x 10000<MM	GEMEENTE ROTTERDAM	RAILS FOR TRAMS	ONLY A FEW ARE AVAILABLE
CLOTHING	TEXTILE	VARIA	MEMOTEX KLEDINGEXPORT	PRIVATE	ARE PRESSED INTO BALES OF 0.7X0.71X1M WHICH ARE EXPORTED
TREETRUNKS	WOOD	Ø 300-400MM LENGTH: 3-6M	SCHORS & SCHEEF Ø 604MM	NATURE PLAYGROUND	MATERIAL FOR PRODUCTION IN , UNKNOWN WHETHER IT IS WASTE-MATERIAL OR STORAGE
CARTYRES	PLASTICS	Ø 500MM WIDTH: 160MM	KUNST & COMPLEX	CARTIRES	MATERIAL FOR PRODUCTION IN , UNKNOWN WHETHER IT IS WASTE-MATERIAL OR STORAGE
CONRETE BLOCKS	STONE	600 x 250 x 250MM	GEMEENTE ROTTERDAM	ROADWORKS	STORAGE OF MUNICIPALITY, UNKNOWN WHETHER IT IS WASTE-MATERIAL
AIRPLANE PARTS	PLASTICS	2500 x 4000-5000MM	KUNST & COMPLEX	AIRPLANES	STORAGE OF ARTISTS, UNKNOWN WHETHER IT IS WASTE-MATERIAL
SHIPPING CONTAINER	METAL	2400 x 2400 x 6000MM	OPTICOOL E.A.	TRANSPORT	UNKNOWN WHEN OR WHETHER THE CONTAINERS ARE DISCARTED + VALUE
MATERIALS FROM DEMOLITION:					
FERRO BUILDING	METAL	Ø 65000MM HEIGTH: 10000	FERRO	GASSTORAGE	BUILDING HAS BEEN EMPTY FOR YEARS, BIG UNUSED SPACE
INSULATION PANELS	PLADTICS	VARIA (E.G.: 2000 x 5000 x 200MM)	OPTICOOL, CITRONAS E.D.	COOL STORAGE FOR FRUITS AND FRUITJUICES	STORAGE BUILDINGS WILL MOVE TO 2ND MAASVLAKTE ON THE LONG RUN, LEAVING THE WELL-INSULATING WALLS BEHIND
WINDOWS	GLASS	800 x 800MM E.A.	GEMEENTE ROTTERDAM	WINDOWS OF GLASSHOUSE	GLASSBUILDING HAS BEEN EMPTY FOR 15 YEARS. IF NO RESTAURATIONPLAN IS MADE, IT WILL BE DEMOLISHED
BRICK	STONE	230 x 120 x 50MM (STANDARD)	VARIOUS DEMOLITIONSITES	CONSTRUCTION OF BUILDINGS TO BE DEMOLISHED	55000M3 BRICK (SOURCE:THE URBANISTEN ON WASTE FROM FUTURE DEMOLISHMENT IN M4H)
CONSTRUCTION STEEL	METAL	VARIA	GEMEENTE ROTTERDAM	CONSTRUCTION OF GLASS-HOUSE	GLASSBUILDING HAS BEEN EMPTY FOR 15 YEARS. IF NO RESTAURATIONPLAN IS MADE, IT WILL BE DEMOLISHED
GYPSUM	STONE	VARIA	VARIOUS DEMOLITIONSITES	WALLS OF BUILDINGS TO BE DEMOLISHED	18000M3 GYPSUM (SOURCE:THE URBANISTEN ON WASTE FROM FUTURE DEMOLISHMENT IN M4H)
CONCRETE GRANULATE	STONE	VARIA	VARIOUS DEMOLITIONSITES	CONSTRUCTION OF BUILDINGS TO BE DEMOLISHED	185000M3 CONCRETE (SOURCE:THE URBANISTEN ON WASTE FROM FUTURE DEMOLISHMENT IN M4H)

App 2: Materiallist scope 2



App 3: harvest map scope 2

SCOPE 1

		GENERAL CRITERIA					ARCHITECTURAL POTENTIAL					
		Harbourspecific	Reuse relevance	Ready to use	Innovative		Construction	Insulation	Façade	Interior		TOTAAL
5	Cardboard	3	2	3	3	11	4	4	0	3	11	22
	galvanized steel sheet	1	3	3	3	10	0	0	4	3	7	17
3	pvc-tube	2	4	4	4	14	3	2	3	3	11	25
	pvc-protection foil	2	4	2	4	12	0	0	4	2	6	18
	pvc tiles	2	4	3	4	13	2	1	3	2	8	21
	sludge	1	3	3	3	10	3	3	0	0	6	16
4	steel sealing ring	4	3	3	4	14	1	0	4	3	8	22
2	oildrum	5	3	3	4	15	4	1	4	4	13	28
3	cushions+blankets	3	4	4	4	15	0	5	1	4	10	25
3	cable reels	4	4	4	2	14	3	2	4	2	11	25
4	plastic buckets	2	4	3	3	12	2	2	3	3	10	22
1	gaspipe	3	5	4	4	16	5	4	2	3	14	30
	hard pvc on roll	2	4	4	4	14	1	1	3	3	8	22
	restwood	2	3	2	2	9	1	3	3	3	10	19
	wooden fence	1	3	3	2	9	1	1	3	3	8	17
	cablesleeves	2	3	3	3	11	0	1	2	3	6	17
	ventilationshafts	1	3	3	2	9	1	1	3	3	8	17
4	juten bags	4	4	3	3	14	0	4	1	4	9	23
2	couplinghead gaspipes	3	4	4	4	15	4	4	2	3	13	28

App 4: scores of the materials on the general criteria and their architectural potential - Scope I

SCOPE 2

		GENERAL CRITERIA					ARCHITECTURAL POTENTIAL					
		Harbourspecific	Reuse relevance	Ready to use	Innovative		Construction	Insulation	Façade	Interior		TOTAAL
4	Pallets	4	3	3	2	12	3	2	3	3	11	23
3	Plastic oildrums	4	4	3	4	15	3	2	2	2	9	24
	Mattress	2	4	4	3	13	0	5	0	2	7	20
	Floatglass (broken)	2	3	2	3	10	0	0	3	4	7	17
	Steel I-profiles	1	2	4	1	8	5	0	2	3	10	18
2	Steel cages	3	2	4	4	13	5	1	3	3	12	25
	Tramrails	1	3	3	4	11	4	0	3	1	8	19
5	Clothing	3	4	4	3	14	0	5	0	3	8	22
	Treetrunks	1	2	3	1	7	2	2	2	3	9	16
	Cartires	2	4	3	2	11	1	2	4	3	10	21
	Concrete blocks	1	2	3	1	7	3	1	1	1	6	13
	Airplane parts	1	2	2	2	7	2	2	2	2	8	15
5	Shipping containers	4	3	4	1	12	4	1	3	2	10	22
4	Ferro building	5	3	4	1	13	5	0	4	1	10	23
1	Insulation panels	5	4	4	2	15	2	5	4	1	12	27
	Windows	2	3	4	1	10	0	0	4	4	8	18
	Steel contruction	2	2	4	1	9	5	0	0	1	6	15
	Bricks	1	3	3	1	8	4	1	3	2	10	18
	Plaster	1	4	3	1	9	0	2	2	3	7	16
	Concrete granulate	1	3	2	2	8	5	1	1	1	8	16

App 5: scores of the materials on the general criteria and their architectural potential - Scope 2

SCOPE 3

		GENERAL CRITERIA					ARCHITECTURAL POTENTIAL					
		Harbourspecific	Reuse relevance	Ready to use	Innovative		Construction	Insulation	Façade	Interior		TOTAAL
3	Truck tarpaulins	x	5	4	4	13	0	0	5	4	9	22
	Electricity posts	x	3	3	4	10	5	0	1	2	8	18
	Diecutting sheet	x	4	5	3	12	1	0	2	5	8	20
	Stelcon slabs	x	3	4	2	9	3	1	0	1	5	14
	Advertisement panels	x	5	4	3	12	1	0	3	4	8	20
	Building billboards	x	5	4	3	12	1	0	3	4	8	20
3	Windowframes	x	4	4	2	10	3	1	4	4	12	22
3	Doors	x	4	4	2	10	2	3	3	4	12	22
	Bigbags	x	4	4	4	12	3	3	1	1	8	20
	Shipping containers	5	3	3	1	7	5	1	2	1	9	16
1	Carpettiles	x	5	4	3	12	3	4	1	4	12	24
2	Ceiling panels	x	5	4	4	13	1	4	1	4	10	23
3	IB-containers	x	4	4	3	11	4	2	2	3	11	22
2	Mooring masts	4	3	4	4	11	2	2	5	3	12	23
	misprints conserve	x	4	4	4	12	0	0	4	4	8	20

App 6: scores of the materials on the general criteria and their architectural potential - Scope 3