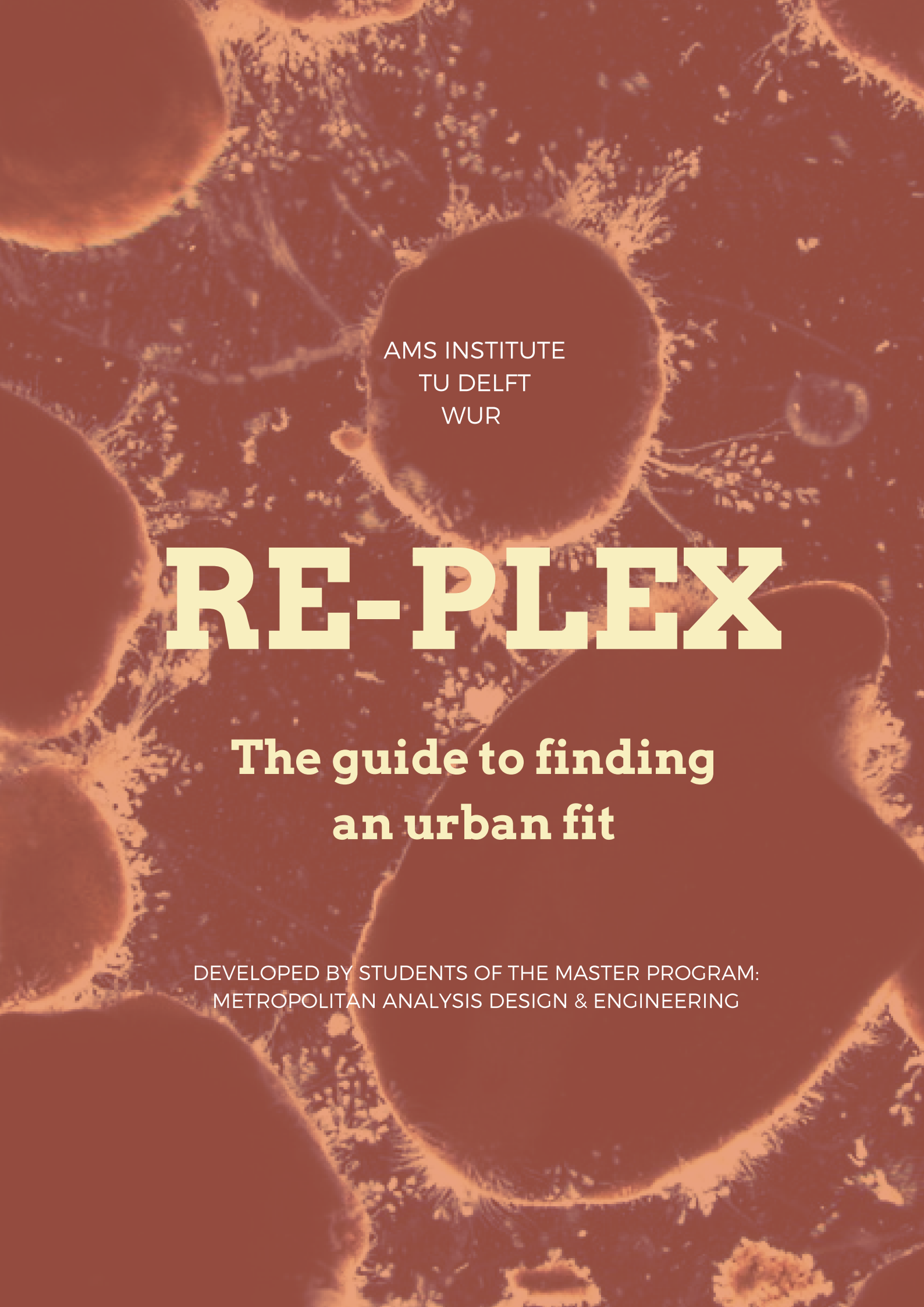


AMS INSTITUTE
TU DELFT
WUR

# RE-PLEX

## The guide to finding an urban fit

DEVELOPED BY STUDENTS OF THE MASTER PROGRAM:
METROPOLITAN ANALYSIS DESIGN & ENGINEERING

MSc MADE

*`Our big dream is to create a biobased, circular city. The small step we took to achieve this dream was to contribute to closing the urban water loop by finding applications for Replex; a material made out of recycled resources derived from wastewater. `*

Re-plex Living Lab team 2020/2021

WAGENINGEN
UNIVERSITY & RESEARCH

TU Delft

# Executive Summary

Re-plex is a wastewater based, 100% biological and fully biodegradable composite material. Materials like Re-plex could be the key to greening our economy and eliminating waste. But where do we apply them? This report shows the results from an urban living lab, that tried to answer specificly that question. The living lab process included material testing, co-creative sessions and many other forms of collaboration. The end-product is a set of typologies for applying Re-plex in the building, public space, green space and underground domain within the urban ecosystem. Moreover, development scenario's have been created to show how Re-plex could be further developed.

## What is a living lab?

A Living Lab is a user-centered, open innovation ecosystem based on a systematic user co-creation approach in public-private-people partnerships, integrating research and innovation processes in real-life communities and settings.

*In order to achieve active roles of users/researchers from multiple disciplines, we aimed to partner up with stakeholders from the private sector, public sector, knowledge institutes and users. An 'active collaboration' is achieved by involving partners from the start of the Living Lab and in multiple stages of the Living Lab. Altogether, these elements will lay the foundation in order to co-create our envisioned end-product, this booklet.*

# The Team

We are three students from the Master program 'Metropolitan Analysis, Design & Engineering'. This master program is a joint degree of Wageningen University of Research, TU Delft and AMS Institute for Advanced Metropolitan Solutions.

## Maartje

**BSc. Liberal Arts & Sciences**
Organizer & Collaboration expert

## Siddarth

**BSc. Architecture**
Communicator & Design expert

## Jesse

**BSc. Future Planet studies**
Finisher & Circularity expert

# Re-Plex in a circular city

CREATING A PATH TO IMPLEMENT WASTE WATER- BASED BIOCOMPOSITES WITHIN URBAN REGIONS

# Re- plex: Towards an Circular urban water loop

One of the most valuable waste streams is urban wastewater as it contains many resources. Like other waste streams, wastewater is still treated as waste and most of the innovations are focused only on the recovery or regeneration of energy at the wastewater treatment plants.

## Re-plex

The re-use of cellulose out of toilet-paper and other waste-water based products will contribute to closing the urban water cycle. Instead of burning the pulp, these recourses can be extracted and used to create other valuable products, like **Re-plex.** Re-plex is a bio-composite consisting of cellulose fibers and a class of biopolymers known as Kaumera. These are the two main effluents from wastewater treatment plants. This Kaumera-cellulose-biocomposites can save energy in comparison to standard fossil-based composites. Therefore, it has the potential to replace many other non-sustainable composites currently being used.

## Goals

The main challenge is to find a suitable application for Re-plex within our linear economy. The aim is to identify the best possible application of the composite material Re-Plex.

# The Circular City

Contrary to nature, urban areas discharge large flows of waste that are not optimally recycled. As resources are becoming increasingly scarce, there is a growing urge to recycle waste streams. As the world becomes more populated and urbanized, the demand for resources is increasing exponentially in an urban context.

## Waste as a resource

Recognizing the value of waste as a resource is an integral part of a circular system. The European Commission recognizes that turning waste into a resource is one of the key paths to achieve resource efficiency and states:

*"If waste is to become a resource to be fed back into the economy as a raw material, then much higher priority needs to be given to reuse and recycling".*

## The circular economy in Amsterdam

The Dutch government and municipality of Amsterdam created several goals to create a circular economy with a focus on increasing the use of recycled and biobased materials. This means that valuable materials and raw materials are reused and no waste is produced. The ambition is to use 50% less new raw materials by 2030 and the city will be 100% circular by 2050.

The model of circular economy consists of three principles (MacArthur, 2013):

**1.** The circular economy attempts to eliminate waste, design products in a way in which the end-of-life point is postponed and recycle original resources.

**2.** The circular economy aspires to be user-oriented instead of a consumer-based economy.

**3.** The energy that is used has to be renewable to eliminate the use of green-house gasses in the system.

With these goals in mind, we zoom in into the waste water resources!

# The bio-based city of future

## 2030
Dutch Government Goal

*"50% decrease in use of new resources"*

## 2050
Dutch Government Goal

*"Circular economy without waste"*

## 2025
Amsterdam's Goal

*"25 % renovations through circular principles"*

# Re-Plex's Core Properties

WHAT MAKES RE-PLEX VALUABLE?

In order to implement the material in Urban context, it is important to know what properties it has. Therefore we started this research with testing the expected properties.

# Properties

As Re-plex is still under development, it's core properties are not known yet. Estimates had been given by NPSP, however uncertainties were very large. This is why we decided to do material tests to test it's: fire resistance, biodegradability, water resistance, weight and strength. From these test the following core properties have been derived:

**Fire resistant**
No flames, no dripping, just charring

**Lightweight**
Relatively low specific weight

**Biodegradable**
Just leaves traces of nutrients

**Strong**
Relatively strong composite

## Material testing

The material tests have been conducted in a home set-up, due to the limited acces to labs in the global pandemic. Re-plex was tested under various conditions, as is elaborated upon below:

| **Air** | **Fire** |
| --- | --- |
| Light box & dark box | Butane torch |
| RH 50% & RH 100% | 15 minutes |
| **Water** | **Soil** |
| Salt water & Tap water | White sand & potting soil |
| Wetting & Immersion | RH 50% & RH 100% |

# Finding an urban fit

WHERE TO APPLY RE-PLEX?

The city is an ecosystem by itself, with uncounatble options for materials to be applied. Where do we see Re-plex in this ecosystem?

# The four urban domains

The urban ecosystem can be roughly divided in four spatial domains: **Buildings**, **Public Space**, **Green Space** and the **Underground**. One could imagine that within these four domains various types of applications for a material like Re-plex can be found. All domains have  an unique environment and thus their own prerequisites for materials. For instance, materials applied within buildings are not exposed to weathering, whereas in public or green space they are. Concurrently, materials within buildings are ought to have a long lifespan, sometimes for over 30 years. In public or green space, this is often not the case. Moreover, materials in the underground function in a completely different environment. UV exposure is not a problem, yet for bio-based materials, biological activity can cause degradation in a rapid rate. These different environments pose both opportunities and challenges in finding an application for Re-plex.

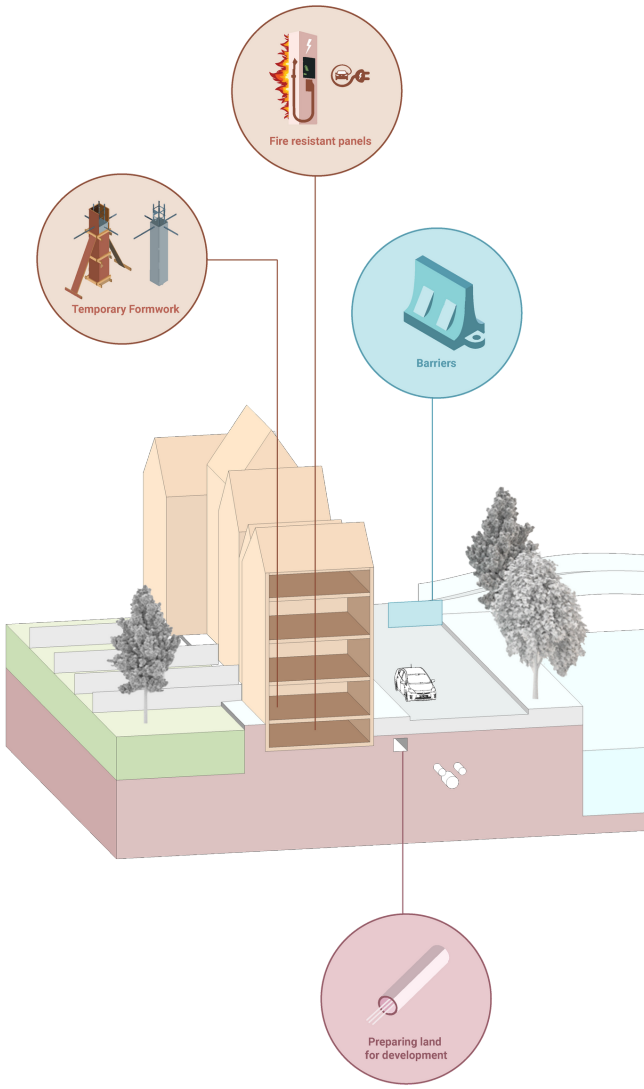
In the following pages the results of our search for applications for Re-plex in the building, public space, green space and underground domain will be showed. In order to organize our findings, we have structured them in the following way. All applications that have been found through co-creative sessions, have been simplified by putting them within typologies. These typologies, are then divided under the four urban domains.

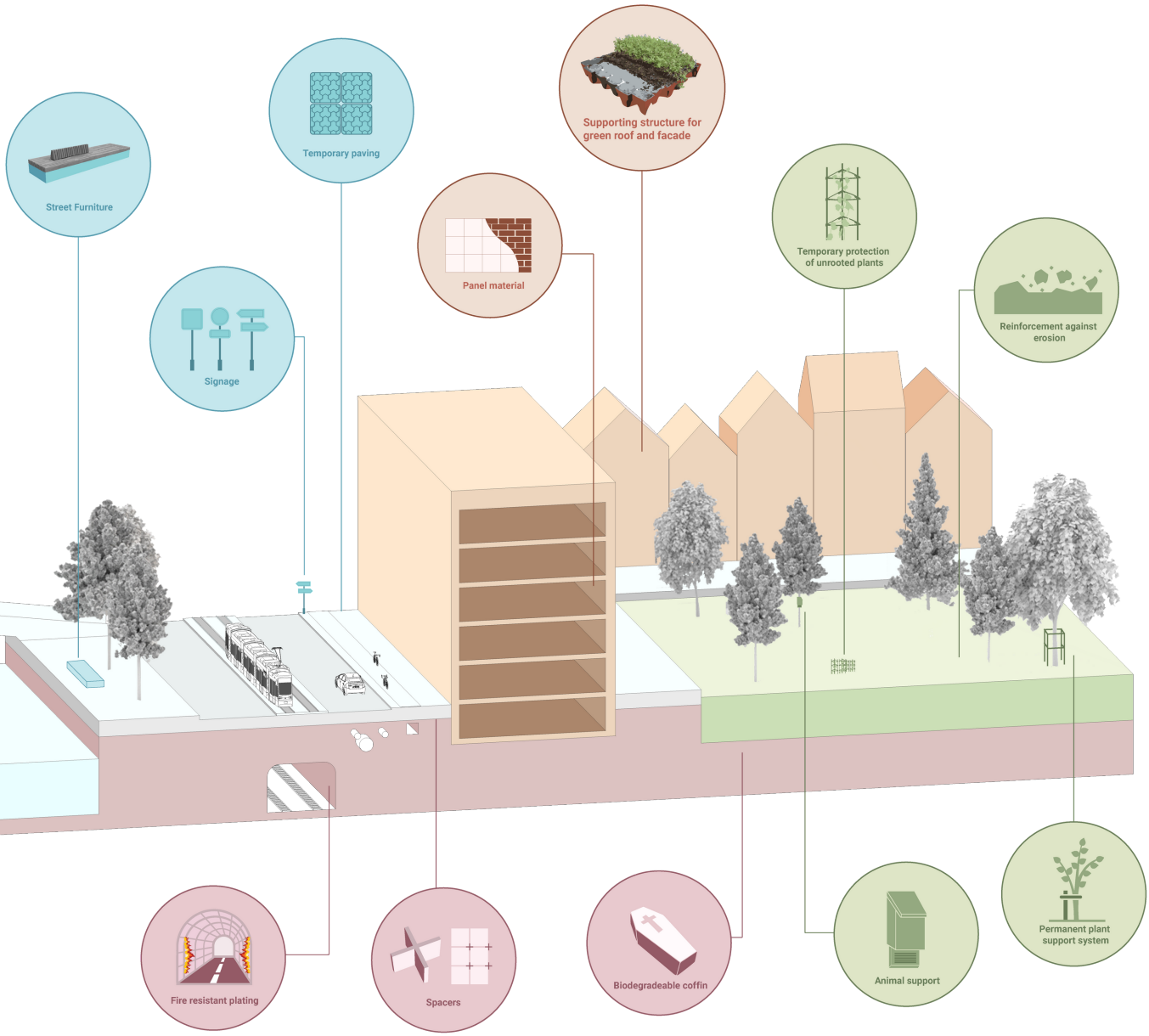
# Urban cross-section

If you look to the cross-section to the right, its is evident: Re-plex can be applied almost everywhere. The cross-sections shows where the typologies for Re-plex, that we developed in this living lab, fit withint the urban ecosystem. These results are based on a co-creative session organized by the Living Lab Team.

## Co-creation

By means of a co-creative session, we identified a heap of applications for Re-plex. The participants of the co-creative session came from many different fields of expertise: building construction, concrete pouring, municipal green services, underwater nature restoration, furniture design and so on. An empty version of the cross-section was presented to the participants, and together applications and remarks were added to it. All participants had an equal say in proposing applications, and afterwards classifying them.




Street Furniture
Temporary paving
Supporting structure for green roof and facade
Panel material
Temporary protection of unrooted plants
Reinforcement against erosion
Signage
Fire resistant plating
Spacers
Biodegradeable coffin
Animal support
Permanent plant support system

# Typologies

THE 16 IDENTIFIED TYPOLOGIES
FOR APPLYING RE-PLEX

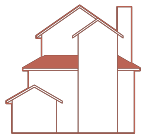
**In the search for an urban fit for re-plex, the typologies described in this chapter should be taken into consideration.**

As the core properties of Re-plex are still subject to change. This made the search for an application very broad, resulting in a great range of possibilities. What could these typologies mean for the development path of Replex? As it's path is not set in stone yet.

# Where and how to apply Re-plex

Within the four domains, we identiefied 16 typologies and 41 applications. Below a small introduction to the domains is given. In the following pages the typologies and coherent applications are given. All typologies defined by 5 indicators: **Weight**, **Strength**, **Biodegradability**, **Fire Resistance** & **Water resistance**.

## Buildings



The construction sector is the largest polluting industry world wide, impacting the natural environment directly and indirectly. Re-plex is an up-cycled secondary generation material, this creates possibilities for it to be used as material to green the sector.

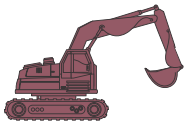
## Green space

An increase in investment in climate-adaptive solutions is necessary to fight the heat island effect, loss of biodiversity, heavy rainfall events and droughts. Re-plex could serve as an alternative for a lot of applications related to nature implementation and support.

## Public space

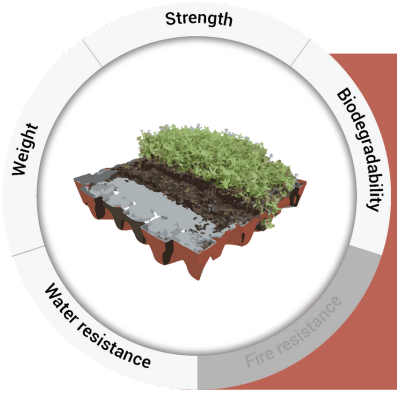
Since urbanization is rapidly increasing worldwide, urban areas will become more crowded which increase the pressure on public space. The environment must not be further polluted with environmentally unfriendly materials.Within the (re)design there is more focus on recyclable materials and products that are CO2 neutral.

## Underground



the lack of management and documentation in the installation of underground infrastructure has often led to a great mess of undocumented and disregarded materials under the city surface. Using bio-based materials  in the underground, like Re-plex, could help preventing having unwanted materials there.

# Building

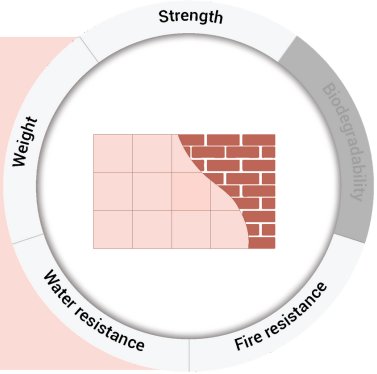


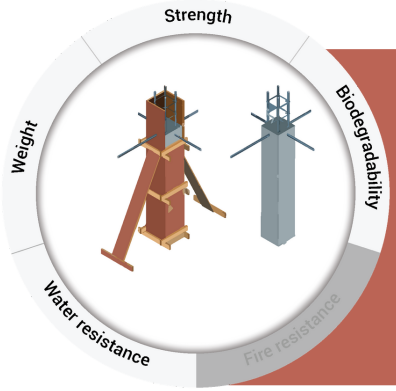

## Supporting structures in green roofs and walls

**Applications:** Green outside cladding, substrate cassette for green roof, noise barrier with nutrients, bioreceptive material

## Panel material

**Applications:** Inner wall, partition wall, facade panel, aucoustic panel, ceiling systems, insulation panel, roofing panel



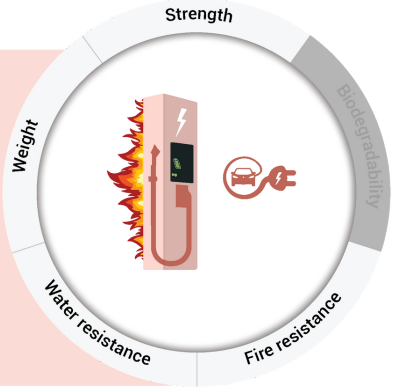




## Temporary formwork

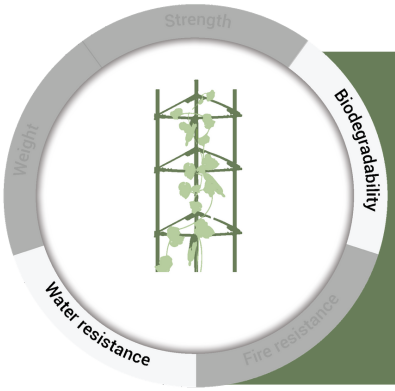
**Applications:** Temporary formwork in building construction, temporary formwork in infrastructure construction

## Flame retardent plating

**Applications:** Fire resistant panel



# Green space

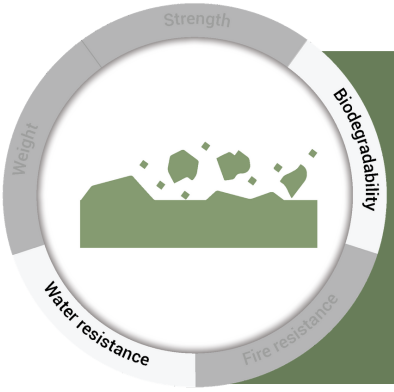



## Temporary protection for young unrooted plants

**Applications:** structures/poles for climbing plants, fencing, pouring edge, tree post, growing mold, protection basket, plant pot

## Permanent plant support

**Applications:** Cultivation pot, vertical farming, plant arch, green noise barrier

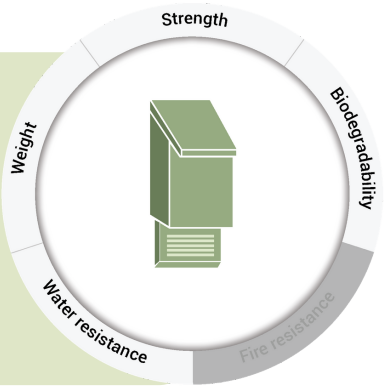




## Reinforcement against erosion

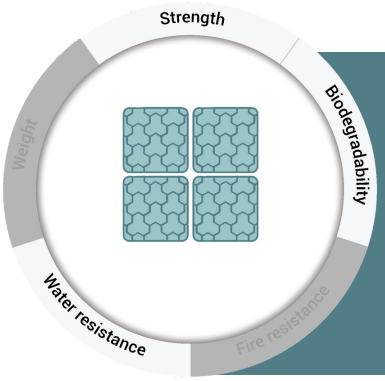
**Applications:** Dyke reinforcement, drifting dune reinforcement

## Animal support

**Applications:** Bat boxes, nesting boxes (for swifts), (bird) food packaging



# Public space

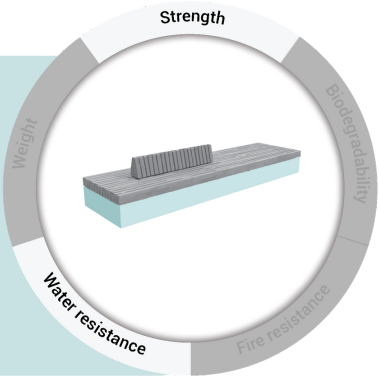


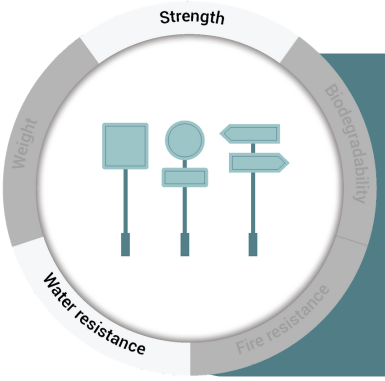

## Temporary paving

**Applications:** temporary sidewalk paving, temporary street paving, temporary driving plates

## Street furniture

**Applications:** Playground equipment, public furniture, luminaire for public lighting



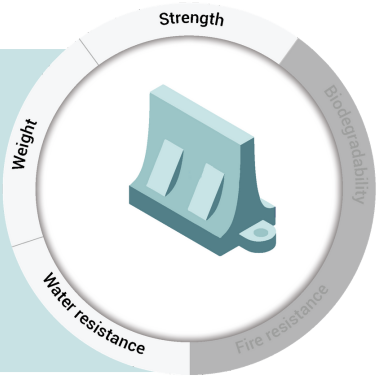




## Signage

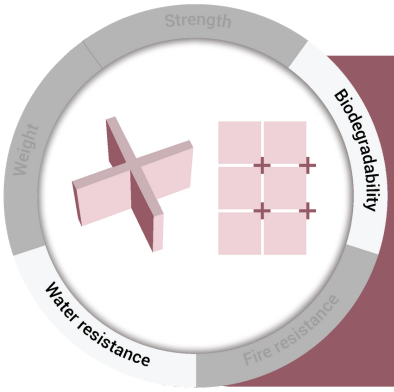
**Applications:** Traffic sing, signposting

## Barriers

**Applications:** Temporary traffic barriers, fencing, construction site fencing, sound barriers



# Underground

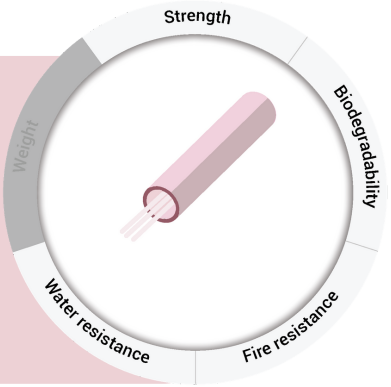


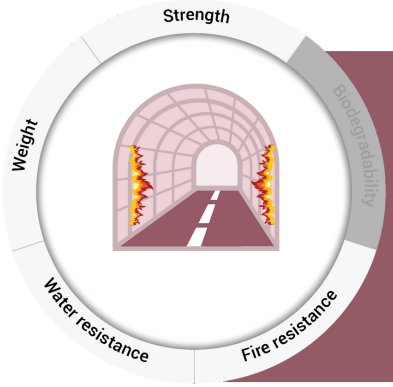

## Spacers

**Applications:** Tile spacers, spacers between surface/concrete plates

## Pipe and cable cases

**Applications:** Temporary casing for placing underground pipes and cables, help in placing conduit protection



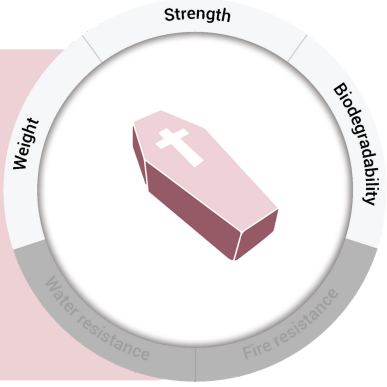




## Fire resistant plating

**Applications:** Tunnel lining, fire resistant lining in infrastructure tunnels

## Biodegradable coffin

**Applications:** Biodegradable coffin



# Development scenarios

This Urban Living Lab tried to indicate the next steps that need to be taken in order to implement  Re-plex into the urban context. We did material tests to indicate the core material properties and we co-created applications together experts. These activities resulted in typologies of different application types. These typologies require different technological development paths for Re-plex as a material. Within this chapter, we elaborate on the possible material development scenarios that fit to certain typologies.

# The four Development Scenarios

Based on the typologies, four different scenarios are identified. Each scenario describes a possible end-status for the Re-plex material after development. All scenarios require specific prerequisites for materials. Typologies with similar property requirements will therefore follow the same pathway towards their common scenario.

In the following pages the results of our search for different types of Re-plex scenarios will be shown. In order to organize our findings, we have structured them in the following way. All typologies have been analyzed based on the required lifespan and core-properties. Typologies with similar requirements are placed into the same scenario. The timeline on the top shows the difference in the amount of effort that must be put into technological development.

# Scenarios

1. 'One time use' → 2. 'Slow exit'

## Start

From a biocomposite material in its R&D phase, towards four different types of material

**COMPRO project goal**
Find an application and produce an prototype made out or Re-plex

2021

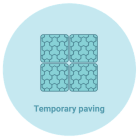
**Temporal application**

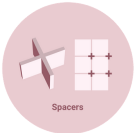
**Lifespan: <1 year**

The **One time use** scenario requires only small changes in the production process since the required core properties are close to the current state of the material. Moreover, it will be an **End-of-life product**, which creates the possibility to leave the material at its last location to degrade.

**Required properties**

- Bio-degradable
- Water repellent



**Temporal application**

**Lifespan: 1-3 years**

The **Slow exit** scenario requires advancements in production or additives like a bio-based coating. This creates the possibility to extend the lifespan while ensuring biodegradability for the **End-of-life** product.

**Required properties**

- Bio-degradable
- Water-resistant
- Relatively high strength




## 3.'Survivor' → 4. 'Serious Shit'

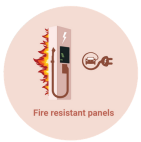
**Permanent application**

**Lifespan: 3-10 years**

The **Survivor** scenario requires an improved production process and a type of coating that ensures the required lifespan and required properties. A lot of change will be necessary since the required properties are far from the properties that the materials have at the moment.

**Required properties**

- High strength
- Fire resistant
- Water-resistant
- Light-weight



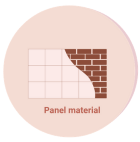

**Permanent application**

**Lifespan: 10-25 years**

The **Serious Shit** scenario requires a greatly improved production process and high-grade coating. The long lifespan prerequisite the most amount of change for the development process. If a coating will be necessary, it is important to realize that this influences the recycling opportunities after depreciation of the application.

**Required properties**

- High strength
- Fire resistant
- Water-resistant
- Light-weight






# Conclusion

**The road has come to an end**

The transition towards a circular (water) system is associated with several challenges. This Urban Living Lab contributed to the transition from a linear economy towards a circular economy by taking the first step to a circular urban water loop. We conducted research on the material properties of Re-plex, co-created possible applications and placed them in different scenarios for the material development directions.

Re-plex's developments can either go towards the scenarios where the material is used in temporal applications. This allows for end-of-life products in an environment where it can degrade and where its components will re-enter the ecosystem.

The other path leads towards more permanent applications that allow more technical improvement for higher strength and longer lifespan. In the discussion, we will elaborate on the next steps and considerations for implementations.

# Discussion

To ensure valuable implementation of Re-plex into urban areas, the following concepts have to be taken into account.

## Temporal vs. permanent applications

The question is whether temporary structures that are bio-based, are more environmental friendly than reusable structures that last longer. What is more environmentally friendly; an end-of-life product that degrades after one-time use but still needs to be produced? Or something that has a higher environmental impact during production, but can also be reused more often? This is an interesting question for the further development of Re-plex. We recommend doing a Life-Cycle Analysis and compare the results with the currently used materials of applications that could potentially be replaced by Re-plex. Keep in mind that circular applications are not always more sustainable.

## Coating

Coating Re-plex can extend the life-span of the material. Doing so, is especially necessary for permanent applications. However, adding a coating will probably lower possibilities for recycling or biodegradation. Therefore, using Re-plex without a coating can increase the performance of its end-of-life cycle.

## Further steps

We recommend COMPRO, the Re-plex research consortium, to continue with the living lab research approach. The next step would be to test the material within different types of applications in a real-world setting. The material can already be applied in applications that are categorized into scenario one: '**one time use**'. Moreover, we recommend to further analyze the market opportunities and changes in regulations for the different typologies.

# The Re-plex L.L. Team

TEAM, COACHES AND CASE OWNER


**Jesse Bergman**
MSc MADE

**Siddharth Agarwal**
MSc MADE

**Maartje Molenaar**
MSc MADE



**Special thanks to**

**Peter Mooij**
AMS - Academic Coach

**Mark Lepelaar**
NSPS - Case owner



**Contact**
**madell.replex@gmail.com**