U.S. DEPARTMENT OF ENERGY

Office of ENERGY EFFICIENCY & RENEWABLE ENERGY

Intersection of lifecycle impacts and circular economy potential for the building sector

Where do buildings come from and where do they go when they die?

Life-Cycle Energy & Related Impacts of Buildings Webinar Series

December 17, 2020

Agenda

I. **Introduction to Life Cycle Carbon**
   Lyla Fadali – AAAS Policy Fellow, U.S. DOE Building Technologies Office
II. **Opening Remarks**
   Joan Glickman– Program Manager & Lead of DOE's Advanced Buildings Construction Initiative, U.S. DOE Building Technologies Office
III. **Amsterdam Circular Strategy**
   Eveline Jonkhoff – Program Manager, Circular Economy, City of Amsterdam
IV. **Circular Economy Design**
   Alastair Reilly – Design Partner, William McDonough+Partners
V. **Lessons from Earth**
   Joe Dahmen – Director of Sustainability and Co-founder, Watershed Materials
VI. **Timber Framing for a Circular Economy**
   Ged Finch – Director, X-frame
VII. **Q&A Session**
   Cedar Blazek – Management & Program Analyst, U.S. DOE Building Technologies Office

Building Life Cycle Impacts DOE Webinar Series

Topic	Date
Overview of life cycle impacts of buildings	Oct. 16
Challenges of assessing life cycle impacts of buildings	Oct. 29
Innovative building materials	Nov. 12
“Real Life” buildings striving to minimize life cycle impacts	Dec. 3
→ Intersection of life cycle impacts & circular economy potential for the building sector	Dec. 17

Poll Questions

- What industry are you from?
- How familiar are you with circular economy concepts?

Building Technologies Office

BTO invests in energy efficiency & related technologies that make homes and buildings more affordable and comfortable, and make the US more sustainable, secure and prosperous.

Budget ~US$285M/year; activities include:

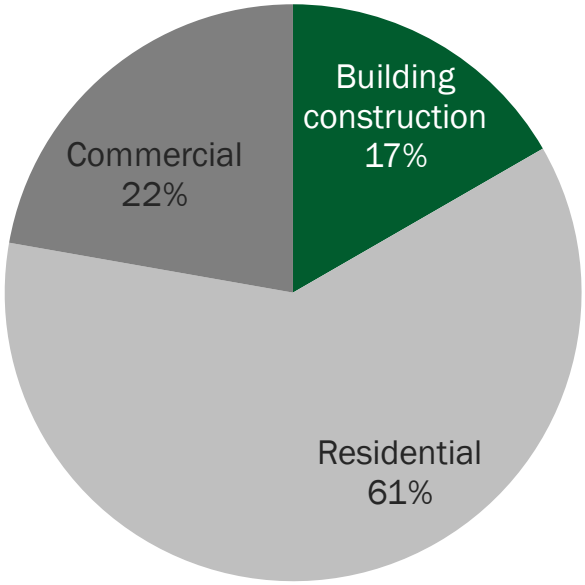
R&D
Pre-competitive, early-stage investment in next-generation technologies

Integration
Technology validation, field & lab testing, metrics, market integration

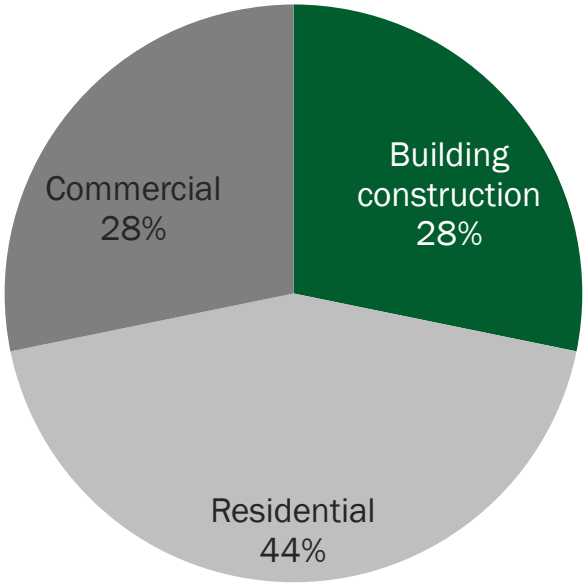
Codes & Standards
Whole building & equipment standards technical analysis, test procedures, regulations

Historically, BTO has focused on operating buildings.

Global energy use in buildings



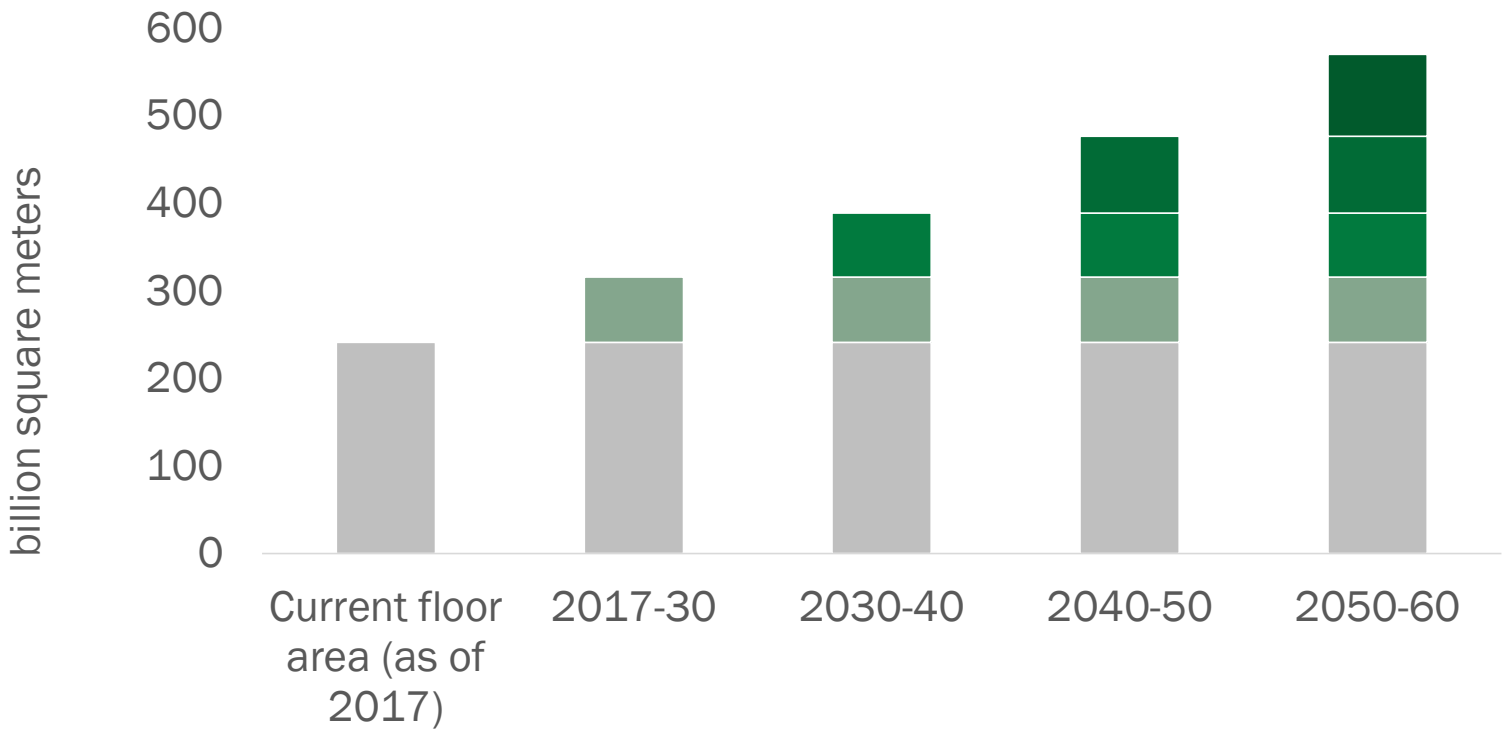
Global emissions from buildings



2018 Global Status Report. United Nations Environment Programme.
International Energy Agency for the Global Alliance for Building and Construction (GlobalABC)

Global building stock expected to more than double, making embodied carbon increasingly important.

Global building stock through 2060



Source data from GlobalABC Status Report in 2017

Let's look at the whole picture:

Lifecycle carbon refers to carbon emissions associated with all stages of a building's life

Resource extraction

Manufacturing

Transportation

Construction/ Installation

Equipment Replacement/ Maintenance

Demolition/ End of life

Operations

Embodied carbon is the carbon associated with all stages of a building's life cycle not including operating the building

Operational carbon is the carbon associated with operating the building

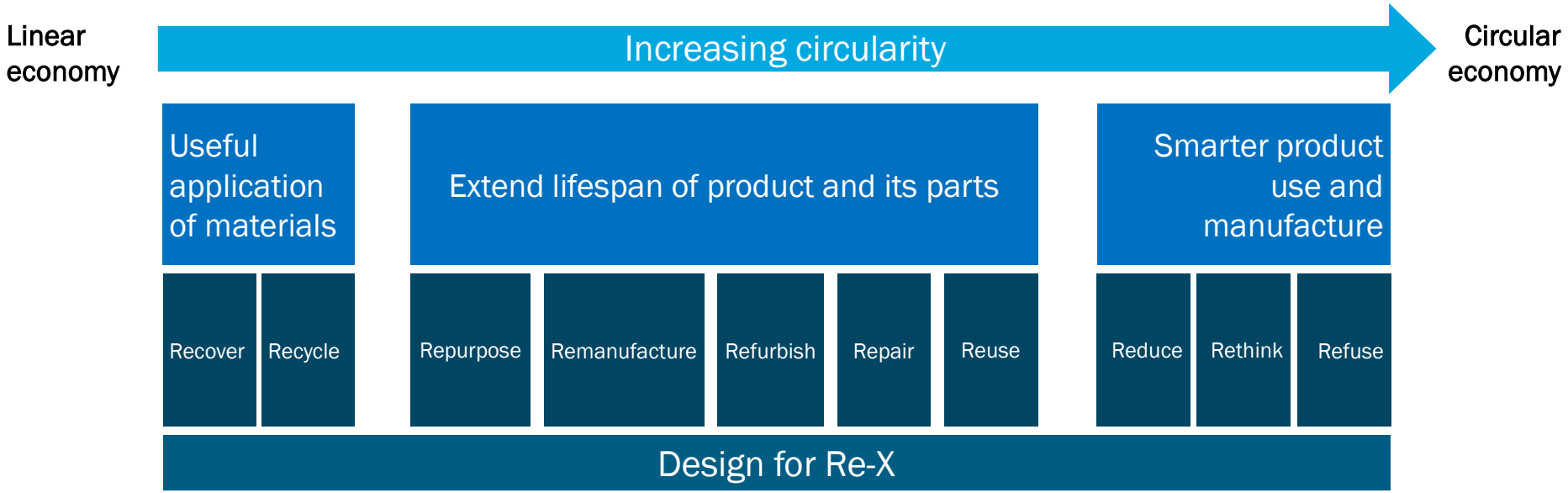
In the US, waste from construction and demolition is more than double all municipal solid waste, 90% from demolition.

About 1/3 comes from buildings.

Source: EPA 2018

What is the Circular Economy?

The **Circular Economy** aims to keep resources in a closed cycle and to eliminate waste and pollution.



Adapted from: Potting, J., et al., 2017. Circular Economy: Measuring Innovation in the Product Chain.

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The Advanced Building Construction "ABC" Initiative

December 2020

There's no easy, fast, cost-competitive way to IMPROVE or BUILD deeply ENERGY EFFICIENT buildings.

"COMMODITY" solutions that deliver deep energy savings DO NOT EXIST.

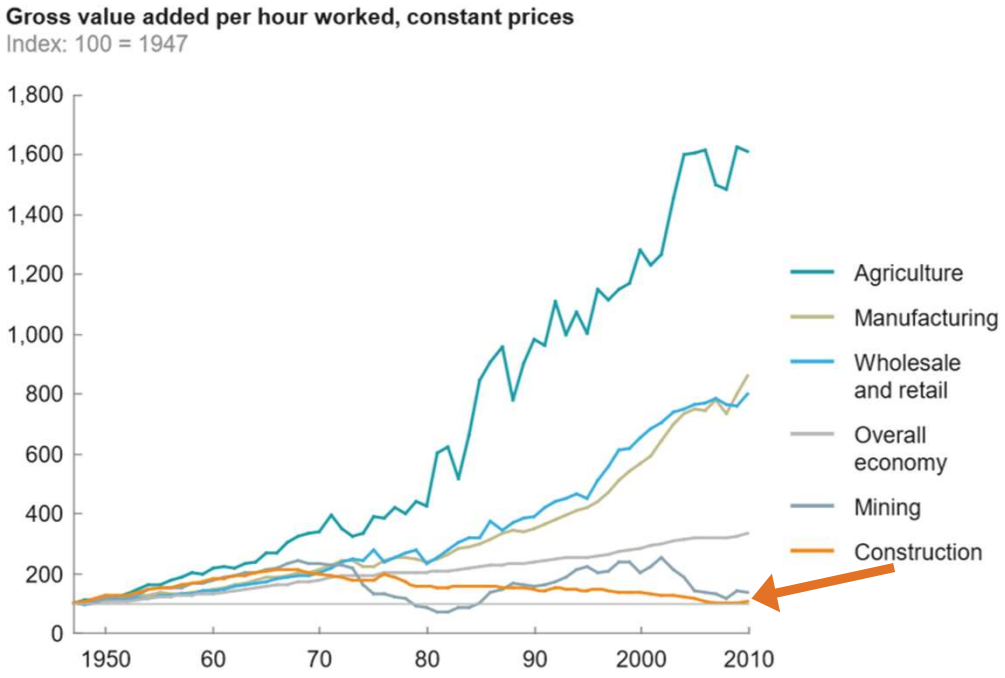
Even basic design, construction, and renovation projects are overly complex.

Primary Barriers:

- Labor-intensive building practices
- Underinvestment in innovation
- Fragmented products & service delivery
- Little automation, digitization
- Inconsistent performance
- Insufficient workforce

Construction Modernization Long Overdue…
Opportunity to Leapfrog to Low Carbon Solutions

Construction sector labor productivity lags sorely behind other sectors



Advanced Building Construction (ABC)
provides a means to
catapult the construction sector
into the 21st century
with
modernized construction solutions
that not only
improve productivity
but result in a
carbon neutral
US building stock
by 2050

ABC Initiative: Investing in R&D & Market Transformation Activities

ABC Initiative: Formally kicked off with announcement of *BTO's FY19 Advanced Building Construction Funding Opportunity* for $33.5 million

Researchers asked to consider how to lower lifecycle impacts:

"In all of these areas, DOE seeks transformative innovation that can dramatically increase the energy efficiency of buildings, while offering more affordability and benefits to enhance their appeal and likelihood of successful commercialization (e.g., faster production, consistent performance, improved reliability, lower lifecycle impacts, and greater resiliency)."

Innovation Across the Supply Chain + Streamlined Delivery of Low Carbon Solutions

Design for Manufacture & Assembly

Materials

Components

Manufacturing

Installation

ABC Collaborative: Scaling low carbon, appealing solutions for new construction & existing buildings

Build Supply & Demand

- Understand & Aggregate Demand
- Organize Supply & Delivery

Address Market Challenges

- Remove Institutional Barriers
- Scale Critical Technologies
- Streamline Financing

Educate & Build Support

- Engage Key Partners
- Leverage Federal, State, Local Interests

For More Information…

To learn more about the ABC Initiative and DOE-funded projects, visit www.buildings.energy.gov/abc or email us at abc@ee.doe.gov

For information on the ABC Collaborative and how to get involved, visit www.advancedbuildingconstruction.org

TOGETHER, we can REINVENT the way BUILDING is done.

TOGETHER, we can create a CARBON NEUTRAL BUILDINGS SECTOR.

Amsterdam Circular 2020-2025 Strategy

Eveline Jonkhoff
Program manager Amsterdam Circular
e.jonkhoff@amsterdam.nl

The Amsterdam Goal:
100% circular and climate neutral in 2050

Main objectives

2030

50% reduction of primarily resources

2050

100% circular and climate neutral

Interim objectives municipality

2022

10% of the city's procurement will be circular

2023

All tenders in de built environment will be circular

Overview of strategy elements

Visual overview of the relationship between the strategy, the implementation programme, the monitor and the city doughnut.

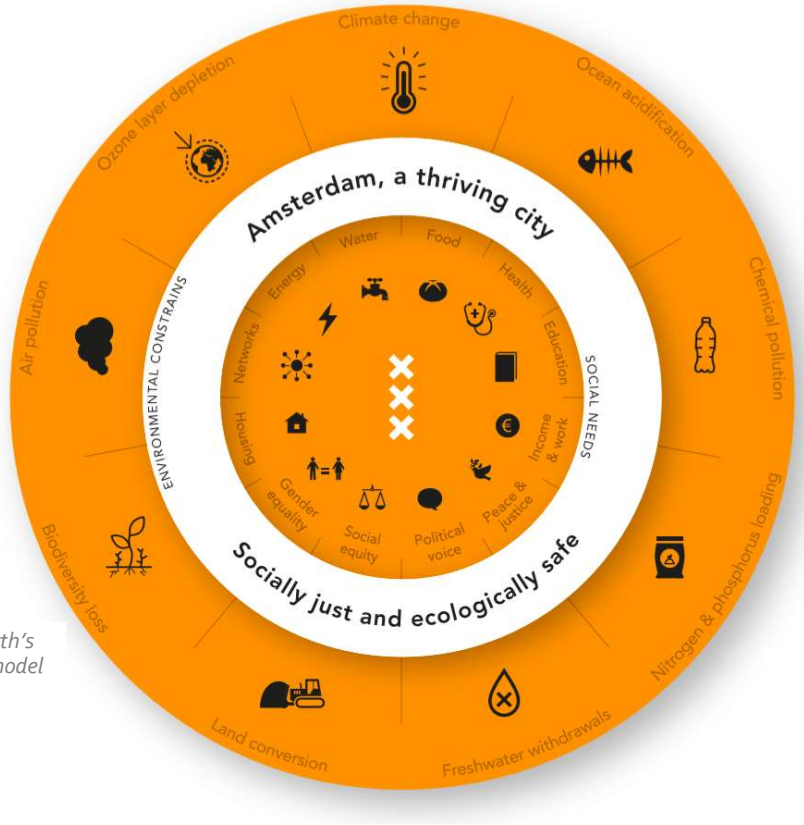
Amsterdam City Doughnut
Strategic framework and policymaking tool whereby city officials can examine the City's circular performance and determine policy accordingly.

Amsterdam Circular Strategy 2020-2025
Vision and definition of a circular Amsterdam
Target groups (municipality, companies, residents)
Value chains, ambitions and courses of action

Innovation and Implementation Programme 2020 -2021
+200 circular projects and initiatives that take place in the City

Monitor Circular Economy
Monitors material flows inside the city from input to regeneration
Will also be monitoring social values in the near future
Operational data for City Doughnut

Inspired by the Doughnut of Kate Raworth



Kate Raworth's doughnut model

- The model describes how societies and businesses can contribute to economic development while still respecting the limits of the planet and our society
- The inside of the doughnut represents the social foundation
- The outside of the doughnut represents the ecological limits of the planet

The first 'City Doughnut'

City Doughnut supports in circular and just recovery and improvement of future policy

The City Doughnut is a testing framework

Four perspectives on which we examine

Each value chain has 3 ambitions

Food & organic waste streams

Consumer goods

Built environment

Production

- Ambition 1: Short food chains provide a robust sustainable food system
- Ambition 1: The City sets the right example by reducing its consumption
- Ambition 1: The transition to circular development requires a joint effort

Use

- Ambition 2: Healthy and sustainable food for the people of Amsterdam
- Ambition 2: Using what we have more sparingly
- Ambition 2: The City sets the right example by formulating circular criteria

Processing

- Ambition 3: High-quality processing of organic waste streams
- Ambition 3: Amsterdam makes the most of discarded products
- Ambition 3: A circular approach to the existing city

City scale projects - The transition to circular area development

Production

Buiksloterham
The former industrial area of Buiksloterham is being transformed into a circular city district for living and working

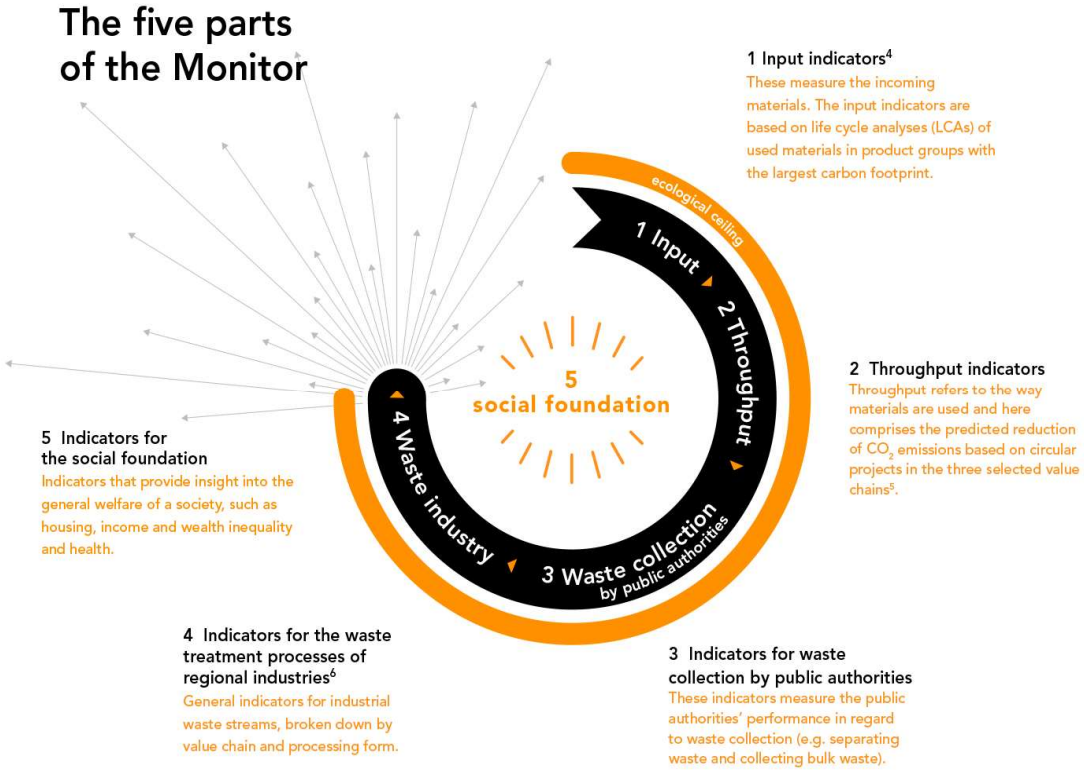
City scale projects – Circular buildings

Use

Wooden buildings
First buildings in wood:
Bio based materials for circular buildings and reduction of CO_2.

Monitoring our progress

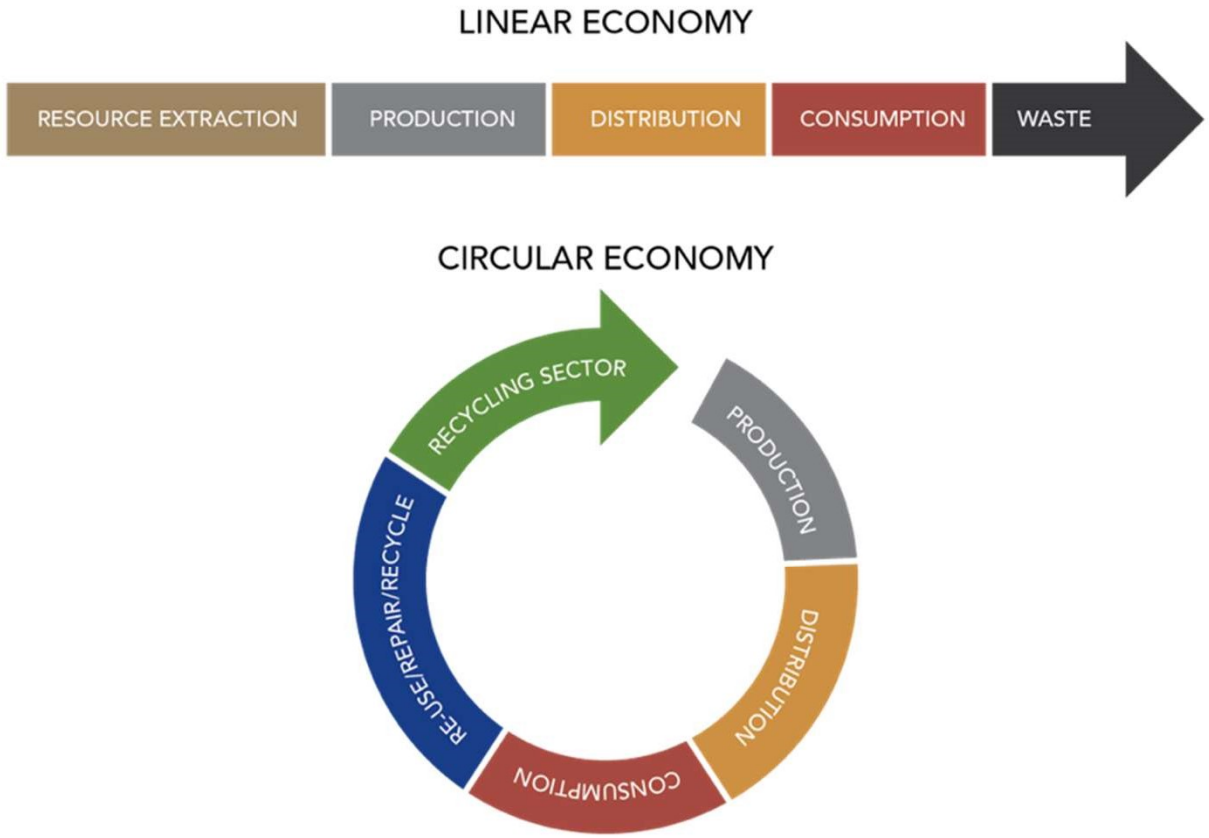
- We are developing a monitor to determine the social and ecological impact of the transition.
- For example, we can see the amounts of raw and other materials that the city consumes and produces as waste and highlight social aspects of the transition.
- By collecting more and more data, the monitor will show where improvements can be made.
- We will further develop and refine the framework for this monitor.




A thriving, regenerative and inclusive city for all citizens, while respecting the planetary boundaries.

design is the first signal
of human intention

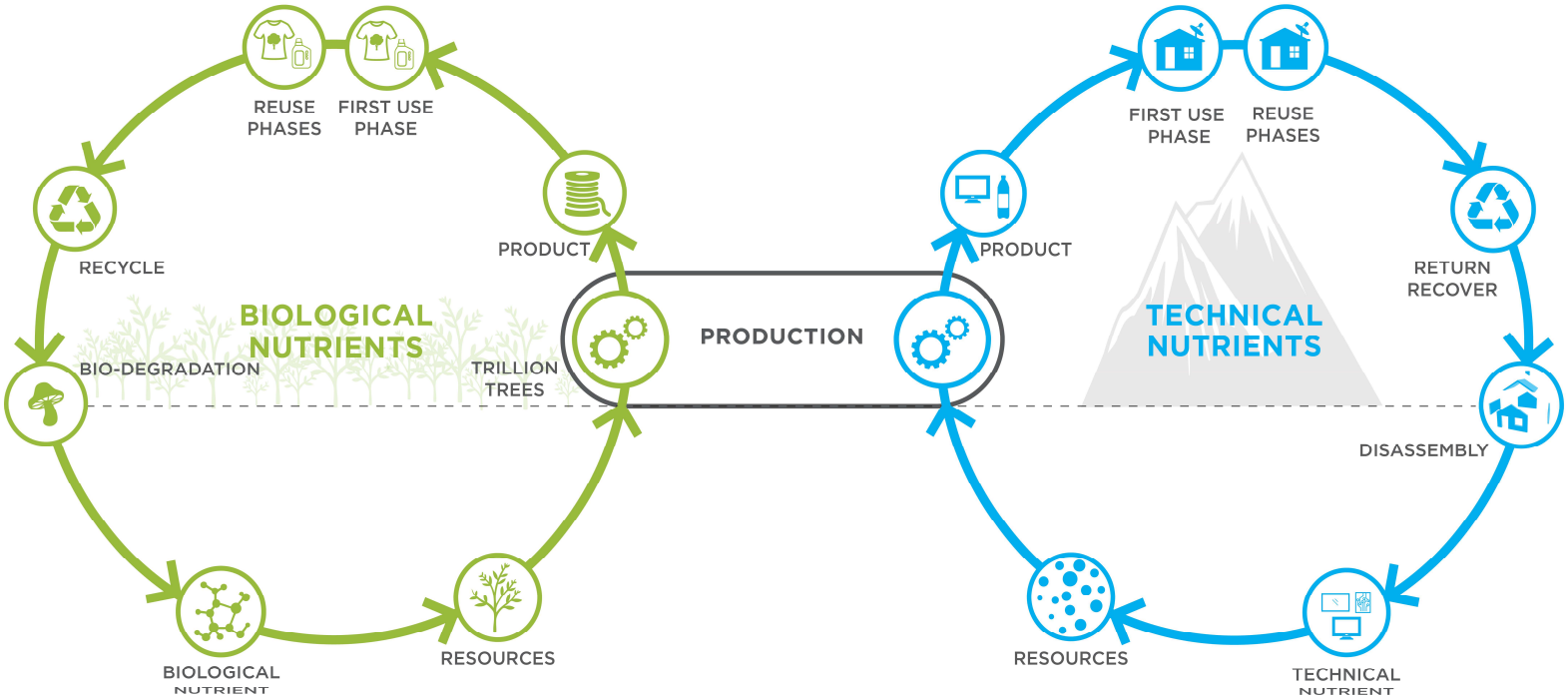
we need a new design



it is more than just closing the loop…

or putting the linear economy in a circle

Image Source: Sustainable Brands



cradle to cradle circular economy

Material Health
In biological and technical metabolisms

Circular Economy
Material reutilization and continuous assets

Renewable Energy
Clean energy and restorative carbon balances

Water Stewardship
Clean water in production and use cycles

Social Fairness
Shared abundance

Cradle to Cradle® concept overview

BIOLOGICAL NUTRIENTS

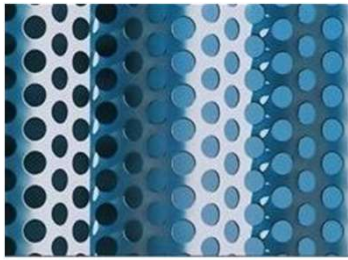




CERTIFIED™ cradle to cradle

PRODUCTS PROGRAM


TECHNICAL NUTRIENTS




products of consumption

products as a service

Cradle To Cradle Products Innovation Institute

emits oxygen
sequesters carbon
fixes nitrogen
accrues solar energy
creates food
creates fuel
distills water
provides habitat
creates microclimate
changes color
self-replicates

a building like a tree

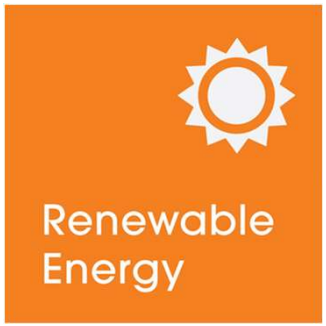
goal: carbon positive behavior

GOOD MATERIALS
Safe biological and technical nutrients

-Prioritize C2C certified materials
-Utilize Mass Timber for the superstructure
-Low embodied carbon materials

GOOD ECONOMY
Circular, sharing, and shared

-Design for adaptability
-Design for disassembly
-Balanced, Intentional, and Repeatable



GOOD ENERGY
100% Renewable Energy

-Net positive for new buildings
-All electric
-Resilient (batteries)

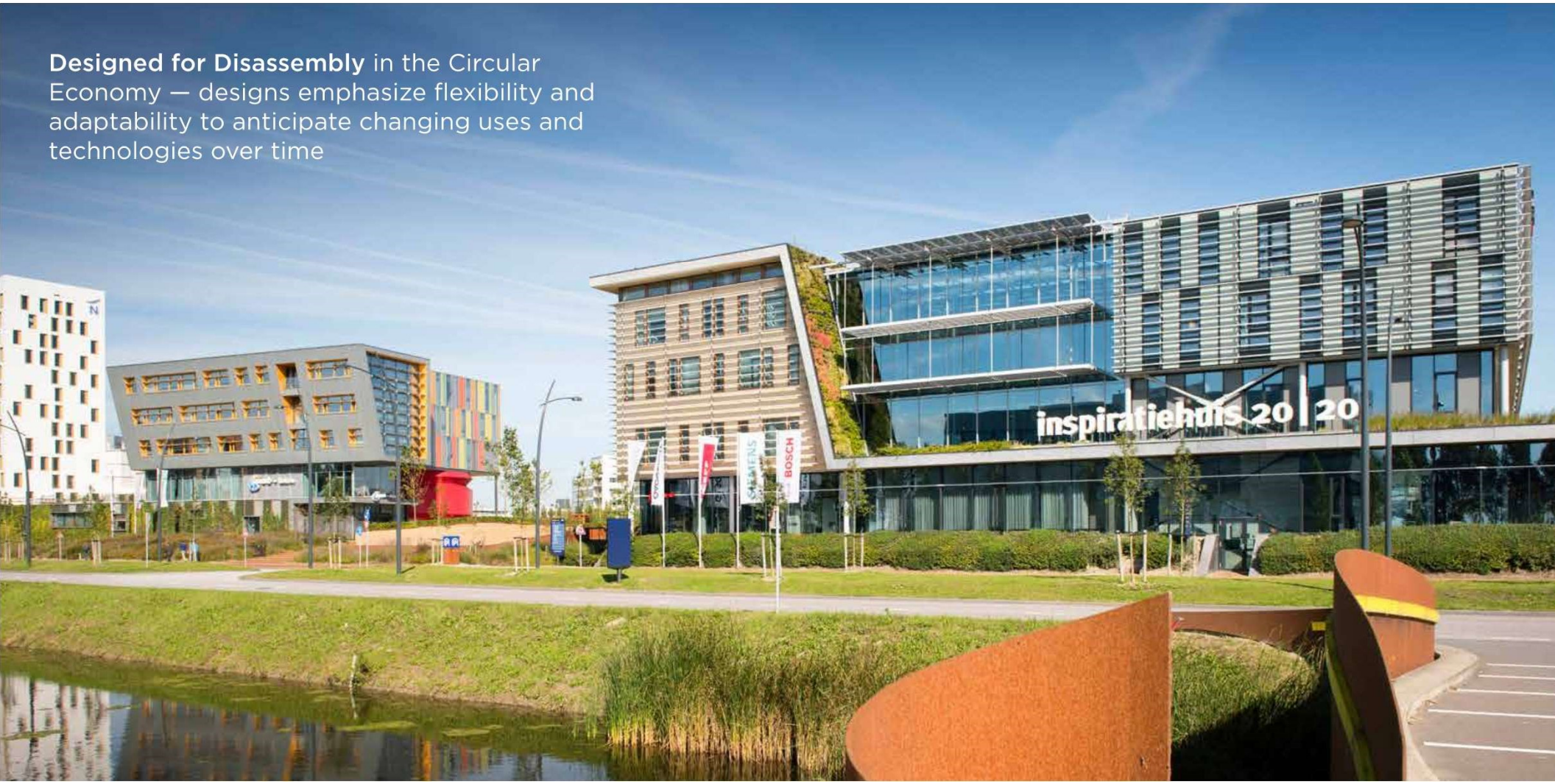
GOOD WATER
Clean and available to all

-Capture stormwater from roofs to reuse in the landscape
-Resilient landscape design.

GOOD LIVES
Safe, meaningful, creative, and dignified.

-Biophilic
-Beauty from Simplicity
-Healthy
-Community

Cradle to Cradle® - inspired The Five Goods™



Designed for Disassembly in the Circular Economy — designs emphasize flexibility and adaptability to anticipate changing uses and technologies over time

A **NOW** Completed 2017	B **Fox Vakanties** Completed 2012	C **SHARE** In Construction	D **Tower** In Development	E **Bosch Siemens Inspiration House** Completed 2012	F **FIFPro Headquarters** Completed 2013	G **Bluewater** Completed 2014	H **Biological Nutrient Pavilion** Completed 2012	I **Plantronics Headquarters** Completed 2016	J **Technical Nutrient Pavilion** Completed 2012

buildings designed for next use

designed for disassembly – perpetual assets

DESIGNED FOR DISASSEMBLY

The buildings are designed with flexibility in mind, anticipating the needs of future tenants. Connections between floors can easily be changed and staircases repositioned, avoiding energy-intensive demolition processes to alter the building's purpose.

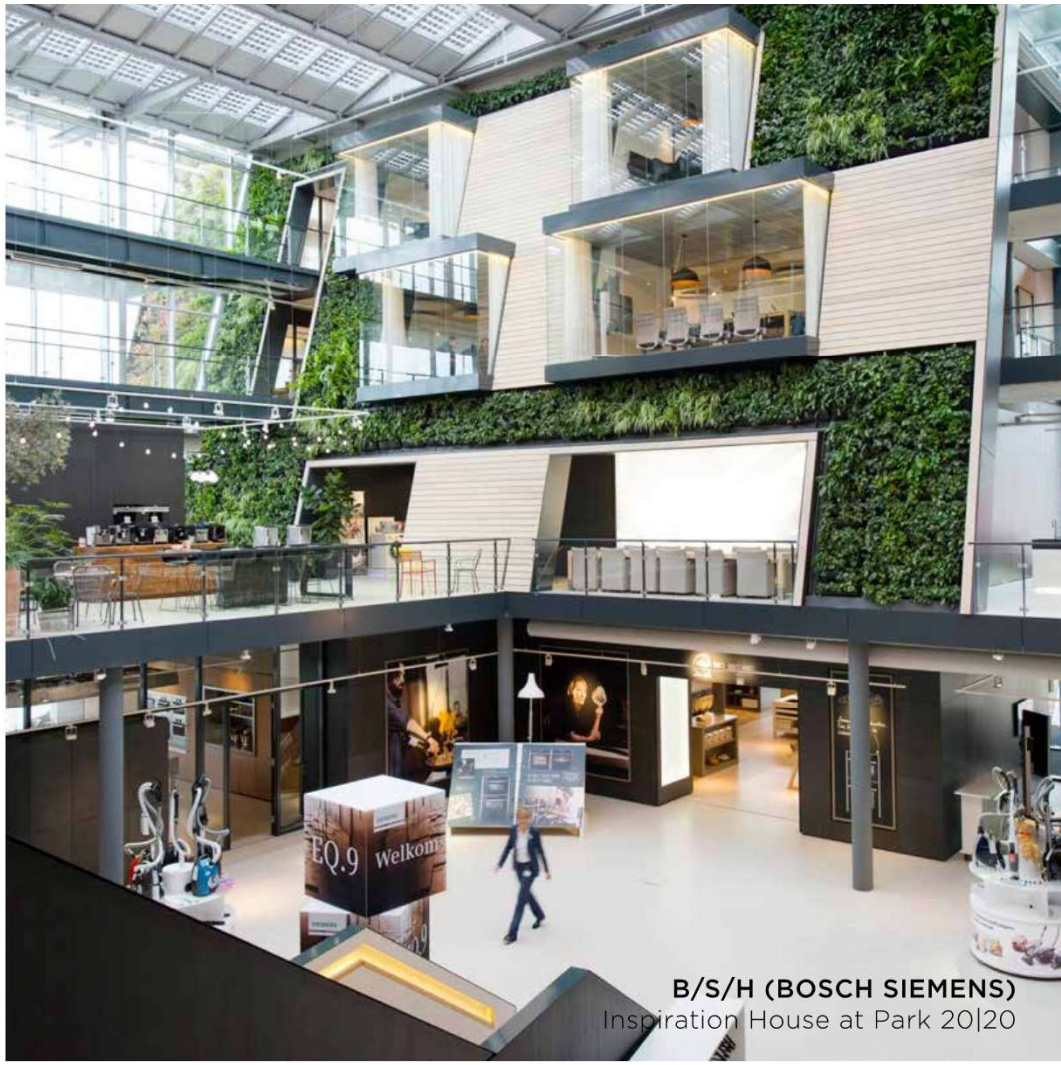
B/S/H (BOSCH SIEMENS)
Bosch Siemens Hausgeräte (B/S/H/) is home to five of the top brands in household appliances – Bosch, Siemens, Gaggenau, Neff and Solitaire – in the first building completed at Park 20|20.

Designed as a flexible, innovative workplace, B/S/H/ includes a full-height atria with a Living Green Wall and Building Integrated Photovoltaic (BIPV) roof that maximizes energy and daylighting to showrooms that can be converted to offices as needed. Interior spaces are designed to encourage occupant well-being through individual user controls, fresh air and sunlight, and materials assessments to ensure that safe and healthy products are used throughout the construction and use of the building.

Area 8,348 gross square meters

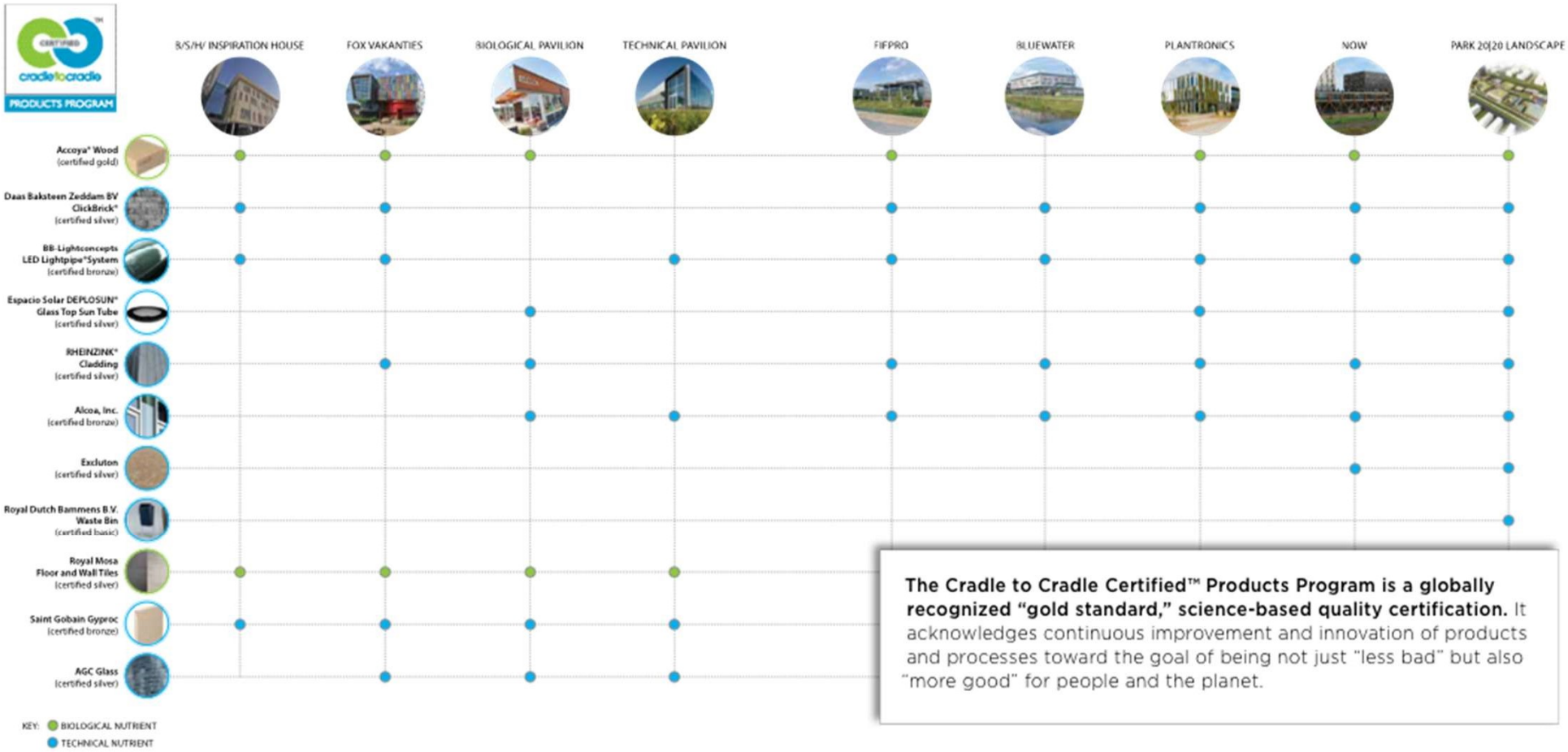
Program A Netherlands headquarters and showroom; includes offices, café

Awards
BREEAM Good
Shaw Contract Design Is…Award 2012



B/S/H (BOSCH SIEMENS)
Inspiration House at Park 20|20

buildings are designed for next use

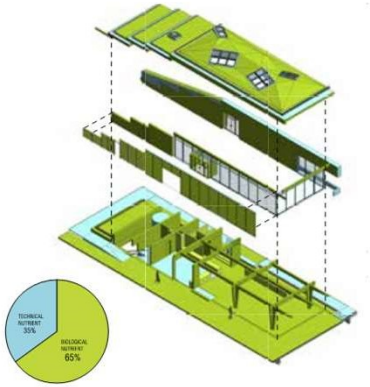


Largest integration of C2C Certified™ Products

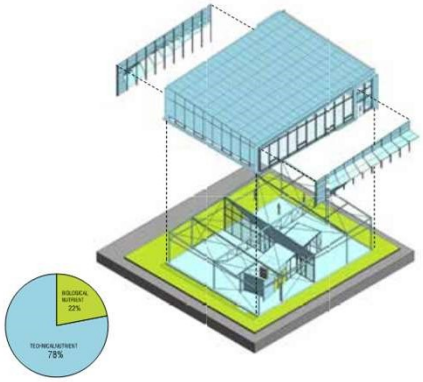
MATERIAL BANKING AND PASSPORTS

The buildings are constructed as "material banks" and are designed for disassembly or reconfiguration if market demand changes. Value is maintained in building products for future use as raw materials. Technologies such as RFID facilitate cataloging of products so that the value is identified, quantified and eventually capitalized, both as present value and future value.

BIOLOGICAL NUTRIENT PAVILION



TECHNICAL NUTRIENT PAVILION



buildings constructed as 'material banks'

PRODUCTS AS A SERVICE

Cradle to Cradle promotes the implementation of product leasing strategies as a business model where manufacturers maintain ownership of the physical product and users lease their service. For example, a facade system could be provided not as a product purchased and then discarded when it becomes worn, but as a service that is leased, which is regularly improved and updated.

"The Cradle to Cradle principle is the basis for all product developments at Schüco"

Stefan Rohrmus, Sustainability Manager

Schüco C2C roadmap

The Schüco C2C roadmap

aluminum takeback program – lighting as service

HEALTH AND WELLBEING

Diversely scaled spaces for collaboration, communication, contemplation and concentration complement abundant daylight access through floor-to-ceiling operable windows, clean fresh air systems, use of numerous healthy Cradle to Cradle Certified™ materials, optimized lighting and controls, and acoustic comfort to create a human-centered place.

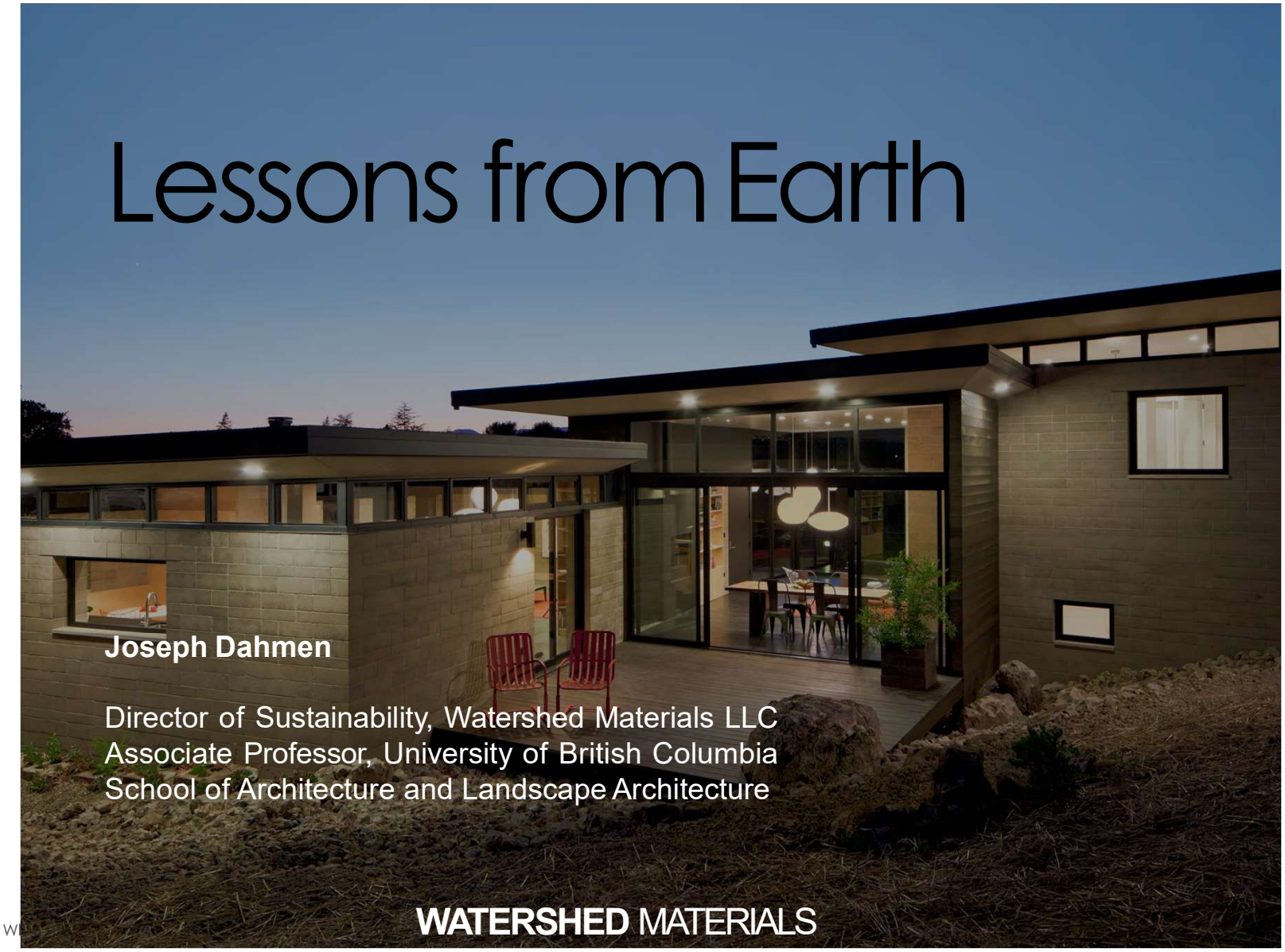
A survey measured staff satisfaction with various design features before and after moving into the new office.

The results show a significant improvement.

Chart is located on page 21 of the report

PLANTRONICS
NETHERLANDS HEADQUARTERS AT PARK 20|20

community of shared systems & community assets

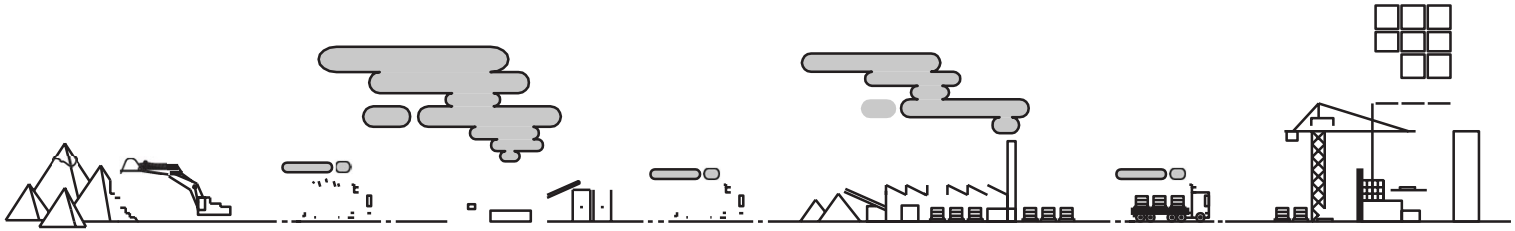


New Potentials for Architectural Materials

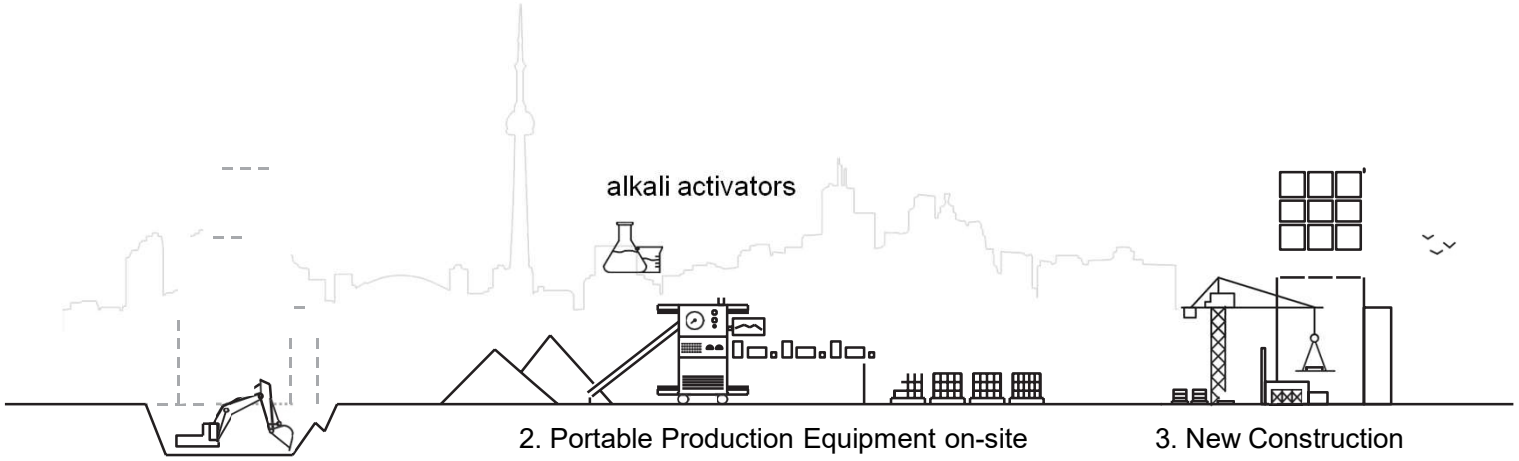
"The Internet of Things and circular economy practices are mutually reinforcing… presenting enormous opportunities to make use of materials previously considered to be waste"

—Janine Benyus,

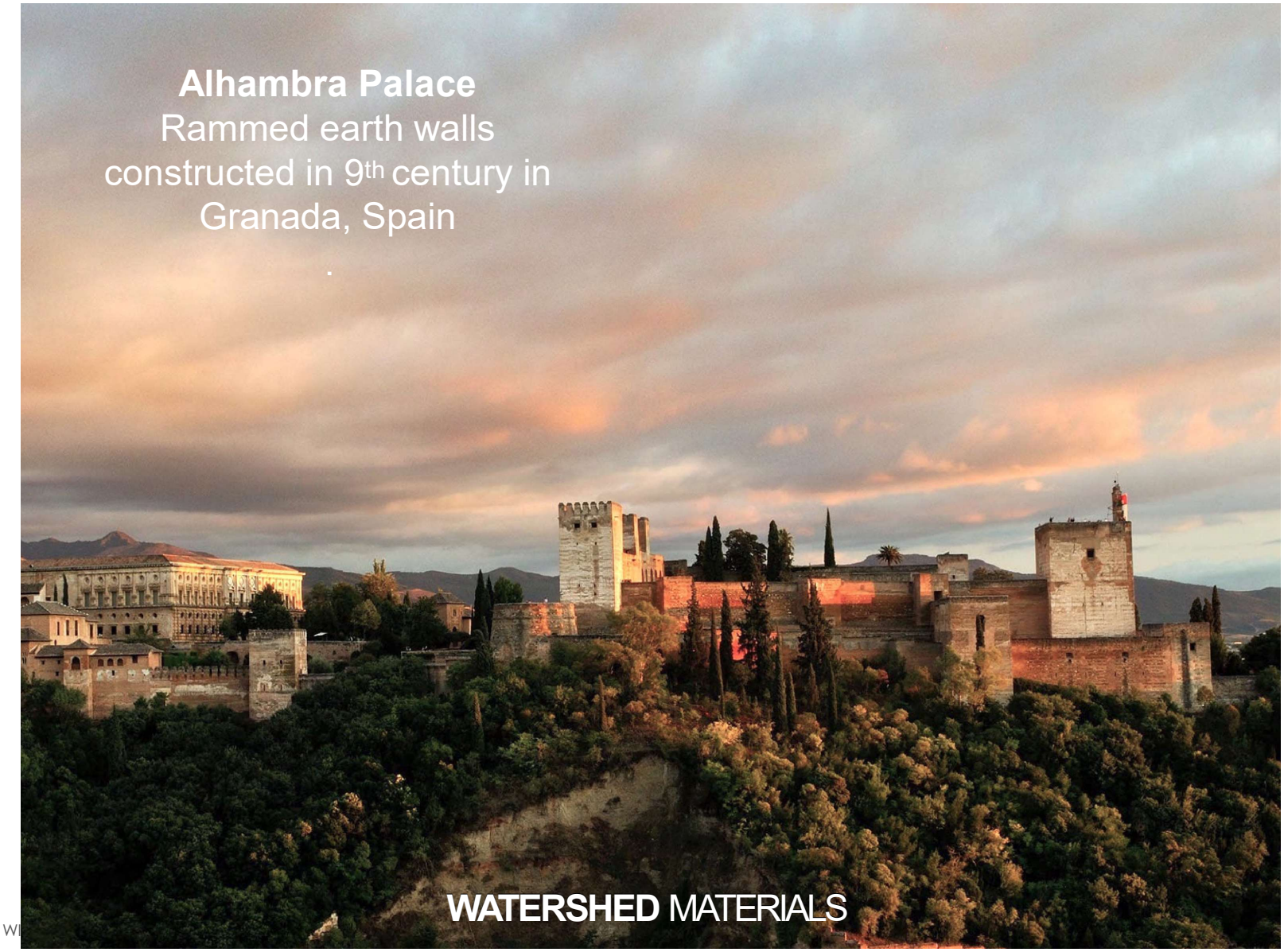
Watershed Technology



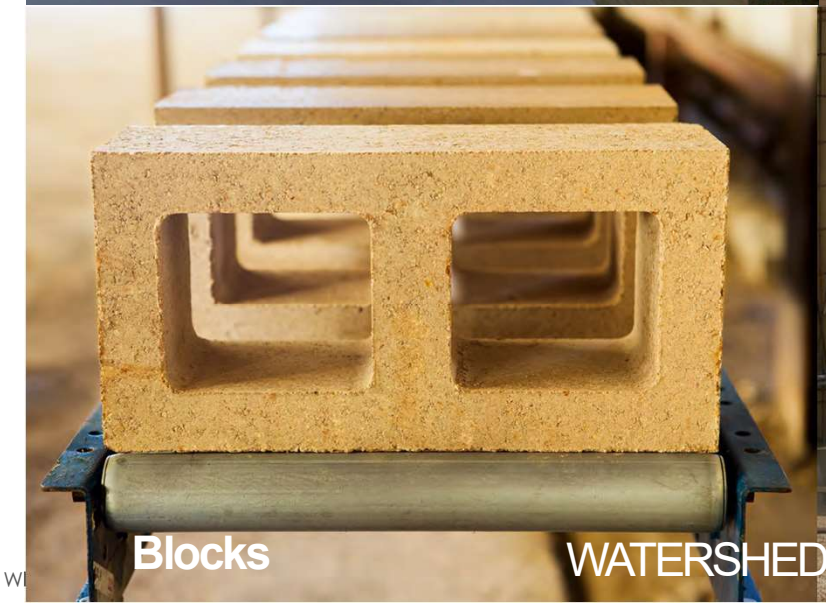
Conventional Construction Materials Production

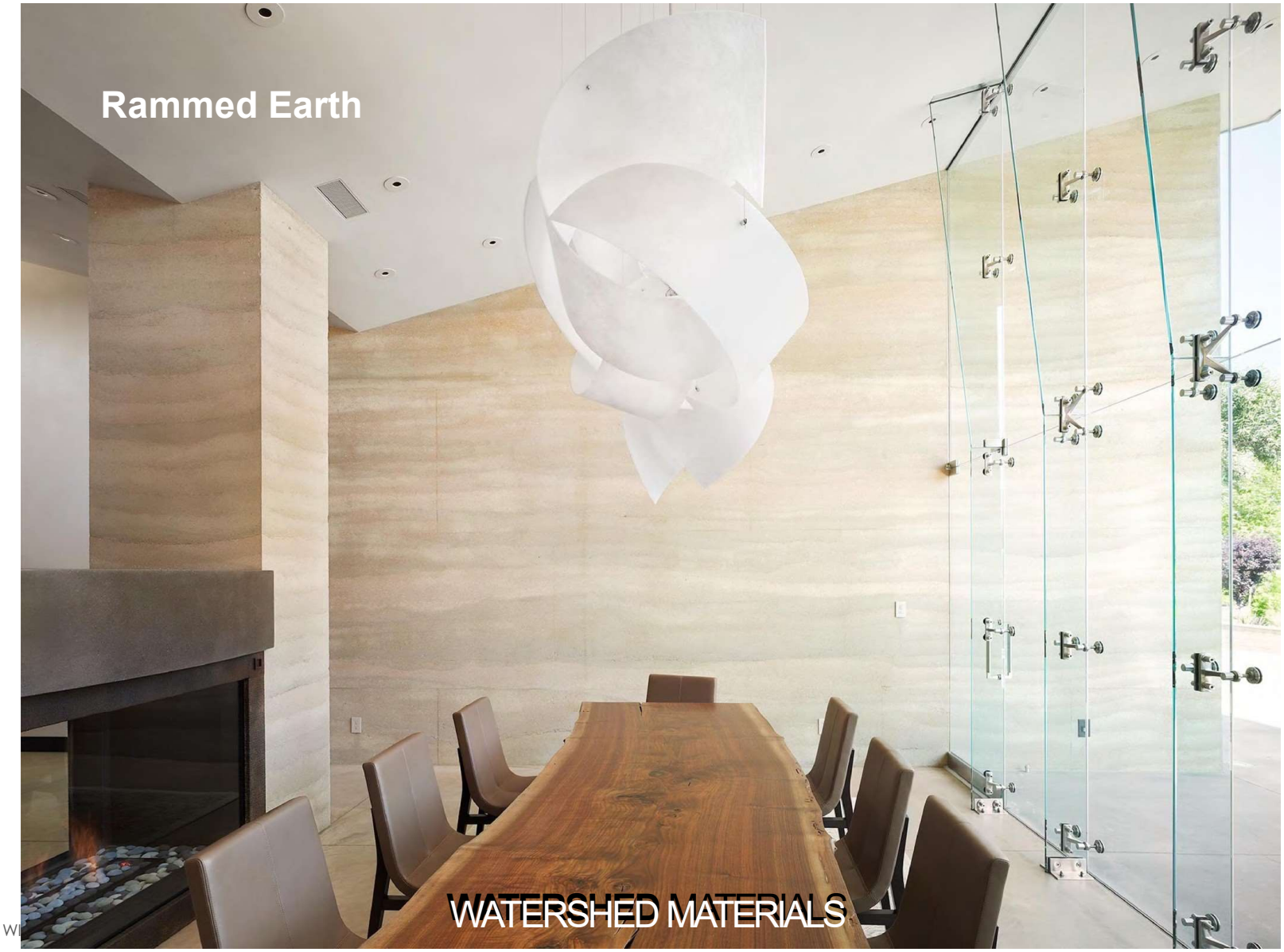


Watershed Materials On-site Production

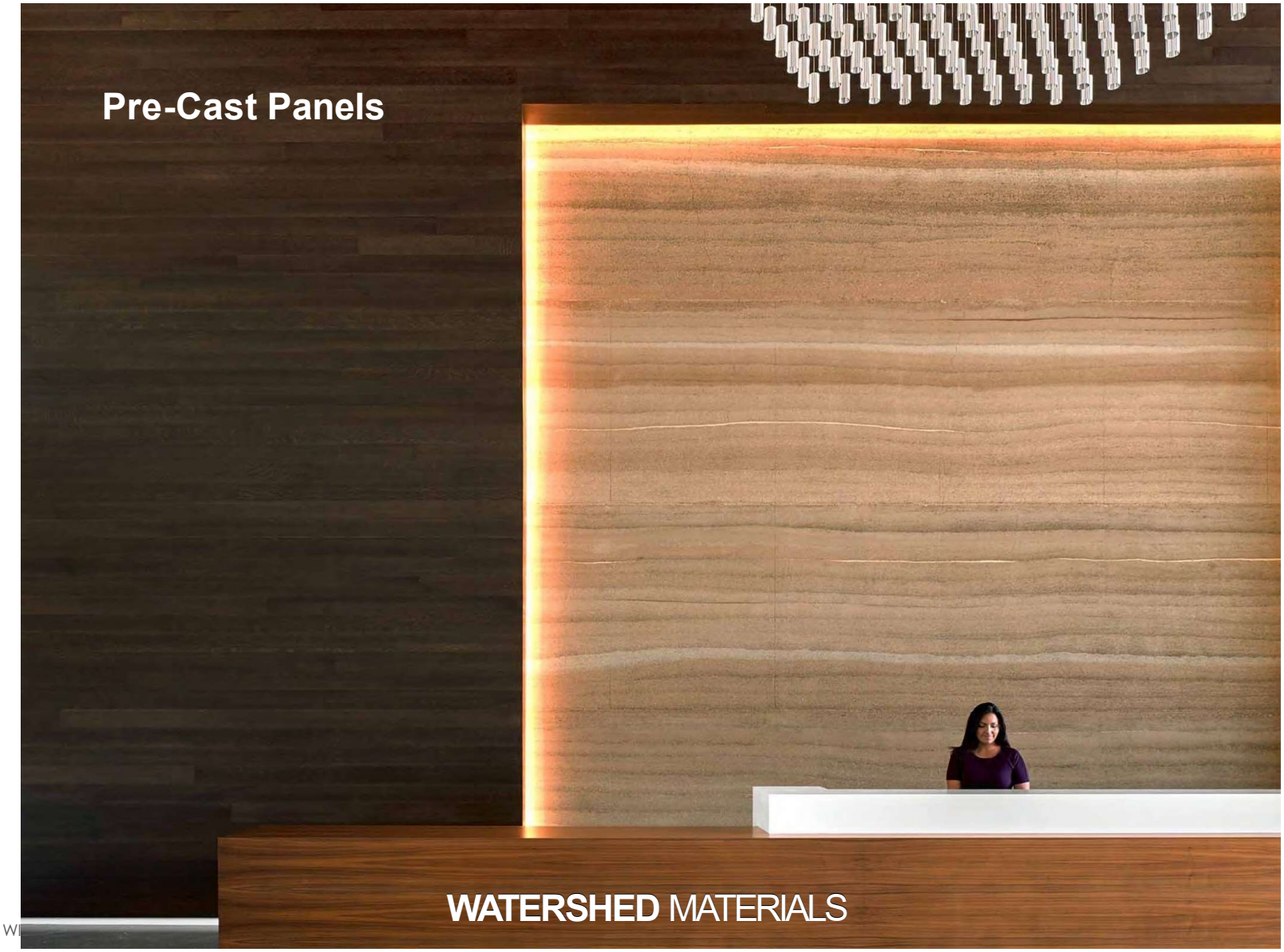


Products

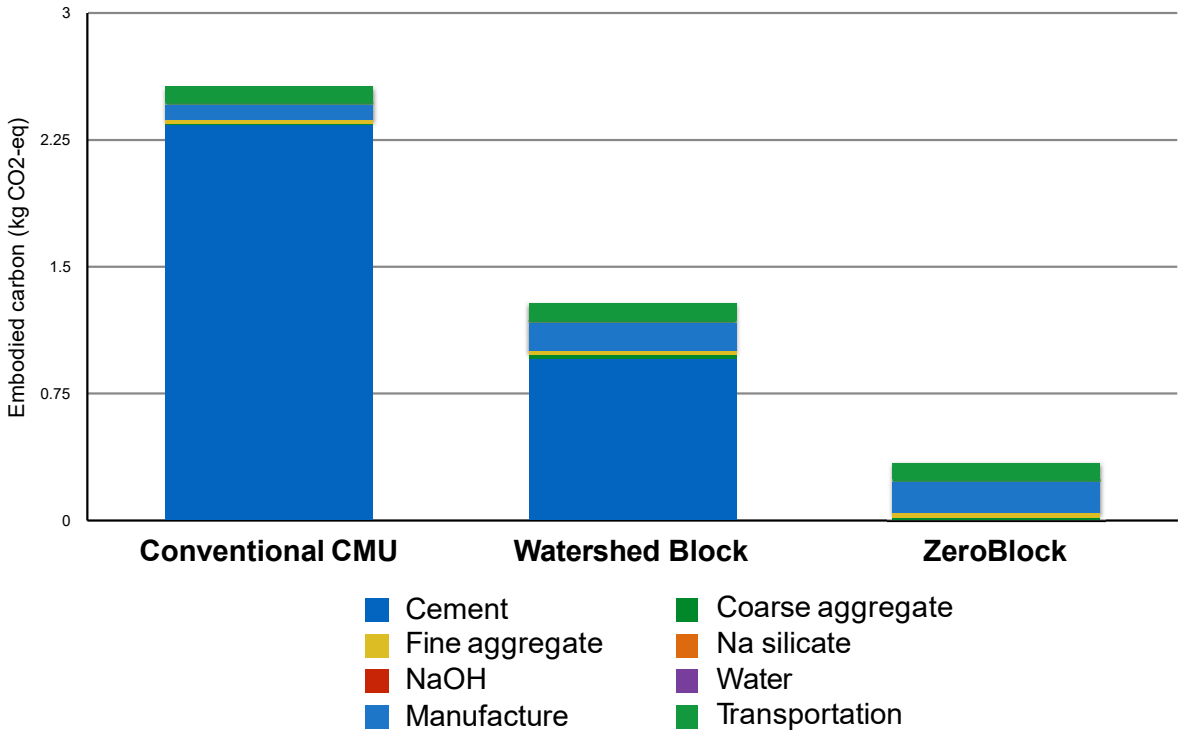




Pre-Cast Panels



Embodied Carbon Analysis of Blocks



- **Watershed Block 45% lower** CO_2e emissions than CMU
- **ZeroBlock** (recycled alkali activators) 87% lower than CMU

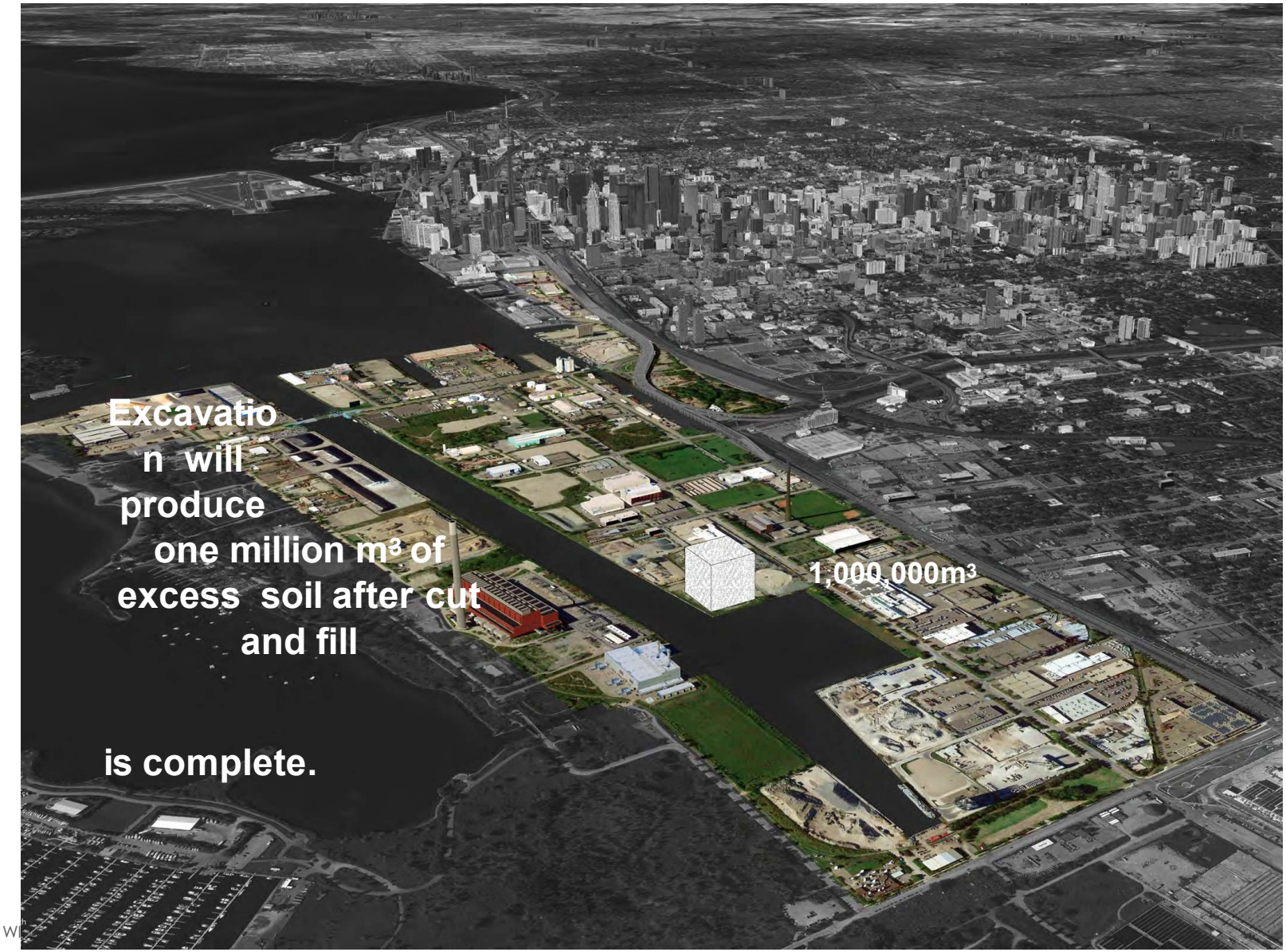
Source: Dahmen, Joseph, Juchan Kim, and Claudianne Ouellet-Plamondon. 2017. "Life cycle assessment of emergent masonry blocks." *Journal of Cleaner Production* 171 (October): 1622-1637.*

Sidewalk Toronto
Quayside Redevelopment

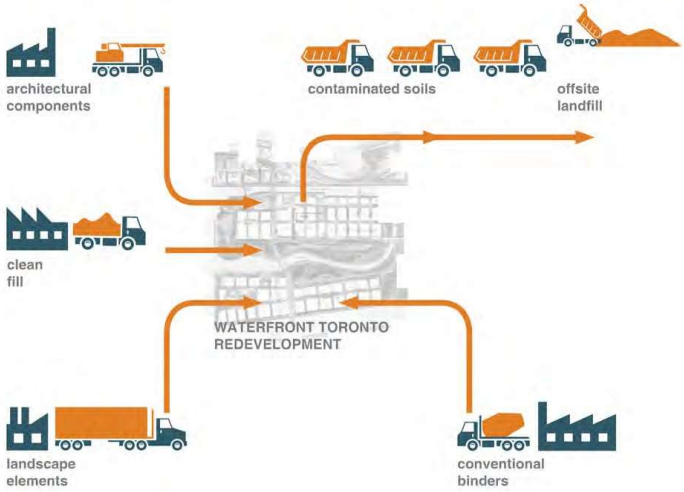
Sidewalk Toronto Quayside Redevelopment

- **US $4.5B 77 hectare (190 acre) proposed sustainable redevelopment of postindustrial land in Toronto**
- **Reroute lower Don River to provide new park**
- **Municipal, provincial, federal and private industry partnership**

WATERSHED MATERIALS

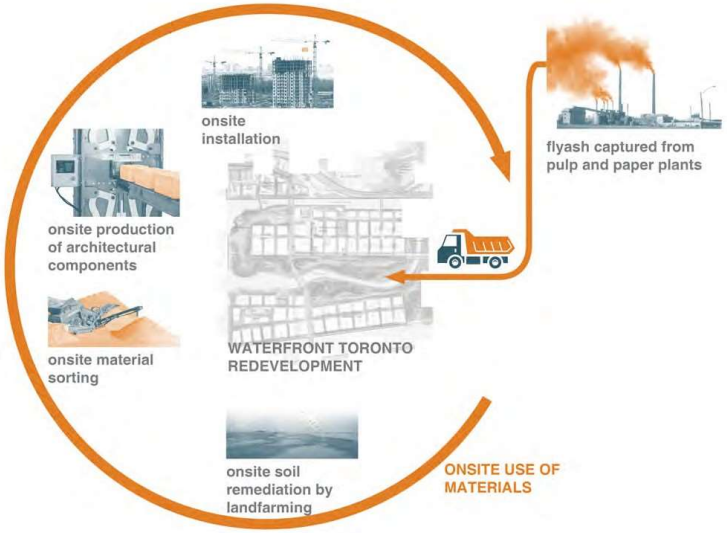


Linear

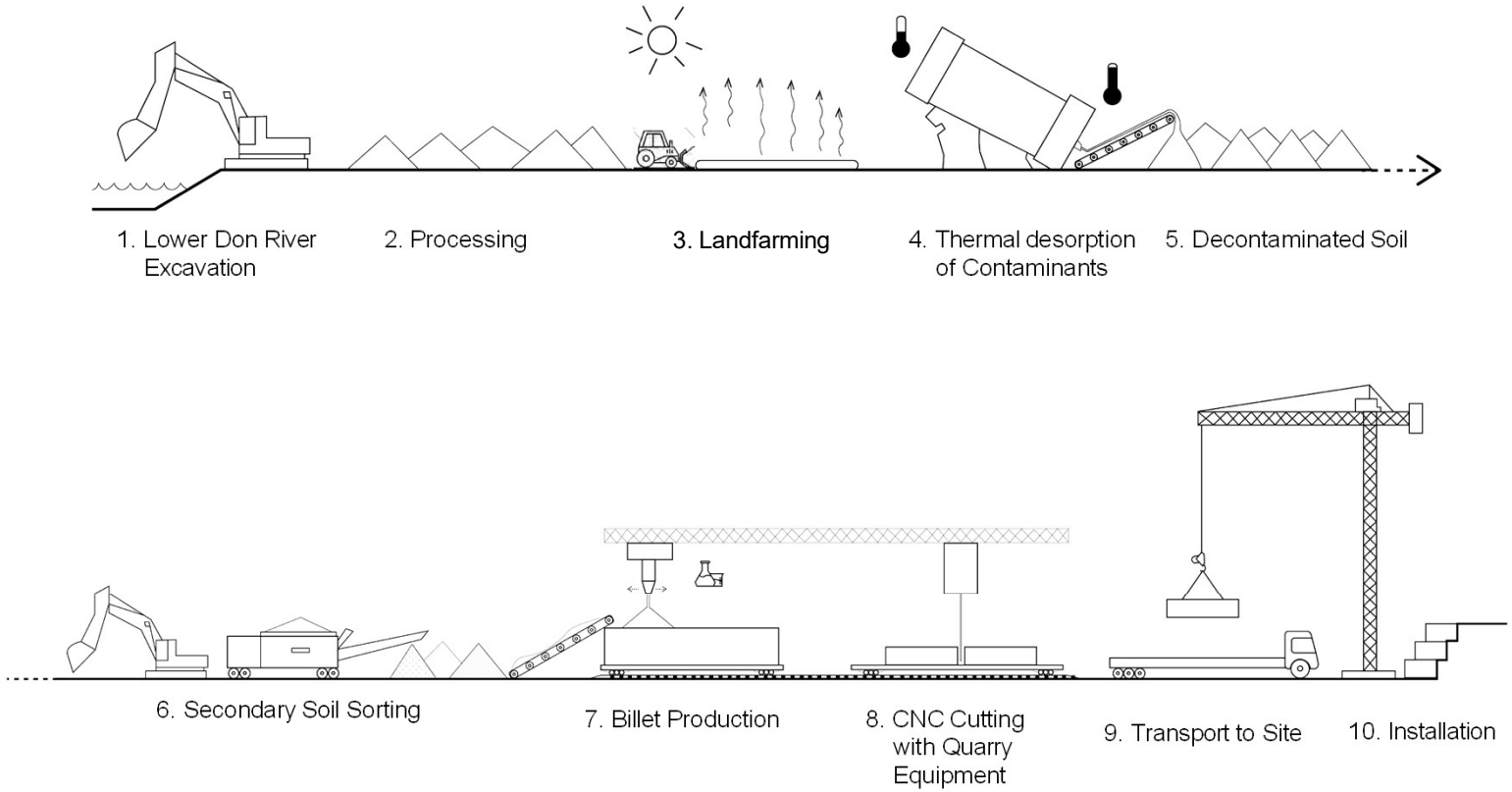


83MMT tonnes of CO_2 emissions
$40-50M Cost of transport and disposal

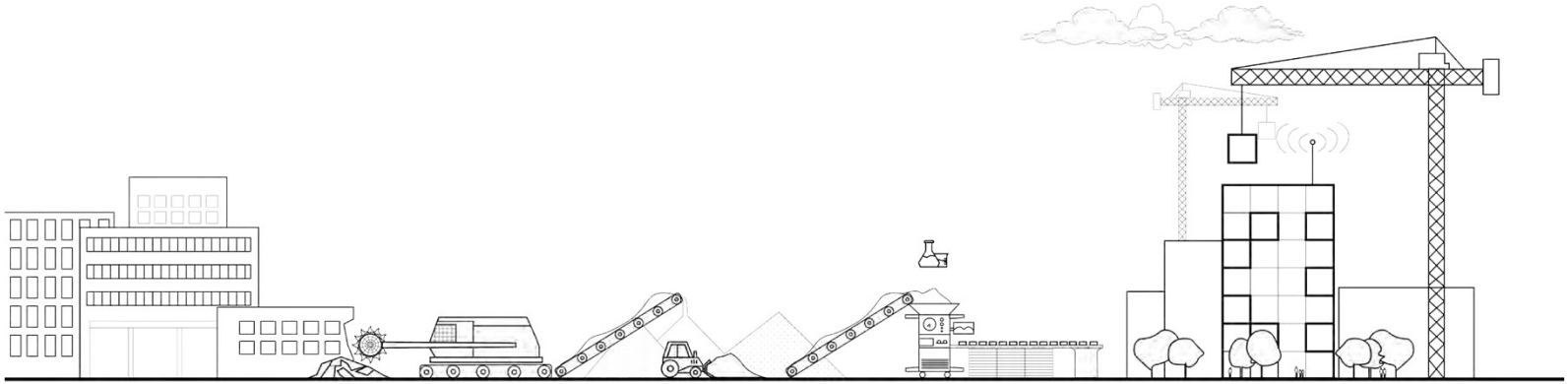
Circular



$350M of materials from local soils
$4-5M cost of transport and disposal



Rerouting the Don River provides materials for constructing the city



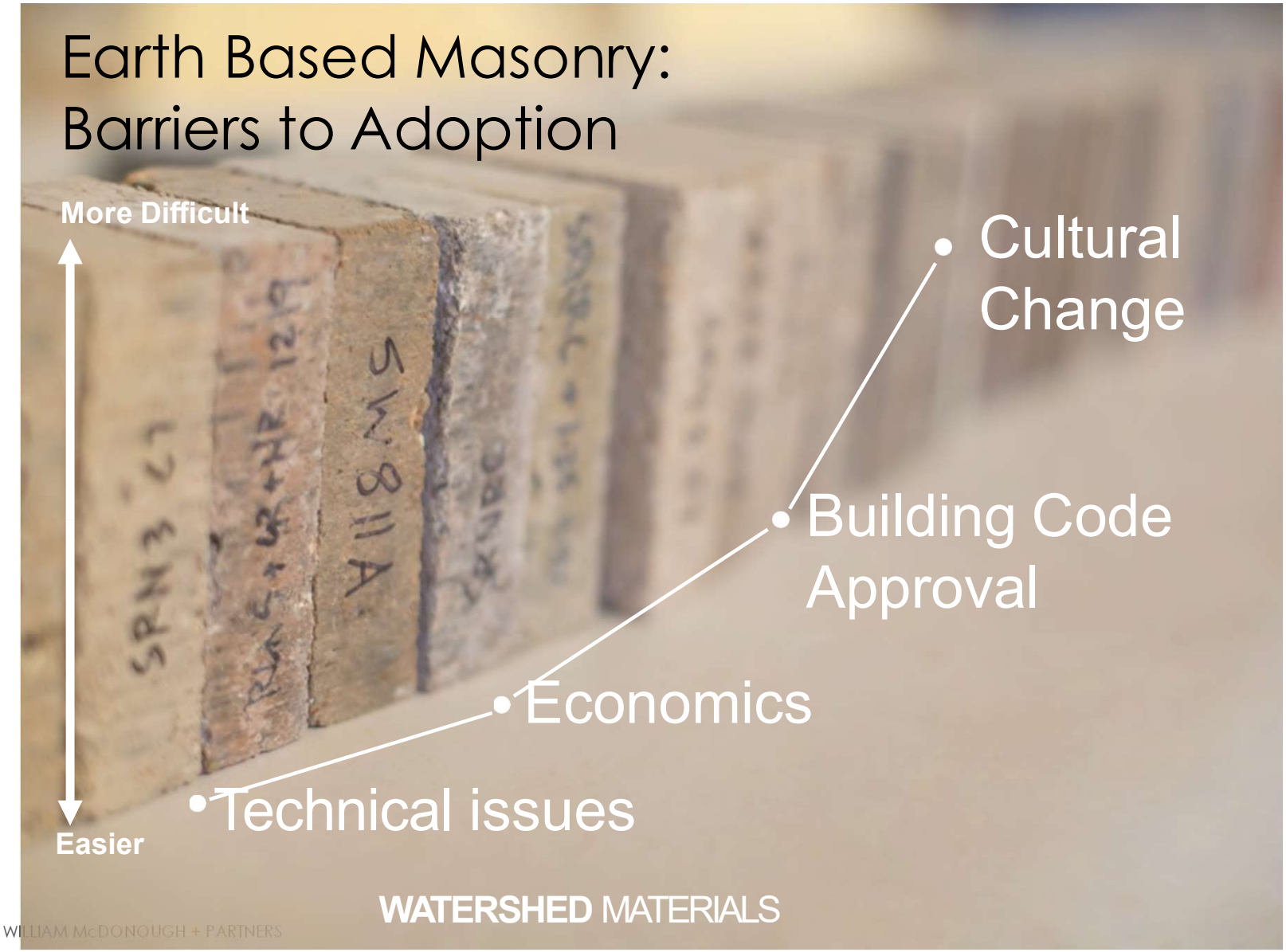
1. Demolition of existing buildings

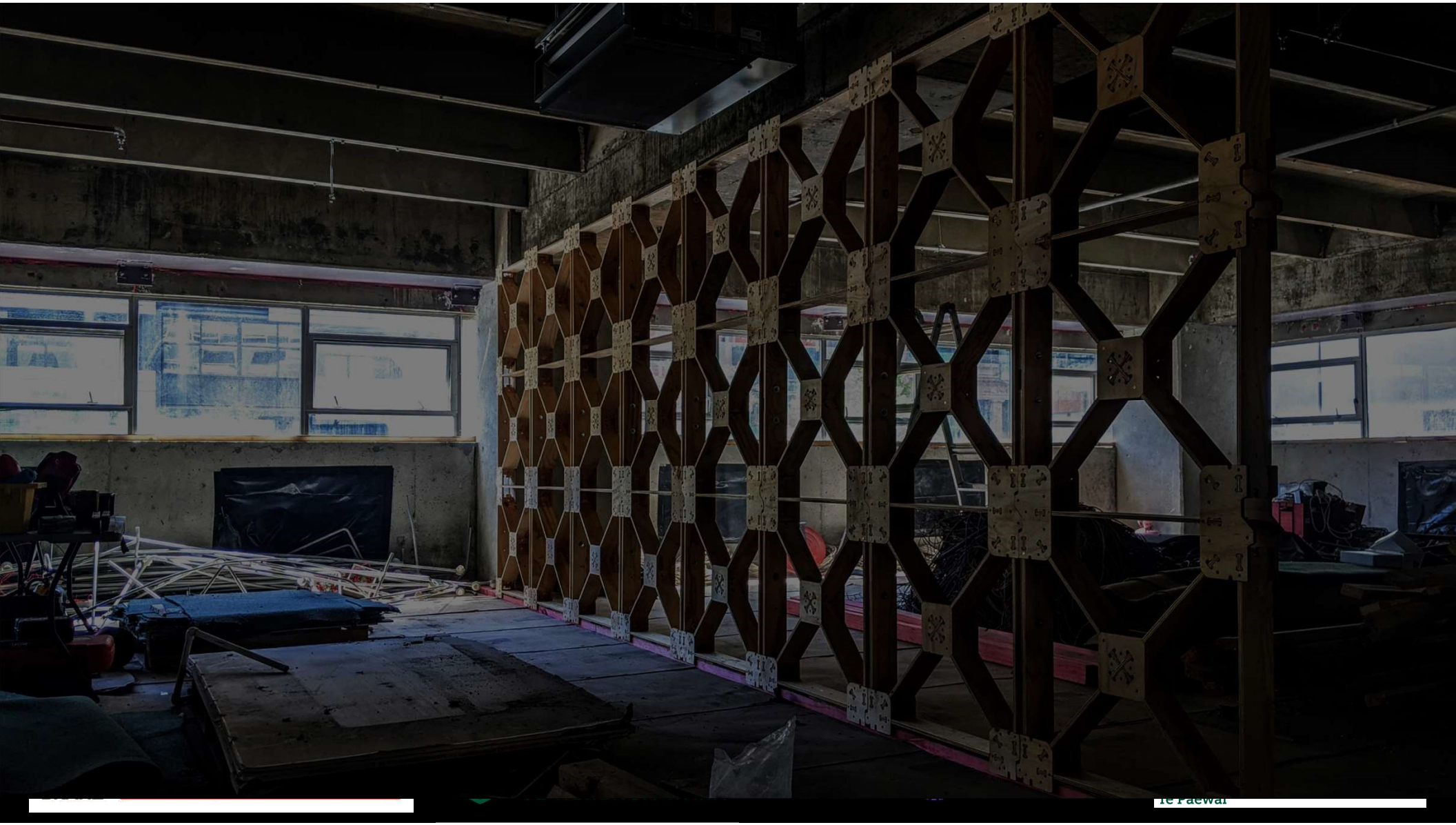
2. Aggregate production from demolition waste and excavation

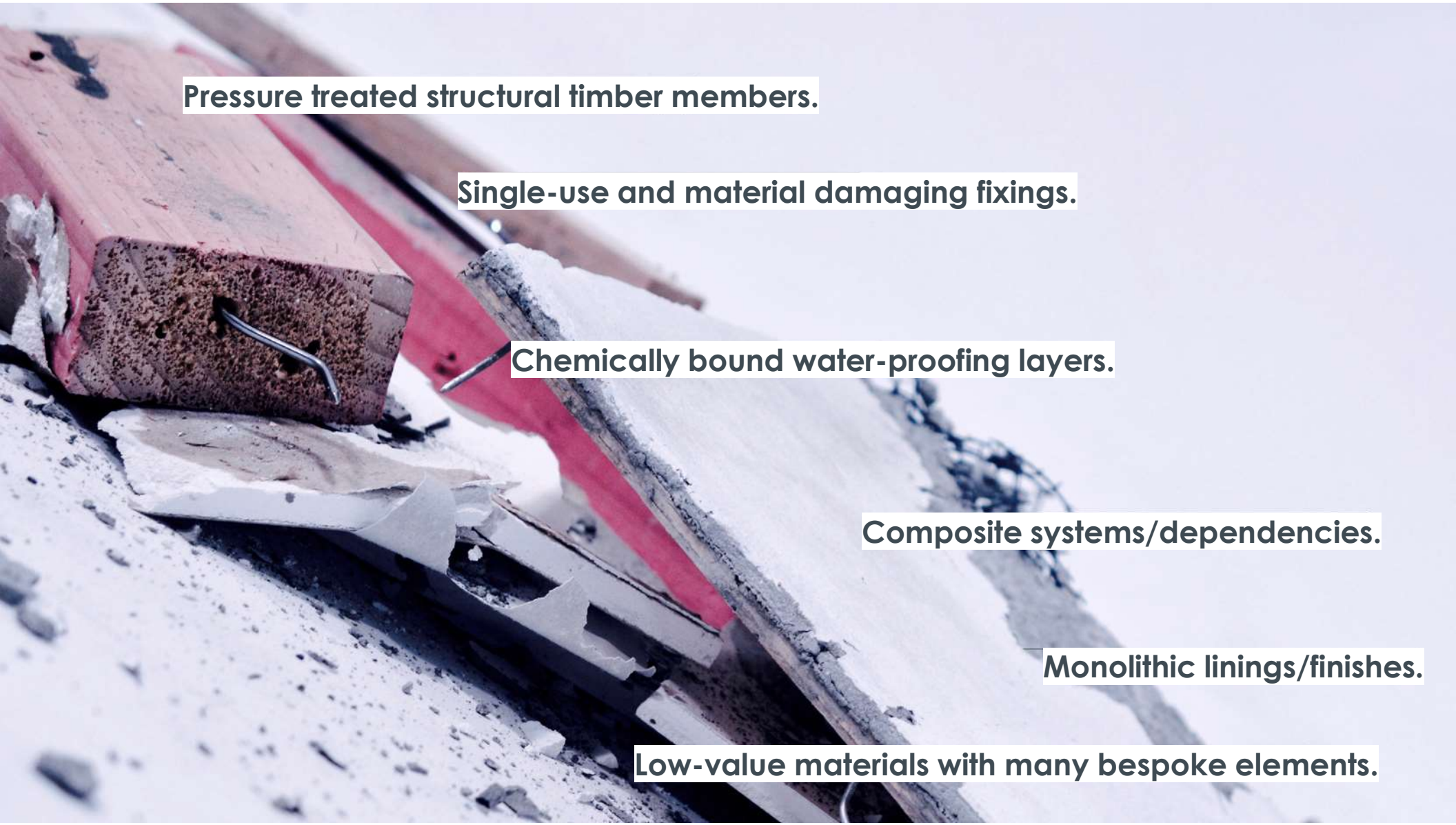
3. Architectural materials produced with Watershed equipment

4. Watershed Blocks used to redevelop the city

Demolition of obsolete buildings provides valuable aggregates





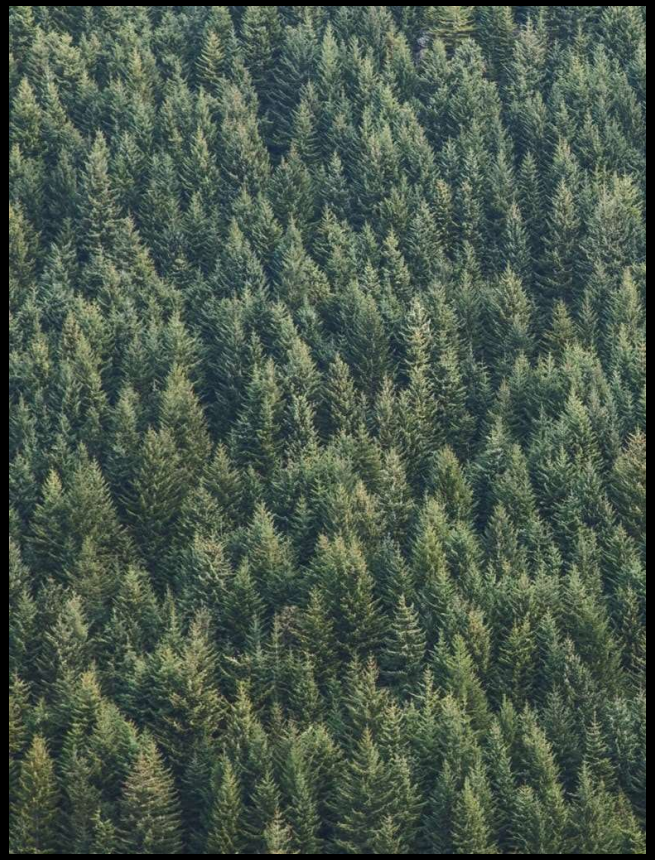

Pressure treated structural timber members.
Single-use and material damaging fixings.
Chemically bound water-proofing layers.
Composite systems/dependencies.
Monolithic linings/finishes.
Low-value materials with many bespoke elements.

Circular Economy Building Design Guidelines: (from Literature)

Discrete Design Characteristics	**Qualitative Design Characteristics**	**Measurable Design Characteristics** (for 1m^2 wall)
Use recycled and recyclable materials.	Use light-weight materials and components.	The number of different material types (lower is better).
Make in-separable subassemblies from the same materials	Provide end-of-life identification of different material types.	The number of connections (lower is better).
Do not use secondary finishes (i.e. such as chemical timber preservatives/modifiers).	Make components sized to suit the means of handling.	The numbers different types of connections (lower is better).
Do not use toxic and/or hazardous materials.	Use modular design (specifically a modular spatial component that allows solid elements to be directly substituted by transparent or transitional elements).	The quantity of materials with local high-value recycling potential after each use cycle (lower is better).
Use mechanical not chemical connections between different materials.	Design for realistic tolerances for assembly and disassembly over multiple use sequences.	The quantity of fully devalued (waste) materials produced after each use cycle (lower is better) (measured in weight and volume).
Separate the structure from the cladding to enable lifecycle based material separation.	Design to use common tools and equipment.	
	Design joints and components to withstand repeated use.	
	Use prefabrication and standardisation.	

Supporting References: *Galle et al, 2019; Moffatt and Russell, 2001; Mulhall and McDonough, 2009; Crowther, 2005; Guy and Ciarimboli, 2007; van de Westerlo, 2012; Schut et al, 2015; Ellen MacArthur Foundation, 2015; Verberne, 2016; Franklin-Johnson et al, 2016; Linder et al, 2016 and 2017; Cayzer et al, 2017; Saidant et al, 2017; Parchomenko, 2018; Nuñez-Cacho et al, 2018; Durmisevic, 2006*

X-Frame

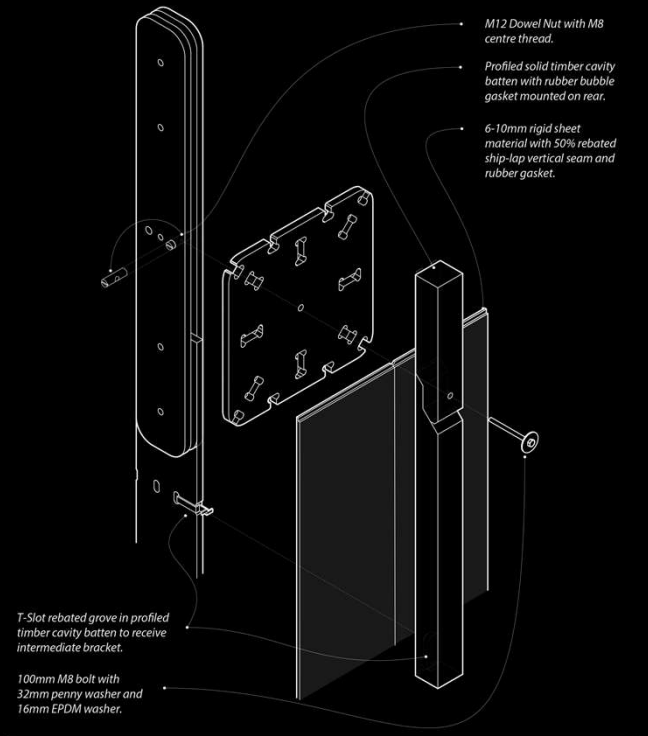


Locally grown and
sustainably harvested timber.

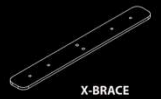
High value add local material and
product manufacturing.

High performance, waste free and
future ready buildings.

X-FRAME Weather Barrier ASSEMBLY
XF Version: Series 3DXf 12mm 900mm
Drawing Version: 310519



X-LOCK 1:1
x1

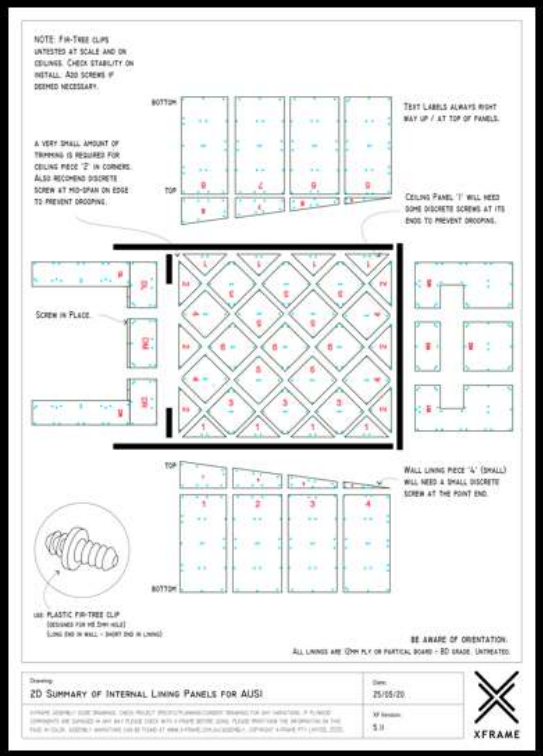


X-BRACE
x2

Components:
1x Dowel Nut
1x 100mm Bolt
1x 32mm Penny Washer
1x 16mm EPDM Washer
2x Profiled Cavity Battens
4x Rigid Air Barrier Sheet with ship-lap edge

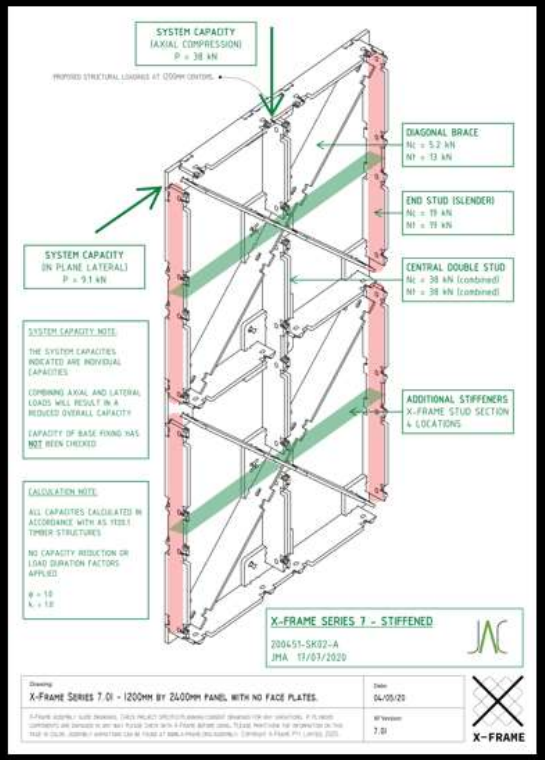
XFL2019 (SCALE 1:20).

A platform for envelope circularity.



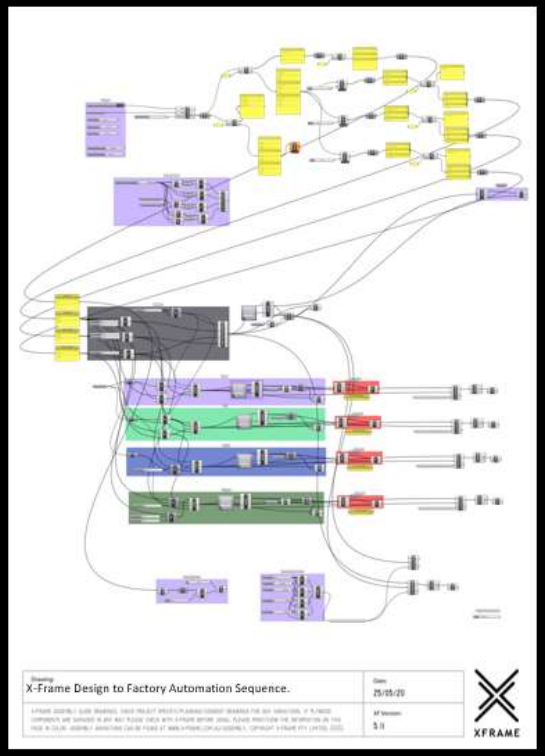
Kit-of-Parts

Flexible geometric rules and fulfillment algorithms mean that bespoke architecture while achieving 90% + standardisation (NS).



Structural Expandability

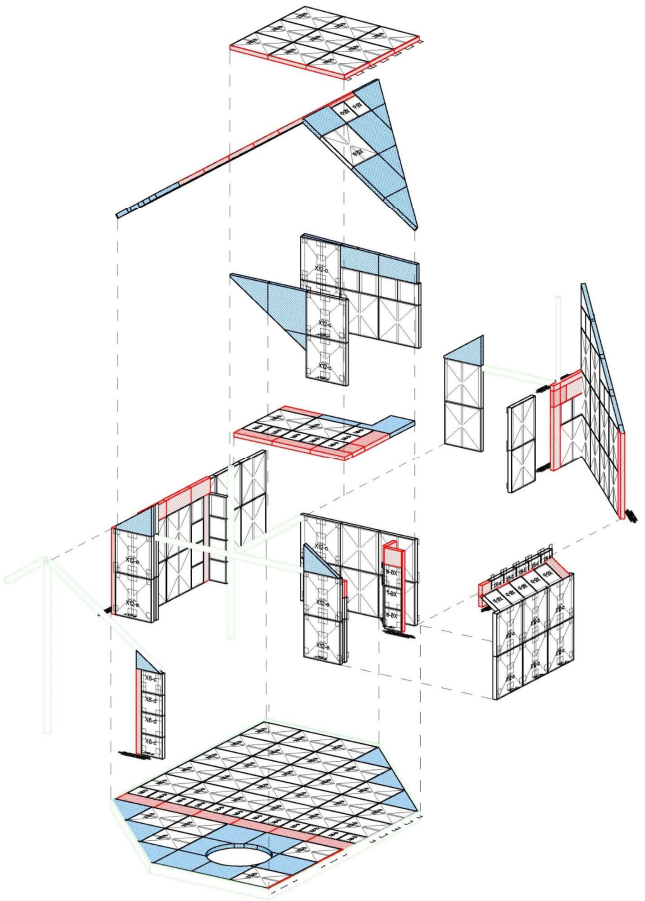
Allows parts to be swapped out as load requirements change based on site and design requirements.



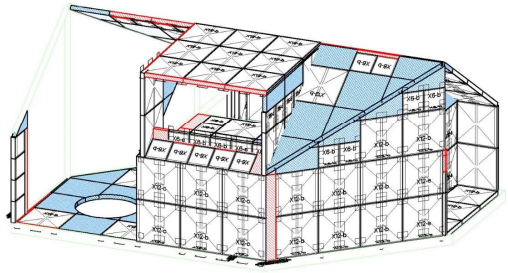
Process Automation

Integration with BIM tools allows for component tagging, custom part generation and logging part history.

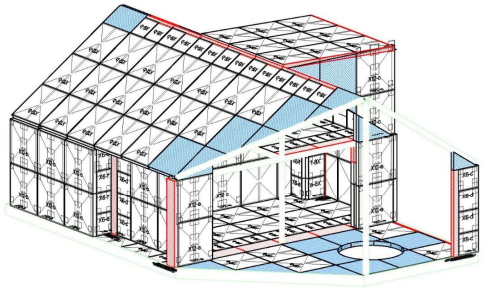
A closed loop system.



Framing 3D View 1
SCALE



Framing 3D View 2
SCALE



Framing 3D View 3
SCALE

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PROJECT
ASSEMBLY 3

DRAWING TITLE
Framing 3D

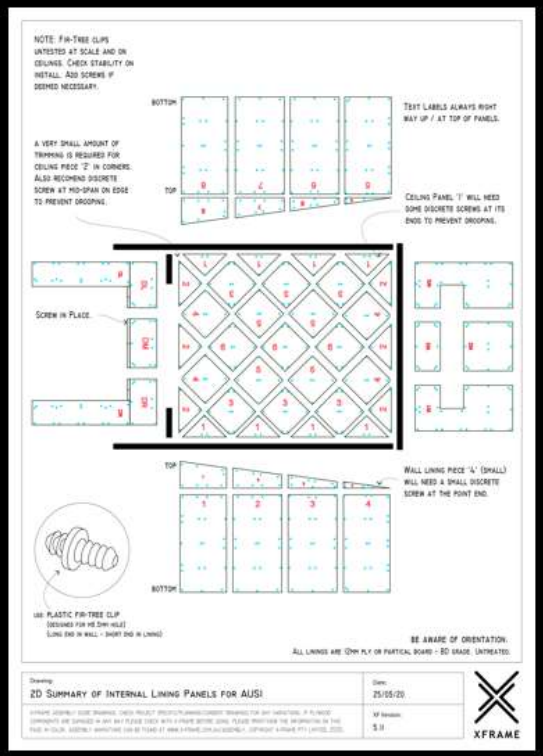
PROJECT NUMBER
0901-393

DRAWING NUMBER
A303

ISSUE
PRELIMINARY

DATE
27.08.2020

Plotted: 31/08/2020 10:45:23 AM File: I:\Library\Projects\0901\0901-393 Assembly 3 Prototype\06 Drawings\02 Revit or CAD\0901-393_3.rvt



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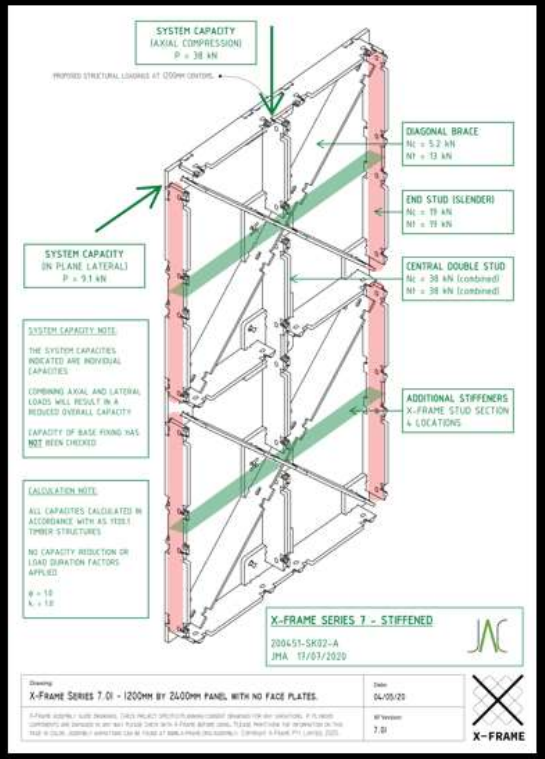

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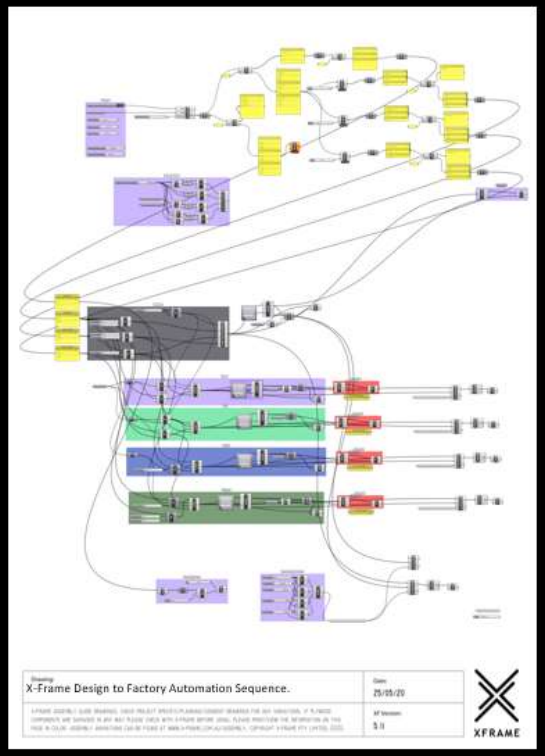


Process Automation

(Architect to X Frame to Fabrication workflow automation).

A closed loop system.

X-Frame ‘*Galloway*’ **Prototype Achieved;**

- **99.4% direct material recovery rate (by weight).**

  That is ‘direct reusability’, not recycling.

- **Living Building Challenge Red-List Free Assembly**

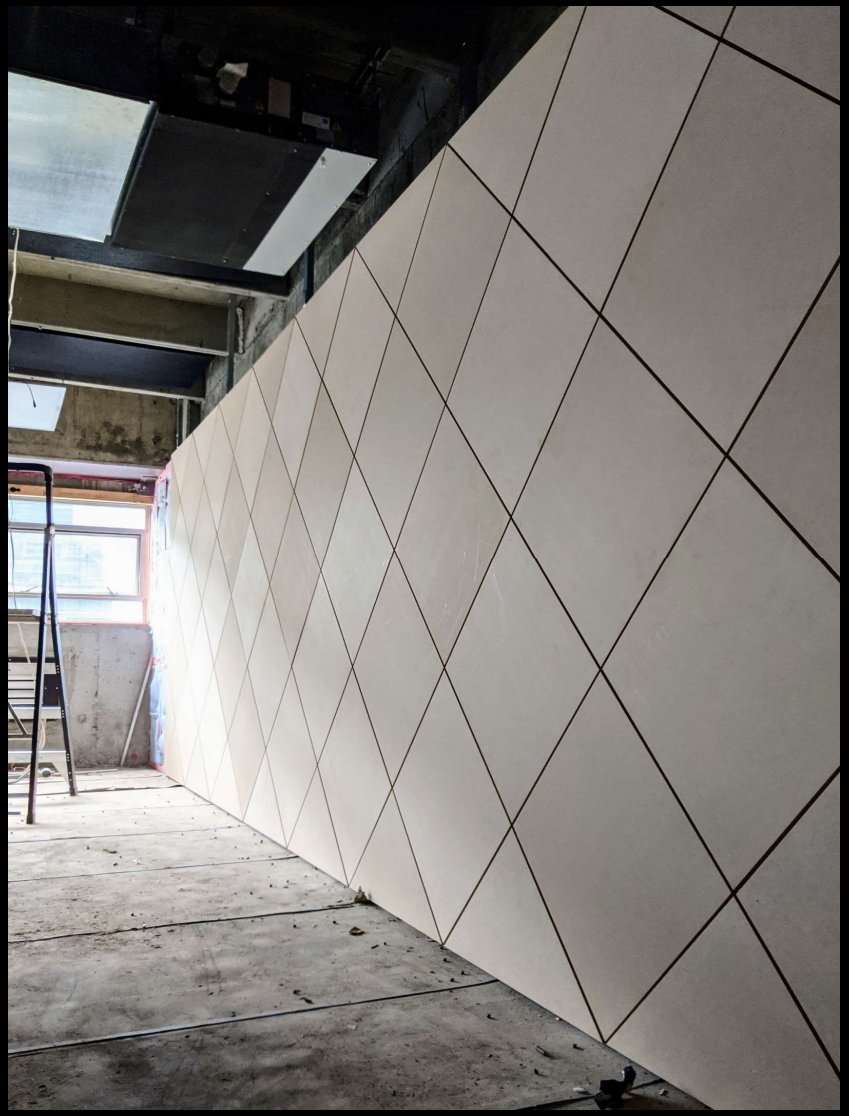
- **2/3rds reduction in material recovery time**.

  A consequence of using 90% less fixings (vs. Platform Framing).

  A consequence of not needing to ‘de-nail’ or ‘process’.

- **Carbon Negative (-35.62kgC0^2-equiv. per m^2 of wall area).**

Performance/What is Achievable/The Potential



- **Regulations/Compliance/Certification**
  - New Zealand Building Codes are Risk Adverse/Conservative.
  - Many building codes prohibit the reuse of structural timbers.
  - Insuring the product(s) through multiple cycles is challenging.

- **Consumer/Client & Building/Architect/Specifier Adoption**
  - Many consumers still operate on a ‘single bottom line’.
  - Consumers do not fully understand the value proposition.
  - Many builders see a product like this as high-risk.

- **Technical Circular Functionality**
  - Buildings long life-cycles pose challenges to technical circularity.
  - High-Performance building envelopes (conventionally) demand circular compromising materials/methods.

Challenges we face.

TIMBER FRAMING FOR A CIRCULAR ECONOMY

Presented by Ged Finch
Doctoral Candidate at Victoria University of Wellington and Director of X-Frame

Contact: ged@xframe.com.au

Thank You!

BRANZ Funded from the Building Research Levy

Victoria University of Wellington Te Herenga Waka

INNOVYZ

Wellington UniVentures Te Paewai

Q&A Session

- **Poll:**
  - In what ways do you think BTO can best contribute to advancing progress of lifecycle carbon in buildings?
- **Use the Q&A feature to ask a question**
- **Panelists**
  - **Eveline Jonkhoff** – Program Manager, Circular Economy, City of Amsterdam
  - **Alastair Reilly** – Design Partner, William McDonough+Partners
  - **Joe Dahmen** – Director of Sustainability and Co-founder, Watershed Materials
  - **Ged Finch** – Director, X-frame
  - **Joan Glickman** – Program Manager & Lead of DOE's Advanced Buildings Construction Initiative, U.S. DOE Building Technologies Office

Slides, recordings and transcripts on our website!

1. Overview of life cycle impacts of buildings
2. Challenges of assessing life cycle impacts of buildings
3. Innovative building materials
4. “Real Life” buildings striving to minimize life cycle impacts
5. Intersection of life cycle impacts & circular economy potential for the building sector

https://www.energy.gov/eere/buildings/articles/bto-life-cycle-impacts-webinar-series