CIRCULAR ECONOMY IN ARCHITECTURE

2021
October

Pic by Etienne Girardet on Unsplash

Architectural Design 3. Ningbo University
Dr. Mia Tedjosaputro

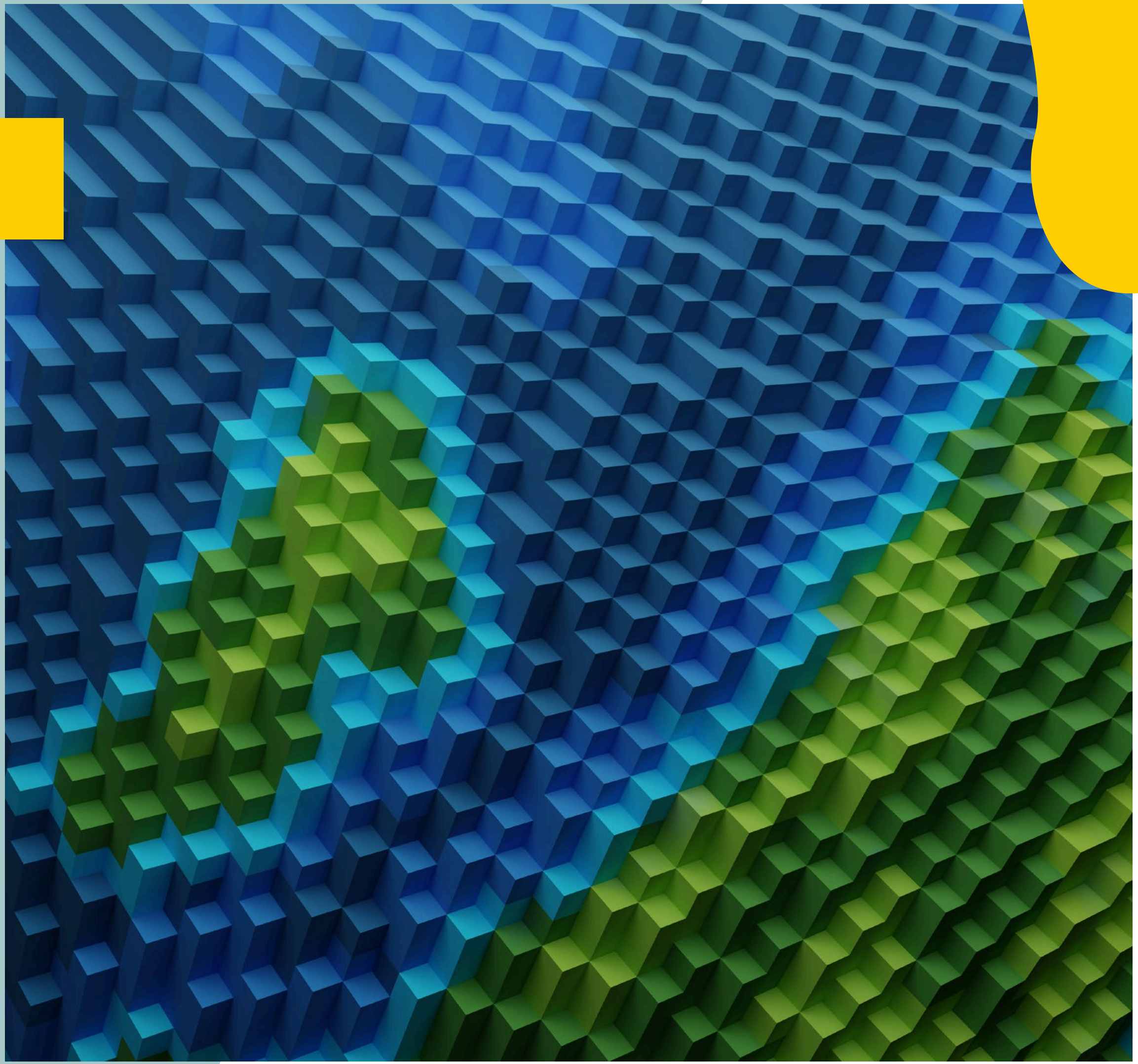


Photo by SIMON LEE on Unsplash

AIMS AND OBJECTIVES

To introduce the Circular Economy in Architecture and its related concepts.

To illustrate that the building industry as one of the main contributors on carbon dioxide emission and material scarcity.

To expand the notion that as future architects, we have the means to contribute through our design practice

LEARNING OUTCOMES

<u>Students will be able to..</u>

Understand the imminent need to change the way built environment is designed

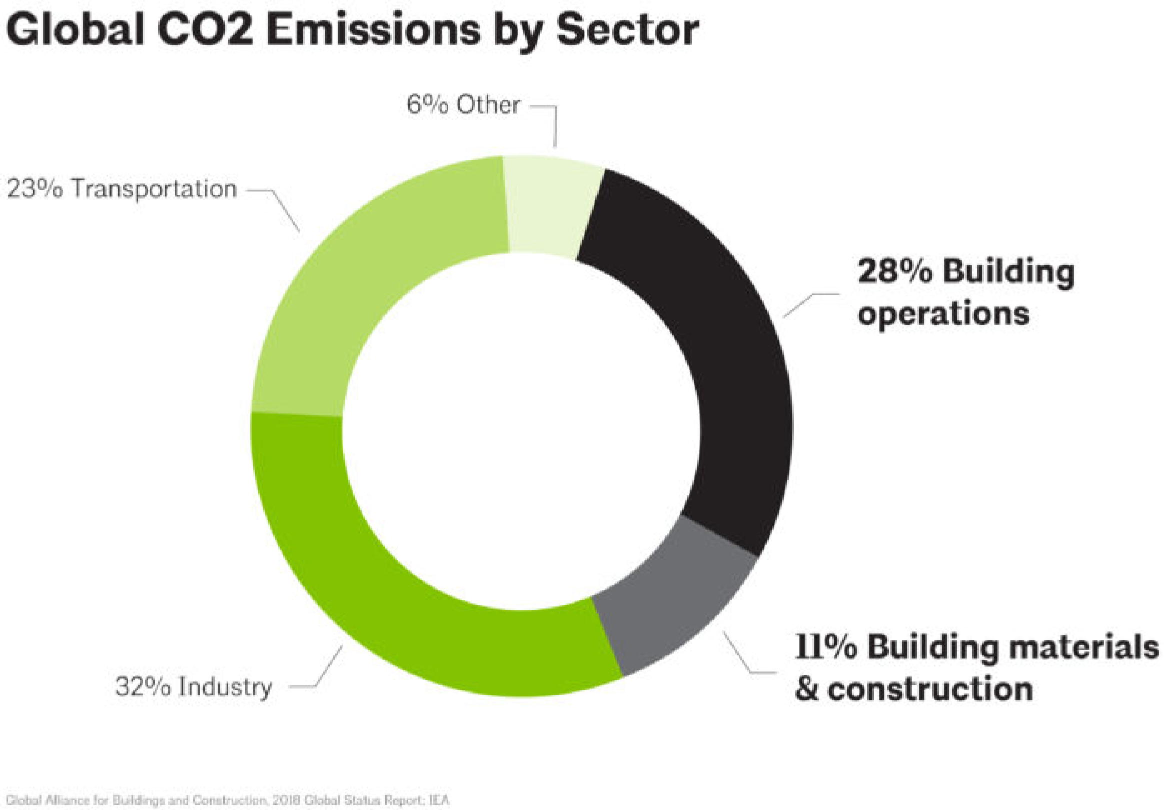
Understand the role of architects in circular economy (CE)

Implement CE strategies for future design practice

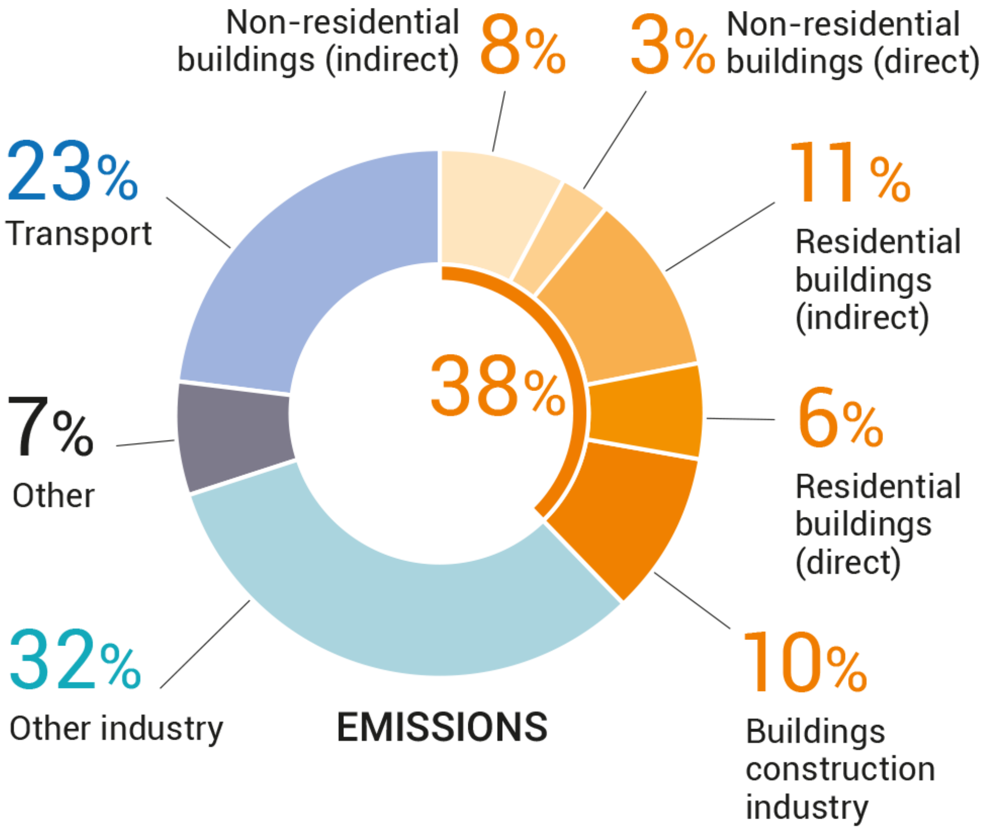
Grasp the potential barriers

OUTLINE

1. Rationale and existing problems
2. Circular Economy (CE) and its related concepts
3. Circular Economy in architecture and Circular Building (CB)
4. Key CB strategies
5. Design precedents
6. Key takeaways



2018



2020

Launched: 2020 GLOBAL STATUS REPORT FOR BUILDINGS AND CONSTRUCTION | Globalabc

Rationale and existing problems

THE LEAST SUSTAINABLE SECTOR

- The largest consumers of natural resources and major user of the world's non-renewable resources that has negative impact toward biodiversity around the world

-

Estimate of global resources used in buildings [1]

Resource	(%)
Energy	45–50
Water	50
Materials for buildings and roads (by bulk)	60
Agricultural land loss to buildings	80
Timber products for construction	60 (90% of hardwoods)
Coral reef destruction	50 (indirect)
Rainforest destruction	25 (indirect)

(Willmott Dixon, 2010)

- Materials used is predicted to three times higher in 2030 due to exponential population growth
- Regeneration rate of resources is lower than the consumption rate (Rahla, Mateus and Braganca, 2021).

WASTE AND EMMISION PRODUCER

- Construction and Demolition Waste (CDW) accounts for at least 30% of the total solid waste produced around the world
- Indonesia estimates to generate 29 million tones of CDW every year
- CDW waste recycled in emerging country like Indonesia is estimated only 15% , while 85% waste dumped or disposed in landfills (Bundesanstalt für Geowissenschaften und Rohstoffe, 2021)
- Other pollution is seen below:

Estimate of global pollution that can be attributed to buildings [2]

Pollution	(%)
Air quality (cities)	23
Climate change gases	50
Drinking water pollution	40
Landfill waste	50
Ozone depletion	50

INCREASING PRICE OF MATERIALS

- Materials price keep increasing over the years causing higher cost in building price
- In Indonesia, price increase of common building materials is more than 17% within the past five years
- Drivers of price incremental:
  - Recession of resources
  - Competition of resources
  - Disruptions of supply
  - Uncertainty of continuity of materials

(Akhimien, Latif and Hou, 2020).

-

[*Linear economy vs Circular economy*]

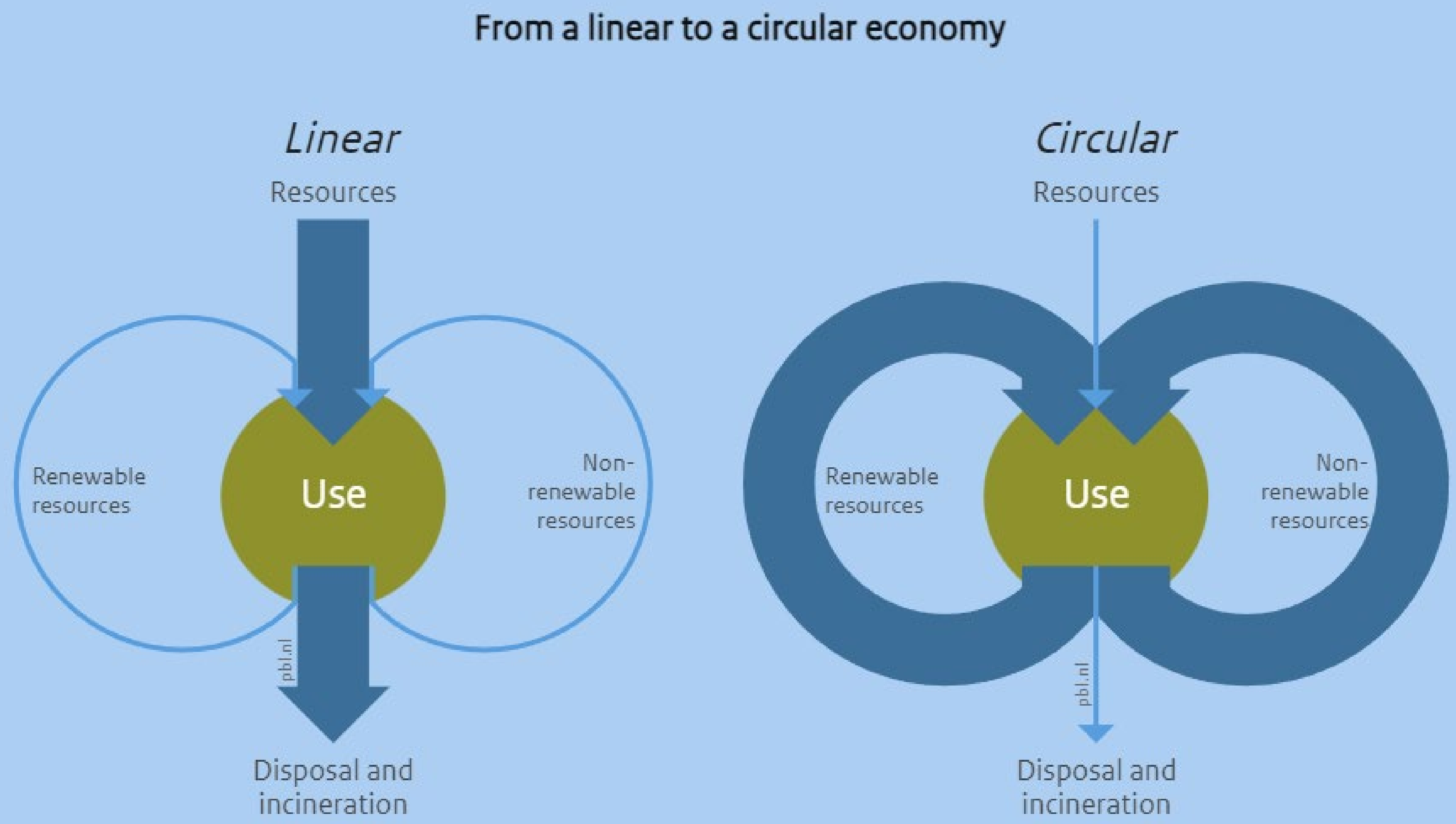
Linear Economy

“Take-make-dispose” sequence. Without recycling elements, this system cannot be sustainable.

Circular Economy (CE)

The core defining element is the “restorative use” of resources. Raw materials shall not become discarded waste.

CE makes use of optimal source of raw materials and resources

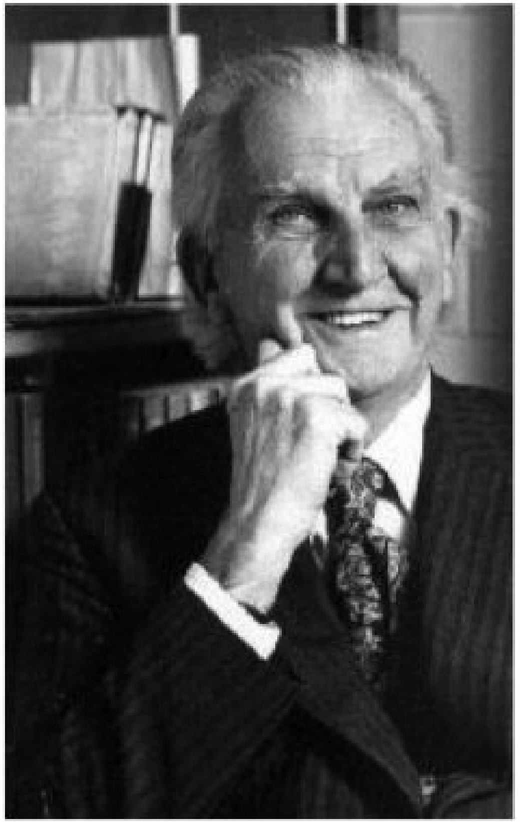


Opportunities for a circular economy - PBL Netherlands Environmental Assessment Agency

How is a circular economy different from a linear economy? - GroeneBrein (hetgroenebrein.nl)

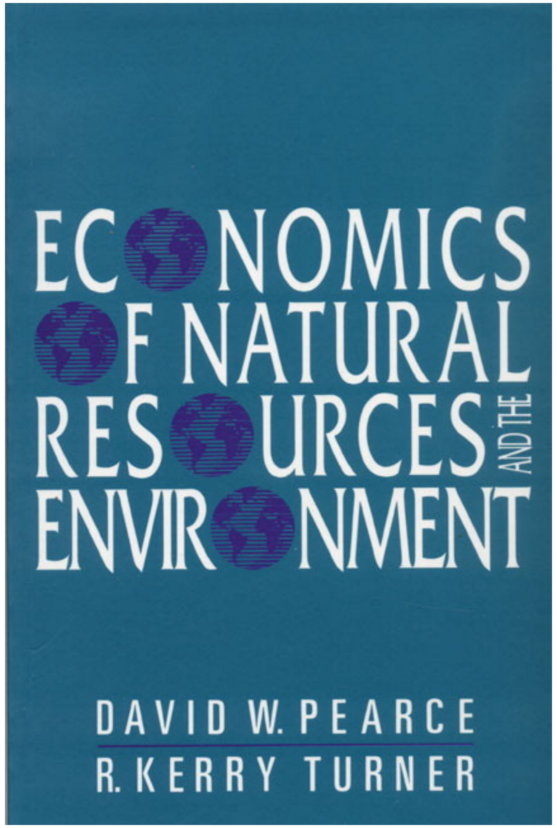
Circular Economy (CE)

The roots



- *The Economics of the Coming Spaceship Earth*

  By Kenneth E. Boulding, 1966



Boulding, K. E. (1966). The economics of the coming spaceship earth. *New York*.

Pearce, D. W., Turner, R. K. & Turner, R. K. (1990). *Economics of natural resources and the environment*, Johns Hopkins University Press.

Circular Economy (CE)

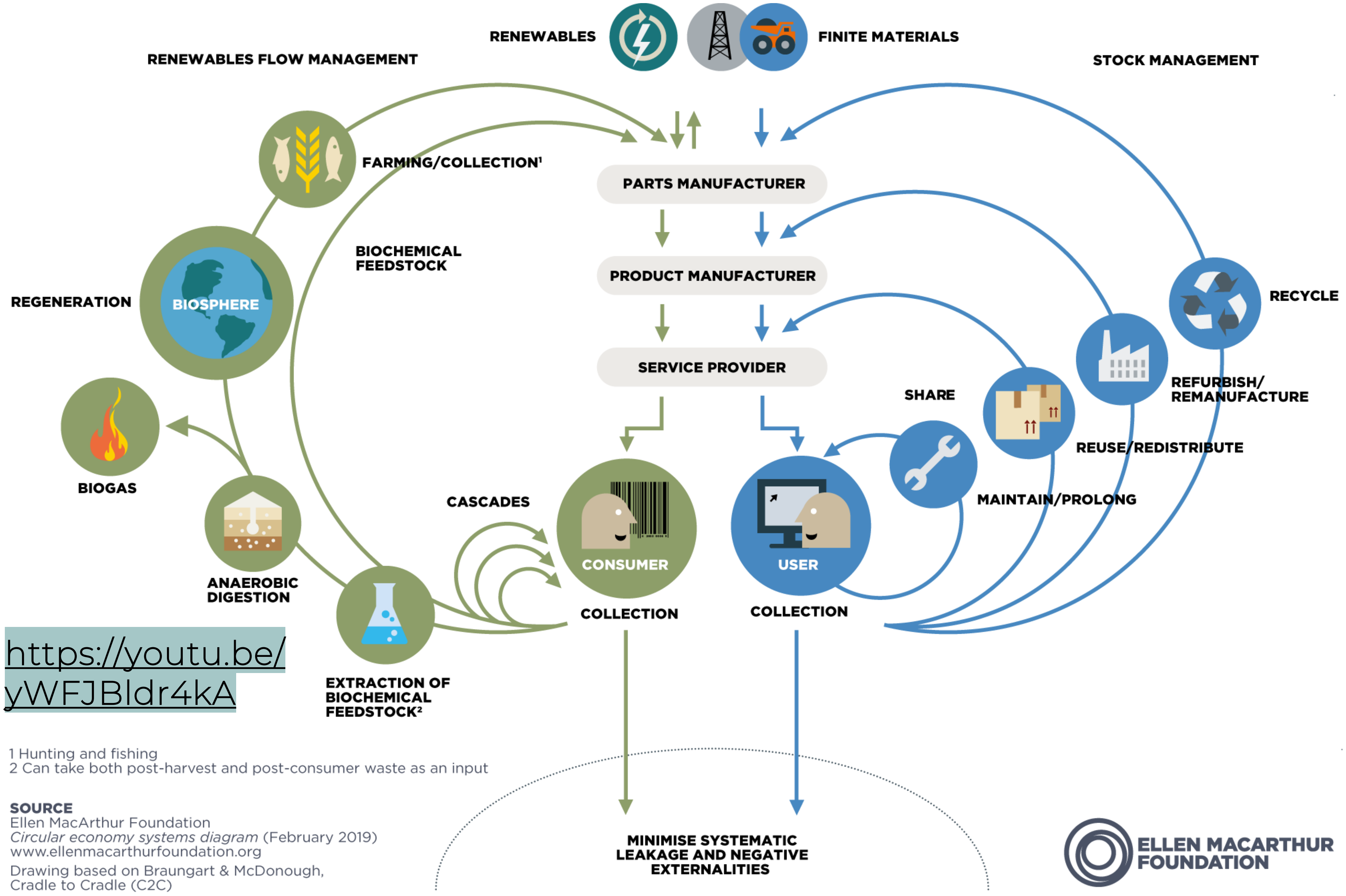
Definition

Most recognized definition in CE is offered by Ellen MacArthur Foundation
"A circular economy is one that is restorative and regenerative by design and aims to keep products, components and materials at their highest utility and value at all times, distinguishing between technical and biological cycles"

Generally it is referring to a 'closed-loop economy' that does not generate excessive waste and whereby any waste becomes a resource. (Wysokińska, 2016)

Kirchherr et al., (2017) analysed 114 definitions of CE, the authors ultimately defined it as:
"An economic system that replaces the 'end-of-life' concept with reducing, alternatively reusing, recycling and recovering materials in production/ distribution and consumption processes.... Operates in micro-level (products, companies, ...), meso-level (eco-industrial parks) and macro-level (city, region, nation and beyond).."

Biological Technical



https://youtu.be/yWFJBldr4kA

Related concepts

Cradle-to-cradle
Blue economy
Regenerative design
Closed-loop supply chain
...

Geisendorf, S. & Pietrulla, F. (2018). The circular economy and circular economic concepts—a literature analysis and redefinition. *Thunderbird International Business Review,* 60, 771-782.

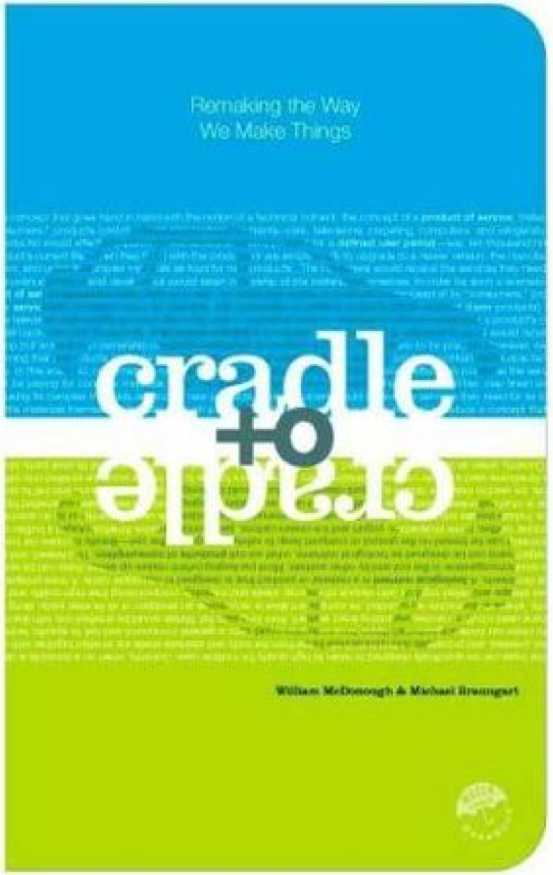
Related concepts

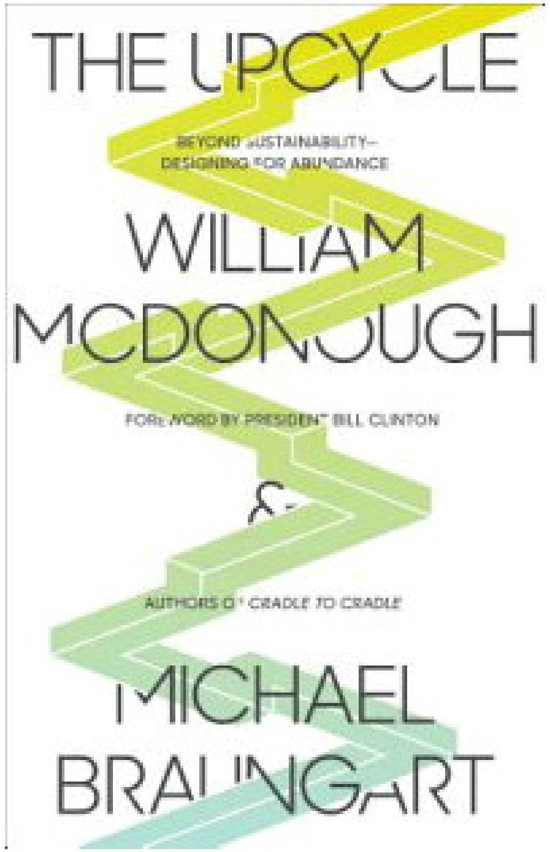
Cradle-to-cradle
Blue economy
Regenerative design
Closed supply chains
…

Geisendorf, S. & Pietrulla, F. (2018). The circular economy and circular economic concepts—a literature analysis and redefinition. *Thunderbird International Business Review*, 60, 771-782.

cradletocradle

https://www.ted.com/talks/william_mcdonough_cradle_to_cradle_design?utm_campaign=tedspread&utm_medium=referral&utm_source=tedcomshare



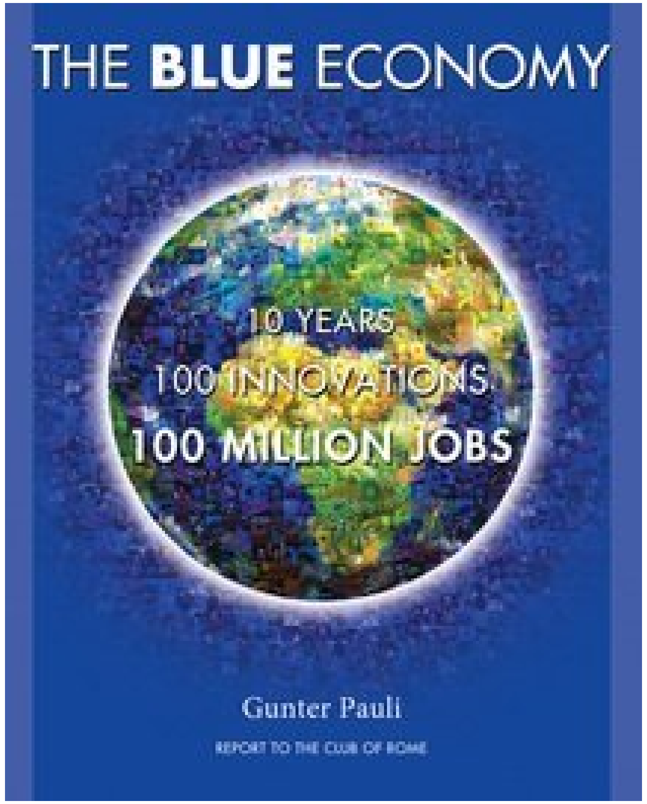


- C2C was developed by chemist Braungart and architect McDonough in 2002.
- The concept aims at minimising environmental damage of products through more sustainable production processes, distribution and disposal practices, and socially responsible products
- Put **emphasis on design stage**

Related concepts

Cradle-to-cradle
Blue economy
Regenerative design
Closed supply chains
…

Geisendorf, S. & Pietrulla, F. (2018). The circular economy and circular economic concepts—a literature analysis and redefinition. *Thunderbird International Business Review*, 60, 771-782.



https://youtu.be/1af08PSlaIs
https://youtu.be/kANI9LrUxUw

- This concept was introduced by Pauli in 2010
- The blue in blue economy refers to the colour of ocean and sky, representing the largest components if the planet.
- Basic principle Is that local environment is the basis of sustainable solutions.
- ***"We use what we have.." and start generating value***
- The blue economy aims at protecting the global ecosystem while creating job opportunities. It pursues a holistic approach, also addressing societal issue.

Related concepts

Cradle-to-cradle
Blue economy
Regenerative design
Closed supply chains
…

Geisendorf, S. & Pietrulla, F. (2018). The circular economy and circular economic concepts—a literature analysis and redefinition. *Thunderbird International Business Review*, 60, 771-782.

- Developed by John T. Lyle (1996), he was a professor in landscape architecture
- The word regenerative stands for the fact that energy and materials used for the design of products can be renewed or revitalised (Cole, 2012).
- All materials or waste need to be reintroduced into the system or metamorphosed into new valuable resources at the end of product's life.

Cole, R. J. (2012). Transitioning from green to regenerative design. *Building Research & Information*, 40, 39-53.
Lyle, J. T. (1996). *Regenerative design for sustainable development*, John Wiley & Sons.

Related concepts

Cradle-to-cradle
Blue economy
Regenerative design
Closed supply chains
…

Geisendorf, S. & Pietrulla, F. (2018). The circular economy and circular economic concepts—a literature analysis and redefinition. *Thunderbird International Business Review*, 60, 771-782.

- CSCs is also described as closed-loop supply chains, highlighting the importance of circularity
- Two factors of "closing the loop" are: product reuse and product recycling
- In other words, at the end of life of a product, consumers can engage in product returns activities: return broken/unwanted products, return reusable packaging.
- Products can also be dismantled
- They can also re-enter supply chain
- Consumer becomes the supplier

Circular Economy In Architecture

Fig. 1. Scheme of linear and circular economy model in construction ratio (own elaboration)

Mazur, Ł. K. (2021). Circular Economy in Housing Architecture: Methods of Implementation. *Acta Scientiarum Polonorum Architectura*, 20, 65-74.

Circular Economy
In Architecture

Circular Building (CB) Design

A successful CB design needs..

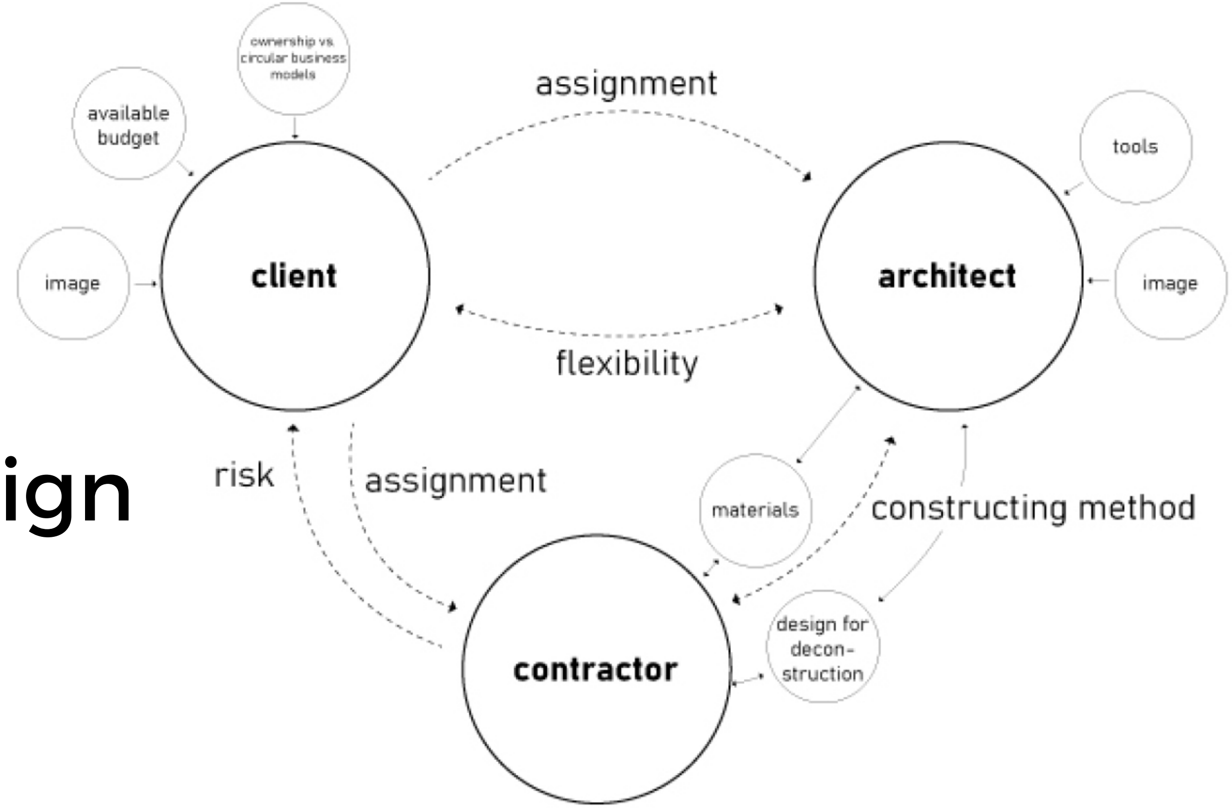


Figure 2. Graphical representation of the theoretical framework.

Kanters, J. (2020). Circular building design: An analysis of barriers and drivers for a circular building sector. *Buildings,* 10, 77.

What are the benefits?

Increased flexibility
Optimised operation and maintenance
Healthier building

Architects' roles

Architects as driver in the process/ flexibility in the process

Architects as innovator/entrepreneur/spin-off

Architect with deep material knowledge

Kanters, J. (2020). Circular building design: An analysis of barriers and drivers for a circular building sector. *Buildings*, 10, 77

What are the **barriers**?

There is **lack of standard methods** and tools to help architects to take the right decision.

Lack of flexibility to do things differently → can be seen as **a higher financial risk**

Transformation to a CE **is more difficult** as it is connected to other sectors → need to transform simultaneously

New circular building materials, components and services are needed to keep up with the demand

Lack of flexibility in **building codes and regulations** → too focus on energy use on operational phase rather than embodied energy

Mismatch between supply and demand of reused materials

Kanters, J. (2020). Circular building design: An analysis of barriers and drivers for a circular building sector. *Buildings*, 10, 77.

Key frameworks for Circular Building design

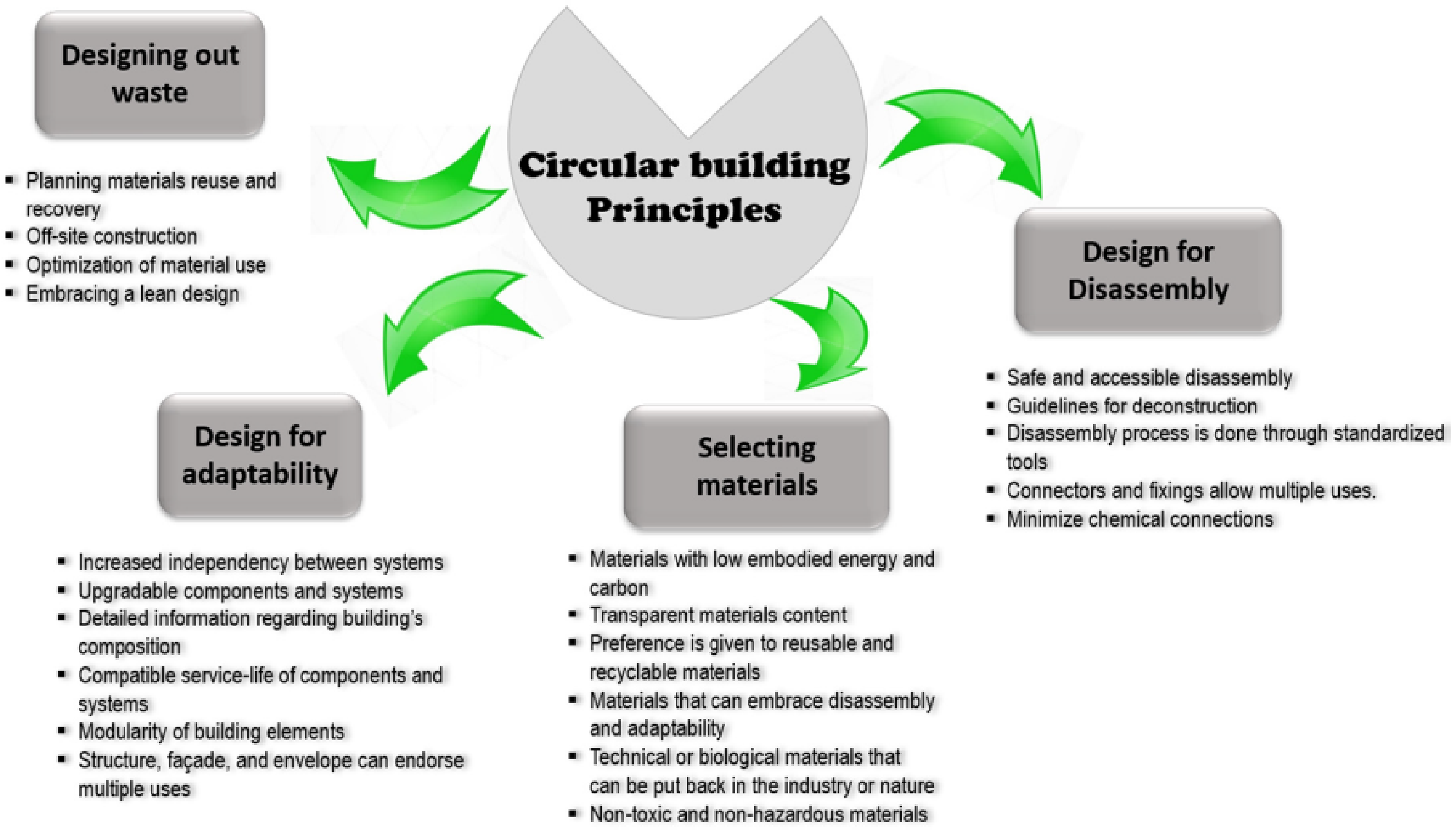
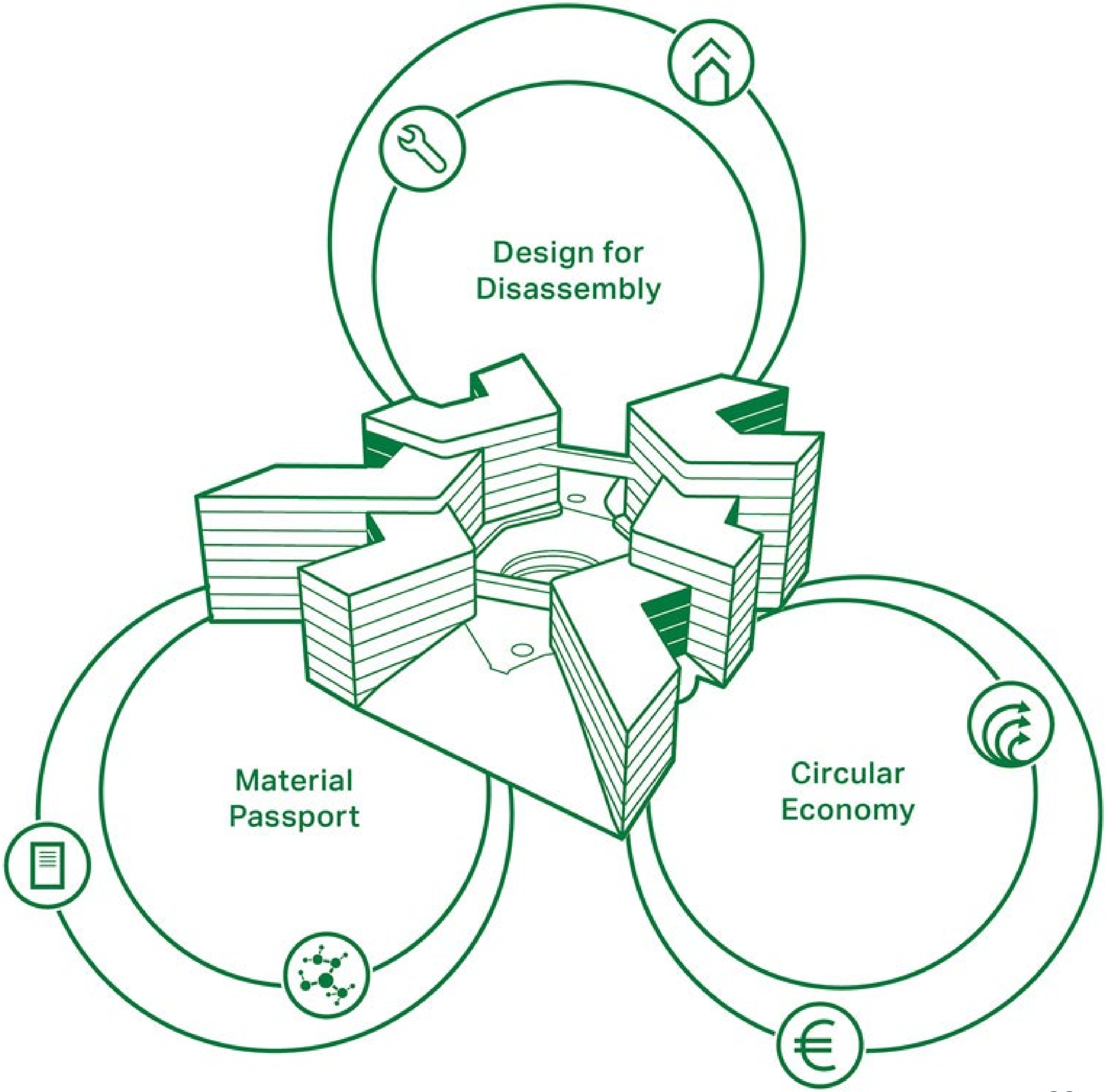


Figure 2. Design for Circular Economy.

Rahla, K. M., Mateus, R. & Bragança, L. (2021). Implementing Circular Economy Strategies in Buildings—From Theory to Practice. *Applied System Innovation*, 4, 26.

Key frameworks for Circular Building design

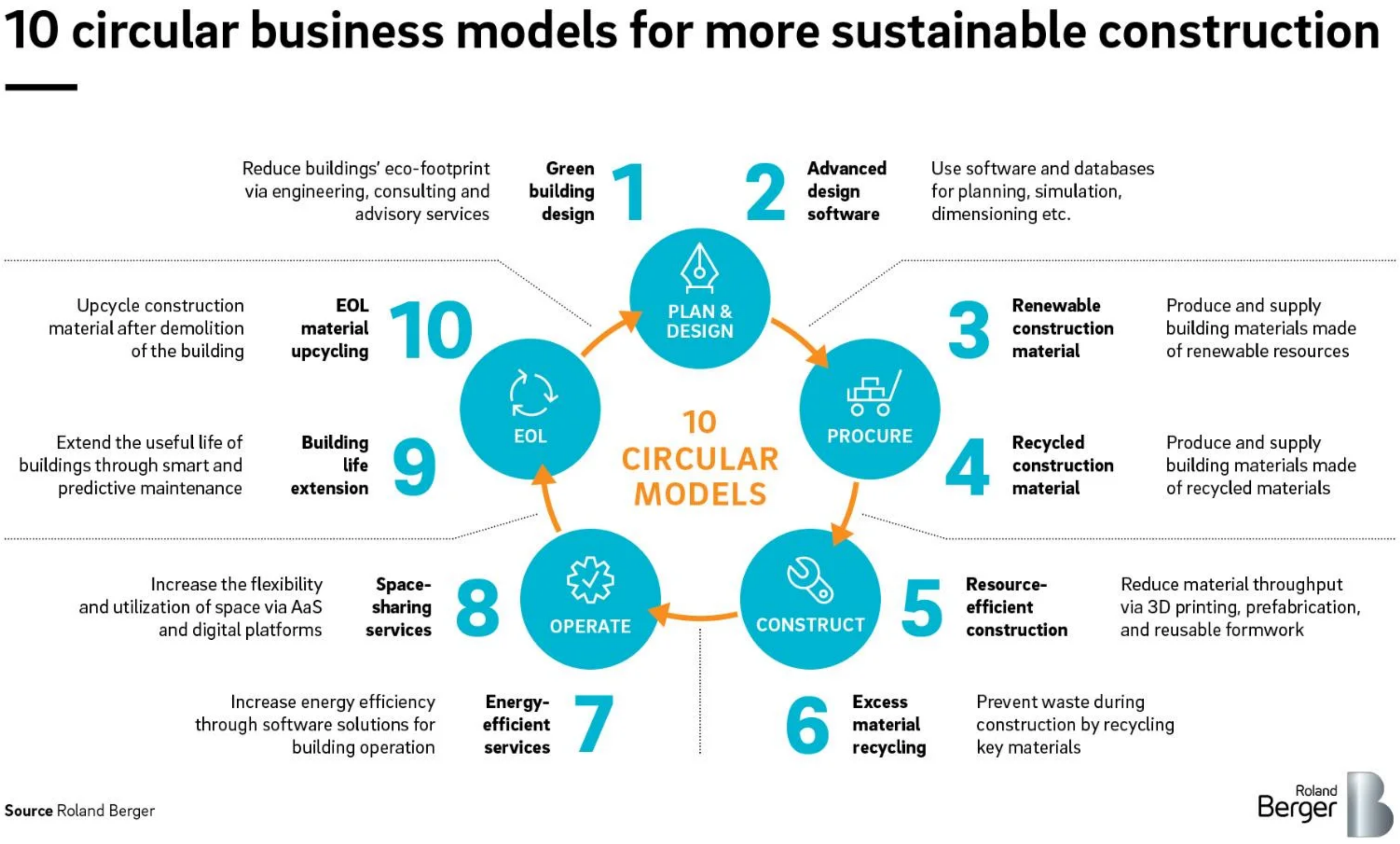


Merrild, H., Jensen, K. G. & Sommer, J. (2016). *Building a circular future*, GXN.

Key frameworks for Circular Building design

Merrild, H., Jensen, K. G. & Sommer, J. (2016). *Building a circular future*, GXN.

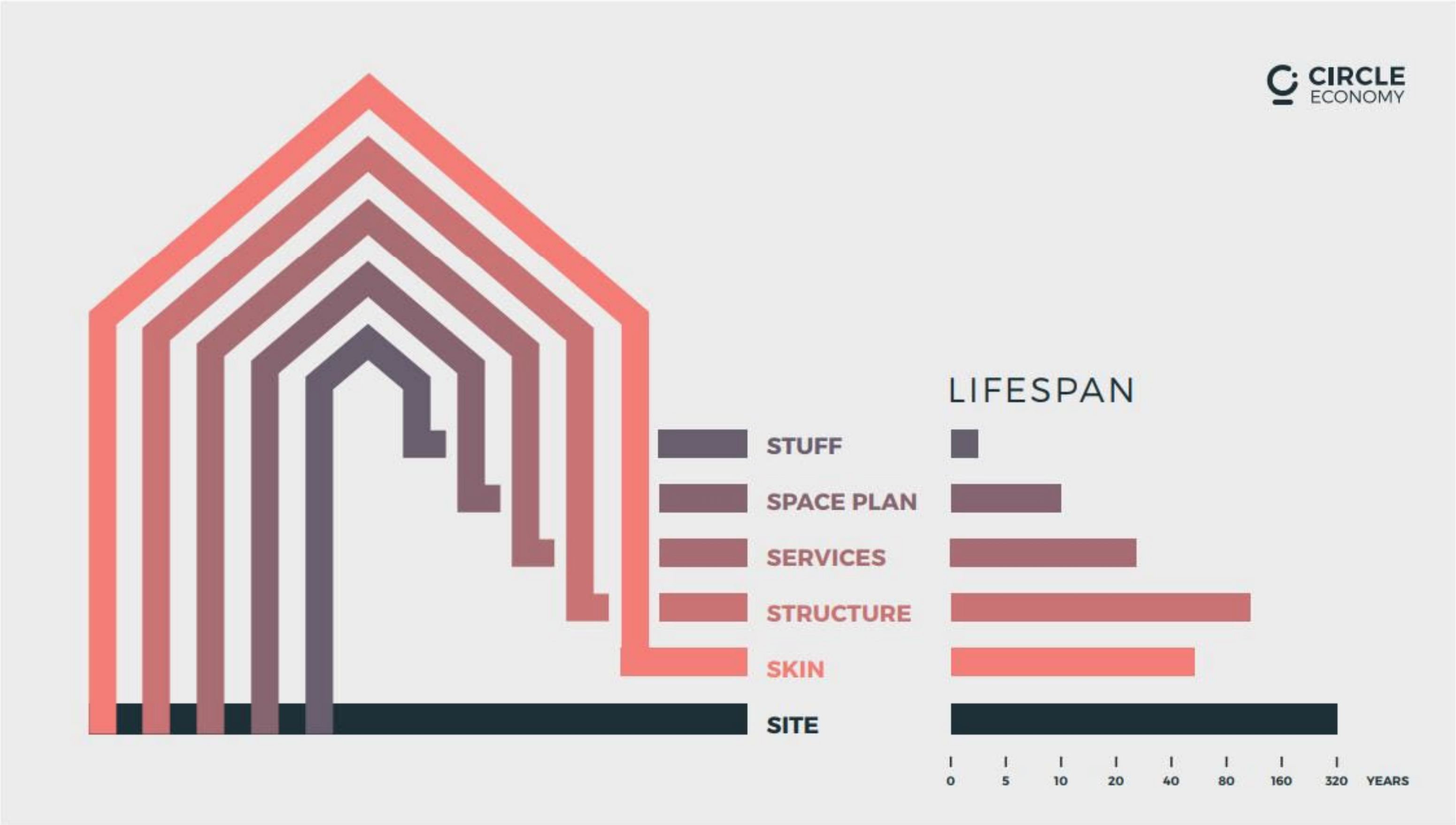
Key frameworks for Circular Building design



[It's time for construction to embrace the circular economy | Roland Berger]

Key frameworks for Circular Building design

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



[Buildings Will Drive Transition to Circular Economy: New Methods of Valuation and Financing Are Key | IFAC]

Key CB design strategies

Design out of waste
Design for adaptation
Design for disassembly
Selecting materials

See attached book

Hebel, D., Wisniewska, M. & Heisel, F. (2014). Building from Waste: Recovered Materials in Architecture and Construction, 2014. Birkhauser Verlag, Basel.

Key CB design strategies

Design out of waste
Design for adaptation
Design for disassembly
Selecting materials

Three dimensions of transformation:
Spatial transformation
Structural transformation
Element and material transformation

Modularity of building elements

Hebel, D., Wisniewska, M. & Heisel, F. (2014). Building from Waste: Recovered Materials in Architecture and Construction, 2014. Birkhauser Verlag, Basel.

Key CB design strategies

Design out of waste
Design for adaptation
Design for disassembly (DfD)
Selecting materials

'Today buildings are statically welded, glued and cast together. By designing for disassembly future buildings will be flexible and function as material banks'

— **Kasper Guldager Jensen**
Architect, Senior Partner 3XN and Director GXN

Introduction
— to design for disassembly

'Design for disassembly' is a holistic design approach where the intention is to make any given product easy to disassemble into all its individual components.

The approach is a cornerstone of the circular economy because it allows the different components to fit into a closed material cycle, where they can be reused, reassembled and recycled to new products of similar or higher quality.

Because of the holistic nature of the philosophy, it can be applied to any type of product in every scale with any level of complexity. Examples range from all the way from materials used in electronic devices, furniture and to buildings.

Overall approach
There are a lot of different ways to make a product able to be disassembled. The main thing to remember is that when two or more components are put together, the connection must be reversible without damaging the components. This means that screws, splits, and nuts and bolts are favoured over nails, as wells binders, like glue, are to be avoided.

To allow for easier deconstruction, connections must be easy to access nad preferably visible. It is also key to ensure that the quality of the material can withstand the use and reuse over time and doesn't get worn out.[04, 05]

On page 46 in this book, we offer five principles of how work with design for disassembly in the built environment.

In the building industry
Design for disassembly has been present in the building industry for decades, but more out of necessity than by conscious choice. Examples includes smaller houses, pavilions and temporary structures that are built to be moved around or in times where resources were scarce, buildings were made so that the building materials would be available again.

This book investigates how to integrate design for disassembly in larger scale buildings and prepare them for a circular future.

04 DfD - Design for Disassembly in the built environment 05 autodesk.com

Merrild, H., Jensen, K. G. & Sommer, J. (2016). *Building a circular future*, GXN.

Key CB design strategies

Design out of waste
Design for adaptation
Design for disassembly (DfD)
Selecting materials

Merrild, H., Jensen, K. G. & Sommer, J. (2016). *Building a circular future*, GXN.

DfD requires a different way of thinking.

Immediate gains:
Product is easier to assemble → simpler and cheaper to produce

Cheaper to maintain and operate

Parts to be upcycled when a broken part is removed

Environmental footprint
Less waste is reproduced

Positive side effects, to sum up:
Quicker and simpler construction process.
Optimised operation and maintenance.
Less waste.
Optimized upcycling, recycling and reuse.
Released pressure on resource scarcity
Buildings as material banks.

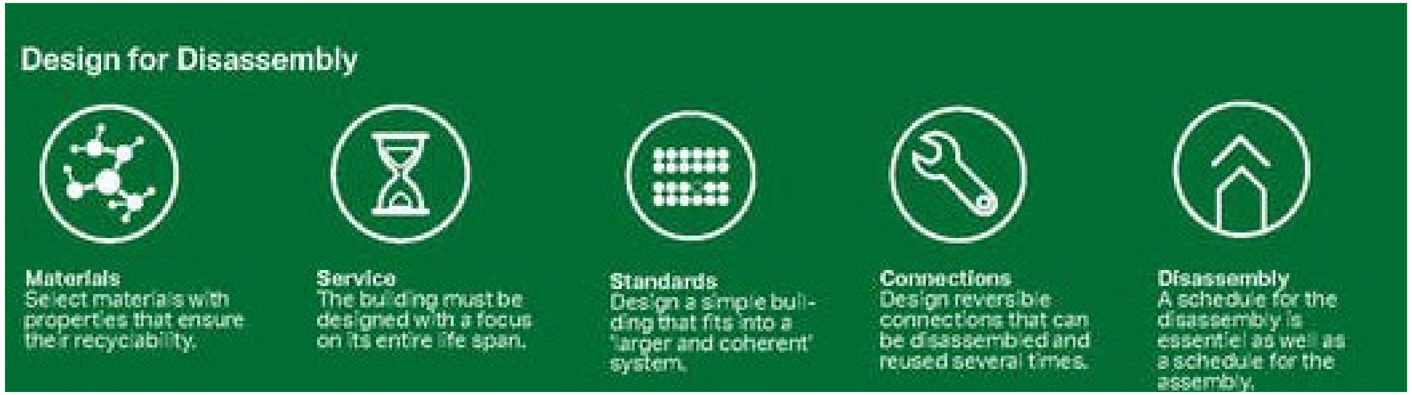
Key CB design strategies

Design out of waste
Design for adaptation
Design for disassembly (DfD)
Selecting materials

DfD requires a different way of thinking.

Common strategies:

1. Connections must be reversible
2. Connections must be easy to access, preferably visible
3. The focus should be on **mechanical joinery**, using bolted, screwed or nailed connections, as opposed to non-removable, chemical ones such as binders, sealers, glues or welding, which would make the material difficult to separate and recycle.



Merrild, H., Jensen, K. G. & Sommer, J. (2016). *Building a circular future*, GXN.

Key CB design strategies

Design out of waste
Design for adaptation
Design for disassembly (DfD)
Selecting materials

Construction materials play an essential role in defining built environment's vision.

CE criteria for building materials and components:

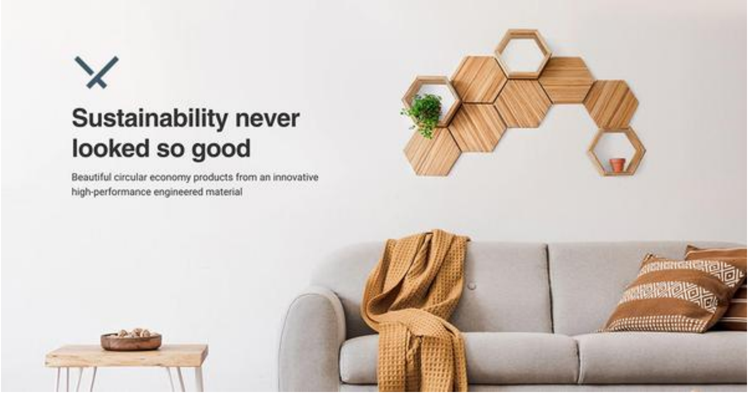
1. Recycled/ recovered content
2. Recyclability
3. Reusability
4. Easy of deconstruction
5. Durability
6. Energy recoverability
7. Upcycling potential
8. Biodegradability

Rahla, K. M., Mateus, R. & Bragança, L. (2021). Selection criteria for building materials and components in line with the circular economy principles in the built environment—A review of current trends. *Infrastructures*, 6, 49.

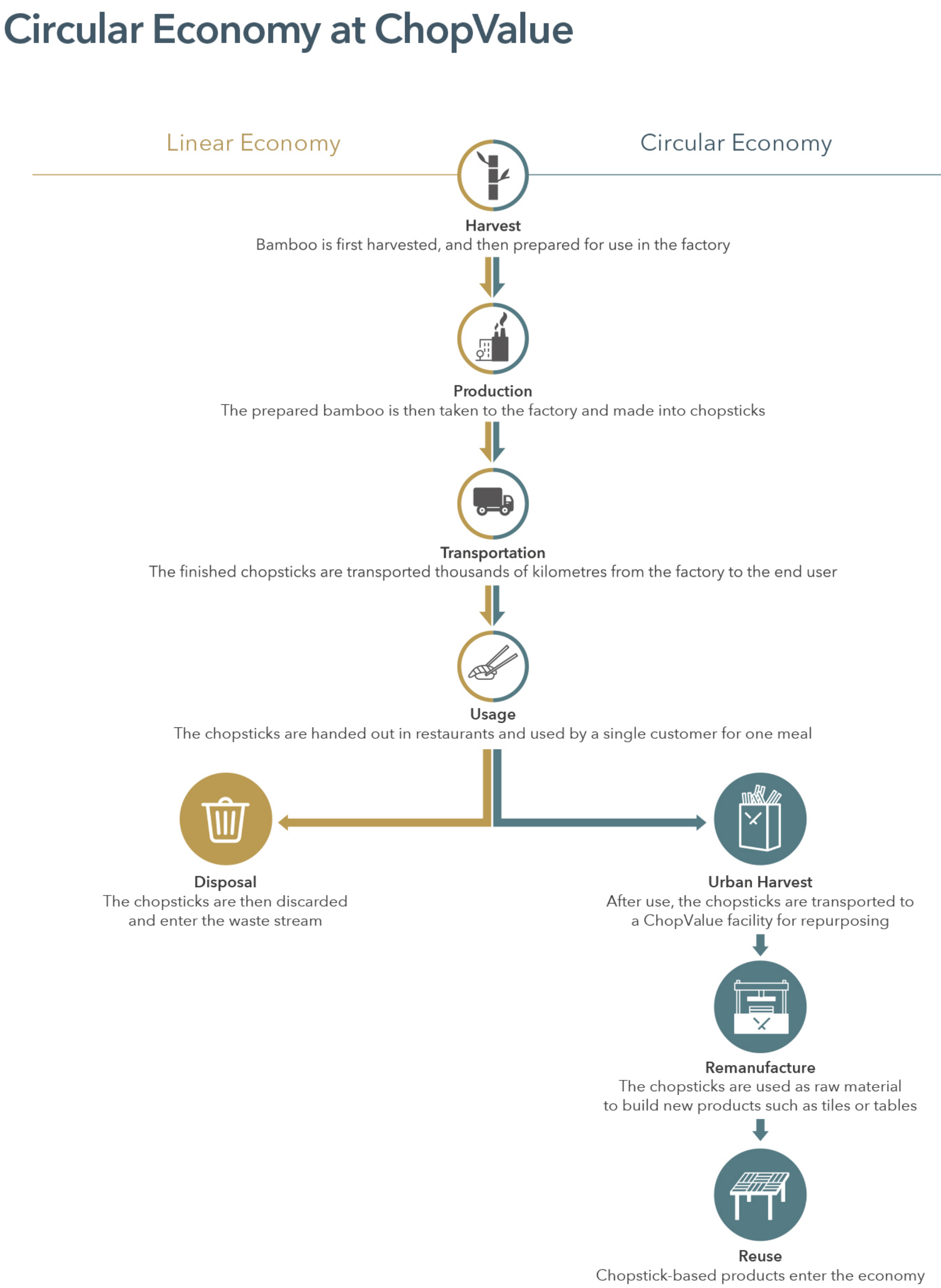
Local materials as much as possible
Less concrete and steel

Design precedent

Chop Value



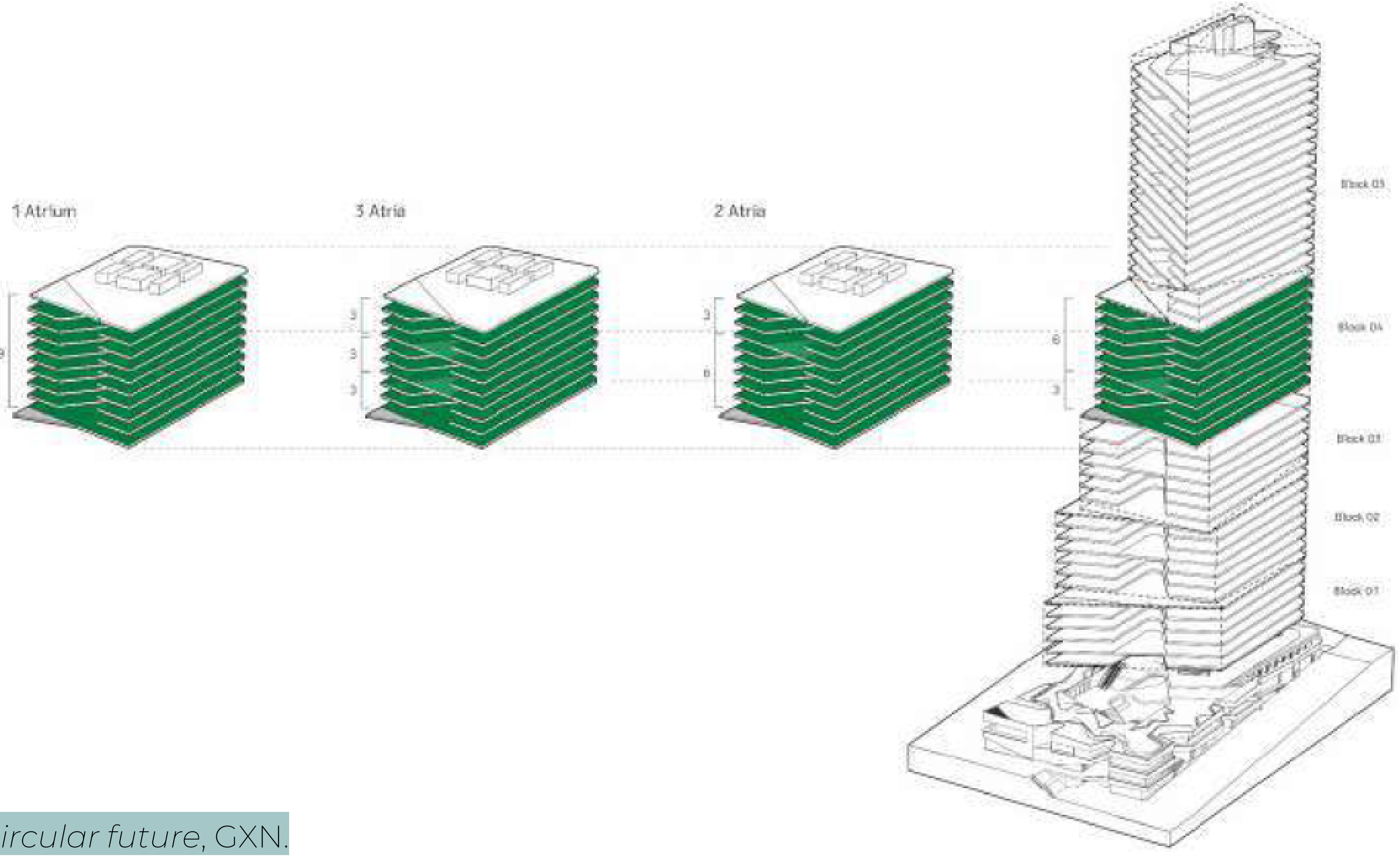
- It is estimated that in Metro Vancouver alone, approximately 100,000 chopsticks are discarded each day.
- Turning chopsticks waste into engineered materials



Design precedent

Quay Quarter Tower
Location: Sydney
Year: 2014
Owner: AMP Capital
Architect: 3XN Architects
Size: 102,000 m2

- Tenants can remove atrium floor
- Flexibility via Design for Disassembly
- Humanises high rise tower



Merrild, H., Jensen, K. G. & Sommer, J. (2016). *Building a circular future*, GXN.

Design precedent

Circularity Lab
Location: San Francisco
Year: 2019
Owner: Google
Architect: 3XN Architects
Engineer: Arup
Contractor: Turner
Size: 50 m2

- A joint prototype to show opportunities and challenges of circular construction
- Design is a vital driver for a circular economy
- A transition from linear economy requires design strategies that are scalable and reach beyond individual instances
- CE is collaborative by definition → design and build for disassembly and keeping materials in circulation in high value requires new partnership in industry

The world's first social housing units built entirely according to circular principles, where 90% of all material can be reused at a high value.

Merrild, H., Jensen, K. G. & Sommer, J. (2016). *Building a circular future*, GXN.

Design precedent

Circle House, Copenhagen
Year: 2018
Owner: Lejerbo
Architects: Lendager Group,
Vandkunsten, 3XN Architects
Size: 5.500 m2 (Final project)
and 40 m2 (Demonstrat

Merrild, H., Jensen, K. G. & Sommer, J. (2016). *Building a circular future*, GXN.

The world's first social housing units built entirely according to circular principles, where 90% of all material can be reused at a high value.

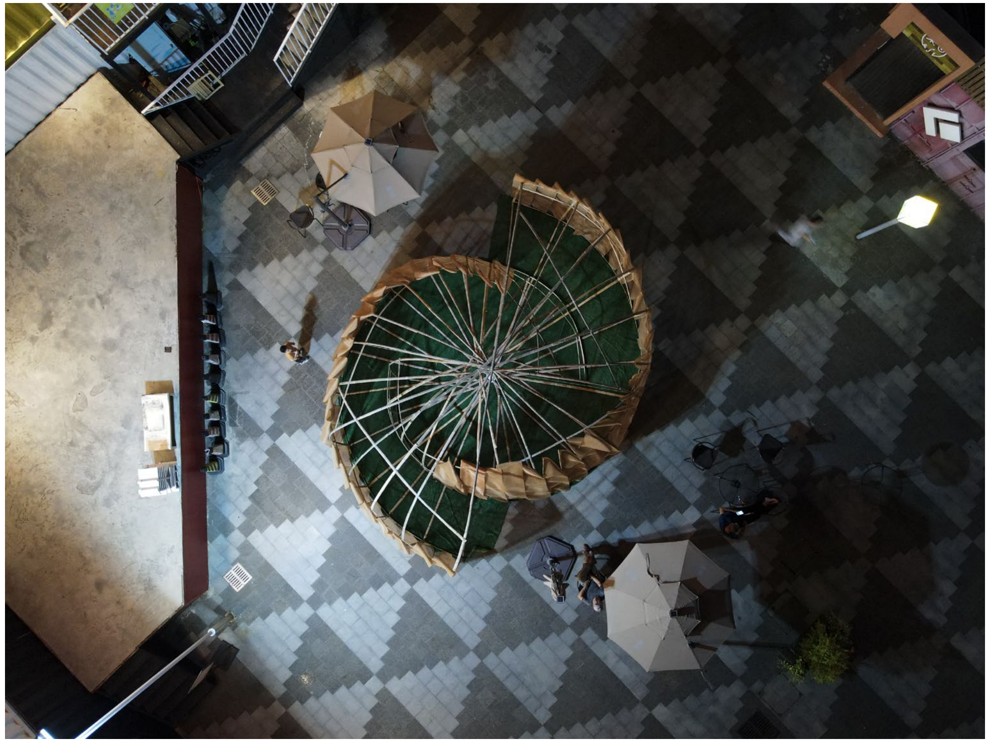
Photo (top): Detail of the prefabricated concrete structure provided by Consolis showing the steel connections that allow for clean dissassembly.

Photo (right): Facade build up using MDfacade expanded insulation cork panels mounted on timber battens.

Bamboo Pod 3

A mini case study

https://youtu.be/V179fJAhe4I



What we learnt:
DfD needs to be an integral part of design-and-build strategies.

Takeaways

- Turn waste into high value building materials
- Working with existing buildings when possible
- Plan to re-use structural elements
- Select appropriate building materials and components from early design stages
- Reduce, Reuse, Recycle
- Increase flexibility through design (flexible mechanical joints, for instance)
- A good design also can enable contractors to build faster
- Clean disassembly system
- CE is collaborative by definition
- Understand building material cycles
- Local sustainable materials research (bamboo, rammed earth, wattle and daub, timber from managed forestry, etc)

Choose <u>one CB</u> strategy and expand in your library design