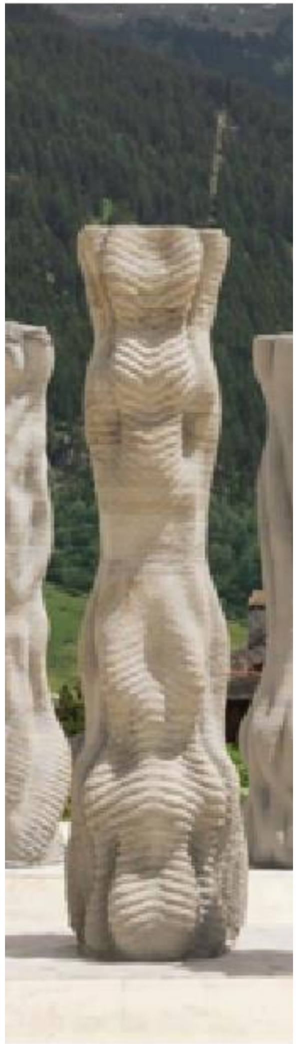
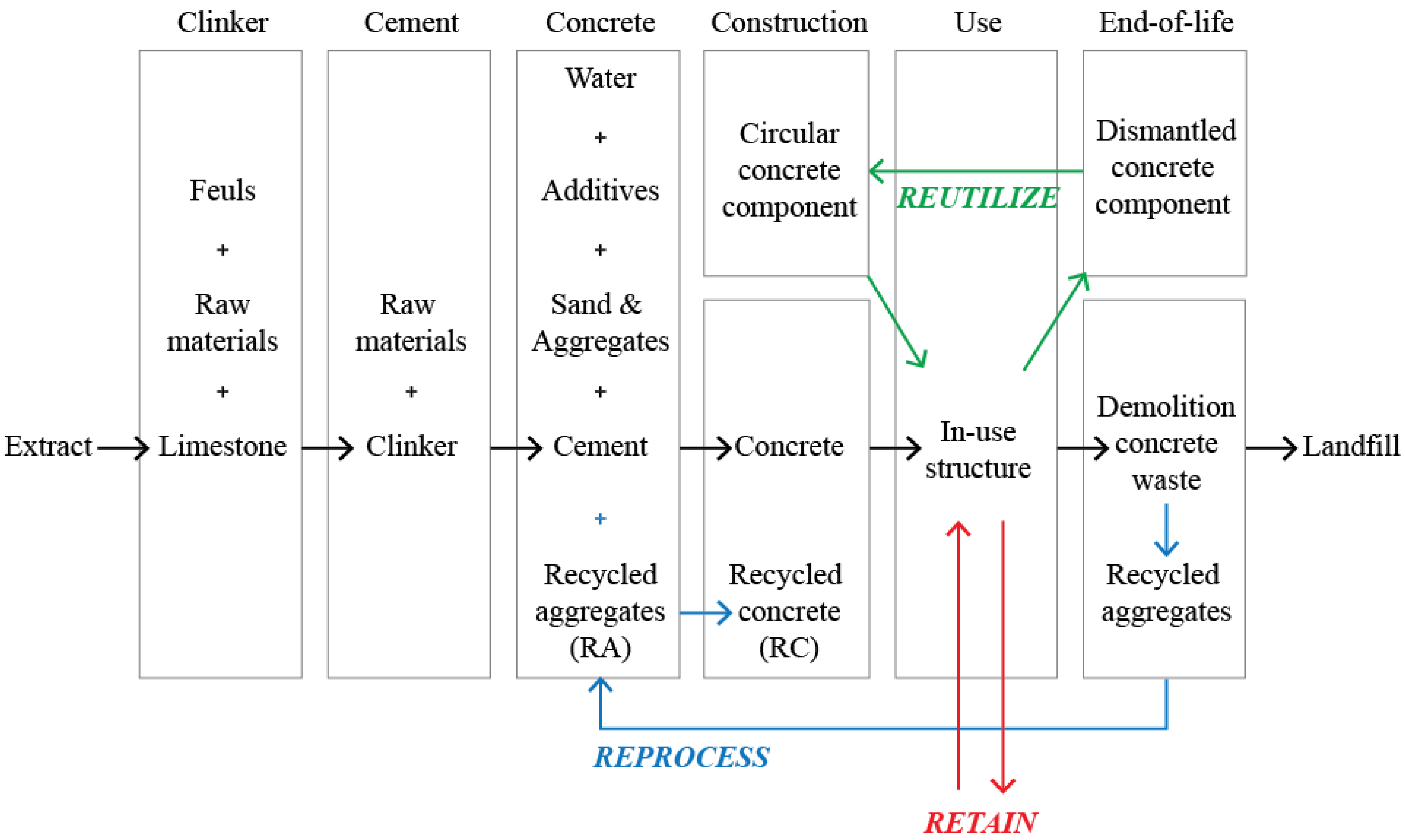
A

B



Research/12-month progress

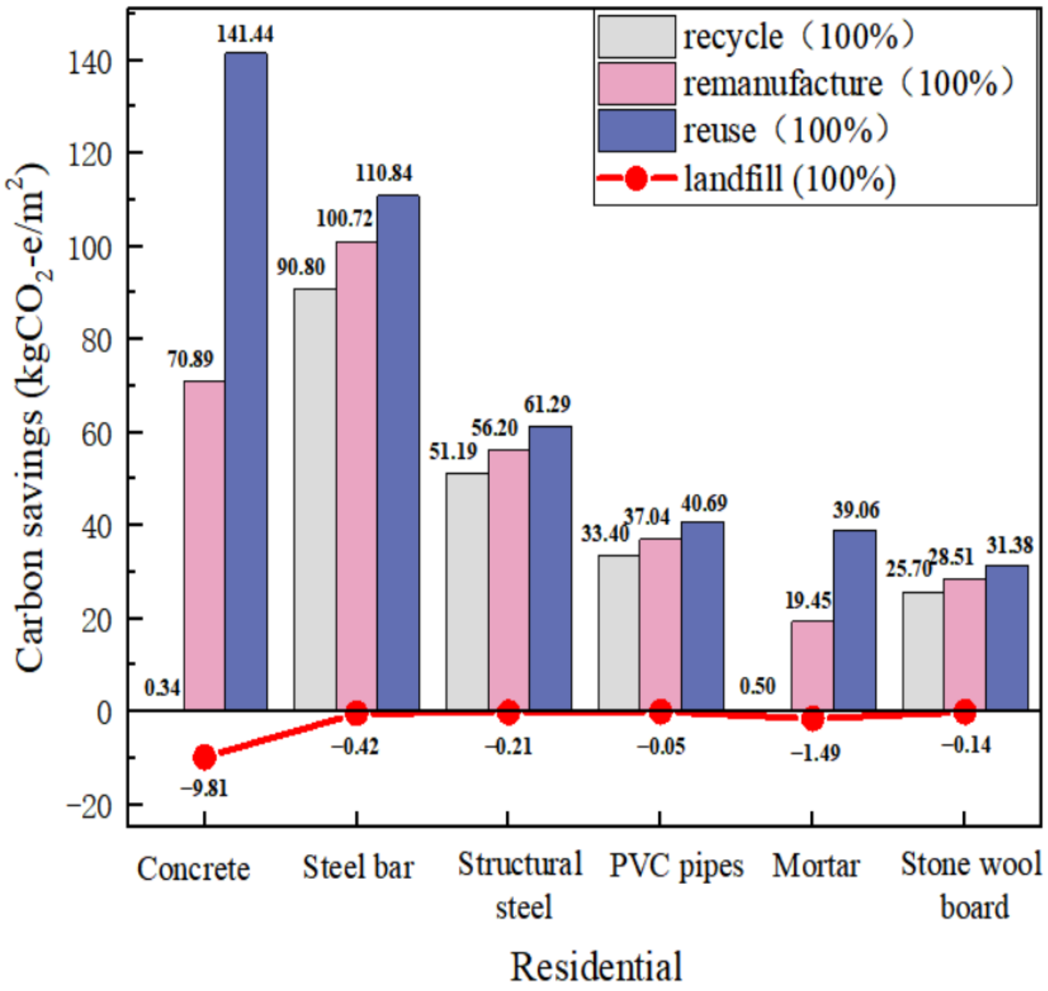
(Lee et al., 2024)



Circular Concrete

Introduction

Fig. 1: Circular concrete strategies. In black, conventional concrete life cycle. In colors, circular strategies to lower the environmental impact of concrete: reusing concrete at the building scale in red, component scale in green, and material scale in blue. Adapted from Küpfer et al., (2022).



- Reutilize (direct)
- Reutilize (refurbish)
- Reprocess

- Various decarbonization effect

Reuse to Decarbonize

State-of-the-art

(Lei et al., 2023)

- Reutilize and alternatives

  a. Reused-concrete block pavement
  b. Pavement with recycled-concrete slab
  c. Pavement with bituminous surfacing

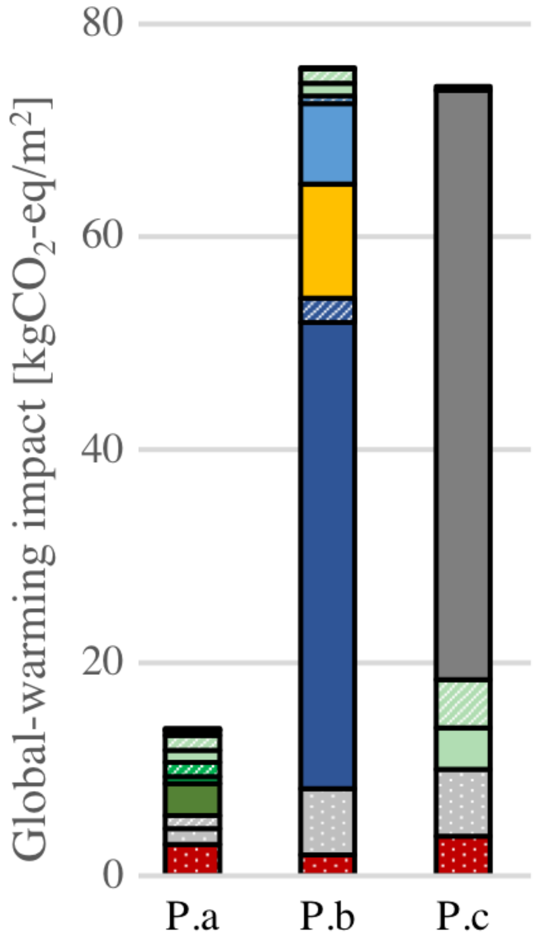
  Left to Right: (1m^2/ year)
  1. Used Concrete Brick Wall
  2. Clay Brick Façade
  3. Light Concrete Brick Wall

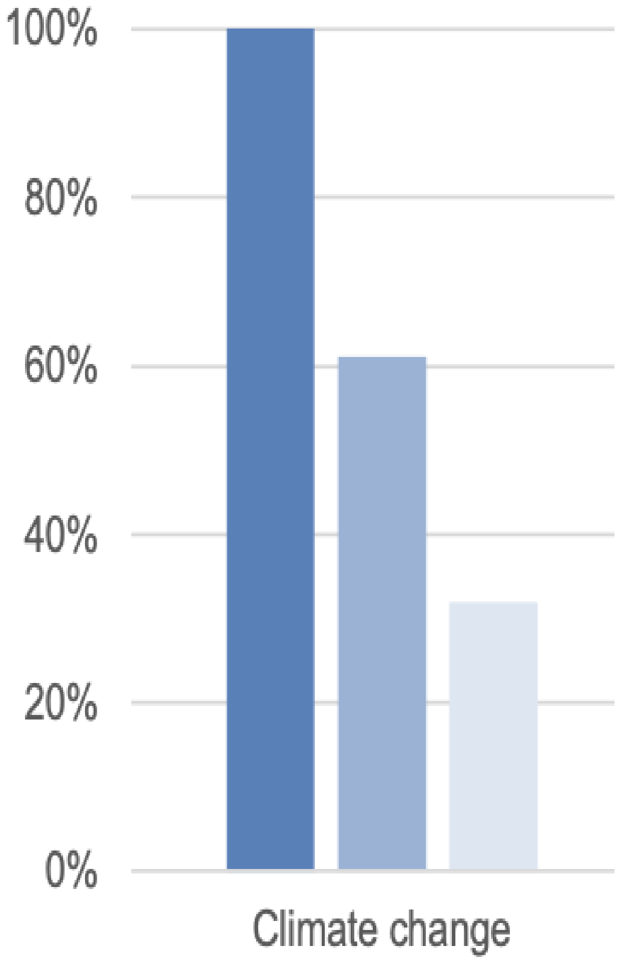
- Various decarbonization effect

Reutilize to Decarbonize

State-of-the-art

(Küpfer et al., 2022; Vankunsten Architects et al., 2016)





- Reutilize and alternatives

a. Pavement reutilized-concrete block
b. Pavement with recycled-concrete block
c. Pavement with bituminous surfacing

Left to Right: ($1m^2$/ year)
1. Reutilized concrete brick wall
2. Clay brick façade
3. Light concrete brick wall

- Various decarbonization effect

Reutilize to Decarbonize

State-of-the-art

(Küpfer et al., 2022; Vankunsten Architects et al., 2016)

N	Compared design alternatives, as described in the records	Environmental impact difference [unit]	Source
1	New cast-in-place concrete building	60 [% CO_2]; 40 [% MJ]	Roth and Eklund (2000)
2	Traditional dike construction	30 [% m^2]	Mettke (2010)
3	Non-reuse alternative	97 [% CO_2]	Mettke (2017)
4	New hollow-core slabs (vs 71% reuse)	53 [% CO_2eq	Naber (2012)
5	New hollow-core slabs (vs 69% reuse)	56 [% CO_2eq]	Naber (2012)
6	Recycled-concrete house	90 [% CO_2eq]	Glias (2013)
7	New concrete building	46 [% CO_2eq]	Van den Brink (2020)
8	(a) Bituminous surface (b)Recycled concrete slab	81 / 82 [% CO_2eq]	Küpfer et al. (2022)
9	Recycled-concrete monolithic arch	63 [% CO_2eq]	Küpfer et al. (2022)
10	New concrete girders	44 [% CO_2eq]	Vergoossen et al. (2021)
11	Conventional cast-in-place structure	71% [% CO_2eq]	Widmer (2022)
12	(a) Clay brick (b) Light concrete brick façade	152 [% CO_2eq]	Vandkunsten et al. (2016)

Overview of Varied Decarbonization Effect of Concrete Reutilization

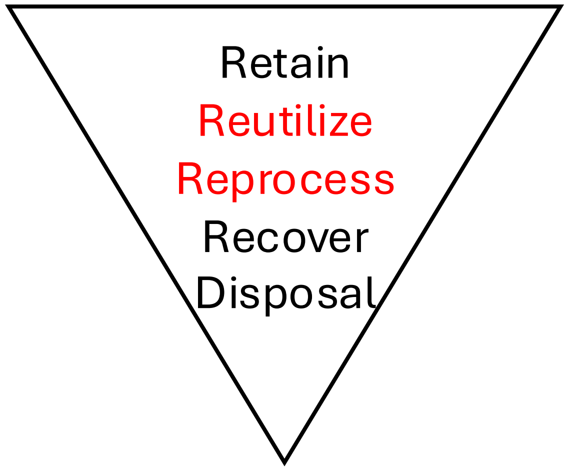
State-of-the-art

(Küpfer et al., 2022; Vankunsten Architects et al., 2016)

State-of-the-Art

Overview of Varied Decarbonization Effect of Circular Concrete Strategies

- New concrete
  - Cast-in (100%)
  - Precast (80-90%)(inter Wang et el., 2016)
  - 3dcp (60%)(inter Muñoz et al., 2021)
- Circular concrete
  - Reutilzed concrete (40-97%)
  - Reprocessed concrete
    - Recycled concrete
      + Conventional construction
      + 3D-printing with recycled concrete (3DRCP) (3% reduction)(inter Han et al., 2022)



Waste hierarchy >> Decarbonization effect?

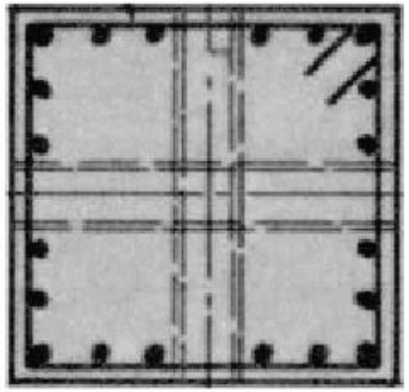
How does this suggest decisions of reuse (circular) design and construction?

Initial Component

Case Study

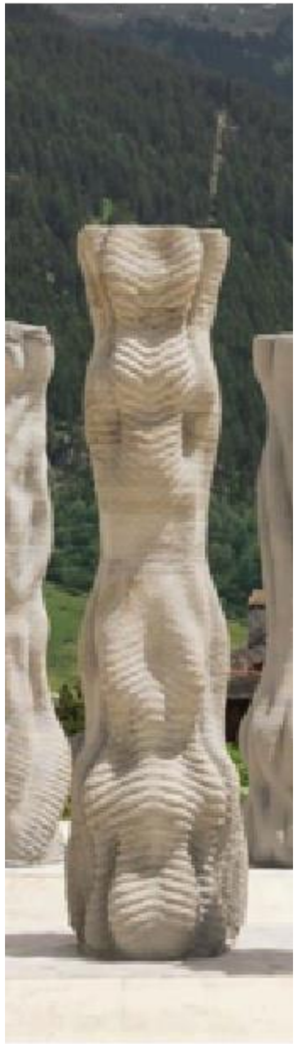
(Parabase, 2022)

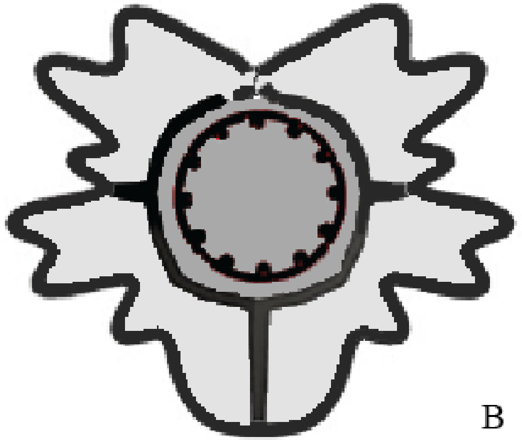
A



A

B



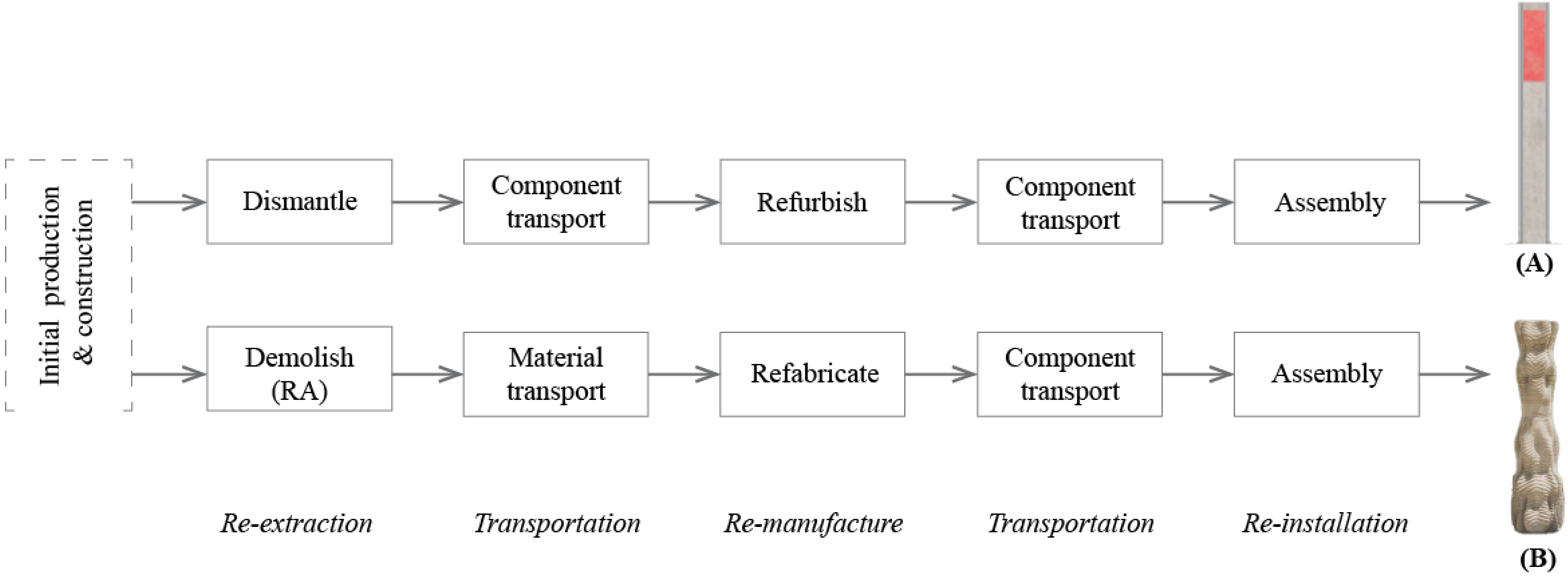


B

Comparison of two circular concrete constructions

Case Study

(Parabase, 2022; Anton et al., 2019)



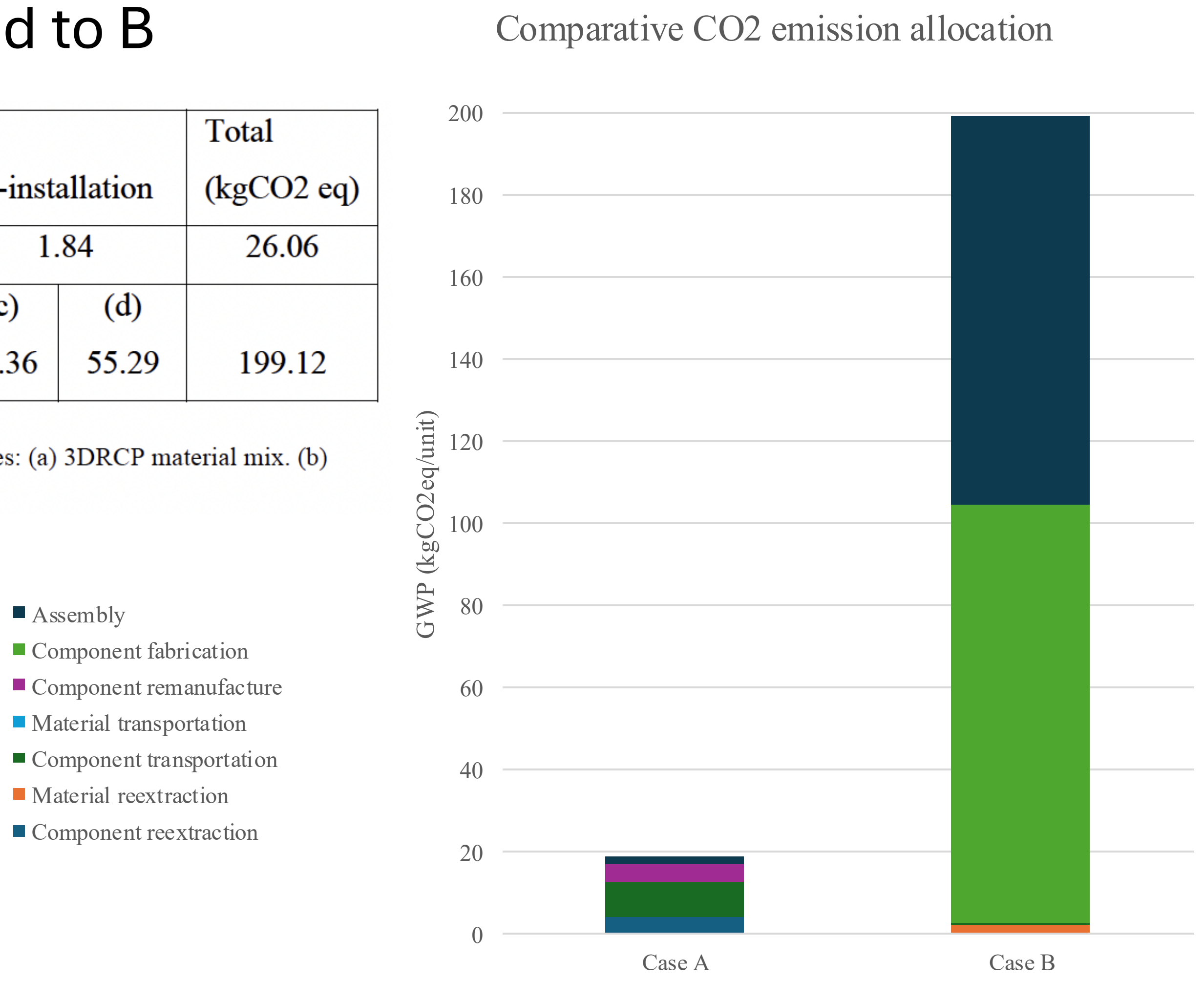
LCA/LCI Analysis

Methodology

A showed 87% carbon savings compared to B

	R1 Re-extraction	R2 Transportation	R3 Remanufacture		R4 Transportation	R5 Re-installation		Total ($kgCO_2$ eq)
(A)	3.75	7.76	4.22		1.17	1.84		26.06
			(a)	(b)		(c)	(d)	
(B)	1.92	0.19	98.8	3.13	0.43	39.36	55.29	199.12

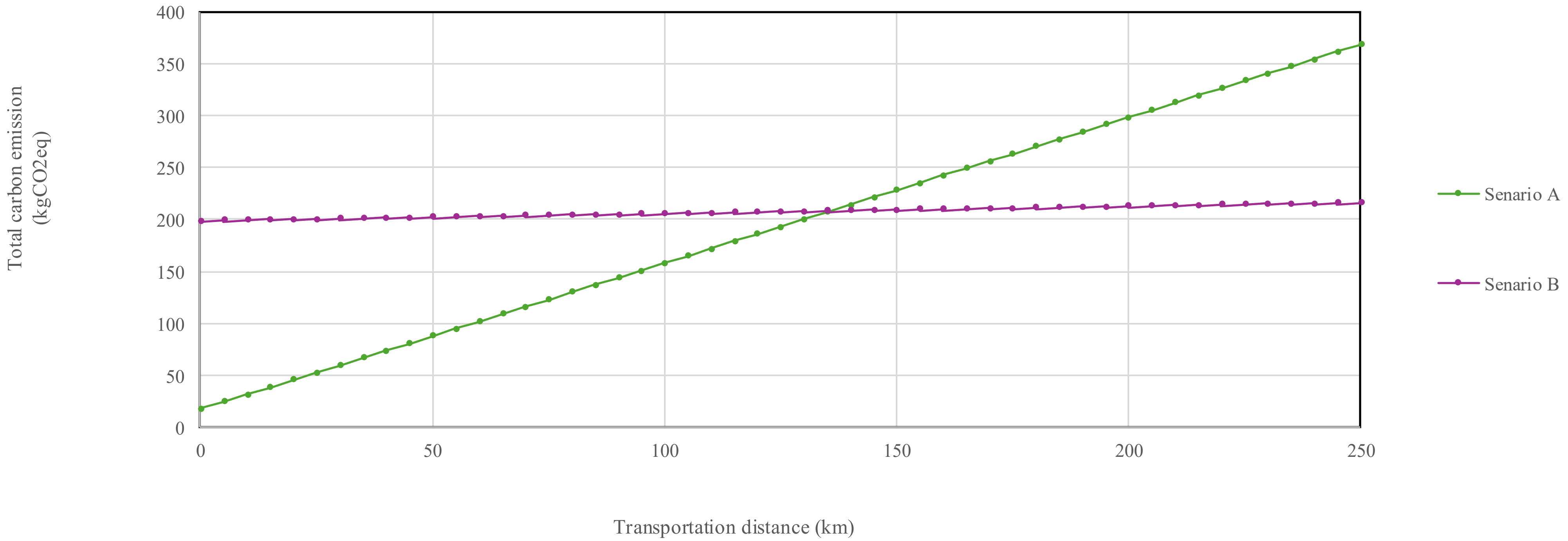
Table 1. Comparative CO2 footprint of circular concrete columns (A) and (B) across stages R1-R5. Subcategories: (a) 3DRCP material mix. (b) Printing and building operations. (c) Cast concrete. (d) Reinforcing steel.



LCA/LCI Analysis

Result

Indicators: Transportation distance, weight



Sensitivity Analysis

Discussion

- Result
  - Effective carbon savings from concrete reutilization
  - Emissions contributed by new materials (cement and steel)
  - Sensitive to transportation distance (between donor and receiver sites)

- Contribution
  - Supports decisions on reintegration of end-of-life concretes (trade-off)
  - Establishes methodological framework to measure reuse decisions

Conclusion

Decarbonization is not just environmental benefits but an essential design objective. Embodied Carbon is an embedded material quality that changes our perception and approaches to materials, components, buildings, and our built environment.

EC as part of materialization

Reflection