Circular Transitional Housing
for displaced people in extreme conditions:
the case of Pakistan

TU Delft

MSc AUBS | Building Technology

Julia Gospodinova
5603714

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Structure

The what & the why

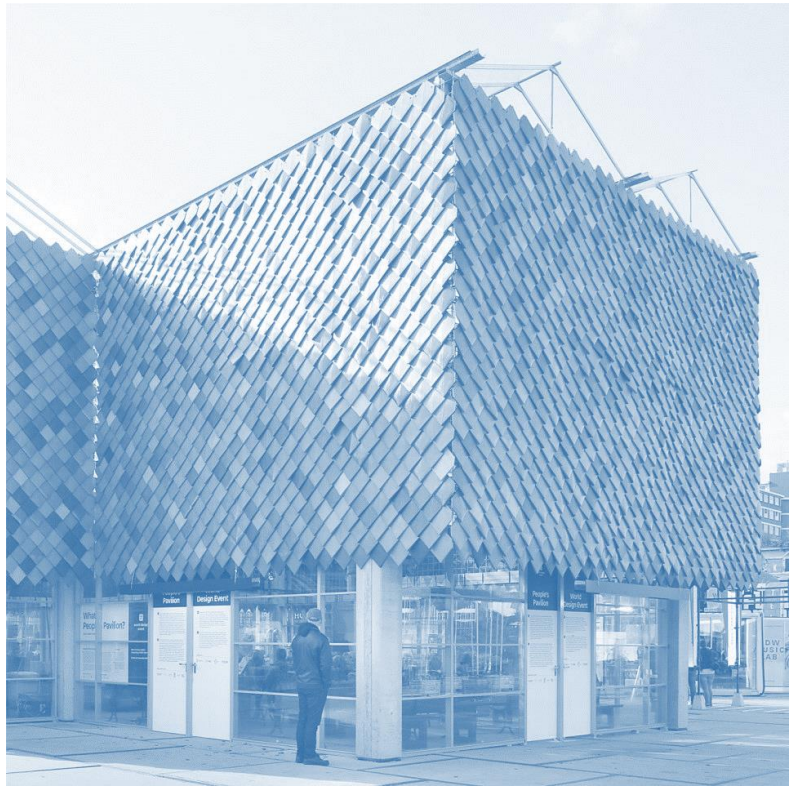
Transitional housing

The role of circularity

Recommendation set & evaluation tool

Design proposal Sindh, Pakistan

Conclusions & discussion



Picture credits: Peoples pavilion – Filip Dujardin; Matiari, Sindh province, Pakistan, August 2022 - AFP/Shakeel Ahmad

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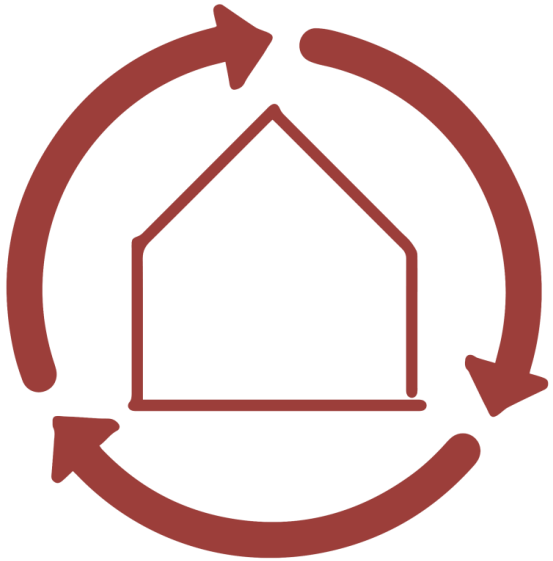

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Circular transitional housing

Research objective

Investigate how **circular building principles** can be integrated in the planning of humanitarian **transitional housing units** (THUs) and thus **reduce the negative impacts** THUs may have.

Case study Pakistan

Research question

How can transitional housing for displaced people

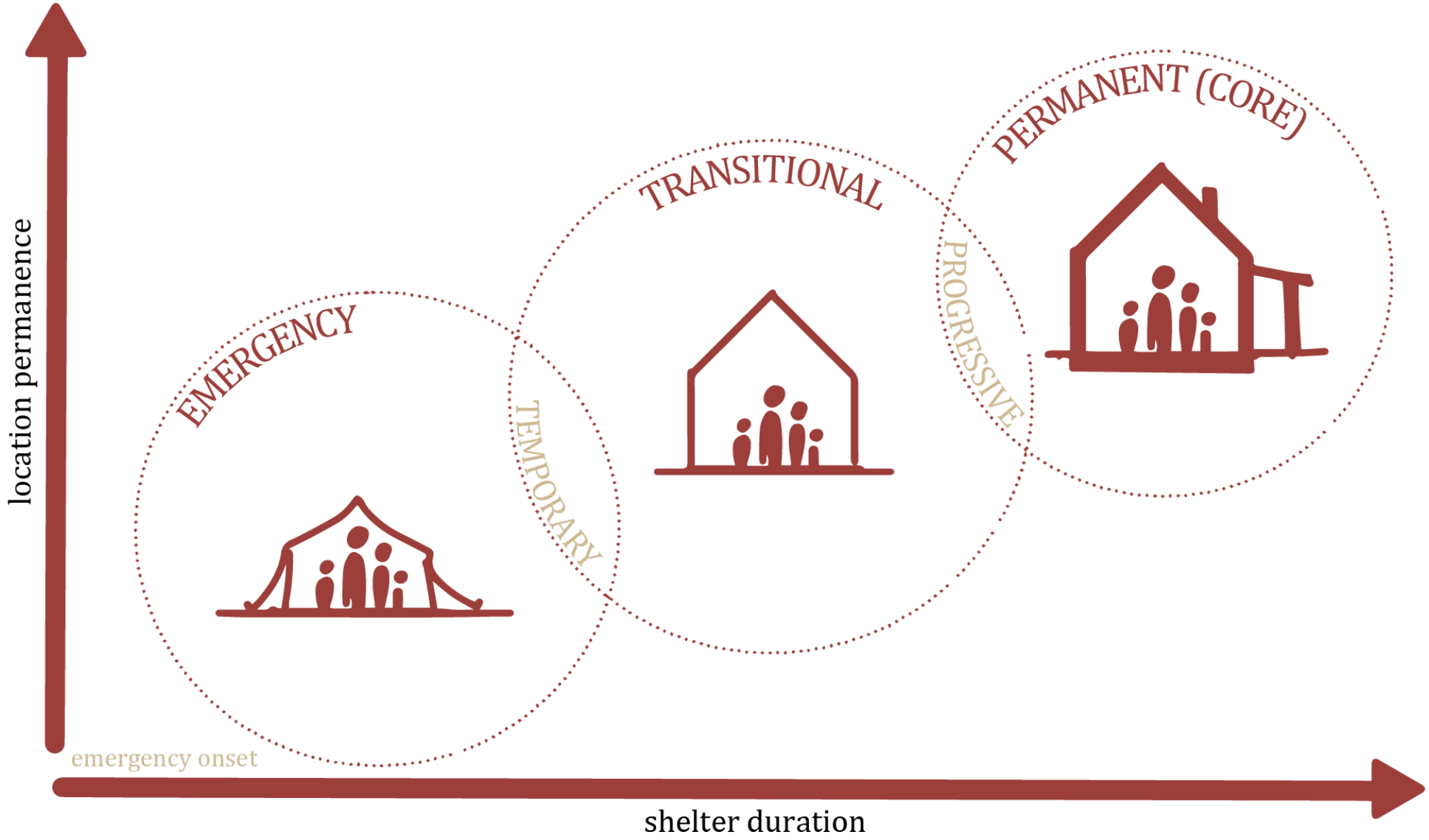
in the **extreme conditions of upper Sindh province in Pakistan**

be made using circular building principles?

Shelter is more than a roof

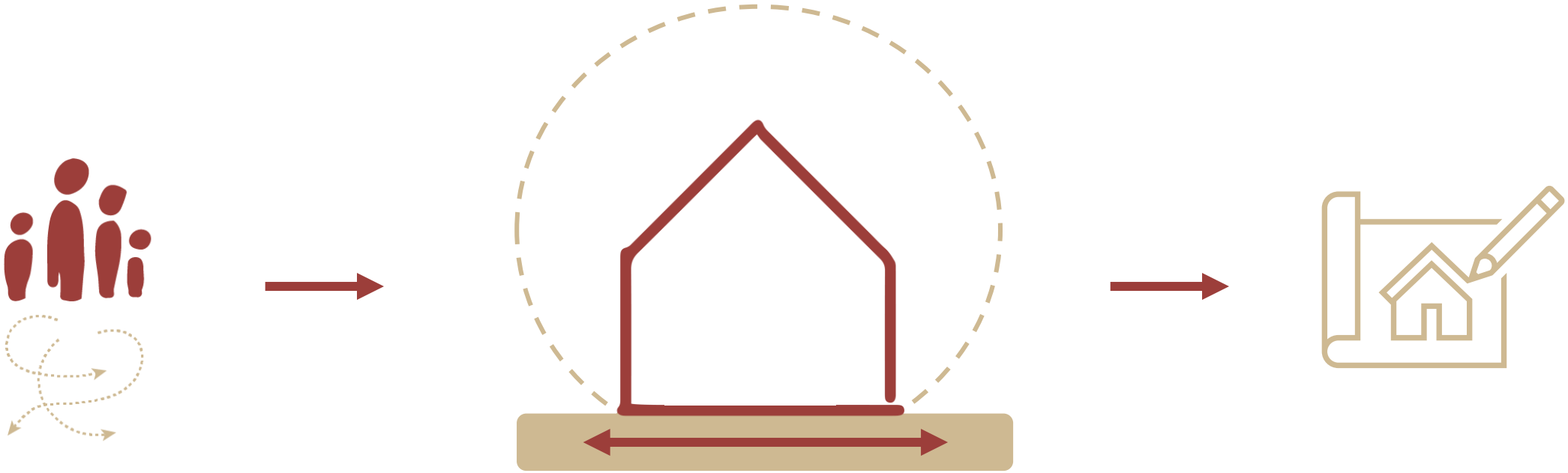
Sources: Adapted Sphere (2018)

Humanitarian shelter



Sources: Adapted from IFRC (2013) and IFRC (2011)

Transitional housing



Transitional Housing

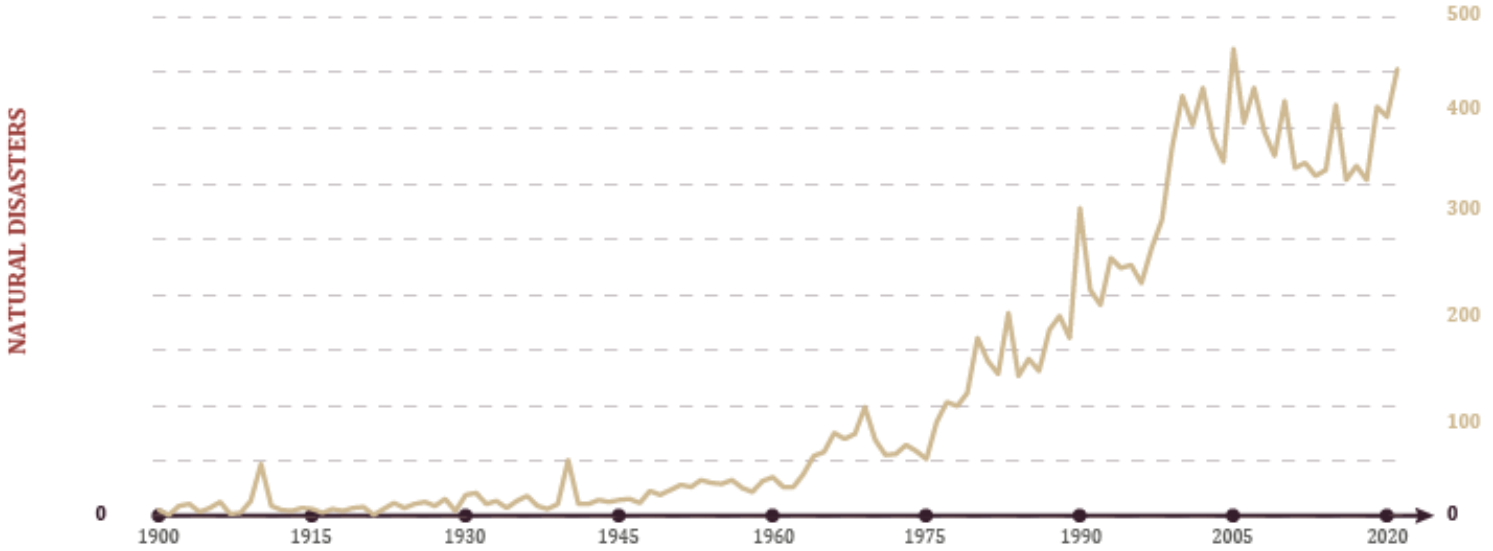
6 months – 3 years
Cannot remain on location

Displaced population

Photo: Dera Allah Yar, district Jafferabad, Balochistan, Pakistan August 25, 2022. REUTERS/Amer Hussain

Displaced population: increasing numbers

Displaced population: increasing numbers

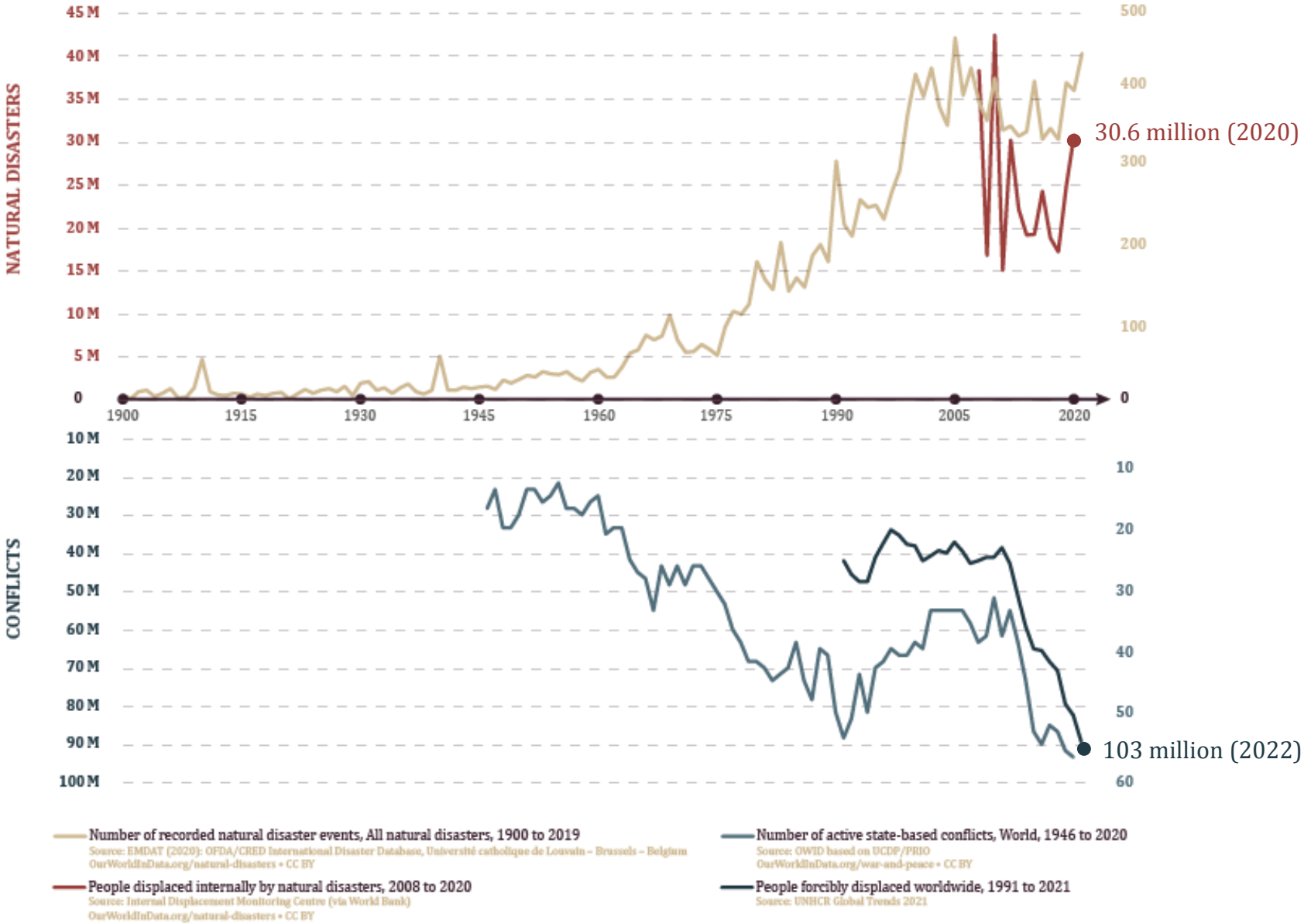


Number of recorded natural disaster events, All natural disasters, 1900 to 2019

Source: EMDAT (2020): OFDA/CRED International Disaster Database, Université catholique de Louvain – Brussels – Belgium
OurWorldInData.org/natural-disasters • CC BY

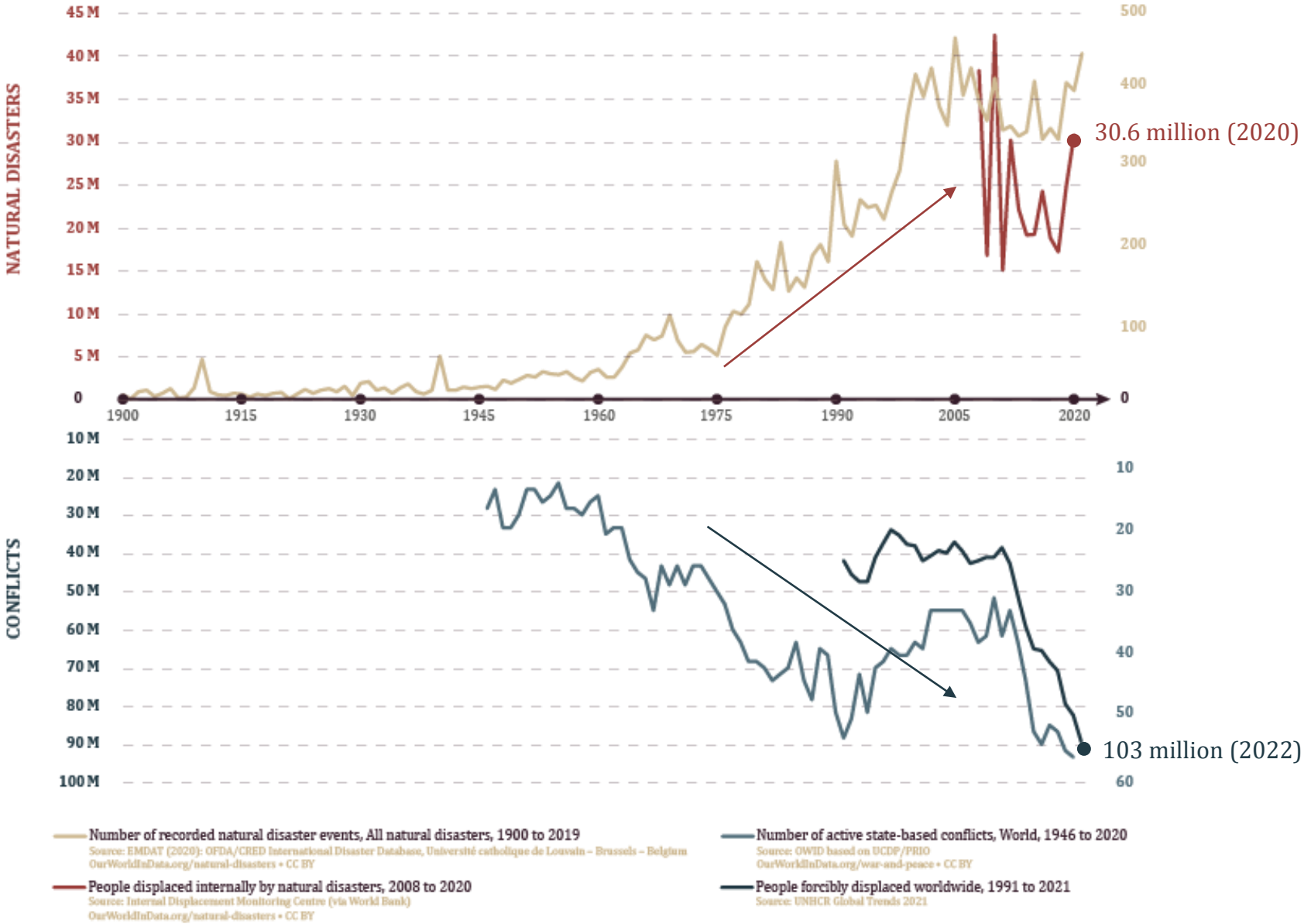
Displaced population: increasing numbers

Displaced population: increasing numbers



Displaced population: increasing numbers

> 1%
of the world's population is NOW displaced
UNOCHA, 2022



Transitional housing: growing demand

Transitional Housing

6 months – 3 years
Cannot remain on location

Transitional housing: problems

Transitional Housing

6 months – 3 years
Cannot remain on location

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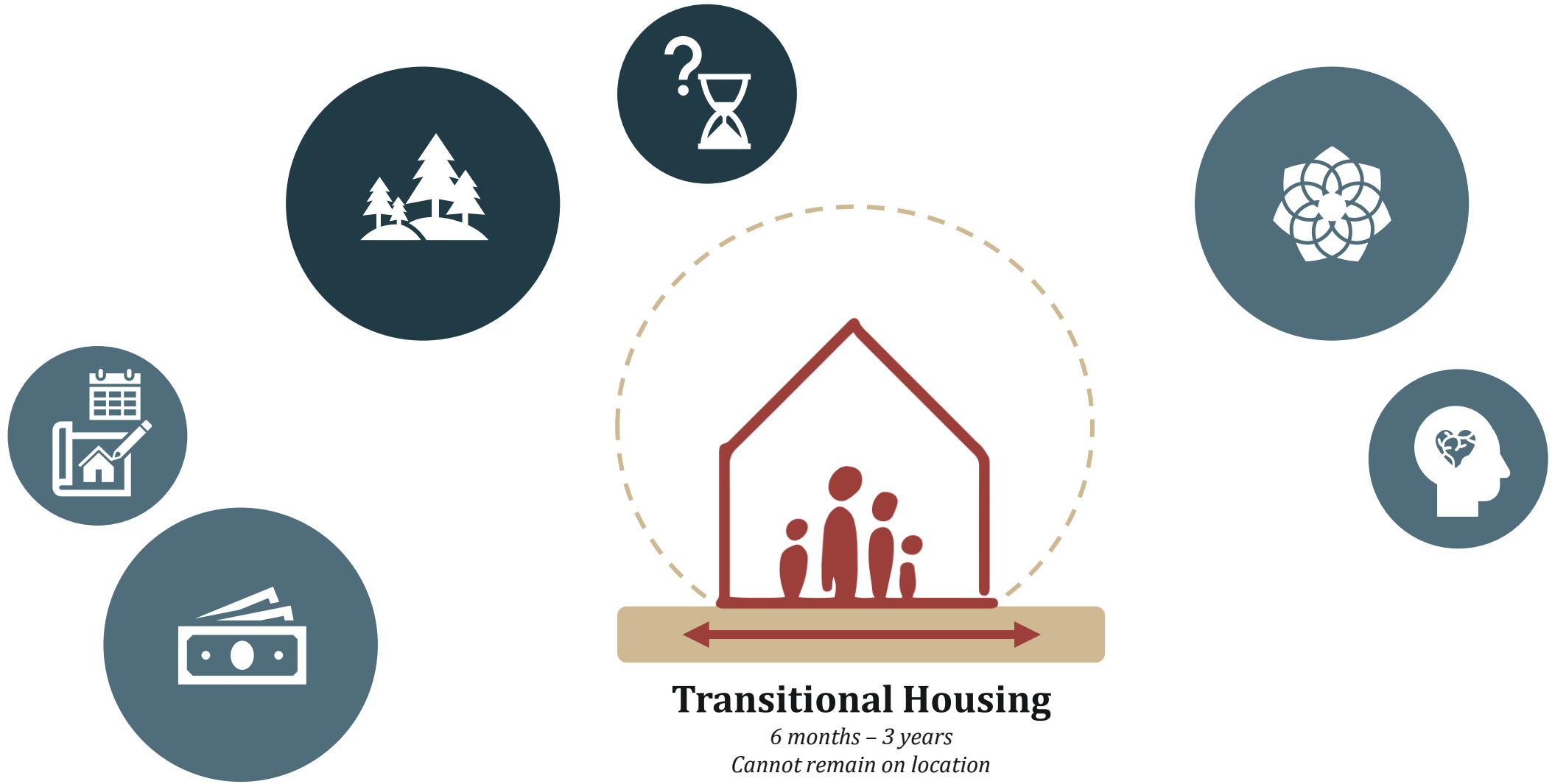

Transitional Housing

6 months – 3 years
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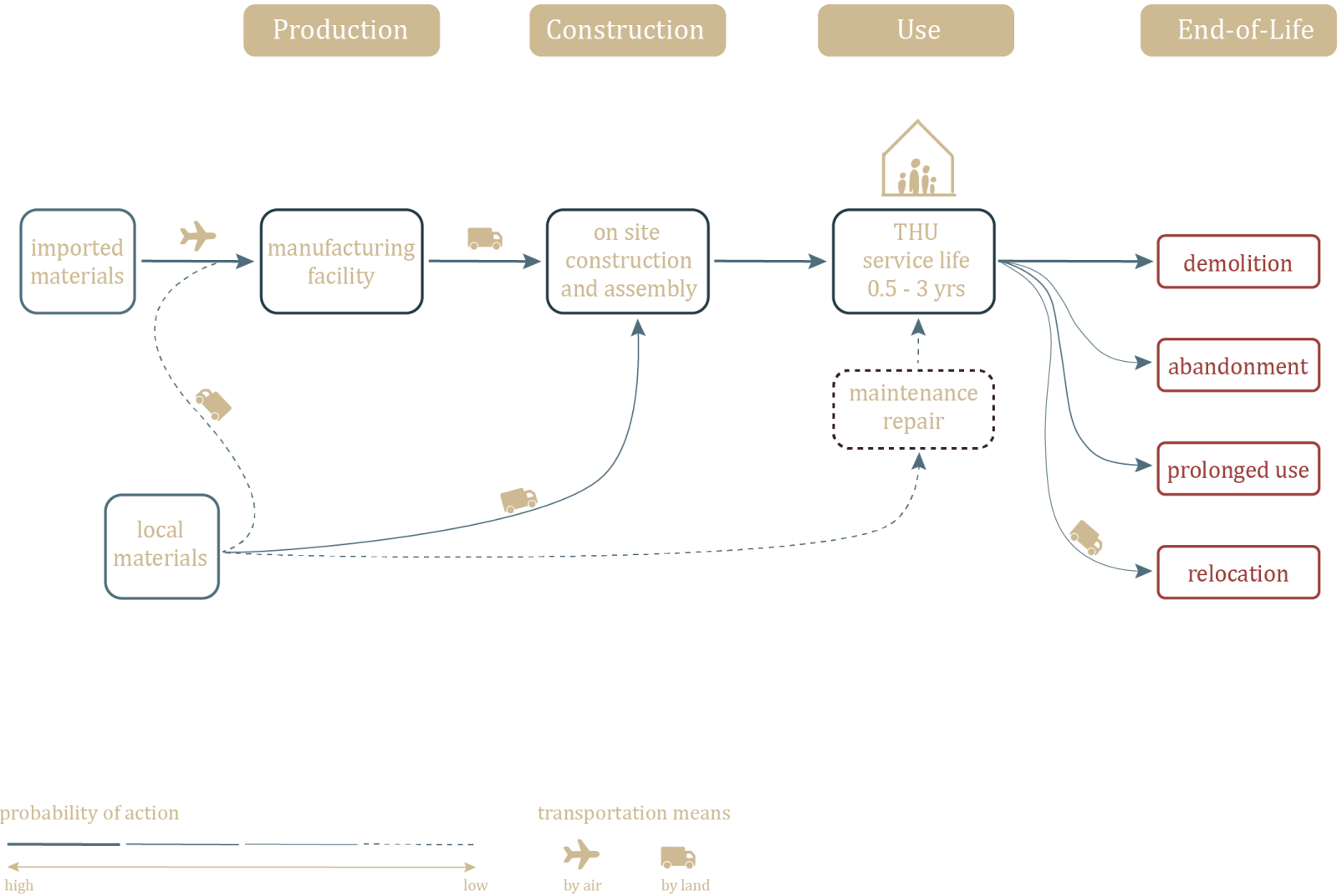
Common lifecycle and EoL scenarios



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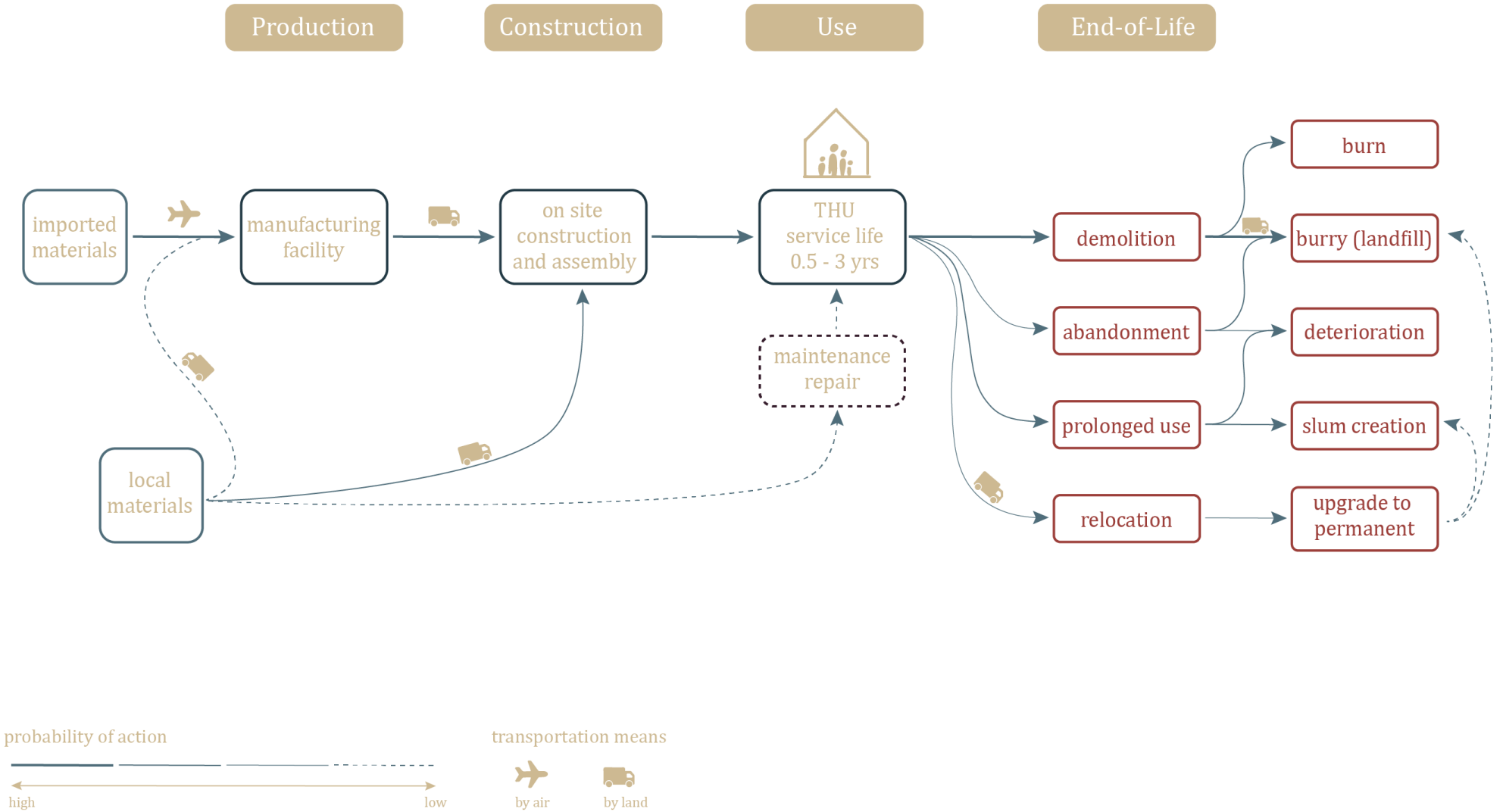

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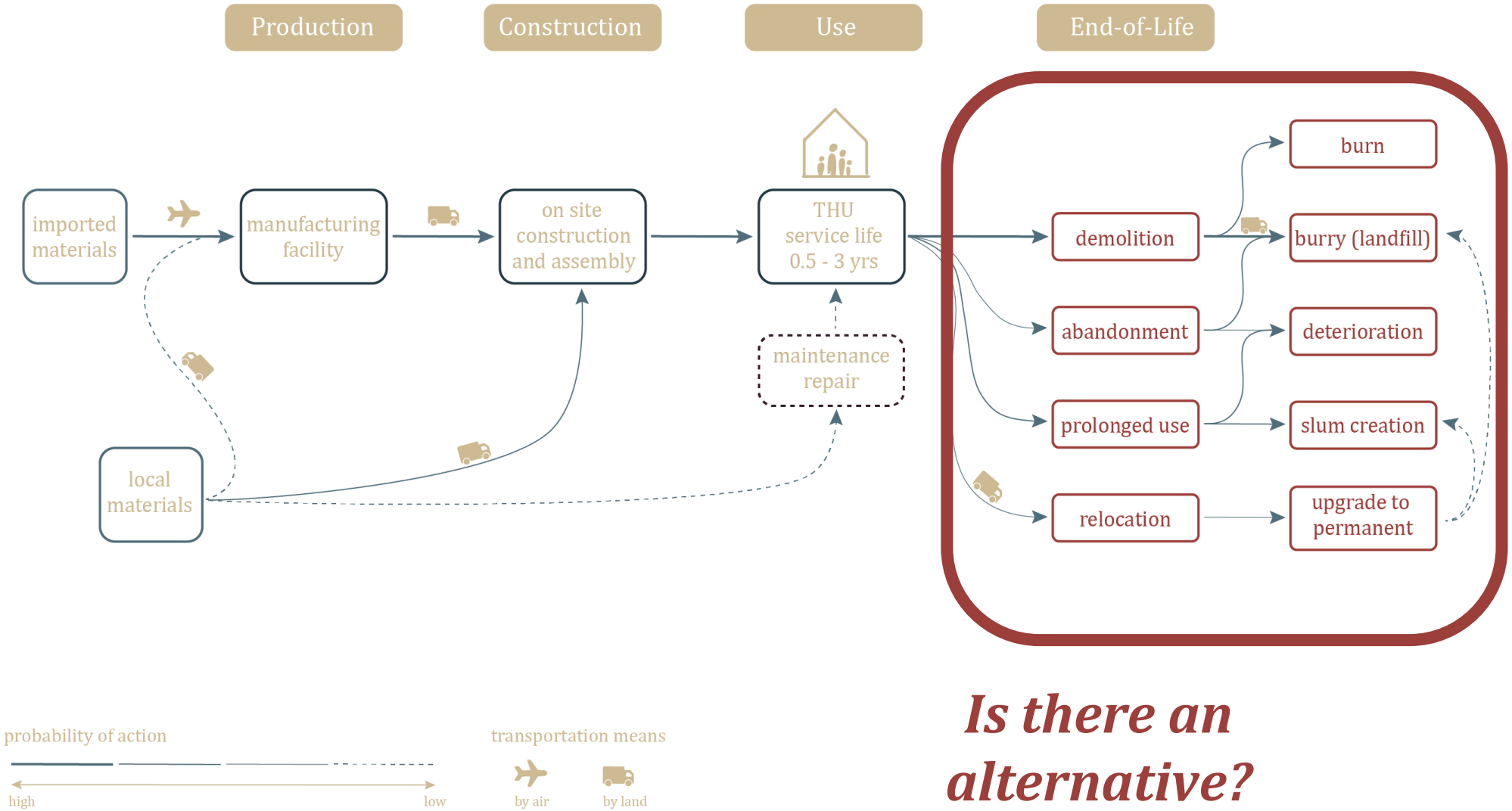


Is there an alternative?

Circularity

Circularity

Use longer
existing materials

Use again
secondary materials

Use less
virgin materials

Make clean
renewables

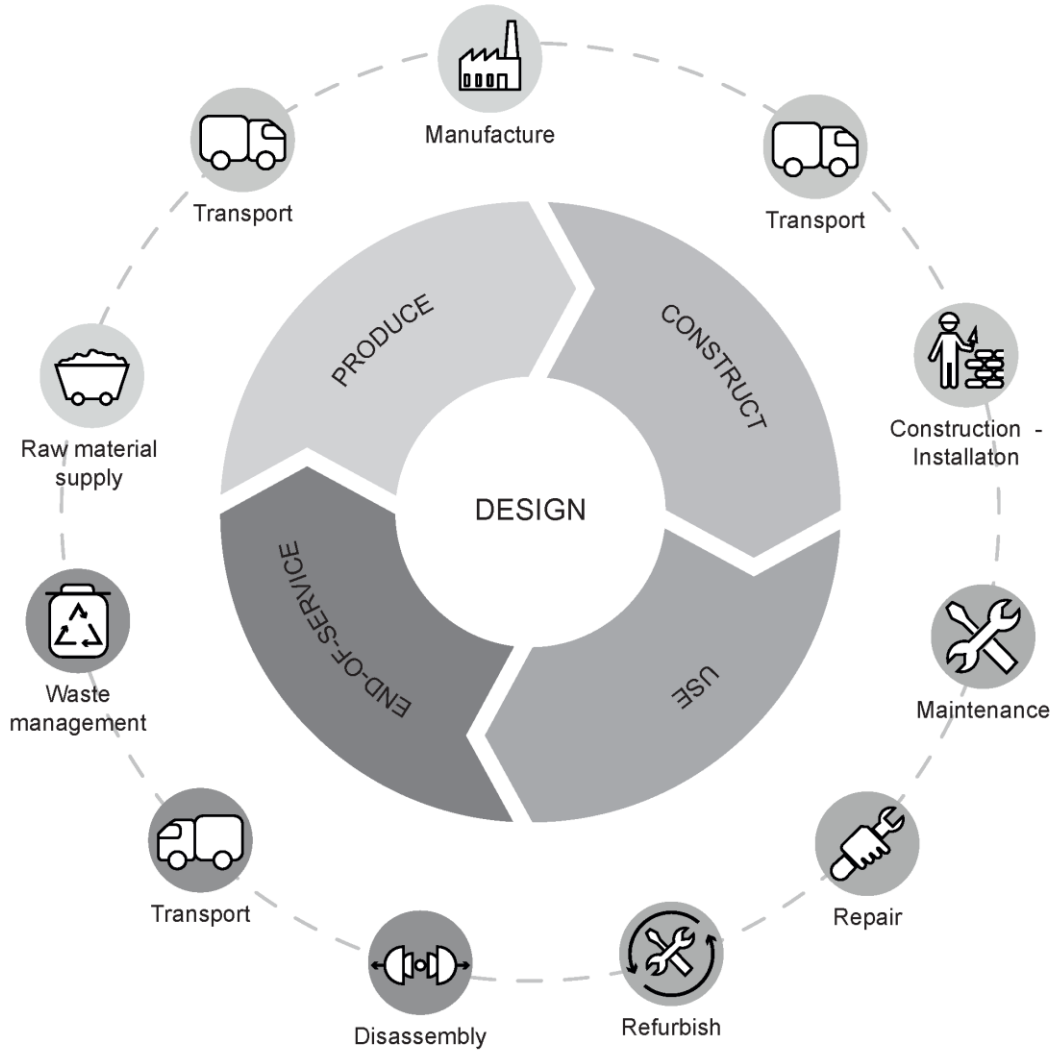
Circularity

Integration of **circular building principles** in the planning of THUs can help **bring economical value** back to the donors, **strengthen the community resilience** and **keep the materials in the technical and biological loop.**

R strategies

circularity potential

- R0 **Refuse**
- R1 **Rethink**
- R2 **Reduce**
- R3 **Reuse**
- R4 **Repair**
- R5 **Refurbish**
- R6 **Remanufacture**
- R7 **Repurpose**
- R8 **Recycle**
- R9 **Recover**



Source: DelftX: CESBE1x Circular Economy for a Sustainable Built Environment

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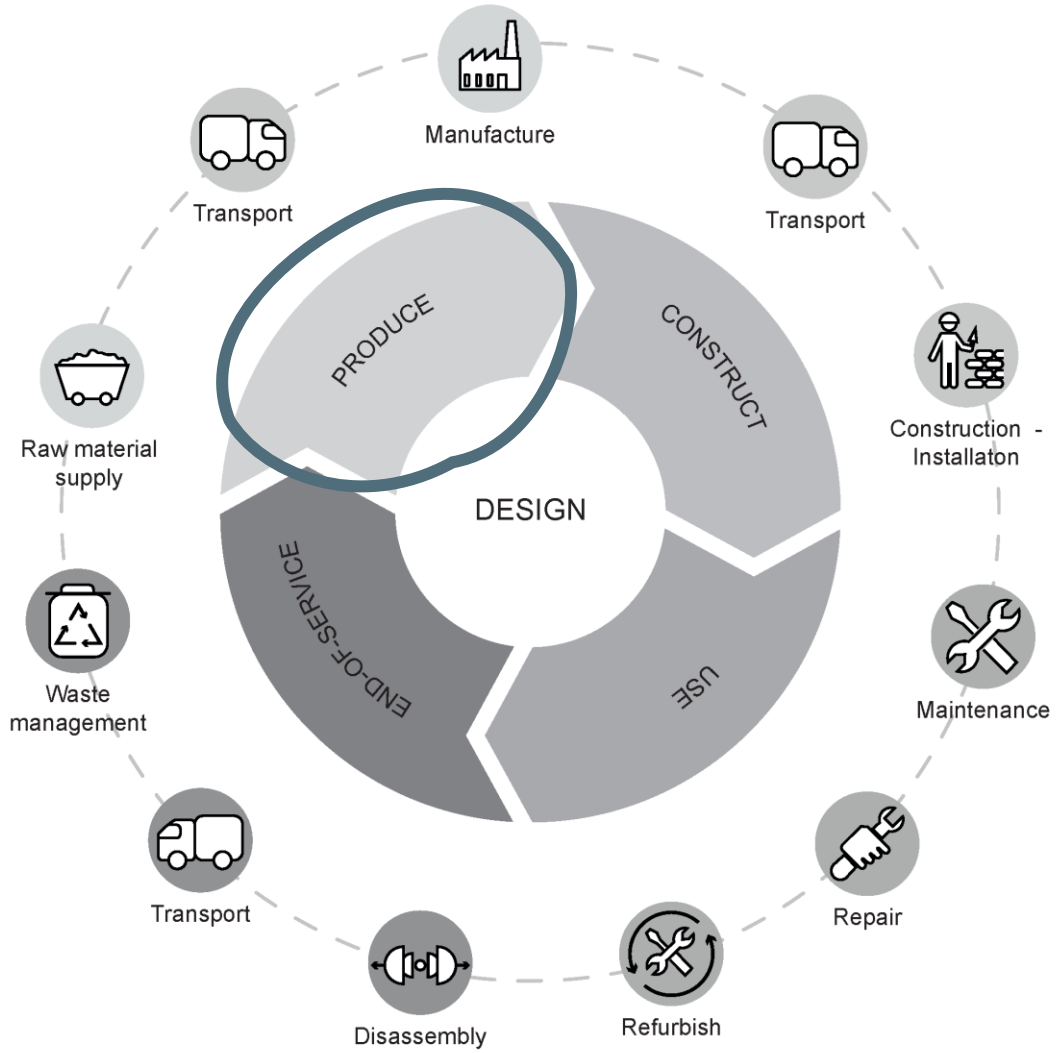

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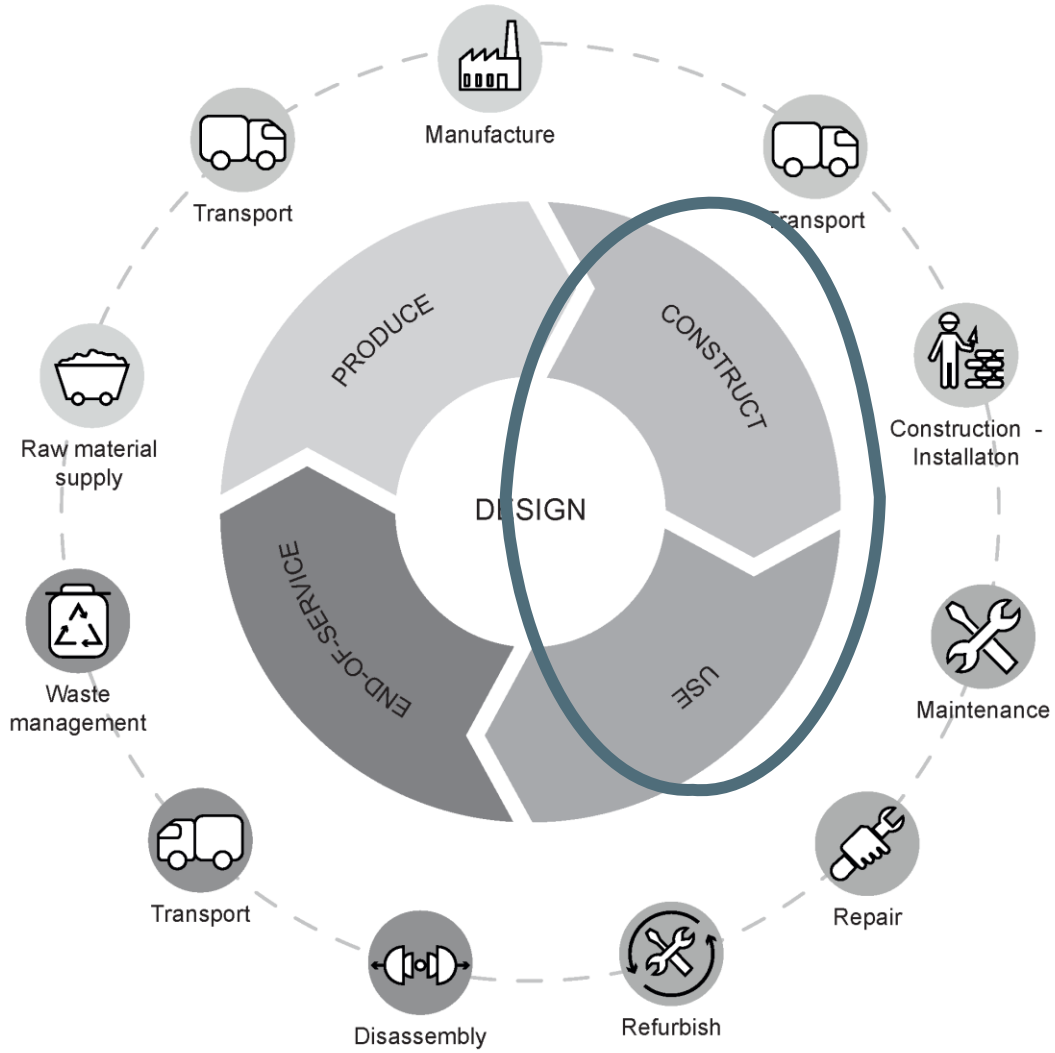

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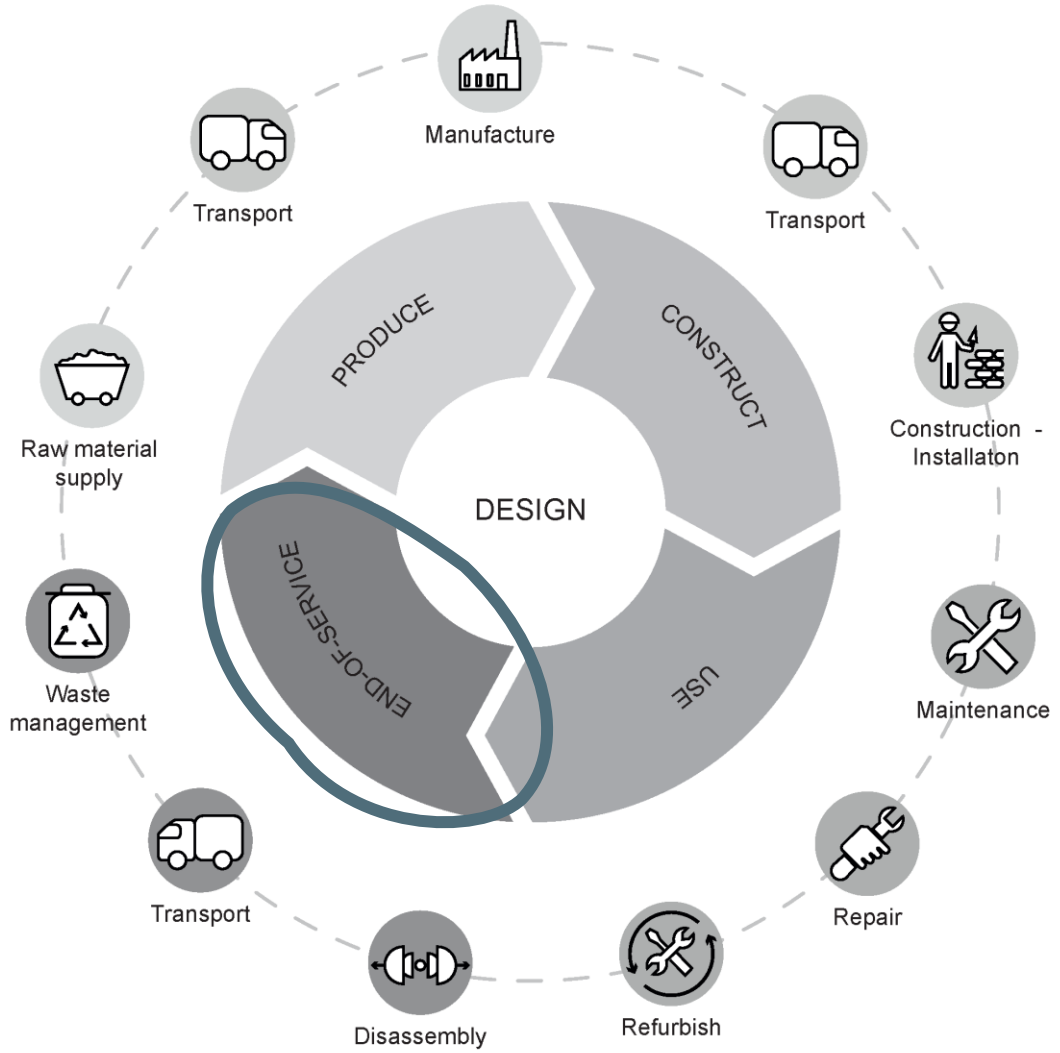

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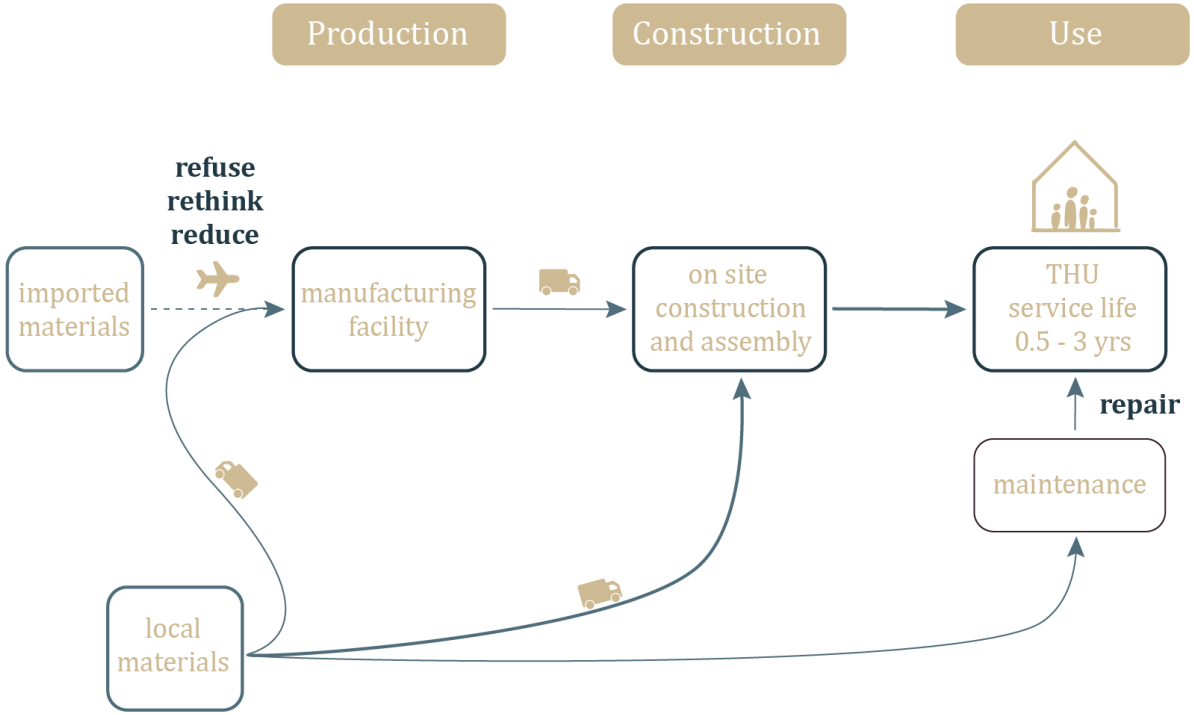
Alternative lifecycle and EoL scenarios



probability of action

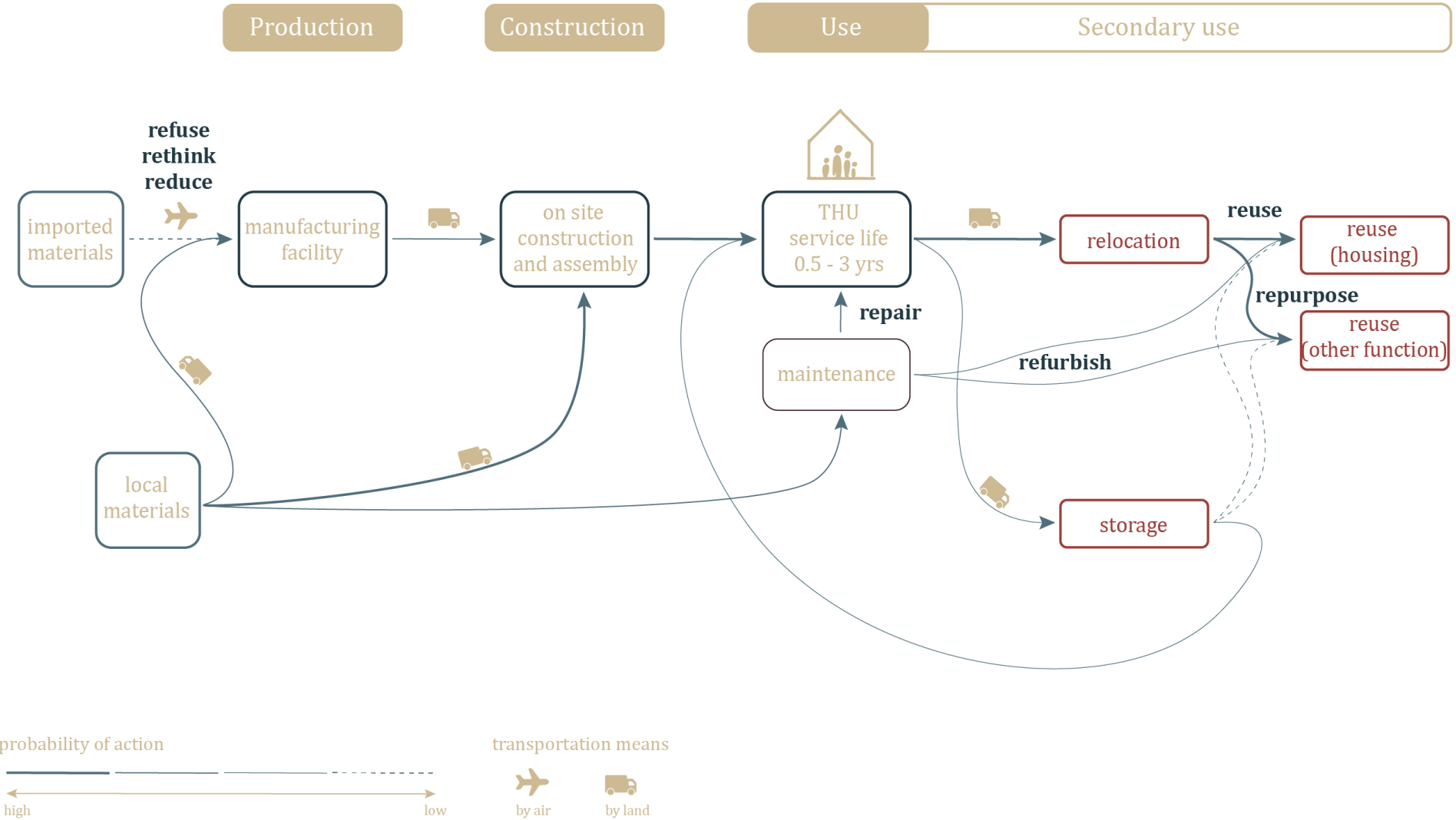
high — low

transportation means

by air

by land

Alternative lifecycle and EoL scenarios



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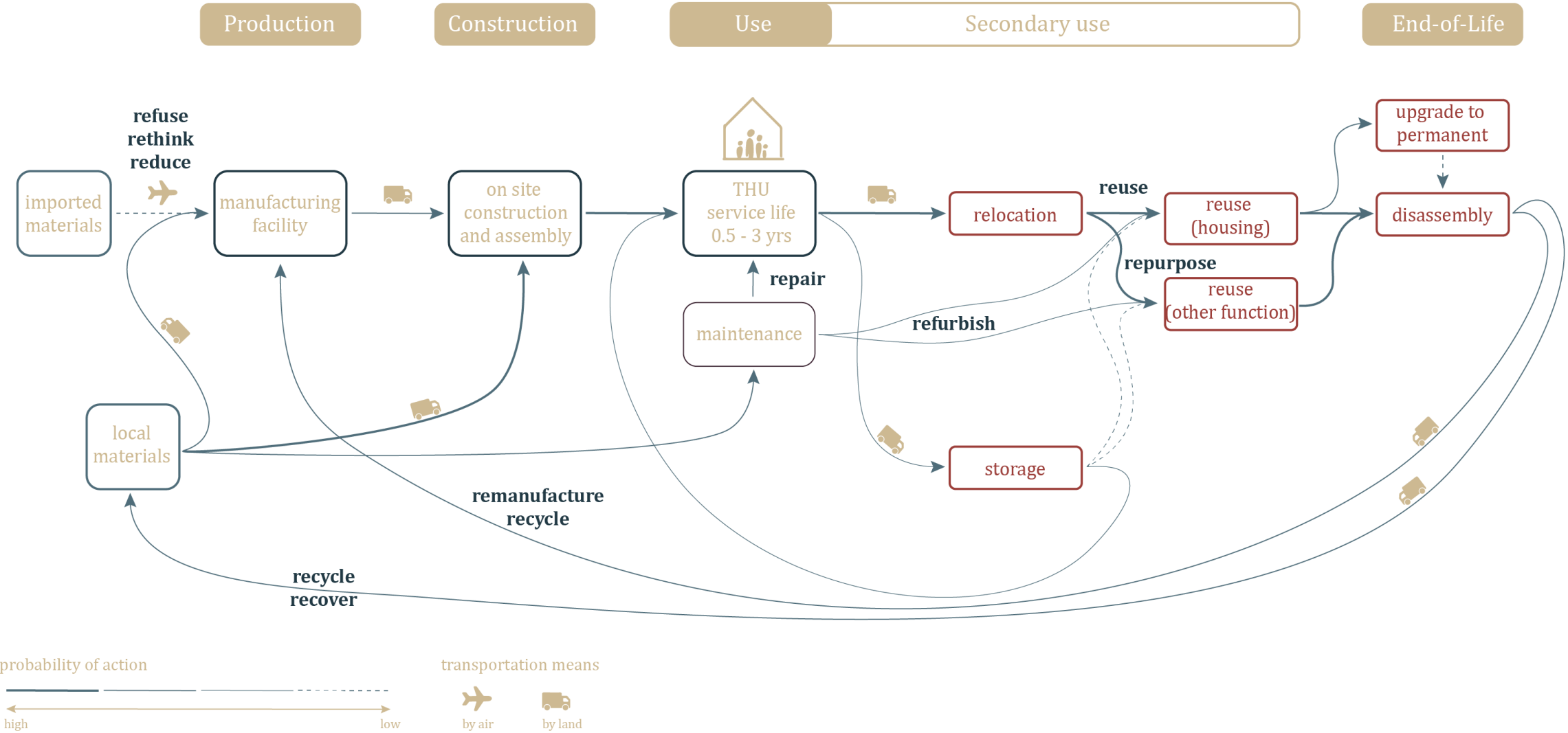
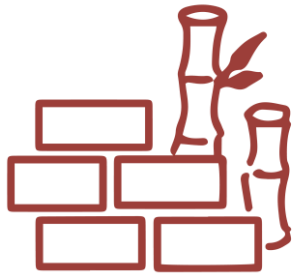


Domains of circularity



Material

Design

Manufacturing

Management

Circularity principles

Material

Local material

Biobased material

Waste material

Recyclable material

Secondary streams

Design

Design for disassembly

Modular design

Design for longevity

Design for standardisation

Design for adaptability

Material optimisation

Design for recycling

Manufacturing

Prefabrication

Additive manufacturing

CNC milling

Robotics

Vernacular building techniques

Management

Create guidelines

Take-back agreements

Scenario planning

Product as a service

BIM

Material passport

BAMB

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Product as a service

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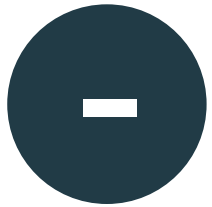
Material passport

BAMB

preventing extraction of raw materials

less emissions and embodied energy



requires quality control

availability might be limited

Circularity principles

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Biobased material

Waste material

Recyclable material

Secondary streams

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Modular design

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Additive manufacturing

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Vernacular building techniques

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Create guidelines

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Scenario planning

Product as a service

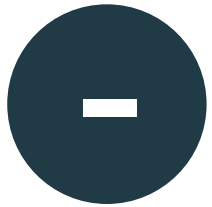
BIM

Material passport

BAMB

controlled production environment

improved safety on construction site



transportation needs to be considered

need for large factory space

Circularity principles

Material	Design	Manufacturing	Management
Local material	Design for disassembly	Prefabrication	Create guidelines
Biobased material	Modular design	Additive manufacturing	Take-back agreements
Waste material	Design for longevity	CNC milling	Scenario planning
Recyclable material	Design for standardisation	Robotics	Product as a service
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CTH*1 pictures; Photos: Sebastian Kolm Source: Archdaily

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B.R.I.C. project details; Source: BAMB 2020

Circularity principles

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Blooming Bamboo Home pictures; Credit: Doan Thanh Ha; Source: Archdaily

Recommendation set and evaluation tool: need

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?

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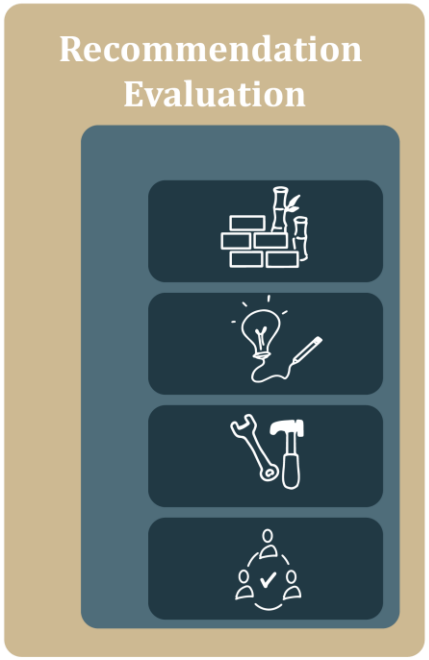


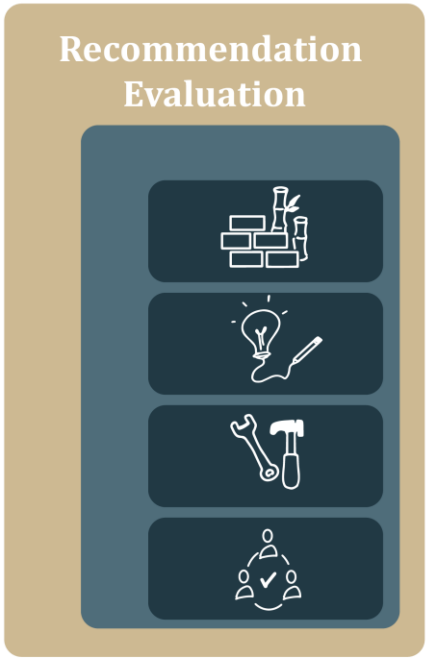
Recommendation set and evaluation tool

Design support

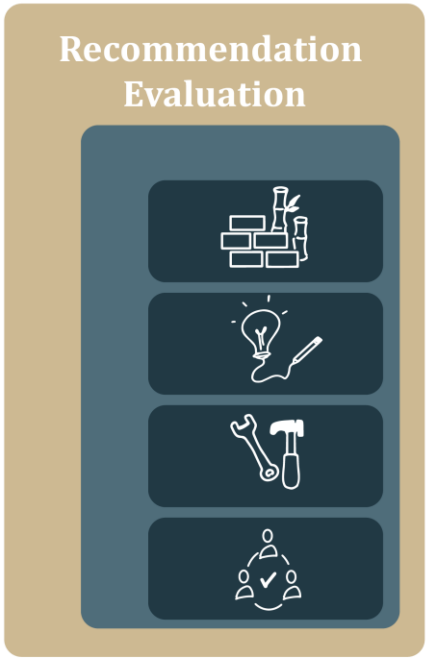
new projects

Design evaluation

exisiting projects



Case study: Pakistan



Pakistan


China
Gilgit–
Baltistan
Khyber
Pakhtunkhwa
Islamabad
Azad Jammu
and Kashmir
Afghanistan
Punjab
India
Baluchistan
Iran
Sindh
Arabic sea

Pakistan

Islamic republic
majority Sunni Muslim

> 231 M
population 2023

53.3% under
25 year old (2016)

6.5
average
household size

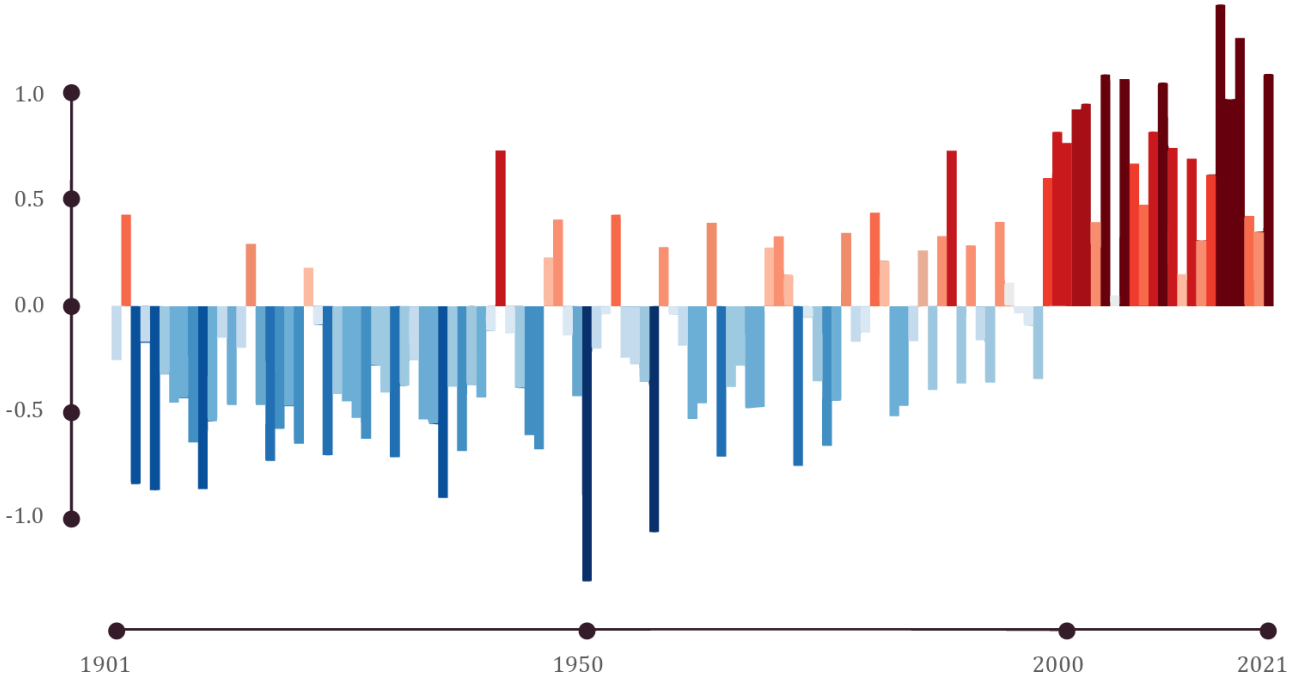
multigenerational
households

wasta
forming
social connection

90% live on less than
$10 per day

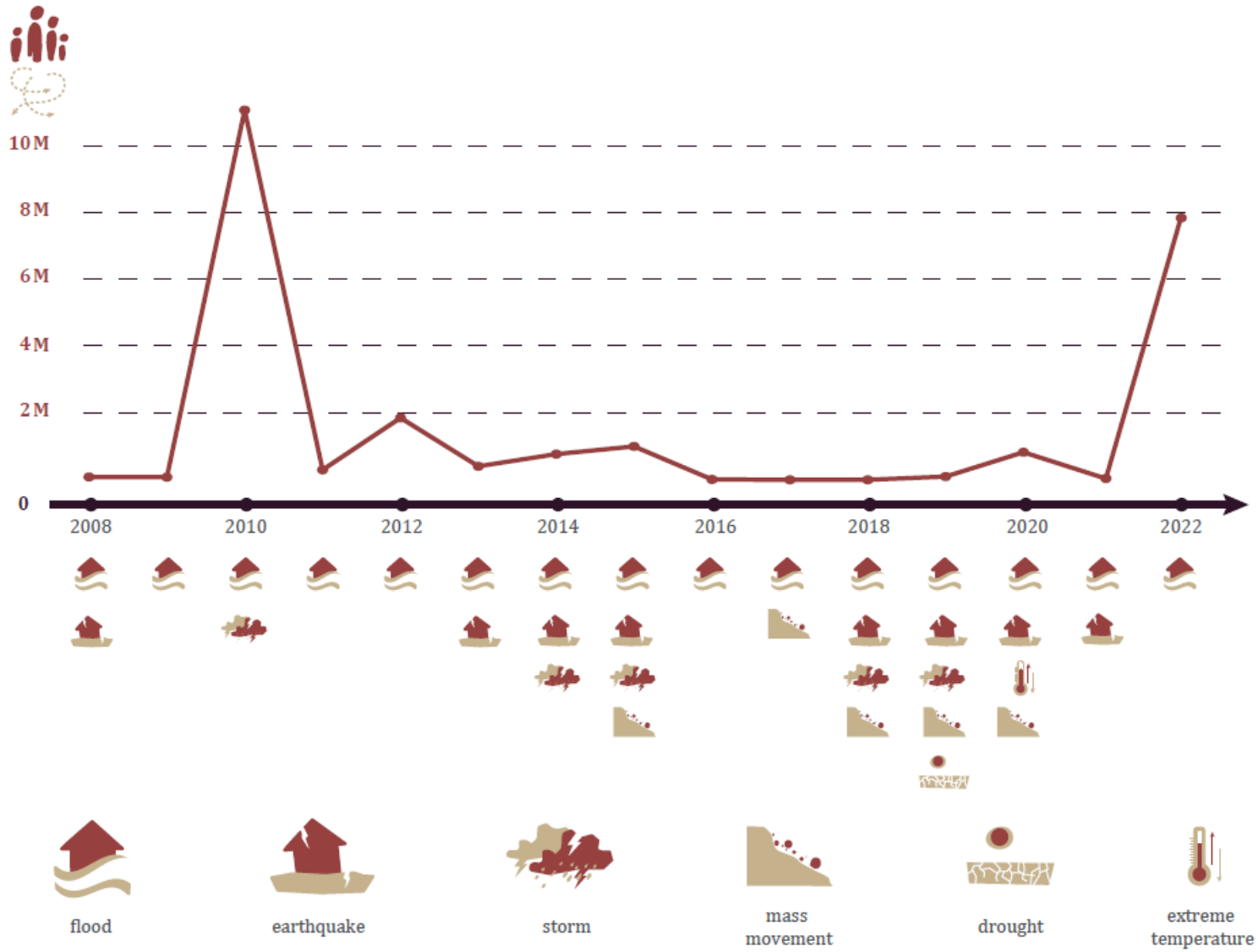
Climate change vulnerability

Temperature change in Pakistan, relative to average of 1971 – 2000 [°C]



Temperature change in Pakistan, relative to average of 1971 – 2000 [°C]; adapted from Ed Hawkins, https://showyourstripes.info/l/asia/pakistan/

Displacement and causes



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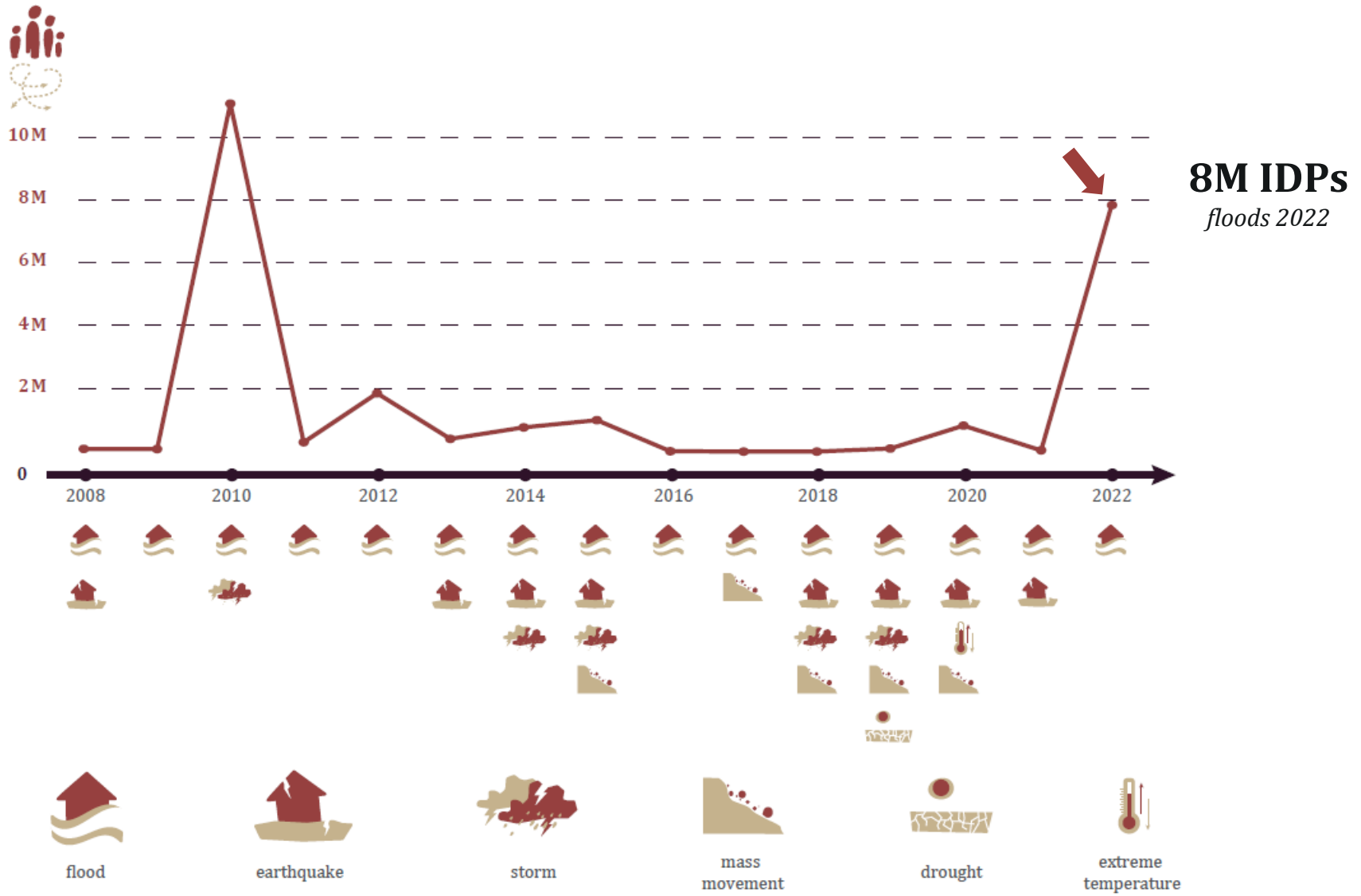


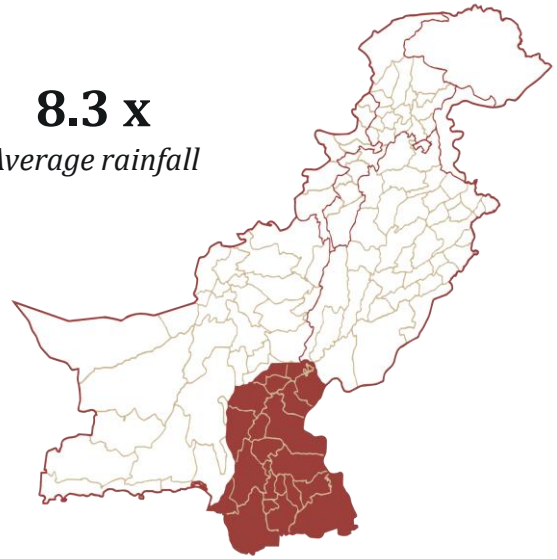
Floods 2022


33M
Affected people


Photo credit: Thomas Koch/Shutterstock.com
2.1M
Houses damaged

Sindh province

8.3 x
Average rainfall

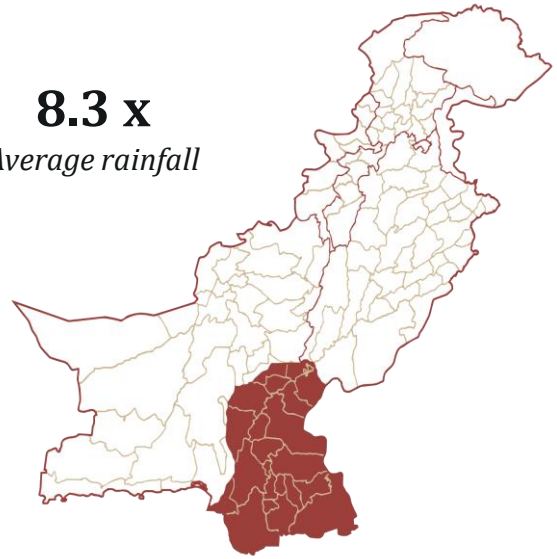


1.1M
Houses damaged

683K
Houses destroyed

430K
Livestock loss

Sindh province



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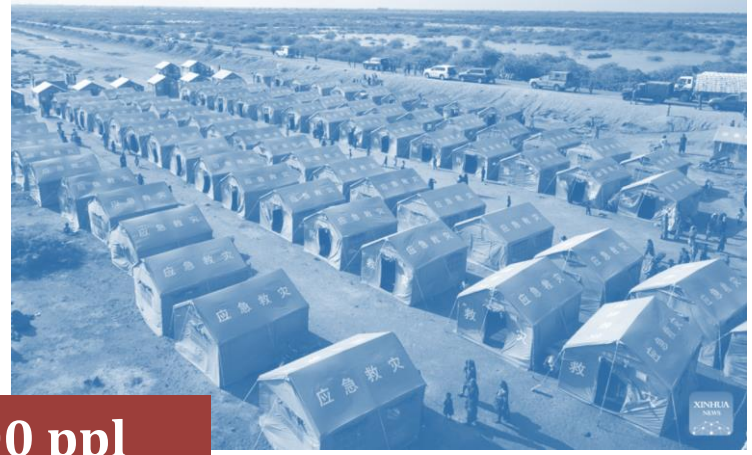
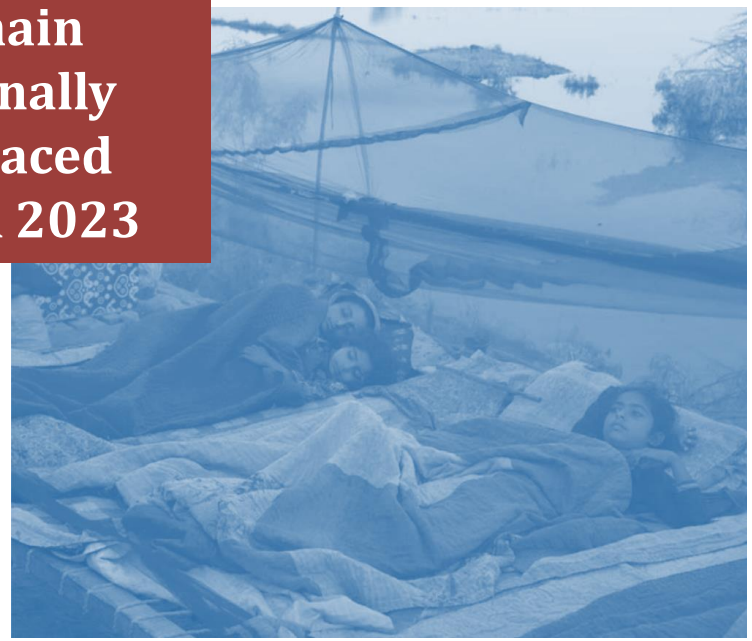


30 000 ppl remain internally displaced March 2023



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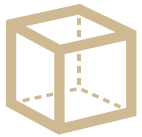
Design requirements

6 person
household

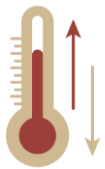


> 21m²
excl. facilities

24 months
exp. occupancy

flood
resistant

Design requirements



climate appropriate

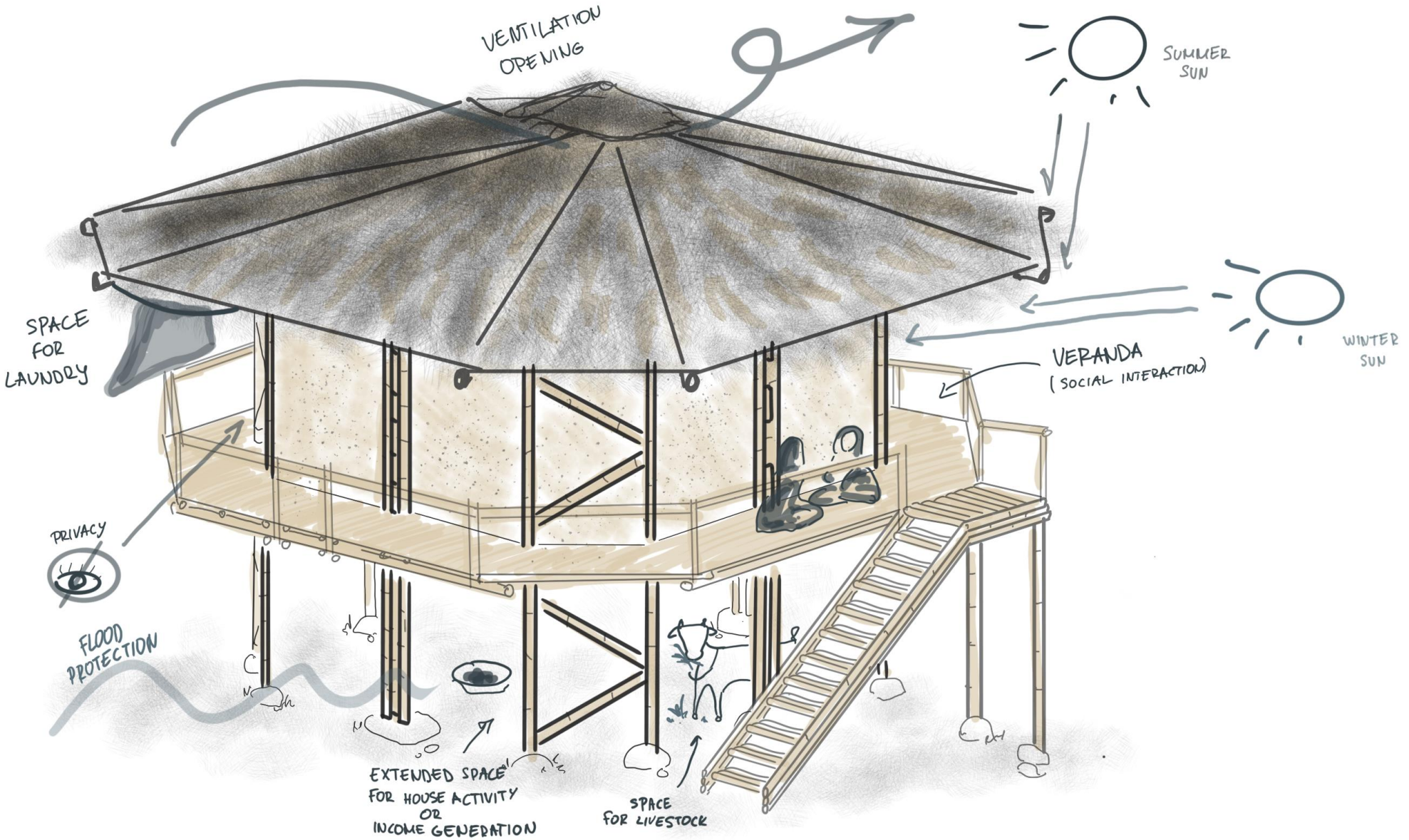
5° to 45°C

culture appropriate

covered outdoor space

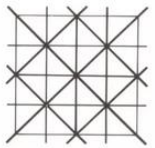
income opportunity

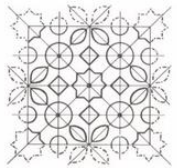
Concept

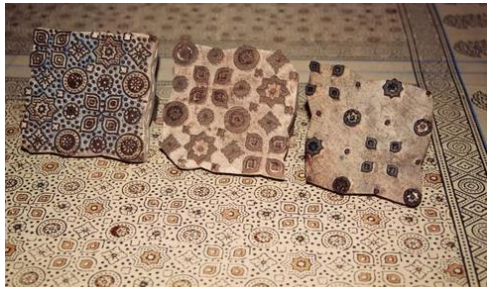

VENTILATION OPENING
SUMMER SUN
WINTER SUN
SPACE FOR LAUNDRY
VERANDA (SOCIAL INTERACTION)
PRIVACY
FLOOD PROTECTION
EXTENDED SPACE FOR HOUSE ACTIVITY OR INCOME GENERATION
SPACE FOR LIVESTOCK

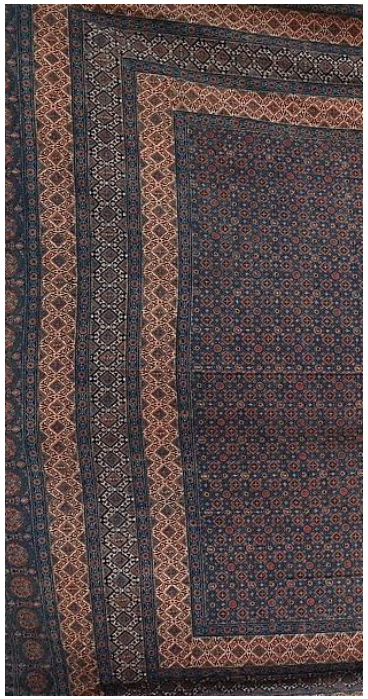
Concept Ajrak

ajrak – *blue* (arabic)



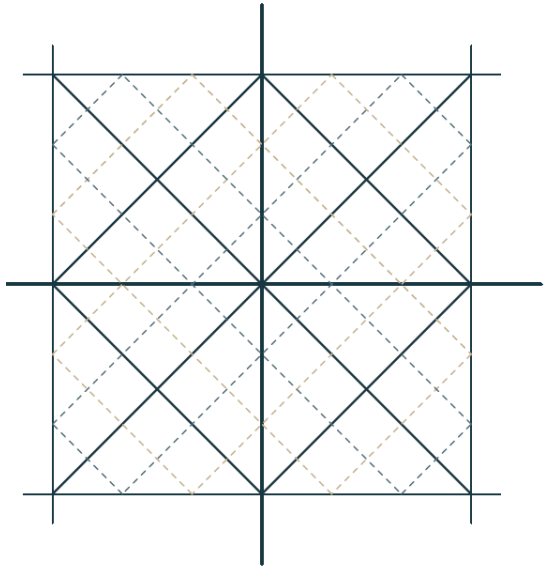




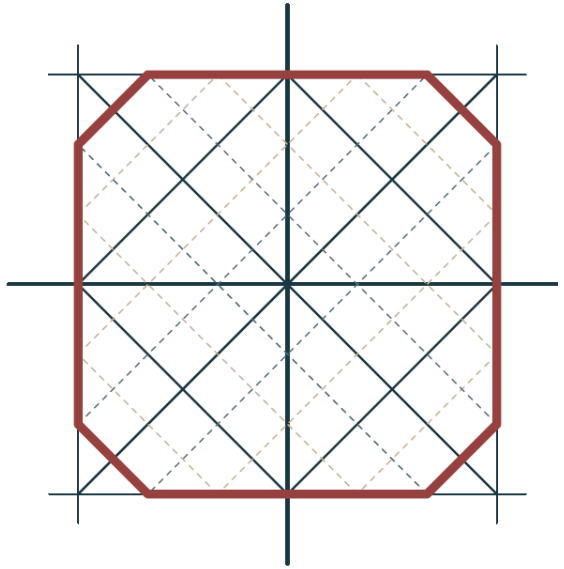


Concept Ajrak

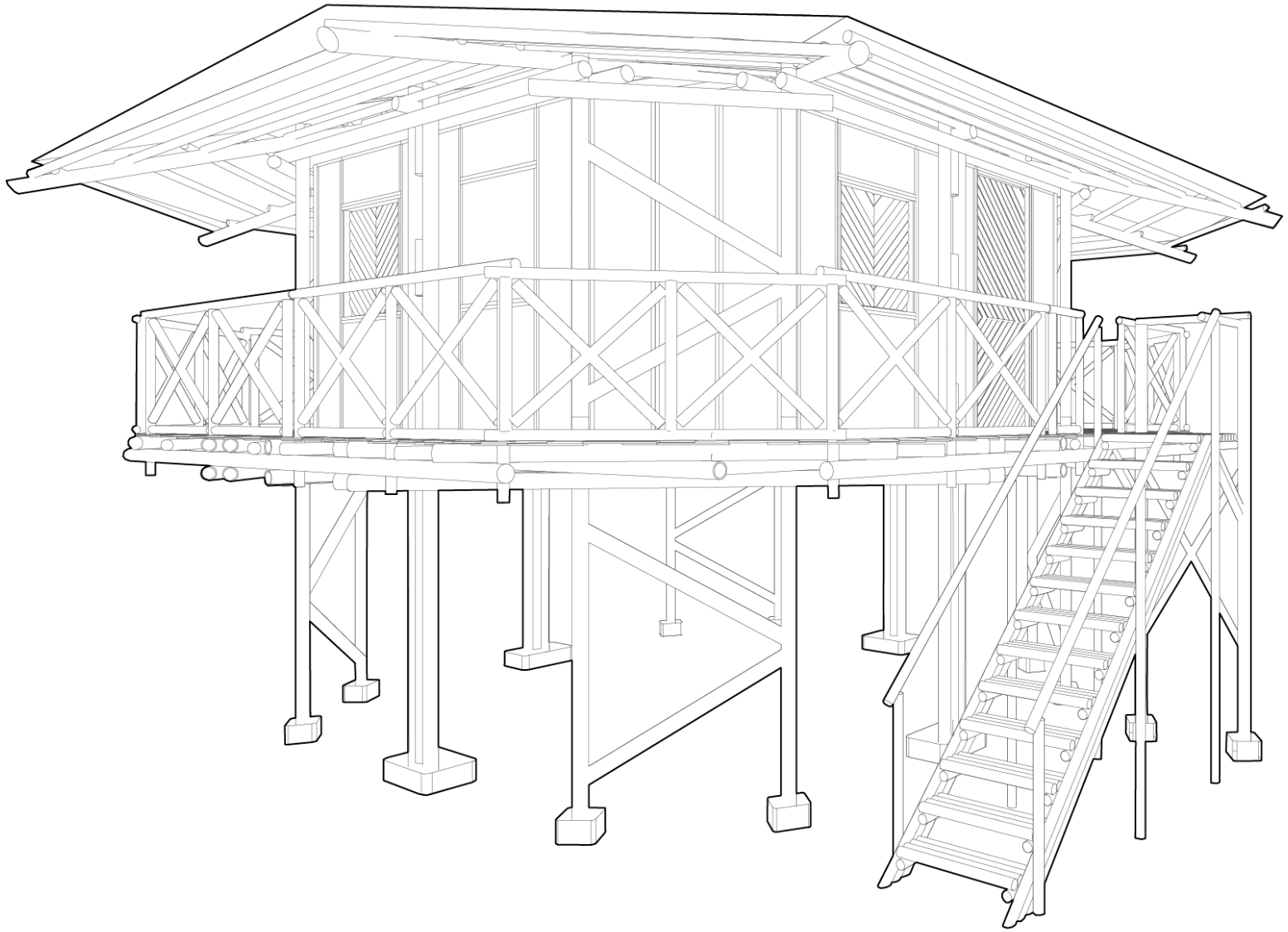
ajrak – *blue* (arabic)

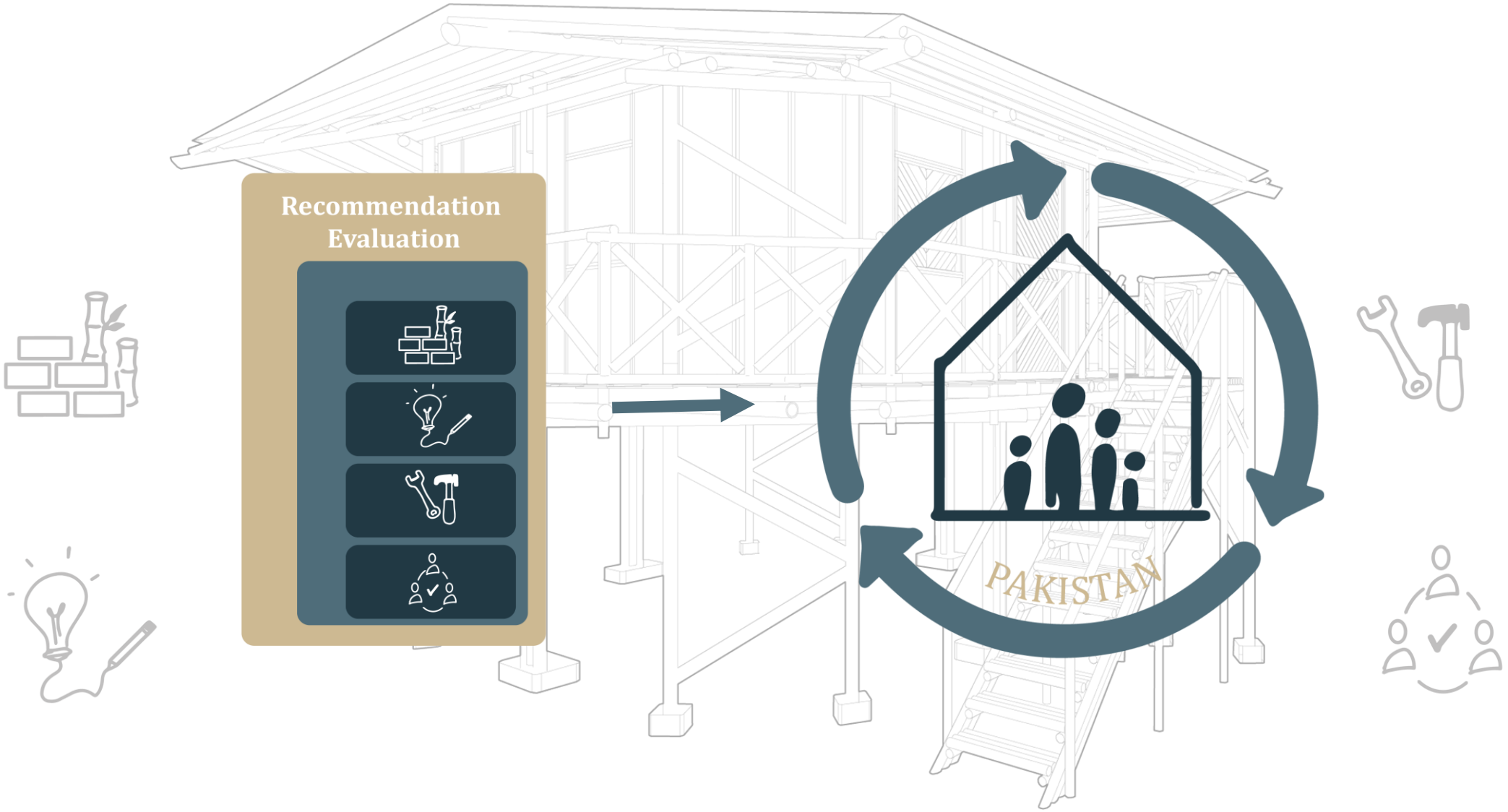


symmetry

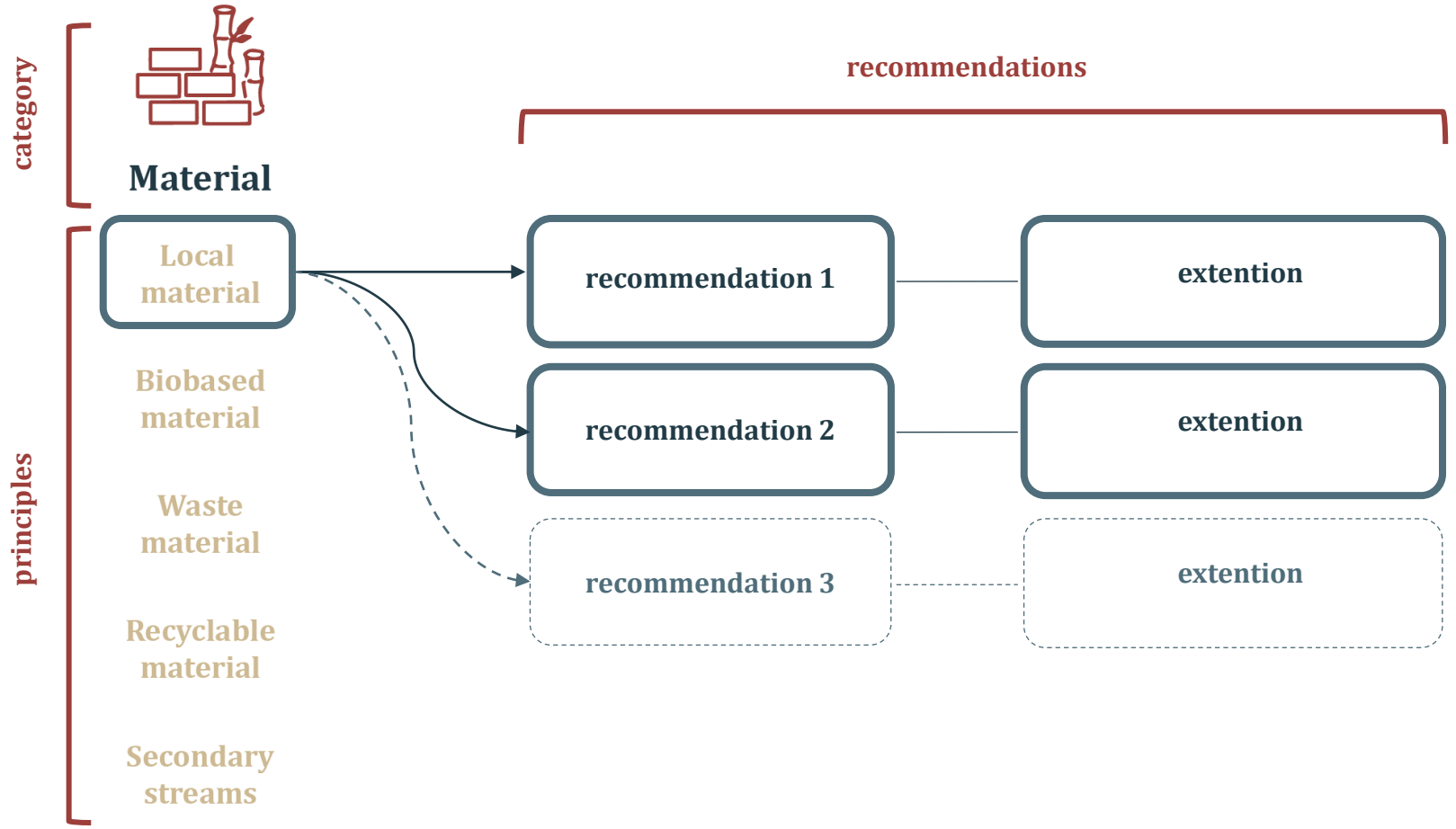


area/ perimeter



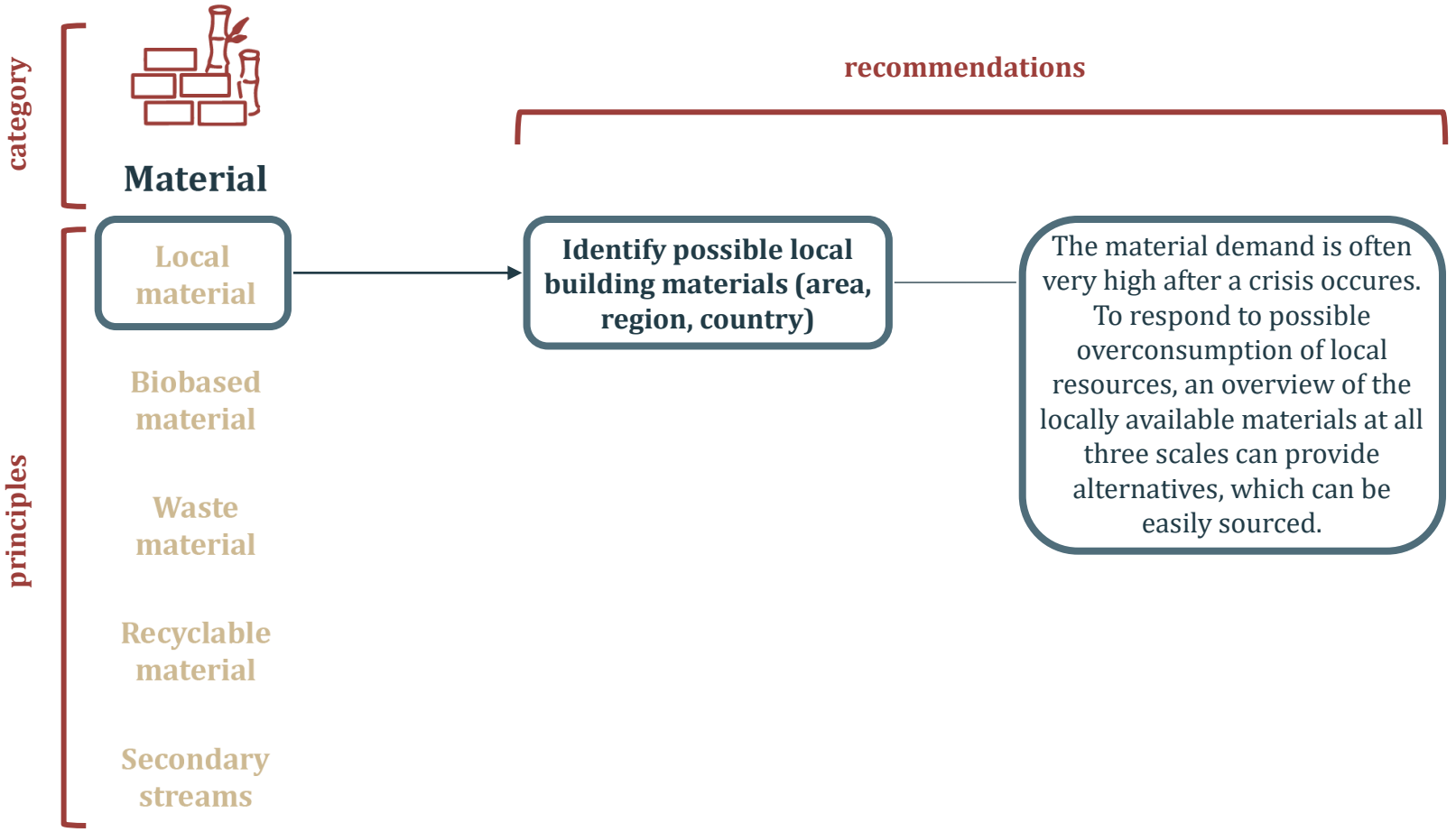

Recommendation
Evaluation
PAKISTAN

Recommendation set and evaluation tool



Recommendation set and evaluation tool

Design support



Material

Material

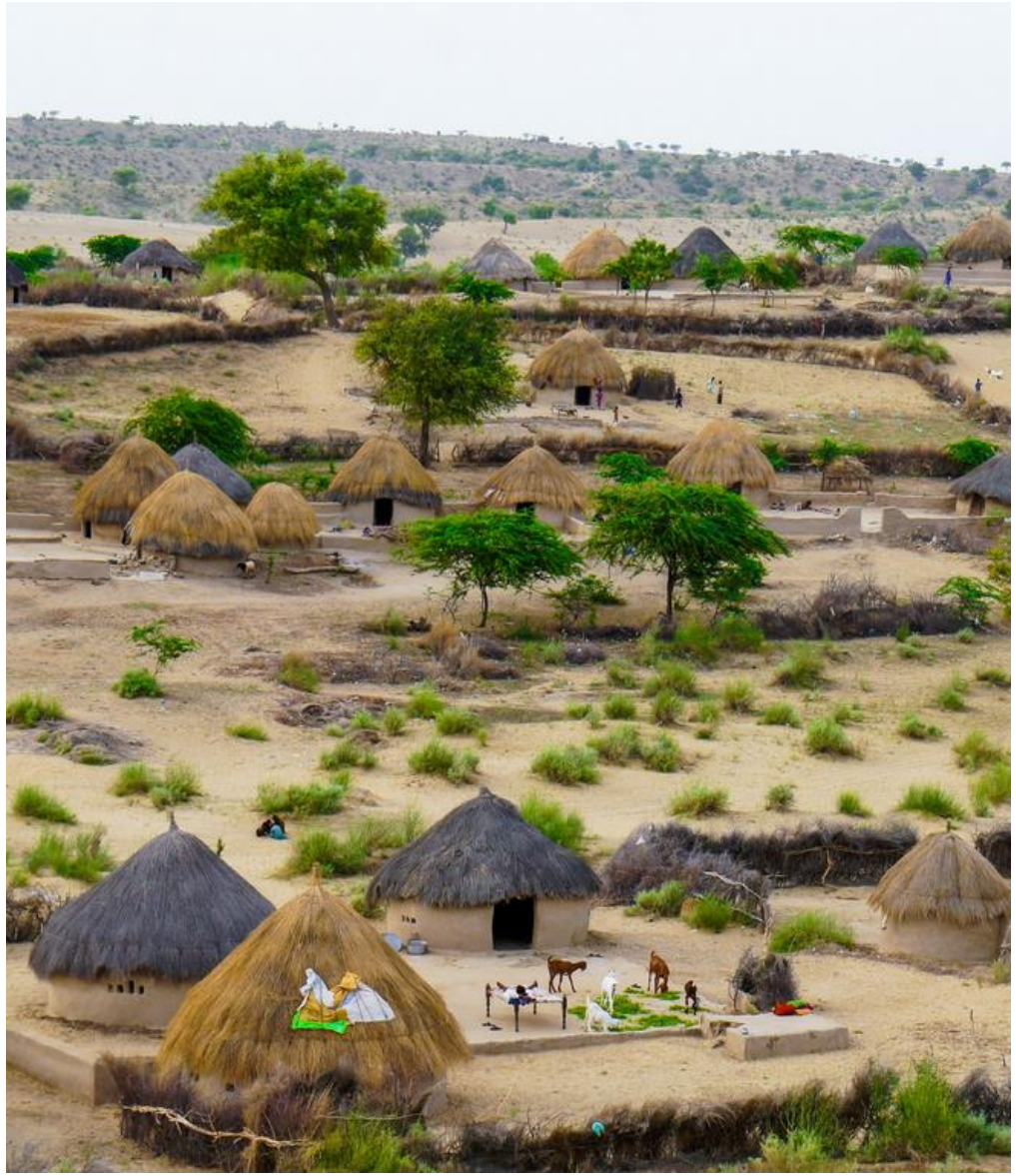
Local material

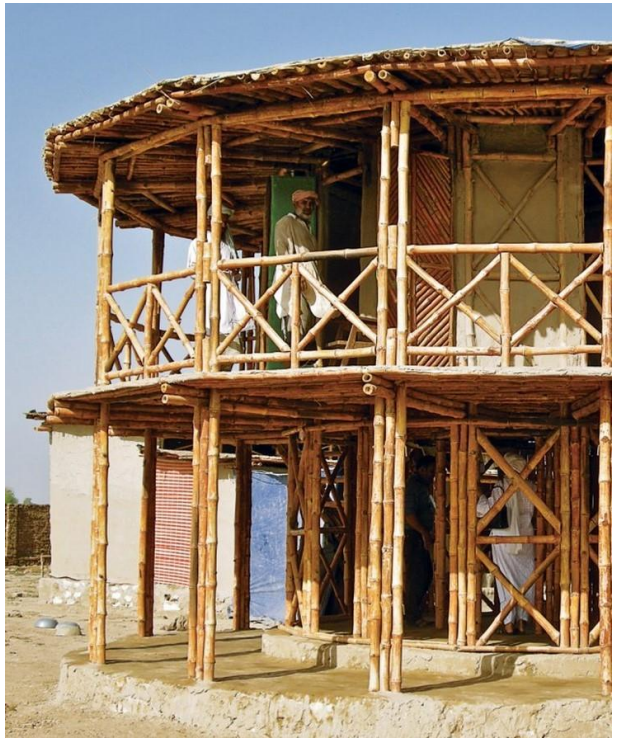
Biobased material

Waste material

Recyclable material

Secondary streams





Photos: Emmanuel Guddu; Heritage Foundation of Pakistan

Material

Material

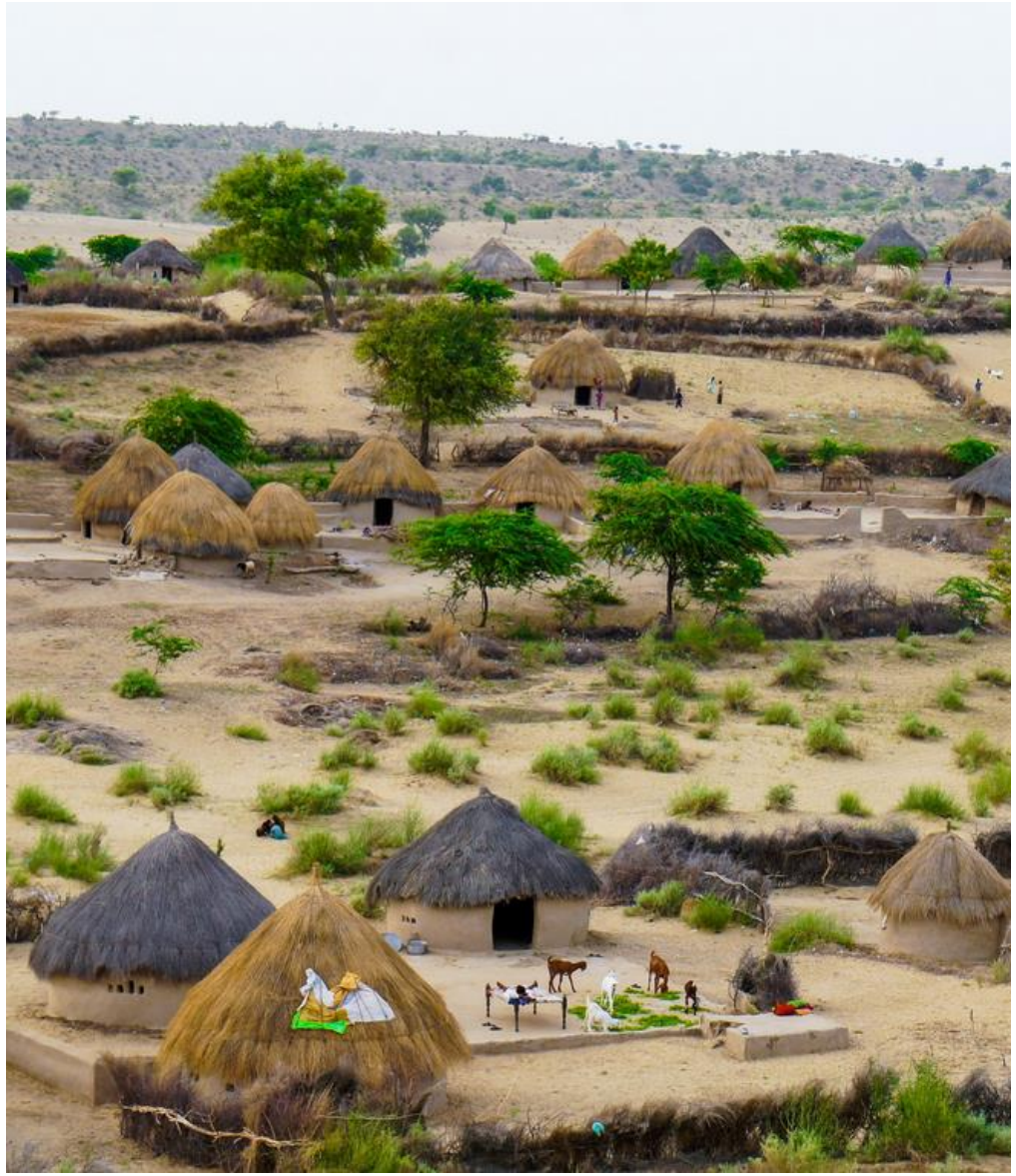
Local material

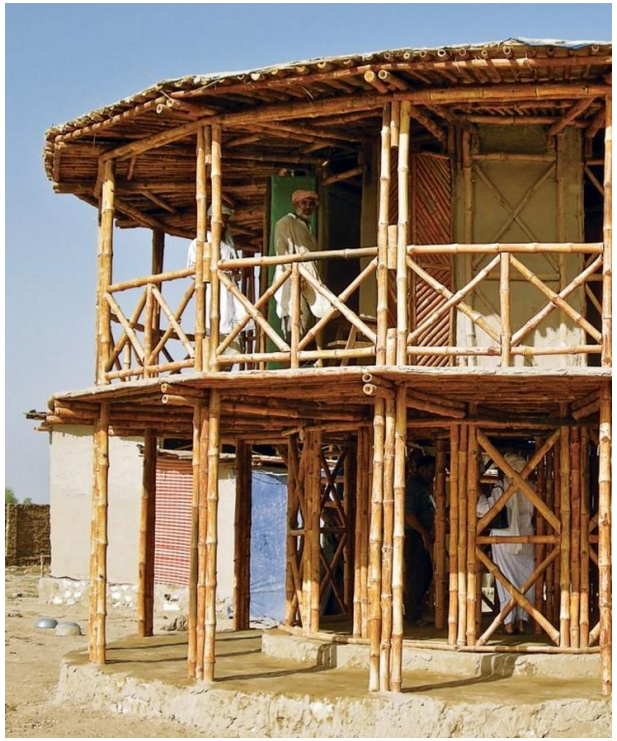
Biobased material

Waste material

Recyclable material

Secondary streams





Photos: Emmanuel Guddu; Heritage Foundation of Pakistan

Material

Material

Local material

Biobased material

Waste material

Recyclable material

Secondary streams

Identify possible local building materials (area, region, country)

Material

Material

Local material

Biobased material

Waste material

Recyclable material

Secondary streams

Material

Material

Local material

Biobased material

Waste material

Recyclable material

Secondary streams

→ **Identify possible local building materials (area, region, country)**

Material

Material

Local material → Environmental impact of materials' sourcing and processing

Biobased material → Consider the harvest season

Waste material

Recyclable material

Secondary streams

Material

Material

Local material

Biobased material

Waste material

Recyclable material

Secondary streams

Identify waste materials (area, region, country)

byproduct

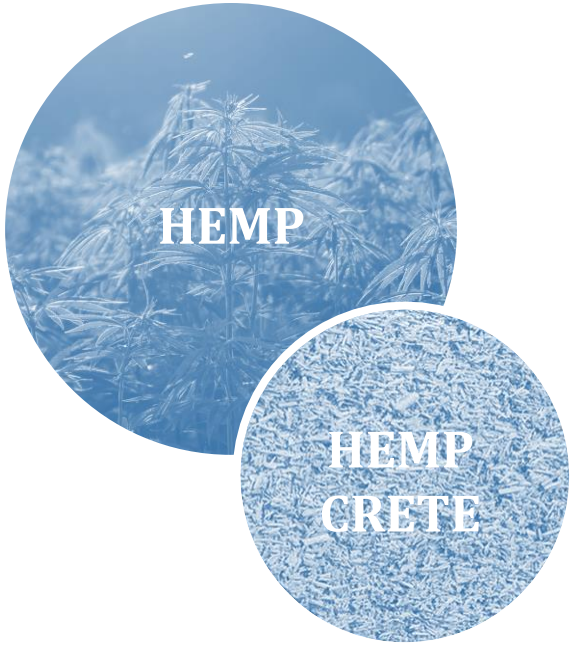
Hemp shives + lime binder + H_2O

CO_2

Material

Material

- Local material → Consider ease of maintenance
- Biobased material → Avoid toxic chemicals
- Waste material
- Recyclable material
- Secondary streams



Photos: ZRS Architecture; Heritage Foundation of Pakistan

Material

Material

Local material

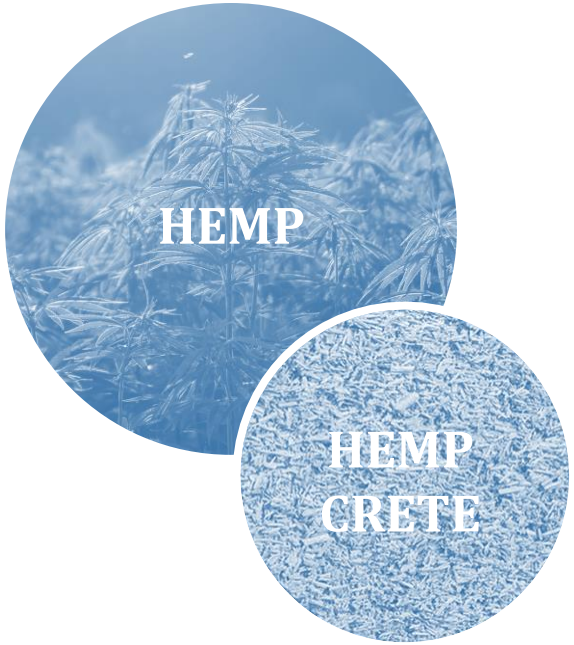
Biobased material

Waste material

Recyclable material

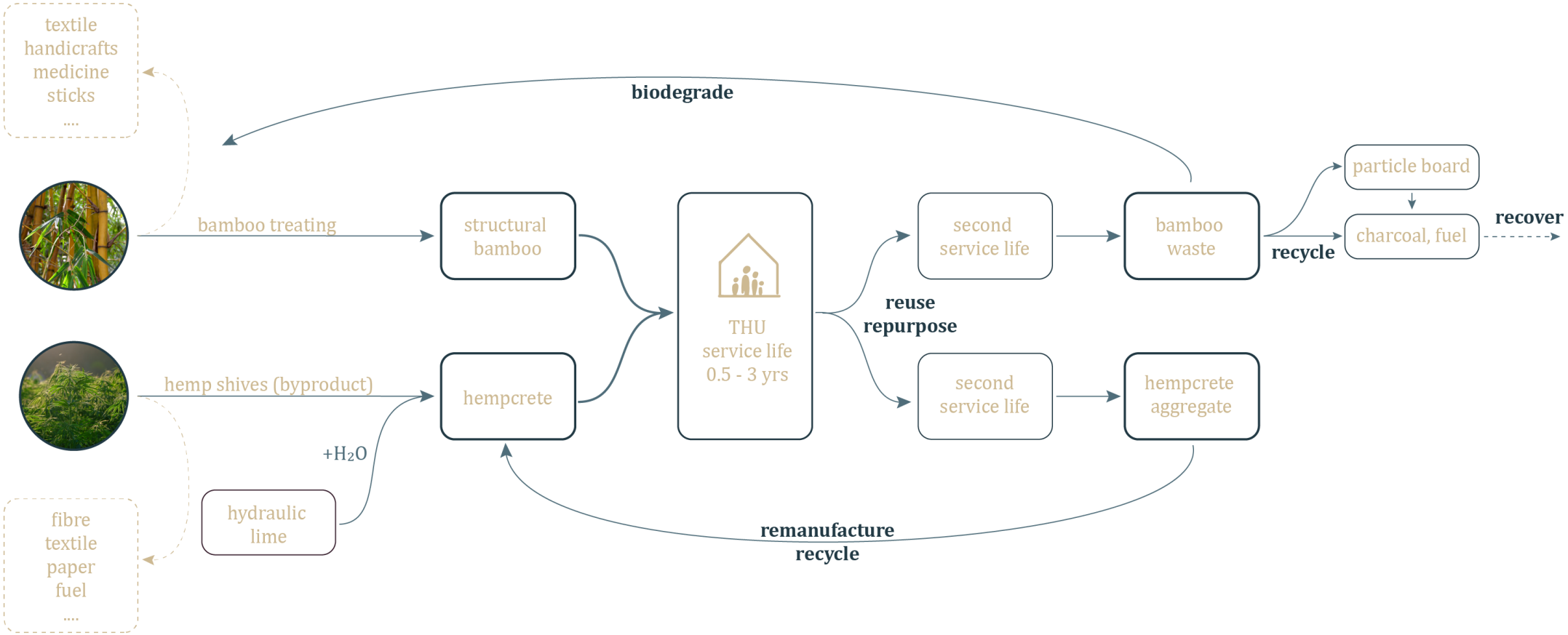
Secondary streams

→ **Identify suitable disposal options and their availability**



Material

Production | Construction | Use | Secondary use | End-of-Life



Design

Design

Design for disassembly

Modular design

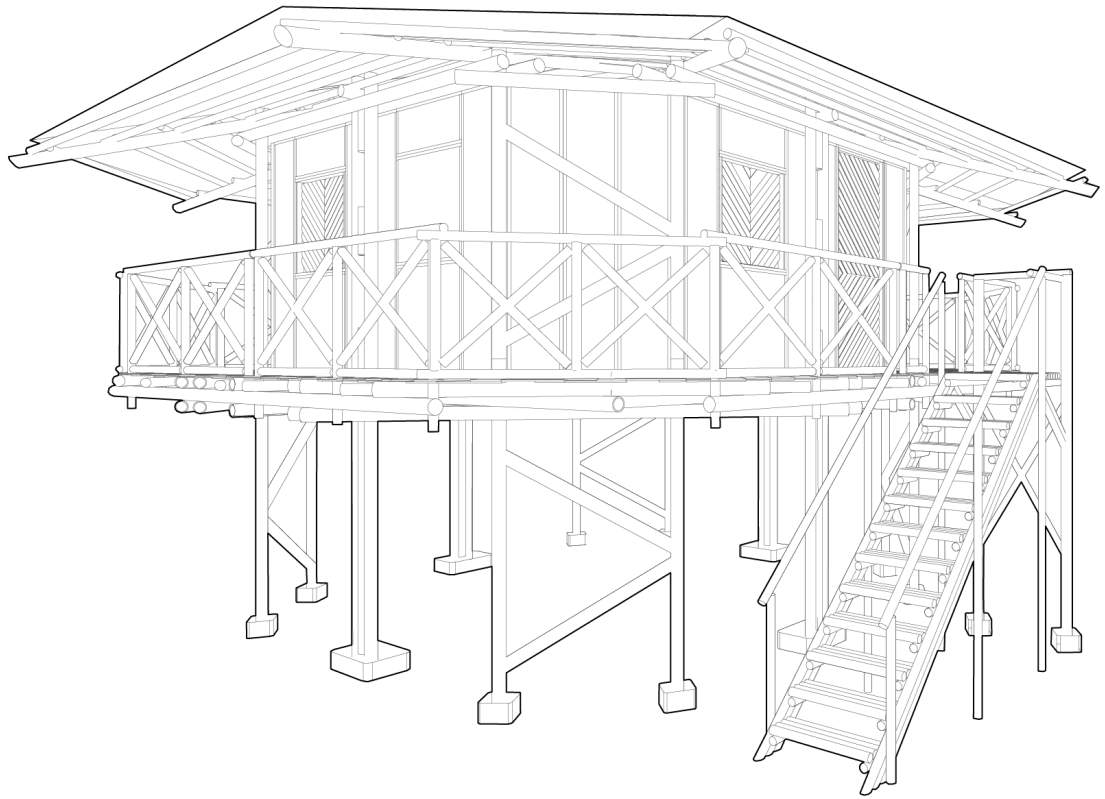
Design for longevity

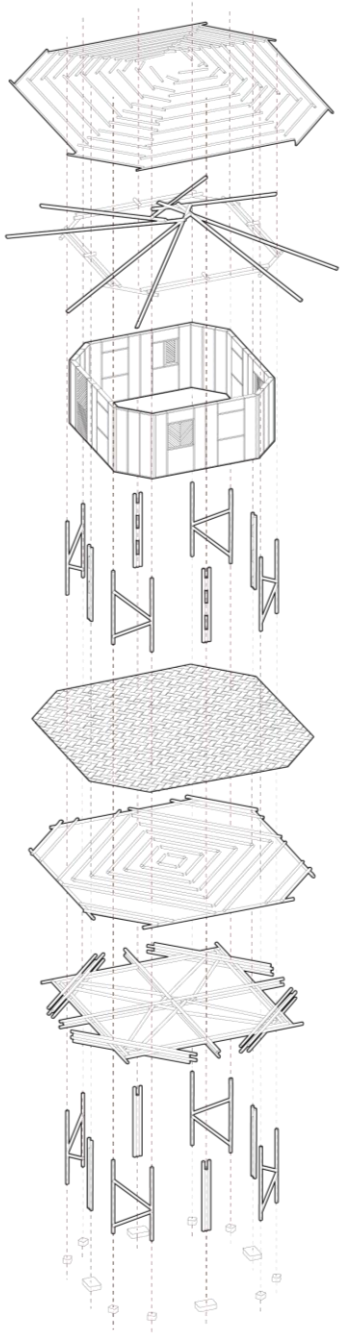
Design for standardisation

Design for adaptability

Material optimisation

Design for recycling



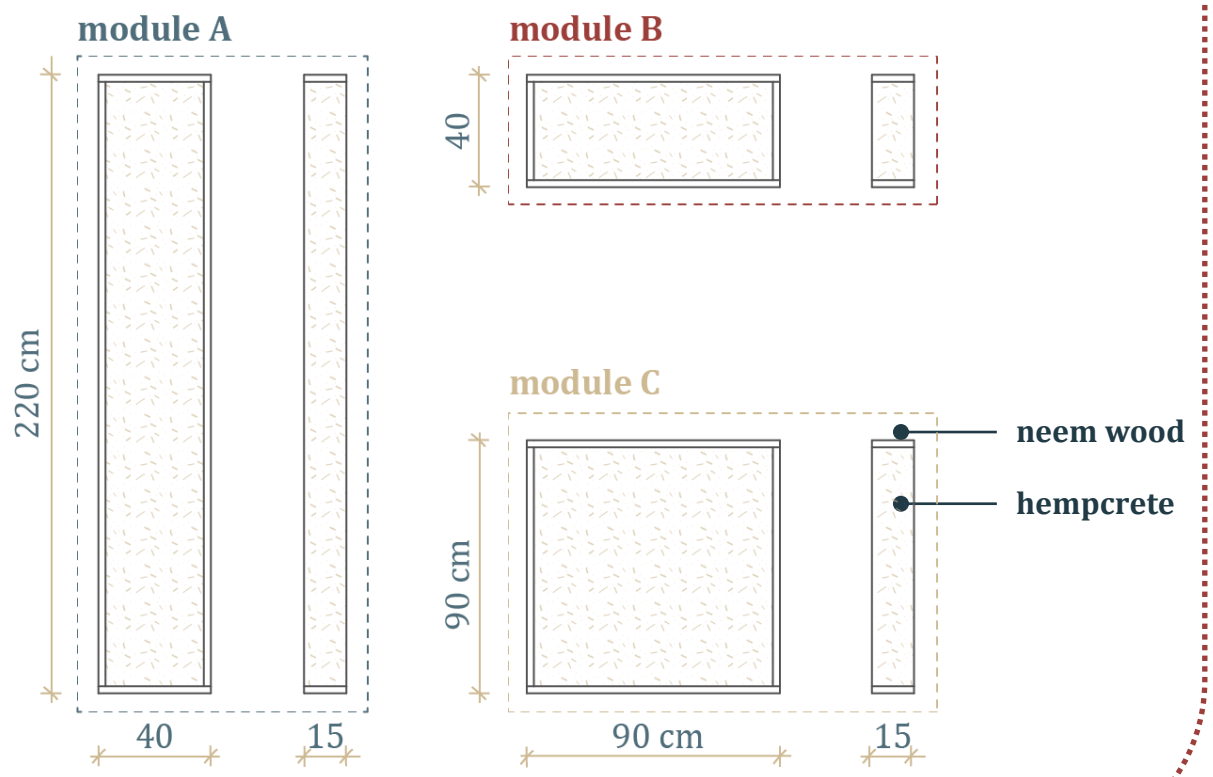


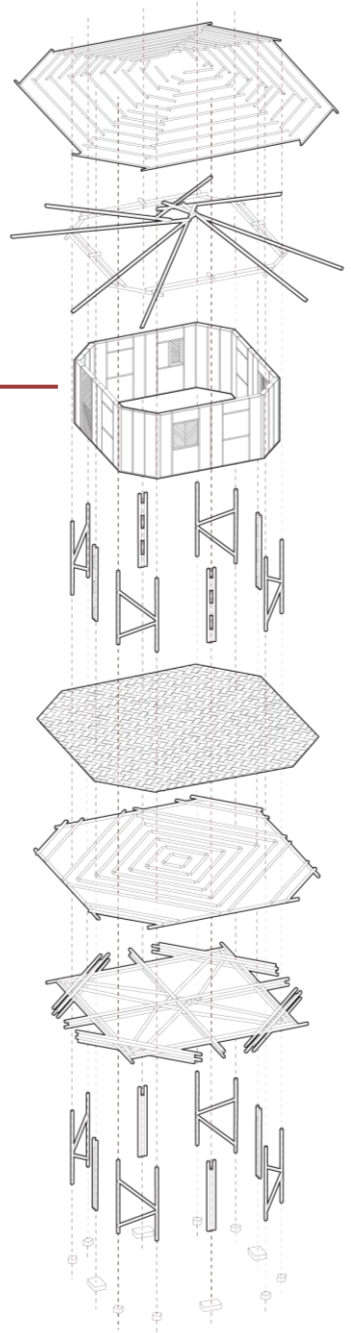
Design

Design

- Design for disassembly
- **Modular design**
- Design for longevity
- Design for standardisation
- Design for adaptability
- Material optimisation
- Design for recycling

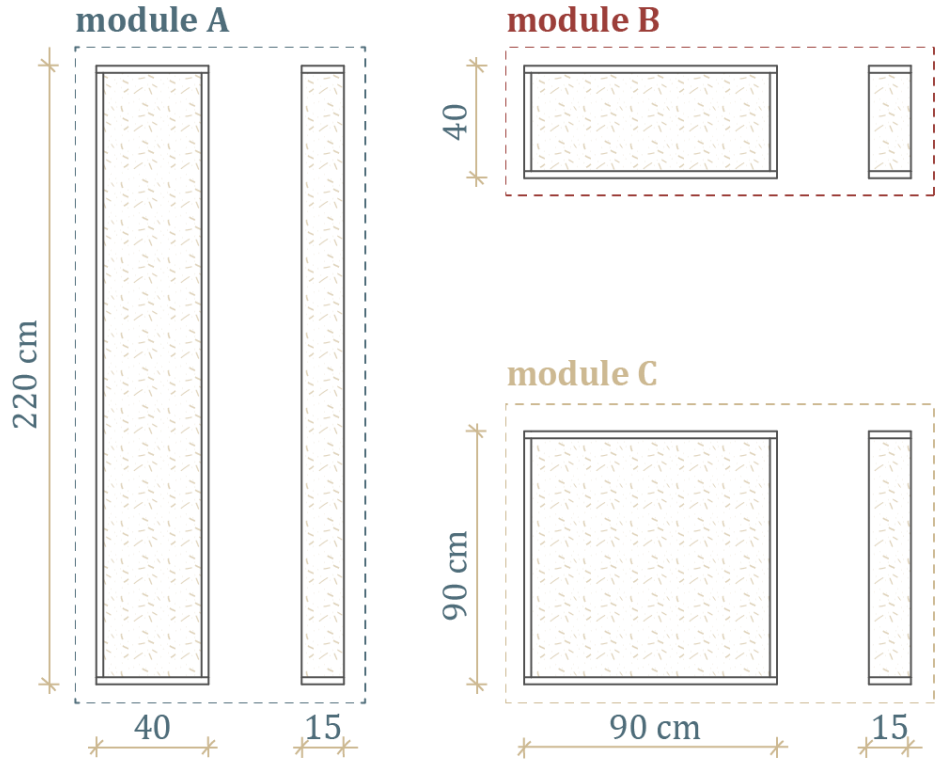
wall panels

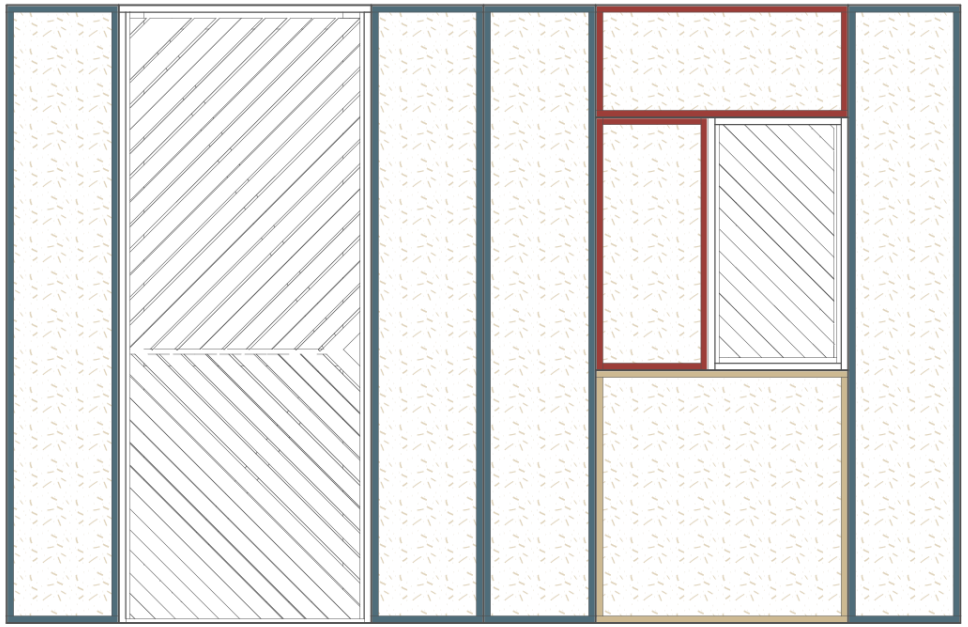




Design

wall panels

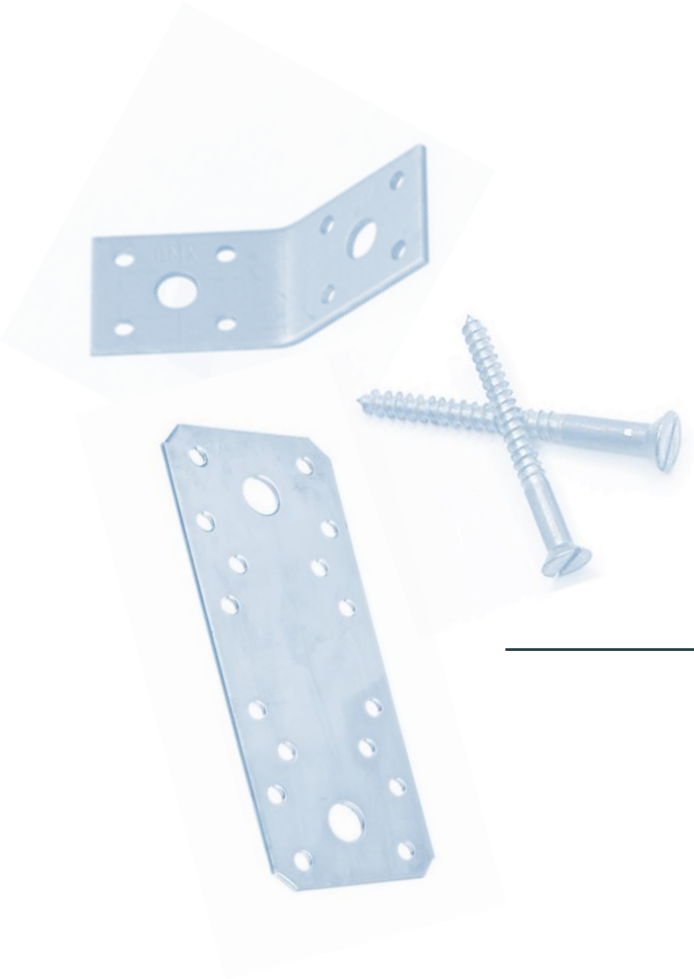


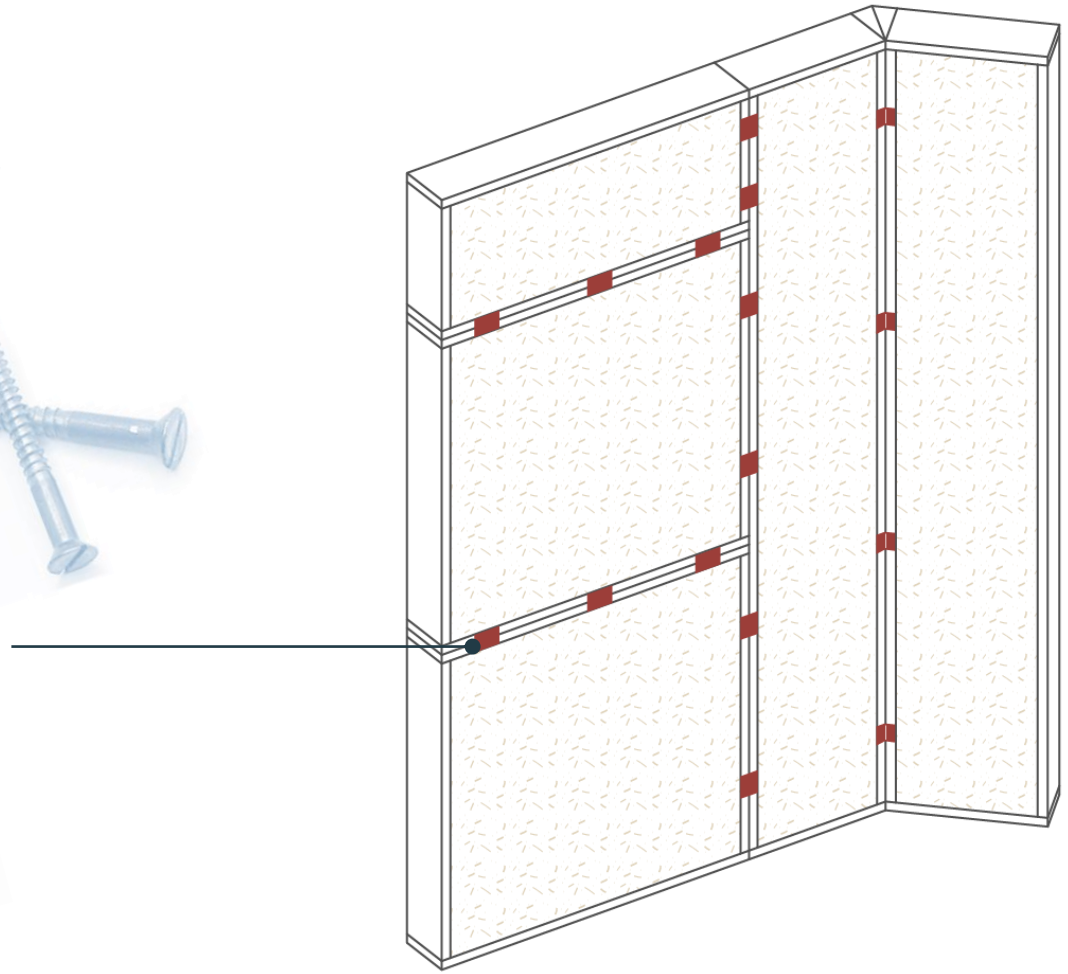


Design

Design

- **Design for disassembly**
- Modular design
- Design for longevity
- Design for standardisation
- Design for adaptability
- Material optimisation
- Design for recycling





Design

Design

Design for disassembly

Modular design

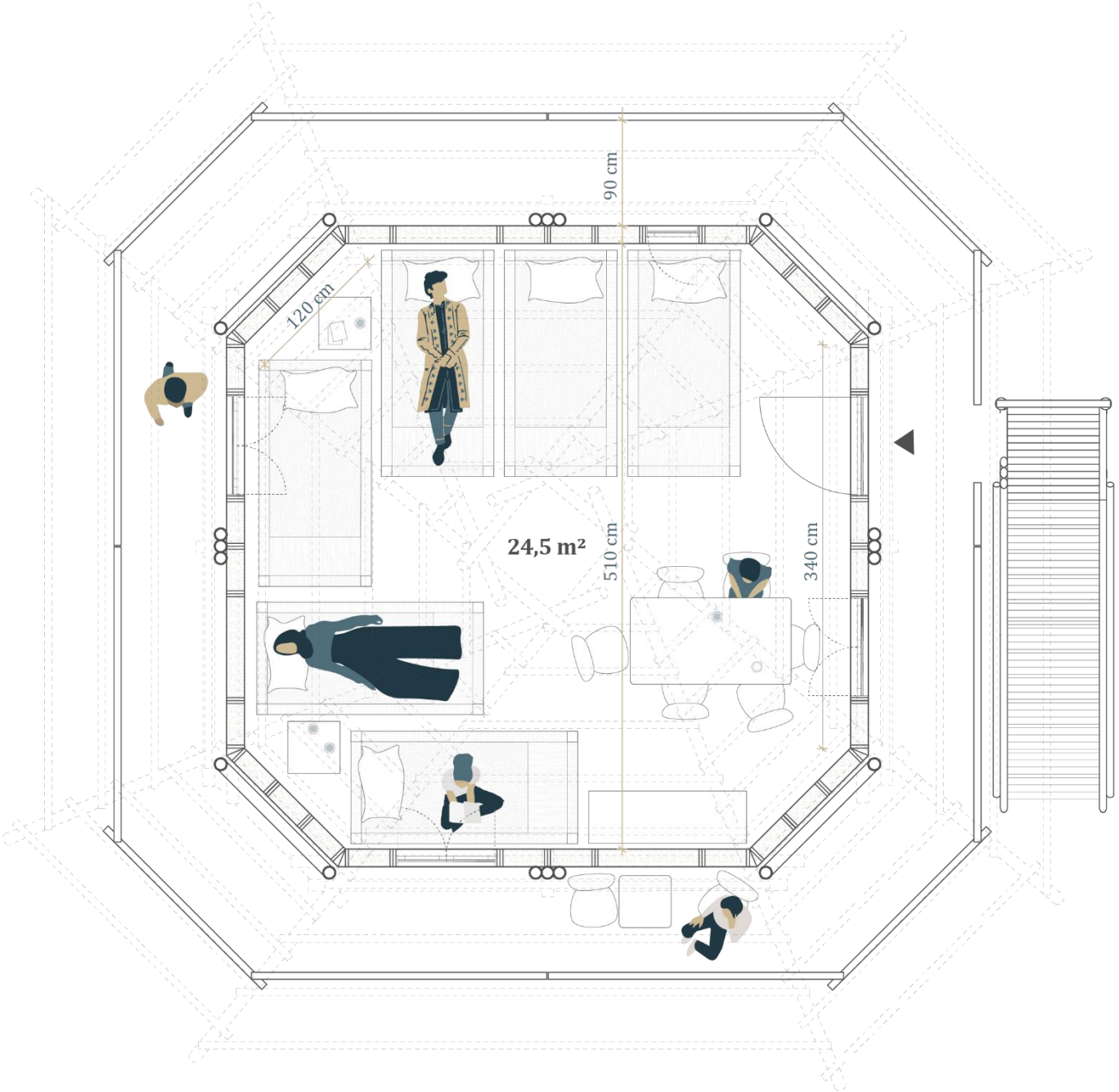
Design for longevity

Design for standardisation

Design for adaptability

Material optimisation

Design for recycling



Design

Design

Design for disassembly

Modular design

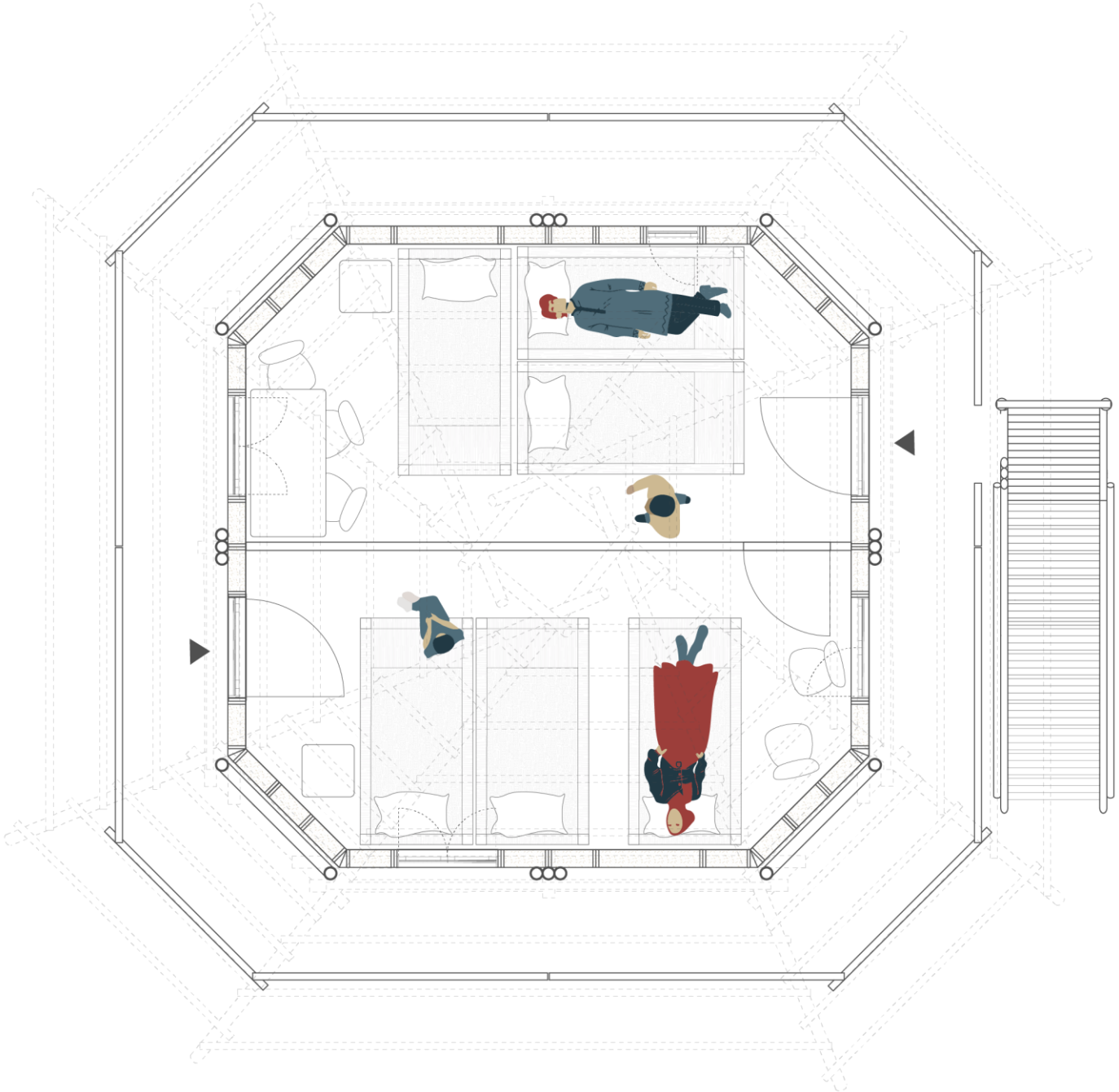
Design for longevity

Design for standardisation

Design for adaptability

Material optimisation

Design for recycling



Design

Design

Design for disassembly

Modular design

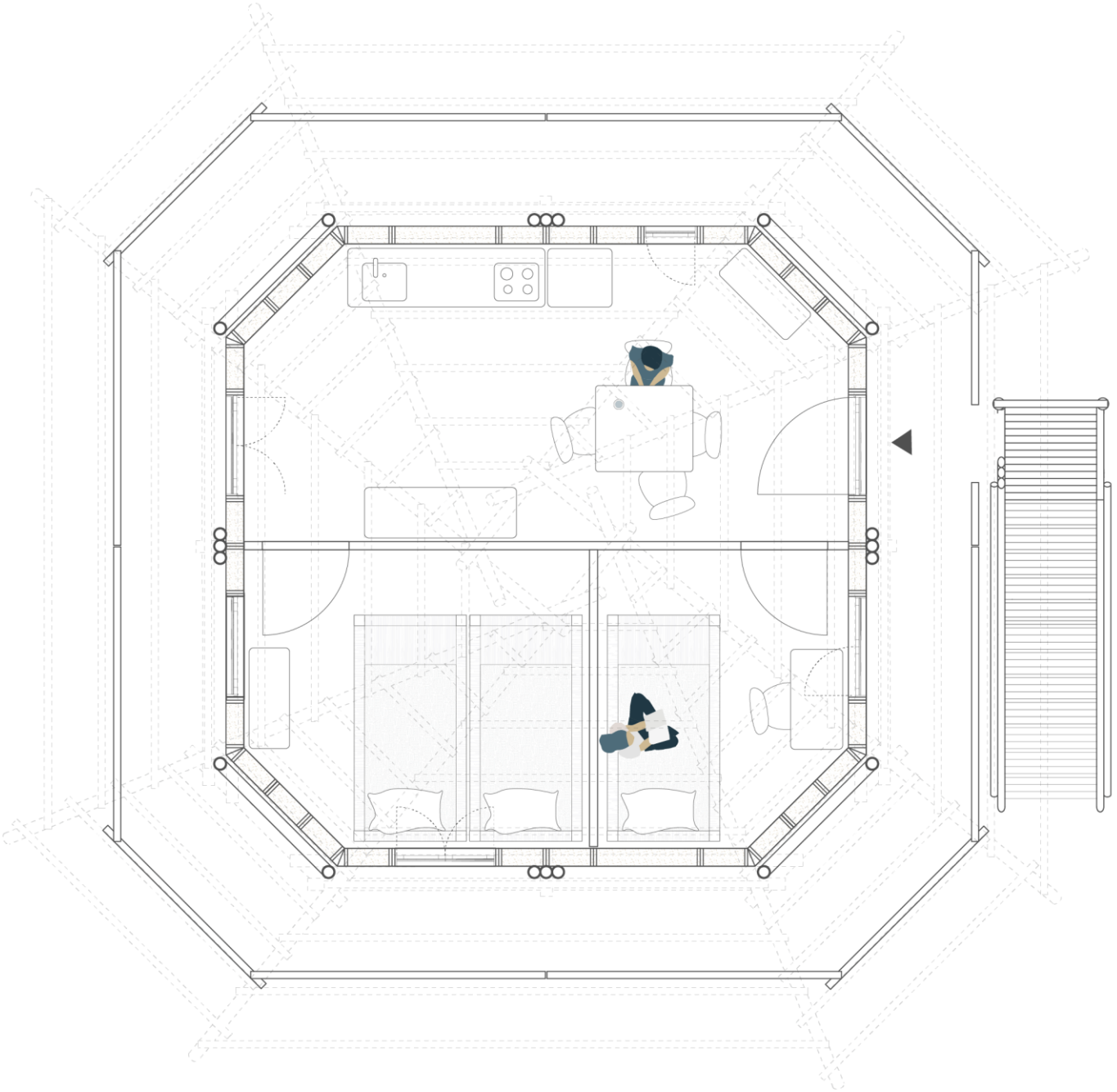
Design for longevity

Design for standardisation

Design for adaptability

Material optimisation

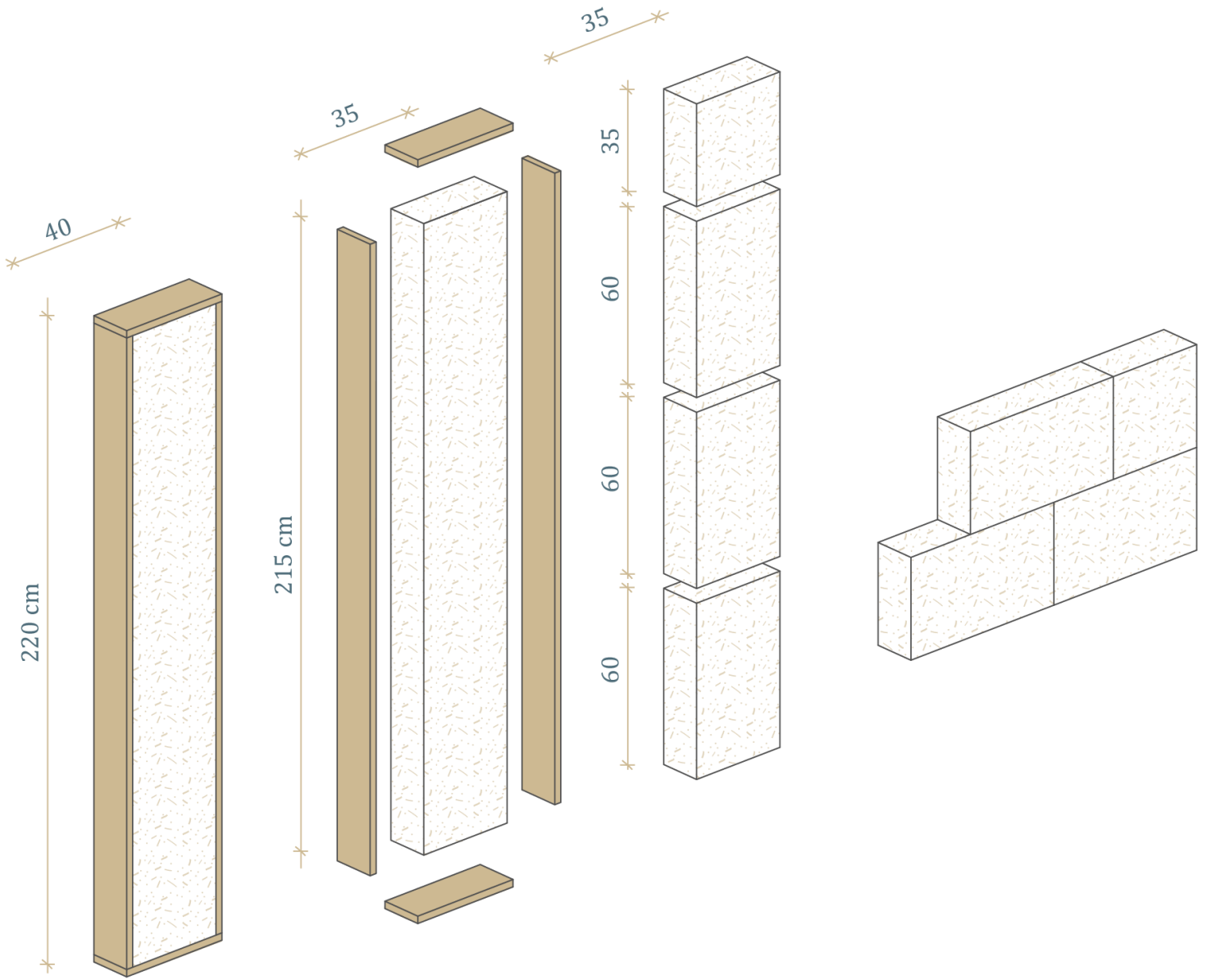
Design for recycling



Design

Design

- Design for disassembly
- Modular design
- Design for longevity
- Design for standardisation
- Design for adaptability
- Material optimisation
- Design for recycling



Design

Design

Design for disassembly

Modular design

Design for longevity

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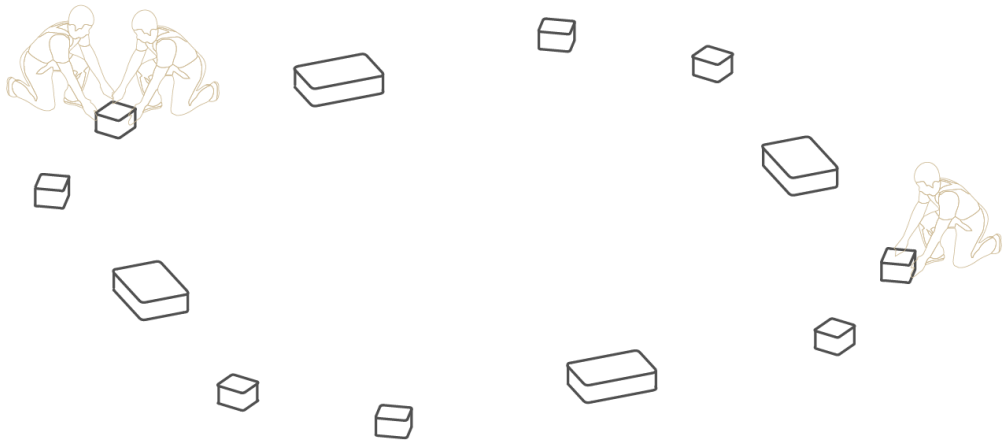
Material optimisation

Design for recycling



Manufacturing

Manufacturing

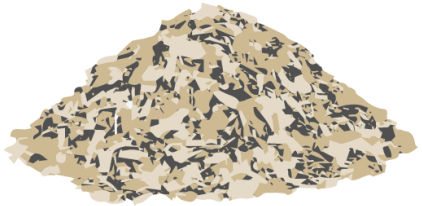
Prefabrication

Additive manufacturing

CNC milling

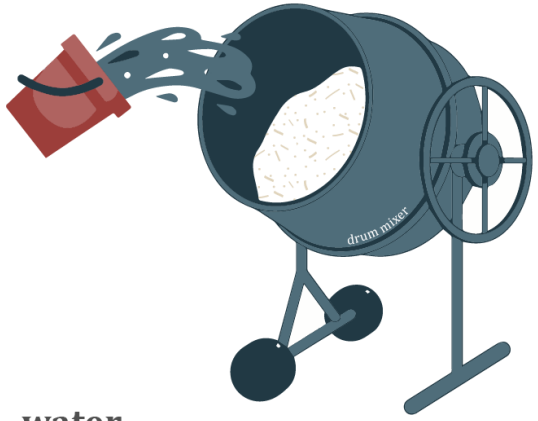
Robotics

Vernacular building techniques



hemp shives
1 kg

lime binder
1.5 kg



water
2 l

Manufacturing

Manufacturing

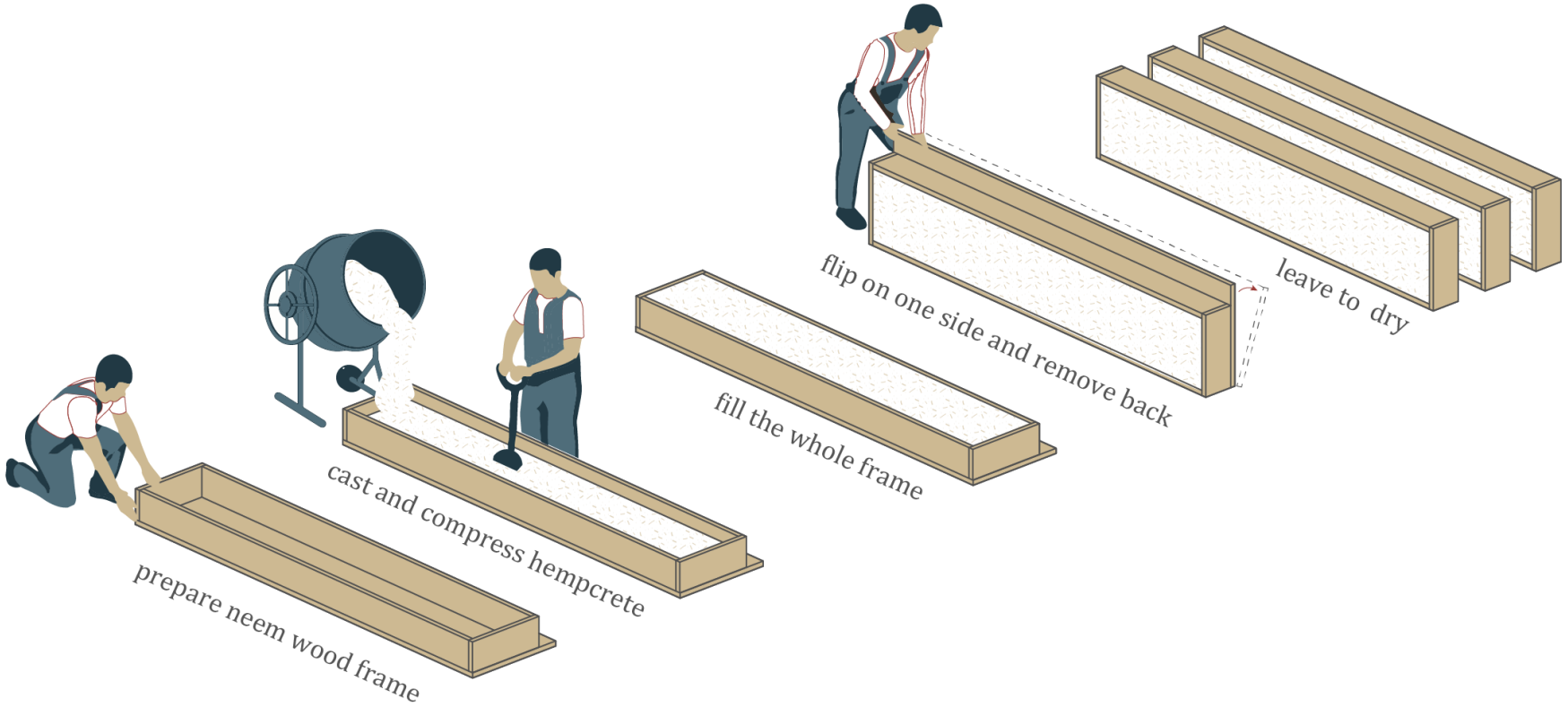
Prefabrication

Additive manufacturing

CNC milling

Robotics

Vernacular building techniques



Management

Management

Create guidelines

Take-back agreements

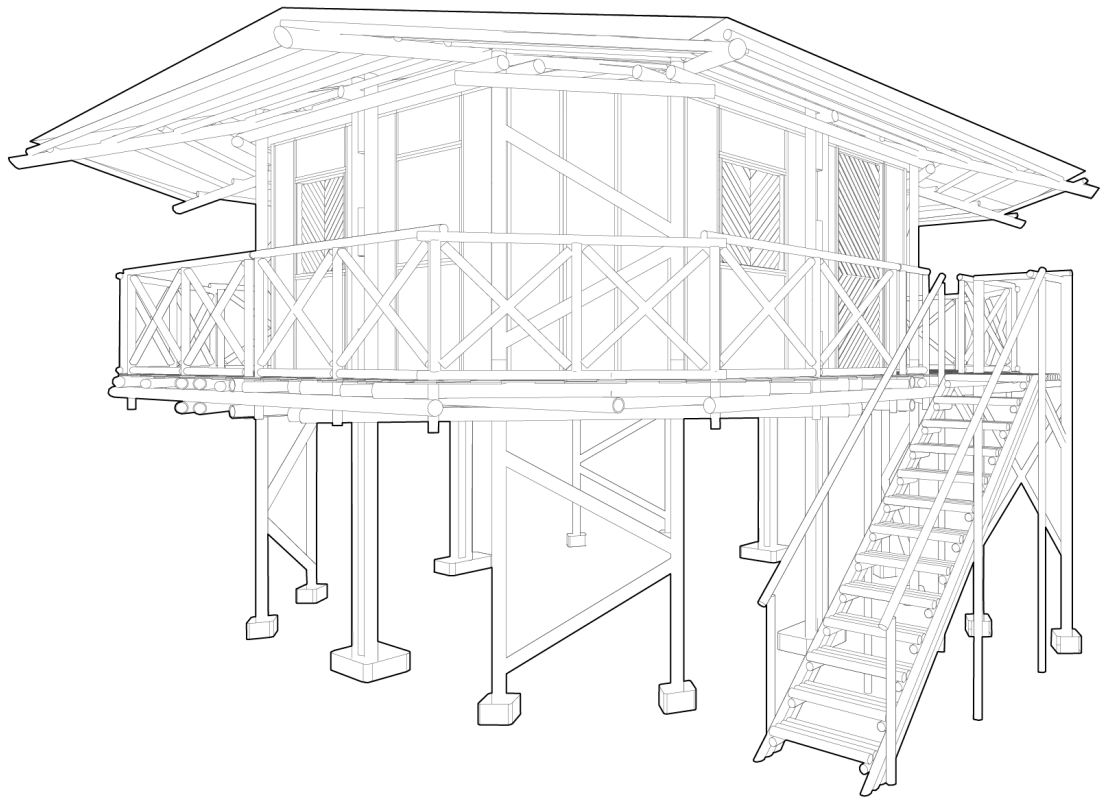
Scenario planning

Product as a service

BIM

Material passport

BAMB



Management

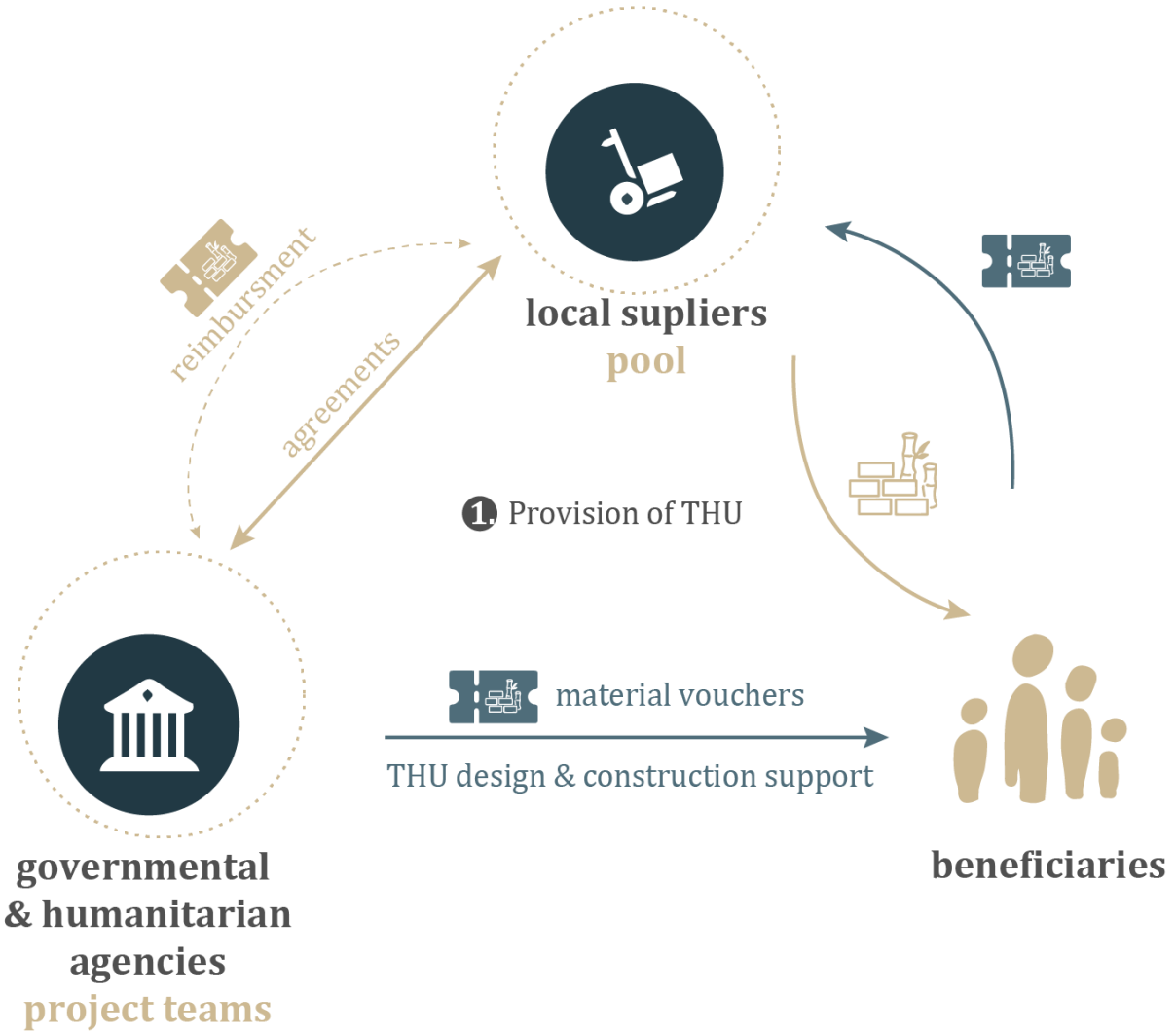
Management

- Create guidelines
- Take-back agreements
- Scenario planning

Product as a service

BIM

- Material passport
- BAMB



Management

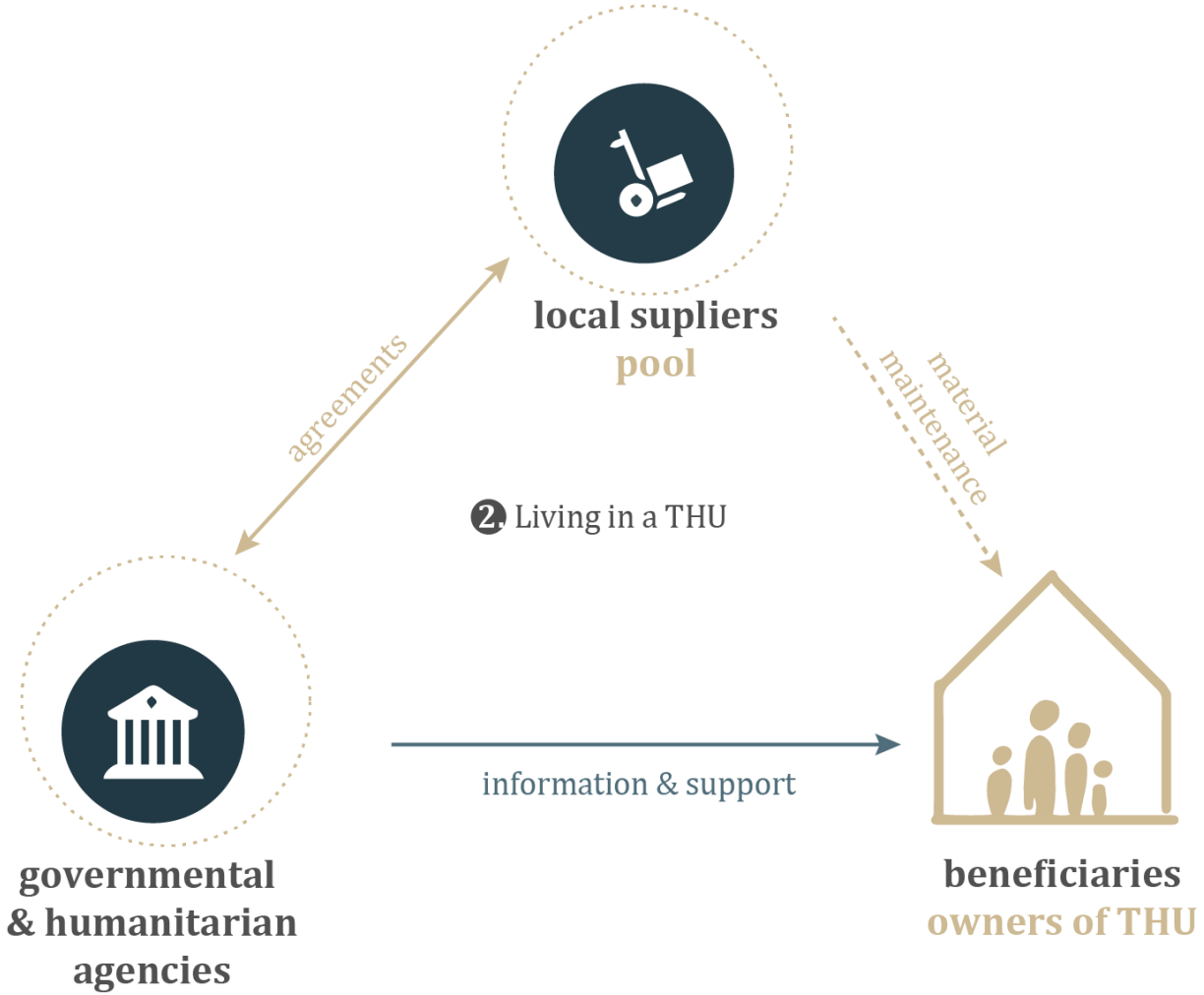
Management

- Create guidelines
- Take-back agreements
- Scenario planning

Product as a service

BIM

- Material passport
- BAMB



Management

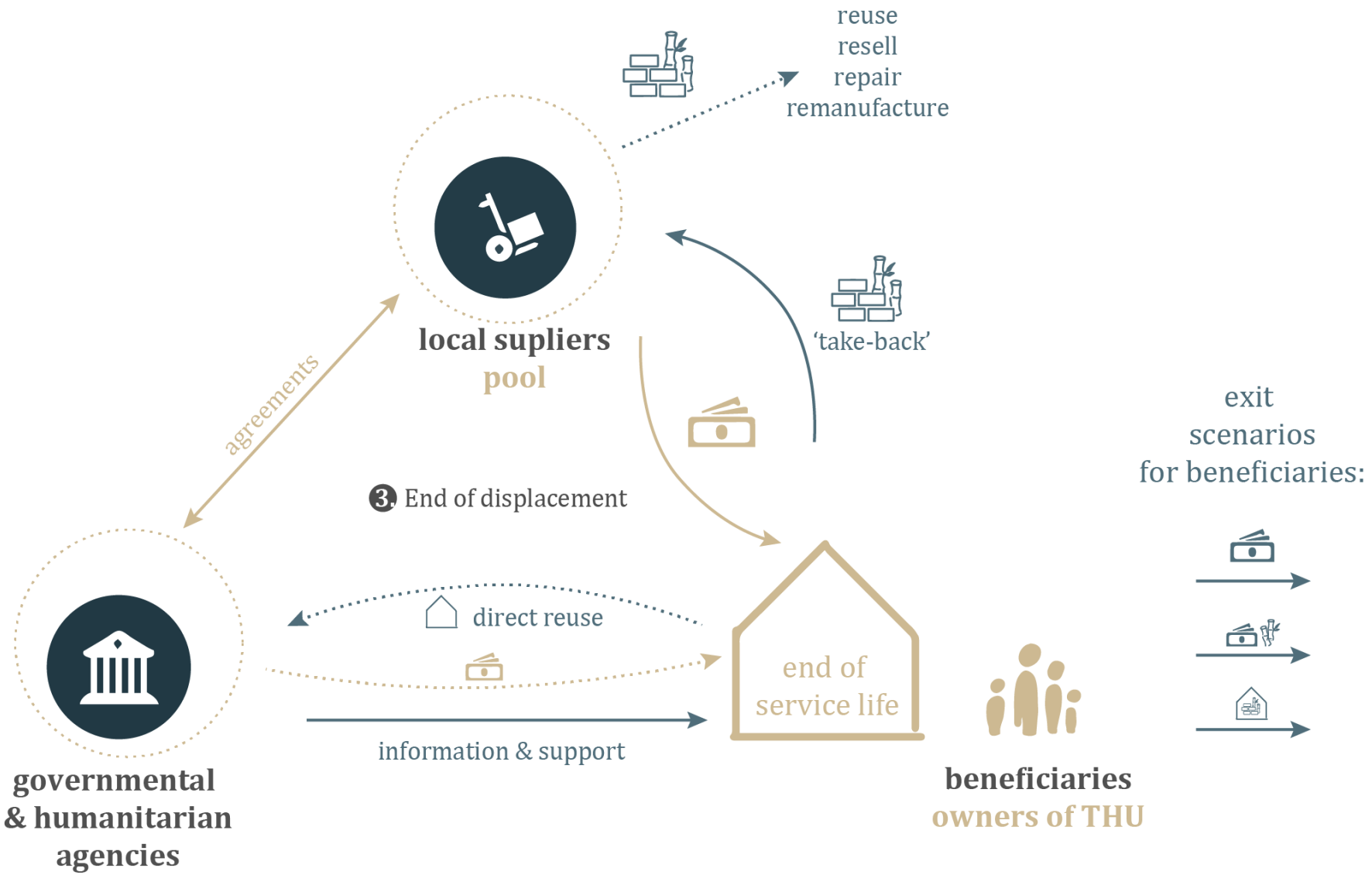
Management

- Create guidelines
- Take-back agreements
- Scenario planning

Product as a service

BIM

- Material passport
- BAMB

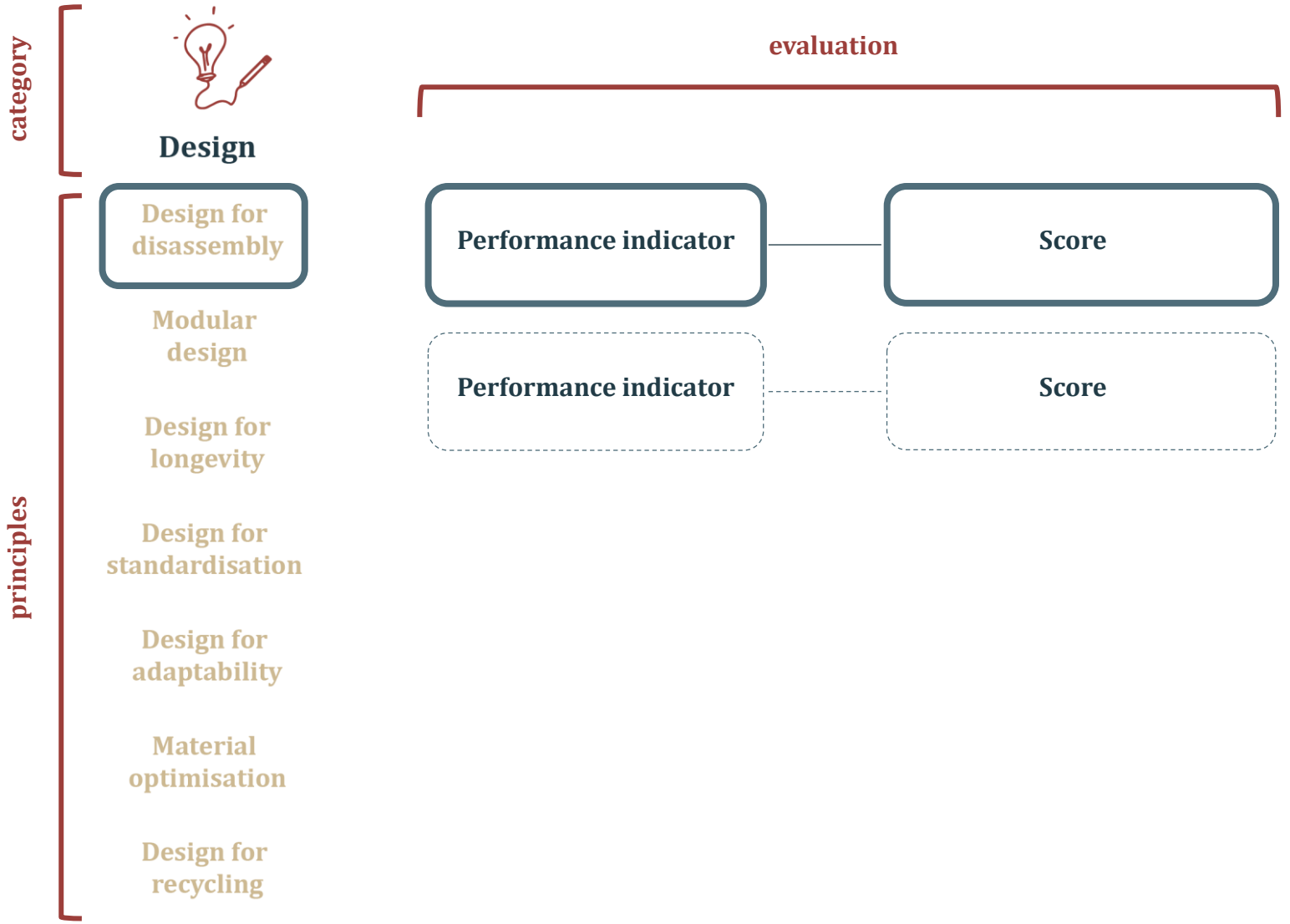


Circularity principles

Material	Design	Manufacturing	Management
Local material	Design for disassembly	Prefabrication	Create guidelines
Biobased material	Modular design	Additive manufacturing	Take-back agreements
Waste material	Design for longevity	CNC milling	Scenario planning
Recyclable material	Design for standardisation	Robotics	Product as a service
Secondary streams	Design for adaptability	Vernacular building techniques	BIM
	Material optimisation		Material passport
	Design for recycling		BAMB

Recommendation set and evaluation tool

Design evaluation



Recommendation set and evaluation tool

Design evaluation

category

Design

principles

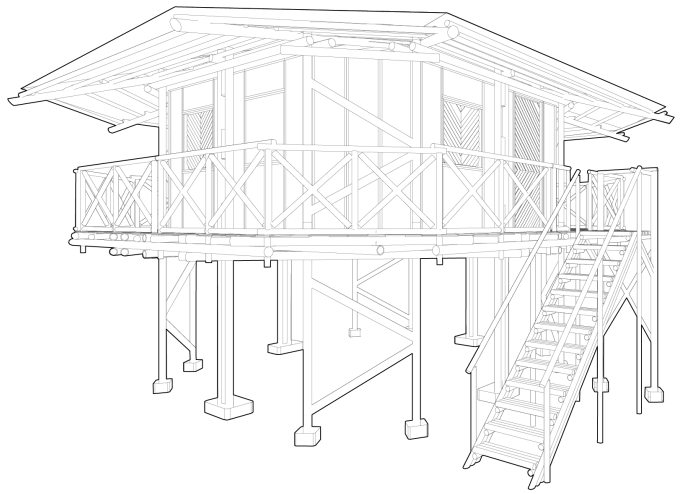
- Design for disassembly
- Modular design
- Design for longevity
- Design for standardisation
- Design for adaptability
- Material optimisation
- Design for recycling

evaluation

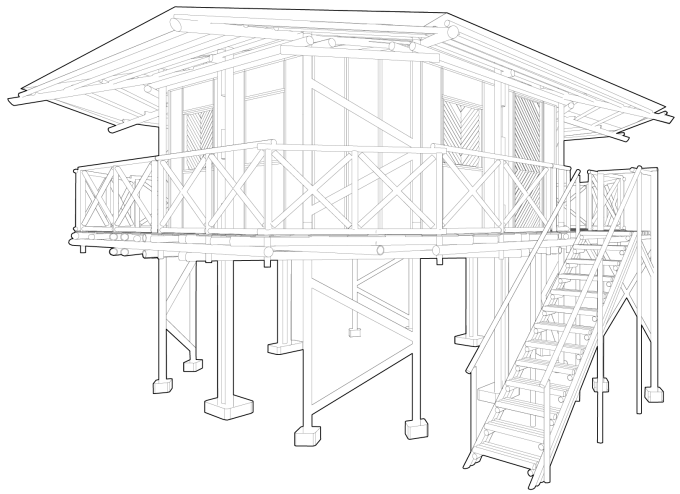
connections are fully reversible; components do not get damaged	best
connections are reversible; components get ligthly damaged	good
some connections are reversible; components get damaged	bad
connections are not reversible; components get damaged	worst
not applicable	

Design evaluation

No	Category	Principle	Evaluation overview
I.	**Material**		
		1.1 Local materials	
		1.2 Biobased materials	
		1.3 Waste materials	
		1.4 Recyclable materials	
		1.5 Secondary streams	
II.	**Design**		
		2.1 Design for disassembly	
		2.2 Modular design	
		2.3 Design for longevity	
		2.4 Design for standardisation	
		2.5 Design for adaptability	
		2.6 Material optimisation	
		2.7 Design for recycling	
III.	**Manufacture**		
		3.1 Prefabrication	
		3.2 Additive manufacturing	
		3.3 CNC milling	
		3.4 Robotics	
		3.5 Vernacular building techniques	
IV.	**Management**		
		4.1 Create guidelines	
		4.2 Take-back agreements	
		4.3 Scenario planning	
		4.4 Product as a service	
		4.5 Building information model (BIM)	
		4.6 Material passport	
		4.7 Building as material banks (BAMB)	



Design evaluation



No	Category	Principle	Evaluation overview
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	2.1	Design for disassembly	
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	4.1	Create guidelines	
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	4.3	Scenario planning	
	4.4	Product as a service	
	4.5	Building information model (BIM)	
	4.6	Material passport	
	4.7	Building as material banks (BAMB)	

High circularity potential

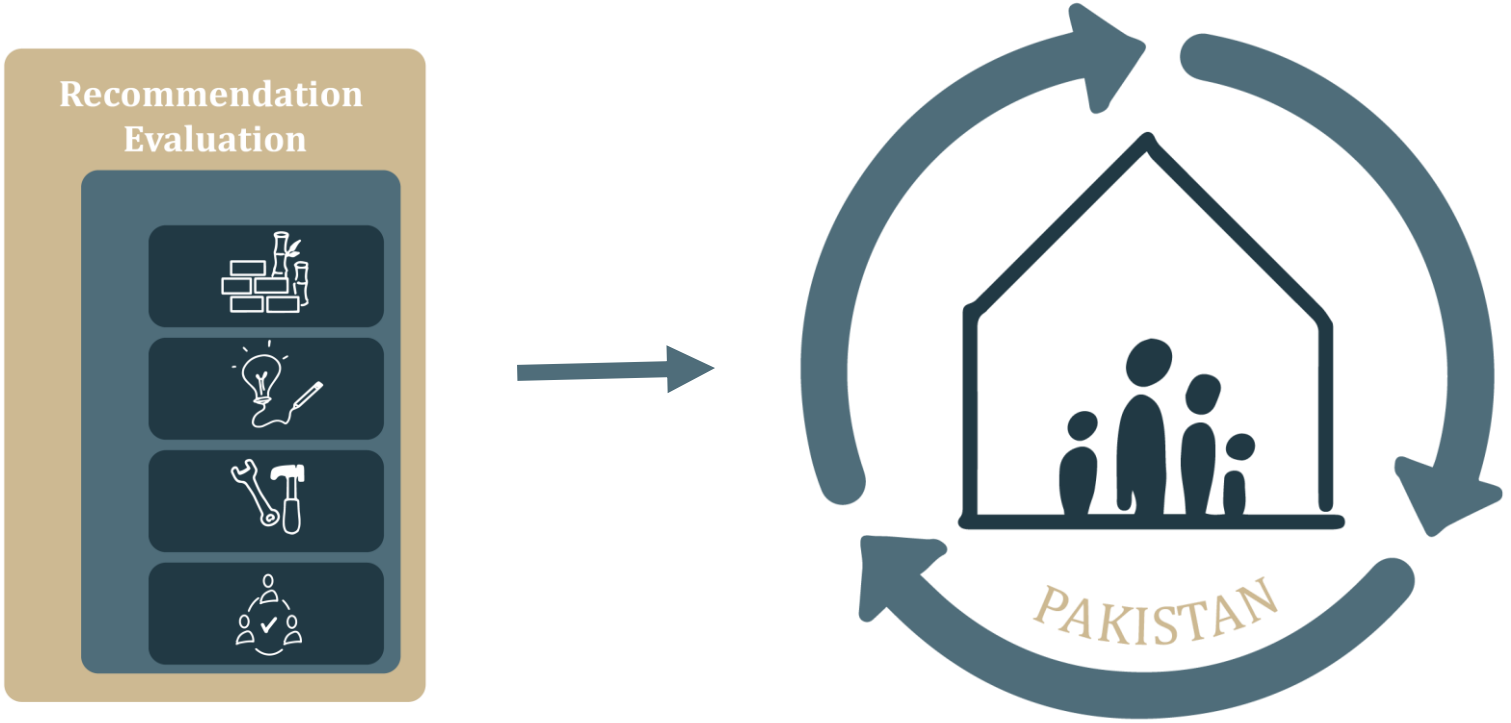
Conclusion

How can transitional housing for displaced people

in the **extreme conditions of upper Sindh province in Pakistan**

be made using circular building principles?

Conclusion



Conclusion

Recommendation Evaluation

many possible combinations of principles

context specific

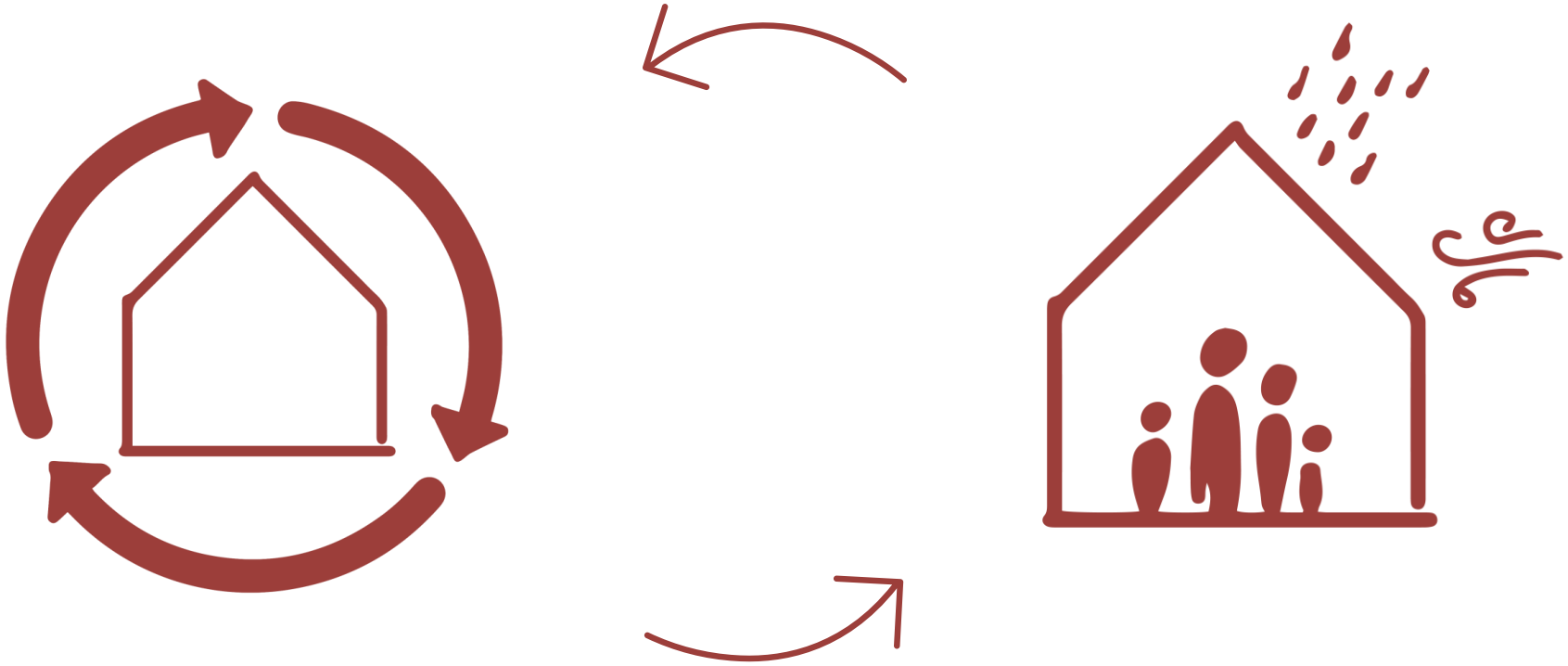
Collaboration of stakeholders is key

real-life application

most effective in preparation phase

Discussion

Innovation under extreme conditions
benefits the built environment



Circularity principles
reduce negative impacts

Thank you for your attention!
Questions?