Modular Building in a Circular Economy

An exploratory research

by Astrid Potemans

Graduation Presentation – July 6th, 2017

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External examiner: Dr. Ir. D.A. Groetelaers

Introduction

Part I:
A Circular
Economy

Part II:
A Circular
Building Stock

Part III:
Modular
Building

Conclusion

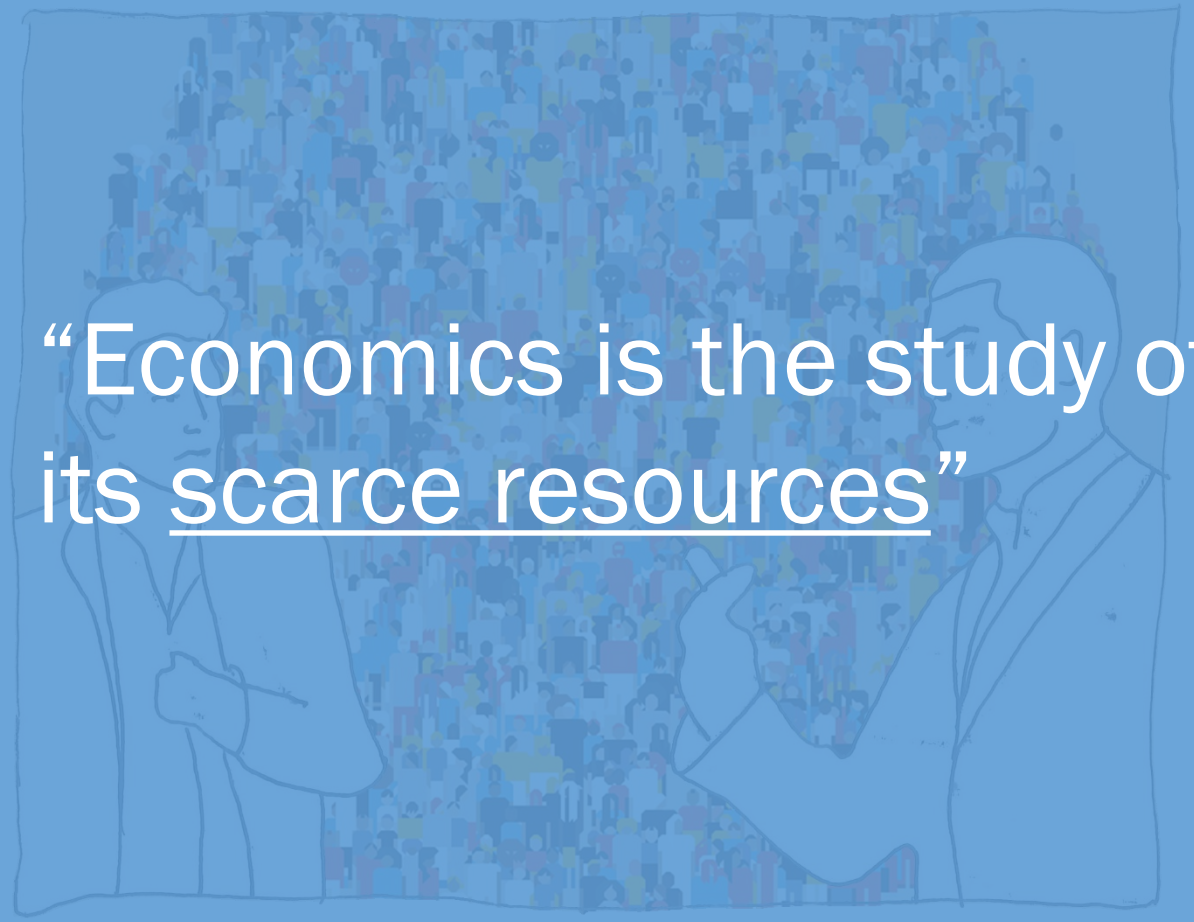
The Economics of the Coming Spaceship Earth

Boulding (1966, p. 1)

Grammos Lodge

Industrial Revolution England

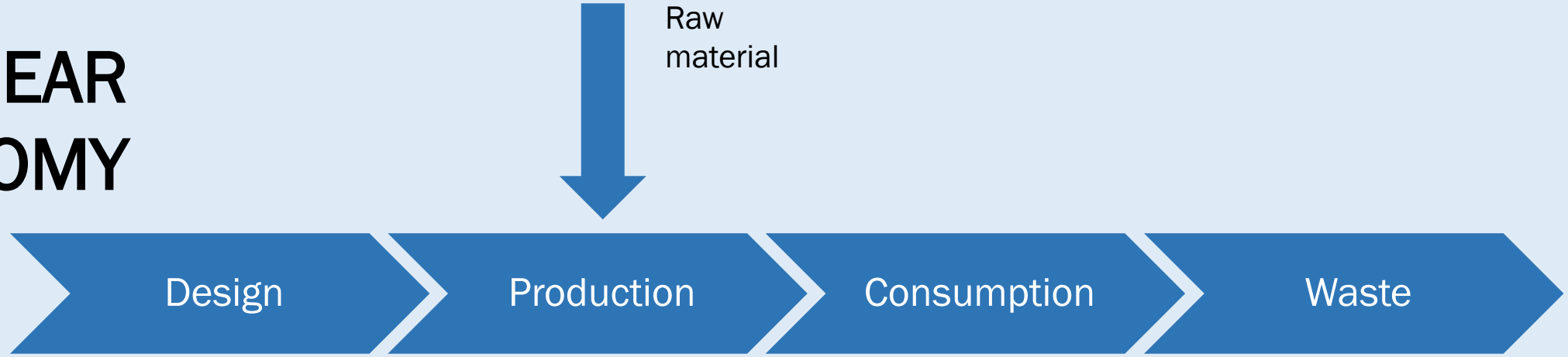
Athens City



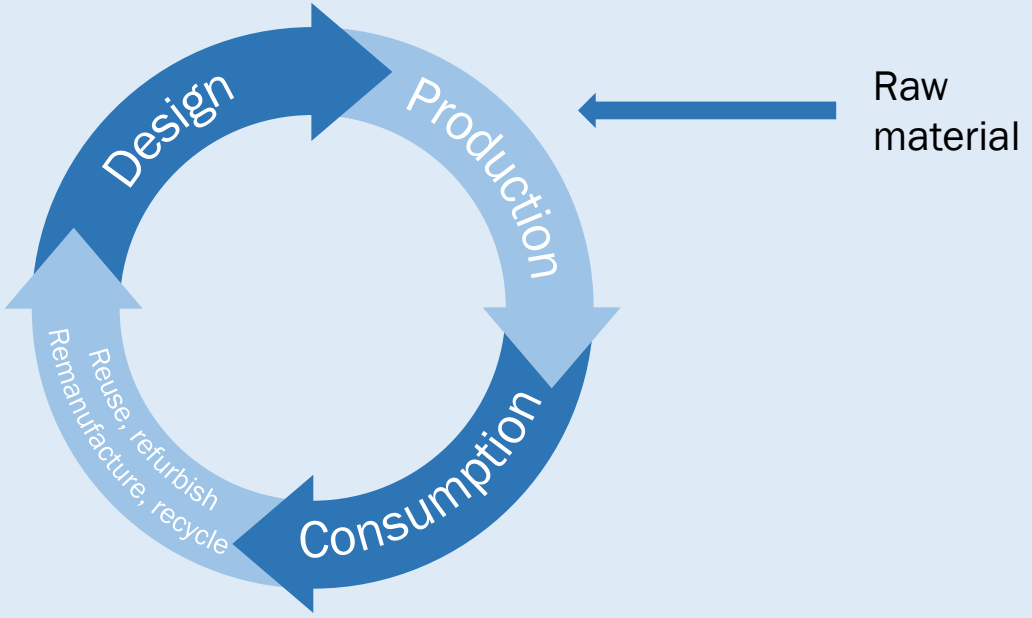
"Economics is the study of how society manages its scarce resources"

Mankiw (2012, p. 4)

LINEAR ECONOMY



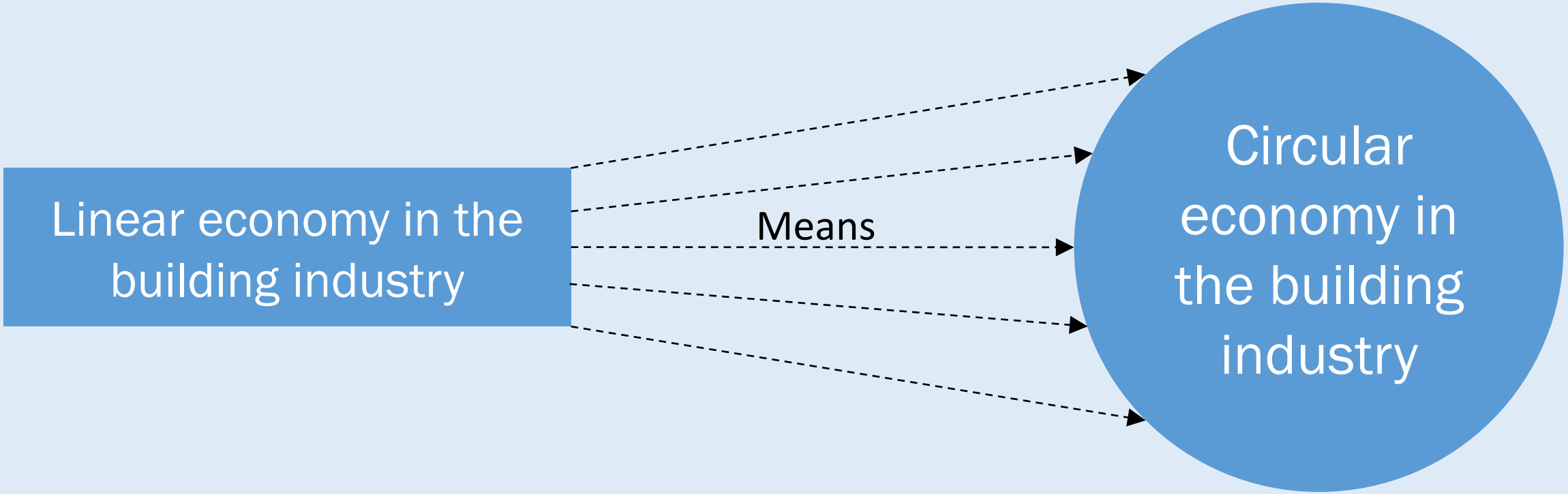
CIRCULAR ECONOMY



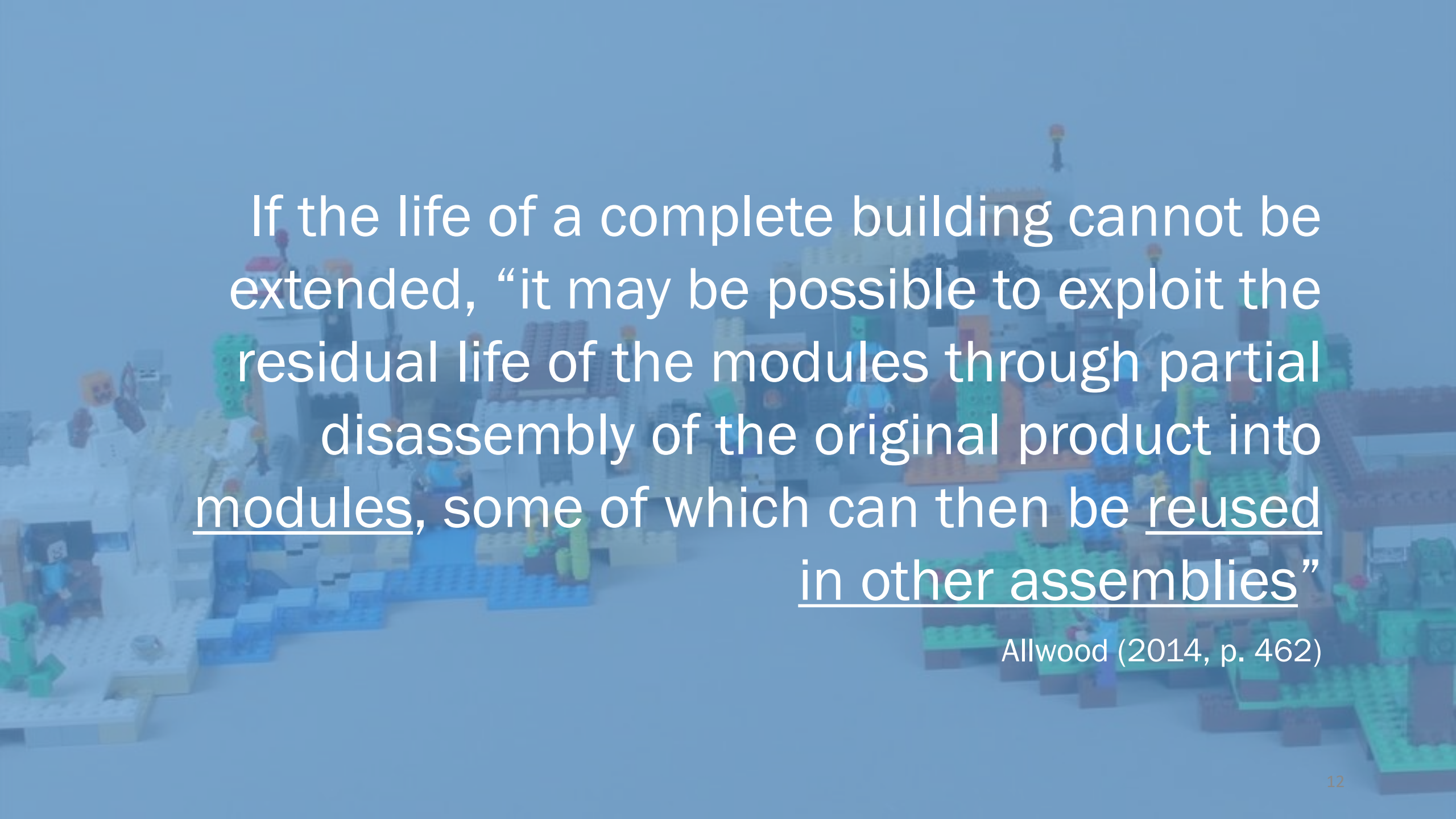

HEEZEI B.V.

The construction industry consumes more than half of the global resources and generates the greatest waste stream globally

Iacovidou & Purnell (2016)


Linear economy in the building industry
Means
Circular economy in the building industry


TNT

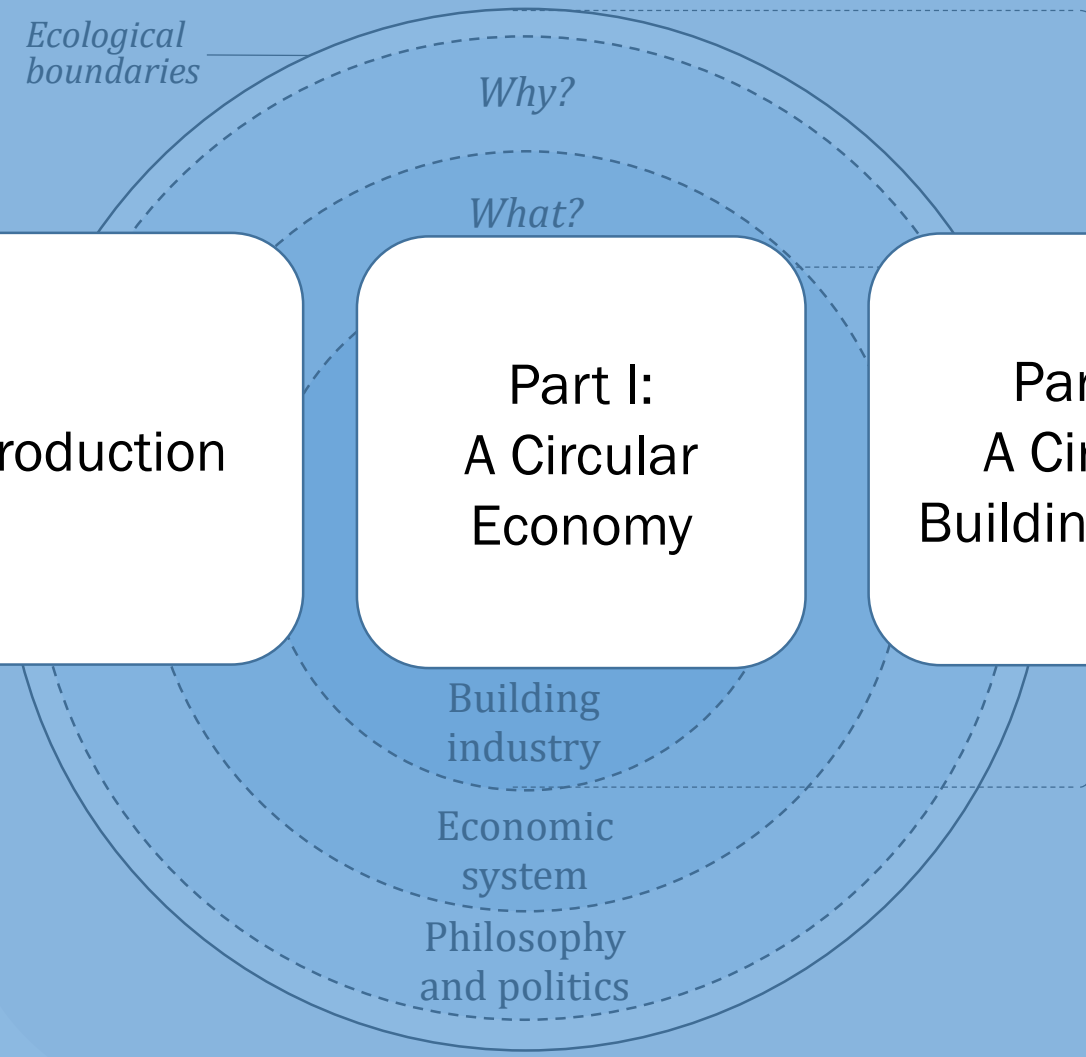


If the life of a complete building cannot be extended, “it may be possible to exploit the residual life of the modules through partial disassembly of the original product into modules, some of which can then be reused in other assemblies”

Allwood (2014, p. 462)

Graduation research

How can modular building contribute to a circular building stock?



1. What is a circular economy and what is the goal of a circular economy?
2. Is a circular economy of growth possible?

6. What is modular building and what is the current practice of modular building in the Netherlands?

Part I:
A Circular Economy

Part III:
Modular Building

Introduction

Part I:
A Circular Economy

Part II:
A Circular Building Stock

Part III:
Modular Building

Conclusion

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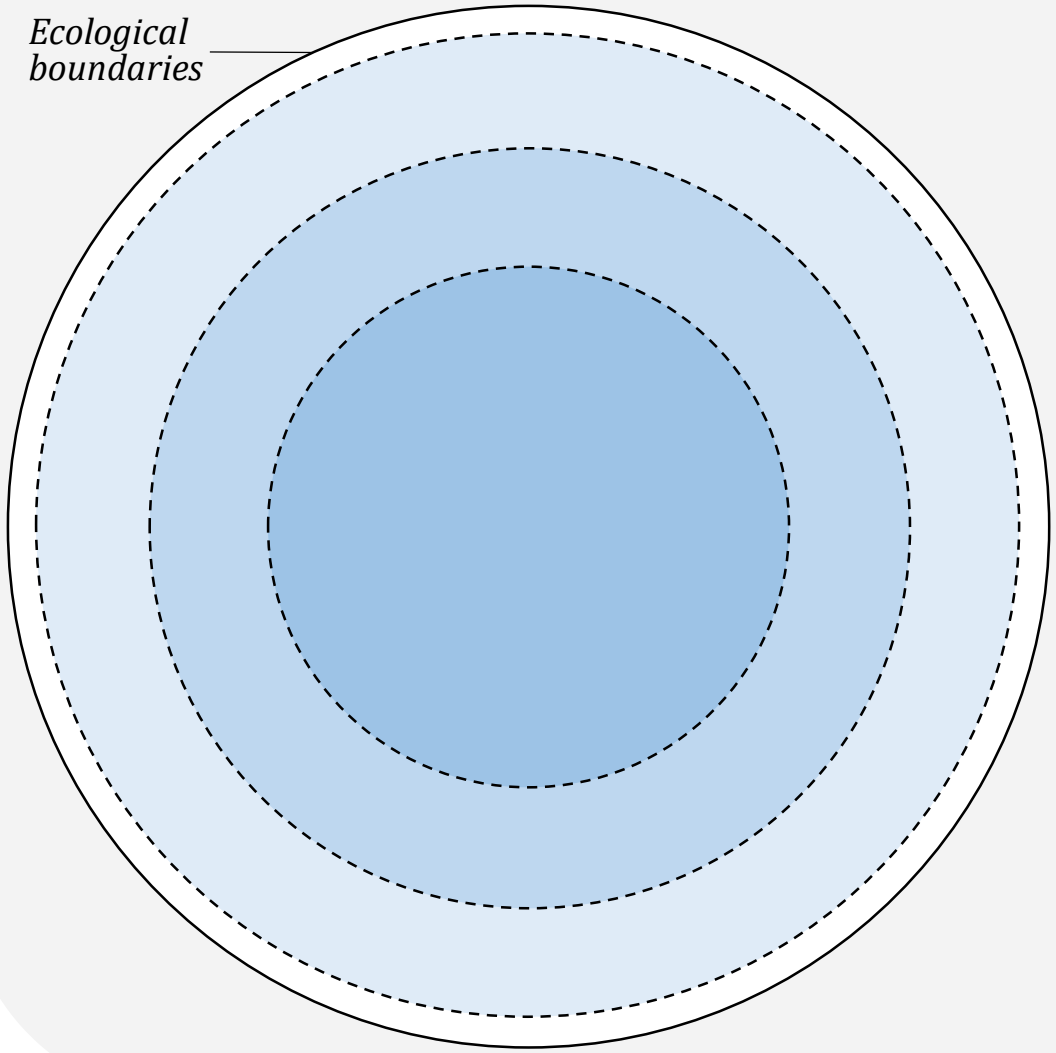
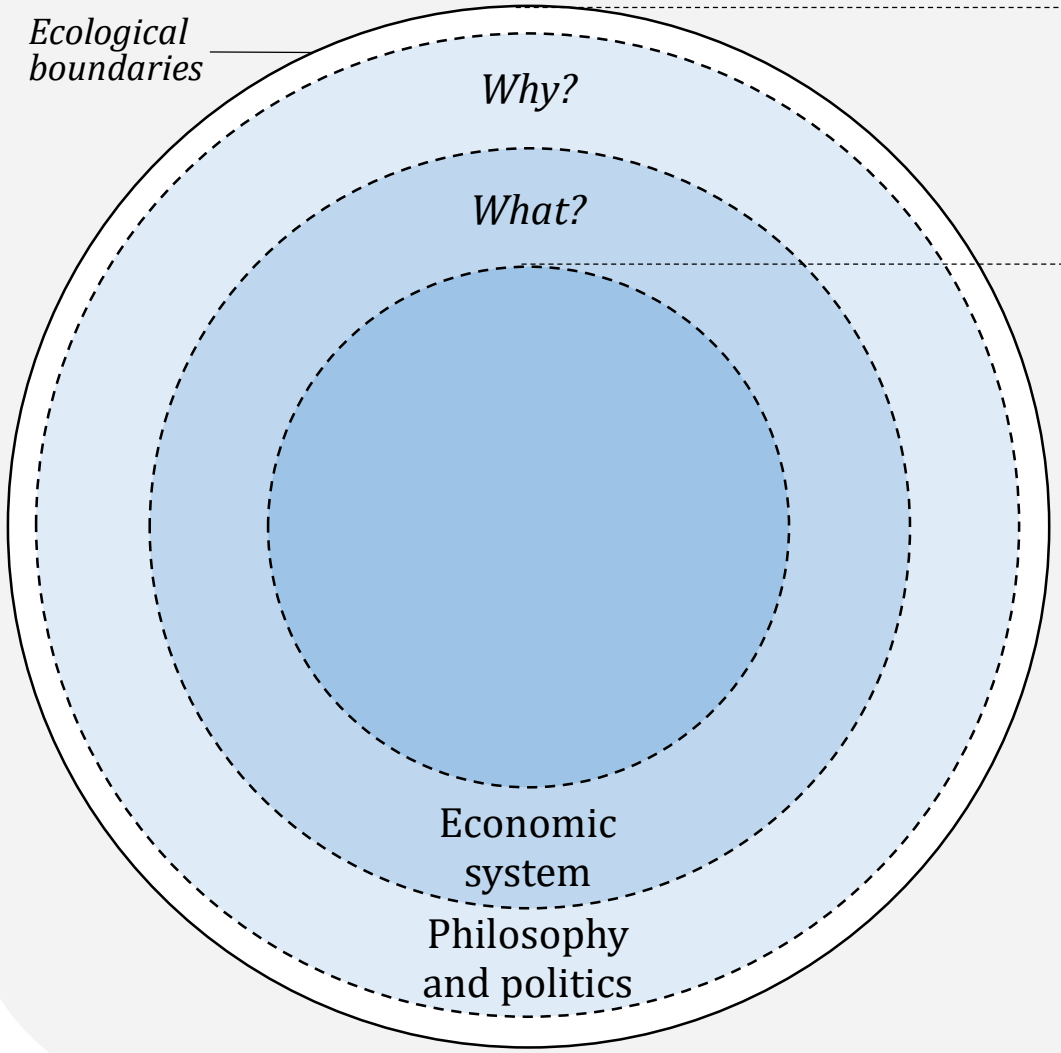


How can modular building contribute to a circular building stock?



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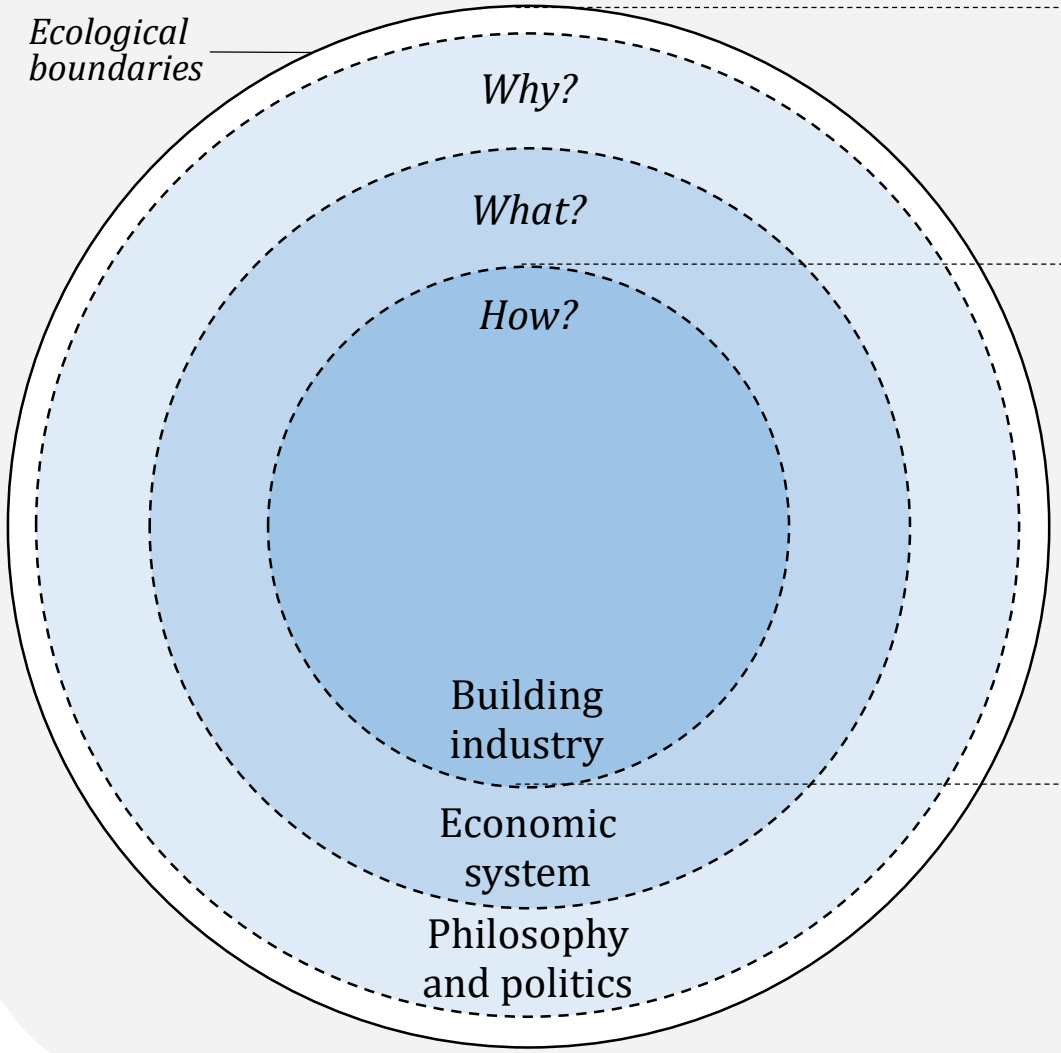
Part I:
A Circular Economy

How can modular building contribute to a circular building stock?



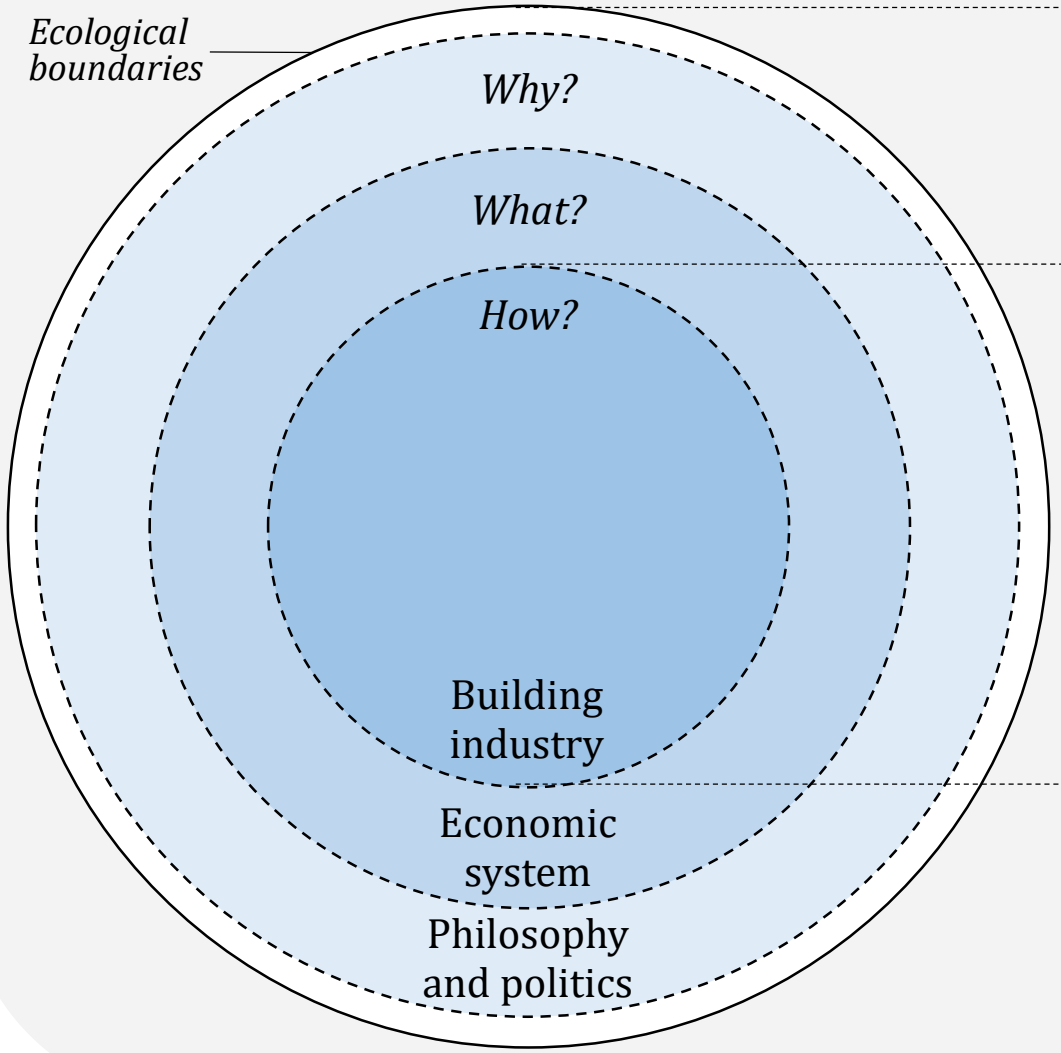
1. What is a circular economy and what is the goal of a circular economy?
2. Is a circular economy of growth possible?

Part I: A Circular Economy

3. What constitutes a circular building stock?
4. How can the current building stock be characterised?
5. What are the different means to make the current building stock more circular?

Part II: A Circular Building Stock

How can modular building contribute to a circular building stock?



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<u>Part II:</u>
A Circular Building Stock

6. What is modular building and what is the current practice of modular building in the Netherlands?

<u>Part III:</u>
Modular Building

Relevance

→ Societal

Growing demand, limited supply; do more with less

→ Scientific

Lack of research on CE in built environment meso-scale (building)

→ Practical

Research

→ Objective: *explore* how modular building can contribute to a circular building stock;

Aiming to resolve or improve a situation in practice – *starting point*

Recommendations for further research

→ Method: qualitative research

Methodology

→ Parts I & II: Literature study and exploratory interviews

→ Part III: Literature study and collective case study
(data from suppliers' website; semi-structured interviews; site visits)

Part I:
A Circular Economy

Circular economy

Common elements:

→ Maximising the value / productivity of materials;

→ Eliminating waste

By keeping materials within a closed loop

Adams, Osmani, Thorpe, & Thornback (2017, p. 16)

Circular economy

Common elements:

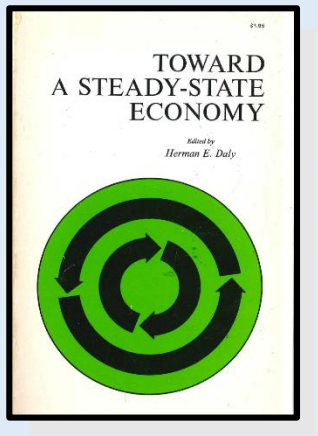
→ Maximising the value of materials;

→ Eliminating waste

By keeping materials within a closed loop

What for?

Adams, Osmani, Thorpe, & Thornback (2017, p. 16)

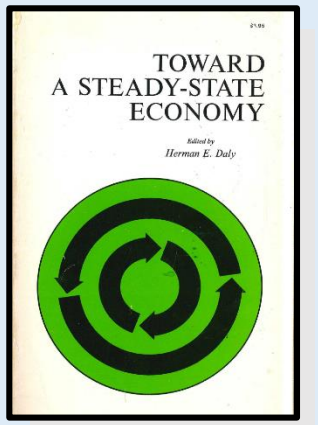


Ultimate source
Scarce resources (low entropy)

← **The ultimates** →

Ultimate goal
Human well-being of current and future generations

Daly (1977)



The economic system; **the intermediates**

Ultimate source
Scarce resources (low entropy)

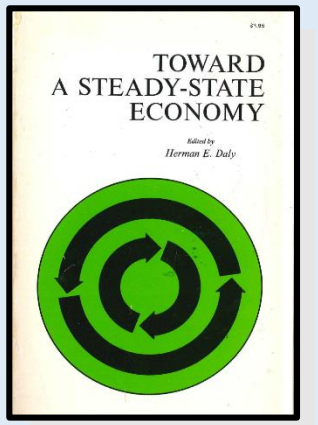
Intermediate means
Factors of production

Intermediate goals

Ultimate goal
Human well-being of current and future generations

The ultimates

Daly (1977)



The economic system; **the intermediates**

Ultimate source
Scarce resources (low entropy)

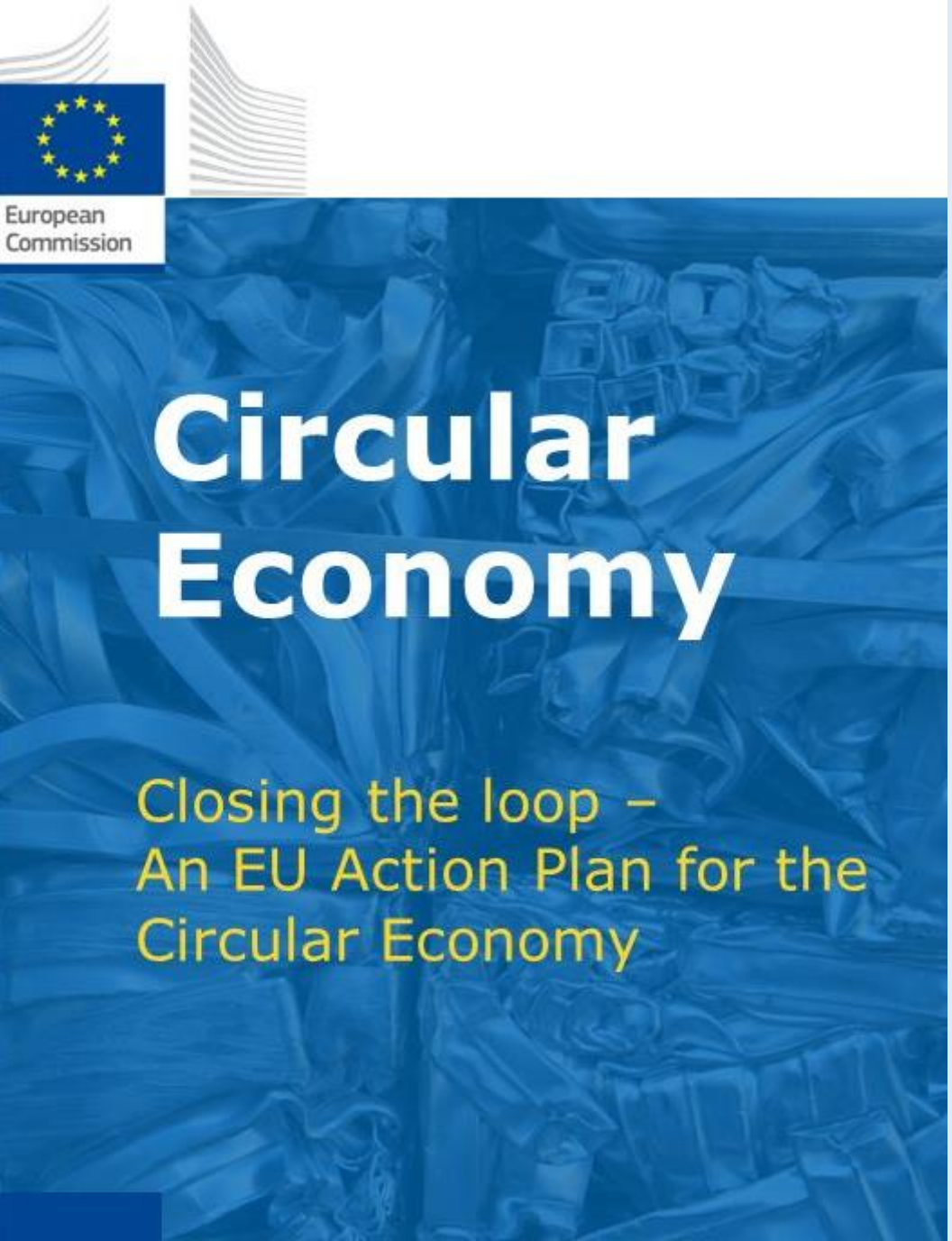
Intermediate means
Factors of production

Intermediate goals
Growth in the GDP

Ultimate goal
Human well-being of current and future generations

The ultimates

Daly (1977)



Based on a report in which a circular economy is said to "translate into a GDP increase of as much as 7 percentage points (….) [that] arise from increasing consumption"

(Ellen MacArthur Foundation & McKinsey Center for Business and Environment, 2012, pp. 7-14).

Increase production

→ Discovering and mining raw materials;
→ Growing the labour force;
→ Creating superior technology;
→ Increasing specialisation

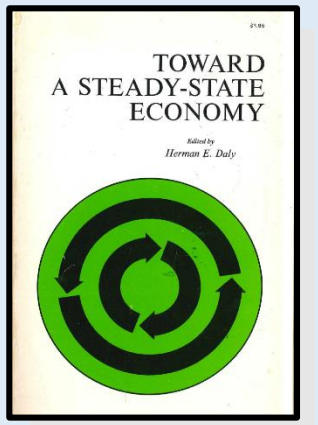
Increase production

→ ~~Discovering and mining raw materials;~~ *limited supply*

→ ~~Growing the labour force;~~ *increasing demand*

→ Creating superior technology;

→ Increasing specialisation



The economic system; **the intermediates**

Ultimate source
Scarce resources (low entropy)

Intermediate means
Factors of production

Intermediate goals
Development of the stock

Ultimate goal
Human well-being of current and future generations

The ultimates

Daly (1977)

Steady-state economy

Development of the stock:

$\rightarrow$ Increasing service-efficiency of the stock:

$$\frac{services}{stock}$$

$\rightarrow$ Increasing durability of the stock:

$$\frac{stock}{throughput}$$

Daly (1977)

Steady-state economy

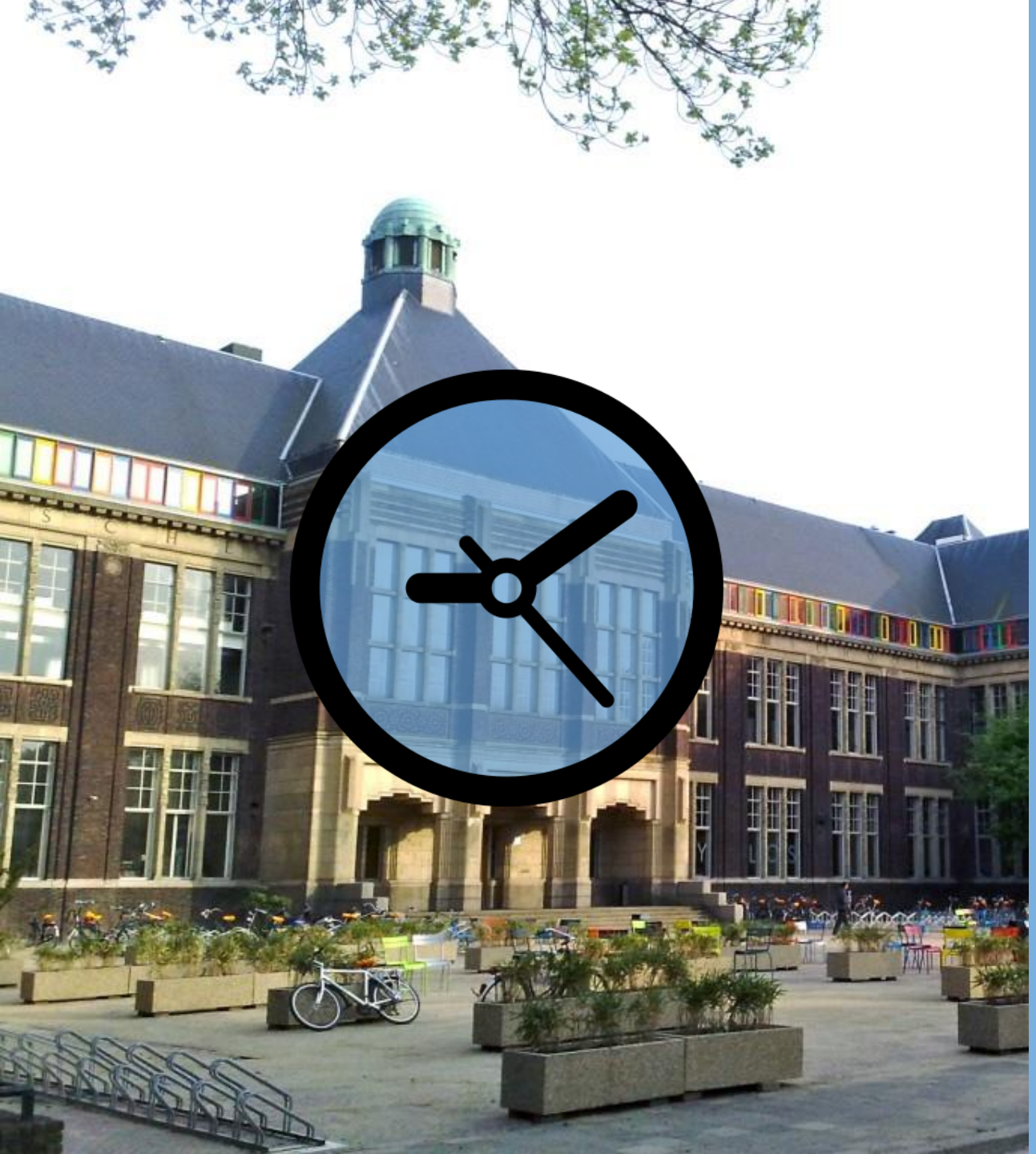
Concepts:

→ Service is the satisfaction experienced needs are met

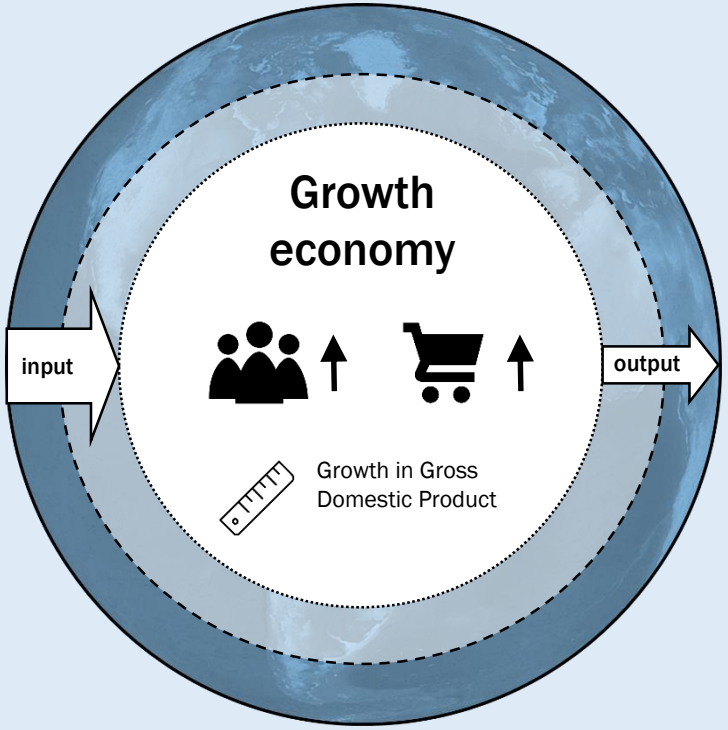
→ Stock is the total inventory of economic goods and human bodies

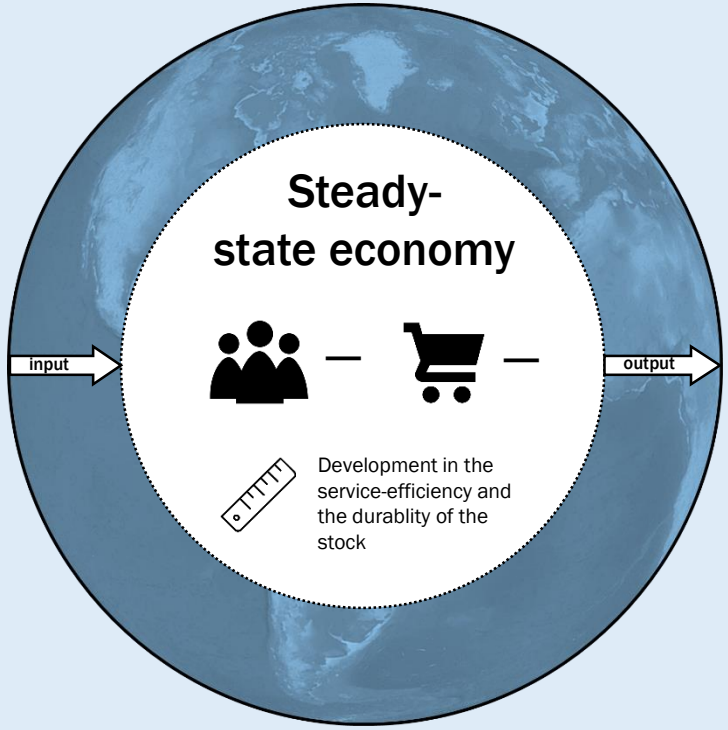
→ Throughput is the entropic physical flow of matter-energy through the economic system

Daly (1977)



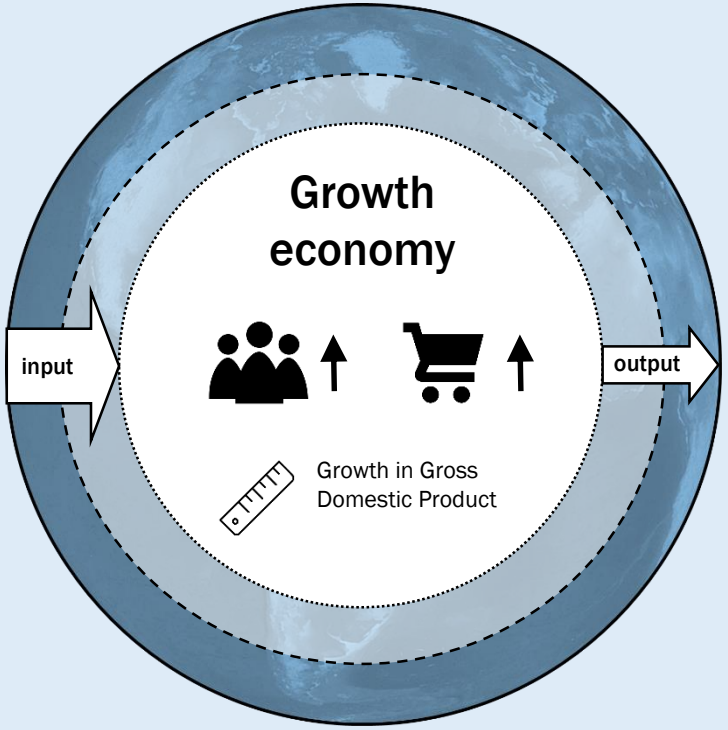
$$\frac{services \uparrow}{stock -}$$

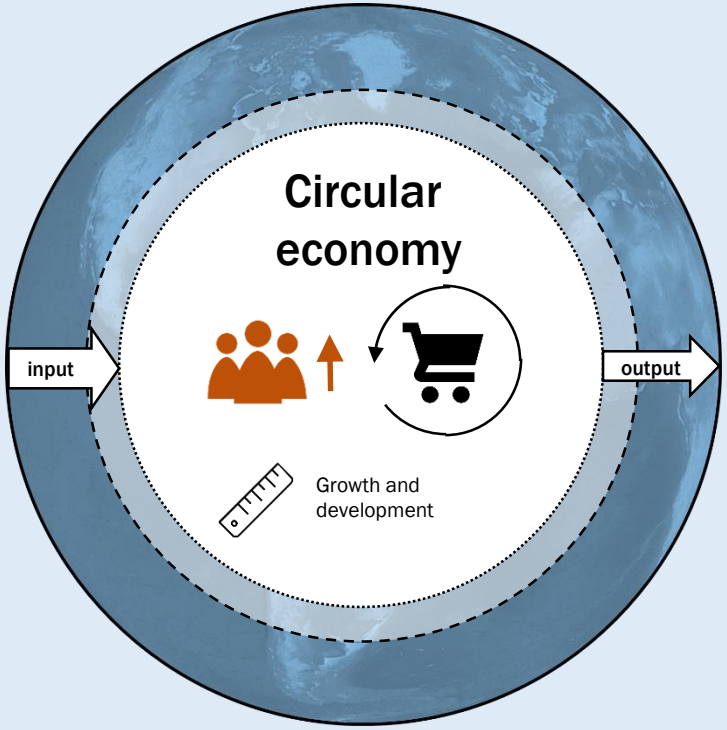


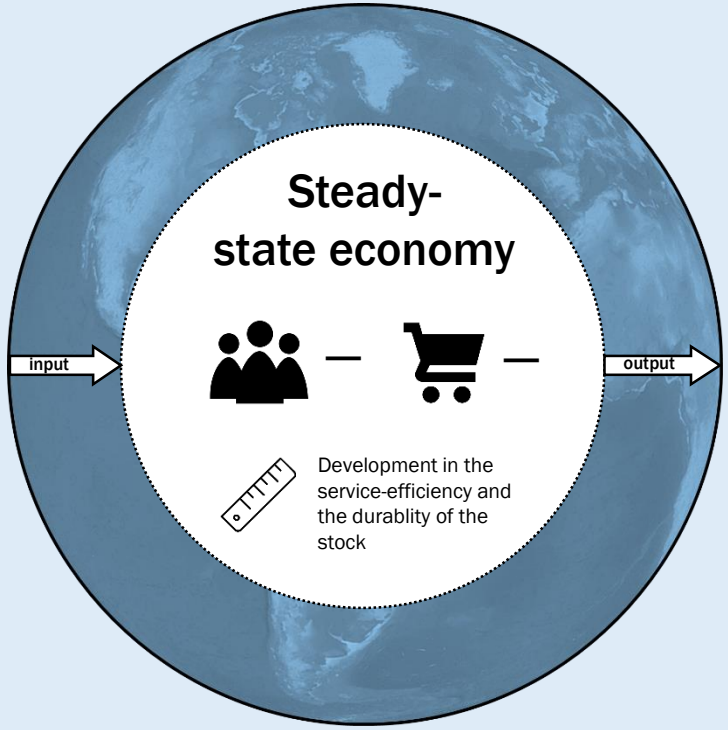


Legend

- Population size
- Stock of goods
- Increase
- Remain constant
- Uncontrollable variable
- Controllable variable







Legend

- Population size
- Stock of goods
- Increase
- Remain constant
- Uncontrollable variable
- Controllable variable

“Practical” circular economy

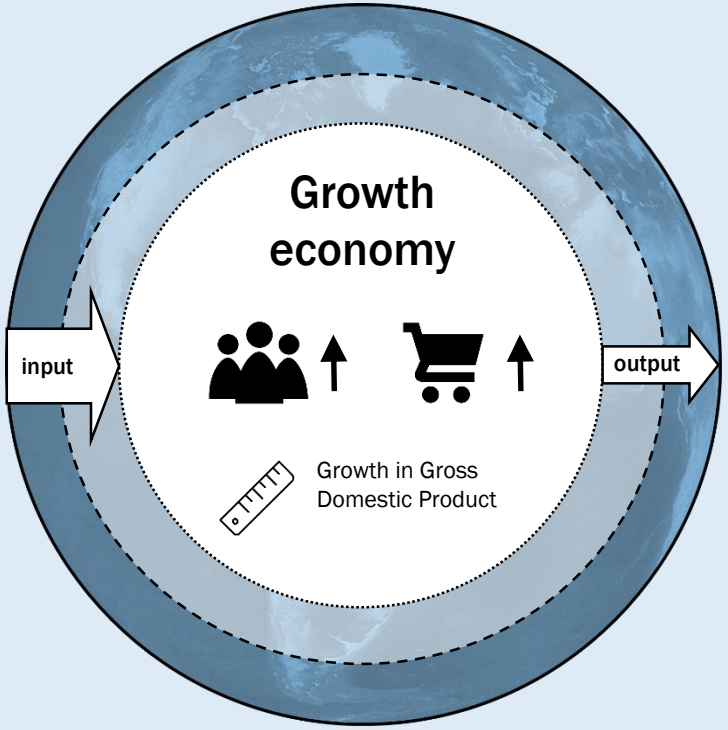
Concepts:

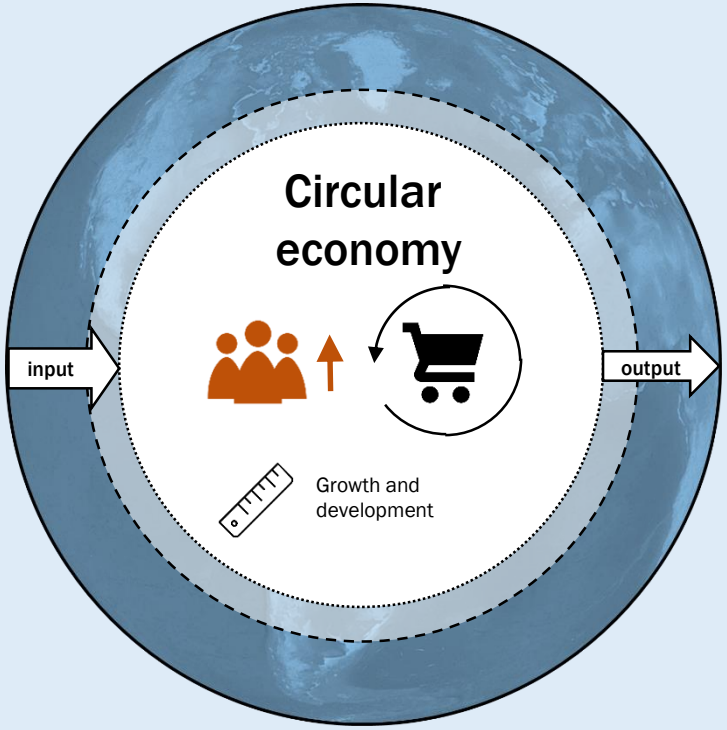
→ Utility is the satisfaction experienced needs are met, indicated in willingness to pay [€/year]

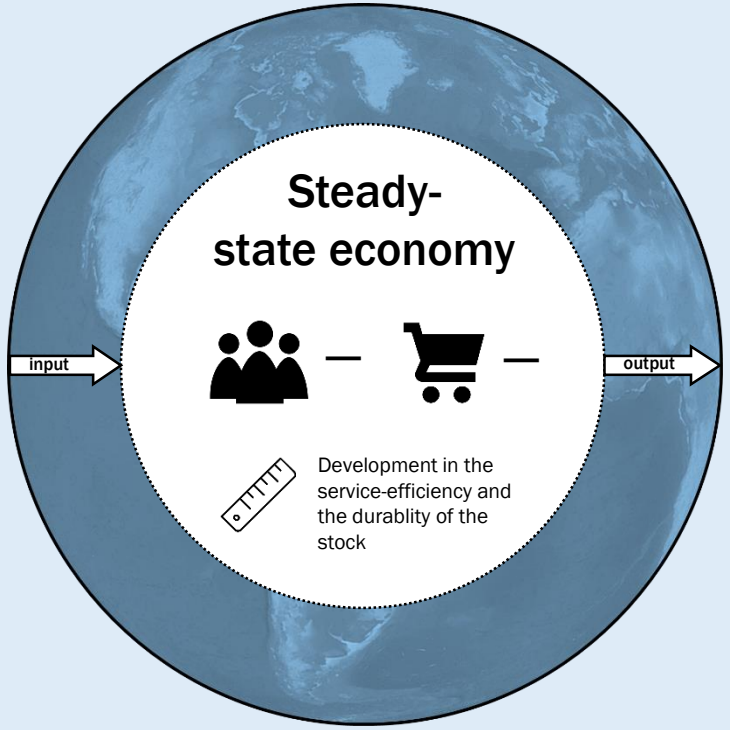
→ Stock is the total inventory of economic goods [kg]

→ Raw material and waste are the entropic physical flow of matter-energy through the economic system [kg/year]

Based on Daly (1977)



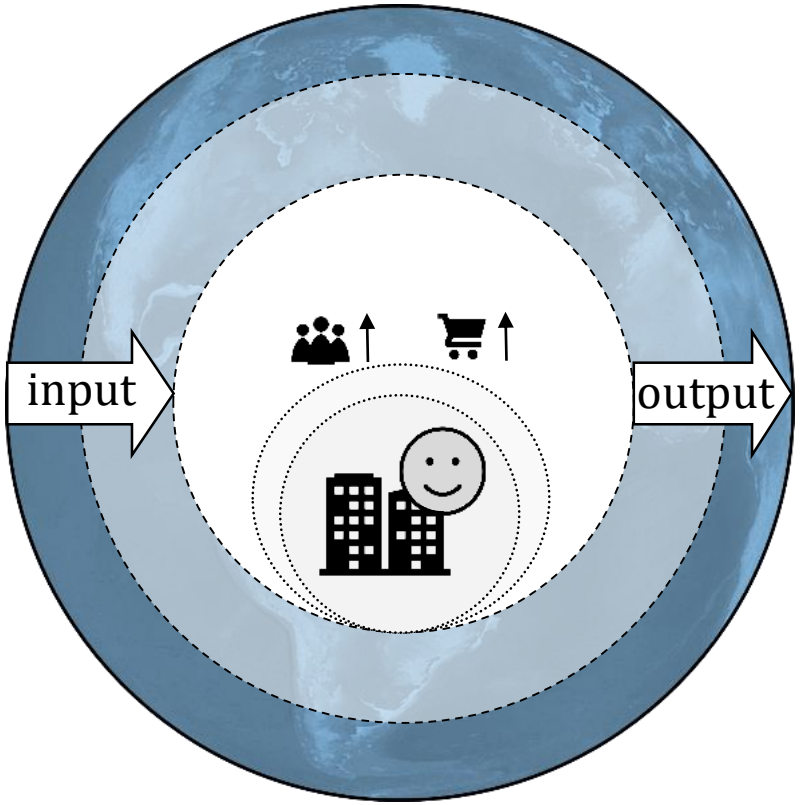




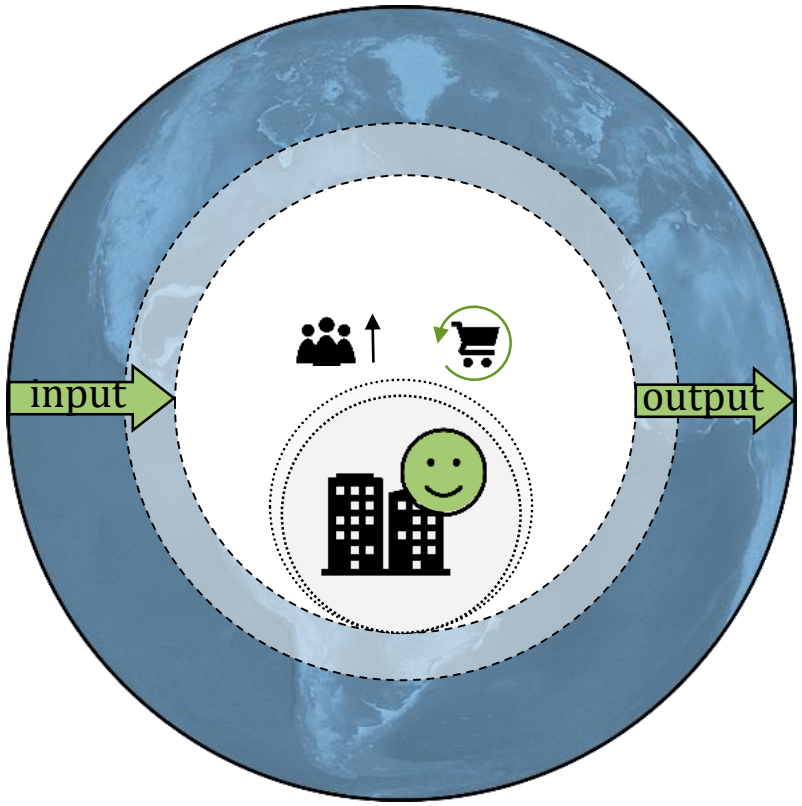
A “practical” circular economy is an economy of both development and growth. The goal is to control the size of the stock of goods* and to increase the utility and the durability of this stock.

Part II:
A Circular Building Stock

Linear economy of growth



“Practical” circular economy



Increase the utility of the building stock

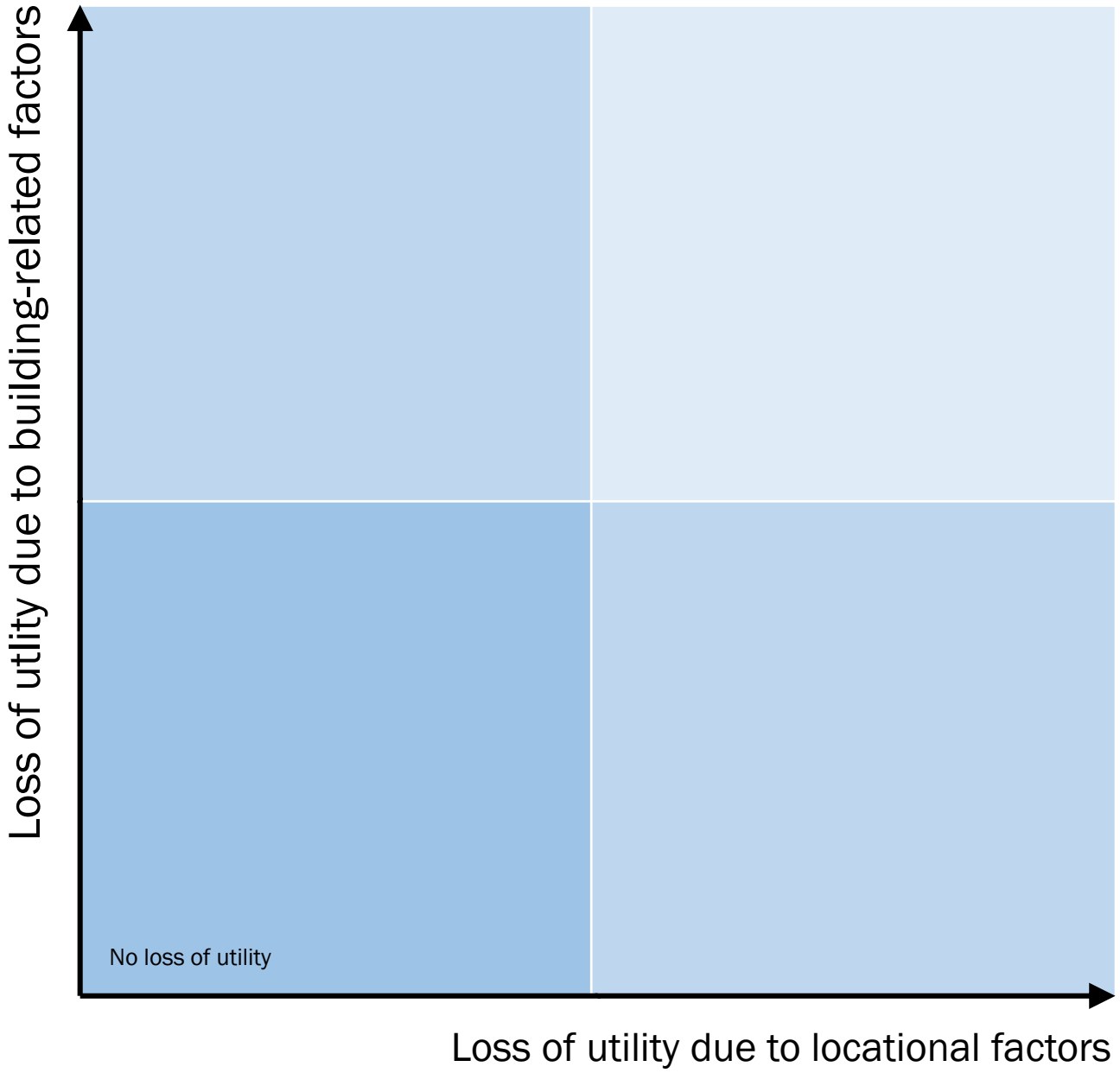
$$\frac{utility\uparrow}{building\ stock-}$$

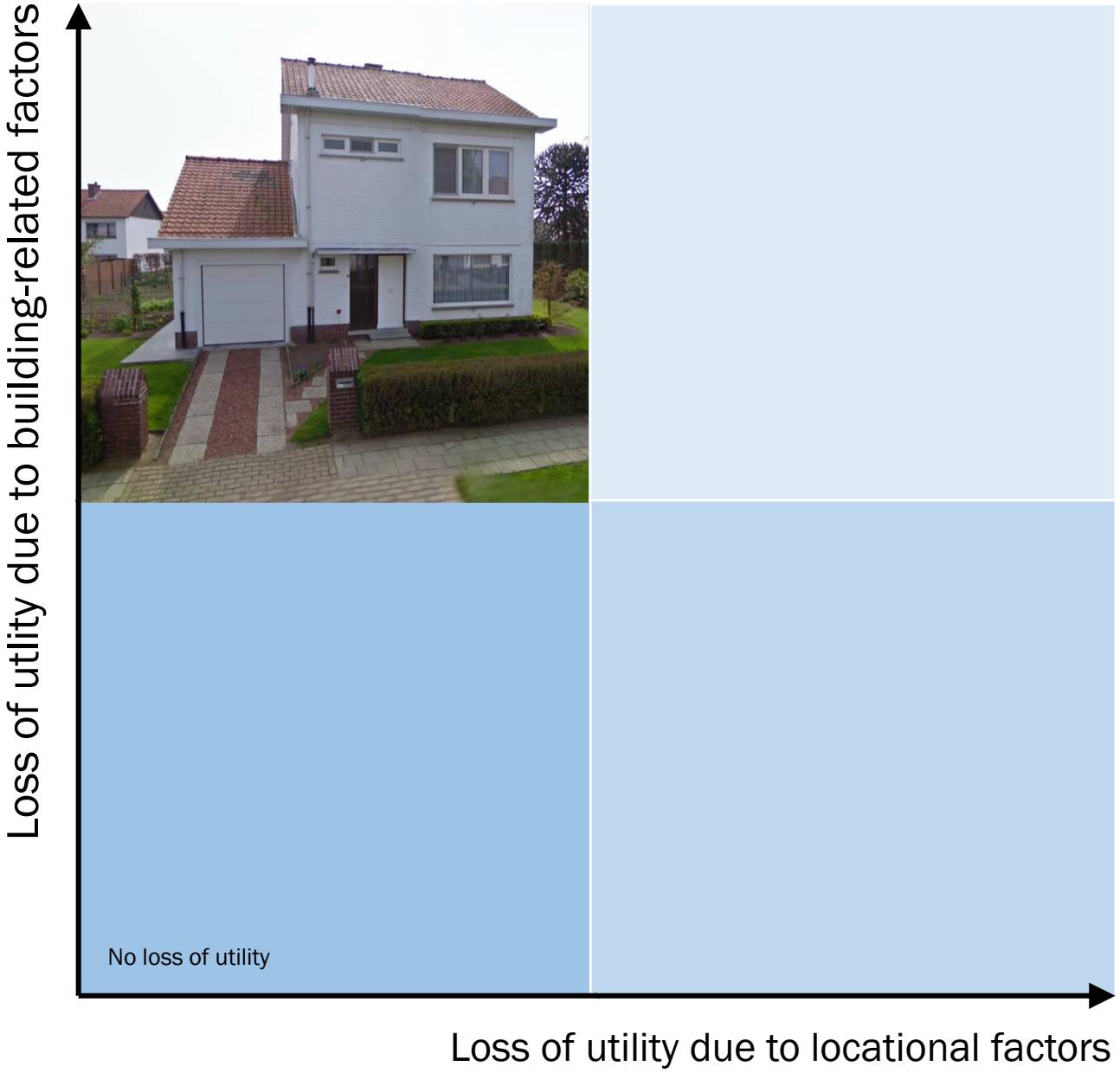
Increase the durability of the building stock

$$\frac{building\ stock-}{primary\ material+waste\downarrow}$$

Utility

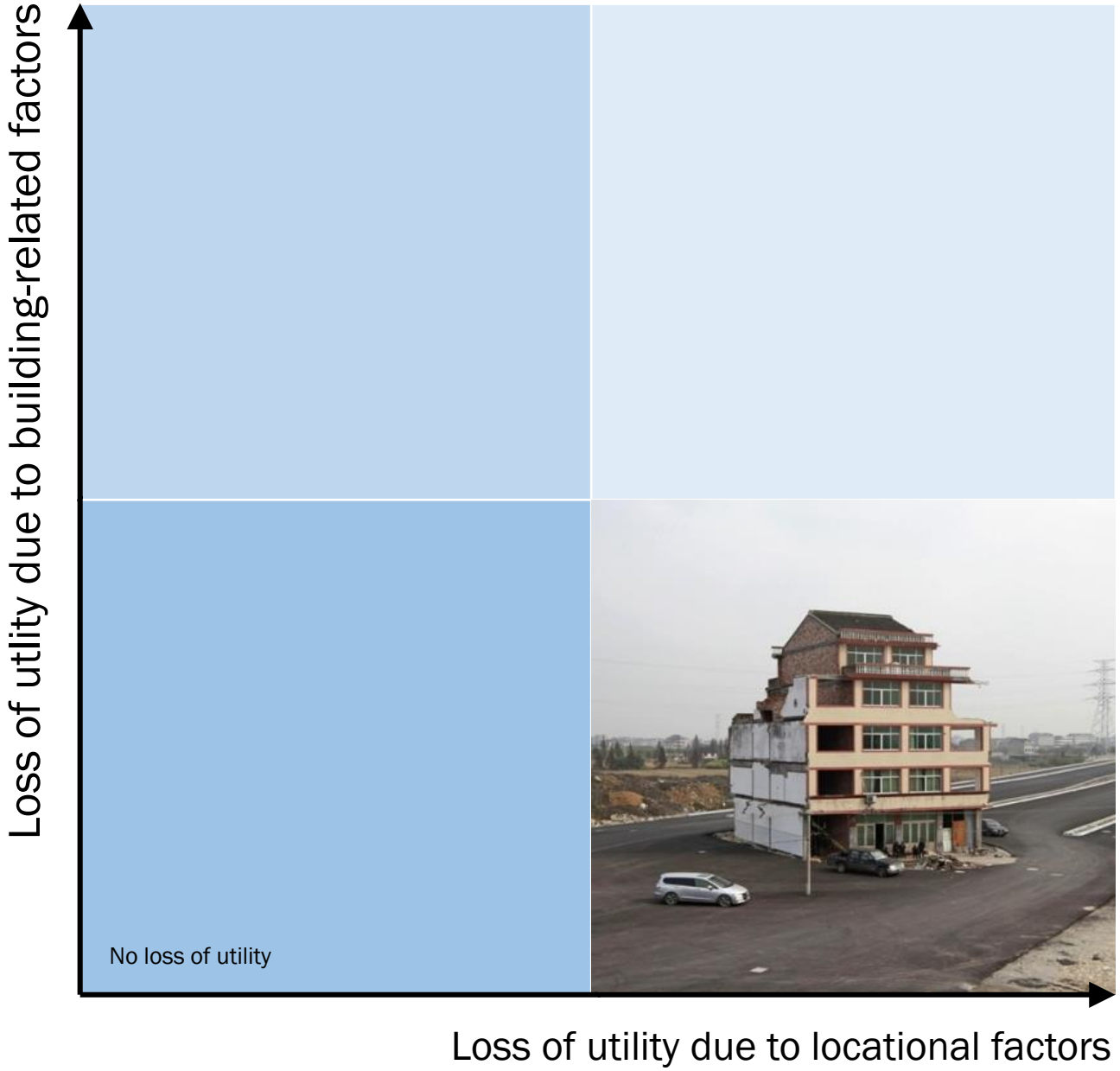
Loss of utility


Loss of utlity due to building-related factors
No loss of utility
Loss of utility due to locational factors

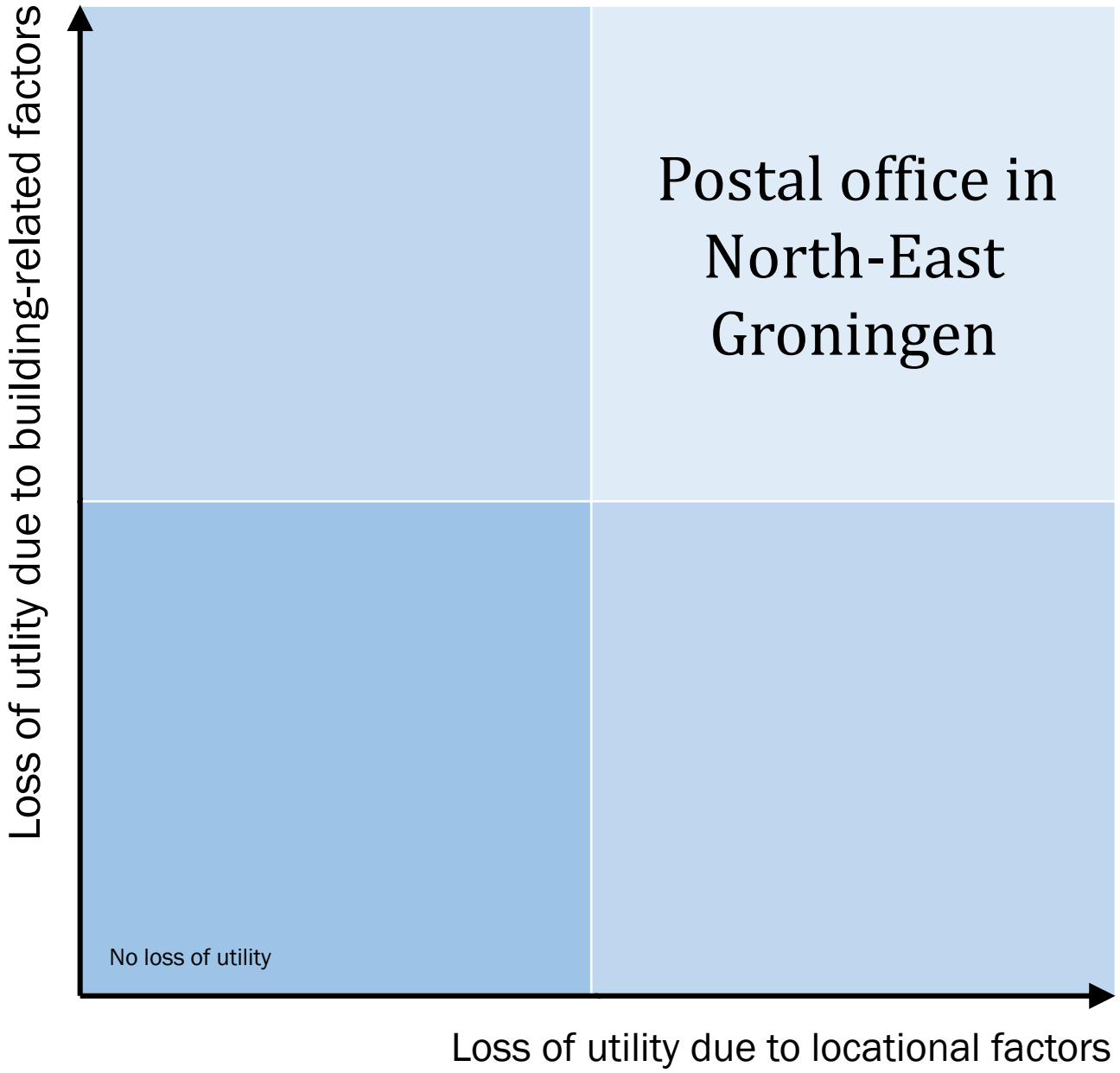


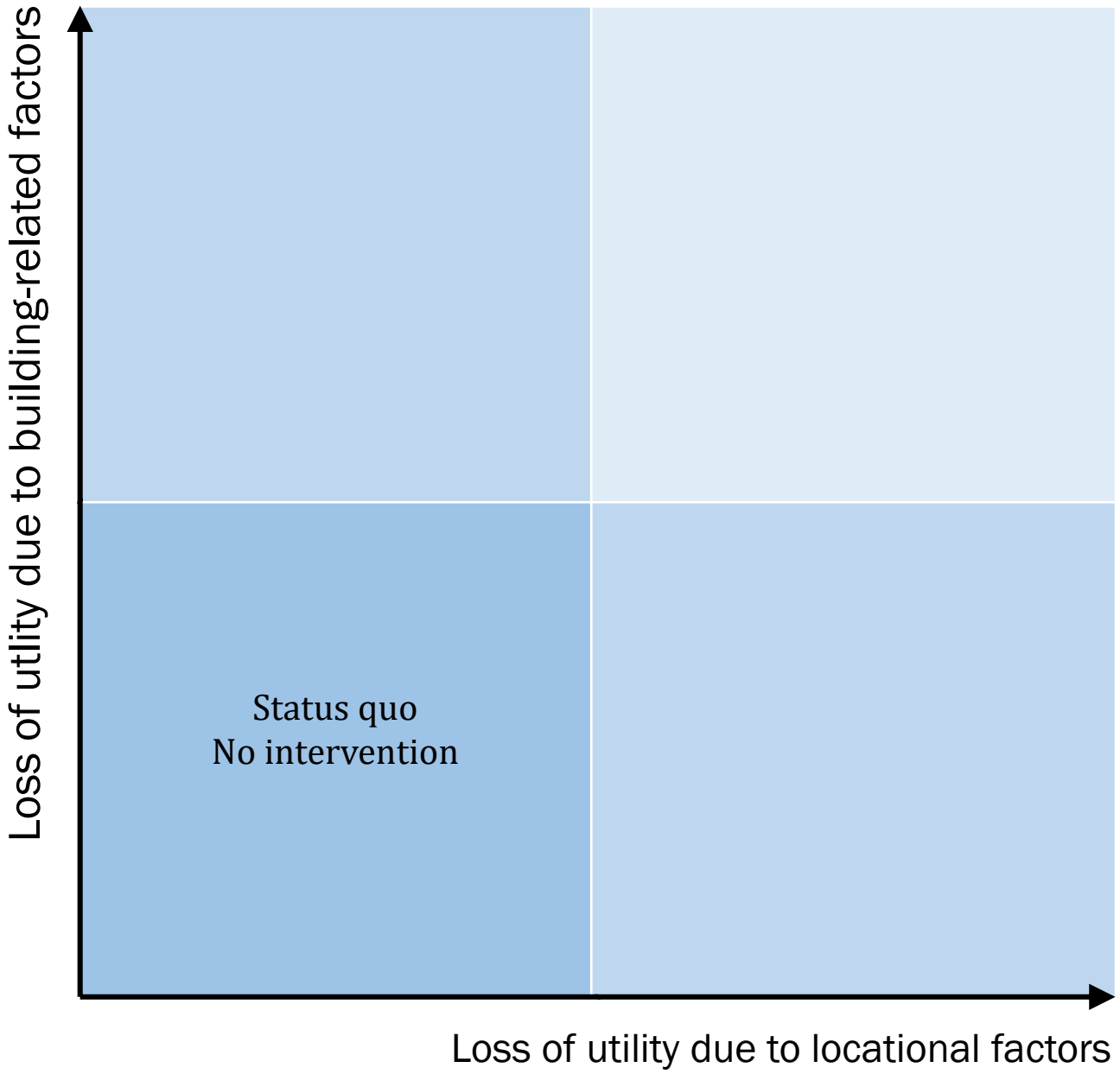
"We are attached to the location of our house. Everything and everyone is within reach: our family, the doctor, the pharmacy, and the supermarket.

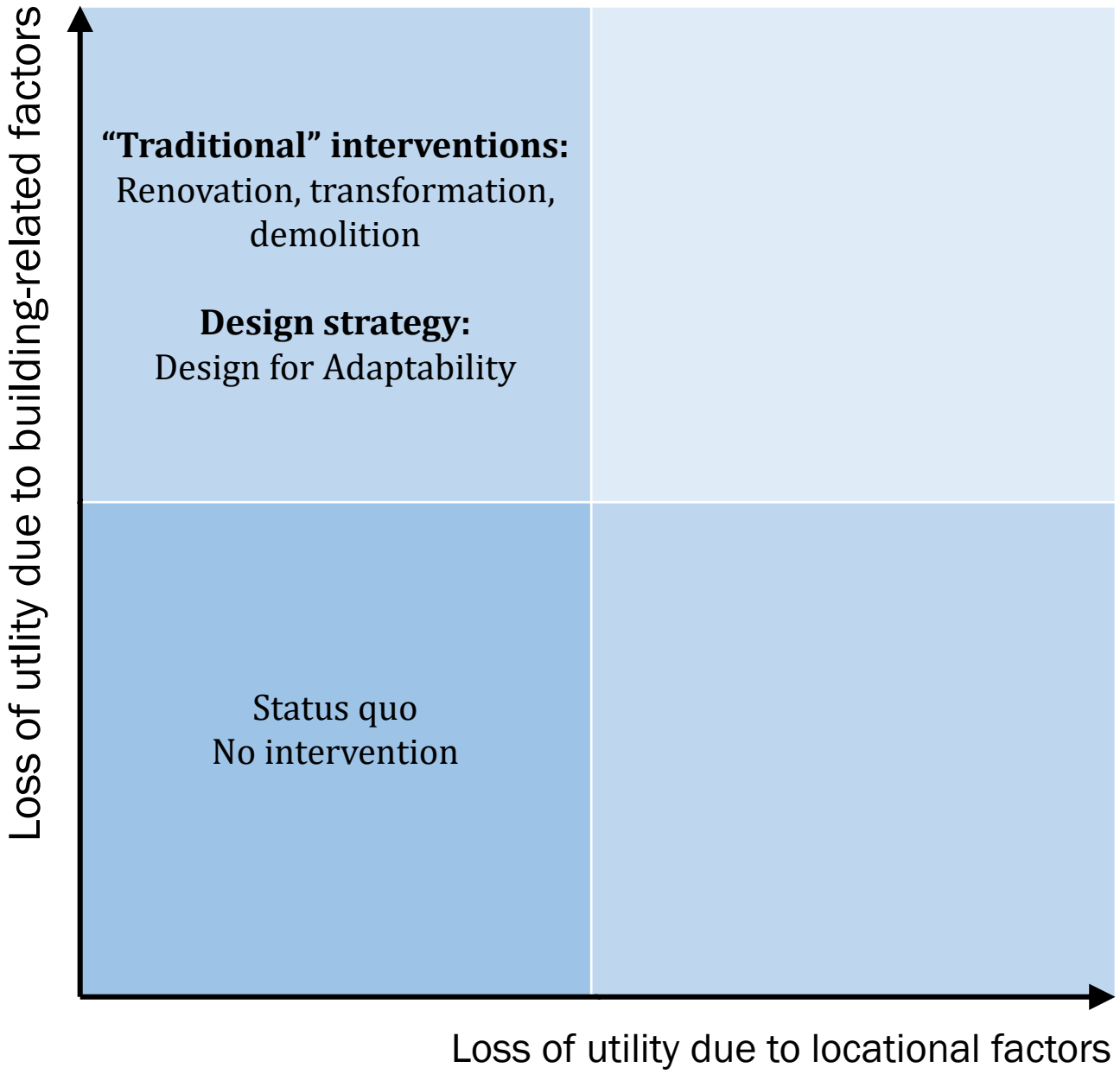
"If we could change anything about the house, we would like to have all amenities on the ground floor"



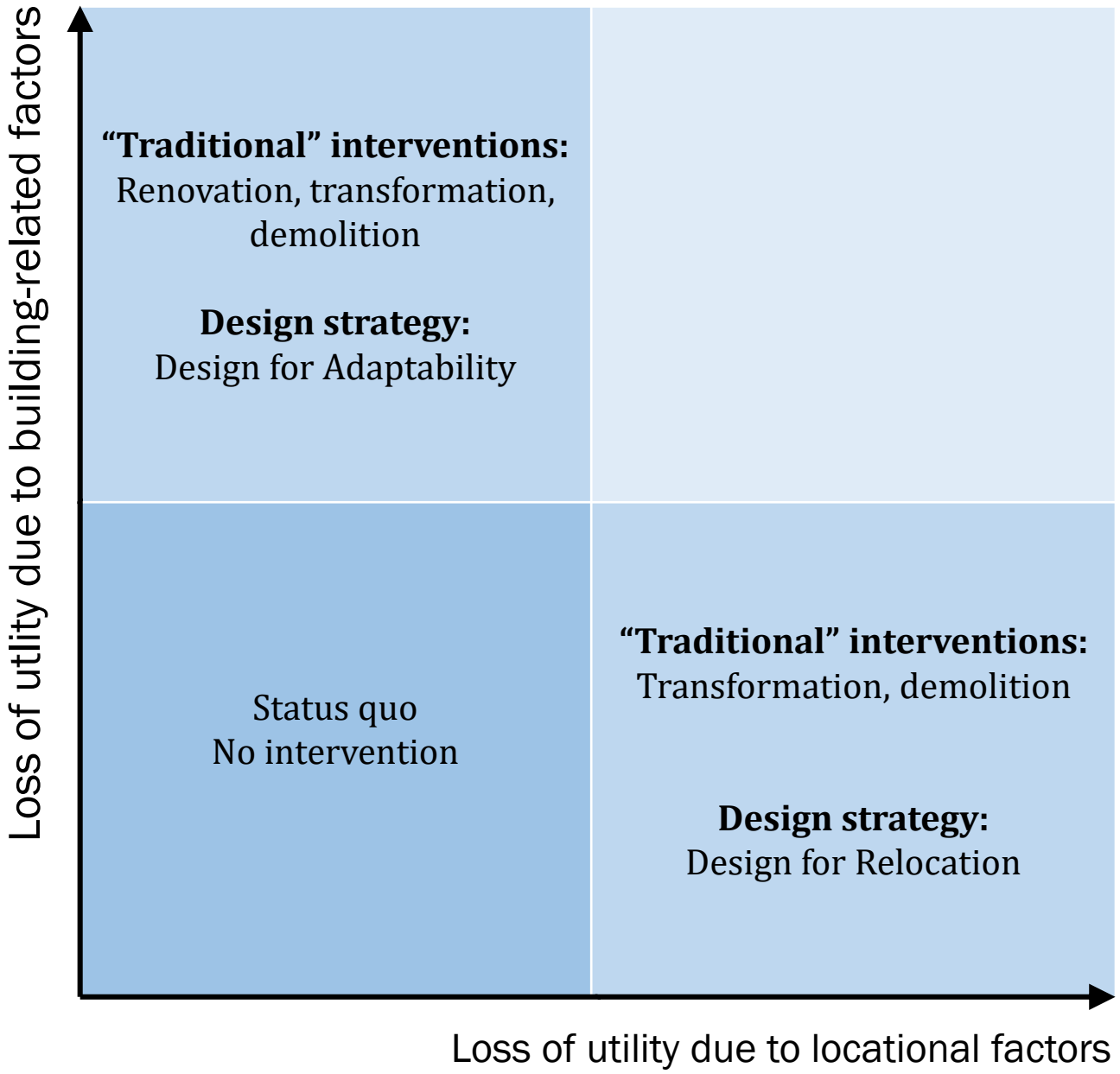
Elderly couple in China refuse to move for road construction

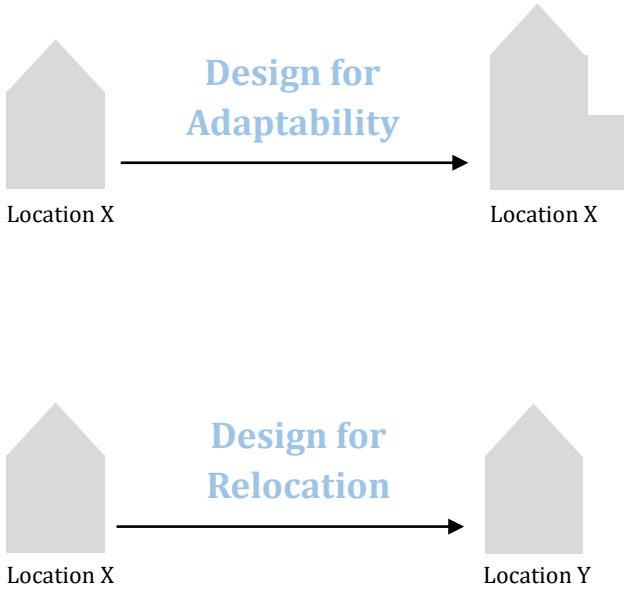

Loss of utlity due to building-related factors
Postal office in North-East Groningen
No loss of utility
Loss of utility due to locational factors

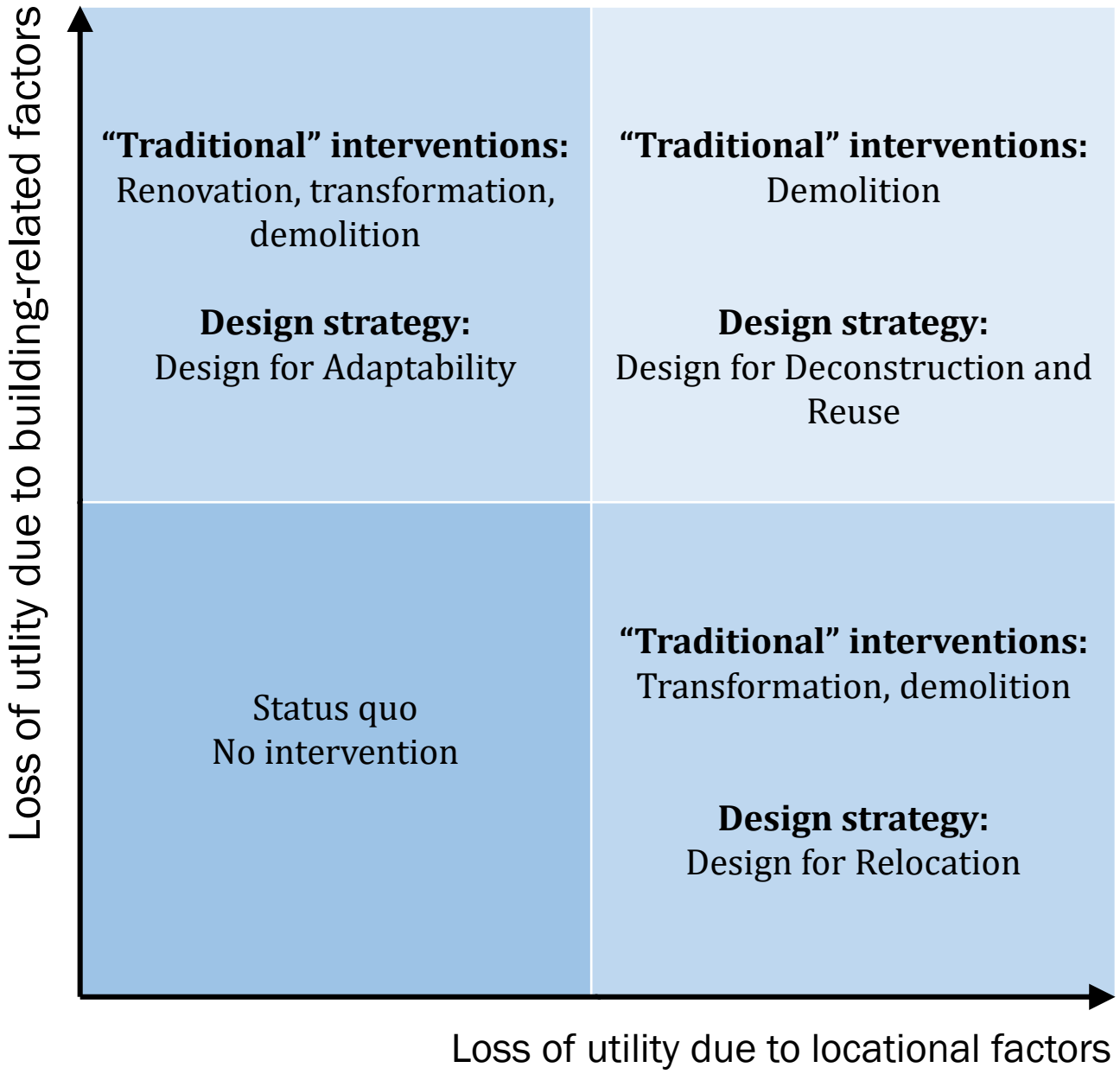

Loss of utlity due to building-related factors
Status quo
No intervention
Loss of utility due to locational factors


Loss of utlity due to building-related factors
"Traditional" interventions:
Renovation, transformation, demolition
Design strategy:
Design for Adaptability
Status quo
No intervention
Loss of utility due to locational factors


Design for Adaptability
Location X
Location X

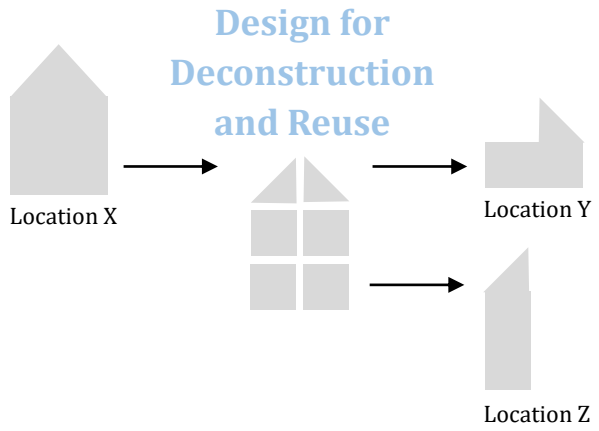

Loss of utlity due to building-related factors
"Traditional" interventions:
Renovation, transformation, demolition
Design strategy:
Design for Adaptability
Status quo
No intervention
"Traditional" interventions:
Transformation, demolition
Design strategy:
Design for Relocation
Loss of utility due to locational factors


Design for Adaptability
Location X
Location X
Design for Relocation
Location X
Location Y

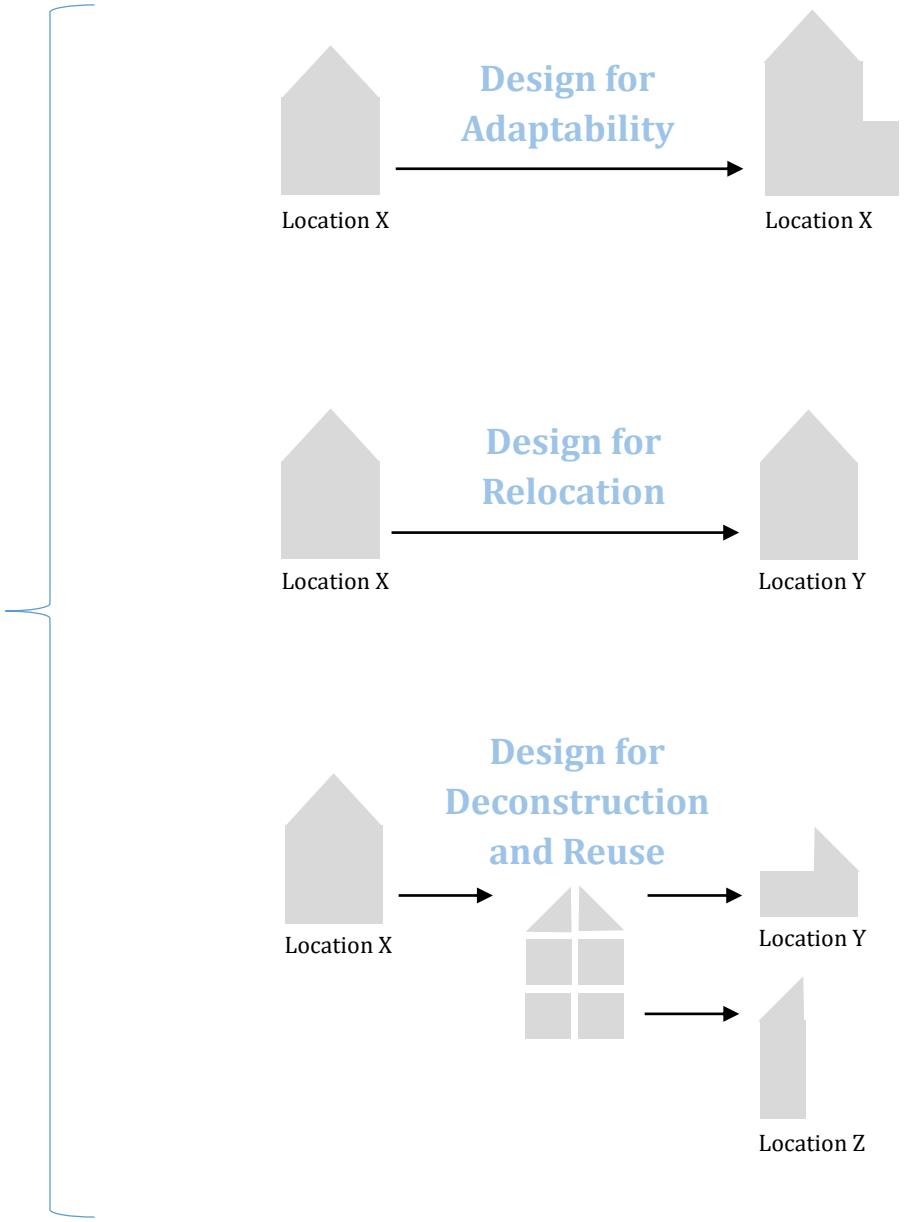

Loss of utlity due to building-related factors
"Traditional" interventions:
Renovation, transformation, demolition
Design strategy:
Design for Adaptability
"Traditional" interventions:
Demolition
Design strategy:
Design for Deconstruction and Reuse
Status quo
No intervention
"Traditional" interventions:
Transformation, demolition
Design strategy:
Design for Relocation
Loss of utility due to locational factors


Design for Adaptability
Location X
Location X


Design for Relocation
Location X
Location Y


Design for Deconstruction and Reuse
Location X
Location Y
Location Z

Modular building



Part III:
Modular Building

Modular building

...

...

Modular building

"Modular construction uses three-dimensional or volumetric units that are prefabricated and are essentially fully finished in factory conditions, and are assembled on site to create complete buildings or major parts of buildings"

Lawson, Ogden, & Goodier (2014, p. 1)

Modular building

"Modular construction systems are closed systems in which the elements are prefabricated by the manufacturers independent of a particular building. For a modular construction system, a particular number of elements are pre-determined which can be organised into complete entities by combining them in a number of different ways"

Staib, Dörrhöfer, & Rosenthal (2008, p. 43)

Modular building

Single-configuration modular building

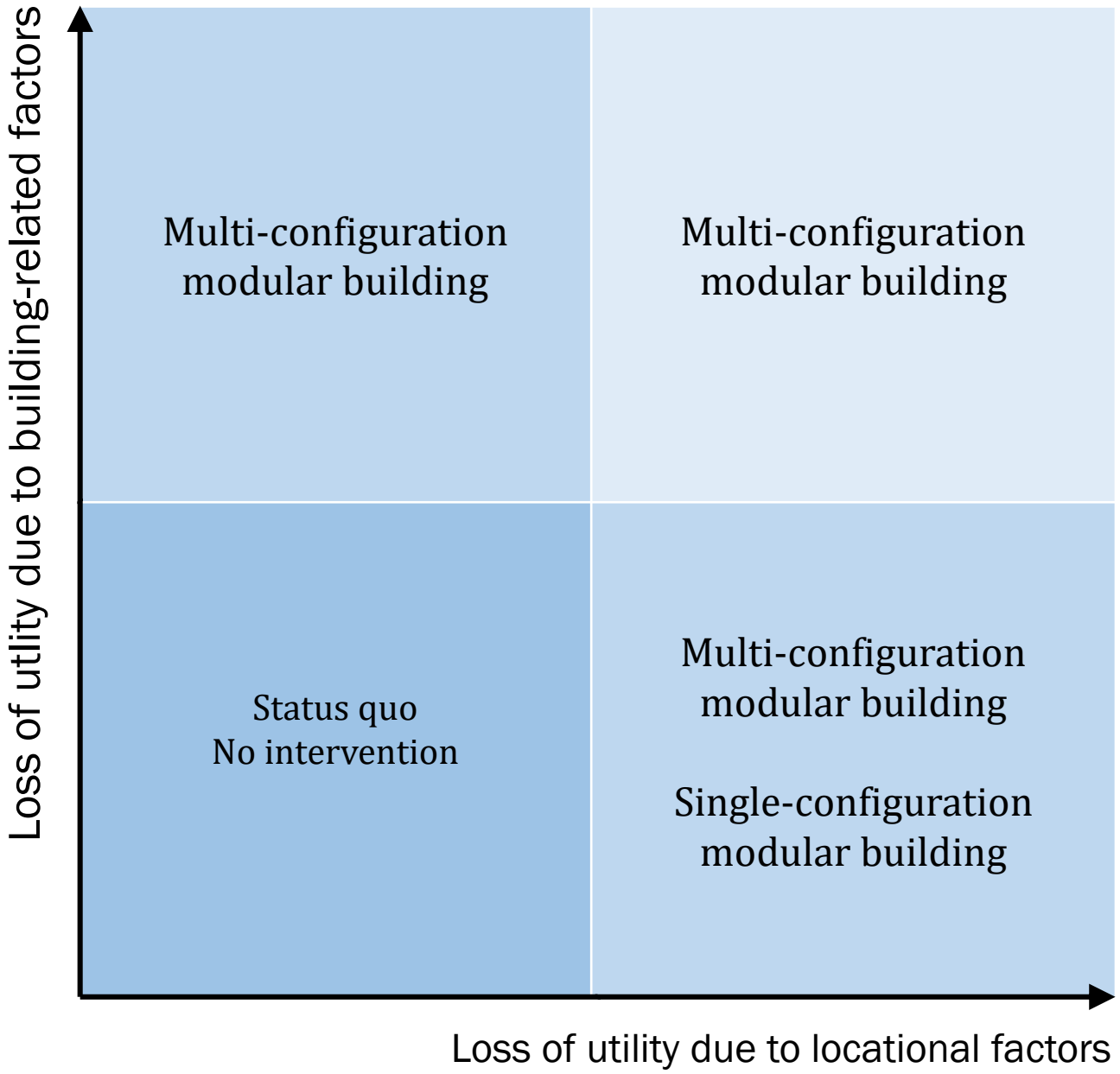
→ Volumetric units;

→ Assembled on site into one configuration

Multi-configuration modular building

→ Elements;

→ Can be combined into a number of different configurations


Loss of utlity due to building-related factors
Multi-configuration modular building
Multi-configuration modular building
Status quo
No intervention
Multi-configuration modular building
Single-configuration modular building
Loss of utility due to locational factors

Collective case study

→ Three to fifteen cases;

→ The firms provide modular housing solutions;

Housing is chosen as a focus, because of its large share in the total building stock

→ The firms describe their product as “modular”;

→ The firms mention “circular economy” or “scarcity of resources” on their website;

→ The firms are located in the Netherlands;

Subject to the regulations laid down in the Building Decree
Practical limitations: Dutch interviews and visits

Firm A

Firm B

Firm C

Firm D

Firm E

Topics

- → Idea behind the firm
- → Modular building
  - The firm’s reasons for building modular
  - Interpretation of modular building
  - What constitutes as a module
- → The characteristics of the product
  - Adjustable
  - Relocatable
  - Deconstructable and reusable

Topics

→ Idea behind the firm

Frustration with the way things go in the building industry, the wish to offer a “better” product than traditional housing;

The wish to give the client freedom in the design (sometimes even after construction) for an affordable price

Topics

→ Reasons for building modular

Being able to offer the client freedom to design an affordable dwelling;

Being able to offer the client freedom to relocate or adapt the building after construction;

Being able to enjoy the advantages of prefabrication: parts are made in factory conditions, transported to the site and constructed mostly within a few days

Topics

→ Interpretation of modular building

Building in a permanently adaptable manner;

An industrial way of building; an advanced form of prefabrication;

Building on a fixed grid; building with modules that have a standardised dimension

Topics

→ Interpretation of modular building

A module is a standardised panel or a volumetric unit, that can be assembled in a number of configurations on site (multi-configuration modular building);

A is a jigsaw puzzle piece, that can be assembled in a single configuration on site (single-configuration modular building).

Topics

→ Characteristics of the product: adaptable?

Most of the products can be customised by the client in the design phase;

Some of the products can customised by the client in the operations phase;

The degree of customisation is constrained by the chosen building construction, rules and regulations and integrated service installations.

Topics

→ Characteristics of the product: relocatable?

Most of the products can be relocated;

A possible constraint is the financing construction: if the building serves as collateral for the bank, it can not simply be relocated.

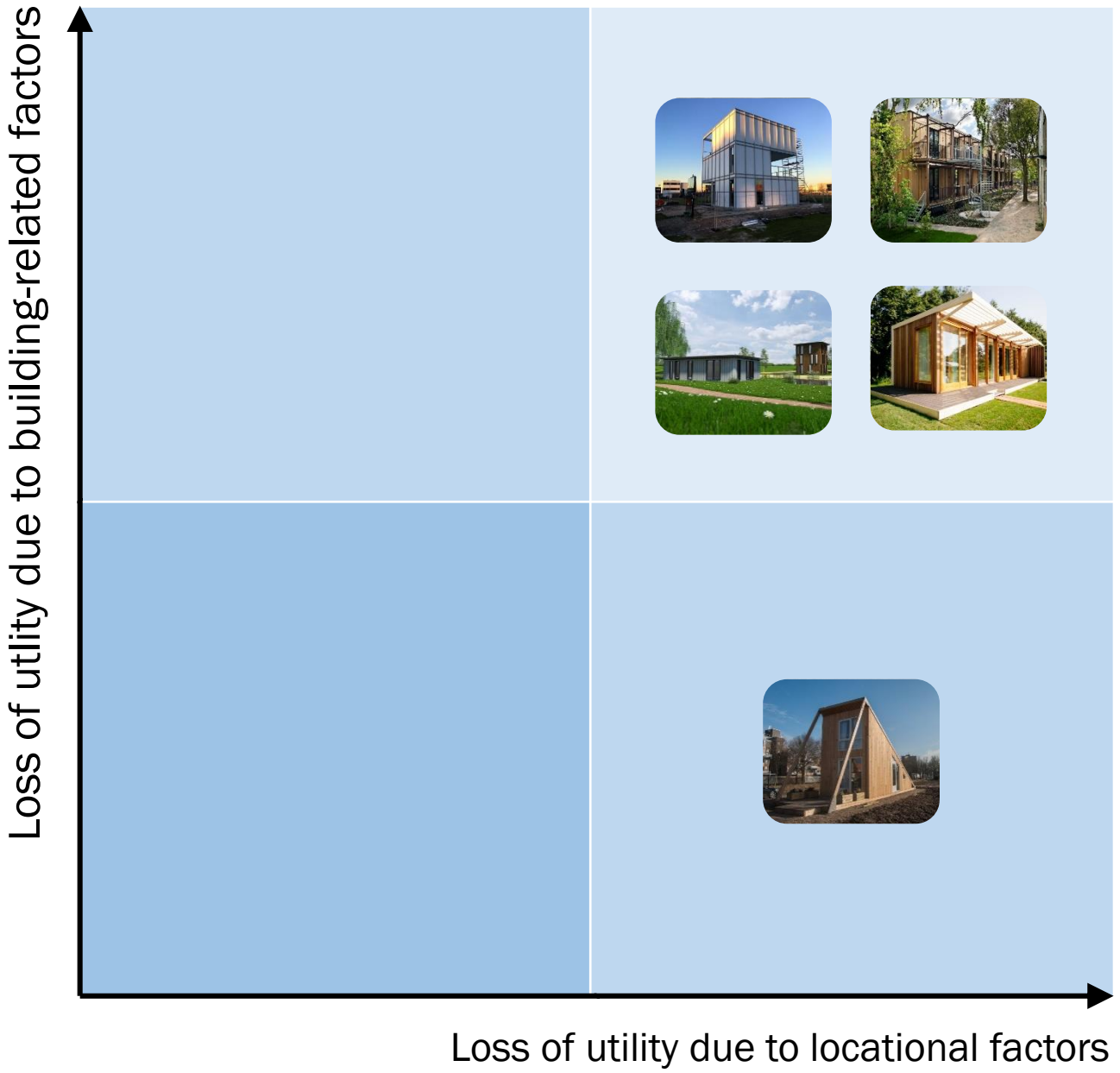
Topics

→ Characteristics of the product: deconstructable and reusable?

All products can be deconstructed, some up until the level of the element as a result of the use of dry connections; others up until the level of the component as the elements are glued together;

The financing construction that constrains relocation also constrains deconstruction;

The parts can be reused within the building system of the firm.



Multi-configuration modular building

Single-configuration modular building

Conclusion

Conclusion

How can modular building contribute to a circular building stock?

Multi-configuration modular building allows for adaptation, relocation, deconstruction and reuse
Prevents loss of utilty

Conclusion

However

- → Constrained by construction system; modules are designed to be used *within* the system (intrafirm modularity);
- → Constrained by rules and regulations;
- → Constrained by financing construction (collateral for the bank)

Discussion / limitations

Complexity of the demand-supply problem

→ Demand: Natural growth rate in NL will be negative as of 2038 (CBS, 2016)

→ Supply: Type of material

Cause of scarcity: Geologically rare; extraction financially unviable; supply concentrated in politically unstable countries (Hobson, 2016)

Scarcity not a driver in building industry (Rijskwaterstaat, 2015):

Discussion / limitations

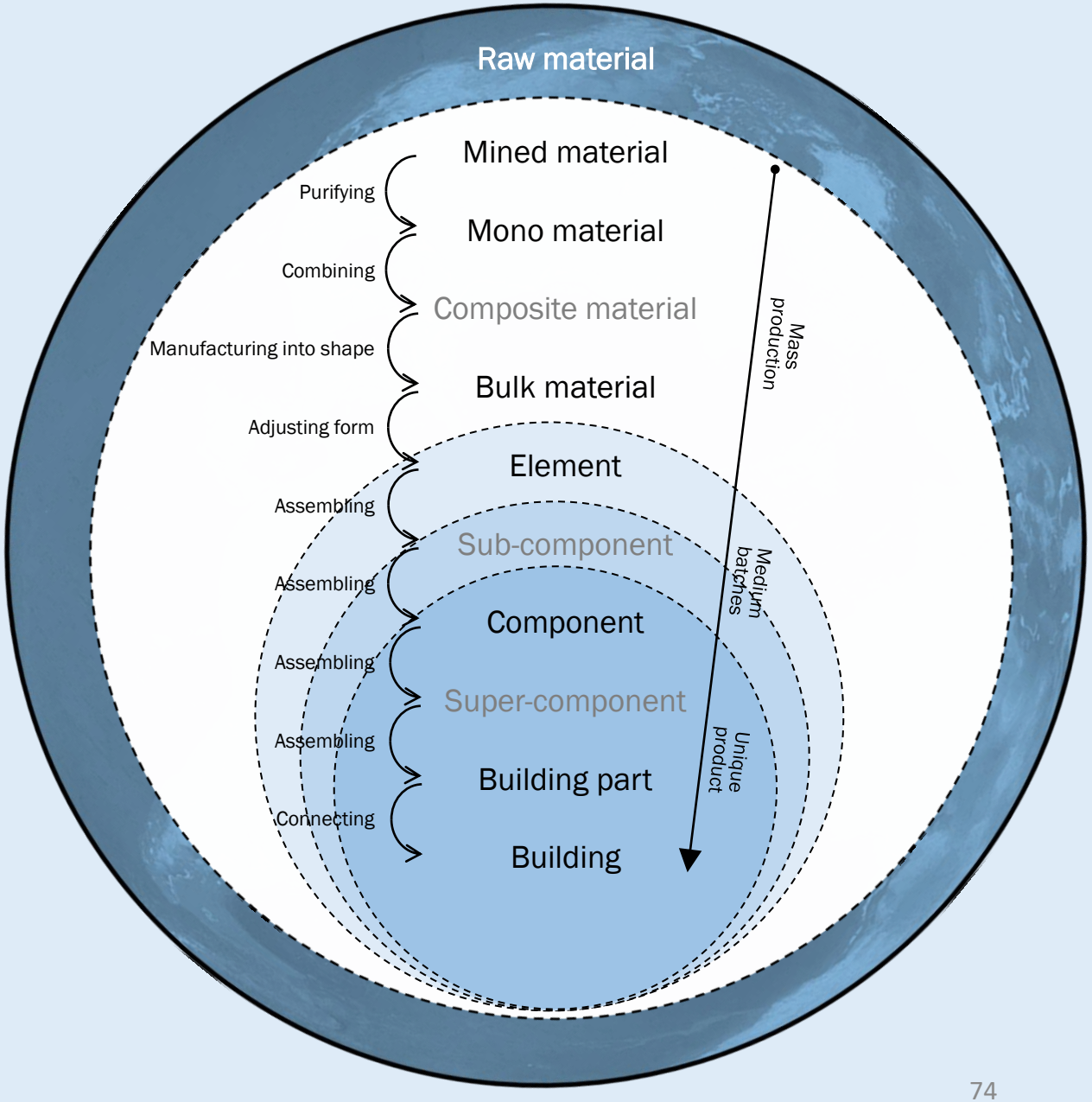
Collective case study

- → Inclusion criteria; niche market (small share)
- → Utility / durability
- → Primary or secondary materials
- → Housing; other typologies?

Discussion / limitations

Sustainability linkages

Recommendations



Reflection

Circular economy as multi-disciplinary subject; both fantastic and terrible

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