KU LEUVEN

Turning the existing building stock into a resource mine

Proposal for a new method to develop building stock models

Presenting author:
Prof. Dr. Ir.-Arch. Karen Allacker
(KU Leuven - Dept. of Architectural Engineering)

Authors: Ir.-Arch. Alberick Lismont, Prof. Dr. Ir.-Arch. Karen Allacker

Context

Demolition Waste Reclamation

Recycling
- lower grade materials
- energy intensive

90%

Reuse / Circular Thinking
- preserve value
- minimize environmental impact

1%

Challenges

Technical

Operational

Economic

Scale / Market

KU LEUVEN

State of the art

Building stock modelling and urban environmental impact

Top-down models

Bottom-up models

→ GIS-enriched archetype models

- scalability of traditional archetype models
- building-by-building granularity

SUITABLE MODEL FOR THE ASSESSMENT OF MATERIAL REUSE IN THE BUILDING STOCK

State of the art

Building stock modelling and urban environmental impact

a. Spatio-temporal material flow model
(Mastrucci et al. 2017)

+ material flow model
– reuse scenario is static

b. Dynamic LCI with changing material flow
(Wu et al. 2016)

+ reuse scenarios are dynamic
– no environmental impact assessment;
only demolition waste

c. Material flow through maintenance and refurbisments
(Tiruta-Barna et al. 2016)

+ other material flows considered
– otherwise incomplete;
proof of concept

d. Dynamic LCA with changing energy supply and demand
(Collinge et al. 2016)

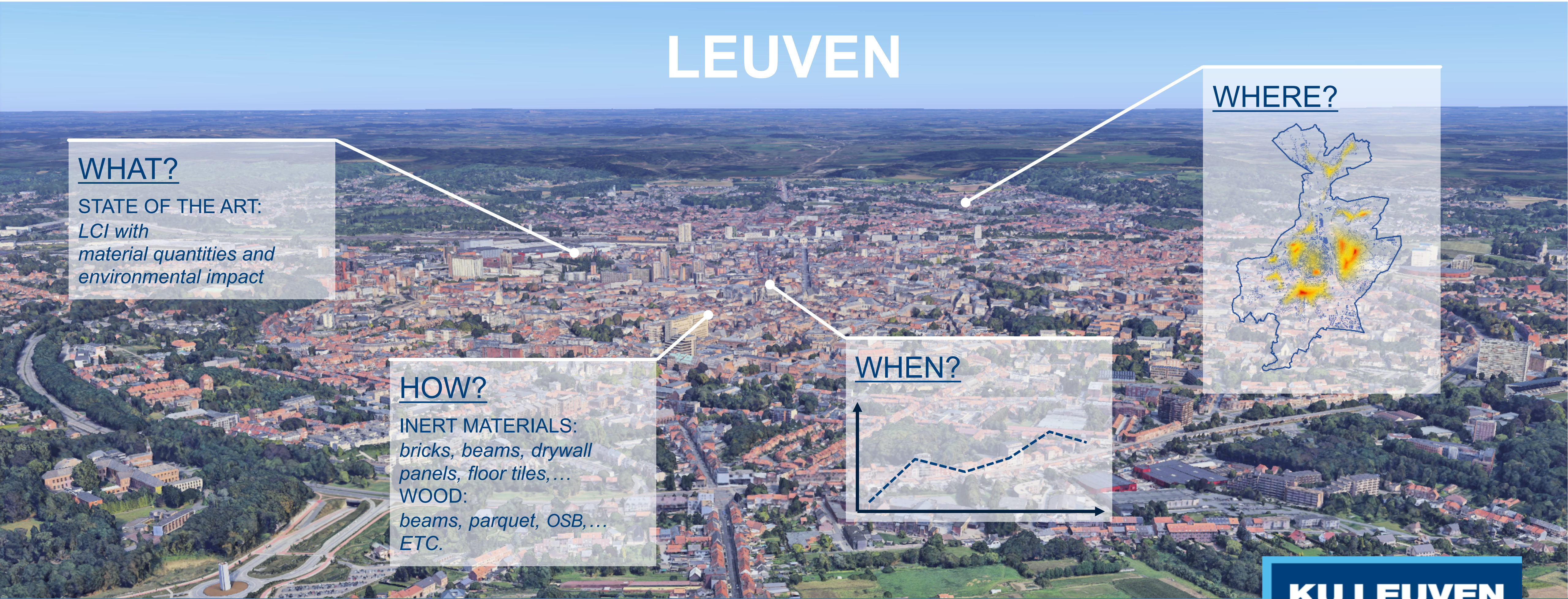
+ dynamic impact based on changing environment
– no material flow model

ALL BUILDING STOCK MODELS CONSIDER MATERIALS AND REUSE ON AN ABSTRACT LEVEL

What are the form and condition of materials?
In what form can they be reused?

Proposed model

Spatio-temporal model of materials in urban building stock



KU LEUVEN

Building stock analysis

A. Statistical analysis

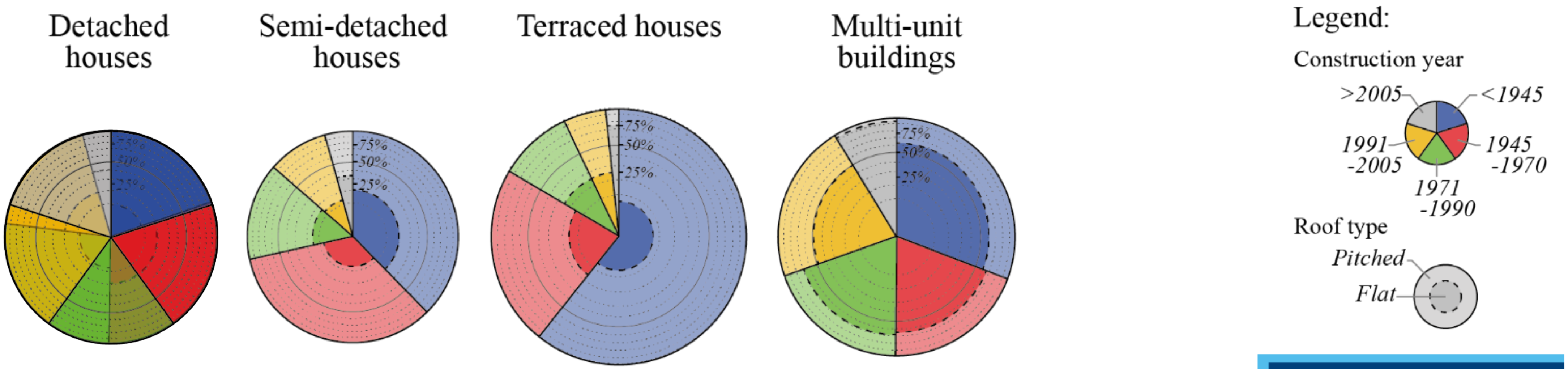
Selection of archetypes through statistical analysis:

5 construction periods x **4** typologies = **20** archetypes (SuFiQuaD, Allacker et al., 2009)

expansion of set with 8 differentiations based on roof type because of impact on materiality

multi-unit buildings for all periods (+5)

other typologies only for the most recent time period (+3)



* circle sizes are weighted by total floor area of buildings

Building stock analysis

Selection of archetypes through k-means clustering:

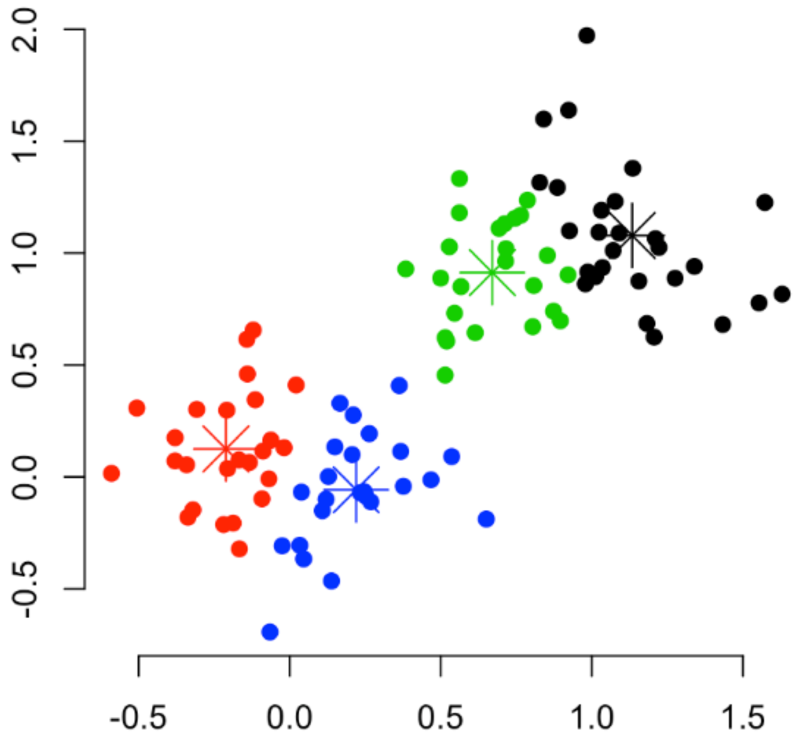


illustration of a k-means clustering

Building stock analysis

B. k-means clustering

Selection of archetypes through k-means clustering:

4 parameters considered out of available data based on relevance to materiality of a building
- construction year
- total floor area
- fraction of exposed façades
- fraction of pitched roofs

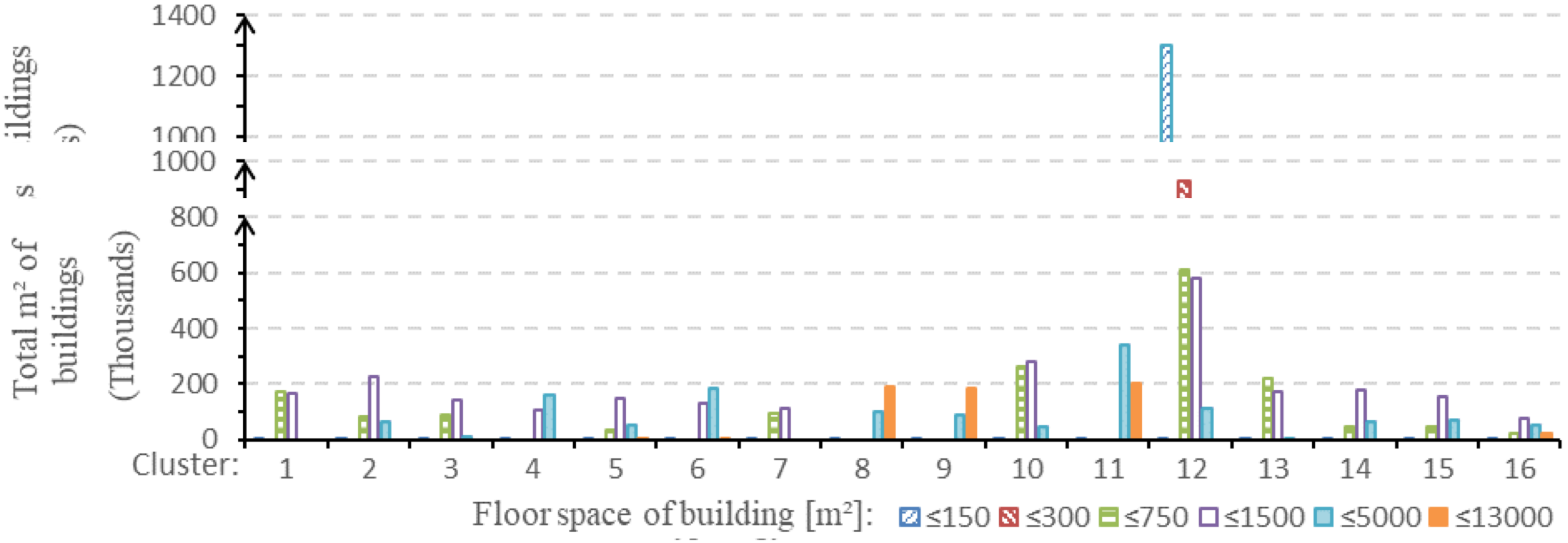
The number of clusters (“k”) was determined empirically.
- k = 28 did not produce coherent clusters
  k-means clustering creates groups of relatively equal size,
  low variance, low number of parameters -> large, homogenous groups get split ‘arbitrarily’
- **k = 16** did produce coherent clusters

KU LEUVEN

Building stock analysis

B. k-means clustering

Selection of archetypes through k-means clustering:

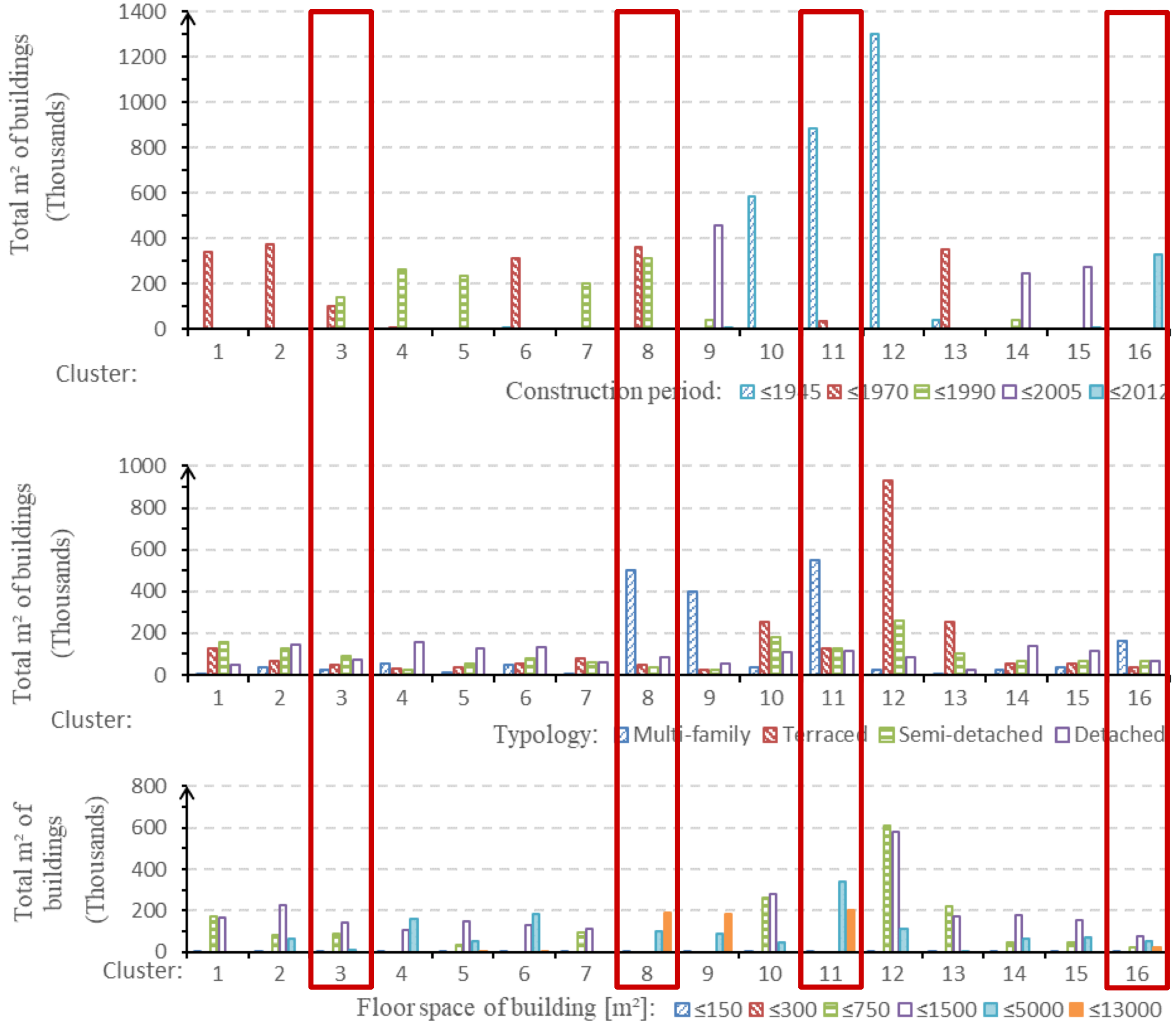


Building stock analysis

B. k-means clustering

Selection of archetypes through k-means clustering:

Cluster	Time period	Typologies
1	1956-1970	Small, compact single-family buildings (<300 m^2)
2	1946-1970	Medium single-family buildings (ca. 300 m^2)
3	Ca. 1970	Small, compact single-family buildings
4	1971-1990	Large „single-family buildings“ (ca. 750 m^2), likely multi-family buildings
5	1971-1990	Medium single-family buildings (ca. 300 m^2)
6	1946-1970	Large single-family buildings (ca. 750 m^2)
7	1971-1990	Small single-family buildings (<300 m^2)
8	Ca. 1970	Multi-family buildings
9	1991-2005	Multi-family buildings
10	Pre 1945	Small single-family buildings (<300 m^2)
11	1921-1945	Very large buildings (>750 m^2), likely multi-family buildings
12	Pre 1920	Small single-family buildings (<300 m^2)
13	1940-1955	Small, compact single-family buildings (<300 m^2)
14	1991-2005	Large single-family buildings (>300 m^2)
15	1991-2005	Large single-family buildings (>300 m^2), more pitched roofs
16	2006 and later	(Almost) all typologies



note that the clusters are not in any particular logical order

KU LEUVEN

Future outlook

Scaling data from archetypes to entire building stock

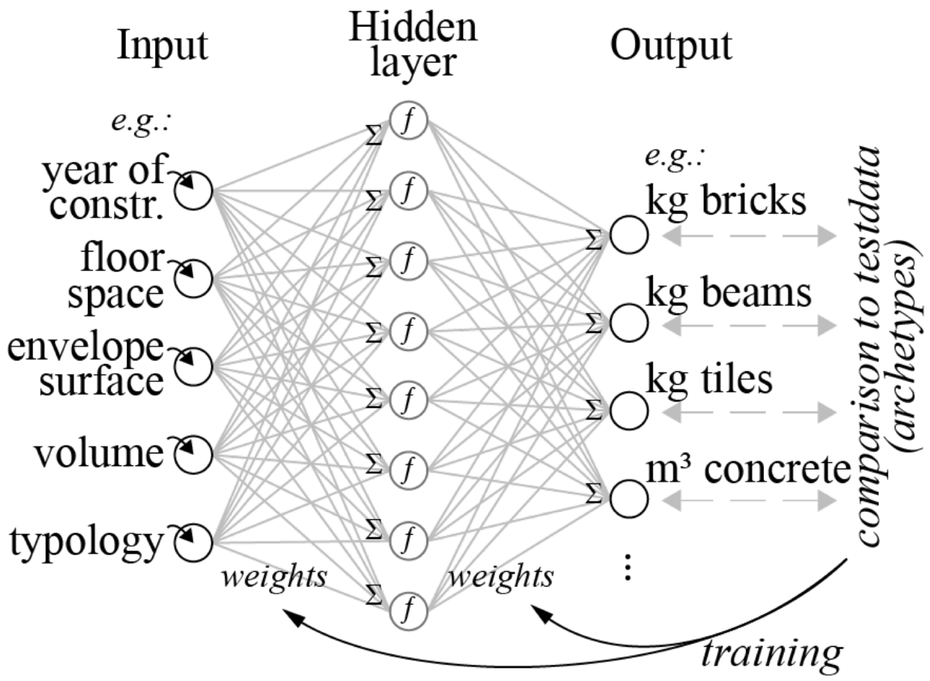
State of the art:

Ties every building to a specific archetype and scales its values proportionally
(e.g. all material volumes scale linearly based on total floor area of a building)

Through machine learning:

a. k-nearest neighbours (kNN) classification
   categorises buildings under the most similar archetype
   (more flexible, as number of archetypes can increase, resulting in automatic recategorization)

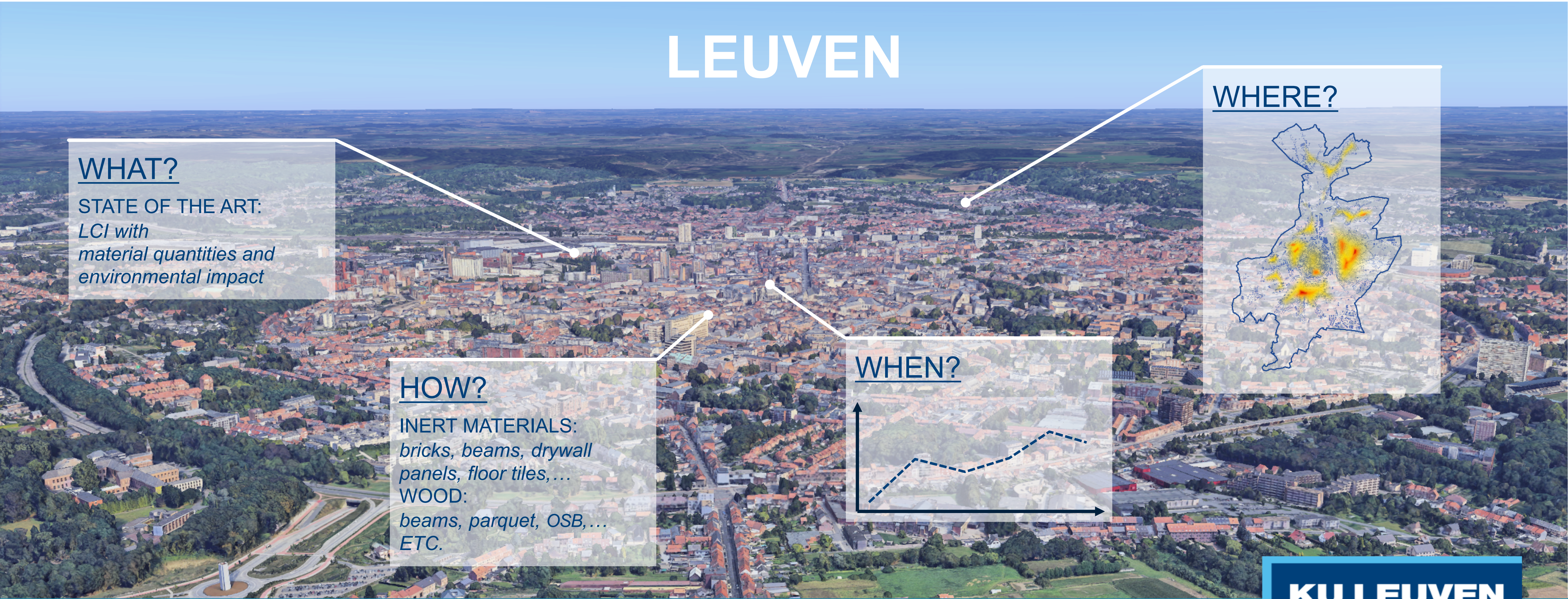
b. artificial neural network (ANN)
   does not segment buildings into categories
   extrapolates unknown values non-linearly



KU LEUVEN

Conclusions

Spatio-temporal model of materials in urban building stock



KU LEUVEN