Transferability of Material Composition Indicators

A conceptual approach based on a German-Japanese Comparison

MINEA WG 1: "Resource potential of construction & demolition waste"
Workshop: „Towards a knowledge base for material reserves and resources in buildings & infrastructures", Session: „Building passport"
Monday, 29th October 2018, Odense, Denmark

Georg Schiller[1], Alessio Miatto[2], Karin Gruhler[1], Regine Ortlepp[1], Clemens Deilmann[1] Hiroki Tanikawa[2]

1 Leibniz Institute of Ecological Urban and Regional Development

2 NAGOYA UNIVERSITY

Vision

- Numerous of MFA Bottom up-studies with regard to built environment in different regional context
- Bottom up Principle:
  Quantity of buildings x MCI = Total Material Mass
- Ideally each building cohort has its own MCI
- Daunting and lengthy process (extensive empirical studies)

->Vision: ready to use cross context database

Challenge

We have

- to discuss the permissibility of applying available MCI
- to understand potentials and limits of MCI- transferability

One way to do so:

- compare and explain the variance of existing ones

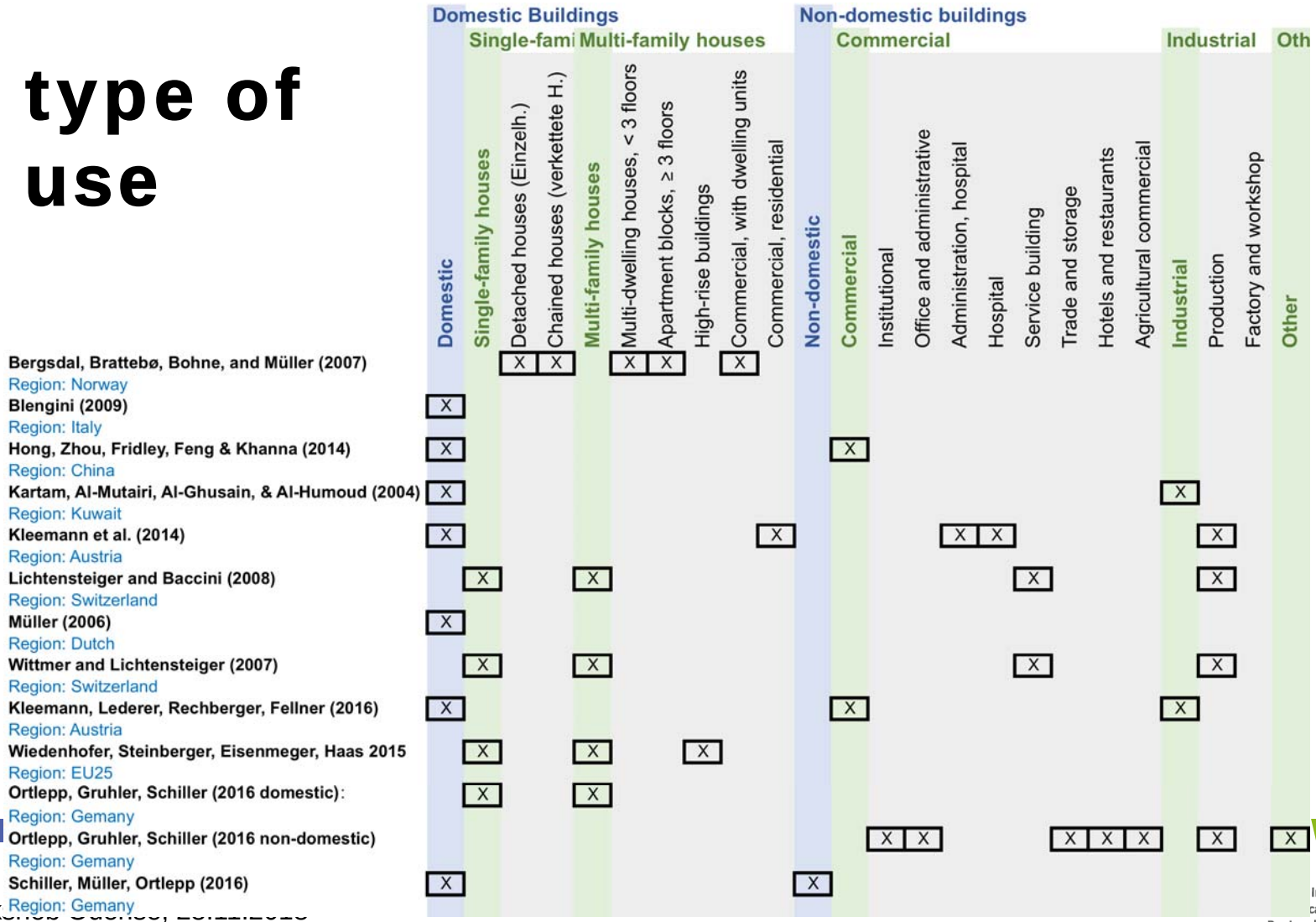
  -> German-Japanese Comparison of MCI

Leibniz Institute of Ecological Urban and Regional Development

NAGOYA UNIVERSITY

Inhomogeneous in terms of:

type of use



Inhomogeneous in terms of:

type of construction

	Wooden (Timber)	Timber or steel frame	Steel frame	Steel-based, 1-story	Steel-based, 2-story	Steel-based, 3-story	Concrete frame	Shearing-force	Steel reinforced concrete	Reinforced concrete	Brick-concrete	Brickwork	Brick-wood and other
	W	TS	S	S-1	S-2	S-3	C		SRC	RC	BC	BW	BWO
Hashimoto, Tanikawa, and Moriguchi (2009)	X		X						X	X			
Hashimoto, Tanikawa, and Moriguchi (2007)	X		X						X	X			
Hu, van der Voet, and Huppes (2010)							X	X			X		
Tanikawa, Managi, and Lwin (2014)	X			X	X	X				X			
Tanikawa, Fishman, Okuoka, Sugimoto (2015)	X	X	X							X			
Wang, Müller & Hashimoto (2015)			X							X	X		X
Ortlepp, Gruhler, Schiller (2016 domestic):										X		X	

Inhomogeneity in terms of

Reference Value

$$m^2 \neq m^2$$

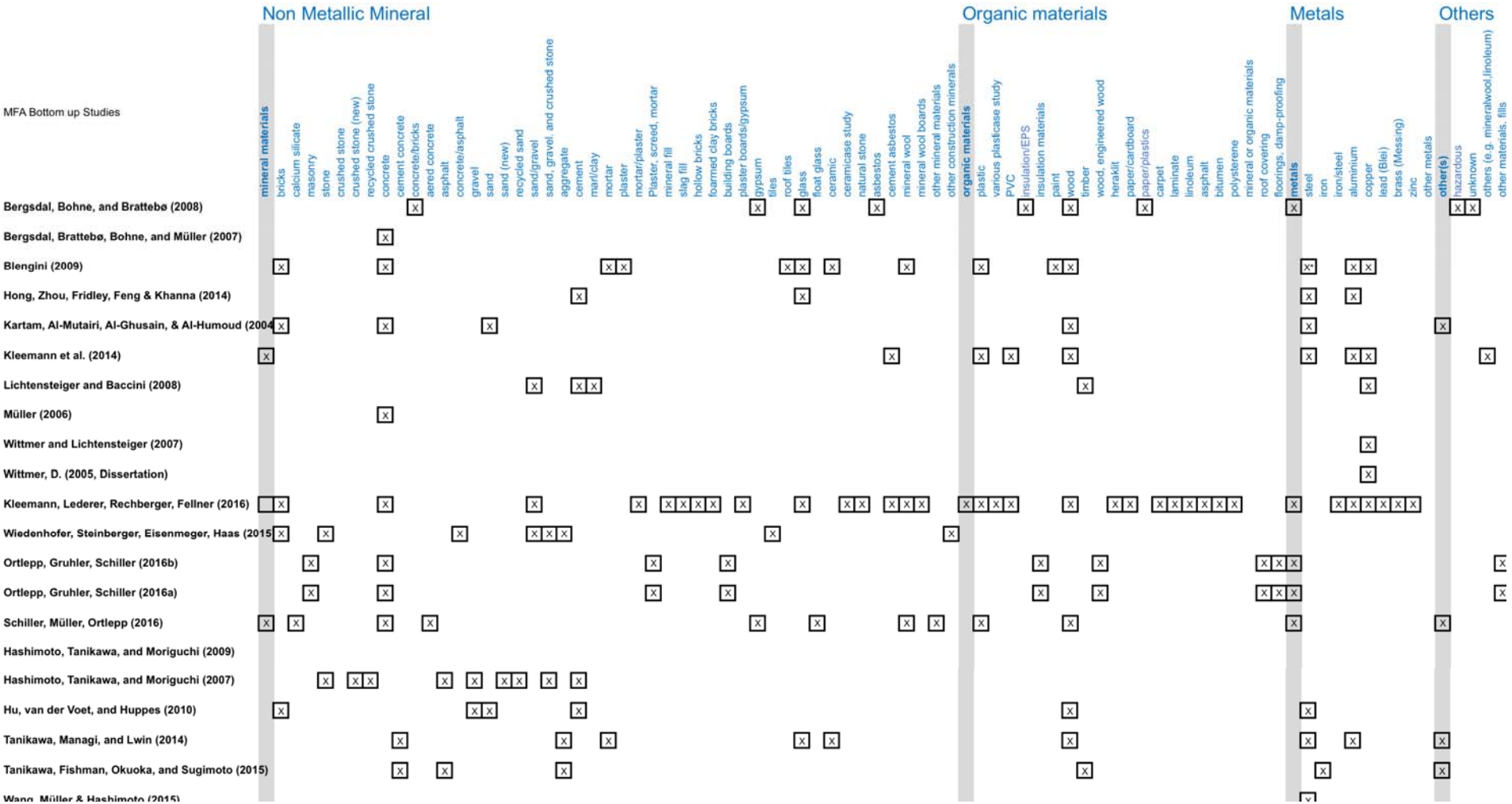
- Floor area
- Gross floor area
- Net floor area
- Usable area
- Gross volume

….

Bergsdal, Bohne, and Brattebø (2008)	kg/m²
Bergsdal, Brattebø, Bohne, and Müller (2007)	kg/m²
Blengini (2009)	kg/m²
Hong, Zhou, Fridley, Feng & Khanna (2014)	kg/m²
Kartam, Al-Mutairi, Al-Ghusain, & Al-Humoud (2(	kg/m²
Kleemann et al. (2014)	kg/m³GV
Lichtensteiger and Baccini (2008)	kg/building
Müller (2006)	kg/m²
Wittmer and Lichtensteiger (2007)	kg/building
Wittmer, D. (2005, Dissertation)	kg/building
Kleemann, Lederer, Rechberger, Fellner (2016)	kg/m³GV
Wiedenhofer, Steinberger, Eisenmeger, Haas (20	kg/building
Ortlepp, Gruhler, Schiller (2016b)	t/m²FS, t/m³GV
Ortlepp, Gruhler, Schiller (2016a)	t/m²FS, t/m³GV
Schiller, Müller, Ortlepp (2016)	no MCI given
Hashimoto, Tanikawa, and Moriguchi (2009)	no MCI given
Hashimoto, Tanikawa, and Moriguchi (2007)	t/m²FS
Hu, van der Voet, and Huppes (2010)	kg/m²
Tanikawa, Managi, and Lwin (2014)	kg/m²
Tanikawa, Fishman, Okuoka, and Sugimoto (201	kg/m²
Wang, Müller & Hashimoto (2015)	kg/m²
Fatta et al. (2003)	t/m³
Fishman, Schandl, Tanikawa, Walker, Krausman	t/m²

Inhomogeneity in terms of

Differentiation of Materials



Method

- Comparing MCI taken from different contexts (GE & JP)
- Describe similarities and differences
- Focus on residential buildings
- Starting with available information taken from published papers (Tanikawa et a. 2009, Ortlepp et al. 2018)
- Producing comparability by harmonizing the data
- Cross context comparison (descriptive)

  use types / construction types
- Analyse, discuss and explain similarities and differences

Initial Data

Criteria to differentiate material composition indicators (MCIs)	*MCIs for Japanese buildings (Tanikawa and Hashimoto 2009)*	*MCIs for German domestic buildings (Ortlepp et al. 2016)*
Building typology	Construction types - Traditional wooden house - 2 × 4 Wooden house - RC building (reinforced concrete) - S (steel-based) factory	Use types - Multifamily houses (MFHs) (Single-family houses [SFHs] are mentioned as additional category but MCIs are only quantified for MFH) Age cohorts - MFH until 1918 - MFH 1919–1948 - MFH 1949–1978 - MFH 1979–1990 - MFH 1991–2010 Construction types - MFH—brickwork - MFH—reinforced concrete
Reference unit	Net floor area (described as "floor space")	Usable area
Material classification	9 material groups 1. Aggregates 2. Cement concrete 3. Mortar 4. Wood 5. Glass 6. Ceramic 7. Steel 8. Aluminum 9. Others	10 material groups 1. Plaster, screed, mortar 2. Concrete 3. Masonry 4. Building boards 5. Wood, engineered wood 6. Insulation materials 7. Roof covering 8. Floorings, damp-proofing 9. Metals 10. Other materials, fills

Source: Data from Tanikawa and Hashimoto (2009) and Ortlepp and colleagues (2018).

Classification to define comparable MCI for domestic buildings

Use-based classification	*Construction-based classification*	
	Japanese context	*German context*
Single-family houses with one to two floors	2 × 4 timber frame	Masonry bricks, wooden frame
Small multifamily houses with three to four floors	Steel frame	Masonry bricks
Big multifamily houses with five or more floors	Reinforced concrete	Reinforced concrete, masonry bricks

Reference value

net floor area

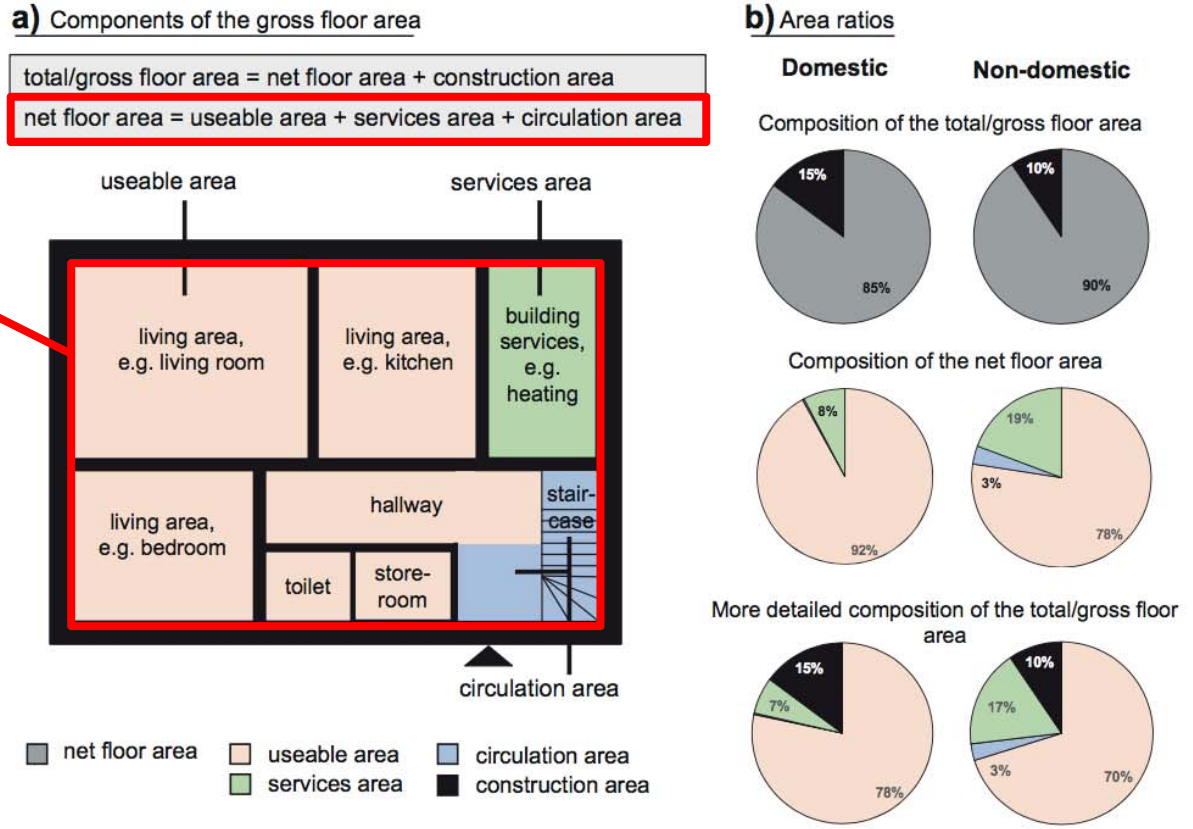
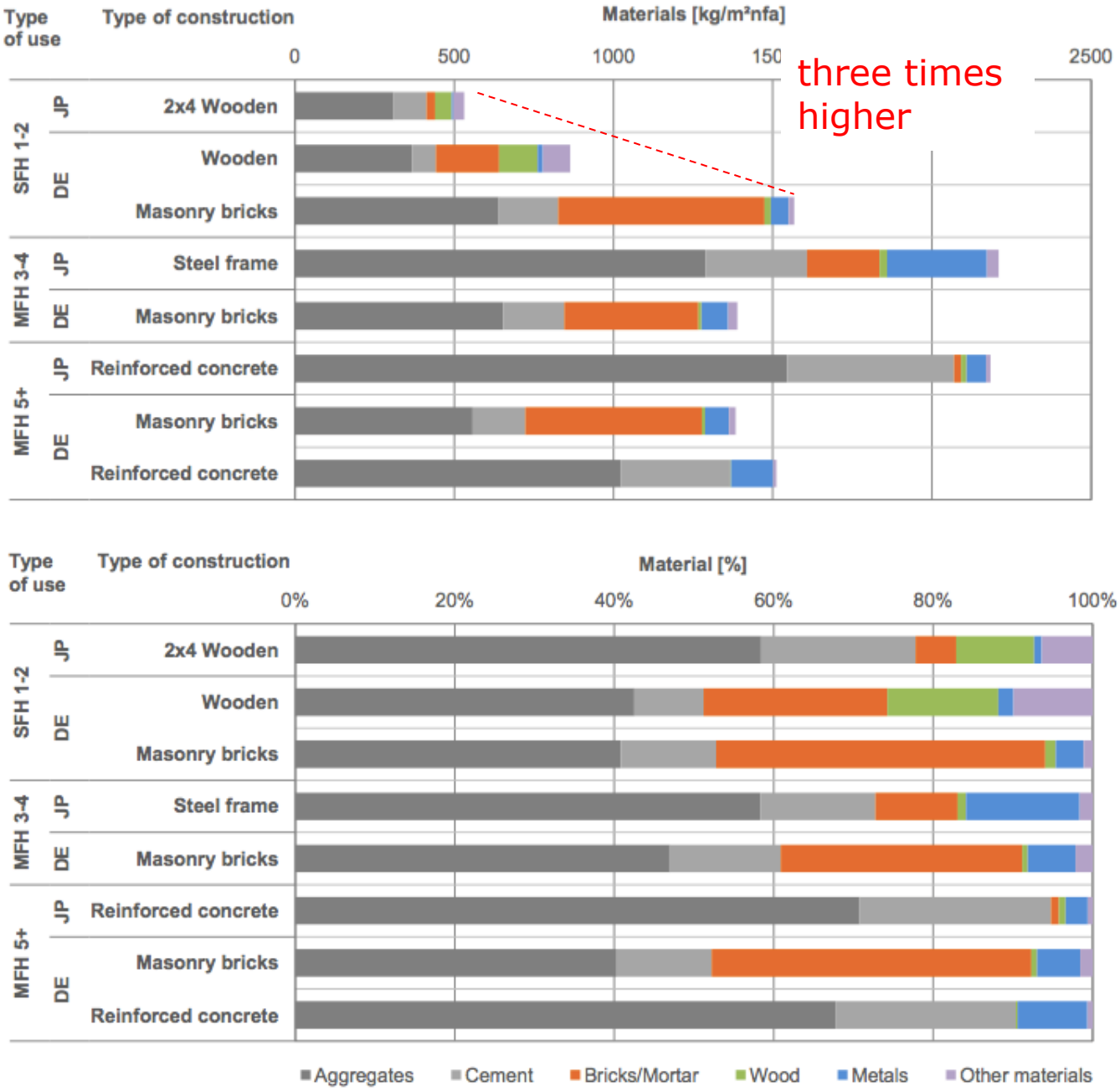


Figure 1 (a) Components of the gross floor area according to ISO 9836:2017-09; and (b) area ratios based on data provided by Gruhler and colleagues (2011) and IOER Information Portal (2017).

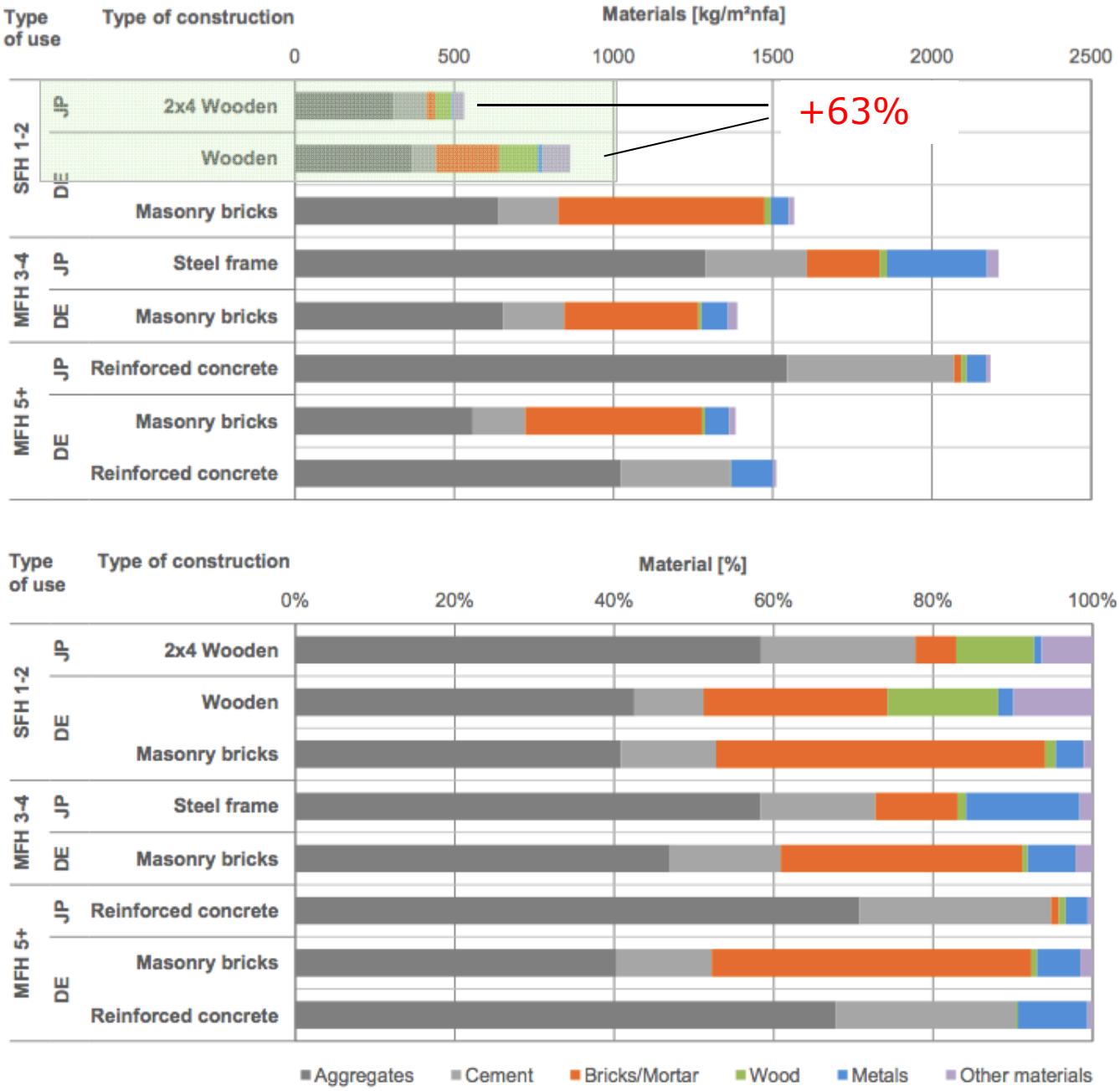
Material Groups

Main material groups	*Assigned materials*
Aggregates	Sand, gravel, grit, aggregates coalesced into concrete
Cement	Cement coalesced into concrete
Bricks, mortar	Clay and other bricks, mortar and plaster
Wood	Wood and engineered wood
Metals	Steel, aluminum, and other metals
Others	Glass, ceramics, and other materials

Results

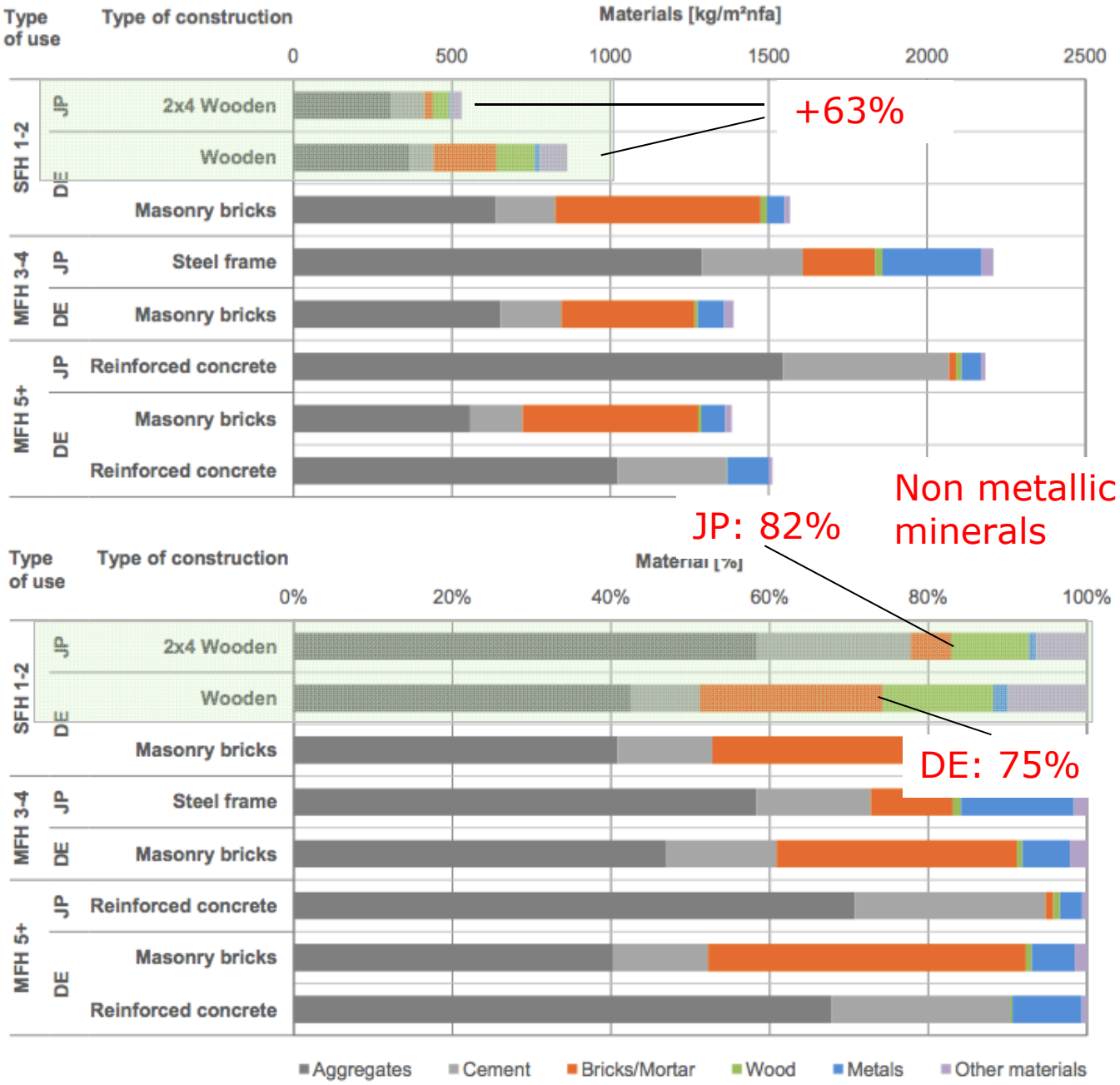

Type of use
Type of construction
Materials [kg/m²nfa]
0
500
1000
1500
2500
three times higher
SFH 1-2
MFH 3-4
MFH 5+
JP
DE
2x4 Wooden
Wooden
Masonry bricks
Steel frame
Masonry bricks
Reinforced concrete
Masonry bricks
Reinforced concrete
Material [%]
0%
20%
40%
60%
80%
100%
Aggregates
Cement
Bricks/Mortar
Wood
Metals
Other materials

Results

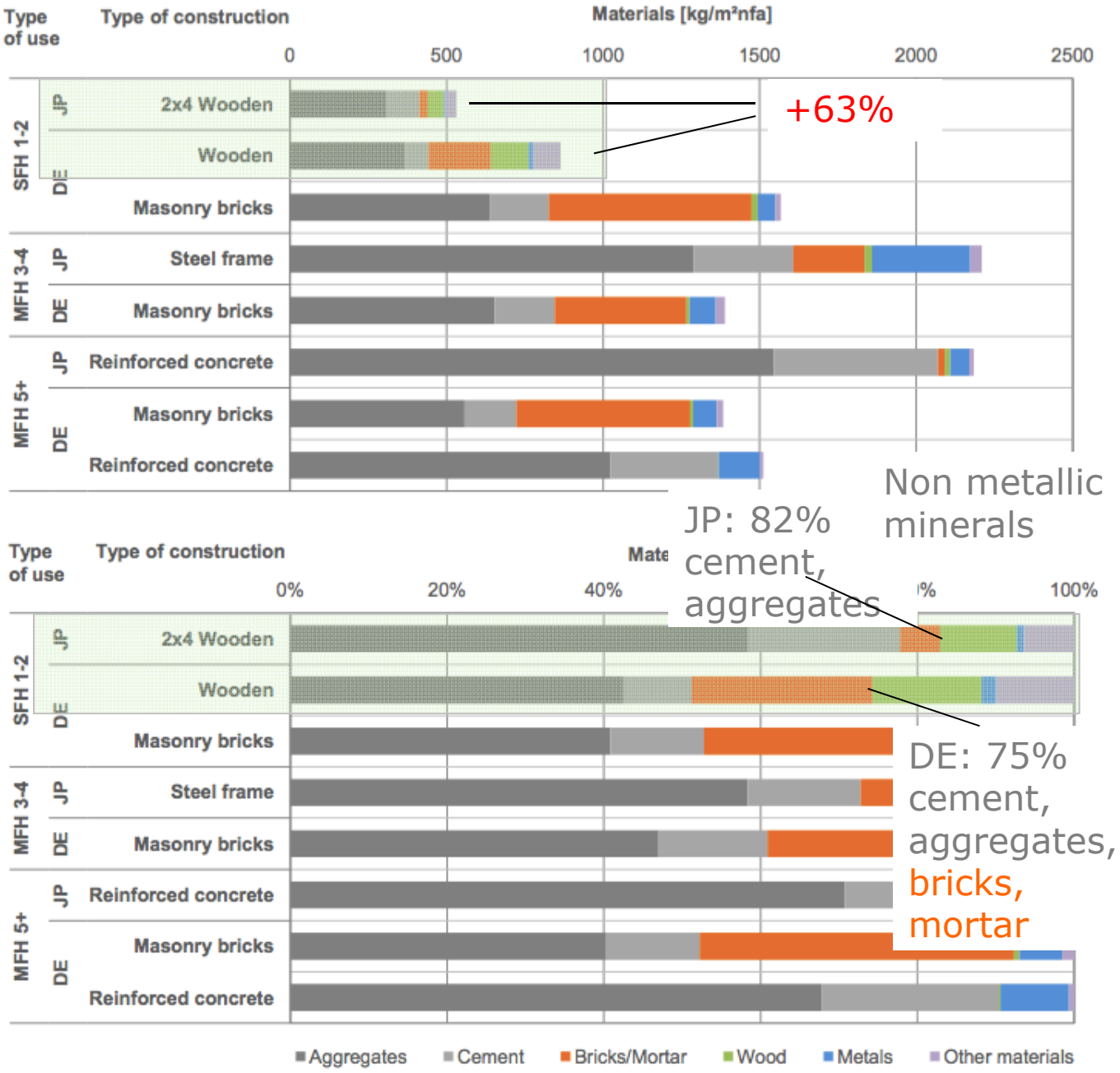


Schiller et al.: Transferability of MCI,
MINEA Workshob Odense, 28.11.20

Results

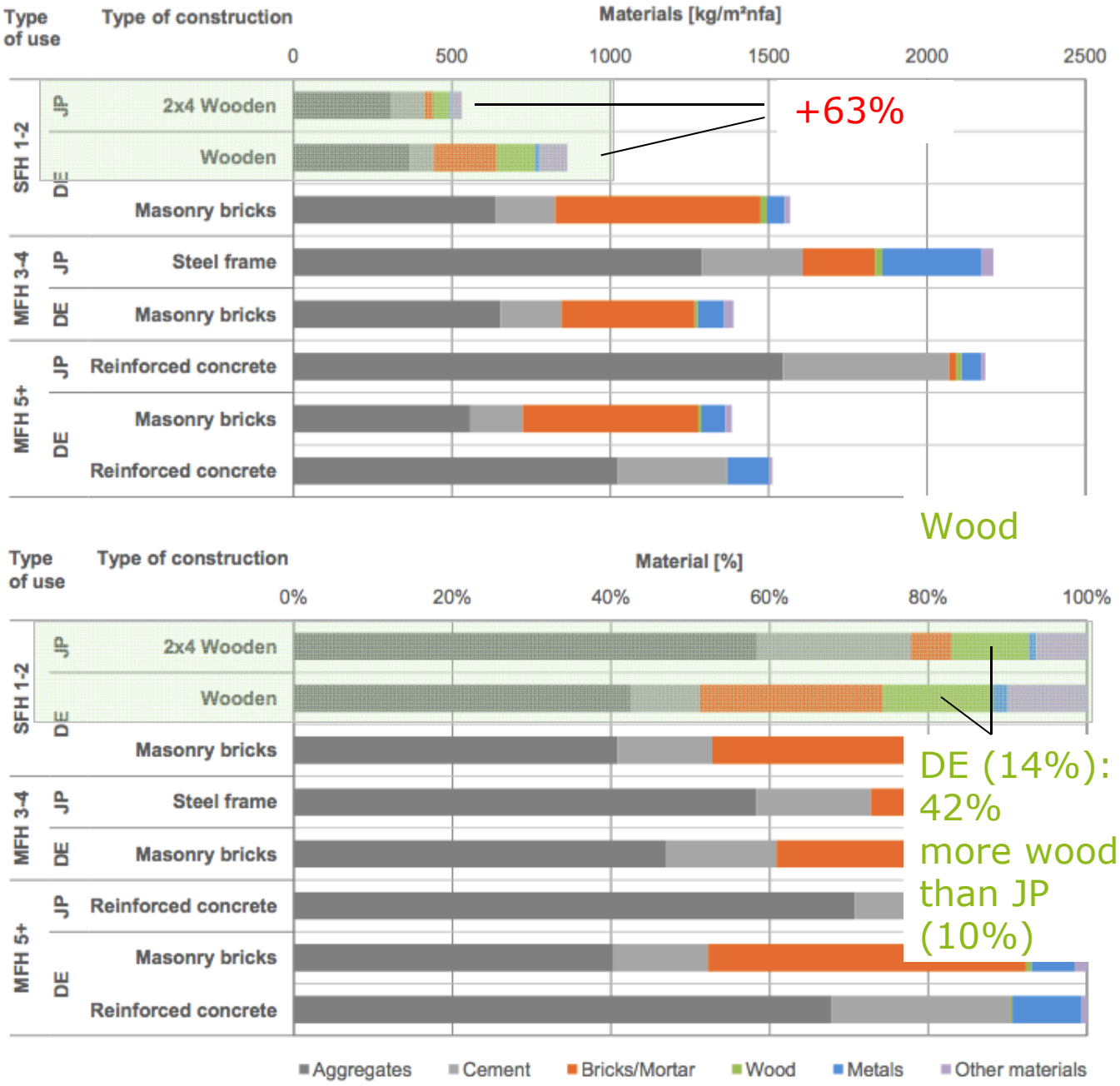

Type of use
Type of construction
Materials [kg/m²nfa]
0
500
1000
1500
2000
2500
SFH 1-2
MFH 3-4
MFH 5+
JP
DE
2x4 Wooden
Wooden
Masonry bricks
Steel frame
Masonry bricks
Reinforced concrete
Masonry bricks
Reinforced concrete
+63%
Non metallic minerals
JP: 82%
DE: 75%
0%
20%
40%
60%
80%
100%
Aggregates
Cement
Bricks/Mortar
Wood
Metals
Other materials

Results



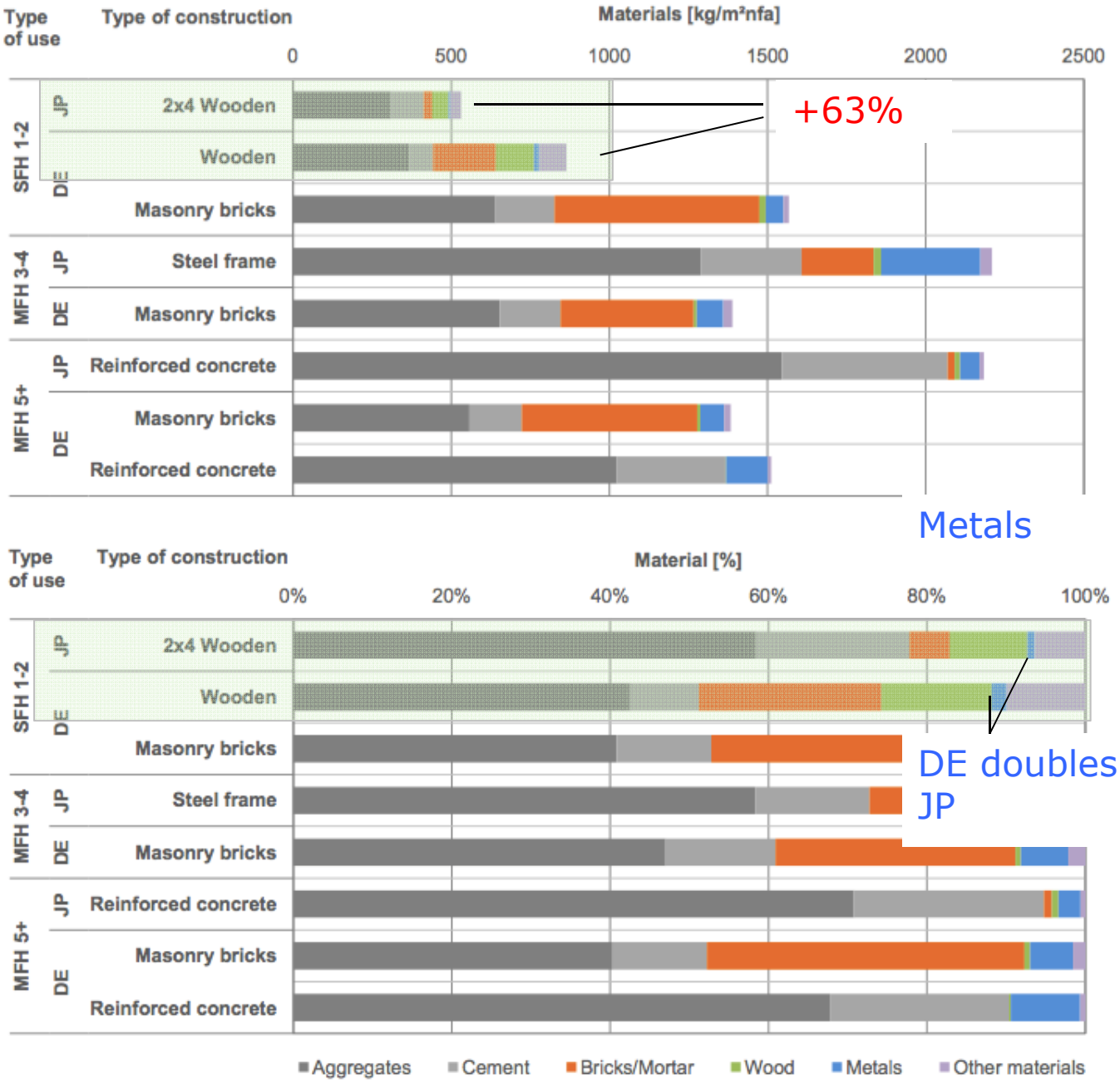
Schiller et al.: Transferability of MCI, MINEA Workshob Odense, 28.11.20

Results

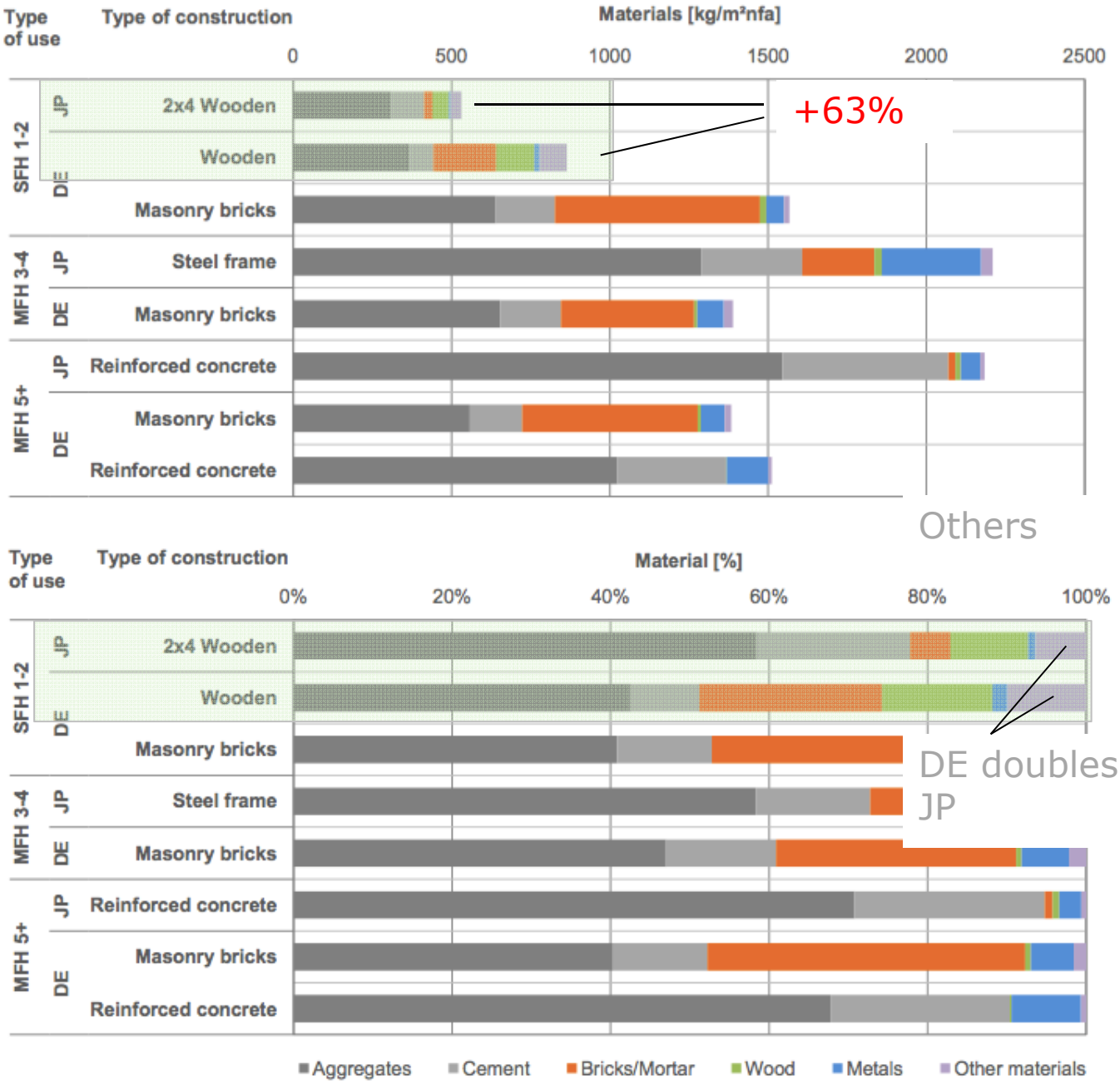


Schiller et al.: Transferability of MCI, MINEA Workshob Odense, 28.11.20

Results

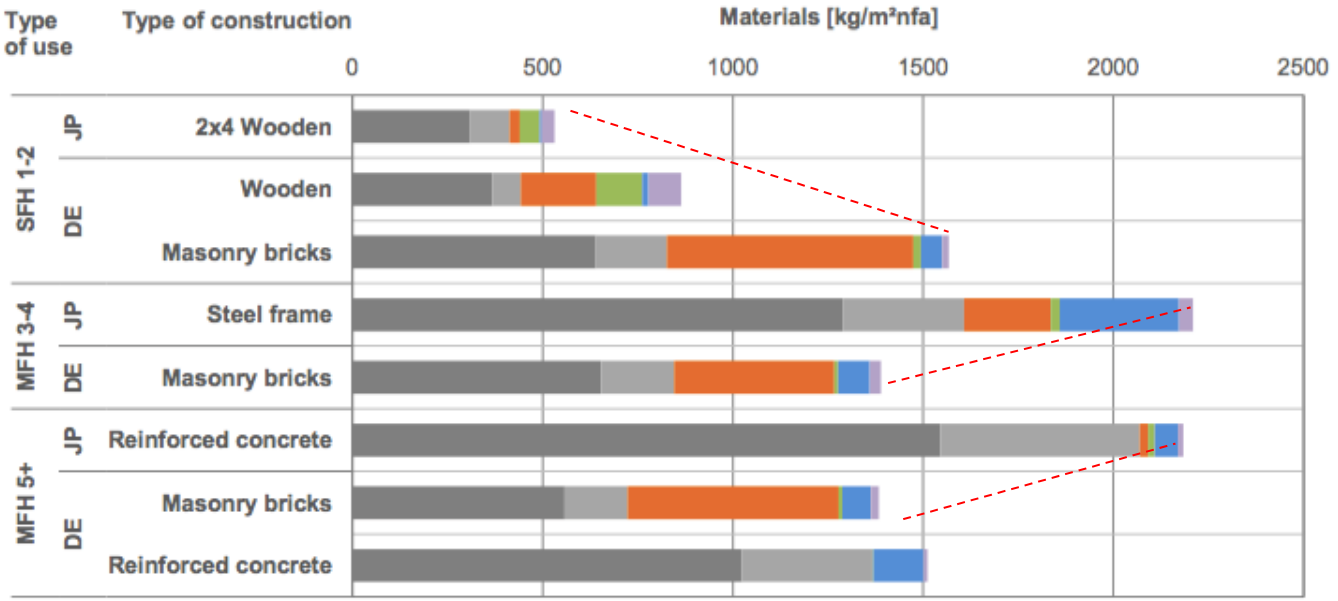

Type of use
Type of construction
Materials [kg/m²nfa]
0
500
1000
1500
2000
2500
SFH 1-2
MFH 3-4
MFH 5+
JP
DE
2x4 Wooden
Wooden
Masonry bricks
Steel frame
Masonry bricks
Reinforced concrete
Masonry bricks
Reinforced concrete
+63%
Metals
Type of use
Type of construction
Material [%]
0%
20%
40%
60%
80%
100%
DE doubles JP
Aggregates
Cement
Bricks/Mortar
Wood
Metals
Other materials

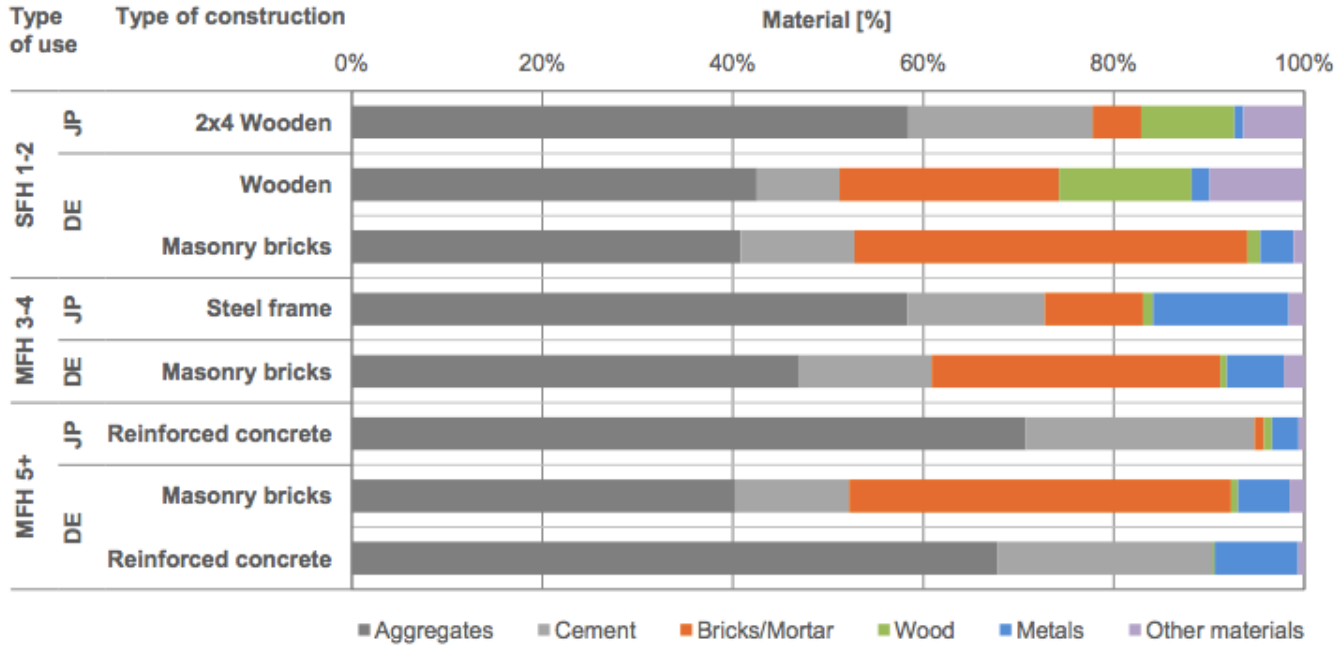
Results



Schiller et al.: Transferability of MCI, MINEA Workshob Odense, 28.11.20

Results





Schiller et al.: Transferability of MCI,
MINEA Workshob Odense, 28.11.20

Discussion:
Why different SFH construction types

JP: built for one generation, no second hand house market

average lifespan: 15-25 years

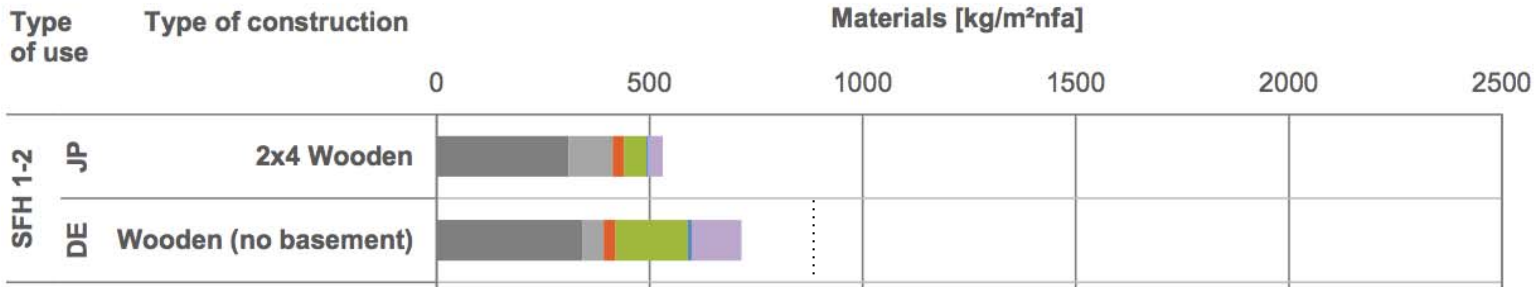
more cost-effective, effective earth quake protection

GE: longevity; average lifespan: 80 years (and much more)

low seismic risk; fire protection a serious issue

-> **first of all socio economic reasons combined with technical arguments**

Discussion:
Why MCI of wooden SFH are significantly different?



JP: basement was forbidden by law (1950-1988)

GE: basement is ubiquitous

remaining differences: different floor plans and different construction methods

-> **first of all socio economic reasons**

Discussion: Why are there different construction types for small MFH?

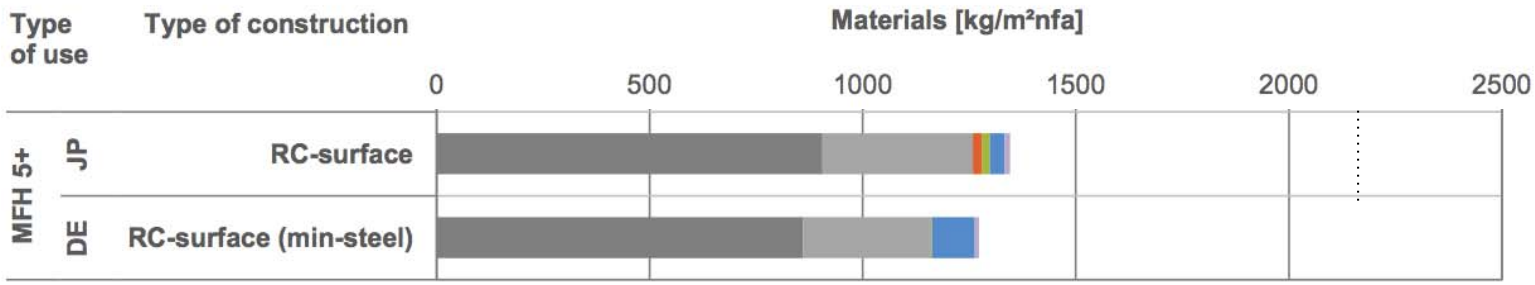
-> **first of all geophysical condition reasons (earth quake risk)**

https://www.ngdc.noaa.gov/nndc/Histogram.jsp?table=HAZ.SIGNIF_TSQP&field=COUNTRY&sourceId=101707&field_type=character&dtype=table)

This table shows the number of occurrences of unique values of *COUNTRY* in the table *HAZ.SIGNIF_TSQP*. Each line shows the number of times each value occurs as a red bar and as a number in parenthesis followed by the value itself. The **Significant Earthquake Database** contains information on destructive earthquakes from 2150 B.C. to the present that meet at least one of the following criteria: Moderate **damage** (approximately $1 million or more), 10 or more **deaths**, Magnitude 7.5 or greater, Modified Mercalli Intensity X or greater, or the earthquake generated a **tsunami**.

COUNTRY	Count	Graph
CUBA	13	
CYPRUS	6	
CZECH REPUBLIC	1	
DJIBOUTI	1	
DOMINICAN REPUBLIC	18	
ECUADOR	63	
EGYPT	15	
EL SALVADOR	37	
ERITREA	1	
ETHIOPIA	13	
FIJI	19	
FRANCE	42	
FRENCH GUIANA	1	
FRENCH POLYNESIA	1	
GABON	1	
GEORGIA	15	
GERMANY	9	
GHANA	5	
GREECE	259	
GRENADA	1	
GUADELOUPE	9	
GUATEMALA	38	
GUINEA	1	
HAITI	16	
HONDURAS	12	
HUNGARY	5	
ICELAND	17	
INDIA	91	
INDIAN OCEAN	3	
INDONESIA	377	
IRAN	376	
IRAQ	24	
IRELAND	1	
ISRAEL	23	
ITALY	325	
JAMAICA	19	
JAPAN	403	
JORDAN	5	
KAZAKHSTAN	10	
KENYA	2	
KERMADEC ISLANDS (NEW ZEALAND)	17	
KIRIBATI	1	
KYRGYZSTAN	14	
LAOS	1	
LEBANON	14	
LIBYA	1	

Discussion:
Why MCIs of reinforced concrete MFHs are significantly different?



-> more massive foundations are needed in Japan for earthquake protection

-> lower load-bearing capacity of average Japanese terrain

-> first geophysical-condition reasons

-> different accounting methods (metals)

Conclusion: Prerequisite

- Basic prerequisite for cross context comparability and transferability of MCI:

  Systematic and harmonized description of the key features of building typologies

  - construction method, underground / above ground
  - use type of buildings
  - Reference value (considering ISO framework)
  - Coherent definition of material groups

Conclusion: Uncertainties

- Uncertainties can be narrowed down significantly (with regard to the total mass)

  analyzed case study (GE/JP):

  - SFH : 195 % to 35%

  - MFH: 37% to 5%

- Uncertainties of the MCI itself has to be acknowledged -> high transferability potential

Conclusion Hypothesis on key points towards a comprehensive MCI database

- Construction techniques for large domestic buildings tend to be similar (in similar geophysical-condition)
  -> high transferability potential
- Serious transferability limitations with regard to SFH (significant affected by social/cultural impacts)
  -> has to be acknowledged adequately

-> systematically discussion is needed
to develop a standardized approach towards a **significantly broade**r and **contextually transferable database**

Source:

Schiller, Georg; Miatto, Alessio; Gruhler, Karin; Ortlepp, Regine; Deilmann, Clemens; Tanikawa, Hiroki (2018): Transferability of material composition indicators for residential buildings – a conceptual approach based on a German-Japanese comparison In: Journal of Industrial Ecology, https://doi.org/10.1111/jiec.12817