Timber-based hybrid on “material level”

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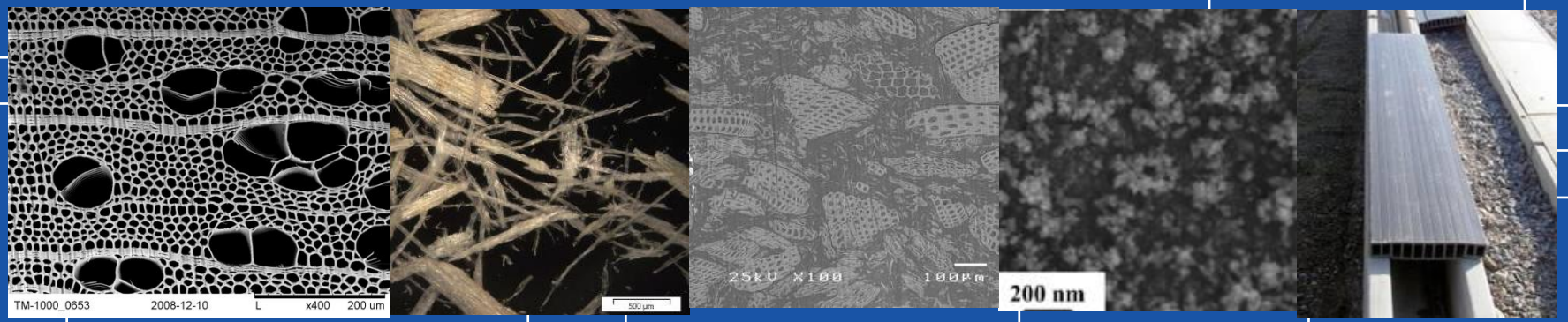
Presentation at seminar on Timber-based hybrid structures
January 19, 2018, Skanska, Stockholm



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Outline

1. Introduction
   - My definition of building material science
   - Building materials flow - Market trends & challenges/ possibilities
2. Hybrids related to different scales
3. Hybrids and wood surfaces
4. Concluding remarks

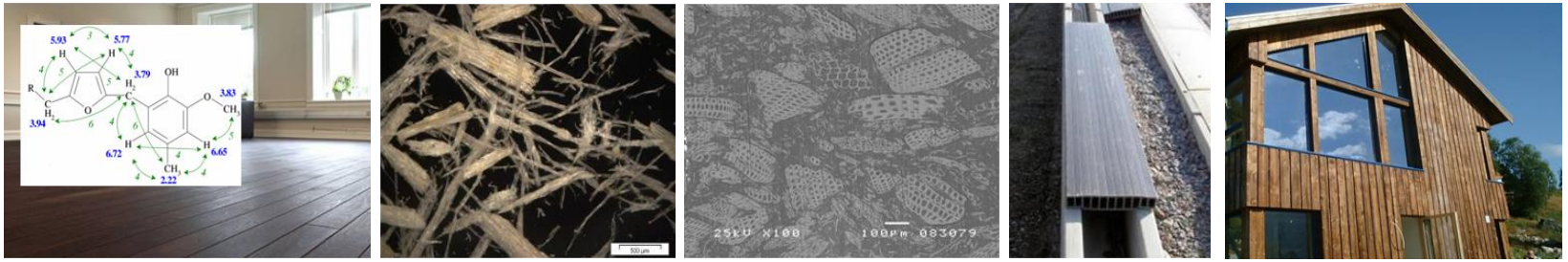
INTRODUCTION ON BUILDING MATERIALS SCIENCE

Building material science

Achieve a deeper understanding of the relation between materials micro-structure, chemical composition and their in-service performance, service life and environmental impacts

linking micro with macro

Civil & Architectural engineering

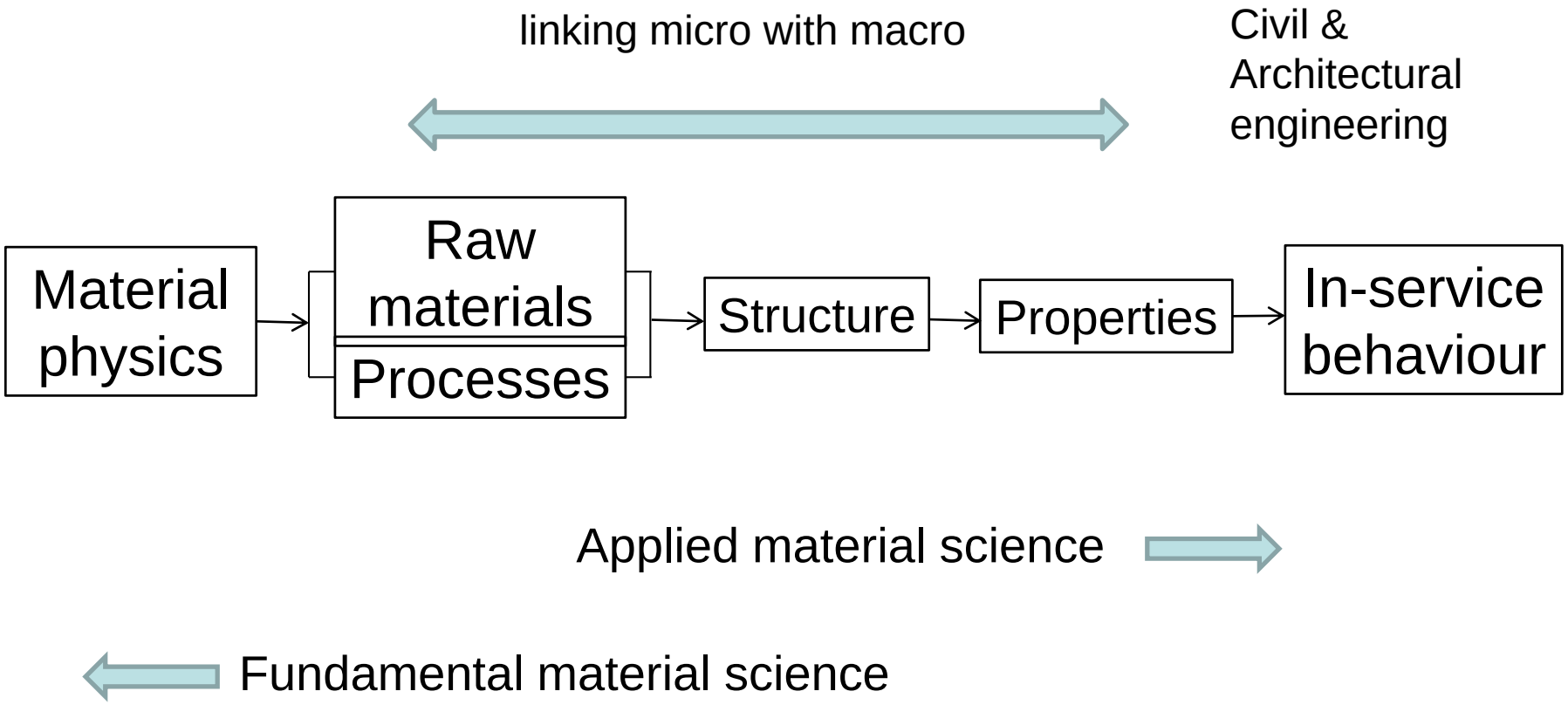


Structure and composition vs. in-service performance in different building applications

Sustainable development of the built environment

Based on robust LCA methodology

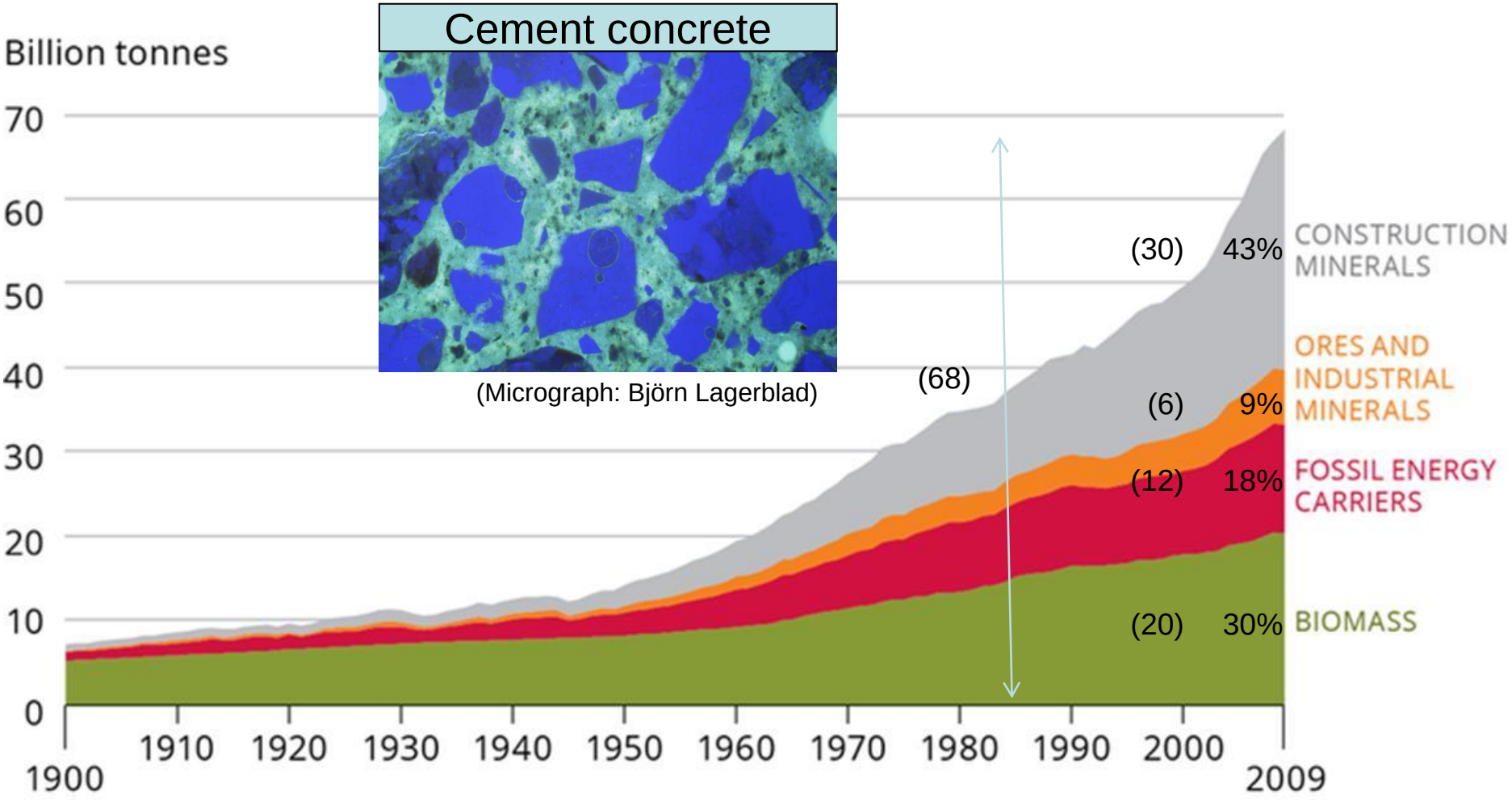
Building material science



(MATERIAL FLOW ANALYSIS)

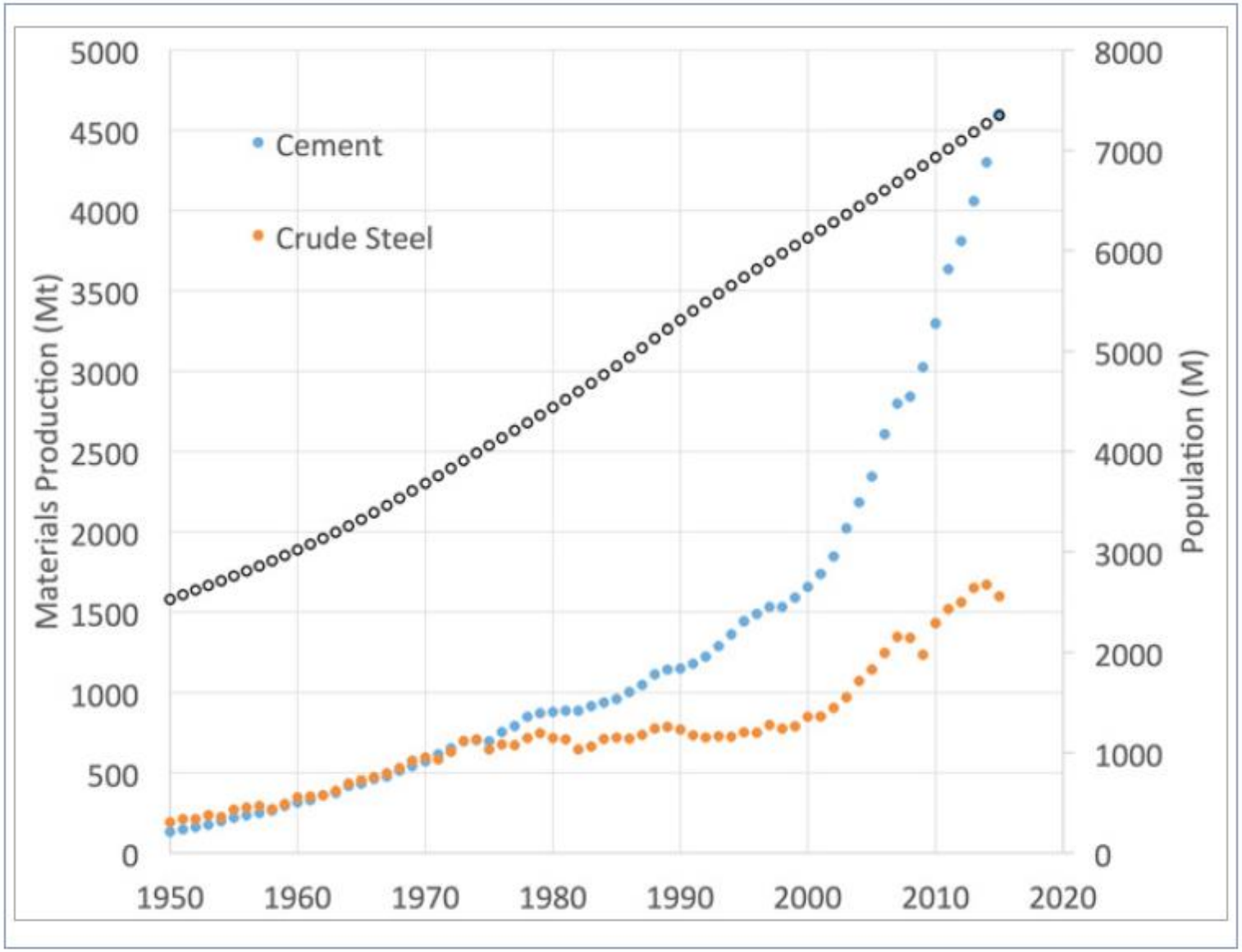
BUILDING MATERIALS & MARKET TRENDS

Consumption of raw materials globally, 1900-2009



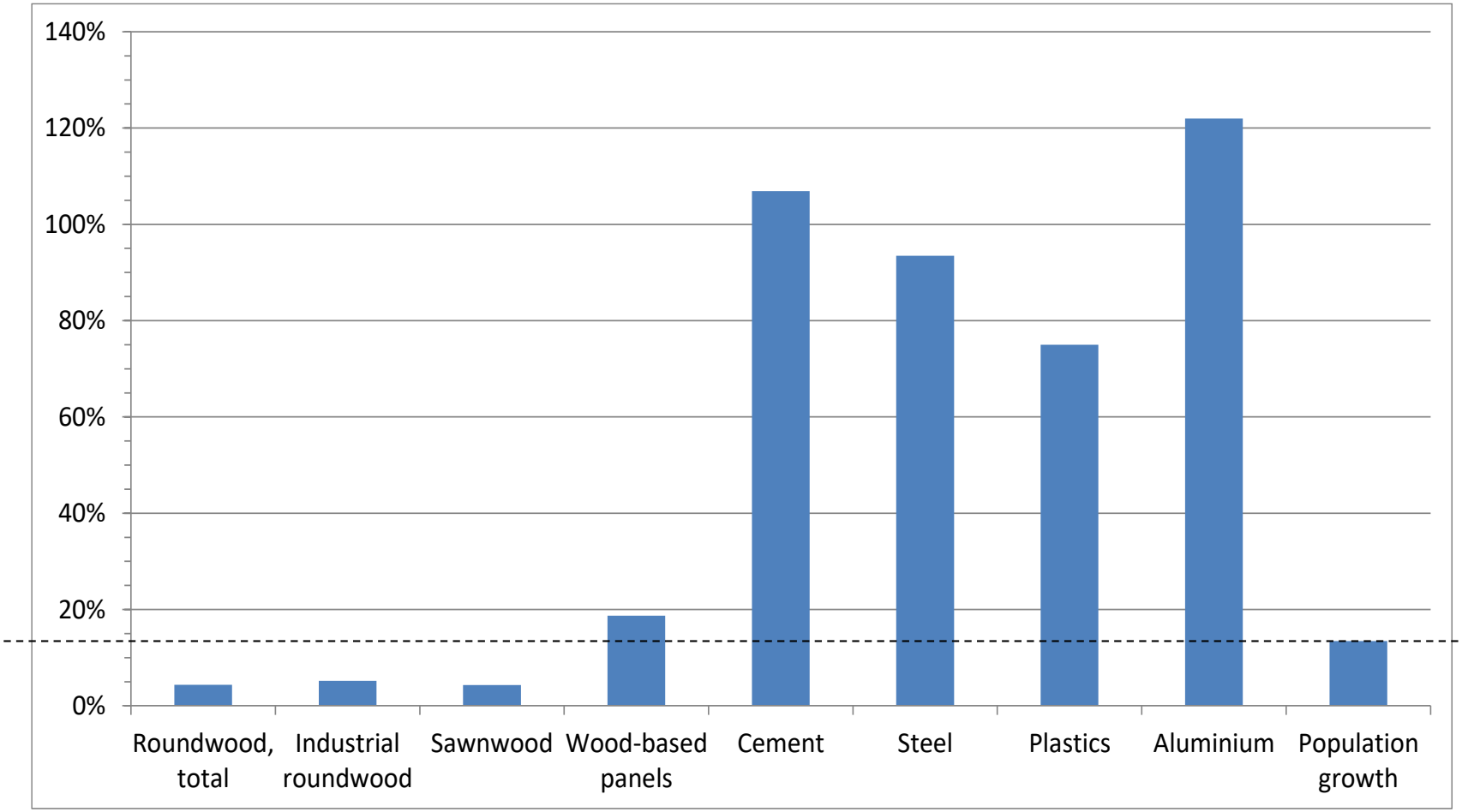
Source: http://www.eea.europa.eu/soer-2015/global/competition

Production of cement, steel, related to population



Source: https://www.lc3.ch/wp-content/uploads/2017/03/2016-UNEP-Report-Complete6.pdf

Increase in world production of materials, between 2000-2011



Sources for production data: www.fao.org, www.plasticseurope.org, http://www.indexmundi.com/en/commodities/minerals/

Globally, wood looses market shares as a building material - why?

High variability, poor durability?

Degraded clear coated wood in outdoor use

Biobased building materials as carbon sink

But availability challenges the most important part!

Substitution of concrete with wood, what is realistic?

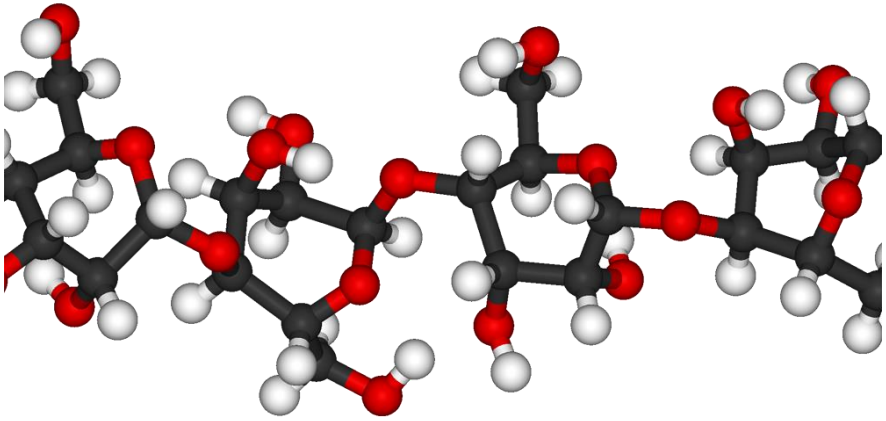
Some production estimates and **in 2015** (**b. = billion**):

- **Ca 18 b.m^3 cement-based materials.**
- Ca 1.8 b.m^3 roundwood for industrial use of which:
  - Ca 0.45 b.m^3 sawn wood
  - Ca 0.40 b.m^3 wood panels
  - Ca 0.40 b.tonnes paper and paperboard
- Ca 1.9 b.m^3 roundwood for wood fuel
- Ca 1.4 b.tonnes bamboo (in China 2005)

Assume a substitution level of 50% - a reduction of 18 b.m^3 concrete to 9 b.m^3 concrete. Could this be substituted with wood+bamboo?

Sources: http://www.fao.org/3/a-i6669e.pdf; https://www.lc3.ch/wp-content/uploads/2017/03/2016-UNEP-Report-Complete6.pdf ftp://ftp.fao.org/docrep/fao/010/a1243e/a1243e00.pdf

Cellulose has the potential to be a renewable resource

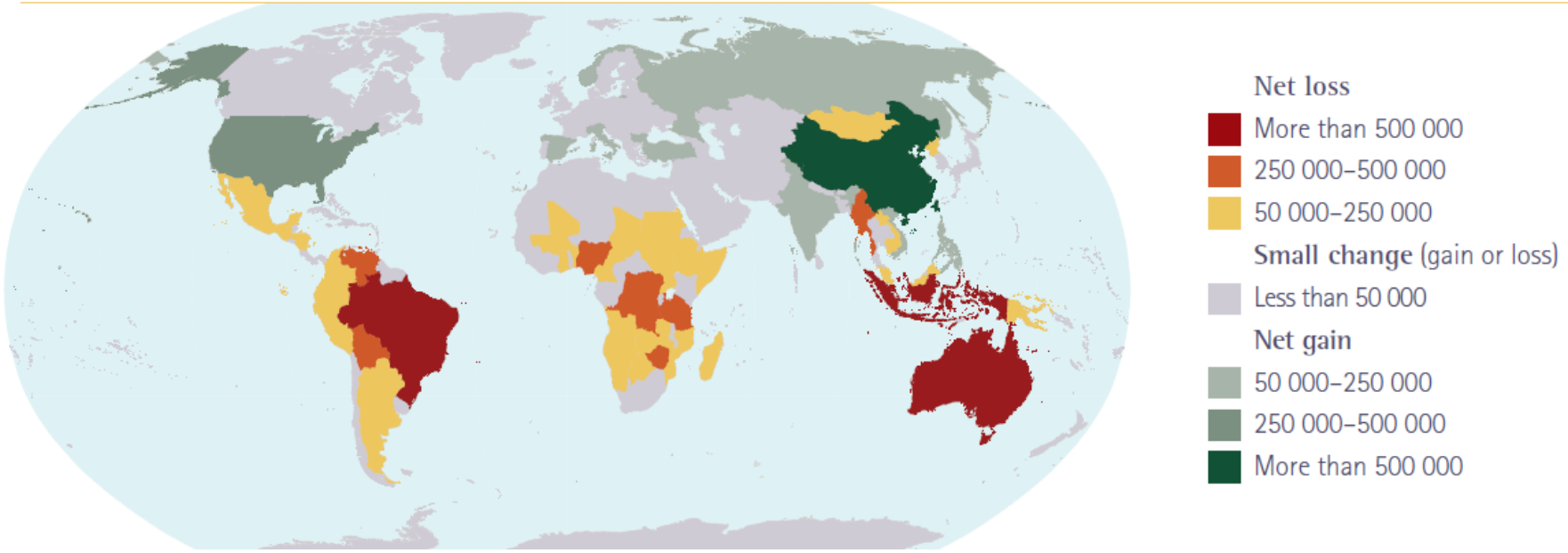


Cellulose is the most common organic material on Earth

Some estimations:

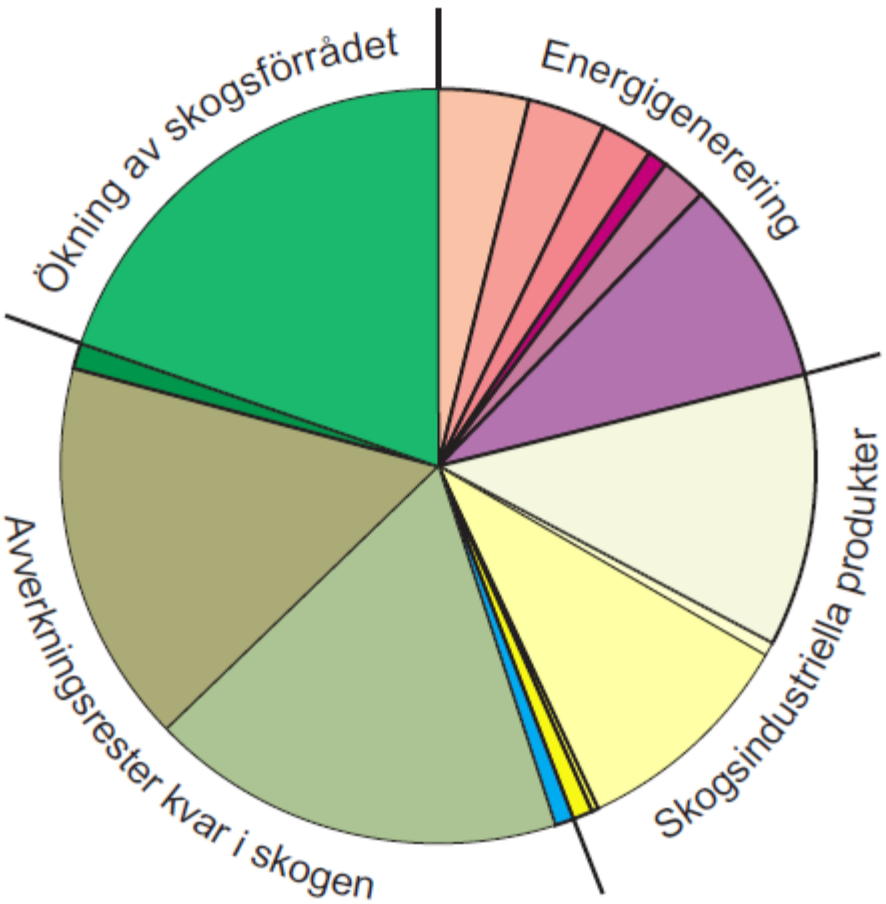
- 700 billion tonnes exists; 40 billion tonnes is renewed each year
- Only a small fraction of this growth is exploited for material production
- Natural reinforcement in wood
- Degree of polymerization ca 10 000
- Length of the cellulose chain in wood ca 5 μm

Net change in forest area by country, 2005-2010 (ha/year)



Source: www.fao.org/forestry/fra2010

Yearly forest biomass ”flow” in Sweden



Energy use

Pulp & Paper, sawn wood

Residuals left in the forest

Net growth

Total growth of forest biomass: 75,9 million tons
Felling: 61 million tons

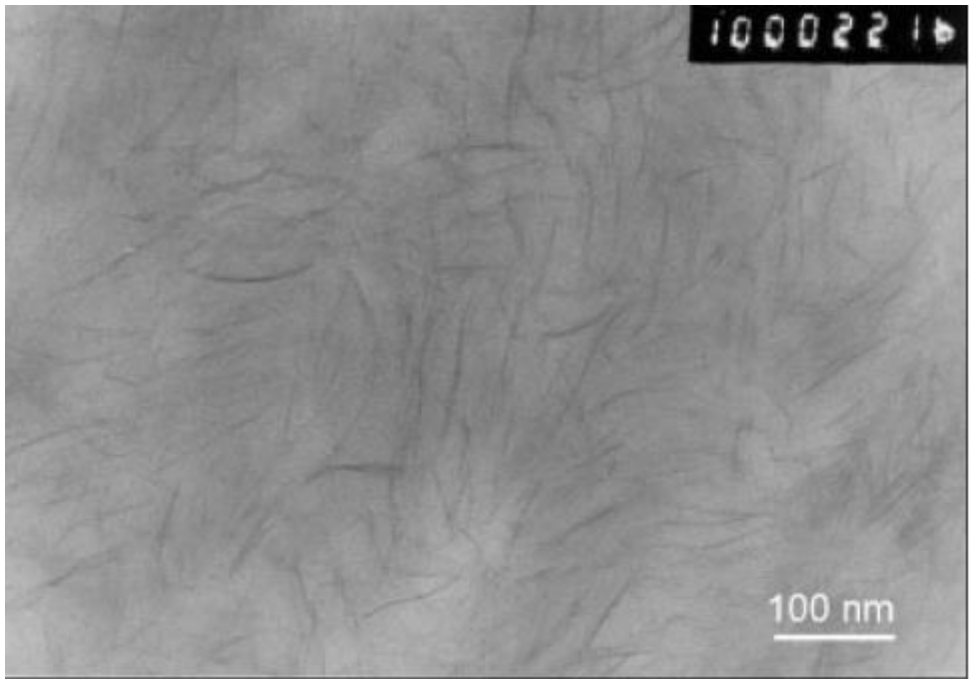
(Source: Nilsson 2004)

HYBRIDS RELATED TO DIFFERENT SCALES

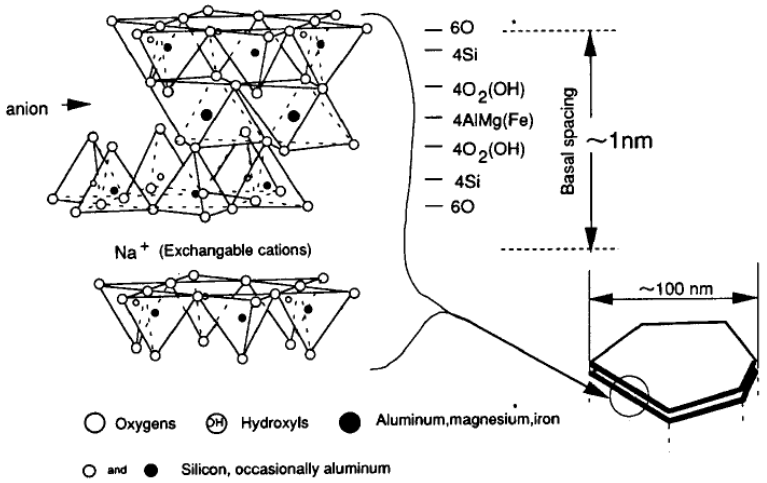
Polymer-clay hybrids

Toyota laboratories 1986:

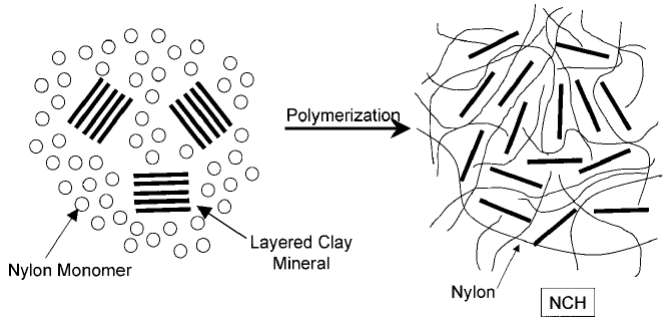
Nylon-6-clay hybrid (NCH)



Hybrid microstructure of nanoclay in Nylon-6



Structure of layer nano clay (montmorillonite)



Exfoliation of clay mineral

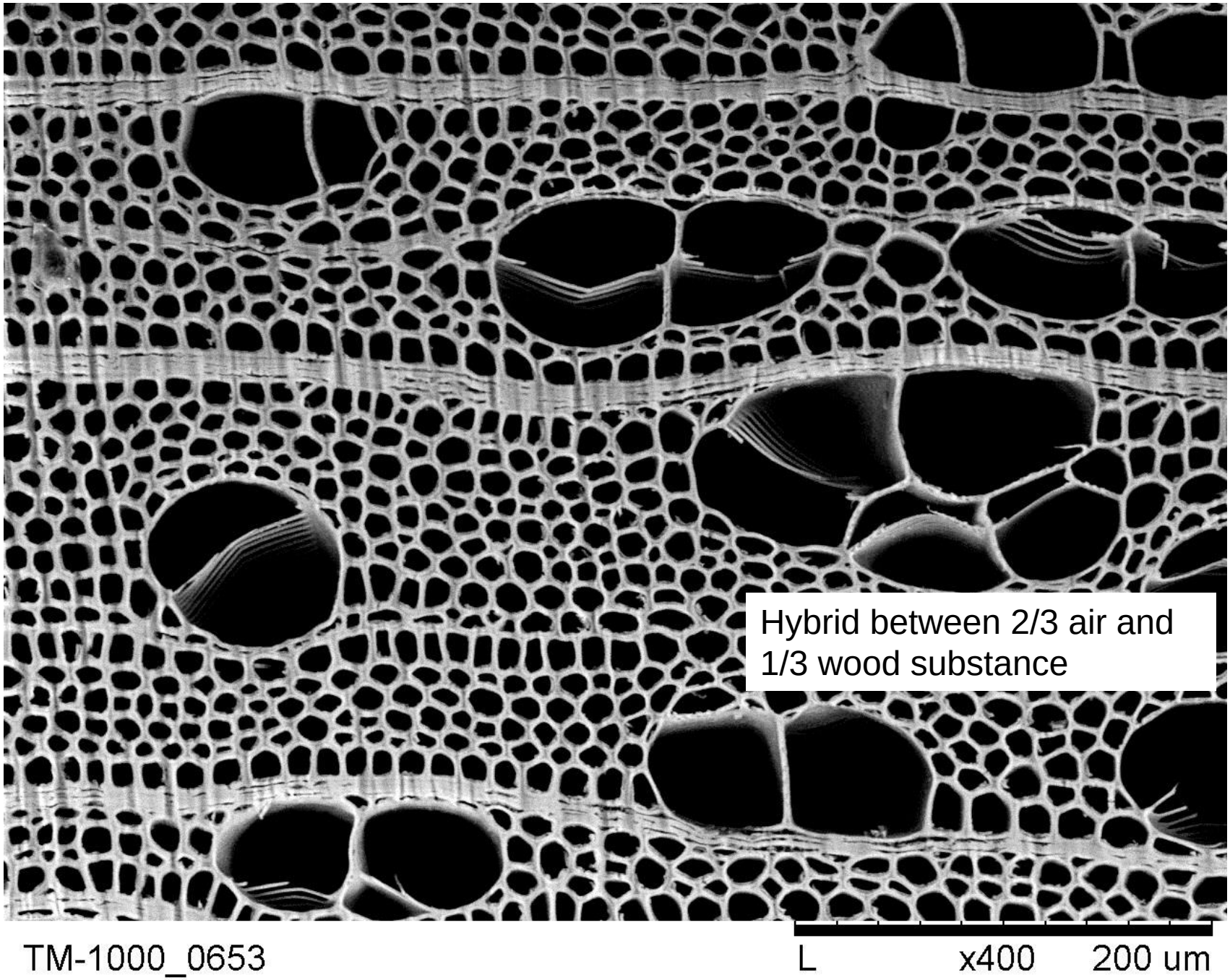
Source: KAWASUMI M. J. POLYM. SCI. PART A: POLYM. CHEM.: VOL. 42 (2004)

Nylon-clay hybrids (NHC)

Timing belt cover injection-molded with NCH, 1991

25% weight reduction

Source: KAWASUMI M. J. POLYM. SCI. PART A: POLYM. CHEM.: VOL. 42 (2004)


Hybrid between 2/3 air and
1/3 wood substance
TM-1000_0653
L
x400
200 um

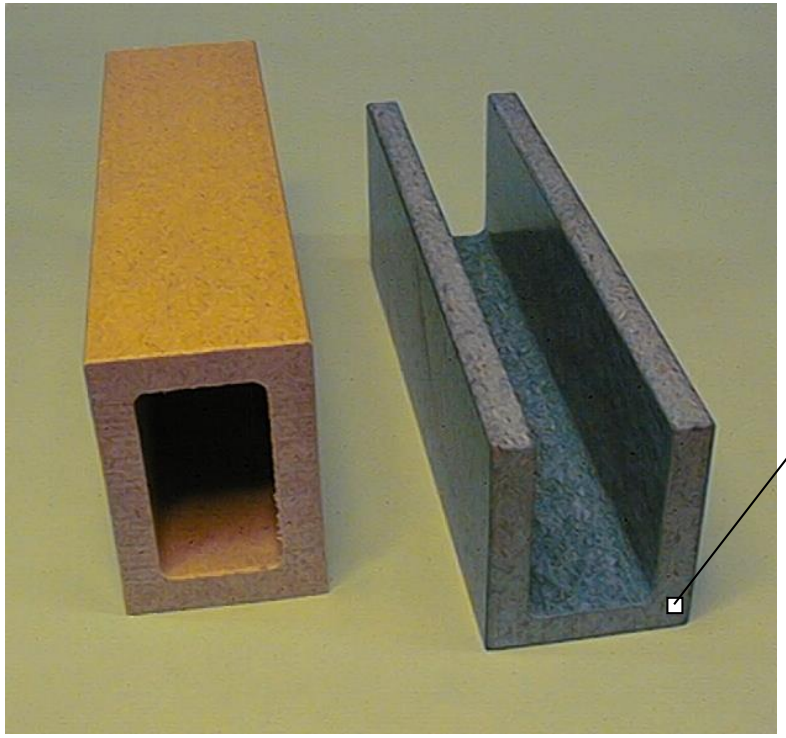
3D thermoformed biocomposites (WPC)

Heat
&
pressure

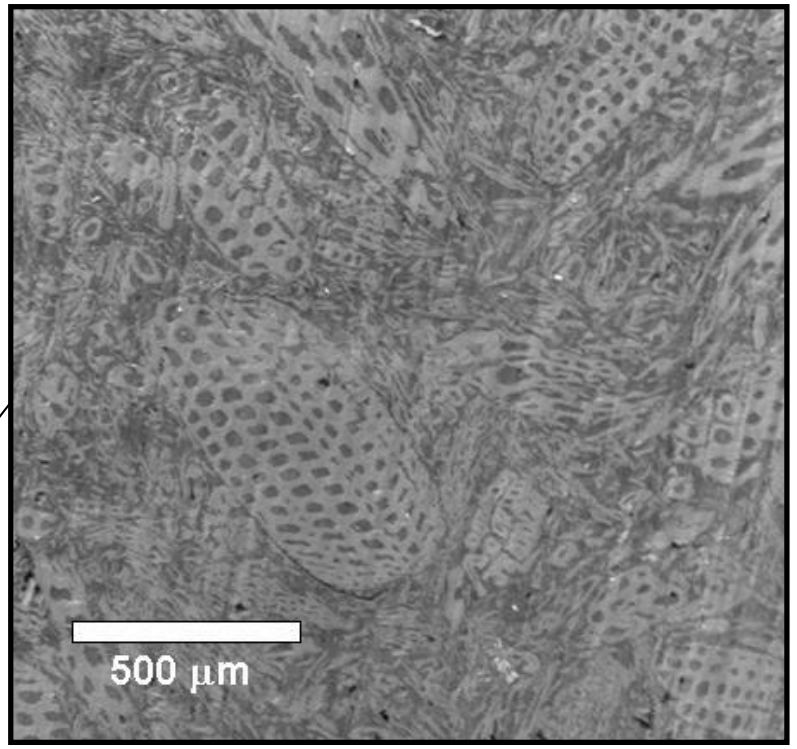
Typical wood plastic composites (WPC) profiles

Wood plastic composites (WPC)

Biocomposites



Wood substance polypropylene hybrid



Extruded WPC

Hybrid between 70 % wood, 25 % poly-propylene and 5 % process additives

Micromorphology

Specimen preparation by UV-laser ablation

3. Wood/polypropylene composite						
Material	Measured density	Weight %	Volume	Vol. %	Theoretical density	Porosity
PP pellets		30,0%	0,331	38,8%	905	
Wood substance		70,0%	0,467	54,6%	1 500	
Pores		0,0%	0,057	6,6%	1	
Total	1 170	100,0%	0,855	100,0%	1 253	6,6%

1 m^3 has 819 kg wood substance

3. Wood/polypropylene composite						
Material	Measured density	Weight %	Volume	Vol. %	Theoretical density	Porosity
PP pellets		50,0%	0,552	64,6%	905	
Wood substance		50,0%	0,333	39,0%	1 500	
Pores		0,0%	0,021	2,4%	1	
Total	1 103	100,0%	0,907	106,1%	1 129	2,3%

1 m^3 has 551 kg wood substance

25kV X100 100µm 083079

(Micrograph: Kristoffer Segerholm)

HYBRIDS AND WOOD SURFACES

Cracking in outdoor use of wood

Causes

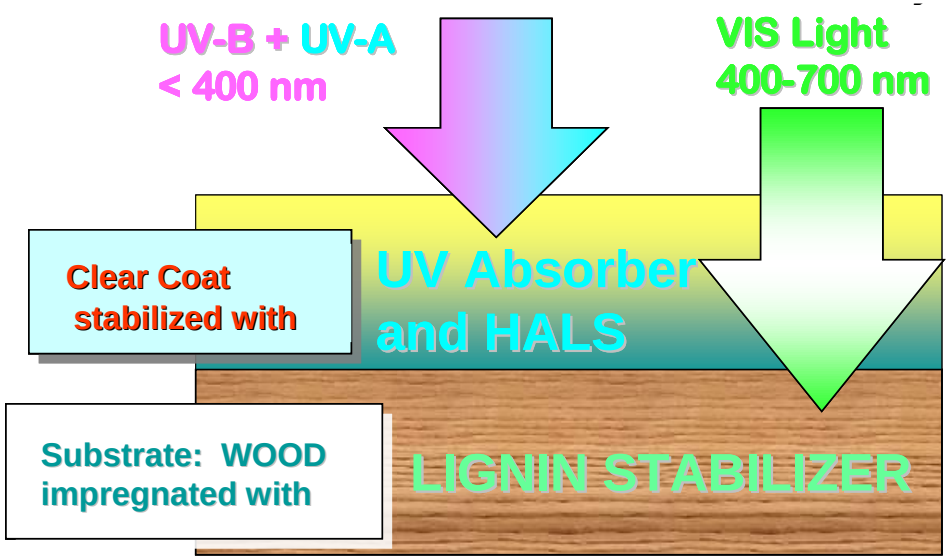
- Cyclic wetting and drying
- UV light

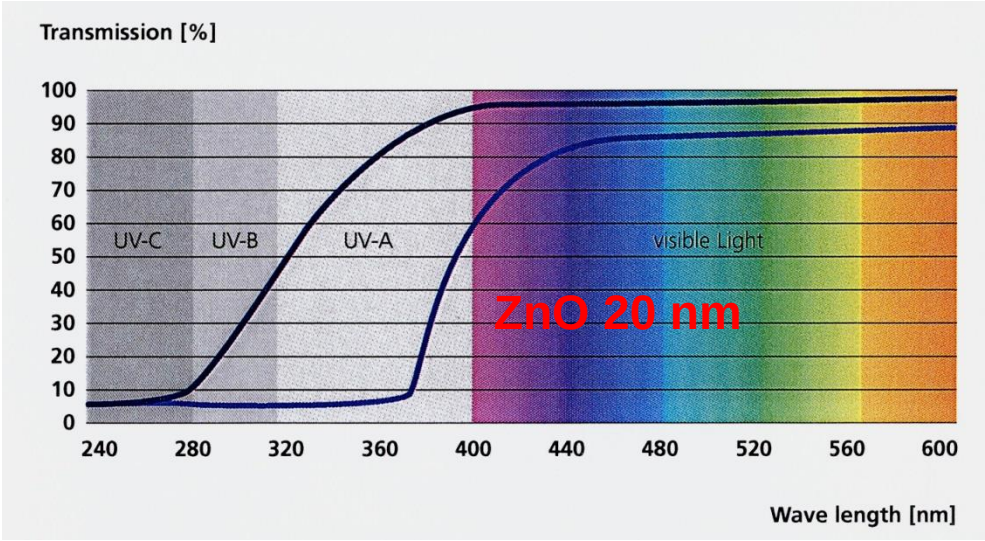
Clear coatings on wood outdoor – poor durability

Organic-inorganic hybrid coatings – a possible solution

- Addition of UV reflective and absorbing nano-scale additives
- Plus: Stabilization of the lignin in the surface

HALS = hindered amine light stabilizers





(Pictures: Jan Ekstedt, previously SP Trätek)

Characterization of wood surfaces

Wilhelmy plate method – liquid sorption and swelling measurements

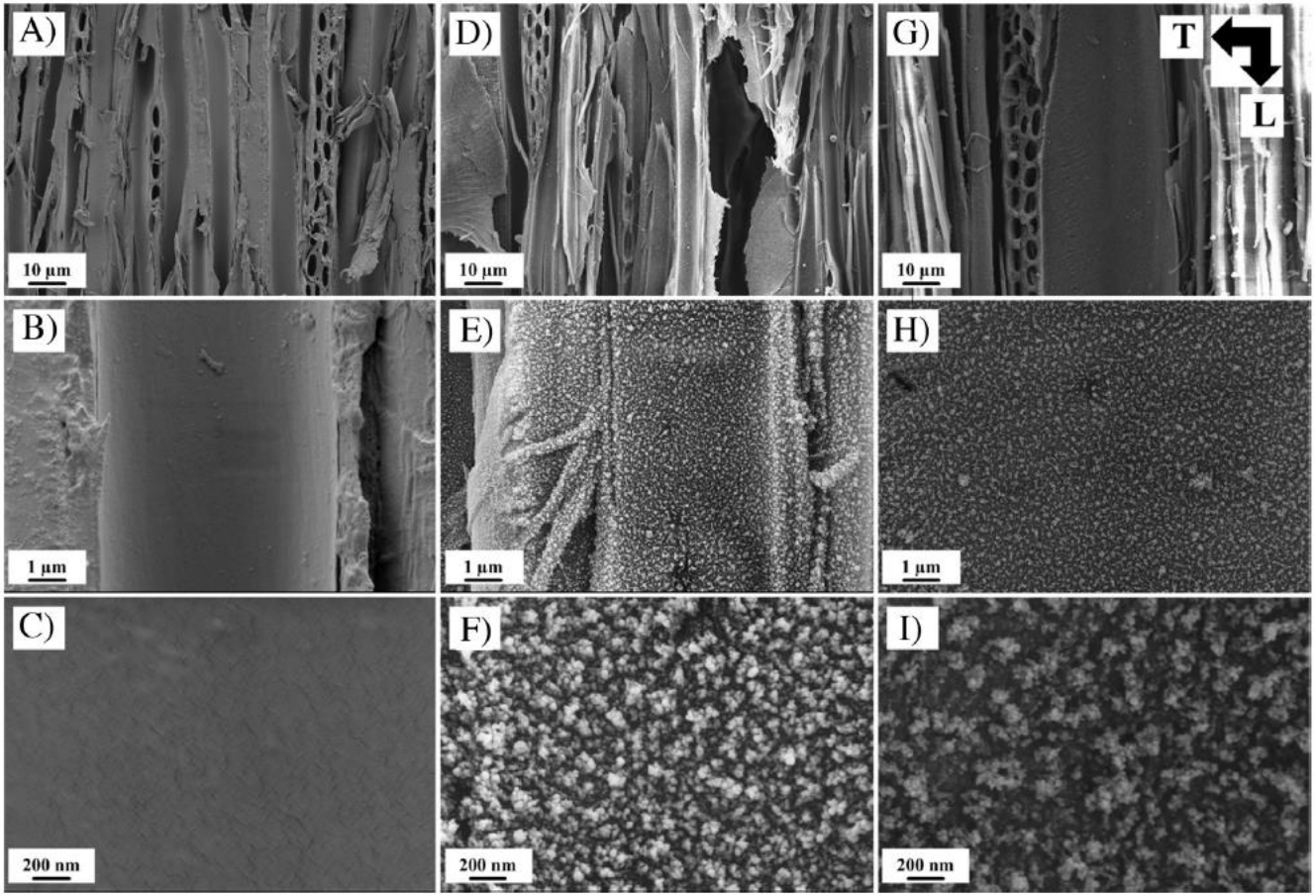
Maziar Sedighi
Postdoc
20/80 KTH/SP

Publications on Studies of W*ettability and Lewis acid-base properties* of wood and modified wood:

Sedighi Moghaddam et al. (2015); Li et al. (2015); Sedighi Moghaddam, et al. (2014); Sedighi Moghaddam, et al. (2013); Wålinder et al. (2013); Bryne and Wålinder (2010); Wålinder and Gardner (2002); Wålinder and Johansson (2001); Wålinder and Ström (2001)

Superamphiphobic hybrid coating on wood on birch

Untreated | 1 x TiO_2 -PFH | 3 x TiO_2 -PFH



Increased magnification

Fig. 1. FEG-SEM images of wood (A–C), 1 × TiO_2-PFH (D–F) and 3 × TiO_2-PFH (G–I) coated wood. The wood fibers are oriented in the longitudinal direction (L).

Touminen et al 2016. Applied Surface Science 389 (2016) 135–143.

Financing from Troedsson

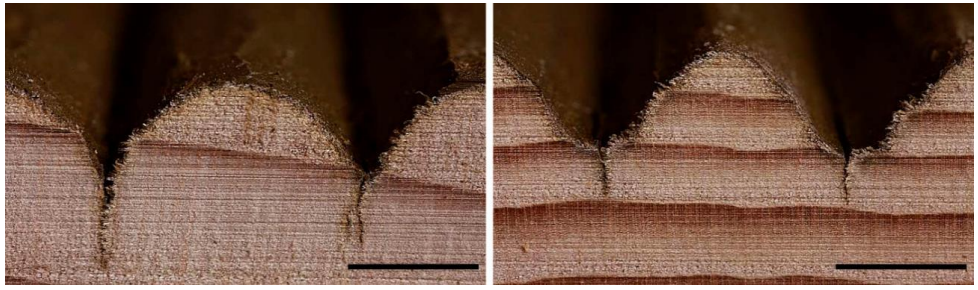
Water droplet

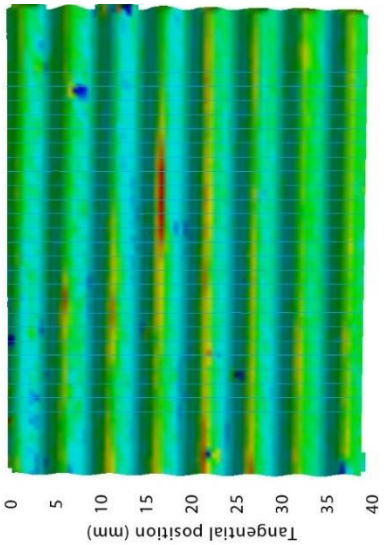
Olive oil droplet

Self-cleaning effect with water droplet

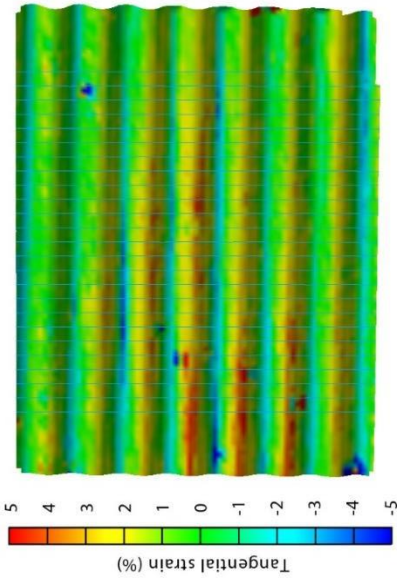
Reduced cracking by profiling

Pofiled wood surface





Drying



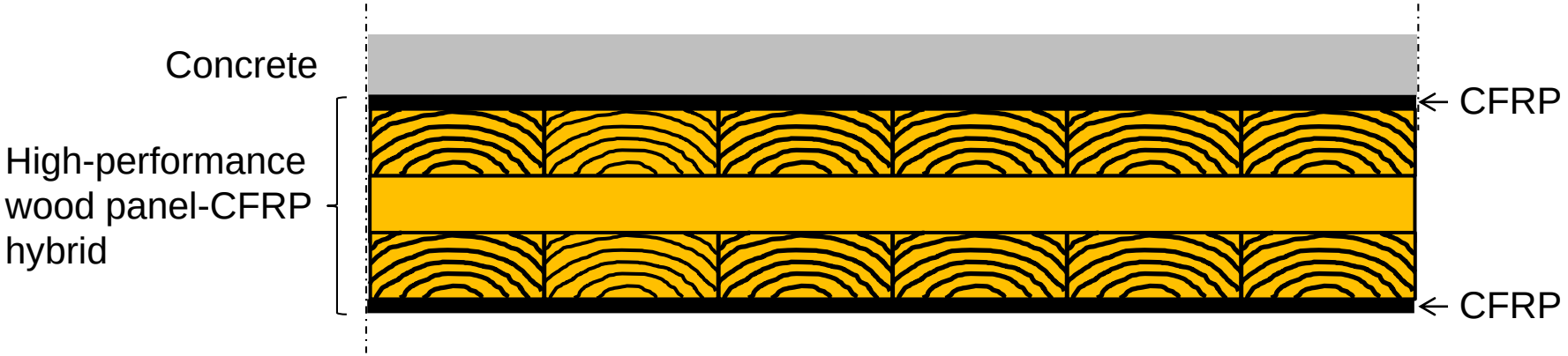
Wetting

Source: Phil Evans UBC, Kanada

Concluding remarks & recommendations

- The hybrid concept/material combinations highly efficient means to reduce the carbon footprint in the building sector by

designing a mix of wood and non-wood elements for an optimal building system with superior performance than each individual element



1 v.u. concrete substituted with 1/10 v.u. concrete combined with 2/5 v.u. wood


Thanks for the attention!