Environmental Impacts of Traditional and New Wood Products

Albert-Ludwigs-Universität Freiburg

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Dr. Wei Xu

Jia Mao, Prof. Gero Becker, Prof. Marie-Pierre Laborie

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Environmental Sustainability

Perform a Life Cycle Assessment (LCA)

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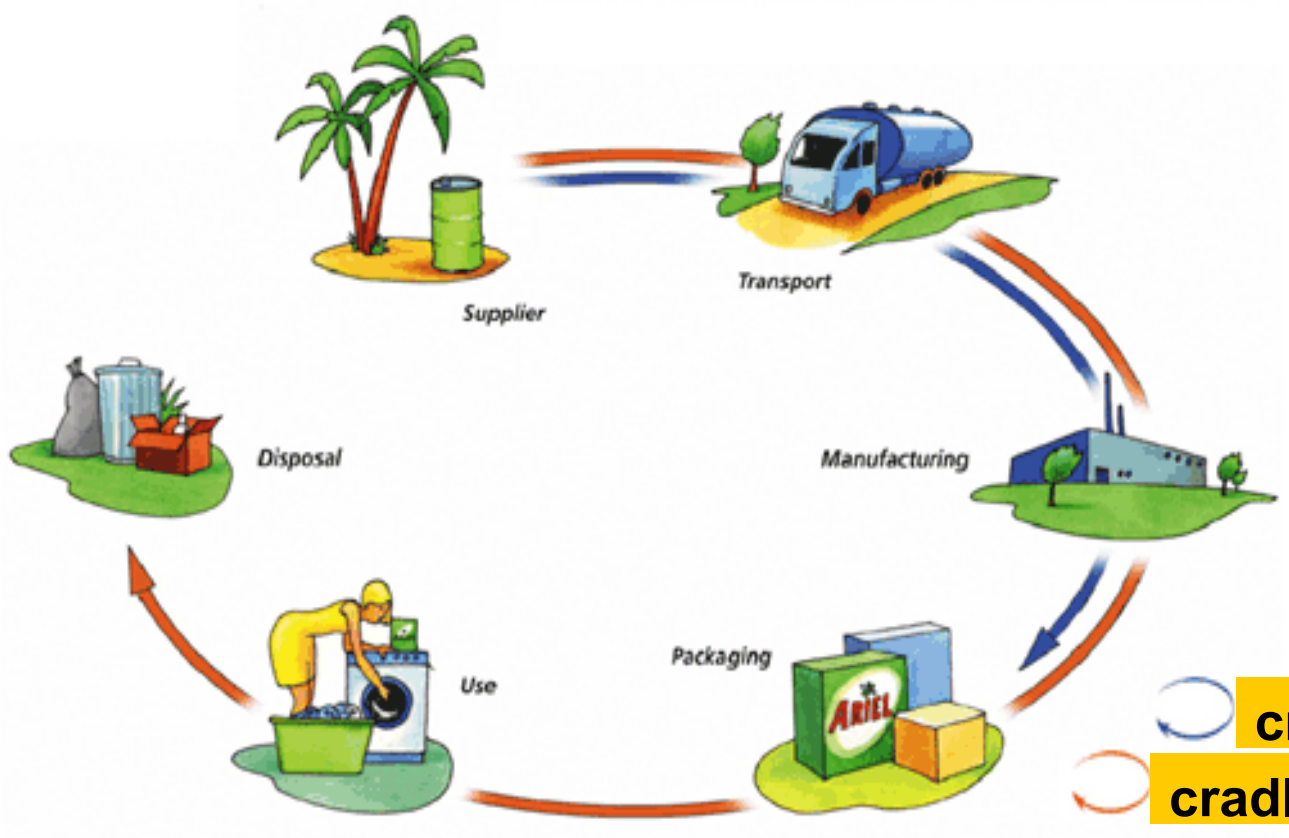
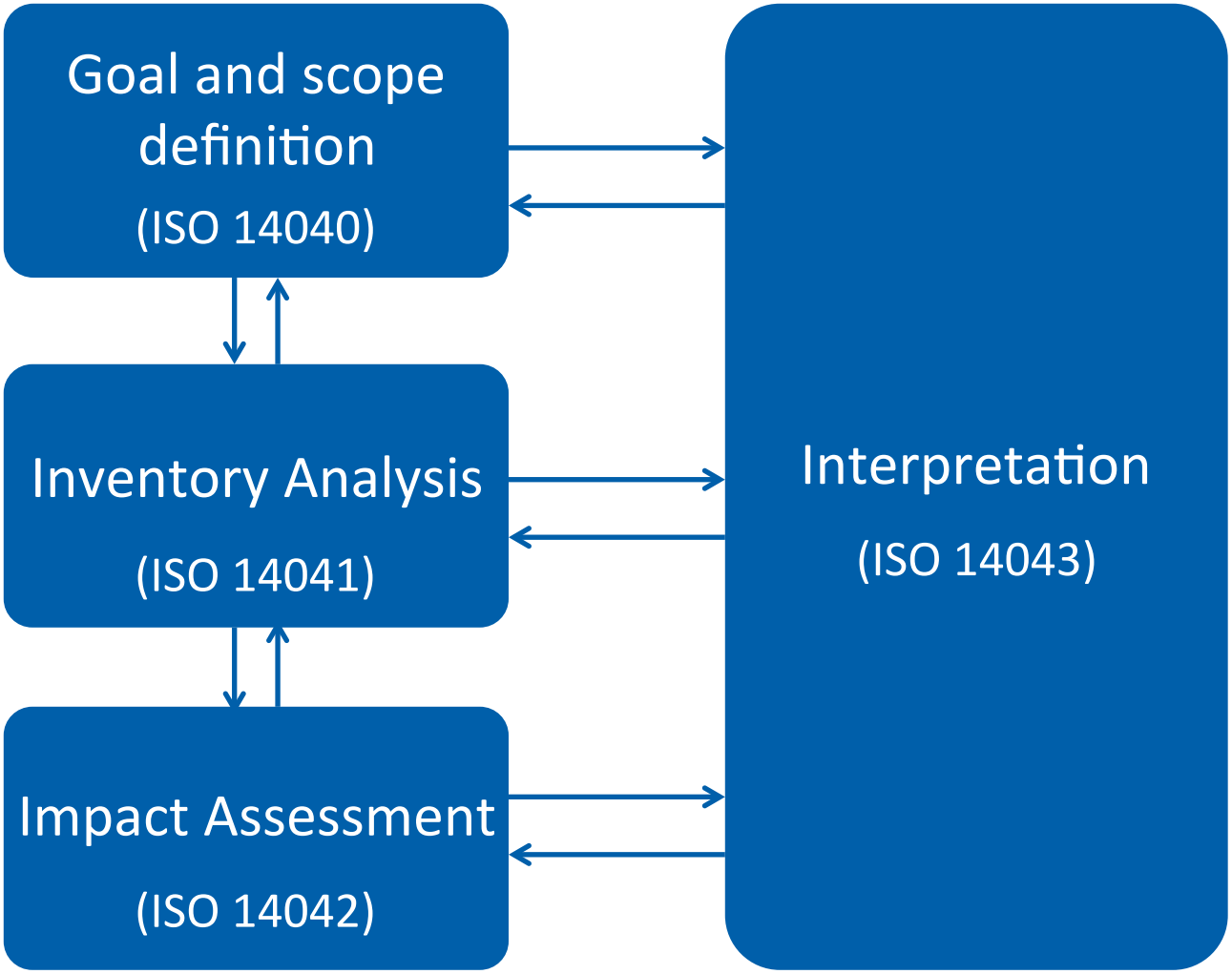
◆ LCA is a useful method to evaluate environmental impacts for a certain *product, process or activity*



cradle to gate

cradle to grave

LCA implementation steps



A wide range of wood utilization

- ***Wood buildings***
- ***Furniture***
- ***Pulp & paper***
- ***Bio-energy***
- ***Wood-based biomaterials...***

LCA on Wood pulp
Since 2009

LCA on Nanocellulose
Since 2013

Part 1. LCA on wood pulp

A case study of wood pulp from eucalyptus plantations in South China

Eucalyptus plantation as pulpwood supply

Eucalyptus plantation

Large-scale establishement (2001-2010)
2.6 Million hectares

Wood pulp mill

Capacity expansion (by 2015)
4.9 Million tons

Environmental Sustainability

(China State Forestry Administration, 2002; China National Development and Reform Commission, 2004 and 2005; He and Barr, 2004; Barr and Cossalter, 2004; Wang and Suo., 2009)

Cradle-to-gate perspective

Raw material supply from eucalyptus plantaion

Transport

Wood pulp Production

Q: What are the environmental impacts related to wood pulp production?

Q:What are the "*hot-spot*" processes leading to higher environmental burdens?

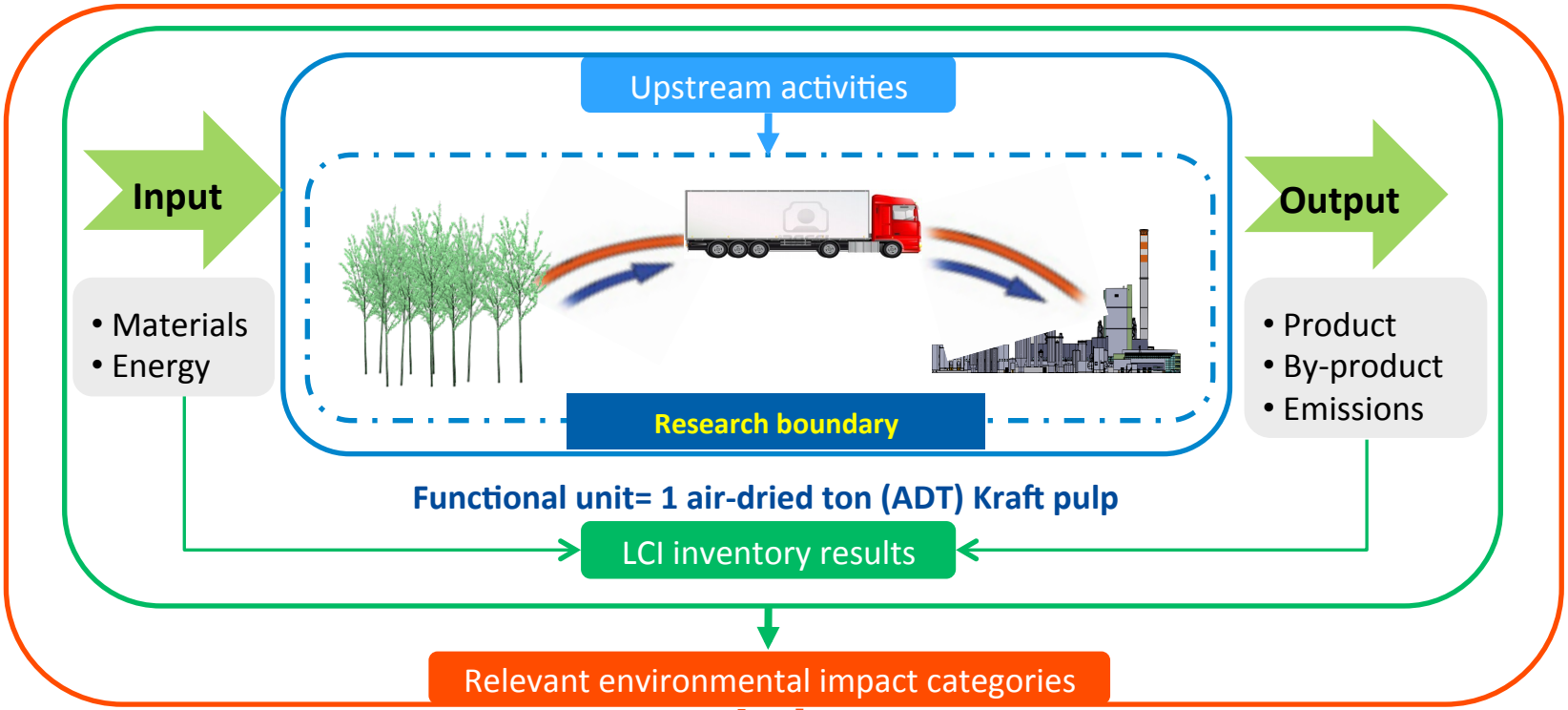
LCA implementation steps

STEP 1
Scope definition

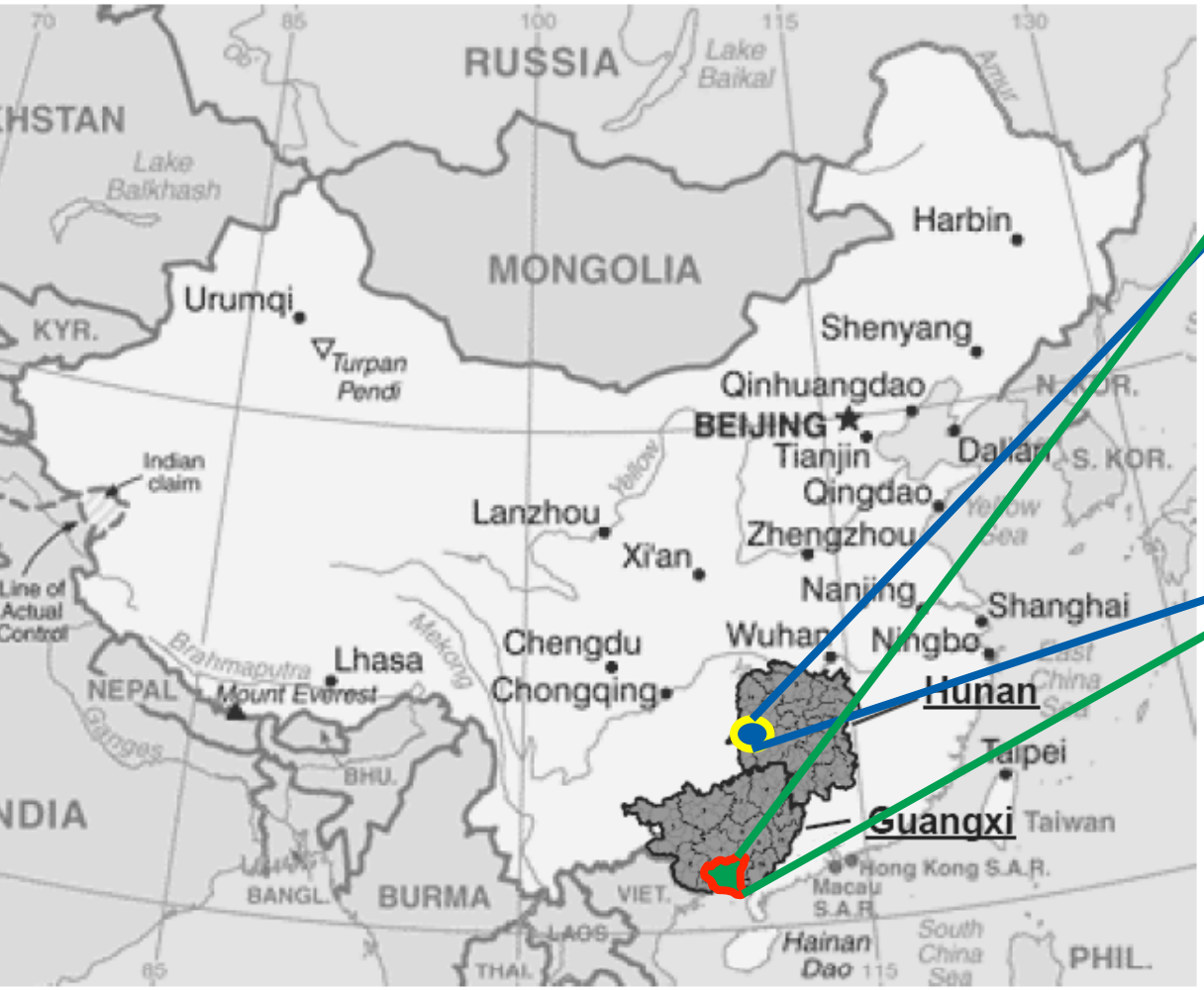
STEP 2
Life cycle Inventory

STEP 3
Impact assessment

STEP 4
Interpretation



Case study profiles



Location of the selected case study

Plantation operator (since 1996)

- 40,000 ha eucalyptus plantations
- a full range operations
- 200+ employees
- data collection: 2009

Principal processes (forest + transport)

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Nursery

Seedling breeding

Silviculture operations

Planting

Fertilization

Tending

Harvest

Chain saw harvest

Skidding

Logging

Extraction

Loading

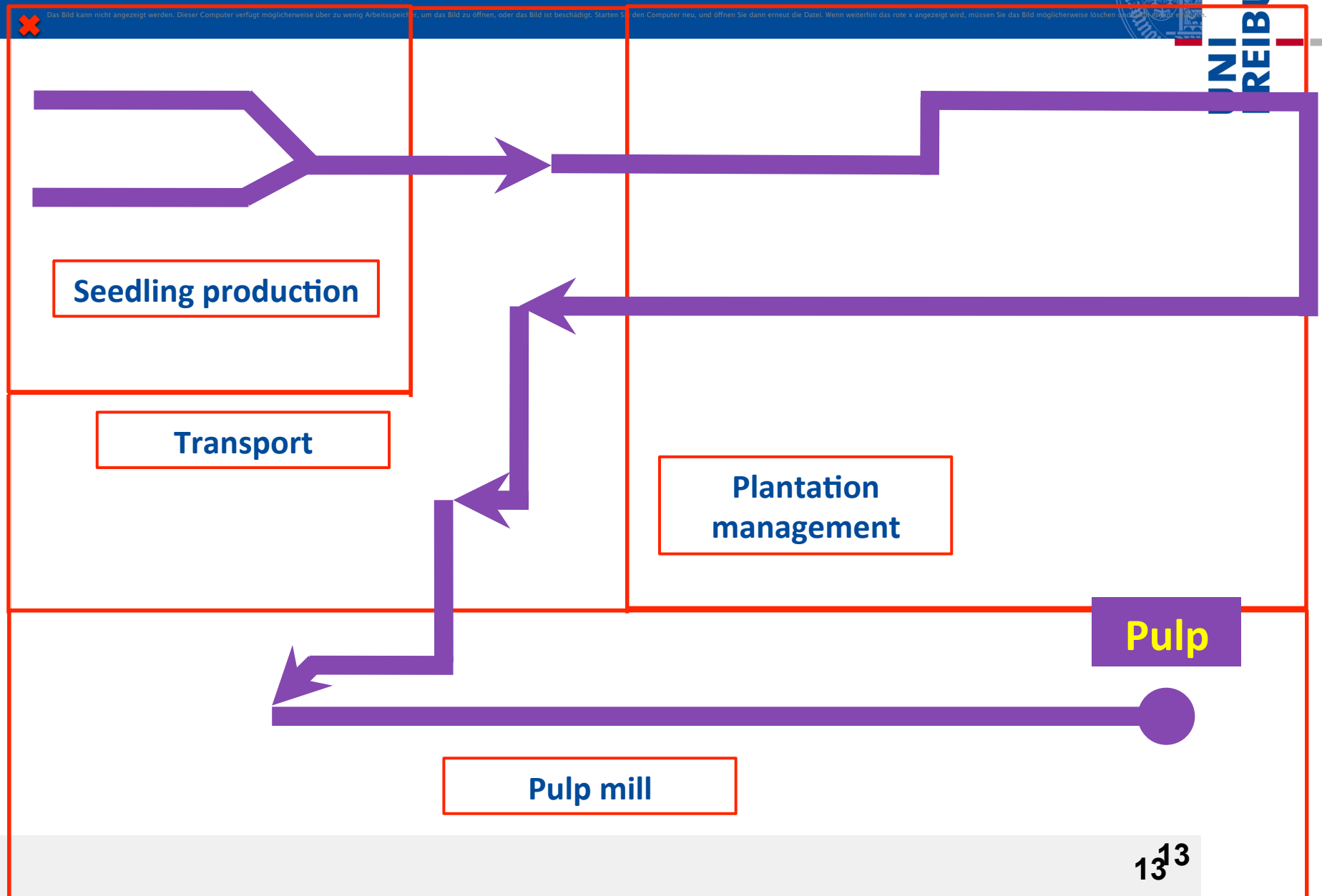
Transport

Out of forest

Delivery to mill

Principal processes (pulp mill)

System modeling with Umberto ®



Inventory analysis results

➢ **Input and output refer to the *functional unit* of 1 air-dried ton pulp**

EMISSIONS TO AIR
- GHGs 611 *kg*
- Biogenic CO_2 2,081 *kg*
- Other pollutants 15 *kg*

RAW MATERIALS
- Fertilizers 143 *kg*
- Chemicals 212 *kg*
- Water 36 m^3

ENERGY
- Fossil fuels 254 *kg*
- Electricity* 8 *kwh*

Carbon sequestration
- CO_2 uptake 31 ton

Cradle-to-gate perspective

PRODUCT
- Market pulp 1 *ton*

BY-PRODUCT
- Electricity to grid 432 *kwh*

EMISSIONS TO WATER
- Effluent 40 m^3
- Pollutant discharge 38 *kg*

SOLID WASTE
- Landfills 86 *kg*

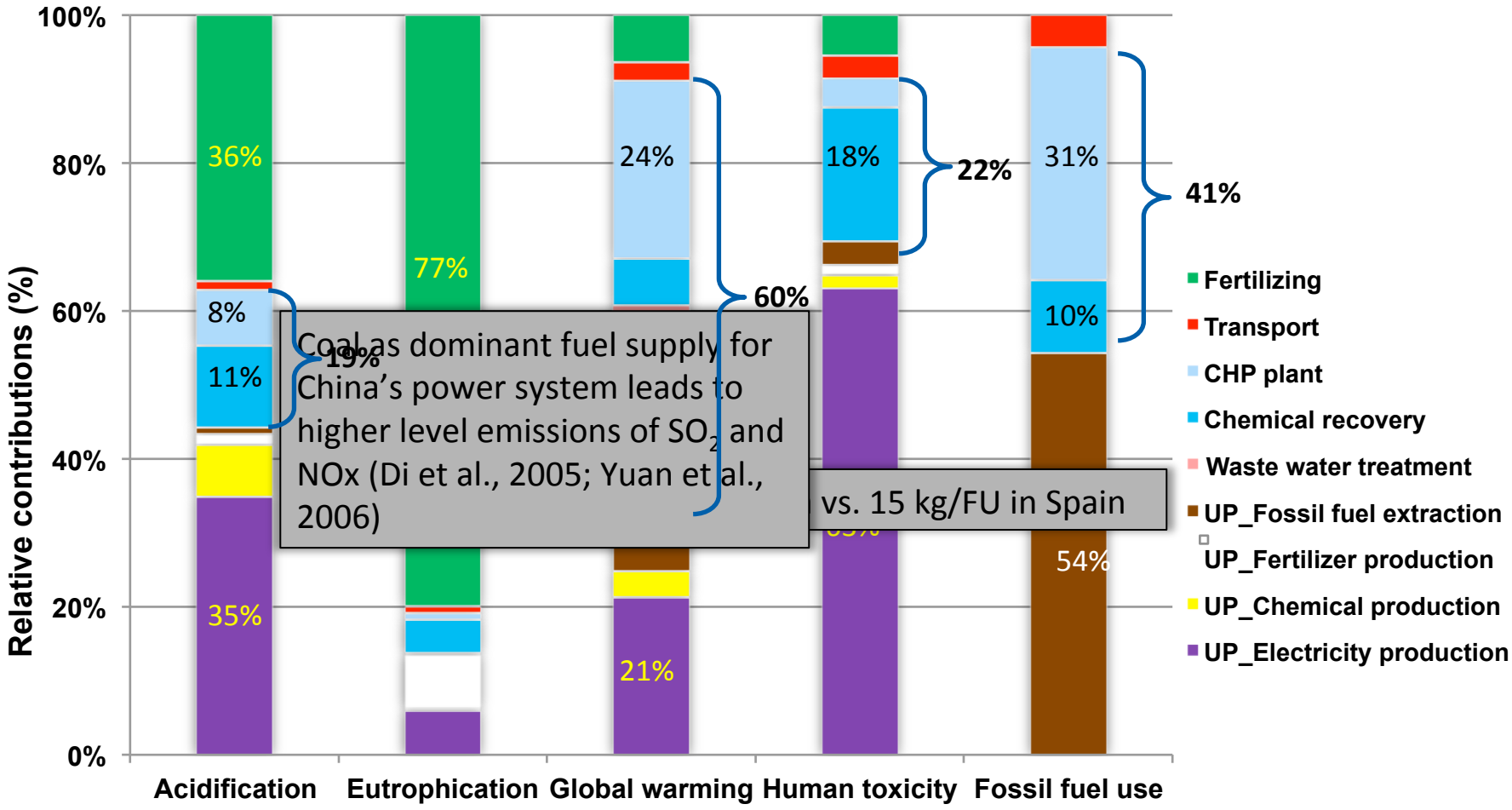
Impact assessment results

➢ **Results refer to the *functional unit* of 1 air-dried ton market pulp**

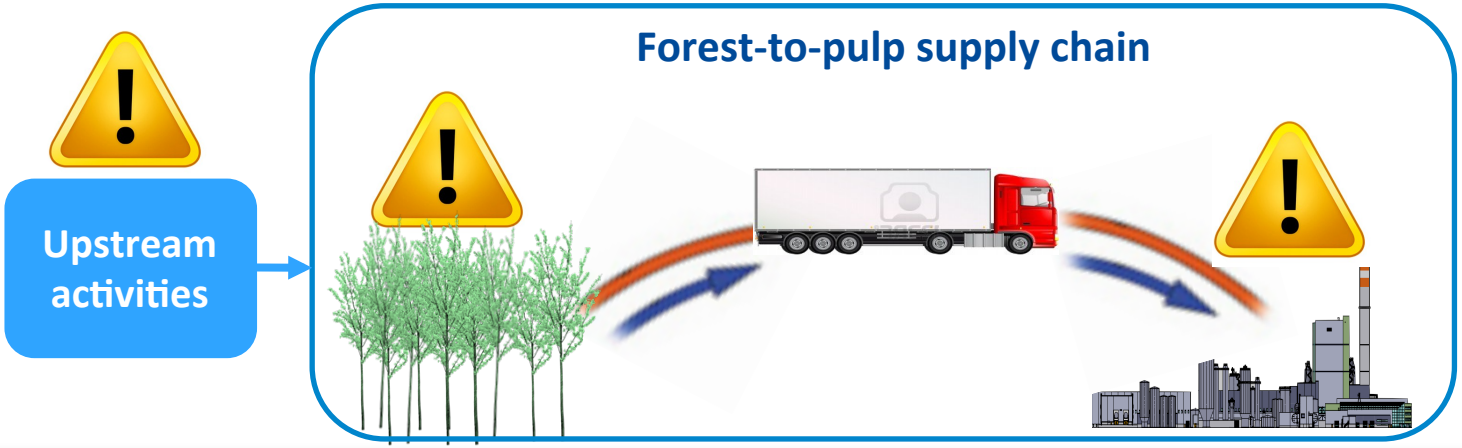
SELECTED IMPACT CATEGORY	This study		In Thailand (Jawjit, 2006)		In Spain (Gonzalez et al.,2009)
Acidification (kg SO_2-eq.)	15.45	>	5.96	>	2.83
Eutrophication (kg PO_4^{3-}-eq.)	5.87	>	3.50	>	0.70
Global warming (kg CO_2-eq.)	2,178.08	>	1,584.33	>	431.30
Human toxicity (kg $C_6H_4Cl_2$-eq.)	16.40	>	11.42	<	39.19
Fossil fuel depletion (GJ)	17.26		-		-

Hot-spot processes

Relative contributions of principal processes to total environmental impacts



Key findings



- **Fertilization** operations of the forest subsystem should be a concern for future eucalyptus plantation management in China
- Optimizations of on-site **supportive units** of chemical recovery, CHP plant and water treatment plant should be taken to reduce the impact of the pulp mill subsystem
- **Supply of raw materials and energy** should be a concern for all the involved activities along the entire forest-to-pulp supply chain

Part 2. LCA on Nanocellulose

An innovative route to produce cellulose nanocrystals (CNCs) with ionic liquid

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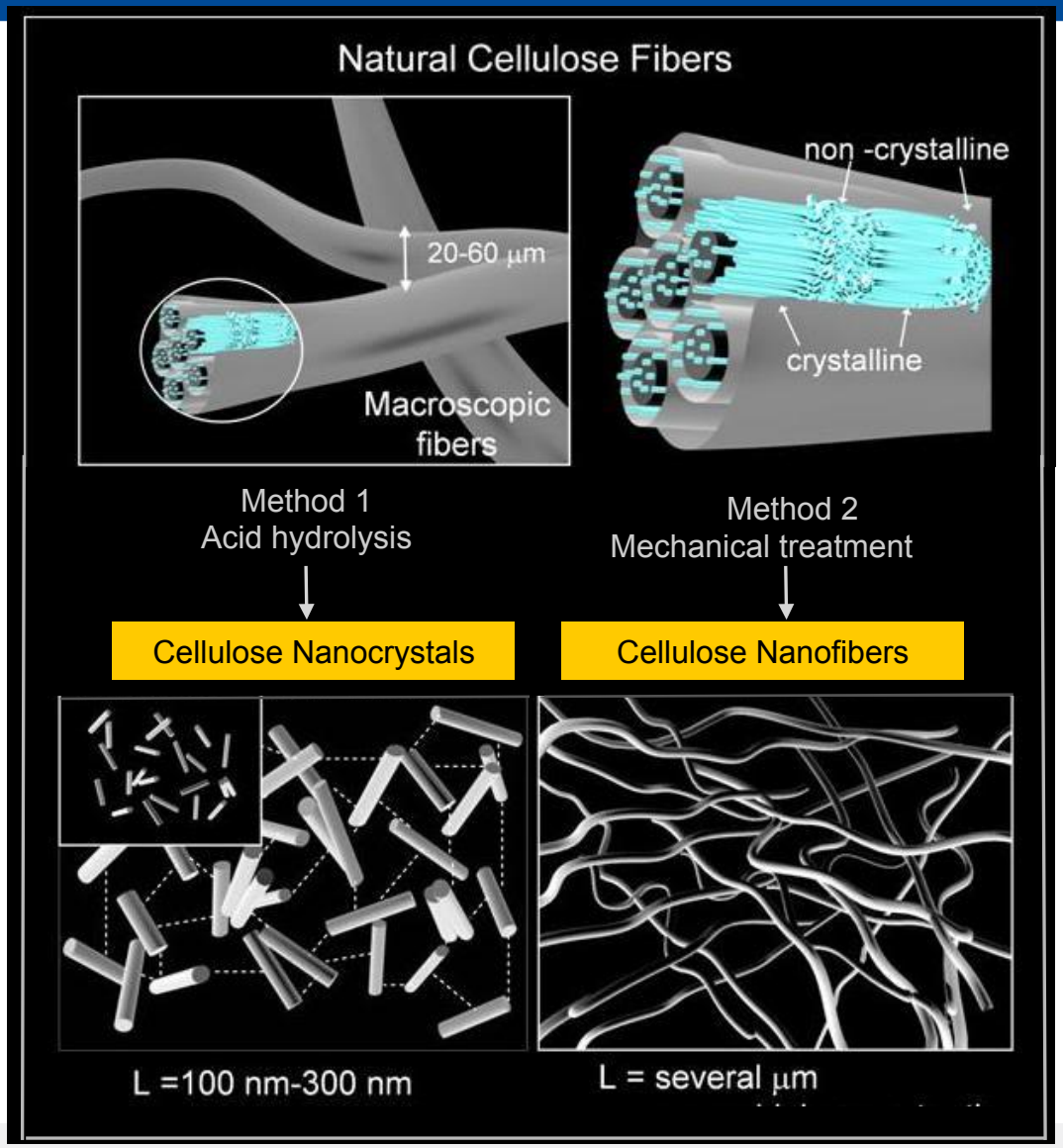
Nanocellulose from wood

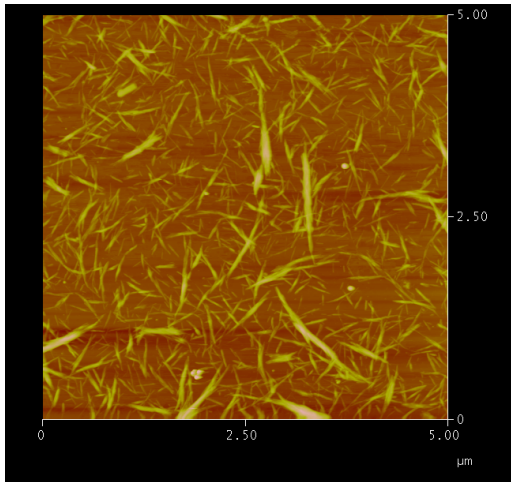


- **Cellulose is the most abundant biopolymers on earth**
- **Nanocellulose is a promising bio-based material for many high performance applications**
- **Environmental impacts remain little understood**

(VTT, 2008)

Cellulose Nanocrystals (CNCs)

CNCs are nano-scale highly crystalline materials obtained from a broad range of cellulose sources by ***acid hydrolysis***

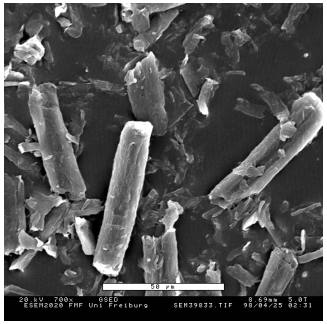


AFM height image of CNCs *(from Mao Jia)*

Many desired properties

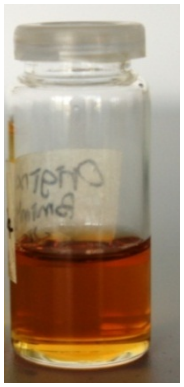
- **High strength and stiffness (high Young‘s Modulus (=steel))**
- **Low weight**
- **Biodegradable and renewable**
- **Reinforcement in polymer-nanocomposites**

Ionic liquid route by Mao et al. (2013)



Microcrystalline cellulose (MCC)

+



[Bmim]HSO_4/H_2O

Heating

120℃, 24h

Centrifugation (12000rpm, 10min)

Sediment

Supernatant

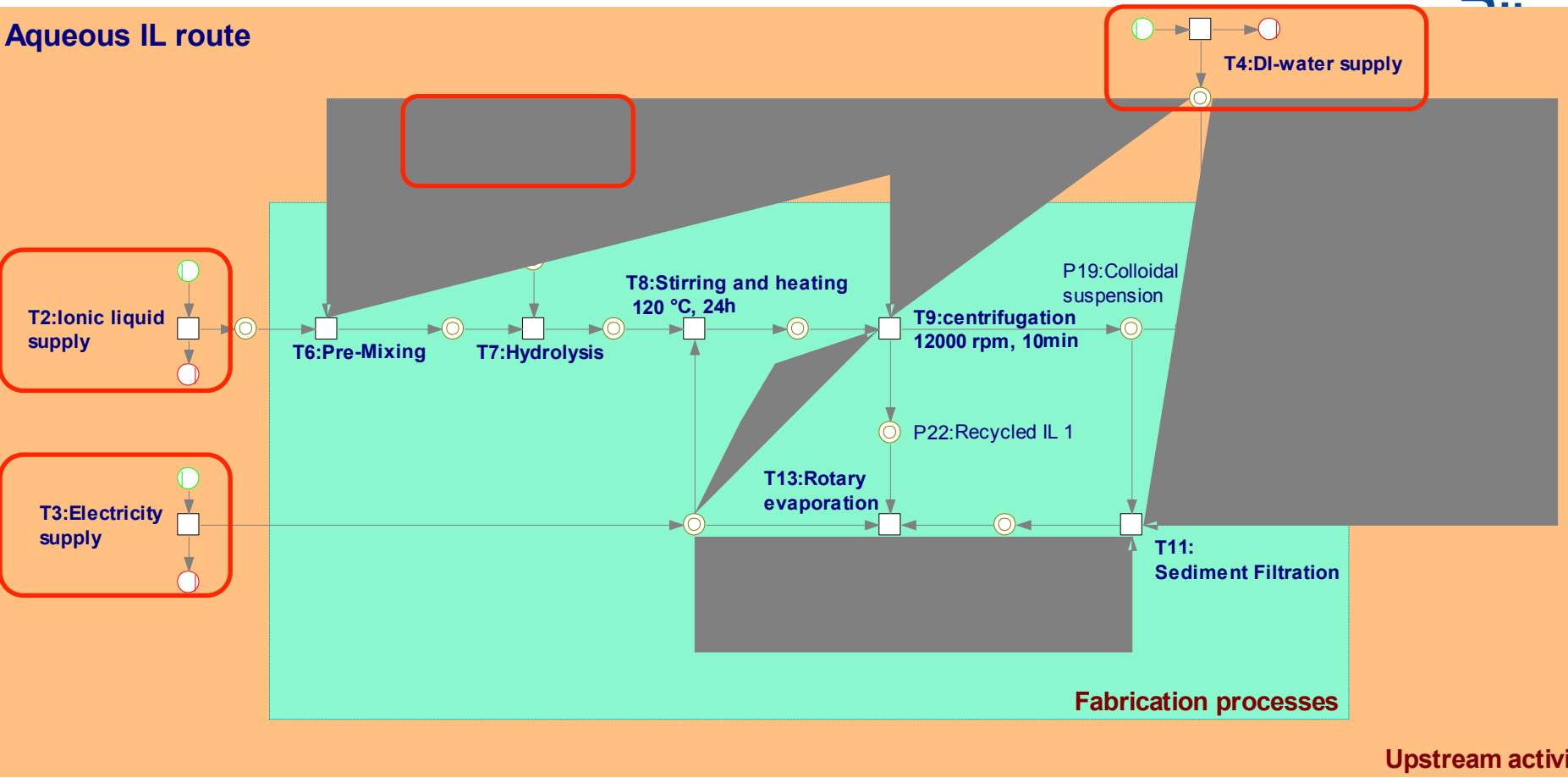
Filtration

Recovered ionic liquid

CNCs

Traditional route	IL route (Mao et al, 2013)
- strong acid (H_2SO_4)	+ green solvent
- corrosive	+ recoverable, reuseable
- low yield	+ higher yield

System modeling with Umberto ®



Functional unit= 10 *g* CNCs at lab gate

Impact assessment results (Eco-indicator 99)

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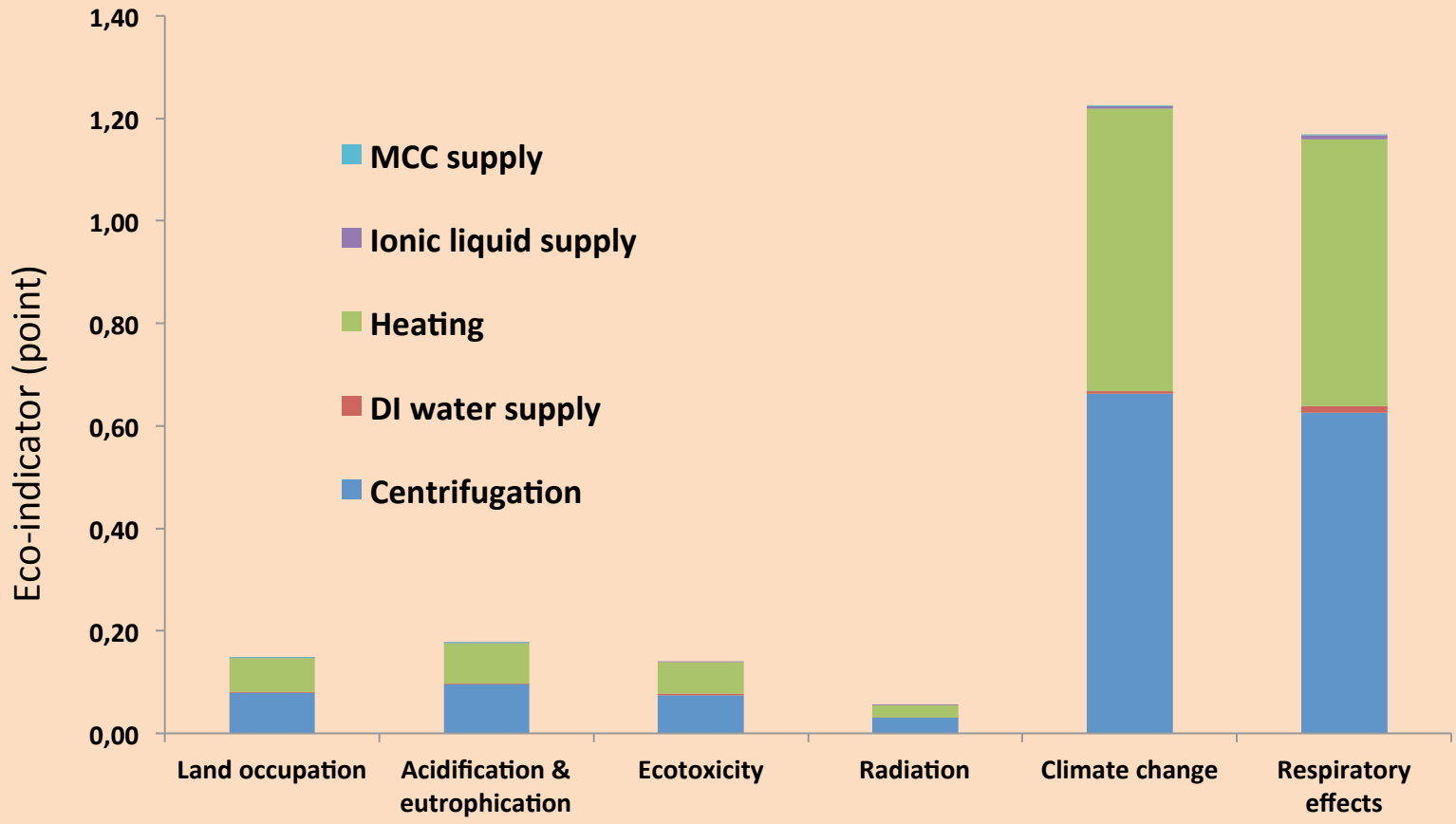
Hot-spot process leading to higher environmental impacts



Outlook

Possible comparative LCAs:

- *IL route vs. traditional routes (e.g. with H_2SO_4)*
- *MCC vs. other starting materials*
- *Optimization scenarios*

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Contact:
wei.xu@fobawi.uni-freiburg.de
0761-203 9240

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