Material Flow Analysis (MFA)

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Outline

1. From LCA to MFA
2. MFA
3. Process-based MFA
4. MFA & LCA
5. Discussion

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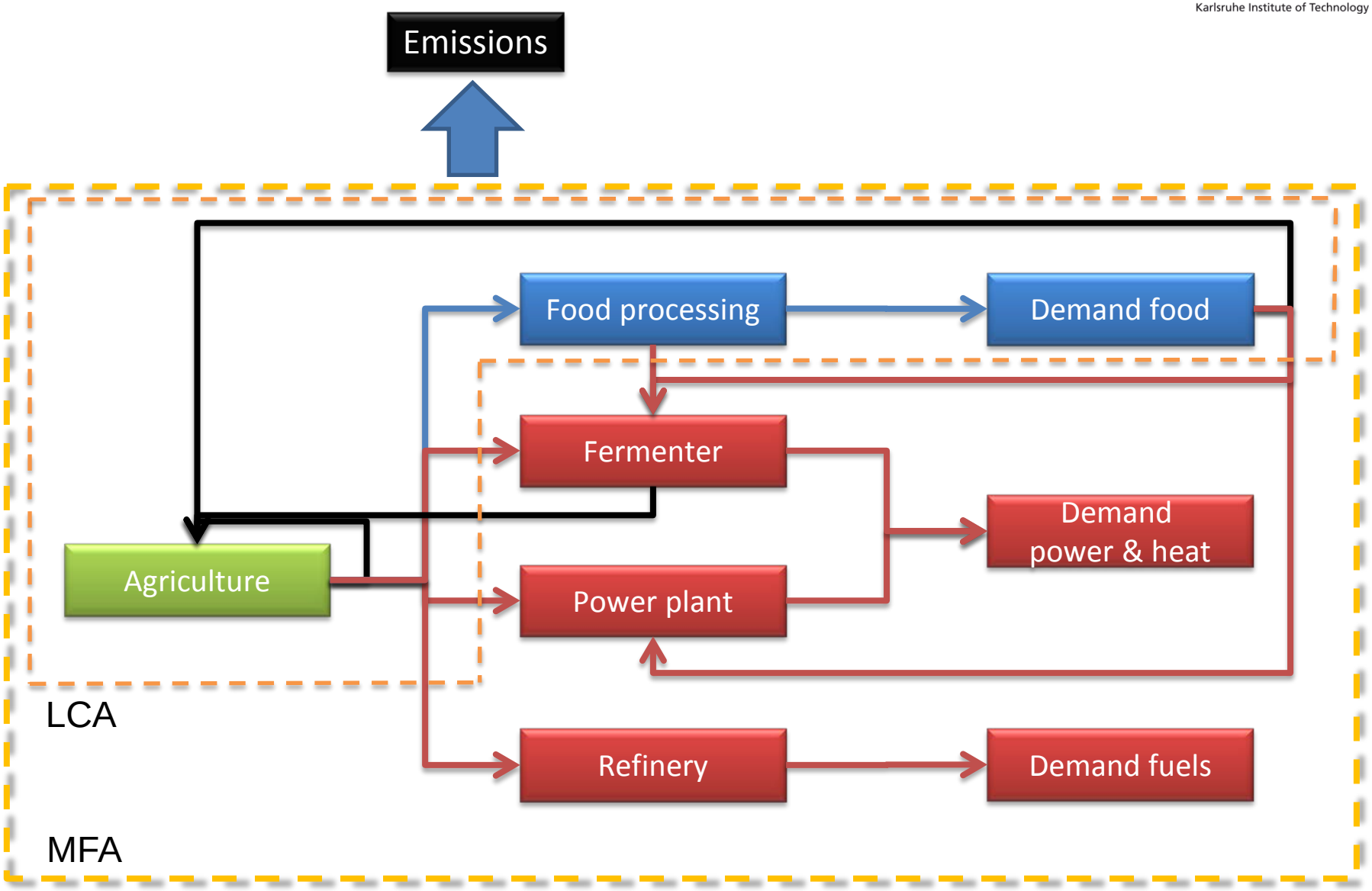
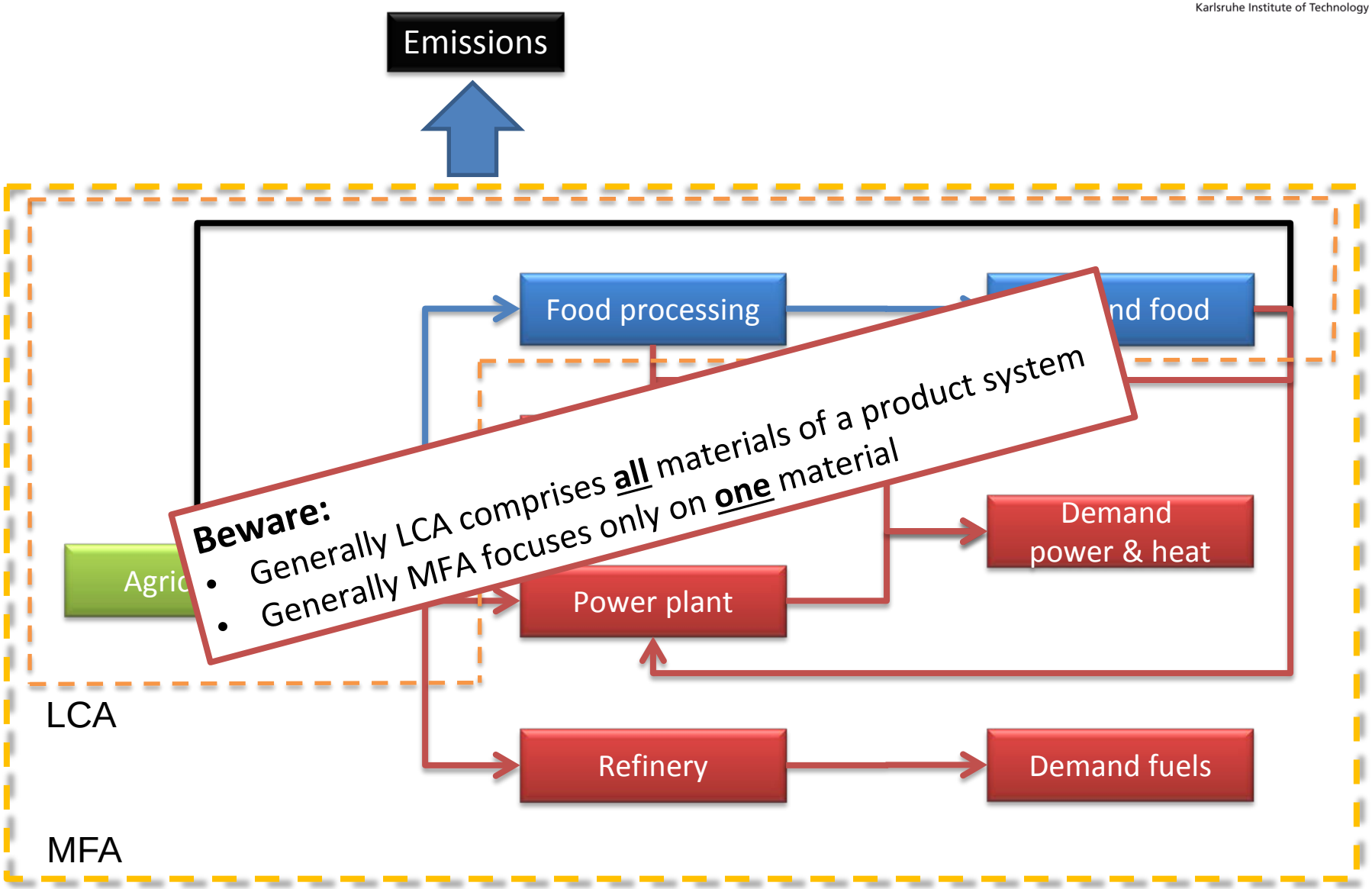
From LCA to MFA



From LCA to MFA



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MFA

- Material flow analysis: aim is to provide a comprehensive assessment of the flows of one material within a chosen system and between the system and its environment

- Methodological foundation: law of the conservation of matter

- Conceptual steps:
  - Systems definition
  - Analysis of processes
  - Modeling
  - Interpretation of results

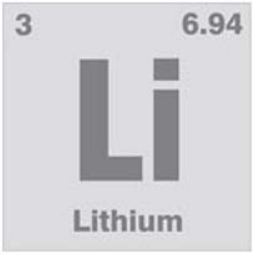
Example: Global lithium flows

- Chemical element:
  - silvery-white light metal
  - density about half that of water
  - most negative redox potential of all elements

- Applications:
  - chemical and pharmaceutical products
  - glass, ceramics, aluminum, and lubricant production processes
  - lithium-based rechargeable batteries

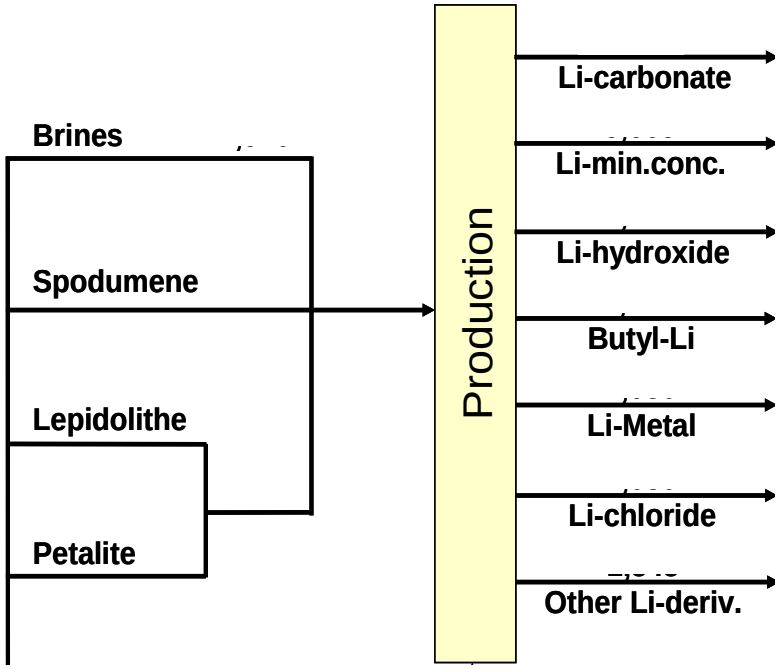
  → E-Mobility!

http://www.chemische-experimente.com/images/Lithium_Schnittstelle.jpg



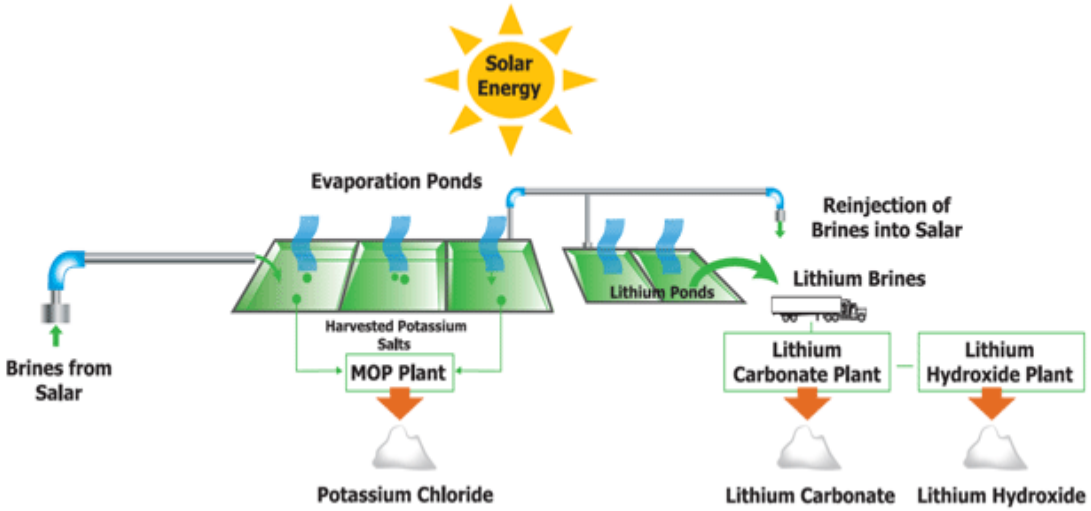
https://www.store.acs.org/ewebimages/ACSStore/119-149_prod.jpg

Systems definition and analysis of processes



Systems definition and analysis of processes

Extraction / Production

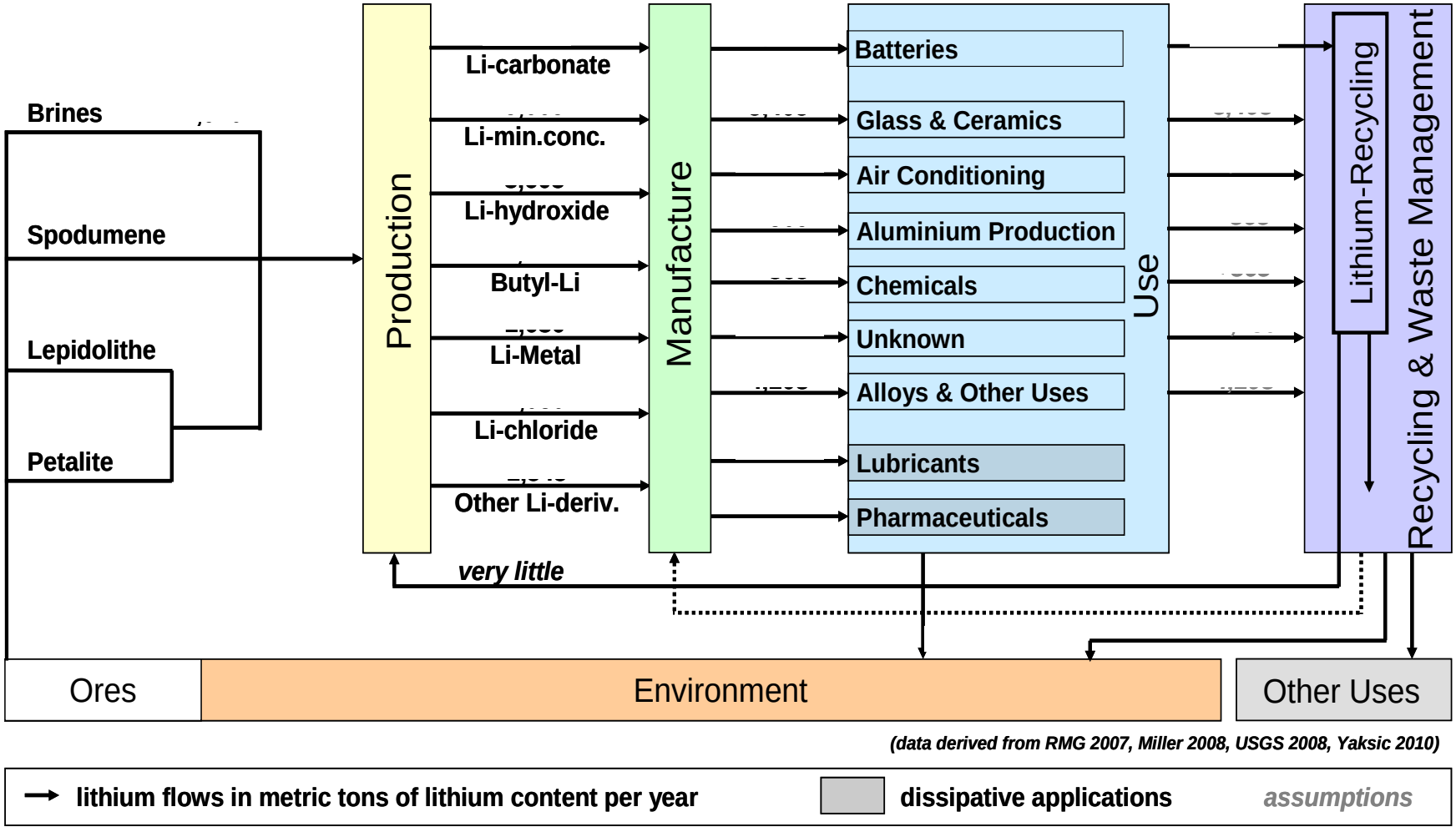


Pegmantit ore

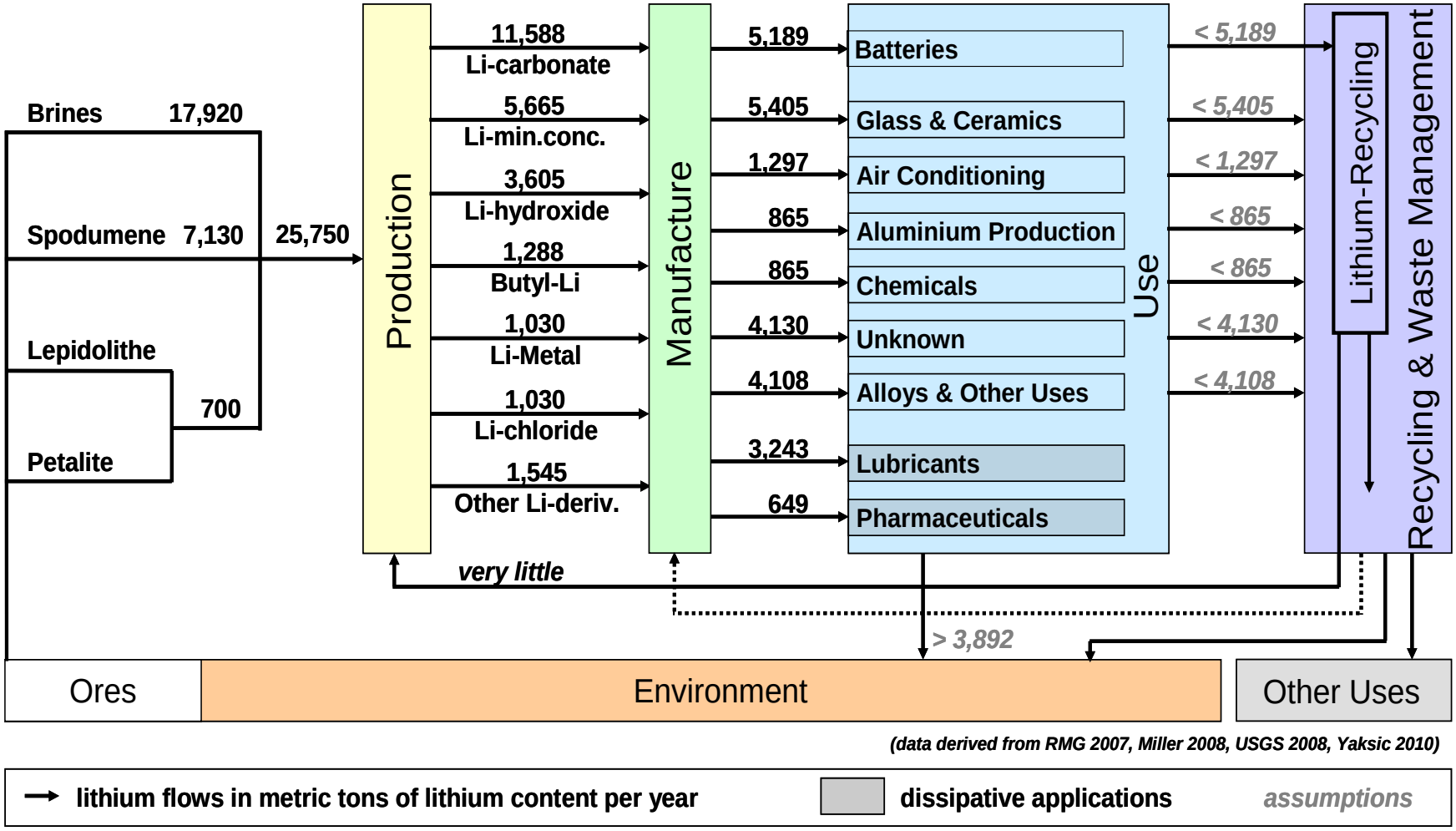
Processed to

- lithium hydroxide
- butyl lithium
- lithium metal
- lithium chloride and
- other lithium derivatives

Systems definition and analysis of processes



Modeling and interpretation of results



Further reading: Schebek, L., Poganietz, W.R., Feifel, S., Ziemann, S. (2015): Technological innovation and anthropogenic material flows. Hartard, S., Liebert, W. (eds.): Competition and conflicts on resource use, Heidelberg: Springer. pp. 135-154.

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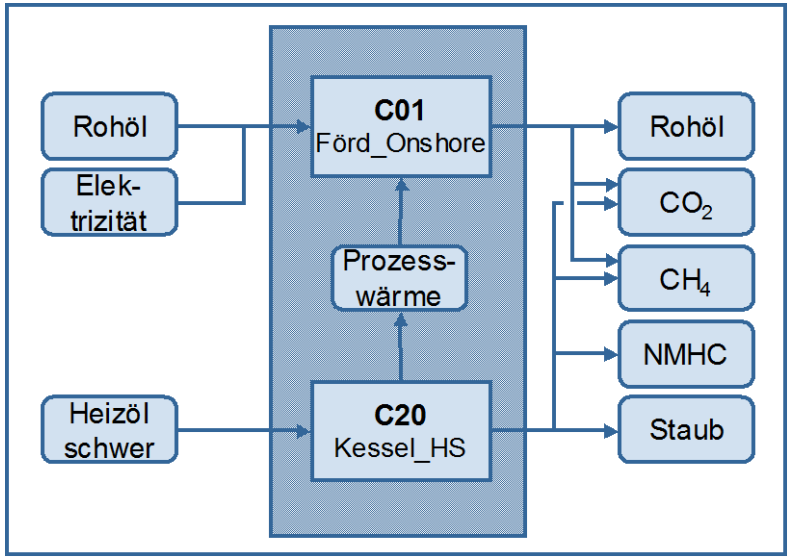
Process-based MFA ~ CarboMoG

- CarboMoG ~ Carbon Flow Model of Germany is a dynamic process-based carbon-carrier energy and material flow model
  - currently about 361 (mainly) carbon-related processes are modeled
  - comparative-static but also dynamic scenarios can be calculated
  - since primary and secondary material flows are included analysis of interdependent life cycle process chains is possible („cradle to grave“)
- Reference year: 2005
- Reference region: Germany

Concept (I)

- Methodological foundation: linear input-output functions (comparable to Life Cycle Inventory (LCI) or IOT)

- Differentiation between
  - extraction,
  - cultivation,
  - production,
  - waste treatment,
  - service and
  - consumption processes



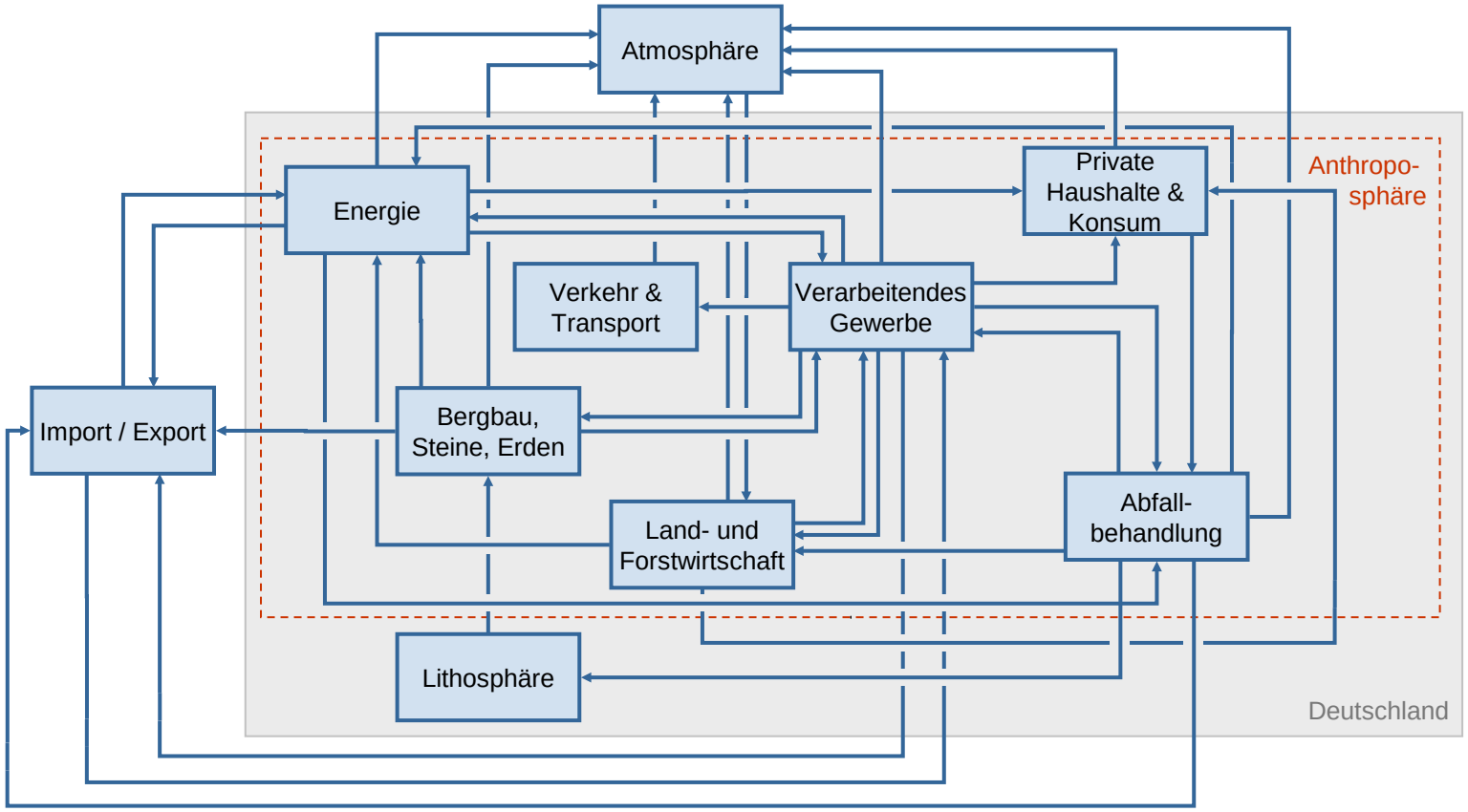
Extraction process crude oil

Distribution of the processes along sectors

Sector	Number	Remarks
Agriculture and forestry	60	o/w 10 forestry processes; 4 auxiliary processes (power proc.)
Mining	11	
Industry	142	o/w 5 food industry processes, 14 wood and paper industry proc., 49 chemical industry processes; 12 auxiliary processes (proc. heat)
Electricity and heat	19	
Private consumption	97	Includes individual transport and private generation of heat
Traffic and transport	11	
Waste treatment	21	Mainly treatment of biogenic by-products, waste and residuals
Total	**361**	

Concept (II)

Connecting of individual processes via market relations

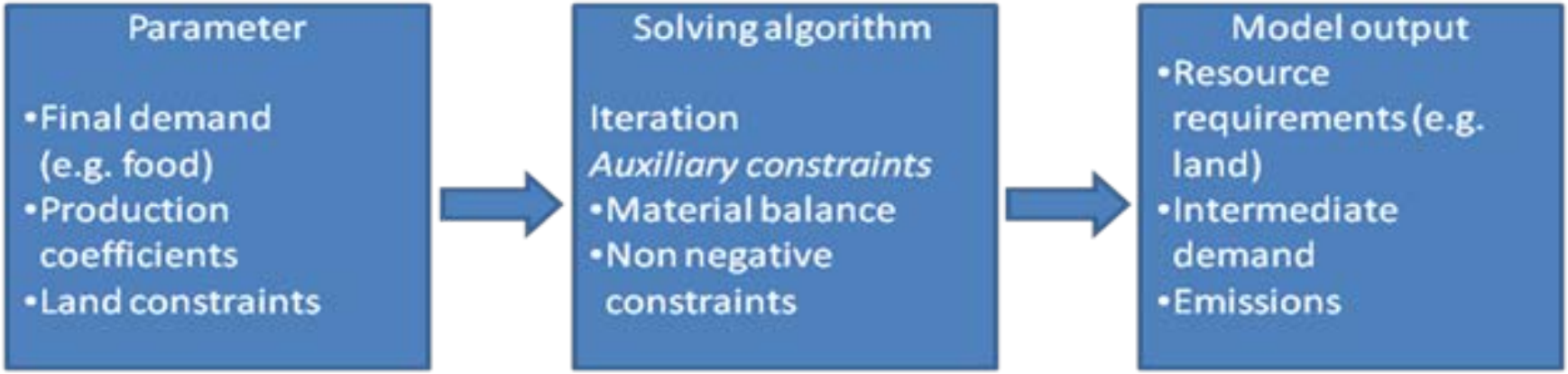


Resources, intermediate and final products

Resources, intermediate and final products	Number
Agricultural products	25
Livestock	19
Forest	10
Mining and rocks	8
Processed products incl. food and wood	131
o/w food	15
o/w wood and paper	16
Energy carriers	26
Transport services	17
(Mainly biogenic) By-products, waste and residuals	47
Total	**314**

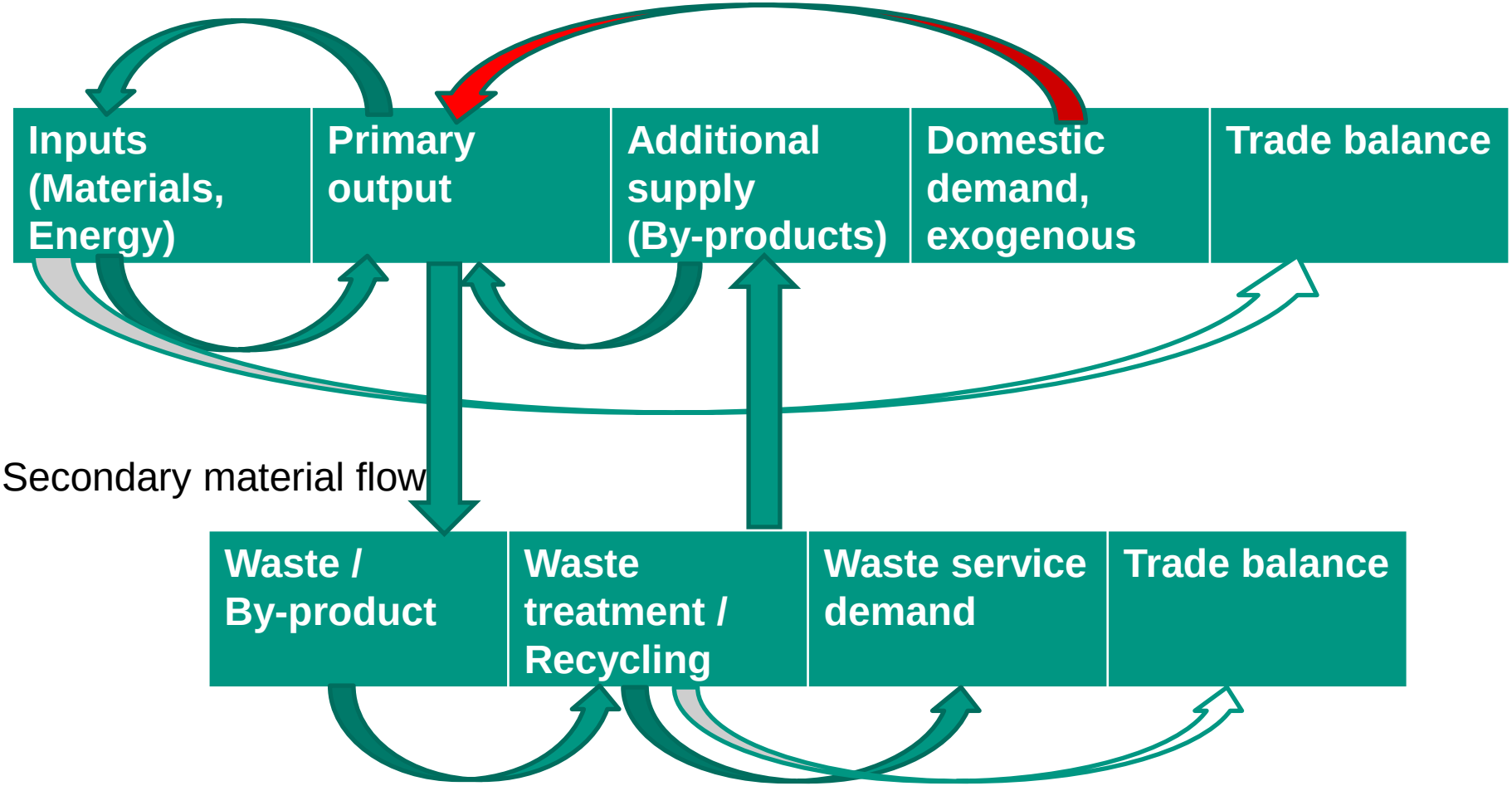
Additionally: CO_2, CH_4, N_2O, SO_2, CO, NO_x, NMHC and dust

Solution algorithm



Solution algorithm

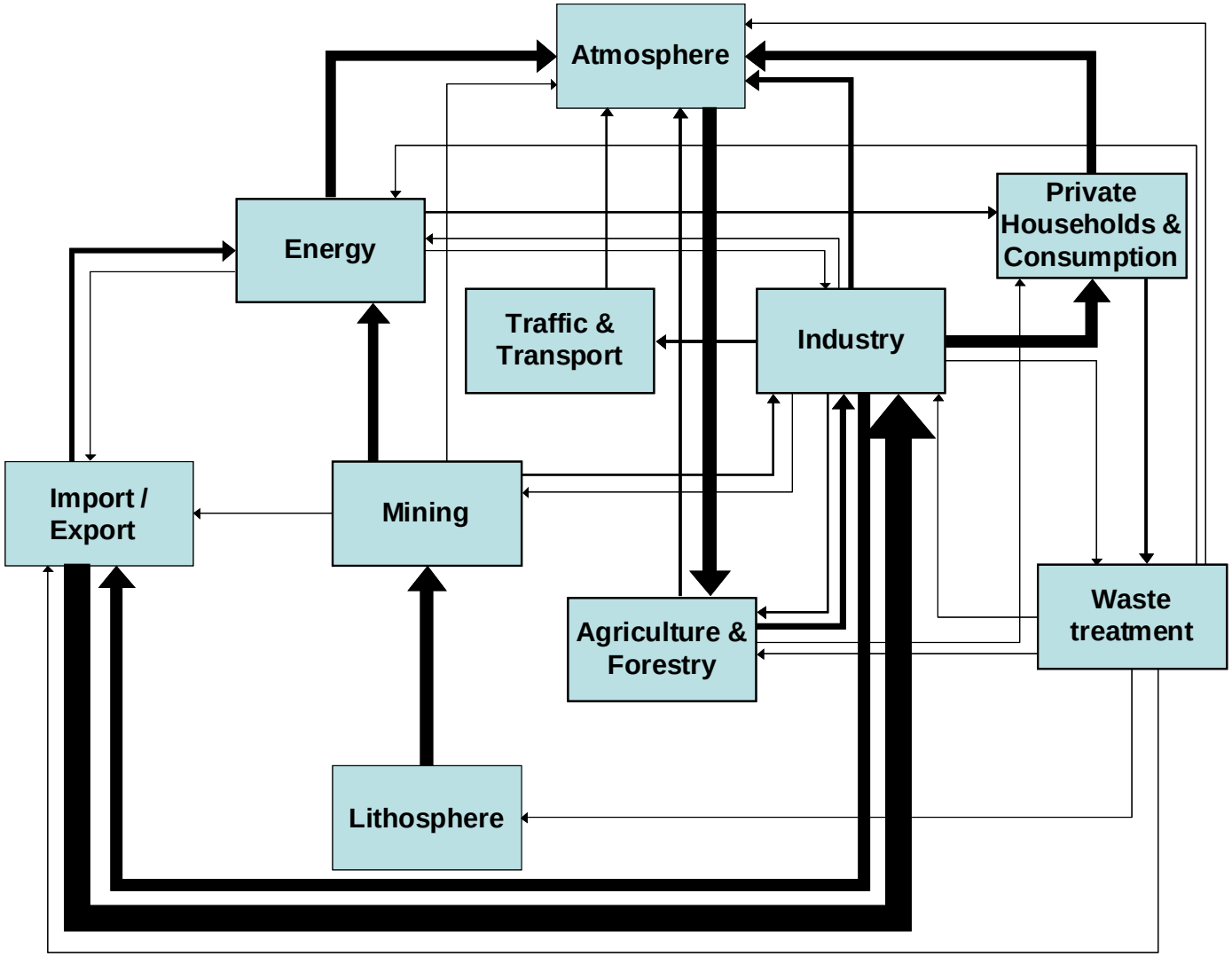
Primary material flow



Data sources

- Process data
  - Life Cycle Inventory (LCI) data (ecoinvent or GEMIS)
  - LCI from different studies
  - Questionnaires
- Sectorial data
  - Statistics
  - Sectorial information of industrial associations
  - EU Project “Forwast”
- Data sources: about 50

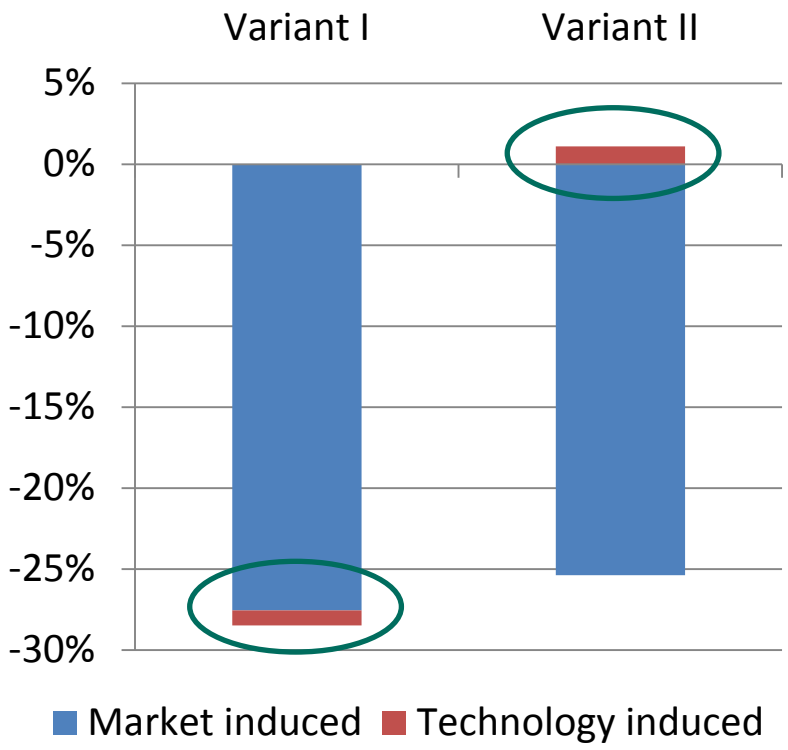
Carbon Flows in Germany, 2000



Further reading: Uihlein, A., Poganietz, W.R., Schebek, L. (2006): Carbon flows and carbon use in the German anthroposphere: An inventory, *Resources, Conservation and Recycling 46,* pp. 410-429.

Load flexible non-conventional power plants

- Aim: to quantify the contribution of load flexible power plants demanding coal, biomass and RDF as inputs in 2050



Change of GWP 100yr., compared to 2005

Change of GWP of selected energy carriers, only by the technology induced

	Variant I	Variant II
Hard coal	+24.5 %	+ 33.1 %
Gas	- 6.8 %	- 6.8 %
Oil (heavy)	- 11.4 %	- 11.4 %

Poganietz, W.R., Kondo, Y., Gehrmann, H.J., Nakamura, S. (2014): Load flexible plant concepts – a comparative analysis from a life-cycle perspective. Ecobalance 2014, Tsukuba, Japan, 27.-30.10.2014: *Creating benefit through Life Cycle Thinking*.

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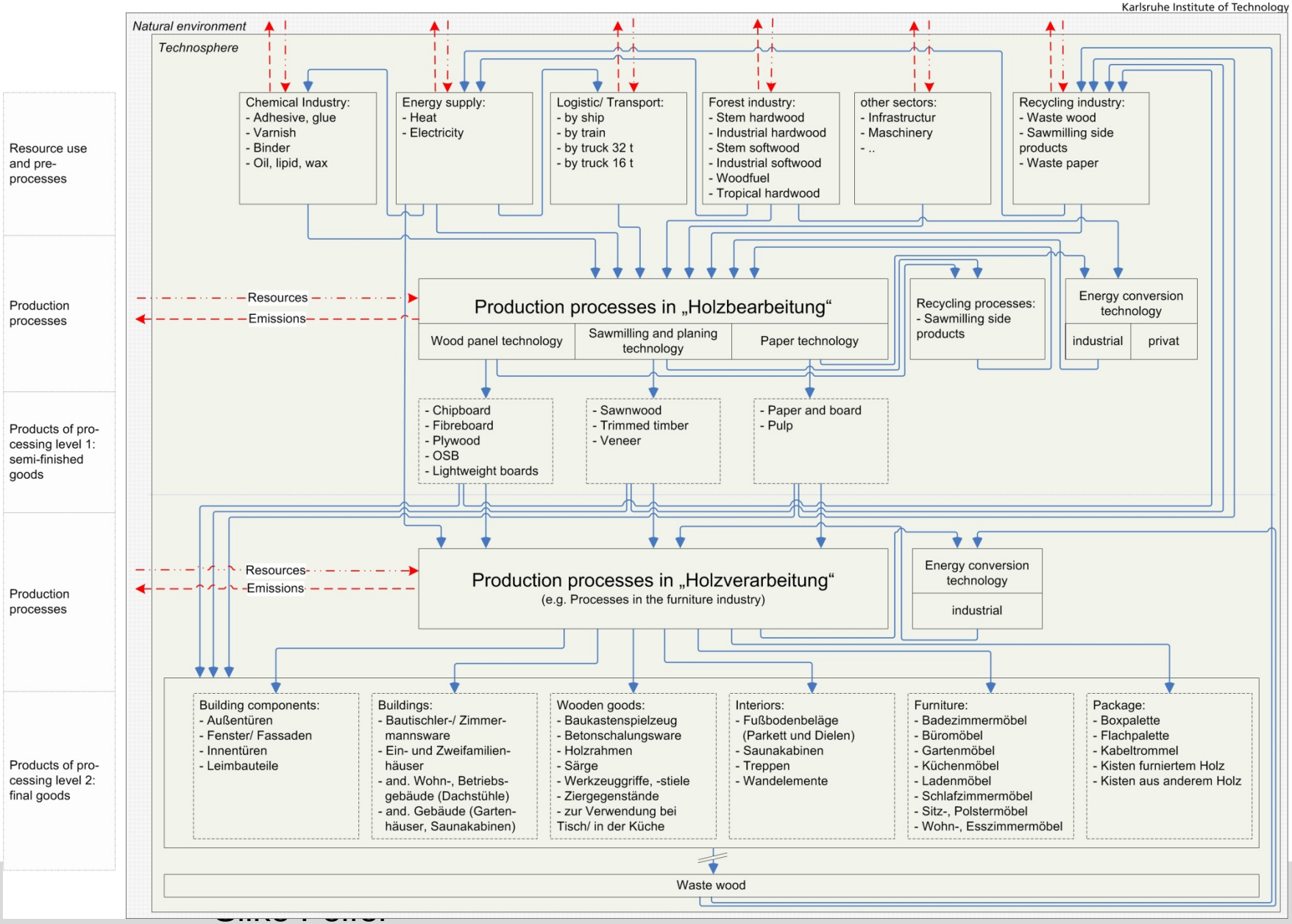
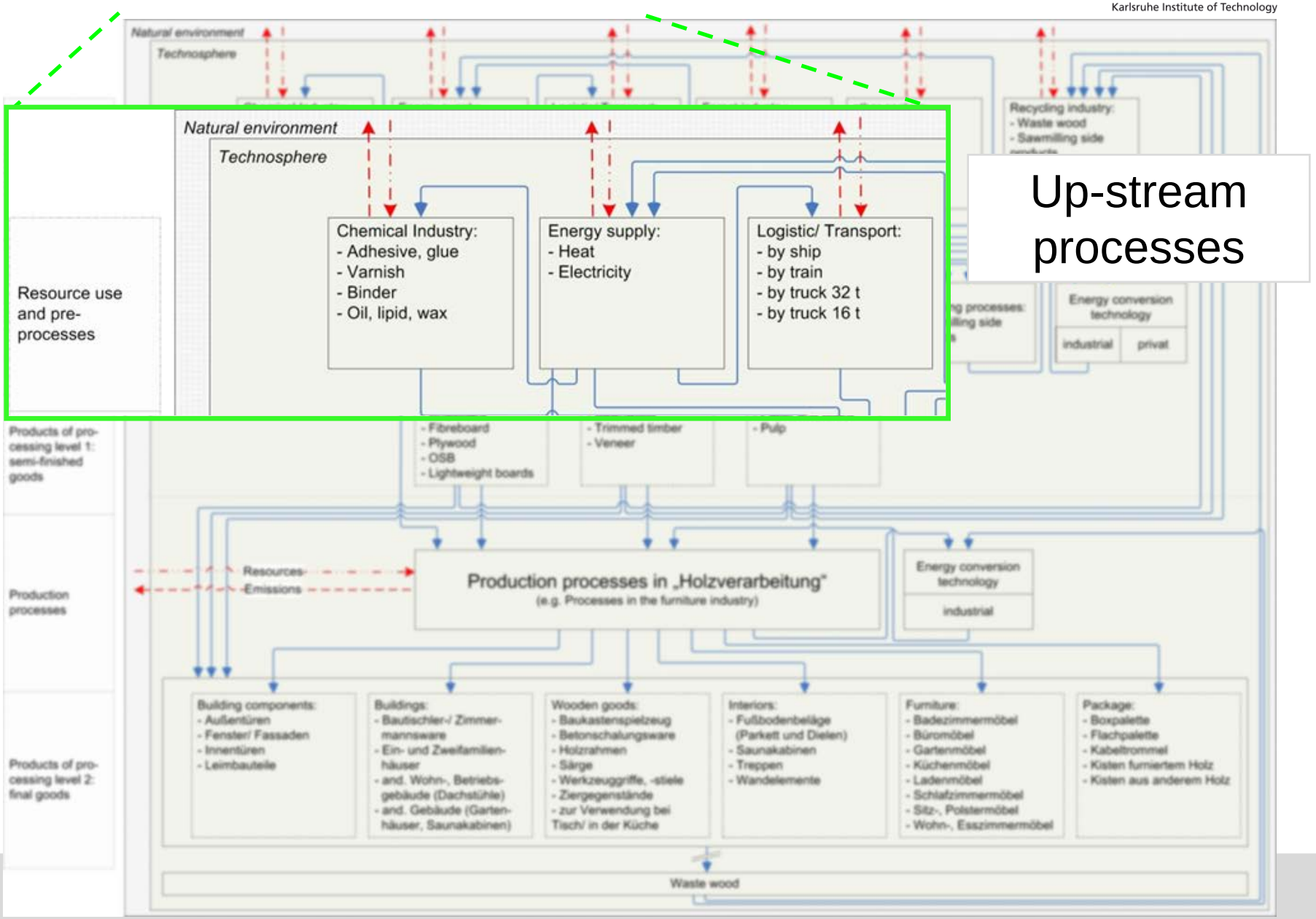
Process-based MFA ~ Wood



Process-based MFA – details



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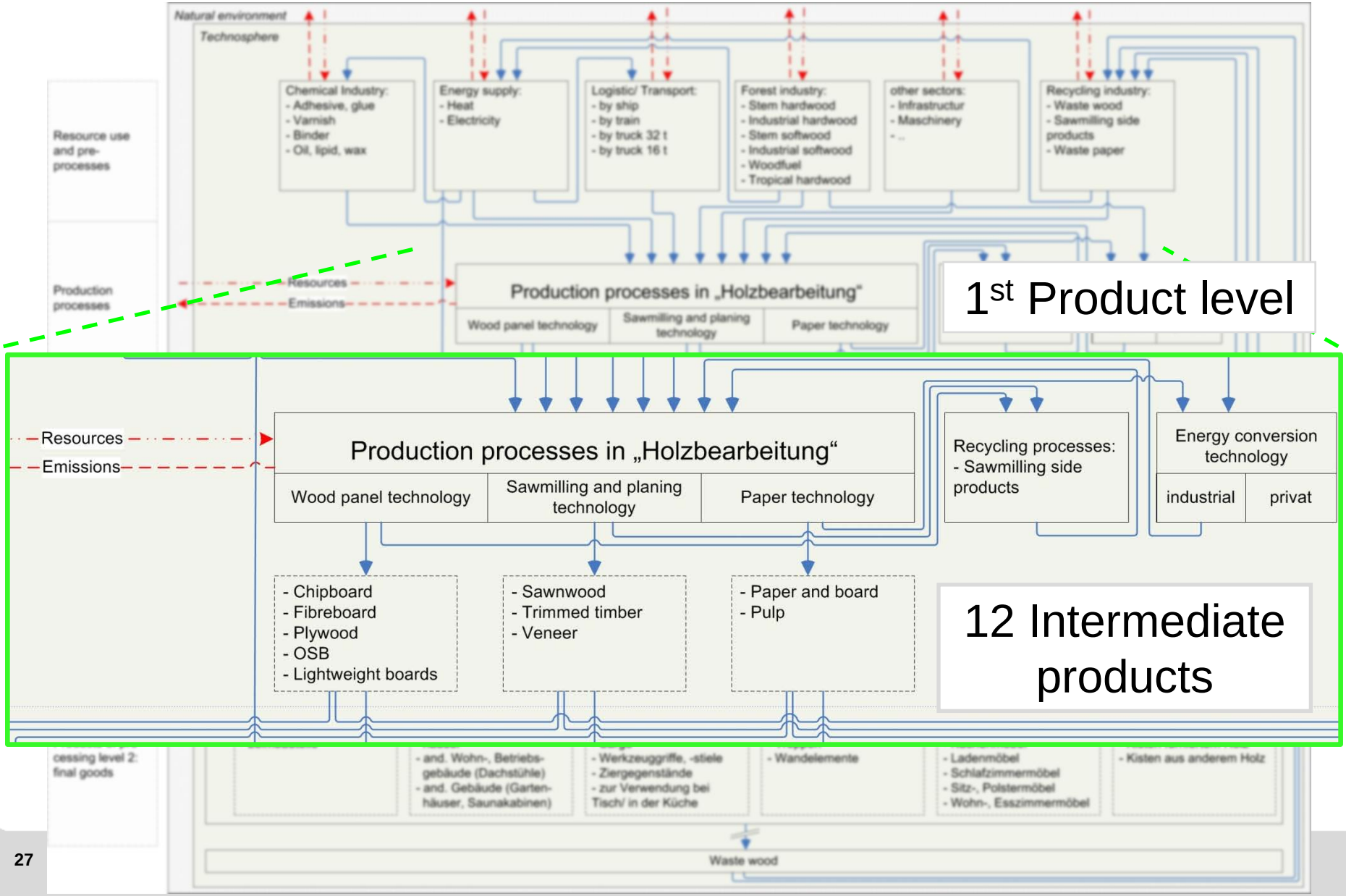

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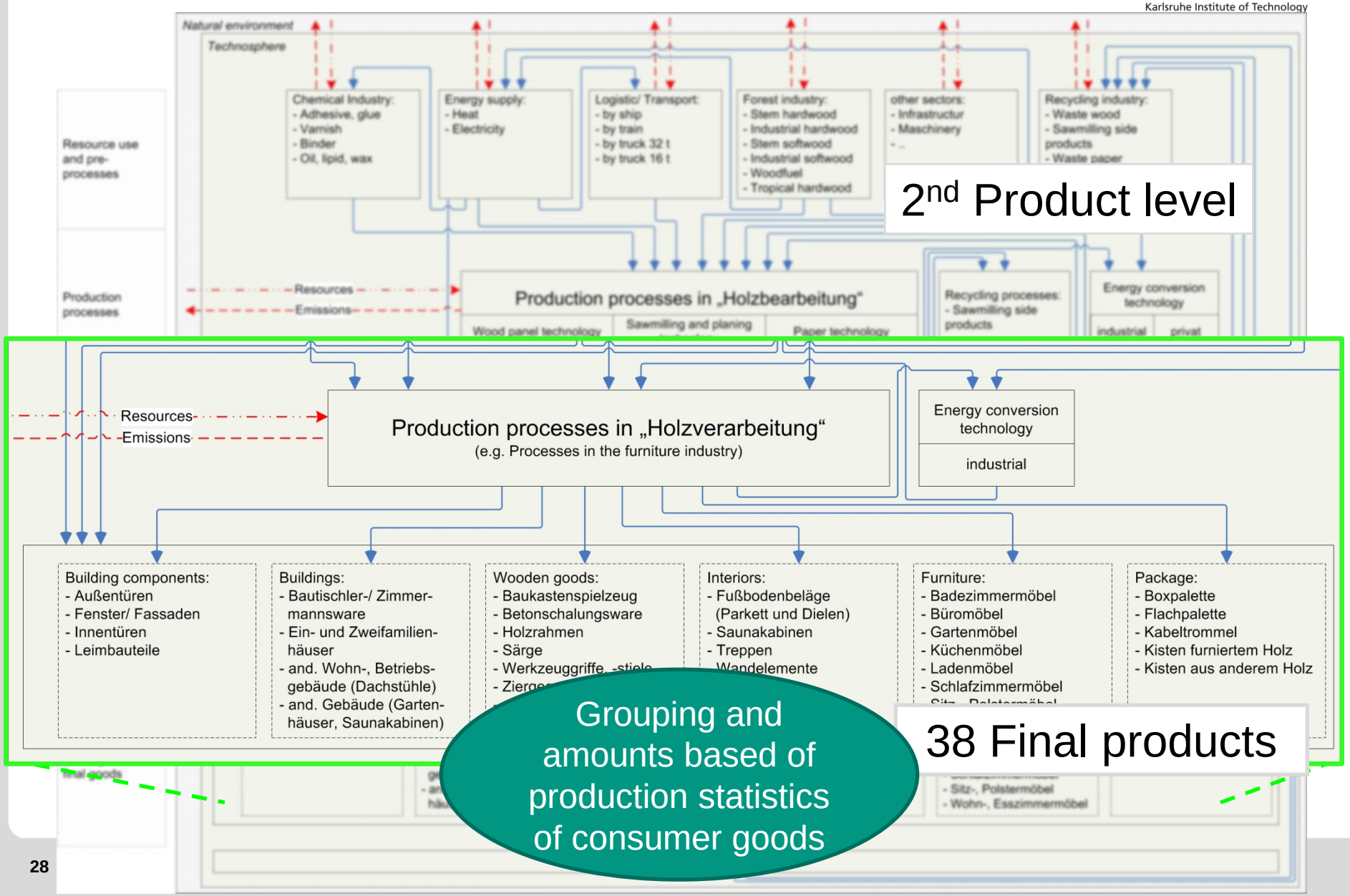
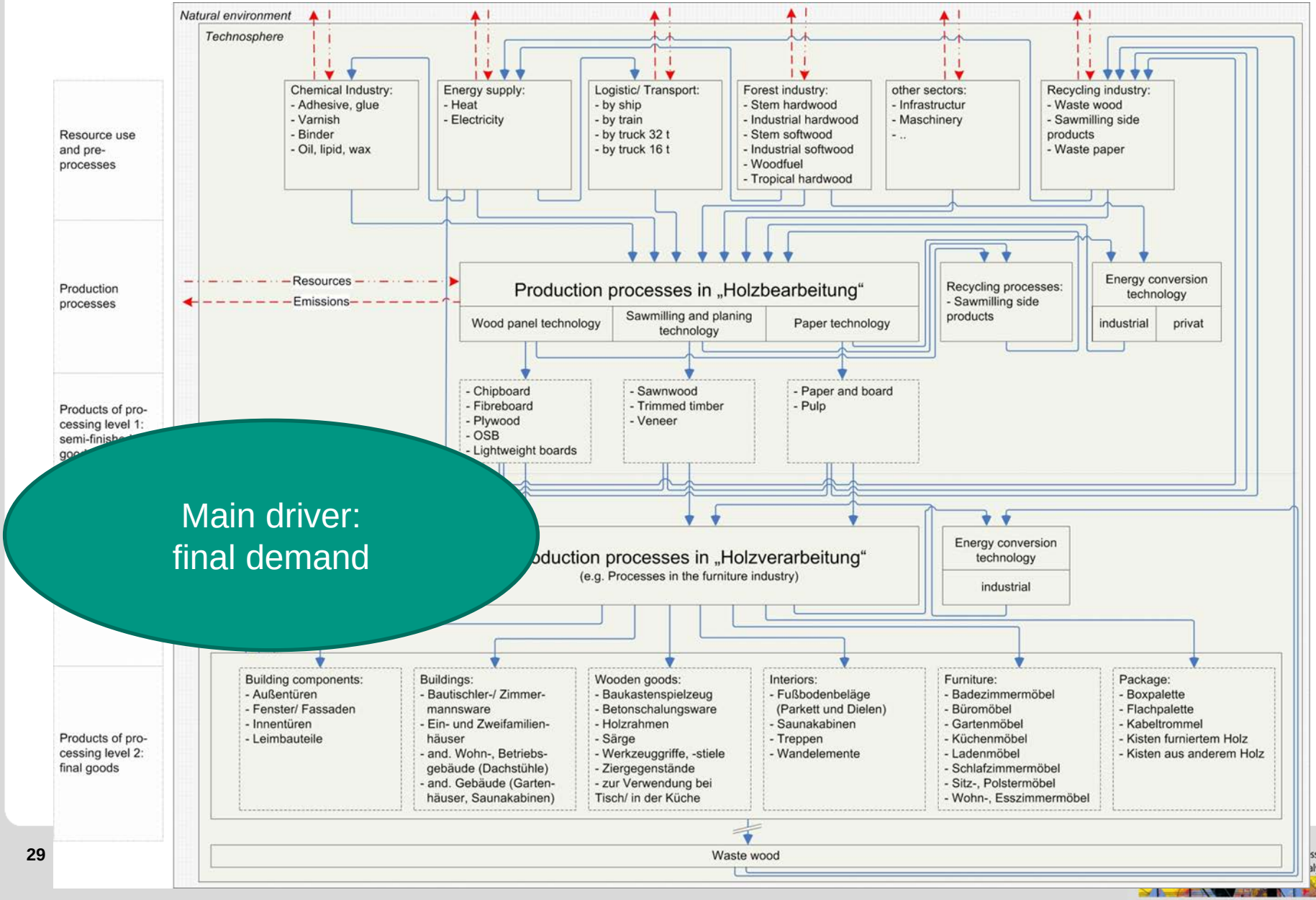


Process-based MFA – driver



Main driver:
final demand

Example

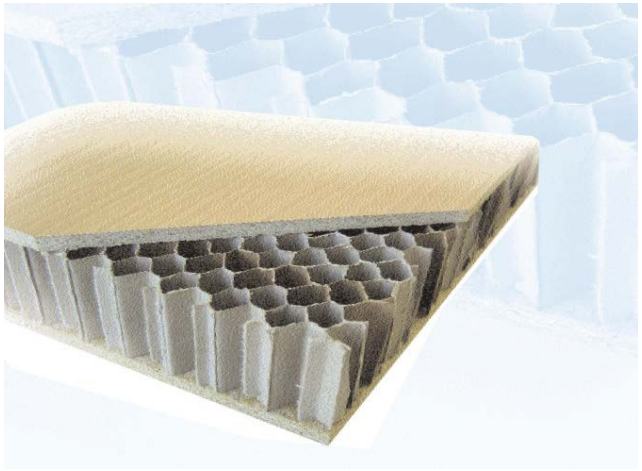
- Objective:

  Identification and quantification of the environmental impacts of using lightweight boards in the German forest-based industry

Conventional chip board

Source: www.glunz.de

Lightweight board



Quelle: Siempelkamp

Example

- Methods:
  - Process-based material-flow model
  - LCIA method such as Impact 2002+
  - Scenario technique
- Approach:
  - Defining of the systems boundaries: by domestic demand for forest-based products induced production in Germany
  - Modeling of all production processes and demand pattern
  - Estimation of future pattern of final demand (target years: 2015, 2025)
  - Evaluation of the system:
    - Requirements of raw materials
    - Environmental impacts of the whole industry

Reference system – status quo in 2005

- Depiction of the forest-based industry considering:
  - Products
  - Material and energy flows
  - Production quantities

- Data sources
  - Process data: ecoinvent data base, various studies, interviews with experts
  - Output data: production statistics of consumer goods
  - Future demand in 2015 and 2025: extrapolation of production statistics

Overview of scenarios

Scenario	2005	2015	2025
Reference system	Base year	Extrapolation of production statistics	Extrapolation of production statistics
Lightweight boards	Base year	**Additionally:** processing of lightweight boards	**Additionally:** processing of lightweight boards

Development of the production of furniture

- 2015: - 55% to + 15% (compared to 2005)
- 2025: - 80% to + 27% (compared to 2005)

Proportion of the lightweight board as share of the production volume of chipboard

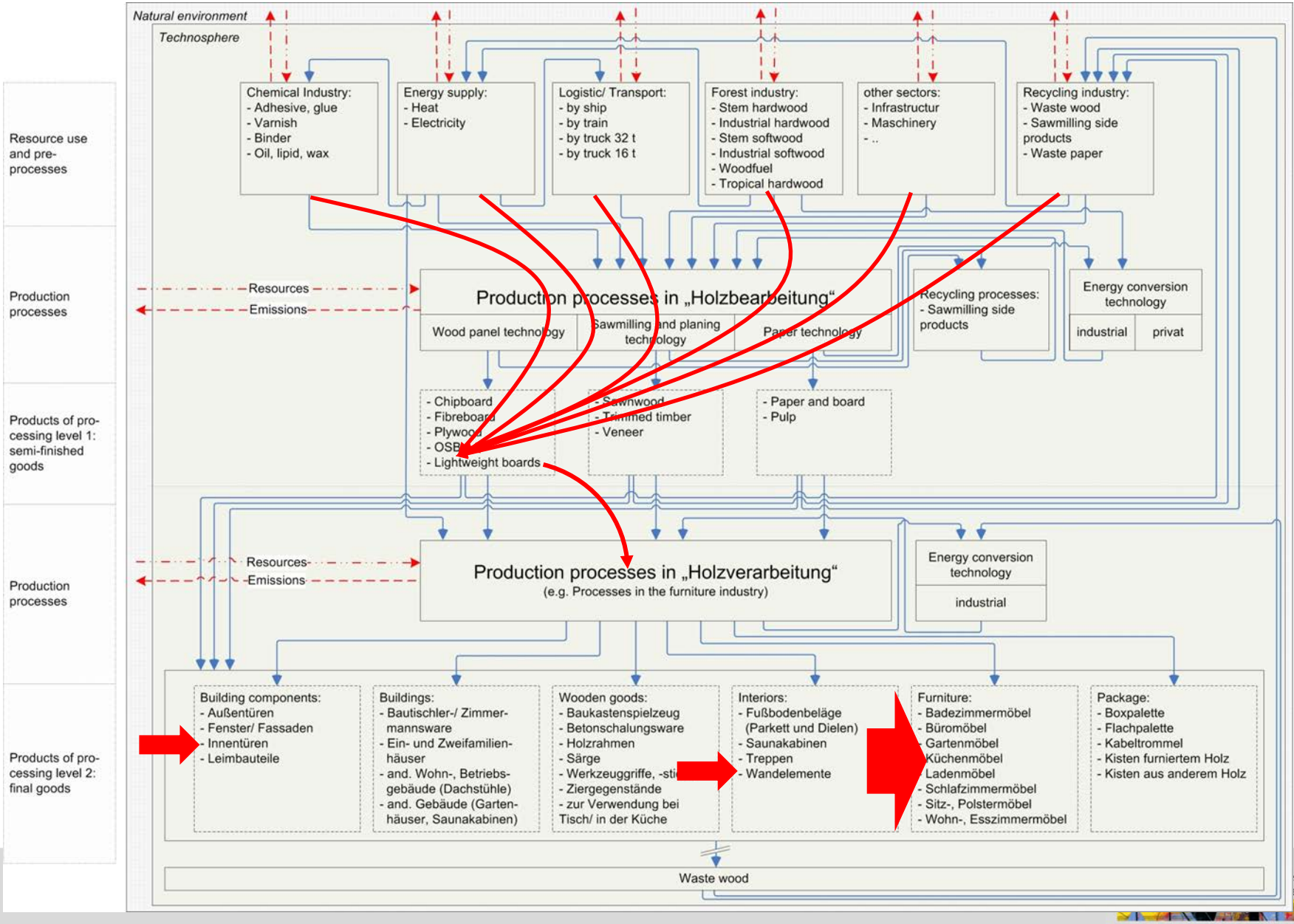
- 2005: 0,0%
- 2015: 13,5%
- 2025: 27,0%

Example of extrapolation: Kitchen corpus

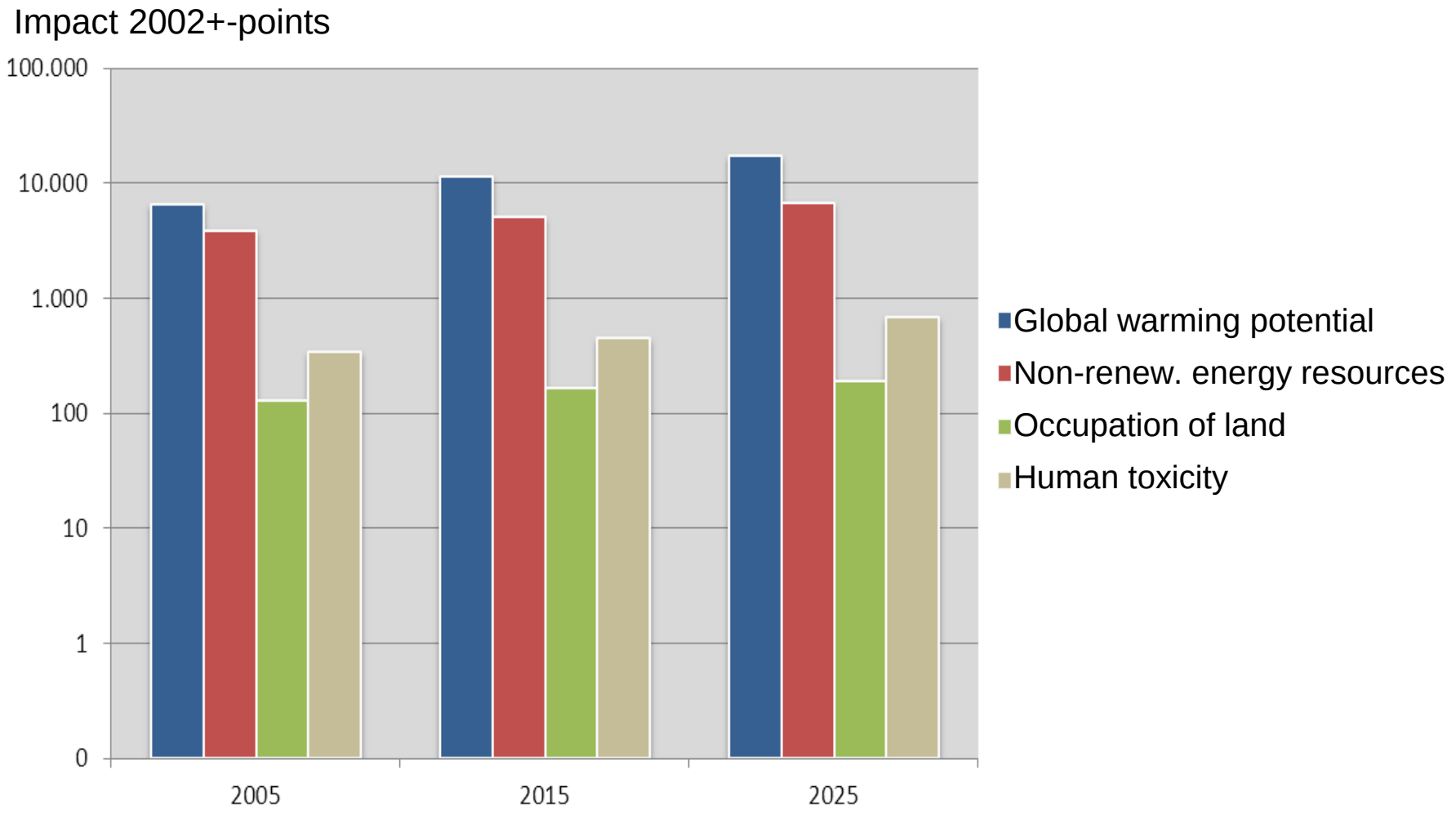
Güterproduktions-statistik Meldenr.		3613 10 500	Kücheneinbauelemente (Korpusse)	
Jahr	Produktion Möbelstücke [1.000 Stück]	Zuwachsrate [%]	arith. Mittel 1996-2007 [%]	Prognose der Produktions-menge [Stück]
1996	23.012	0,543%		
1997	23.137	3,540%		
1998	23.956	2,734%		
1999	24.611	-0,532%		
2000	24.480	0,768%		
2001	24.668	-2,663%		
2002	24.011	-2,028%		
2003	23.524	5,463%		
2004	24.809	3,297%		
2005	25.627	6,587%		
2006	27.315	-0,626%		
2007	27.144	-0,910%		
2008	26.897		1,348%	26.897.000
2009	..			27.162.261
2010				27.430.137
2011				27.700.656
2012				27.973.842
2013				28.249.723
2014				28.528.324
2015				**28.809.673**
2016		….		
2025				**31.780.375**

- Reference data: production in the years 1996 – 2007
- Calculation of mean average of growth (degrowth)
- Extrapolation of the production for the years 2015 and 2025

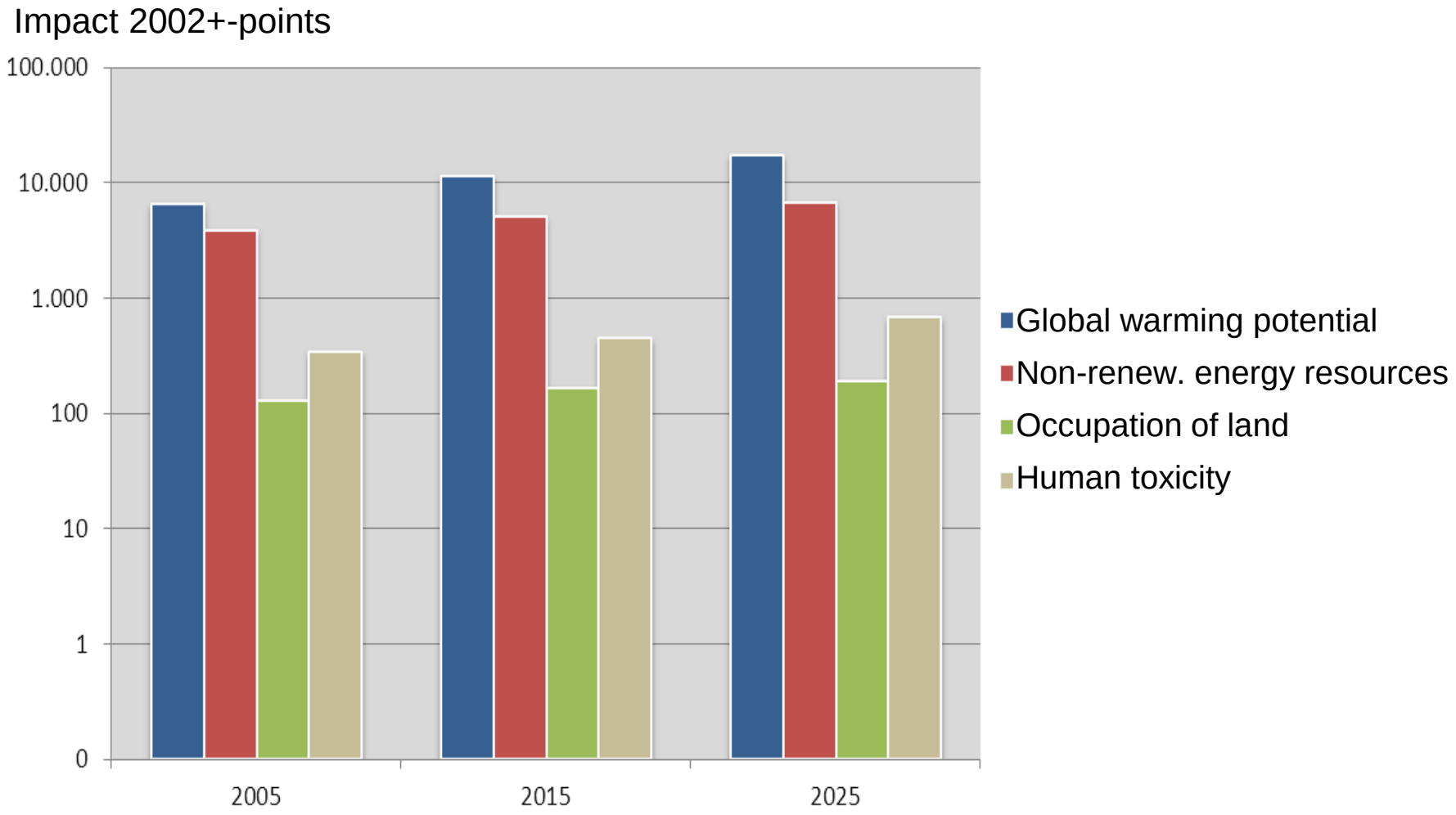
Lightweight boards in the system



Results of the reference system: development of the overall environmental impacts

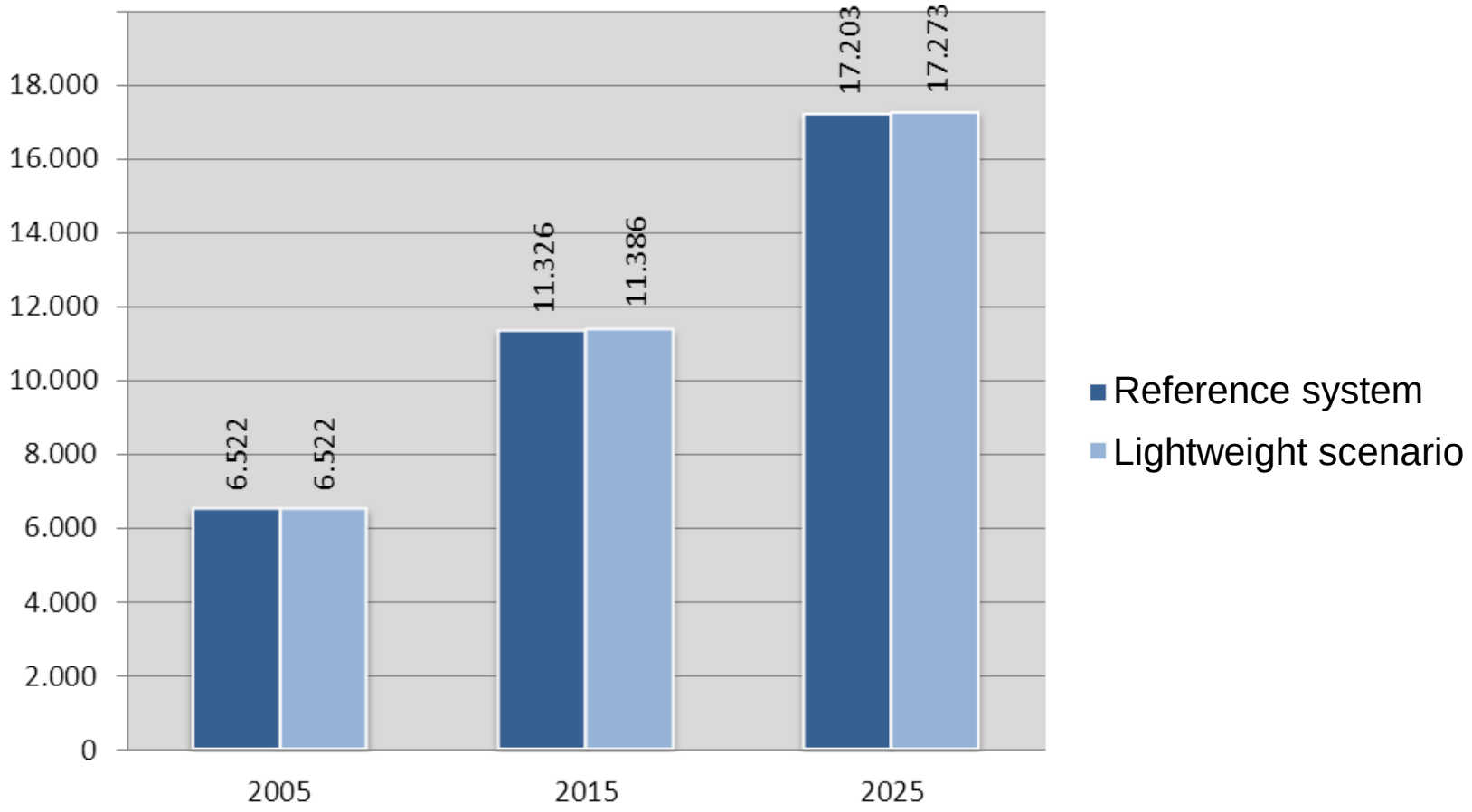


Results of the lightweight boards scenario: development of the overall environmental impacts



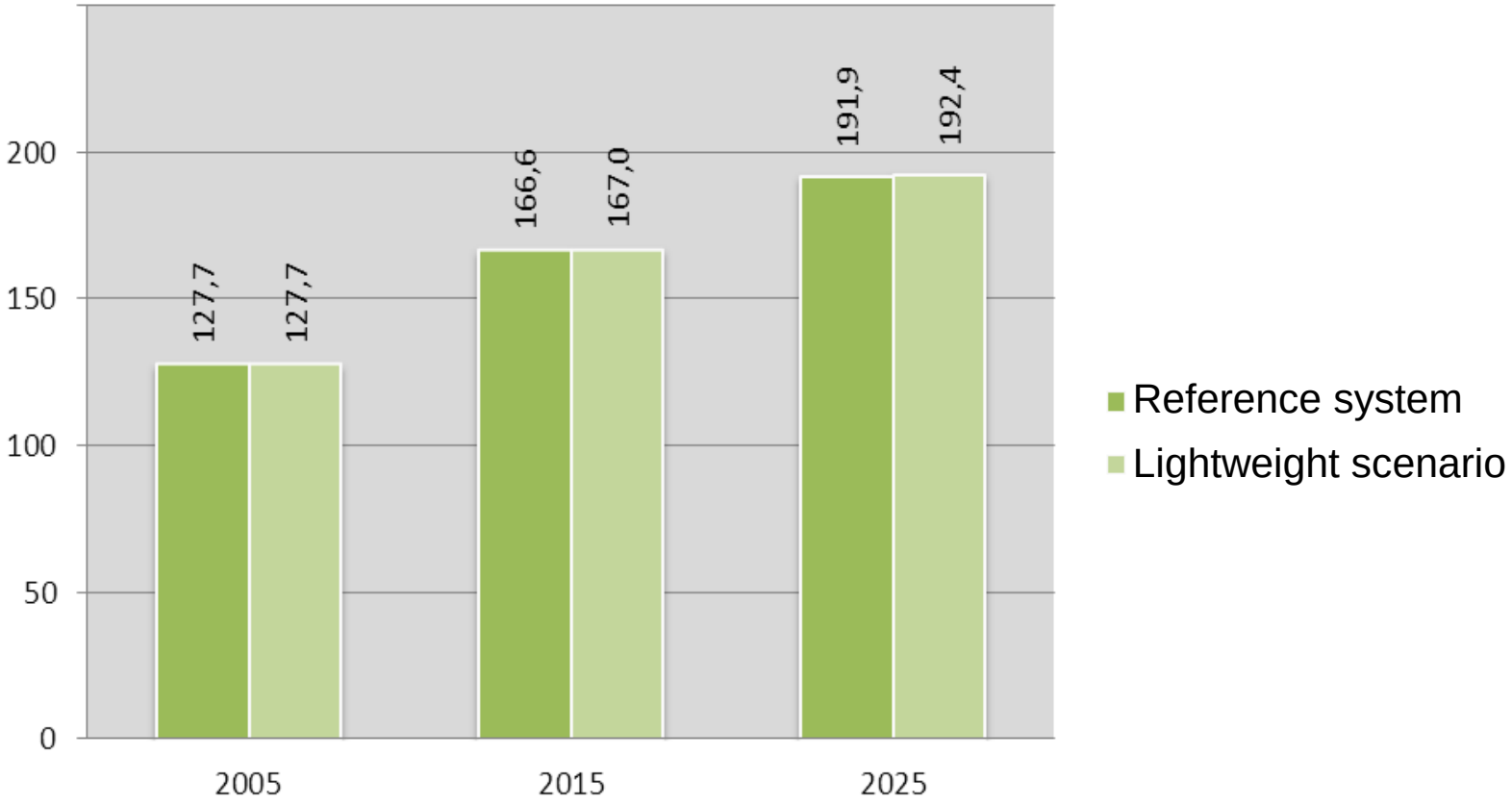
Results *Reference* vs. *Lightweight* – Global warming potential

Impact 2002+-points



Results *Reference* vs. *Lightweight* – Occupation of land

Impact 2002+-points



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Conclusions

- Process-based MFA ~ extended LCI

- Continuous increase of total impacts from 2005 until to 2025
  with linear behavior
- Environmental performance of sector is getting worse
  due to a overall increase of production

- Environmental impacts by using lightweight boards in the forest-based industry is barely recognizable, i.e.
  no significant environmental benefits
  but also no significant disadvantages

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