Die Kreislaufwirtschaft im Energiesystem

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IEK-3: Techno-Economic Systems Analysis

WELTGESCHICHTE

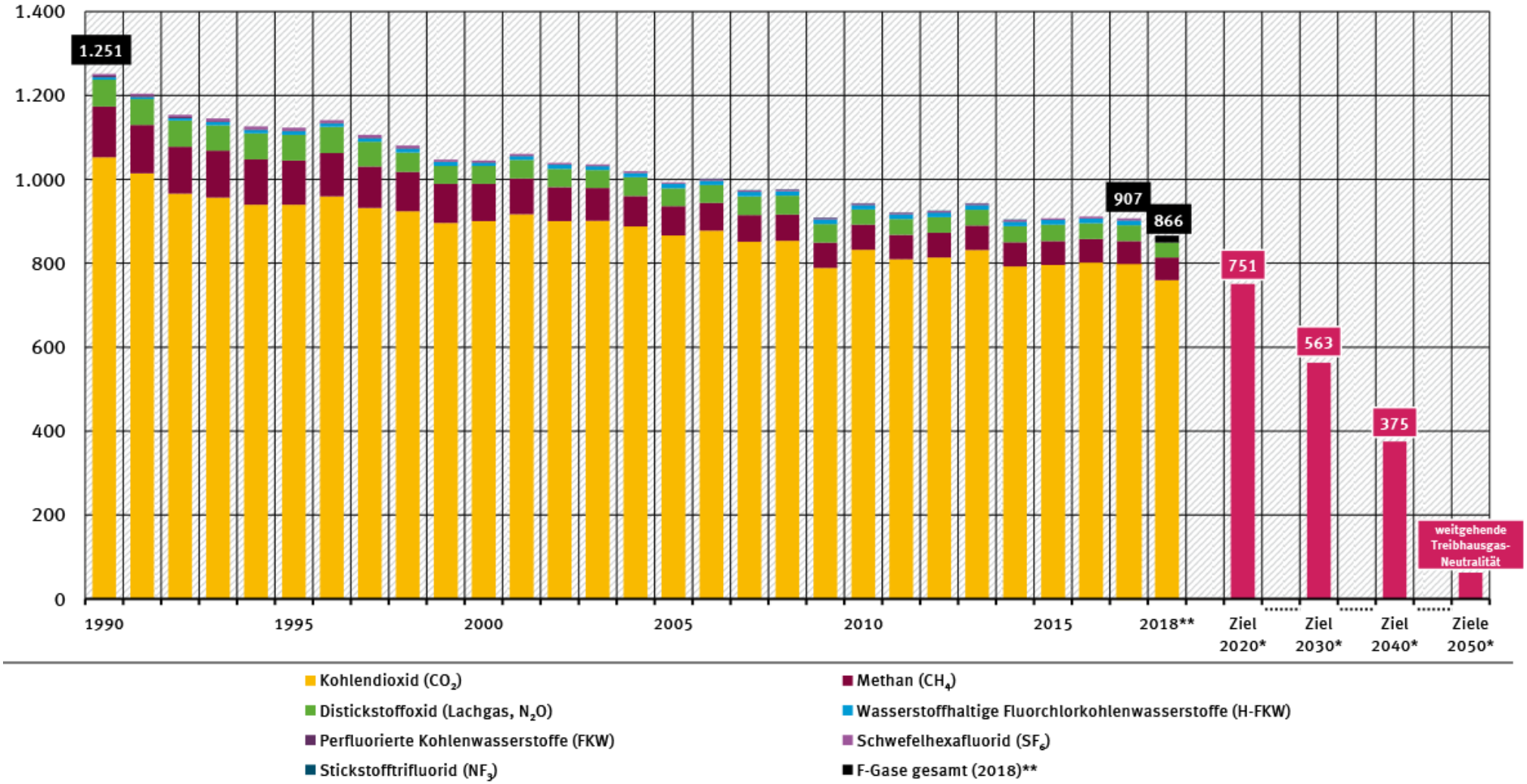
Asien schickt Abfall zurück nach Europa und Amerika

Asiatische Schwellenländer fühlen sich vom Westen als Mülldeponie missbraucht. Jetzt wehren sie sich – und schiffen den Müll wieder zurück. Das scheint erst der Anfang zu sein.

https://www.handelsblatt.com/politik/international/weltgeschichten/peer/weltgeschichte-asien-schickt-abfall-zurueck-nach-europa-und-amerika/24414430.html

The need to reduce greenhouse gas emissions

Million tons CO_2-equivalents of Germany



[1] https://www.umweltbundesamt.de/daten/klima/treibhausgas-emissionen-in-deutschland

Agenda

- Circular Economy
- Energy System Analysis
- Impacts of Energy Transition on Resource Availability
- Impacts of Resource Use on German Energy Transition

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- **Circular Economy**
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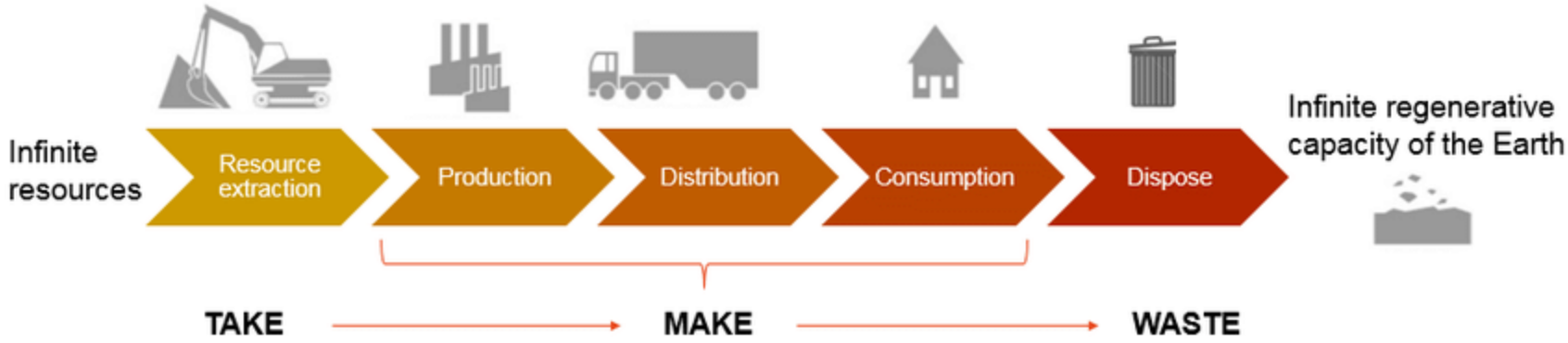
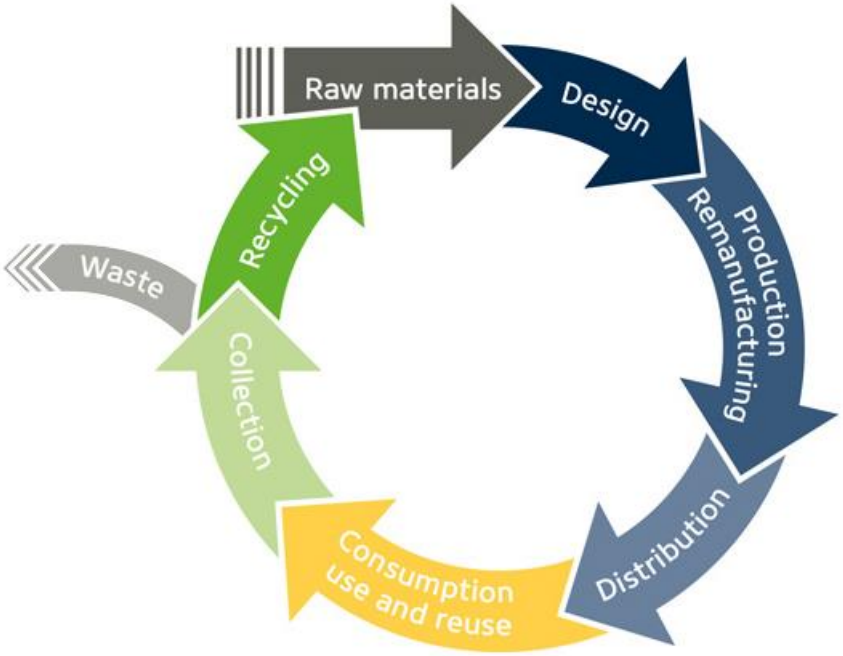
What is a Circular Economy?





Regenerative System

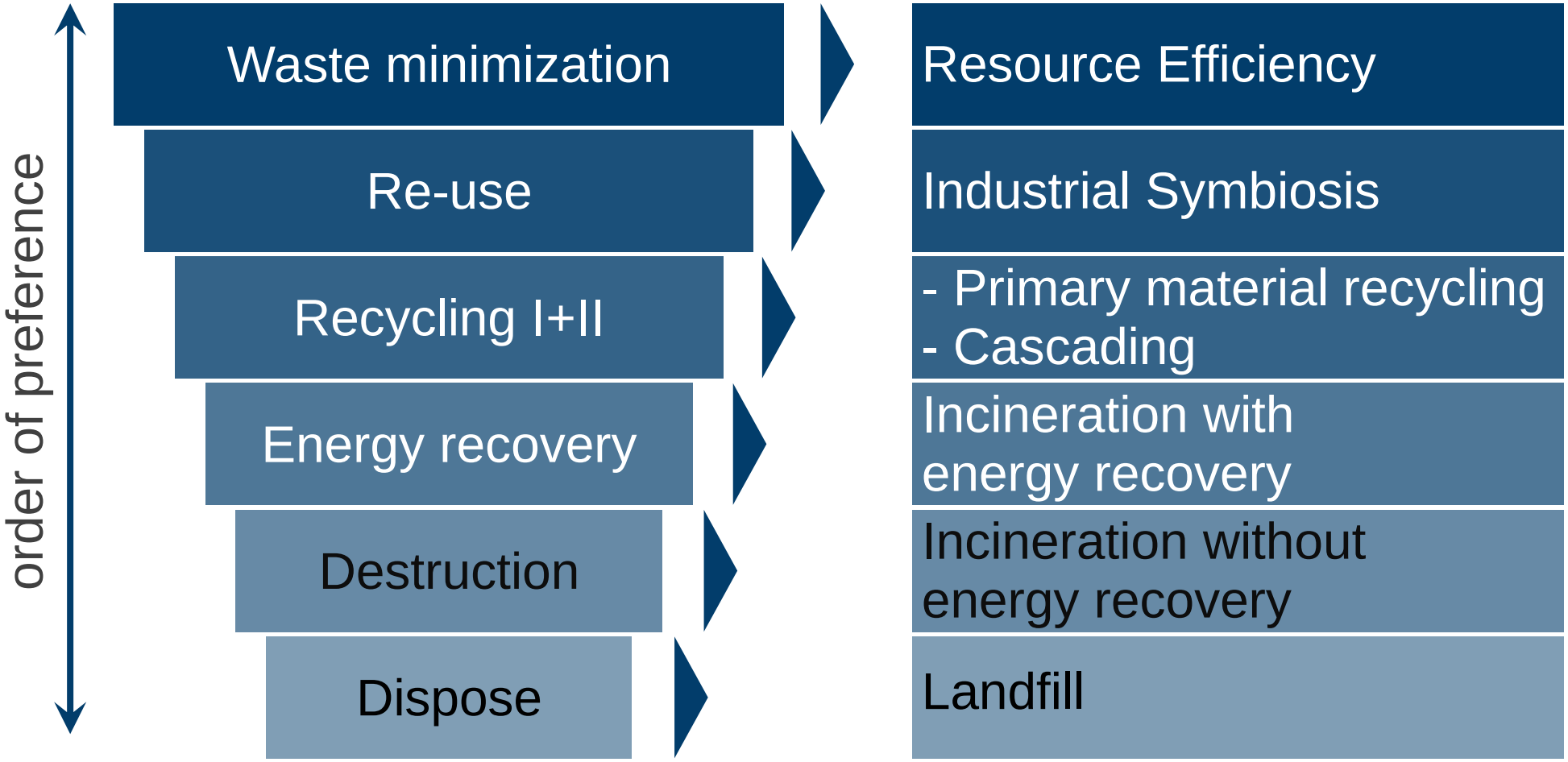
reduction of
- ▶ raw material input
- ▶ waste output
- ▶ emissions
- ▶ energy use

implementation of
- ▶ dfx (design for X)
- ▶ repair
- ▶ reuse
- ▶ recycling

[1] Wautelet, Thibaut. (2018). Exploring the role of independent retailers in the circular economy: a case study approach.
[2] https://www.nordic-ecolabel.org/why-choose-ecolabelling/circular-economy/

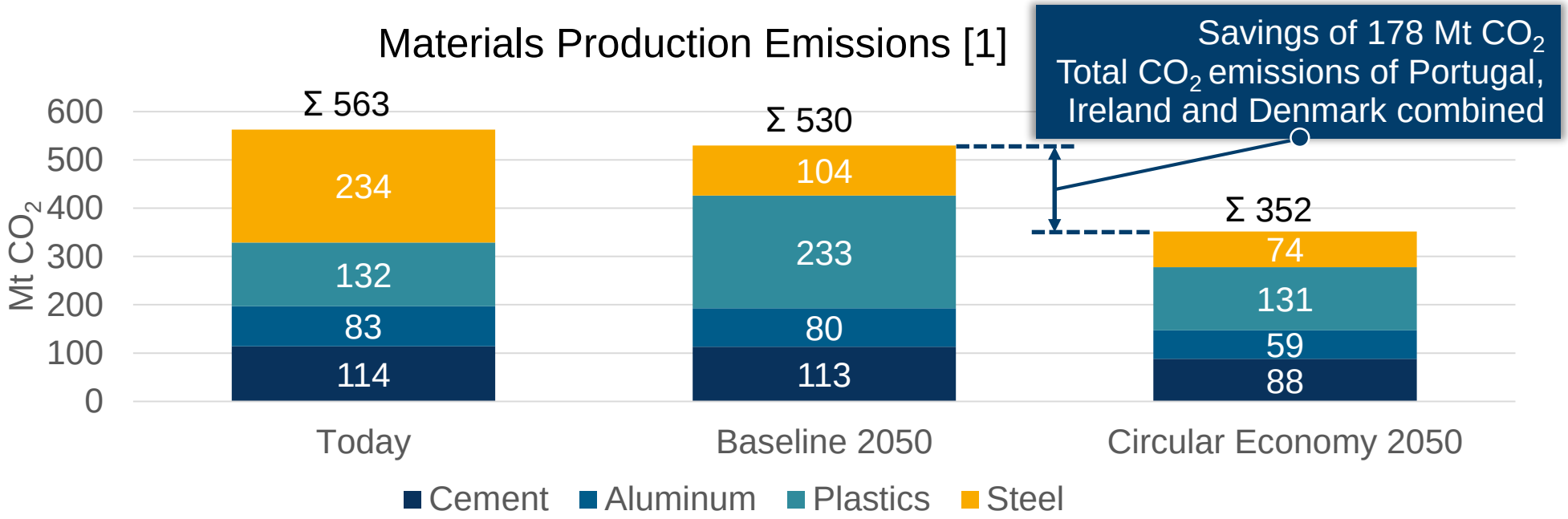
How to close material loops?

Waste Hierarchy



Why do we need a Circular Economy?

EU Emission Reduction Potential Using a Circular Economy



Baseline 2050

Steel	160 Mt/year, scrap-based production increases to 65%
Plastics	49 → 62 Mt/year production
Aluminum	12 → 16 Mt/year production
Cement	184 Mt/year production

Circular Economy 2050

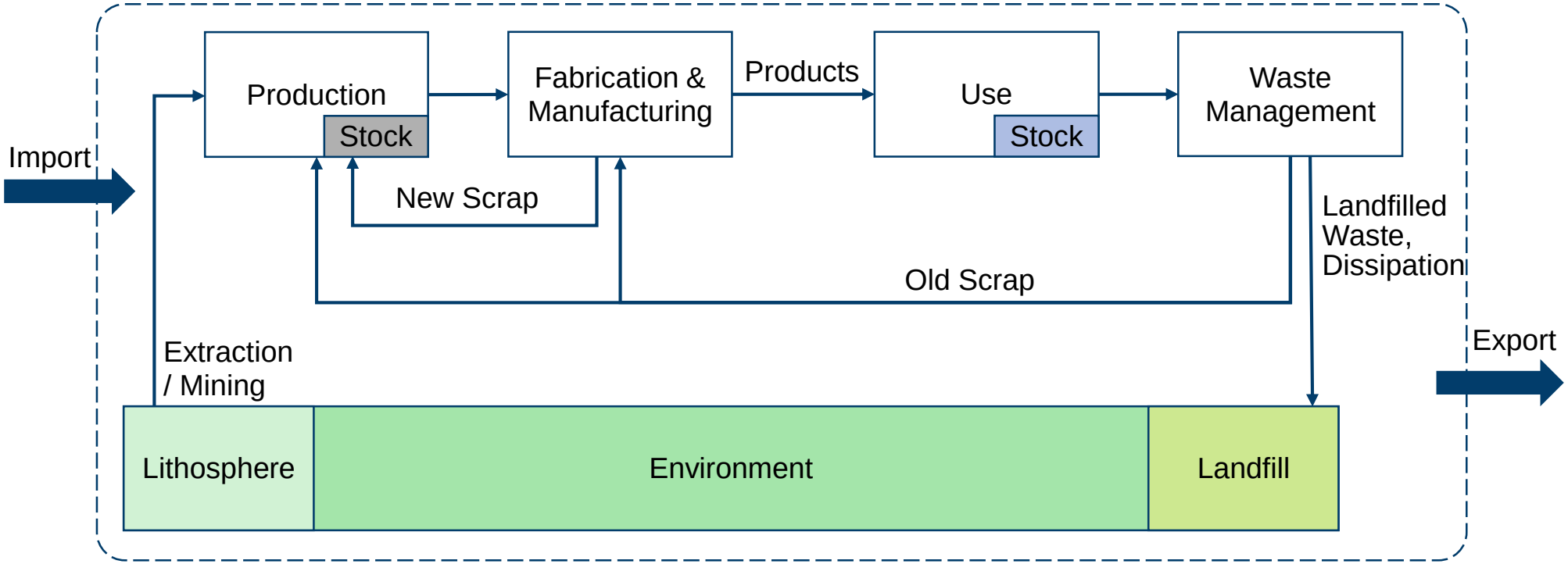
Steel	85% scrap-based production
Plastics	collection rate of 85%
Aluminum	60% scrap-based production
Cement	30-50% unreacted cement in demolition waste

[1] European Commission, 2018. In-depth analysis in support of the commission communication com-773

How to assess a Circular Economy?

Material and Substance Flow Models

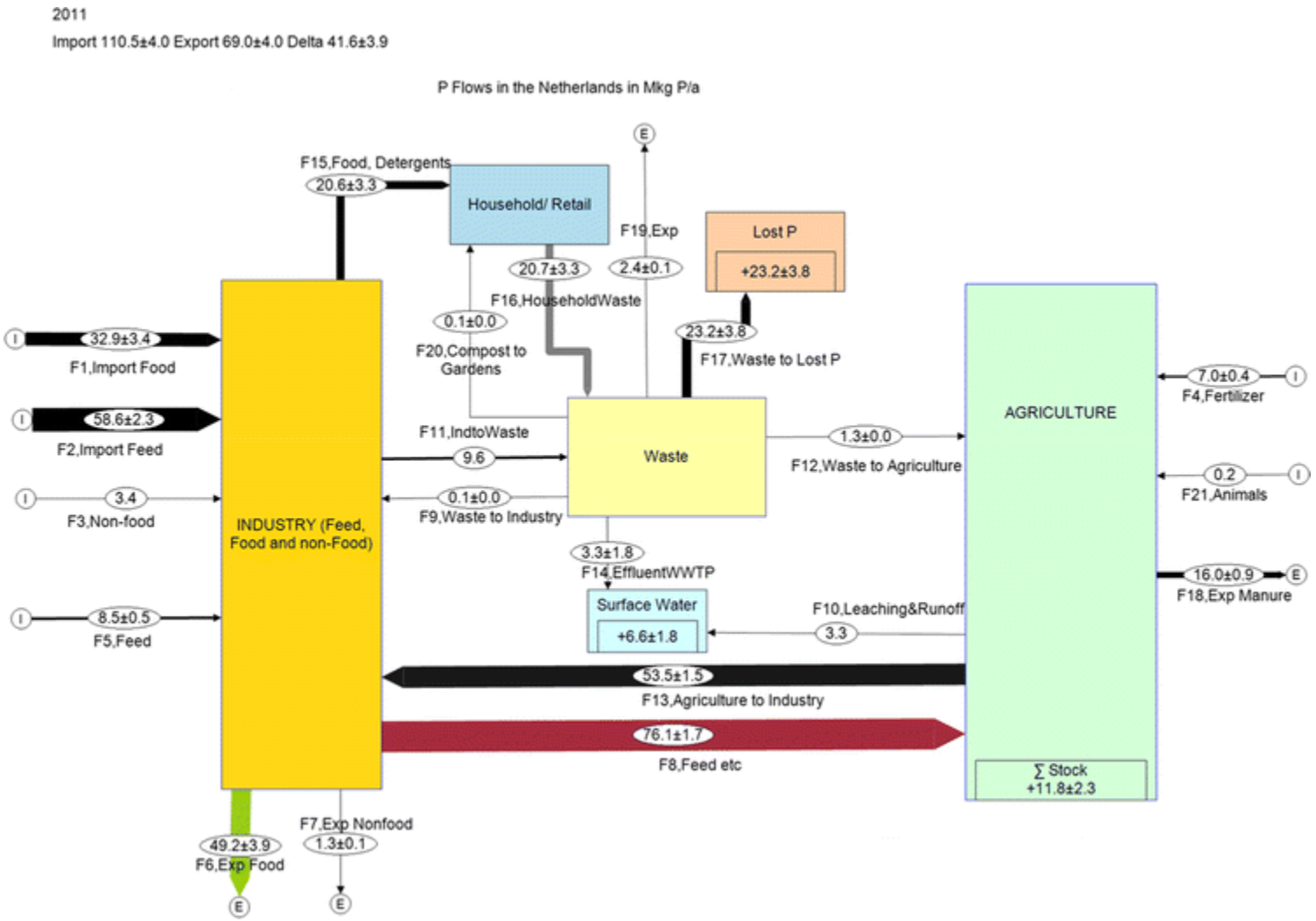
"Material flow analysis provides a systematic assessment of flows and stocks (of a specific material) within a defined system in space and time"[1]



[1] Smith et al. 2015. A substance flow analysis of phosphorus in the food production, processing and consumption system of the Netherlands. Nutrient Cycling in Agroecosystems 103 (1), pp. 1-13

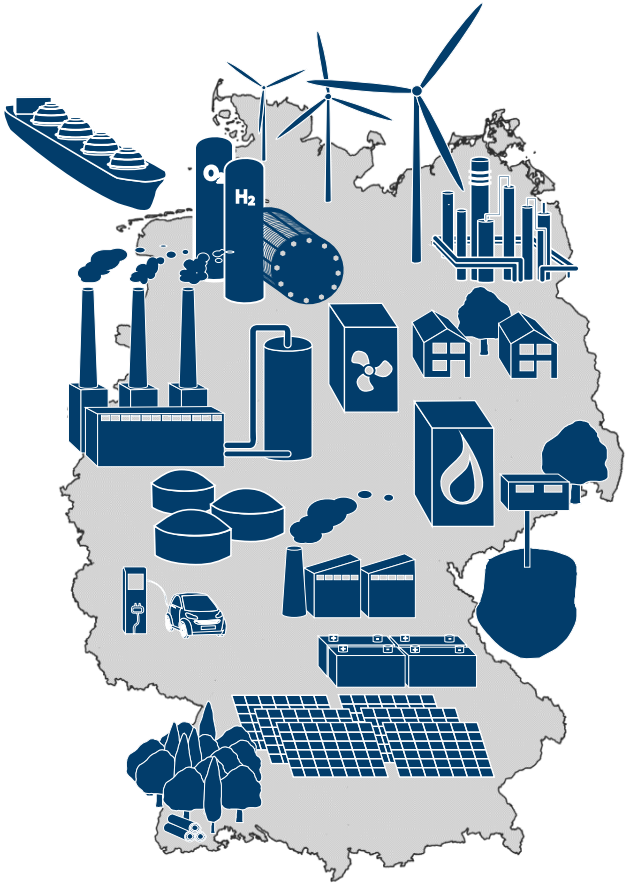
How to assess a Circular Economy?

Material and Substance Flow Analysis



[1] Smith et al. 2015. A substance flow analysis of phosphorus in the food production, processing and consumption system of the Netherlands. Nutrient Cycling in Agroecosystems 103 (1), pp. 1-13

How does a circular economy influence the German energy system?



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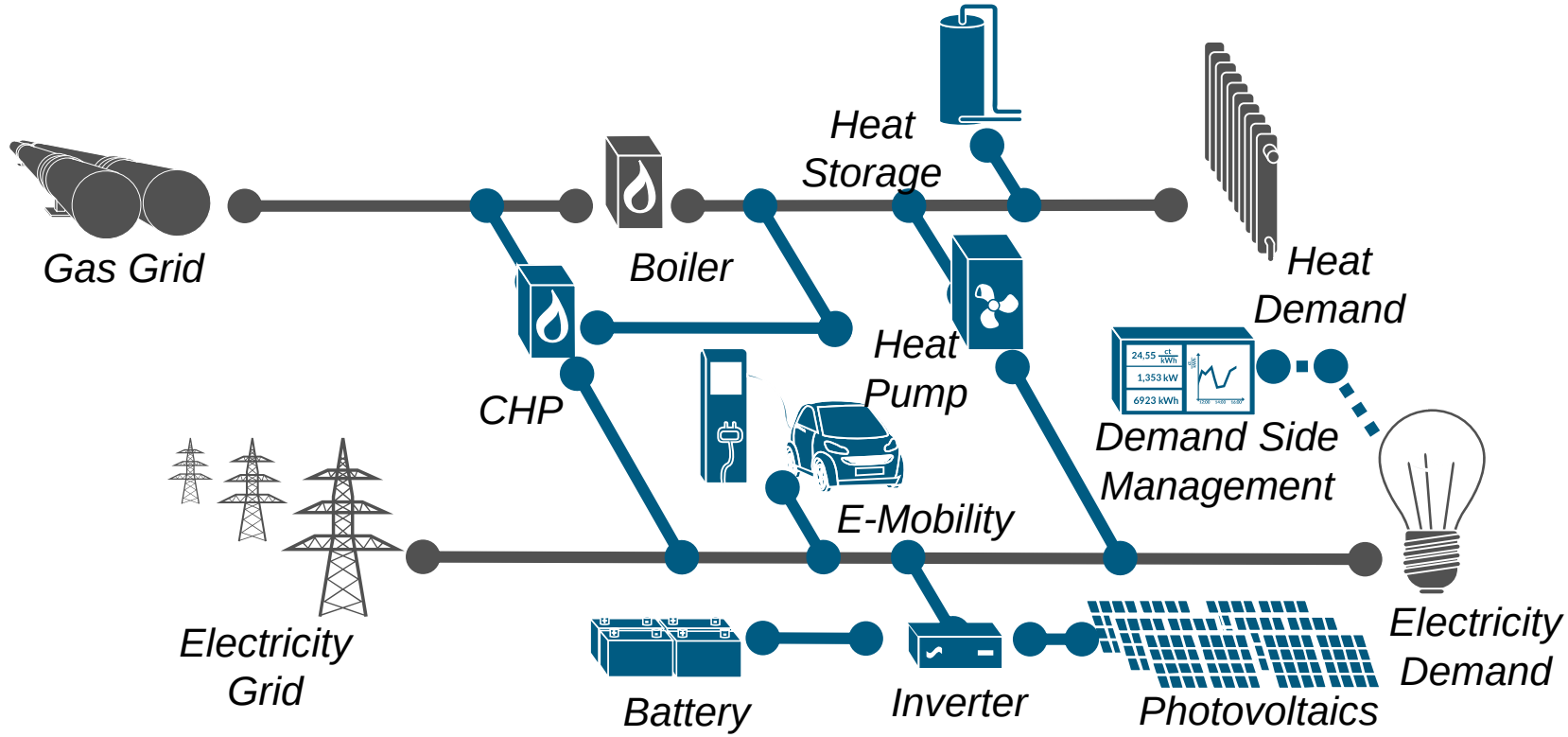
- Circular Economy
- **Energy System Analysis**
- Impacts of German Energy Transition on Resource Availability
- Impacts of Resource Use on German Energy Transition

What are Energy System Models?

'Energy systems models are important methods used to generate a range of insight and analysis on the supply and demand of energy.' [1]



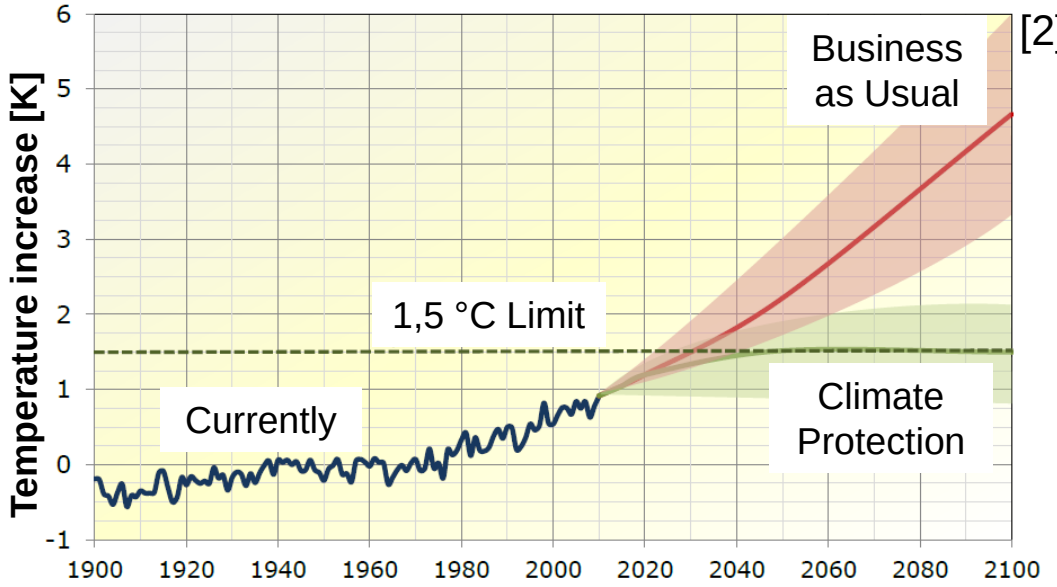
[1] S. Pfenninger, A. Hawkes and J. Keirstead: Energy systems modeling for twenty-first century energy challenges. Renewable and Sustainable Energy Reviews, 33, pp. 74-86. 2014.

Why do we need Energy System Models?

Example

Find and evaluate transformation strategies to achieve GHG-reduction

'Holding the increase in the global average temperature to well below 2 °C above pre-industrial levels and to pursue efforts to limit the temperature increase to 1.5 °C above pre-industrial levels […]' [1] (Aim of Paris Agreement)

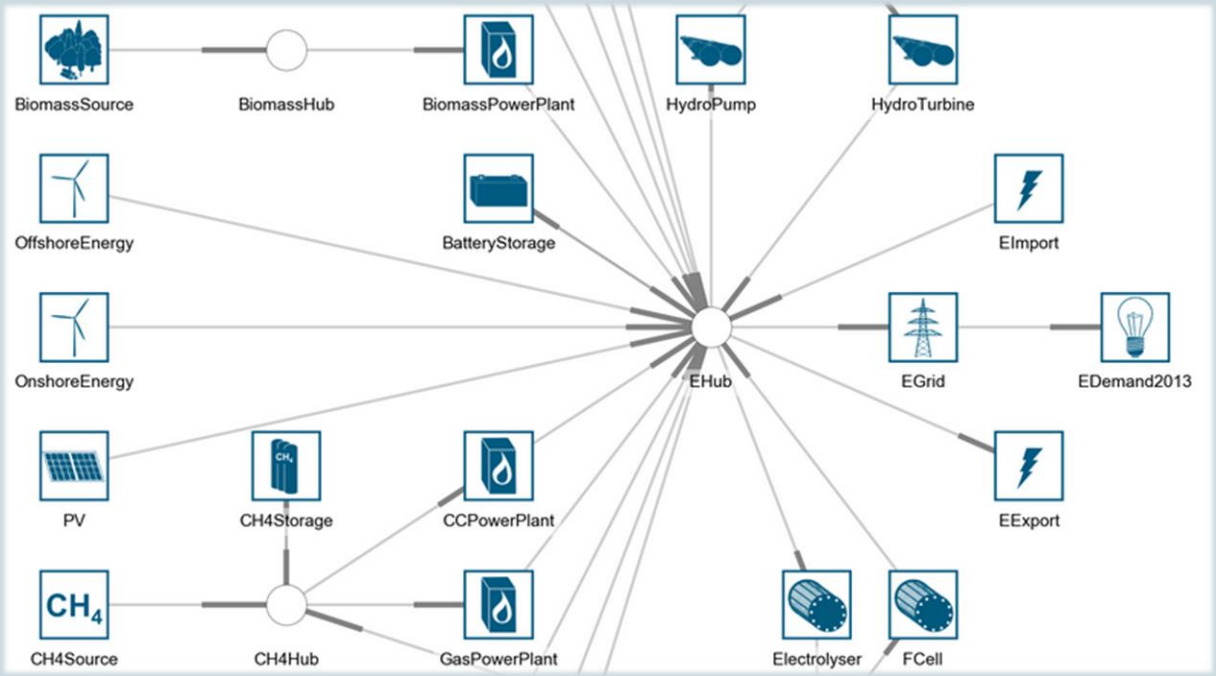


[2]

[1] United Nations Framework Convention on Climate Change, Paris Agreement (FCCC/CP/2015/L.9/Rev.1), § 2.1(a). 12/12/2015
[2] V. Quaschning. Sektorkopplung durch die Energiewende. Hochschule für Technik und Wirtschaft HTW Berlin. 2016

General Approach of an Energy System Model

Network of defined **nodes**
(sources, sinks, storages, transformers, hubs)
and **edges** (energy and mass flows).

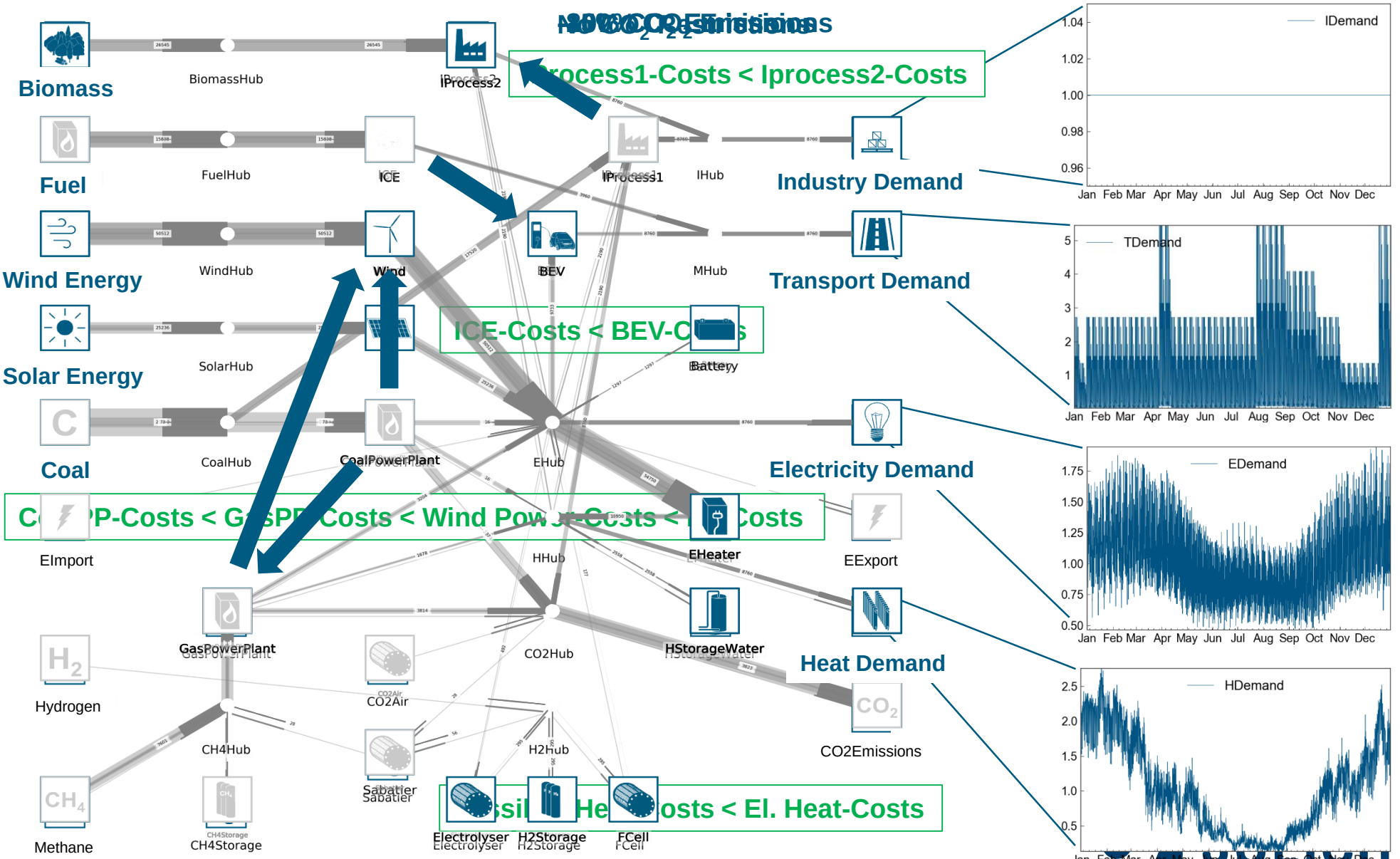


System of linear equations (LP)

- Data processing
- Objective function
- Constraints
- Visualization

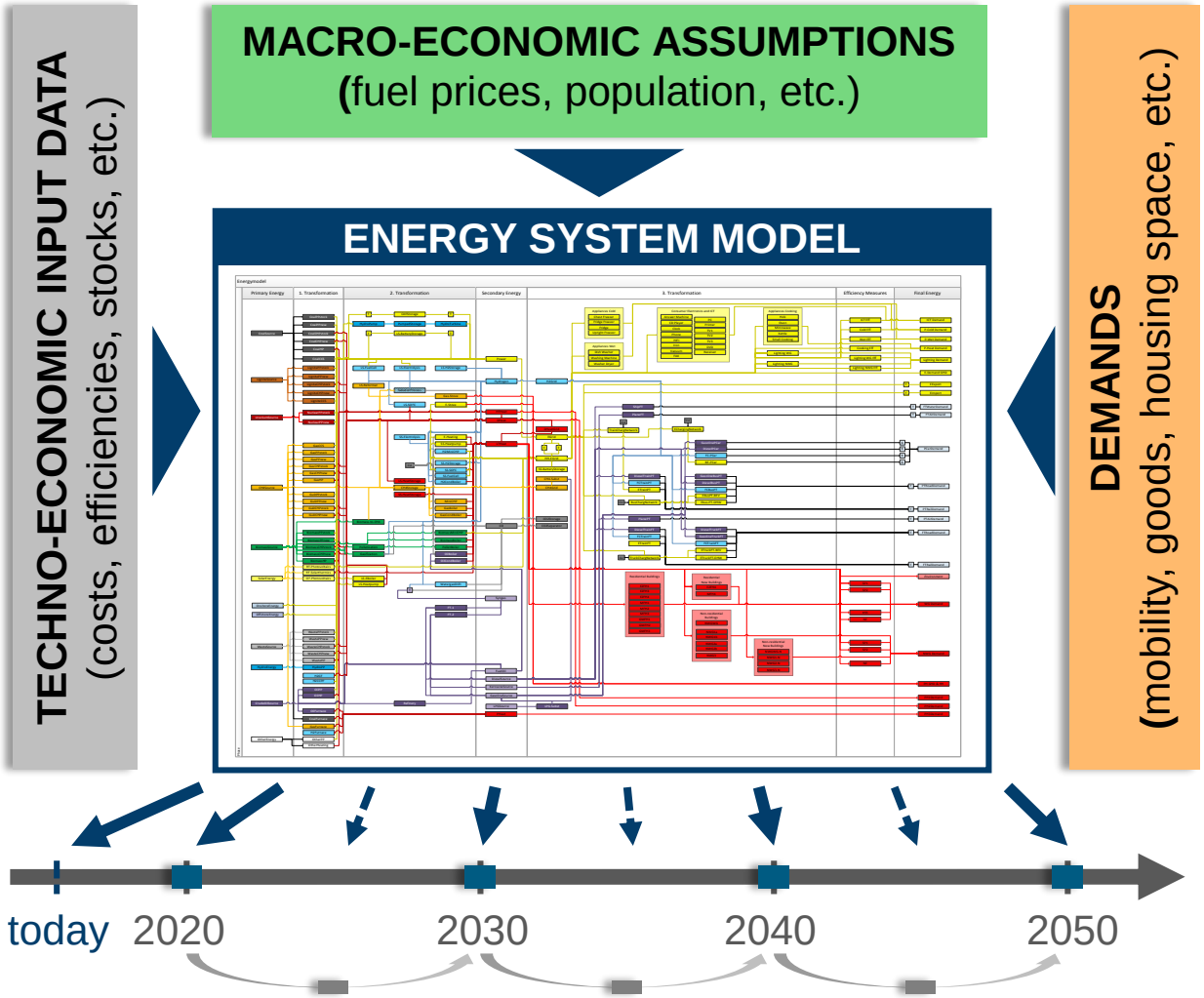
→ **Least-cost energy system**

General Approach of an Energy System Model



Energy System Model

'How does the least-cost future energy system of Germany look like under consideration of climate goals?'



Basic Approach

Integrated energy system model

- Hybrid bottom-up approach
- Quadratic Programming – Cost Optimization
- Myopic transition analysis
- Time series aggregation
- Temporal resolution of 1 hour
- Spatial pseudo-resolution of 9 regions

Highlights

- Detailed implementation of:
  - PtX technologies
  - Infrastructural aspects
  - Biomass allocation
  - Energy efficiency measures
  - Energy storage technologies
- Consideration of cost uncertainties
- Interaction with other models

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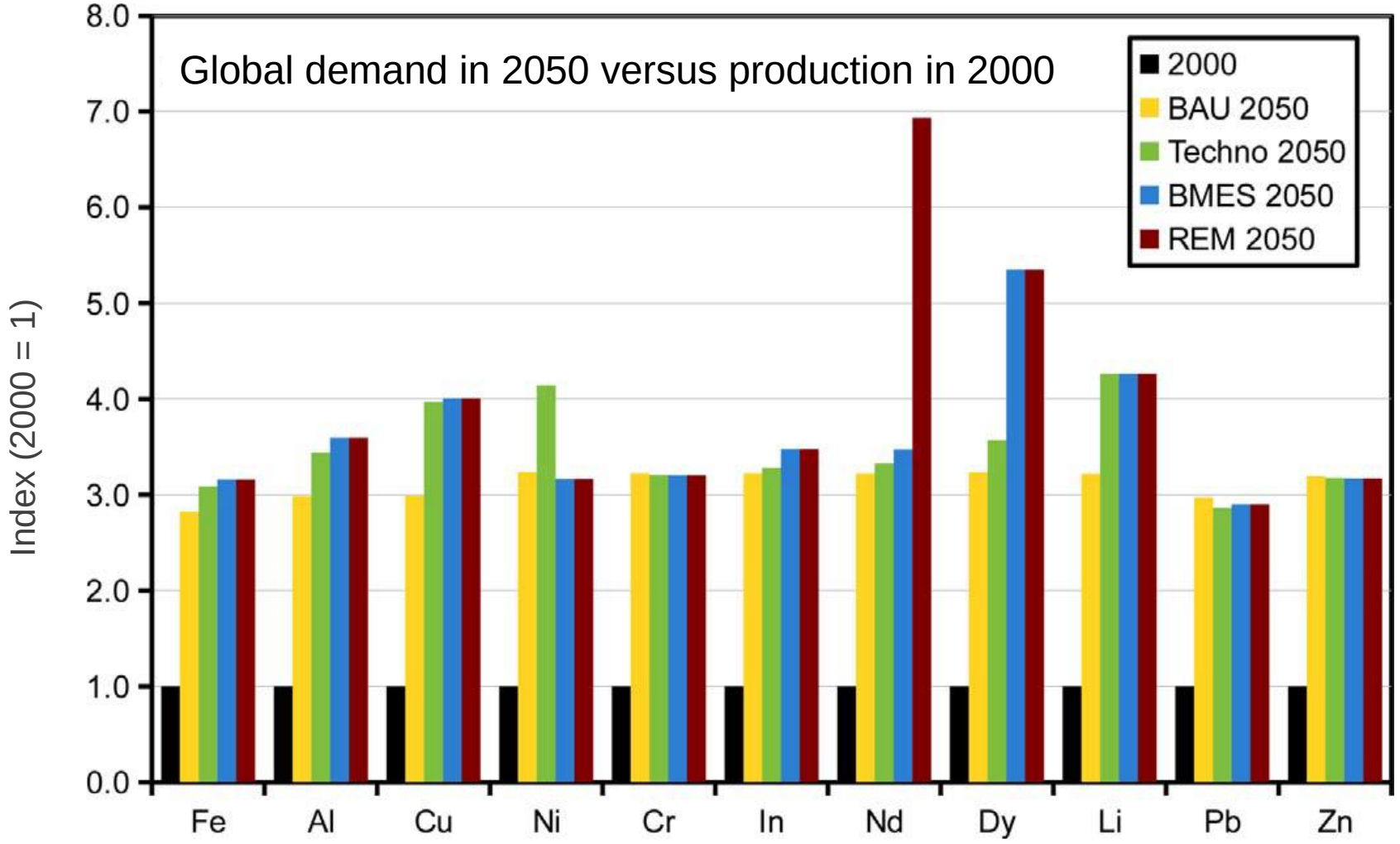
How does the low-carbon energy transition impact resource availability?

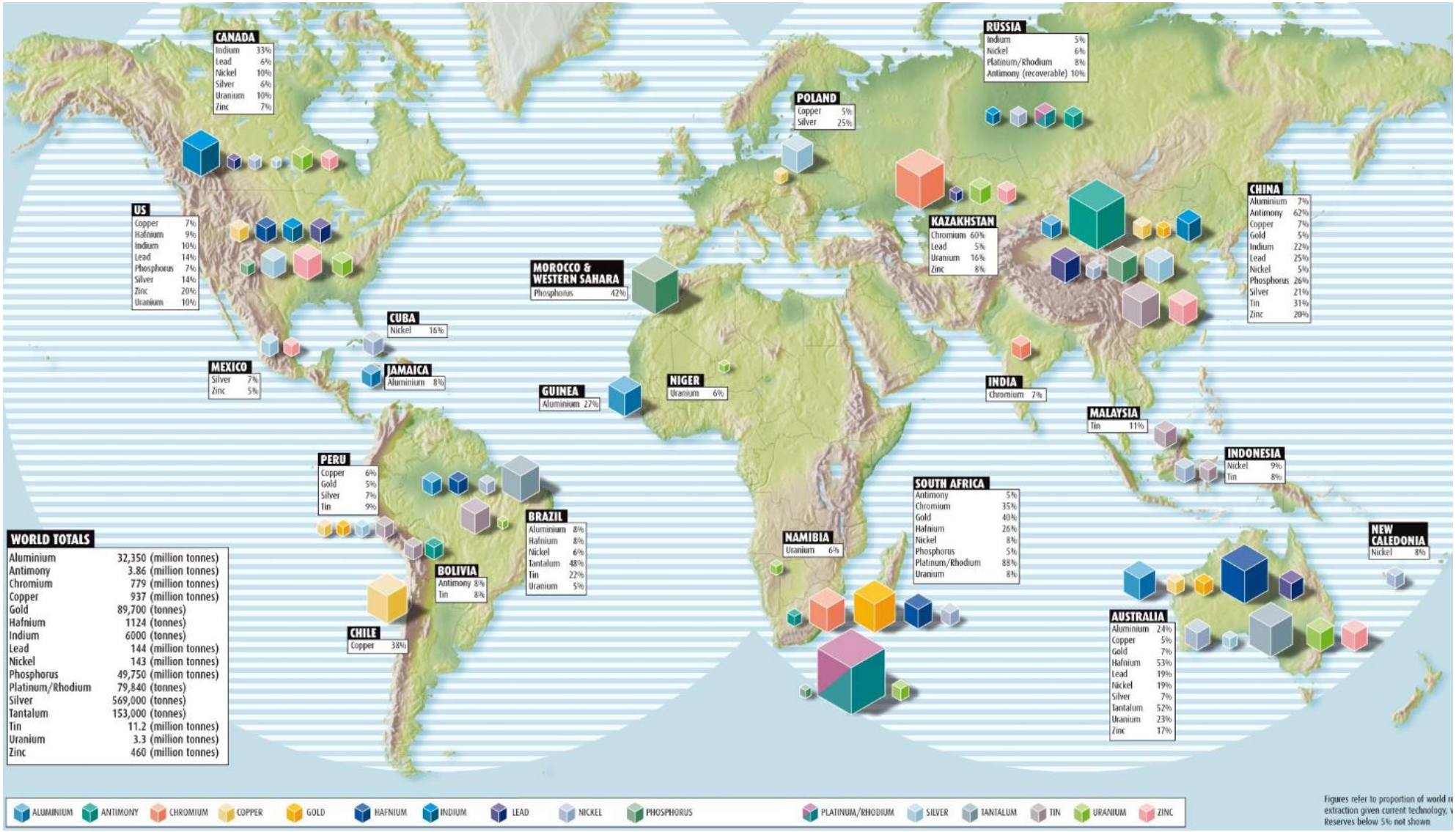
[1] Vidal et al. (2013) Metals for a low-carbon society. Nature Geoscience (6)

How does the low-carbon energy transition impact resource availability?



[1] Koning et al. (2018) Metal supply constraints for a low-carbon economy

Where are the metals and minerals?



[1] https://www.newscientist.com/article/mg19426051-200-earths-natural-wealth-an-audit/

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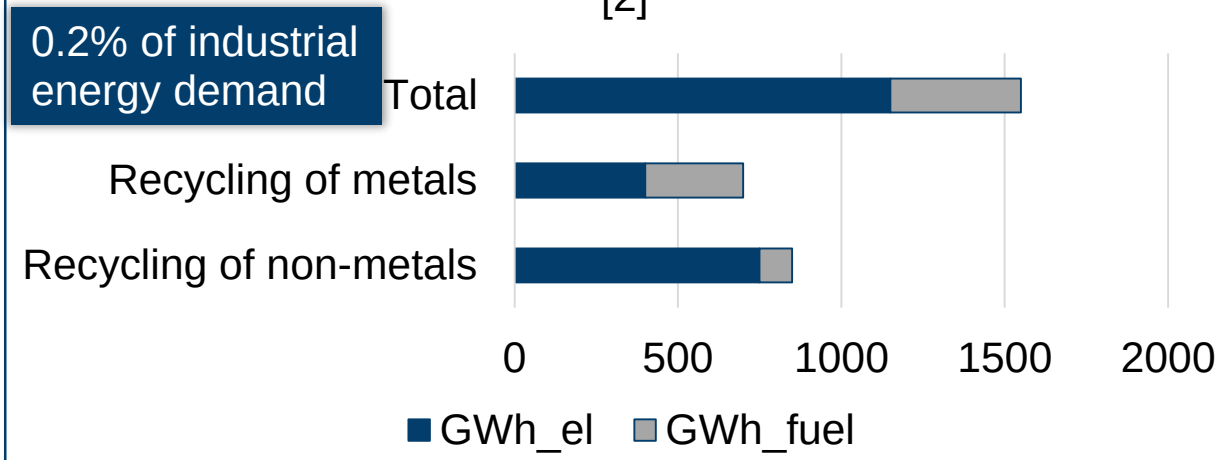
Recycling in Germany – Example: Steel

German primary and secondary steel production [1]

Blast Furnace 70.4 %	Electric Arc Furnace 29.6%
Yearly production 2015	
30.05 Mt	12.6 Mt
CO_2 emissions per ton of steel	
1.744 t CO_2	0.395 t CO_2
Energy use per ton of steel	
4.93 MWh	1.20 MWh

Energy demand of the German recycling industry [2]



Specific energy demand [2]
~150 kWh / t of recycled metal

Recycling can provide significant energy savings for a small trade-off

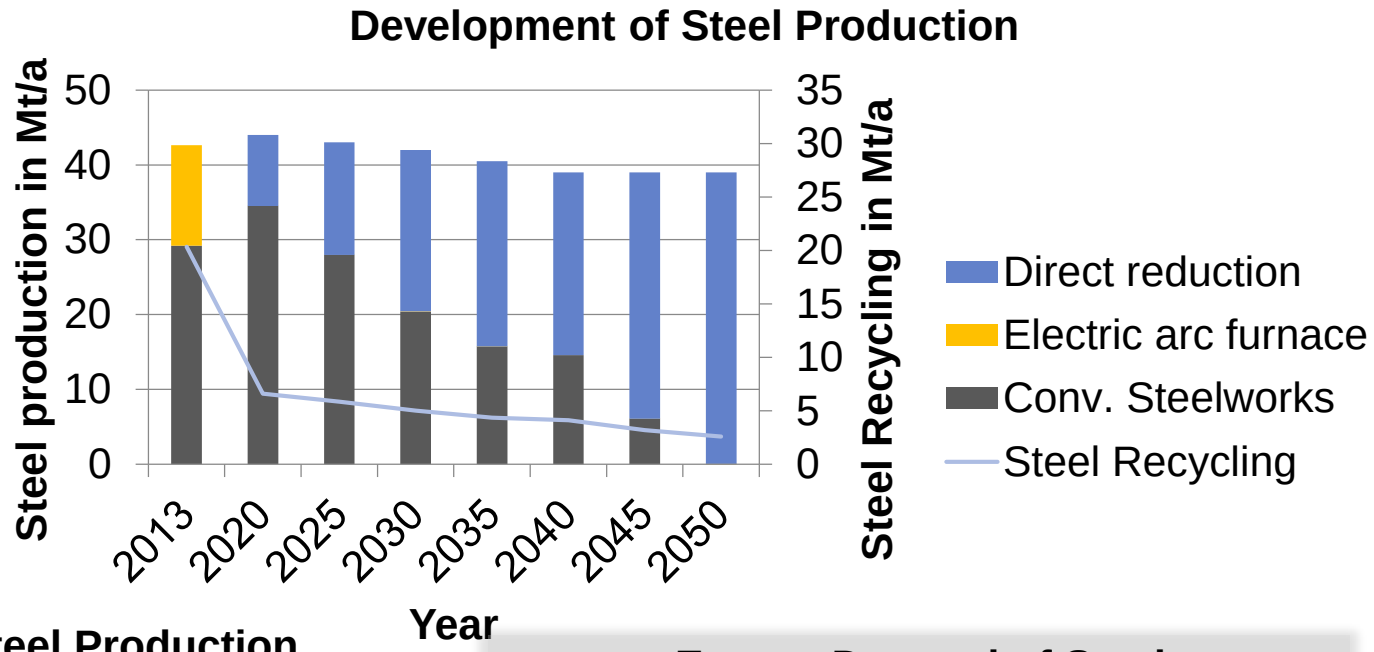
[1] Hiebel, M.; Nühlen, J. (2016)
[2] Arbeitsgemeinschaft Branchenenergiekonzept Recycling (2009)

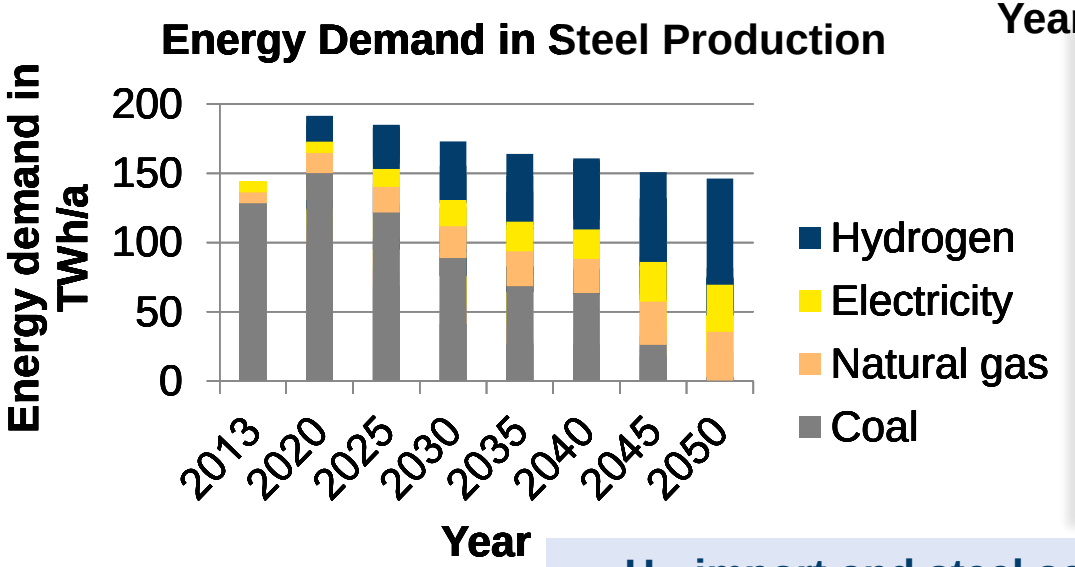
First Results – Steel

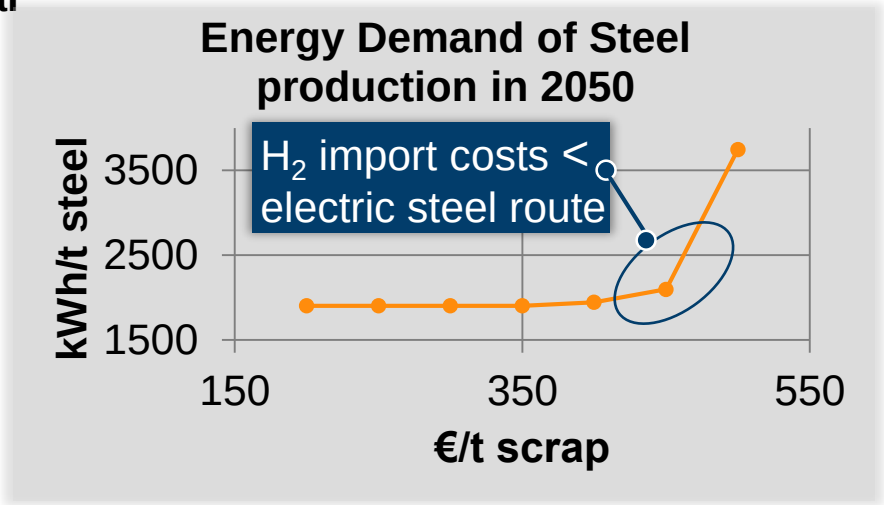
Scrap Price Sensitivity

Implications

- How does steel production and energy use change?
- How much may recycling cost?

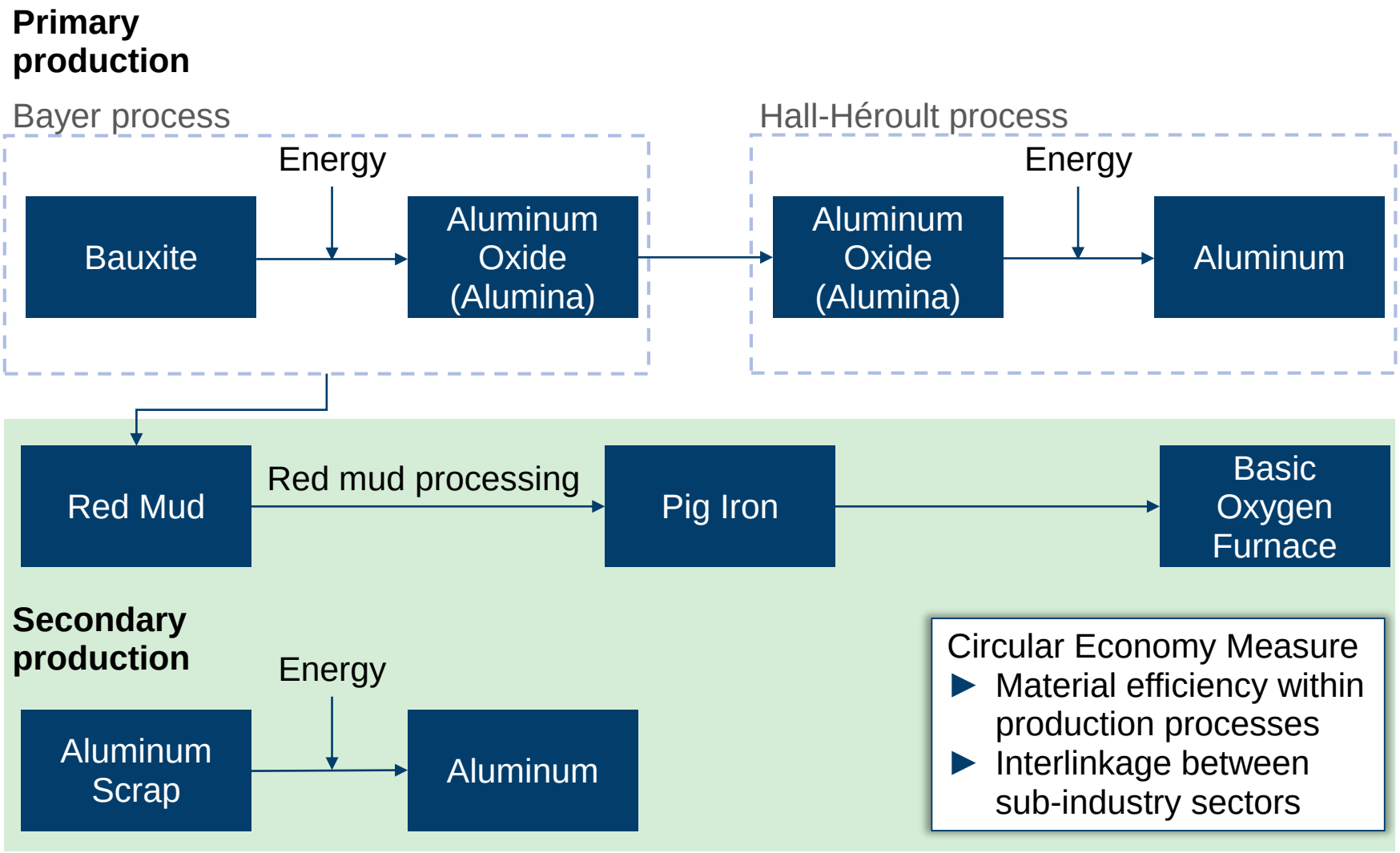






H_2–import and steel scrap costs are deciders for steel production development

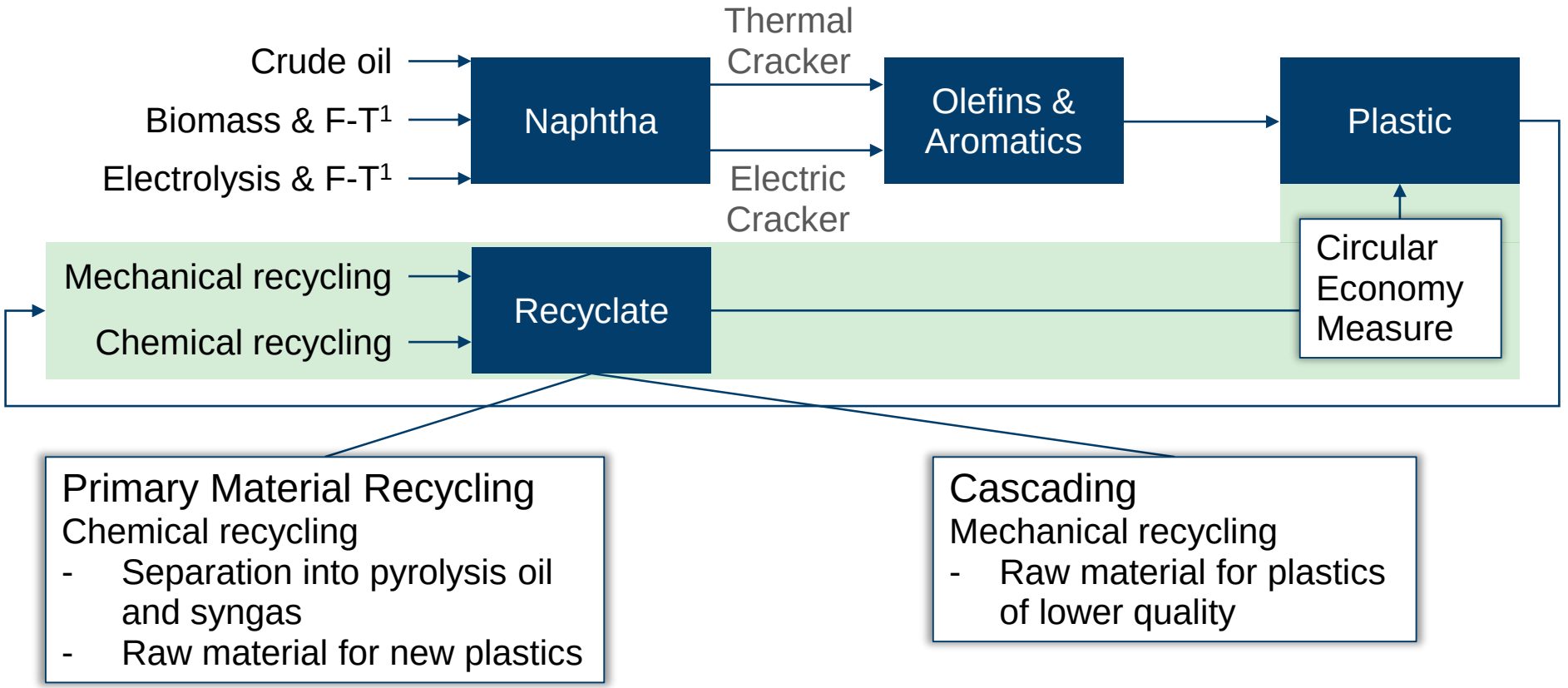
Example: Aluminum Production



Example: Basic Chemicals – Primary Material Recycling & Cascading

- 45 Mt CO_2 – emissions (**1/4** of all emissions in industry sector ~181 Mt CO_2)

Production of olefins and aromatics and recycling



Primary Material Recycling
Chemical recycling
- Separation into pyrolysis oil and syngas
- Raw material for new plastics

Cascading
Mechanical recycling
- Raw material for plastics of lower quality

[1] Fischer-Tropsch process

Summary

Circular Economy

"Shift from 'take, make, dispose' towards a regenerative approach of resource use" [1]

→ **Material flow analysis is used to assess whether material cycles are closed**

Energy System Models

'Energy systems models are important methods used to generate a range of insight and analysis on the supply and demand of energy.' [2]

→ **Necessary tools to support planning processes of the German 'Energiewende'**

Results

- The German **"Energiewende"** leads to a **"Ressourcenwende"**
- **Energy and material efficiency** play an important role in future energy scenarios
- Circular economy measures are not considered in recent energy system models

[1] https://www.ellenmacarthurfoundation.org/circular-economy/concept
[2] S. Pfenninger, A. Hawkes and J. Keirstead: Energy systems modeling for twenty-first century energy challenges. Renewable and Sustainable Energy Reviews, 33, pp. 74-86. 2014.

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THANK YOU FOR YOUR ATTENTION