Technical University of Leoben

CCU Pathways in Austria

A Life Cycle-Based Assessment of Climate Target Compatibility and Mitigation Potentials

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Austrian framework

2030

- 46% GHG reduction relative to 2005

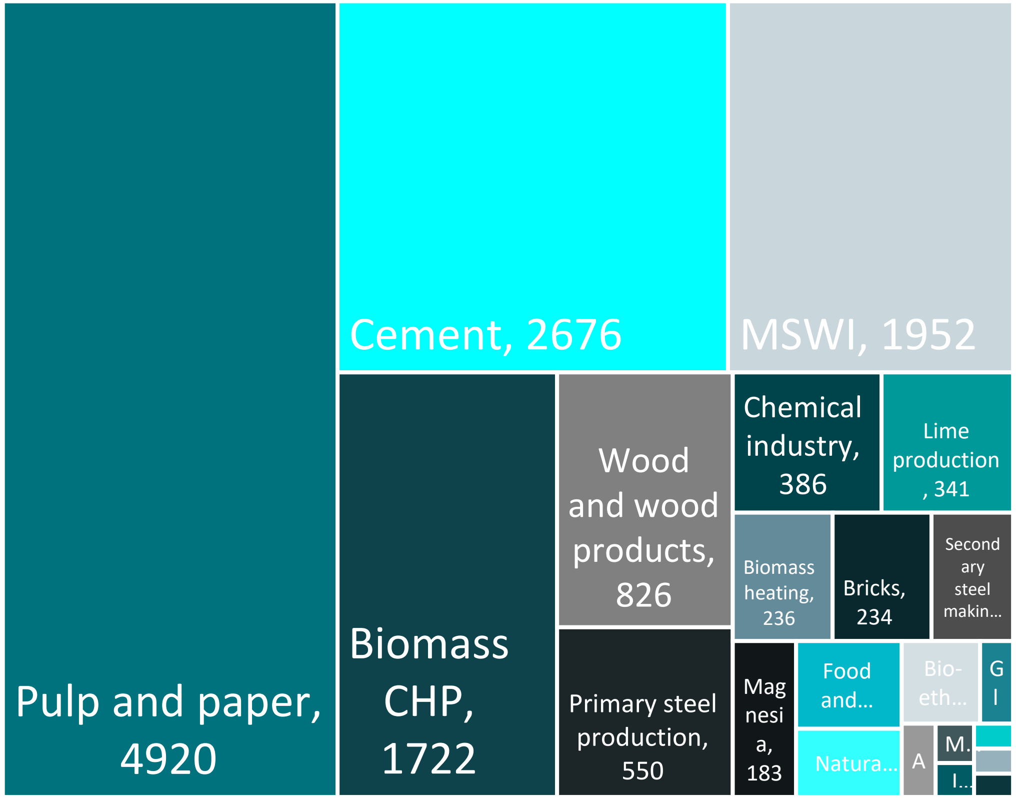
- Reduction and efficiency measures
- 100% electricity from renewable sources
- 80% green H_2

2040

Net-zero emissions

- Reduction and efficiency measures
- Fossil free heat supply
- CCS and CCU (hard-to-abate)

Transition scenario 2040:
~15 ktCO_2e hard-to-abate



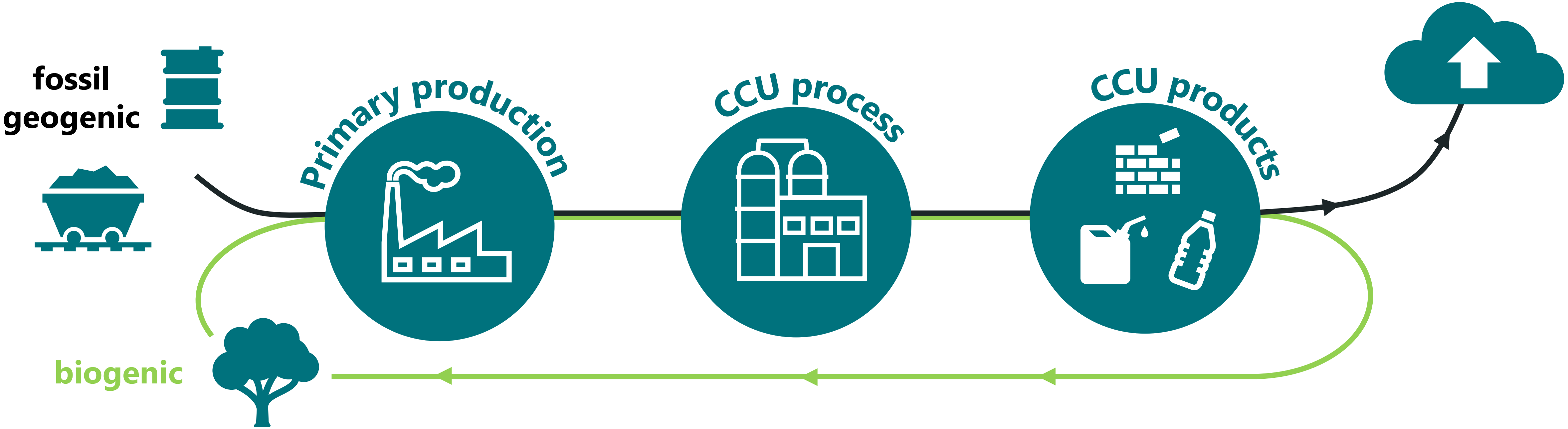
Sources:
BMK, Integrierter nationaler Energie- und Klimaplan für Österreich, 2024
Hochmeister et al., A methodology for the determination of future carbon management strategies: A case study of Austria, 2024

Harmonization of LCA-data

1. **Functional unit**
   FU = 1 kgCO_2 utilized
2. **System boundaries**
   Cradle-to-grave
3. **Electricity mix**
   22 gCO_2e/kWh_{2030}
4. **Hydrogen mix**
   4.32 kgCO_2e/kg$H_{2,\ 2030}$
   1.10 kgCO_2e/kg$H_{2,\ 2040}$
5. **Heat mix**
   0.21 kgCO_2e/kWh_{2030}
6. **CO_2 recovery**
   absorption, adsorption, membranes, cryogenic
7. **Multifunctionality**
   CCU vs primary process
8. **Storage effects**
   Product specific life-times and re-emissions

Emission factors E_{CCU}
Comparability
Austrian context

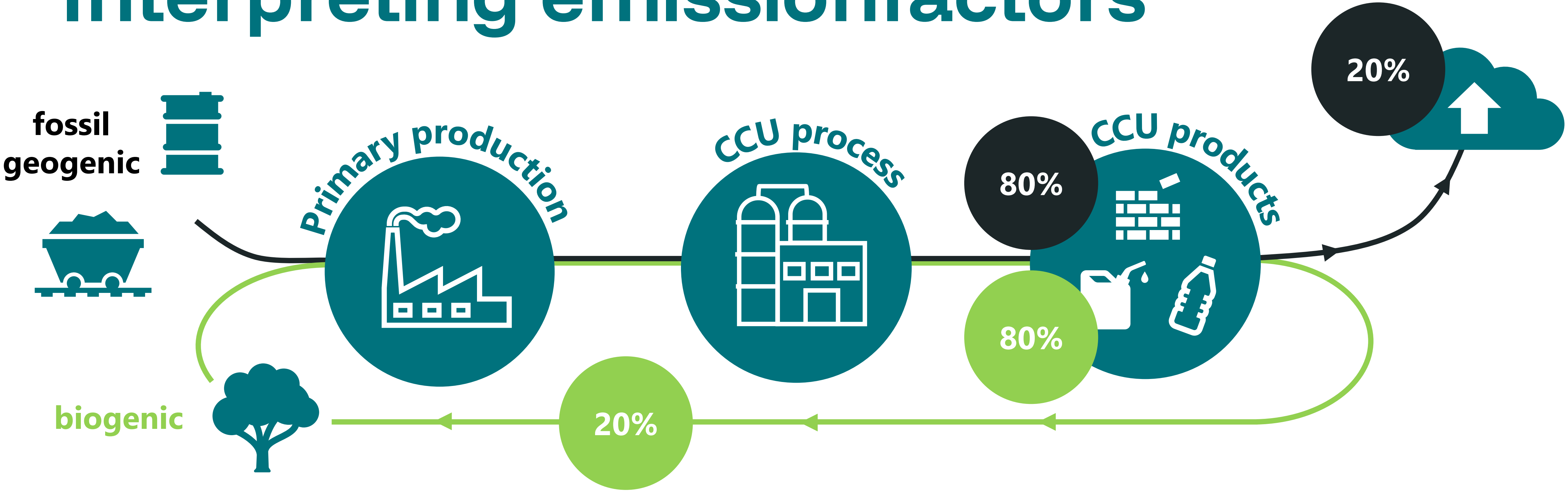
Interpreting emissionfactors



$$E_{CCU} = -E_{Utilized} + E_{Capture\ process} + E_{Conversion} + E_{Released} + E_{Other}$$

$$[kgCO_2e/kgCO_2 utilized]$$

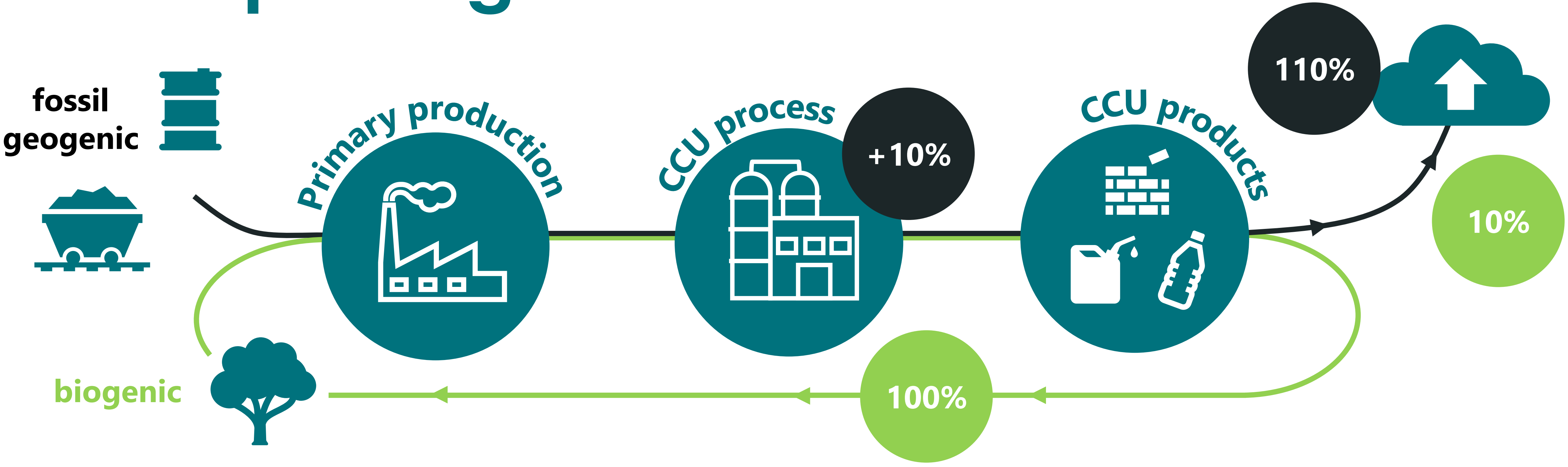
Interpreting emissionfactors



E_{CCU} = -0.8 $kgCO_2e/kgCO_2$ utilized

E_{CCU} = 0.1 $kgCO_2e/kgCO_2$ utilized

Interpreting emissionfactors



E_{CCU} = -0.8 $kgCO_2e/kgCO_2$ utilized

E_{CCU} = 0.1 $kgCO_2e/kgCO_2$ utilized

Technologies and compatibility criteria

- Carbonation of steel slag blocks
- High gravity steel slag carbonation
- Direct hydrogenation to methane
- Direct hydrogenation to methanol
- Fischer–Tropsch & reversed water gas shift
- Hydrogenation in methanol to DMM
- Electrochemical reduction to ethylene
- Bio–fermentation to acetone
- CO_2–based polyol production

2030

$\mathrm{TRL} \geq 6$ in 2020

$$\frac{E_{CCU,2030}}{E_{substitute,2020}} \leq 65\%$$

2040

$\mathrm{TRL} \geq 4$ in 2020

Biogenic, atmospheric CO_2:

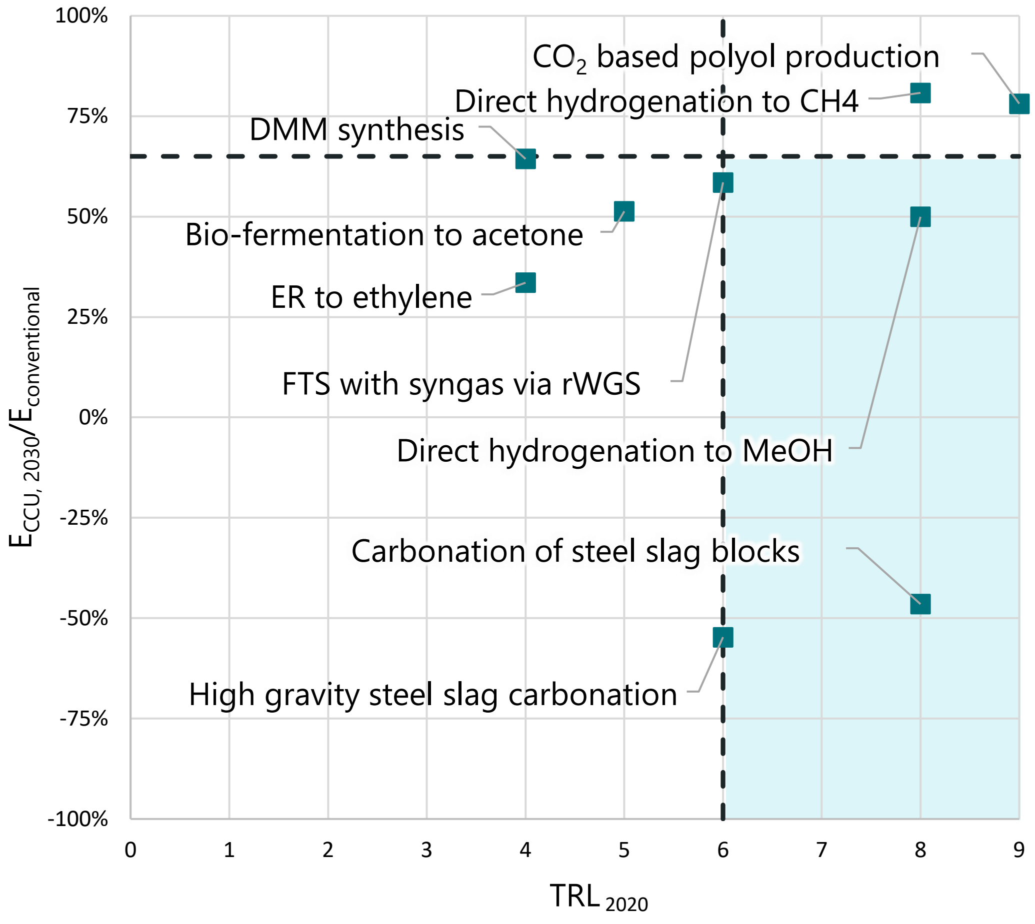
$$E_{CCU,2040} \leq 0 \ \mathrm{kgCO_2e/kgCO_2u.}$$

Fossil, geogenic CO_2:

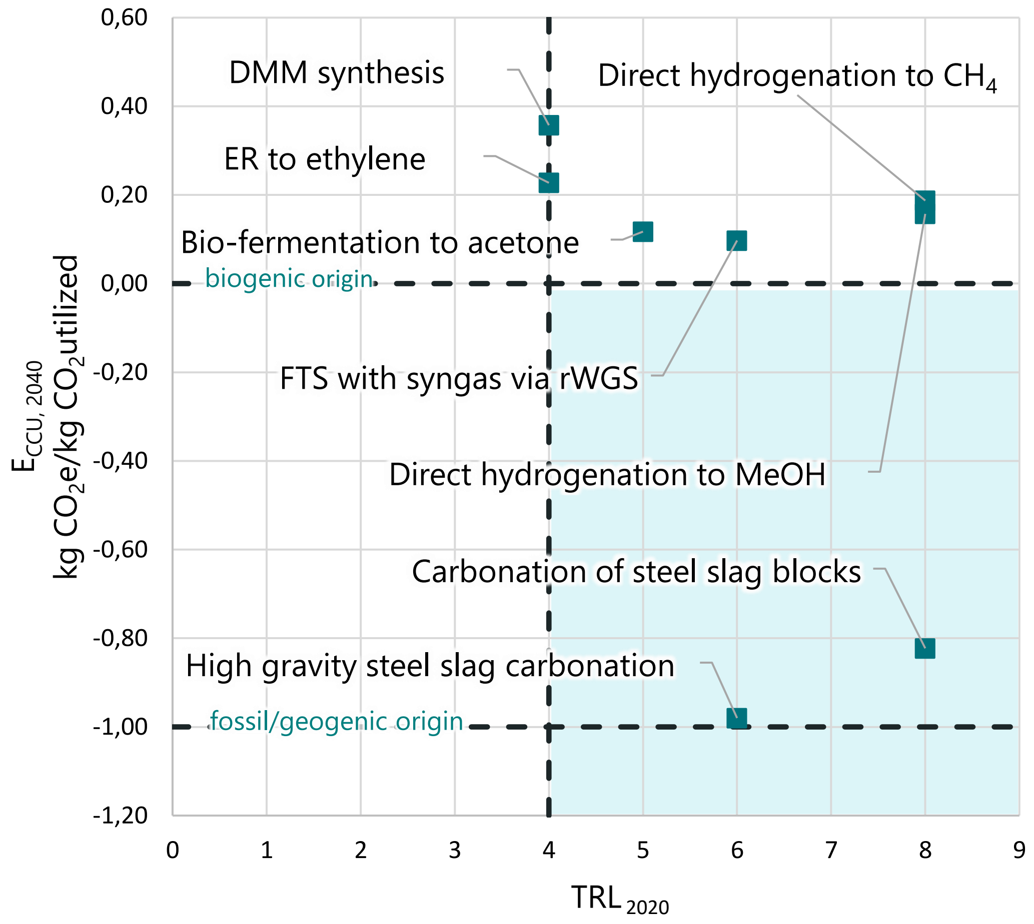
$$E_{CCU,2040} \leq -1 \ \mathrm{kgCO_2e/kgCO_2u.}$$

National climate target compatibility

2030



2040



Estimating mitigation potentials

Point sources

- Identification and quantification
- Off-gas CO_2-concentrations
- CO_2 origins: geogenic, fossil, biogenic

CCU pathways

- Carbon capture (CO_2 content)
- Accumulation prevention
- Similar markets
- Waste utilization

E_{CCU}

Substitution

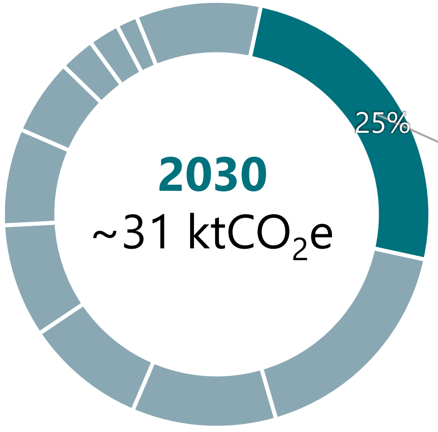
1:1 replacement of conventional products

Theoretical GHG mitigation potentials

Limitations

Pathway examples and potentials

Source characterization | CCU application | Product substitution



Primary steel production

- 13 – 40% CO_2 content
- > 85% fossil origins
- Raw materials (steel slag)

Physical adsorption +cryogenic purification

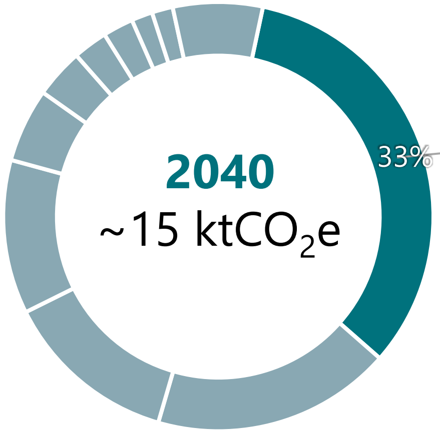
Carbonation of steelslag blocks

E_{CCU} = -0.80 $kgCO_2e/kg\ CO_2u.$

Portland cement based blocks

- 80 g CO_2e/kg block
- $E_{con.}$ = 1.30 $CO_2e/\ CO_2u.$

16 Mt CO_2e theoretical mitigation



Pulp and paper

- 7 – 20% CO_2 content
- 100% biogenic origins
- Natural carbon cycle

Chemical absorption

Fischer-Tropsch synthesis via syngas from rWGS

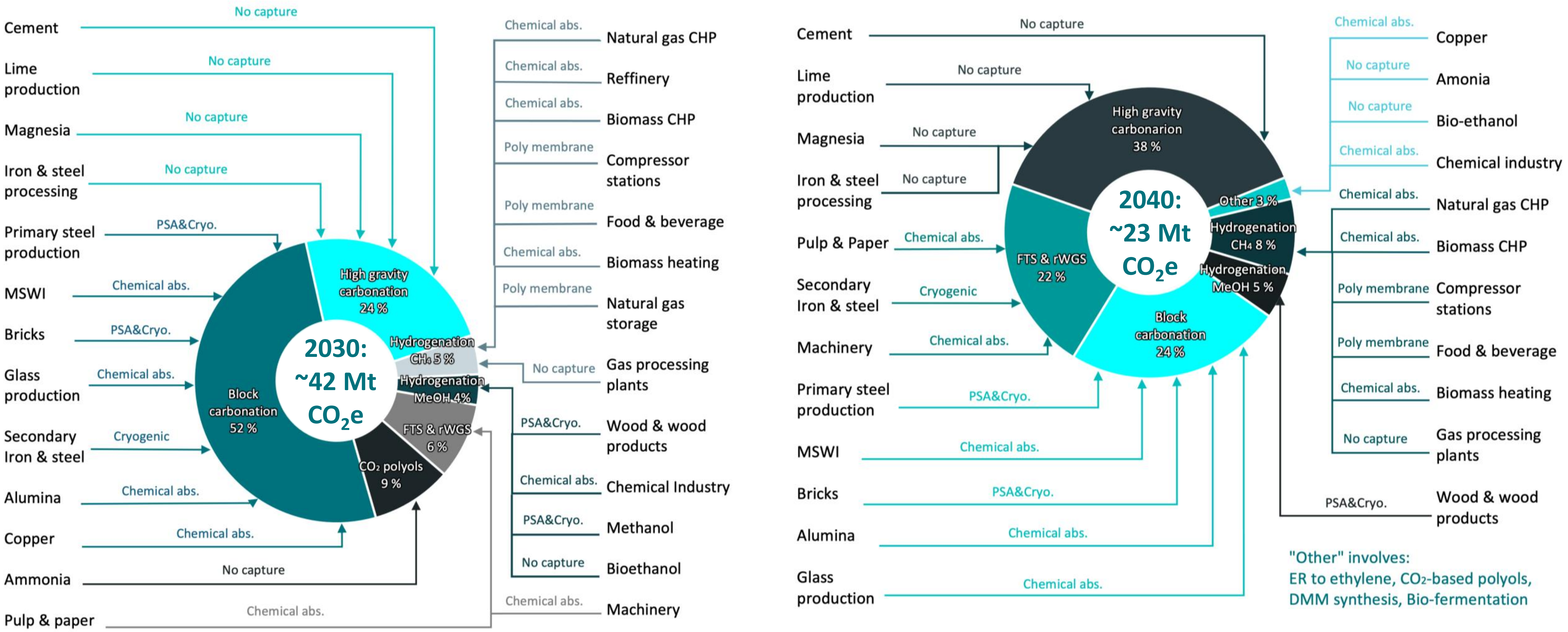
E_{CCU} = 0.37 $kgCO_2e/kg\ CO_2u.$

Diesel fuel

- 20 g CO_2e/MJ diesel
- $E_{con.}$ = 1.48 $CO_2e/\ CO_2u.$

4.3 Mt CO_2e theoretical mitigation

Theoretical mitigation potentials



Mitigation constraints

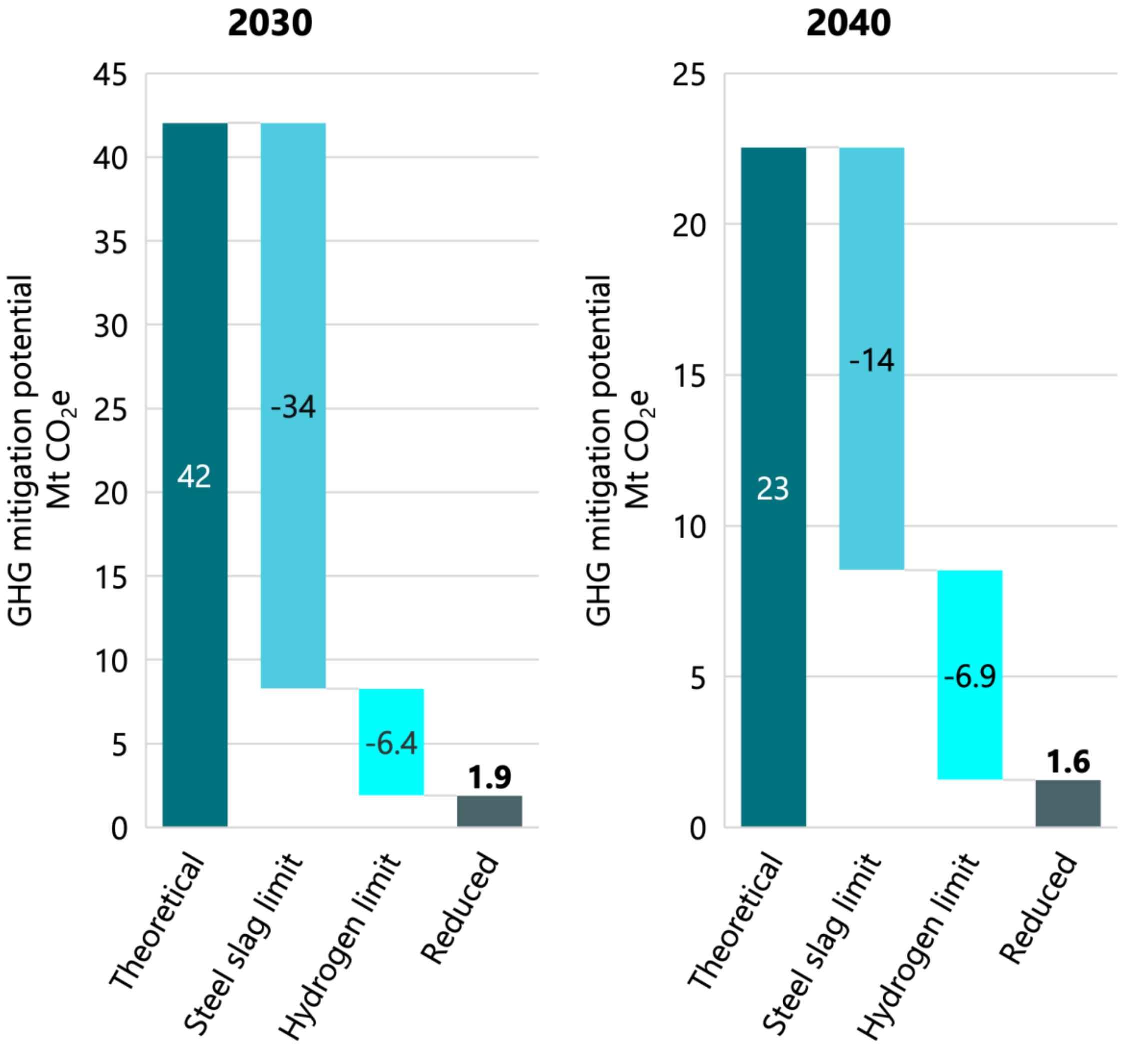
▪ Resource availability		Demand 2030	Demand 2040
Renewable electricity	95 [TWh]	139	69
H_2 electrolysis capacity	1 [GW]	14	7
Steel slag	0.8 [Mt]	80	32

Others:

- Storage capacities, scalability
- Product demands
- Socio–ecological factors

Red. mitigation potential

< 2 Mt CO_2e/a



Main findings: CCU in Austria

Climate target compatibility

- 2030: four distinct CCU technologies
- 2040: two carbonation technologies
- Mitigation measures through substitution

GHG mitigation potentials

- High theoretical potentials
- Green energy and raw materials limitations
- Total annual potential:

~ 2 Mt CO_2e

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Thank you!