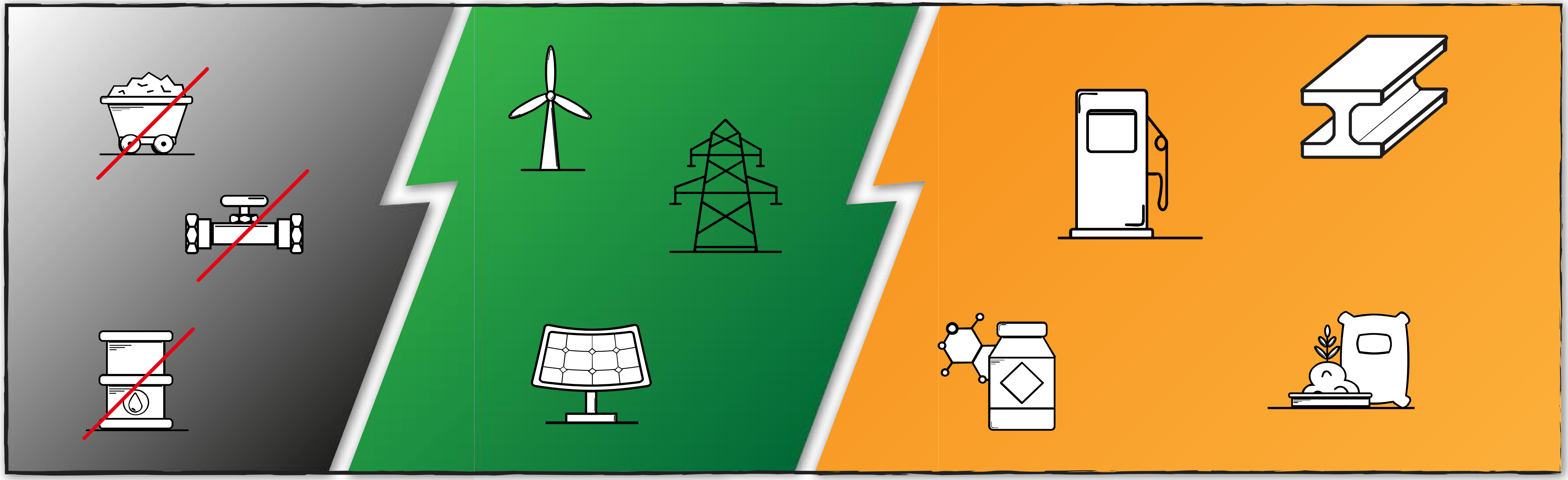
SYSTEM INTEGRATION – THE CENTER PIECE OF CARBON2CHEM®

Markus Oles, thyssenkrupp
Görge Deerberg, Fraunhofer UMSICHT
3rd Carbon2Chem® Conference, Berlin, 28.10.2020



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Carbon2Chem Objectives & Challenges

System Integration

Carbon2Chem Assessment

Conclusions and final Remarks

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The approach of Carbon2Chem is to create cross-industrial network by using CO_2 emissions

- Reduction of CO_2 emissions in steel production
- Development of a new raw material source for chemical production through the holistic use of C-sources
- Creation of cross-industry value chains
- Increase of energy efficiency by building a cross-industry network
- Making energy consumption more flexible and thus providing control energy to achieve the energy transition
- Use and integration of volatile and fluctuating renewable energy
- Production of chemical products with a higher added value than electricity or heat (e.g. methanol, ammonia etc.)
- Transfer of the results to other applications with an effect on energy system transformation

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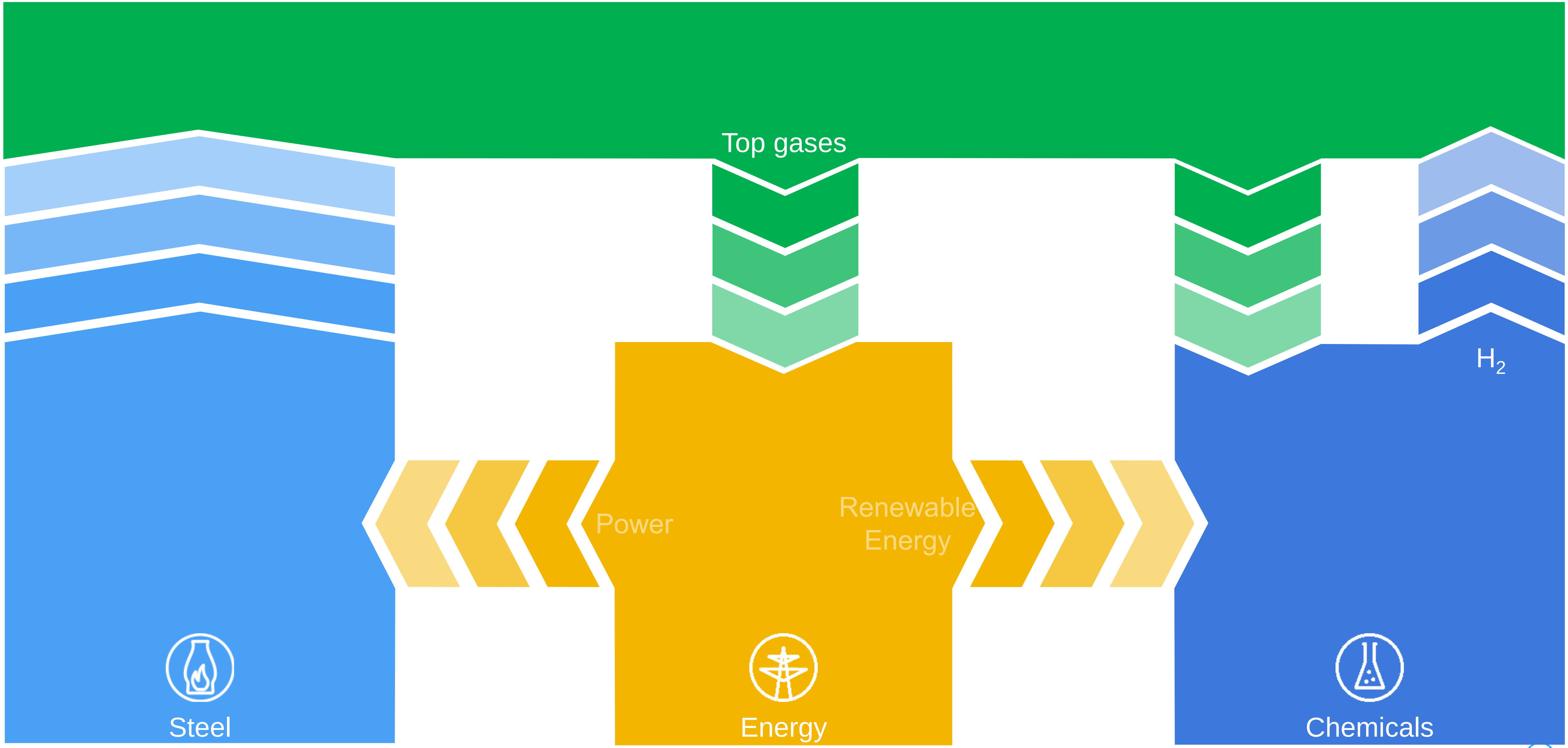


The cross-industrial network has a significant share in the economy

GDP Germany: 3.400 Mrd € in 2019

Steel

Sales: 40 Mrd.€

Employees: 100.000

Depreciation of fixed assets: 20-25 Years

Energy

Sales: 561 Mrd.€

Employees: 235.000

Depreciation of fixed assets: 25 Years

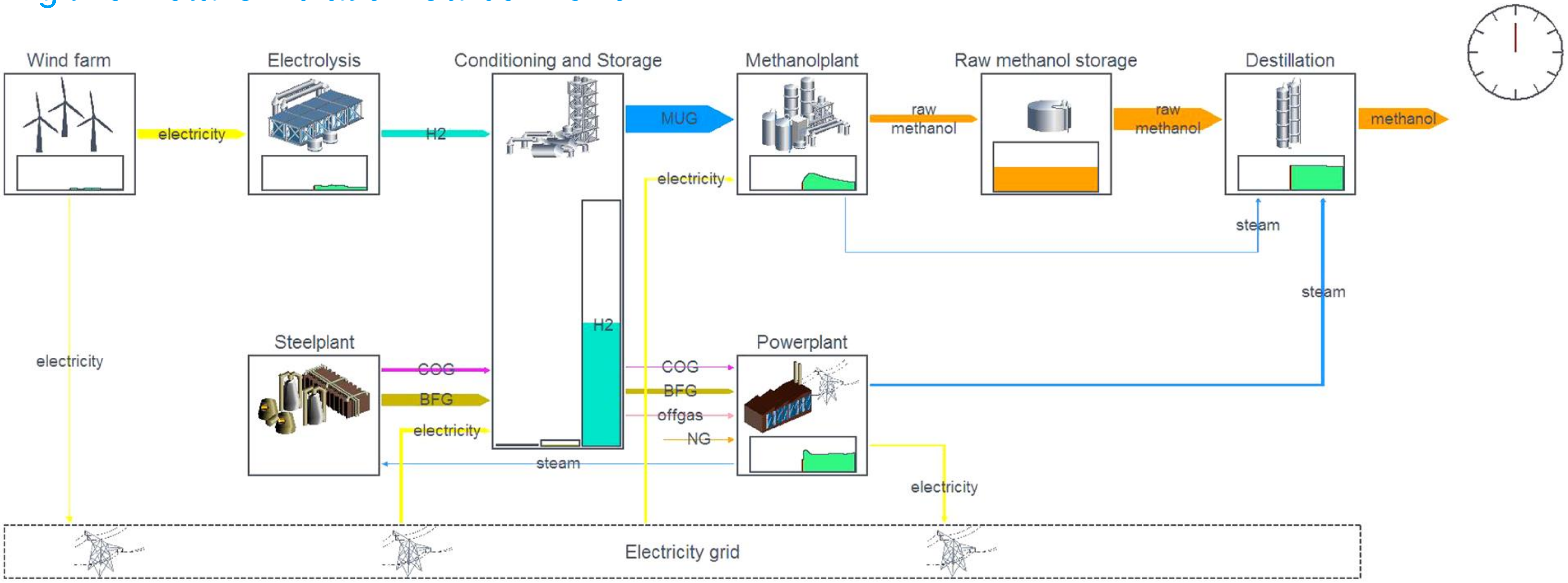
Chemicals

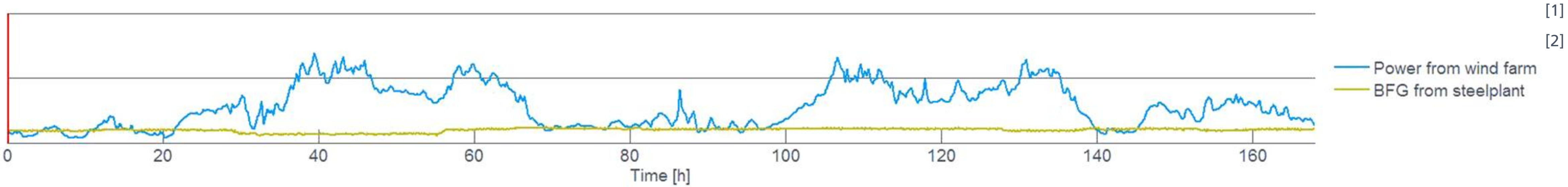
Sales: 200 Mrd.€

Employees: 464.000

Depreciation of fixed assets: 20 Years

Digitize: Total simulation Carbon2Chem





[1] Derived from: Fraunhofer ISE (2016), Energy Charts, www.energy-charts.de

[2] Real-world data from steel mill thyssenkrupp Duisburg

Challenges

System Dynamics	• Dynamic process gases (composition, amount) • Volatile renewable energy
Green Hydrogen	• Electrolysis (dynamic, capacity) • Renewable energy
Gas Treatment	• Amount of gases • Minor components
Synthesis	• Stability / durability

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Options in Steel Production

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CCU

- Conventional blast furnace with liquid product (2000°C)

Fe_2O_3, C → [ ] → CO/CO_2, Fe/C

CO/CO_2 → C_nH_m (with H_2)

- Direct reduction with natural gas (methane), solid reaction (1000°C)

Fe_2O_3, CH_4 → [ ] → H_2O, Fe, CO_2

CO_2 → H_2 → CH_4

Direct reduction with NG (state of the art)

Synthetic methane:

P2G (Power2Gas):

El. Energy + $2H_2O \rightarrow 2H_2 + O_2$

$4H_2 + CO_2$ $CH_4 + 2H_2O$

- Hydrogen as reducing agent, solid reaction (1000°C ?)

Fe_2O_3, C, H_2 → [ ] → H_2O, CO_2, Fe

Direct reduction with H_2 (in RTD phase)

CDA

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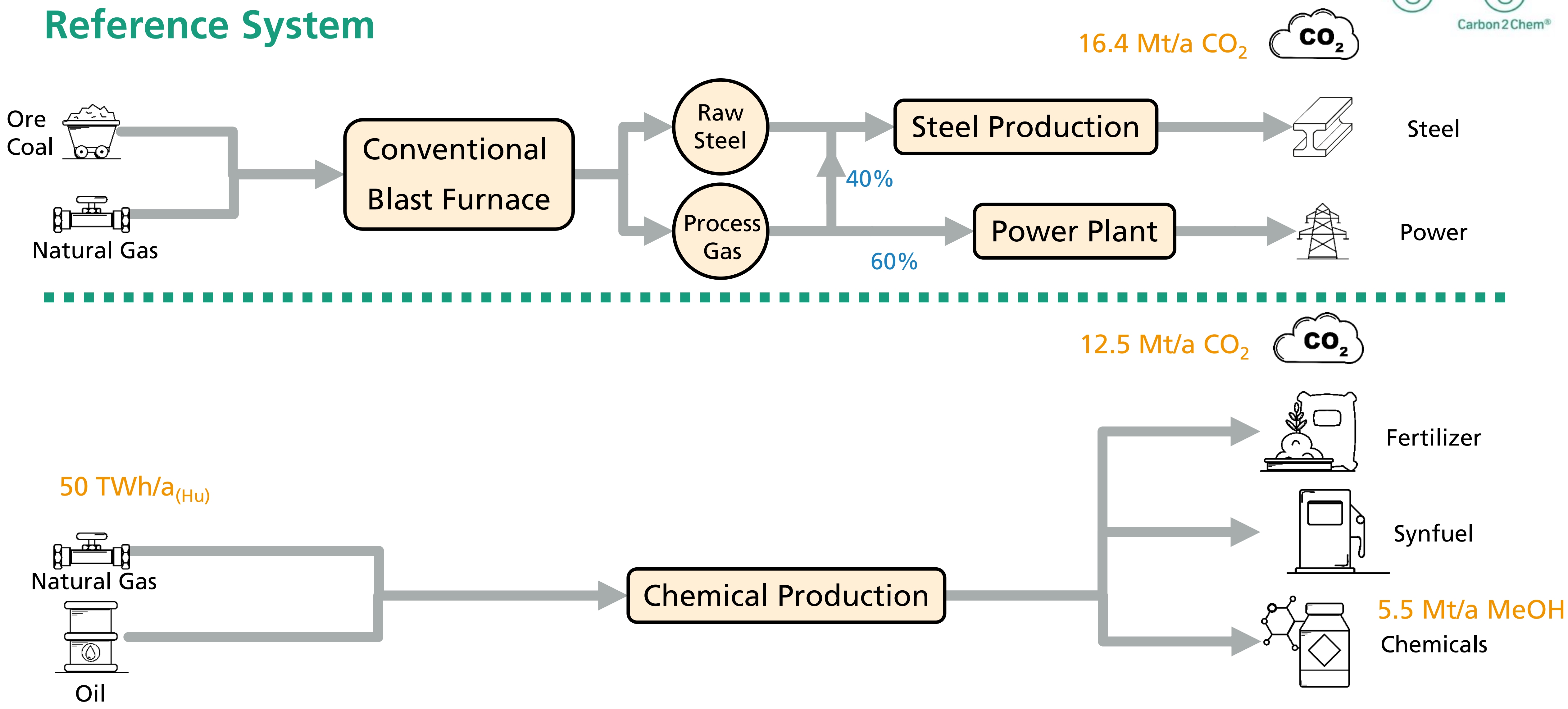
Conventional Processes
Reference System



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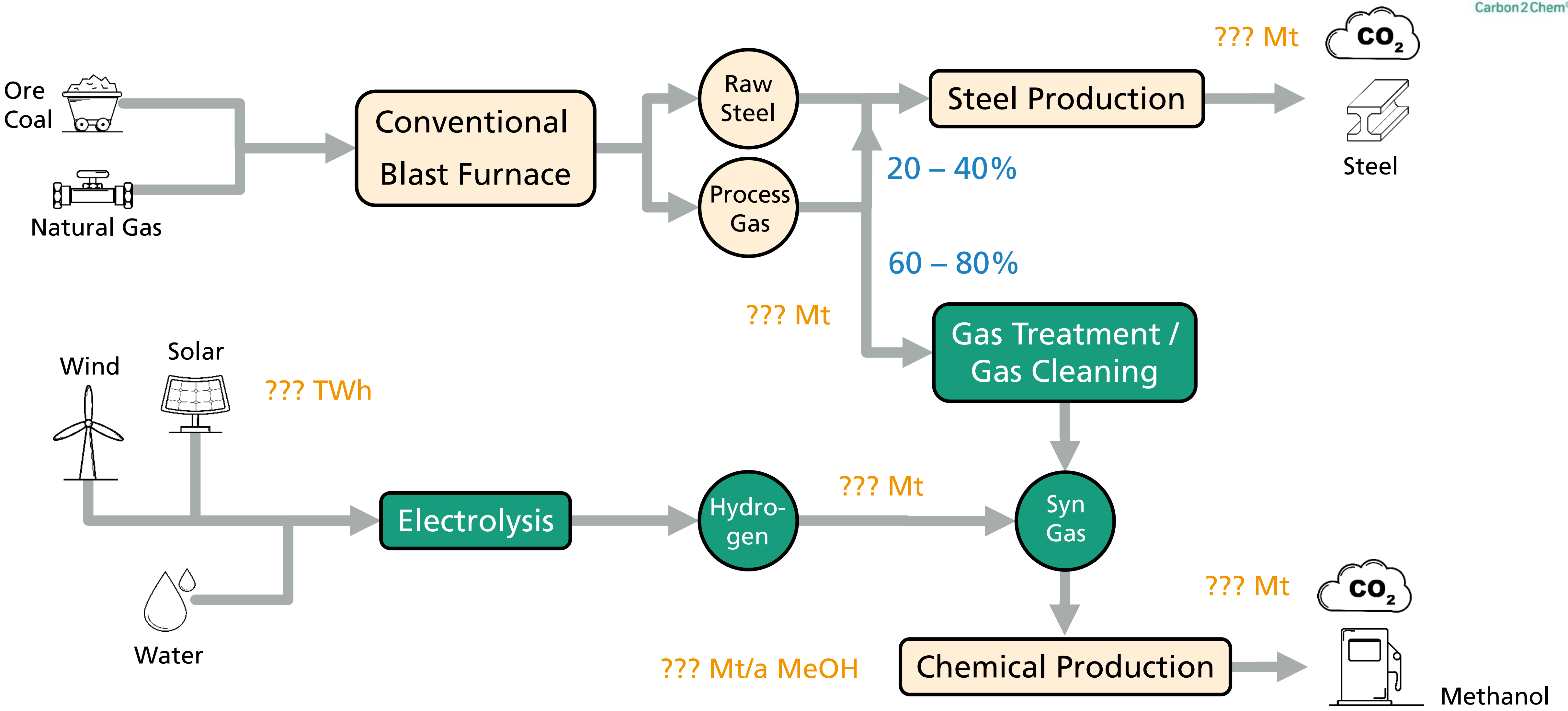
Cross-industrial Network



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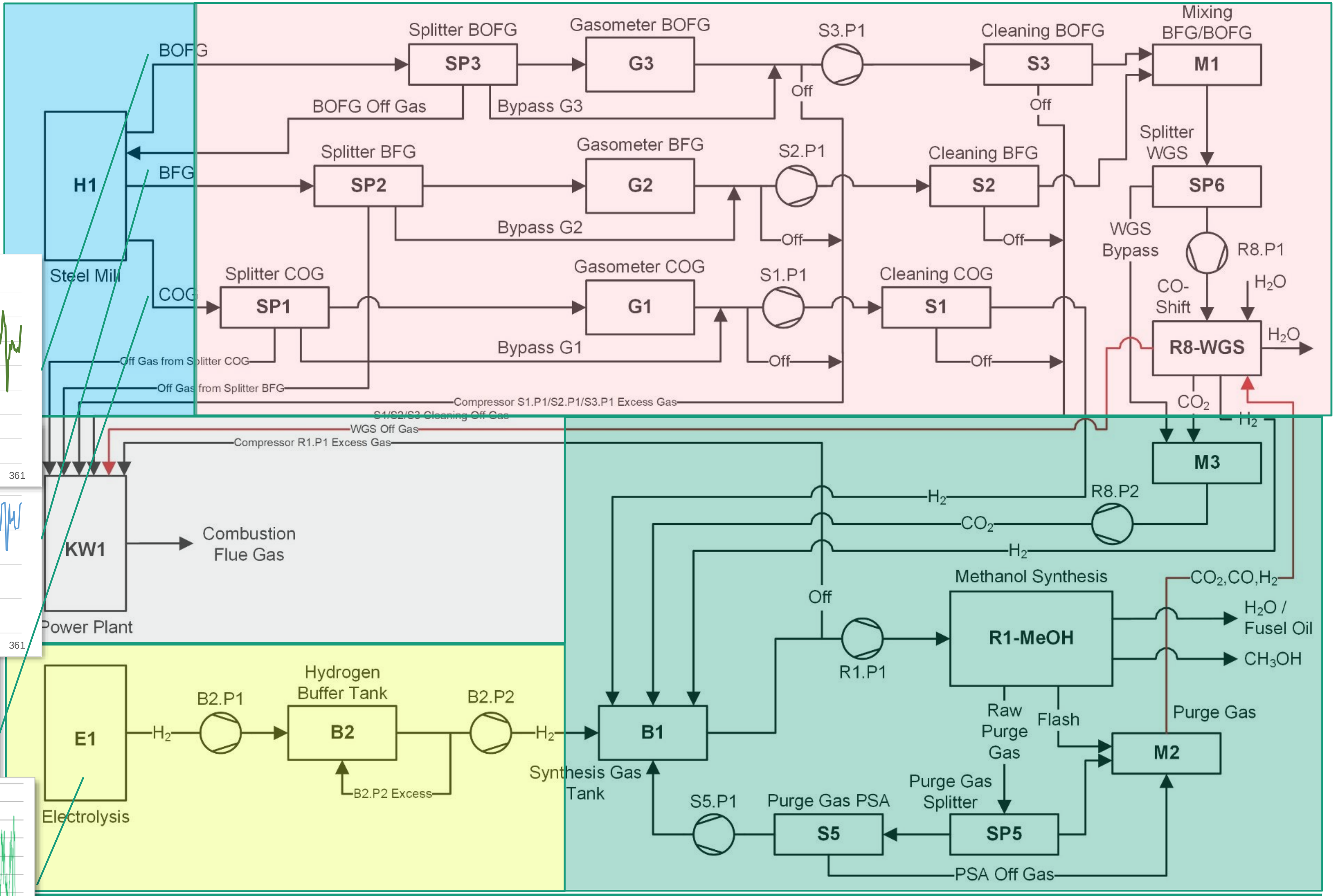
Integrated System
Basis for Simulation



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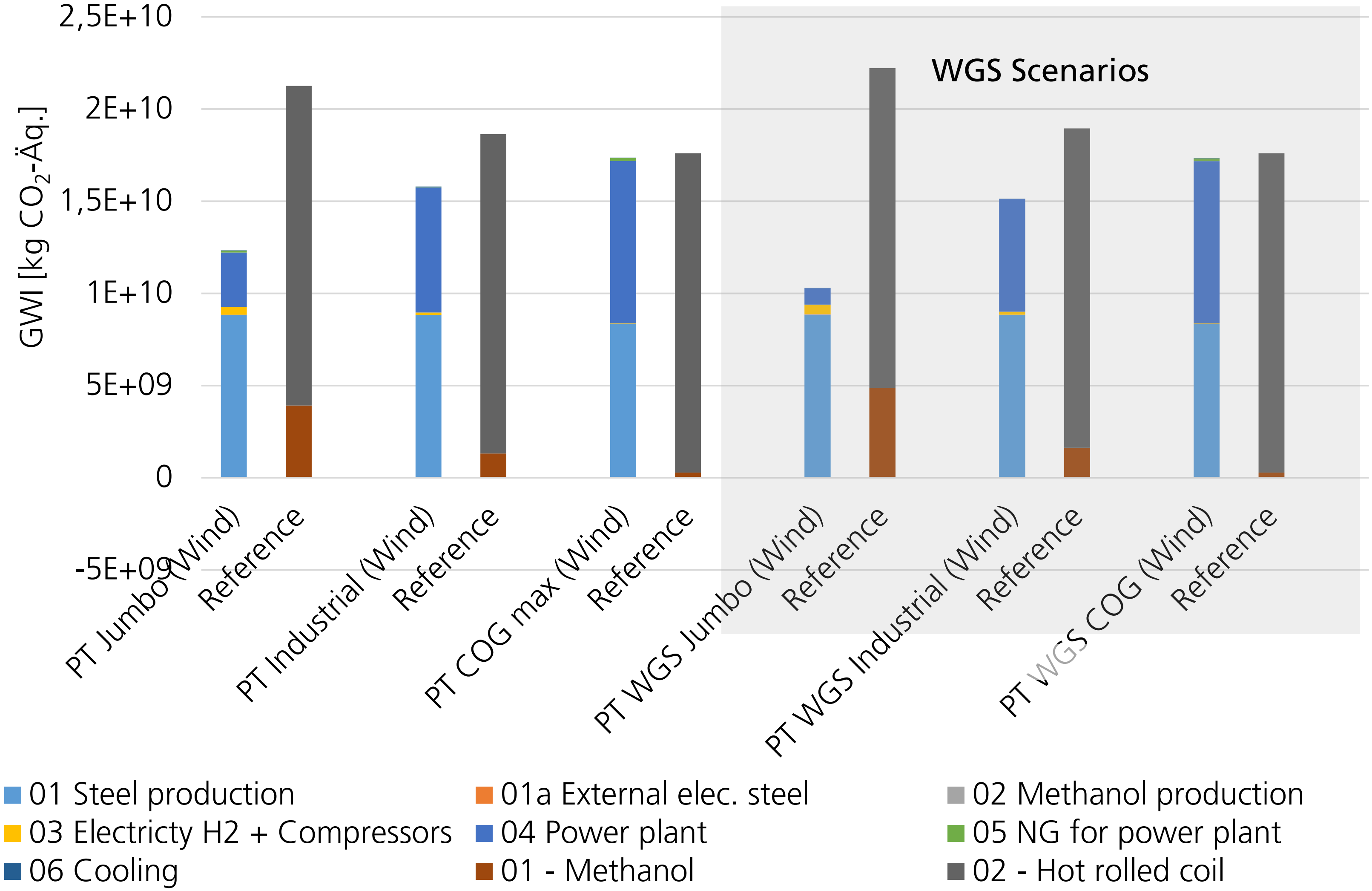
Different integration schemes: Results for methanol production

Global warming impact

- Products
  - ~ 0.3 - 5.8 Mt/a methanol and 8.4 Mt/a steel
- Power provided by wind
- Integrated production of steel and methanol shows smaller global warming impact compared to stand-alone production
- Results are strongly dependent on integration scheme



GWI = Global Warming Impact
WGS = Water Gas Shift
NG = Natural Gas

Further information by Dr. Daniel Maga

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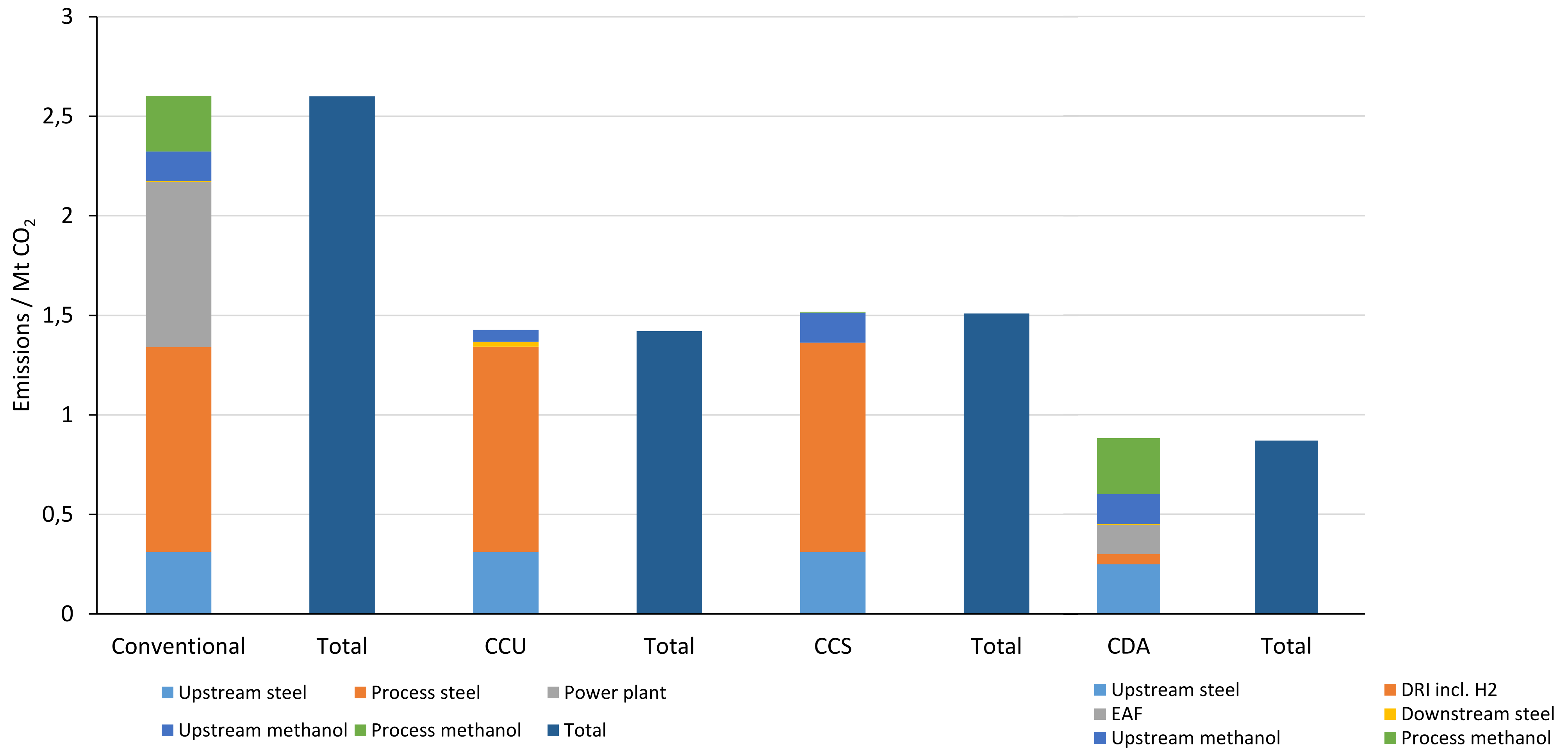
Comparison of CO_2 Emissions

Reference: Steel (1 Mto) + Methanol (0,53 Mto)



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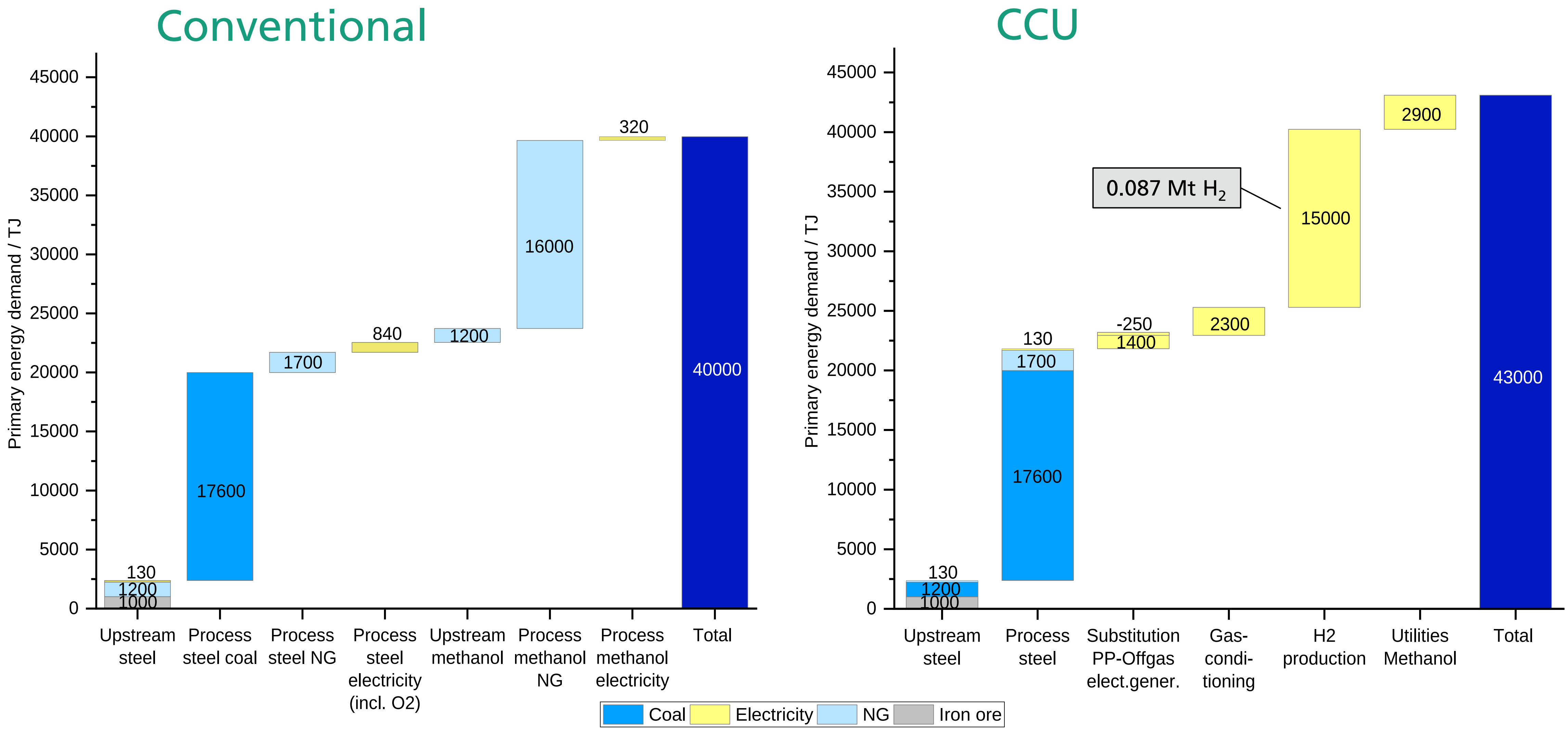
Source: Wich-Konrad, Lüke, Deerberg; Chemie Ingenieur Technik; **2020**; Assessment of Industrial Greenhouse Gas Reduction Strategies Within Consistent System Boundaries

Energy demand



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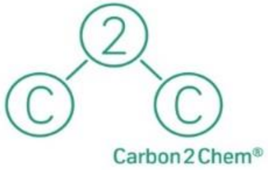
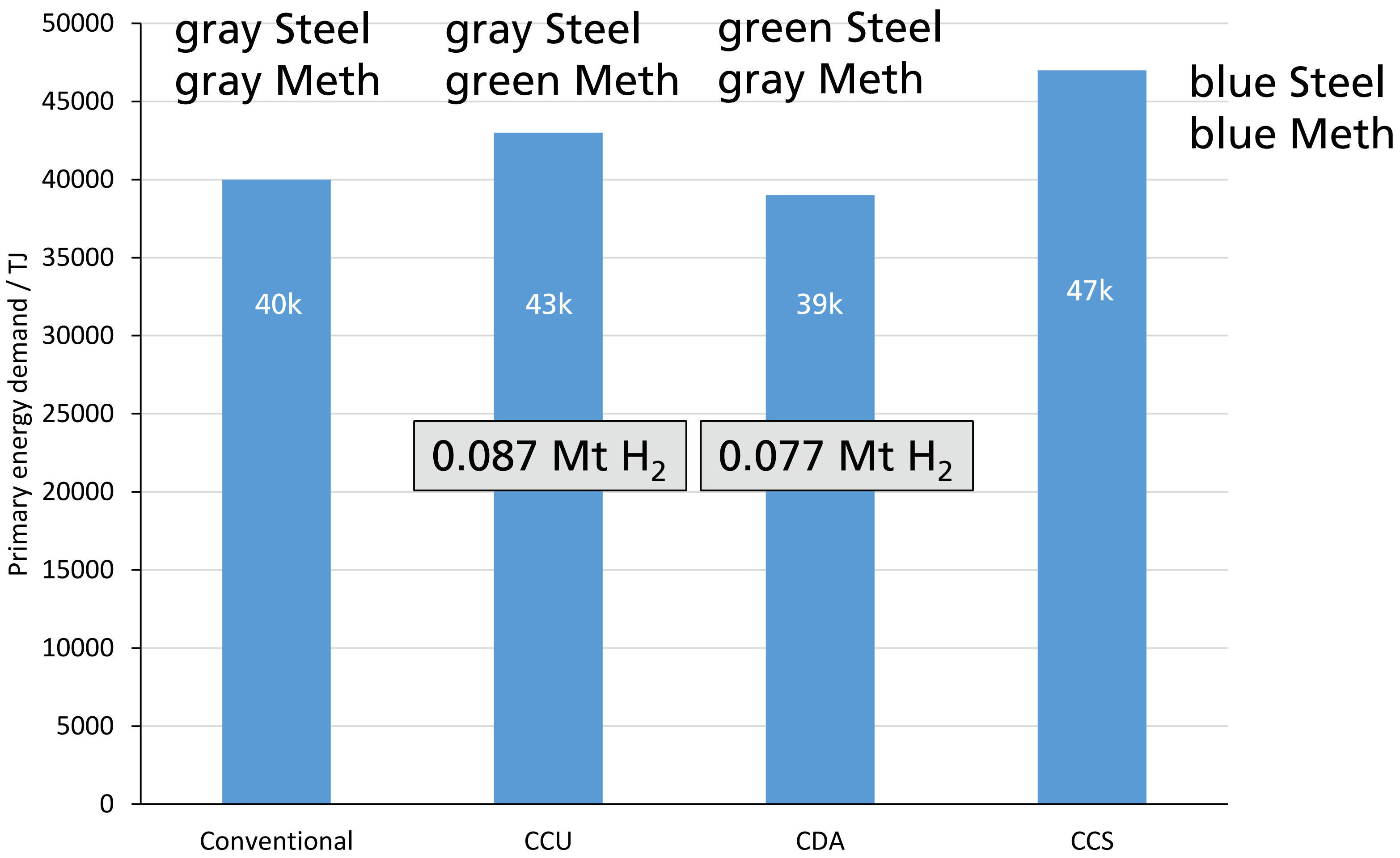
Source: Wich-Konrad, Lüke, Deerberg; Chemie Ingenieur Technik; **2020**; Assessment of Industrial Greenhouse Gas Reduction Strategies Within Consistent System Boundaries

Energy Demand
CCU, CDA: Mainly Green Power for Hydrogen Production





Source: Wich-Konrad, Lüke, Deerberg; Chemie Ingenieur Technik; **2020**; Assessment of Industrial Greenhouse Gas Reduction Strategies Within Consistent System Boundaries

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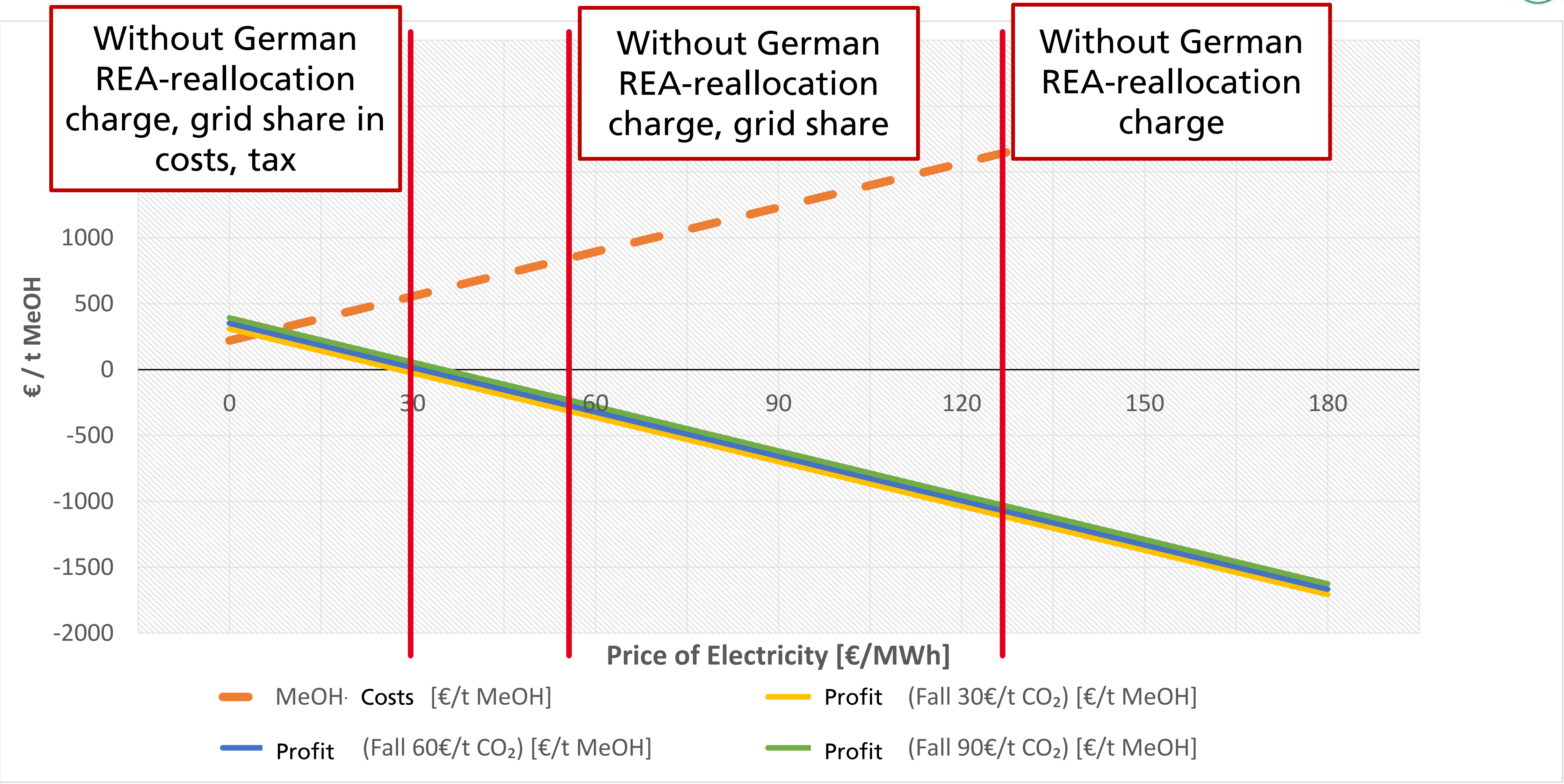
Economy - all cost on Methanol !! – Sensitivity



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Conclusions so far

- Depending on Process Integration CO_2-Reduction up to approx. 50% is possible
  - Without general Changes in the Steel Production
- Essential: Renewable Energy - Green Hydrogen
- Dynamics can be controlled
  - flexible and adaptive processes
- Costs are in reachable range, if green Hydrogen is excepted from shared costs

- Transfer of Carbon2Chem Approach to other Industries is to be considered
  - Other Steel production Sites
  - Cement Production
  - Waste Incineration
  - Combination with Direct Reducing Steel making Process (CDA)

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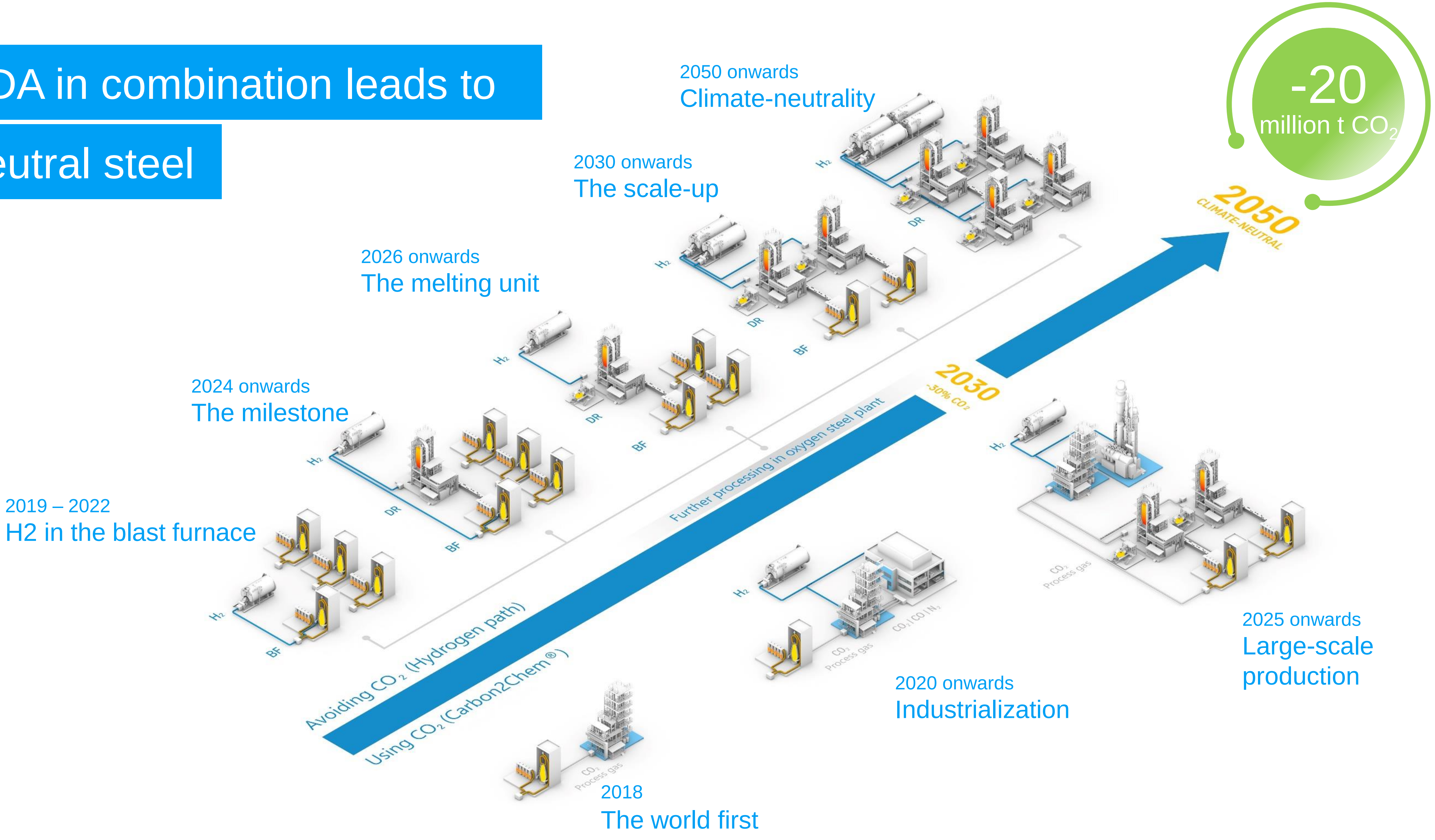
tkH2Steel

CCU & CDA in combination leads to climate-neutral steel



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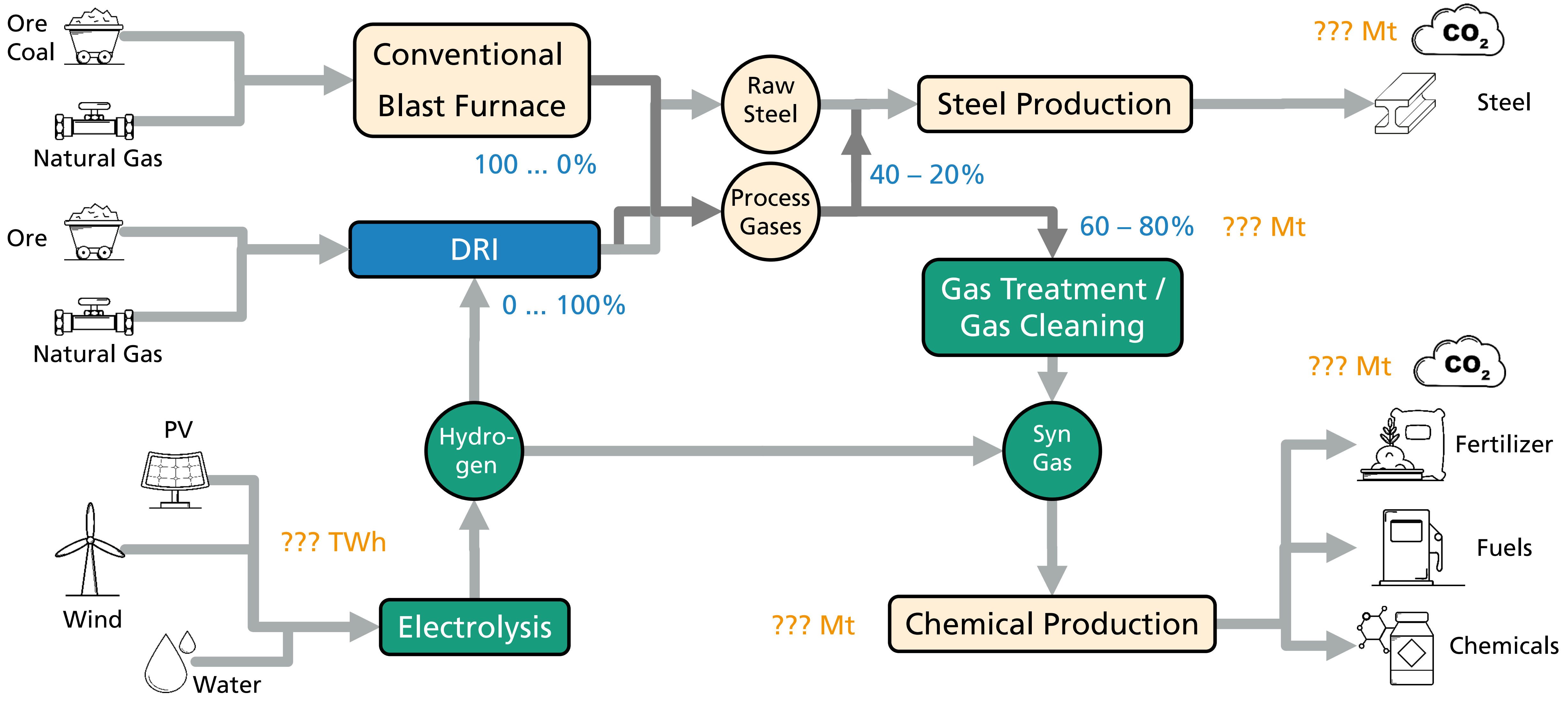
CCU & CDA: Combination with Direct Reducing Steel making Process



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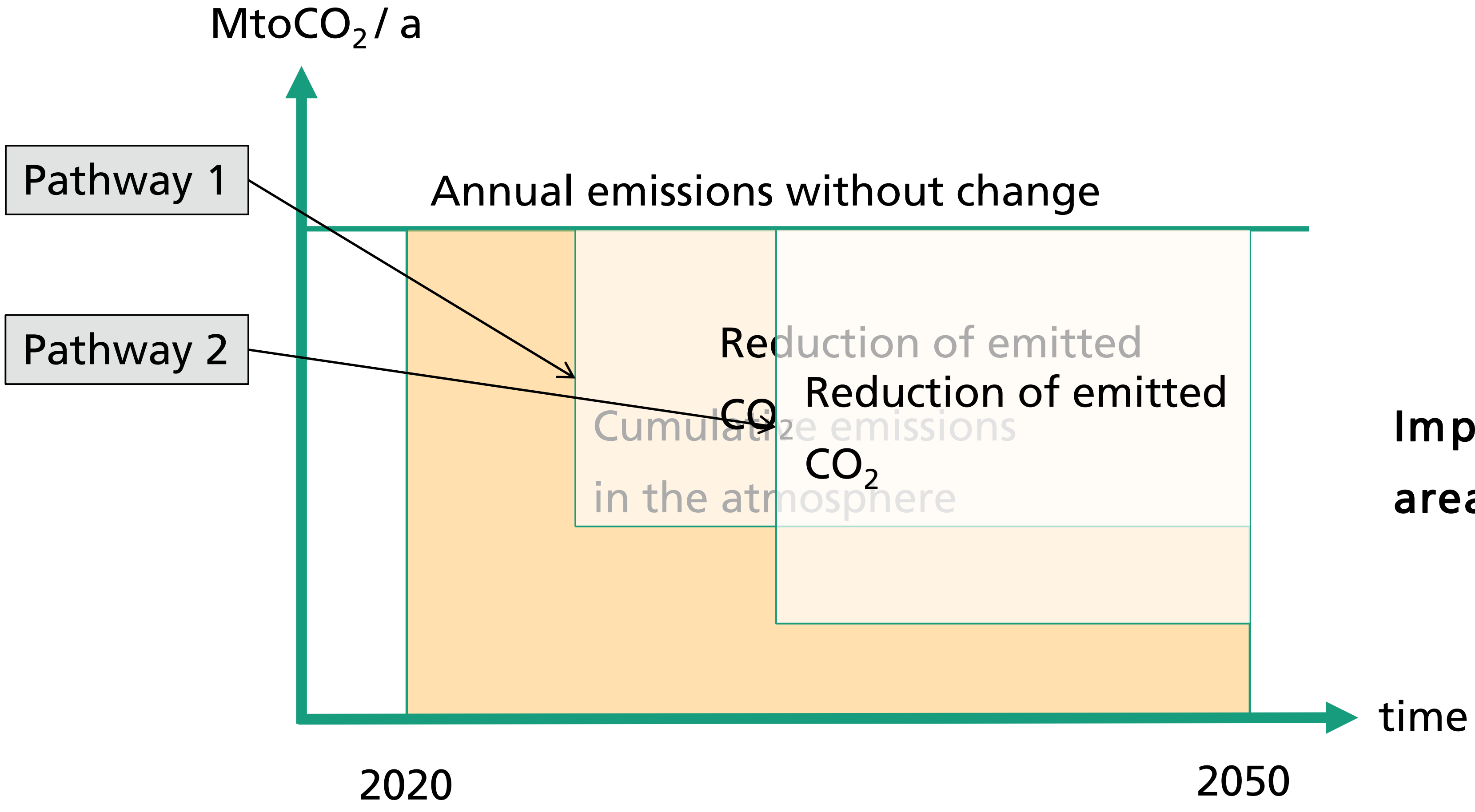
Final Remarks: Pathways for Reduction of CO_2 Emission



Important: Minimize area under the curve!

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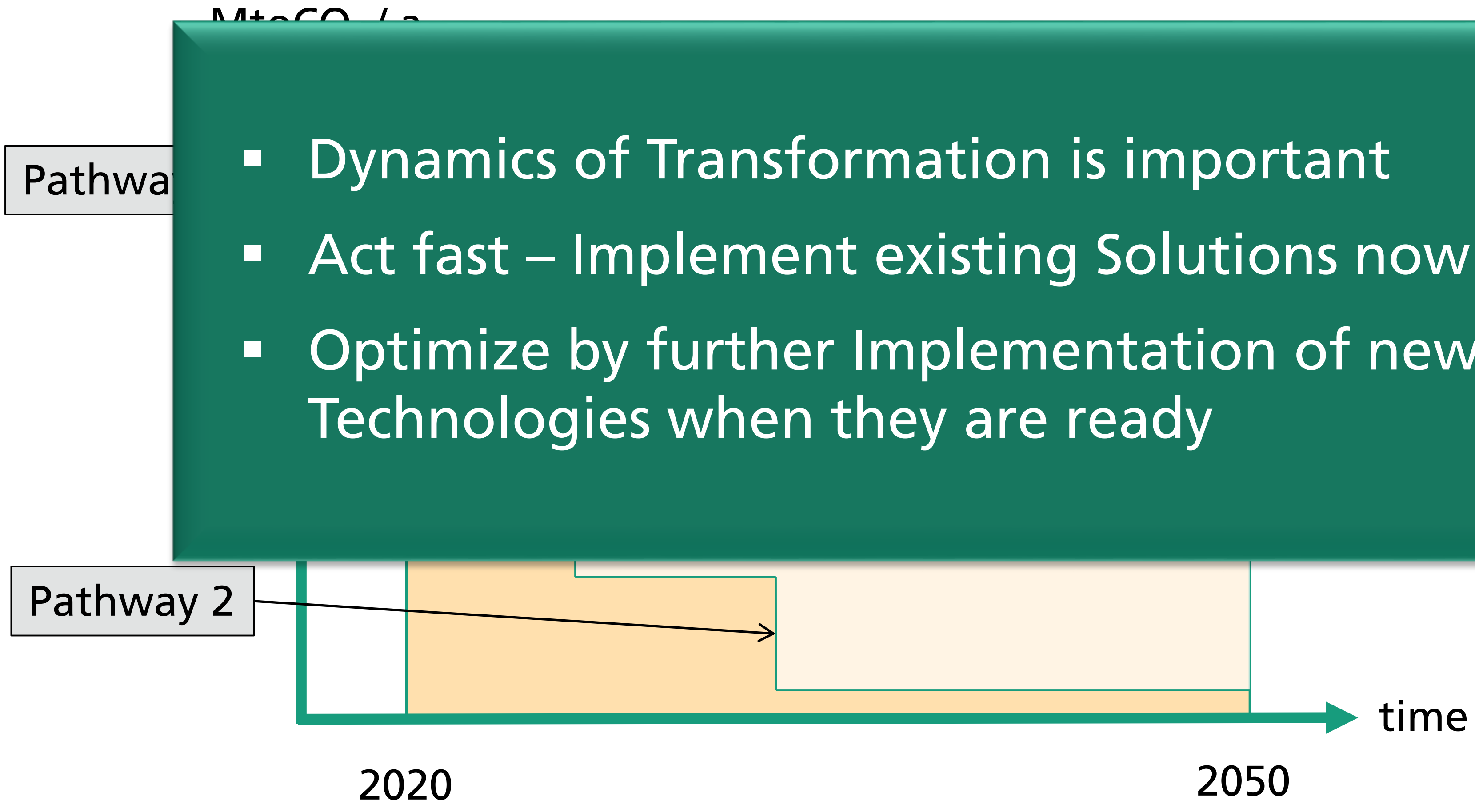
Final Remarks: Pathways for Reduction of CO_2 Emission



- Dynamics of Transformation is important
- Act fast – Implement existing Solutions now
- Optimize by further Implementation of new more efficient Technologies when they are ready

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Many thanks for your attention

Further information:
https://www.umsicht.fraunhofer.de/carbon-cycle

Prof. Dr.-Ing. Görge Deerberg
Deputy Director
Division Director Processes
☏ +49 (0) 208-8598-1107
✉ goerge.deerberg@umsicht.fraunhofer.de

Volume 90, Issue 10

Special Issue:Carbon2Chem®

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Volume 92, Issue 10

Special Issue:Carbon2Chem® Teil 2

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Contact

Fraunhofer UMSICHT
Osterfelder Straße 3
46047 Oberhausen

Germany
E-Mail: info@umsicht.fraunhofer.de
Internet: http://www.umsicht.fraunhofer.de

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