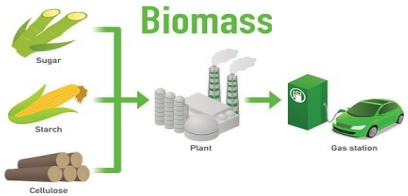
The need to scale up novel process concepts to store electricity in fuels and bulk chemicals

Wiebren de Jong (3mE, Process & Energy)

TU Delft

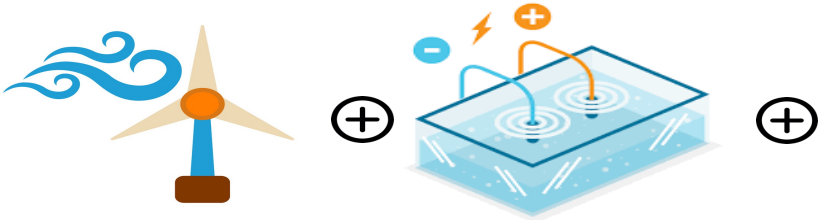
Large Scale Energy Storage section

'Biomass route'



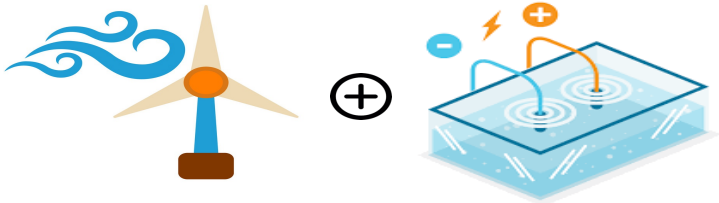
Prof. dr. Wiebren de Jong

'Indirect route'



Dr. Wim Haije

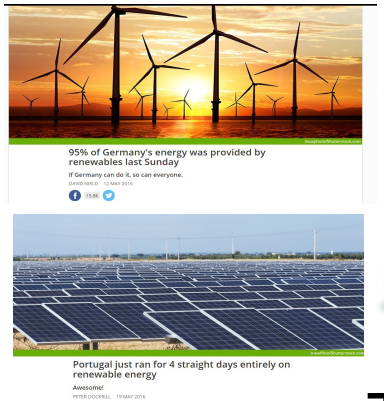
'Direct route'



Dr. Ruud Kortlever

TU Delft

Wind/solar is intermittent…



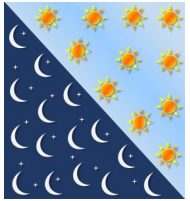
Timescales

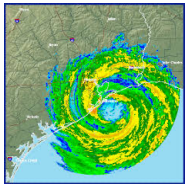
<~15-30 min

~12 h

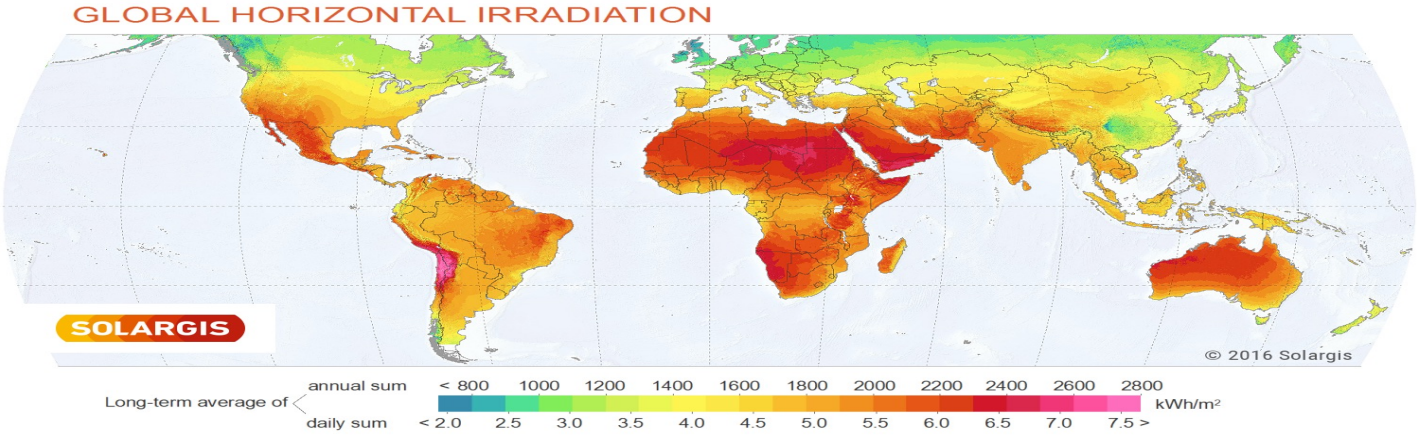
days

weeks-months



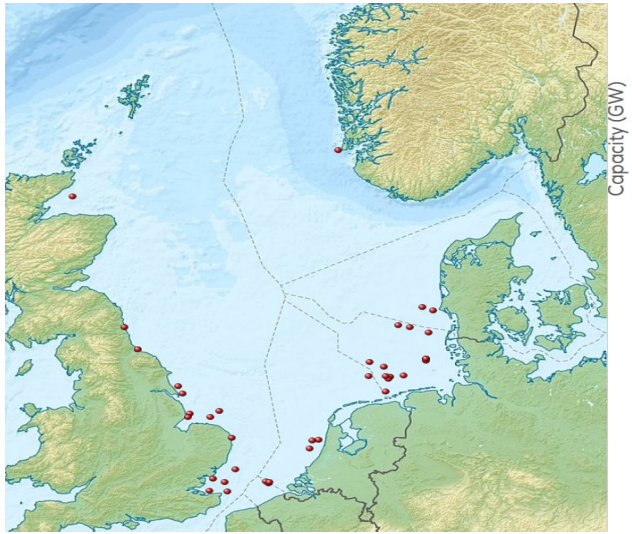


Geographic mismatch demand/supply

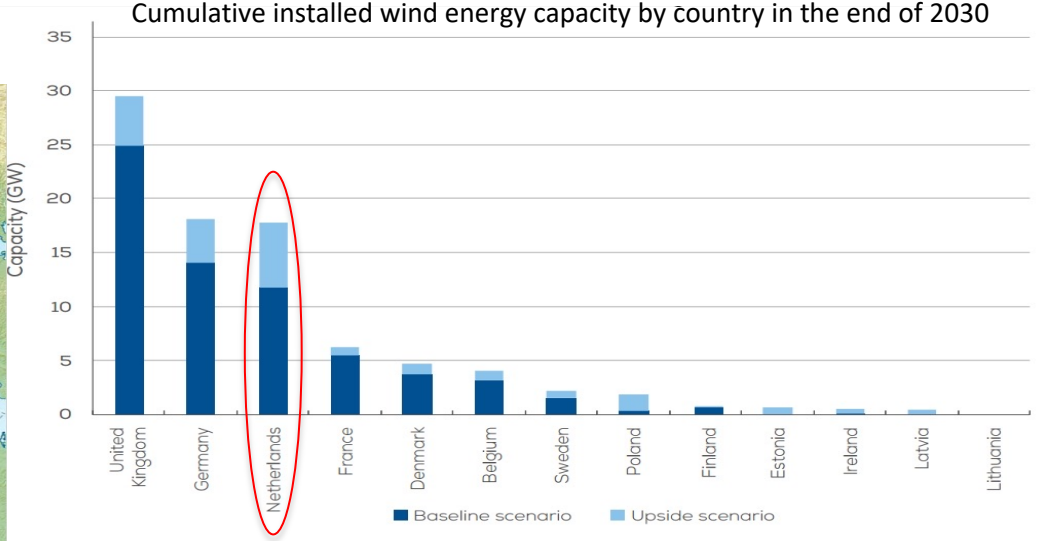


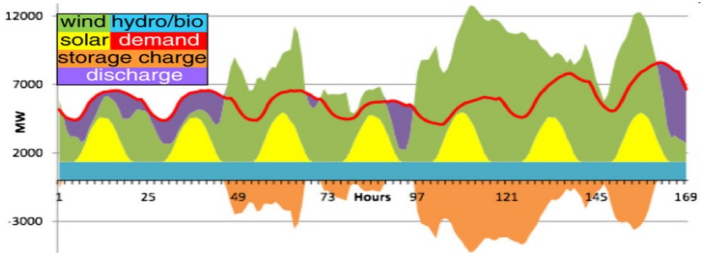
Need for energy storage

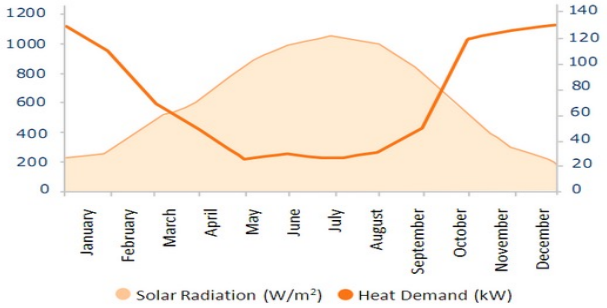
Offshore wind farms overview - 2017



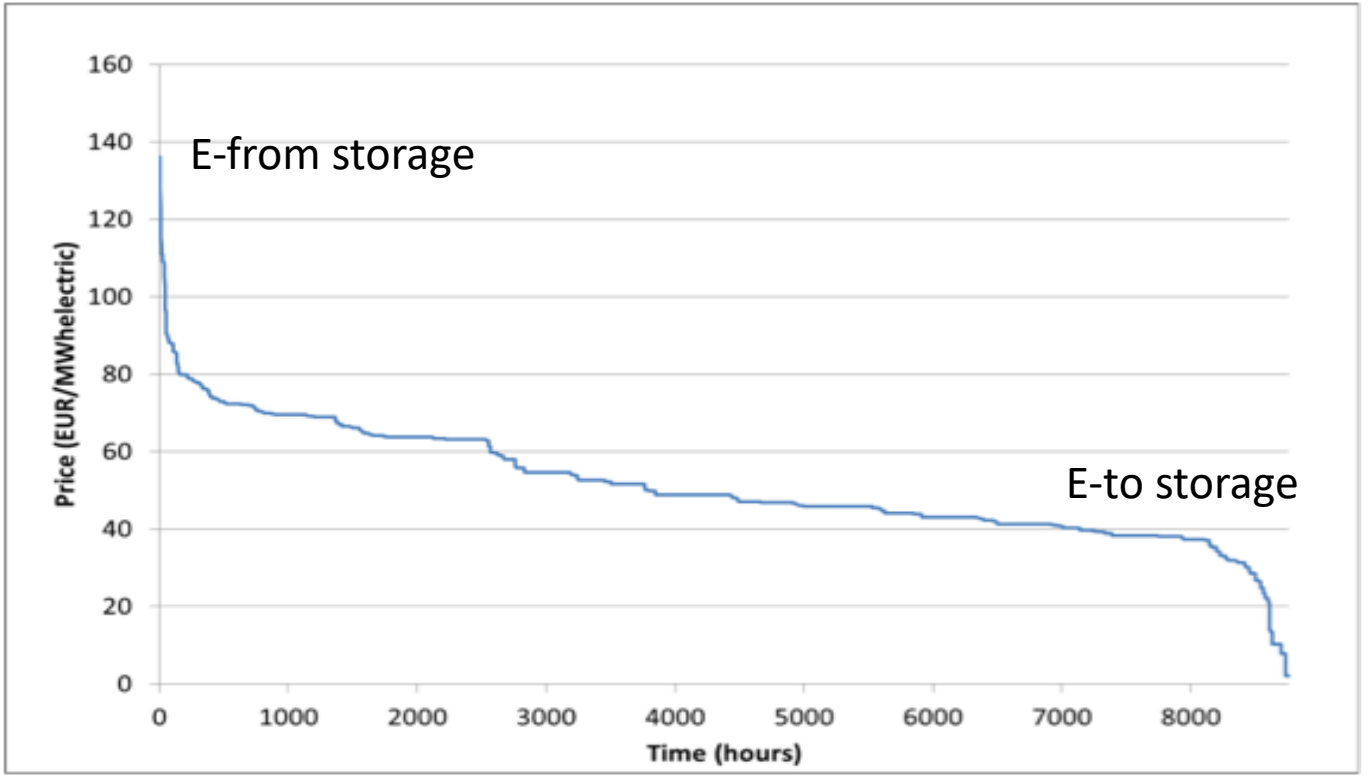
Cumulative installed wind energy capacity by country in the end of 2030







Possible scenario for power price-duration curve 2030



Source (adapted): http://www.voltachem.com/news/when-why-power-2-heat

Modes of energy storage

Fluctuations

Battery storage

Electricity Storage 50 TWh*

Mechanical storage

Storage in chemical bonds

Hydrogen

Ammonia

Hydrocarbons

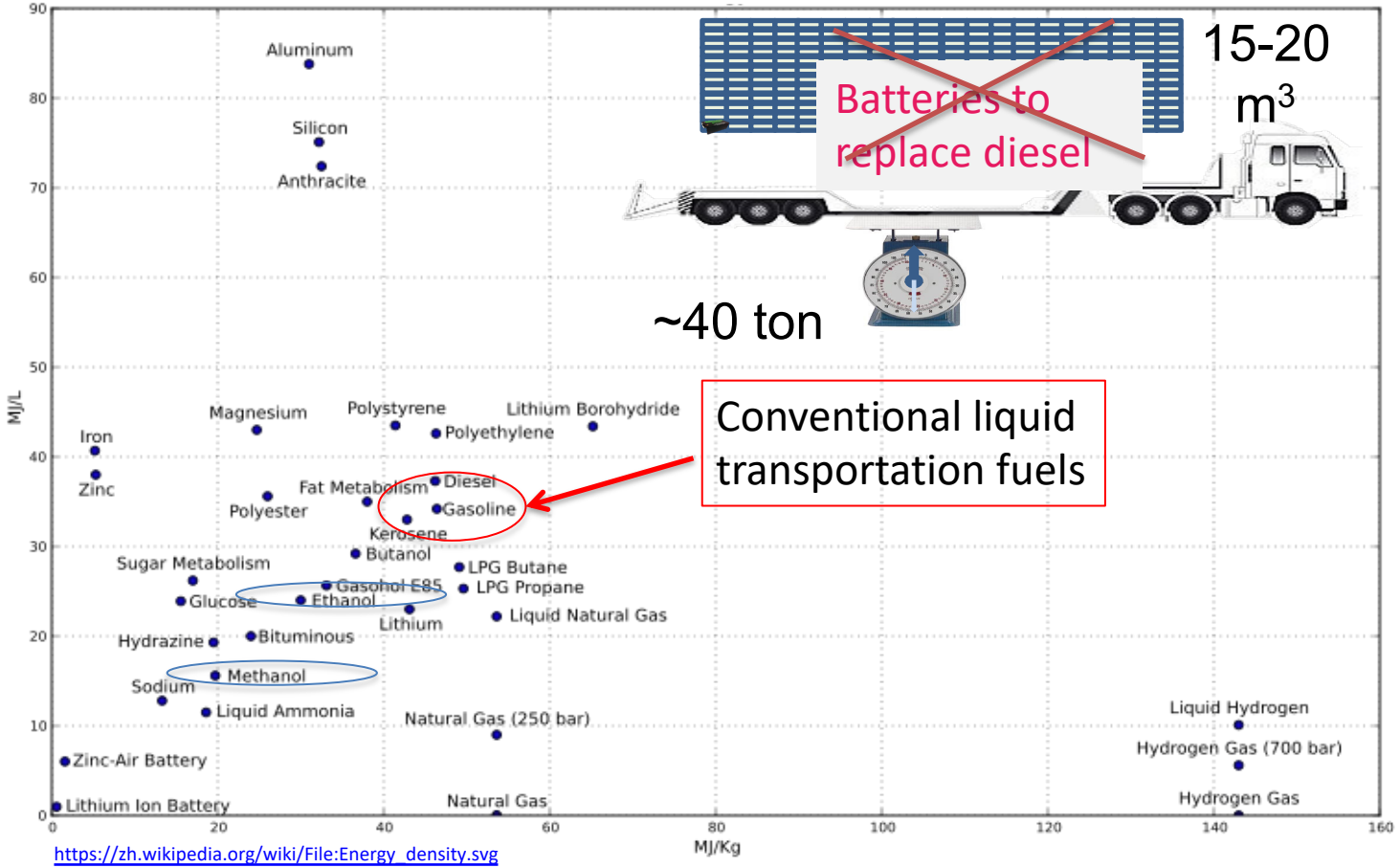
Fuel

Resource

*Based on DNW report

TU Delft

Energy density of fuels

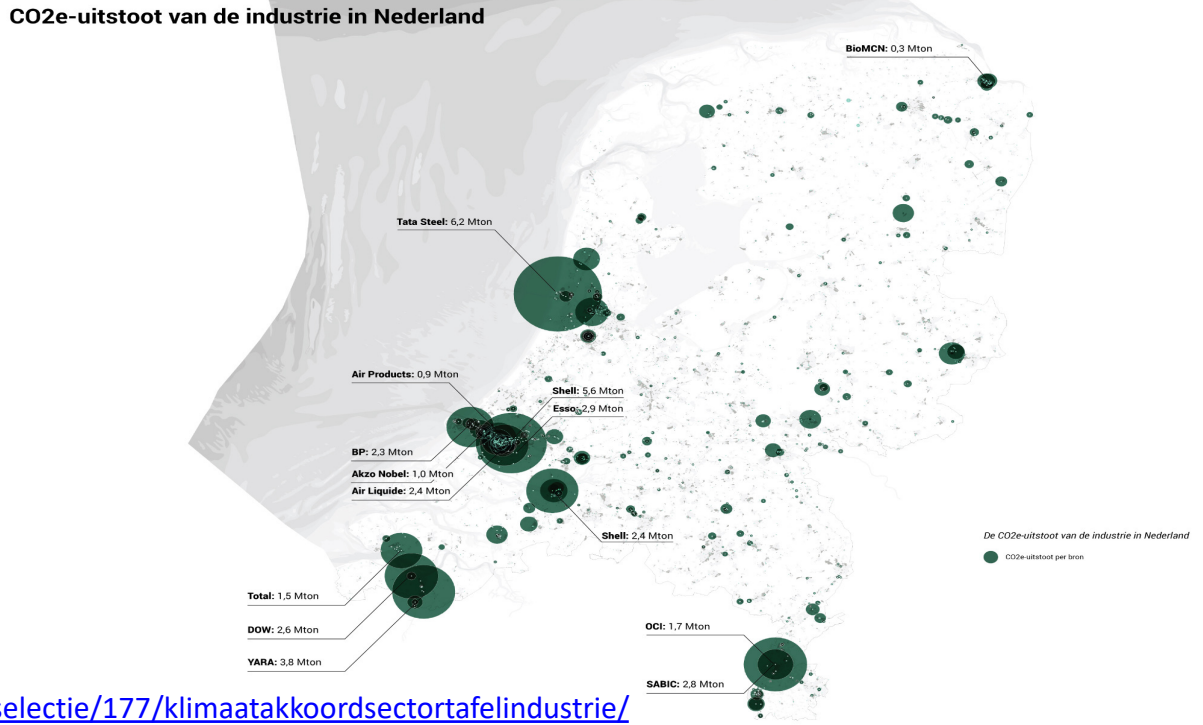


https://zh.wikipedia.org/wiki/File:Energy_density.svg

Picture truck, courtesy prof. Philip de Goey (TU Eindhoven)

Dutch industry CO_2 reduction

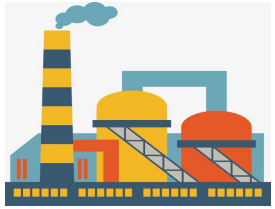
- Reduction by 14.3 Mton/yr (2030)
- All different point sources



http://marcovermeulen.eu/projecten/selectie/177/klimaatakkoordsectortafelindustrie/

Scenario's for future production of chemicals and fuels

'Conventional'



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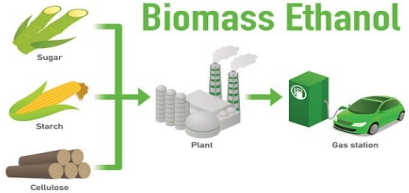

'Direct route'

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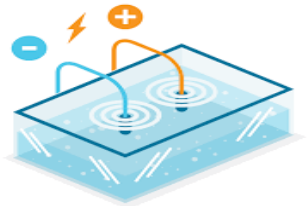
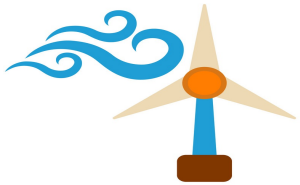


e-Refinery

'Indirect route'



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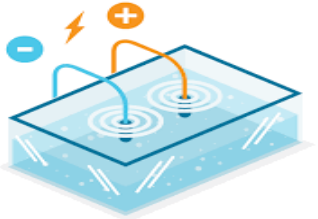

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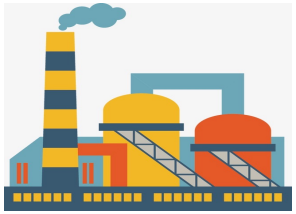
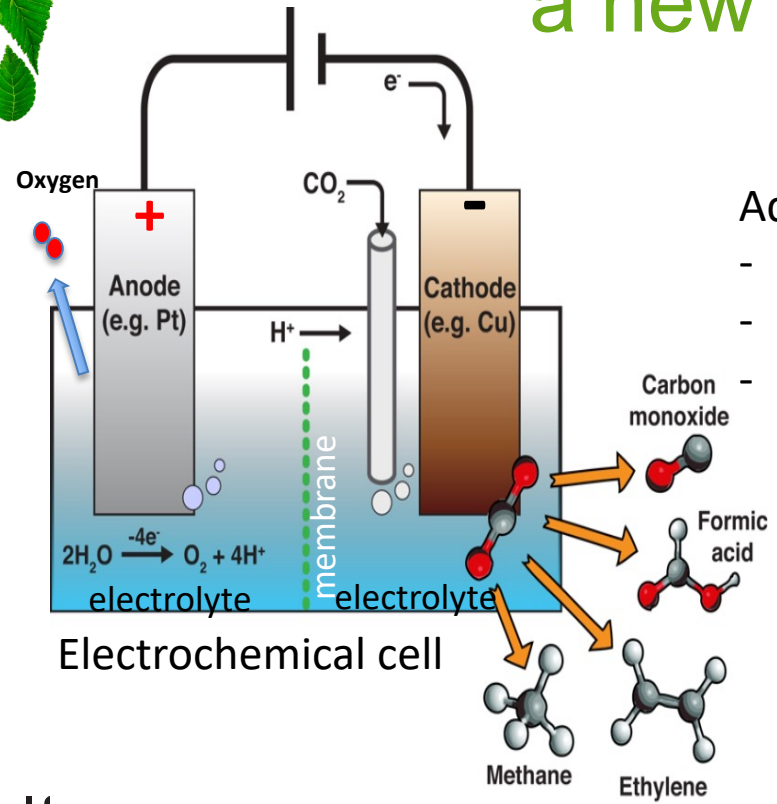


TU Delft

Electrochemical CO_2 conversion, a new research area



Electrochemical cell

Advantages of using electrochemical conversion:

- Using DC electricity
- Mild process conditions
- Can be carried out relatively selectively

$$\Delta V = \Delta E + \Sigma\eta + IR$$

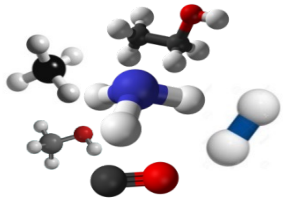
Equilibrium Potential (thermodynamics)

Overpotentials

Ohmic (resistance) loss

Delft Initiative: “The e-Refinery”

Bulk chemicals



Process

Water

Air (CO_2 /N_2)

Biomass

Electricity

Electro-synthesis

Fuels

Chemicals

CO_2 neutral Fuel

Seasonal Energy Storage

e-Refinery

Defossilized chemical industry

Use

CO_2

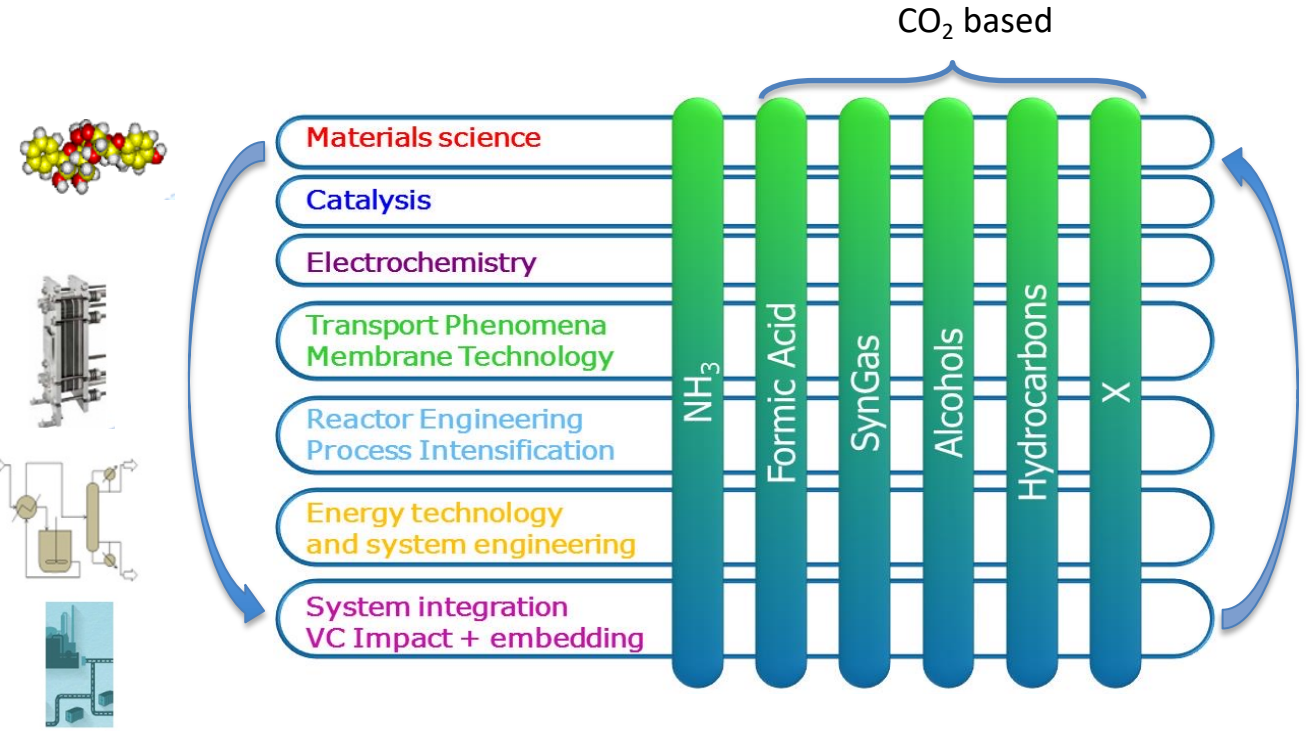
Waste & Emissions

TU Delft e-Refinery

Towards sustainable production of chemicals and fuels

e-Refinery development at TU Delft

Fuels, bulk chemicals

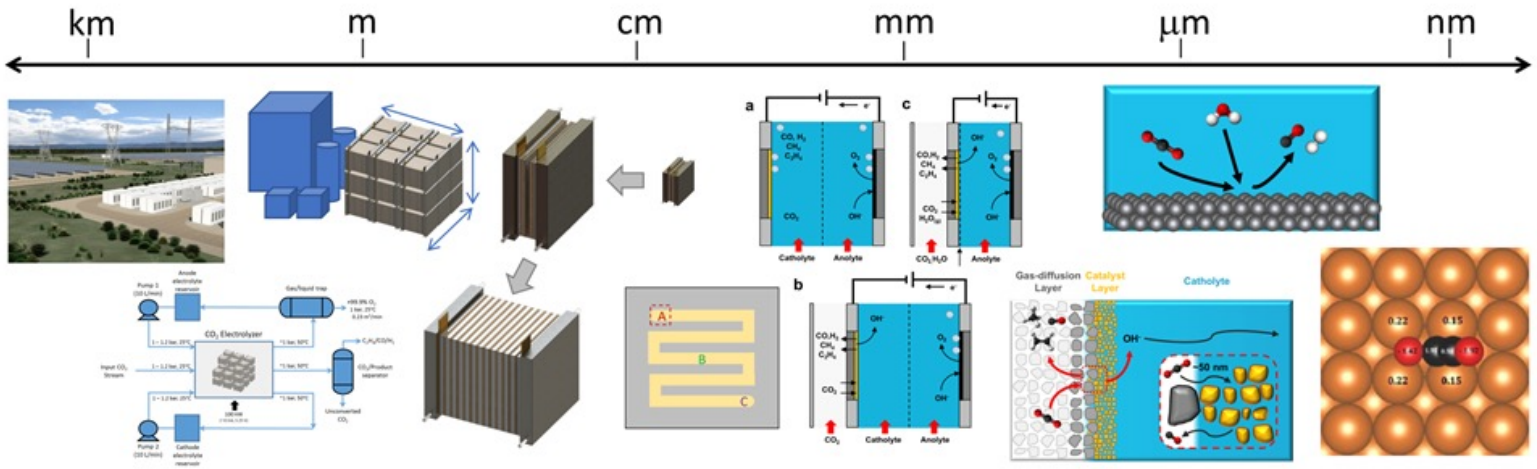


e-Refinery
Towards sustainable production of chemicals and fuels

TU Delft

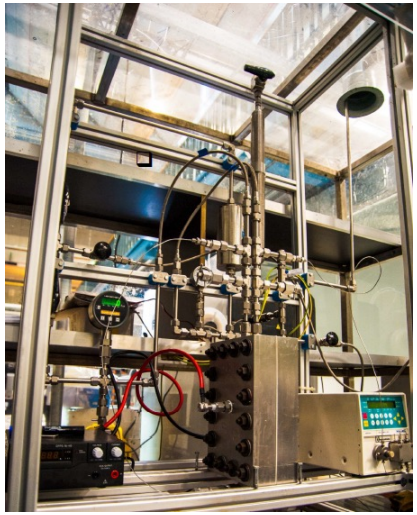
Need for Speed: not strictly sequential development together with our industry!

Bridging scales

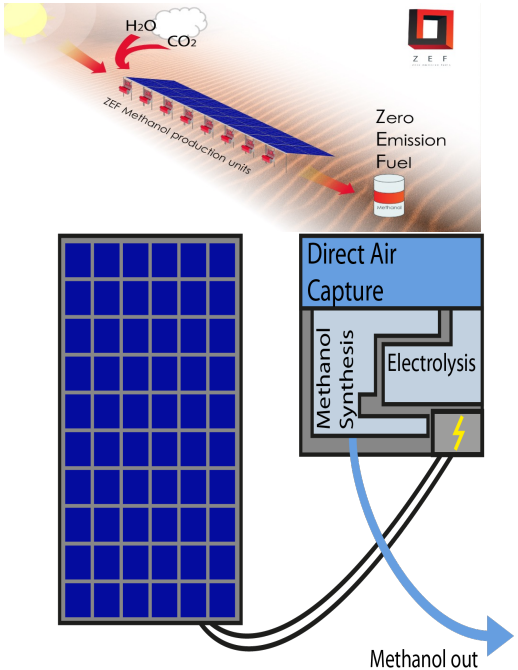


Large scale research: high current densities using abundant materials

Bridging TRL levels: idea to pilots



Electrochemical conversion
Reactor CO_2 to formic acid



System Integration and
Process Intensification
3D Printing of Components

Validation

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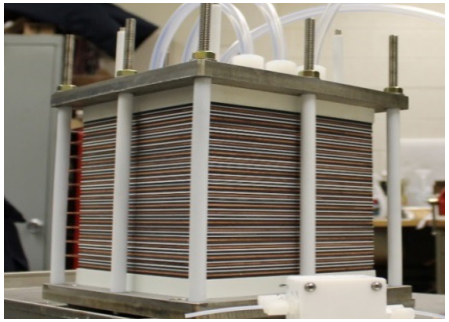
Ambition: 100 kW electrolyser for ethylene production

Operating parameters

Total amperage:	~31 kA
CO_2 converted:	217 kg CO_2/day
C_2H_4 Produced:	~38 kg C_2H_4/day
H_2O consumption:	24 kg H_2O/day
O_2 produced at anode:	430 kg O_2/day

Goals

- Feasibility test
- Find design rules
- Basis for large scale design
- Provide input for LCA



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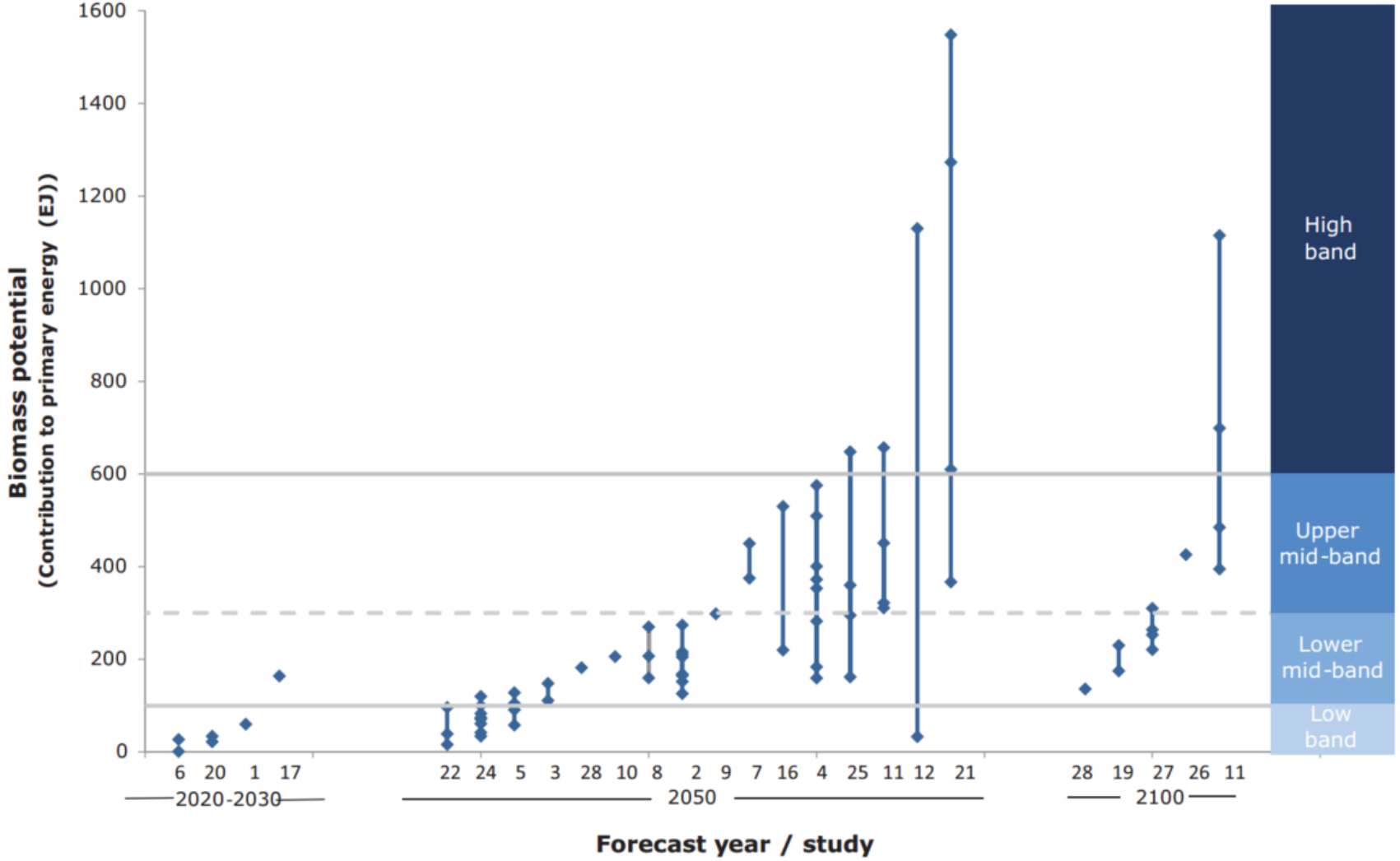
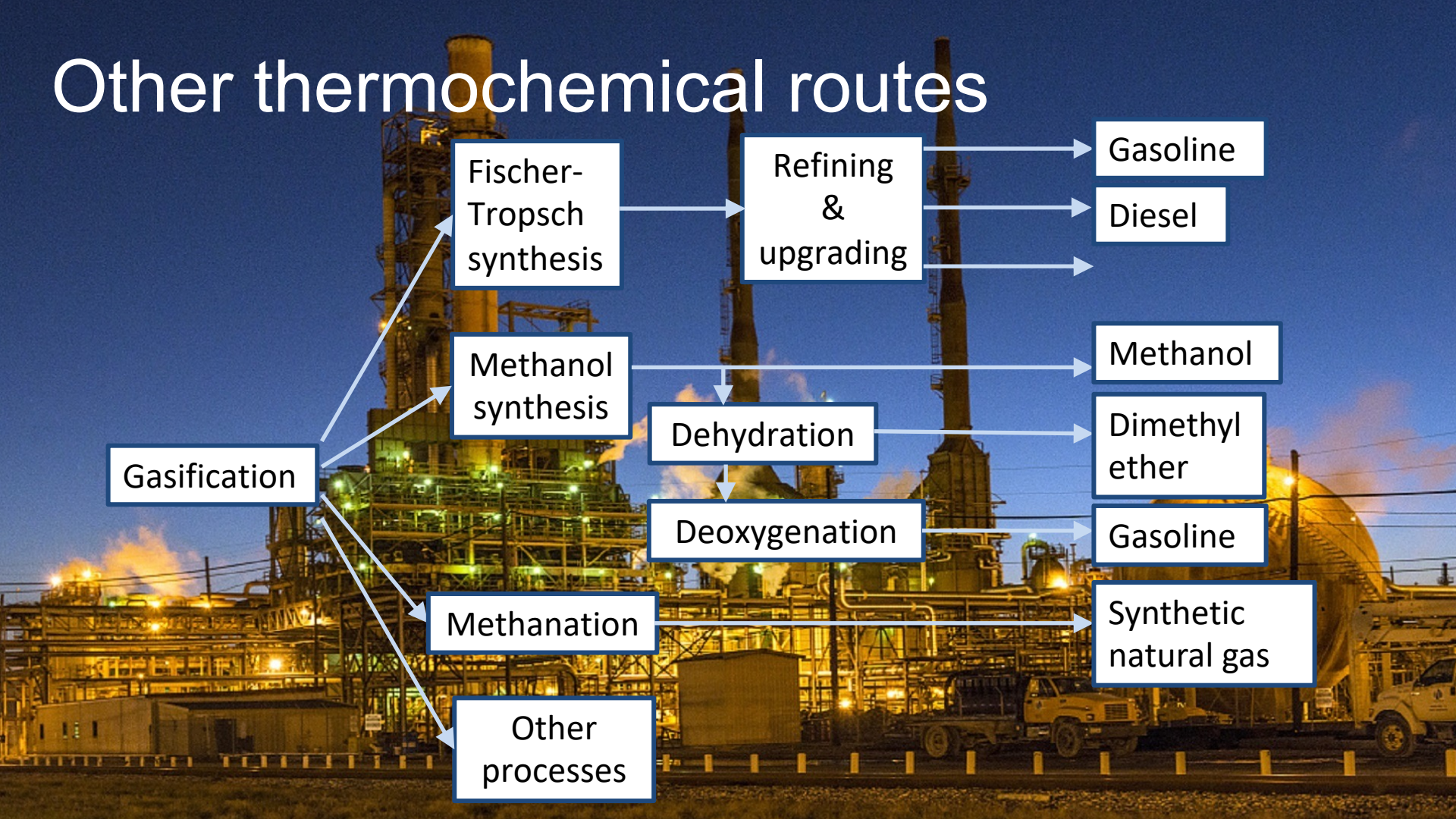


Slade, R., Saunders, R., Gross, R., and Bauen, A. (2011) Energy from biomass: the size of the global resource - An assessment of the evidence that biomass can make a major contribution to future global energy supply. Report. Imperial College, London, UK.

Other thermochemical routes