VOLTA CHEM

Electrification of the Chemical Industry

Electrification of chemistry

"Towards a CO_2 neutral process industry"

Martijn de Graaff

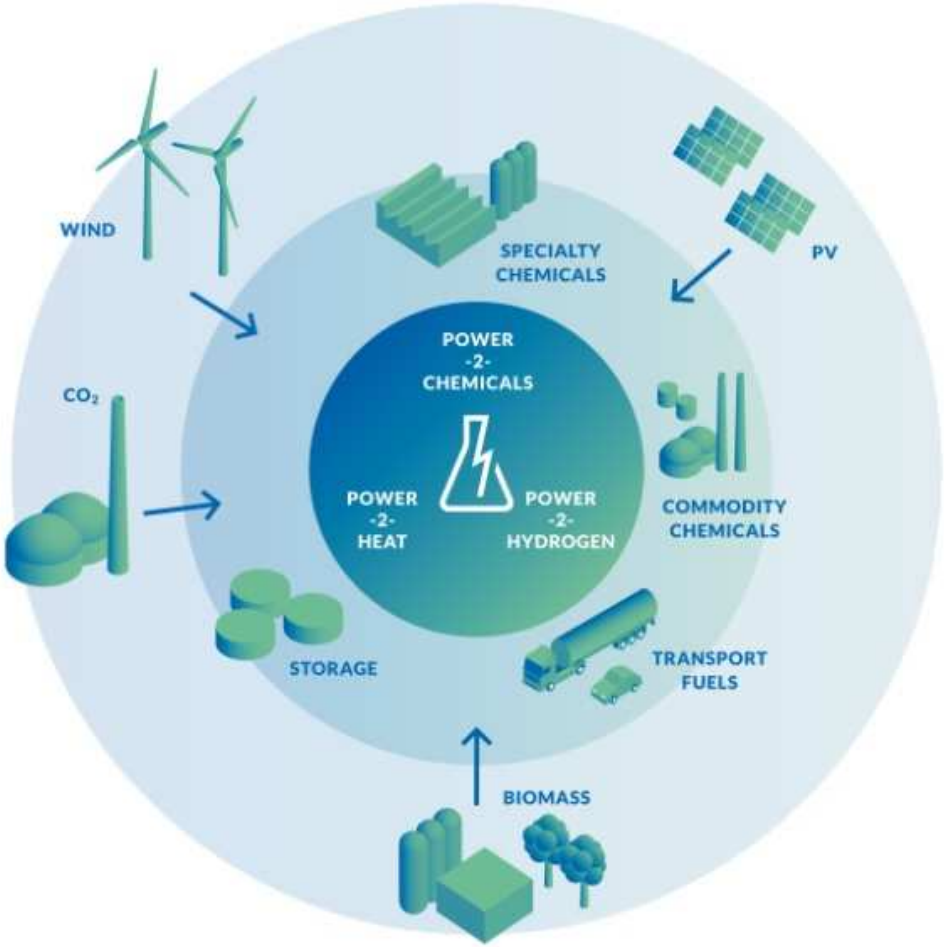
Utrecht, 22 november 2016

KIVI Engineering Society

UTRECHT SUSTAINABILITY INSTITUTE

Powered by: TNO innovation for life ECN

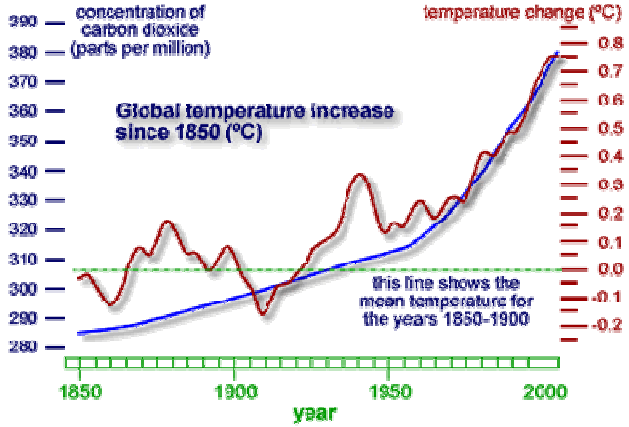
VoltaChem: Our mission



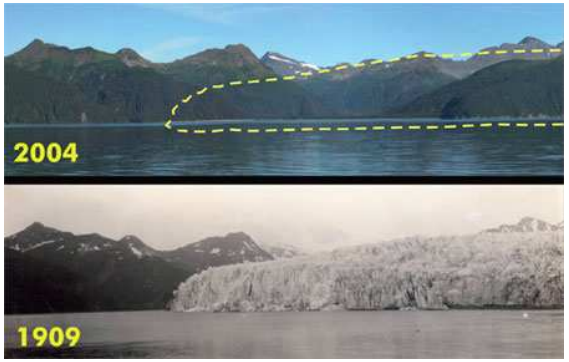
- Accelerate innovation and implementation of ***electrification & decarbonization*** in chemicals.
- Initiate and facilitate ***collaborative development*** *of technology and associated business models*.
- Addresses both the *indirect and direct use of electricity* within the chemical industry, involving stakeholders from ***chemicals***, ***energy & equipment supply***.

Societal drivers for change…

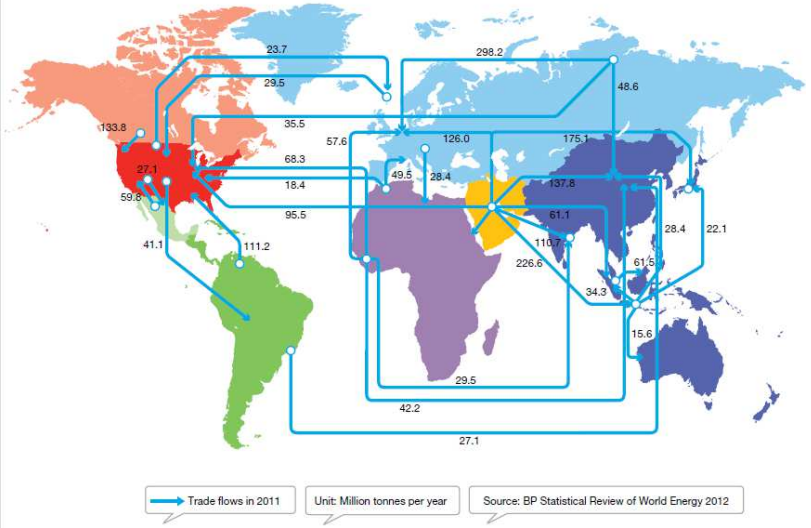
Global Warming



Source: ClimateChoice.org.uk



Security of Supply



Source: BP Statistical review 2012

… a chemical industry under pressure …

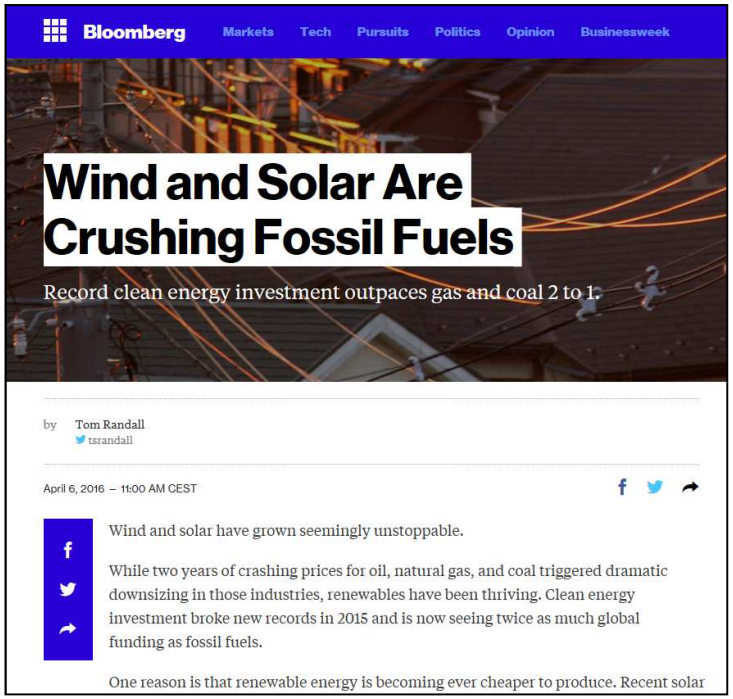
- Increased global competition.
- Weak position on feedstock and energy.
- Operational costs are high.
- Geographical shifts in demand.

Figuur 5: Indicatieve ontwikkeling van concurrentiefactoren; relatieve score van regio's

		Europa			VS			Midden-Oosten			Azië		
		2005	nu	2020	2005	nu	2020	2005	nu	2020	2005	nu	2020
Productiekosten	Feedstockkosten												
	Energiekosten												
	Overige productiekosten ❶												
Structuur chemiesector	Mate van integratie ❷												
	Chemiekennis ❸												
	Downstream activiteiten ❹												
Eindmarkten	Omvang eindvraag ❺												
	Groei eindvraag												

From: "De Chemie in Nederland, Een voorwaardelijke toekomst", Rabobank, 2014

… and new energy sources emerging …


Bloomberg Markets Tech Pursuits Politics Opinion Businessweek

Wind and Solar Are Crushing Fossil Fuels

Record clean energy investment outpaces gas and coal 2 to 1.

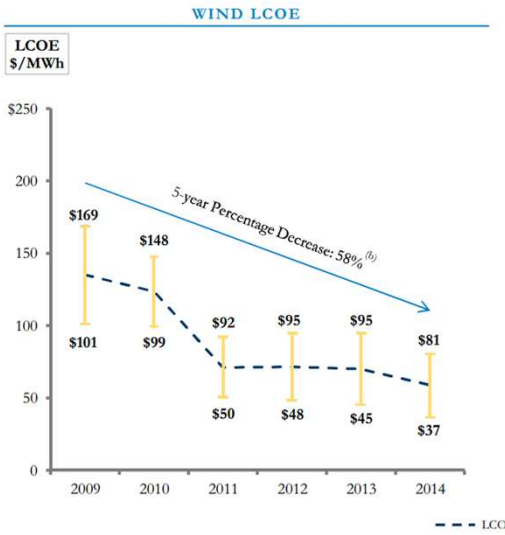
by Tom Randall
tsrandall

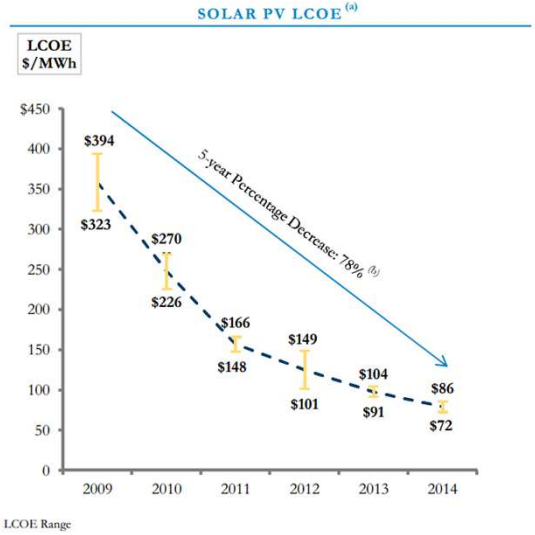
April 6, 2016 – 11:00 AM CEST

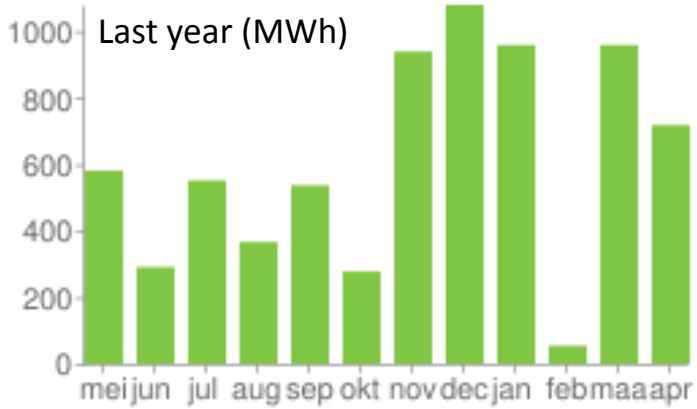
Wind and solar have grown seemingly unstoppable.

While two years of crashing prices for oil, natural gas, and coal triggered dramatic downsizing in those industries, renewables have been thriving. Clean energy investment broke new records in 2015 and is now seeing twice as much global funding as fossil fuels.

One reason is that renewable energy is becoming ever cheaper to produce. Recent solar







… generates opportunities for industry …

Energy solutions

Flexible supply

Demand response

Interconnection

Energy Storage & conversion

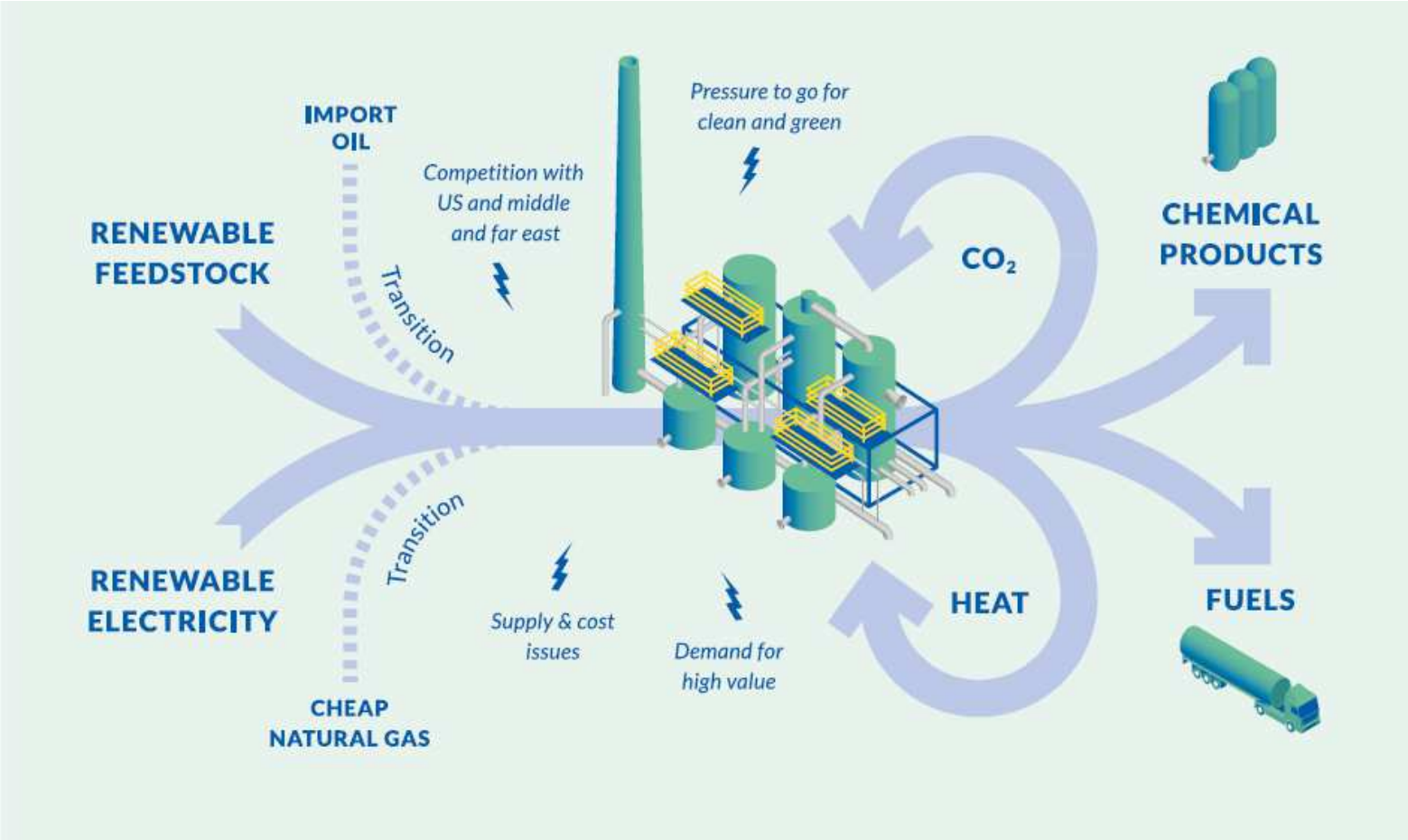
Chemicals solutions

Specialties

Commodities

Refineries

… taking a leading role in the transition.



TOPSECTOR ENERGIE
Empowering the new economy

Topsector Chemie

Holland High Tech
High Tech Solutions for Global Challenges

Some facts and figures

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Question

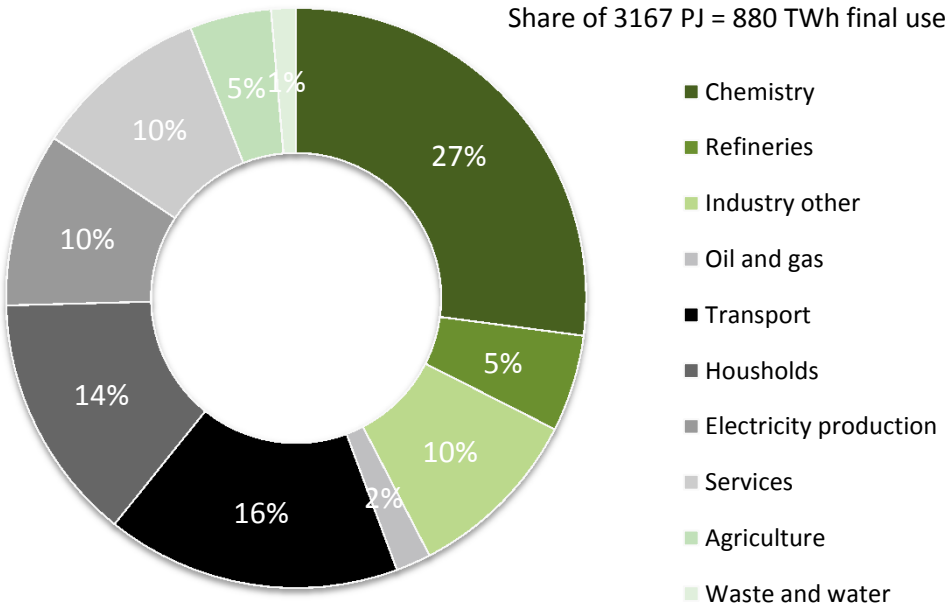
- What is the share of energy use of industry in the Netherlands?

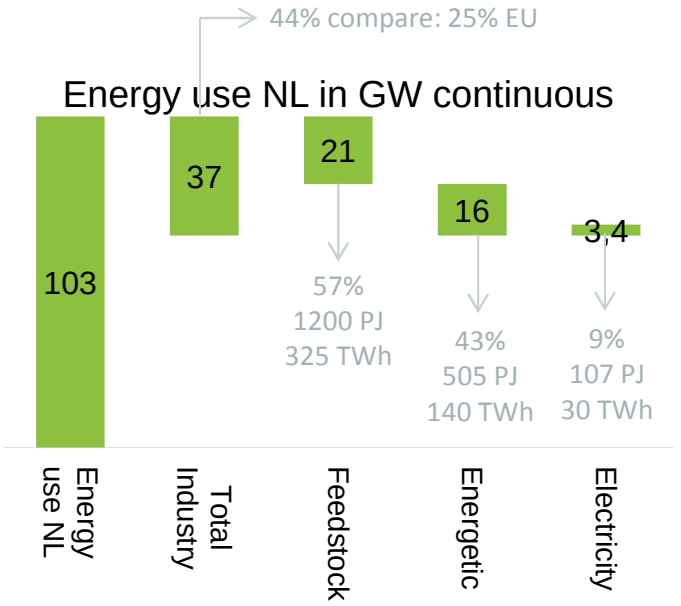
  → 0-10% / 10-25% / 25-50%

- How does this compare to Europe?

  → Lower / Equal / Higher

Energy use in Dutch process industry





Year	Source	$GW_{eq\ cont}$	$GW_{installed}$
2013	Total electricity generated	13.5	30
2013	renewable electricity	1.4	
2030	Total electricity generated	14.1	
2030	renewable electricity (53%)	7.5	
2030	intermittent solar/wind (87%)	6.5	26

→ 12 TWh = 44 PJ (1.4%)

→ 65 TWh = 236 PJ (~7%)

Source: Nationale Energieverkenning, 2014

Question

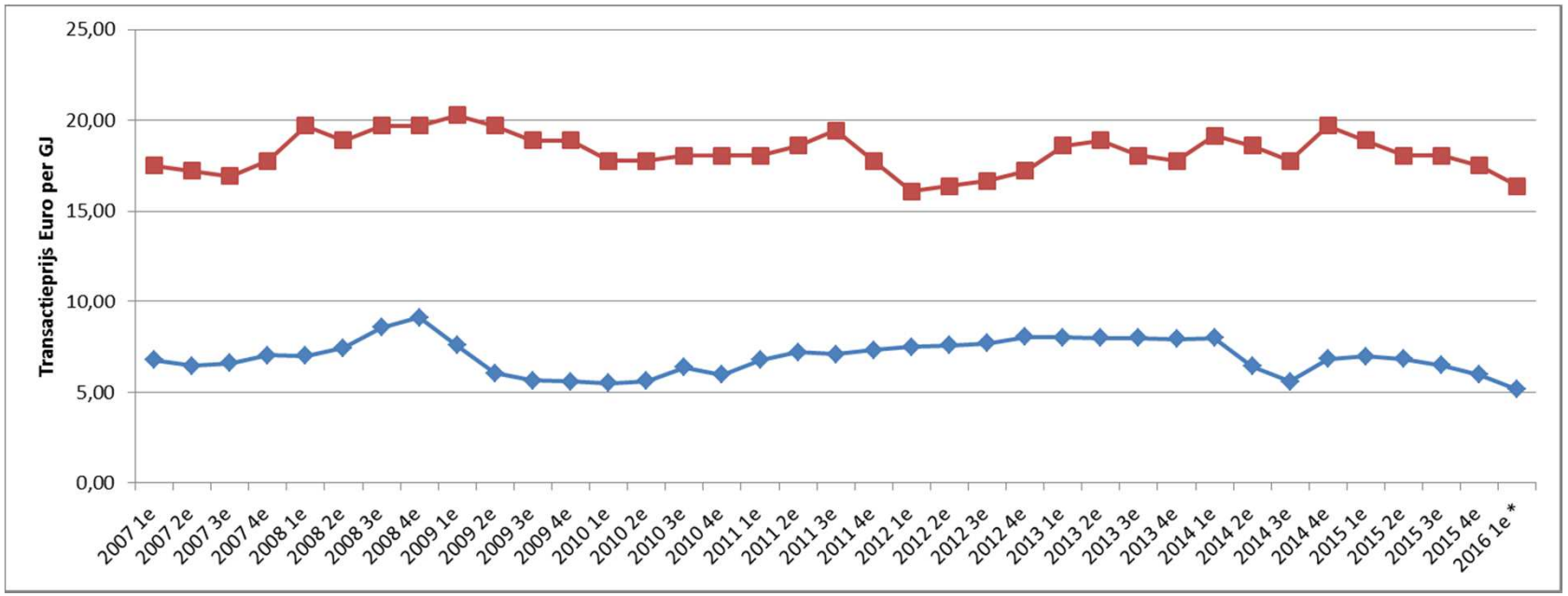
- How much is the difference between prices in electricity and natural gas for industrial use?

  → Equal / 3x / 5x

Energy prices electricity vs. gas

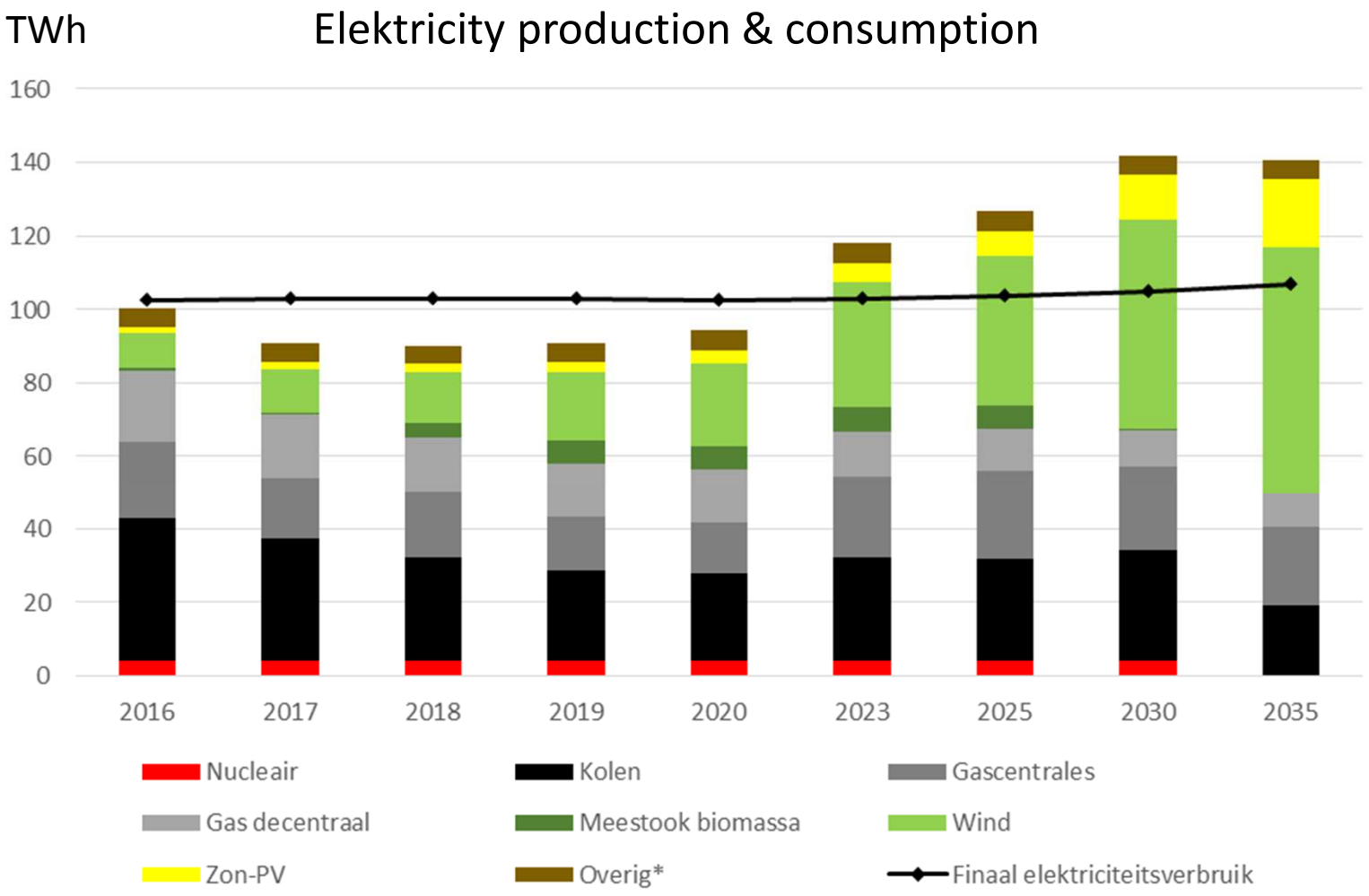
2007-2016 NL

Average transaction prices Natural Gas (blue) & Electricity (red), industry ex BTW incl Tax



Source CBS

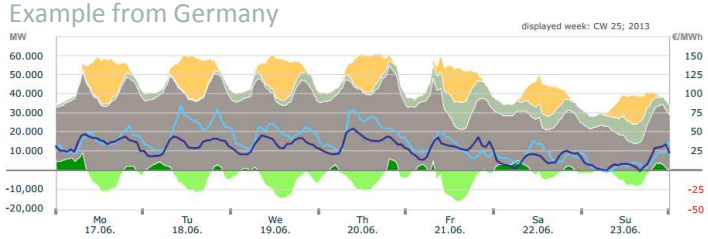
Increasing share of renewable electricity

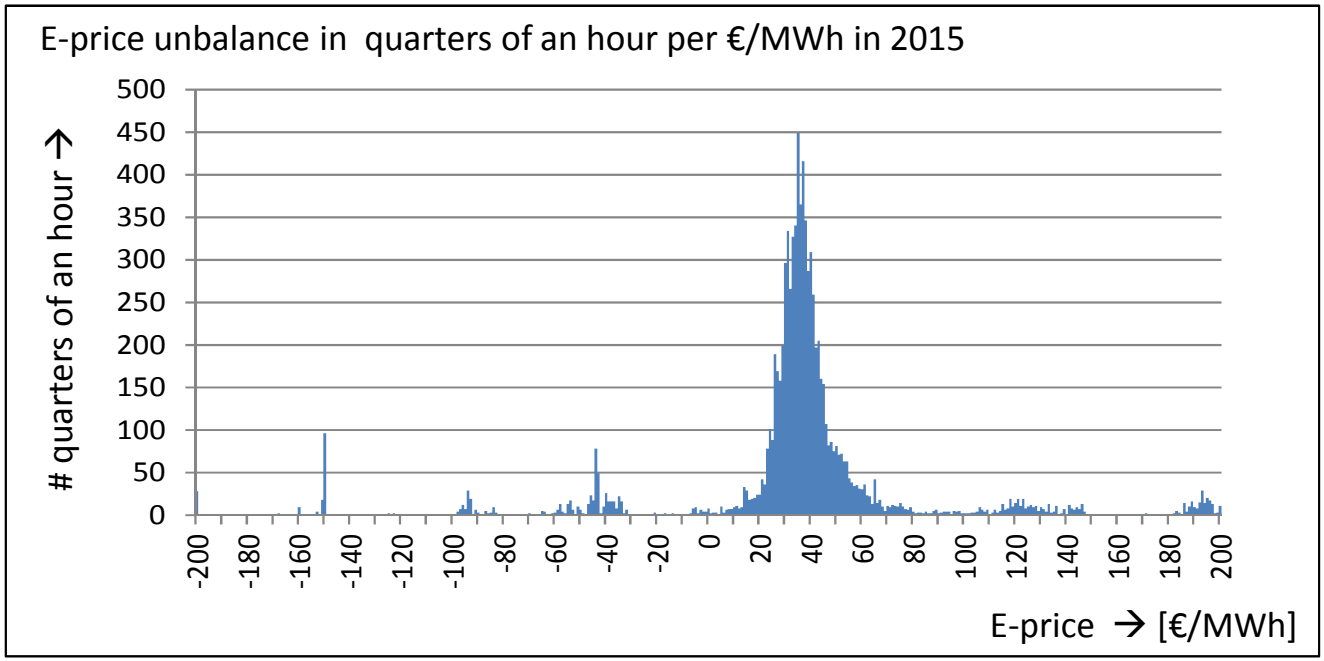


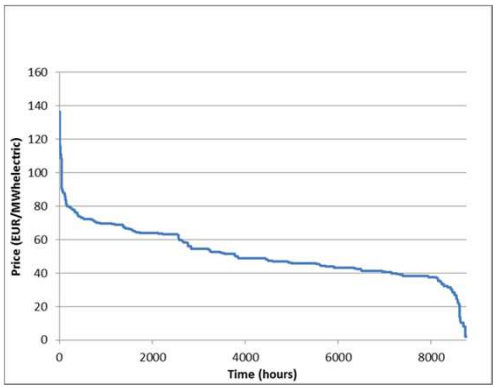
Source: Nationale energieverkenning 2016

Variability of electricity prices

Example from Germany







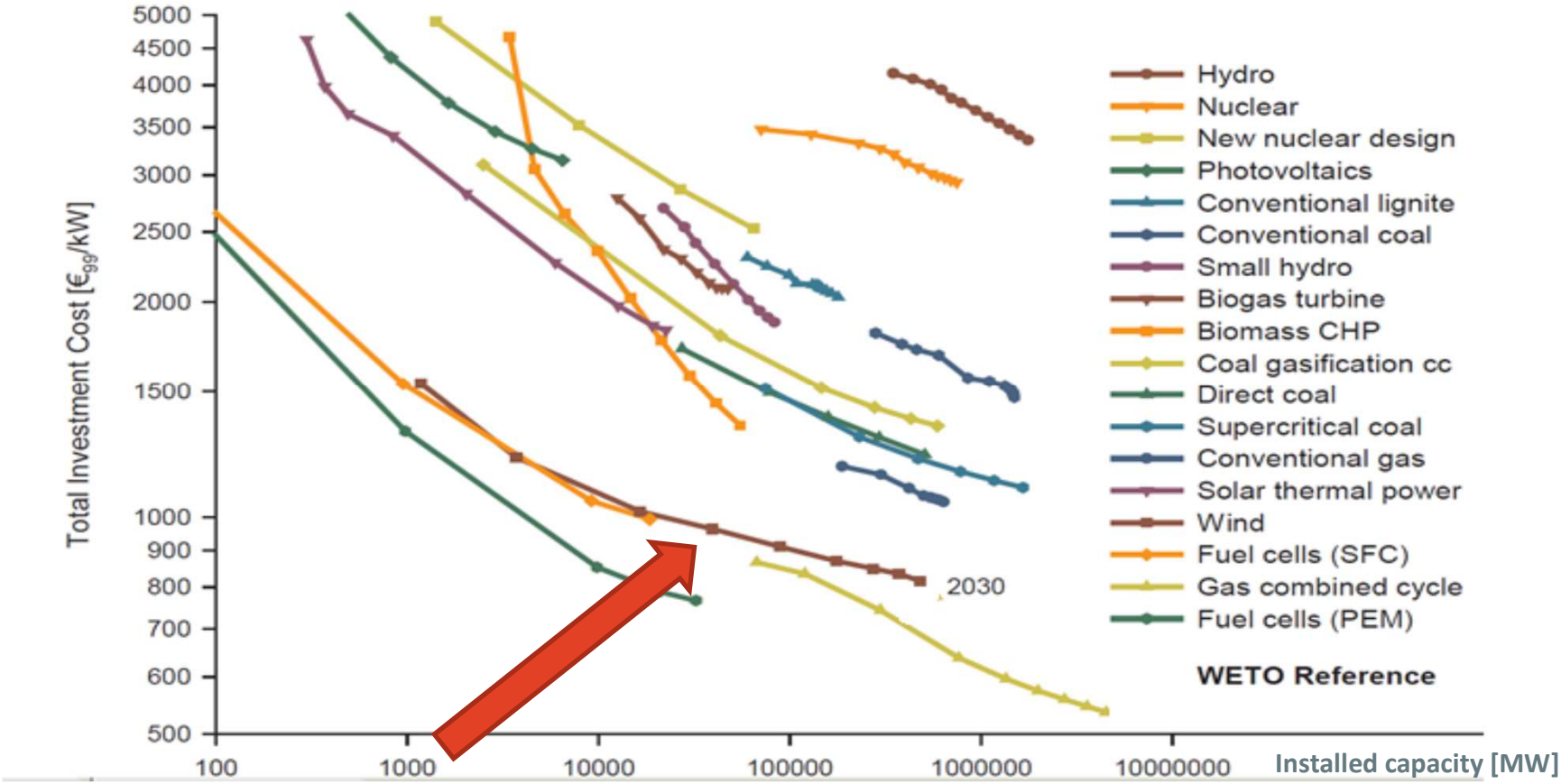
Price duration curve 2030

Question

- The investment costs of solar and wind technology decrease much more quickly than for conventional energy.

  → True / False

Price development of energy tech

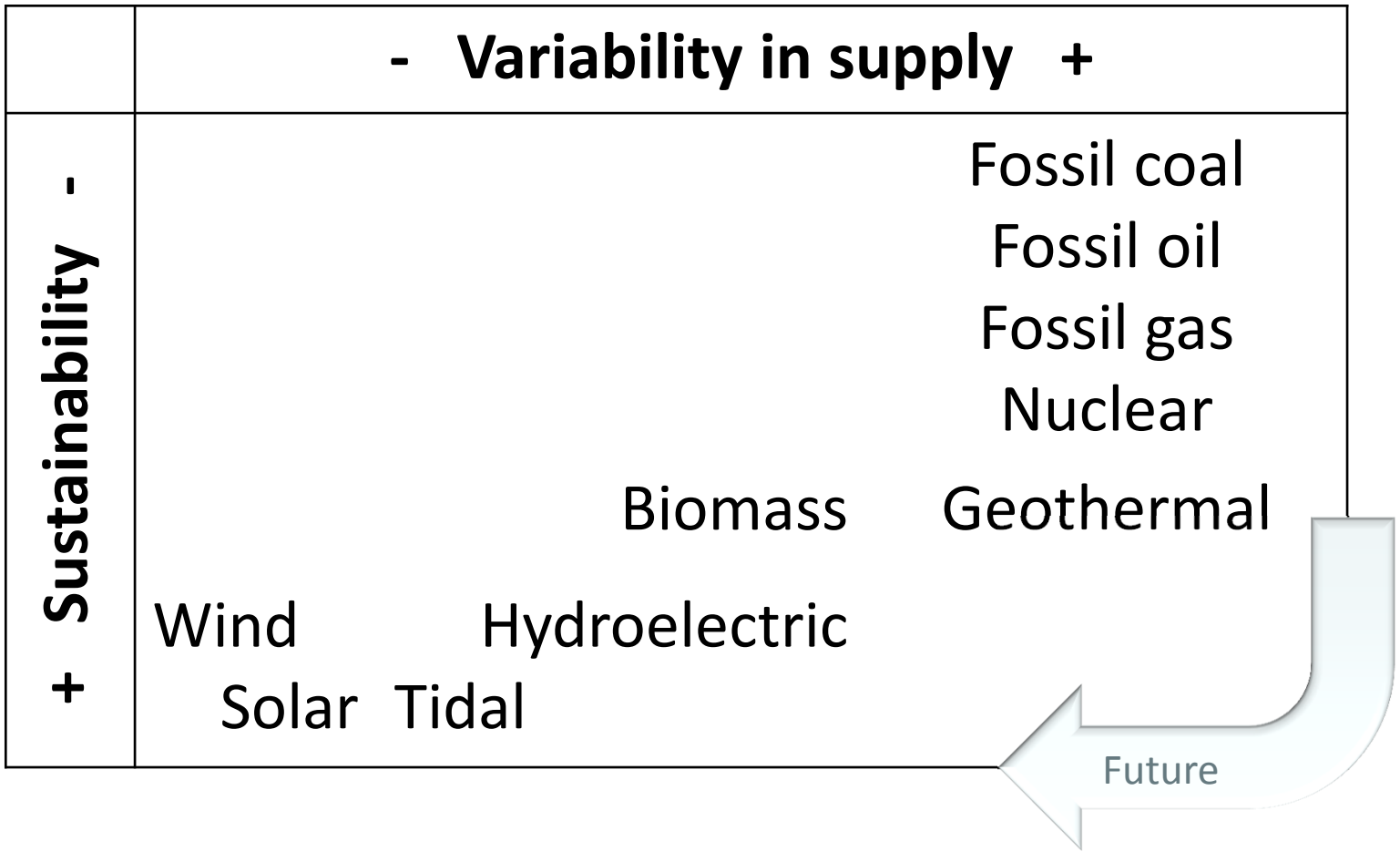


Source: European Commission World energy, technology and climate policy outlook, WETO 2030

Why & when electrification

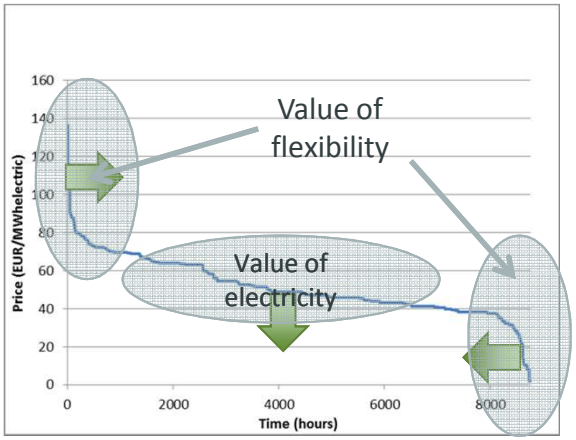
Powered by: TNO innovation for life ECN

Development in sources & variability

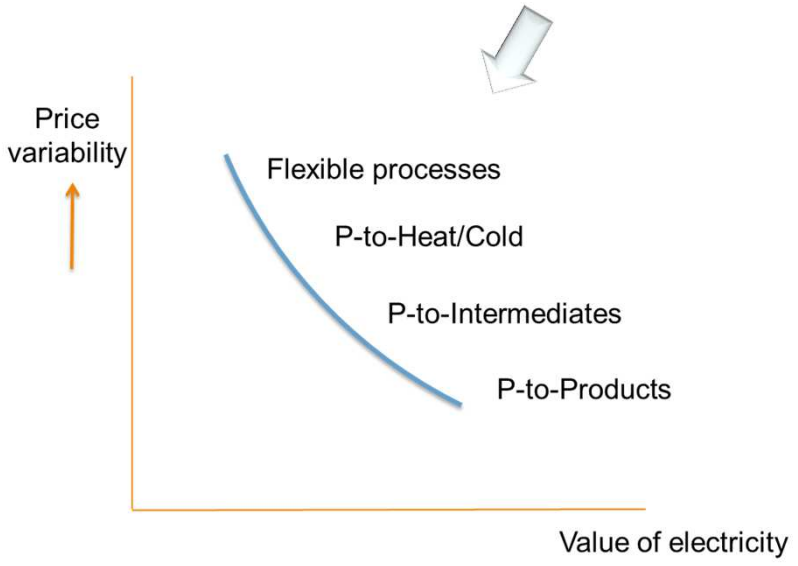


Electricity value vs. variability value

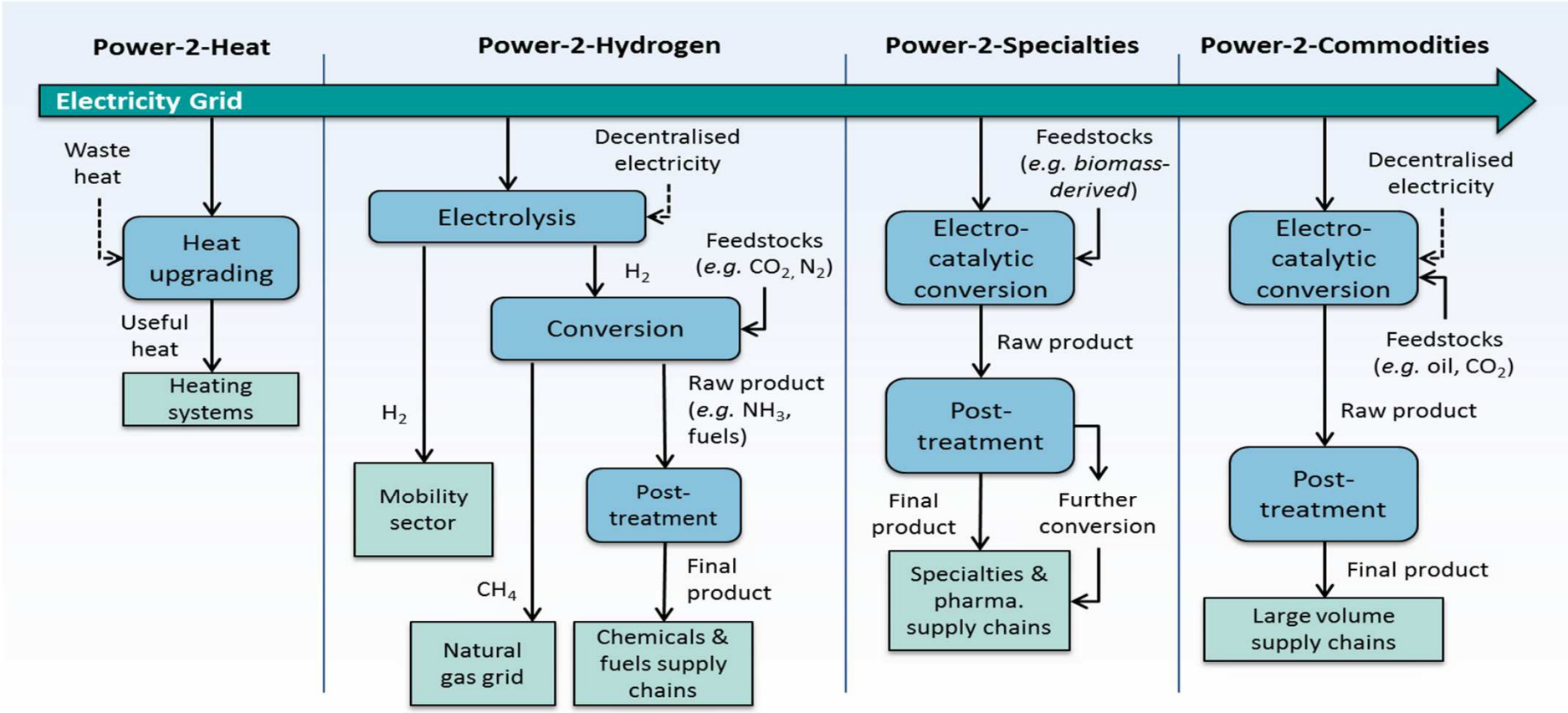
- **Value as heat (short-term)**
  - Electricity replaces conventional heating using mostly natural gas.
- **Value as intermediates (mid-term)**
  - Electricity is used to make intermediates (e.g. Hydrogen, Methanol, NH_3).
- **Product value (long-term)**
  - Electricity used directly to make end products (chemicals and fuels).



Price duration curve 2030



Main routes for electrification



Why & when electrification?

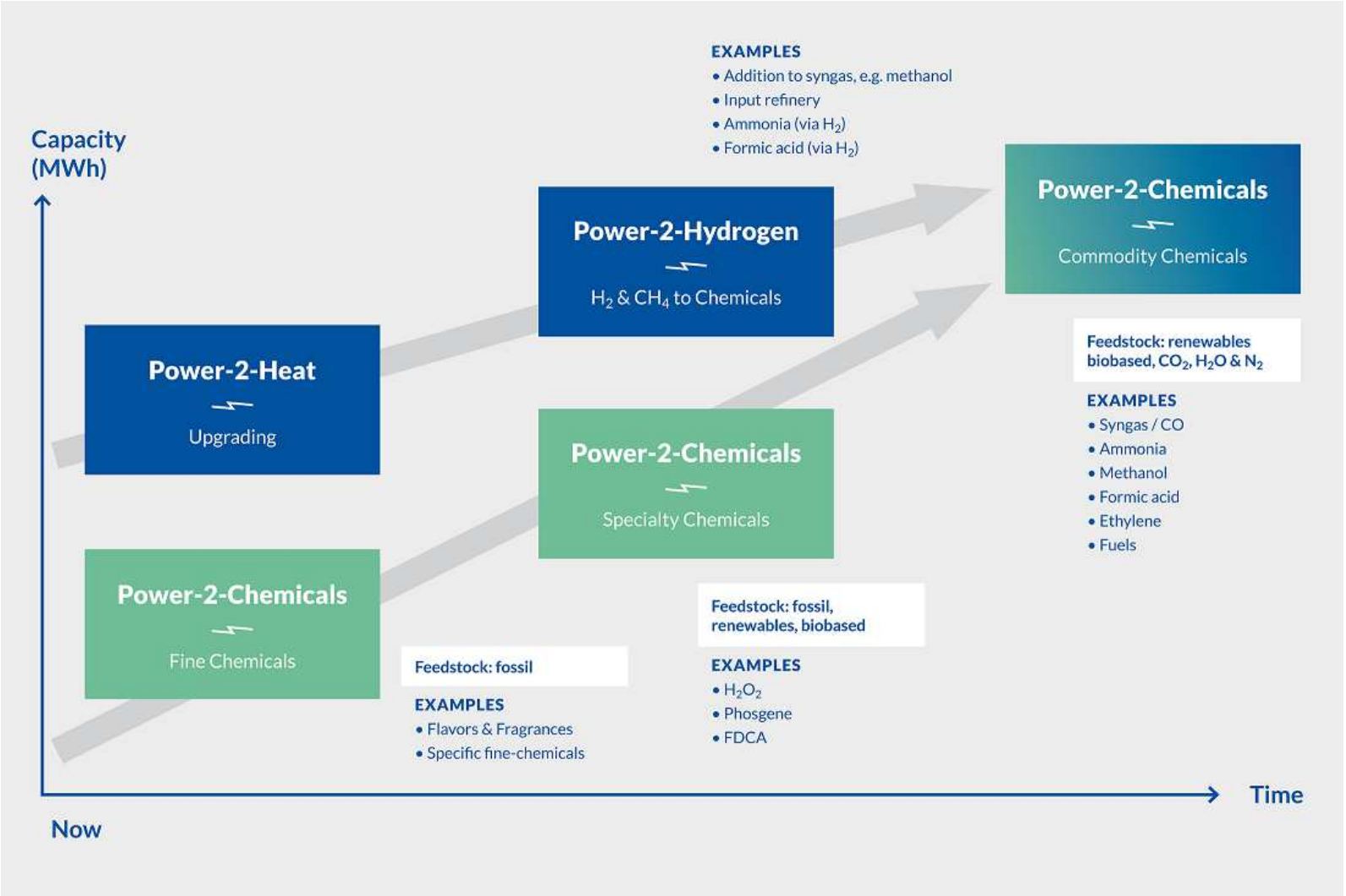
- *Flexibility*
  - Response time - short
  - Operating hours – relatively low
  - Allowable investment costs – low
  - Technologies at high TRL

- **Short-term option**
- Power-2-Heat
- Power-2-Hydrogen

- *Electrification*
  - Response time – less an issue
  - Operating hours – high (base load)
  - Allowable investment costs – higher
  - Technologies at mid/low TRL

- **Mid/Long-term option**
- Power-2-Heat
- Power-2-Hydrogen
- Power-2-Commodities

The VoltaChem roadmap



Upcoming technologies

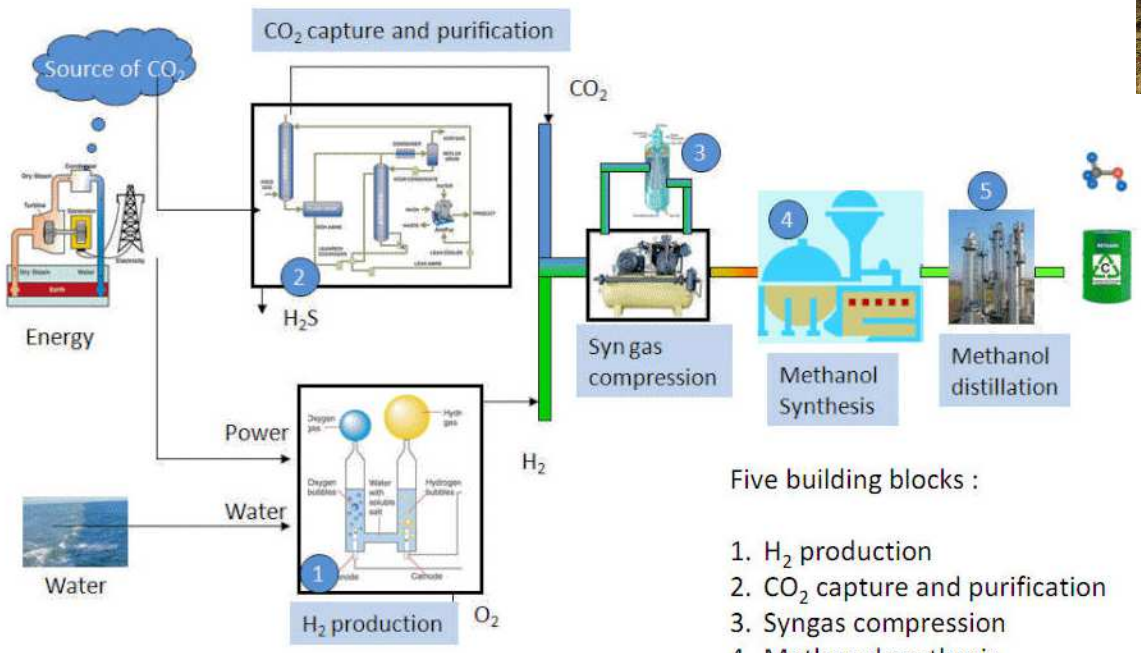
Inspiring examples for Power-2-Commodities

Powered by: TNO innovation for life ECN

Power to Methanol

Approximately TRL 8 (out of 9)

Demo plant, CRI, Reykjanes (Iceland)



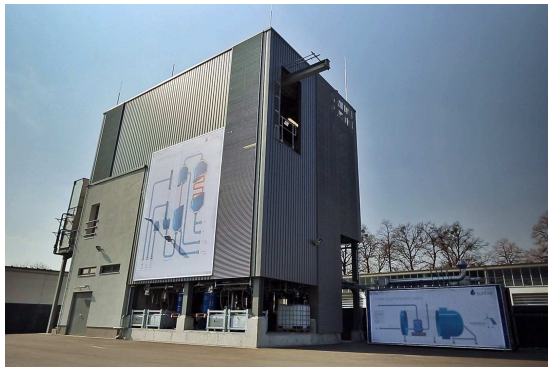
Five building blocks :

1. H_2 production
2. CO_2 capture and purification
3. Syngas compression
4. Methanol synthesis
5. Methanol distillation

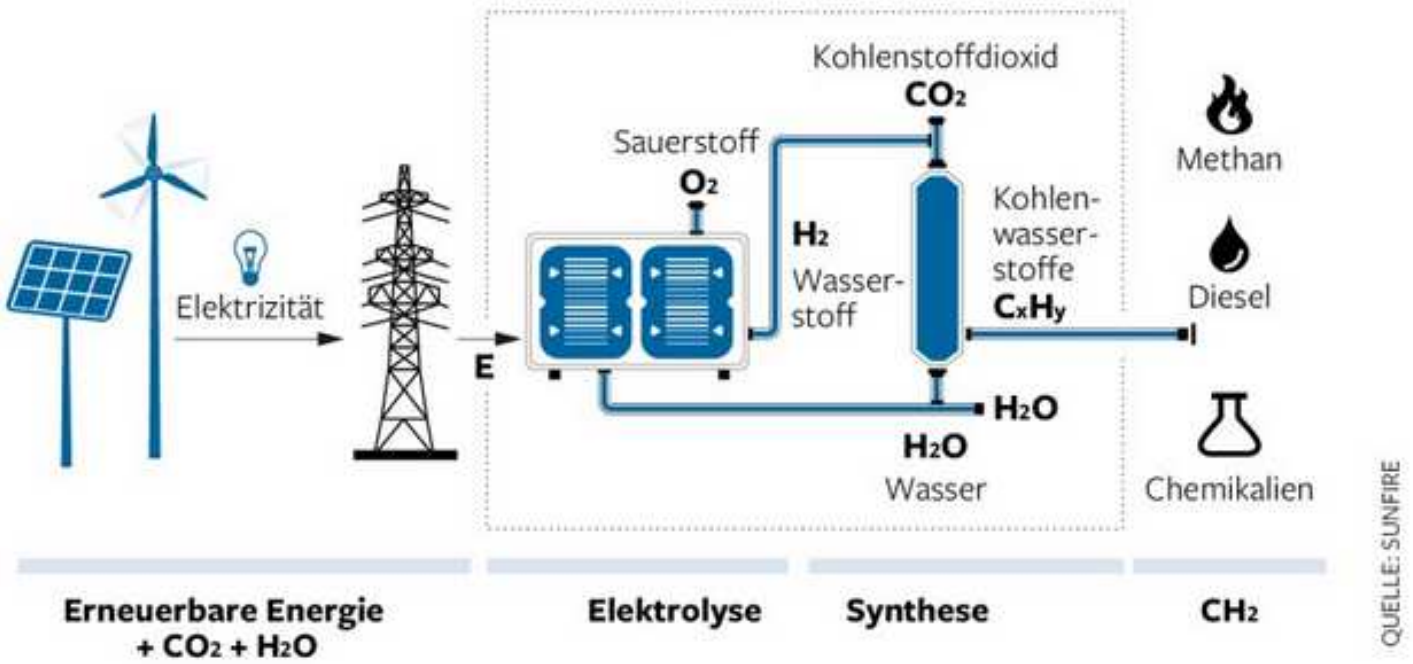
CARBON RECYCLING INTERNATIONAL

Power to FT-liquids

Approximately TRL 7 (out of 9)



Demo plant, Sunfire, Dresden (Germany)

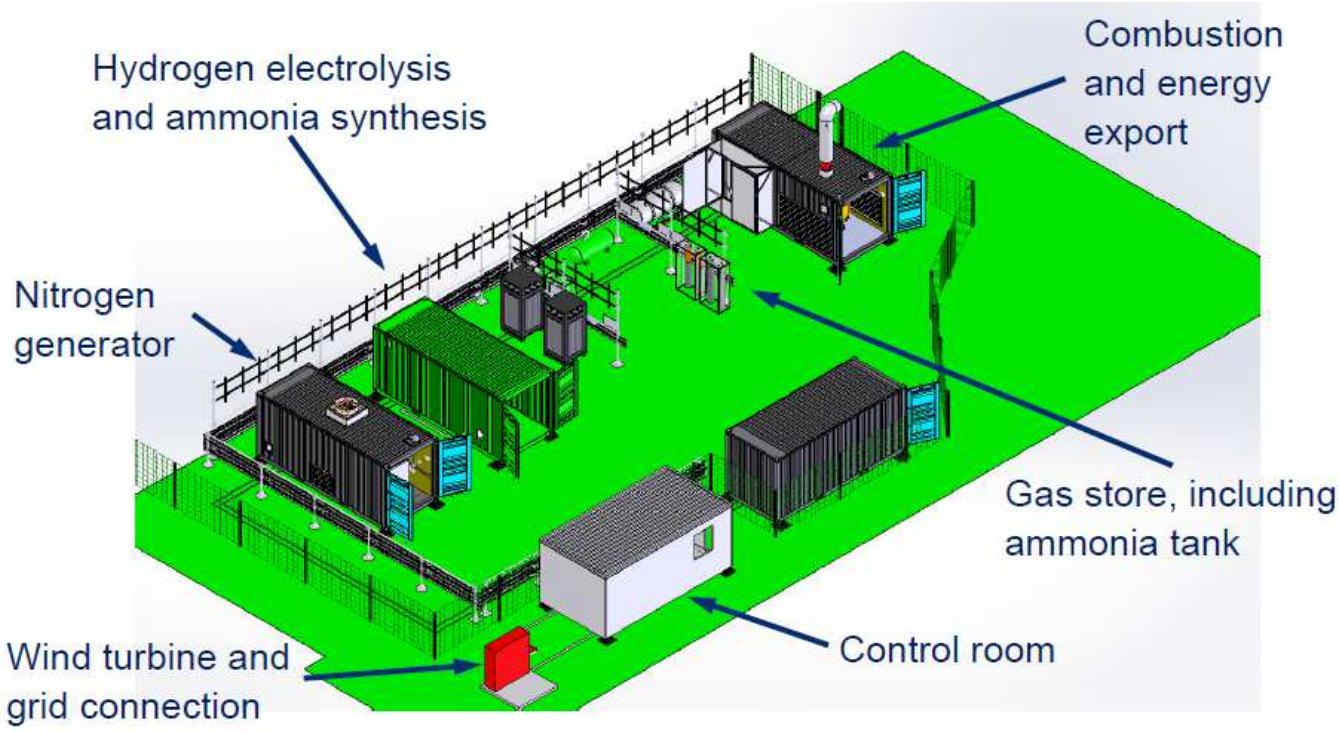


sunfire

Power to Ammonia

Approximately TRL 6 (out of 9)

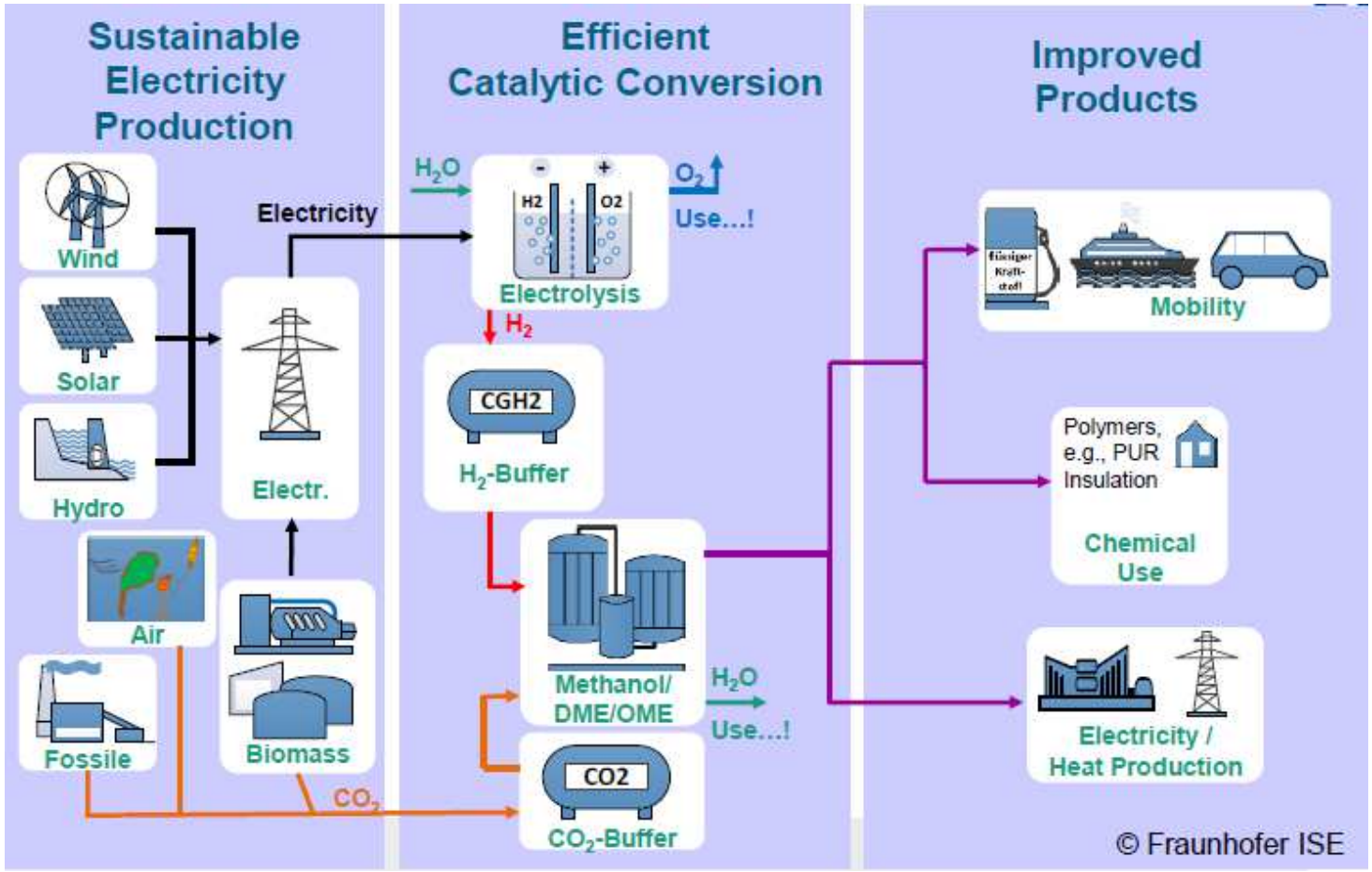
Pilot plant [2017], Siemens, Oxford (UK)



SIEMENS

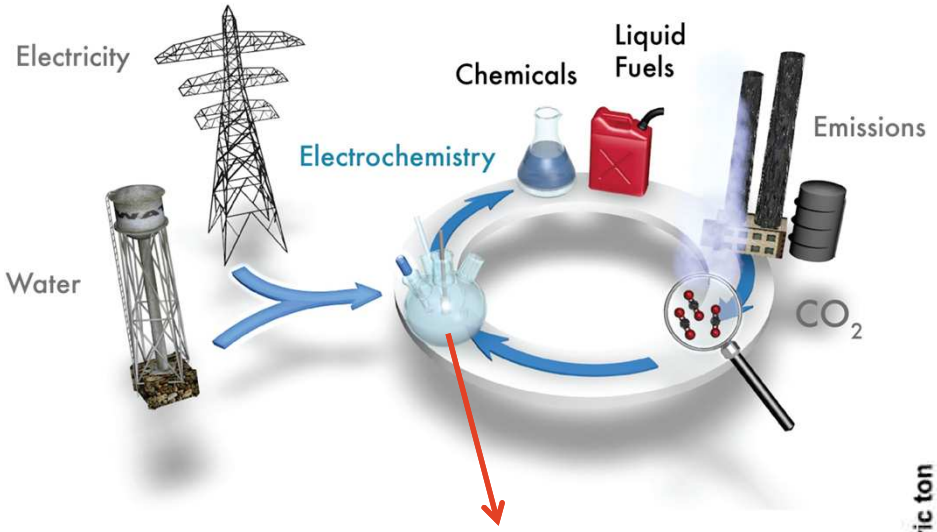
Power to MeOH/DME/OME

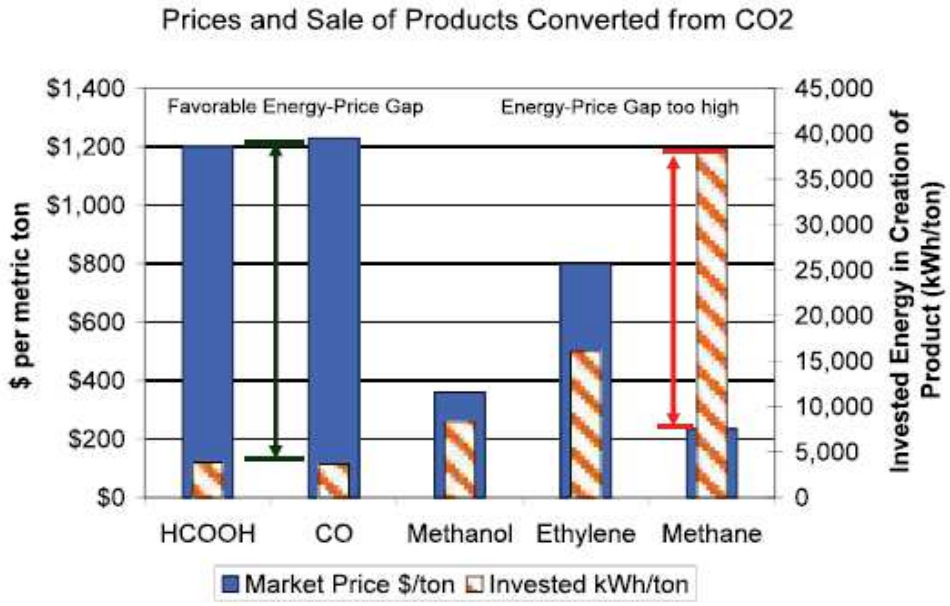
Approximately TRL 3 (out of 9)



Power to hydrocarbons (from CO_2)

Approximately TRL 1 (out of 9)





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Electrification of the Chemical Industry

Short-term electrification scenario

Implementing Power-2-Heat & Power-2-Hydrogen in NL

A *sustained innovation* scenario

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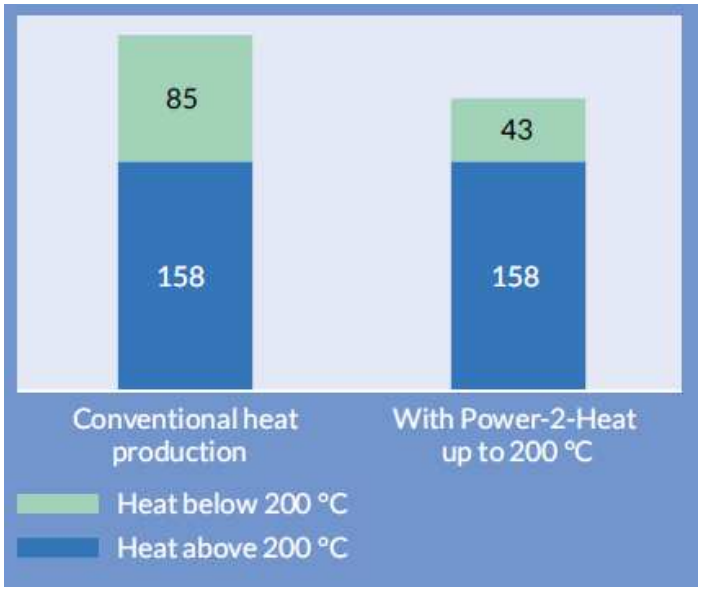
Short-term potential Power-2-Heat

- Assumptions:
  - Current heat consumption in chemical industry 243 PJ (43% > 200°C).
  - Full implementation of Heat Pumps & residual steam upgrading by Mechanical Vapour recompression in industry.
  - Giving 50% savings for high temperature steam.

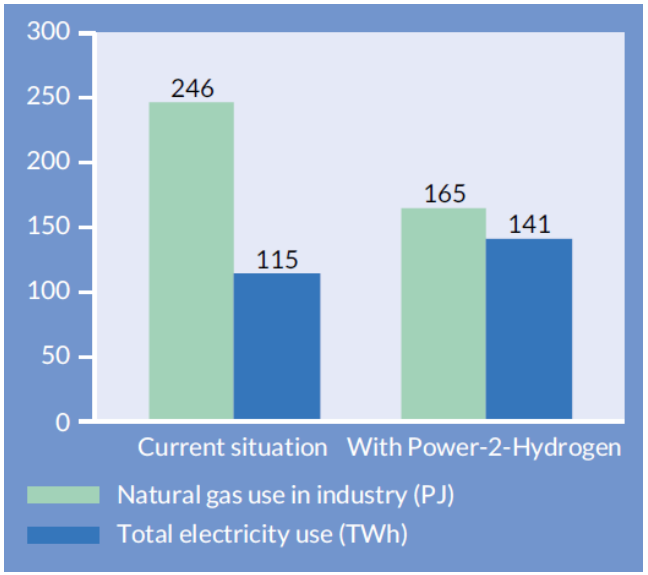
- Result:
  - 15-20% energy savings.
  - 2 TWh / year electricity consumption.
  - 6 Mt / year CO2 reduction.
  - 1 GW peak electricity use.
  - 4% of renewable capacity in 2030.



Short-term potential Power-2-Hydrogen

- Assumptions:
  - Current hydrogen consumption in Netherlands 63 PJ (requiring 81 PJ of natural gas as feedstock).
  - Full replacement of SMR by electrolyzers.

- Result:
  - 4.1 Mt / year CO2 reduction.
  - 26 TWh / year electricity consumption.
  - 6 GW electricity use at 50% load.
  - 20% renewable capacity in 2030.



VOLTA CHEM

Electrification of the Chemical Industry

Long-term electrification scenario

Implementing Power-2-Commodities in NL

A *disruptive innovation* scenario

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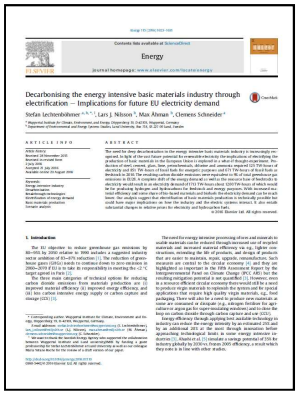
Industrial electrification 2050

A scenario based on EU study

Wuppertal Institute for Climate, Environment and Energy

LUND UNIVERSITY



- Scenario “Decarbonizing the energy intensive basic materials industry through electrification” (Lechtenbohmer, 2015)

- Looking at top-8 most energy intensive basic materials in EU:
  - Primary & secondary steel, cement, glass, lime, olefins (plastics), chlorine, ammonia (fertilizers).
  - Current EU emissions: 415 Mt / year CO_2 (8% of total)
  - Current EU energy use: 1.6 PWh/year (~8% of total)

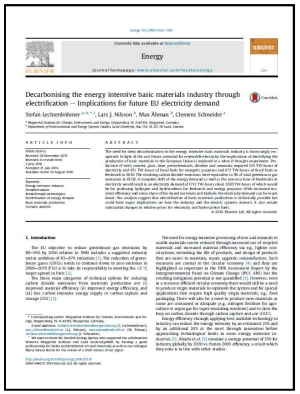
- Assumptions:
  - Complete conversion to energy from sustainable electricity.
  - Production levels constant.

Full industrial electrification 2050

Technology assumptions

Wuppertal Institute for Climate, Environment and Energy

LUND UNIVERSITY



Complete shift to low-carbon technologies:

- *Electrothermal processes for heating:*
  - Electrofurnaces.
  - Steam boilers & heat pumps.
  - Advanced electrothermal technologies (e.g. plasma, microwave, infrared).

- *Electrolysis technologies:*
  - Electrolysis of salt.
  - Electrolysis of water.
  - Electrolysis of iron ore.
  - Electrolysis of CO2.

- *Green ammonia synthesis:*
  - Using nitrogen and green hydrogen.

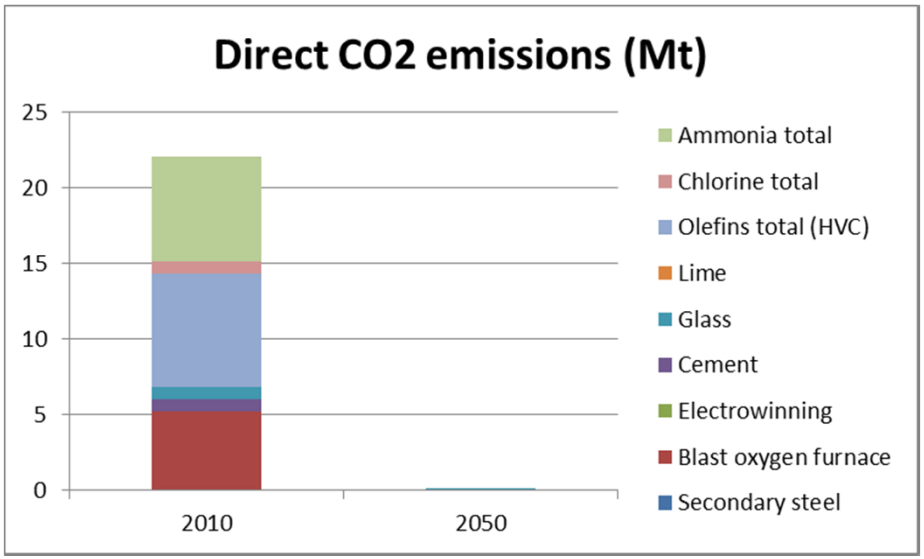
- *Producing hydro-carbons from hydrogen, CO2 and syngas:*
  - CO2 (air) capture.
  - Syngas from biomass gasification or CO_2/H_2 conversion.
  - Methane and Fischer-Tropsch Naphta from syngas or direct conversion of CO_2/H_2.
  - Olefin production from Fischer-Tropsch Naphta or Synthetic Methane.

Full industrial electrification 2050 NL

- Assumptions for The Netherlands:
  - Steel:
    - Steel production approximately *constant* at 6.5 Mt/year (6% of EU).
  - Minerals:
    - Cement and lime (ENCI) production *disappear* from NL.
    - Glass production *stays constant* at 1.3 Mt/year (4% of EU).
  - Chemicals
    - Olefin *stays* at 7.8 Mt/year (19% of EU).
    - Chlorine *stays* at 0.7 Mt/year (7% of EU).
    - Ammonia *stays* at 2.3 Mt/year (18 % of EU).

- Observations of top-8 basic materials production in NL:
  - CO_2 emission is 22 Mt/year in 2010 = 10% of total (compare EU 8%)
  - Energy use in 210 TWh/year in 2010 = 21% of total (compare EU 8%)

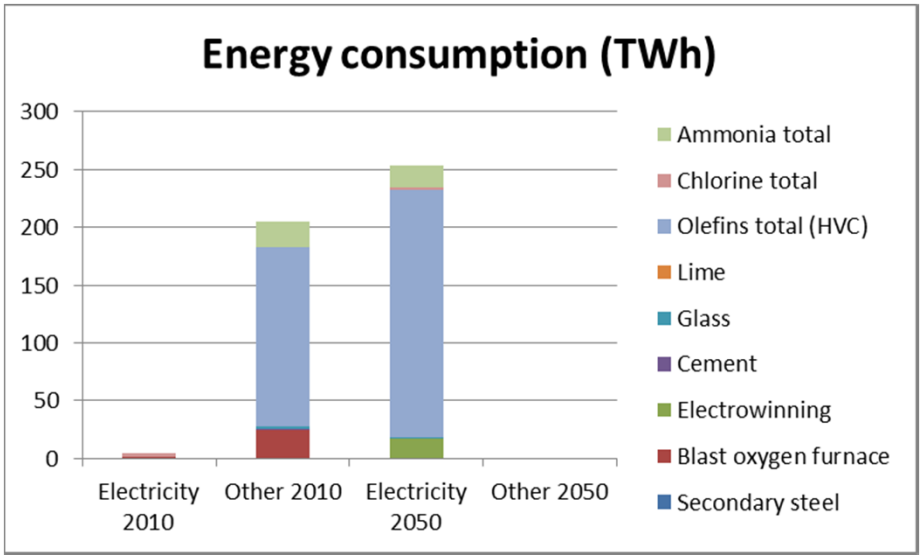
Full industrial electrification 2050 NL



Full electrification needs
250 TWh / year

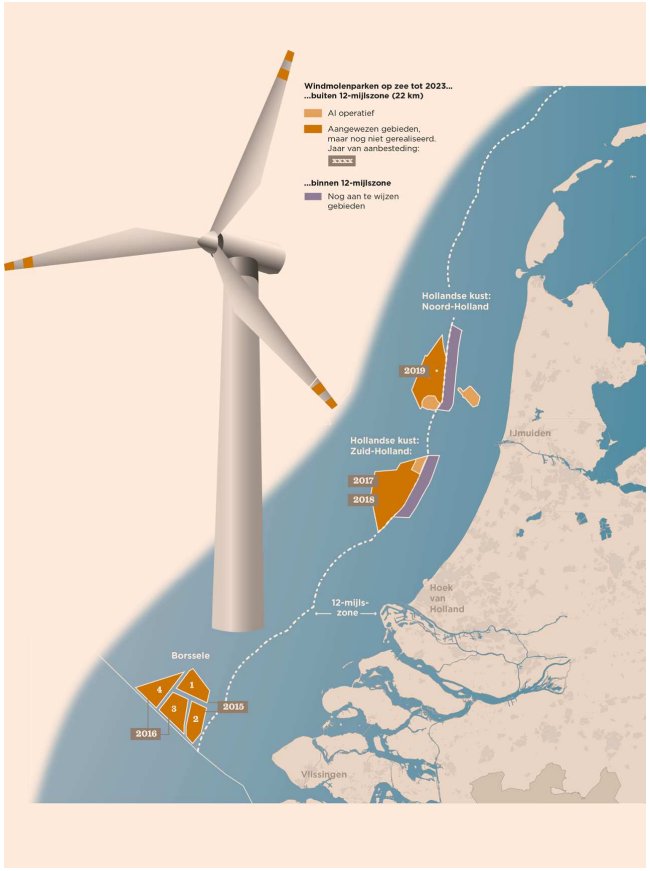
Full electrification decreases CO_2
22 Mt / year

CO2 as feedstock with 3 t_{CO_2} / $t_{olefins}$
23 Mt/year CO2 use

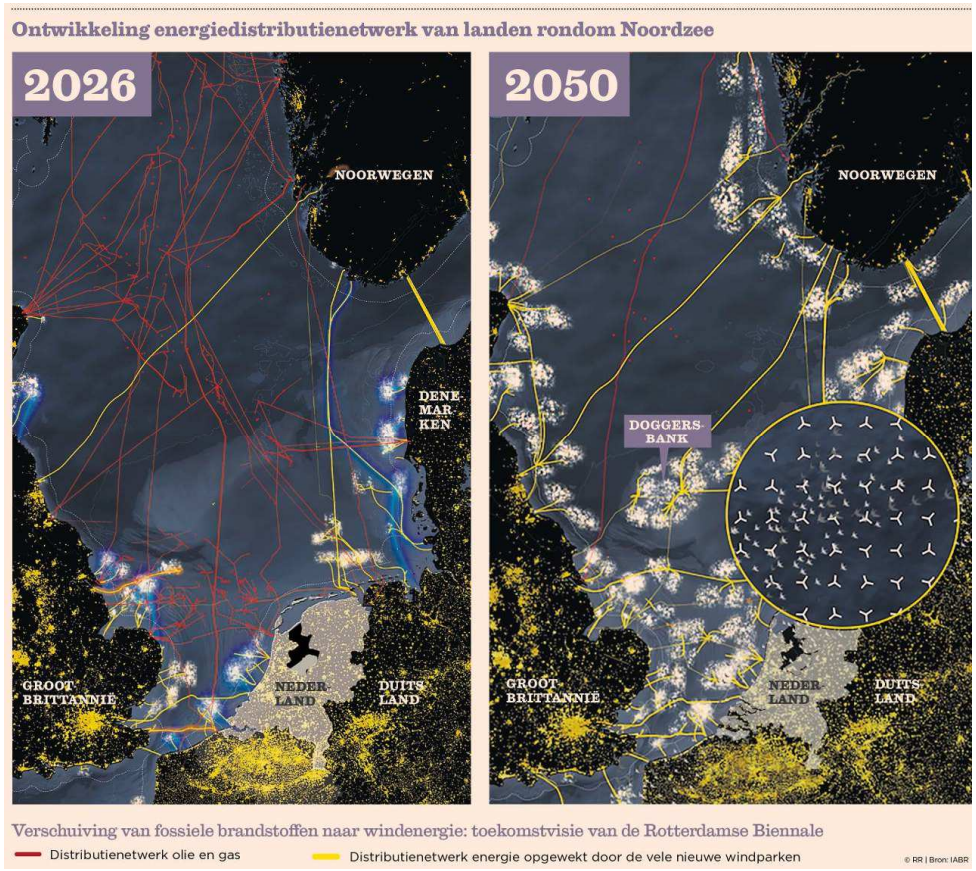


Is this scenario technically realistic???

Source: FD, 22-3-2016



Source: FD, 15-4-2016



2016: 0.9 GW = 4 TWh ➡ 2023: 4.5 GW = 18 TWh ➡ 2050: 250 GW = 1000 TWh

Conclusions & discussion

Powered by: TNO innovation for life ECN

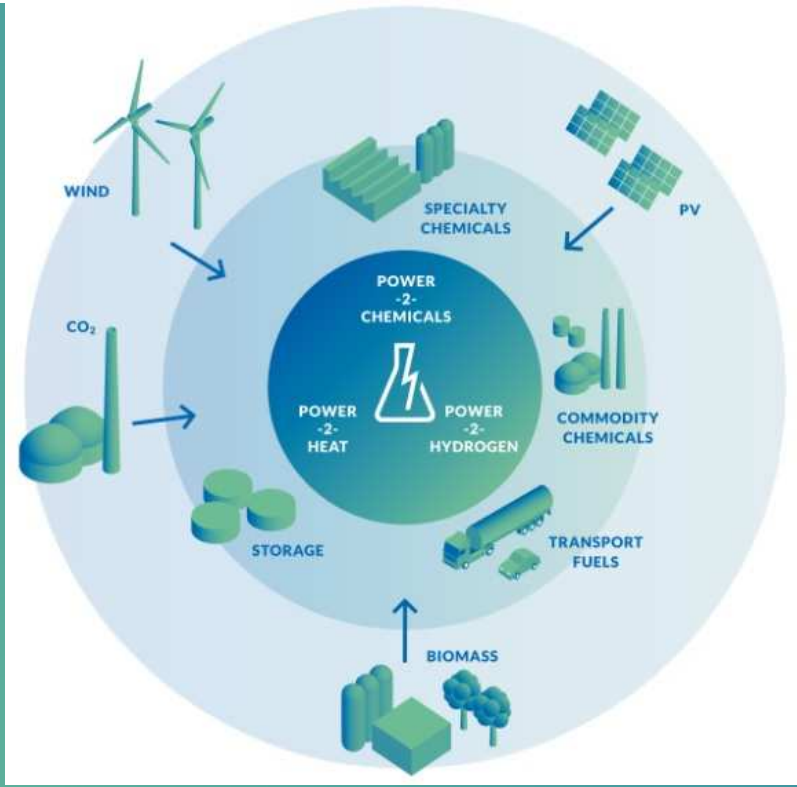
Conclusions

- <u>The future is unpredictible but industry will play an important role</u>
  - The (chemical) industry uses 44% of all energy in The Netherlands.
  - Future determined by step-changes in *technology development*, by the *societal and market* conditions and by *regulations*.
  - Keep options open and invest at the right time with the right business driver.

- <u>Short-term electrification potential in flexibility</u>
  - Businesscases driven by flexibility & incentives.
  - Power-2-Heat & Power-2-Hydrogen.
  - Upward potential:
    - 10 Mt/year CO_2 reduction.
    - 28 TWh/year electricity use.

- <u>Long-term electrification potential in products</u>
  - Businesscases driven by product value & CO_2 regulations.
  - Power-2-Commodities.
  - Upward potential:
    - 45 Mt/year CO_2 reduction.
    - 250 TWh/year electricity use.

Want more information?



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