

#### **Electrification of the Chemical Industry**

# **Electrification of chemistry**

"Towards a CO<sub>2</sub> neutral process industry" Martijn de Graaff Utrecht, 22 november 2016





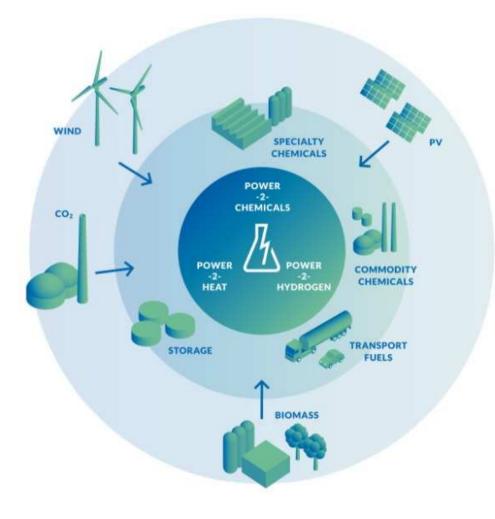
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### **VoltaChem: Our mission**



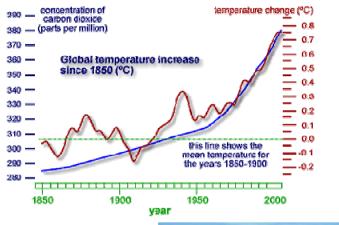
- Accelerate innovation and implementation of *electrification* & *decarbonization* in chemicals.
- Initiate and facilitate *collaborative development* of technology and associated business models.
- Addresses both the *indirect and direct use of electricity* within the chemical industry, involving stakeholders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



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### **Societal drivers for change...**

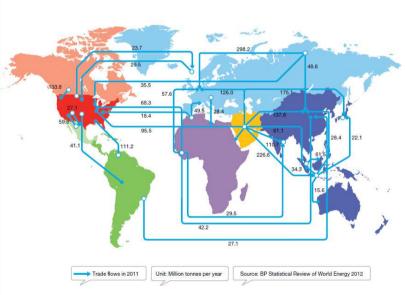
#### **Global Warming**



Source: ClimateChoice.org.uk



Security of Supply



Source: BP Statistical review 2012

**Д** VOLTA СНЕМ

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### ... a chemical industry under pressure ...

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

		Europa		VS		Midden-Oosten		Azië					
		2005	nu	2020	2005	nu	2020	2005	nu	2020	2005	nu	2020
Productiekosten	Feedstockkosten												
	Energiekosten												
	Overige productiekosten 0												
Structuur chemiesector	Mate van integratie 🛛												
	Chemiekennis 🖲												
	Downstream activiteiten @												
Eindmarkten	Omvang eindvraag 🛛												
	Groei eindvraag												

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

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



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### ... and new energy sources emerging ...



VOLTA

200

0



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### ... generates opportunities for industry ...

Flexible supply

Demand response

Interconnection

Energy Storage & conversion







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Specialties



Commodities

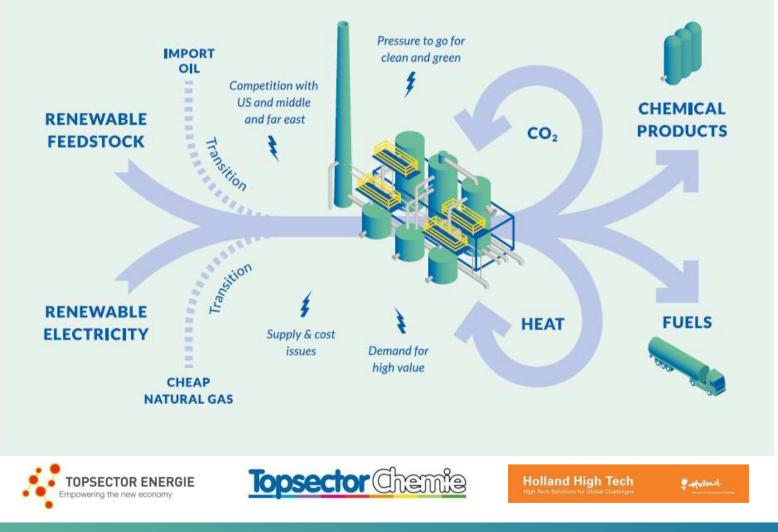


Refineries



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### ... taking a leading role in the transition.



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Electrification of the Chemical Industry

# Some facts and figures

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### Question

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

ightarrow 0-10% / 10-25% / 25-50%

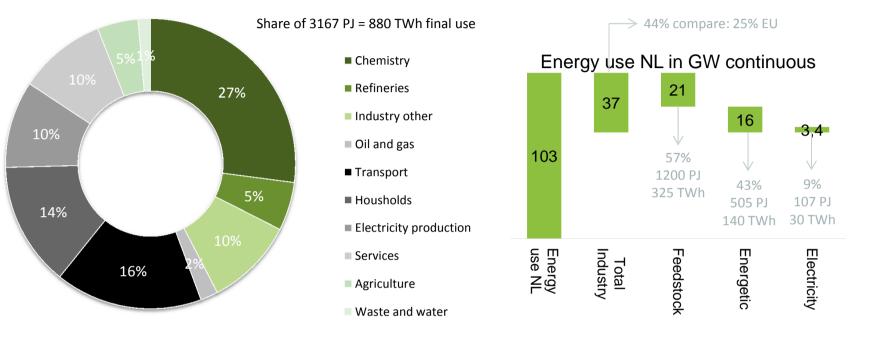
• How does this compare to Europe?

### → Lower / Equal / Higher



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### **Energy use in Dutch process industry**



Year	Source	GW <sub>eq cont</sub>	<b>GW</b> <sub>installed</sub>
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

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Source: Nationale Energieverkenning, 2014

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### Question

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

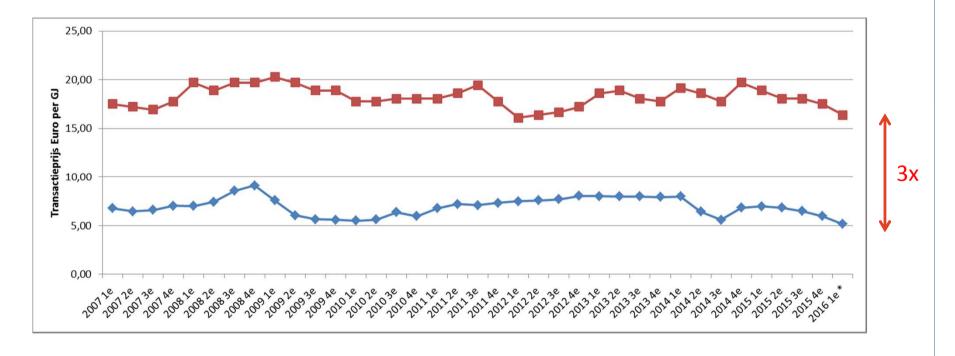
 $\rightarrow$  Equal / 3x / 5x



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### **Energy prices electricity vs. gas** 2007-2016 NL

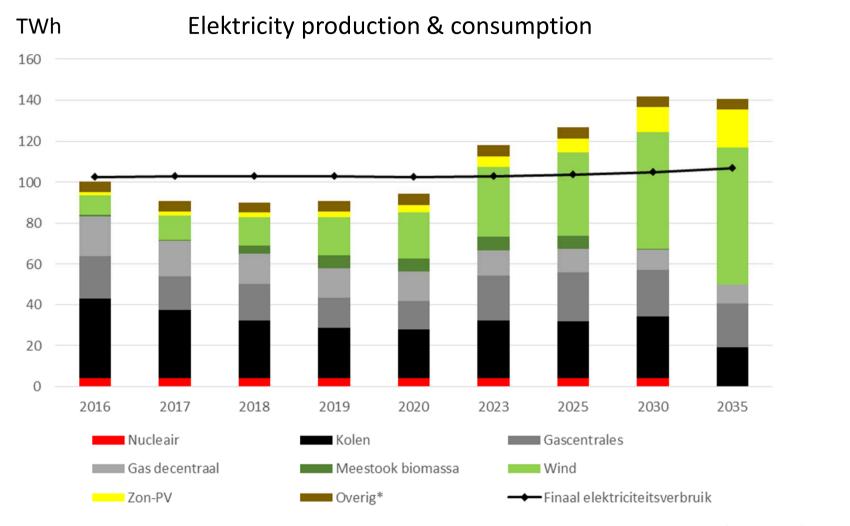
Average transaction prices Natural Gas (blue) & Electricity (red), industry ex BTW incl Tax



Source CBS



### Increasing share of renewable electricity

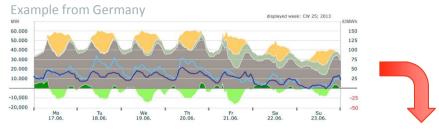


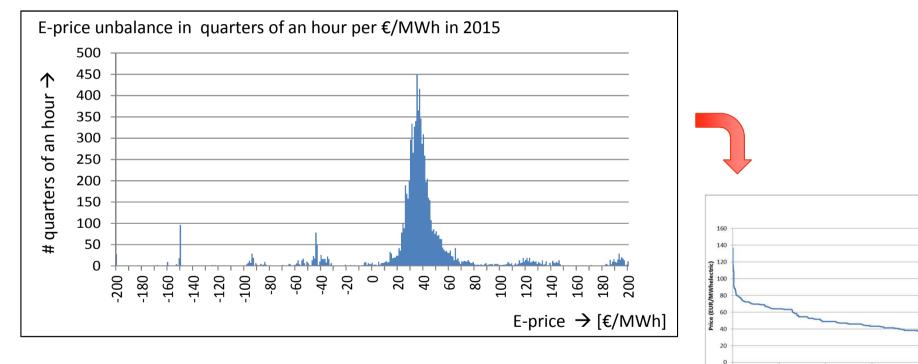
Source: Nationale energieverkenning 2016



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### Variability of electricity prices





Price duration curve 2030

4000

2000

0



22-11-2016 14

6000

8000

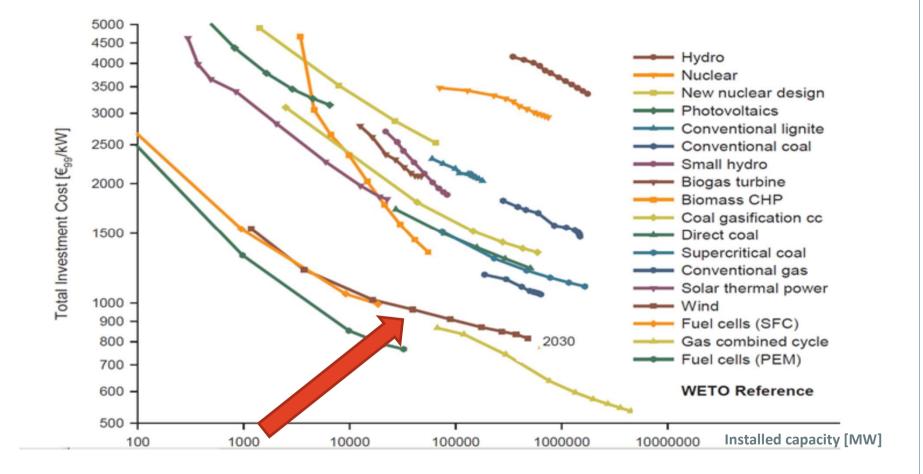
### Question

- The <u>investment costs of solar and wind technology</u> <u>decrease much more</u> quickly than for conventional energy.
  - $\rightarrow$  True / False



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### **Price development of energy tech**



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



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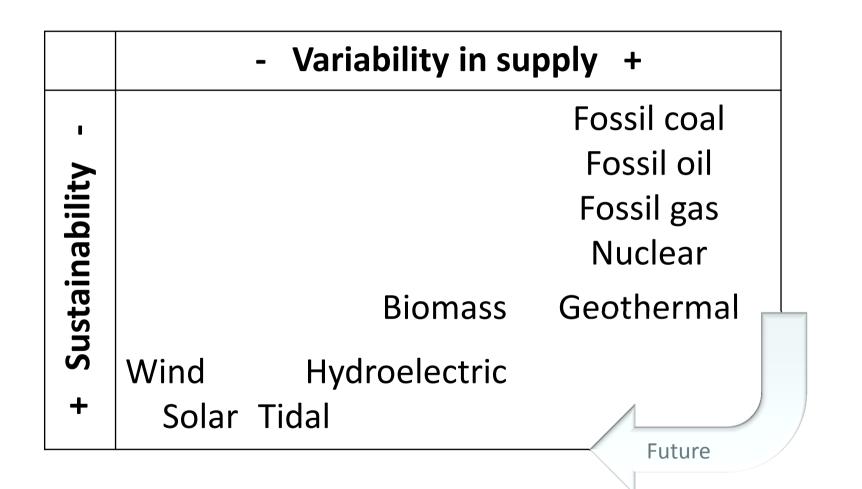
## Why & when electrification

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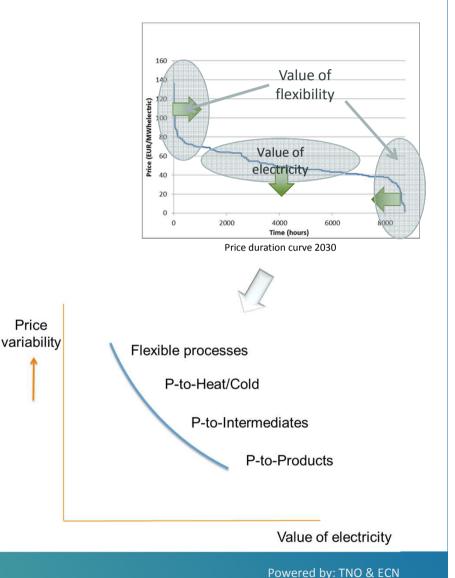
### **Development in sources & variability**





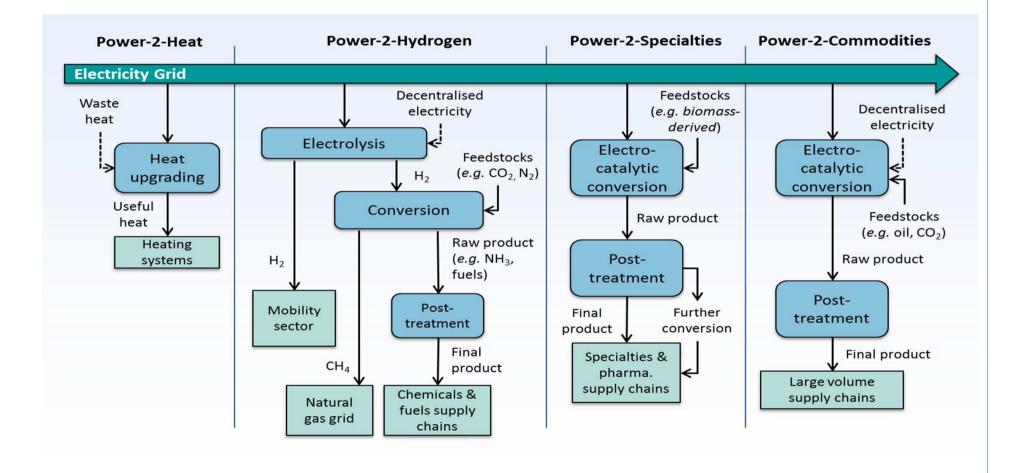
### **Electricity value vs. variability value**

- 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<sub>3</sub>).
- Product value (long-term)
  - Electricity used directly to make end products (chemicals and fuels).





### **Main routes for electrification**





## Why & when electrification?

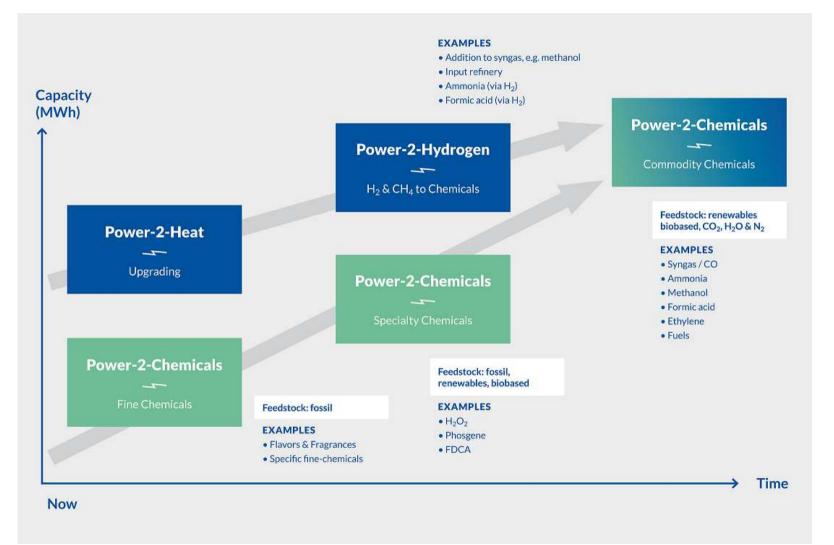
- Flexibility
  - Response time short
  - Operating hours relatively low
  - Allowable investment costs low
  - Technologies at high TRL
- Electrification
  - Response time less an issue
  - Operating hours high (base load)
  - Allowable investment costs higher
  - Technologies at mid/low TRL

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

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



### **The VoltaChem roadmap**





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## **Upcoming technologies**

### Inspiring examples for Power-2-Commodities

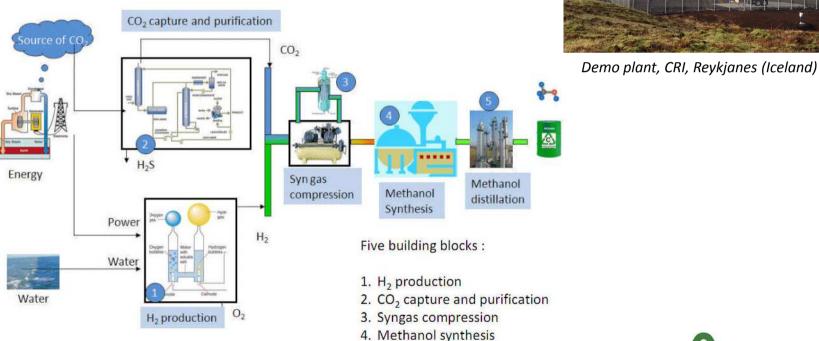
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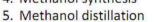




### **Power to Methanol**

### Approximately TRL 8 (out of 9)









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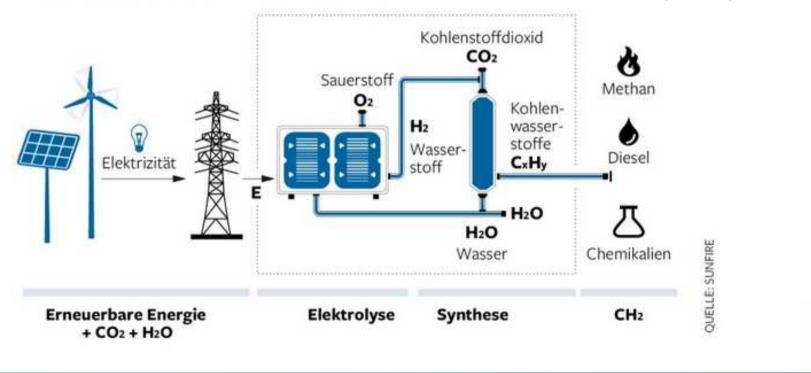
### **Power to FT-liquids** Approximately TRL 7 (out of 9)

#### SO FUNKTIONIERT POWER-TO-LIQUIDS

Synthese nach dem Fischer-Tropsch-Verfahren



Demo plant, Sunfire, Dresden (Germany)





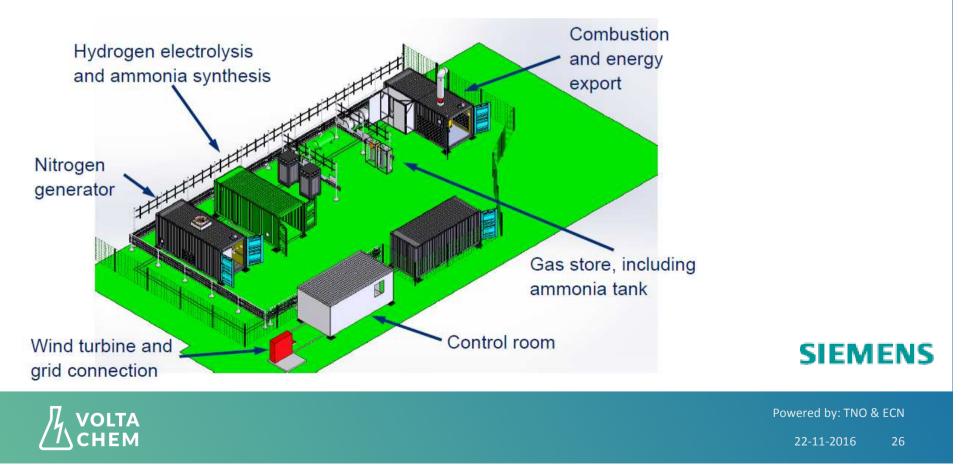
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# Power to Ammonia

### Approximately TRL 6 (out of 9)

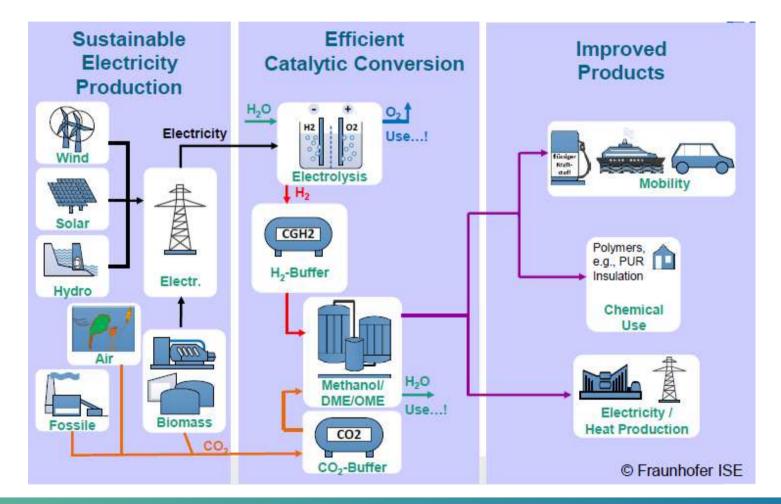


Pilot plant [2017], Siemens, Oxford (UK)



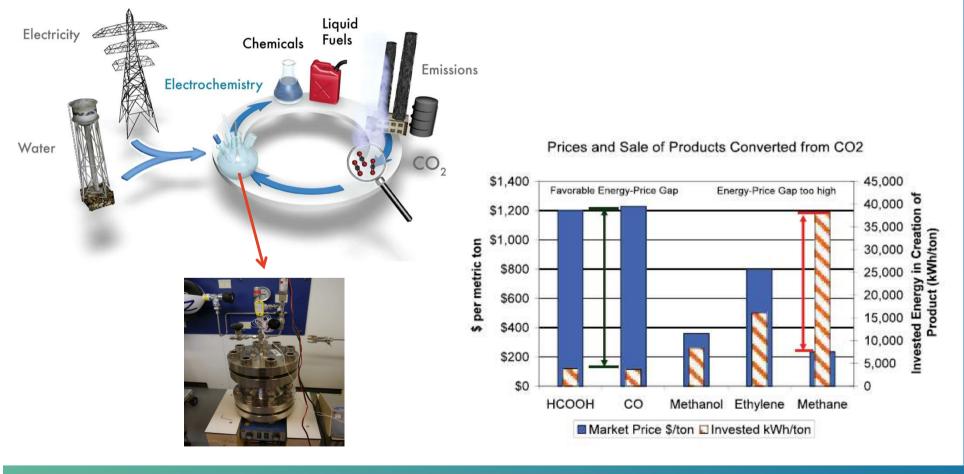
### **Power to MeOH/DME/OME**

#### Approximately TRL 3 (out of 9)





### **Power to hydrocarbons (from CO<sub>2</sub>)** Approximately TRL 1 (out of 9)







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## **Short-term electrification scenario**

Implementing Power-2-Heat & Power-2-Hydrogen in NL A *sustained innovation* scenario



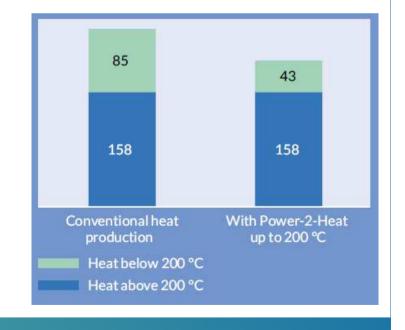




### **Short-term potential Power-2-Heat**

#### • Assumptions:

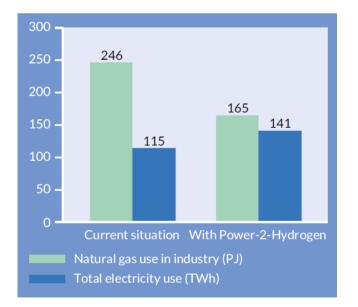
- Current heat consumption in chemical industry 243 PJ (43% > 200°C).
- Full implementation of Heat Pumps & residual steam upgrading by Mechanical Vapour recompression in industry.
- Giving 50% savings for high temperature steam.
- Result:
  - 15-20% energy savings.
  - 2 TWh / year electricity consumption.
  - 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.







Electrification of the Chemical Industry

## **Long-term electrification scenario**

Implementing Power-2-Commodities in NL

A disruptive innovation scenario







# Industrial electrification 2050

### A scenario based on EU study

- 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<sub>2</sub> (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.

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## Full industrial electrification 2050

#### **Technology assumptions**

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<sub>2</sub>/H<sub>2</sub> conversion.
  - Methane and Fischer-Tropsch Naphta from syngas or direct conversion of CO<sub>2</sub>/H<sub>2</sub>.
  - Olefin production from Fischer-Tropsch Naphta or Synthetic Methane.



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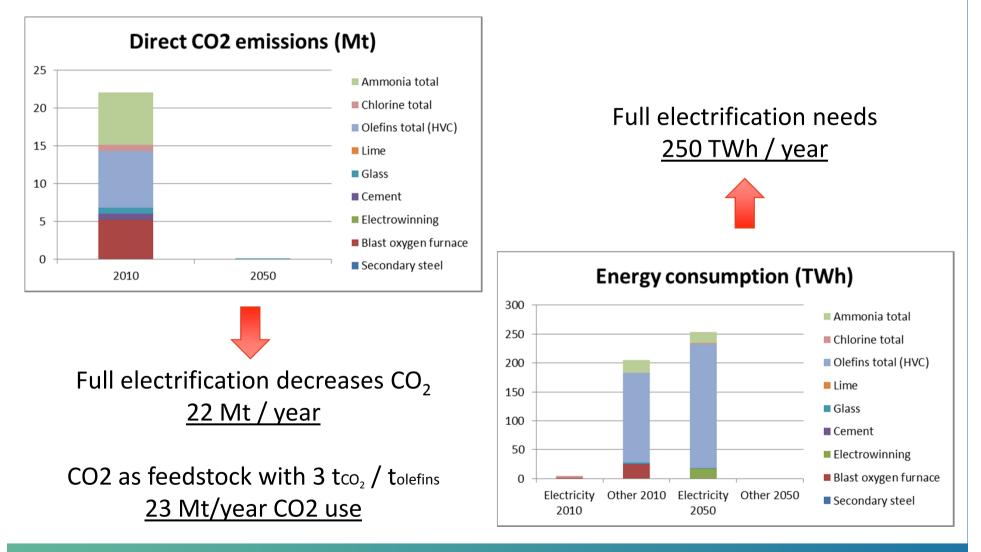
### Full industrial electrification 2050 NL

- 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%)



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### Full industrial electrification 2050 NL

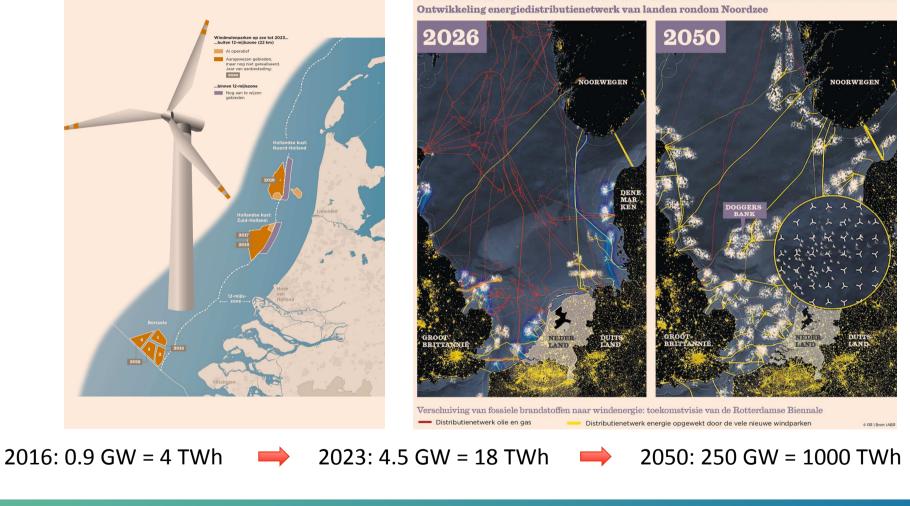




### Is this scenario technically realistic???

Source: FD, 15-4-2016

#### Source: FD, 22-3-2016





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Electrification of the Chemical Industry

### **Conclusions & discussion**

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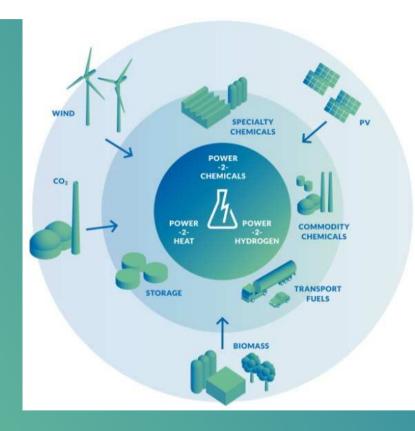
### Conclusions

- The future is unpredictible but industry will play an important role
  - 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<sub>2</sub> reduction.
    - 28 TWh/year electricity use.
- Long-term electrification potential in products
  - Businesscases driven by product value & CO<sub>2</sub> regulations.
  - Power-2-Commodities.
  - Upward potential:
    - 45 Mt/year CO<sub>2</sub> reduction.
    - 250 TWh/year electricity use.



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### Want more information?





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