Accelerating industrial electrification

Power-2-Fuels: Towards a more sustainable future for truck transport, shipping and aviation

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- Richard Smokers (Principle advisor, TNO Traffic & Transport)

Contents

Introduction

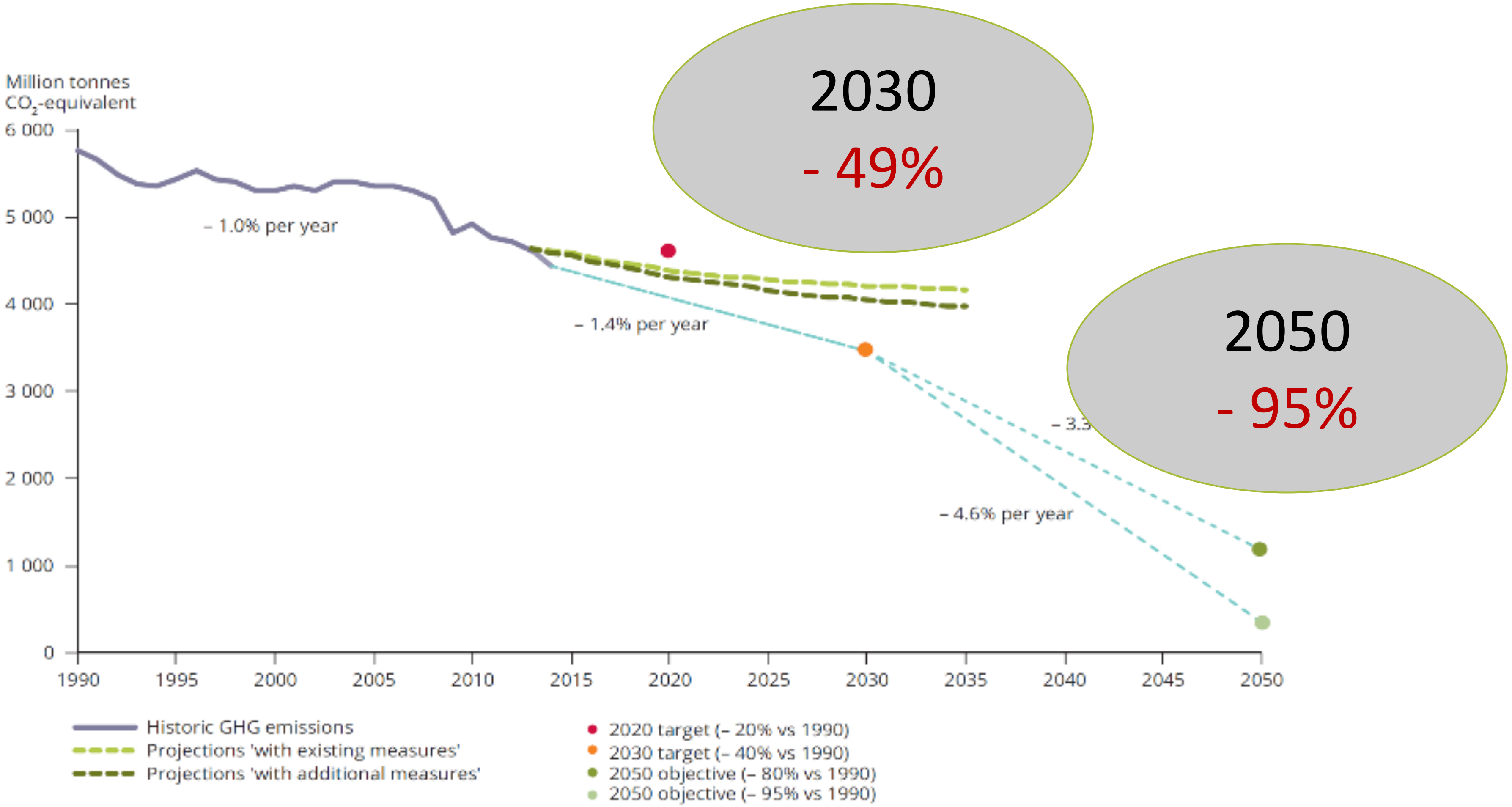
- **Cooperative project** between stakeholders from the logistics sector, industry and knowledge institutes, with participation from a wide range of organisations from the value chain

- **Decarbonisation of long-distance heavy transport** is lagging behind → **e-fuels** can offer a solution for truck transport, shipping and aviation

- Questions:
  - **Which e-fuels** are suitable for which **modalities**?
  - **Future costs** throughout the value chain of the various e-fuels?
  - **Consequences** for renewable **energy** production and **land use**?
  - **Stakeholder actions** to promote development and application?

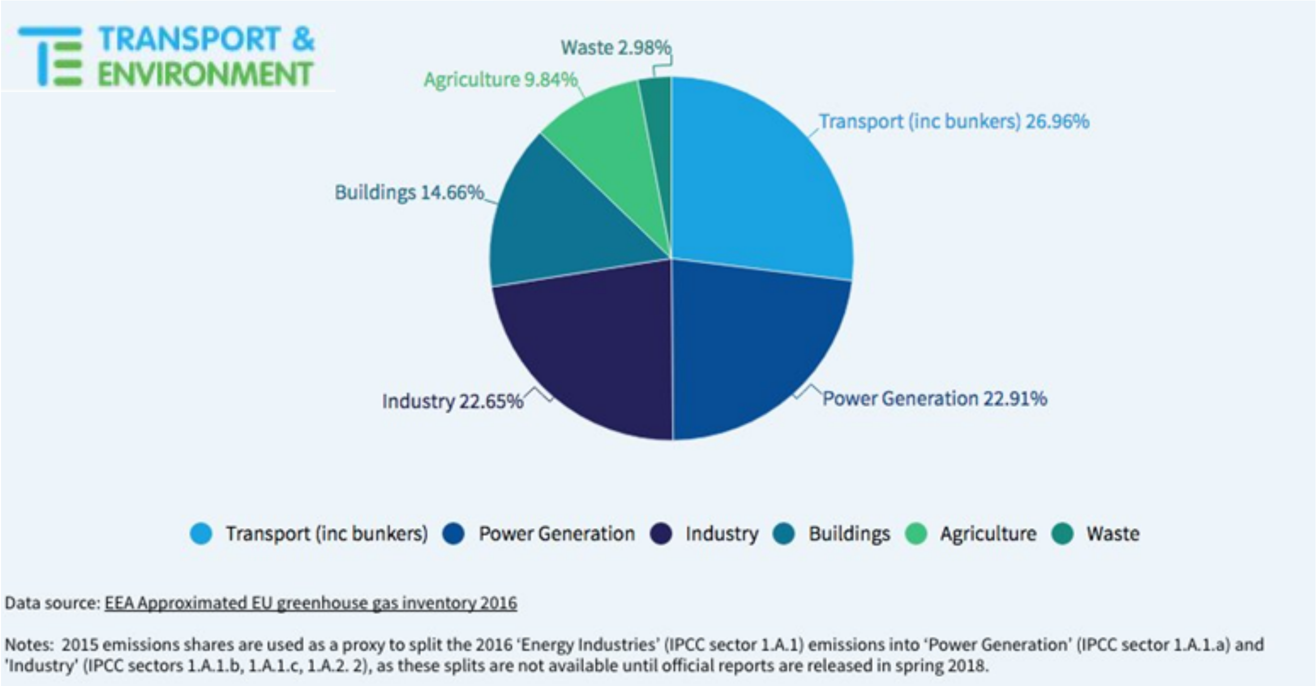
SMART PORT
TNO innovation for life
Port of Rotterdam
Maritiem Kennis Centrum
westerman multimodal logistics
Port of Amsterdam
Deltalinqs
nlr
SkyNRG
EICB Expertise- en InnovatieCentrum Binnenvaart
VIV
spliethoff
envin
dmt Environmental Technology

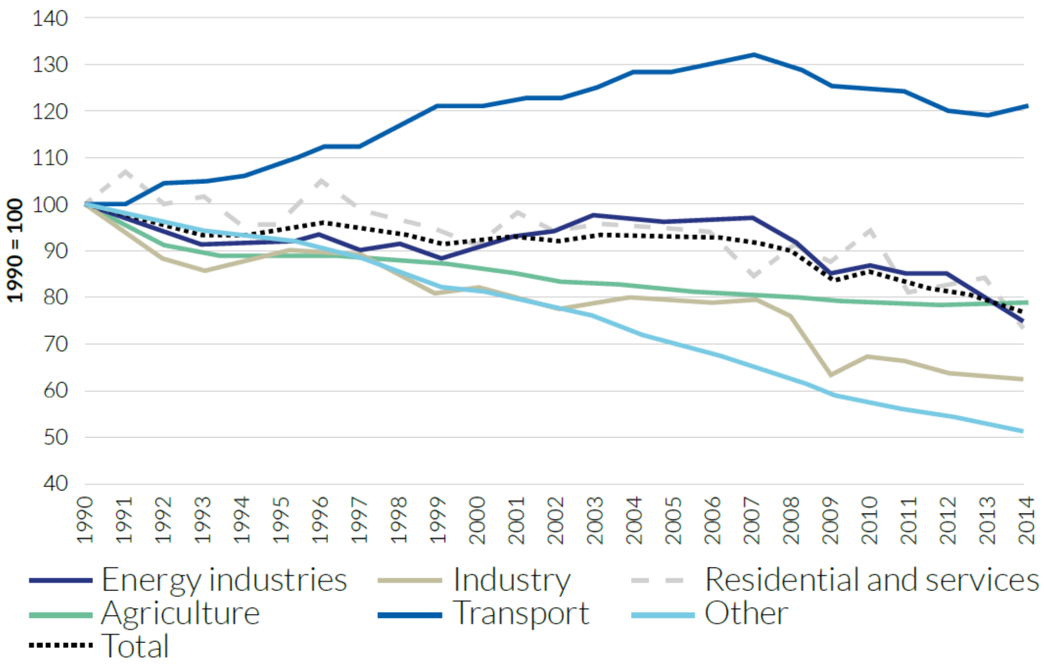
The climate challenge



European CO2-emission reduction curve: Carbon budget < 100 Gton

Largest EU contributors: power, industry & transport





https://ec.europa.eu/clima/policies/transport_en

Solution space for industry and transport

Dutch Climate Agreement

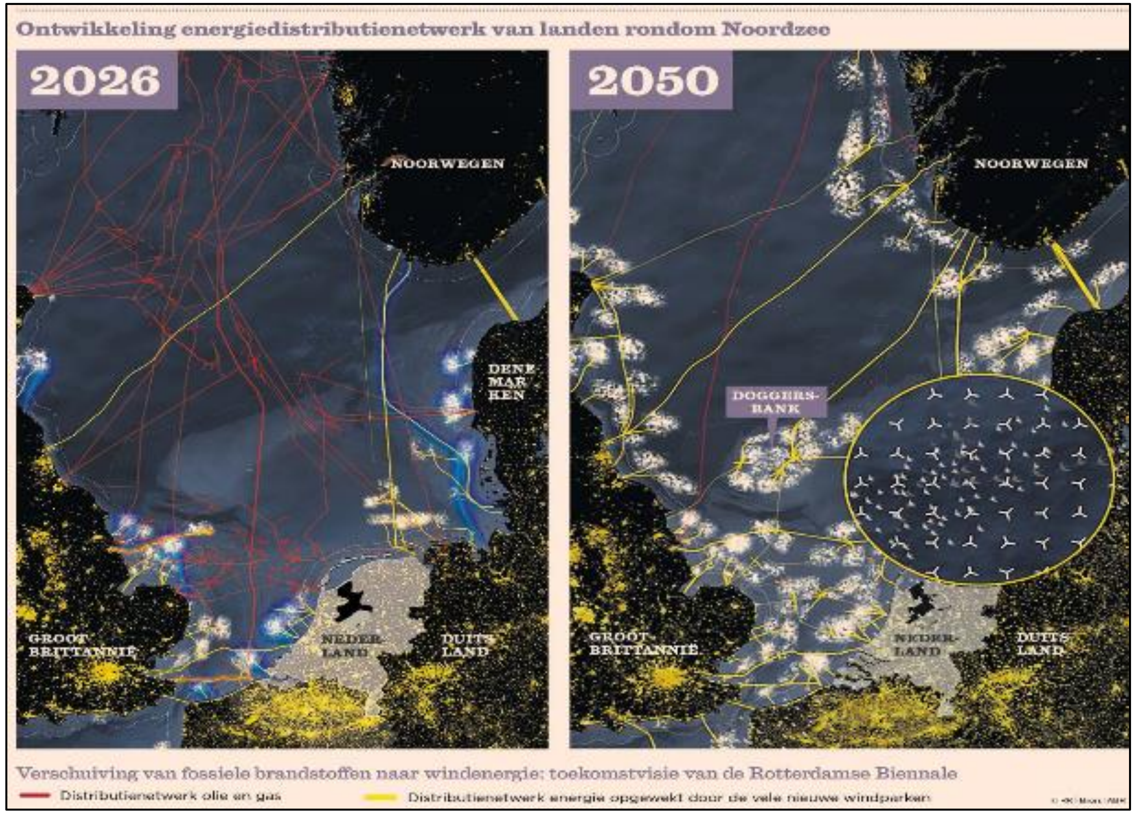
Industry

- F gases & nitrous oxide reduction
- Carbon capture & storage
- Process efficiency & sustainable heat
- ***Electrification and hydrogen***
- ***Recycling, CCU, biobased***

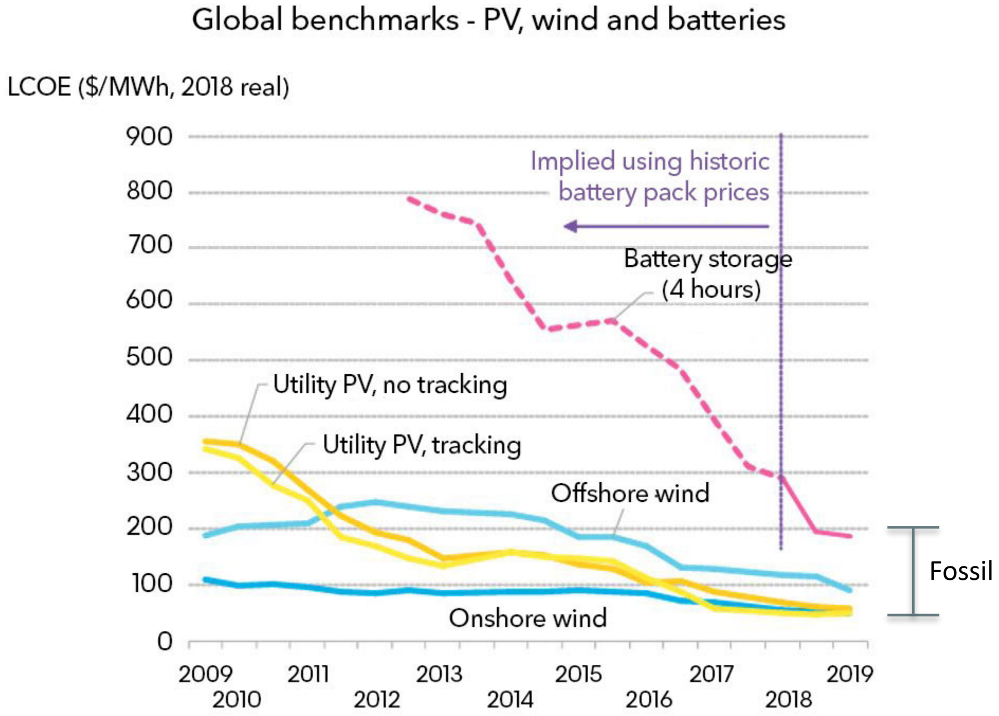
Transport

- Electric transport
- ***Renewable energy carriers***
- Smart mobility
- Susttainable logistics

Opportunity of renewable energy

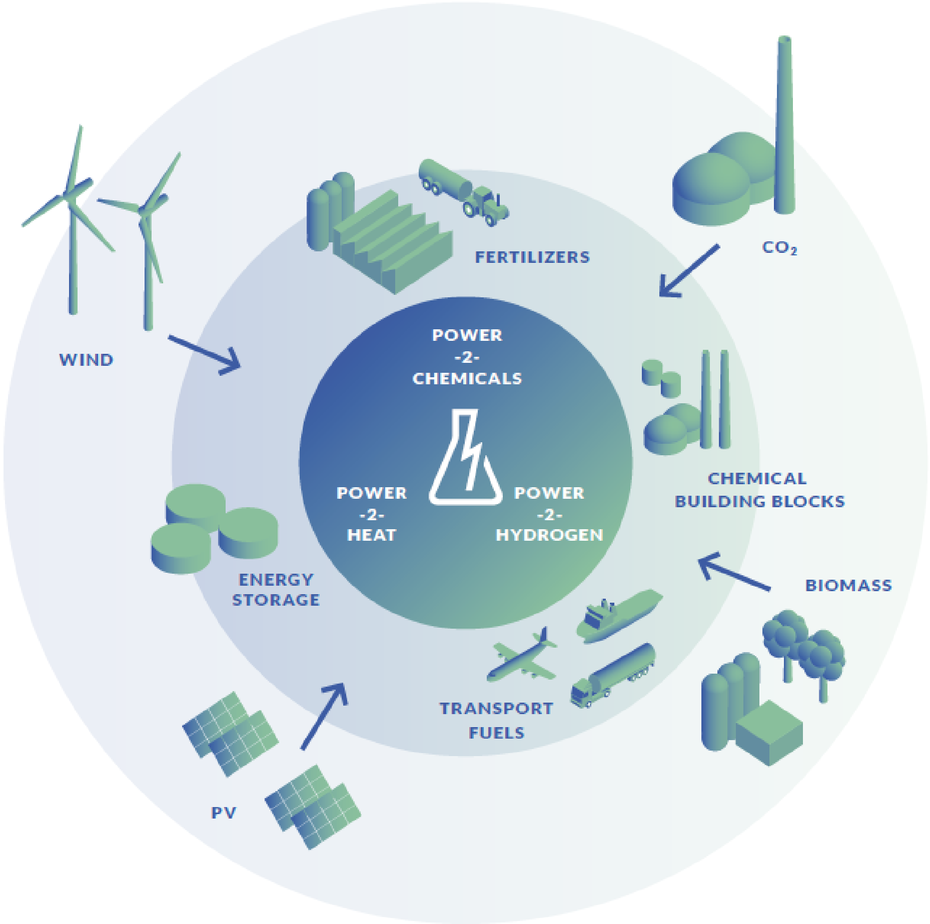


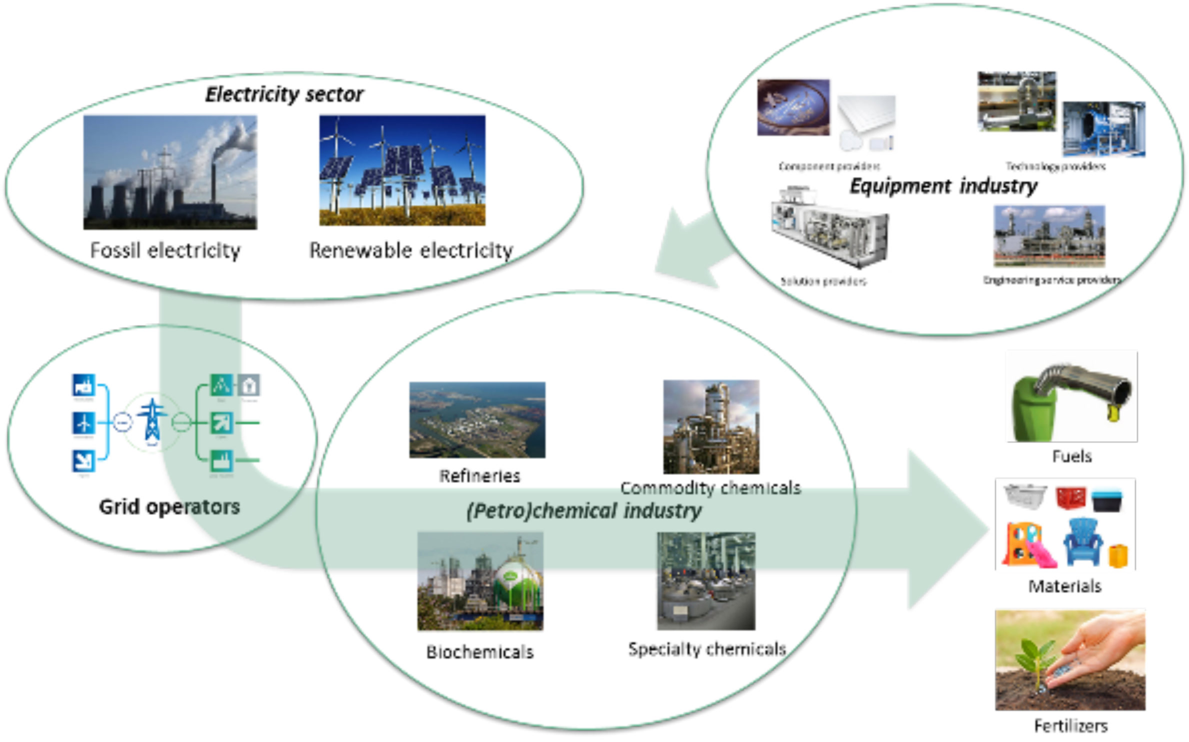
0.9 GW (2016) → 11 GW (2030) → 60 GW (2050)



Source: BloombergNEF. Note: The global benchmark is a country weighed-average using the latest annual capacity additions. The storage LCOE is reflective of a utility-scale Li-ion battery storage system running at a daily cycle and includes charging costs assumed to be 60% of whole sale base power price in each country.

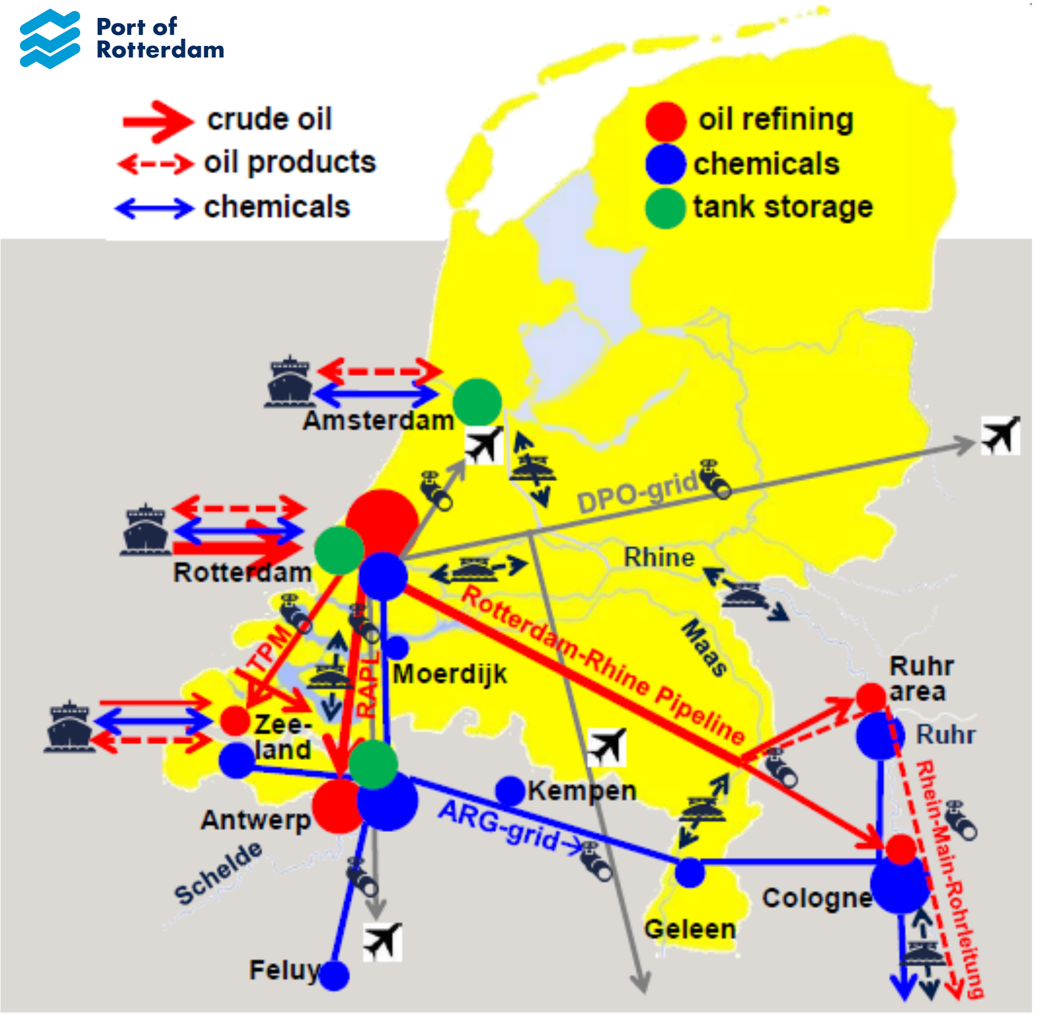
Electrification of industrial production



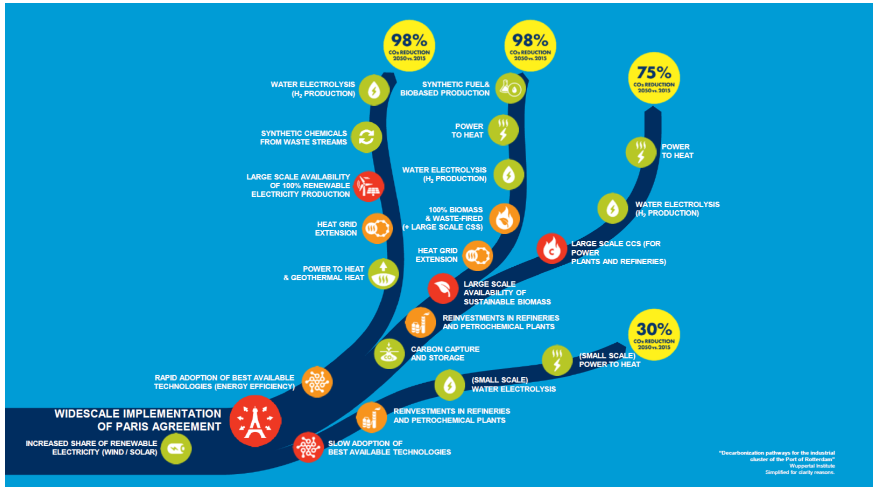


Renewable energy: a key solution for sustainable production of materials and fuels

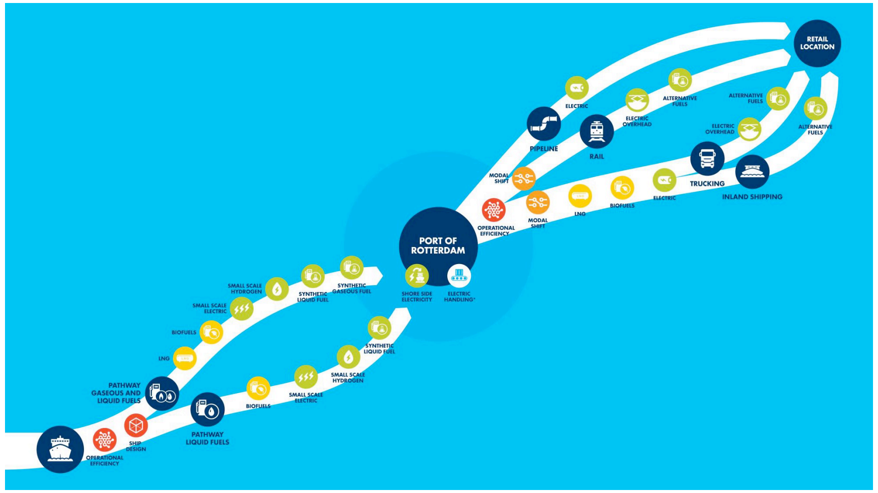
The vision and role of large sea ports



SMART PORT



Decarbonization pathways industry

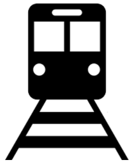


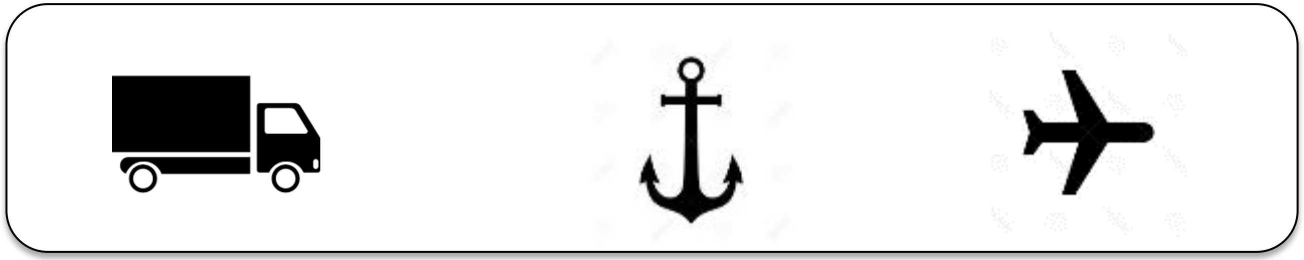
Decarbonization pathways transport

Transport fuels – Options towards 2050

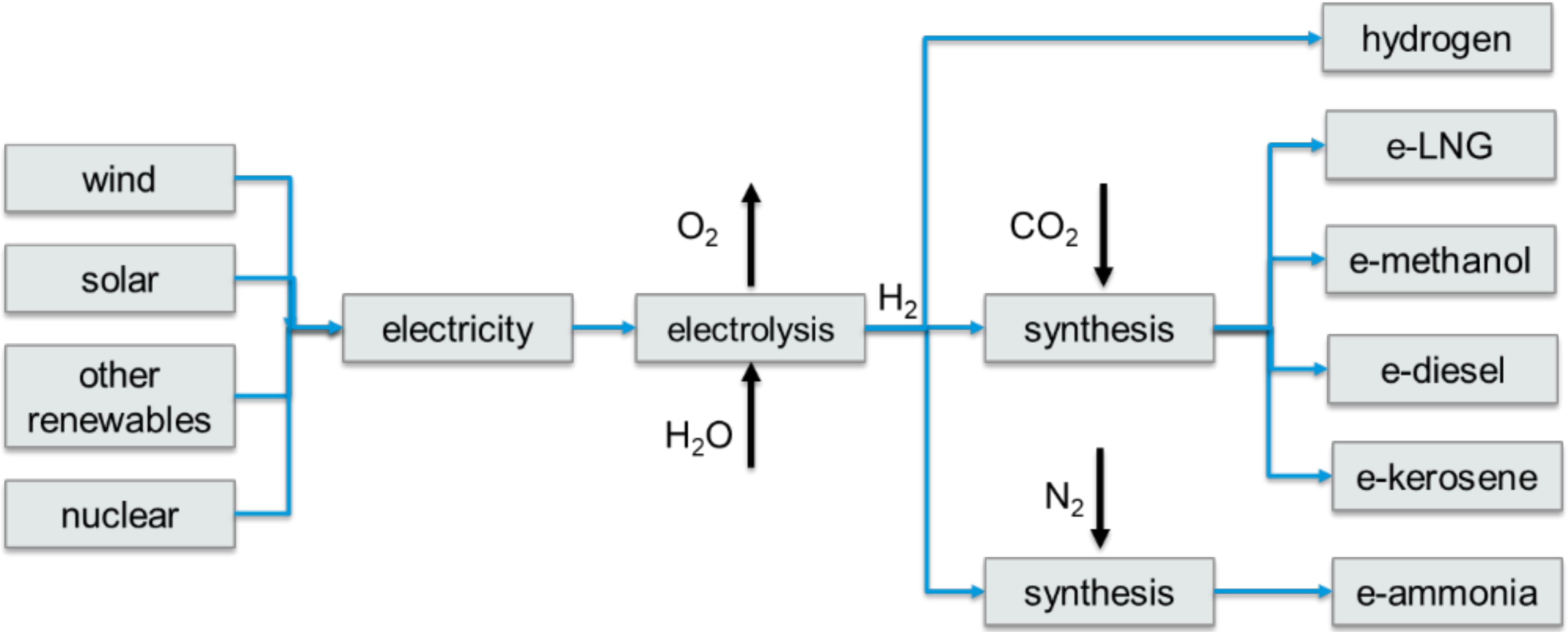
– Battery electric

– High density energy carriers:
  - Traditional fuels - from oil
  - Synthetic fuels - from natural gas
  - Biofuels - from biological origin and waste
  - E-Fuels - from renewable energy
  - Solar fuels - from sunlight





Production of fuels from renewable energy (e-fuels)



Key questions to be answered

- **Which e-fuels** are suitable for which modalities?
- **Future costs** throughout the value chain of the various e-fuels?
- **Consequences** for renewable energy production and land use?
- **Stakeholder actions** to promote development and application?

Accelerating industrial electrification

E-fuels from an end-user perspective

Richard Smokers

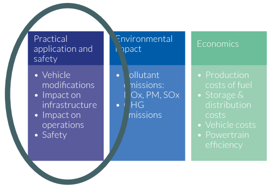
Assessment of transport applications of e-fuels

- Trucks
  - distribution
  - long haul
- Shipping
  - inland
  - short-sea
  - deep-sea
- Aviation

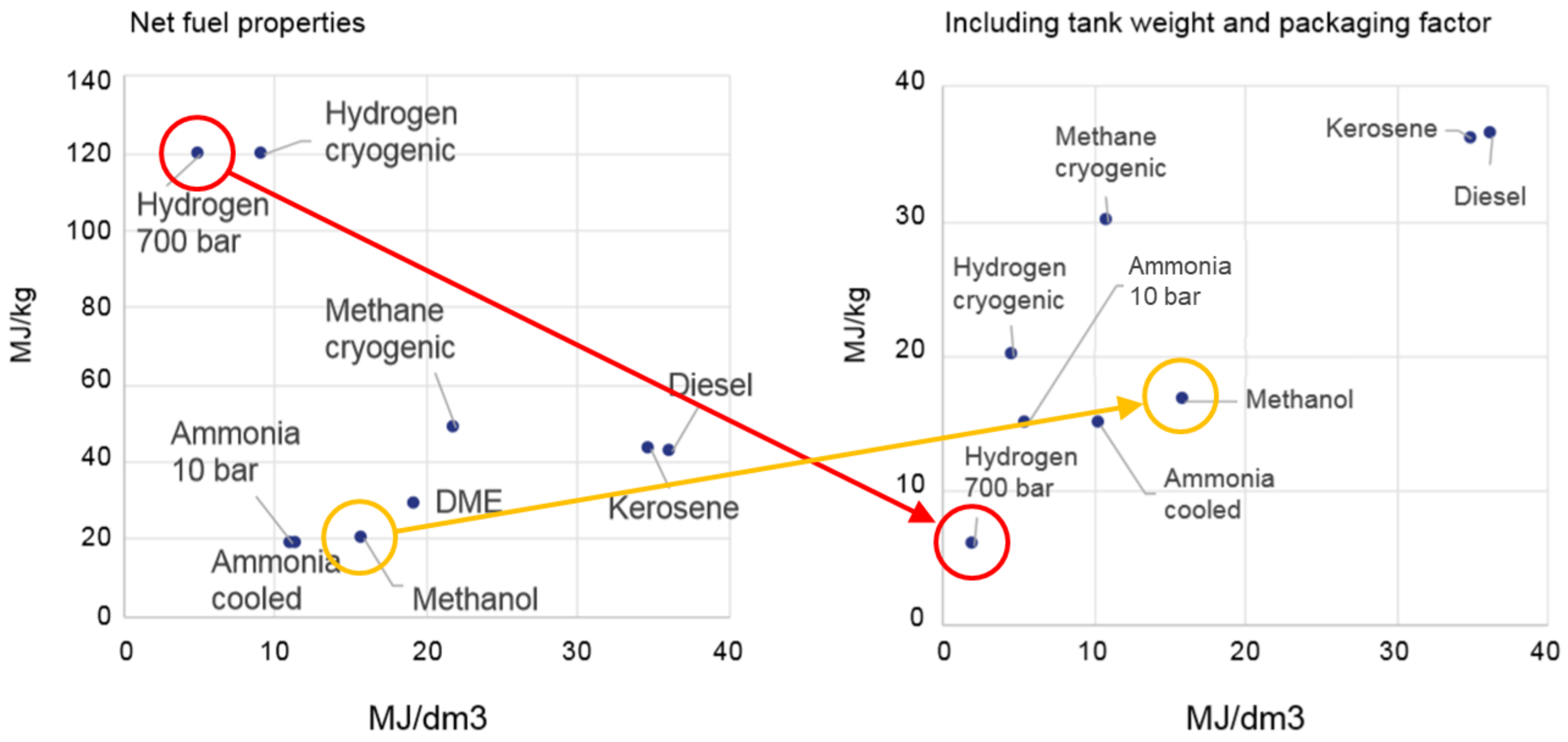
Assessment on 3 categories of KPIs

Practical application and safety	Environmental impact	Economics
• Vehicle modifications • Impact on infrastructure • Impact on operations • Safety	• Pollutant emissions: NOx, PM, SOx • GHG emissions	• Production costs of fuel • Storage & distribution costs • Vehicle costs • Powertrain efficiency

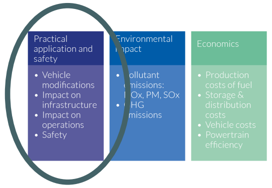
Practical application and safety (1)



- Energy density of fuel is important factor



Practical application and safety (2)



Impact on **safety**:

- All e-fuels have additional safety concerns compared to diesel
- Ammonia is considered unsafe for road transport
- Methanol is toxic and has an invisible flame
- LNG and hydrogen are gases and can easily form ignitable mixtures

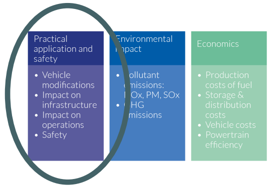
Impact on **operations**: more frequent bunkering compared to diesel

- Daily instead of weekly refuelling for compressed hydrogen
- For e-methanol, e-LNG and e-ammonia 1,5 to 2 times more refuelling

- Daily for compressed hydrogen; 2-4 days for cryogenic hydrogen
- For e-methanol, e-LNG and e-ammonia up to 2 times more refuelling

- Hydrogen is not an option
- For e-methanol, e-LNG and e-ammonia tank size will be increased to 60 days

Practical application and safety (3)



Storage in vehicle	green hydrogen	e-methanol	e-diesel (FT)	e-ammonia	e-kerosine	e-LNG
Distribution & long-haul trucks	compressed or cryogene	standard liquid	standard liquid	compressed (± 10 bar)	n.a.	cryogene (or compressed)
Inland shipping	compressed or cryogene	standard liquid	standard liquid	compressed (±10 bar) or cooled (ca -33°)	n.a.	cryogene
Short-sea shipping	cryogene	standard liquid	standard liquid	cooled (ca -33°)	n.a.	cryogene
Deep-sea shipping	–	standard liquid	standard liquid	cooled (ca -33°)	n.a.	cryogene
Aviation	–	–		–	standard	cryogene

Easy · Quite feasible · Feasible · Not impossible · Impossible

Type of storage on-board vehicle

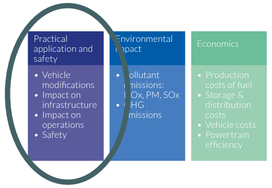
	Impact on vehicle costs
Hydrogen	Fuel cell or new engine; costly tank: high pressure or cryogenic
E-methanol	Some modifications on engine and tank
E-diesel	No modification
E-ammonia	New engine type or fuel cell; significant impact on tank
E-LNG	Some modifications on engine; expensive tank
E-kerosine	No modification

No impact · Small impact · Medium impact · Significant impact

Additional vehicle costs

Practical application and safety (4)

Impact on **distribution infrastructure**

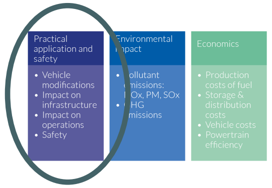


- Need for (expansion of) existing infrastructure or new infrastructure

	distribution infrastructure		**tank infrastructure / filling stations**	
	existing	new	existing	new
E-diesel				
Hydrogen (compressed)				
Hydrogen (cryogenic)				
E-methanol				
E-ammonia (compressed)				
E-ammonia (cooled)				
E-LNG				
E-kerosine				

Practical application and safety (5)

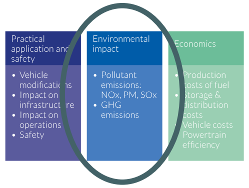
Impact on **distribution infrastructure**



- Energy density also affects the transport movements associated with fuel distribution

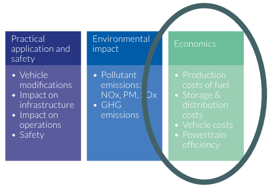
	Tanker truck		Ratio of tanker trucks to diesel reference
	Tonne	GJ	
E-diesel	16	683	1.0
Hydrogen (compressed)	1	120	5.7
Hydrogen (cryogenic)	4	480	1.4
E-methanol	16	315	2.2
E-ammonia (compressed)	16	298	2.3
E-LNG	16	784	0.9

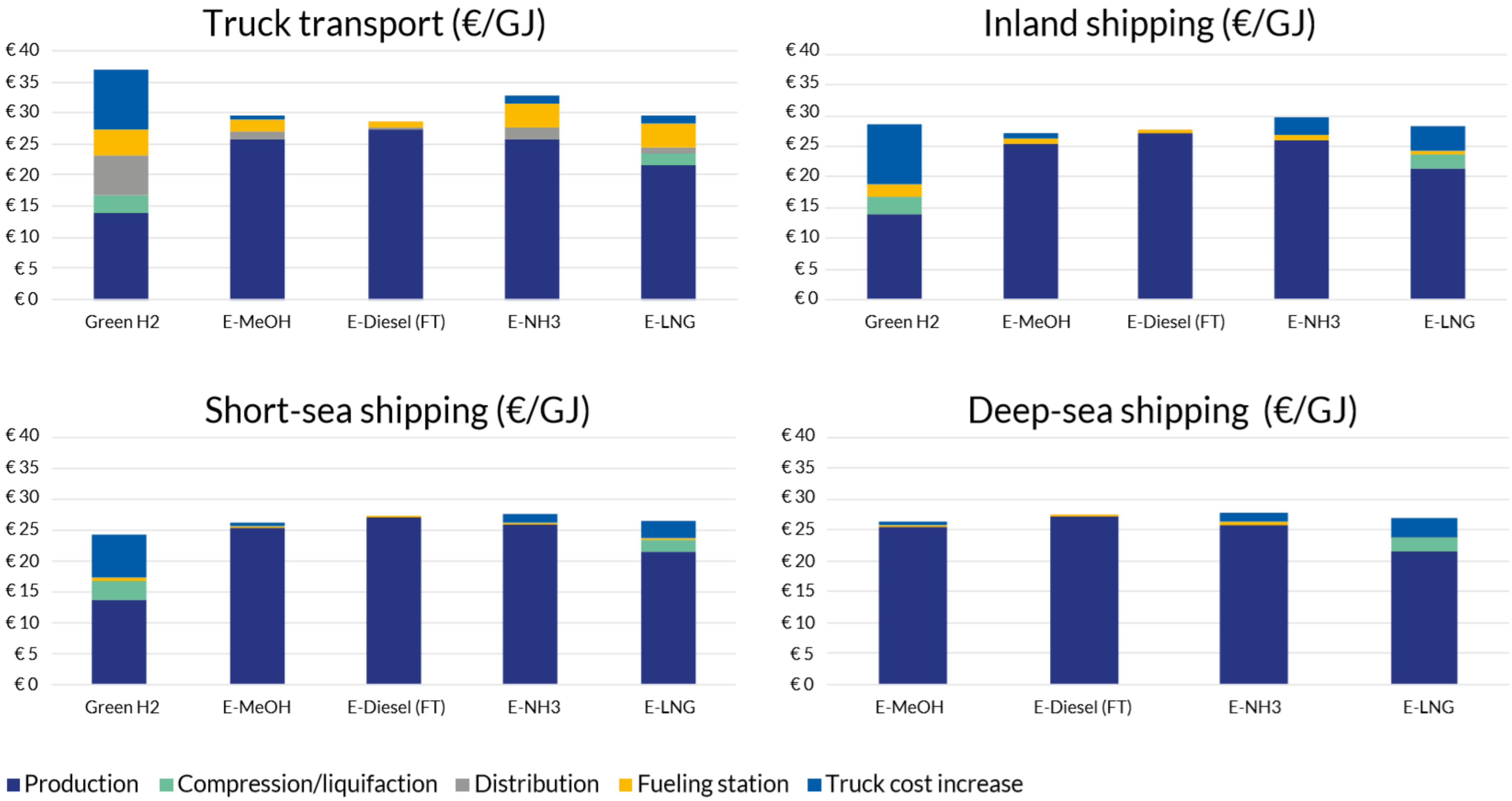
Environmental impact



	Pollutant emissions	CO_2 emissions
Hydrogen	Zero emission	Zero WTW & TTW CO_2 emissions
E-Ammonia	Combustion engines: stringent legislation leads to equal pollutant emissions of all e-fuels	Zero WTW & TTW CO_2 emissions
E-Methanol		Zero WTW CO_2 emissions if all CO_2 is circular When CO_2 for e-fuels is derived from fossil sources (CCU) the CO_2 reduction is around 50% How much reduction is attributed to industry sector vs. transport sector depends on legislation / regulation
E-Diesel		
E-LNG		
E-Kerosene		

Economics (1)



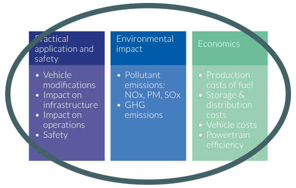


2030: electricity costs of €30/MWh and CO_2 costs of €40/ton

- High uncertainty in future cost levels
- Small differences between options
- Lower fuel production costs for H_2 are compensated by higher costs for distribution and vehicles / vessels

Projection for 2030, includes fuel production and distribution costs and additional vehicle/ship costs calculated back to €/GJ, taking into account powertrain efficiency.

Comparative assessment: conclusions



			
Hydrogen	For short distances, in case of high electricity and CO_2 costs		
E-methanol	Feasible		
E-diesel			
E-LNG			
E-ammonia	Unsafe	In case of high CO_2 cost	
E-kerosene			Only feasible option

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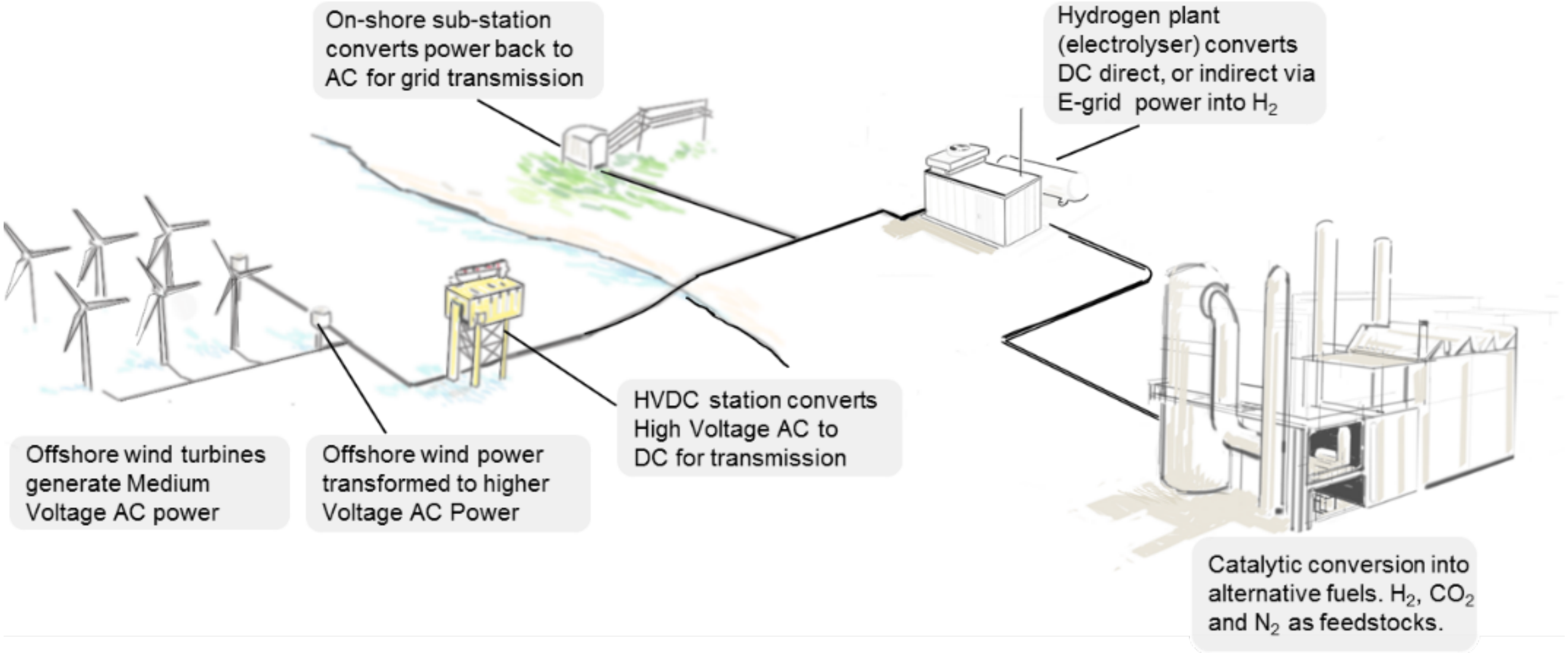
E-fuels from a production perspective

Martijn de Graaff

Visualization of envisioned production



Production technologies

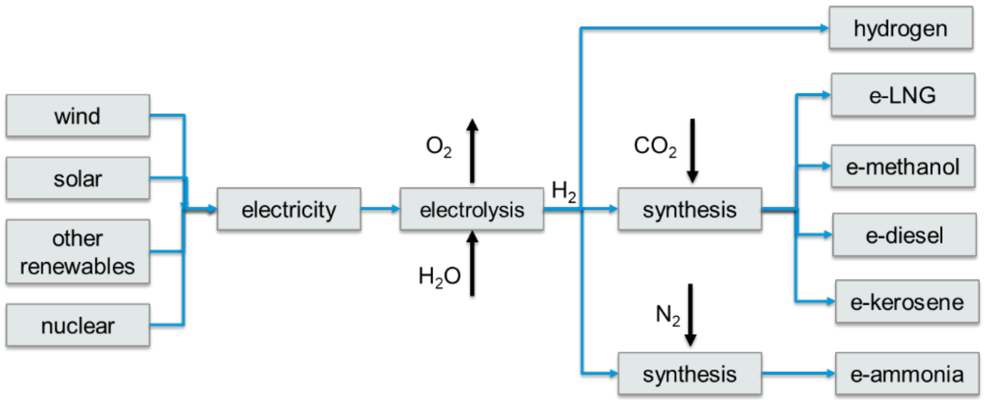
Production technologies are at pilot/demo scale and can be further scaled up dependent on projected economics towards 2050

Power-2-Liquid (sunfire, D)

Power-2-Methanol (CRI, IS)

Power-2-Ammonia (Fukushima, J)

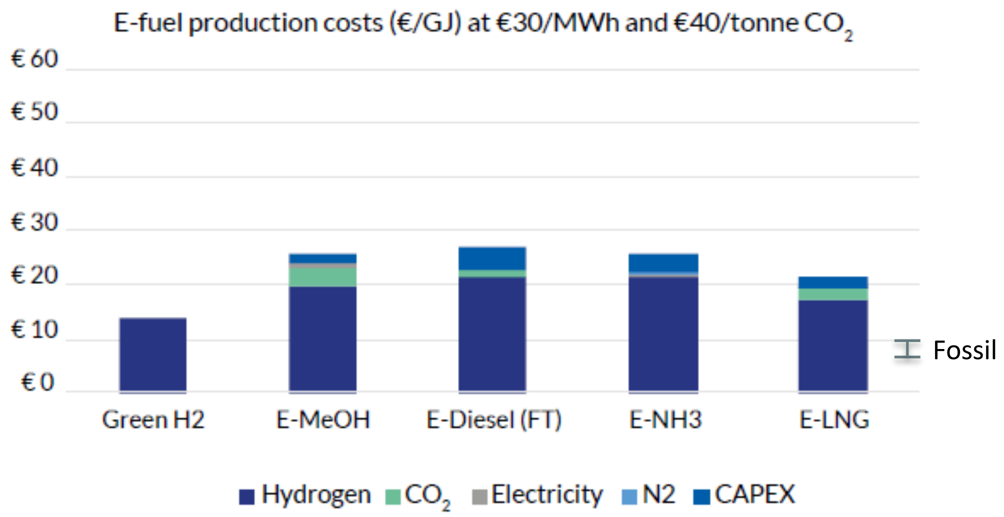
E-fuel production costs determining factors



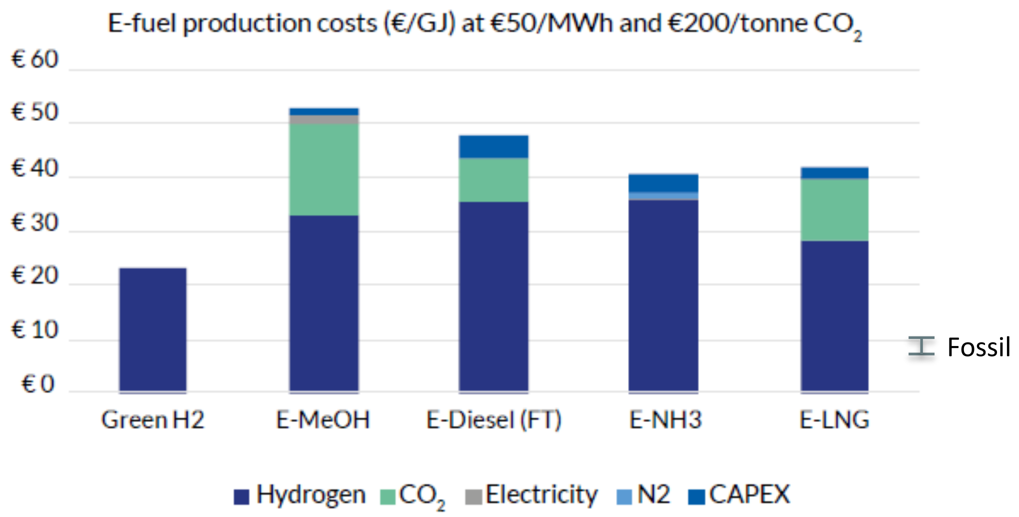
- CO2 emissions regulations:
  - Costs of CO2 emission (industry, transport).
  - Allocation principles (ETS & RED-II).
- Price of electricity:
  - Determined by (regional) electricity market.
  - Dependent on renewable energy regulations.
- Price of hydrogen:
  - Dependent on price of electricity (when produced locally).
  - Determined by international hydrogen price (when imported).
- Price of purchased CO2 (for carbon based e-fuels):
  - Source of CO2: Fossil, bio or air capture.
  - Associated price of CO2 as feedstock.

Economics of production

Production costs are highly sensitive to **electricity/hydrogen price** and, in case of carbon-based fuels, to **CO_2 price**

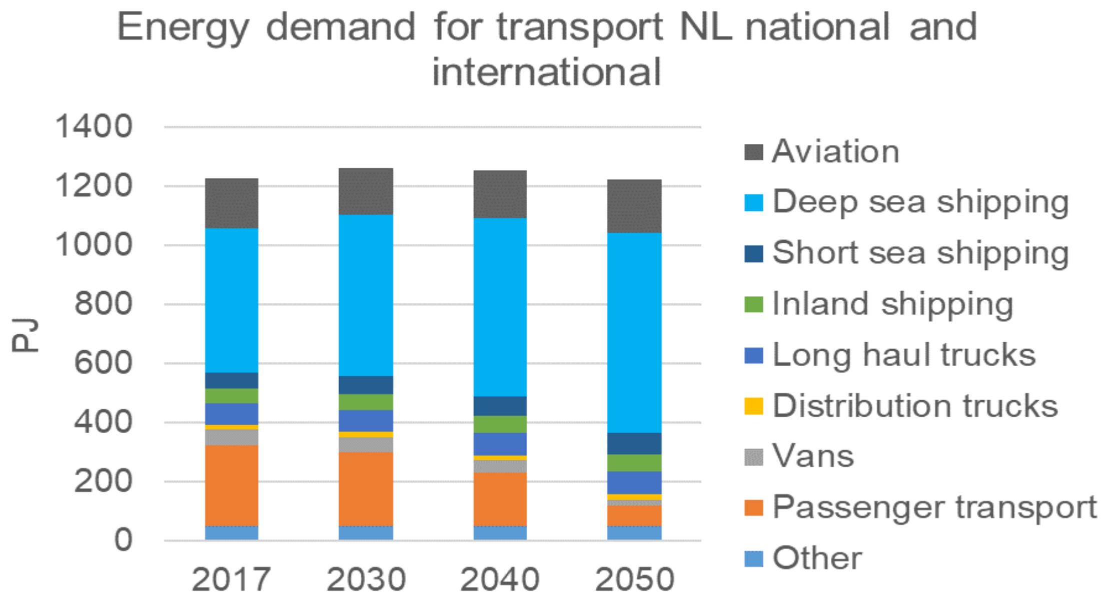


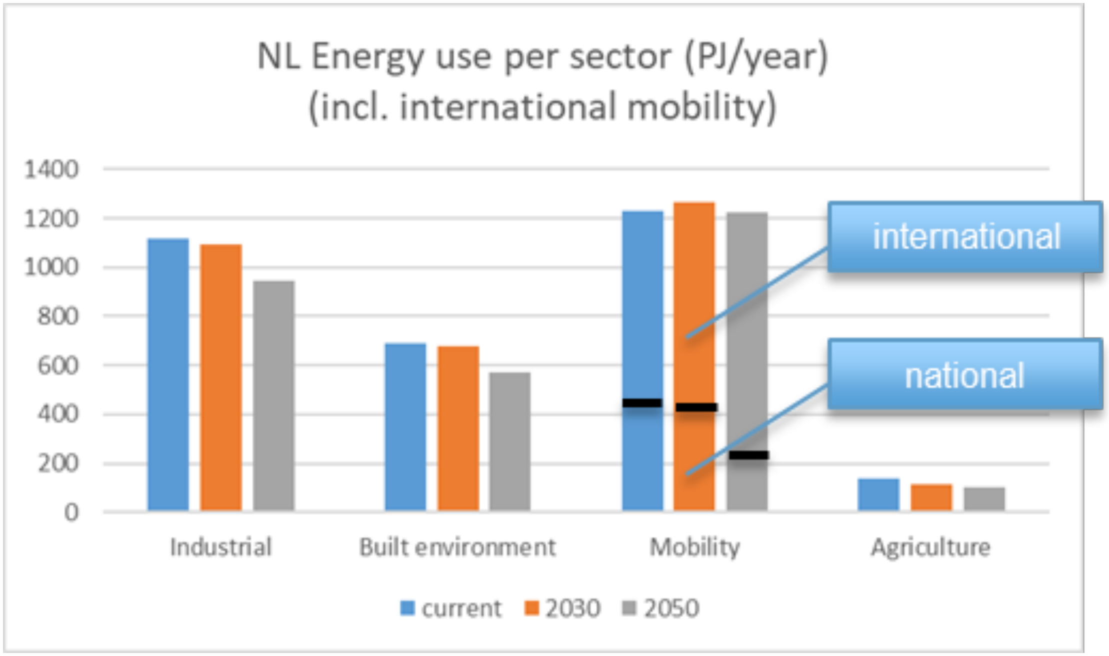
2030: e-fuel **production costs** electricity costs at **€30/MWh** and CO_2 costs of **€40/ton**



2030: e-fuel **production costs** electricity costs at **€50/MWh** and CO_2 costs of **€200/ton**

Large production needed international bunkers





Energy & space requirements locally produced fuels

showcase for all international transport modes in 2050 (960 PJ/year)

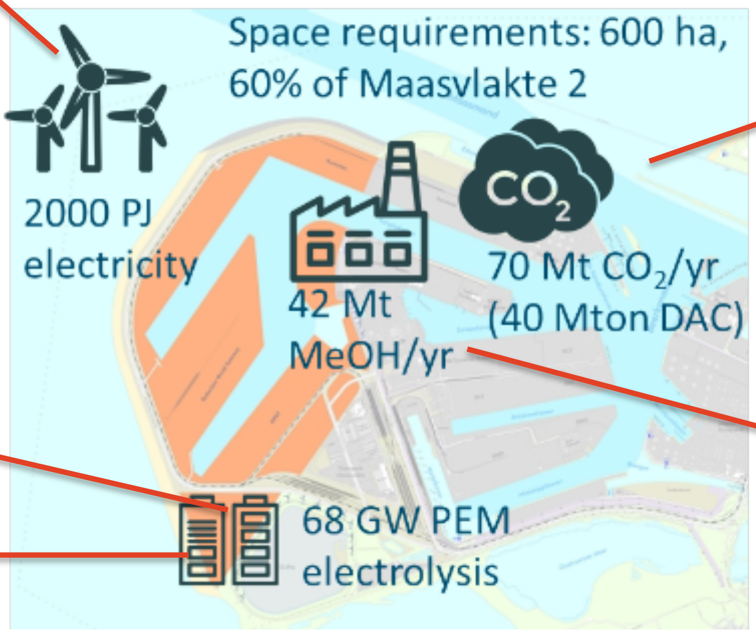
2x North Sea potential of 60 GW (PBL)

50% of current Dutch emissions

Amount of hydrogen: 10 MT
12x current NL demand (0,8 MT)
70% of total projected NL demand in 2050

Seawater desalination plant needed

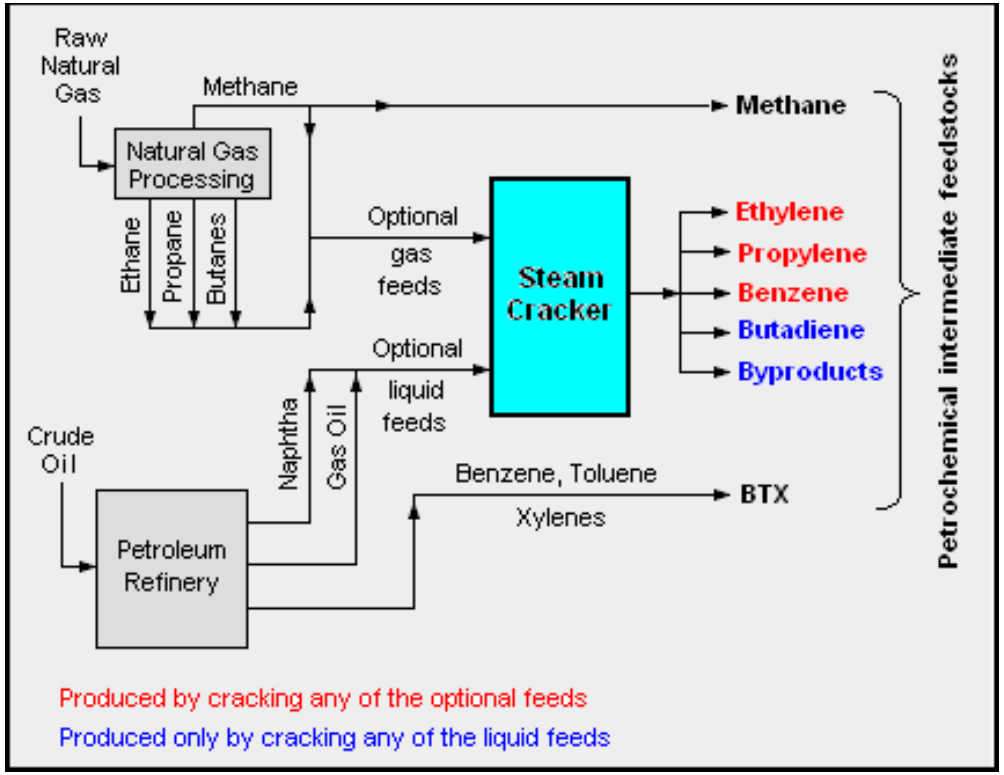
50% of current global production

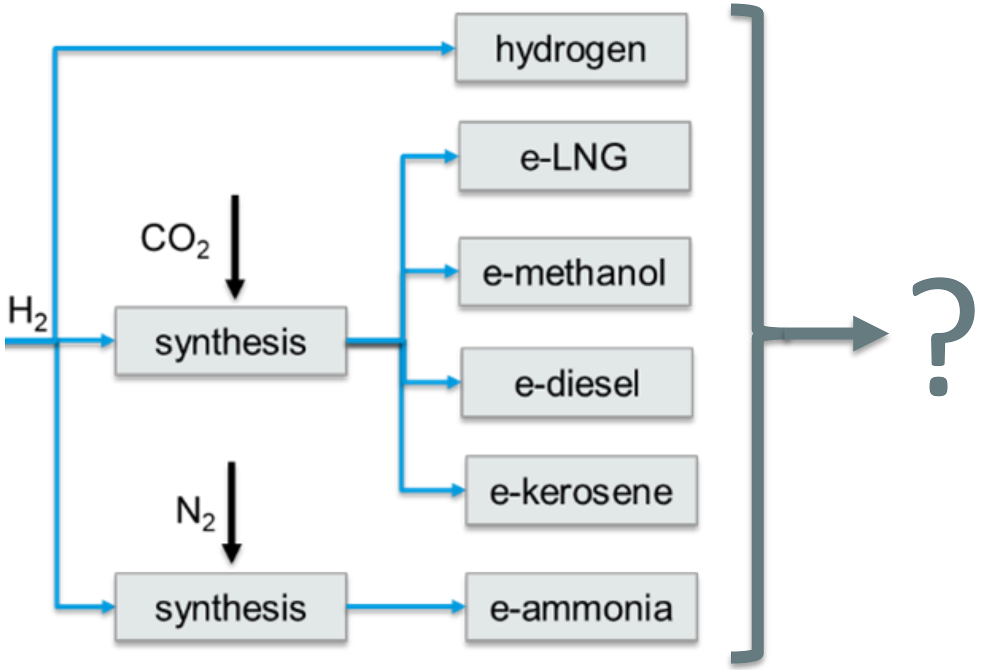


Requirements for the production of 960 PJ e-methanol per year

Alternatives: Use of imported (hydrogen or e-fuel)

Impact on petrochemical industry?



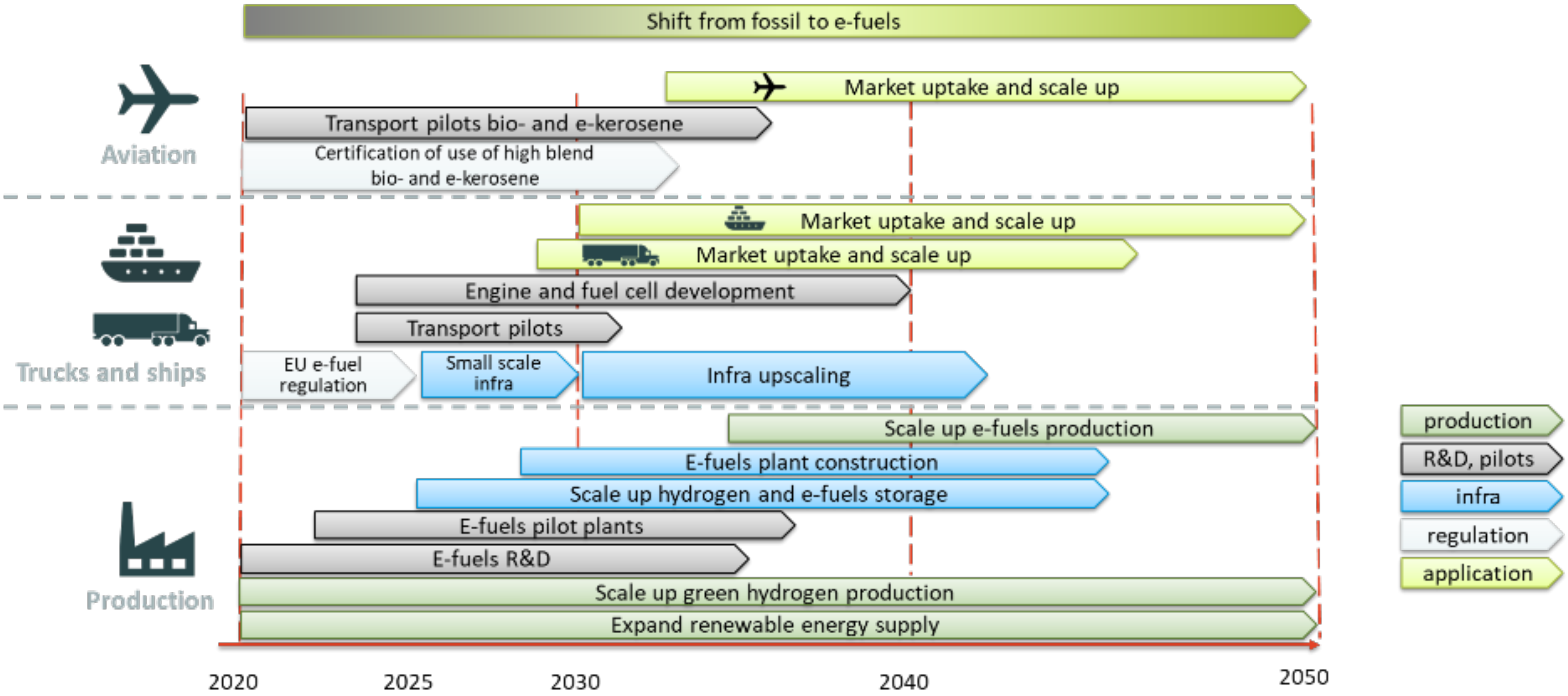


Impact of transition to e-fuels on petrochemical sector unclear, but large.

Steps to be taken

- ***Governments***: Develop a e-fuels vision and associated policies, legislation and incentives for mid- and long-term deployment.
- ***Customers and logistic providers***: Prepare for higher costs of sustainable fuels compared to traditional fuels.
- ***Energy providers***: Invest in large scale sustainable energy production, transport & storage, nationally and internationally.
- ***Fuel producers & providers***: Start scouting and piloting of sustainable fuels technologies to learn and be prepared for deployment.
- ***Port industrial complexes***: Include e-fuels production and import/export explicitly in mid-/long-term planning and support pilot developments.

E-fuels roadmap towards 2050: A first sketch



Conclusions & next steps

Conclusions

- ***E-fuels are an important option*** for decreasing CO_2 emissions transport, next to battery electric and biofuels, with application in heavy long-distance transport.
- Different e-fuels have different application area's, ***there is not 1 winner***.
- ***Large amounts of renewable energy and hydrogen*** are needed. This implies dependency on international markets for these products and this import.
- Costs of e-fuels are heavily dependent on ***CO_2 regulations, renewable energy production development, international hydrogen markets and CO_2 availability***.
- The transition towards e-fuels will bring ***disruptive changes in petrochemical and port industrial activities***.
- A ***well-supported cross-sectoral public-private roadmap*** is needed as soon as possible, to be able to anticipate on the changes that will be coming in the fuels and industry domains.
- ***Small-scale experimental projects and pilots should be started*** as soon as possible to learn and adapt in the fuels and industry transition towards 2050.

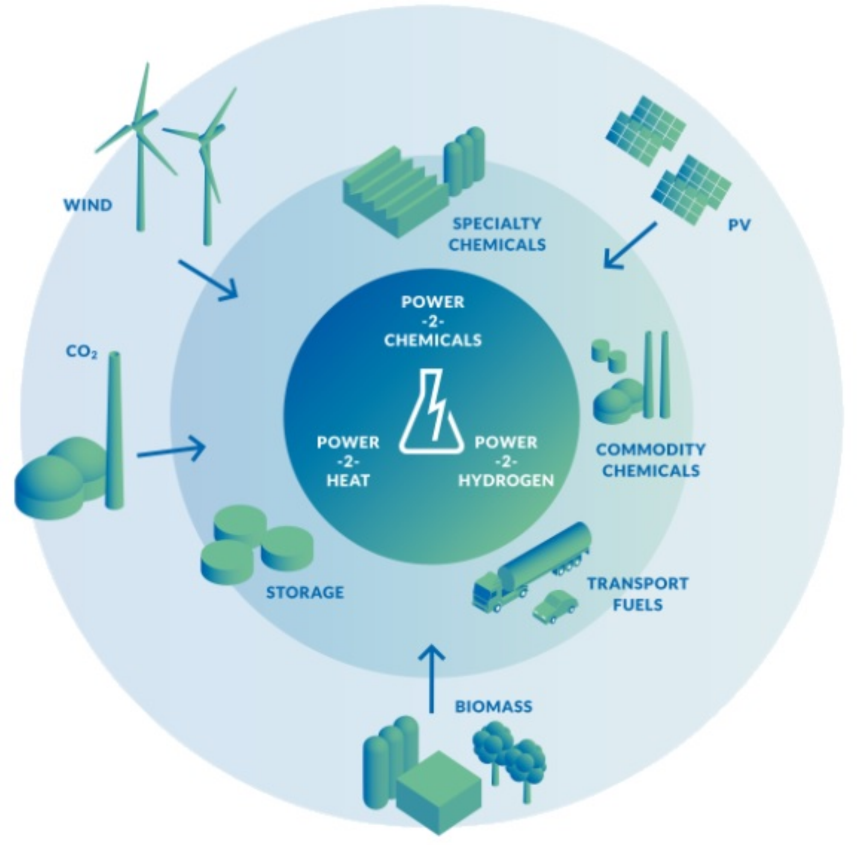
Next steps

The partners are already further working on the next projects:

– Studies
  - CHAIN: import/export and industrial value chain impact assessment.
  - STRIVE: implications of e-fuels implementation in truck transport.

– Technology developments and pilots:
  - TAKE-OFF: Highly efficient production of e-kerosene.
  - Power-2-DME: Production of Methanol/DME from CO2 and hydrogen.
  - Application of Methanol as fuel for shipping.
  - Use of hydrogen in short-distance trucking (fuel-cells and combustion).

Let’s energize innovation together



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