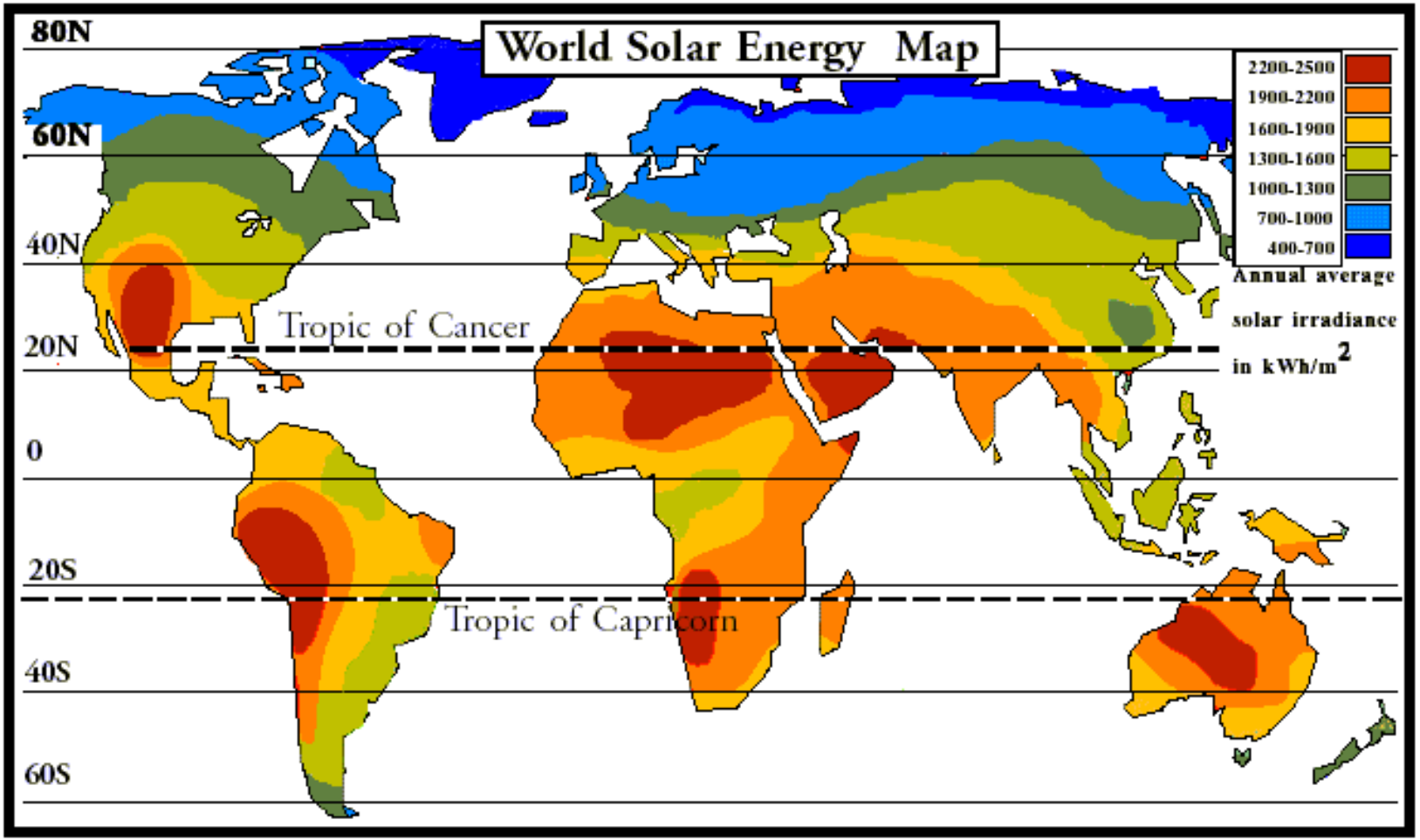
Green Hydrogen Economy in the Northern Netherlands

Prof. Dr. Ad van Wijk

7-5-2018

Bids for Saudi Arabia's 300 MW Solar Plant


World Solar Energy Map
80N
60N
40N
20N
0
20S
40S
60S
Tropic of Cancer
Tropic of Capricorn
2200-2500
1900-2200
1600-1900
1300-1600
1000-1300
700-1000
400-700
Annual average
solar irradiance
in kWh/m2

Tokyo Olympic Games 2020

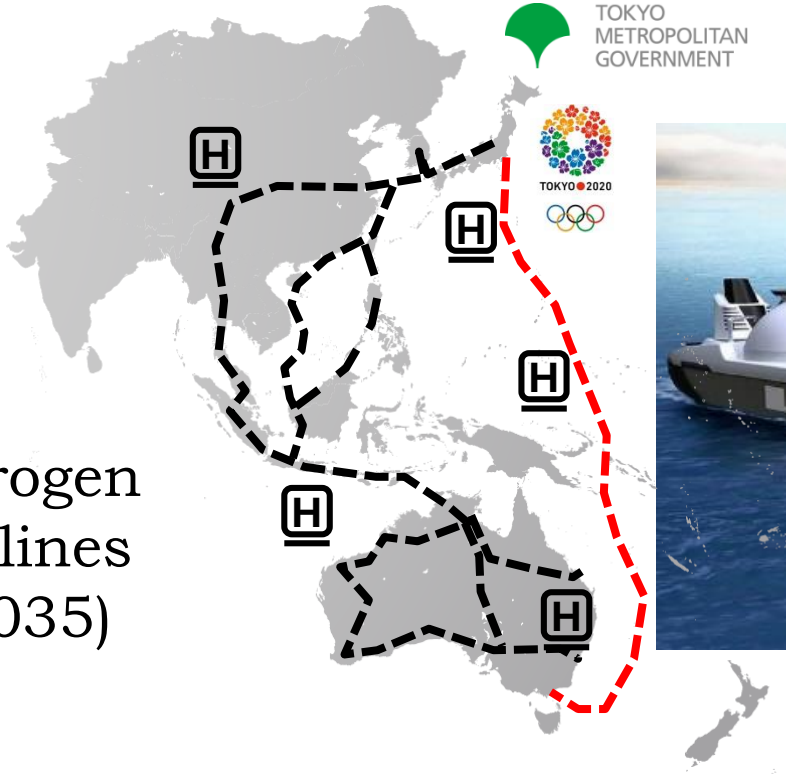
GRENATEC
Green Renaissance through Advanced Technology

ADB
Asian Development Bank

AIIB
THE ASIAN INFRASTRUCTURE INVESTMENT BANK

TOKYO METROPOLITAN GOVERNMENT

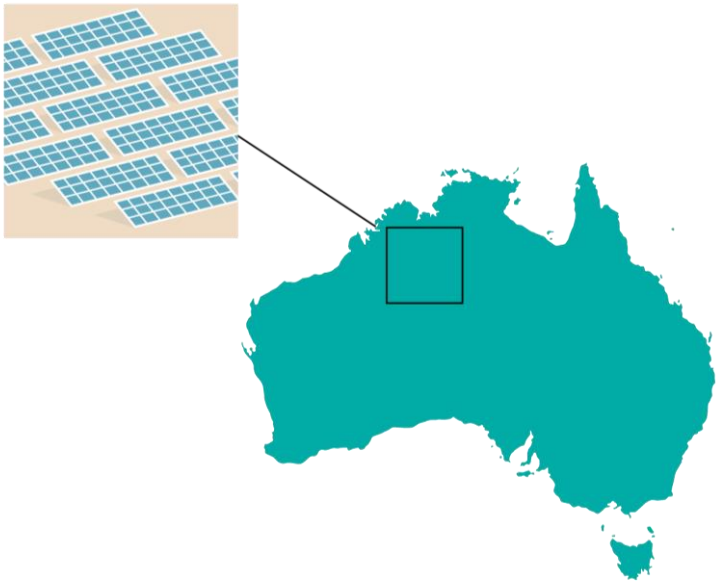
TOKYO 2020



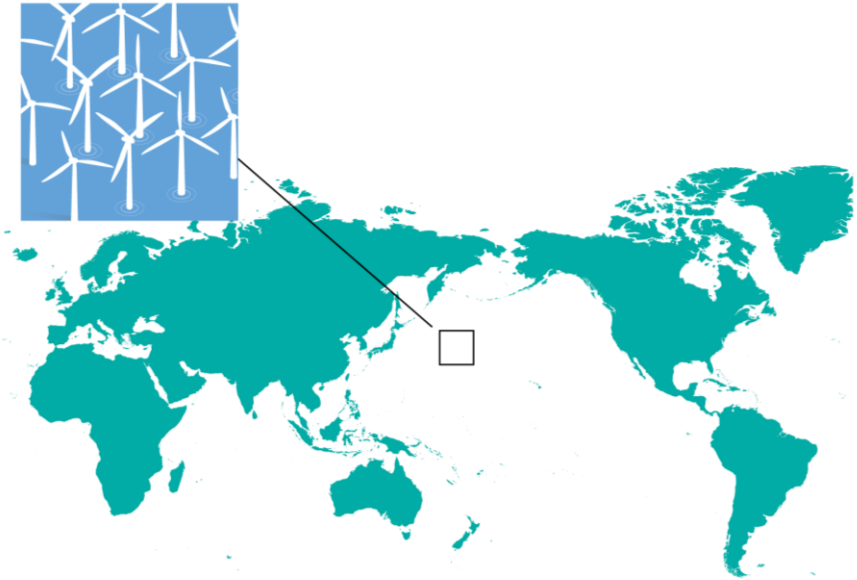
Hydrogen Pipelines (~2035)

Hydrogen Shipping (~2025)

Surface needed to produce all the world's energy 556 EJ = 155.000 TWh

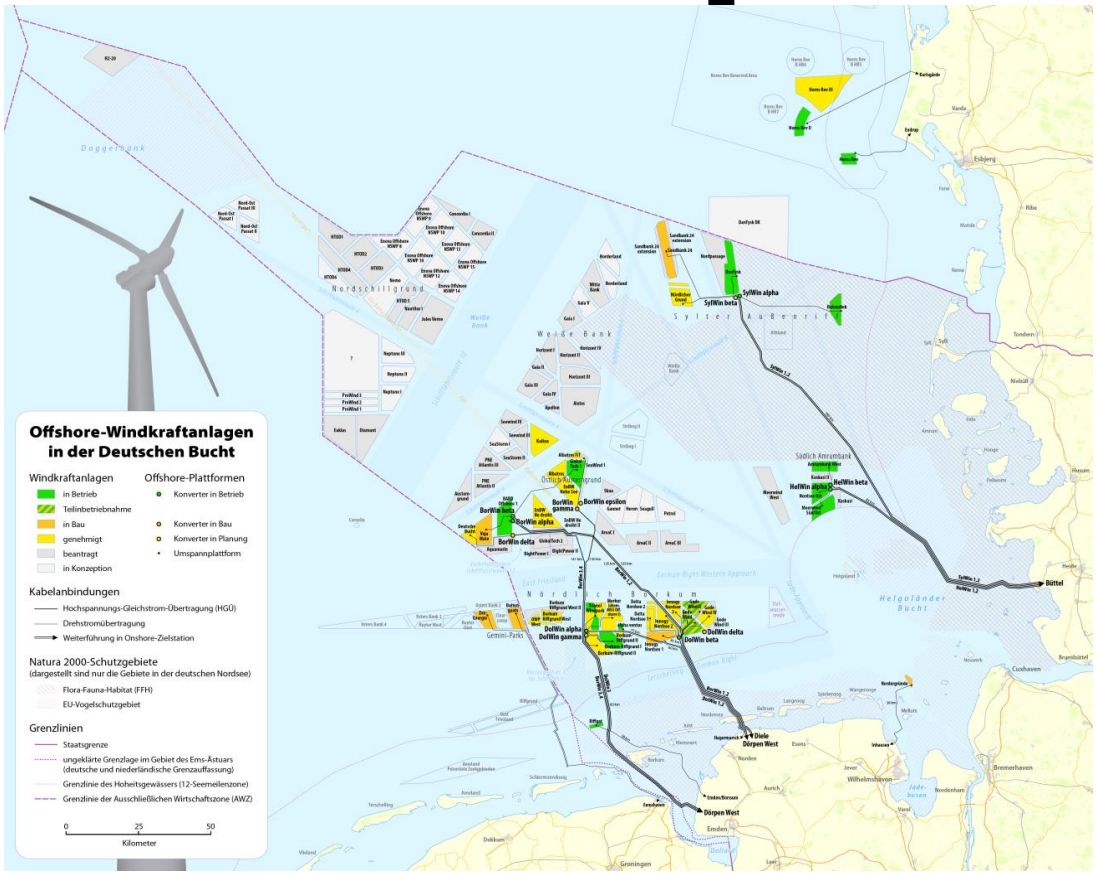


10% SOLAR AUSTRALIA



1.5% WIND PACIFIC OCEAN

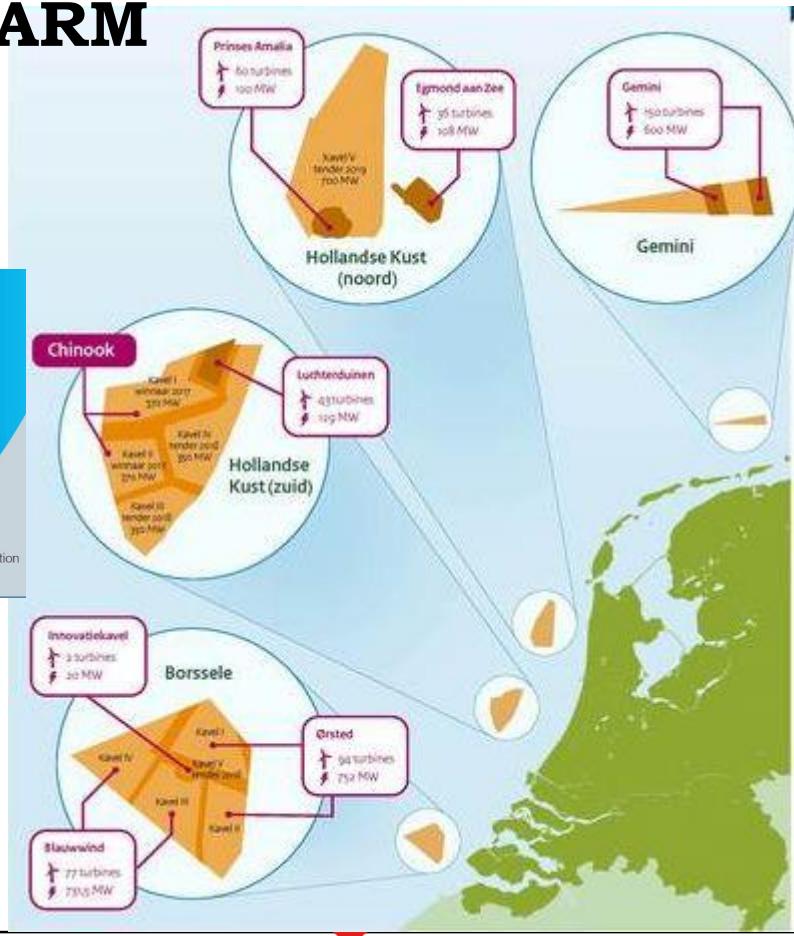
Offshore Wind Development Germany



VATTENFALL BUILDS WIND FARM WITHOUT SUBSIDY

19 MARCH 2018

- Chinook, daughter Vattenfall
- 700 MW wind farm
- Operational 2022
- Location Hollandse Kust (Zuid)
- 22 km from the coast



Eemshaven; The Energy Harbor

Norned Cable 700 MW

Cobra Cable 700 MW (2019)

Gemini Offshore Wind Farm 600 MW

Onshore Wind Farms > 275 MW

Nuon Magnum power plant 1,320 MW

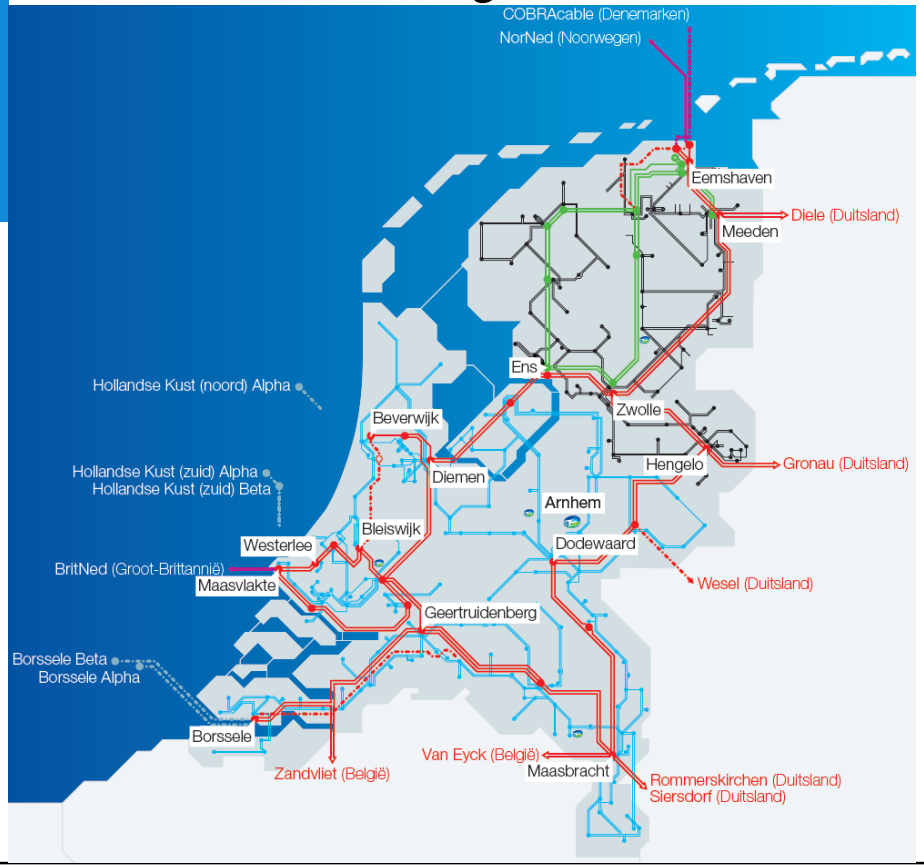
RWE Coal fired power plant 1,560 MW

Engie Gas fired power plant 2,450 MW

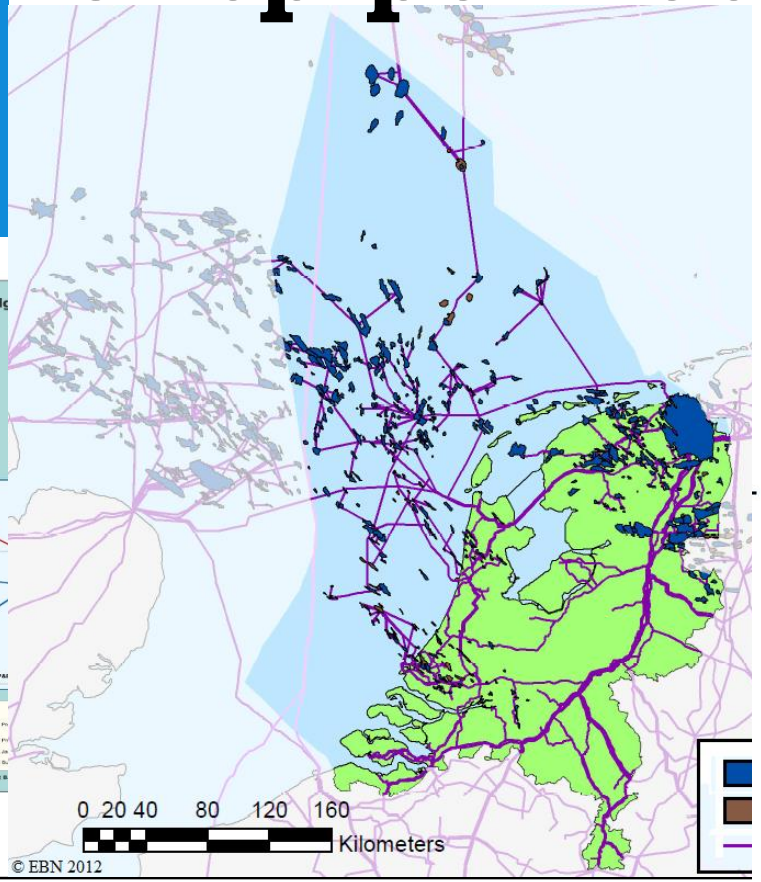
Cable Inland 4,000 MW

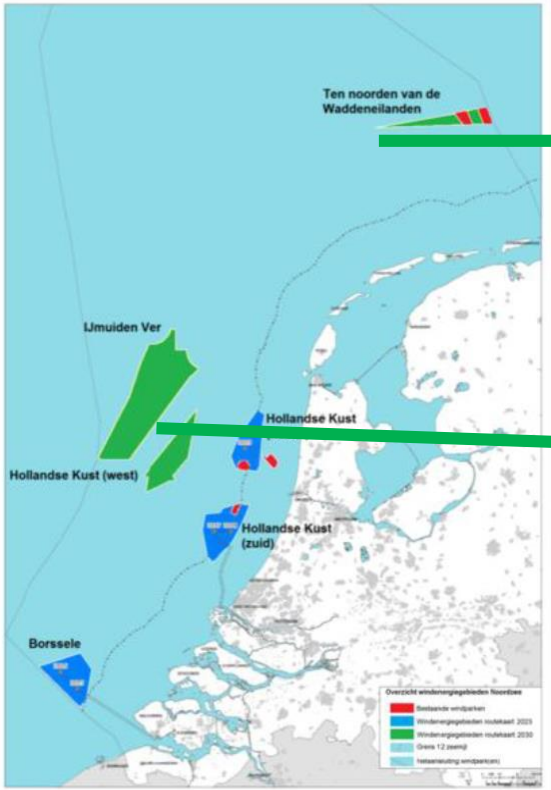
Expansion to 5,610 MW

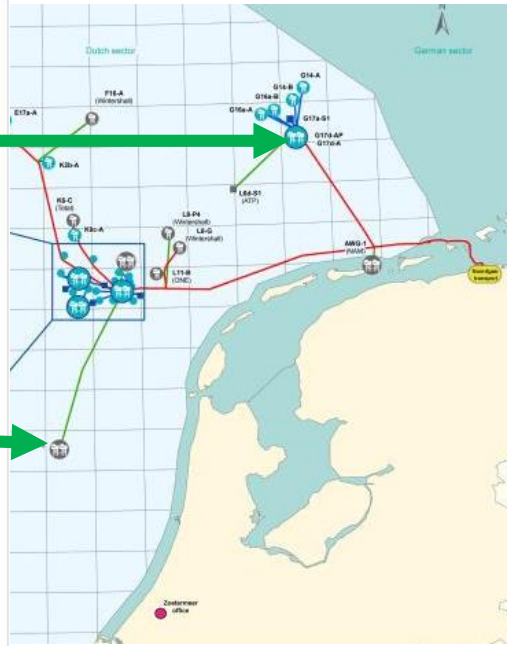
Electricity and Gas Transport Grid



Gaspipelines at the North Sea







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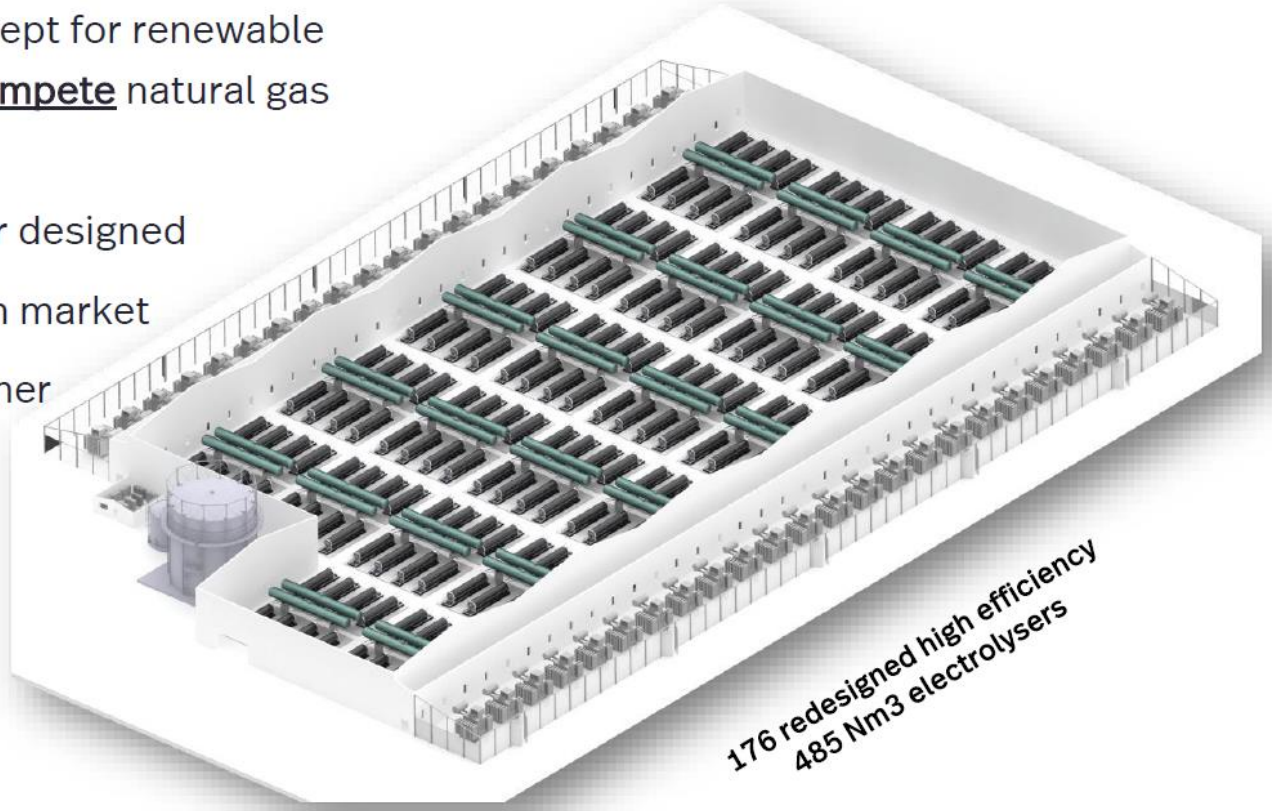
Doggersbank Energy Island

Cable versus pipeline cost

	Cable (BritNed)	Pipeline (BBL)
Capacity	1 GW	15 GW
Construction Cost	€ 500 mln	€ 500 mln
Volume (year)	8 TWh	120 TWh

NEL 400 MW Alkaline Electrolyzer

- Working on GIGA factory concept for renewable hydrogen production to **outcompete** natural gas reforming
- Largest electrolyser plant ever designed
- Addressing a USD ~ 150 billion market
- International industrial customer
- Tied to solar power
- CapEx of USD ~175 million
- **Benchmark CapEx ratio:**
  - **0.45 MUSD/MW**



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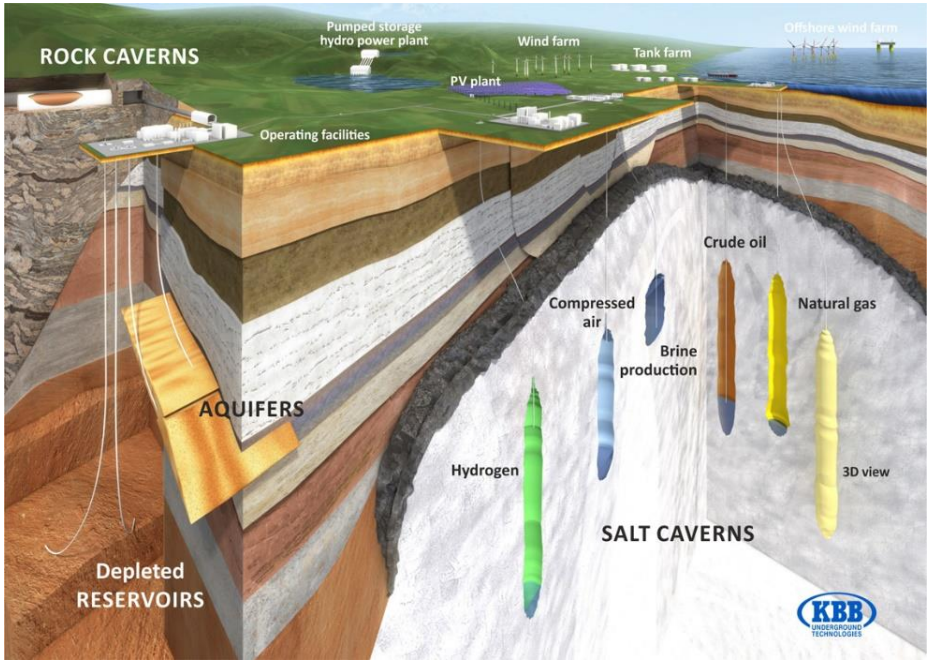
July 2017

Green Hydrogen competitive with Blue Hydrogen

- **Grey Hydrogen**; Hydrogen from fossil fuels without CCS. Production cost by steam methane reforming natural gas between 1-1.5 Euro/kg
- **Blue Hydrogen**; Hydrogen from fossil fuels with CCS. Production cost with Carbon Capturing and Storage between 2.0-3.0 Euro/kg, year 2020-2025
- **Green Hydrogen**; Hydrogen from renewable energy. Production cost by electrolysis
  - 2020-2025 between 2.0-3.0 Euro/kg
  - 2025-2030 between 1.5-2.5 Euro/kg
  - >2030 around 1 Euro/kg

Hydrogen storage in Salt Caverns

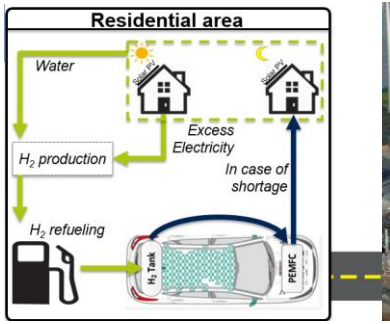


1 salt cavern can contain 6,000 ton hydrogen
Equivalent of 17 million Tesla Power walls

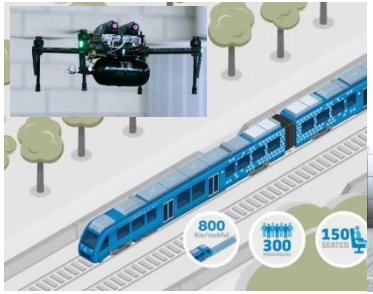
Green Hydrogen Markets

Chemical Feedstock

Electricity Balancing



Transport



Heating

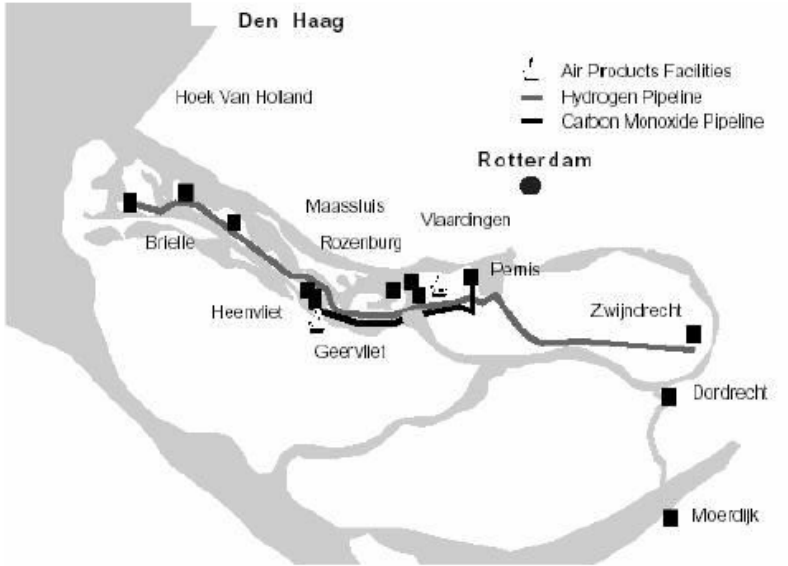
Delfzijl chemical site

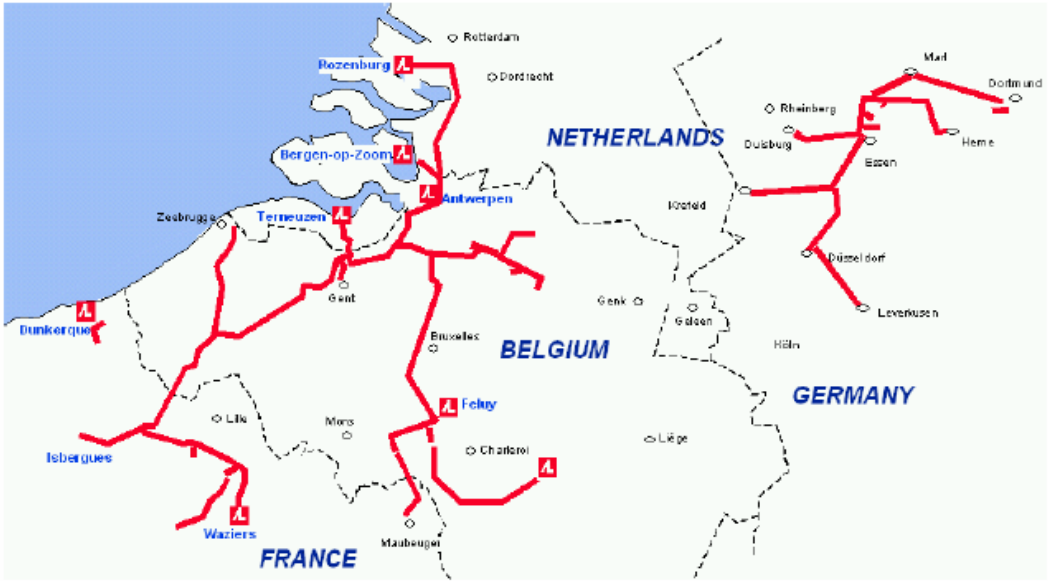
Ammonia,Methanol, Hydrogen-Peroxide production

Existing hydrogen pipelines

Air products

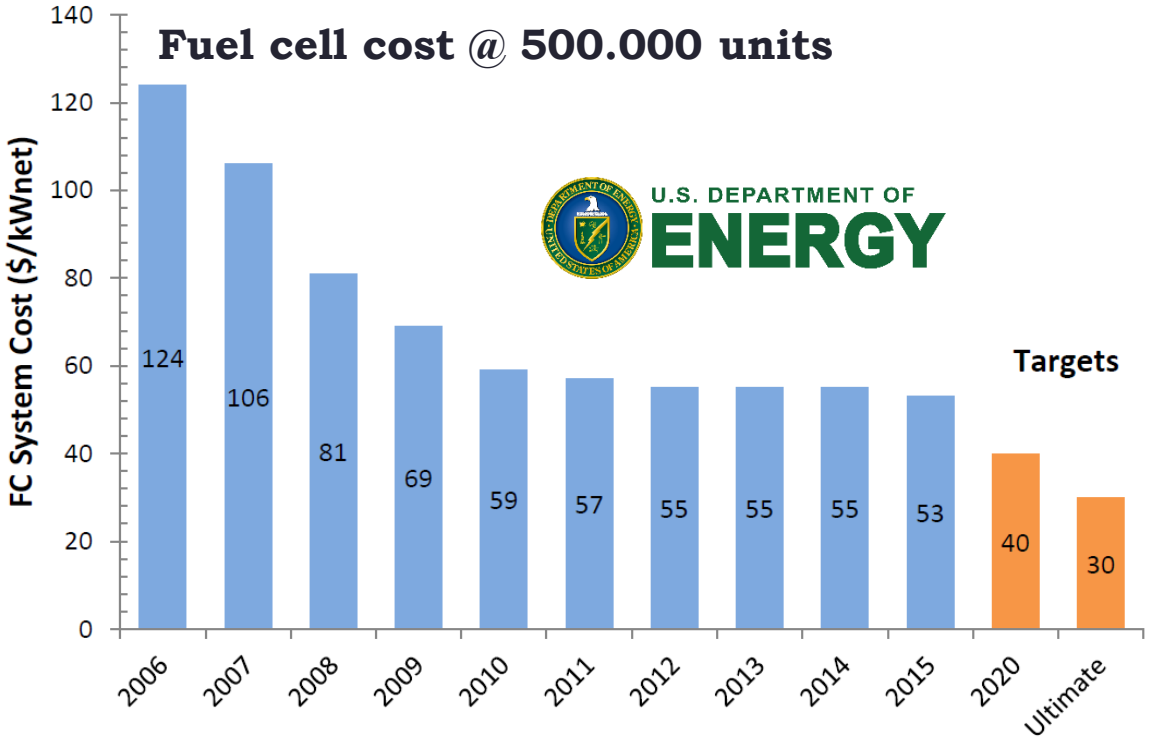
Air Liquide





Toyota Mirai; Fuel cell car

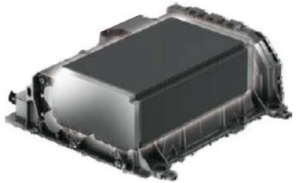
Fuel cell cost



TOYOTA

2008 FUEL CELL STACK

Weight	Volume	Power
-48%	-43%	+26%

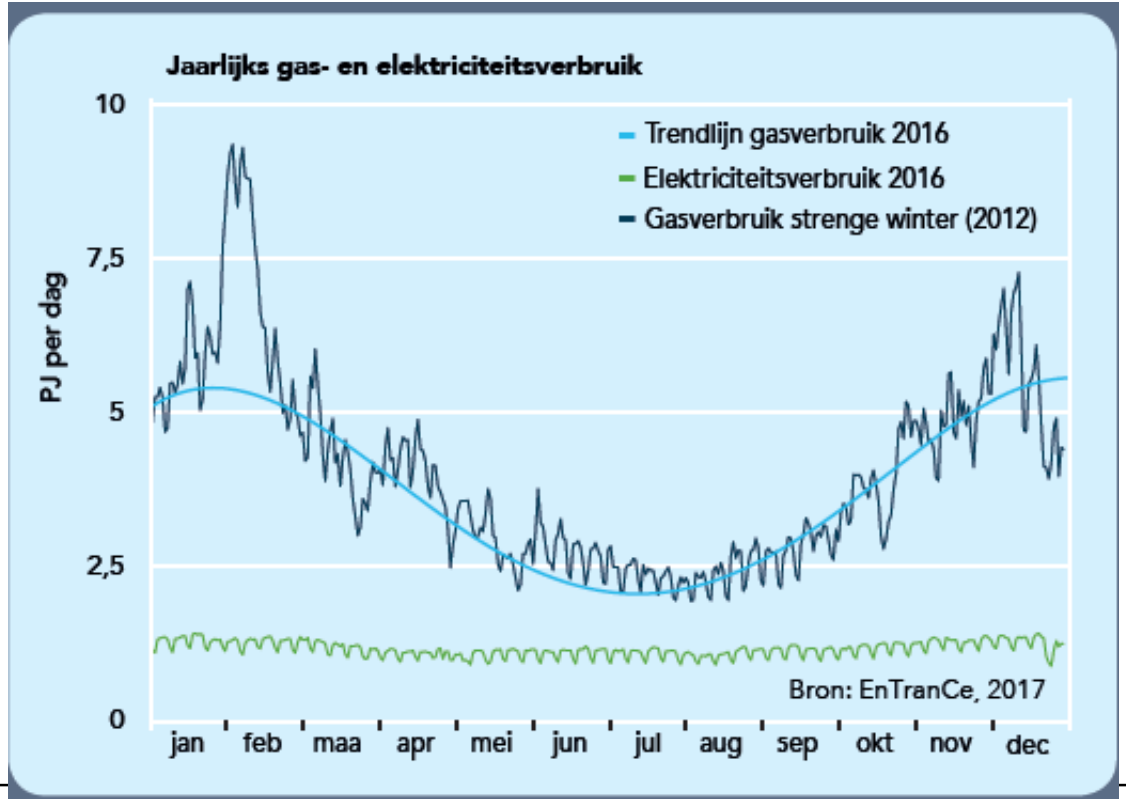


2016 FUEL CELL STACK

City Groningen vehicles on hydrogen

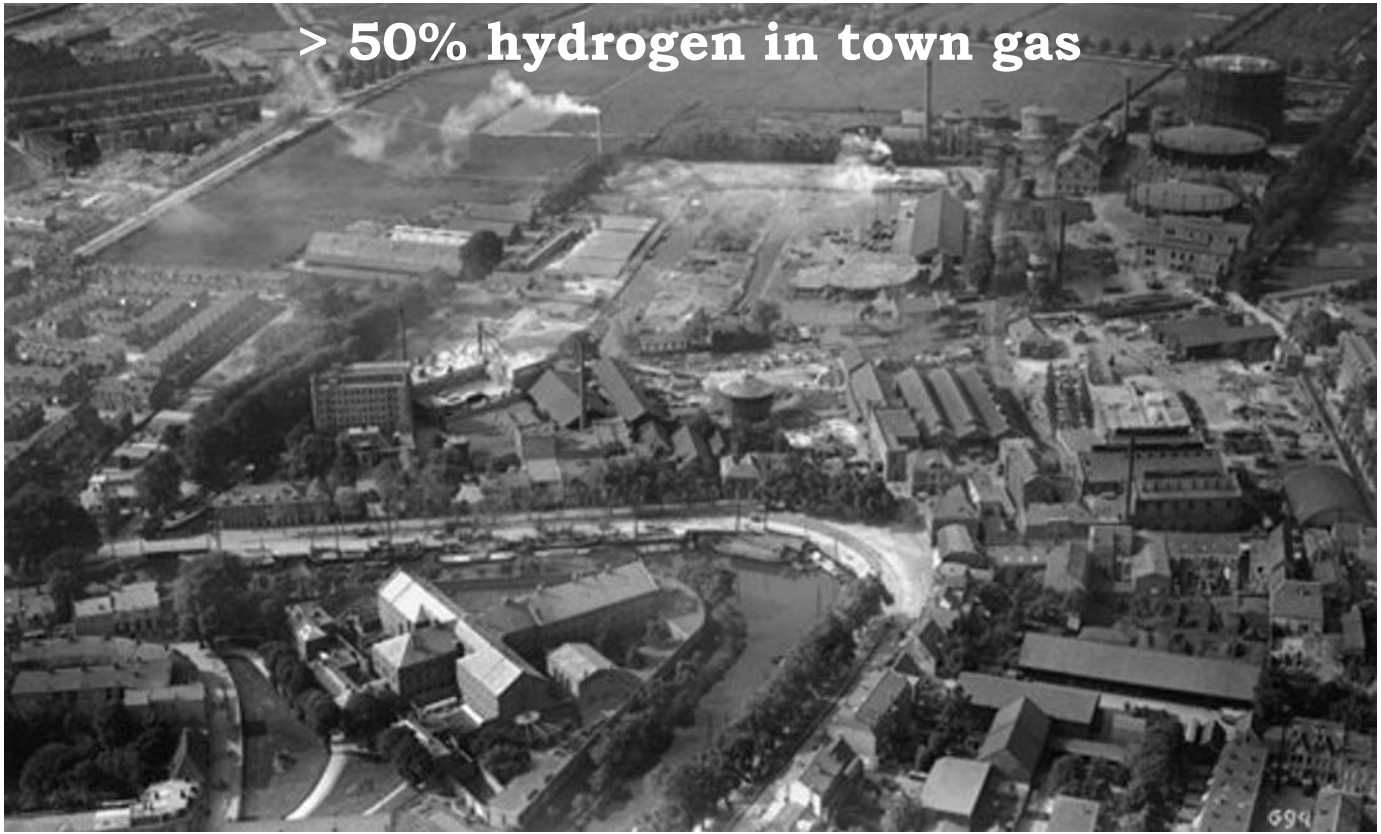
Company Holthausen converts vehicles to fuel cell hydrogen;
Garbage trucks and sweepers for the city of Groningen, may 2017

Gas and Electricity consumption the Netherlands

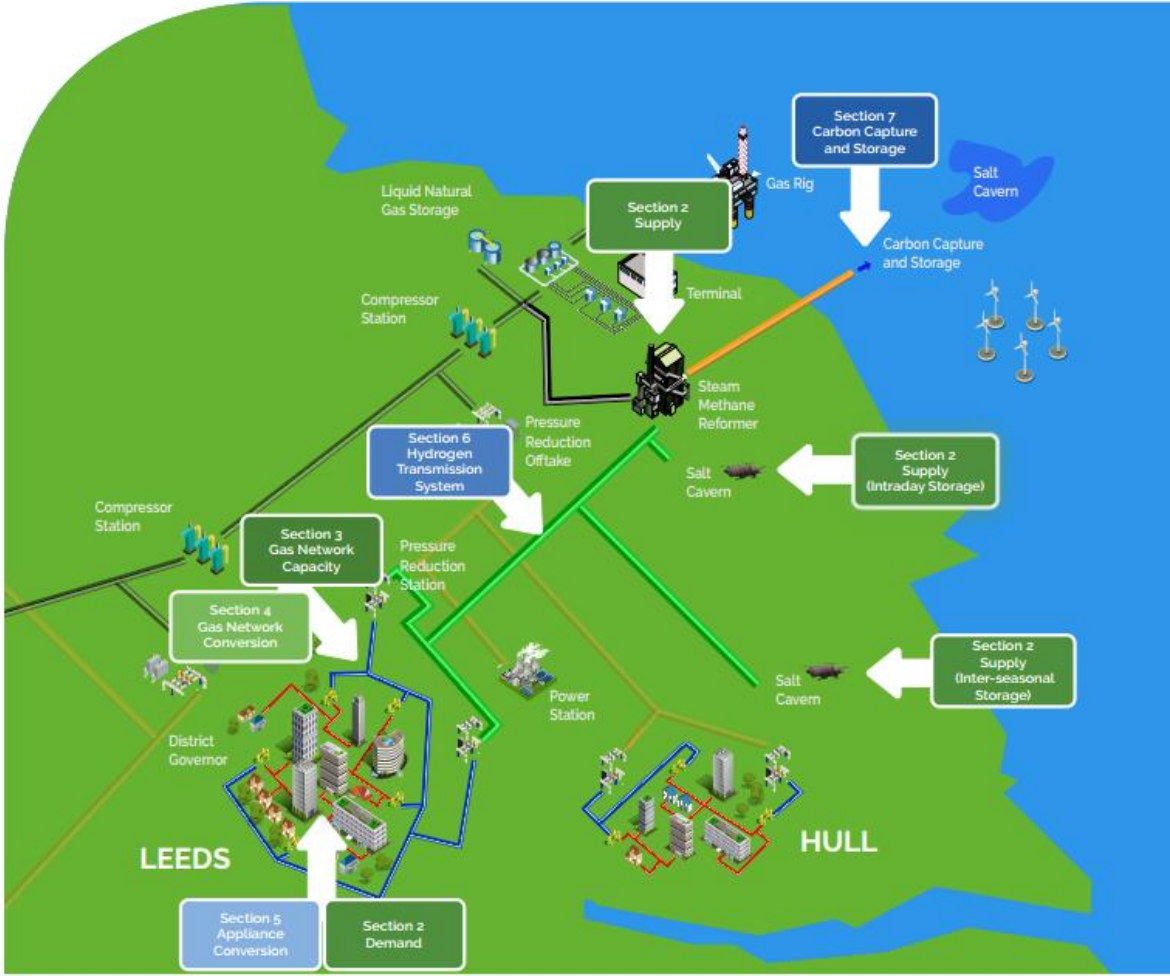


Large seasonal difference in gas consumption due to heating demand. Therefore a huge need for seasonal storage.

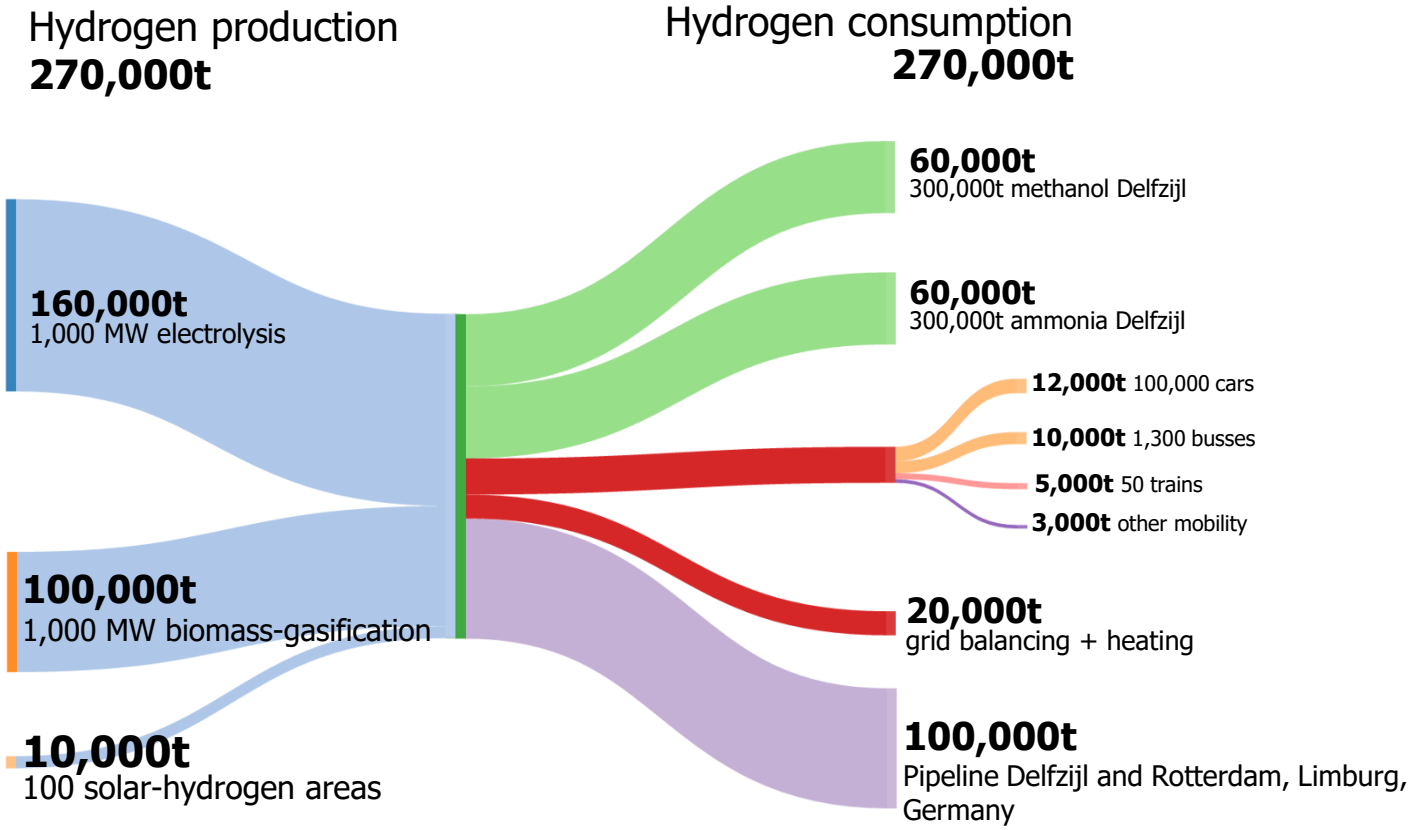
Town Gas production Utrecht 1862-1959



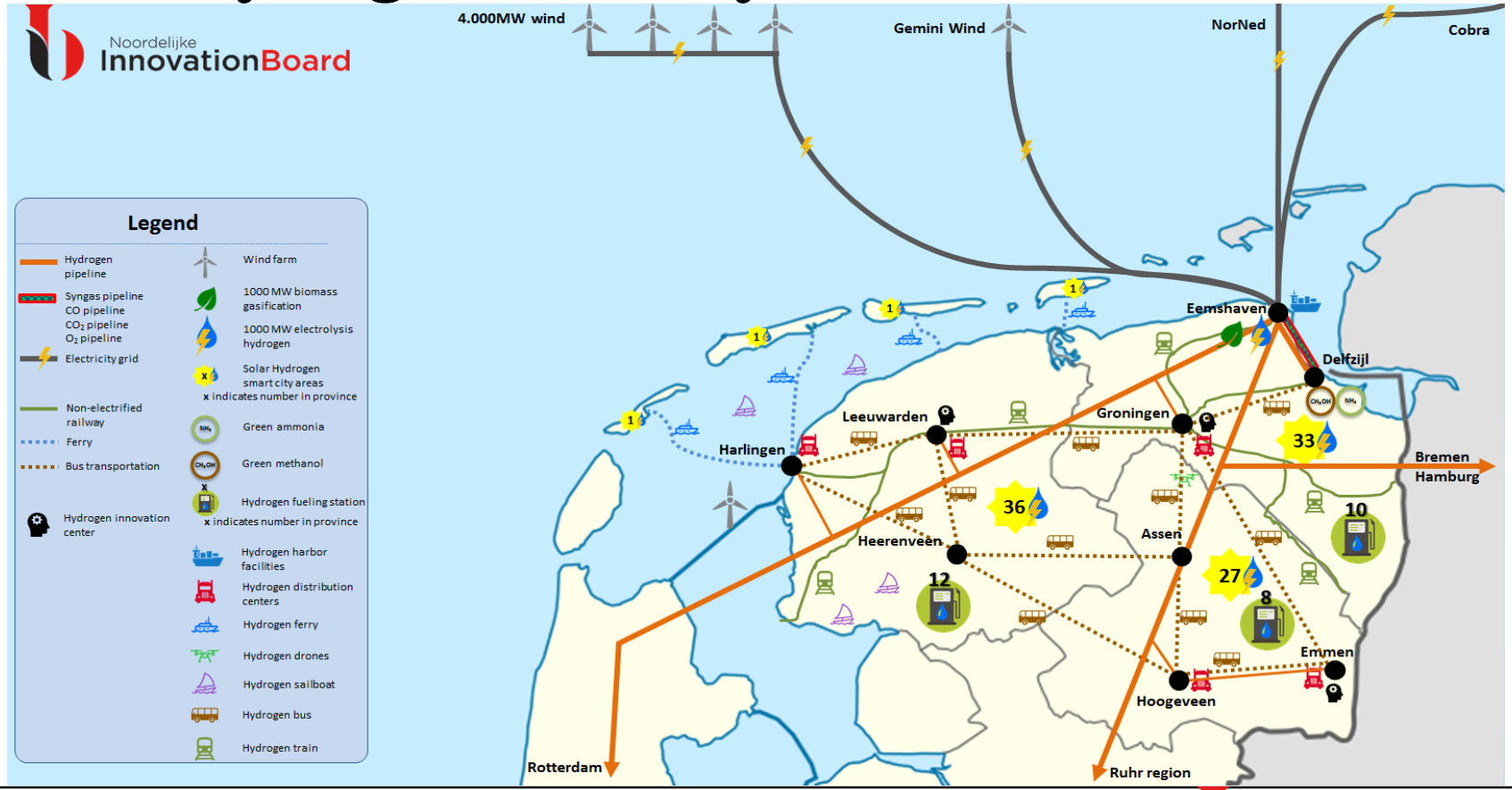
Leeds City Gate Project



Green Hydrogen Economy Northern Netherlands 2030



Green Hydrogen Economy Northern Netherlands 2030



The Northern Netherlands uniquely positioned for green hydrogen

- Large scale green electricity production
- Large scale green electricity import
- Existing gas knowledge infrastructure
- Existing chemical clusters; Delfzijl and Emmen
- Space in the Eemshaven
- **Existing gas infrastructure which can be retrofitted easily and cheaply to transport hydrogen**

Defying Death Valley