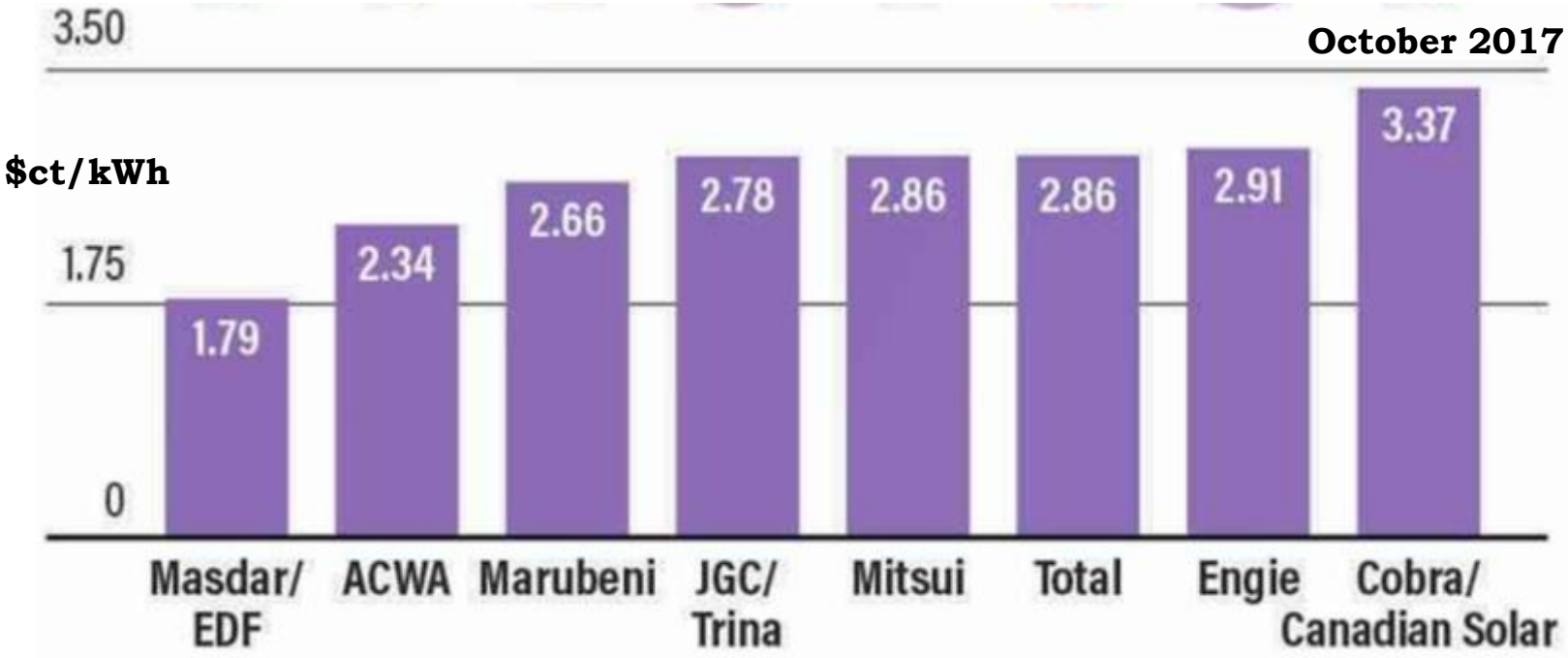
Hydrogen
key to the energy transition

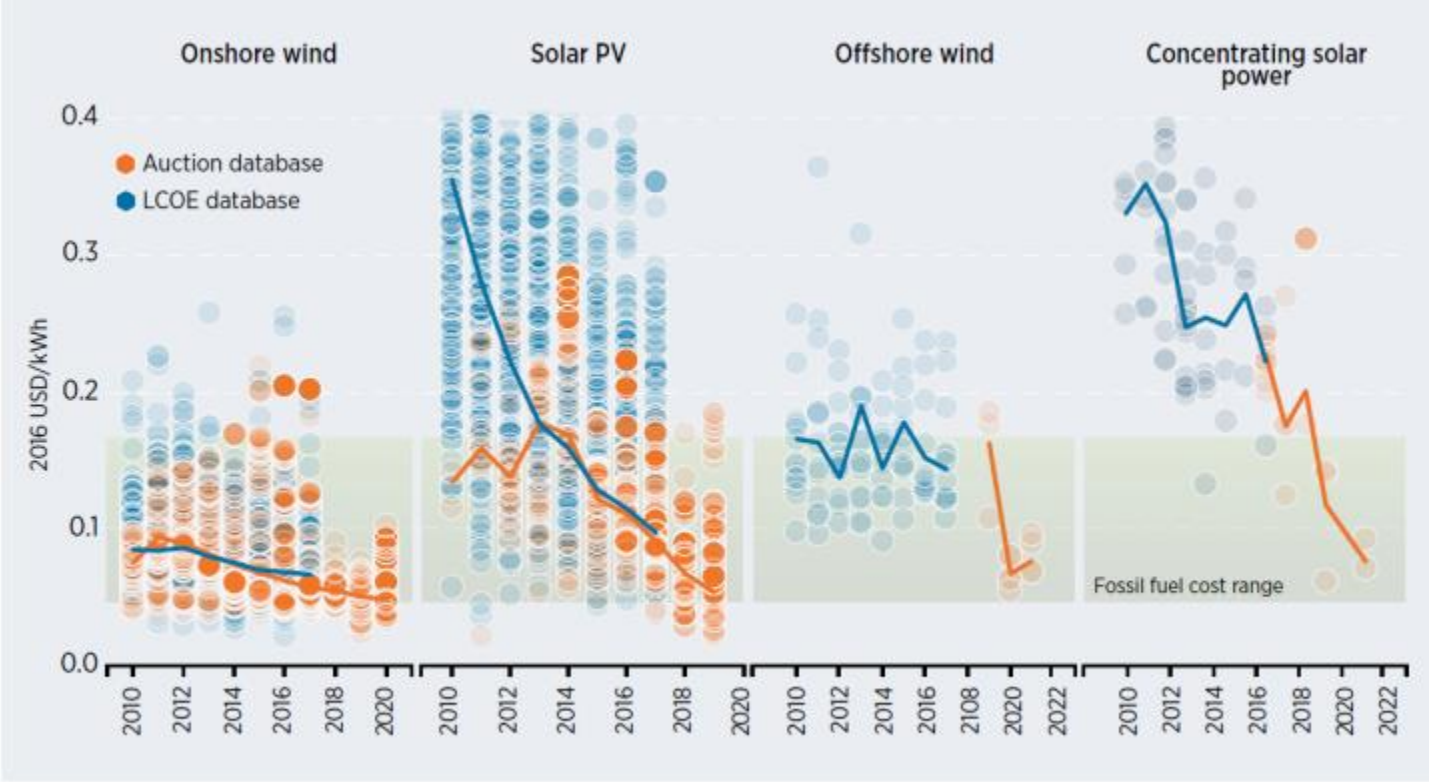
Prof. Dr. Ad van Wijk

14-6-2018

Bids for Saudi Arabia's 300 MW Solar Plant

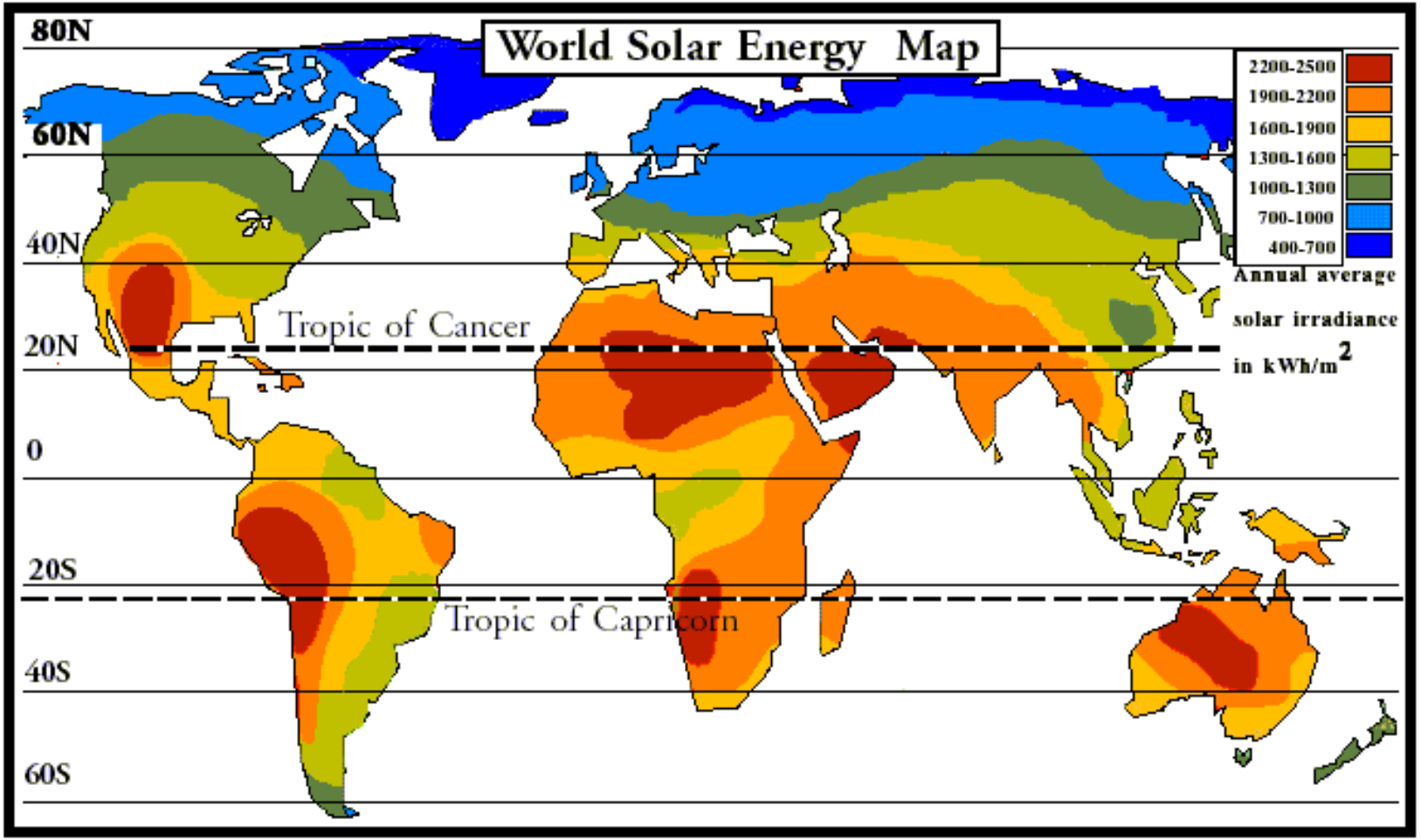


Levelized Cost of Electricity

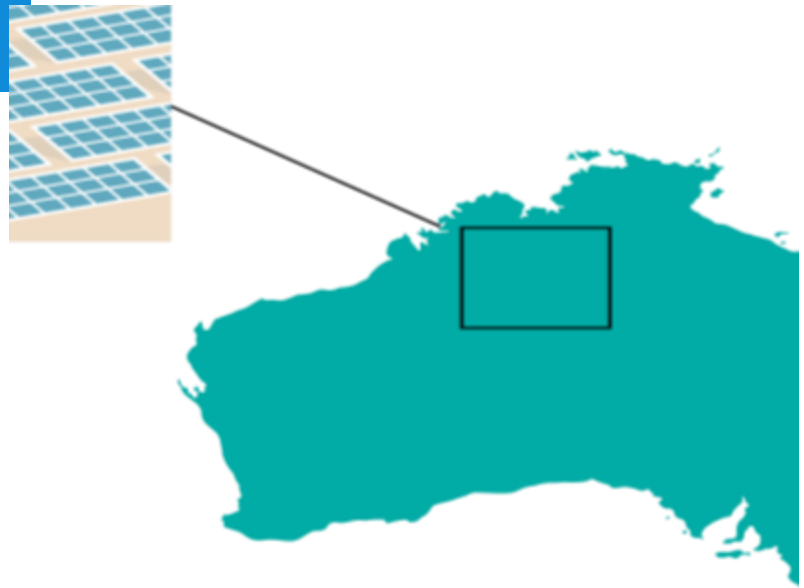


Source: IRENA Renewable Cost Database and Auctions Database.

IRENA, January 2018, Renewable Power Generation Costs 2017


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

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



10% SOLAR AUSTRALIA

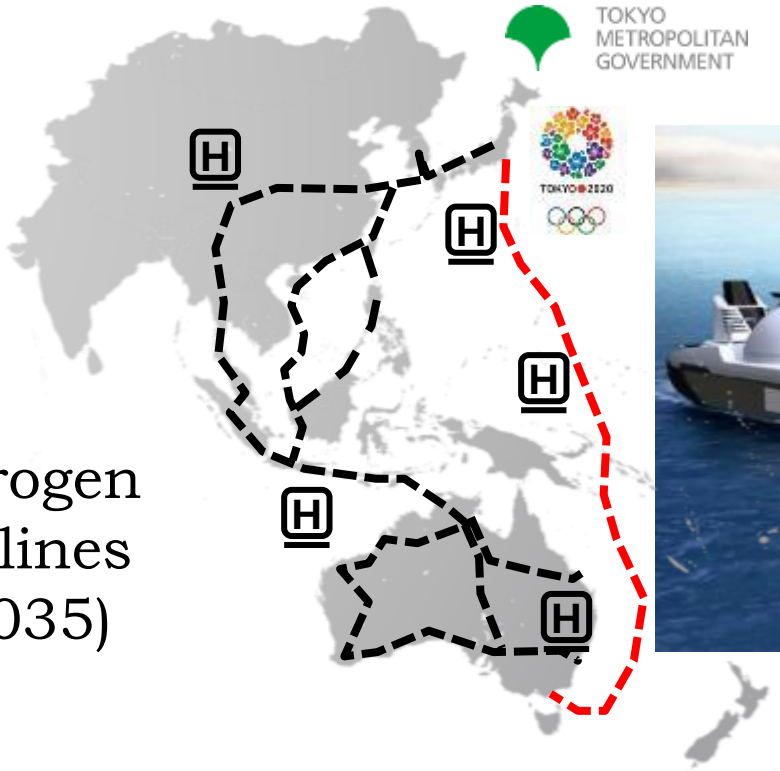
1.5% WIND PACIFIC OCEAN

Tokyo Olympic Games 2020

GRENATEC
Green Renaissance through Advanced Technology

ADB
Asian Development Bank

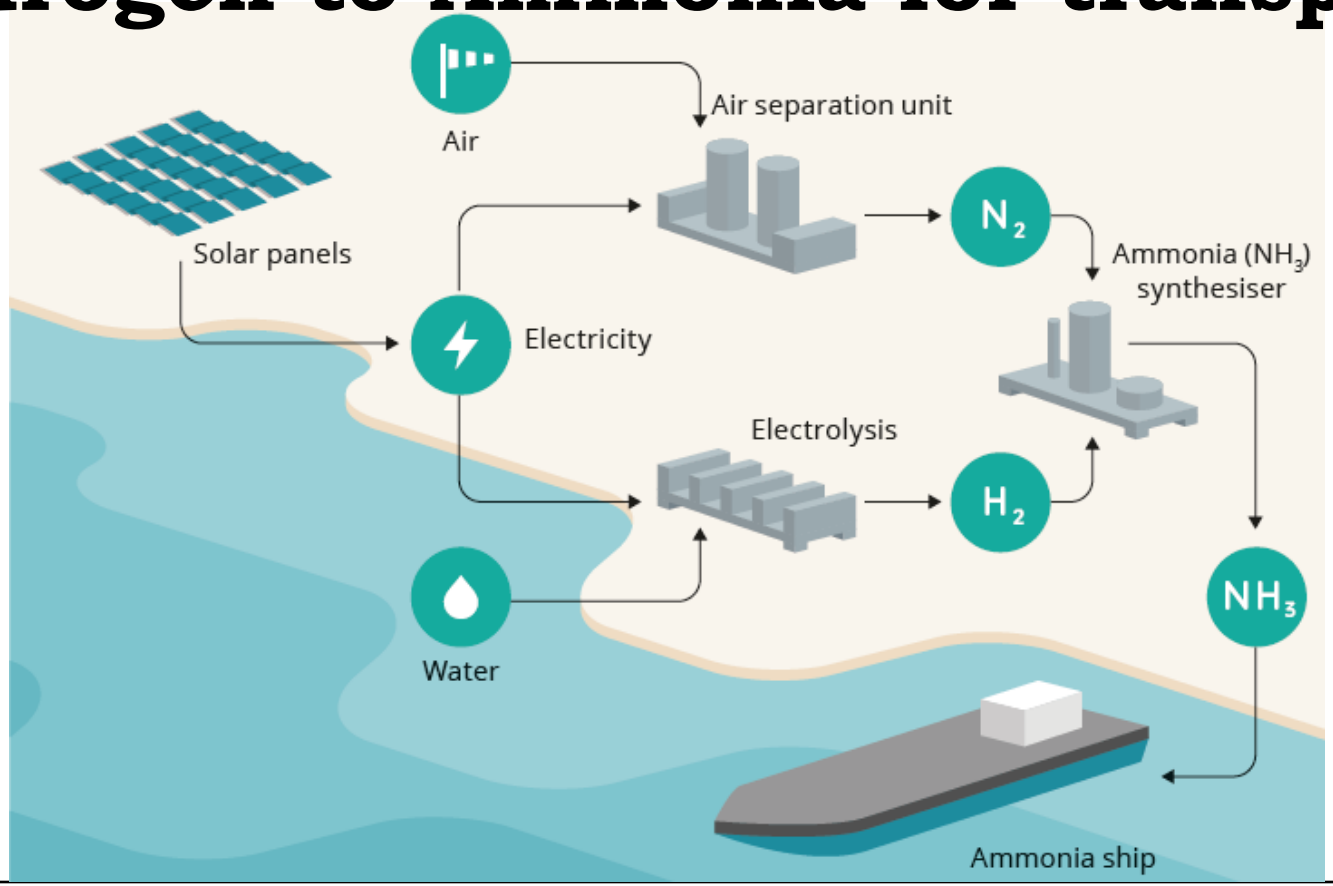
AIIB
THE ASIAN INFRASTRUCTURE INVESTMENT BANK



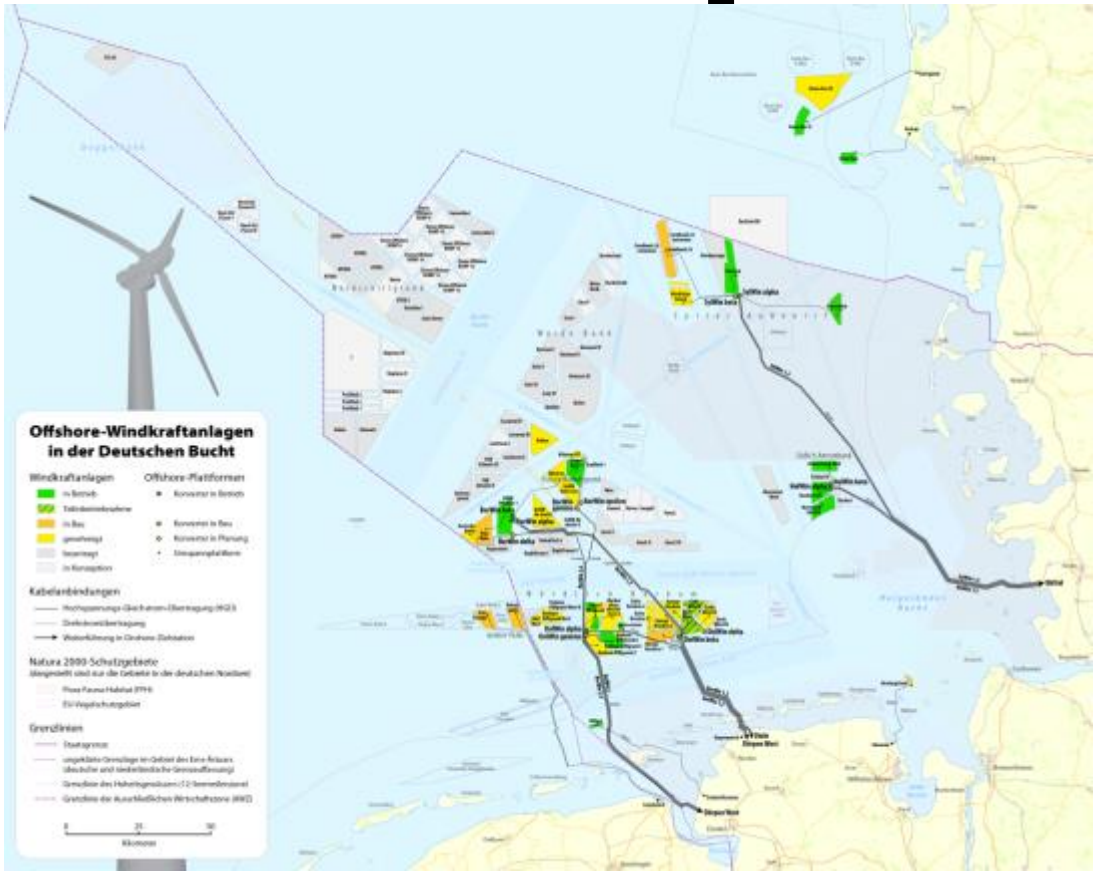
Hydrogen Pipelines (~2035)

Hydrogen Shipping (~2025)

Hydrogen to Ammonia for transport



Offshore Wind Development Germany



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

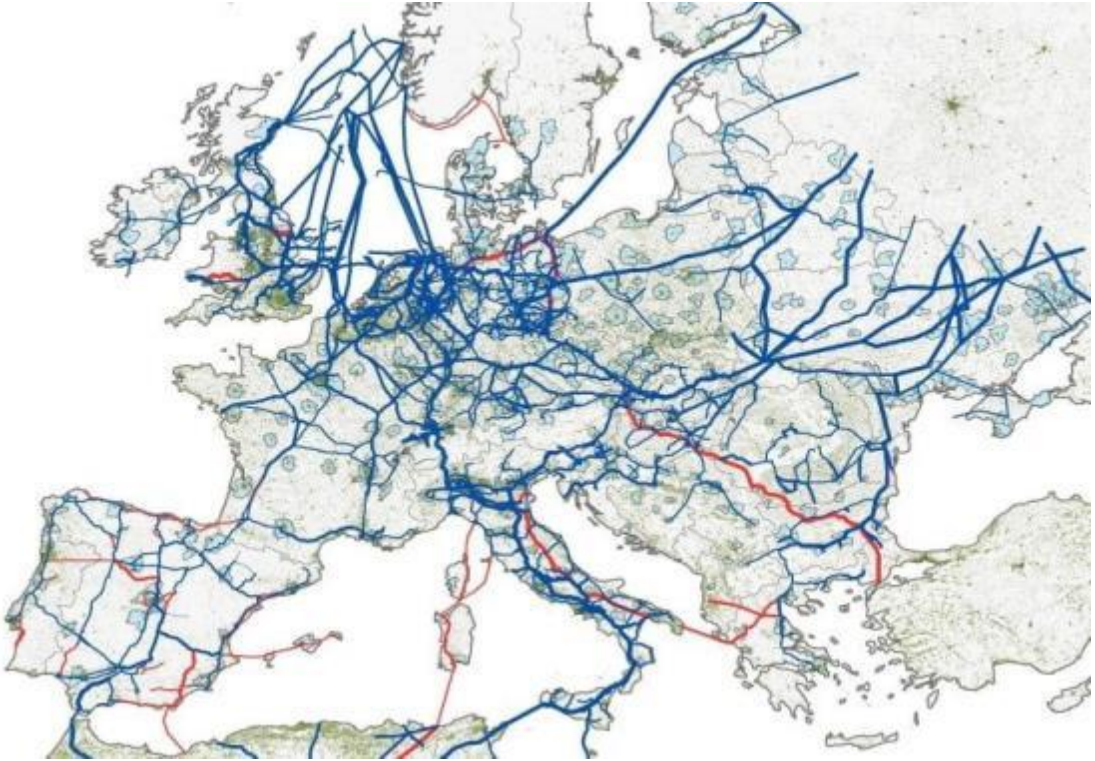
Expansion to 5,610 MW

Electricity and Gas Transport Grid

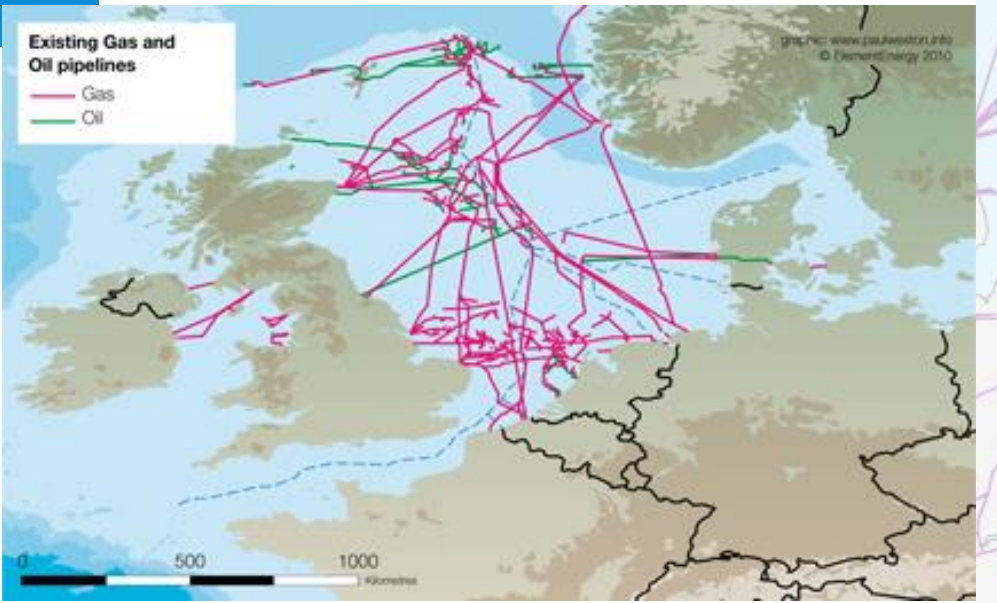
Cable versus pipeline cost

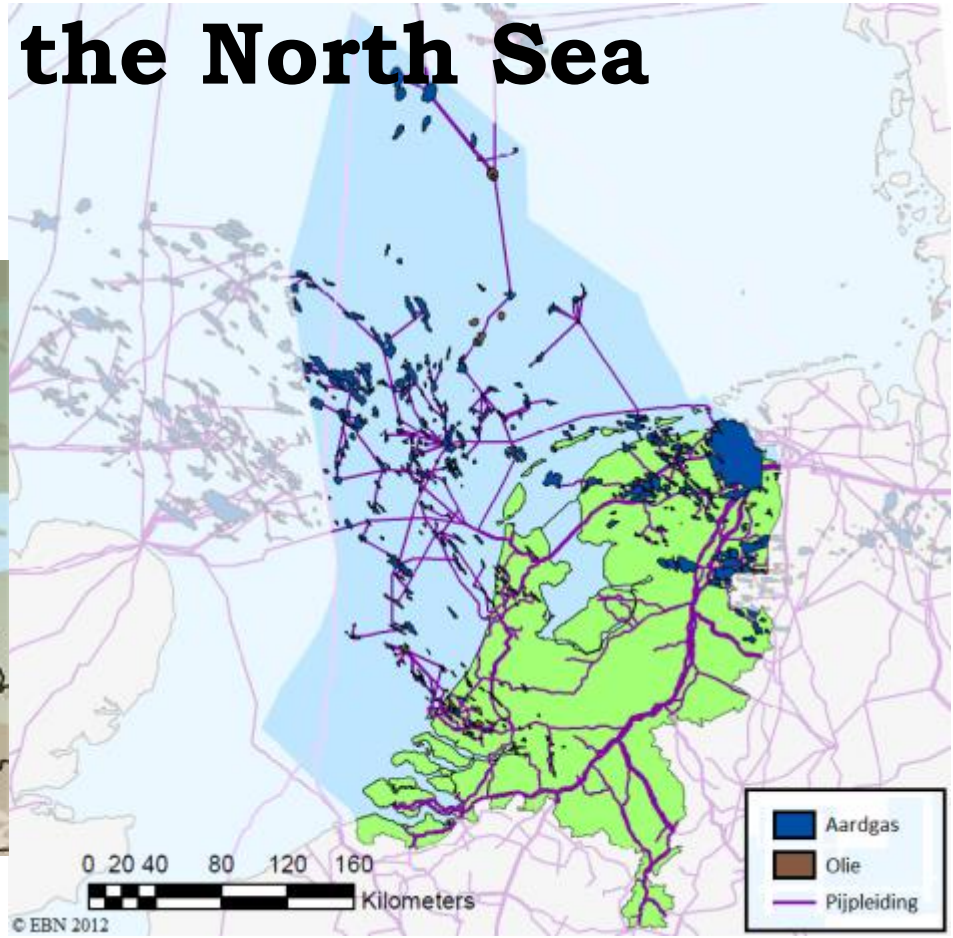
	Cable (BritNed)	Pipeline (BBL)
Capacity	1 GW	15 GW
Construction Cost	€ 500 mln	€ 500 mln
Volume (year)	8 TWh	120 TWh

European Gas Infrastructure



Gas Pipelines at the North Sea





5 GW Mohammed Bin Rashid Al Maktoum Solar Park in Dubai

Largest CSP project in the world

- 700MW CSP, 15 hours storage
- $3.9 billion investment
- Central Tower 100 MW
- Parabolic Troughs 3x200 MW
- Auxiliary solar PV 4x33 MW
- Tariff 7.3 ct/kWh
- PPA 35 years
- Dispatch: between 4pm and 10am

Gas Pipelines

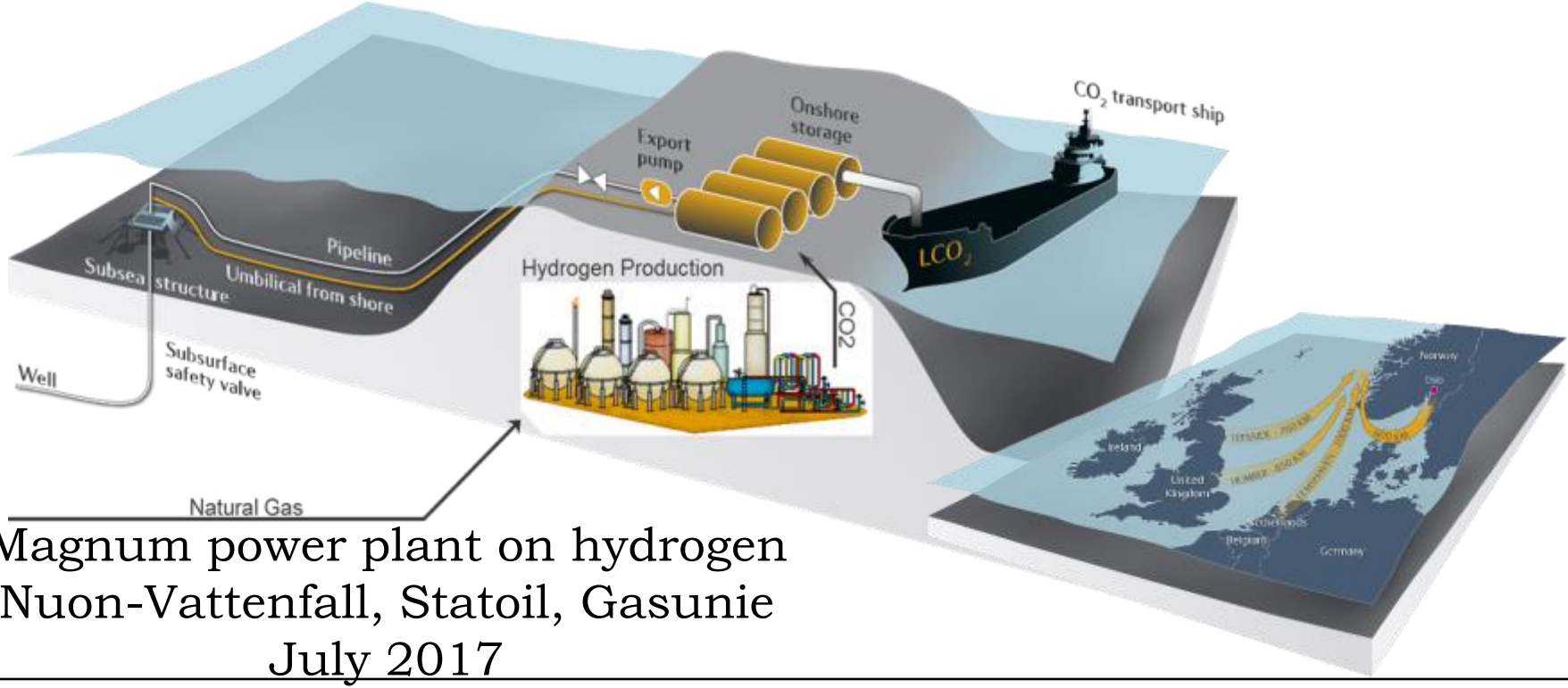
North Africa – South Europe

Solar Electricity-Hydrogen production in Morocco, Algeria, Spain and Italy can be transported throughout Europe via existing gas pipelines converted to hydrogen pipelines

Hydrogen production

Source	Process	Efficiency Today
Natural gas **Bio Gas**	Steam reforming Solid Oxide Fuel Cell	72% 80% (40%-40%)
Coal/Oil	Gasification	56%+ (=syngas)
Biomass	Gasification	44%+ (=syngas)
Electricity + Water	Electrolysis Alkaline and PEM	75-80% (90% exp.)
Sunlight + Water	Photoelectrochemical	14% (lab)

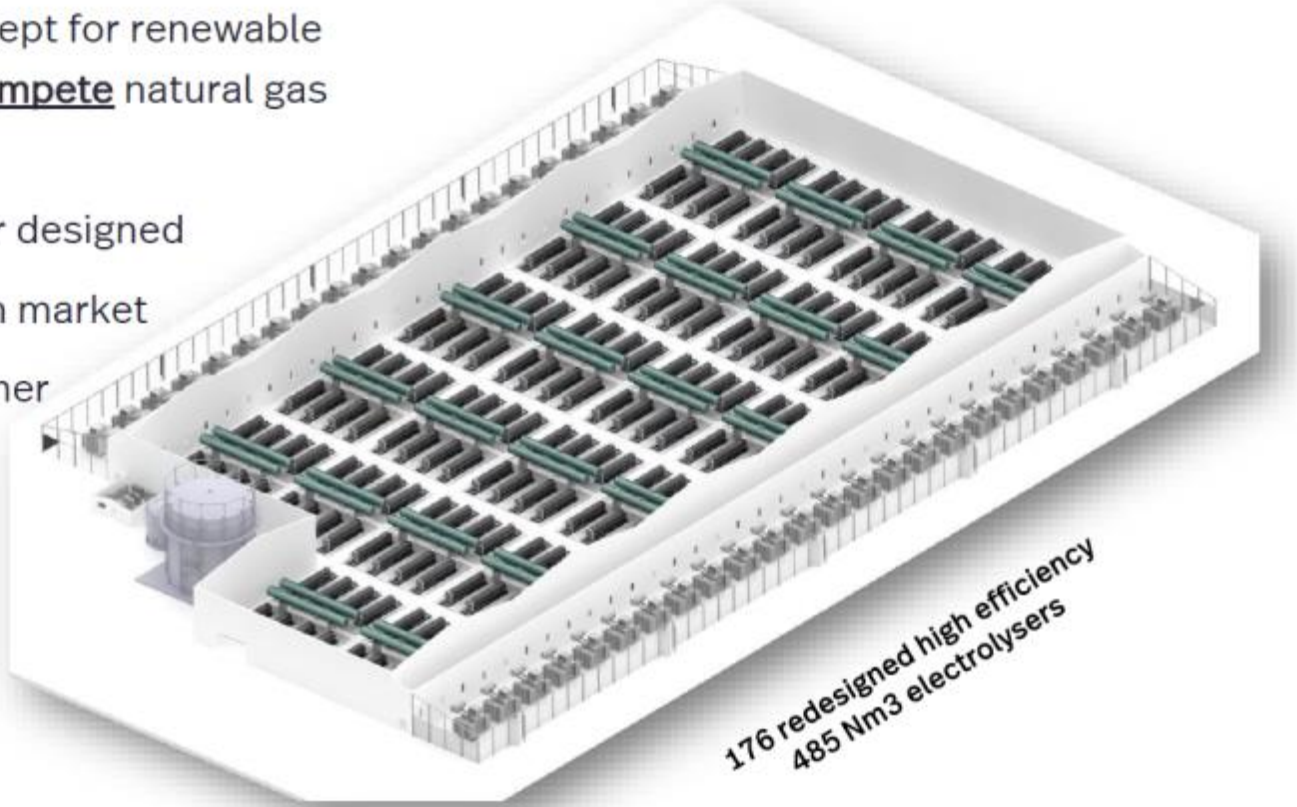
Gas-Hydrogen production with CO_2 storage in Smeaheia field



Magnum power plant on hydrogen
Nuon-Vattenfall, Statoil, Gasunie
July 2017

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**



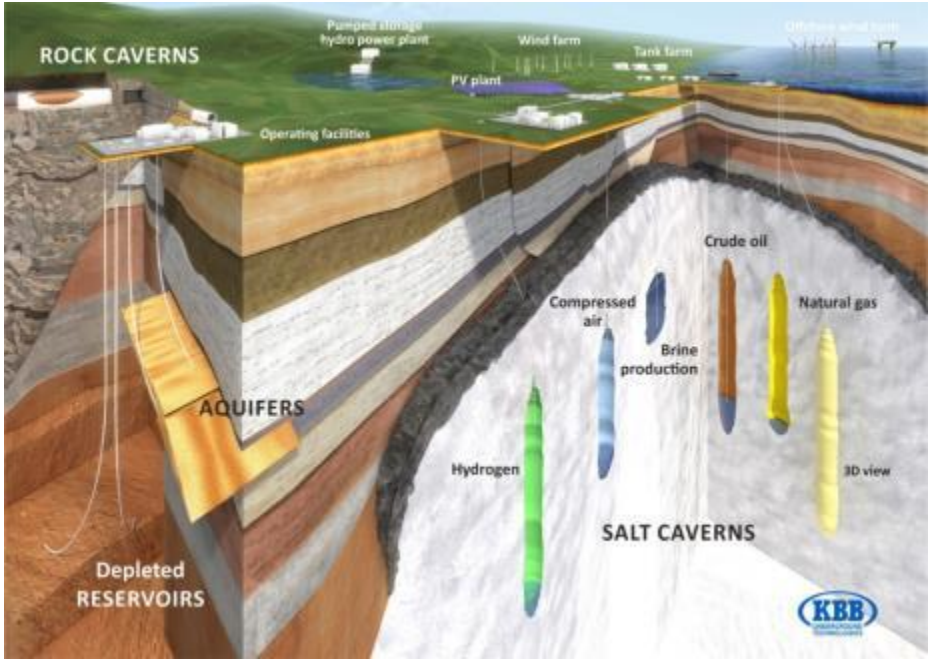
nel

July 2017

Green Hydrogen Cost development

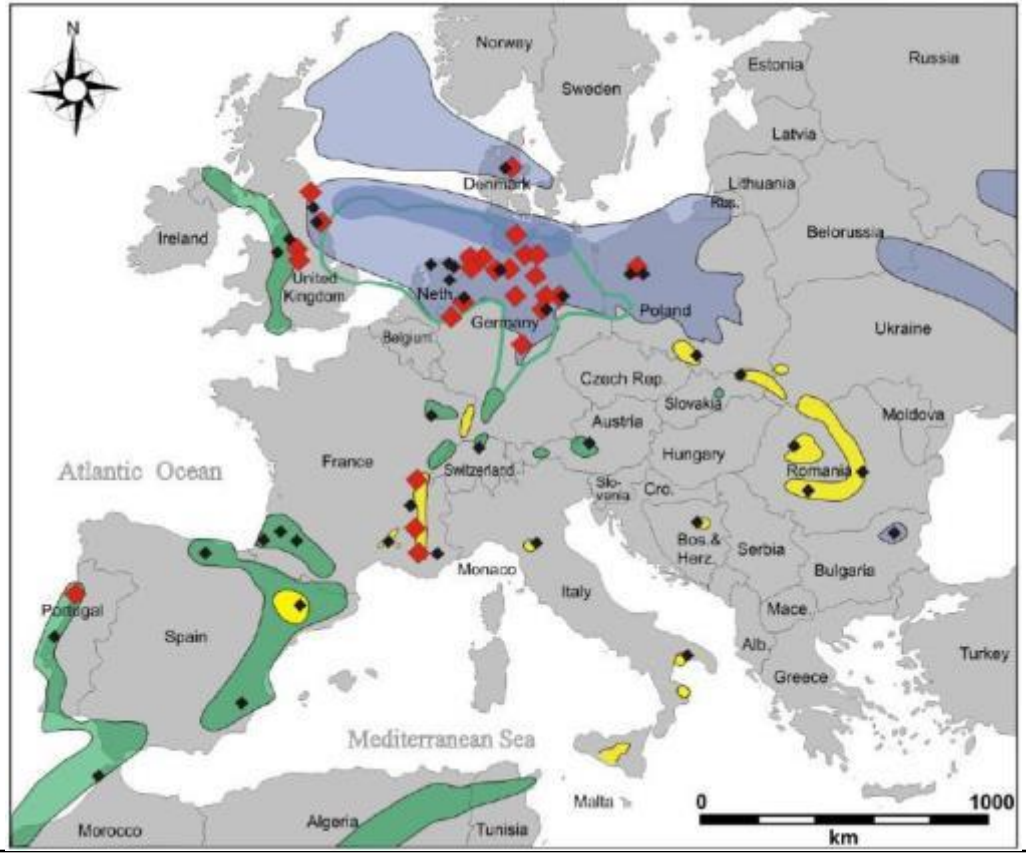
	Investment cost	Efficiency	Electricity Price Offshore Wind	Hydrogen Price
Till 2020	600-900 Euro/kW	72-75%	40-50 Euro/MWh	3-4 Euro/kg
2020-2025	300-600 Euro/kW	75-78%	30-40 Euro/MWh	2-3 Euro/kg
2025-2030	250-400 Euro/kW	78-80%	25-35 Euro/MWh	1.5-2.5 Euro/kg
After 2030	<250 Euro/kW	>80%	20-30 Euro/MWh	1-1.5 Euro/kg

Hydrogen storage in Salt Caverns

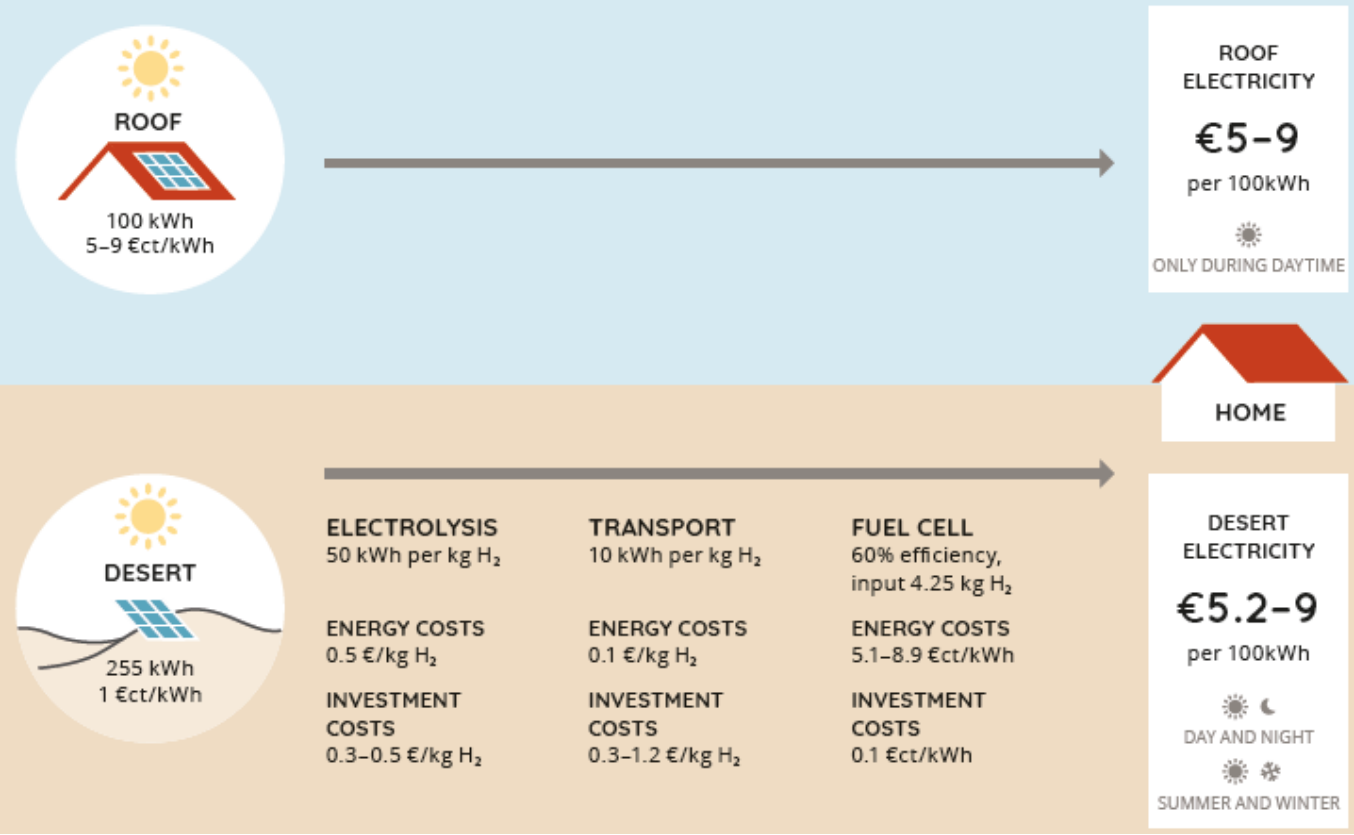


1 salt cavern can contain 6,000 ton hydrogen
Equivalent of 17 million Tesla Power walls

Salt formations and caverns in Europa



Roof versus Desert Solar



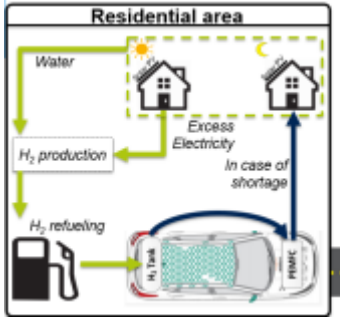
In a renewable energy system it is all about cost and not energy-efficiency

- Comparison of production, transport or storage cost is important, but in the end the total cost from energy production, transport, storage, distribution and use has to be compared between different energy chains.
- In a renewable energy system and in comparing renewable energy chains, the energy-efficiency is no longer important because the renewable energy resources are vast, there is enough space for renewable energy production and there are no emissions anymore in the system. **It is all about cost!**

Green Hydrogen Markets

Chemical Feedstock

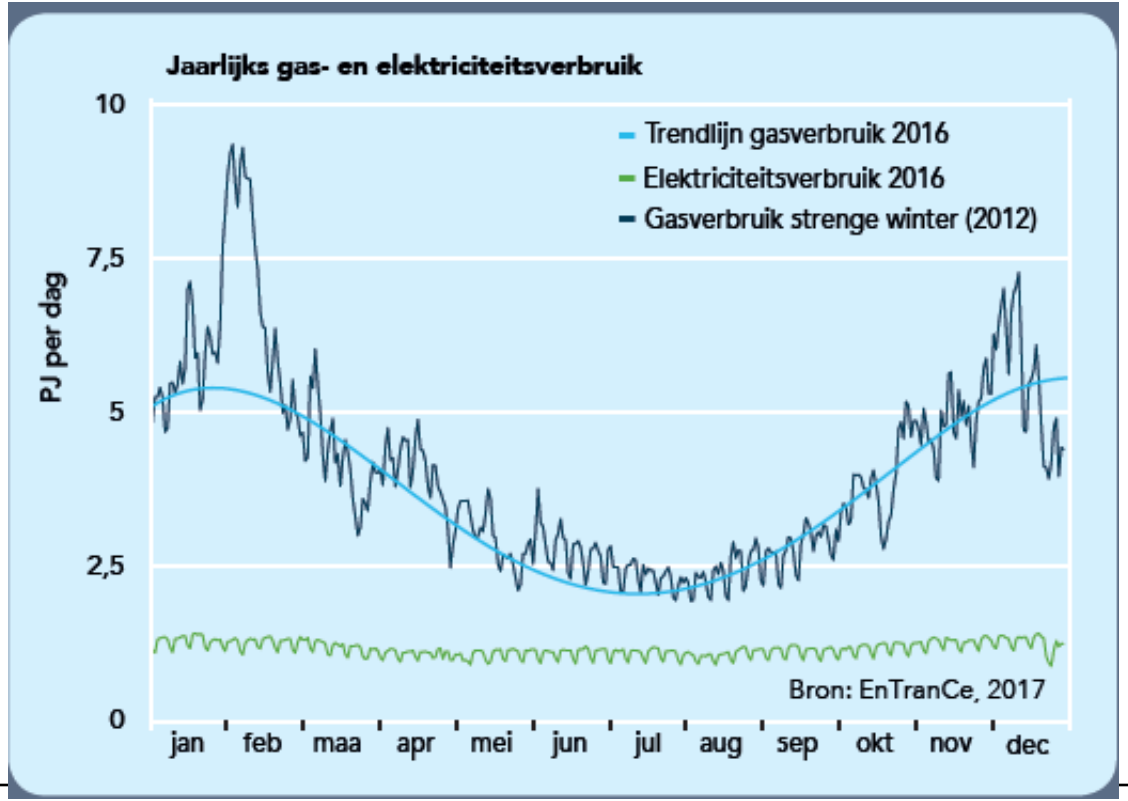
Electricity Balancing



Transport

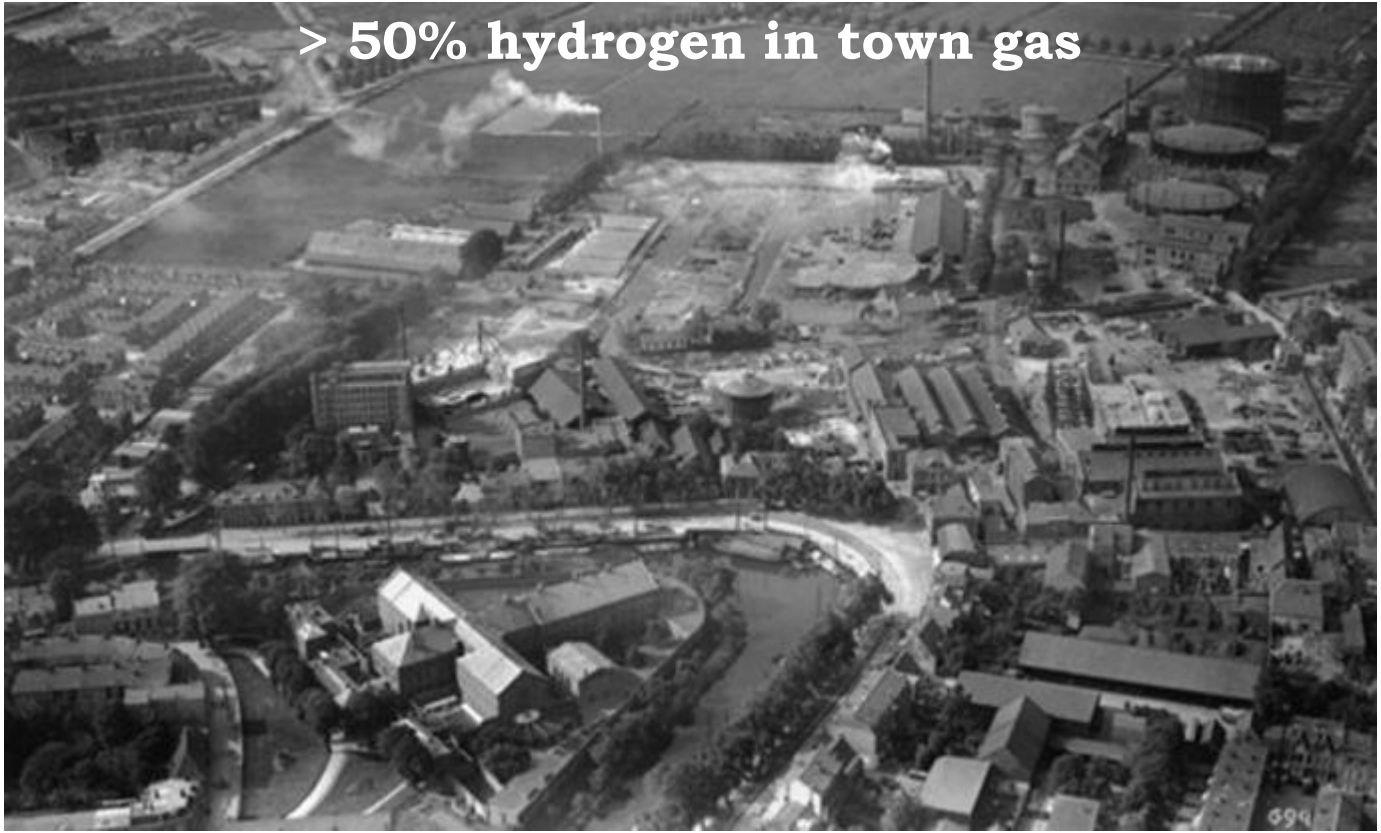
Heating

Gas and Electricity consumption the Netherlands

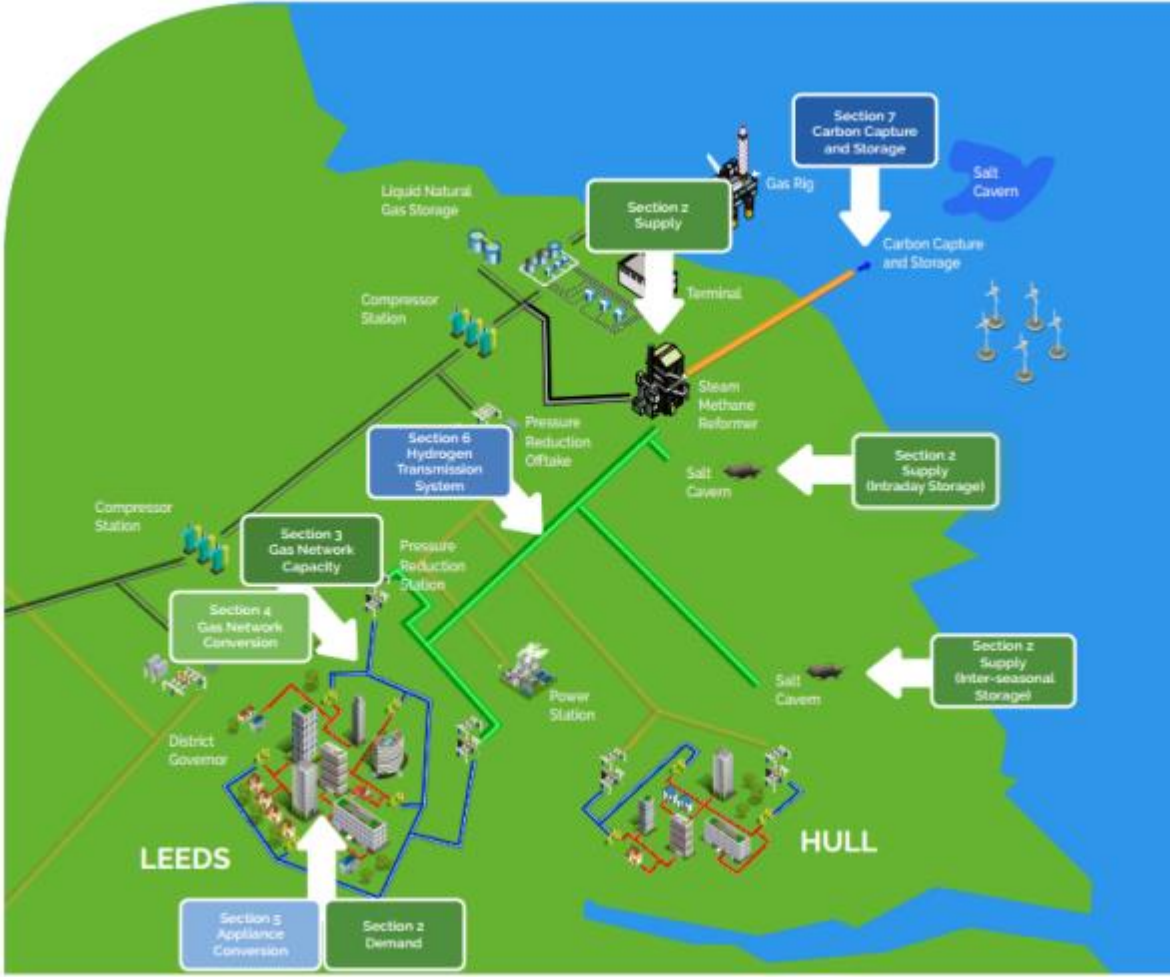


Large seasonal difference in gas consumption due to heating demand. Therefore a huge need for seasonal storage.

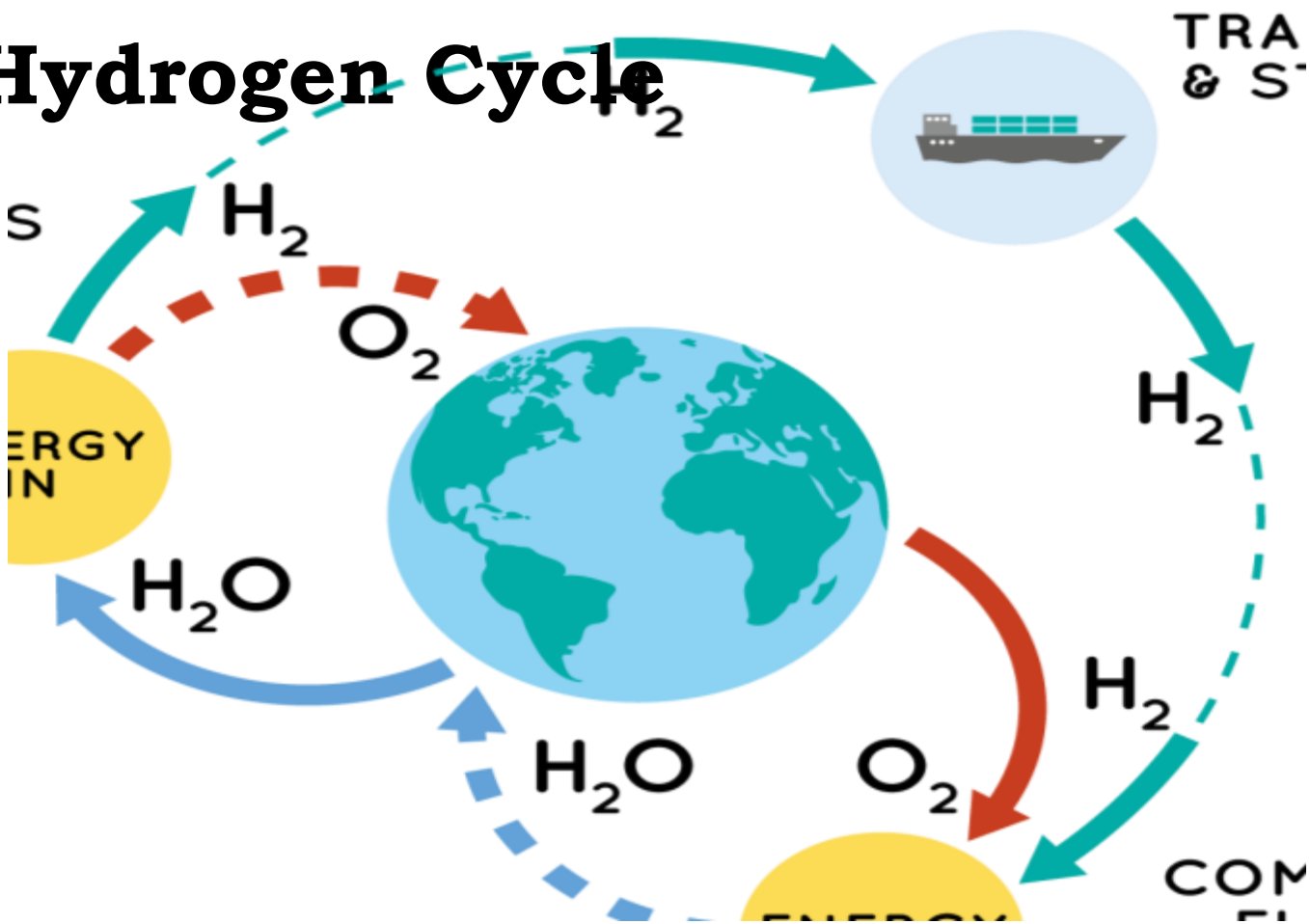
Town Gas production Utrecht 1862-1959



Leeds City Gate Project



The Hydrogen Cycle



Defying Death Valley