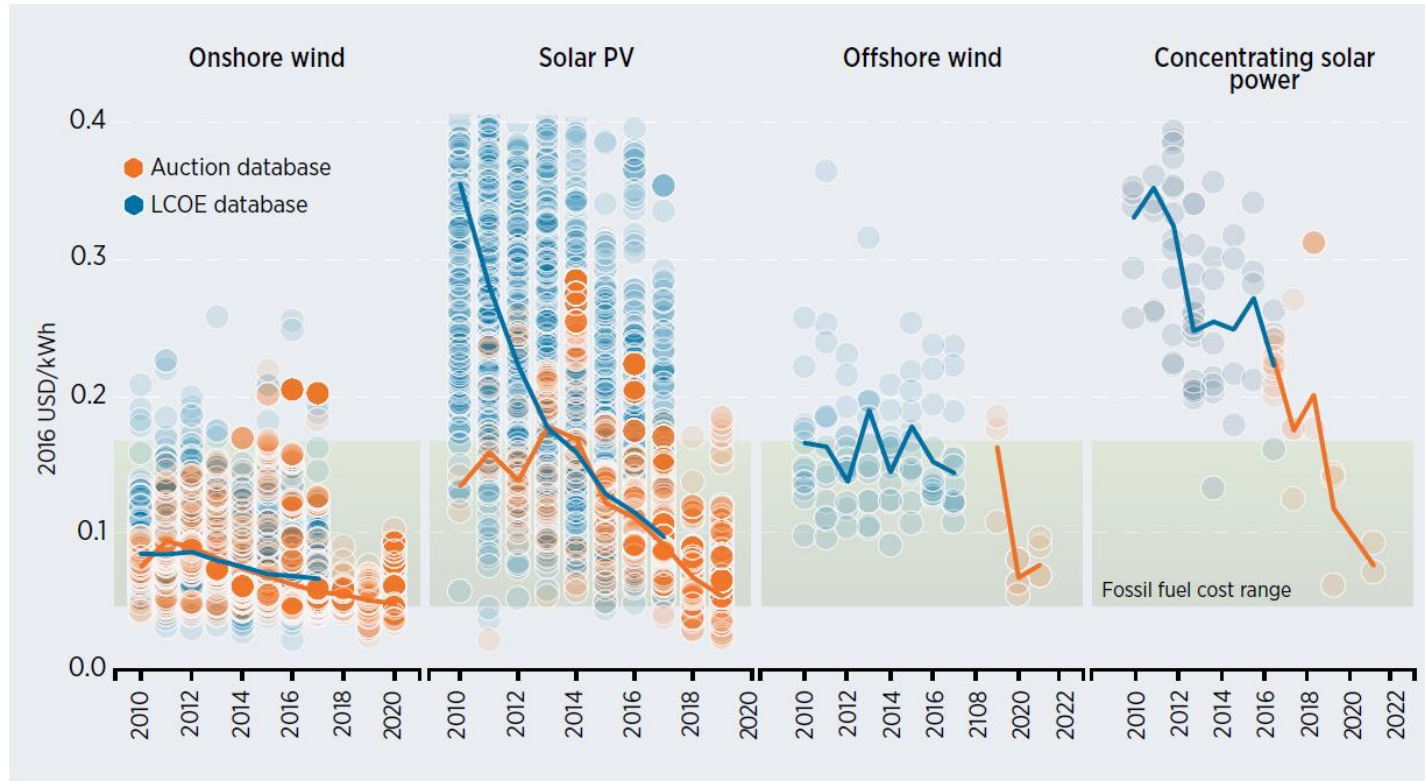
The background image shows a large, modern amphitheater with wide, light-colored concrete steps. Many people are sitting on the steps, some in groups, some alone. In the background, a large, cylindrical concrete structure with a tall, thin metal lattice tower on top is visible against a clear blue sky. To the right, there is a green lawn and a modern building with a glass facade. The overall scene is bright and sunny, suggesting a pleasant day at a university event.

Hydrogen; the key to a sustainable energy system

23-10-2019

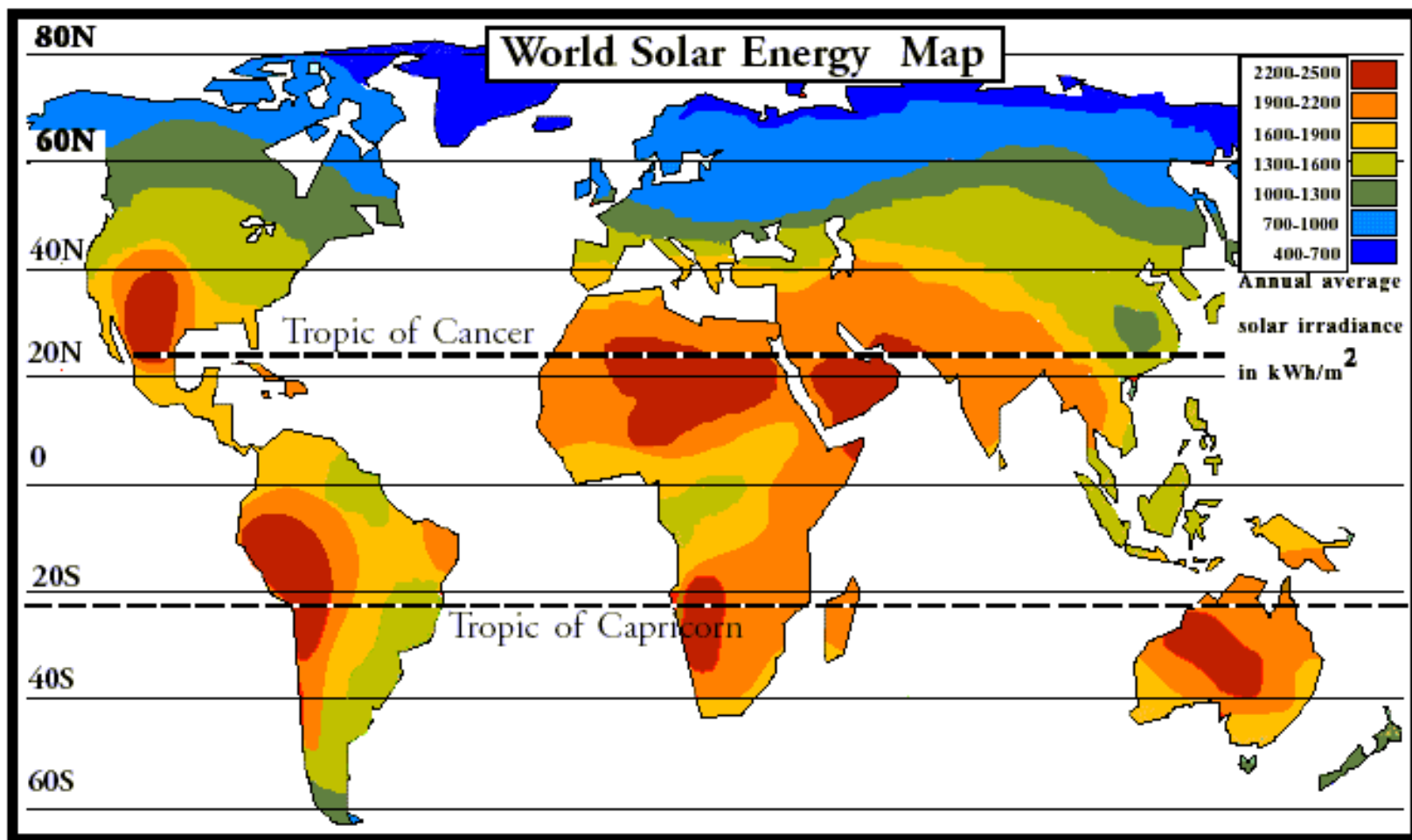
Prof. Dr. Ad van Wijk

Levelized Cost of Electricity



Source: IRENA Renewable Cost Database and Auctions Database.

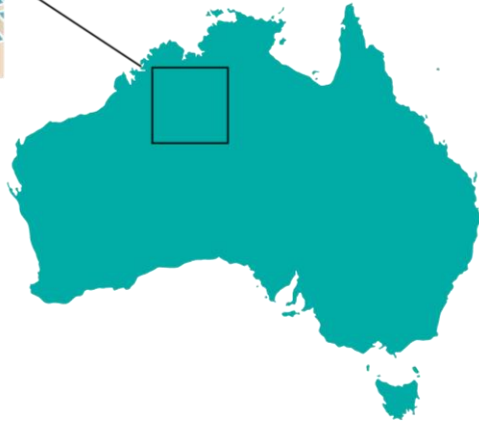
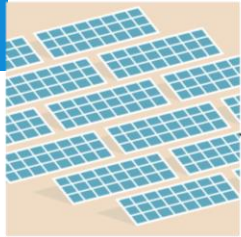
IRENA, January 2018, Renewable Power Generation Costs 2017



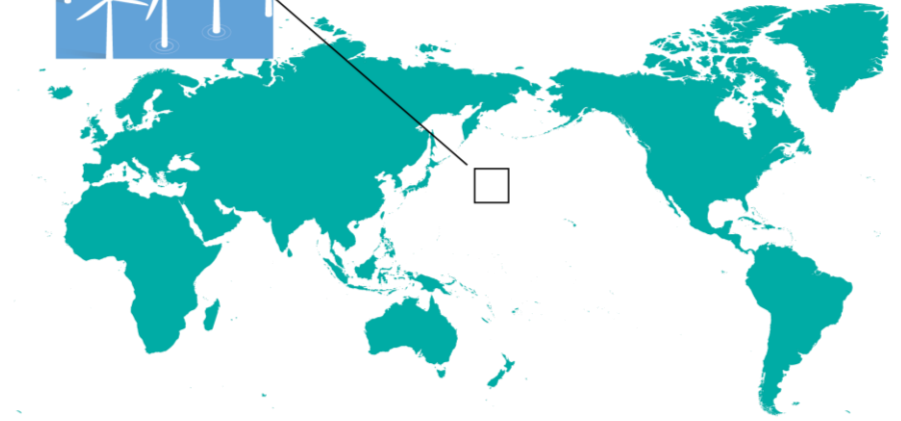
5 GW Mohammed Bin Rashid Al Maktoum Solar Park in Dubai



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



10% SOLAR AUSTRALIA

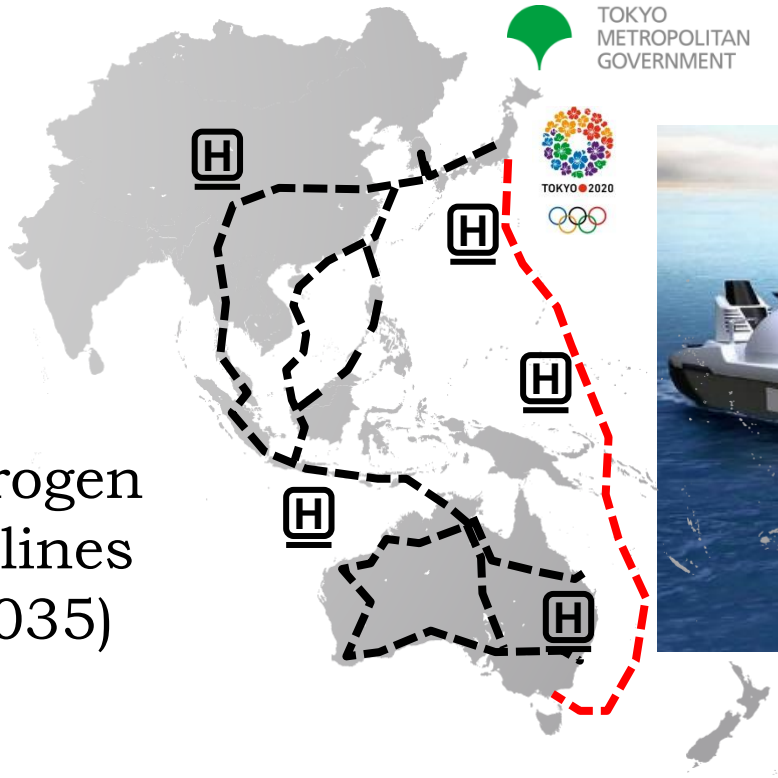


1.5% WIND PACIFIC OCEAN

Tokyo Olympic Games 2020



Hydrogen Pipelines (~2035)

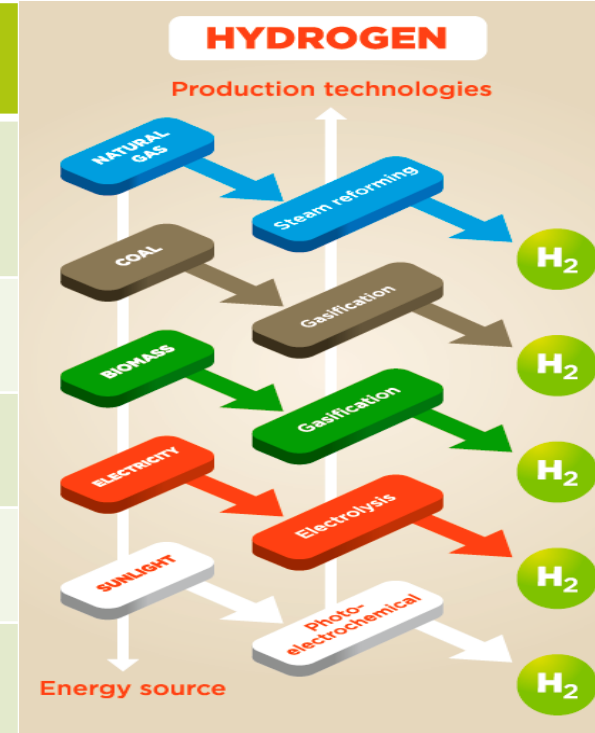


Hydrogen Shipping (~2025)

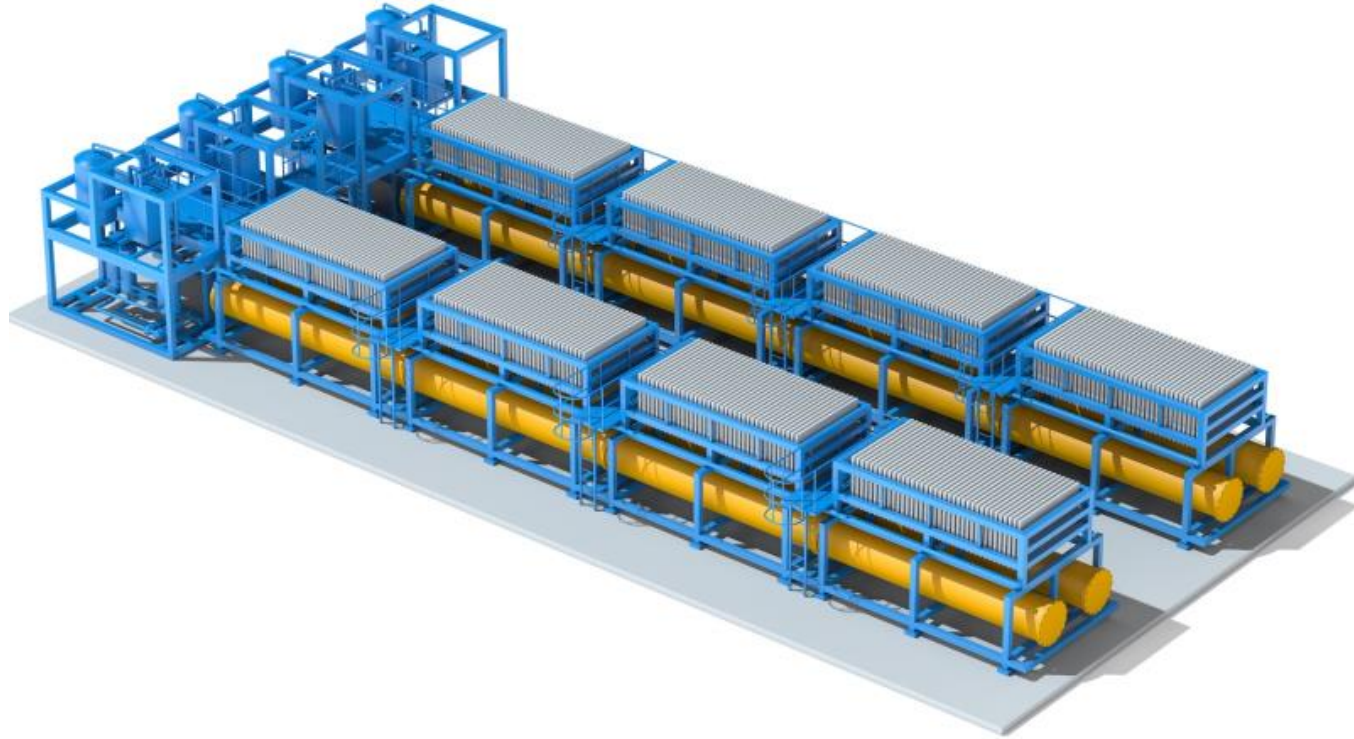


Hydrogen is an energy carrier

Source	Process	Efficiency Today
Natural gas Bio Gas	Steam reforming Auto-thermal reforming Solid Oxide Fuel Cell	70-75% >75% 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)



20 MW Alkaline Electrolyser; ThyssenKrupp

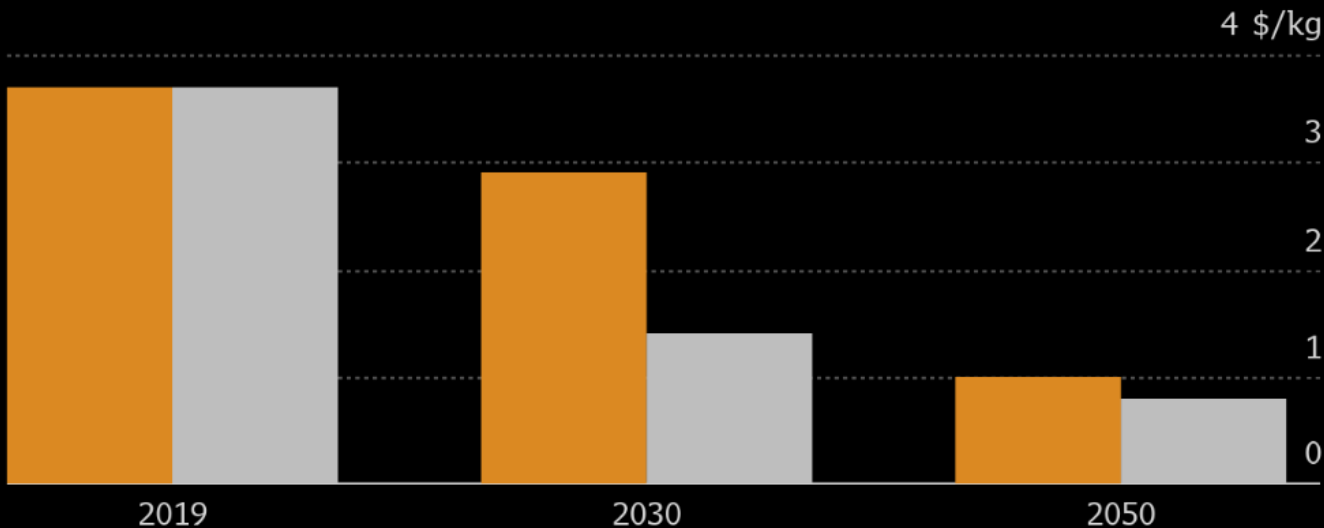


Bloomberg NEF, August 2019

Cost of Hydrogen

Hydrogen is set to decrease in price powered by green electricity

■ Conservative estimate ■ Optimistic



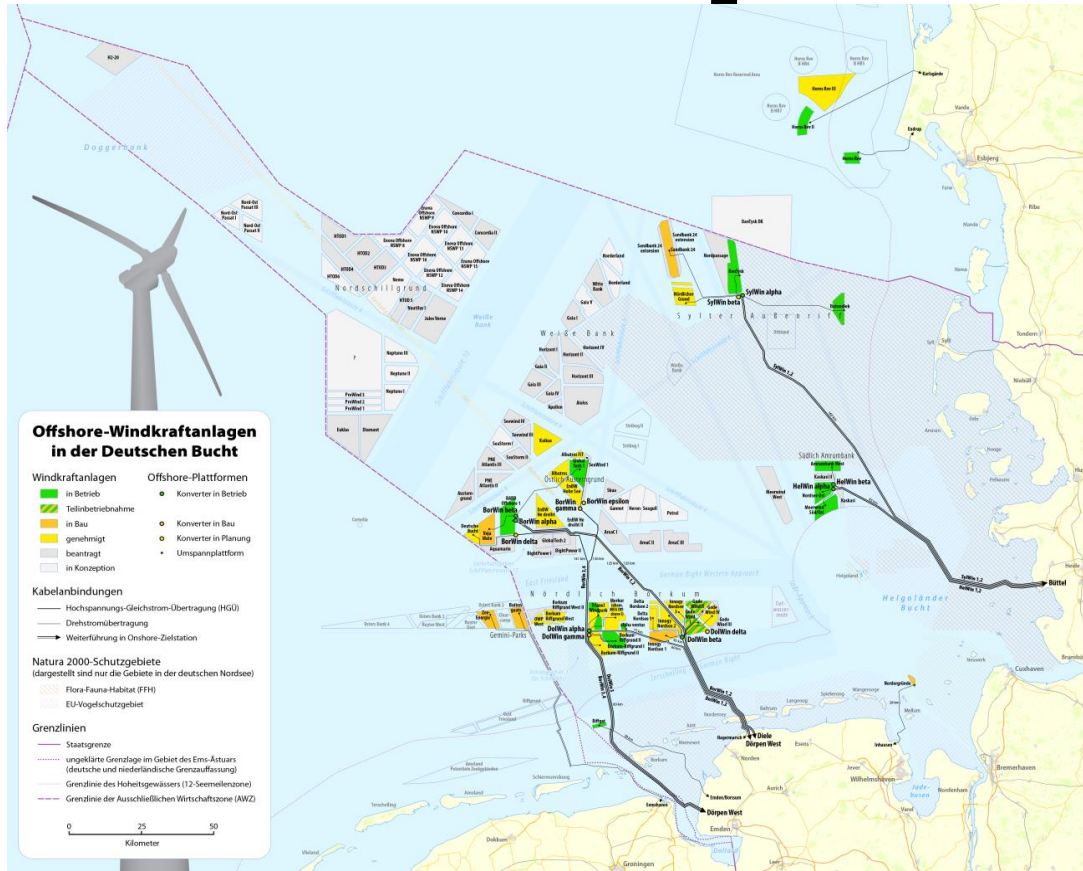
Source: BNEF

Refers to hydrogen produced from alkaline electrolysis

Bloomberg

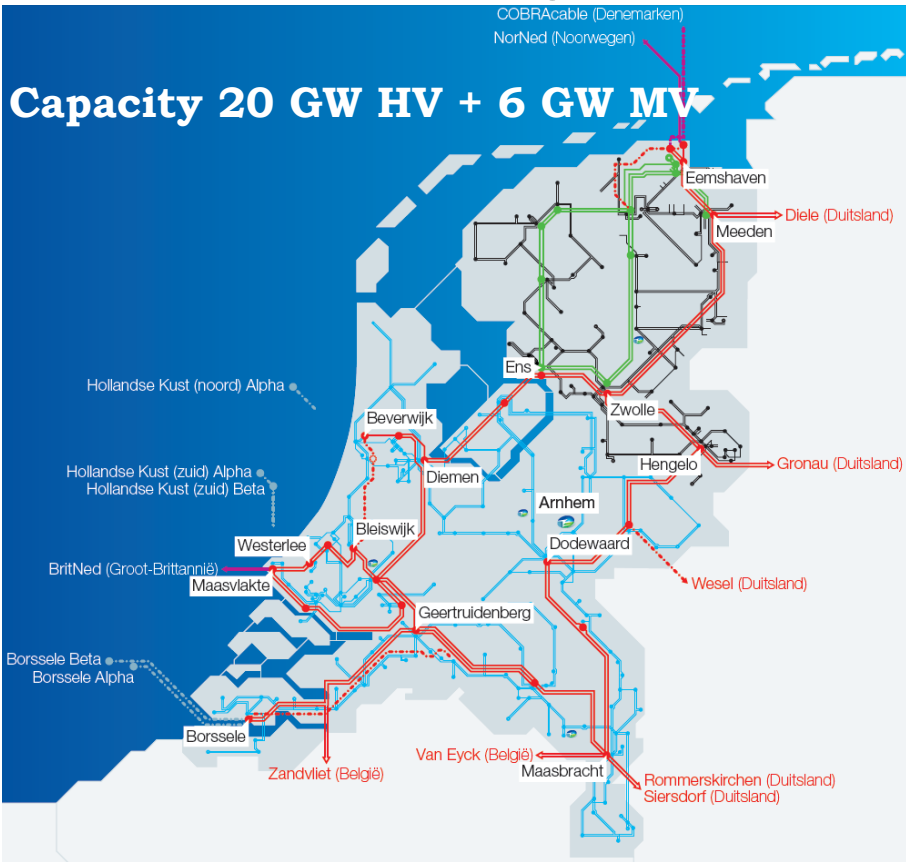
1 \$/kg = 0,025 \$/kWh

Offshore Wind Development Germany

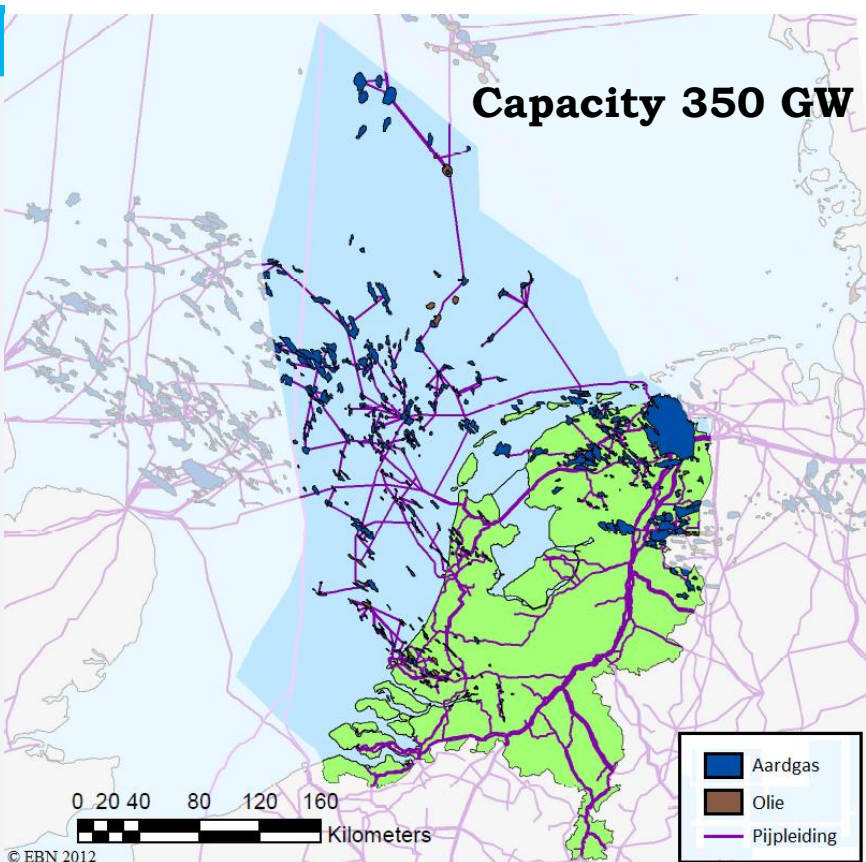


Electricity and Gas Transport Grid

Capacity 20 GW HV + 6 GW MV



Capacity 350 GW



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

Hydrogen backbone the Netherlands 2030



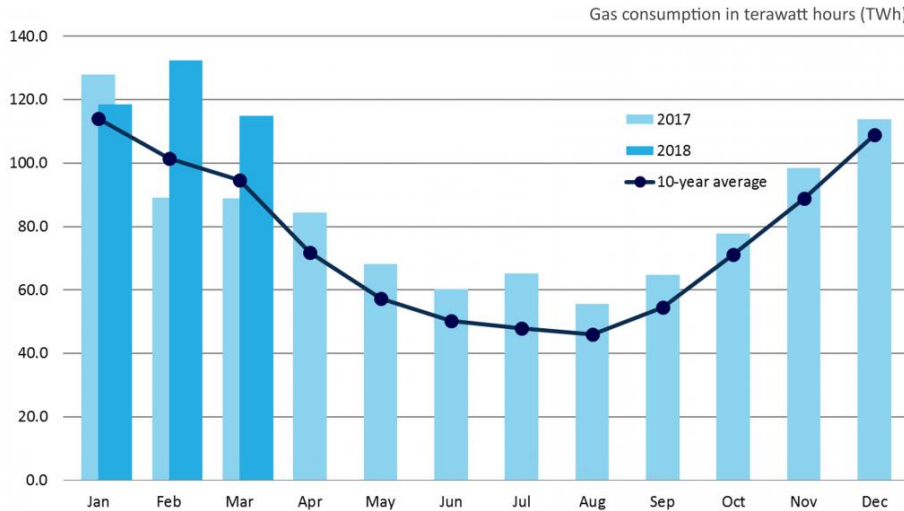
- Low caloric gas pipelines will become available, because the Groningen gas field has to reduce production to 0 in 2022
- 1 Transport pipeline capacity for hydrogen about 12 GW
- Conversion cost to hydrogen about 1.5 billion Euro
- Connections to Germany (Ruhr-area, Bremen-Hamburg and Belgium (Antwerp, Zeebrugge)
- European connections to France, Austria, Italy, etc.

- Existing gas pipeline
- ⊕ Retrofitted compressors
- New hydrogen pipeline
- ⚙ Industrial cluster
- ⊕ Hydrogen storage in salt cavern

Monthly Gas consumption and Solar power generation in Germany

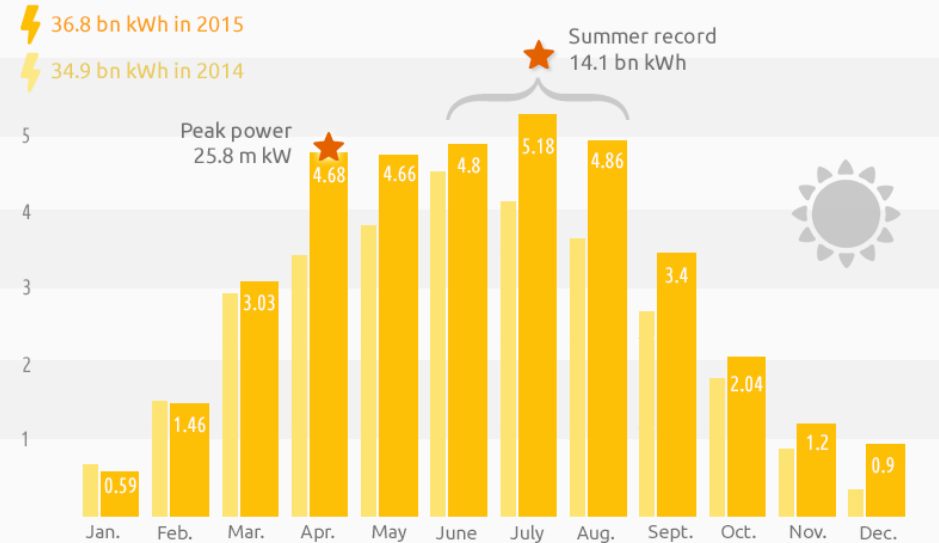
Monthly natural gas consumption in Germany.

Data: BDEW 2018.



SOLAR POWER GENERATION IN GERMANY 2015

Solar energy sets a new all-time summer record and beats peak power output

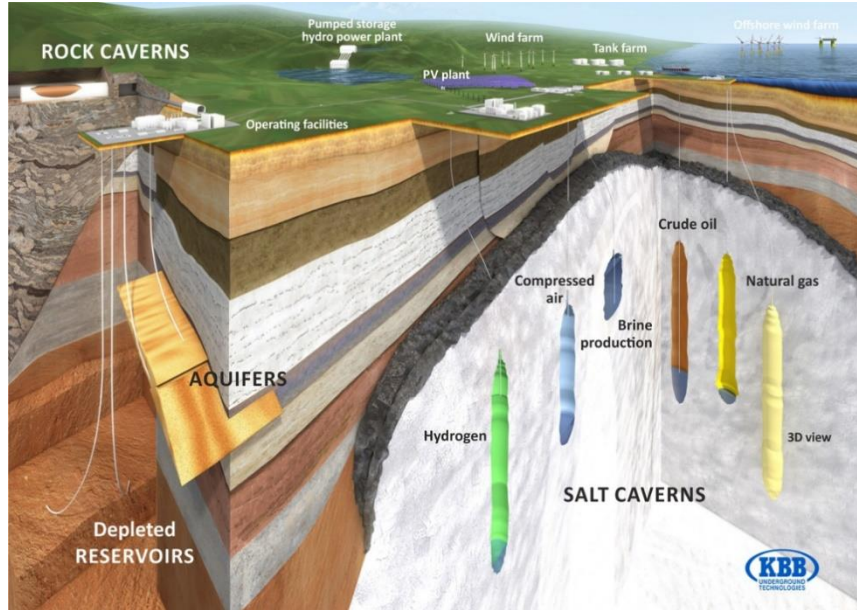


© BY SA

Source 2014, 2015: Fraunhofer ISE, EEX

CC BY SA STROM-REPORT.DE

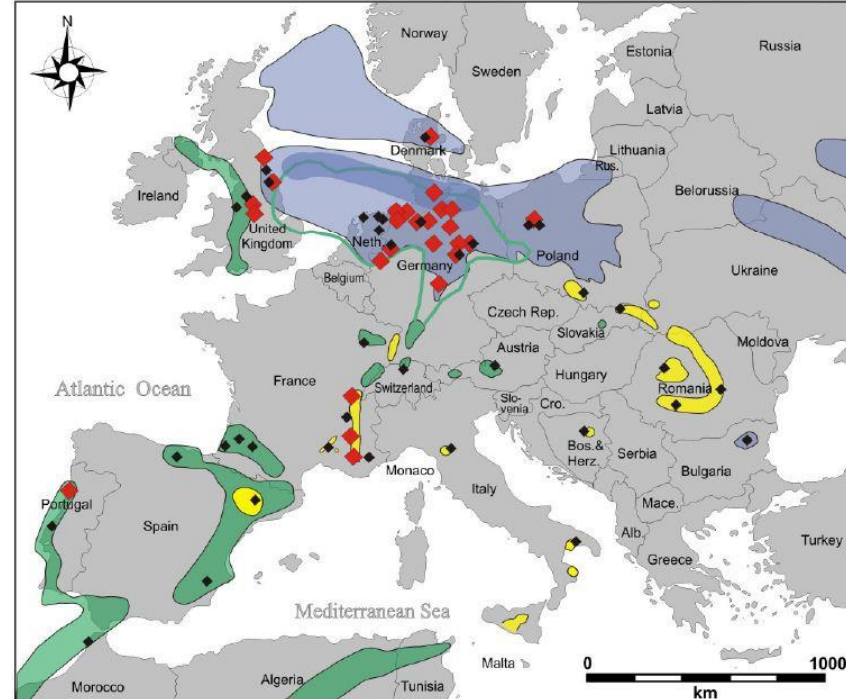
Hydrogen storage in Salt Caverns



1 salt cavern can contain 3,000-6,000 ton hydrogen
(100 million Euro)

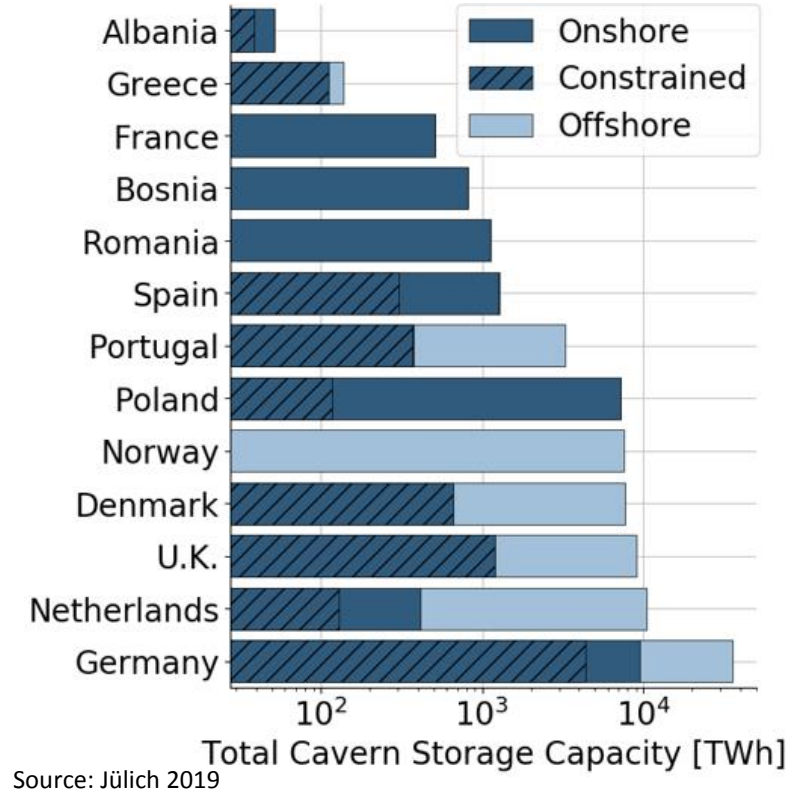
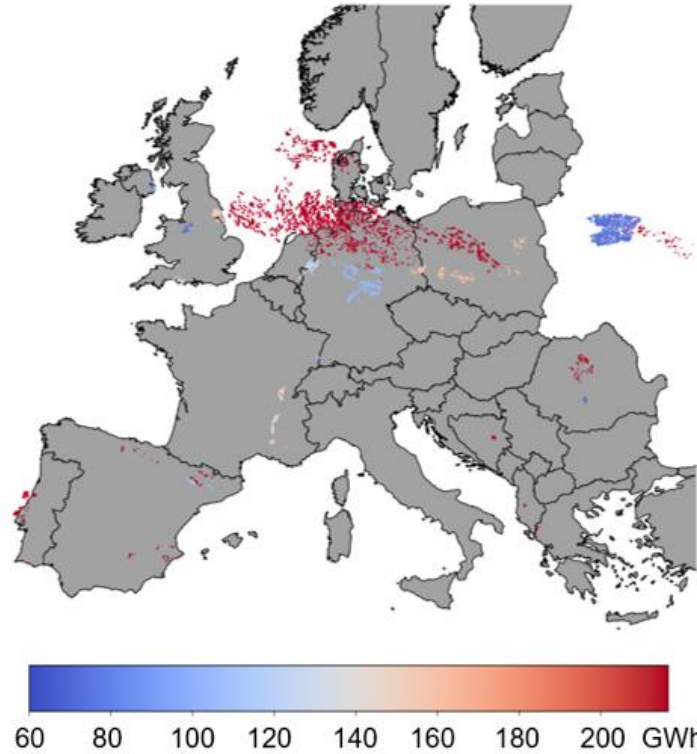
Equivalent of 120-240 GWh or 8,5-17 million home batteries (14 kWh)
(12-24 billion Euro)

Salt formations and caverns in Europa



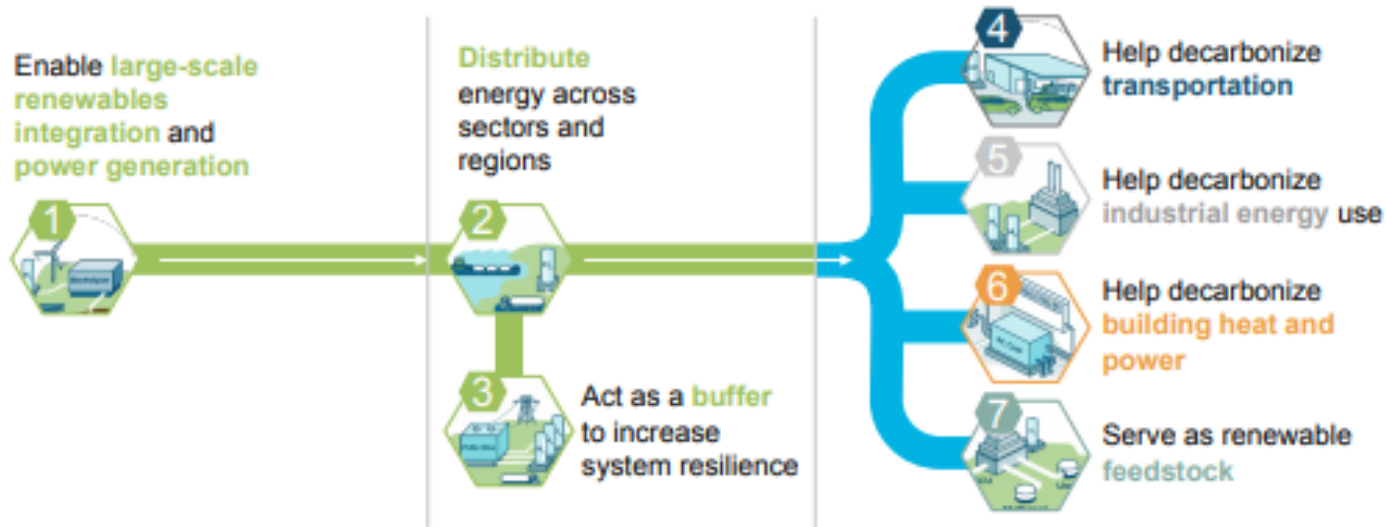
Red colored caverns in use for natural gas storage

Potential for Hydrogen Storage in Salt Caverns



Hydrogen is a carbon free energy carrier

Enable the renewable energy system → Decarbonize end uses



SOURCE: Hydrogen Council

Further reading about hydrogen

www.profadvanwijk.com

