

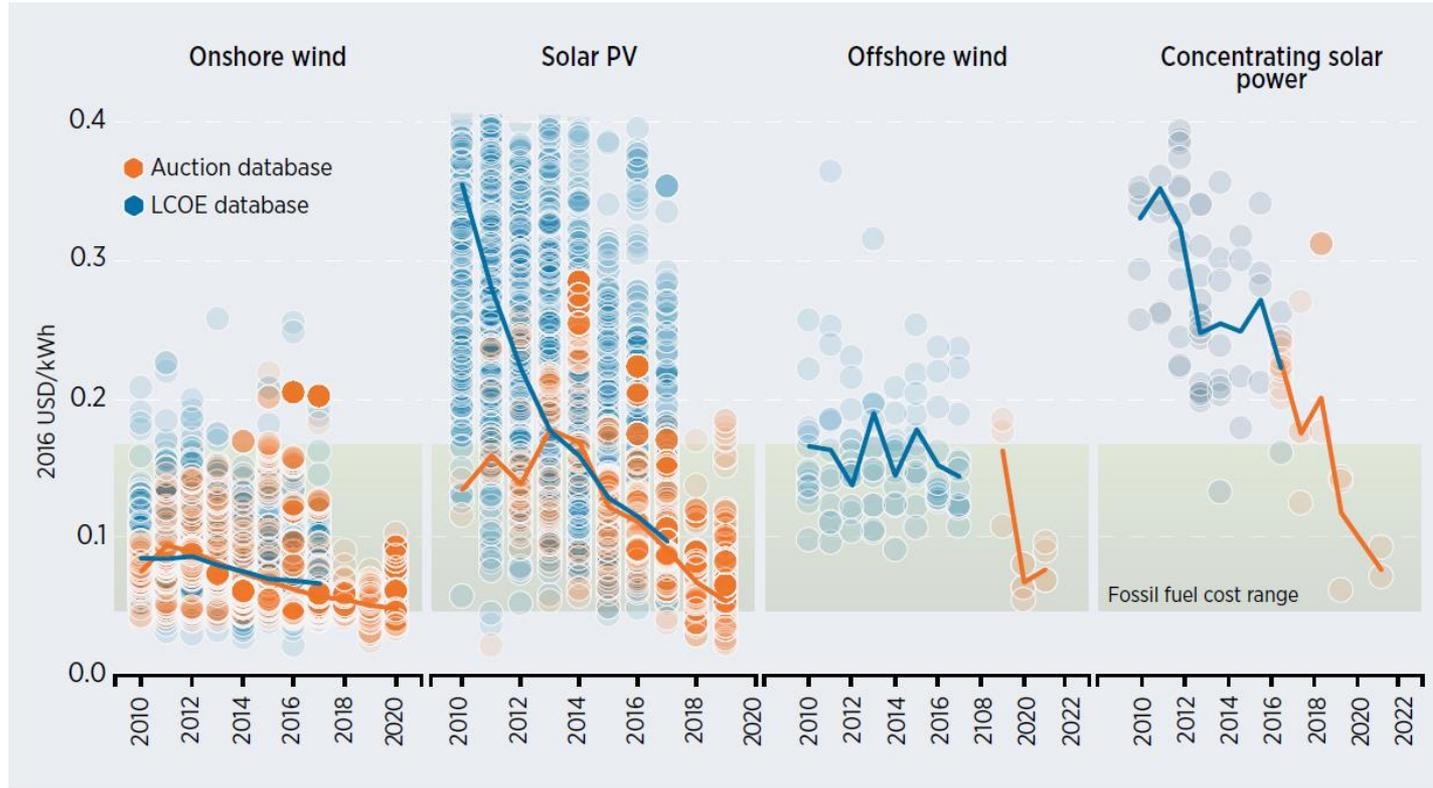
The background image shows a large, modern amphitheater with wide, light-colored concrete steps. Many people are sitting on the steps, some in groups, some alone. In the background, a large, cylindrical concrete tower with a metal lattice structure on top stands against a clear blue sky. To the right, 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.

Green Hydrogen Economy

Prof. Dr. Ad van Wijk

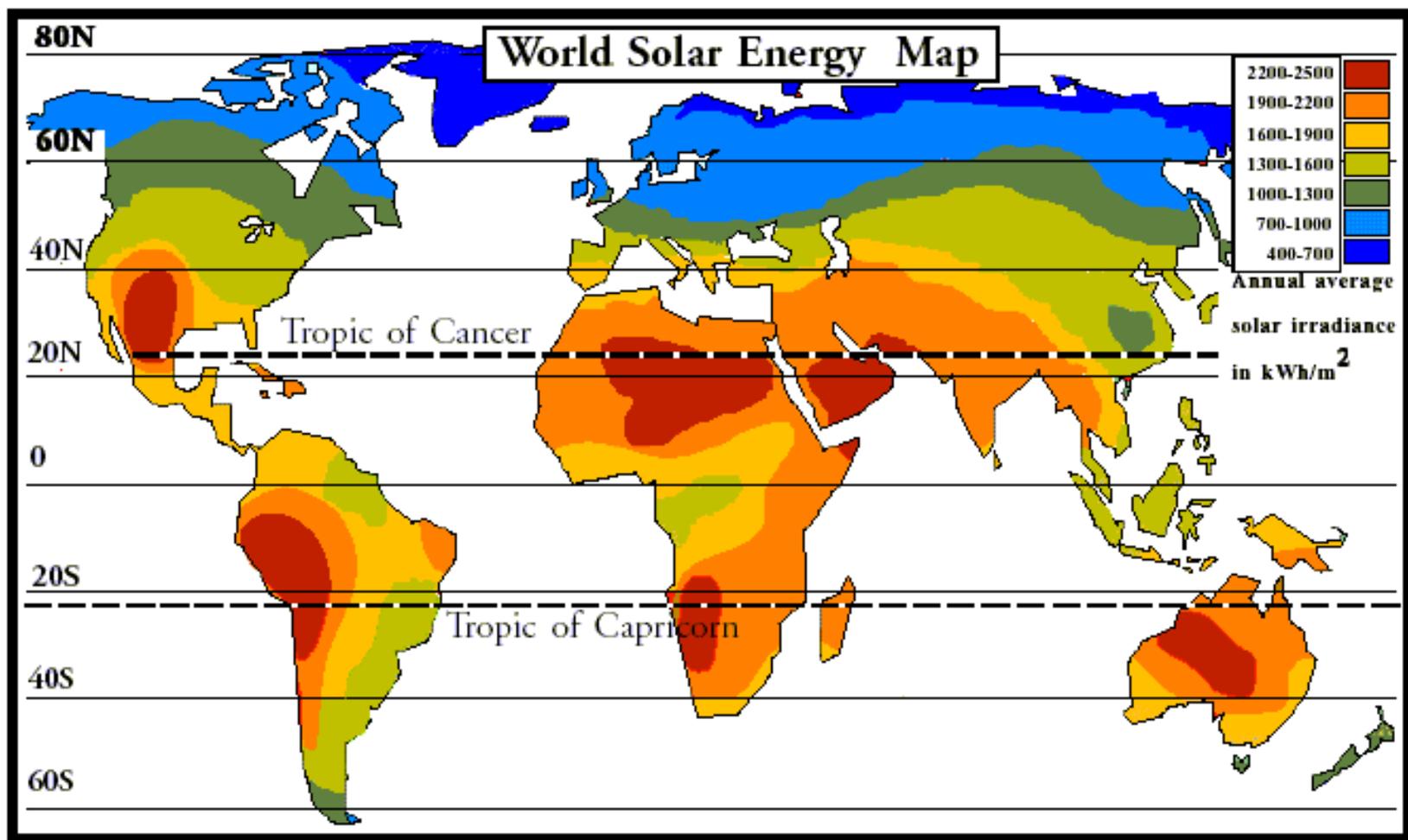
22-10-2018

Levelized Cost of Electricity

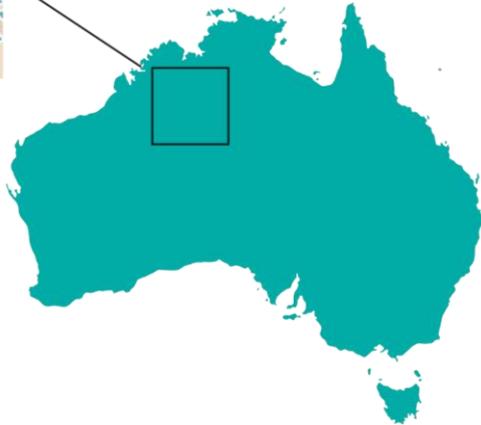
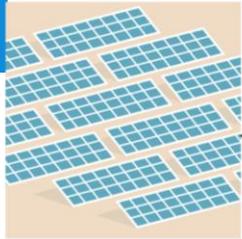


Source: IRENA Renewable Cost Database and Auctions Database.

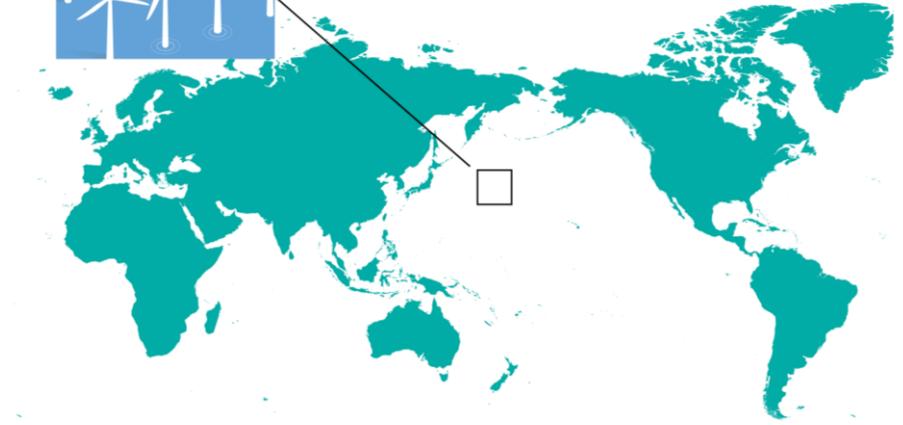
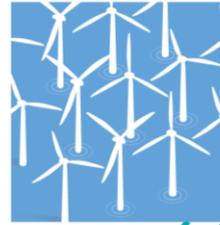
IRENA, January 2018, Renewable Power Generation Costs 2017



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



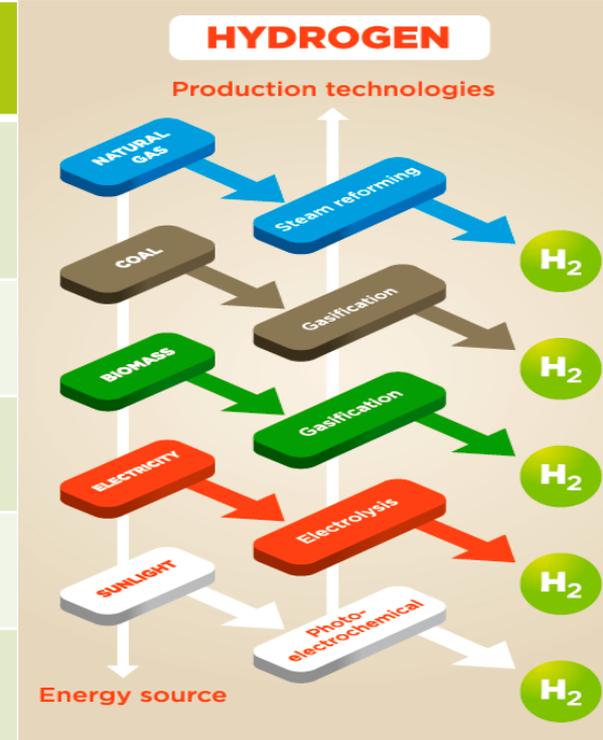
10% SOLAR AUSTRALIA



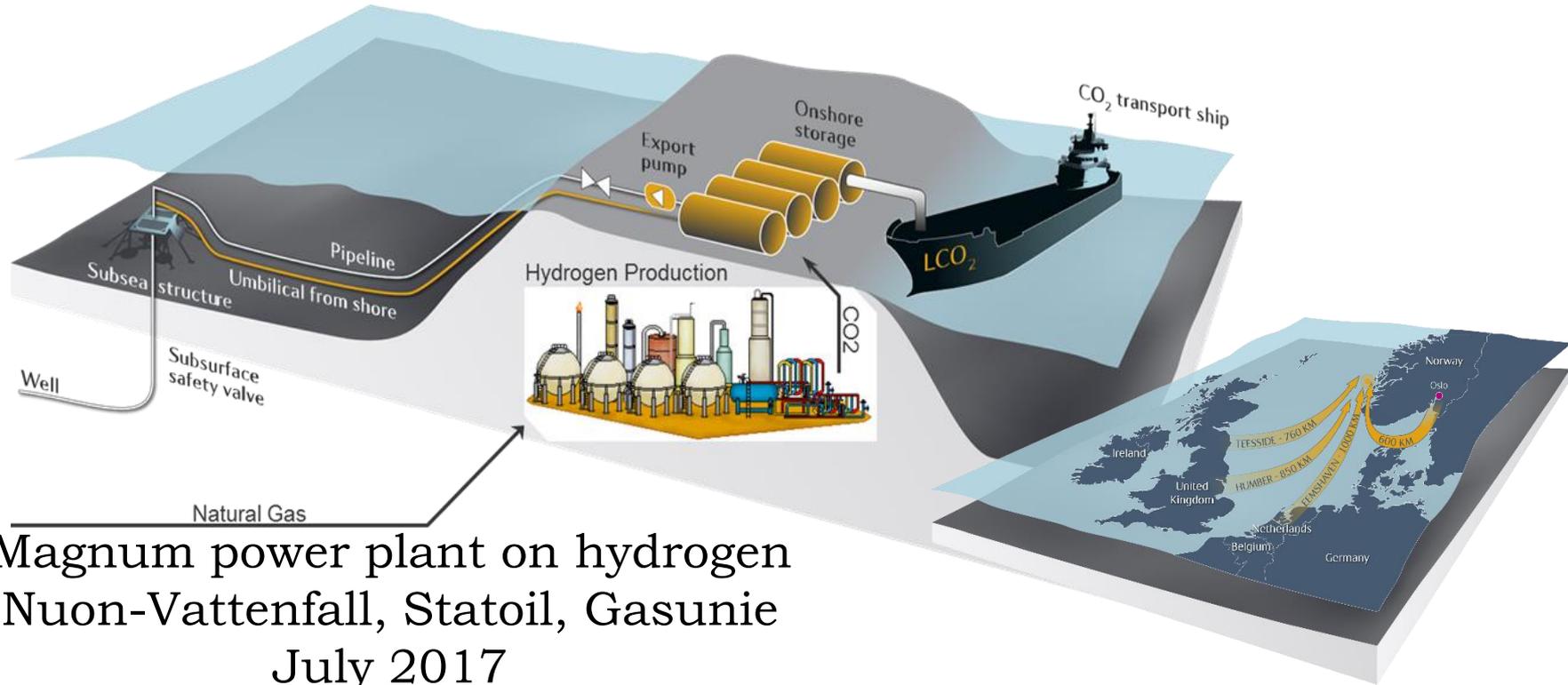
1.5% WIND PACIFIC OCEAN

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)

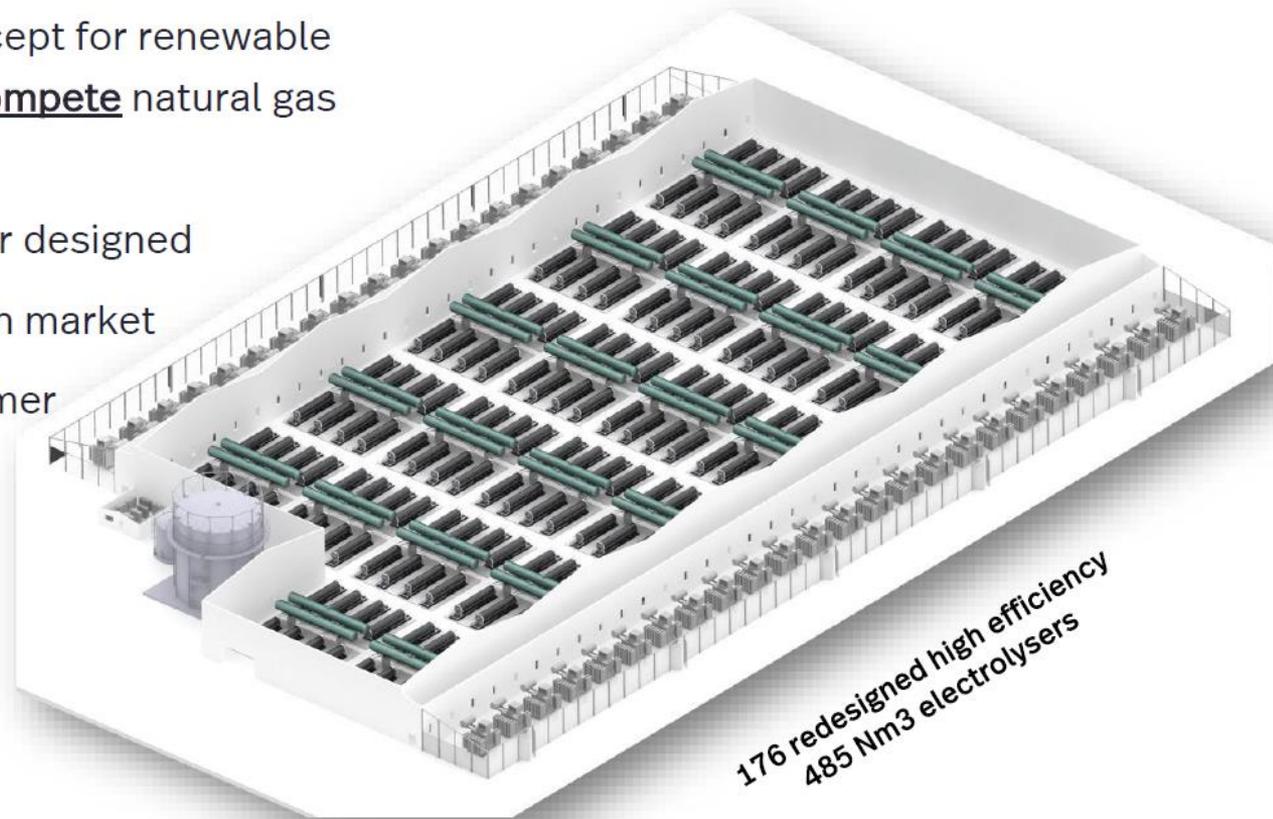


Gas-Hydrogen production with CO₂ storage in Smeaheia field



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

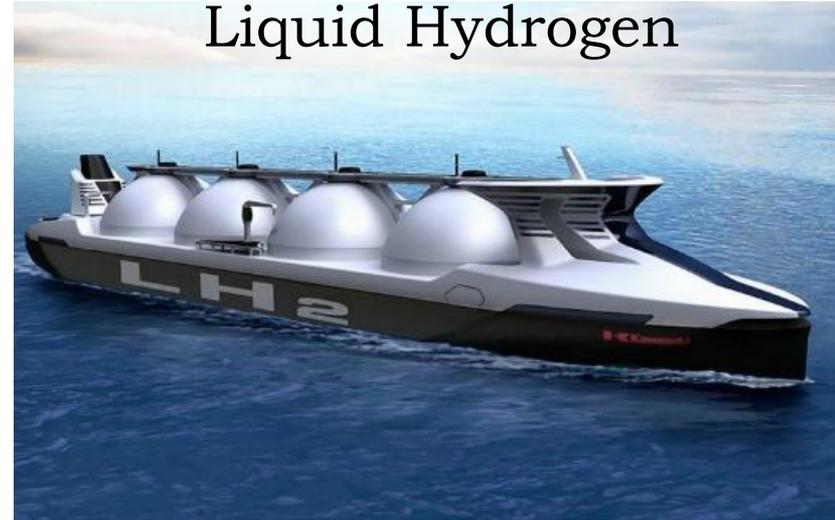


176 redesigned high efficiency
485 Nm³ electrolysers

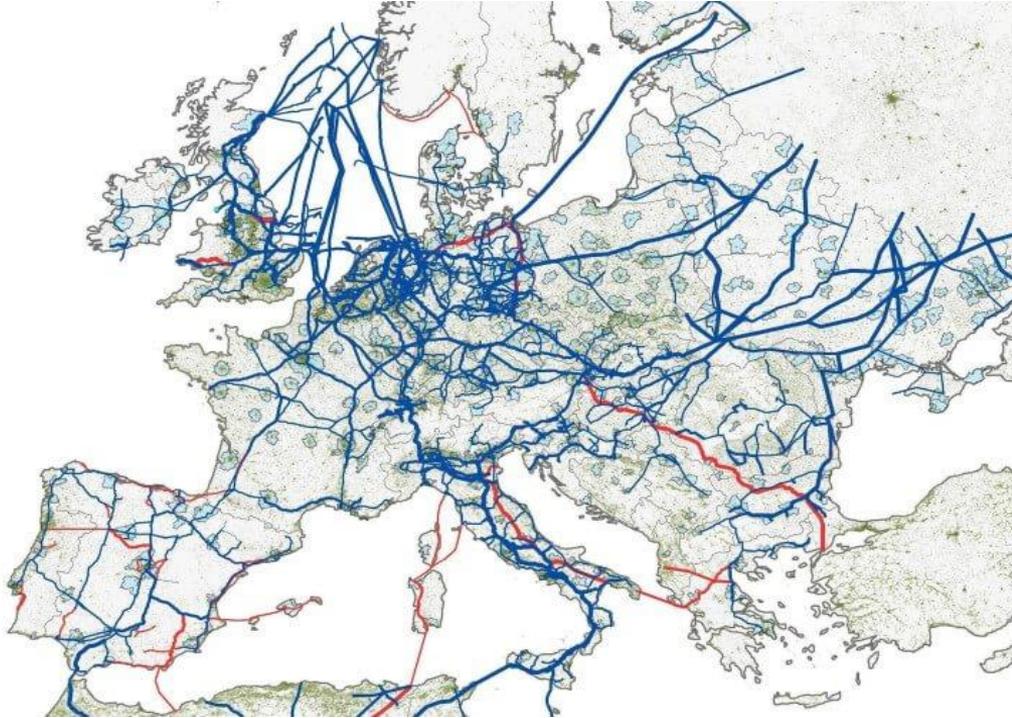
Green Hydrogen Cost development

	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	250-500 Euro/kW	78-80%	25-35 Euro/MWh	1.5-2.5 Euro/kg
After 2030	<250 Euro/kW	>80%	20-30 Euro/MWh	1.1-1.7 Euro/kg

Hydrogen and Ammonia shipping



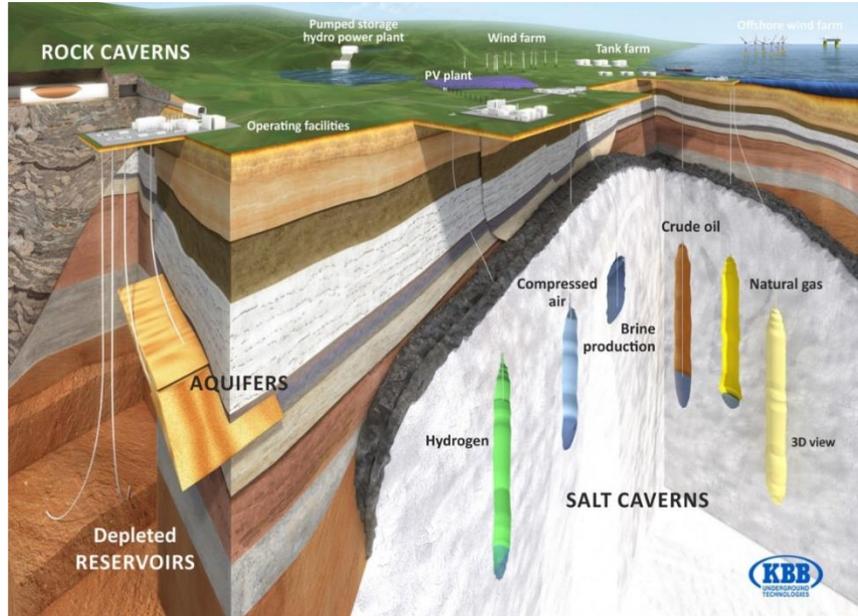
European Gas Infrastructure



Cable versus pipeline cost

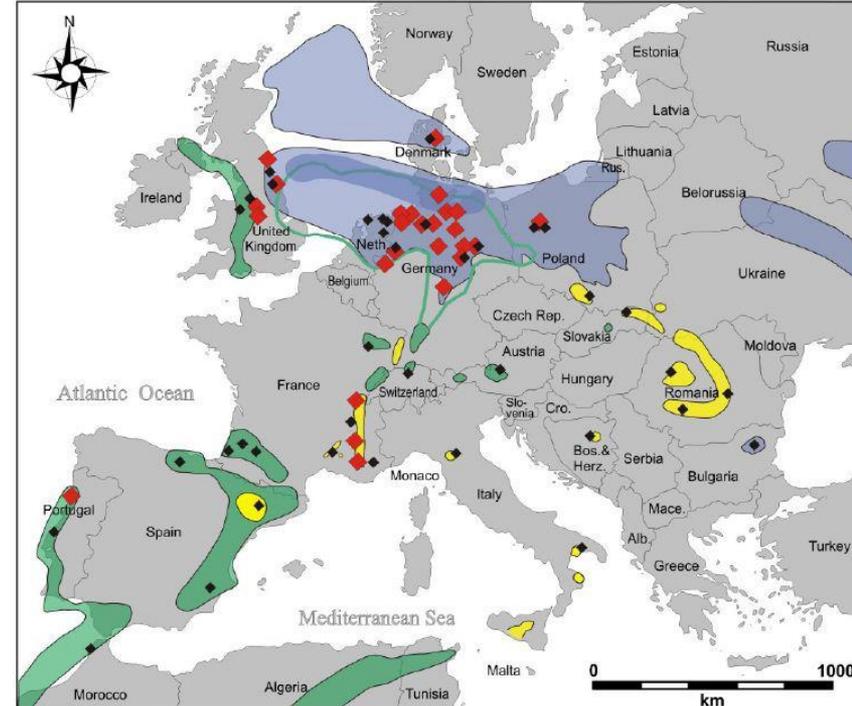
	Cable (BritNed)	Pipeline (BBL)
Capacity	1 GW	15 GW
Construction Cost	€ 500 mln	€ 500 mln
Volume (year)	8 TWh	120 TWh

Hydrogen 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



European Green Hydrogen Action

Production

- Electrolyser Coalition 40 GW in 2030
- Blue Hydrogen production from coal and gas
- Import Hydrogen by pipeline or by ship (liquid hydrogen or ammonia)

Infrastructure

- Natural gas infrastructure conversion to hydrogen; Backbone ready in 2030
- Hydrogen large scale storage, salt caverns
- Hydrogen Harbor facilities with LHG terminals
- Hydrogen Fueling infrastructure

Regional European Hydrogen Implementation

Markets

- Hydrogen market development roadmaps;
- Feedstock (petro)chemical industry
 - High temperature heat industry
 - Mobility
 - Electricity Balancing
 - Heating houses and buildings

Policy and Regulations

- Hydrogen Market Design;
- Hydrogen market regulations
 - Hydrogen quality standards
 - Hydrogen safety regulations
 - Hydrogen human resource agenda

