

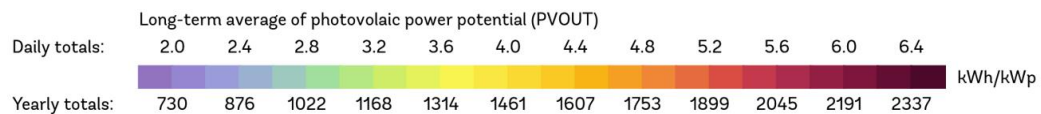
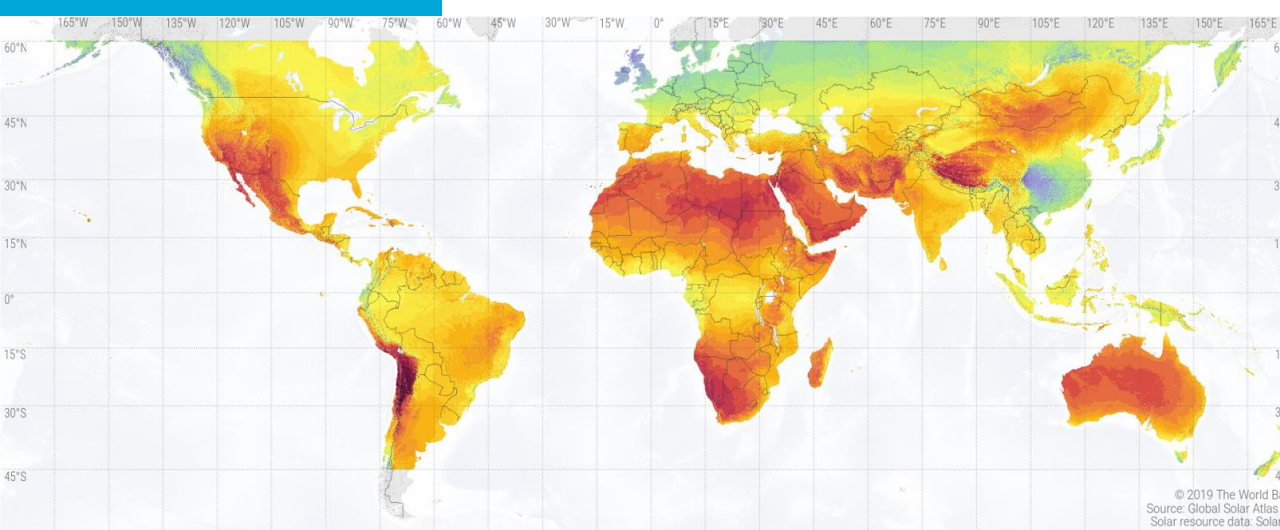


# Hydrogen and water from the deserts

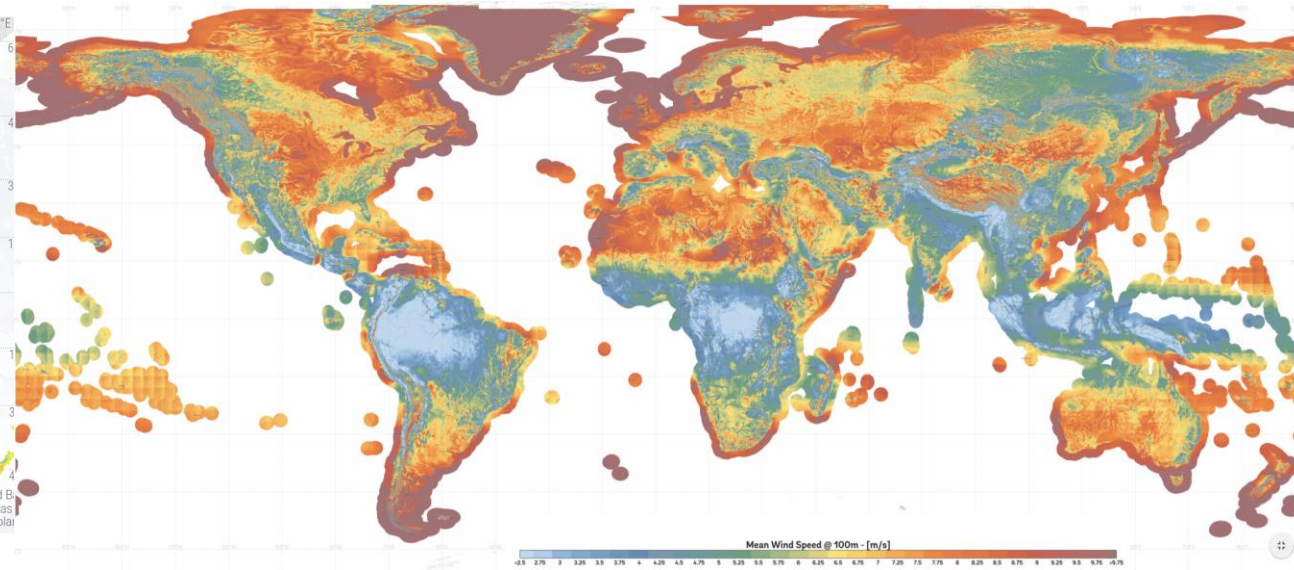
22-6-2023

Em. Prof. Dr. Ad van Wijk

# Low cost solar and wind electricity only at locations with high solar irradiation or high wind speeds AND lots of available cheap space



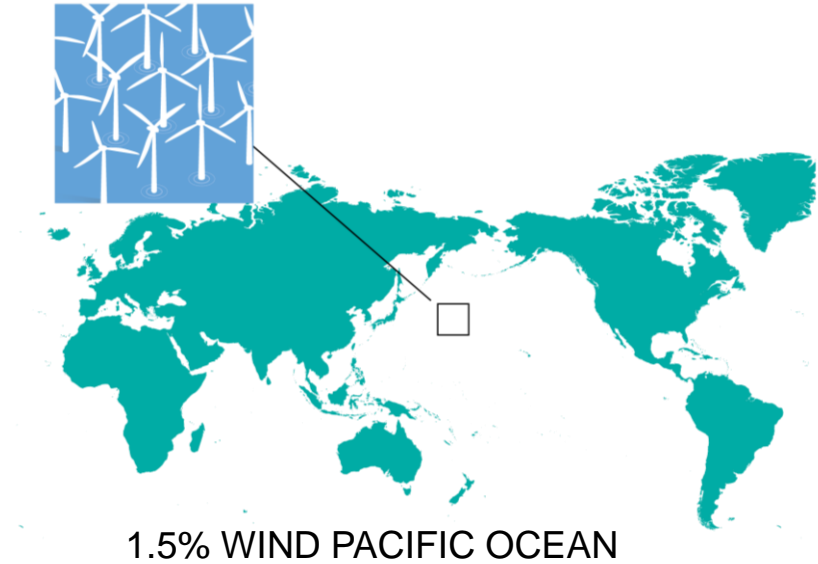
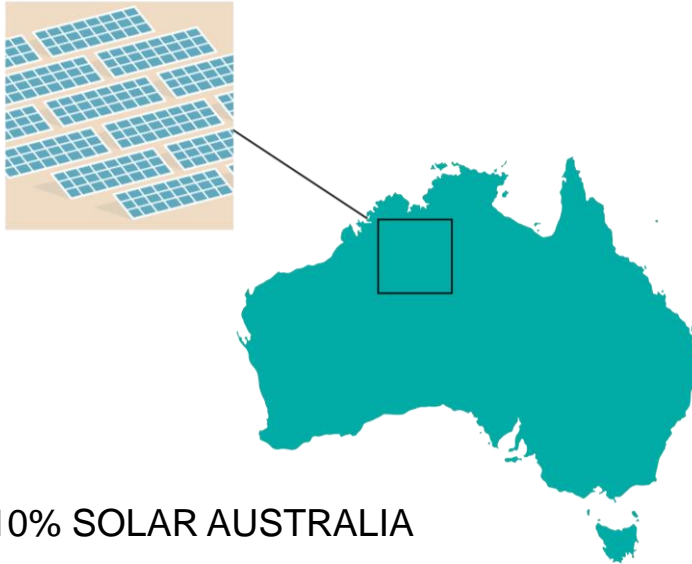
Solar Resources Map



Wind Speed at 100-meter height Map

# Surface needed to produce all the world's energy

## 556 EJ = 155.000 TWh

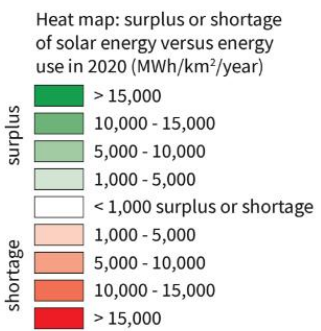
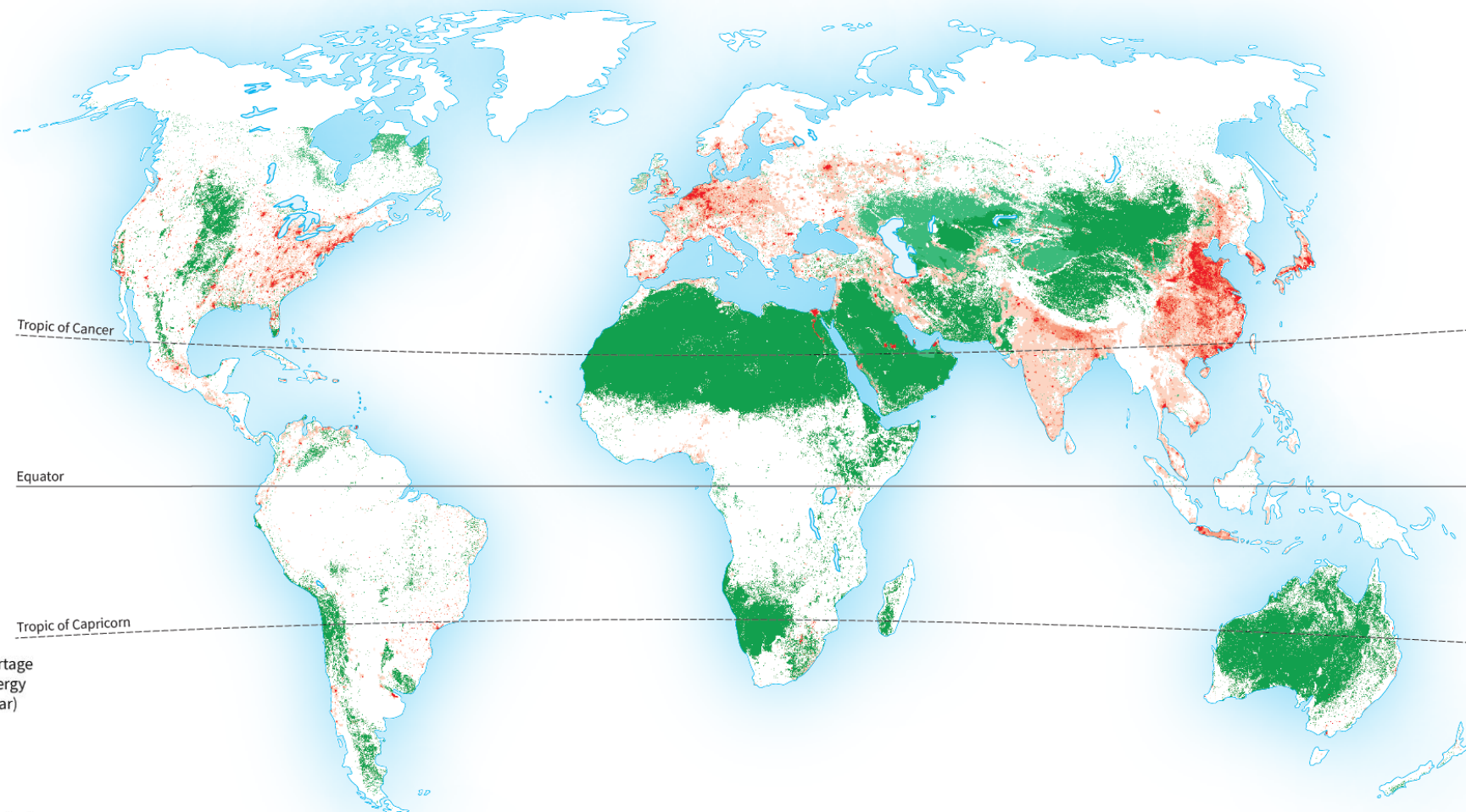
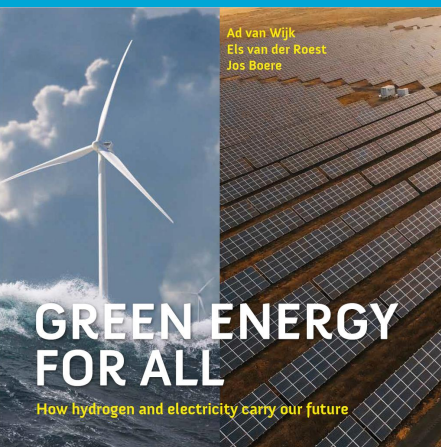


Mohammed Bin Rashid Al Maktoum Solar Farm Dubai;  
3.000 MW ready, expansion to 5.000 MW



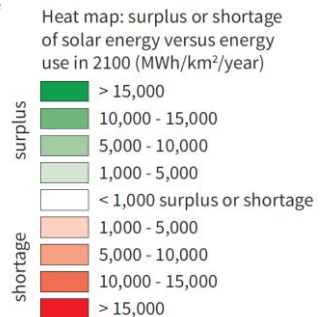
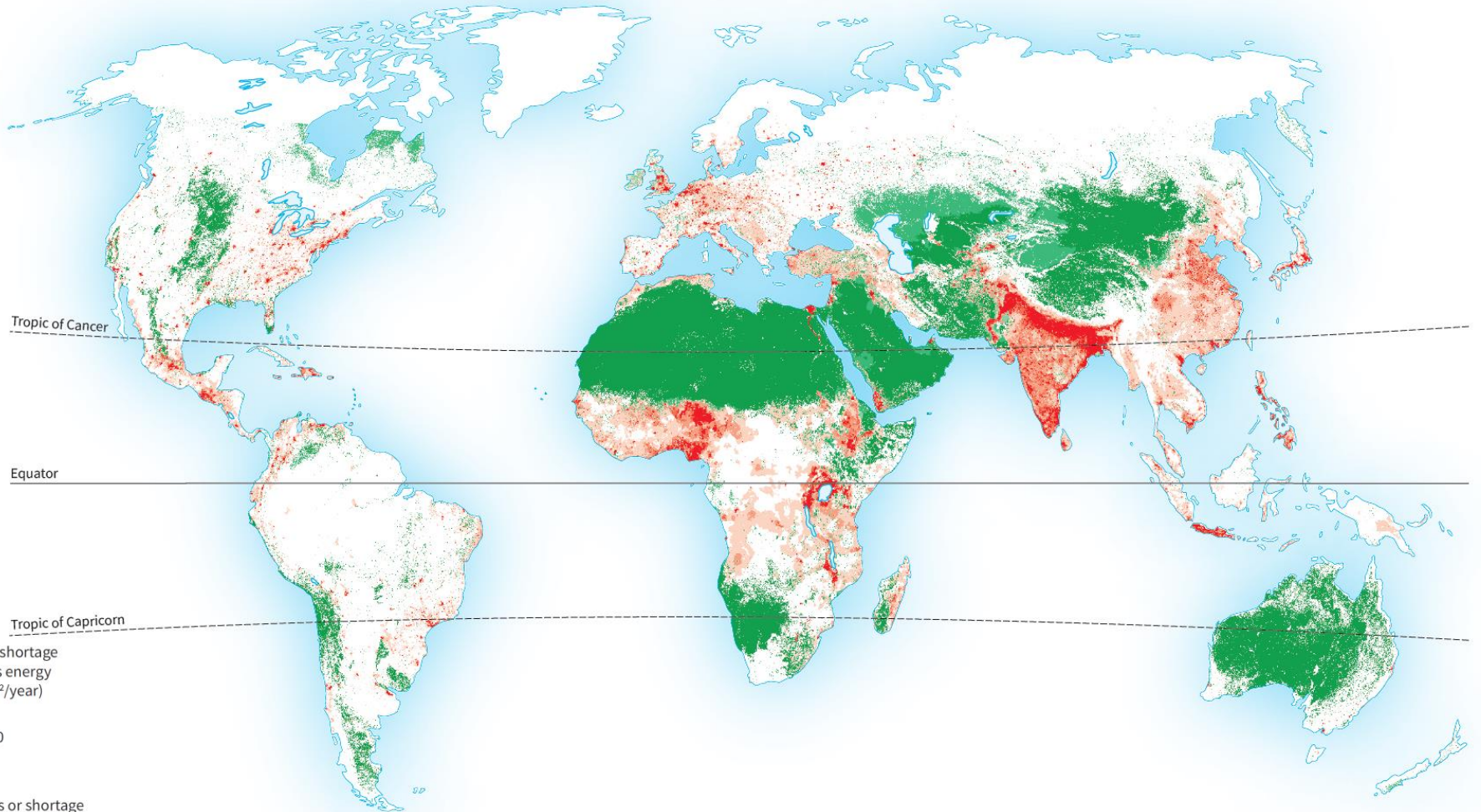
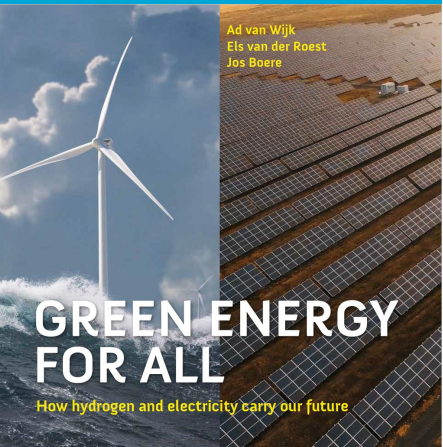
SiemensGamesa 14-15 MW offshore wind turbine  
Rotor diameter 222 meter

# Heat map Solar Energy 2020; Surplus (green) or shortage (red) solar energy - energy use per km<sup>2</sup>



# Heat map Solar Energy 2100;

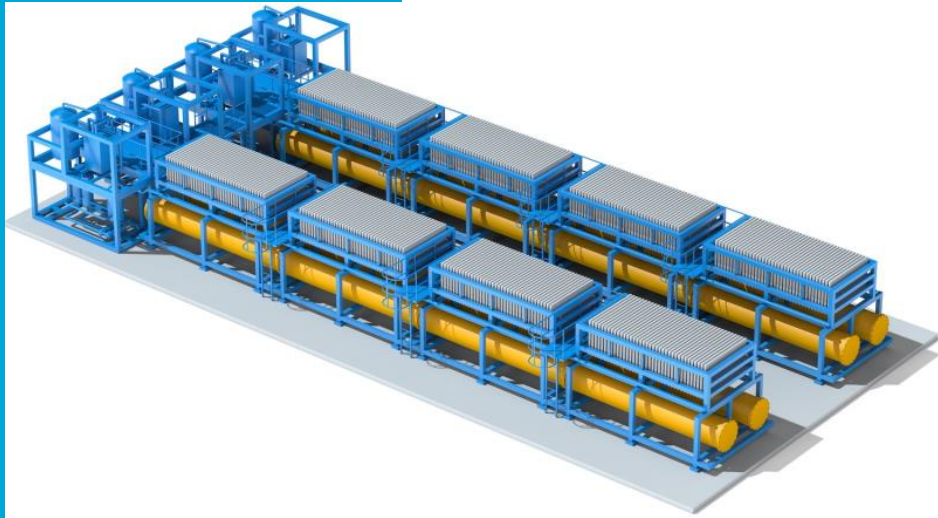
Surplus (green) or shortage (red) solar energy - energy use per km<sup>2</sup>



# Hydrogen, like electricity, is an energy carrier

## Hydrogen is also a feedstock

Hydrogen production technologies, without CO<sub>2</sub> emissions



20 MW alkaline electrolyser  
Thyssen Krupp Germany



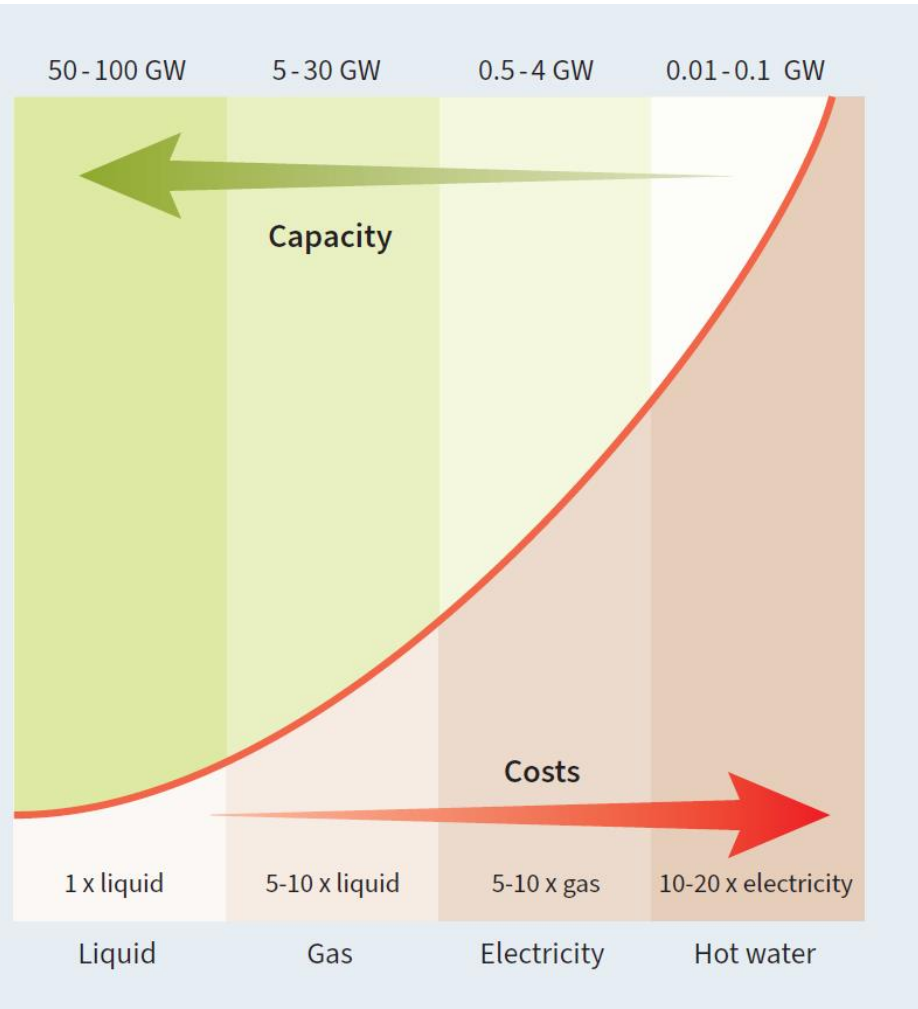
Methane Pyrolysis Plant  
Monolith Nebraska US



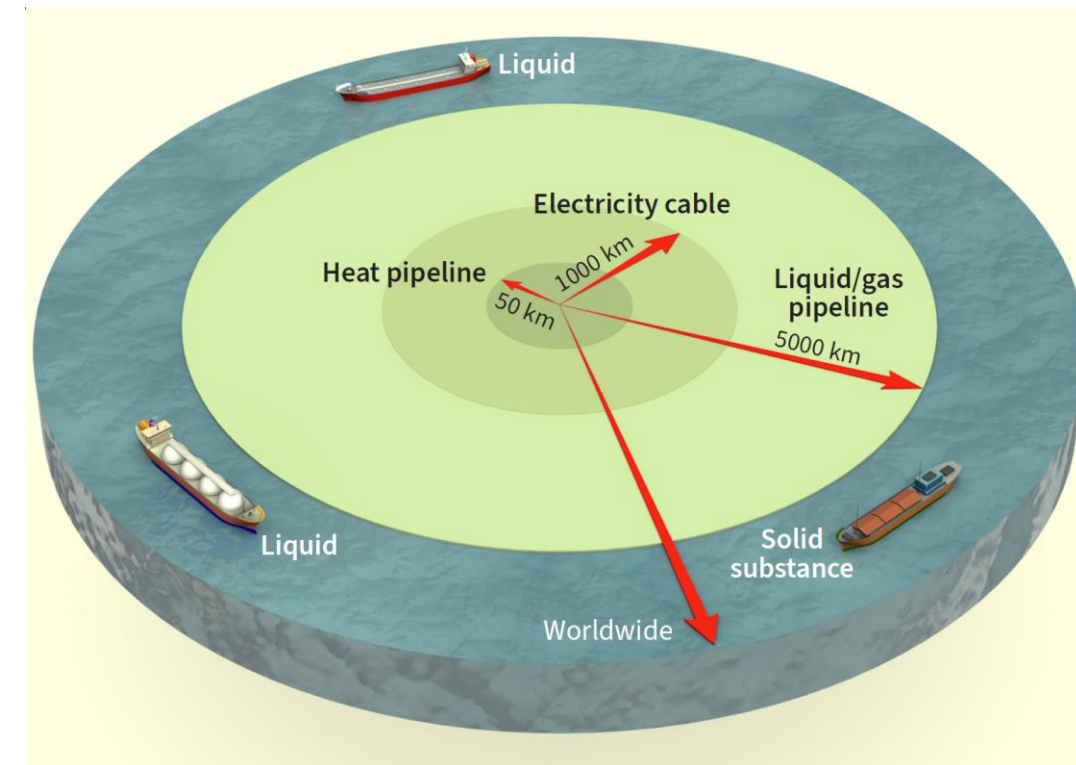
Photolysis Module  
Solhyd start up Belgium

# Energy Transport system costs, capacities and configuration

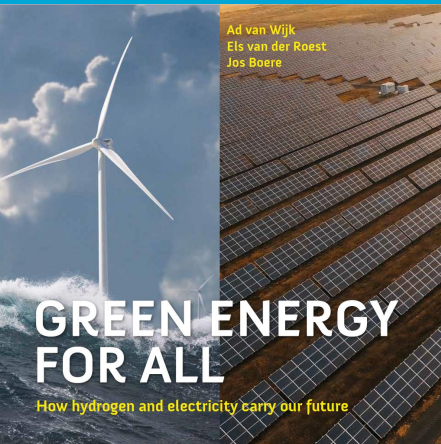
Hydrogen transport cost 5-10 times cheaper than electricity transport



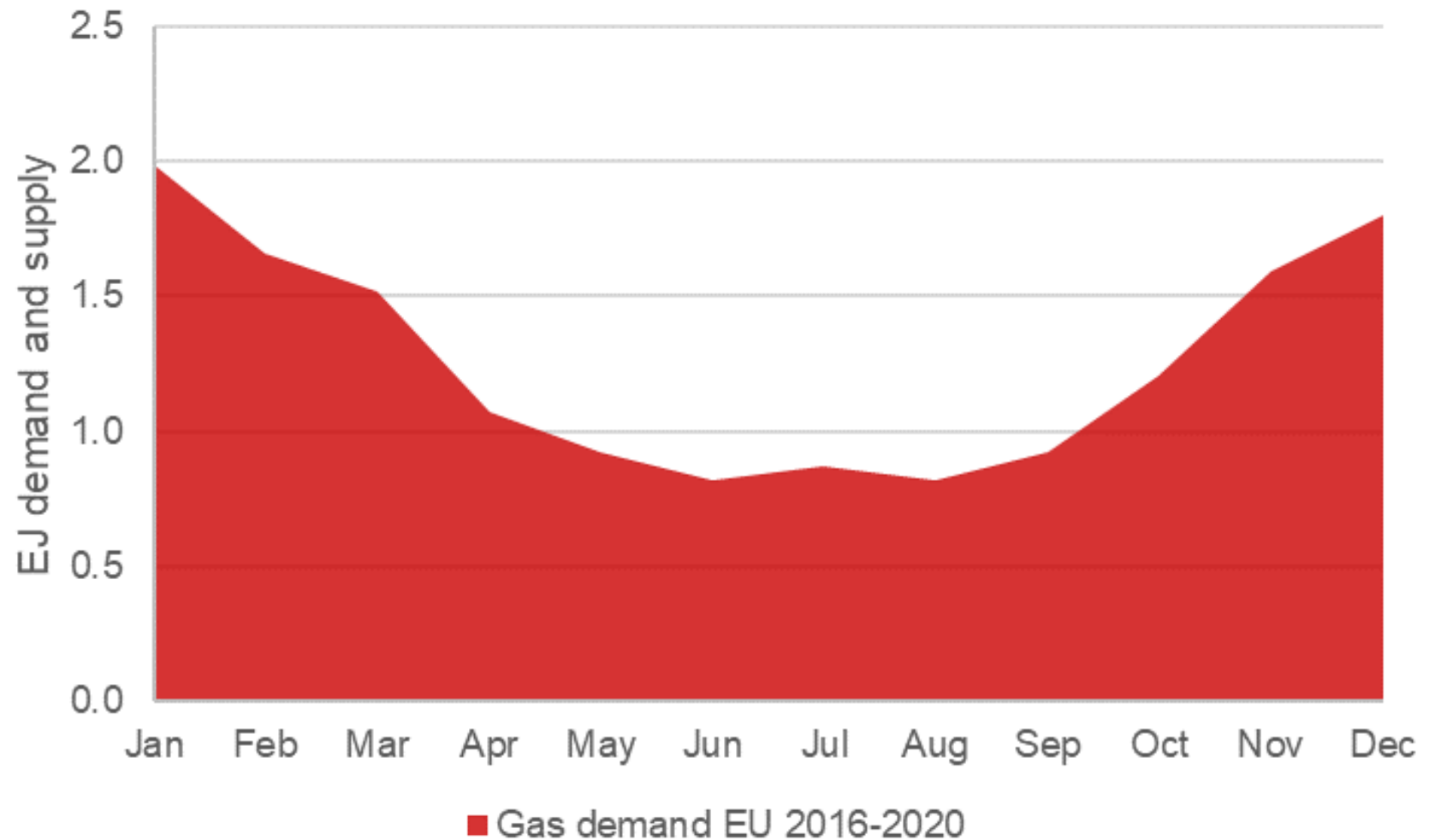
Energy pipeline transport costs and capacities



Worldwide energy transport system



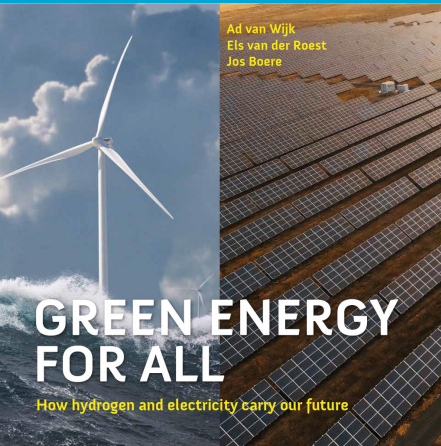
# Energy storage is needed to deal with renewable resource fluctuations in time AND with energy demand fluctuations in time



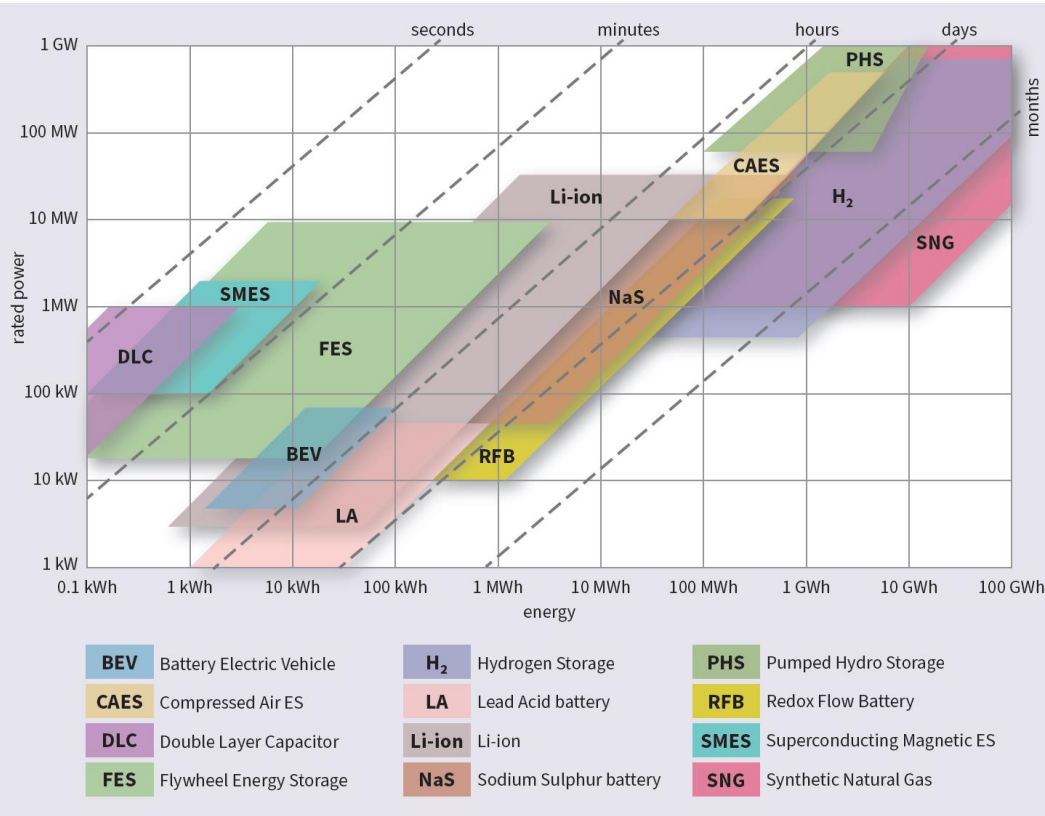
Eurostat 2023



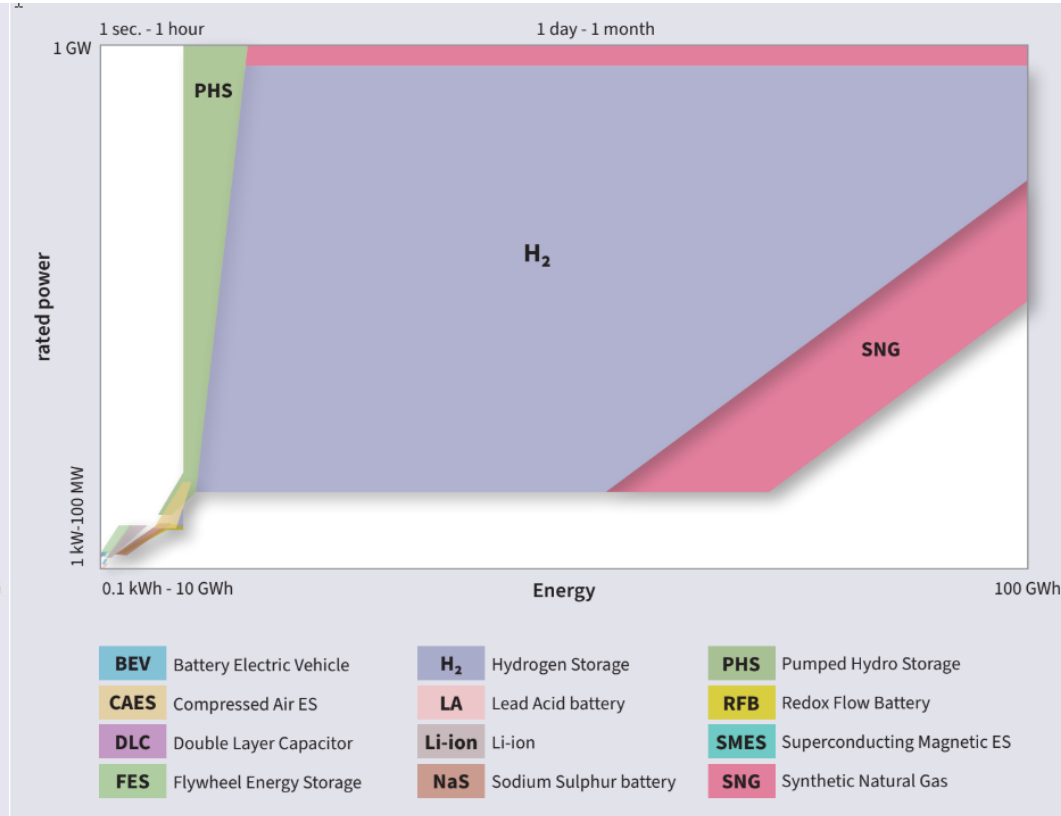
# Energy storage characteristics: energy volume, power and charge/discharge time scale



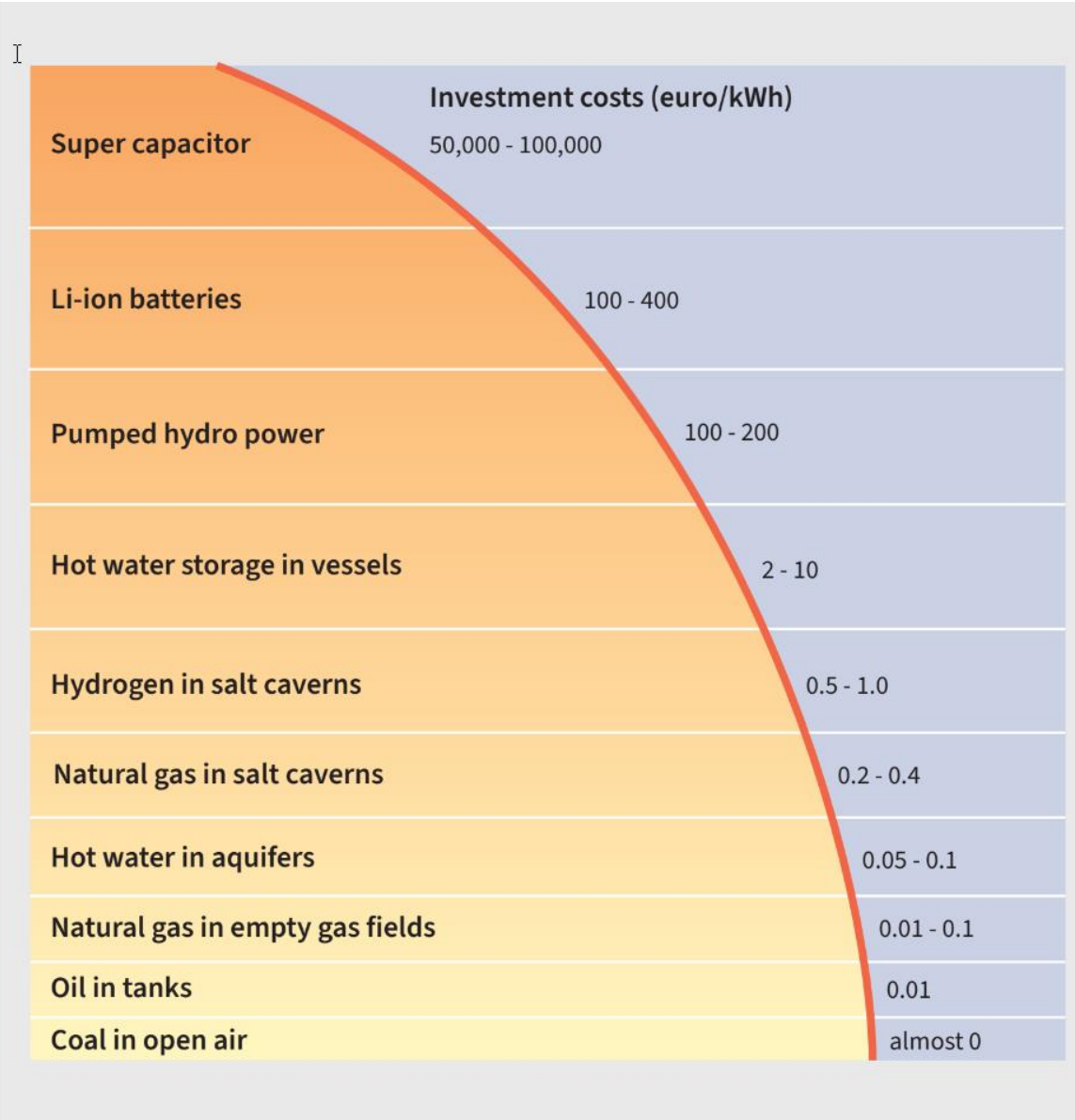
Presented at a double logarithmic scale



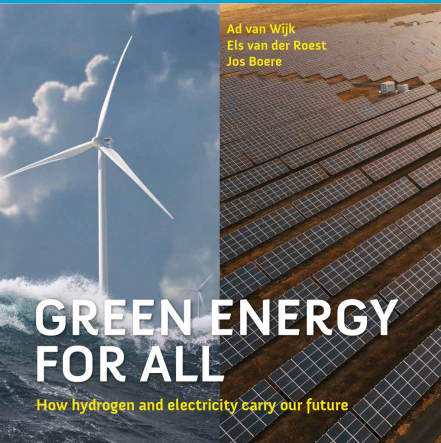
Presented at a double linear scale



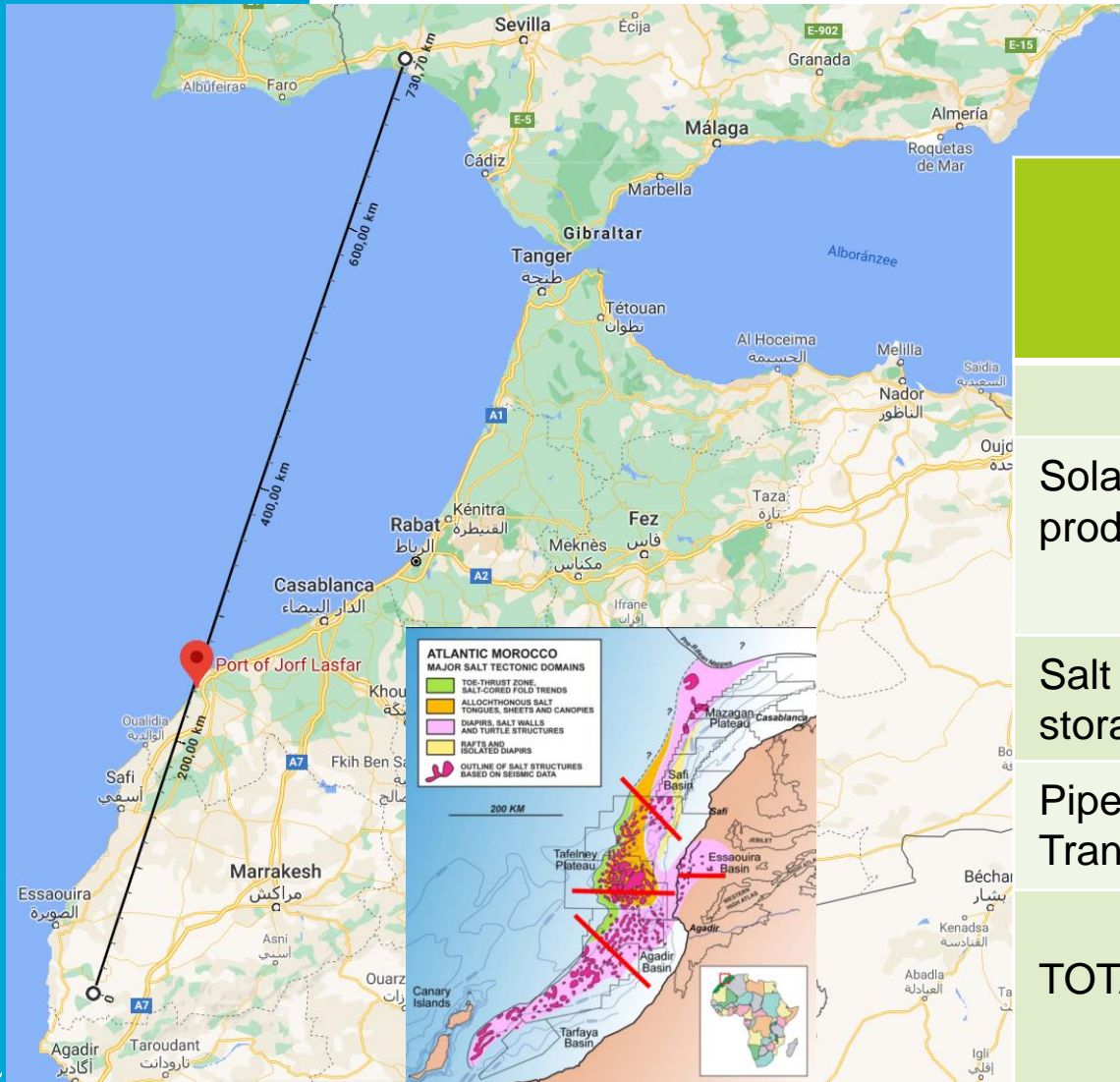
# Energy storage Investment Costs



**Hydrogen storage in salt caverns is 100 to 200 times cheaper than electricity storage in pumped hydro power**



# Base load solar hydrogen Morocco to Germany

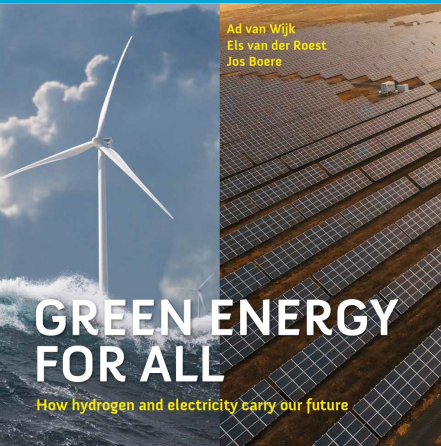


Base load solar H <sub>2</sub> from Morocco to Germany		Levelized Cost of Hydrogen LCoH €/kg H <sub>2</sub>
	Assumptions	
Solar-Hydrogen production	Solar electricity cost = 0.01 €/kWh Full load hours = 2,000 hours/yr Electrolyser efficiency = 50 kWh/kg H <sub>2</sub> 100 GW solar = 4 million ton H <sub>2</sub> Required surface = 1,800 km <sup>2</sup>	1.0-1.5
Salt cavern storage	Flexible production to base load; daily cycles	0.1-0.2*
Pipeline Transport	Pipeline capacity = 20 GW Full load hours = 8,000 hours/yr Pipeline length = 3,000 km	0.3**
<b>TOTAL</b>		<b>1.4-2.0 €/kg H<sub>2</sub></b>  =0.035-0.050 €/kWhH <sub>2</sub> (HHV)

\*Pedro Quintela de Saldanha; Sines H<sub>2</sub> Hub; a cost perspective of the transmission & storage infrastructure of the Sines green hydrogen hub, TU Delft, MsC thesis, April 2021

\*\*Gas for Climate/Guide house; "Extending the European Hydrogen Backbone; A European Hydrogen Infrastructure vision covering 21 countries." April 2021

# Demineralized water cost from sea water transported over 1,000 km is only 4% of total hydrogen production cost at 1 €/kg



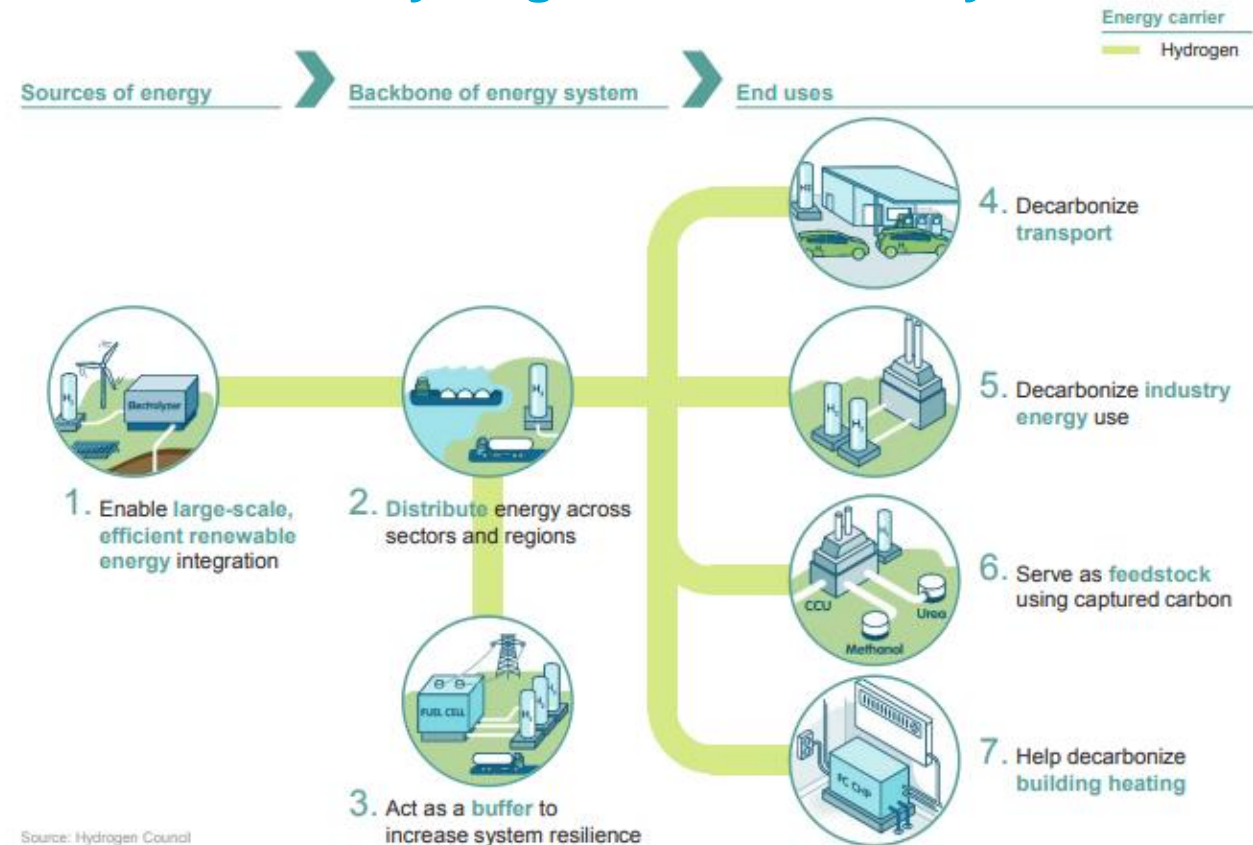
	DISTANCE FROM SEA (km)	COSTS (€/m <sup>3</sup> demineralized water)
Transport costs seawater (2 m <sup>3</sup> seawater per m <sup>3</sup> demineralized water)	1,000	1.0
Production costs demineralized water		2.0
Transport costs brine (1 m <sup>3</sup> brine per m <sup>3</sup> demineralized water)	1,000	0.5
Other costs (pump energy)		0.5
<b>Total (€/m<sup>3</sup> demineralized water)</b>		<b>4.0 €/m<sup>3</sup></b>
<b>Costs of demineralized water for production of 1 kg hydrogen (€/kg hydrogen)</b>		<b>0.04 €/kg Hydrogen</b>

# Hydrogen/hydrogen carriers in a carbon-free energy system

1. To deliver cheap solar and wind energy cost-effectively at the right time and place (transport and storage)
2. To decarbonize hard to abate energy use (industry, feedstock, mobility, heating and balancing electricity system)

Finally cost competition between imported hydrogen with regionally produced

## hydrogen and electricity

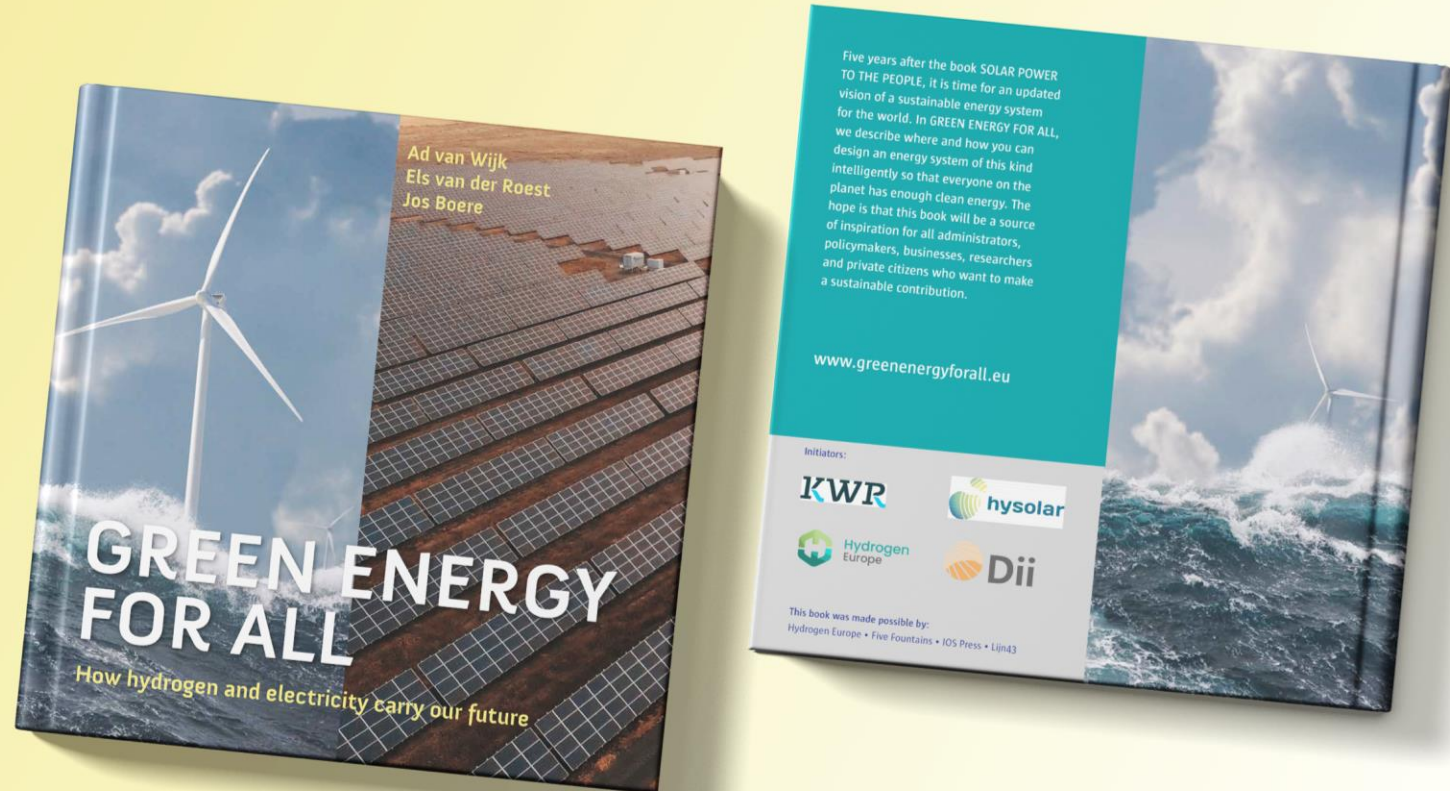


Source: Hydrogen Council

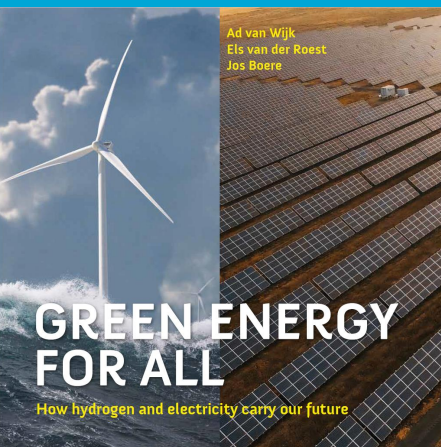
# New book release

Expected October 2023

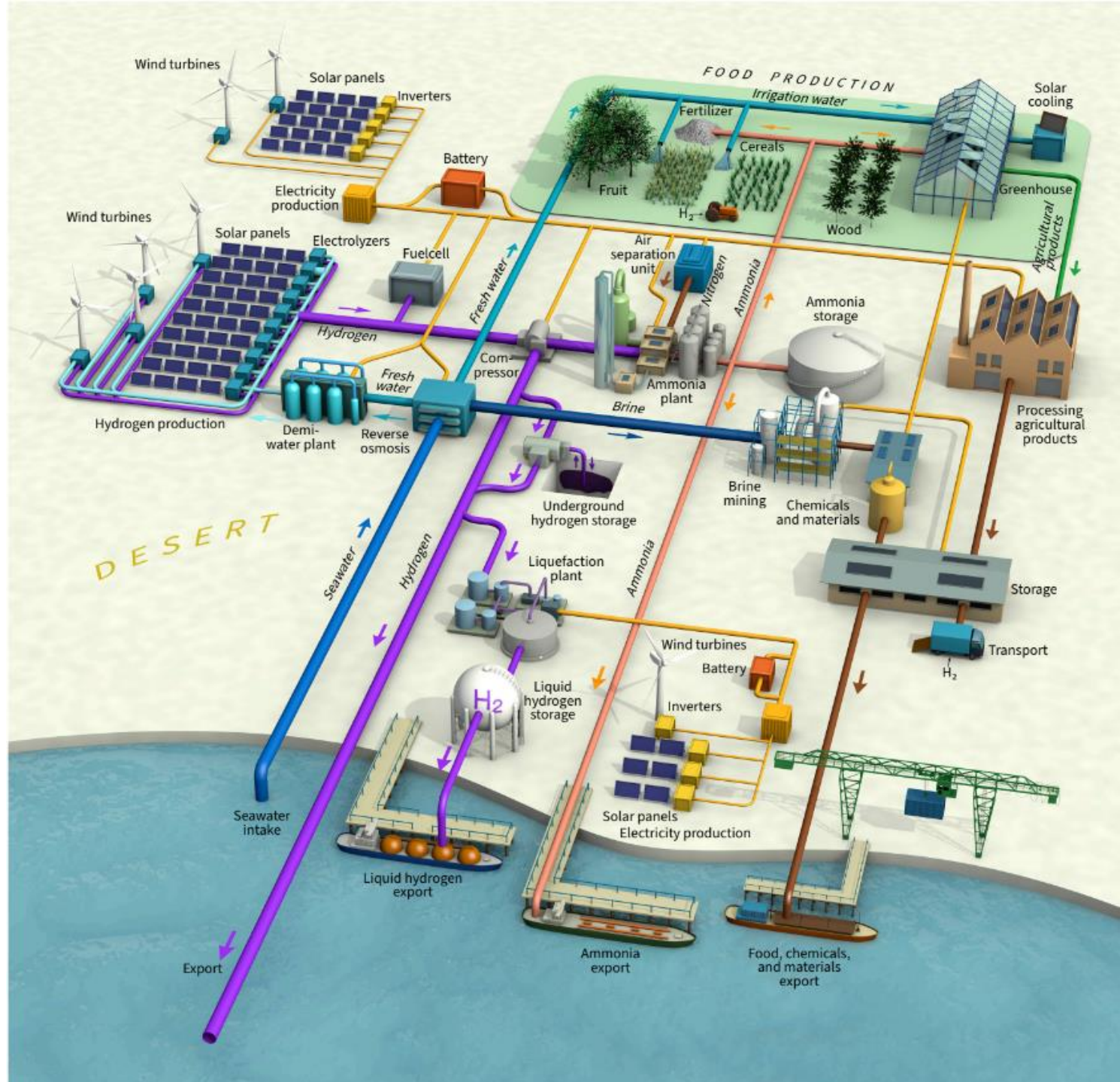
Pre-order  
from  
July 6



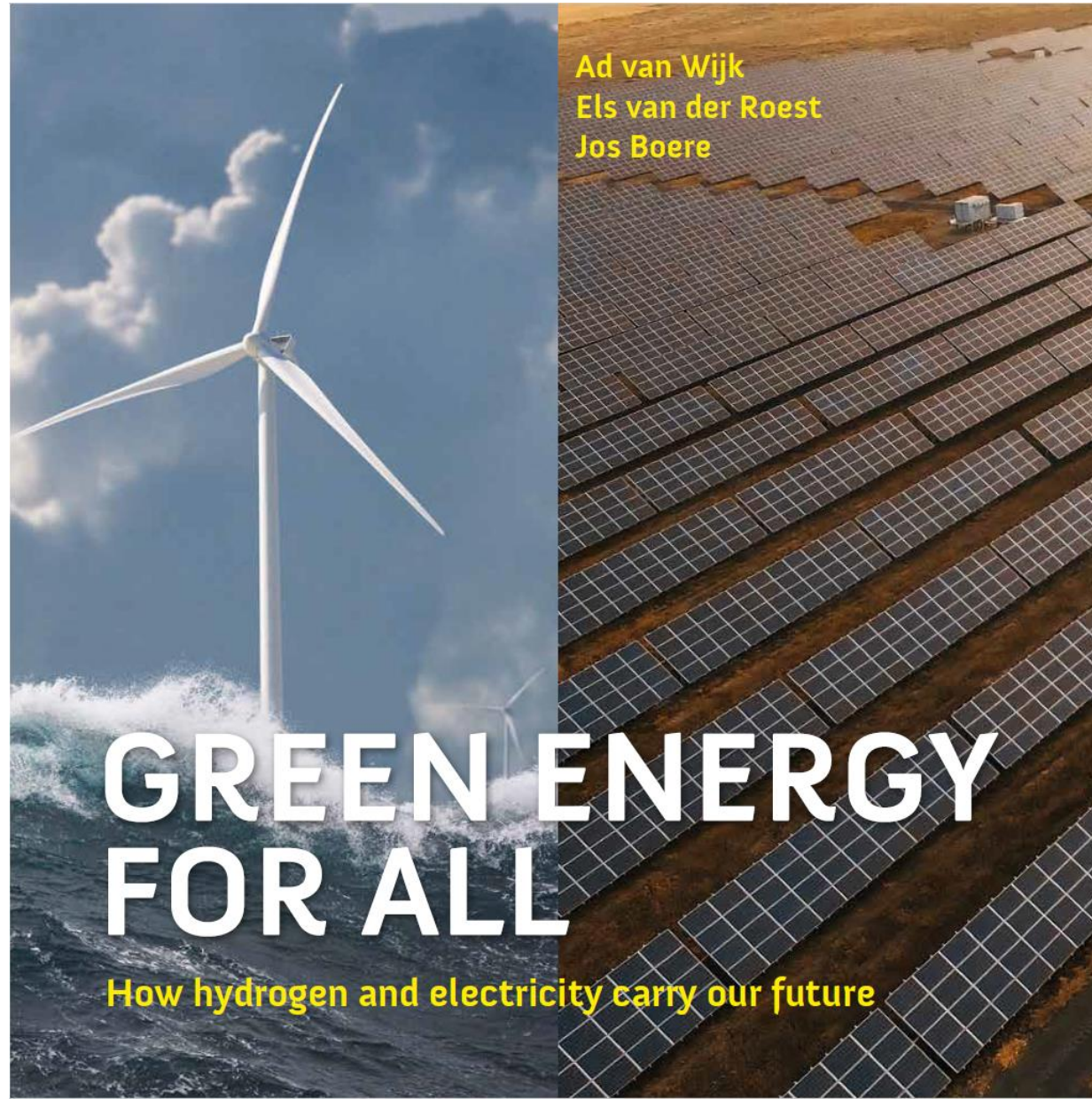
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How hydrogen and electricity carry our future