

```
modifier_ob.select = False # set to mirror_ob, hope the other is a mesh
#mirror_ob
mirror_ob = bpy.context.active_object
mirror_ob.select = False # pop modifier_ob from sel_stack
print("popped")

#modifier_ob
modifier_ob = bpy.context.selected_objects[0]
print("Modifier object:" +str(modifier_ob.name))

#modifier_ob.select=1

print("mirror_ob",mirror_ob)
print("modifier_ob",modifier_ob)

t_mirror_modifier_on_mirror_ob

mirror_mod = modifier_ob.modifiers.new("mirror_mirror","MIRROR")

t_mirror_object_to_mirror
mirror_mod.mirror_object = mirror_ob

"MIRROR_X":
operation
mirror_mod.use_x True
mirror_mod.use_y True
mirror_mod.use_z True
```



# IAM RESPONSIBLE

26 SEPTEMBER 2019 - SCHIPHOL HOOFDGEBOUW



The background image shows a large, modern architectural structure with a tall, conical tower and a wide, tiered seating area. The tower is made of a dark material and has a network of cables or ropes supporting its top. The seating area is made of light-colored concrete or stone and is surrounded by green grass. Many people are sitting on the steps, and some are standing. The sky is clear and blue.

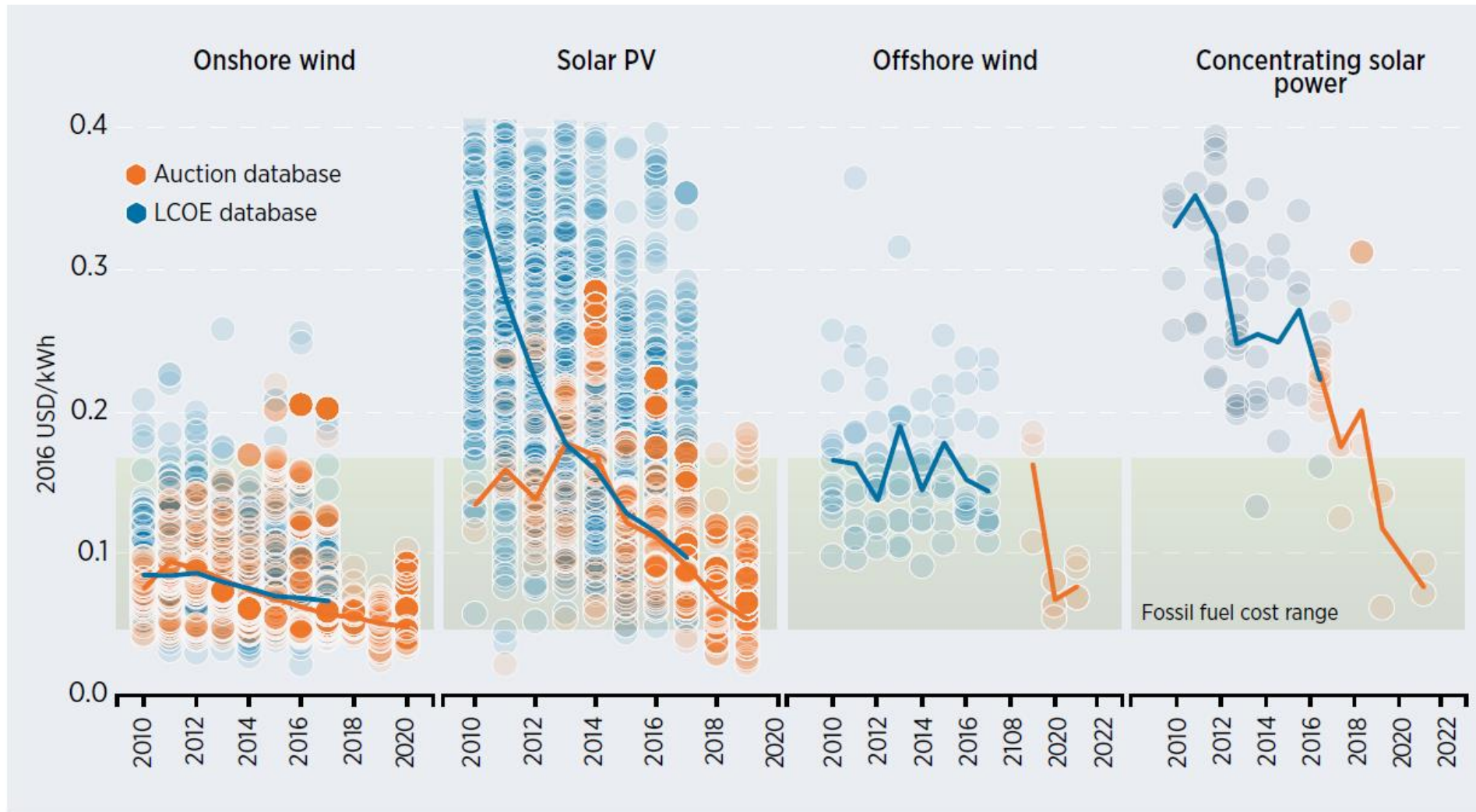
# Future Energy Systems

26-9-2019

Prof. Dr. Ad van Wijk

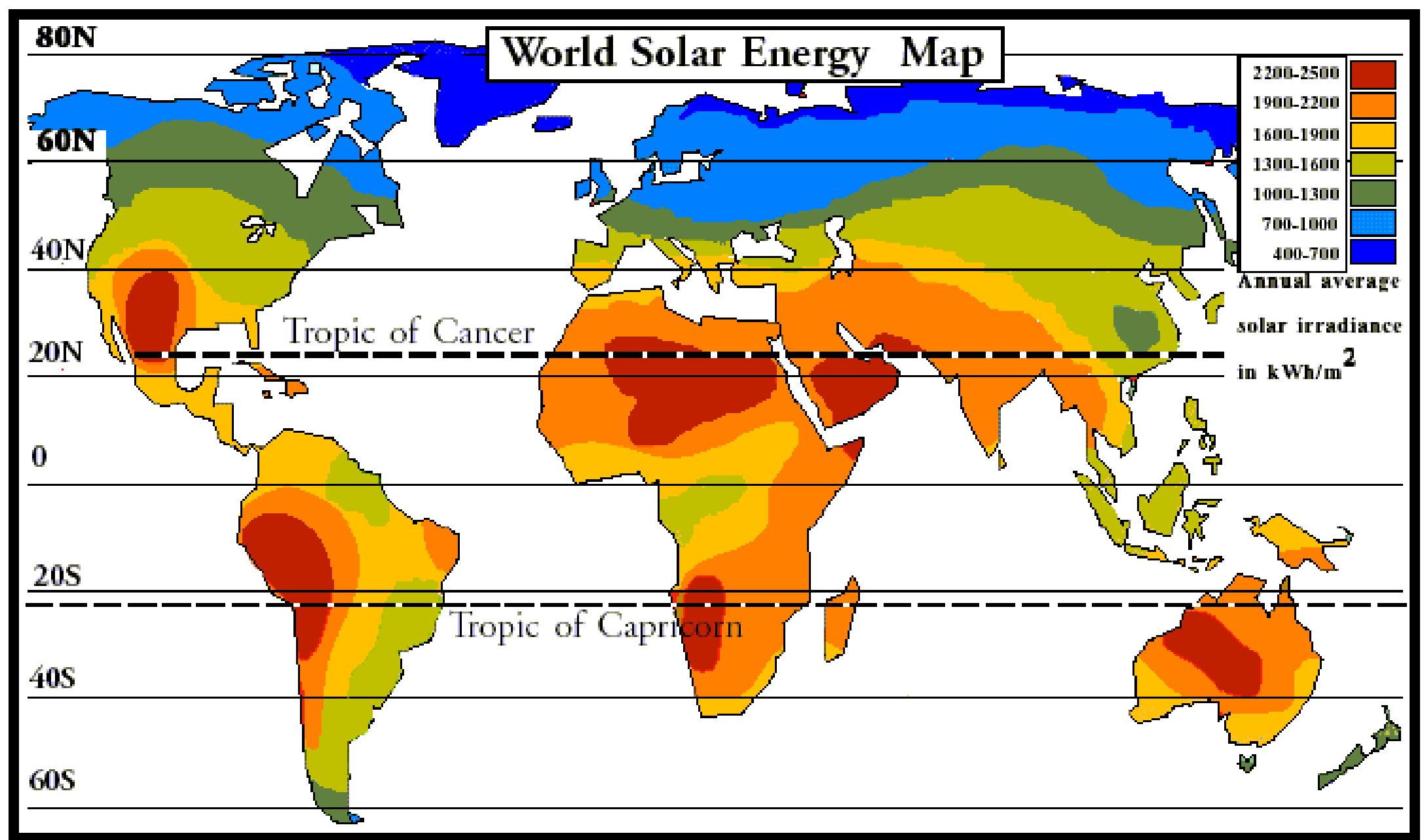


# Levelized Cost of Electricity



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



- 700MW CSP,
- \$3.9 billion investment
- Central Tower
- Parabolic Troughs
- Auxiliary solar PV
- Tariff
- PPA
- Dispatch:

15 hours storage

100 MW

3x200 MW

4x33 MW

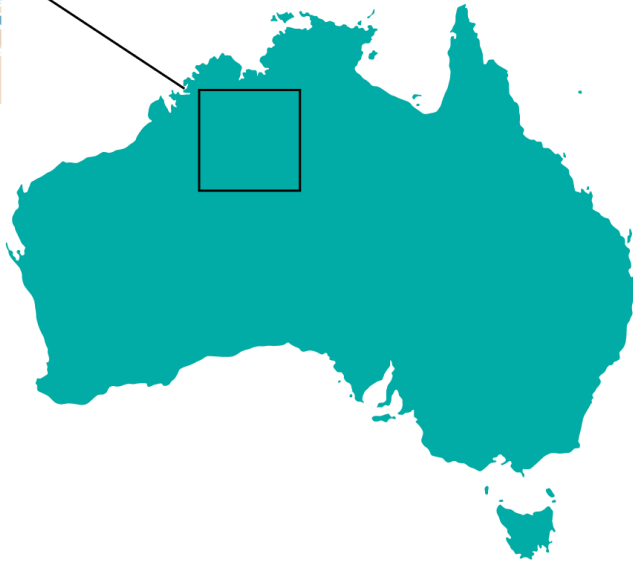
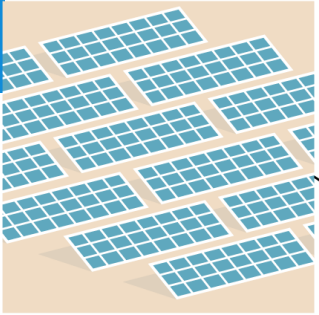
7.3 ct/kWh

35 years

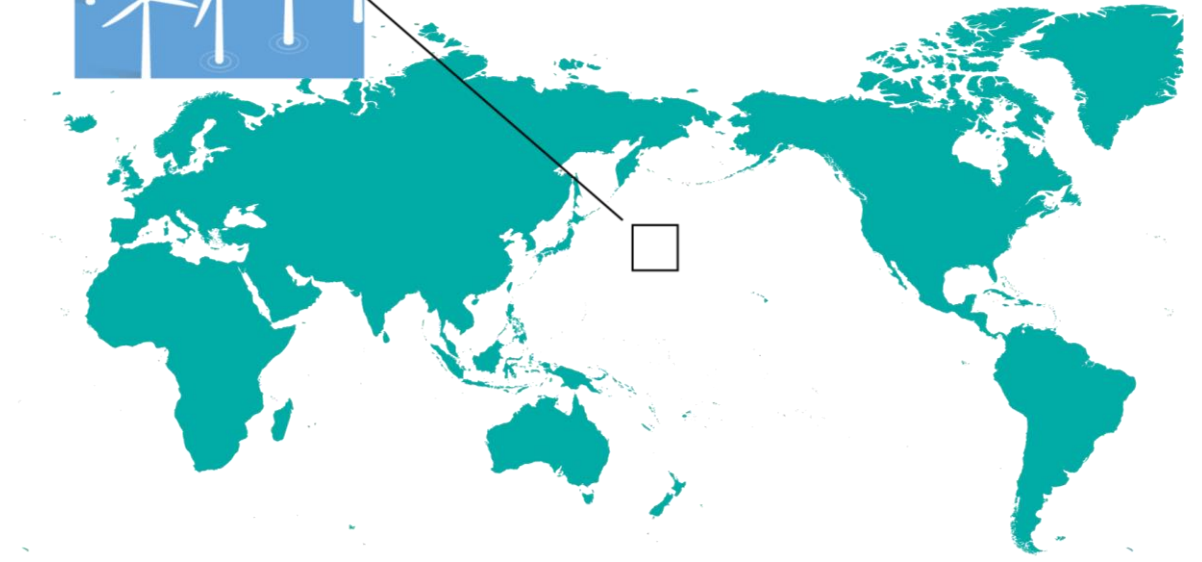
between 4pm and 10am



# Surface needed to produce all the world's energy $556 \text{ EJ} = 155.000 \text{ TWh}$



10% SOLAR AUSTRALIA

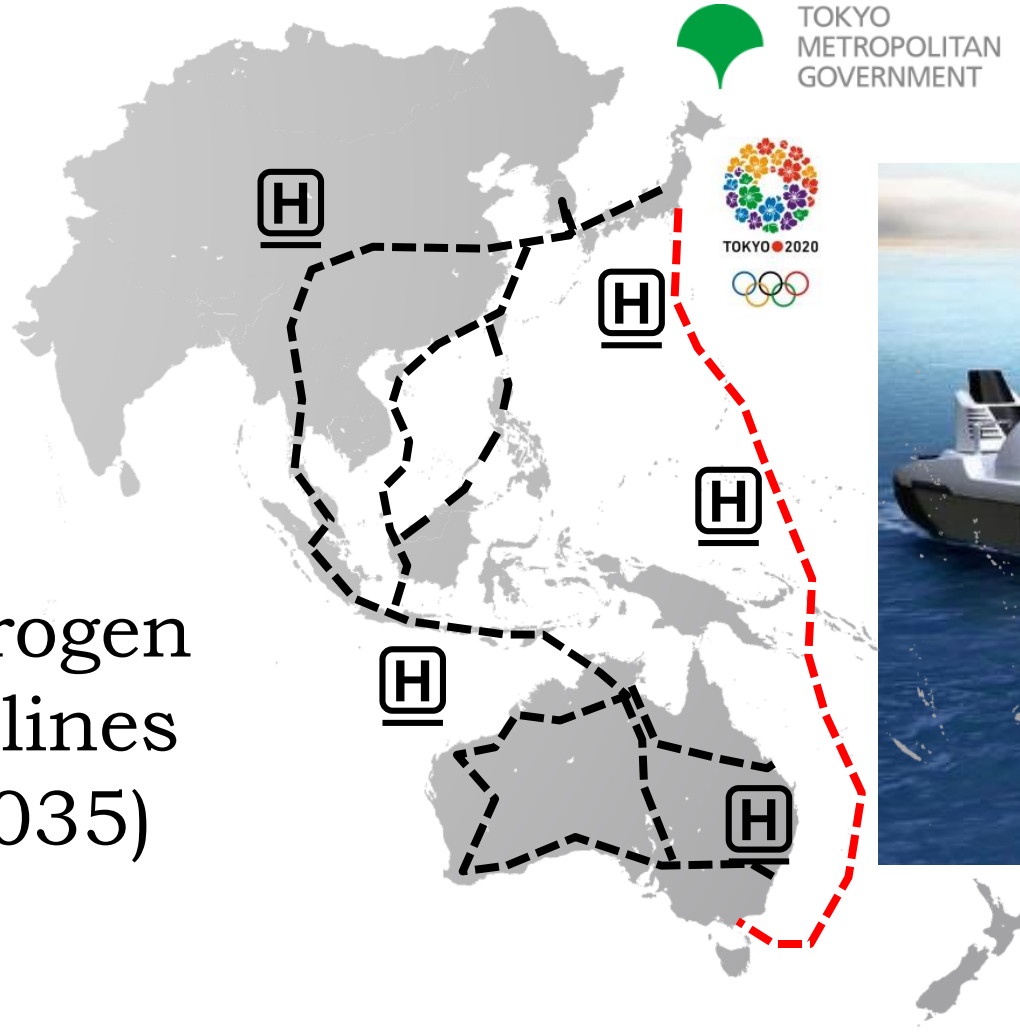


1.5% WIND PACIFIC OCEAN

# Tokyo Olympic Games 2020



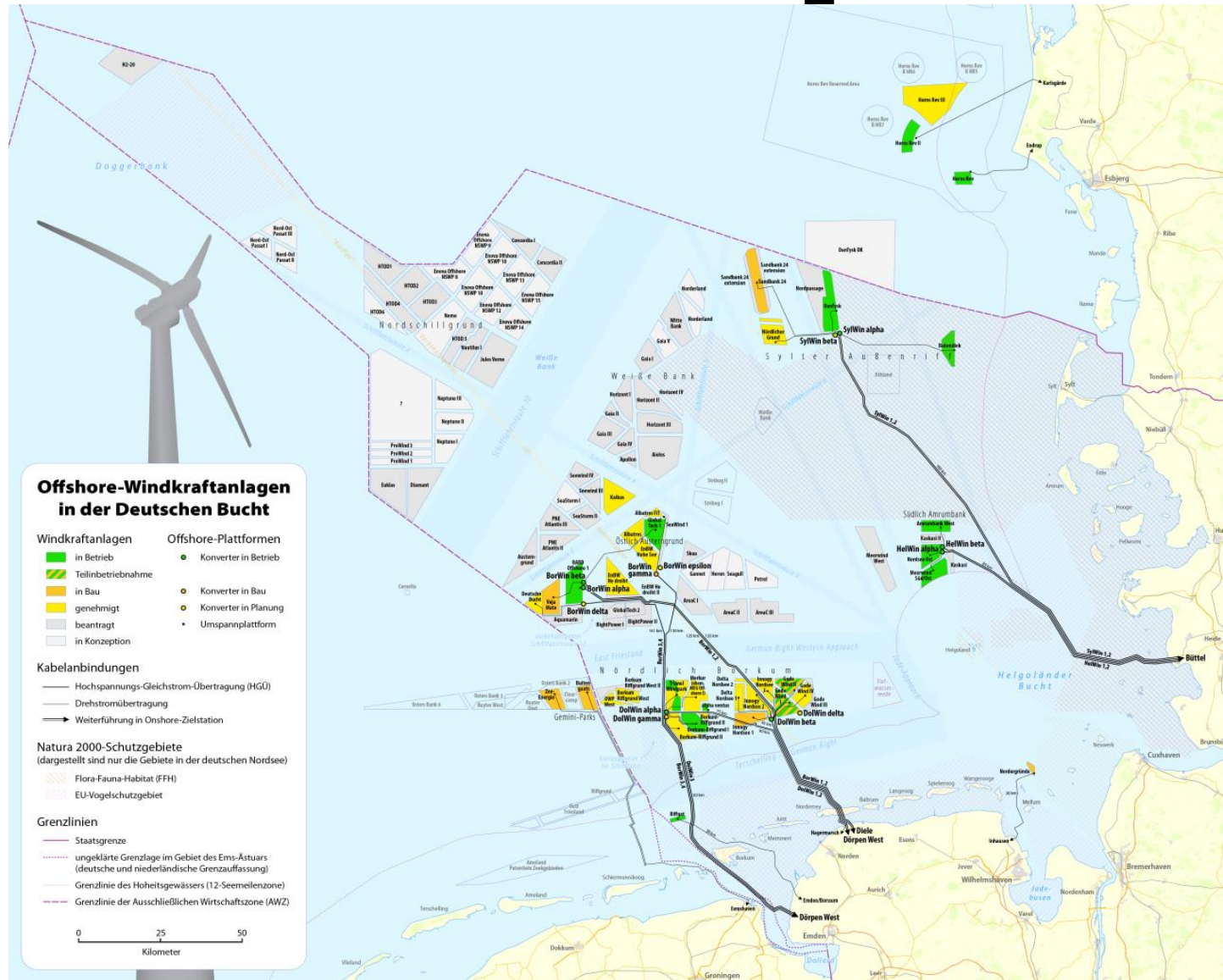
Hydrogen  
Pipelines  
(~2035)



Hydrogen  
Shipping  
(~2025)



# 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

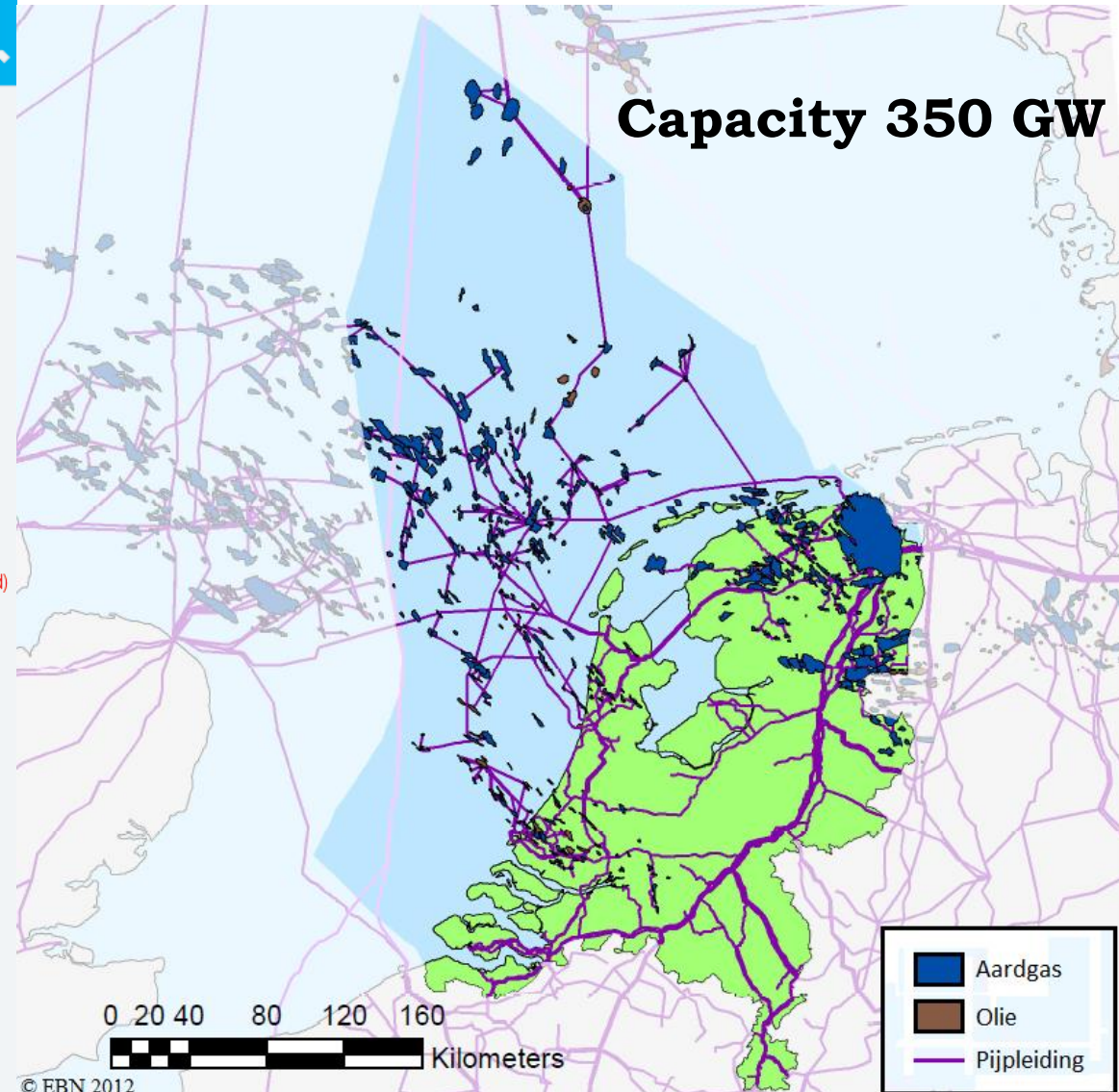
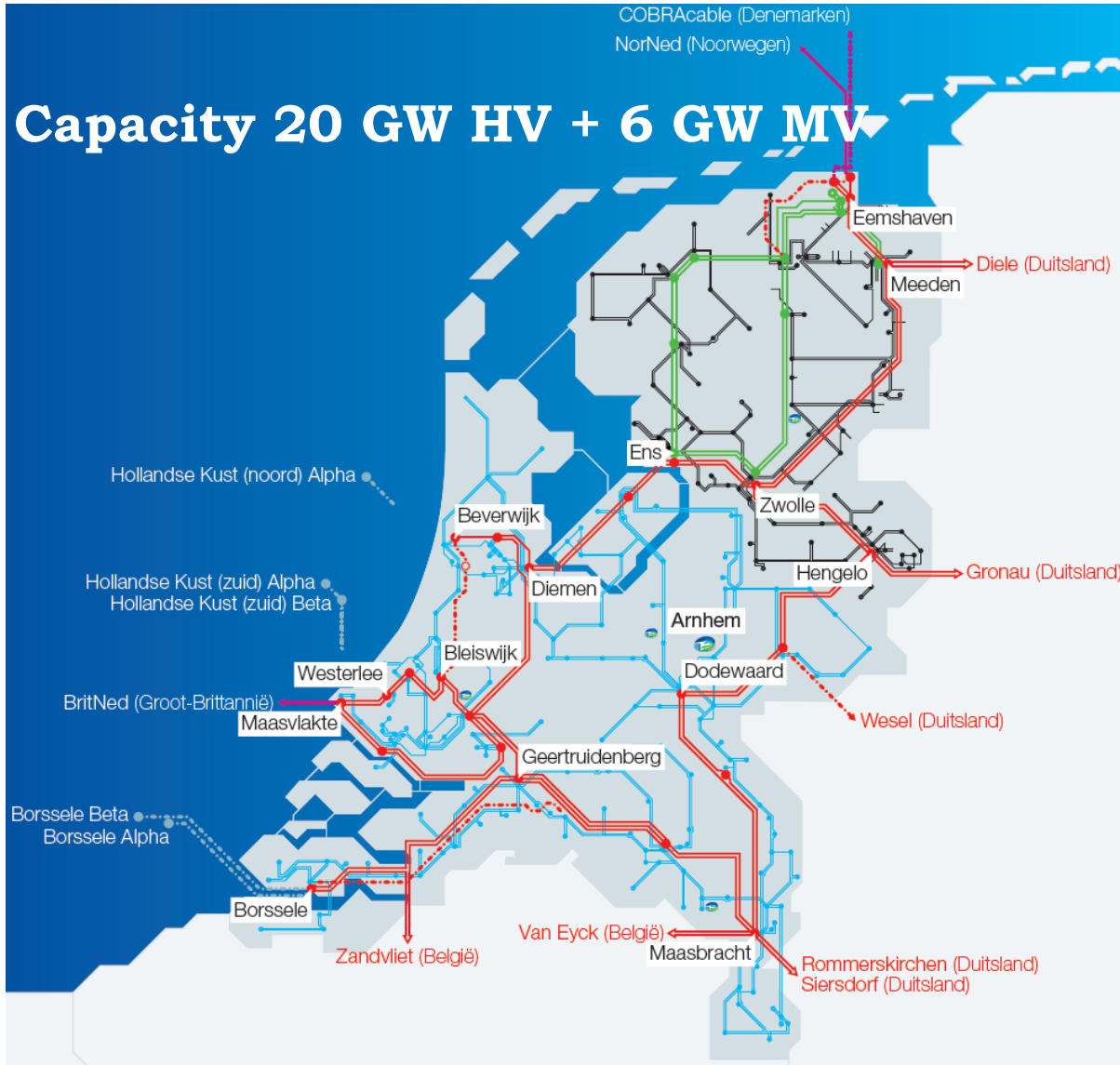
RWE Coal fired power plant 1,560 MW

Engie Gas fired power plant 2,450 MW

Cable Inland 4,000 MW

Expansion to 5,610 MW

# Electricity and Gas Transport Grid





# Hydrogen backbone the Netherlands 2030

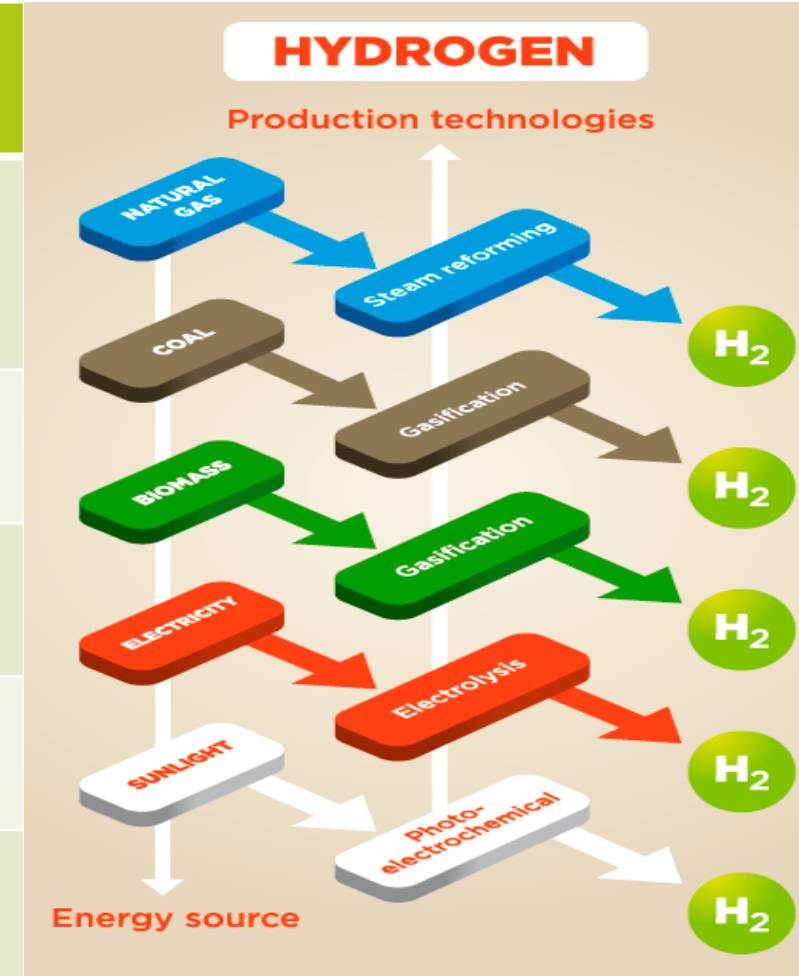


- Low caloric gas pipelines will become available, because the Groningen gas field has to reduce production to 0 in 2030
- 1 Transport pipeline capacity about 10-15 GW
- New hydrogen pipeline connections to offshore wind farms
- Connections to Germany (Ruhr-area, Bremen-Hamburg and Belgium (Antwerp, Zeebrugge)
- European connections to France, Austria, Italy, etc.

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

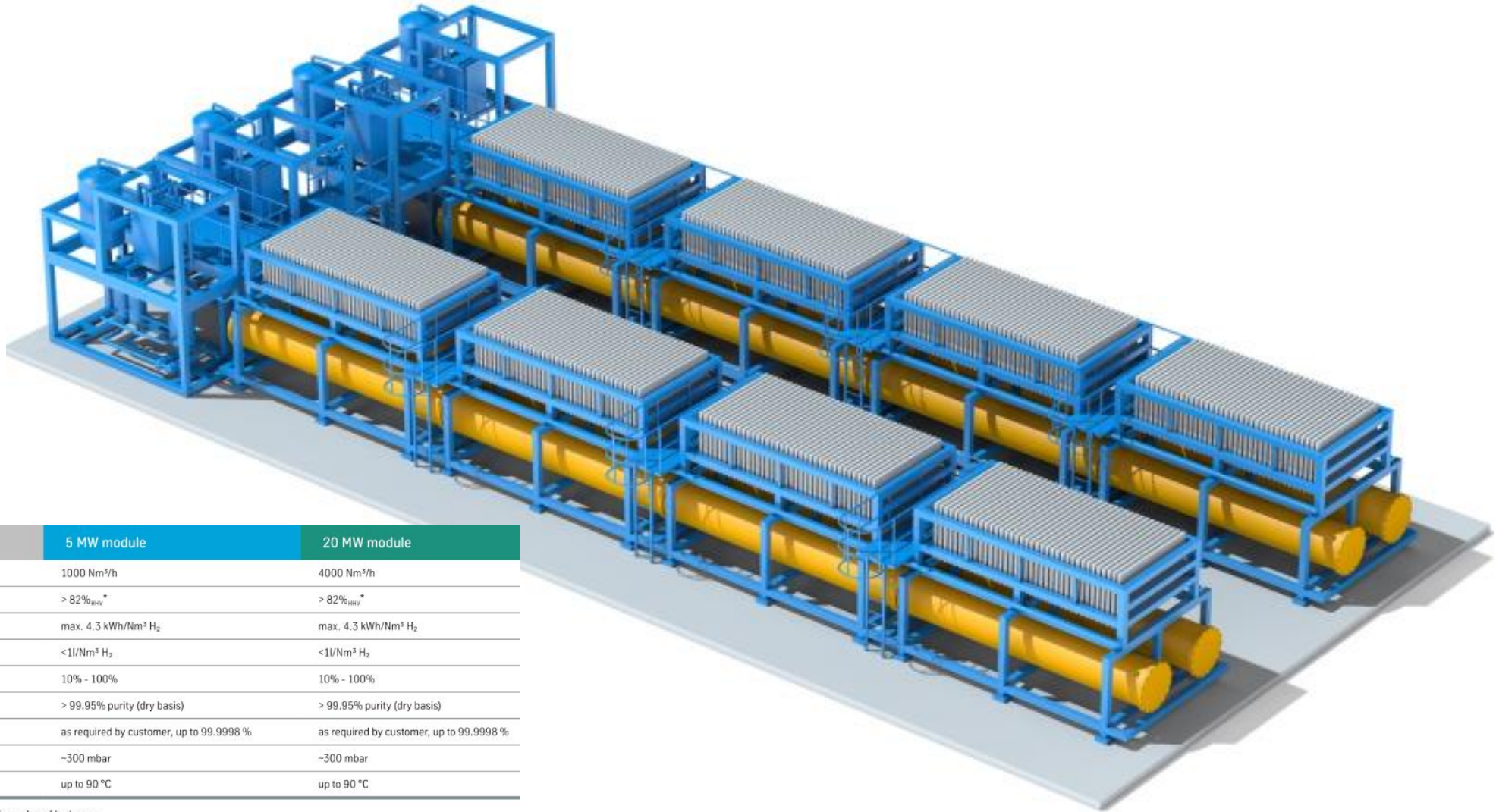
# Hydrogen production

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)



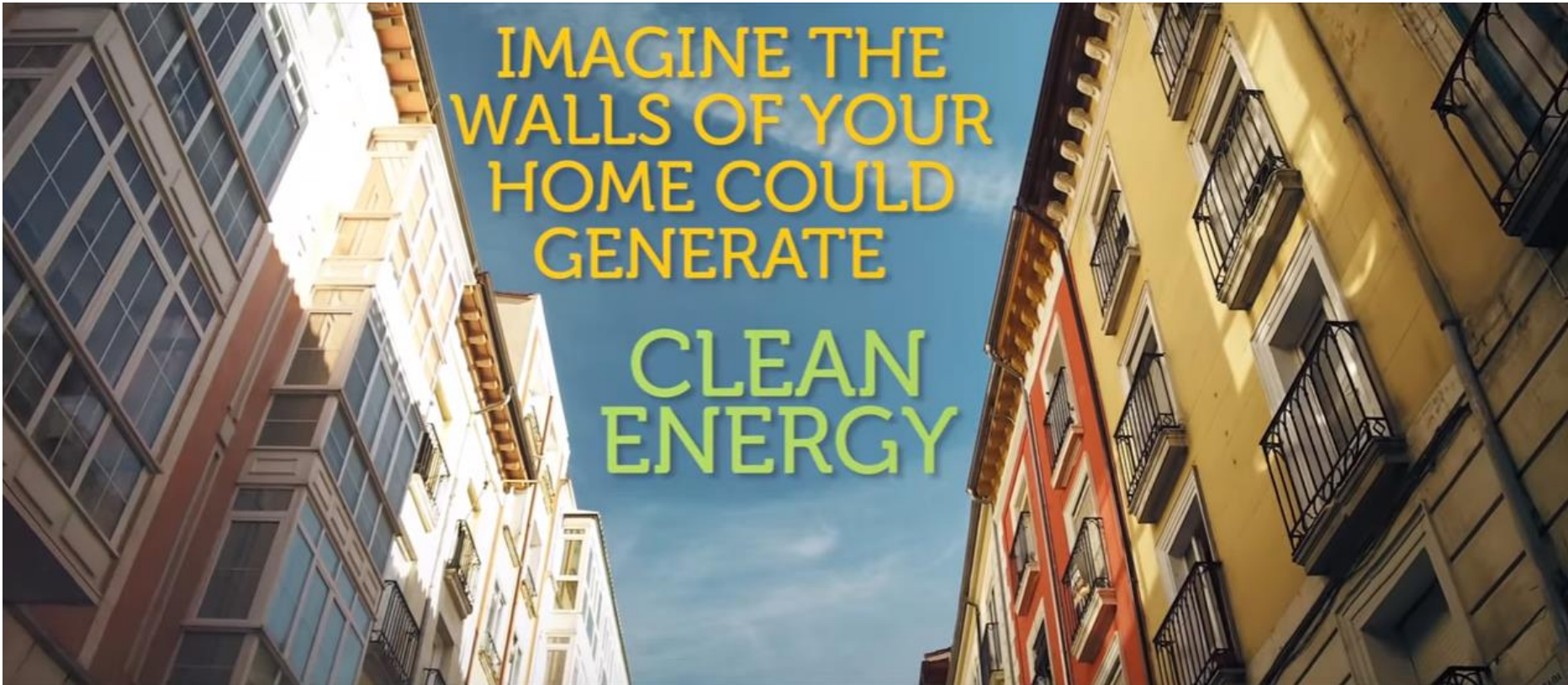


# 20 MW Alkaline Electrolyser



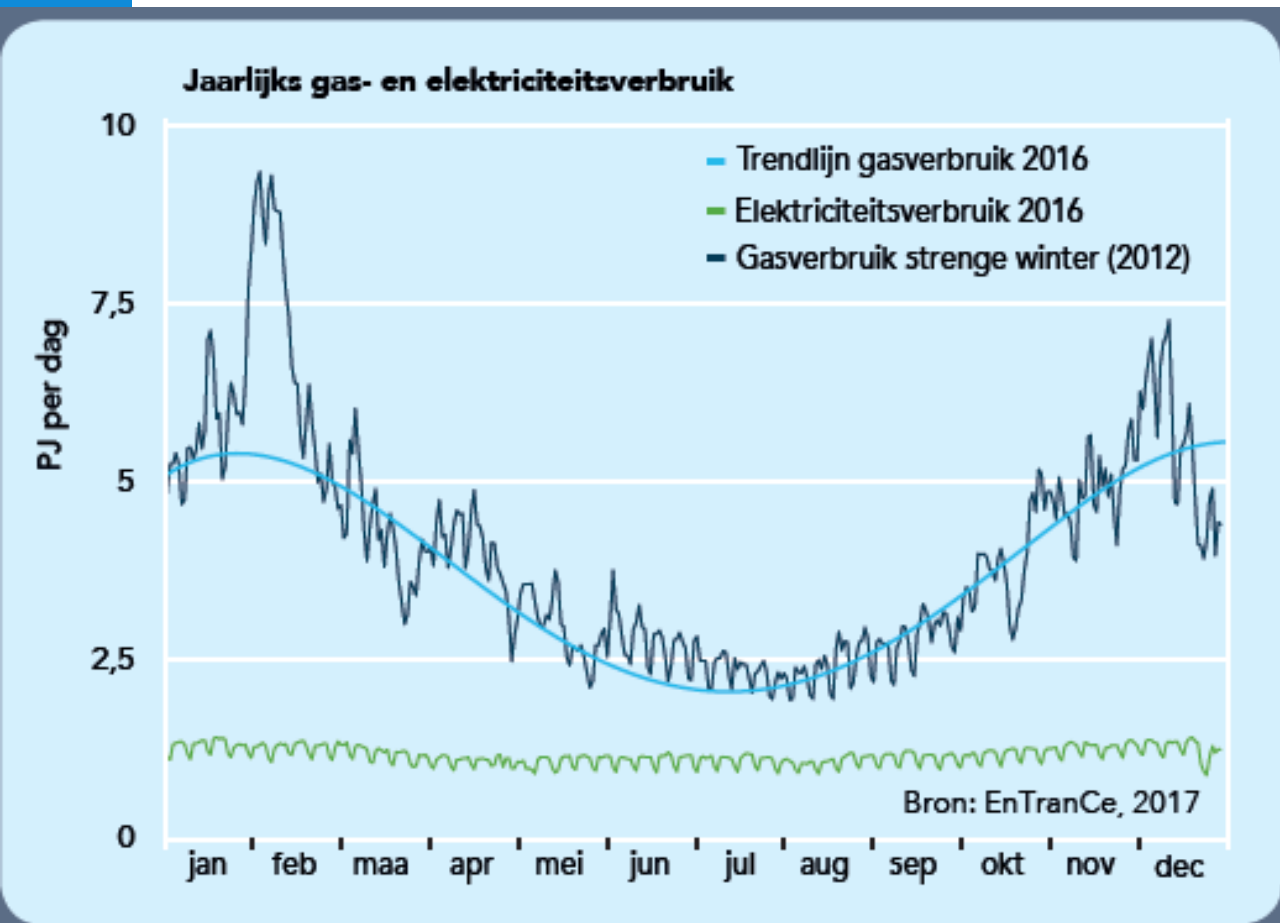
	5 MW module	20 MW module
Design capacity H <sub>2</sub>	1000 Nm <sup>3</sup> /h	4000 Nm <sup>3</sup> /h
Efficiency electrolyzer (DC)	> 82% <sub>HHV</sub> *	> 82% <sub>HHV</sub> *
Power consumption (DC)	max. 4.3 kWh/Nm <sup>3</sup> H <sub>2</sub>	max. 4.3 kWh/Nm <sup>3</sup> H <sub>2</sub>
Water consumption	<1l/Nm <sup>3</sup> H <sub>2</sub>	<1l/Nm <sup>3</sup> H <sub>2</sub>
Standard operation window	10% - 100%	10% - 100%
H <sub>2</sub> product quality at electrolyzer outlet	> 99.95% purity (dry basis)	> 99.95% purity (dry basis)
H <sub>2</sub> product quality after treatment (optional)	as required by customer, up to 99.9998 %	as required by customer, up to 99.9998 %
H <sub>2</sub> product pressure at module outlet	~300 mbar	~300 mbar
Operating temperature	up to 90 °C	up to 90 °C

\* HHV = calculated with reference to higher heating value of hydrogen.  
All values may vary depending on operating conditions.





# Gas and electricity consumption in the Netherlands



# Solar power production in Germany

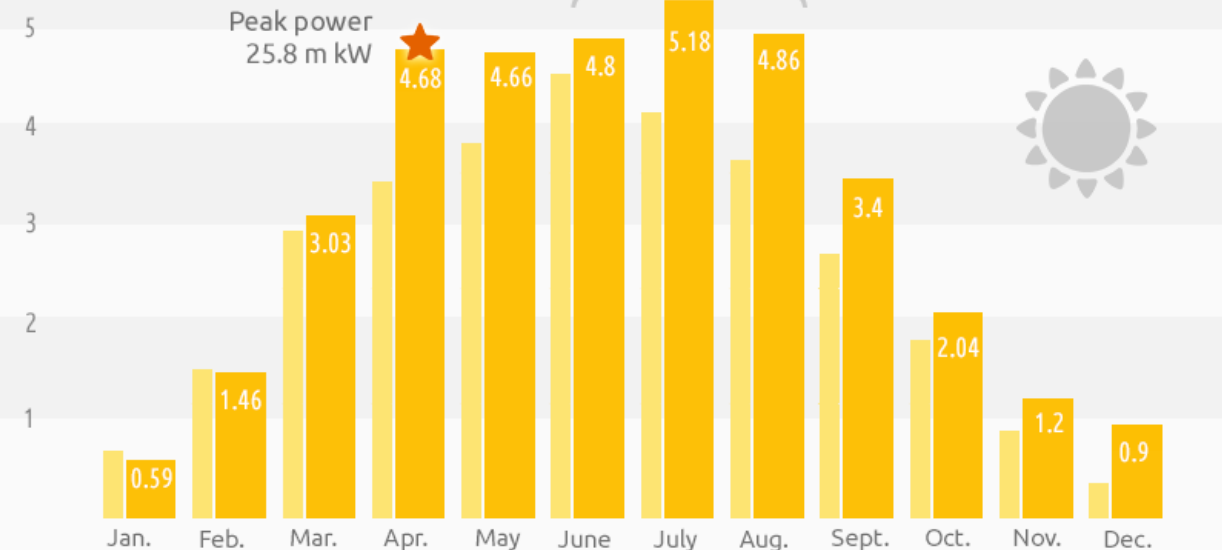
## SOLAR POWER GENERATION IN GERMANY 2015

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

⚡ 36.8 bn kWh in 2015

⚡ 34.9 bn kWh in 2014

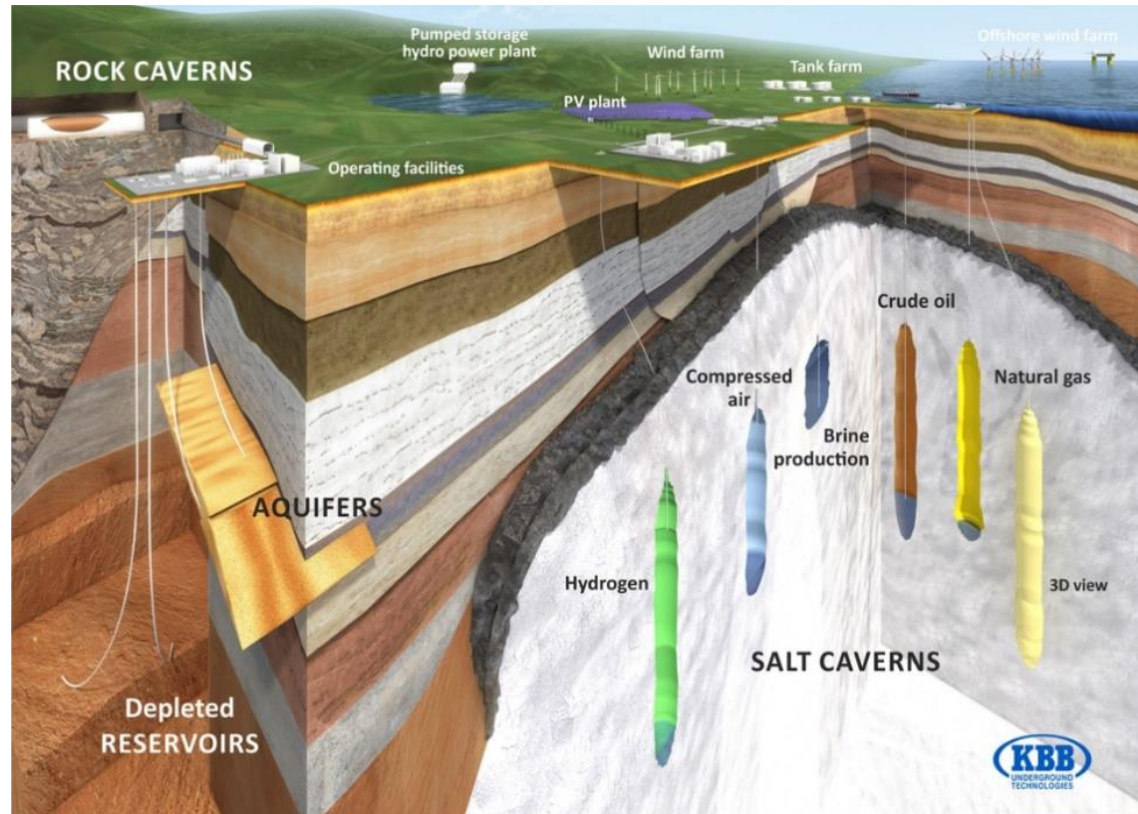
Summer record  
14.1 bn kWh



Source 2014, 2015: Fraunhofer ISE, EEX

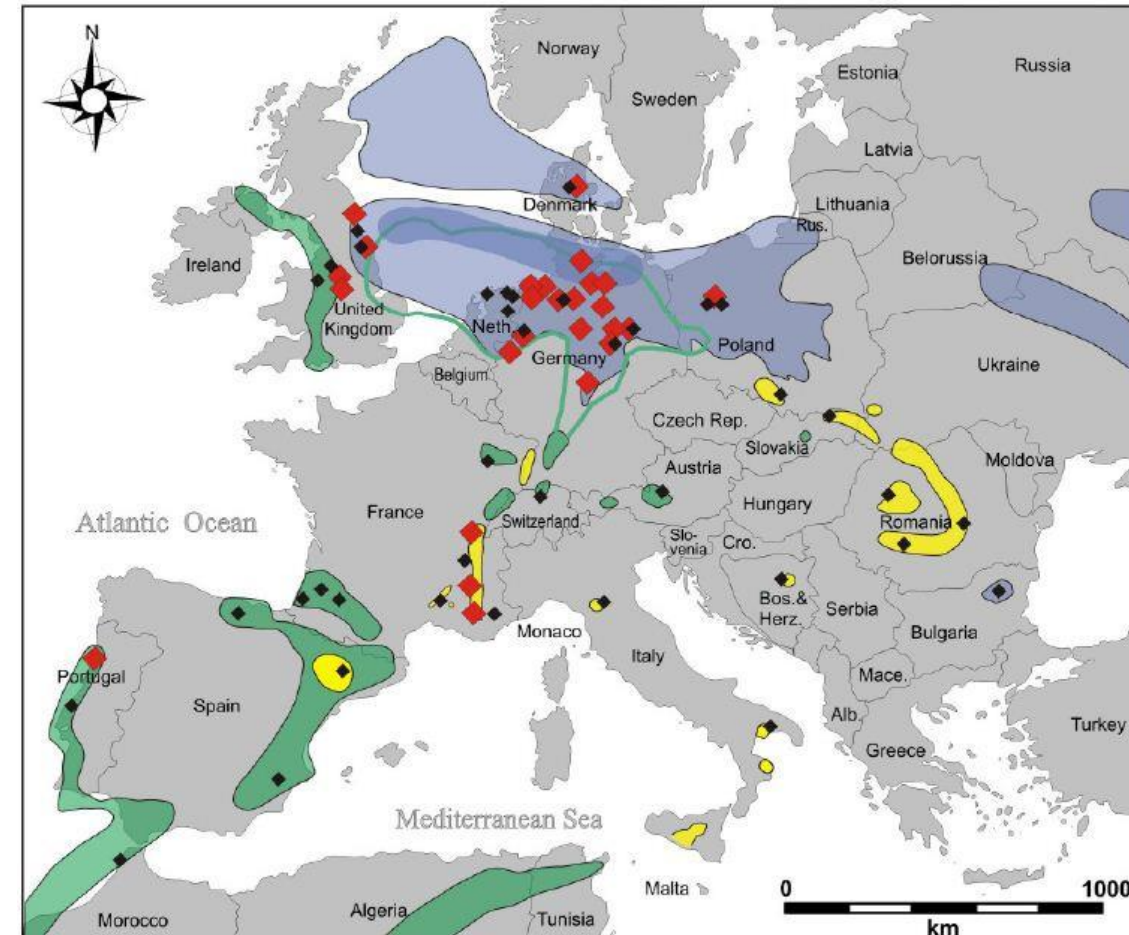
CC BY NC ND STROM-REPORT.DE

# Hydrogen storage in Salt Caverns



**1 salt cavern can contain 6,000 ton hydrogen  
Equivalent of 240 GWh or 17 million home batteries (14 kWh)**

# Salt formations and caverns in Europa



**Red colored caverns in use for natural gas storage**



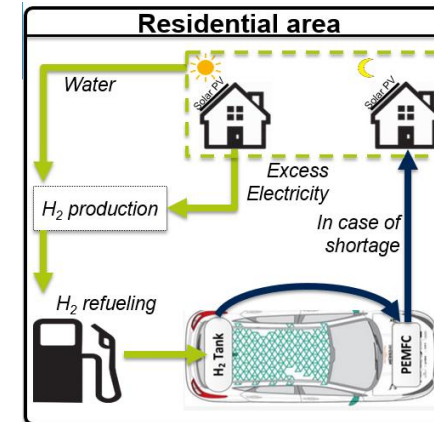
# Green Hydrogen Markets

## Chemical

### Feedstock/Steam



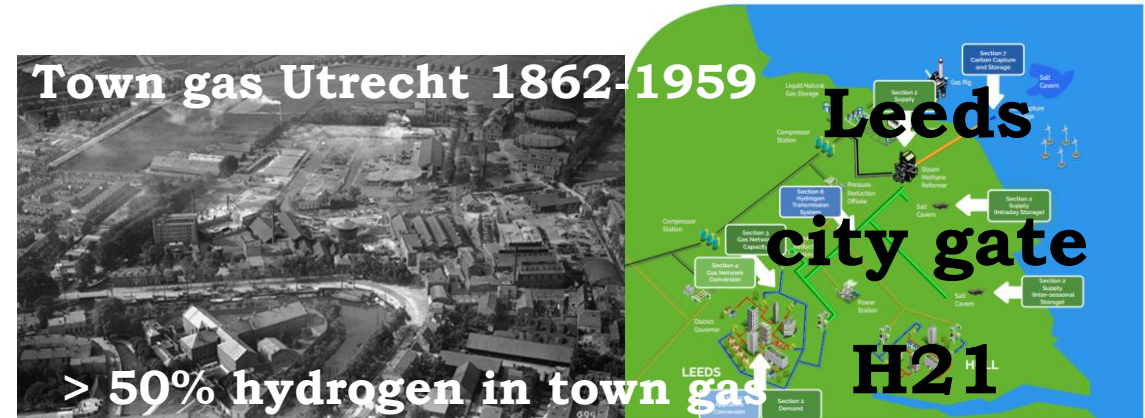
## Electricity Balancing



## Transport



## Heating



# The Future is Electric!



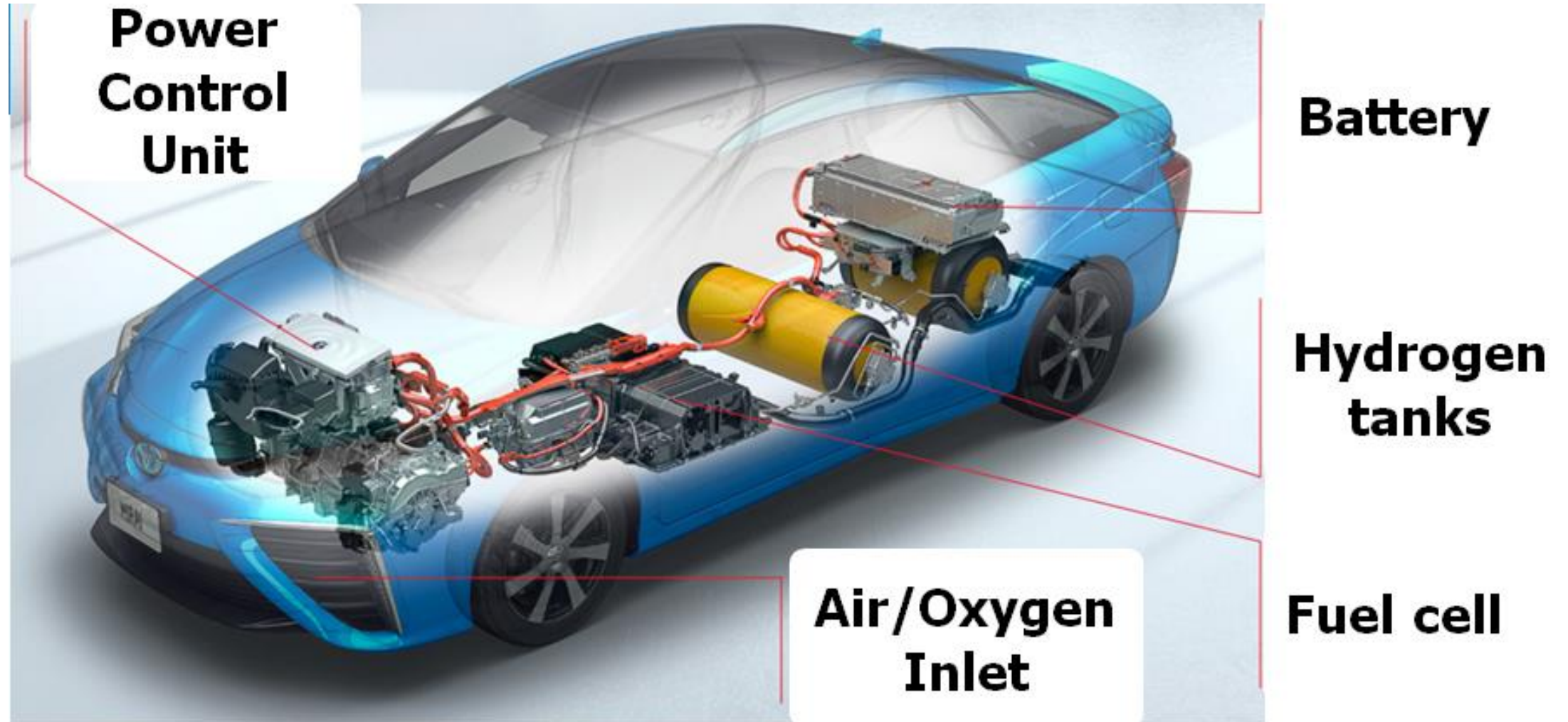
**Tesla Model S**



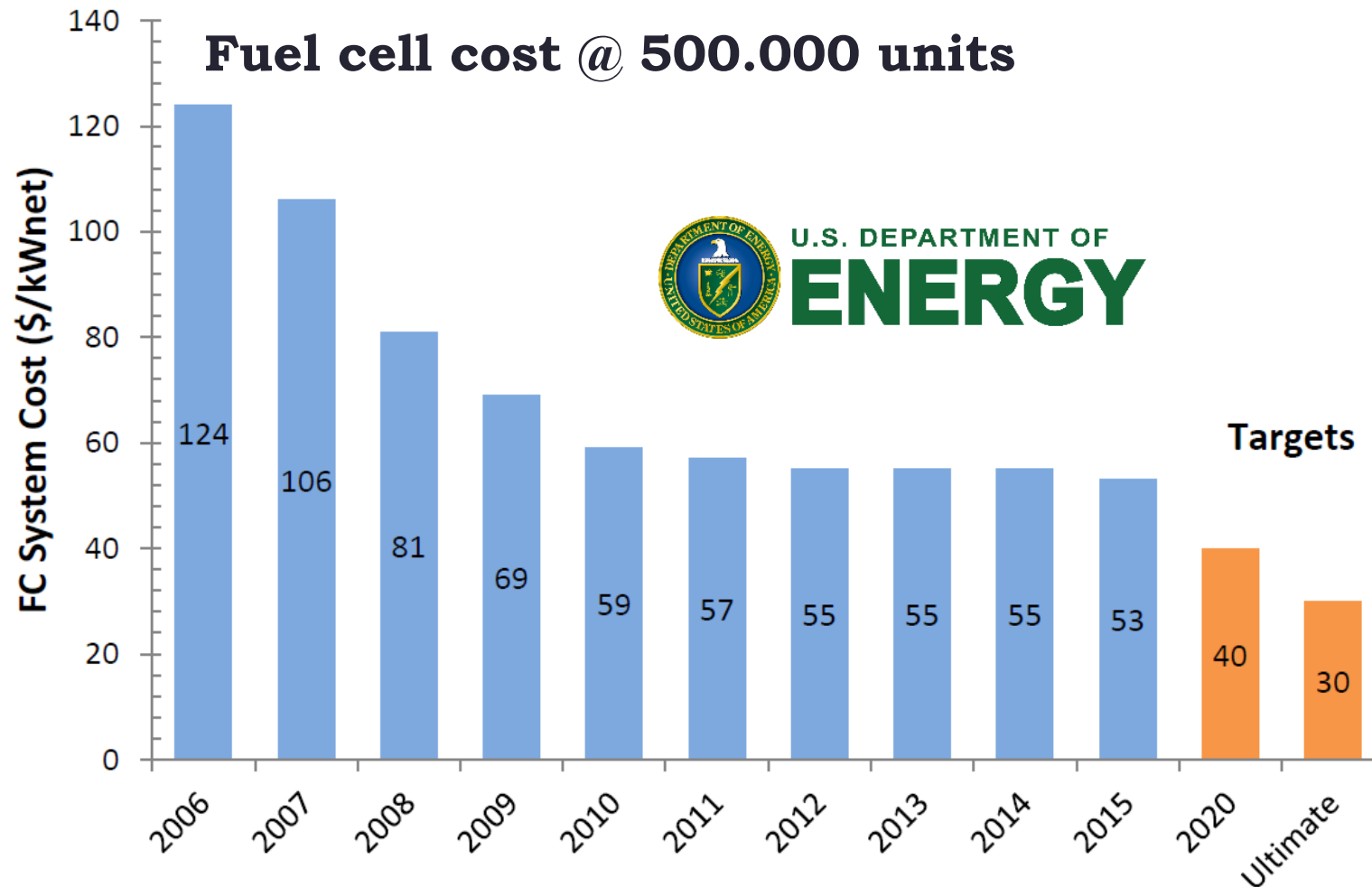
**Toyota Mirai**



# Toyota Mirai; Fuel cell car



# Fuel cell cost

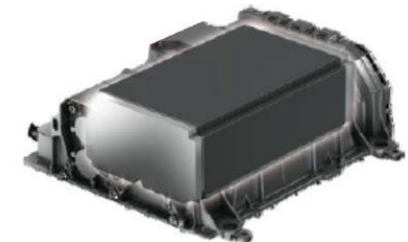


**TOYOTA**

2008 FUEL CELL STACK



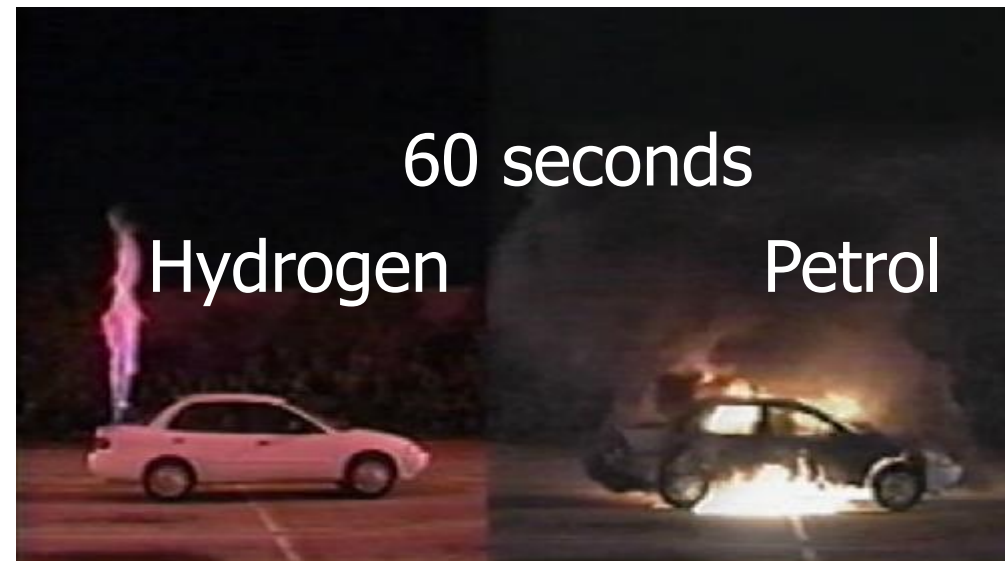
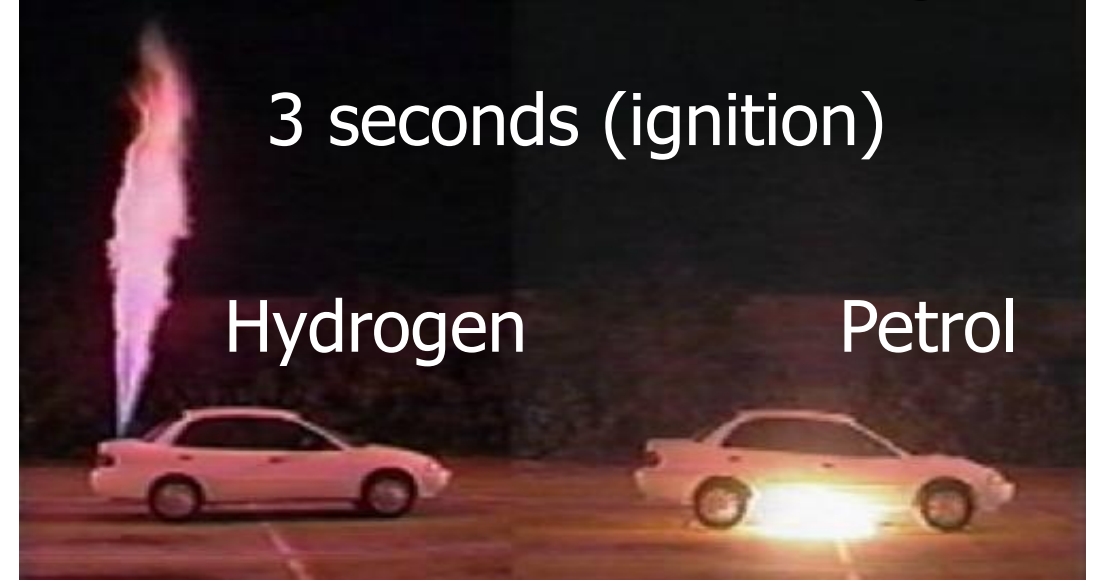
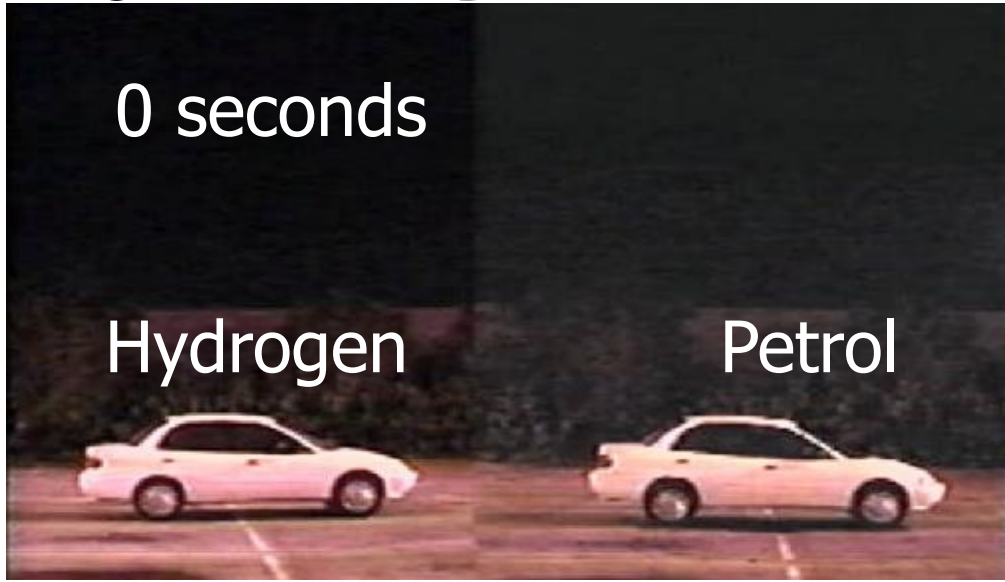
Weight **-48%** Volume **-43%** Power **+26%**



2016 FUEL CELL STACK

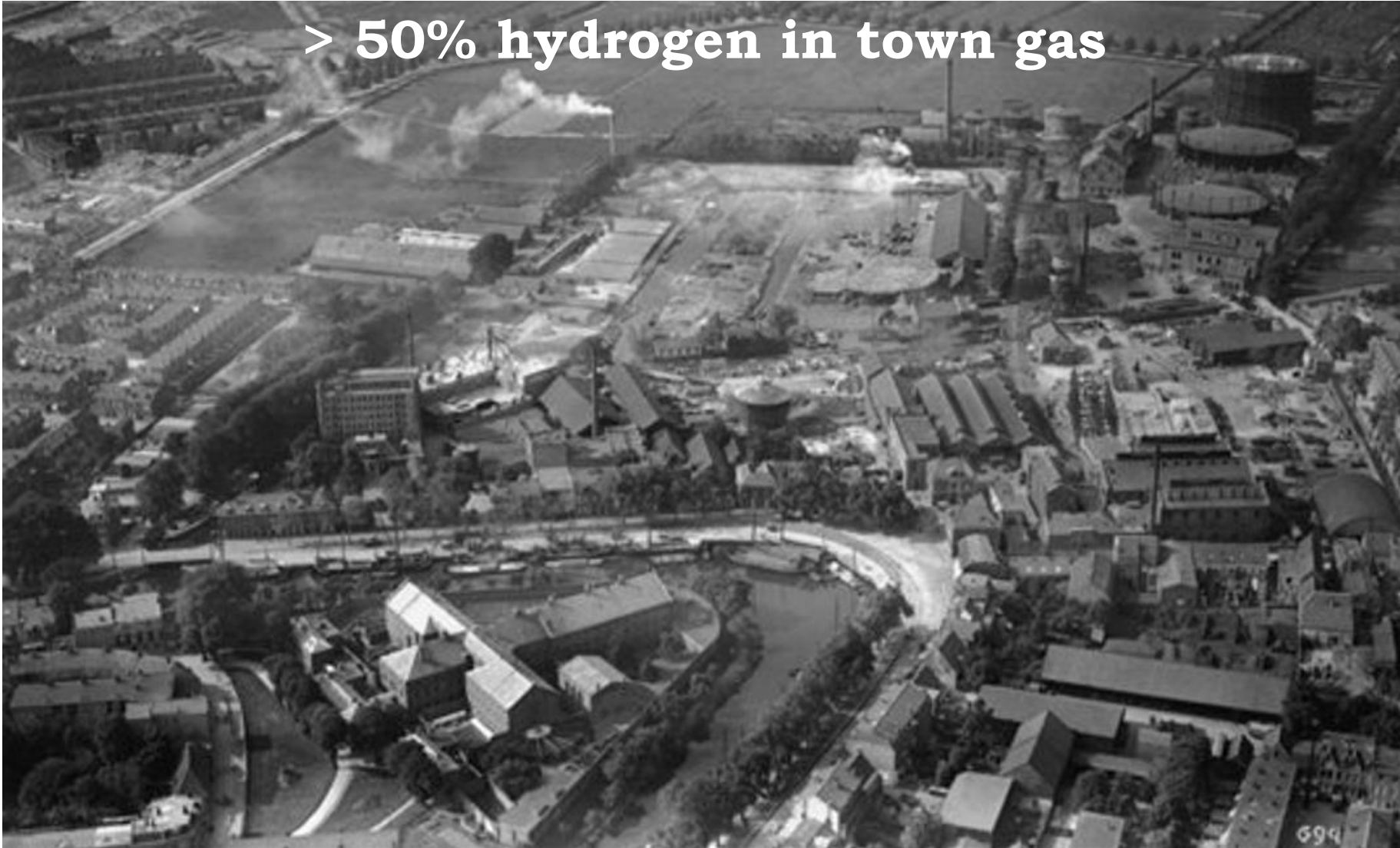


# Hydrogen versus petrol safety



# Town Gas production Utrecht 1862-1959

> 50% hydrogen in town gas





# Remeha Hydrogen Boiler



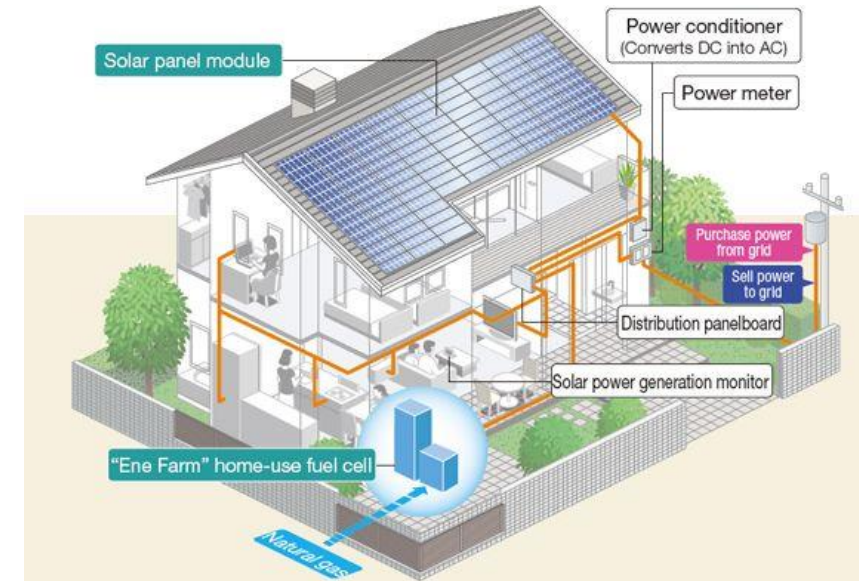
# Ene Farm: Home Fuel cell systems Japan

- Japan 200.000 sold 2017
- Aim 1.4 million end 2020
- Panasonic with Viesmann started sales in UK and Germany in 2017
- Kyocera makes systems for restaurants, hotels, etc.



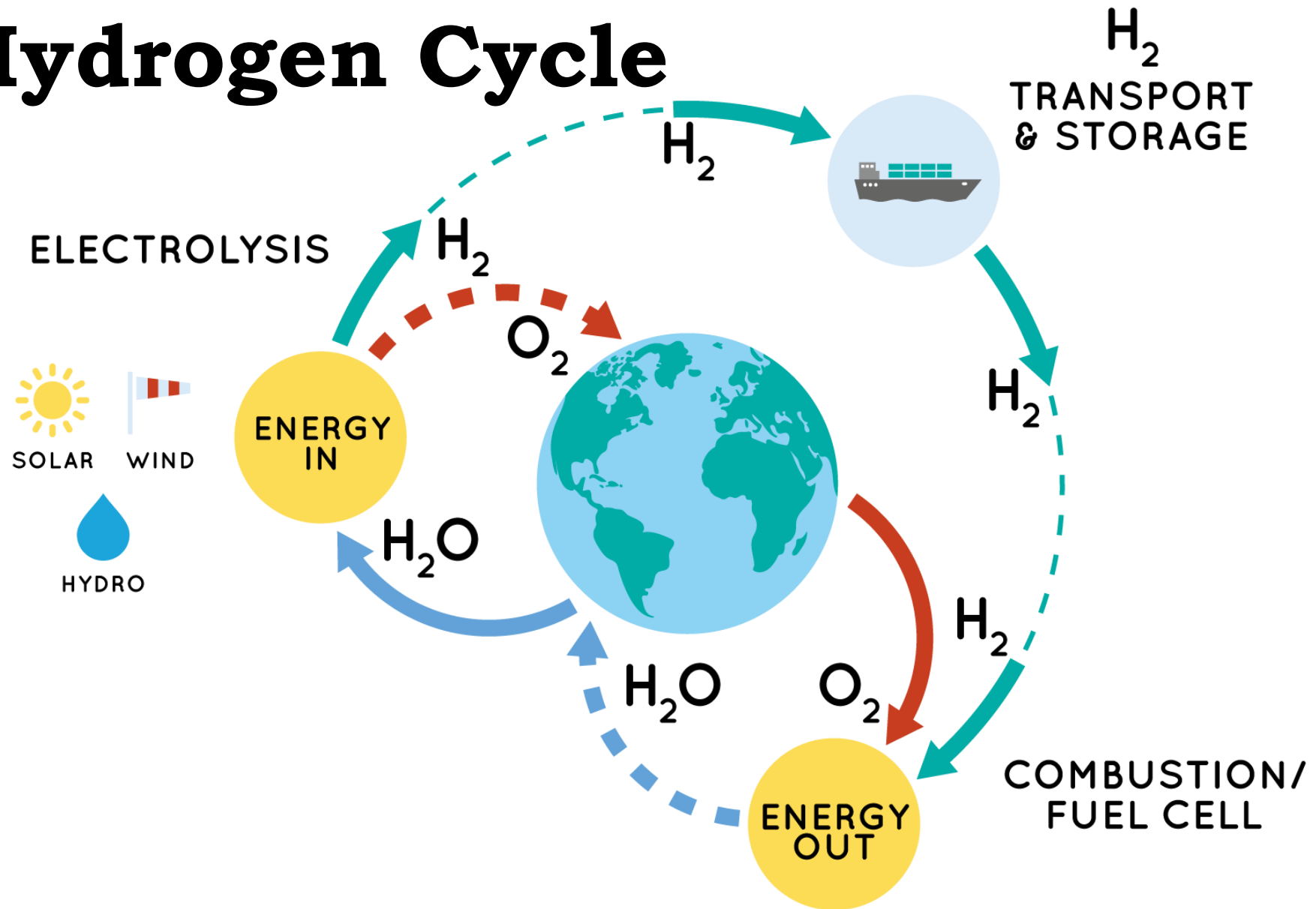
Hot water unit

Fuel cell





# The Hydrogen Cycle



# Defying Death Valley





# Further reading about hydrogen

[www.profadvanwijk.com](http://www.profadvanwijk.com)

