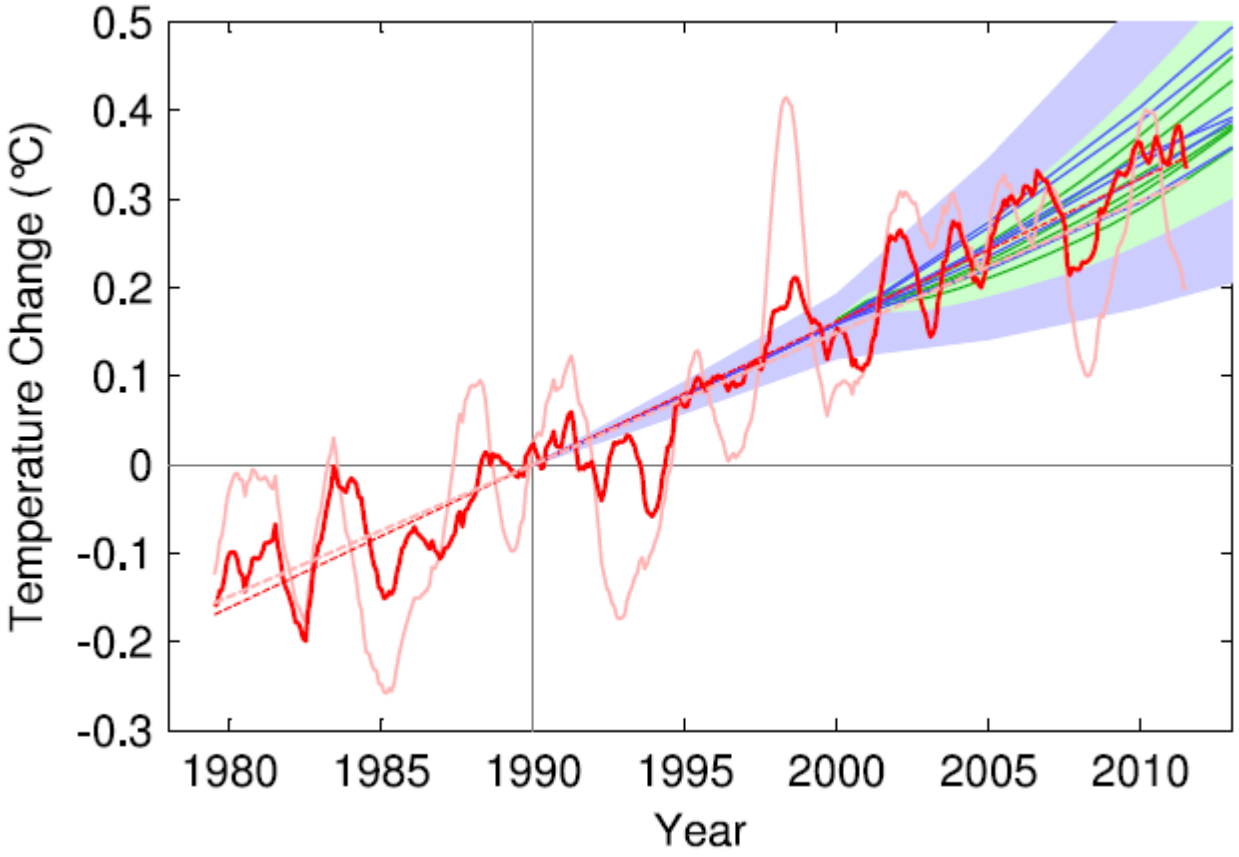
Waterstof als energiedrager

Bernard Dam

MECS, Chemical Engineering, Faculty of Applied Science, Delft University of Technology

Transitie naar een duurzame energiehuishouding is urgent!



Temperatuur (rose) gecorrigeerd voor intensiteit zon, vulkaan activiteit en aerosolen (rood) volgt de IPCC voorspellingen (groen)

Environ. Res. Lett. **7** (2012) 044035

Waterstof als brandstof

1-cylinder Hydrogen Vehicle by Lenoir, 1860

Hydrogen Space Shuttle 1980

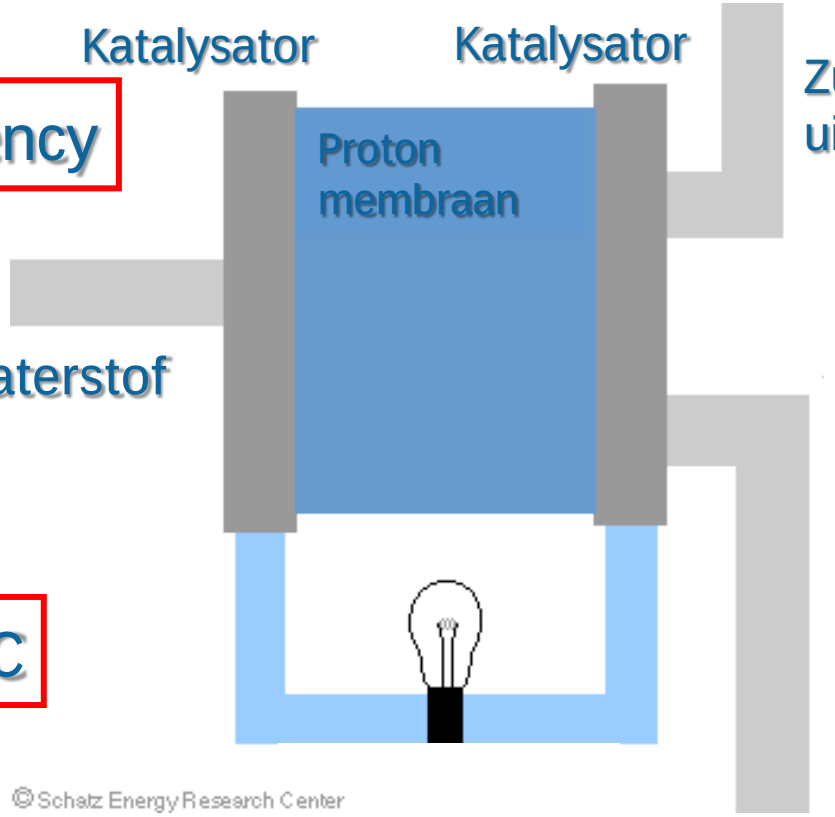
Ford Model U Hydrogen ICE Vehicle 2004

Hydrogen ScramJet Nasa 2004

Internal Combustio
Hydrogen Engine
2004

Brandstofcel

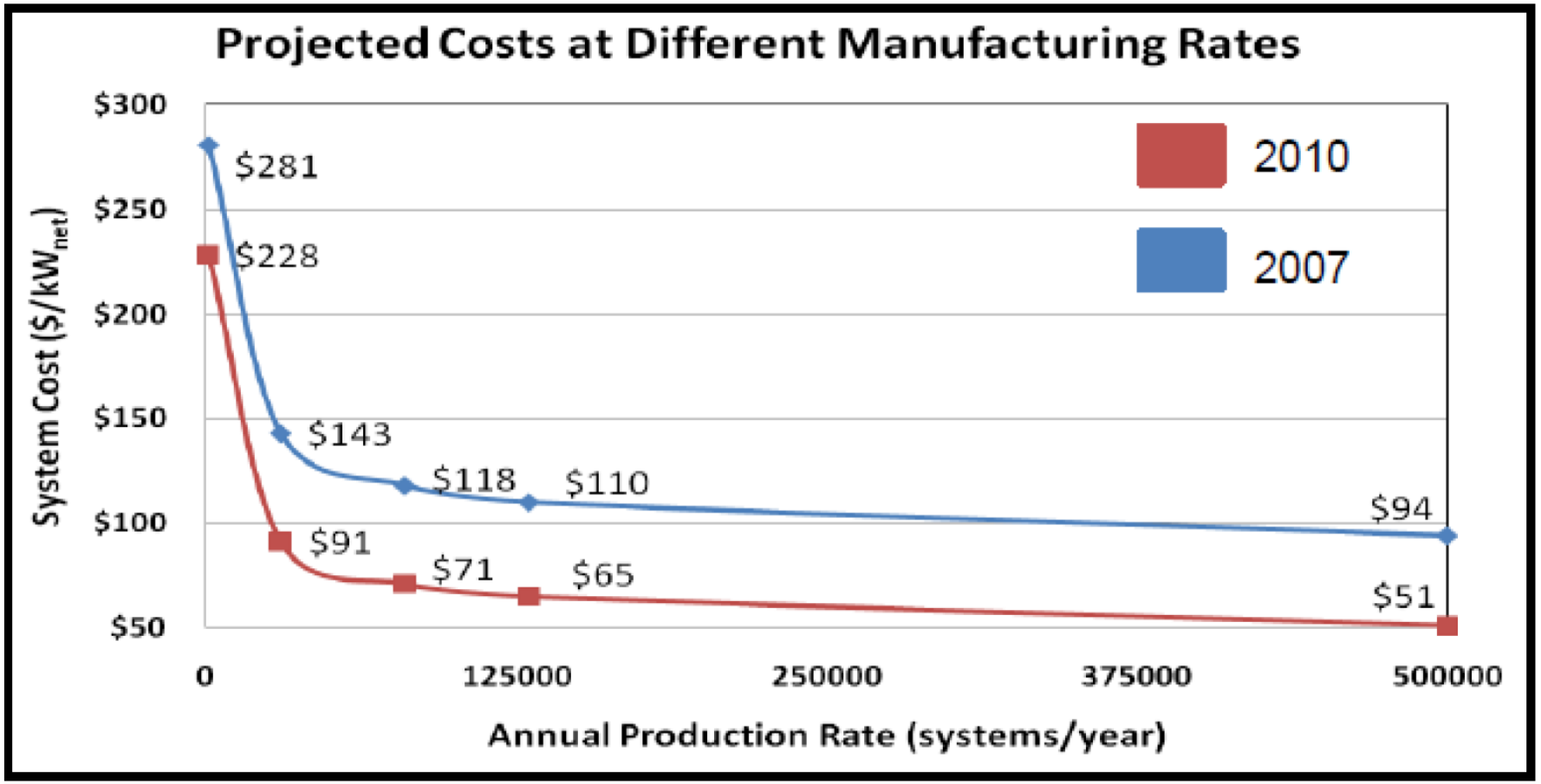
40-50% efficiency



Werkt bij 80 °C

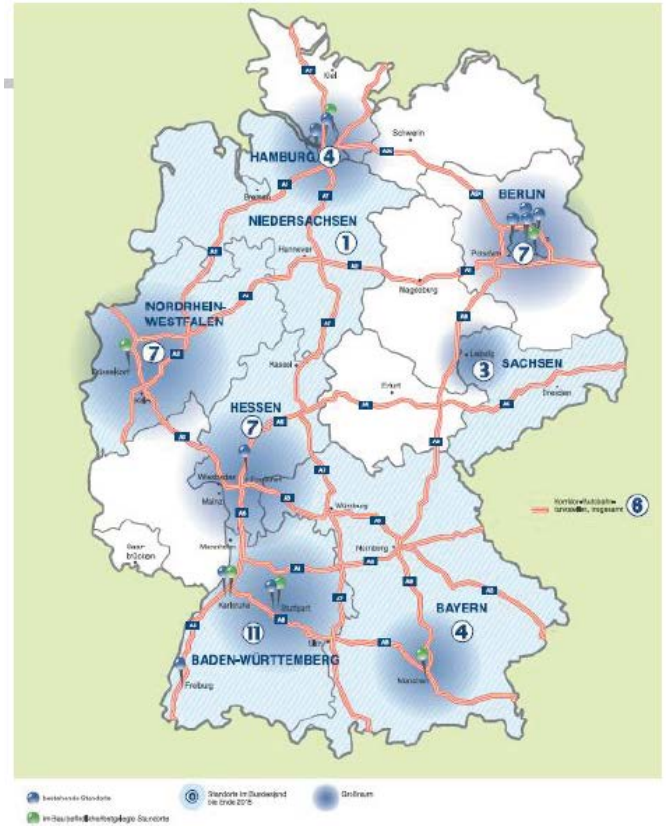
Waterstof + Zuurstof => water + elektriciteit

Huidige technologie is in staat een lage prijs te realiseren bij massa productie



Hyundai als eerste op de markt, anderen zullen in 2015 volgen

Publiek-private partnerschappen



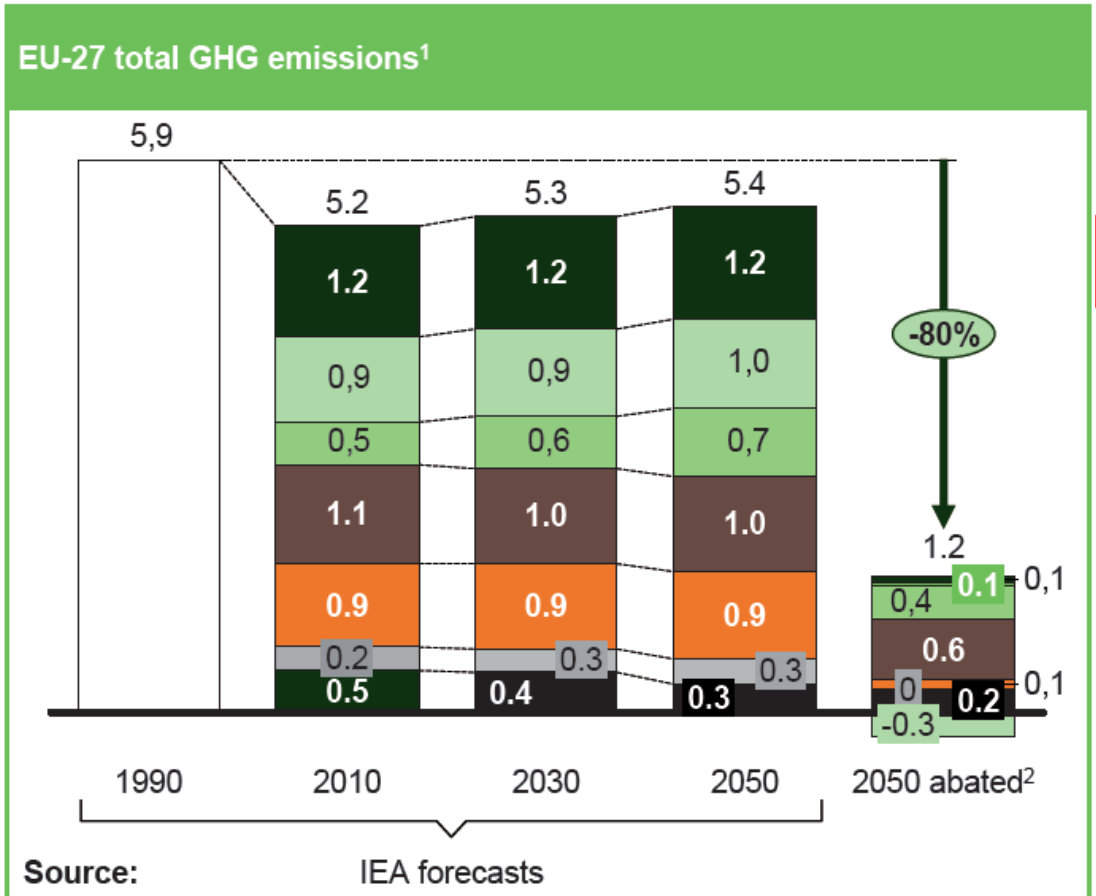
„To facilitate market introduction [of fuel cell vehicles] we need a hydrogen station network covering and connecting the metropolitan regions.“

Dr. Peter Ramsauer, Federal Minister for Transport, Building and Urban Development

UK H_2 Mobility

McKinsey 2011: electrification of road transport is needed to achieve the required level of CO_2 abatement

Gt CO2e per year



Sector	Total abatement
Power	95-100%
Road transport	95%
Air & sea transport	50%
Industry[3]	40%
Buildings	95%
Waste	100%
Agriculture	20%
Forestry	-0.25 Gt CO_2e

1 Large efficiency improvements are already included in the baseline based on the International Energy Agency, World Energy Outlook 2009, especially for industry
2 Abatement estimates within sector based on Global GHG Cost Curve
3 CCS applied to 50% of large industry (cement, chemistry, iron and steel, petroleum and gas, not applied to other industries)

SOURCE: www.roadmap2050.eu

CO_2 emissions much less than ICE-hybrid

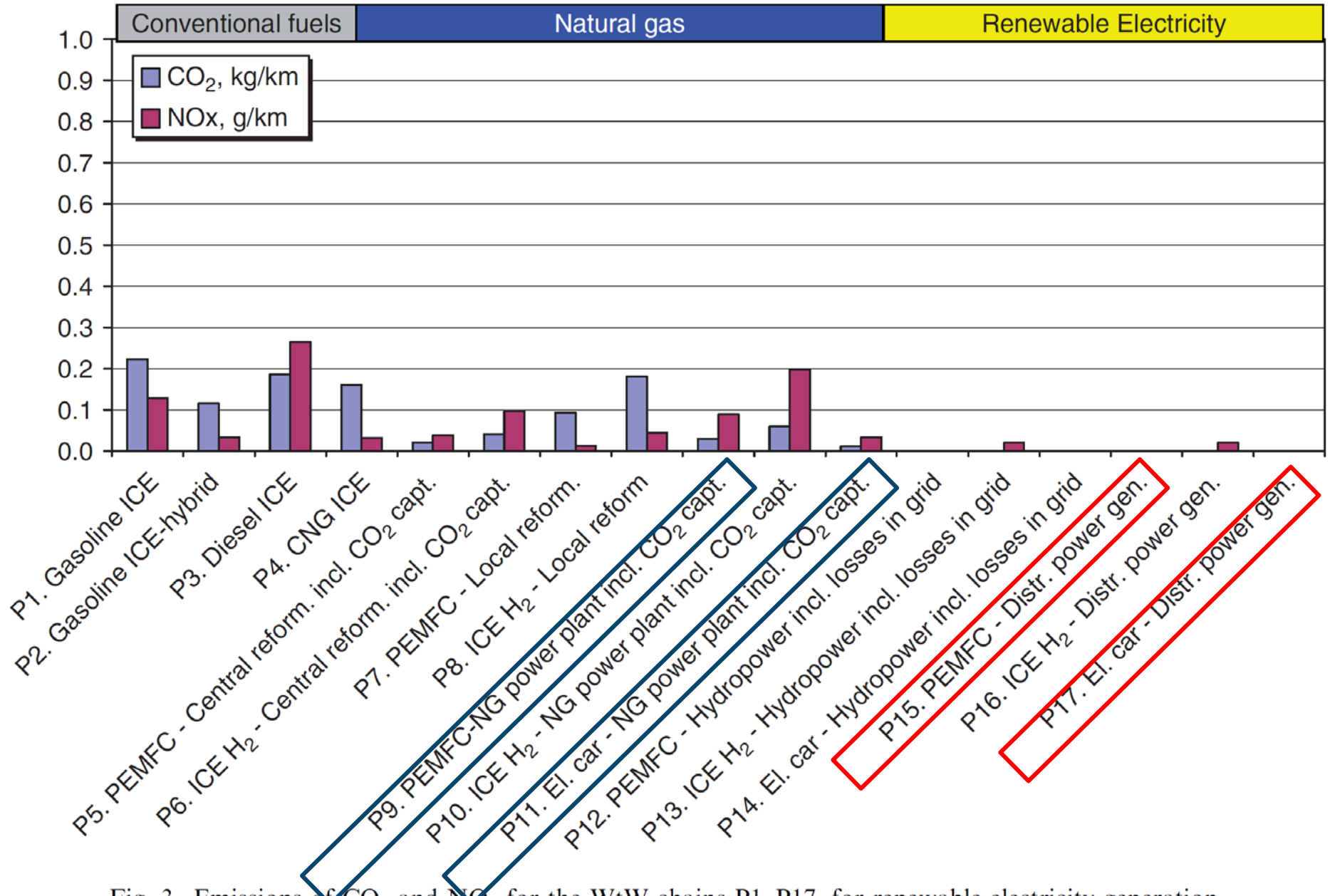
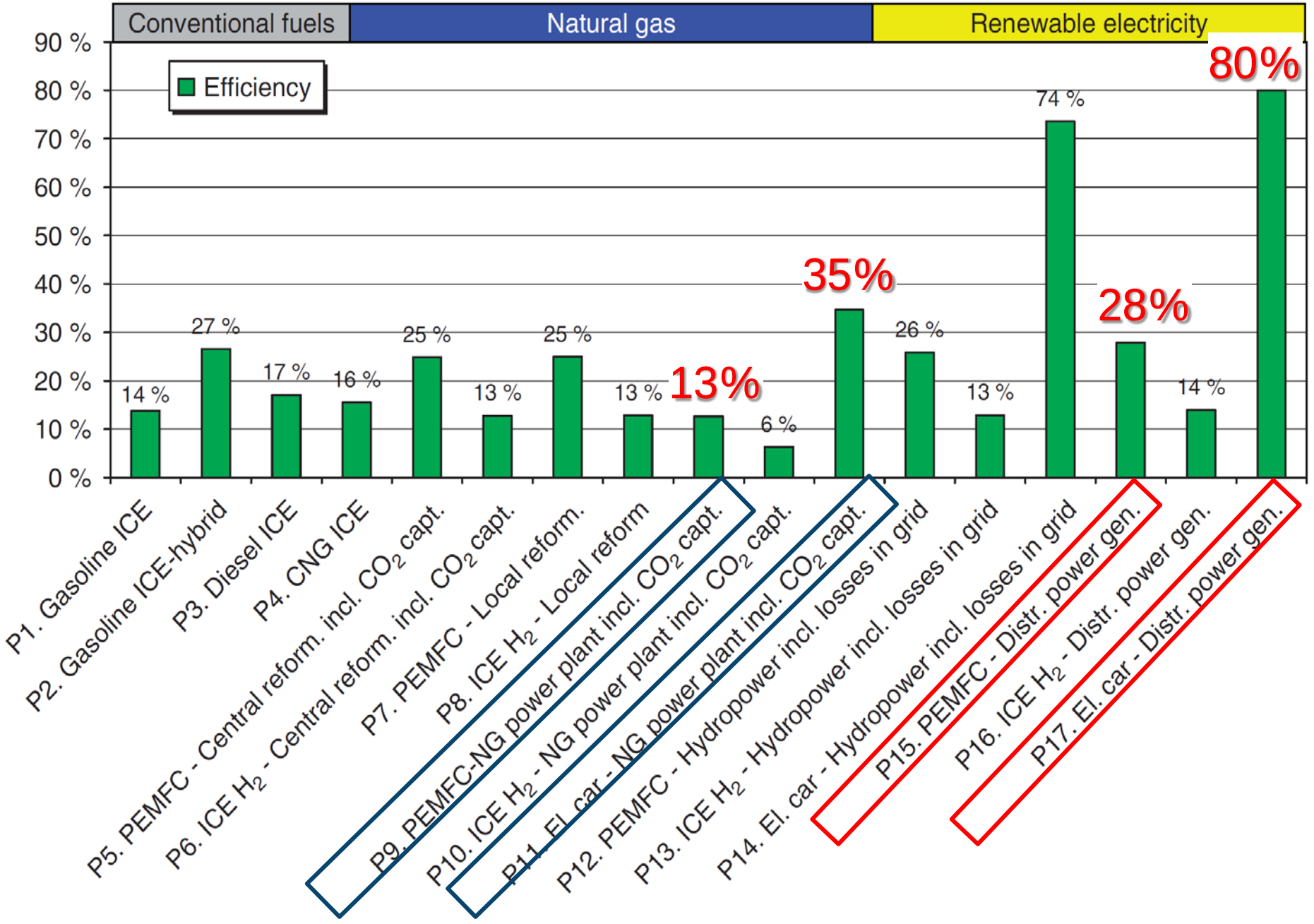


Fig. 3. Emissions of CO_2 and NO_x for the WtW chains P1–P17, for renewable electricity generation.

Well-to-wheel analysis

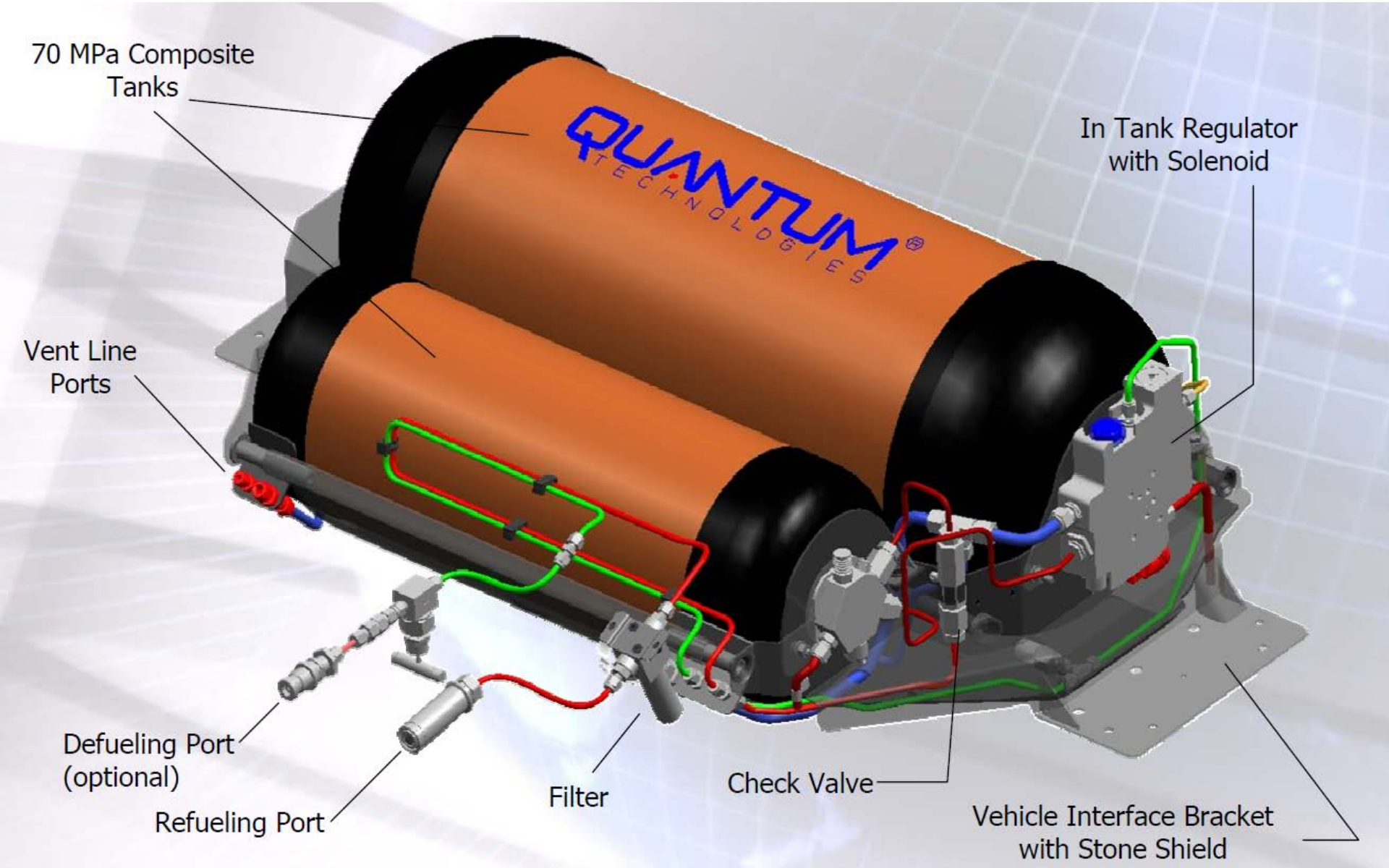
Energy 32 (2007) 437



2.

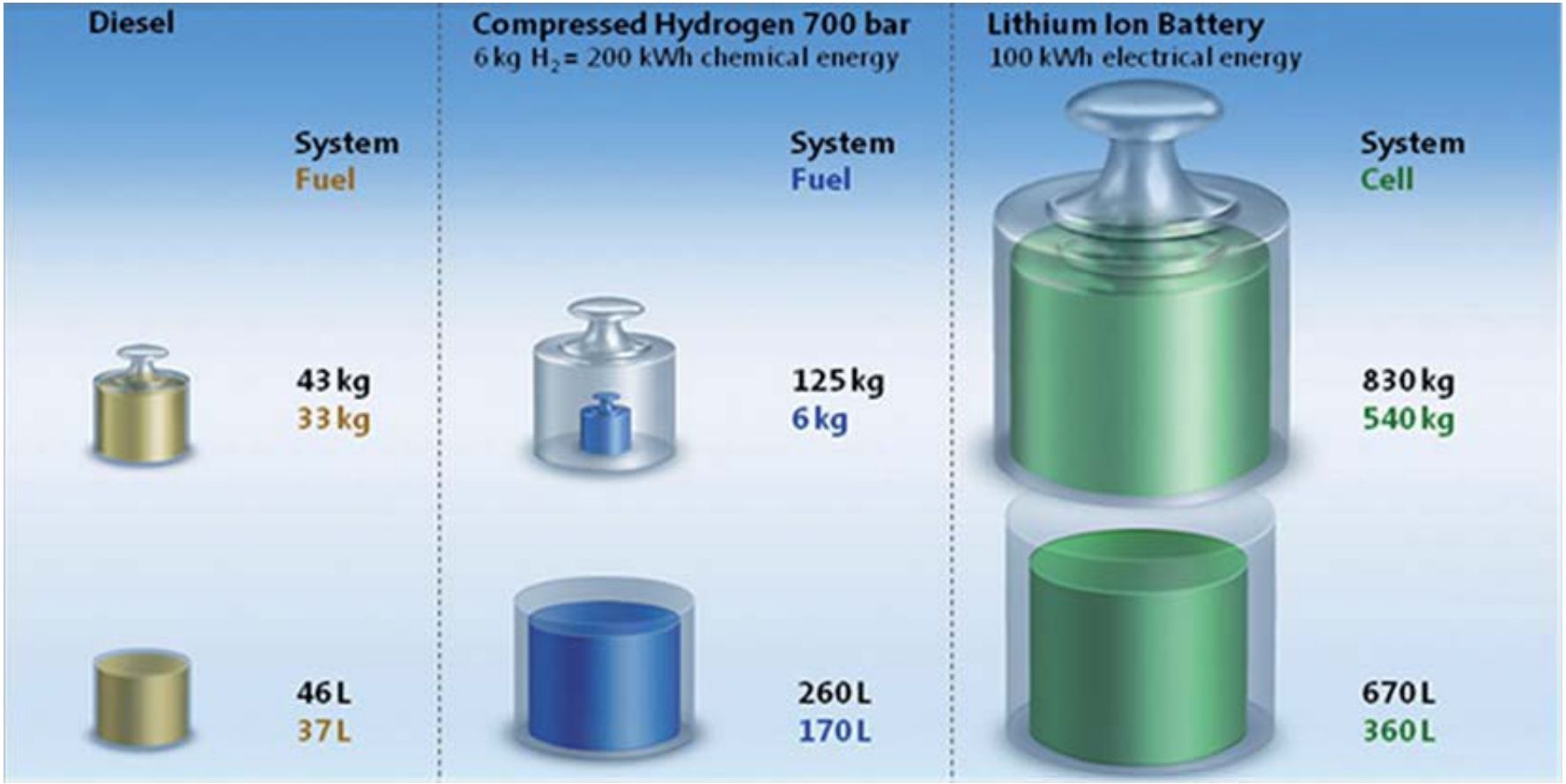
Opslag

Industrie-standaard: 700 bar cylinder



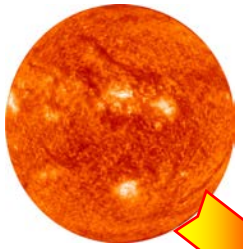
QUANTUM

Vergelijking in de capaciteit van opslagsystemen



Gebaseerd op een 500km range (Eberle, GM)

Waterstof kan ook dienen als (gedistribueerd) opslagmedium, maar dat geeft wel verliezen!



H_2O electrolyse

H_2

O_2

H_2 opslag

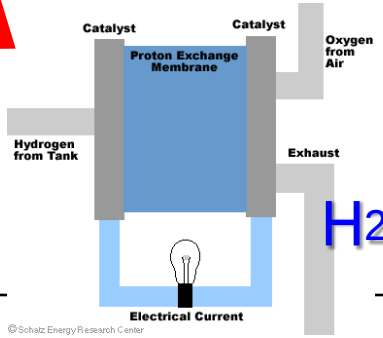
200 kWh H_2 per auto(500km bereik)

8.10^6 auto's (staan 23 uur/dag stil)

8.10^6 x 200 = 1600 GWh

0.06k€/kWh, paid by the consumer!

O_2

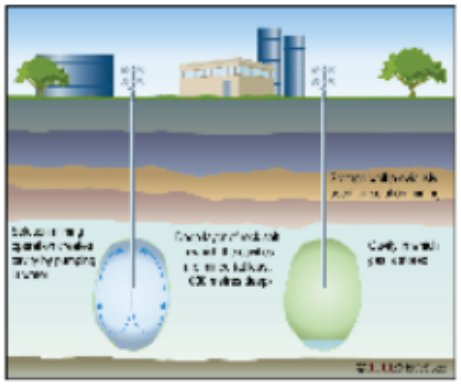


H_2

Figuur 1 Schets van het Energie-eiland.

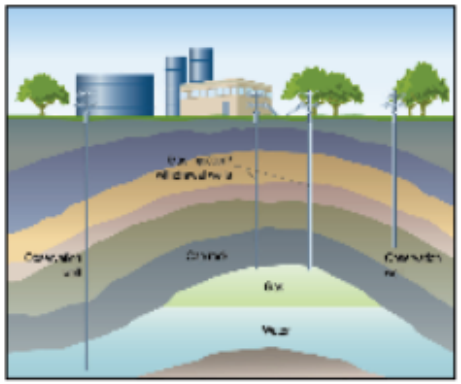
Ondergrondse waterstofopslag:

Compressed air storage in a 4.10^6 m^3 salt cavern =>8 GWh
The same amount of hydrogen converts to 12000 GWh!



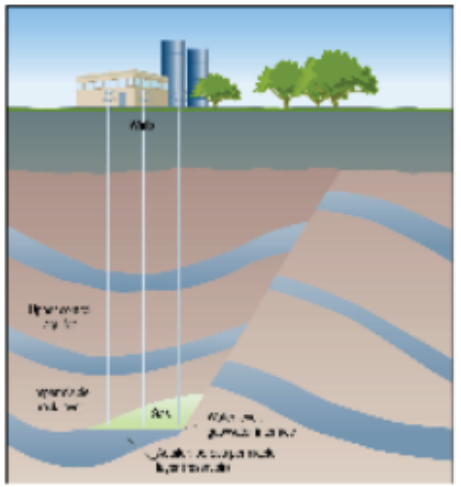
Salt Caverns

- Salt caverns are solution mined cavities within either salt domes or bedded salts that do not match reservoir volume capacity.



Depleted Oil/Gas Reservoirs

- Depleted reservoirs are proven gas reservoirs that are easy to develop and operate due to existing infrastructure.



Aquifers

- Aquifers are similar in geology to depleted reservoirs, but have not been proven to trap gas and must be developed.

Source: Anna S. Lord, Peter H. Kobos, and David J. Borns,"Underground Storage of Hydrogen: Assessing Geostorage Options with a Life Cycle Based Systems Approach", 28th USAEE/IAEE North American Conference, New Orleans, Louisiana, SAND2009-7739C. Images source: MJMENERGY.com

Sandia National Laboratories

3.

Production

Stoomreformatie van Methaan

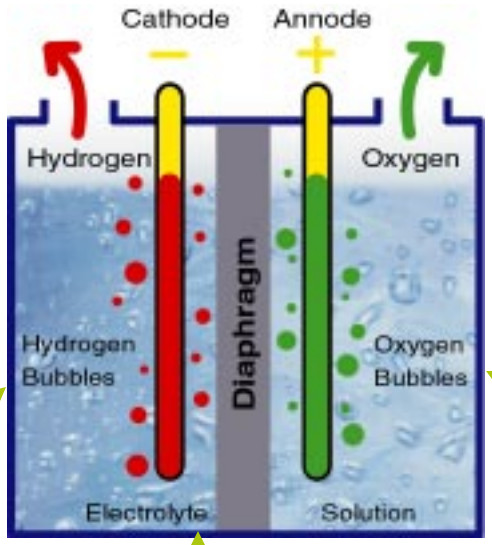
$$CH_4 + 2\ H_2O \rightarrow CO_2 + 4\ H_2$$

75 % efficiency

1euro/kg

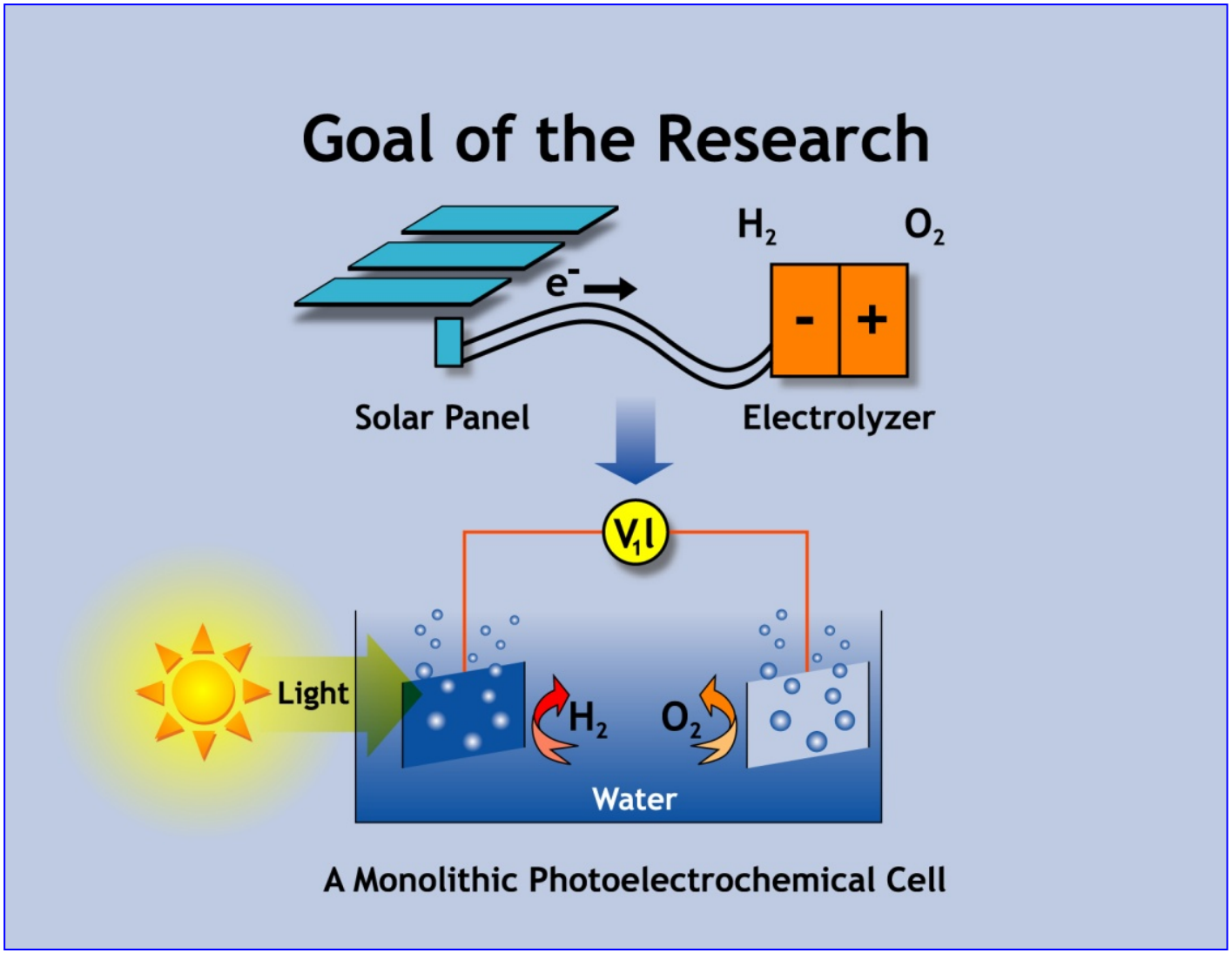
Kleine eenheden mogelijk

Duurzame waterstofproductie met electrolyse



Electrische energie wordt omgezet in chemische bindingen

Water splitting: solar panel and electrolyzer in one



Key role of hydrogen as an energy carrier to facilitate the energy transition in Germany