Centrale en decentrale reconversie van elektriciteit uit solarfuels

Bendiks Jan Boersma
b.j.boersma@tudelft.nl

Process and Energy Department

May 7, 2014

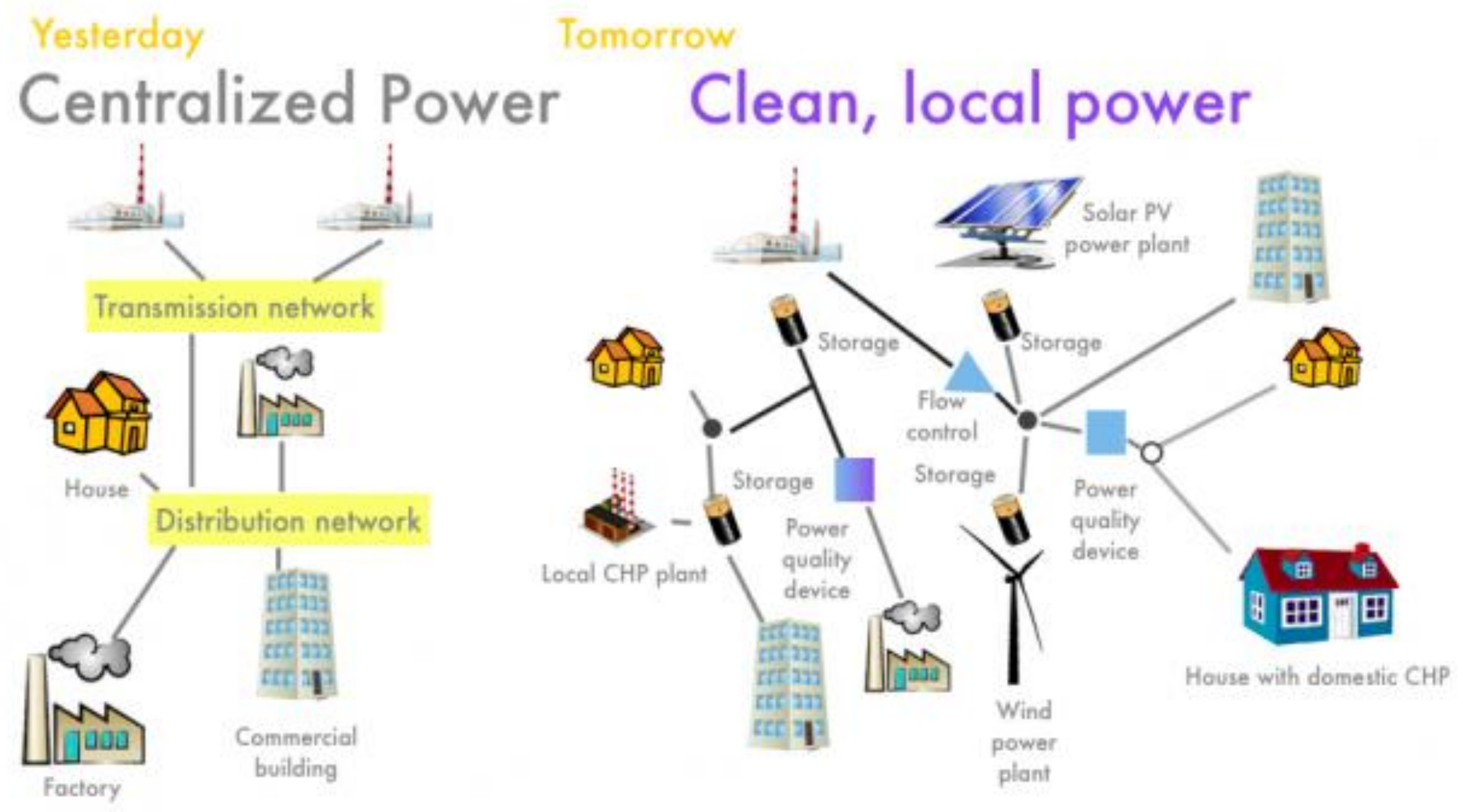
Lecture 4, chapter 2

TU Delft
Delft University of Technology

Visie 2030-

- Electriciteits overschot gedurende de zomer
- Sterke fluctuaties in electriciteits productie met verschillende tijdschalen
- Opslag is nodig voor zowel korte termijn (minuten-uren) als lange termijn (weken/maanden)
- Politieke instabiliteit zal blijven. Reken dus niet te veel op de "buren"

Centralized / decentralized



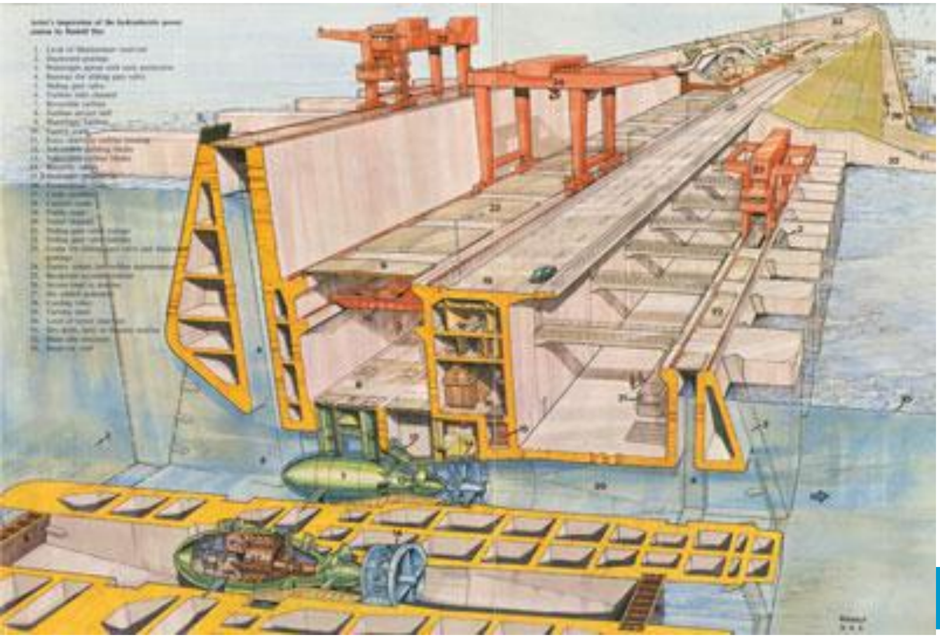
TUDelft

Opslag

- Pumped hydro
- Compressed air
- Flywheels
- Batteries

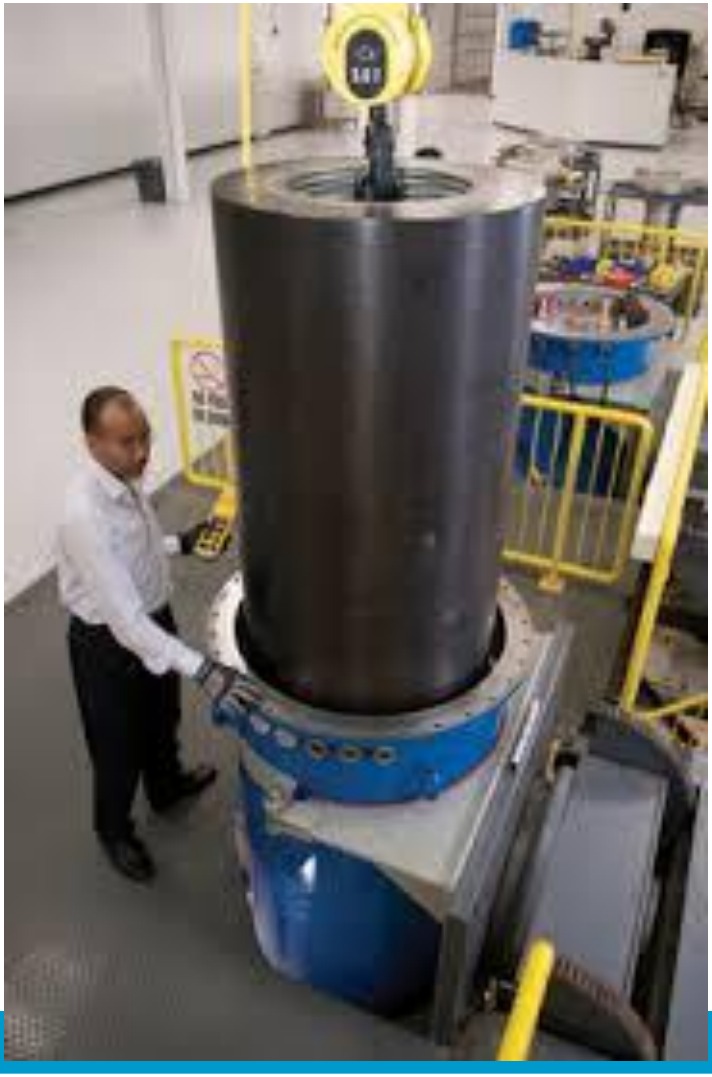
- Chemical

Pumped hydro



$$E = mgh$$

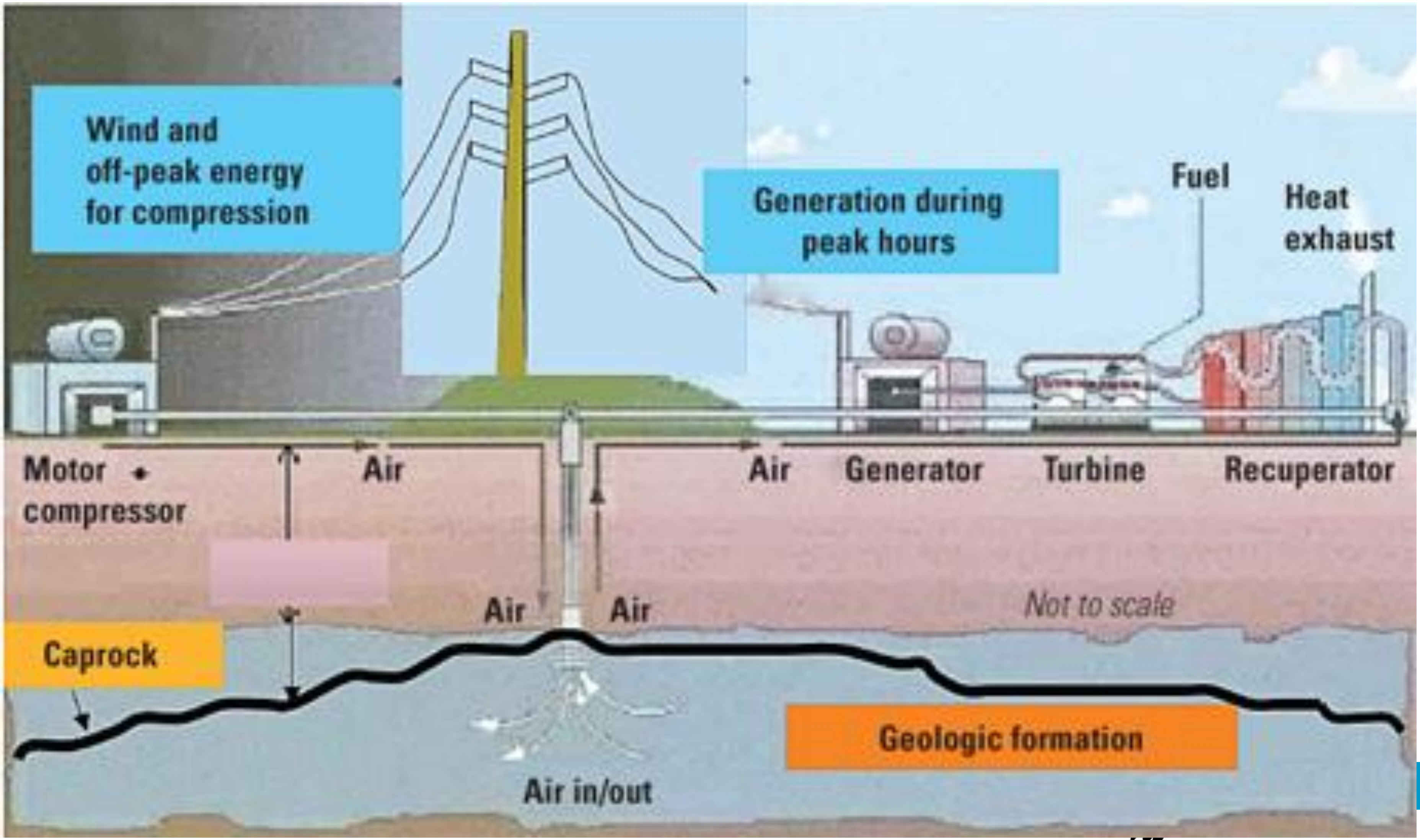
Flywheel storage



$$E = \frac{1}{2} m v^2$$

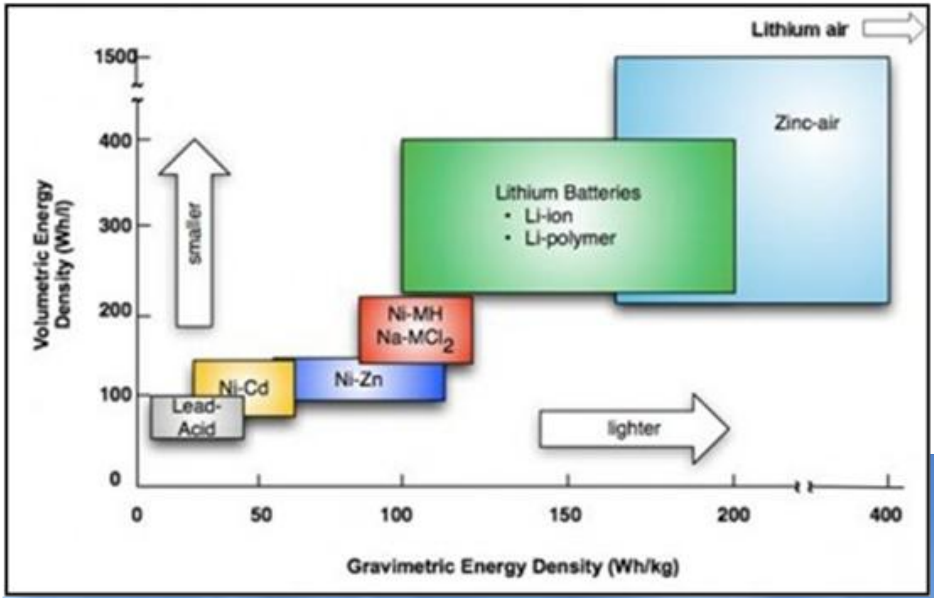
Compressed air storage

$$E = (Vol)\Delta p$$

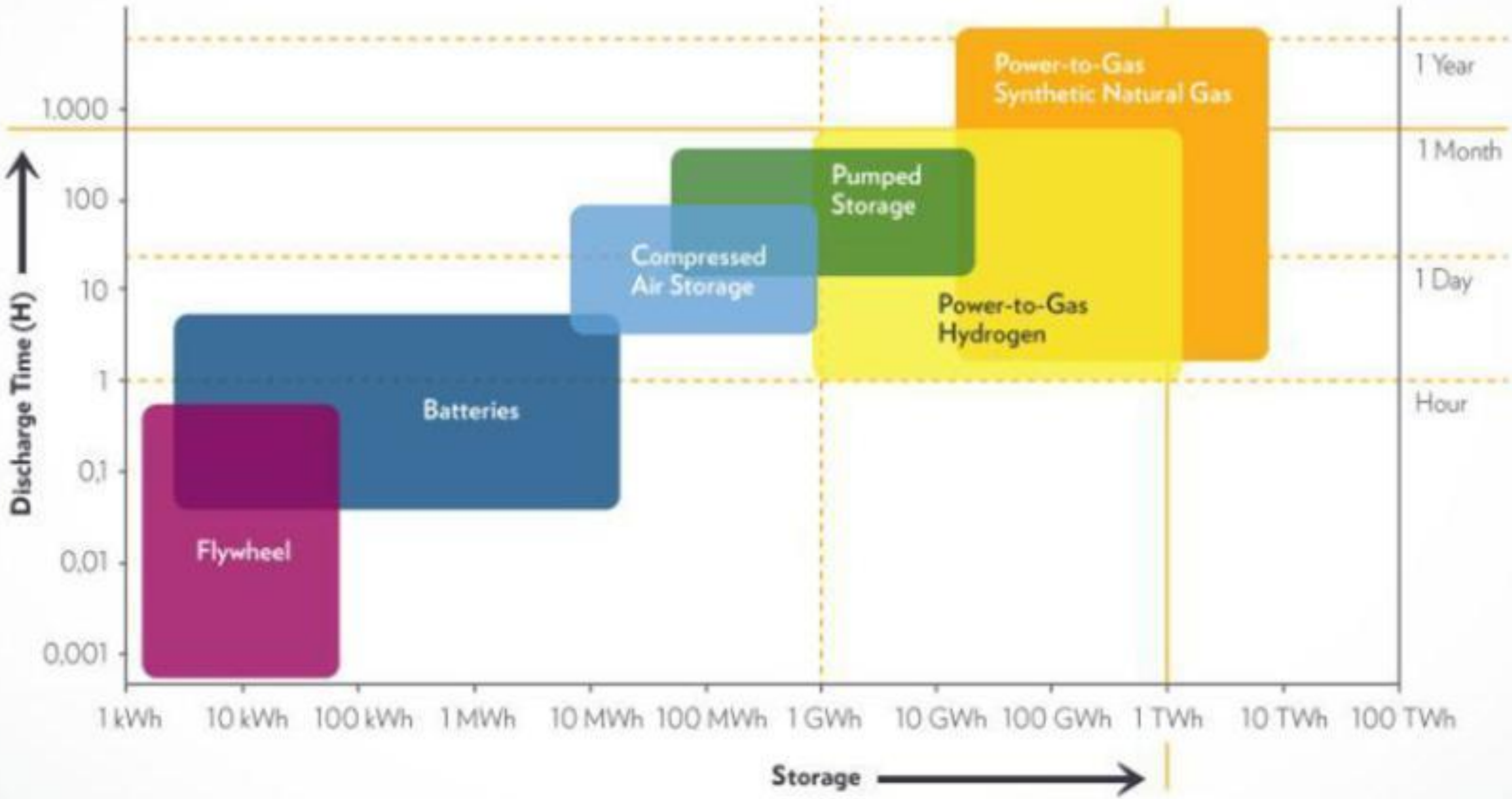


TU Delft

Battery storage

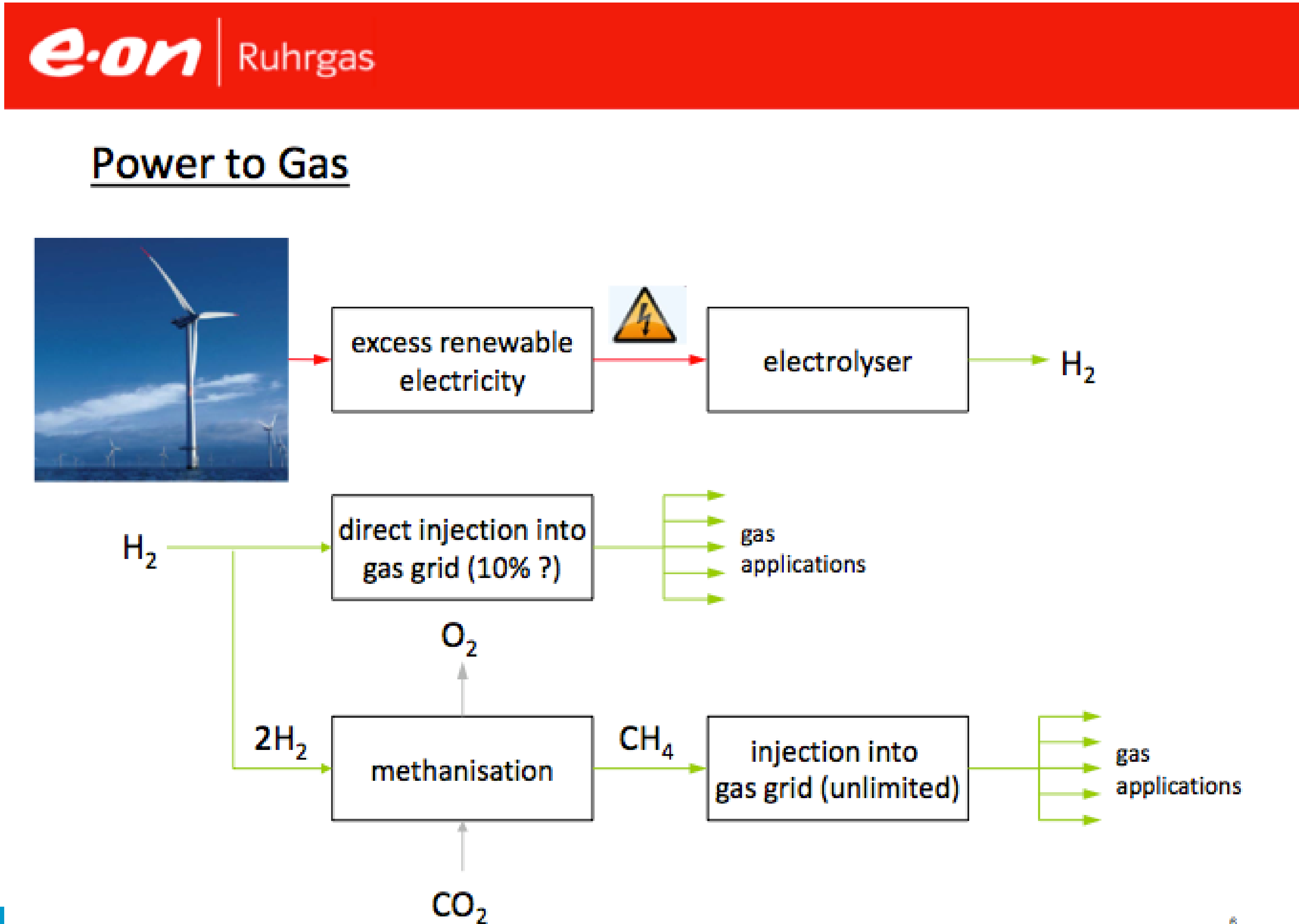


ENERGY STORAGE TECHNOLOGIES



ENERGY STORAGE TECHNOLOGIES

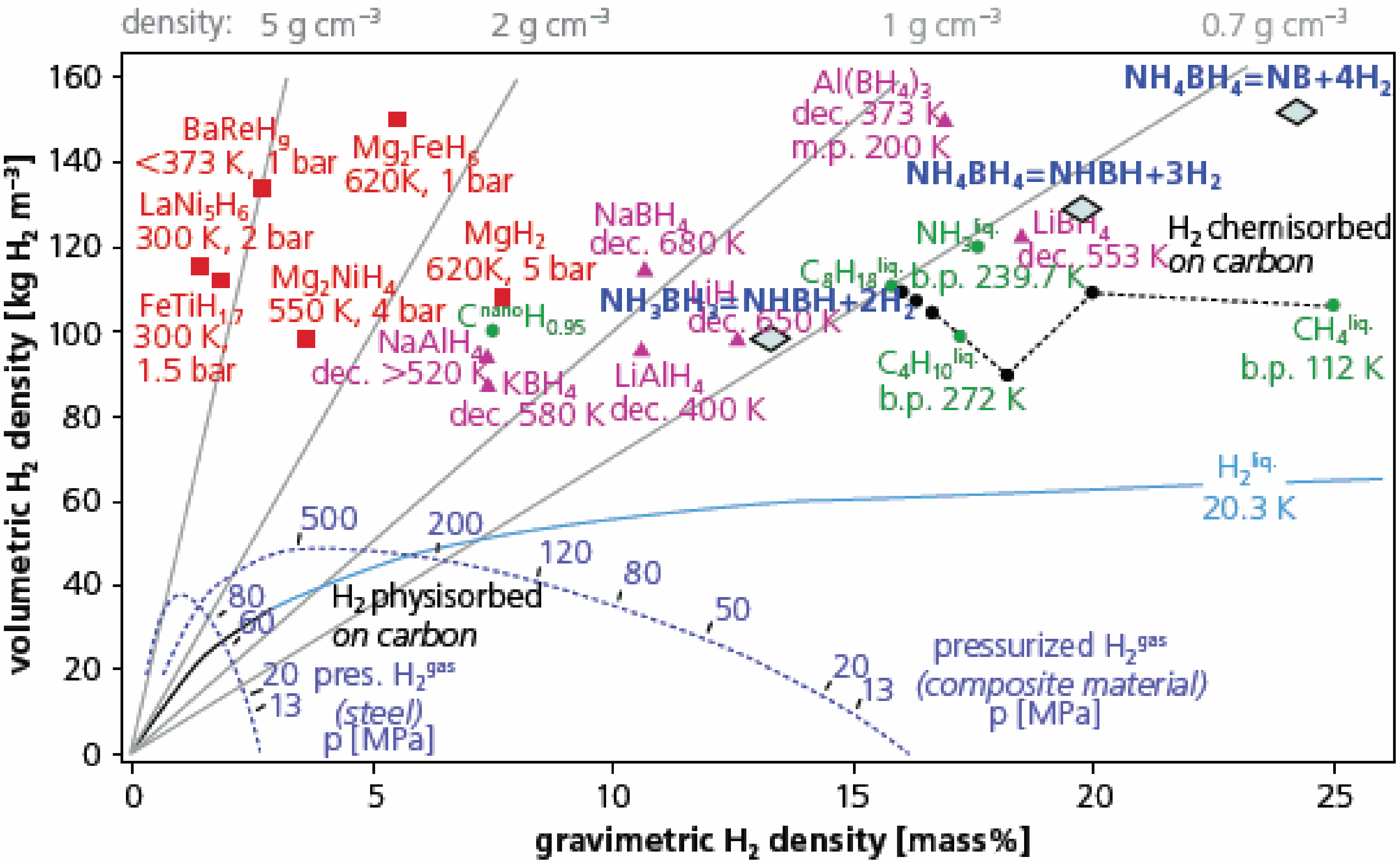
From power to gas



Waterstof opslag

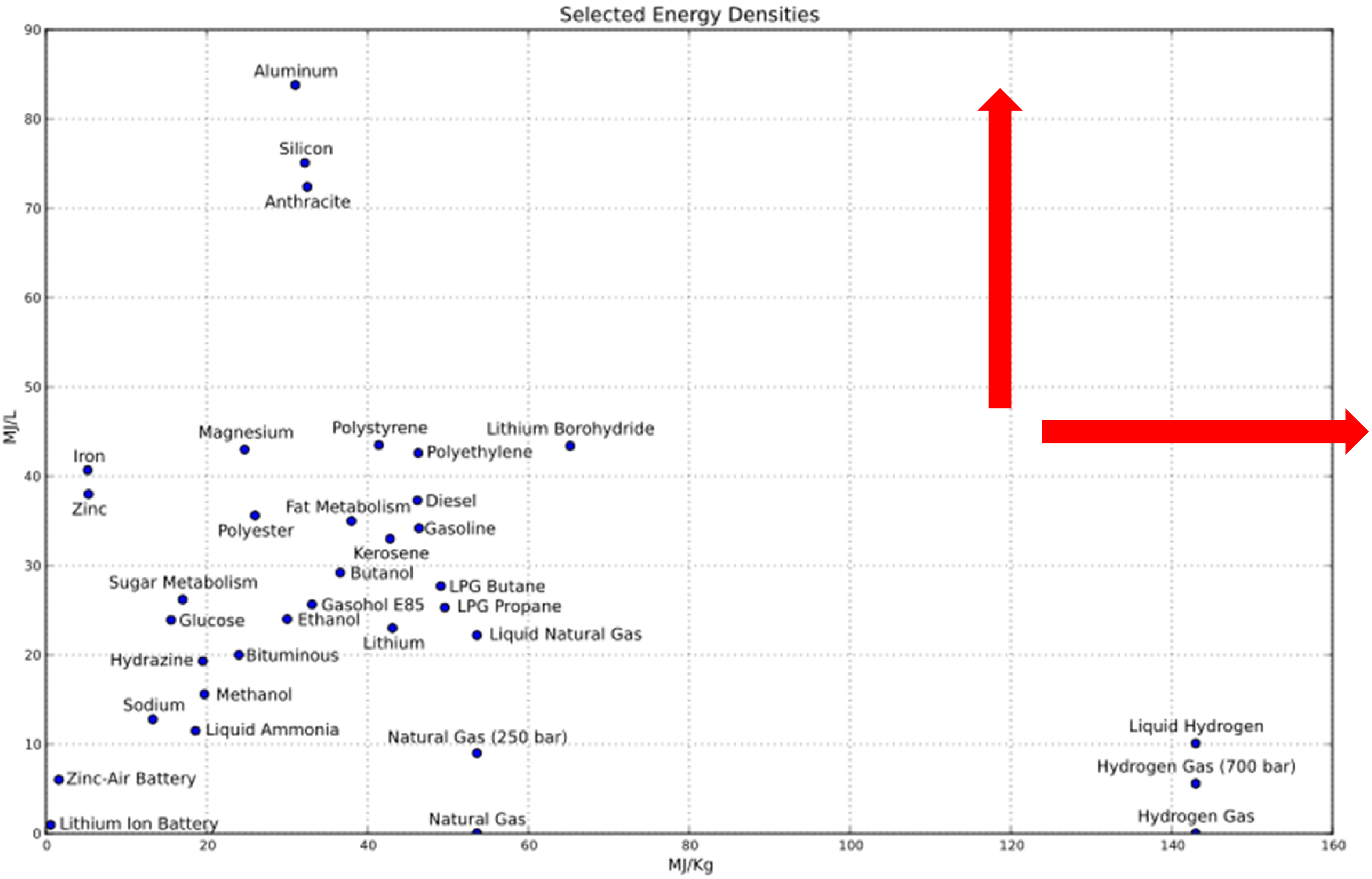
Waterstof bijna niet vloeibaar te maken

Waterstof opslaan in chemische verbindingen



TU Delft

Waterstof opslag in meer gangbare gassen/vloeistoffen



Chemical storage, via Hydrogen

- Hydrogen injection in gas network
- Metalhydrates
- C – H bonds (f.i. methane CH4)
- N – H bonds (f.i. ammonia NH3)

HHV Methane versus Ammonia

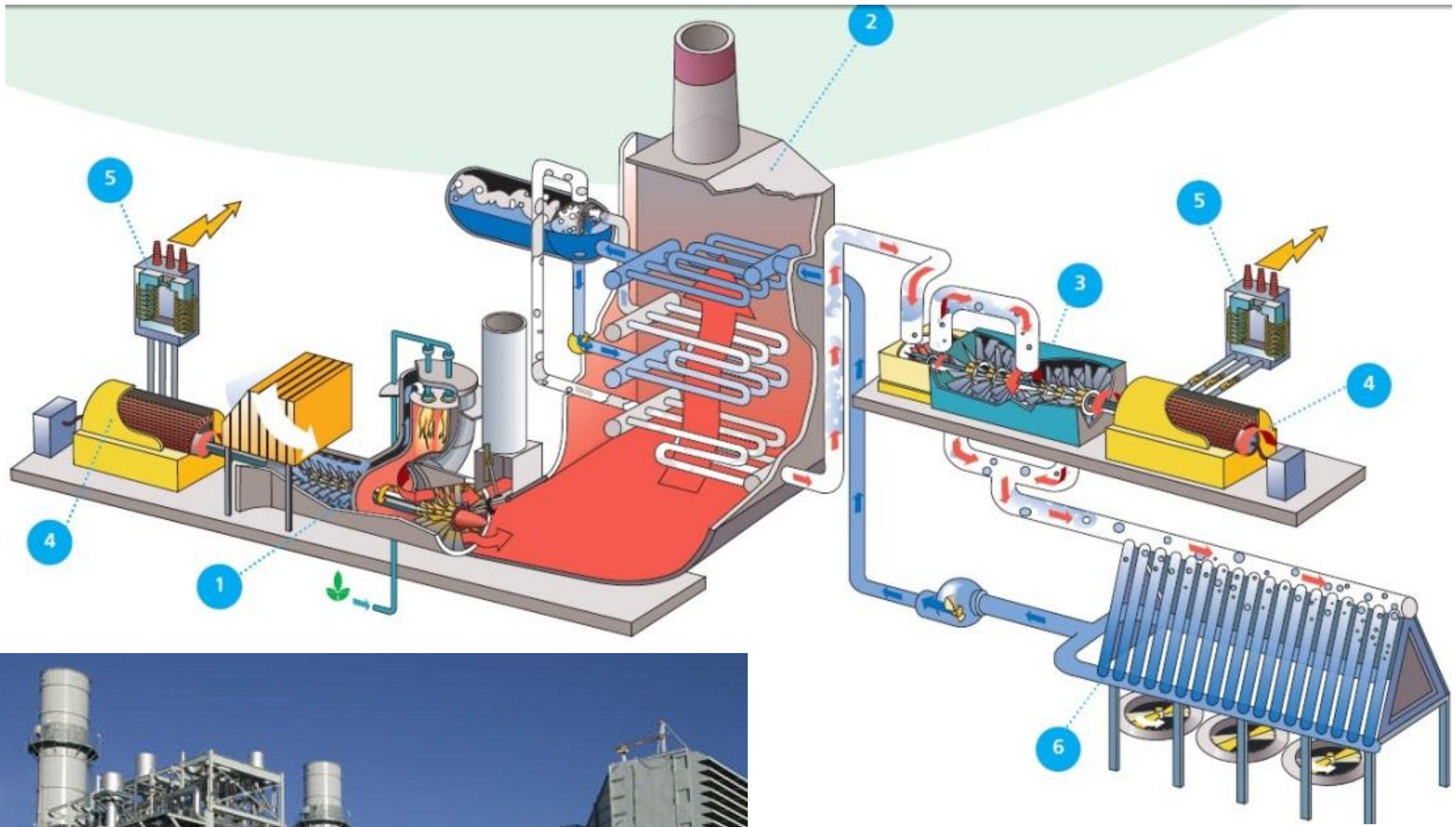
$CH_4 + 2\ O_2 \rightarrow CO_2 + 2\ H_20$ -889KJ/mol
(1mol = 16 gram)

$4NH_3 + 3O_2 \rightarrow 2N_2 + 6H_20$ -382 KJ/mol
(1mol = 17 gram)

Energy density methane almost three times the density of Ammonia

Gas to power: medium scale

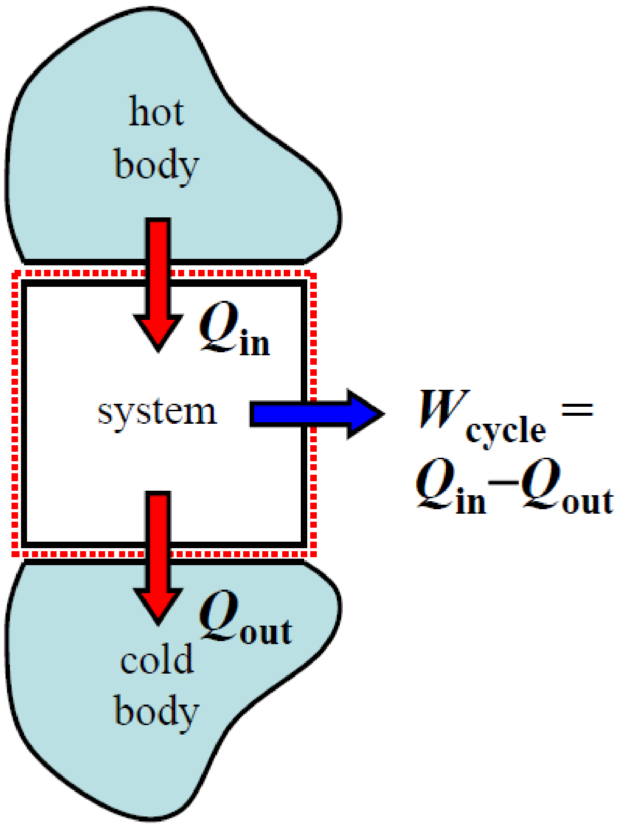
Gas to power: large scale



TUDelft

Thermisch; limitaties

- Conversion of heat in to power
- Thermodynamic limitations, not very efficient
- Maximum theoretical efficiency, the Carnot Efficiency



$$\eta = \frac{W_c}{Q_{in}} = 1 - \frac{|Q_{out}|}{Q_{in}}$$

$$\eta_{\max} = \eta_{Carnot} = 1 - \frac{T_C}{T_H}$$

Watergas-shift + methanation

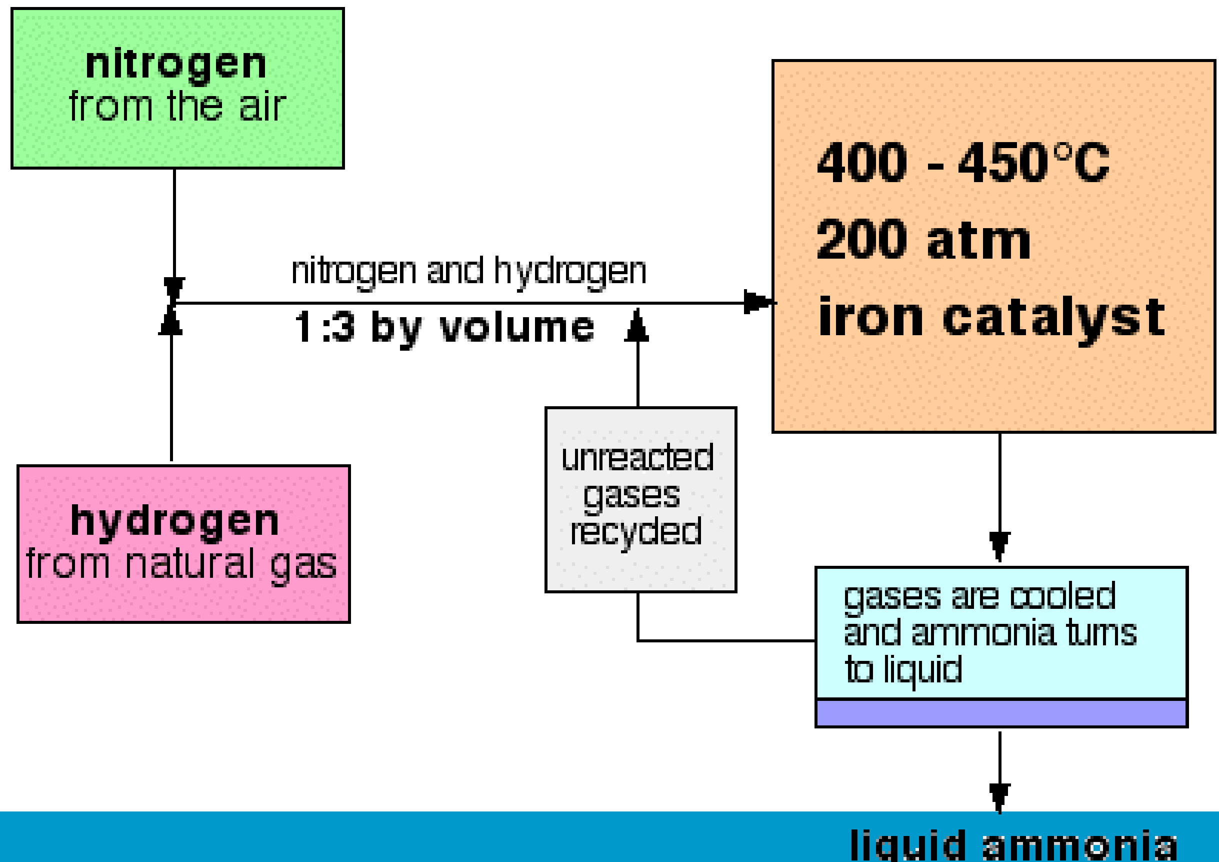
$$CO + H2O <-- > CO2 + H2$$

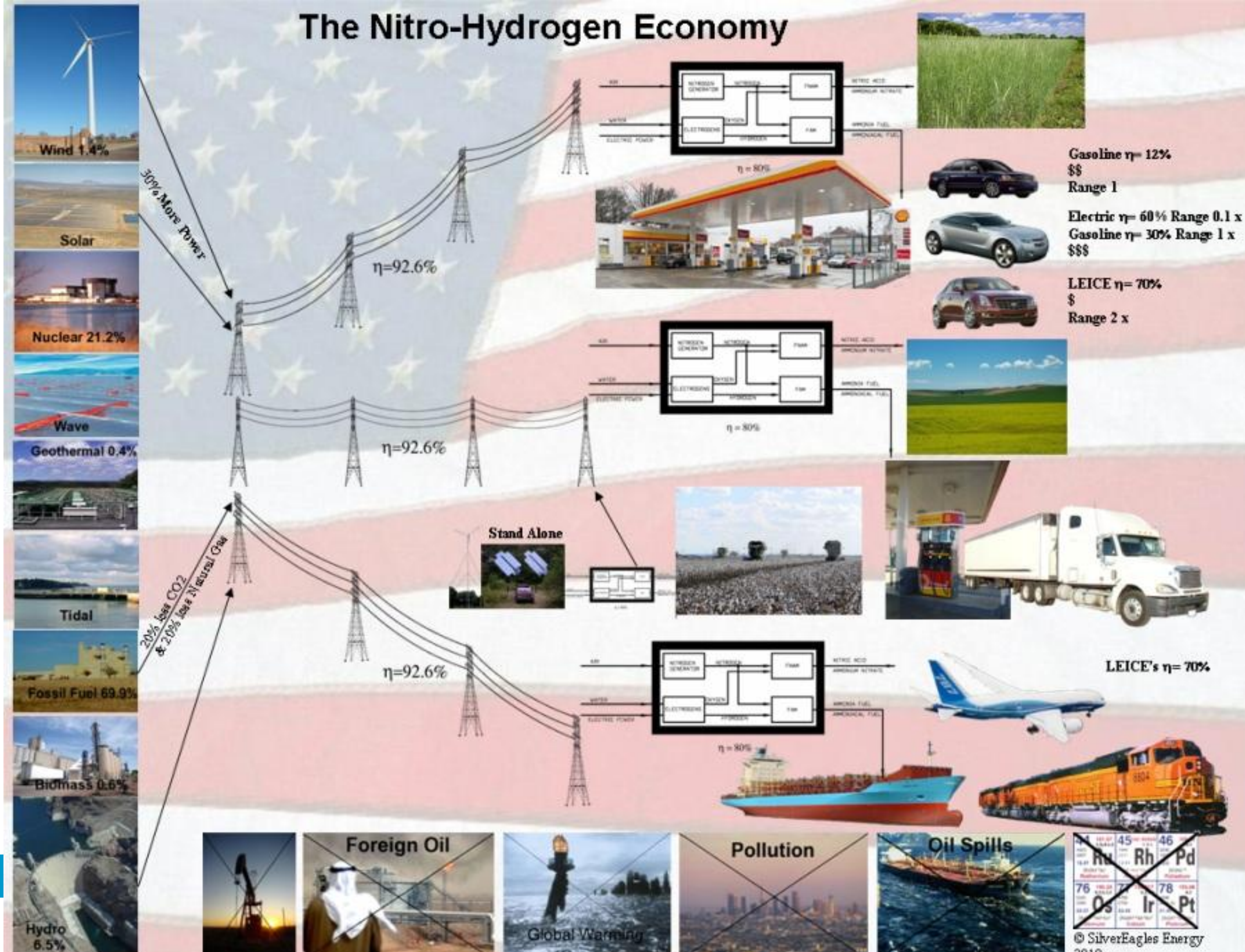
CO+3H2← → CH4+ H20
CO2+4H2←→ CH4+2H20

Waar komt de CO2 vandaan?

Haber-Bosch

$$N_2 + 3\,H_2 \rightarrow 2\,NH_3 \quad (\Delta H = -92.4\ \mathrm{kJ \cdot mol^{-1}})$$



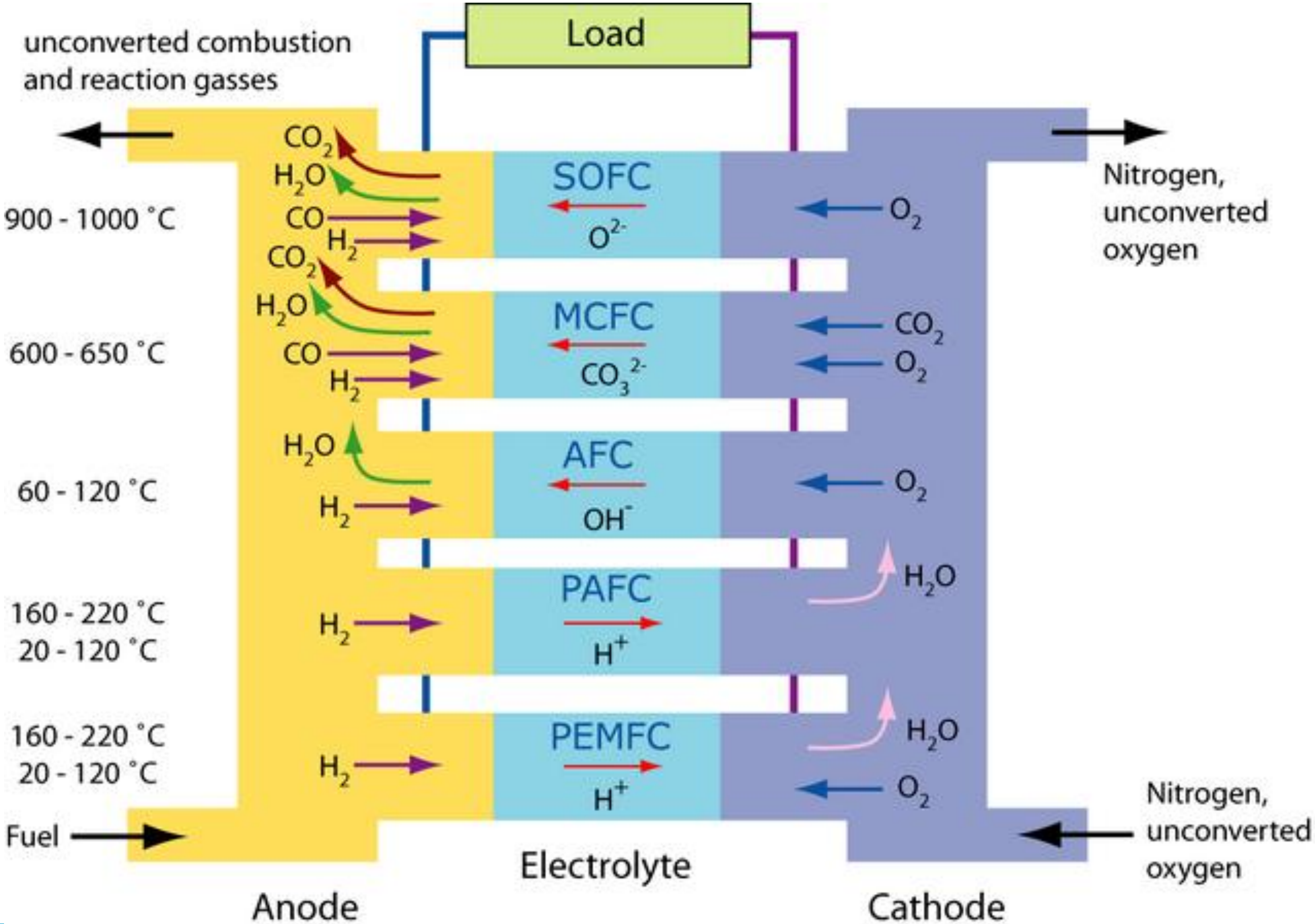

The Nitro-Hydrogen Economy
Wind 1.4%
Solar
Nuclear 21.2%
Wave
Geothermal 0.4%
Tidal
Fossil Fuel 69.9%
Biomass 0.6%
Hydro 6.5%
30% More Power
20% less CO2 & 20% less Natural Gas
η=92.6%
η=92.6%
η=92.6%
η = 80%
η = 80%
η = 80%
Stand Alone
Gasoline η= 12%
$$
Range 1
Electric η= 60% Range 0.1 x
Gasoline η= 30% Range 1 x
$$$
LEICE η= 70%
$
Range 2 x
LEICE's η= 70%
Foreign Oil
Global Warming
Pollution
Oil Spills
© SilverEagles Energy 2010

NH3 to Power, engine?

NH3 to power?

- **NH3 can be combusted, but modifications to existing device are needed**
- **New concept? Fuel cell?**

Type brandstof cellen



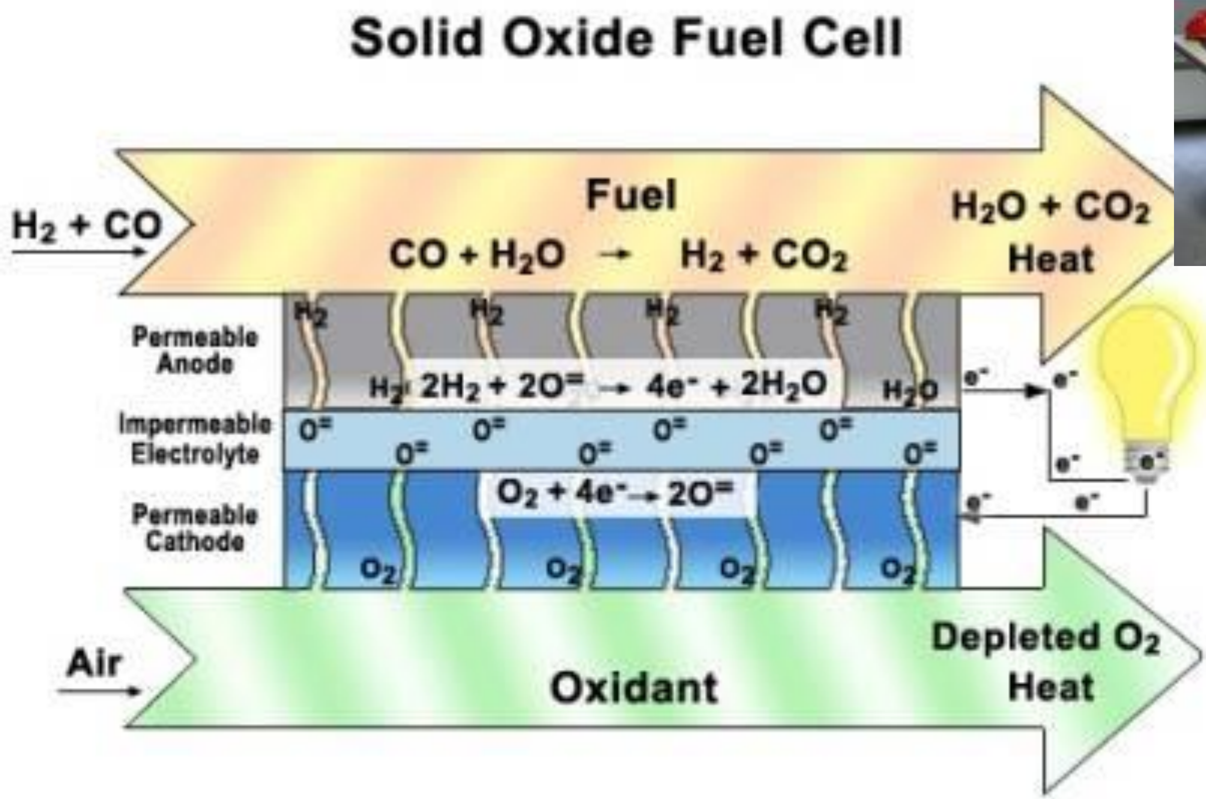
Fuel Cell types

The most common types with names according to their electroly

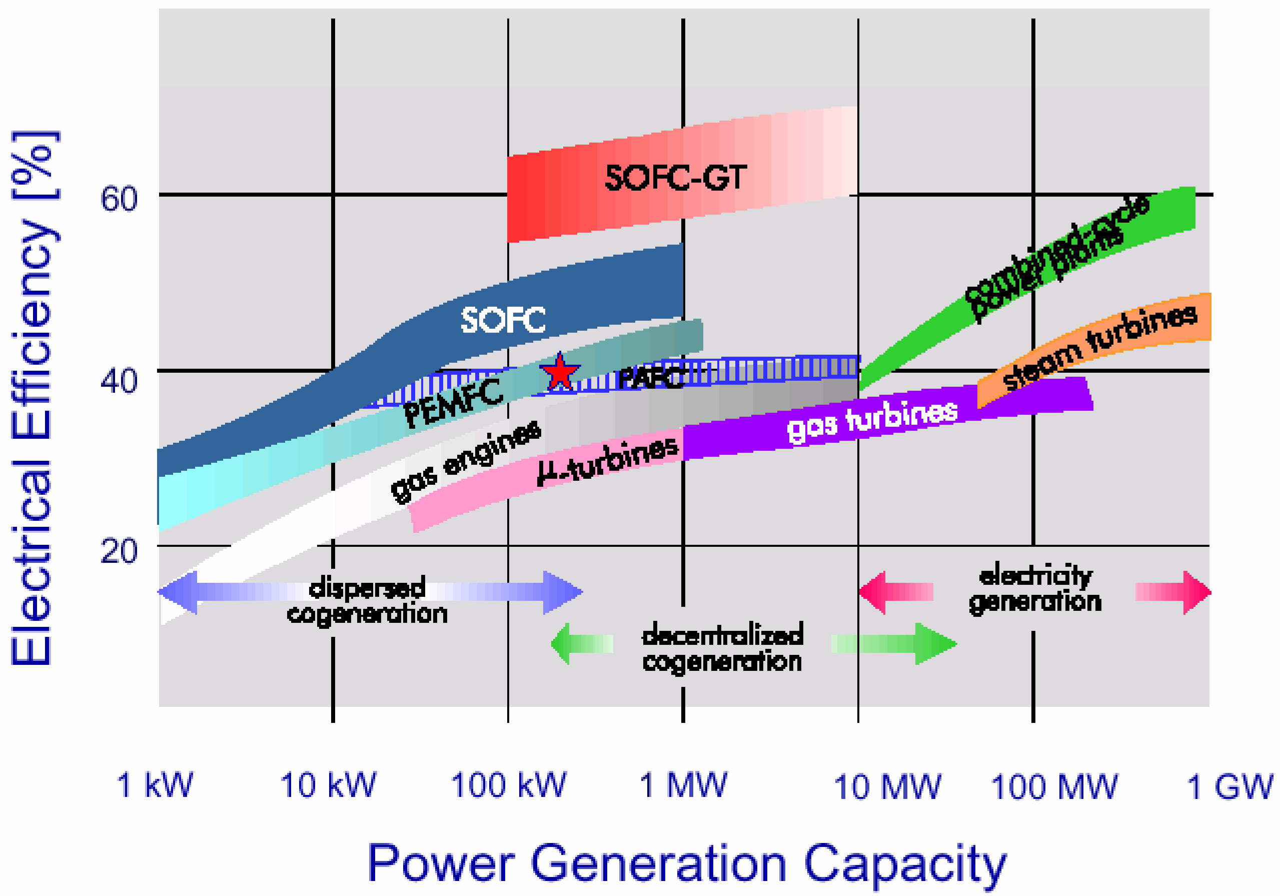
	FC Type	Anode Fuel	Cathode Fuel	Operating temp (°C)	Efficiency (LHV)	Application
Low temperature	**PEM**	H_2	Air	60 – 100	30 – 40	Portable Small residential Transportation
	AFC	H_2	O_2	60 – 120	30 – 40	Portable Small residential Transportation
Intermediate temperature	**PAFC**	H_2	Air	150 – 250	35 – 45 50 – 70 *	Med. Residential Commercial
High temperature	**MCFC**	H_2, CO, NH_3, CH_4	Air+CO_2	550 – 700	45 – 55 80 – 90	Industrial Commercial Large residential
	SOFC	H_2, CO, NH_3, CH_4	Air	650 – 850	45 – 55 80 – 90 *	Industrial Commercial Large residential

* Co-generation

FUEL Cells, SOFC



TU Delft


Electrical Efficiency [%]
60
40
20
SOFC-GT
SOFC
PEMFC
PAFC
gas engines
μ-turbines
gas turbines
combined-cycle power plants
steam turbines
dispersed cogeneration
decentralized cogeneration
electricity generation
1 kW
10 kW
100 kW
1 MW
10 MW
100 MW
1 GW
Power Generation Capacity

TU Delft

Opmerkingen/conclusie

- **Waterstof opslag is probleem**
- **Opslag in chemische verbindingen**
- **CH_4, C_2H_6,… CO_2 nodig**
- **NH_3 alternatief**

- **Electriciteits productie via conventionele weg (motoren)**
- **Brandstof cellen**