SIEMENS

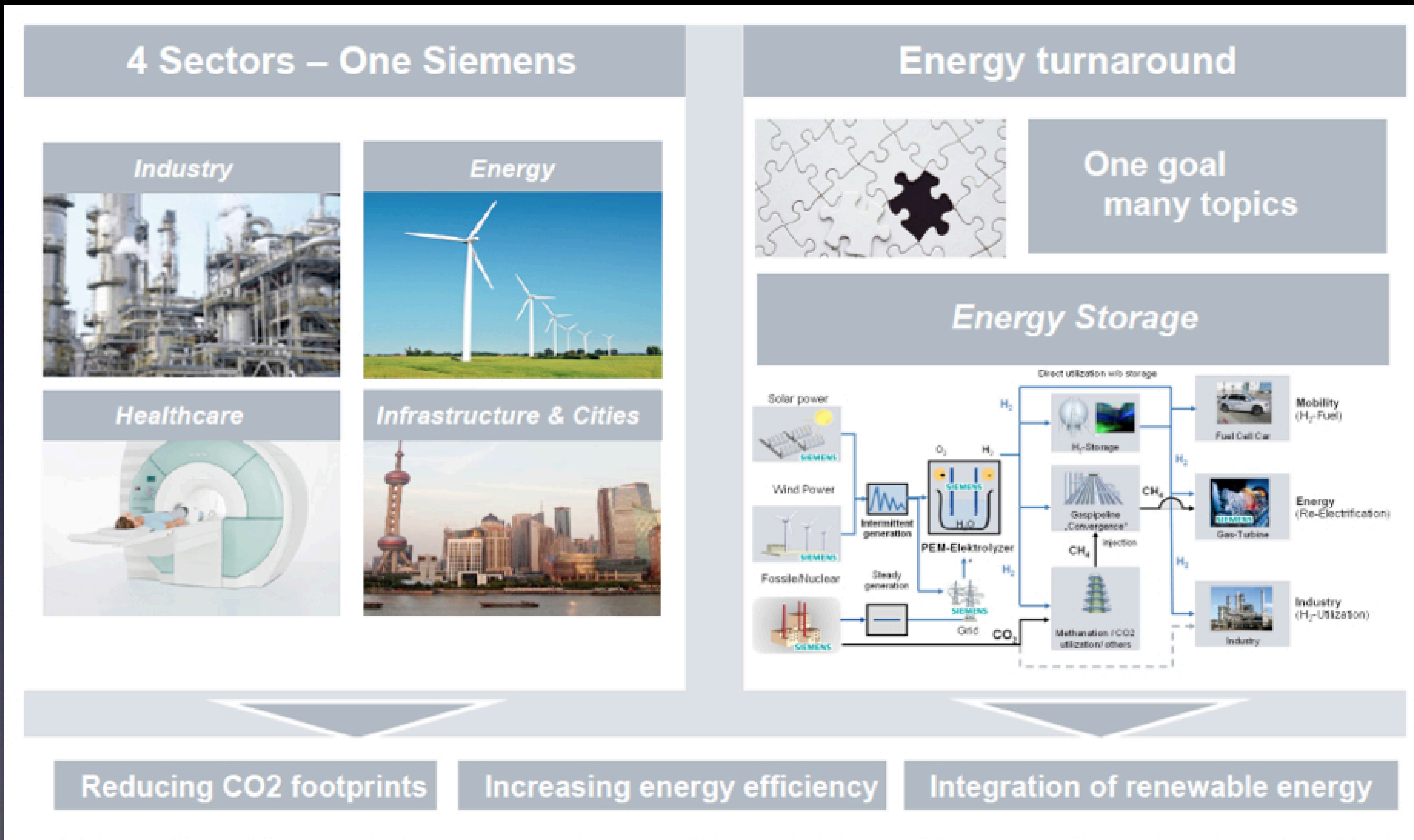
Hydrogen Energy Storage

HTAC
Washington DC, May 10th 2012

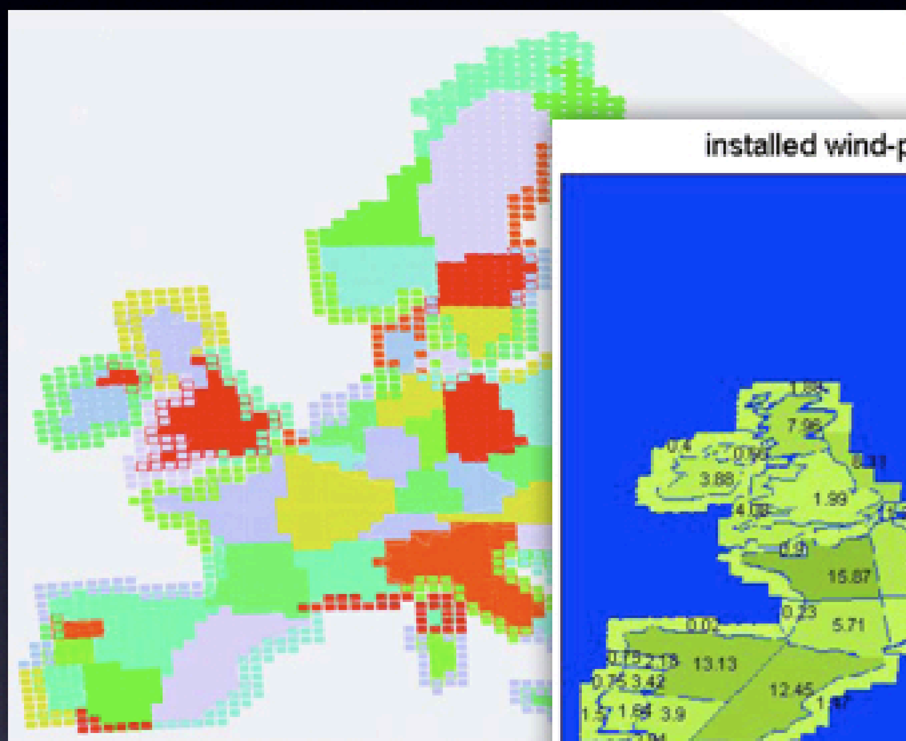
Siemens AG

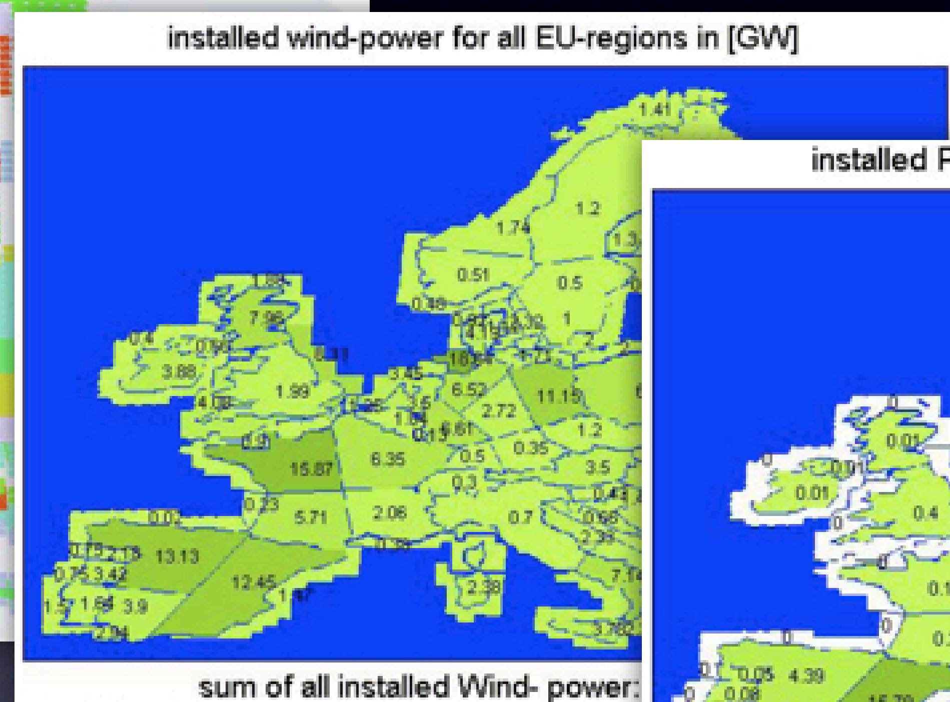
Sector Energy
Erik Wolf

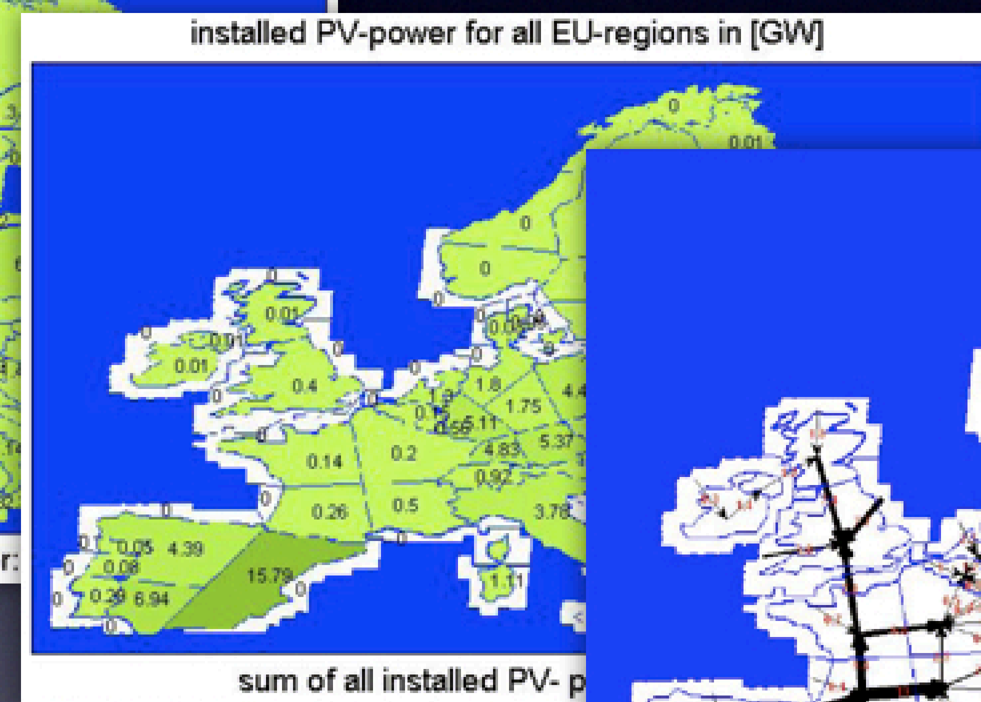
What drives us?



System analysis



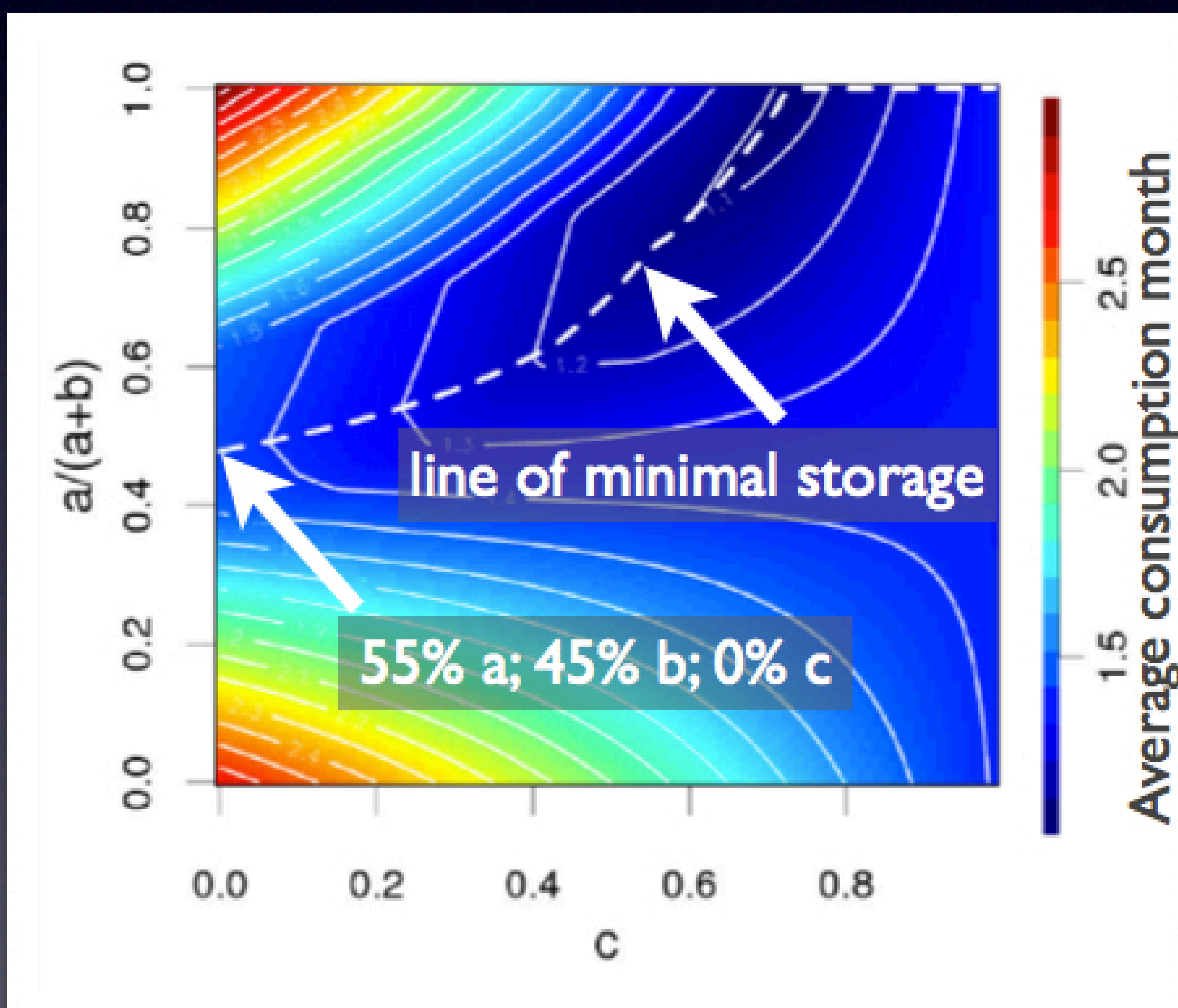




Weather data of 8 years of 1h time resolution for 45km x 45km squares

Storage capacity EU

a% Wind + b% Solar + c% Conventional / Must run *)



Storage minimum

55% wind to 45% solar generation ratio

1.4 av. consumption month

*) Copper plate approach

Motivation for Storage

Grid requirements

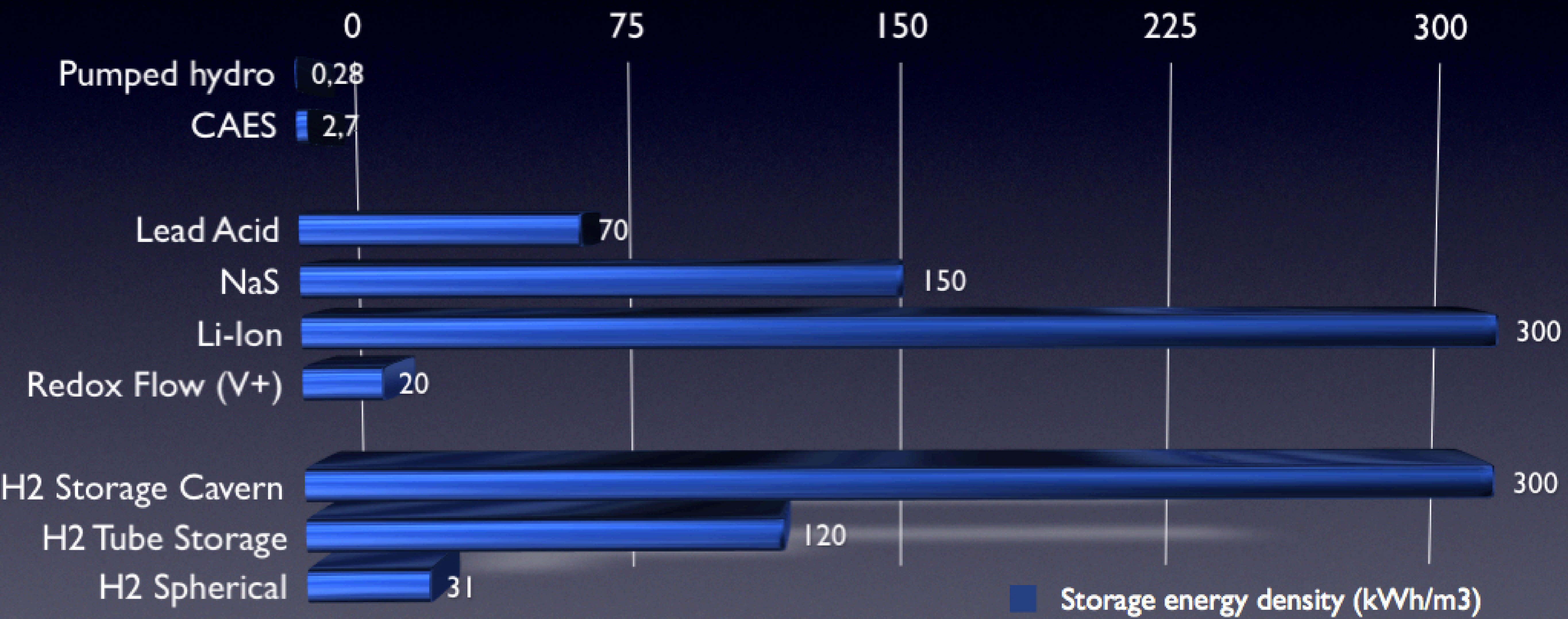
The **bench mark setting storage technology** in terms of grid compliance is **pumped hydro.** It provides all features for safe & reliable transmission grid operation.

- Frequency control
- Black start capable
- Fast load rejection
- Long duration self sustain operation (e.g. prior to grid restart)
- Reactive / active power adjustment
- Seasonal - like storage capacities, similar to gas system

Storage systems must offer a very flexible operation mode. CCPP provide these flexibility and consequently H2 storage systems as well.

Volumetric energy density

Physical < Electrochemical < Chemical



Pumped Hydro: dh = 100m

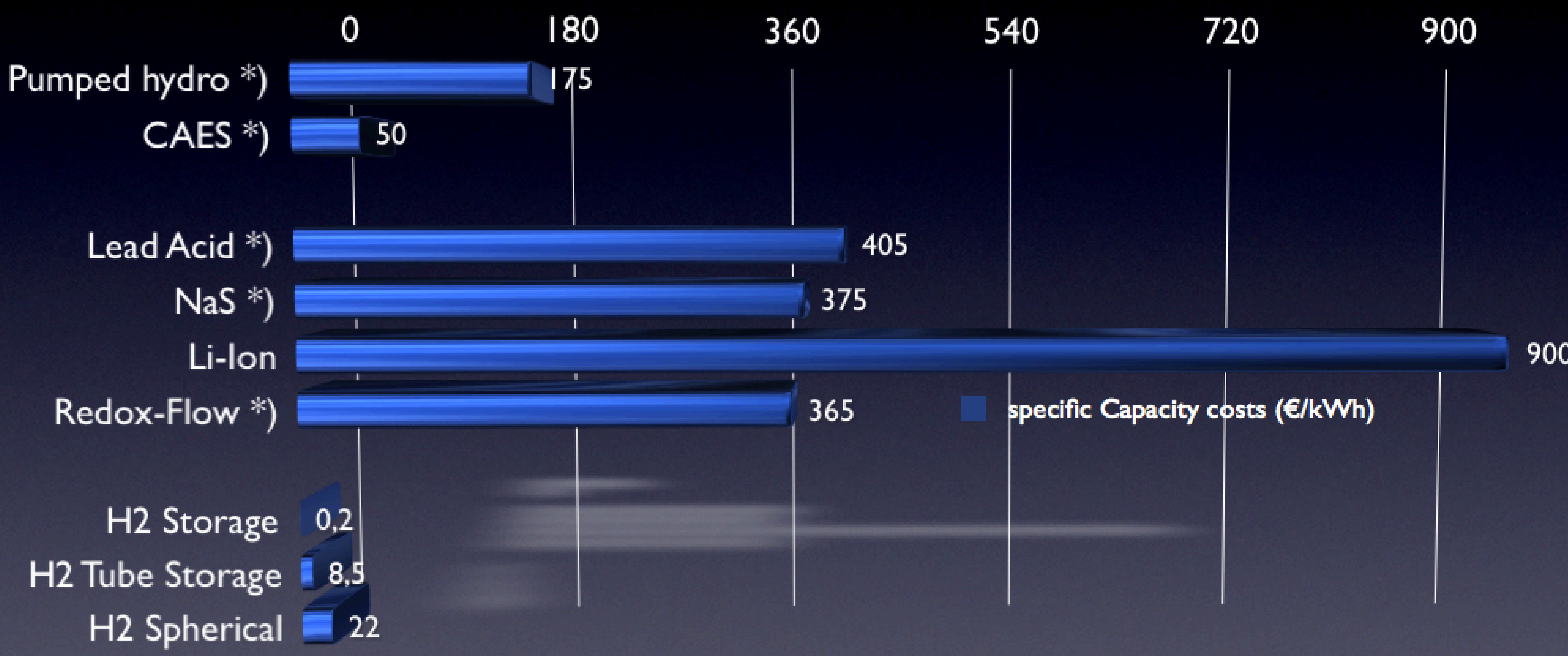
CAES: dp = 2MPa; CAES = Compressed Air Energy Storage

H2 Storage underground: dp = 200bar, eta = 0,58

H2 Tube Storage: dp 120bar, eta = 0,57

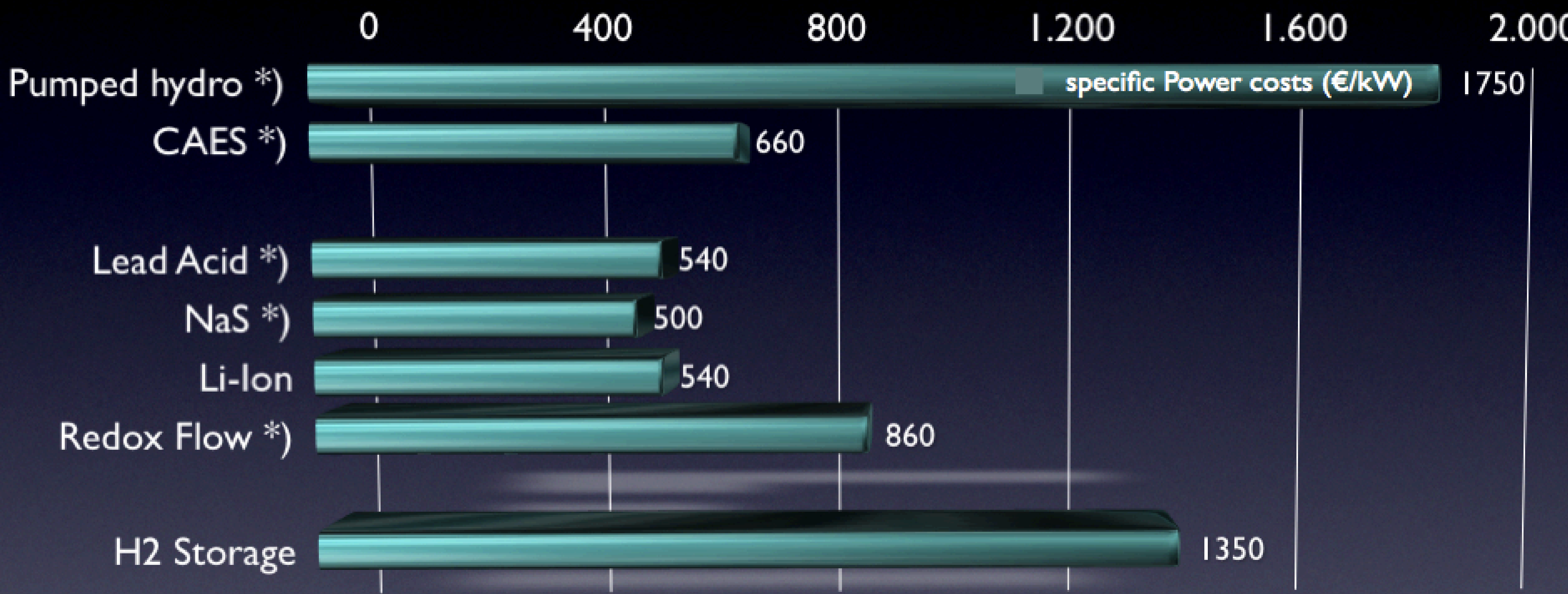
H2 Storage aboveground: dp 18bar, eta = 0,57

Specific Capacity Costs



*) Source: EPRI Study on Commercial Energy Storage

Specific Power Costs



*) Source: EPRI Study on Commercial Energy Storage CCBJV1N11EnergyStorage

LCOE-Methodology

Initial investment & yearly depreciations

- Reduction of cost
  - Material
  - Manufacturing
  - System integration
  - Commissioning
- Supply chain management
- Elimination of components
- **Minimize additional invest of storage solution**

Operations & Maintenance expenditures

- Availability
- Equivalent forced outage rate (EFOR)
- Automated operation
- Total plant management
- Serviceability
- **Minimize additional O&M cost for storage solution**

Fuel expenditures

not applicable for RE plants

$$LCOE = \frac{\sum_{t=1}^{n} \frac{I_t + M_t + F_t}{(1+r)^t}}{\sum_{t=1}^{n} \frac{E_t}{(1+r)^t}}$$

Life-time of system

- Increased durability of components
- Preventive maintenance to extend lifetime

Electricity generation

- Increased efficiency
  - Optimized receiver
  - Higher operation temperatures
  - Steam turbine enhancements
  - Front surface mirror with higher reflection rate
- **Energy storage solution**
  - Store thermal energy to optimize utilization of solar energy
  - Increase operation time & electricity generation of power plant
- Economy of scales

Discount rate

- Decreased interest rates
  - Increased bankability
  - Support of SFS

LCOE-Methodology

CAPEX

Hardware
Electrolyzer
Storage
Power Plant

Σ Costs
(€)

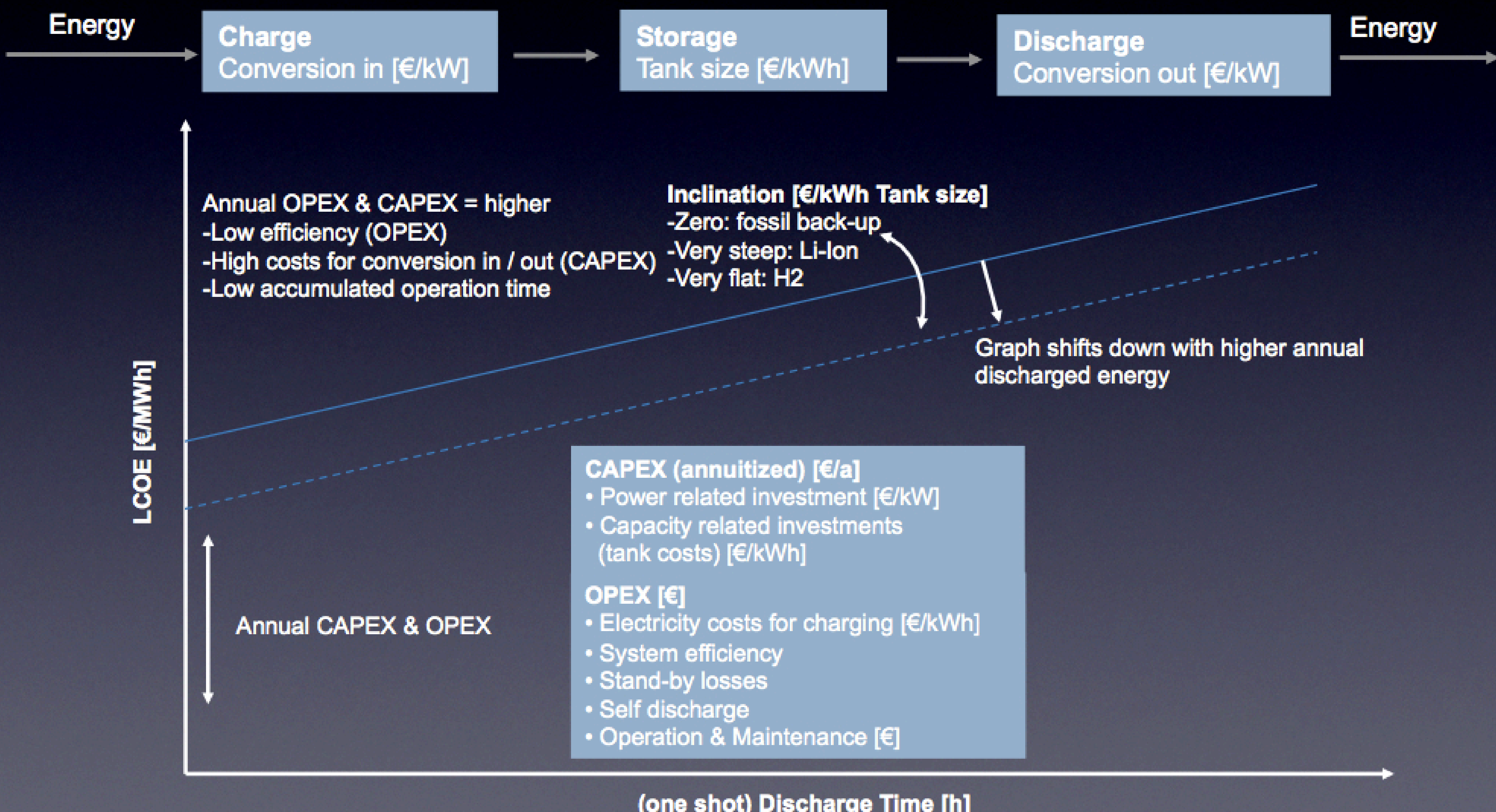
Power
(MWh)

LCOE

OPEX

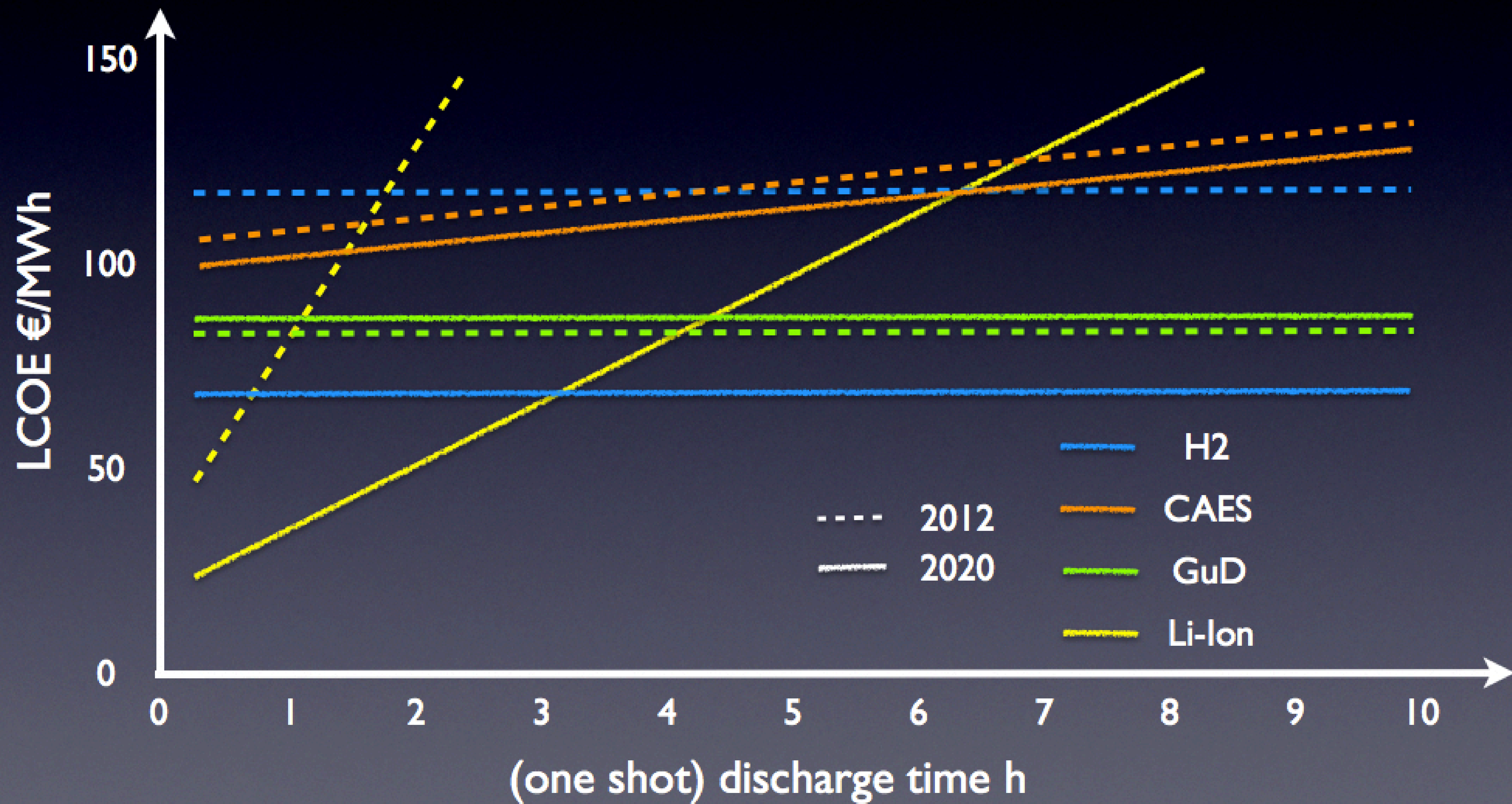
Consumables
O&M
Energy for Charge
Self Discharge

LCOE Storage

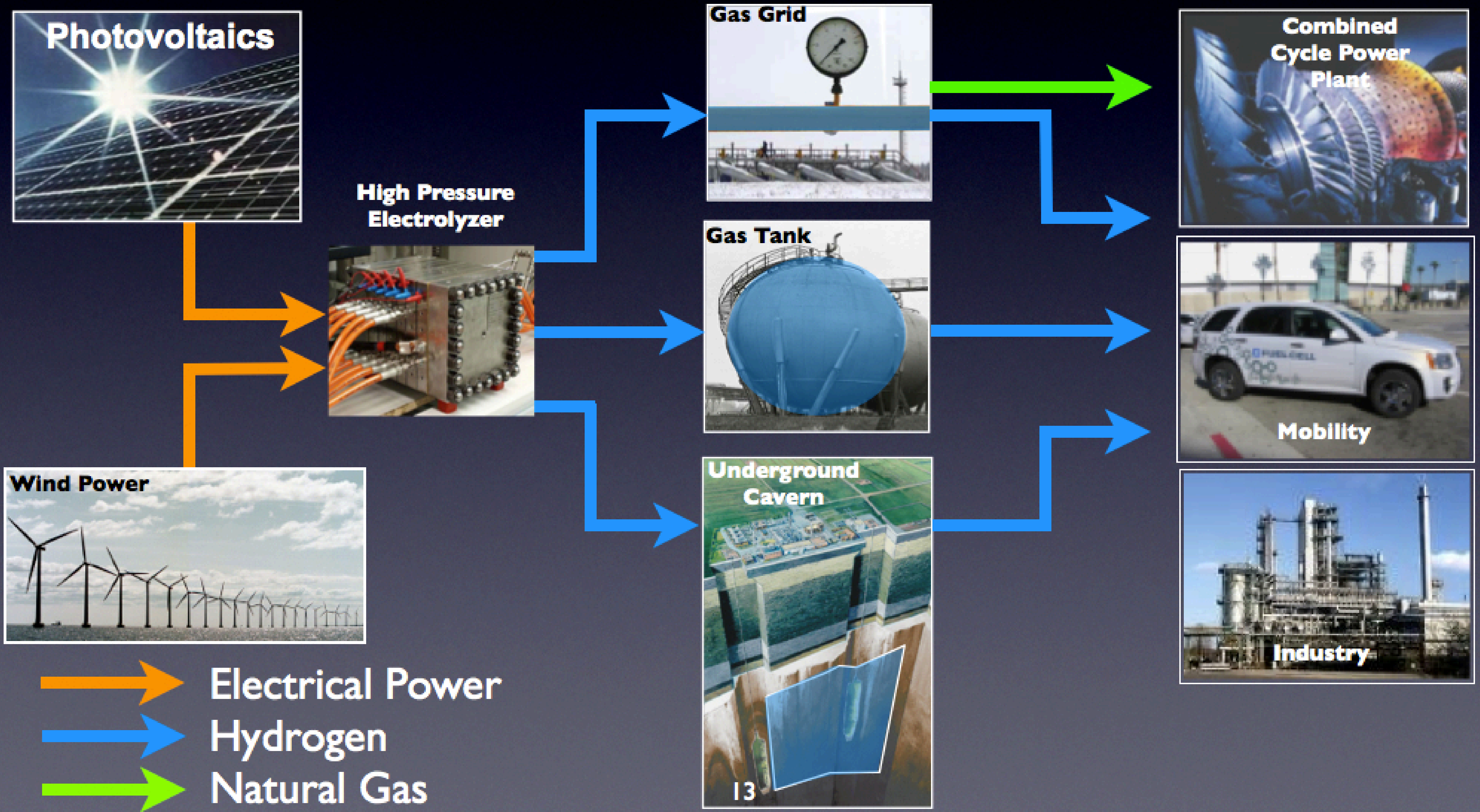


LCOE Storage

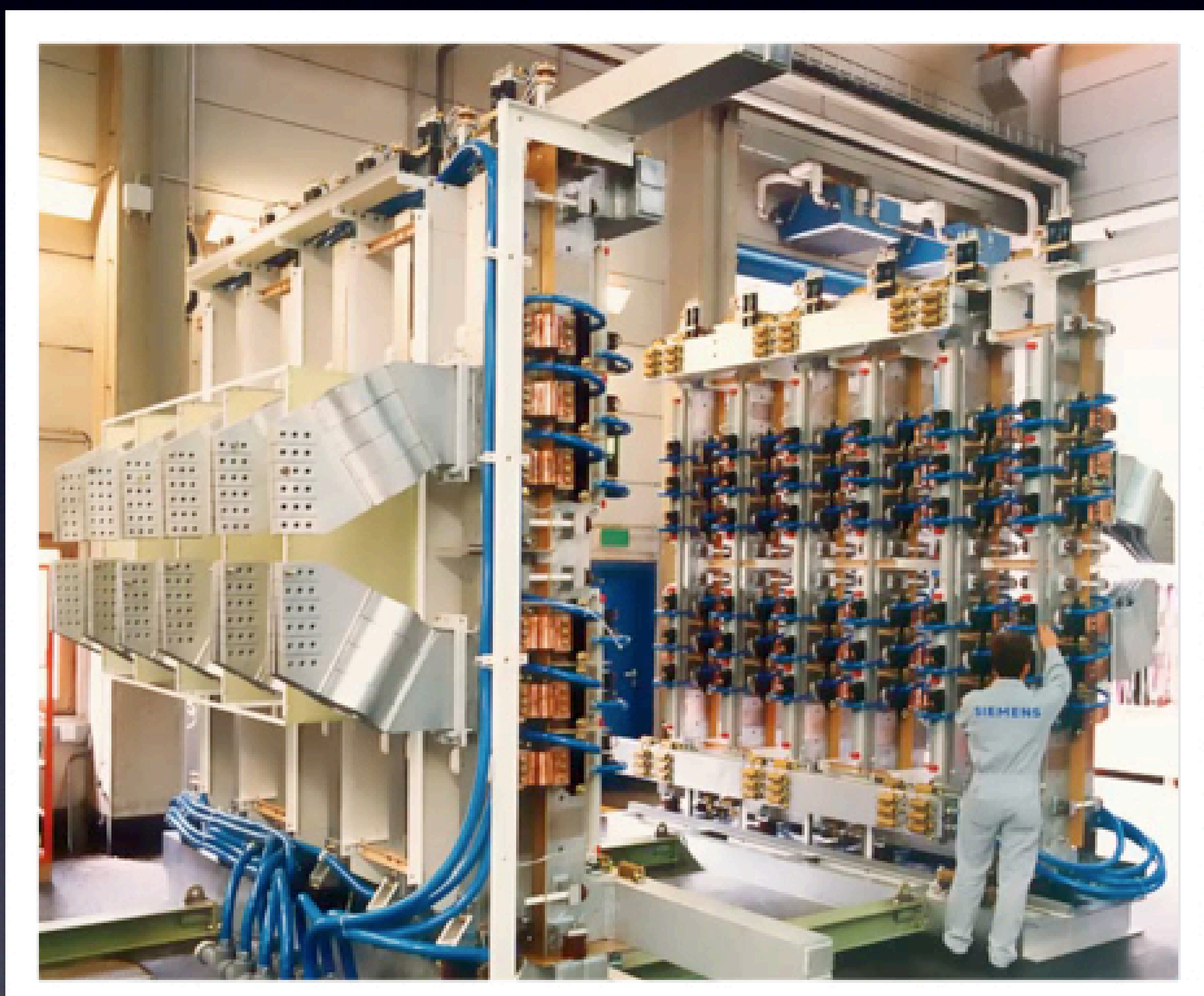
3000h/a Operation



Dispatchable Renewable Power



Electrolyzer @ Siemens



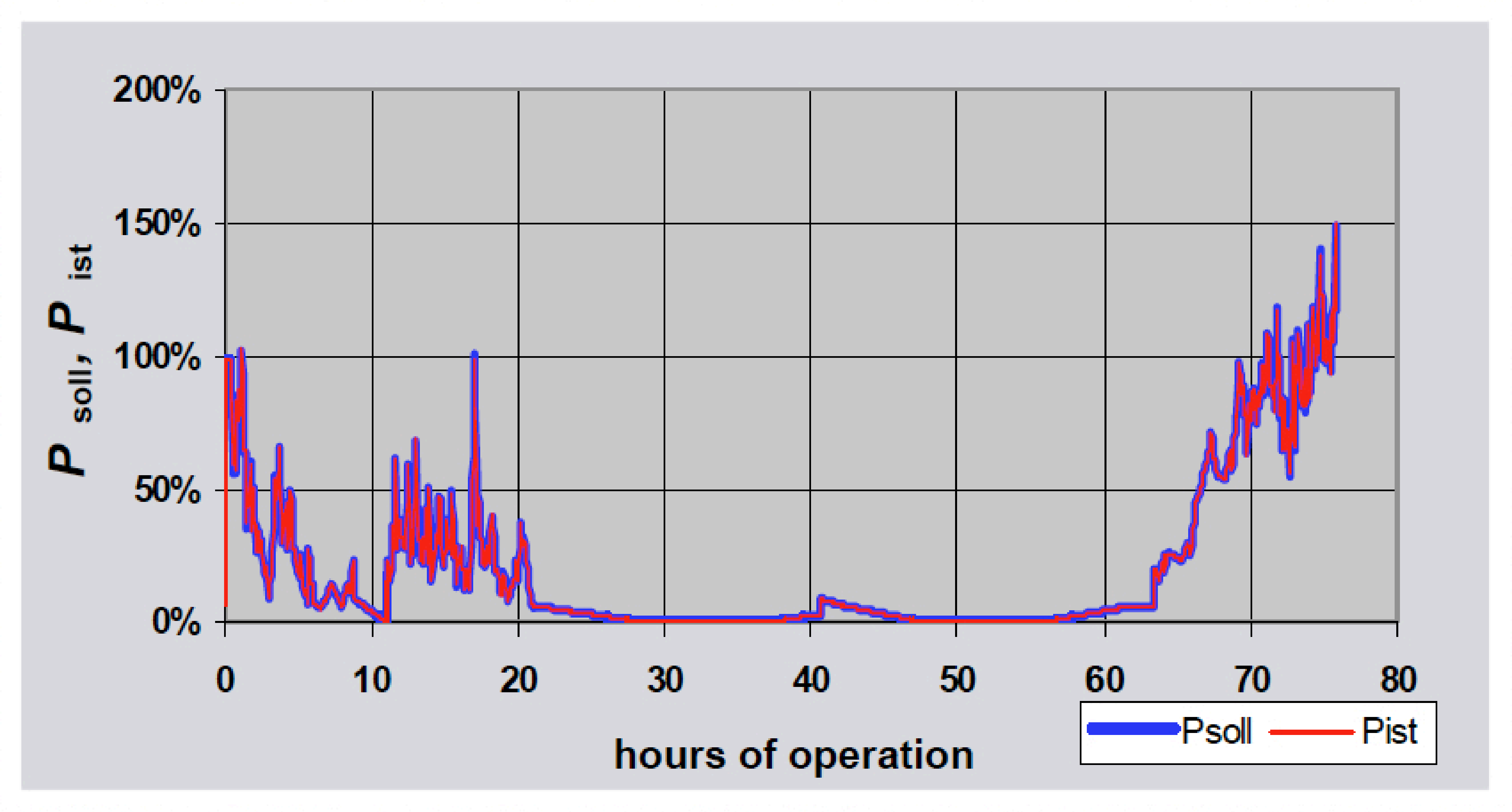
PEM elektrolyzer development since 1998

- ★ continuous lab operation >40kh
- ★10y fiel operation
- ★100bar prototype
- ★40y electrode know-how
- ★>50y heavy duty rectifiers

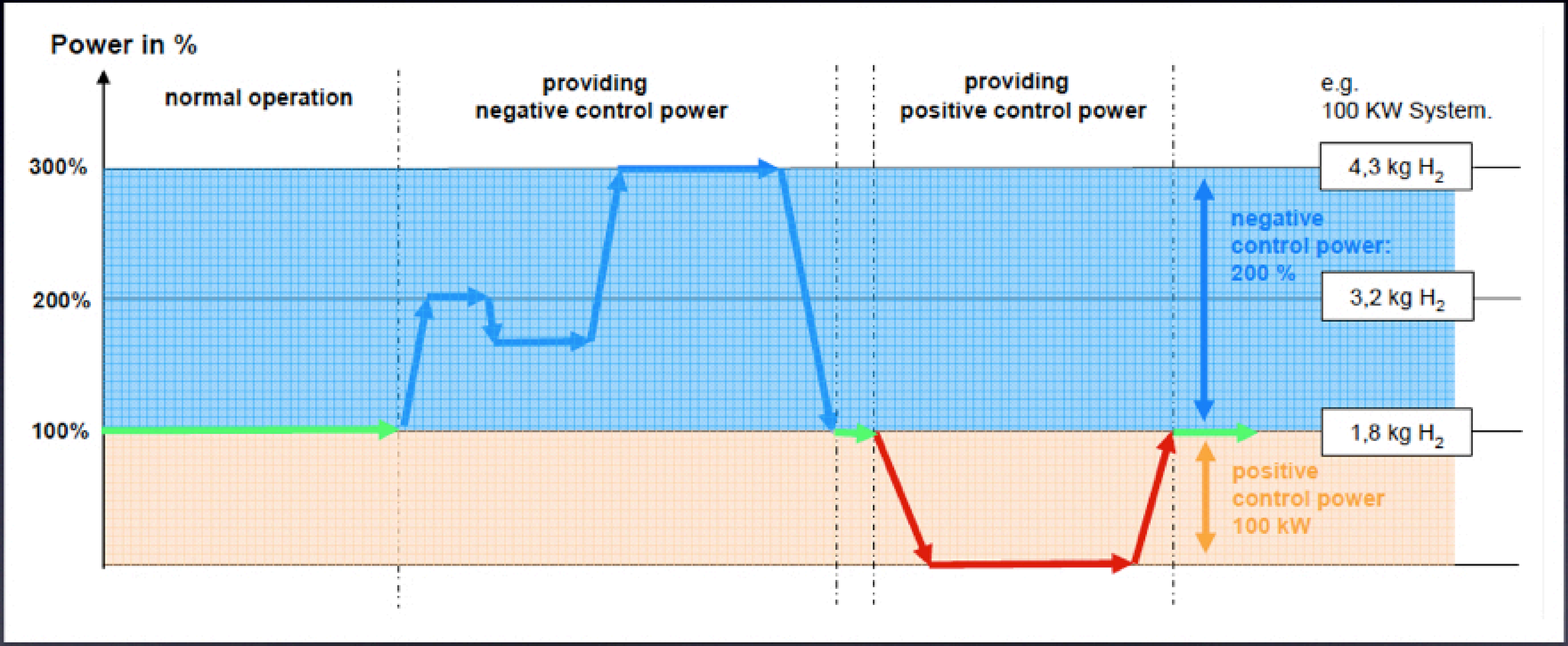
Solution provider

- ★heavy duty rectifier up to 70kA
- ★transformer & control units
- ★grid connection

PEM Electrolyzer
Best fit for Energy Storage

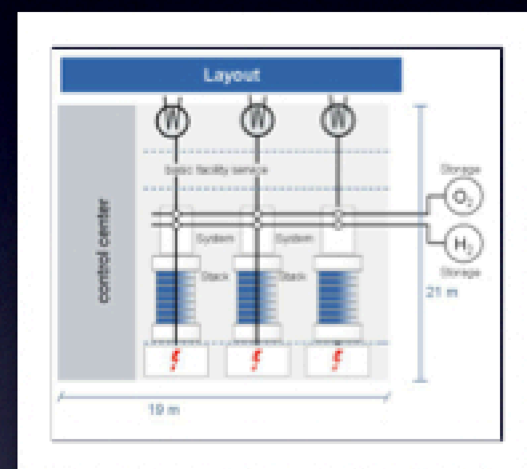


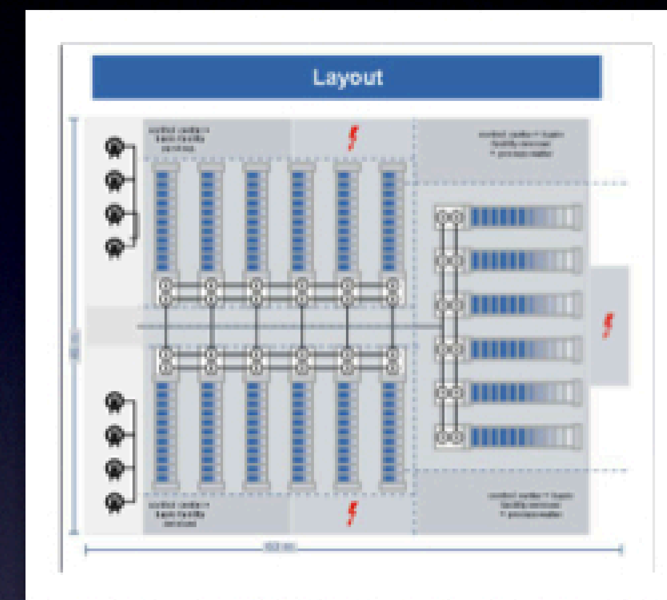
Elektrolyzer & Control Power



- ★cold start 10min
- ★warm start <10s
- ★load dynamic 0% to 300%
- ★secondary and even primary control power possible

Product Road Map





Gen I
0,1MW

Gen II
2,1MW

Gen III
90MW

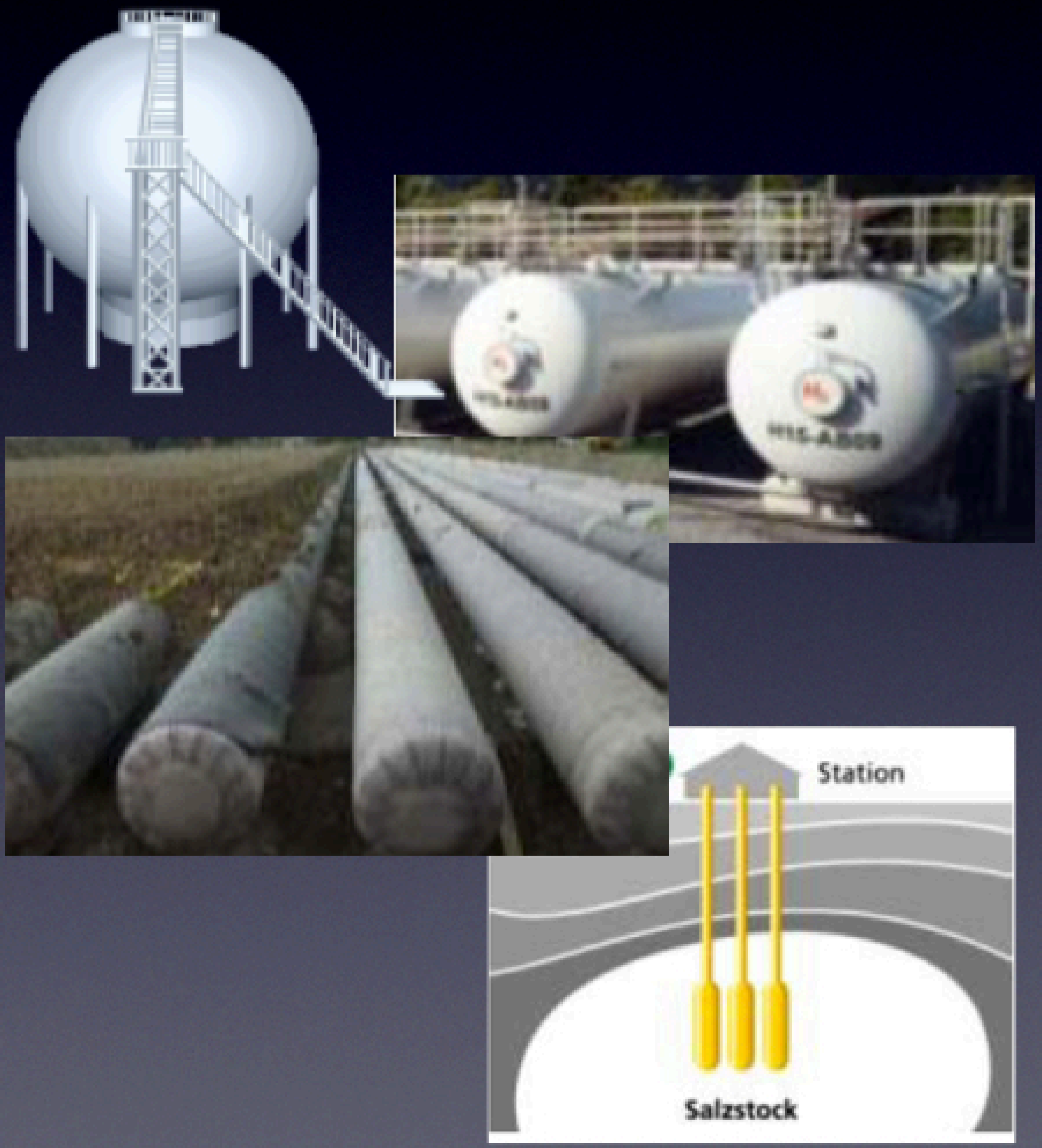
2012

2015

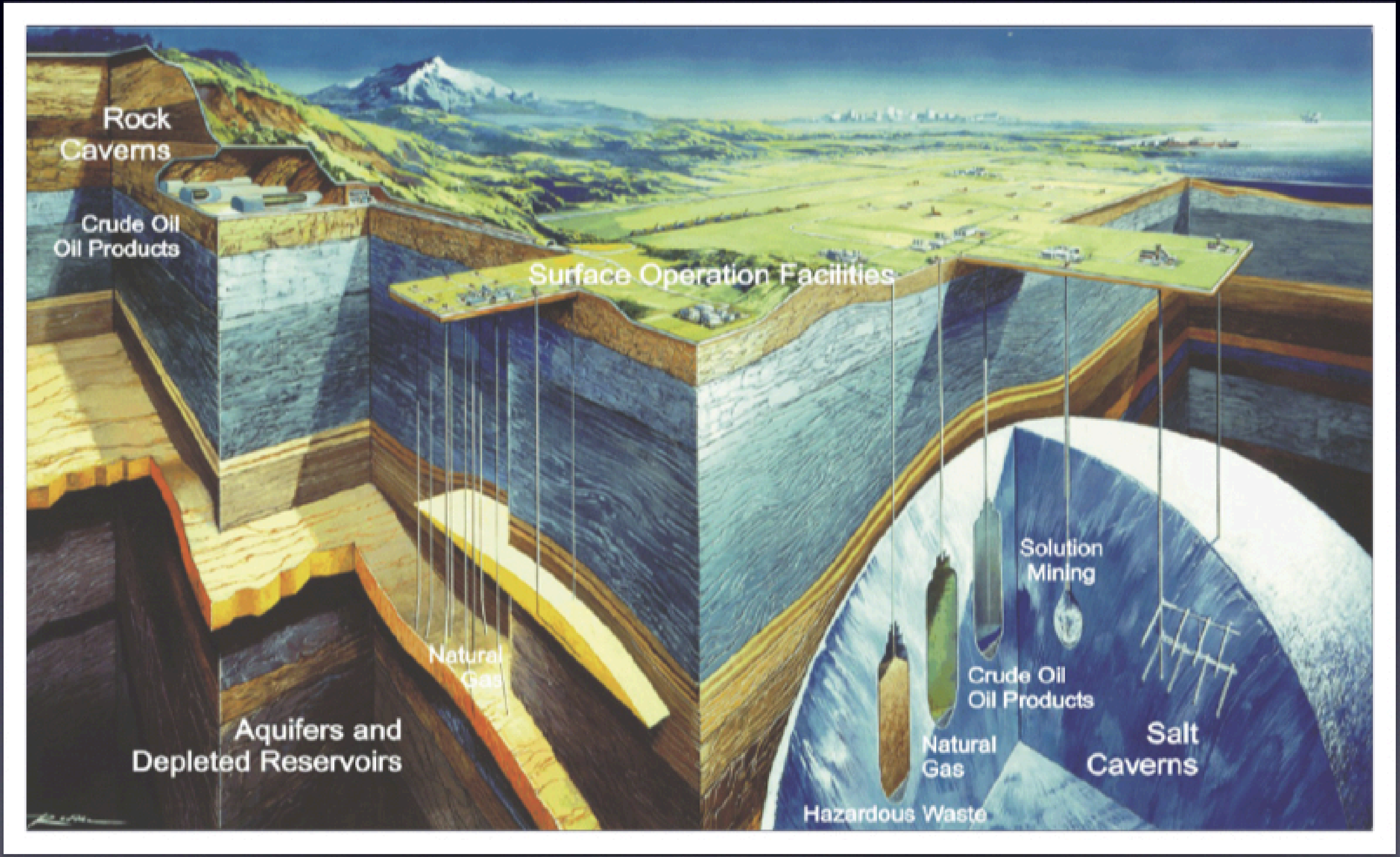
2018

H_2 Gas Storage

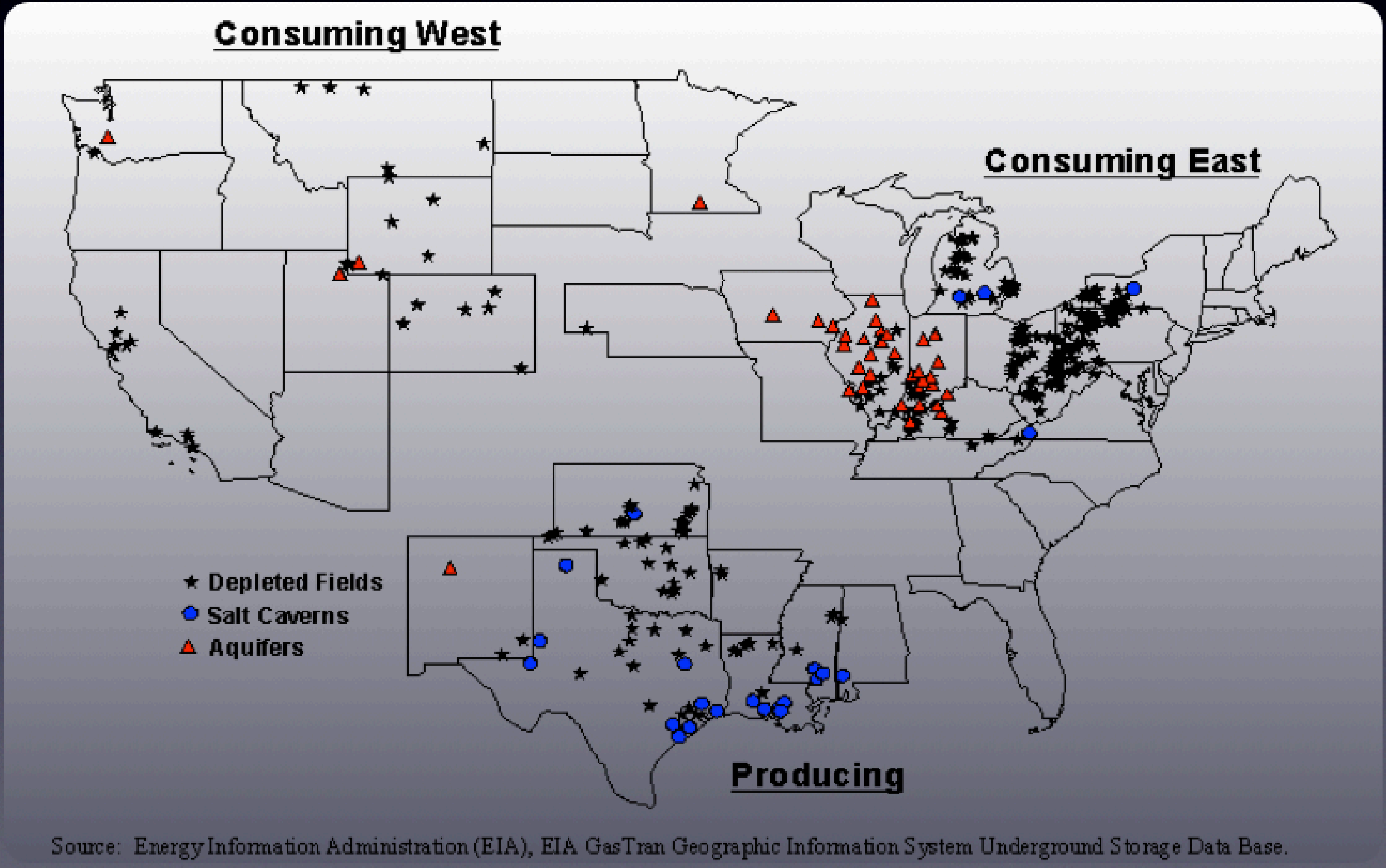
Low pressure vessel	150 MWh
High pressure vessel	2.250 MWh
High pressure tube	4.300 MWh
Cavern	240.000 MWh



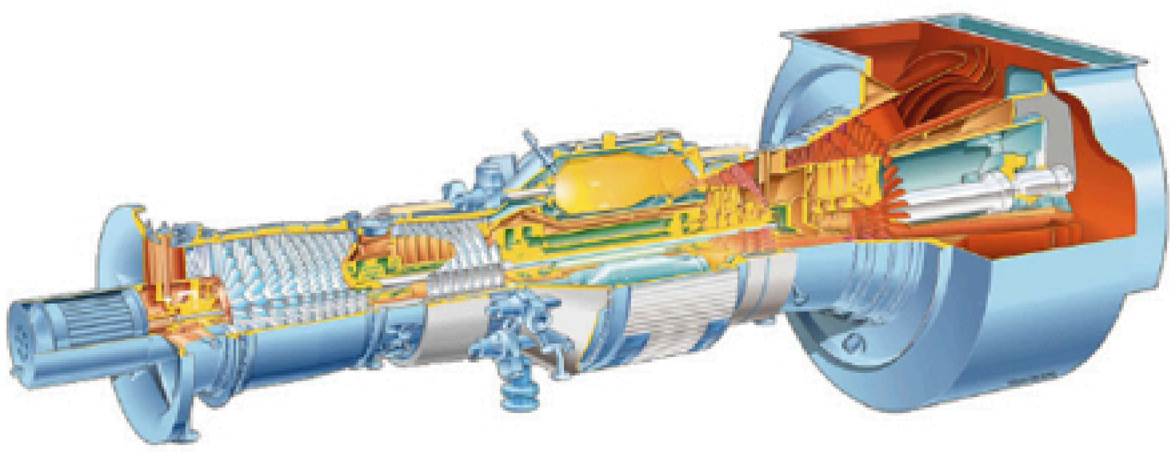
Underground Storage



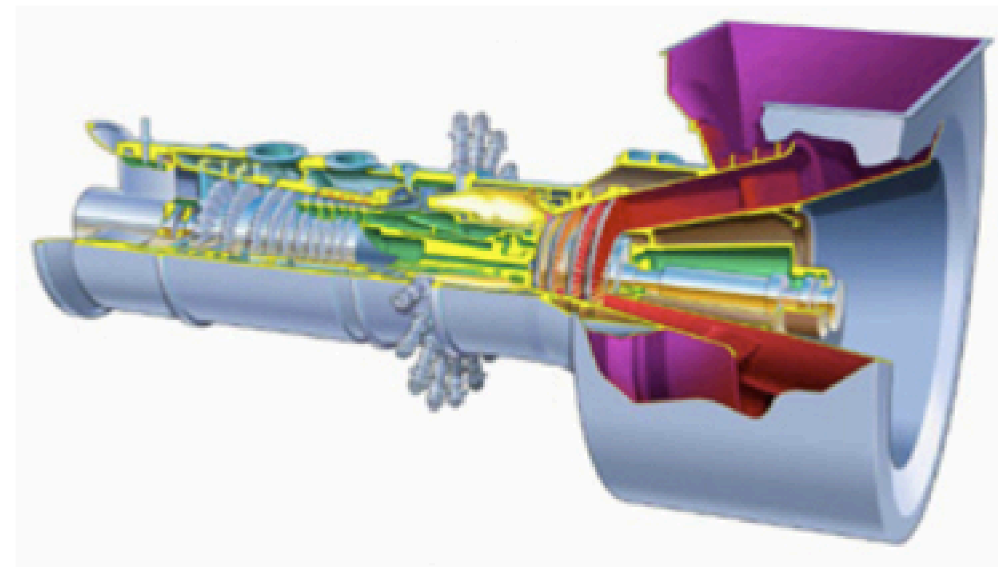
Underground Storage in the USA



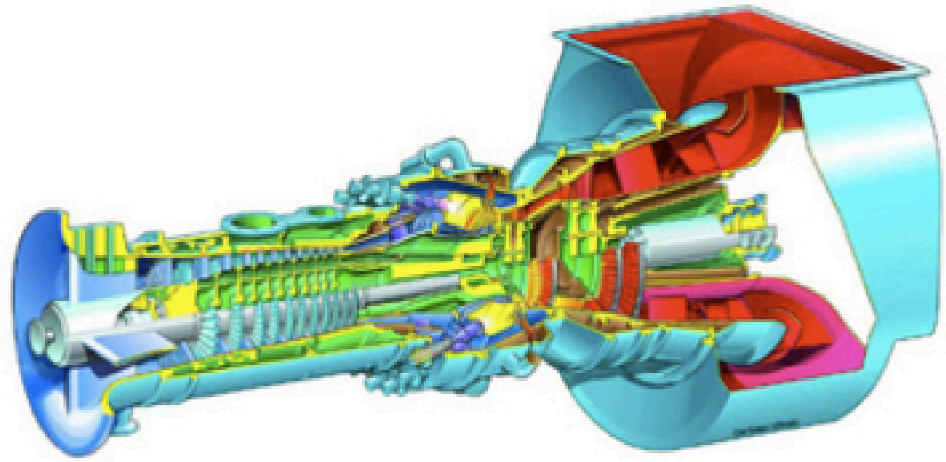
Gas Turbines 15-50MW



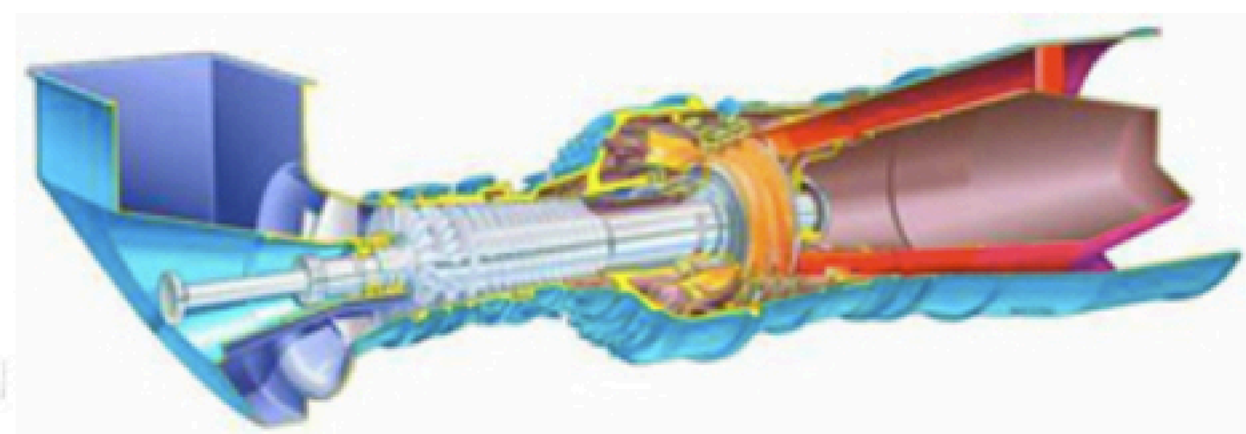
SGT-500 (GT35): 17 MW, 32%



SGT-600 (GT10B): 25 MW, 34%



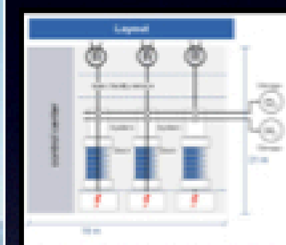
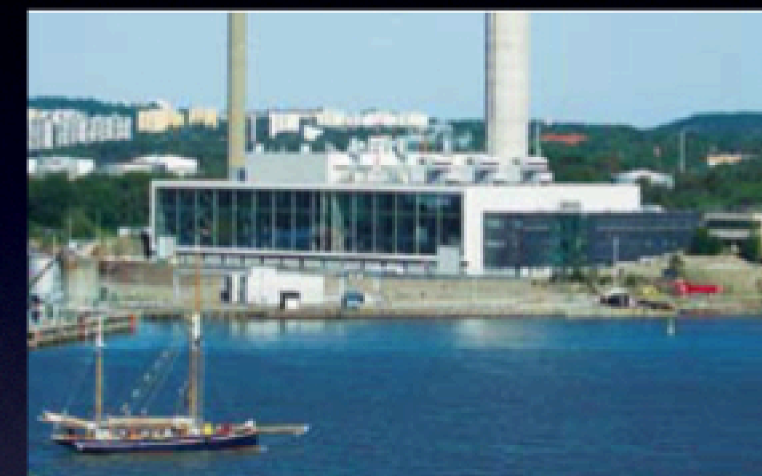
SGT-700 (GT10C): 29 MW, 36%



SGT-800 (GTX100): 47 MW, 38%

Fully dispatchable small wind

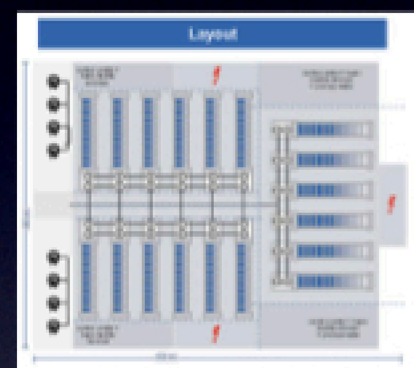
60MW @ 2 days

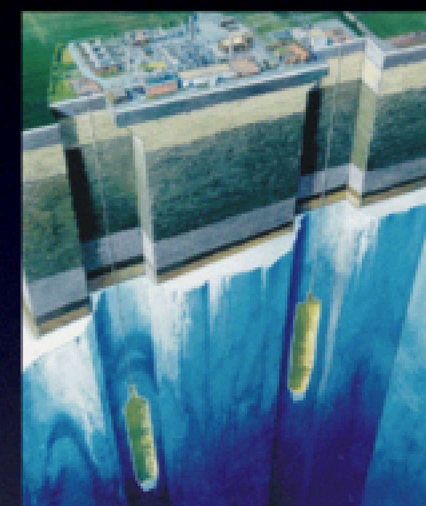
   

CAPEX 20y, 8%					OPEX		
			Mio€/a	Σ Costs (€)	Mio€/a		
Electrolyzer	20(60)MW	900€/kW	1,8		2,4	5%/a	**O&M**
Storage	48h	10€/kWhel	3	**Power (MWh)**	4,9	10€/MWh	**Energy**
CCPP	60MW	650€/kW	4				
				91			

Fully dispatchable big wind

500MW @ 11 days





CAPEX 20y, 8%					**OPEX**		
			Mio€/a	**Σ Costs (€)**	Mio€/a		
Electrolyzer	180(540)MW	700€/kW	13		22,5	5%/a	**O&M**
Storage	11d	0,2€/kWhel	3	**Power (MWh)**	40,5	10€/MWh	**Energy**
CCPP	500MW	650€/kW	33				
				74			

Thank you for your attention!

Time to discuss.

Disclaimer

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