Possibilities using gas in energy systems integration solutions / Storage need in future energy systems

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Allan Schrøder Pedersen, DTU Energy Conversion

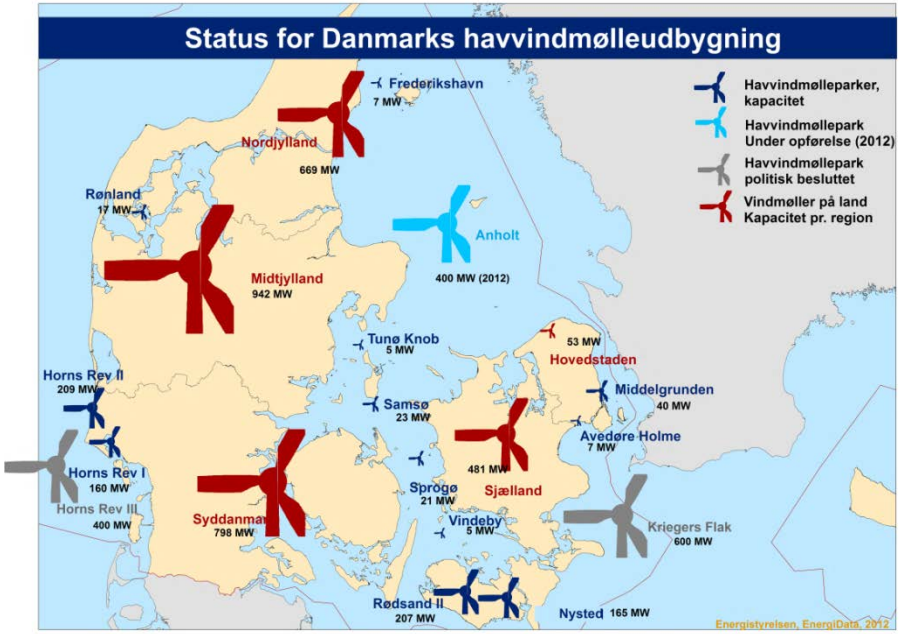
DTU Energy Conversion
Department of Energy Conversion and Storage

Why energy storage?

…. and why gas?

Electricity generation capacity in Denmark

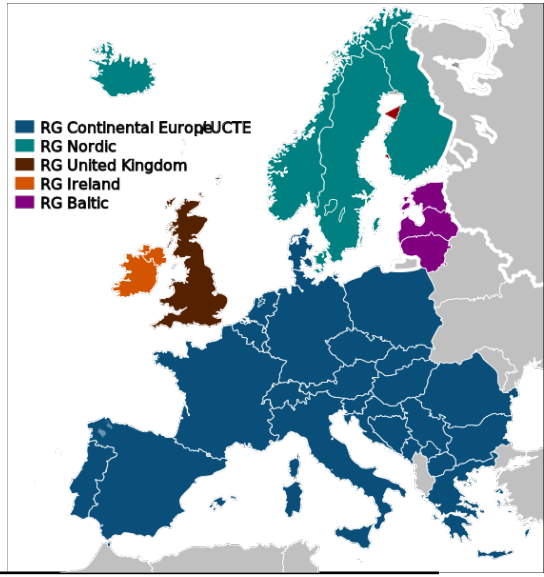
- After commissioning the Anholt Off-Shore wind mill farm (400 MW) Denmark now has 4500 MW installed wind power capacity
- New capacity is planned to reach 50% electricity from wind in 2020 and 100% in 2035
- Present thermal generation capacity in Denmark is 7000 MW
- Bad business case for fossil generation. Availability in 2035? 2050?



Ancillary services

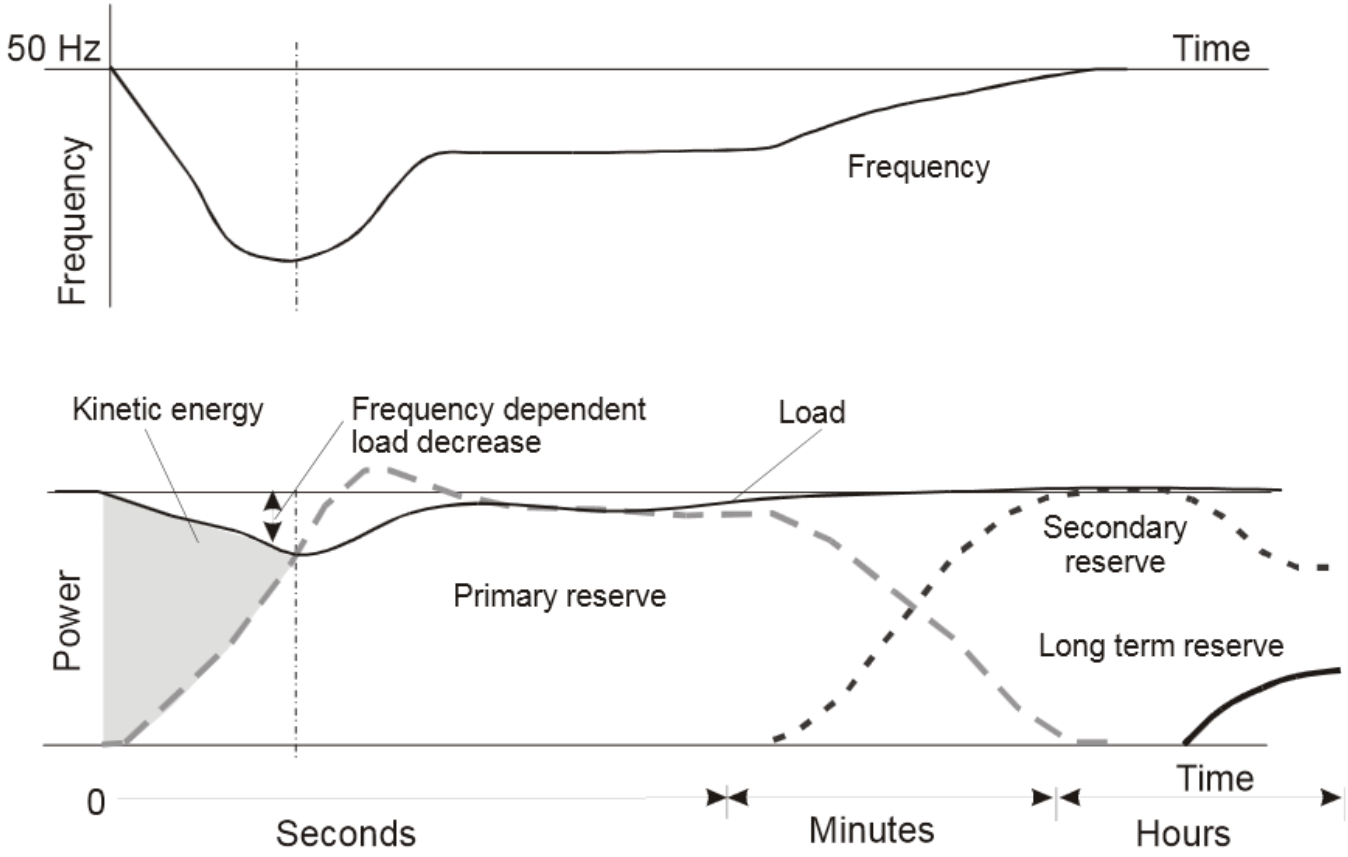
Are services required for the security and stability of the transmission system and for maintaining the quality of electricity supply

Presently, Energinet.dk buys the below ancillary services



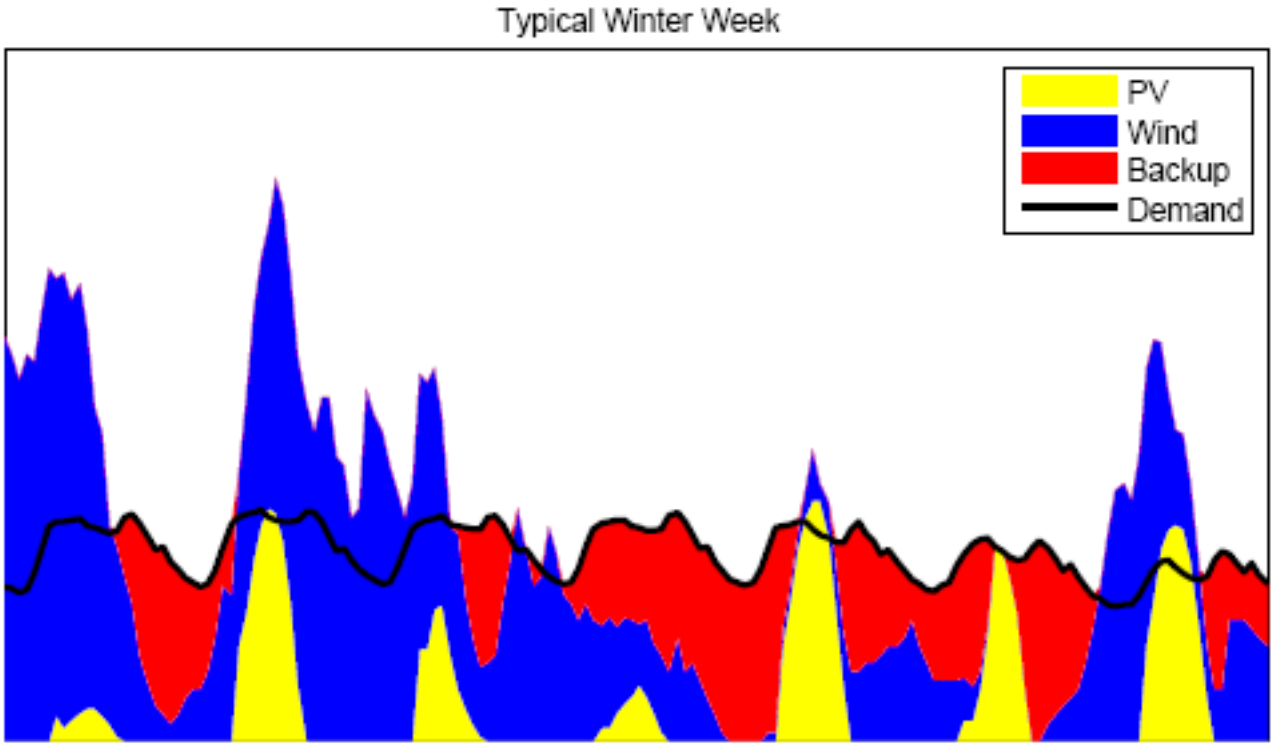
DK1 – West Denmark	DK2 – East Denmark
• Primary reserves - 26 MW Proportional to frequency deviation, 50% 15 s, 100% 30 s, maintain 15 min	• Frequency controlled operational disturbance reserve - 23 MW Proportional to frequency deviation and completely within 150 s
• Secondary reserves (LFC) - 90 MW	• Frequency controlled normal operational reserve 175 MW
• Manual regulating reserves	• Manual regulating reserves
• Black start services	• Black start services
• Short circuit power, reactive power and voltage control	• Short circuit power, reactive power and voltage control

Activation of power reserves and frequency of power system as a function of time when a large power plant is disconnected from the power system



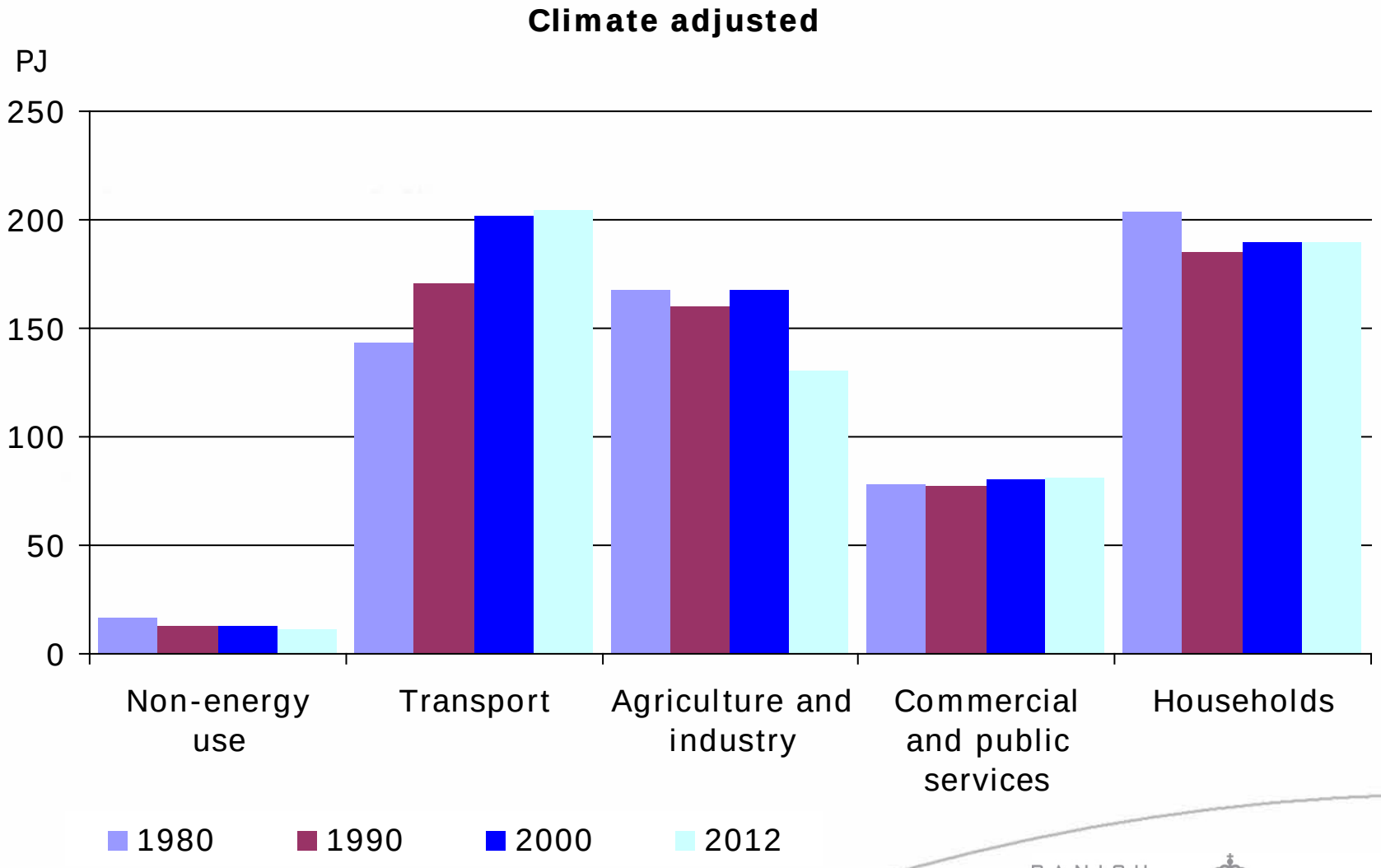
(Holttinen, VTT PUBLICATIONS 554)

PV and wind power production as well as demand in one week – an example from Germany



Steinke, Wolfrum and Hoffmann, 2012

Final energy consumption by use



DANISH ENERGY AGENCY

Storing energy

Energy density for different materials

	w-% H	g H/l	kJ/ml	kJ/g
Hydrogen at 200 bar	100.0	17	2.4	141.0
Magnesium Hydride	7.6	101	14.4	10.9
Complex Hydride	12.0	120	16.9	17,0
Hydride of La-Ni	1.4	89	12.7	1.9
Liquid Hydrogen	100.0	70	10.0	141.0
Methanol	12.5	99	18.0	22.7
Gasoline			33.4	47.6
Lead/Acid Battery				0.2
Advanced battery				0.7
Liquid Methane	25.0	106	25.0	55.7
Liquid Ammonia	17.6	120	17.9	25.2
Fly Wheel				0.5

Numbers do not include weight of containment and system components

Where will the needs for energy storage emerge ?

Energy Storage can be integrated at different levels of the Electrical System:

- **Generation level**: Arbitrage, capacity firming, curtailment reduction
- **Transmission level**: frequency and voltage control, investment deferral, curtailment reduction, black starting
- **Distribution level**: voltage control, capacity support, curtailment reduction
- **Customer level**: peak shaving, time of use cost management, off-grid supply
- **TRANSPORT**
- "Competitors": demand side adaptation, transmission, installed capacity

Chemical energy storage

- Highly versatile energy storage technology
- Low round cycle efficiency
- Solves:
  - The difficult problem of providing proper fuel for the transport transport
  - Need for large-scale (seasonal) storage capacity

Electrolysis at high temperature is interesting because:

- Less electrical input required at high temperatures
- High electrochemical process rates
- Relatively inexpensive ceramic materials
- Possibility to split both H_2O and CO_2:

$$2CO_2 \rightarrow 2CO + O_2$$
$$2H_2O \rightarrow 2H_2 + O_2$$
$$\Big\} \rightarrow \text{Mixtures of H2 and CO}$$

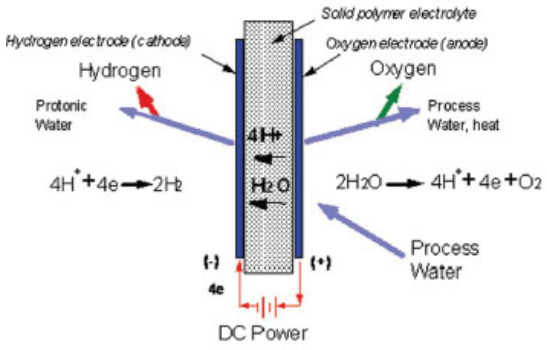
- Still many problems, which must be solved, before commercial products are available – but high potential

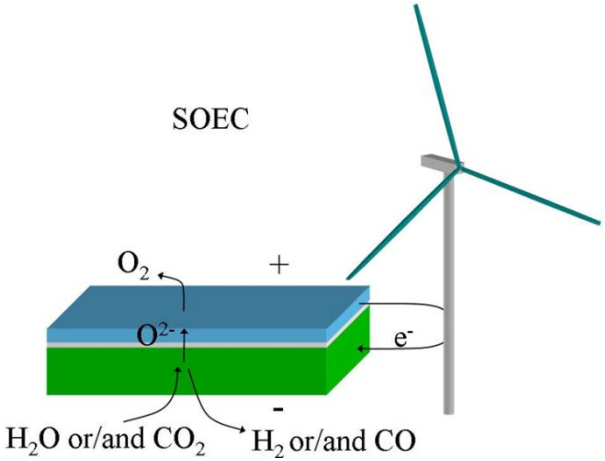
How is gas produced from electricity

Electrolysis – Electrochemical splitting of molecules:

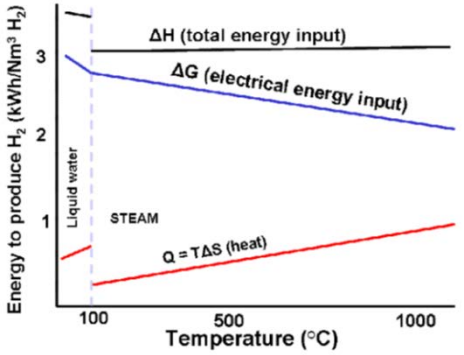
$$2\ CO_2 \rightarrow 2\ CO + O_2$$
$$2\ H_2O \rightarrow 2\ H_2 + O_2$$

PEM electrolysis

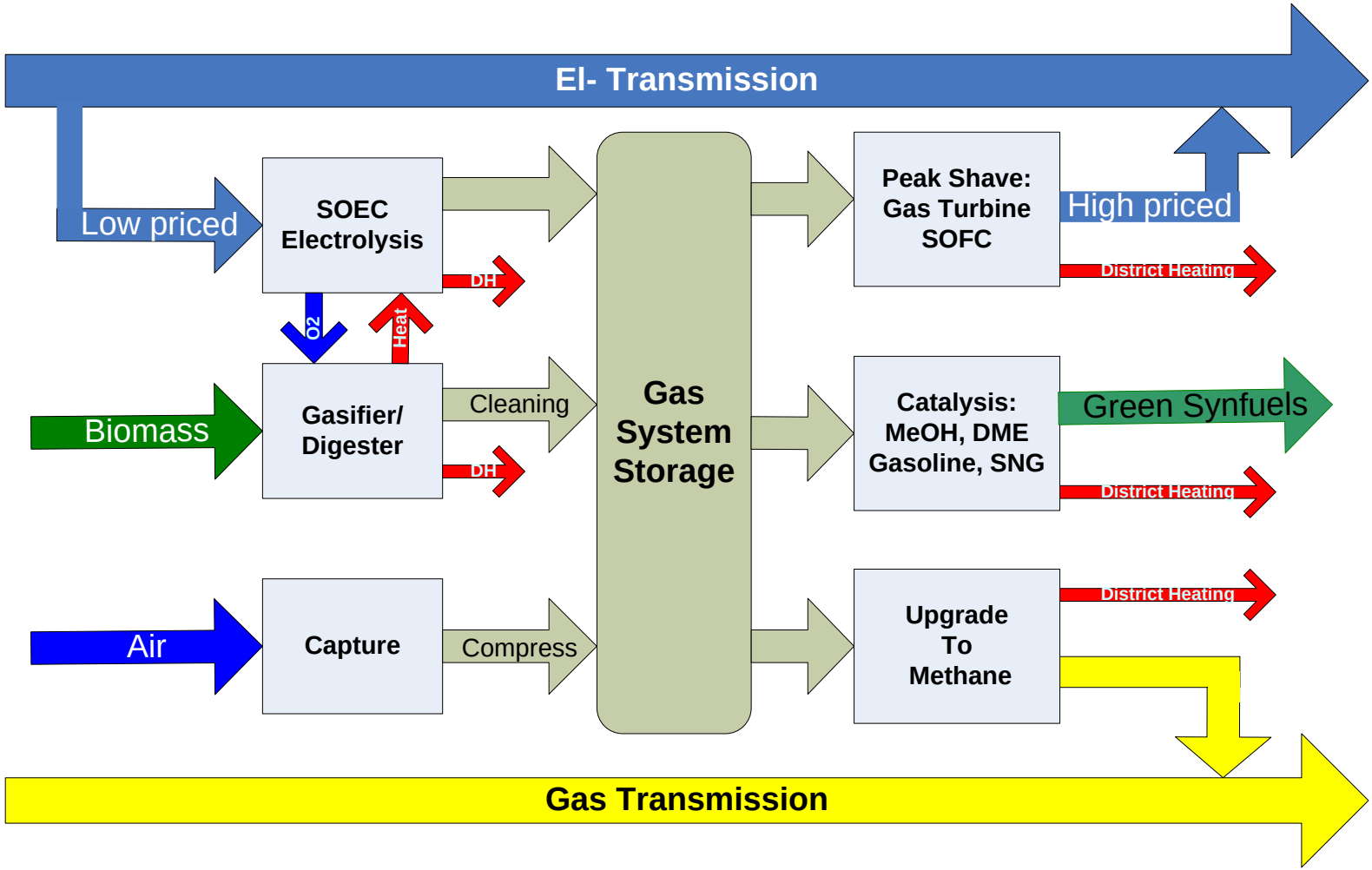




Thermodynamics

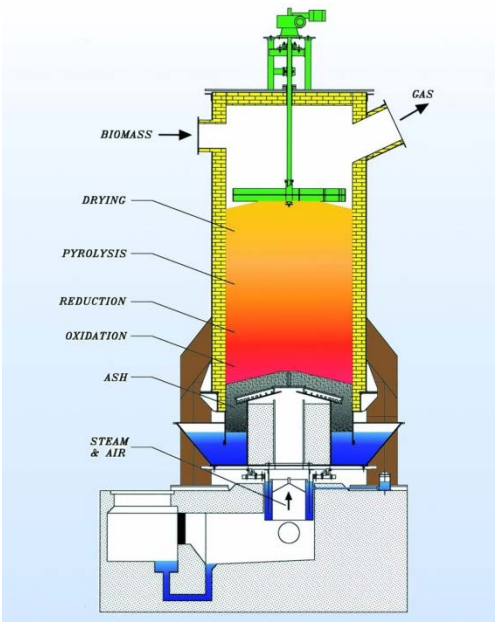


How does chemical energy storage fit into the future energy system ?



Synergy with utilization of biomass

- Gasification of biomass primarily forms mixtures of CO and H_2 (lesser amounts of CO_2 and CH_4)
- Fermentation/digestion of biomass forms mixtures of basically 60% CH_4 and 40% CO_2 which can be upgraded by methanation of CO_2 with hydrogen



http://www.chamco.net/Gasification.htm

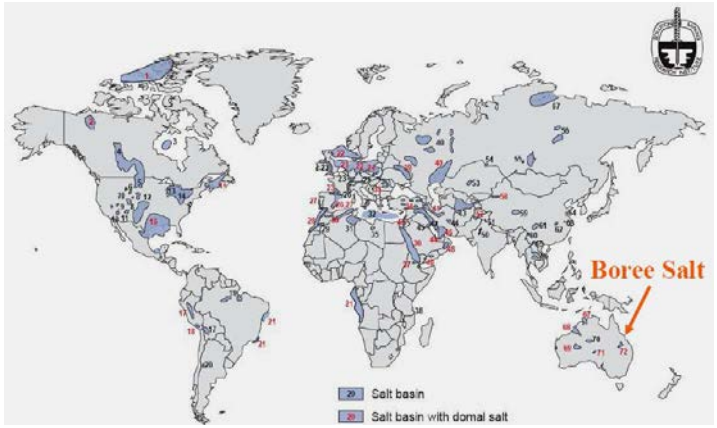
Photo: Mikael Kau/

Storage and distribution

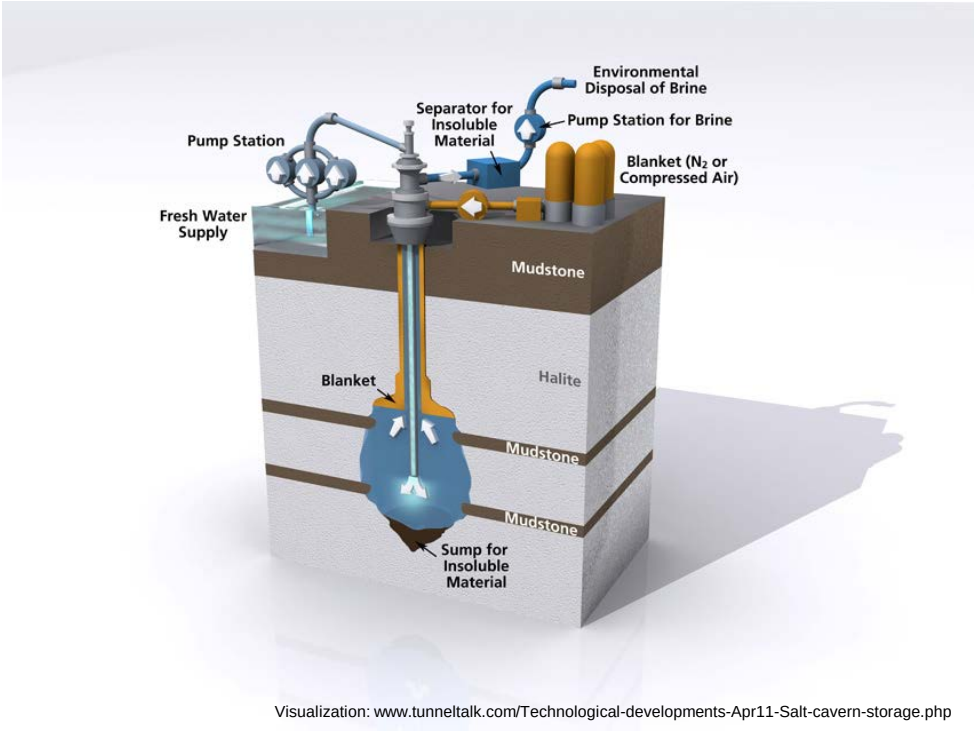
- Synthetic fuels can be stored in huge quantities in surface containments or underground
- High energy density – about 10-15 times that of batteries
- Existing (and depreciated) fine-meshed gas transmission and distribution grid covering major parts of Europe
- Consumers are conversant with chemical fuels and conversion equipment

European underground gas storage potential

- Europe has suitable geological conditions for salt caverns
- Solution mining is a competence utilized for gas storage for decades



Major World Salt Deposits, Source: Solution Mining Research Institute



Visualization: www.tunneltalk.com/Technological-developments-Apr11-Salt-cavern-storage.php

..... many thanks for your attention