



Produzione di metano da fonti energetiche rinnovabili

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Workshop AIDIC

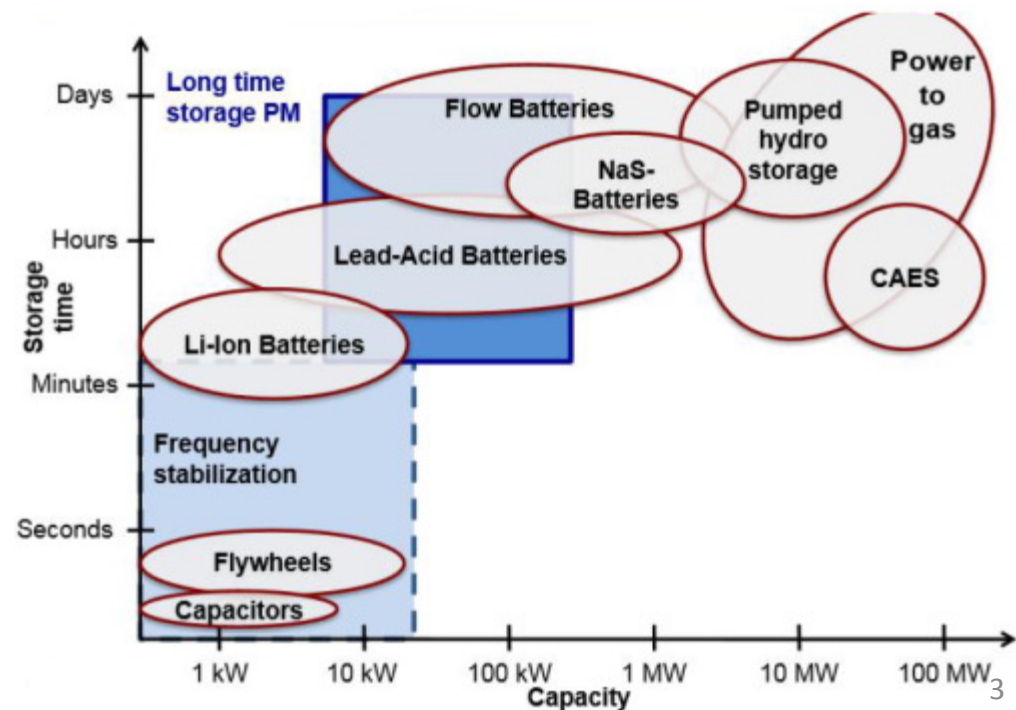
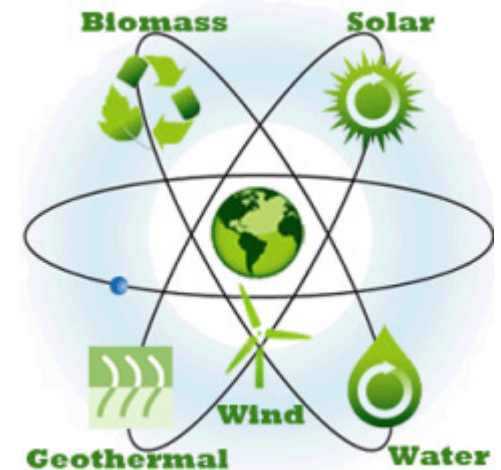
"Tecnologie di accumulo energetico, un viatico per le rinnovabili"

Roma, 24 Aprile 2013

- Storage of renewable energies
- Energy storage via production of fuels and chemicals
- Description of the new process
- Application to the Sulcis coalfield: an economic analysis

Storage of renewable energies

- Renewable power (photovoltaic, solar thermal or wind) is inherently intermittent and fluctuating
- Several energy storage systems are under study:
 - batteries (Lead-acid, Na-S, Li-ion)
 - hydrogen storage - fuel cells
 - flow batteries
 - pumped hydro storage (PHS)
 - compressed air energy storage (CAES)
 - flywheels
 - superconducting magnetic energy storage (SMES)
 - capacitors/supercapacitors



Storage of renewable energies

Technology	Advantage	Disadvantage	Commercial maturity	Application	Cost	Remarks
Mechanical energy storage – Pumped storage hydro (PSH)	High capacity, Low efficiency	Special site requirement	High	Energy management	Low cost	Suitable for Load leveling
Compressed air energy storage (CAES)	High capacity	Special site requirement need gas fuel, Low energy density	High	Energy management	Low cost	Suitable for Load leveling
Flywheel	High power	Low energy density	High	Power quality management		Suitable for short duration in sec or min (voltage dip)
Electrical energy storage – Capacitors and Supercapacitors	Long cycle life/high efficiency	Low energy density	Medium	Power quality management		Suitable for short duration in sec or min (voltage dip)
Superconducting magnetic energy storage (SMES)	High power	Low energy density and high production cost	Medium	Power quality management	High production cost	Suitable for short duration in sec or min (voltage dip)
Lead-acid		Limited cycle life when deeply discharged	High		Low capital cost	Renewables and power plants
Chemical energy storage – Flow batteries: VRB, ZnBr, PSB	High capacity, independent power and energy ratings	Low energy density	Medium	Power quality management		Renewables and power plants
NiCd	High power/high efficiency	High energy density, High cost	High	Power quality and energy management		Renewables and power plants
Li-ion	High power/high efficiency	High cost and needs special charging circuit	Medium	Power quality and energy management		Power quality management
Metal-air		Electrically not re-chargeable				
NaS			Medium	Power quality and energy management		Renewables and power plants

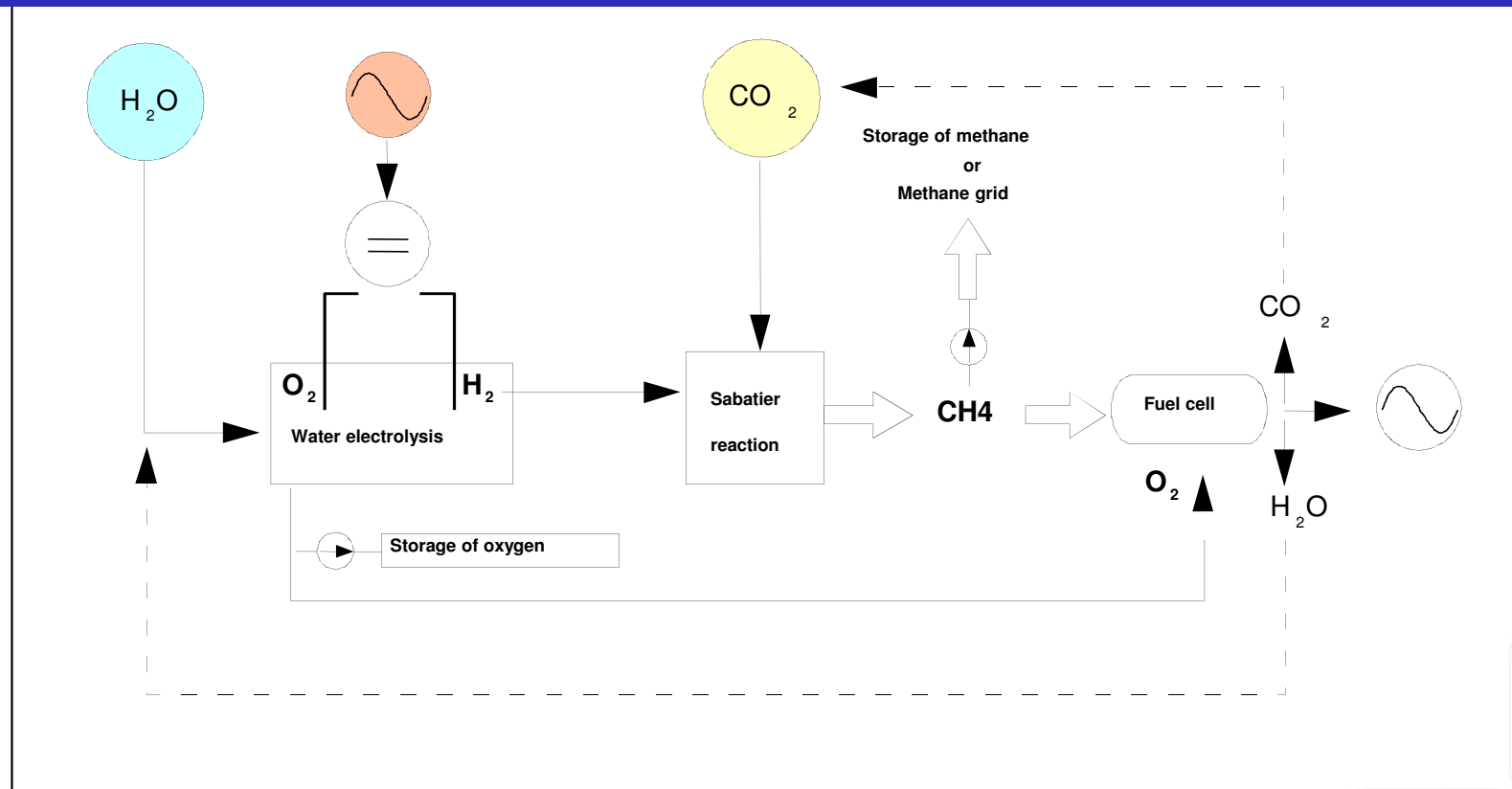
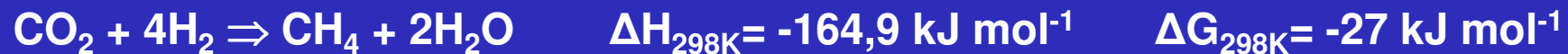
Energy storage via production of fuels and chemicals



- So far, technologies for safe and economic storage, transportation and use of the hydrogen are not still available
- Hydrogen produced from renewable energies can be used for producing fuels and chemicals
- Several studies considered the reaction of hydrogen and CO_2 for producing:
 - methane
 - fuels and chemicals (Green Freedom)
 - gasoline

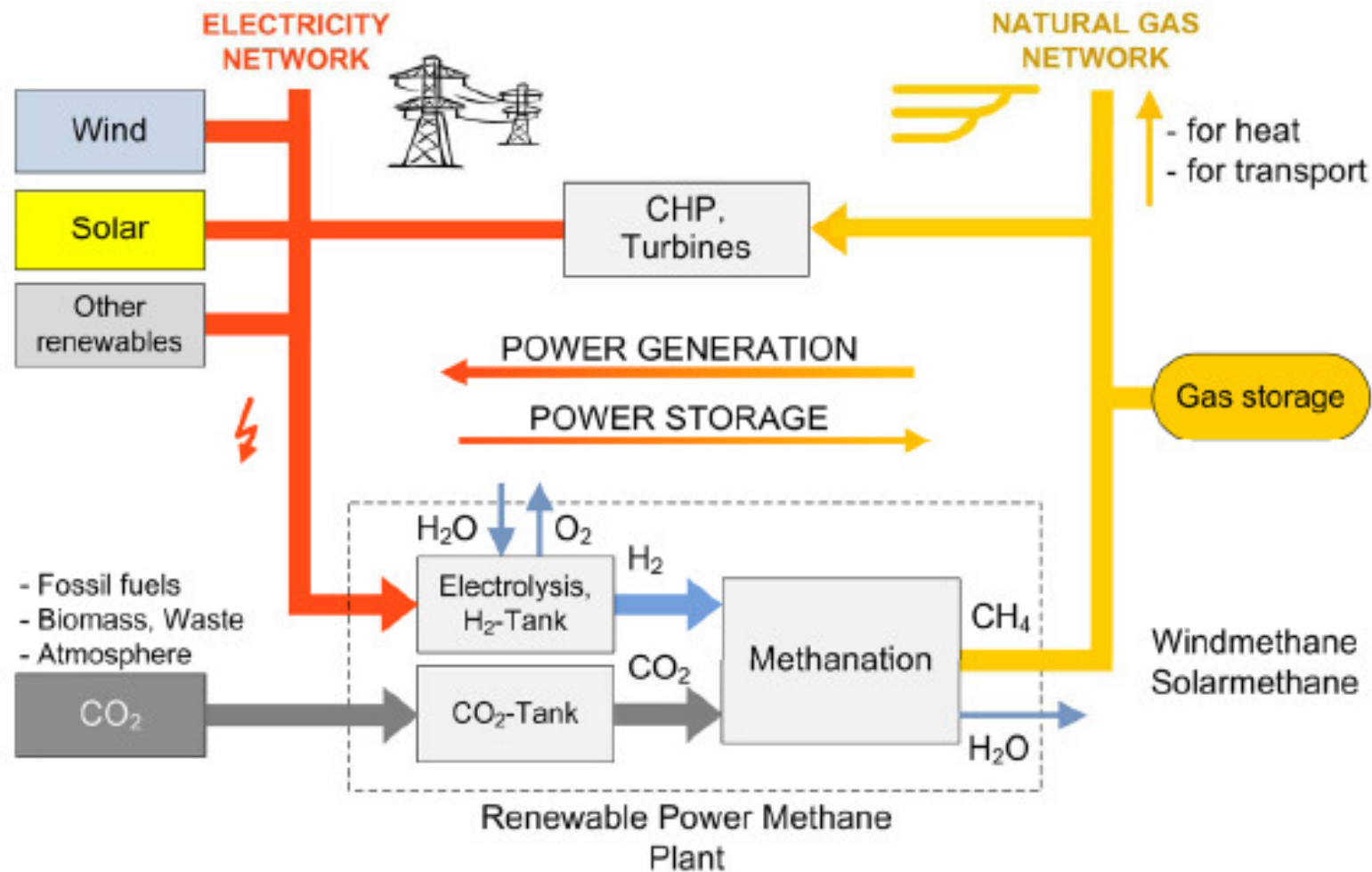
Energy storage via production of fuels and chemicals

A process for the methanation of CO₂ (Sabatier reaction) has been developed at ENEA (2007)



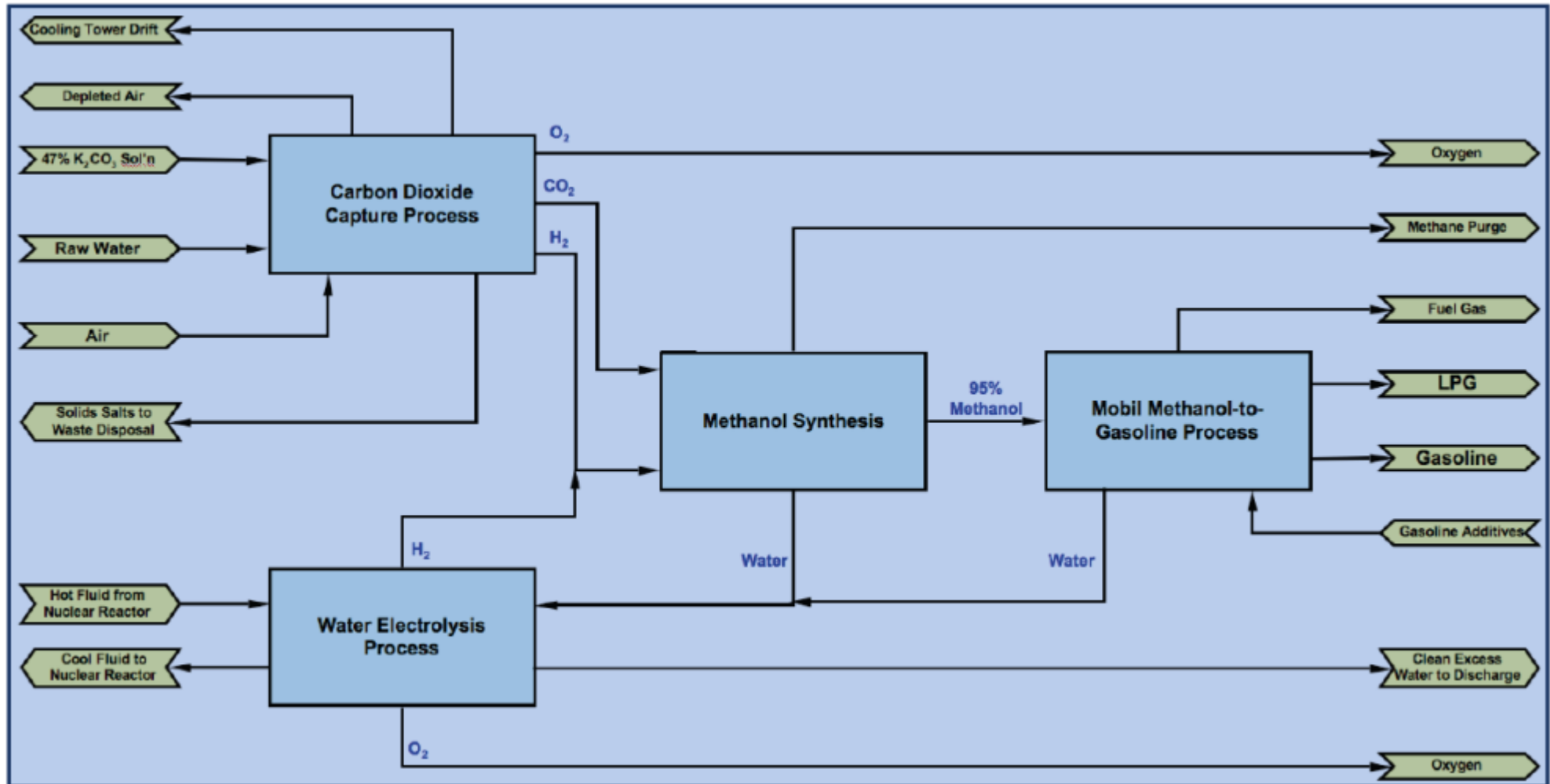
Energy storage via production of fuels and chemicals

A similar process for the methanation of CO_2 has been developed in Germany/Austria (2009)



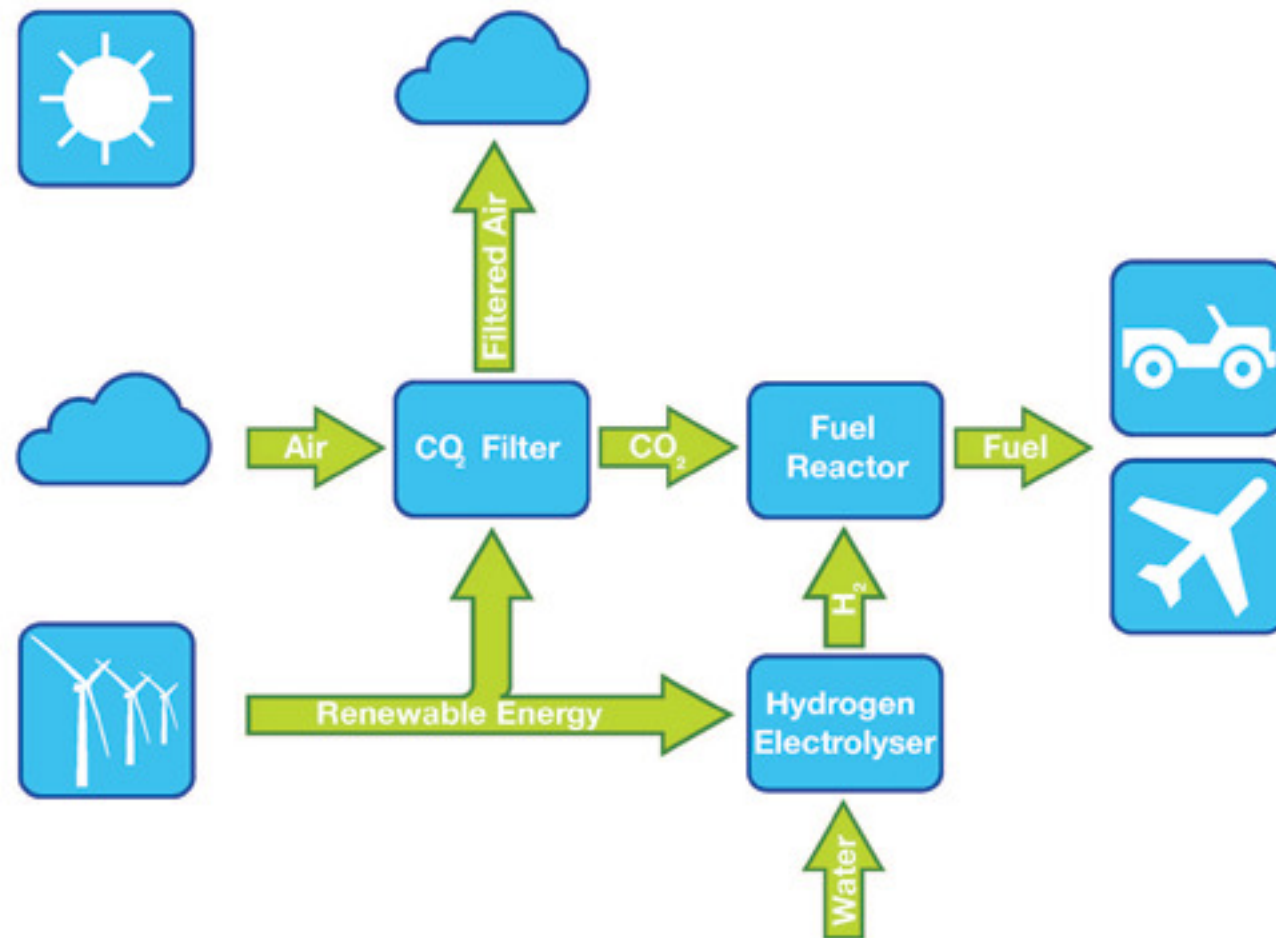
Energy storage via production of fuels and chemicals

Green Freedom produces synthetic gasoline from CO₂ (in air) and hydrogen (via water electrolysis) (2007)



Energy storage via production of fuels and chemicals

In the Air Fuel Synthesis (AFP) process, the carbon dioxide (from air) and hydrogen (via water electrolysis) react together to make liquid hydrocarbon fuels



Description of the new process

- Basic process: water electrolysis and coal hydrogasification:



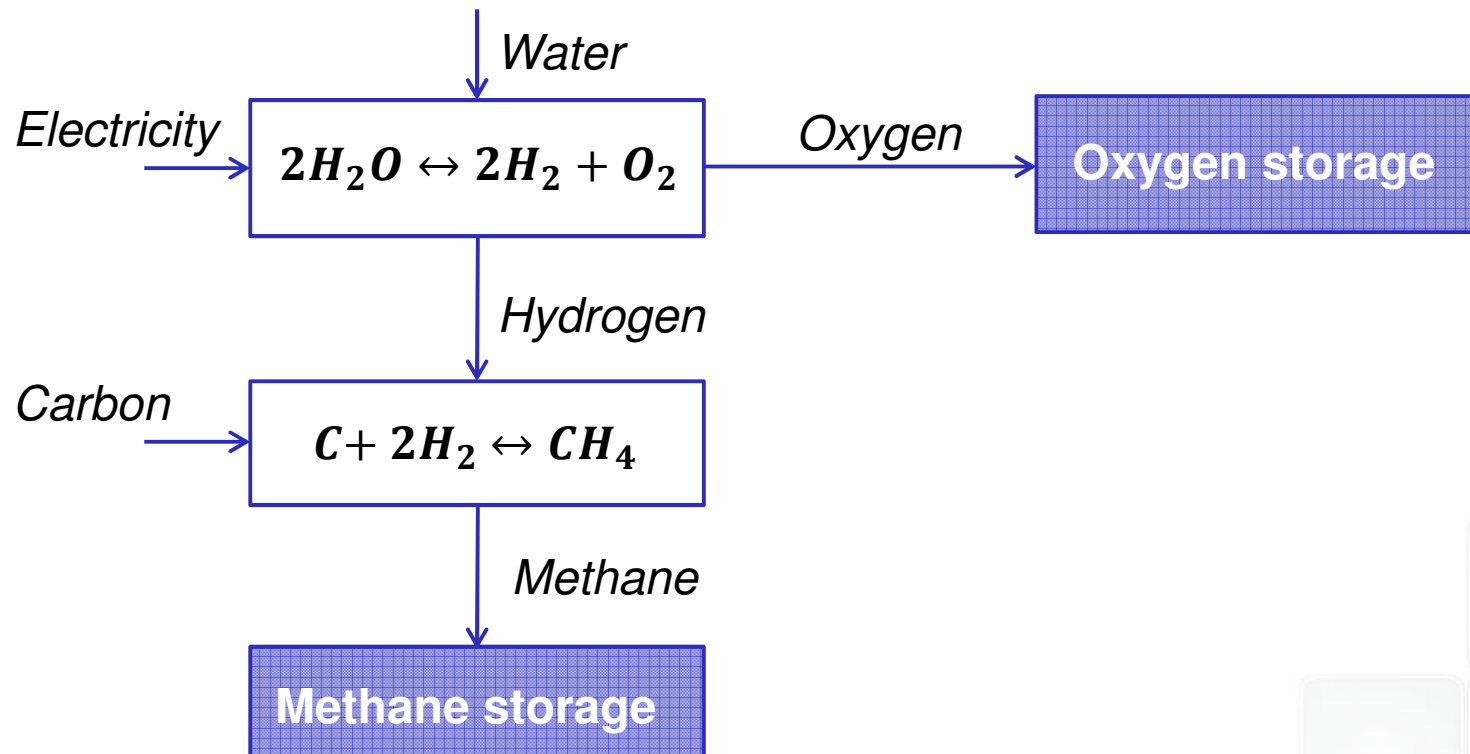
$$\Delta H_{298\text{K}} = 483.71 \text{ kJ mol}^{-1}$$



$$\Delta H_{298\text{K}} = -74.87 \text{ kJ mol}^{-1}$$



$$\Delta H_{298\text{K}} = 408.84 \text{ kJ mol}^{-1}$$



Water electrolysis and coal hydrogasification

For producing 1 mole of CH_4 :

- electrolysis of 2 moles of water
- use of 1 mole of carbon
- production of 1 mole of oxygen



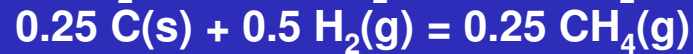
Large amounts of oxygen produced: is there a market?

Description of the new process

Combination with partial oxidation and water gas shift



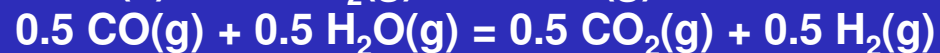
$$\Delta H_{298\text{K}} = 120.93 \text{ kJ mol}^{-1}$$



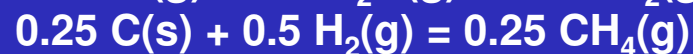
$$\Delta H_{298\text{K}} = -18.72 \text{ kJ mol}^{-1}$$



$$\Delta H_{298\text{K}} = -55.27 \text{ kJ mol}^{-1}$$



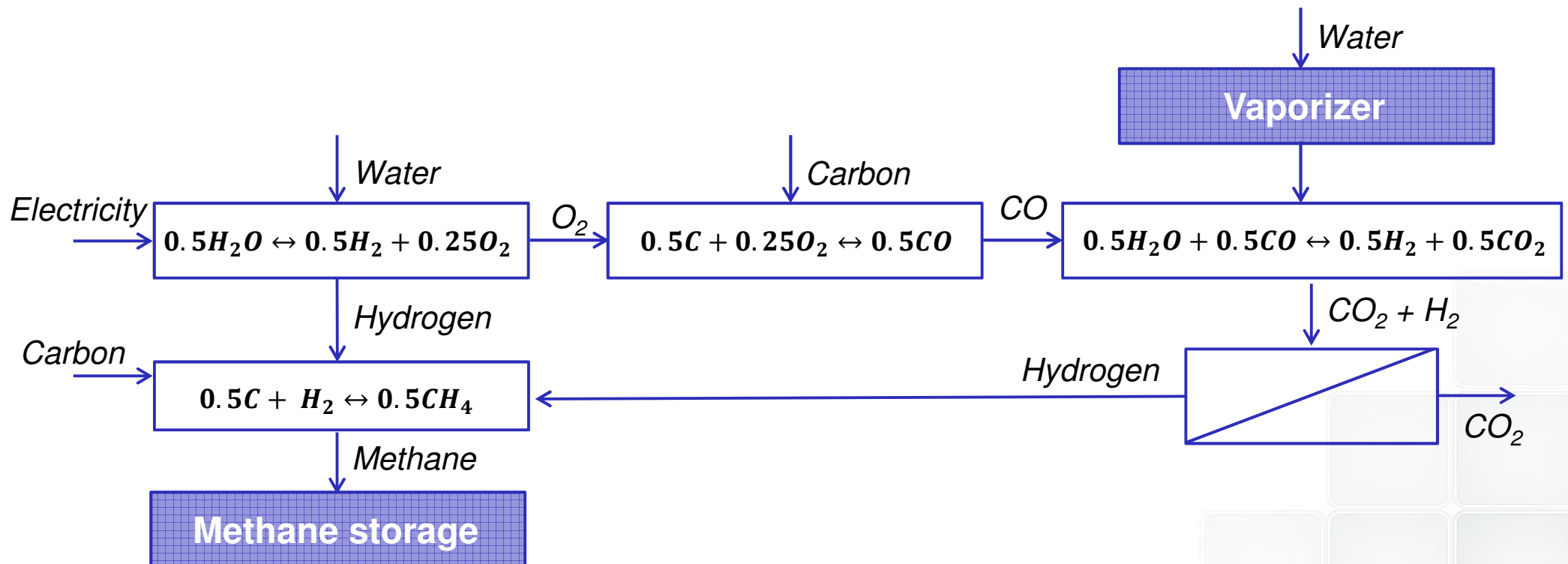
$$\Delta H_{298\text{K}} = -20.55 \text{ kJ mol}^{-1}$$



$$\Delta H_{298\text{K}} = -18.72 \text{ kJ mol}^{-1}$$



$$\Delta H_{298\text{K}} = 7.67 \text{ kJ mol}^{-1}$$



Description of the new process

Combination with partial oxidation and water gas shift:

For producing 1 mole of CH_4 :

- electrolysis of 1 mole of water
- use of 2 moles of carbon
- production of 1 mole of CO_2



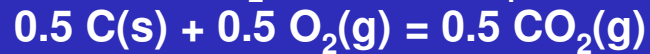
Lower electricity consumption

Larger use of coal

Production of CO_2 (need of separation and storage...)

Description of the new process

■ Combination with oxy-combustion



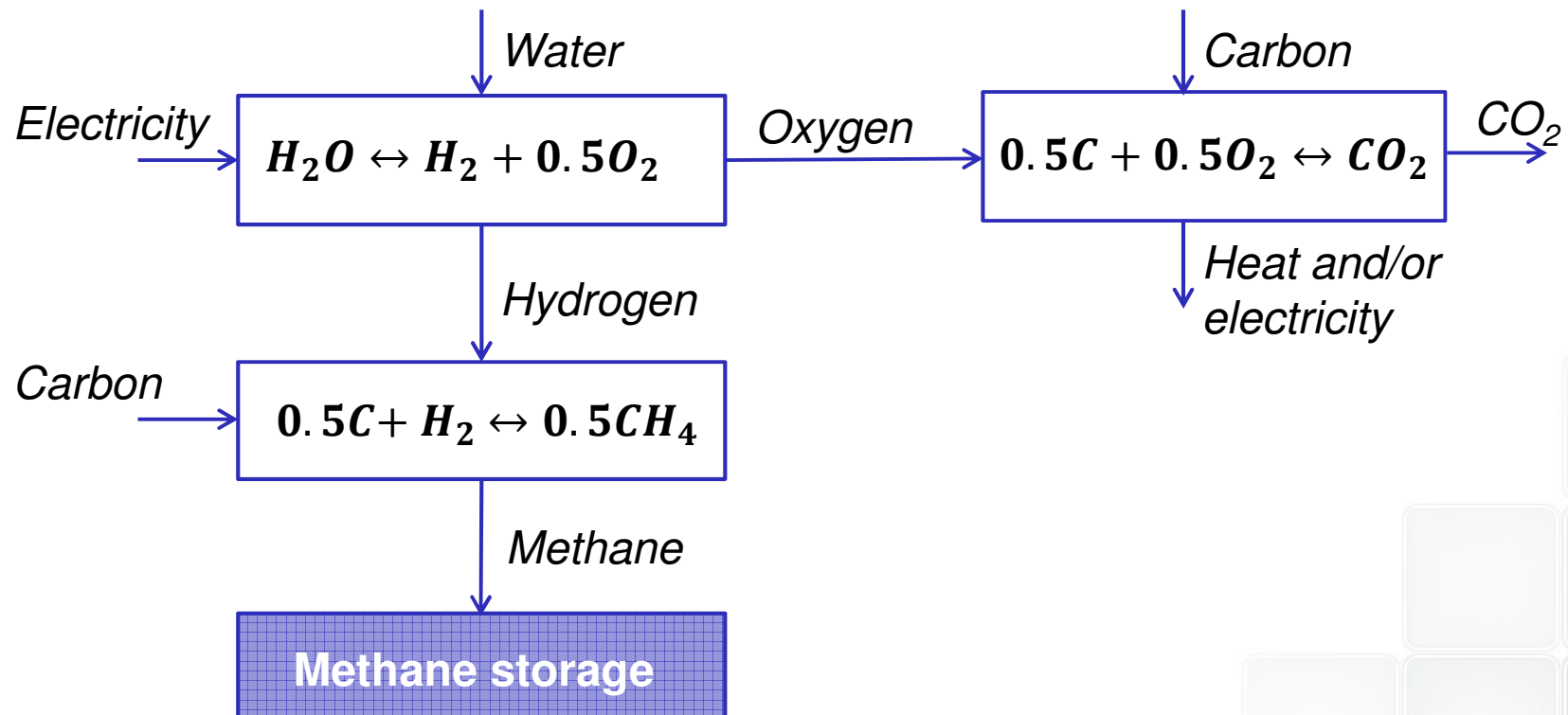
$$\Delta H_{298\text{K}} = 241.86 \text{ kJ mol}^{-1}$$

$$\Delta H_{298\text{K}} = -37.44 \text{ kJ mol}^{-1}$$

$$\Delta H_{298\text{K}} = -196.75 \text{ kJ mol}^{-1}$$



$$\Delta H_{298\text{K}} = 7.67 \text{ kJ mol}^{-1}$$



Description of the new process

Combination with oxy-combustion:

For producing 1 mole of CH_4 :

- electrolysis of 2 moles of water
- use of 2 moles of carbon
- production of 1 mole of CO_2



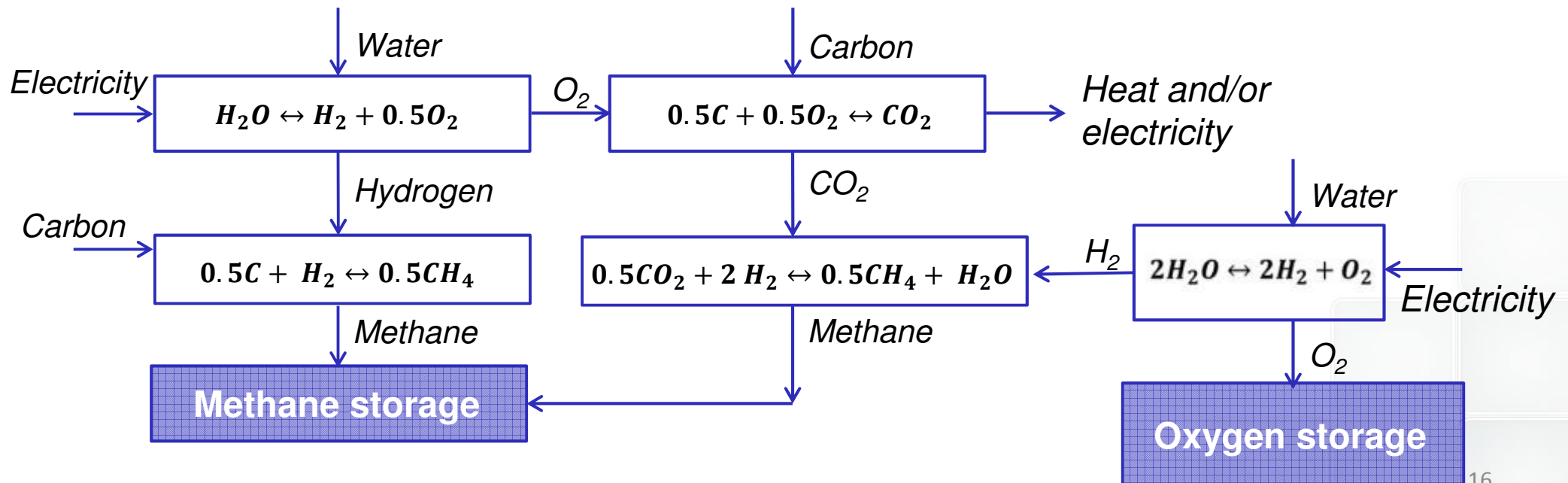
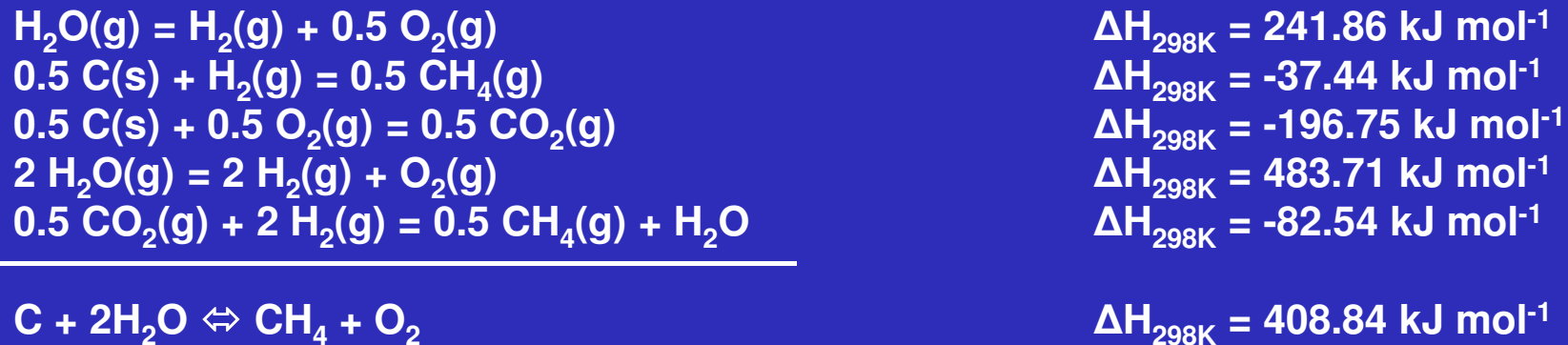
**Electricity consumption can be partially balanced
(oxy-combustion power plants)**

Larger use of coal

**Production of enriched- CO_2 ready for segregation
(no CO_2 separation required)**

Description of the new process

■ Combination with oxy-combustion and Sabatier reaction



Description of the new process

Combination with oxy-combustion and Sabatier reaction:

For producing 1 mole of CH_4 :

- electrolysis of 3 moles of water
- use of 1 mole of carbon
- production of 1 mole of oxygen



**Much higher electricity consumption (partially
balanced by its production in oxy-combustion
power plants)**

Large amounts of oxygen produced

Application to the Sulcis area: an economic analysis

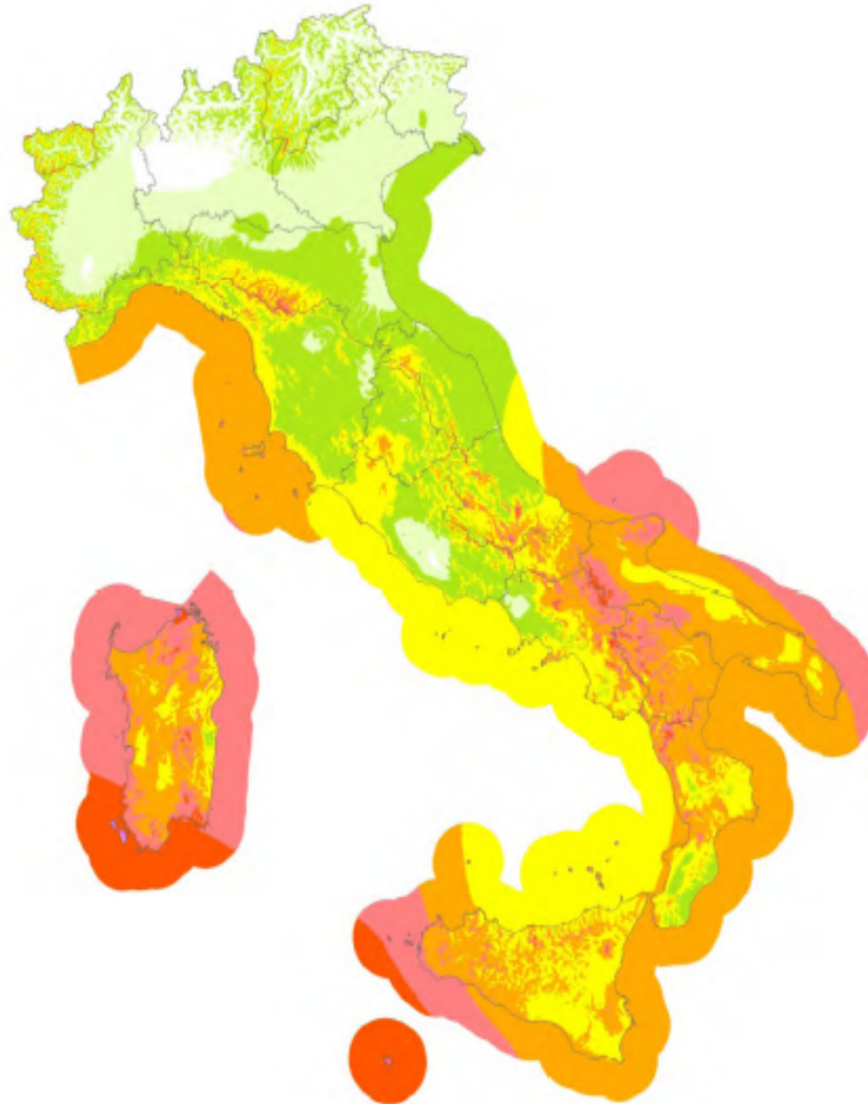
- The Sulcis coalfield produces about 300 kt/y of coal which are burnt at the Portovesme power plant

- The Sulcis area is one of the most windy of Italy

- In 2011 Sardinia produced more than 1000 GWh of electricity from wind plants (more than 900 MW installed)

Application to the Sulcis area: an economic analysis

Annual wind map @ 75 m AMSL
(Source – RSE, Ricerca sul Sistema
Energetico)

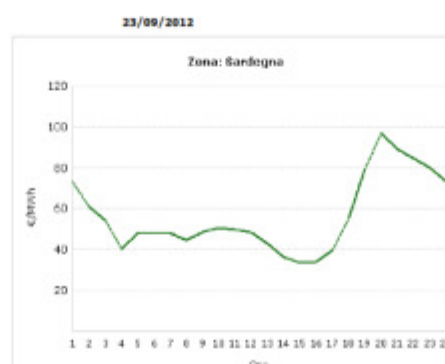
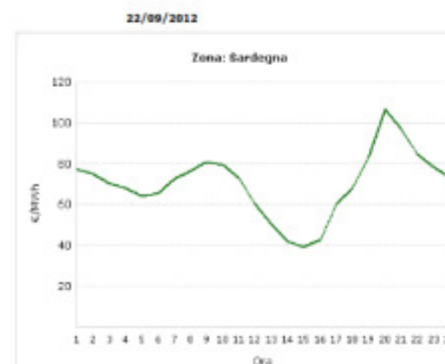
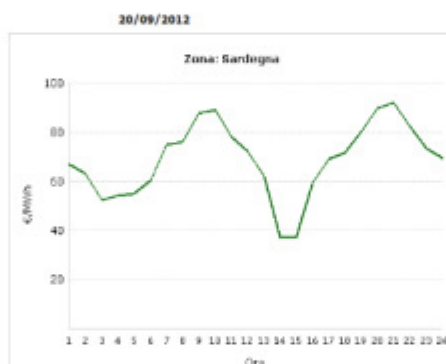
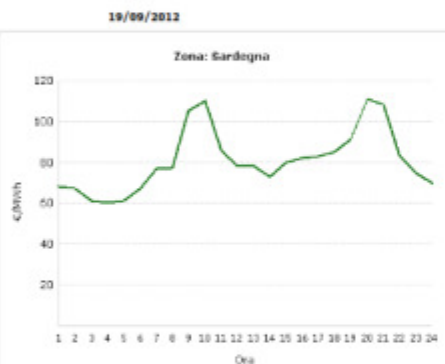
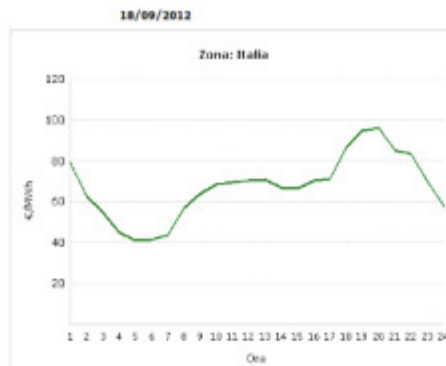
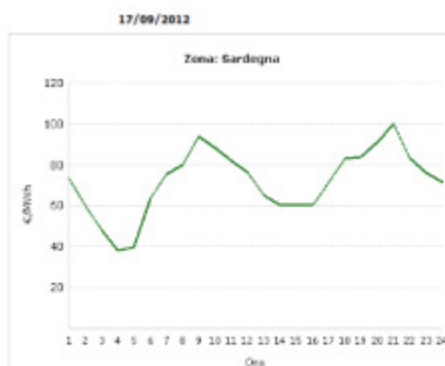


Wind velocity



Application to the Sulcis area: an economic analysis

Electricity cost (Sardinia, 17-23 Sept. 2012)



Application to the Sulcis area: an economic analysis

Economic analysis:

- cost of coal: 65 €/t
- cost of electricity: 0.04-0.06 €/kWh
- cost of methane: 0.20 €/Nm³
- cost of oxygen: 0.25 €/Nm³
- carbon content of coal: 60% wt.
- efficiency of oxy-combustion: 30%



Application to the Sulcis area: an economic analysis

- Cost analysis for the treatment of 300 000 t/y of carbon from the Sulcis coalfield assuming an electricity cost of 40 €/MWh

	H ₂ produced Nm ³ /y 10 ⁶	CH ₄ produced Nm ³ /y 10 ⁶	O ₂ produced Nm ³ /y 10 ⁶	Electricity required (from the grid) GWh/y	Electric power, MW	Income CH ₄ M€/y	Income O ₂ M€/y	Cost of carbon M€/y	Cost of electricity M€/y	Income/ cost
Basic process	673	336	336	3300	382	67.3	84.1 (-)	19.5	132	1.00 (0.44)
with WGS	168	168	-	825	95.5	33.6	-	19.5	33	0.64
with oxy-combustion	336	168	-	1430	165	33.6	-	19.5	57.2	0.44
with oxy-combustion + Sabatier reaction	1010	336	336	4730	547	67.3	84.1 (-)	19.5	189	0.73 (0.32)

Application to the Sulcis area: an economic analysis

- Cost analysis for the treatment of 300 000 t/y of carbon from the Sulcis coalfield assuming an electricity cost of 60 €/MWh

	H ₂ produced Nm ³ /y 10 ⁶	CH ₄ produced Nm ³ /y 10 ⁶	O ₂ produced Nm ³ /y 10 ⁶	Electricity required (from the grid) GWh/y	Electric power, MW	Income CH ₄ M€/y	Income O ₂ M€/y	Cost of carbon M€/y	Cost of electricity M€/y	Income/ cost
Basic process	673	336	336	3300	382	67.3	84.1 (-)	19.5	198	0.70 (0.31)
with WGS	168	168	-	825	95.5	33.6	-	19.5	49.5	0.49
with oxy- combustion	336	168	-	1430	165	33.6	-	19.5	85.7	0.32
with oxy- combustion + Sabatier reaction	1010	336	336	4730	547	67.3	84.1 (-)	19.5	284	0.50 (0.22)

The process permits:

- *production of methane from coal (with reduced environmental impact + better social acceptability)*
- *storage of renewable energies*
- *the methane produced is a mix of renewable en. and fossil en.*

Particular interest for the re-qualification of the Sulcis area:

- *economics of installing wind plants (but need electricity storage)*
- *valorization of the coalfield (that produces low quality coal)*
- *valorization of the Portovesme power plant (oxy-combustion → CO₂ capture and storage)*
- *investments for the electrolyzers (re-conversion of Alcoa Al electrolyzers?) and hydrogasification plants*

« Tout ce qui est imaginable par l'homme est réalisable par l'homme »

Thomas Sankara

THANK YOU FOR THE ATTENTION