



中国科学院上海高等研究院
SHANGHAI ADVANCED RESEARCH INSTITUTE, CHINESE ACADEMY OF SCIENCES

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For IEA

Towards greener hydrogen production in China

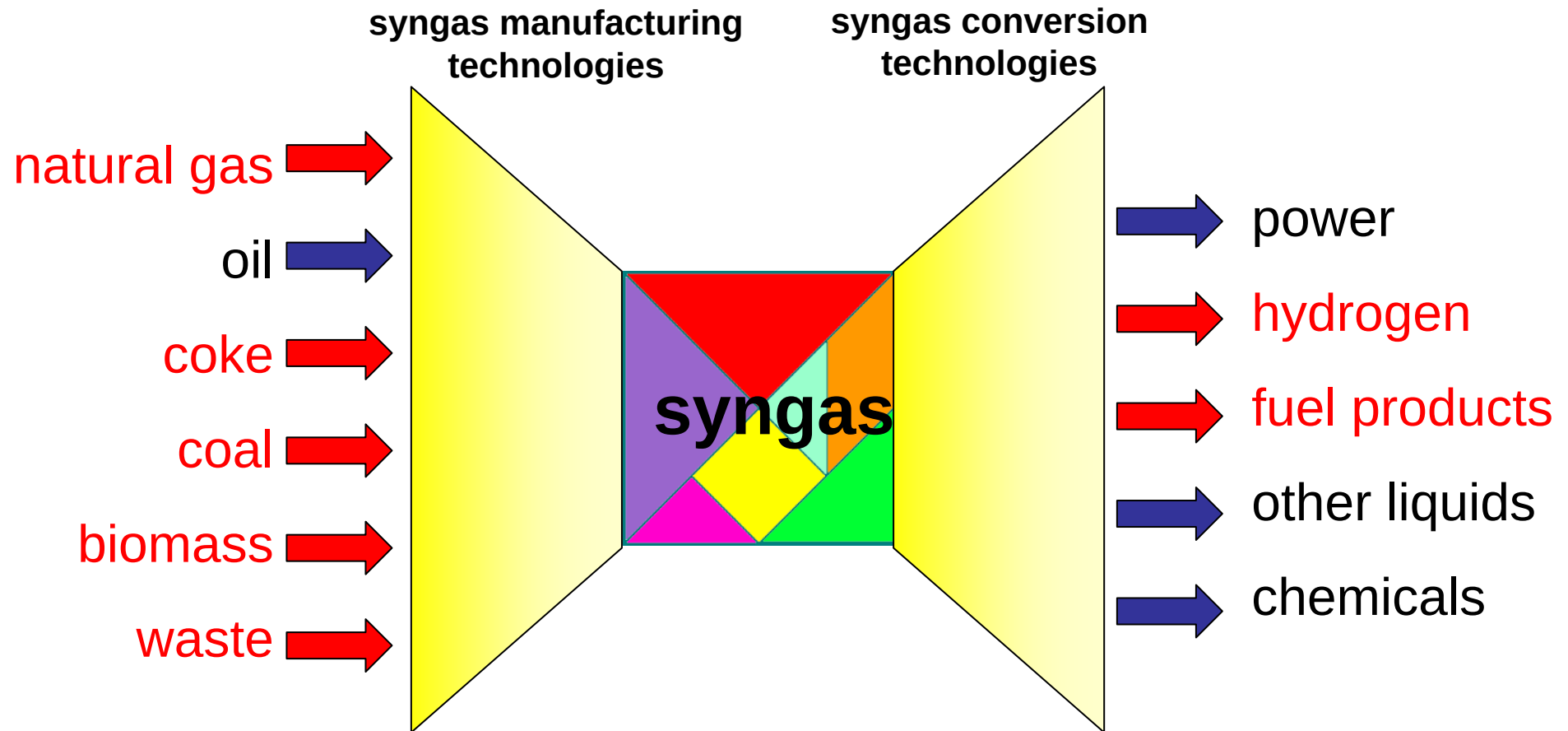
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Hydrogen from fossil fuels



Hydrogen production routines in China



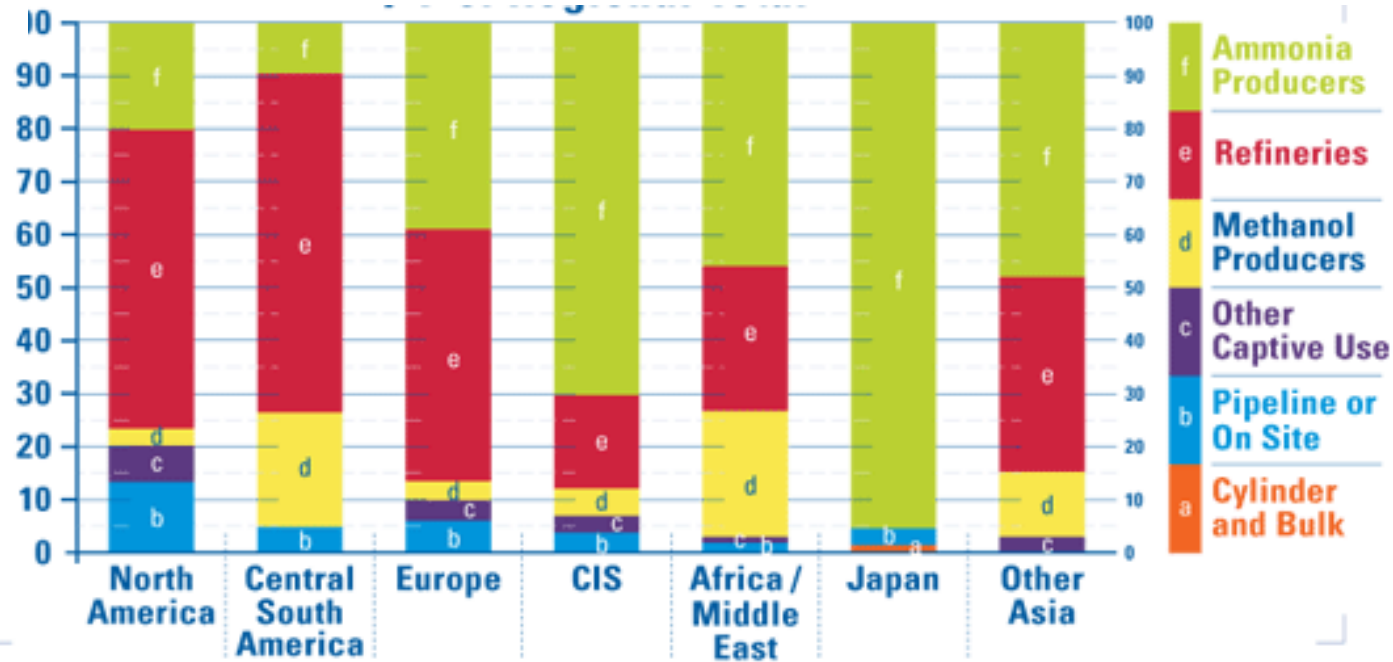
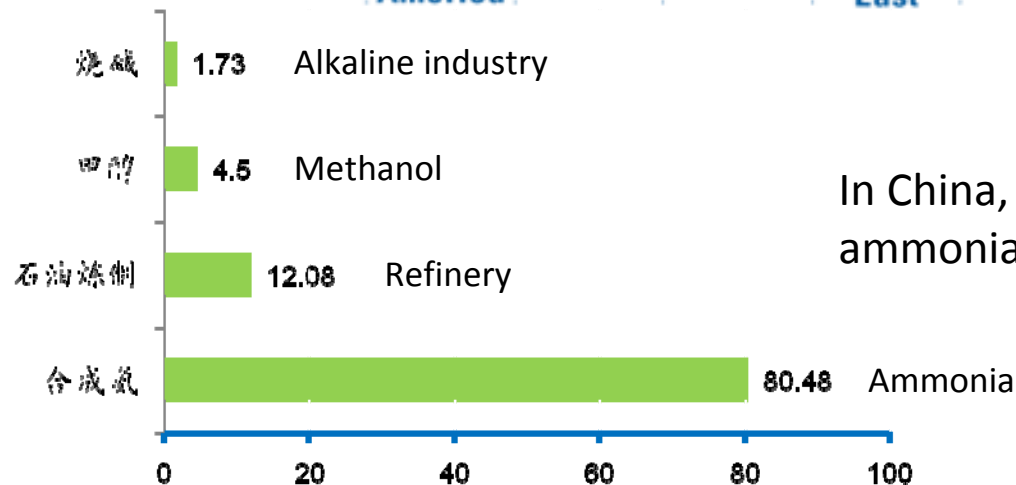
Hydrogen is not a full commodity at present



Hydrogen production route is highly dependent on locally rich sources



Hydrogen consumption in China



In China, the produced hydrogen is mainly for ammonia and refinery

Hydrogen use in China



Hydrogen production from coal

Resources	Cost of raw materials, RMB/t	H ₂ price,RMB/Nm ³
Coal	760	1.07
Petroleum coke	950	1.12
Refinery gas	3000	1.40
Residue oil	4000	1.88

For 20MT/y refinery

Due to availability of coal and lower cost, hydrogen production from coal will continue mainly for ammonia synthesis

Gasification processes is a key step to produce hydrogen



Comparison of entrained gasification technology

Comparison	A Coal			B Coal	
	Coal-water slurry	Pulverized with quench	Pulverized with boiler	Pulverized with quench	Pulverized with boiler
CO+H ₂ (dry base), %	84.3	91.3	91.3	89.8	89.8
O ₂ consumption/ 1000 m ³ (CO+H ₂)	357	281	281	327	327
Coal consumption/ 1000 m ³ (CO+H ₂)	551	495	495	674	674
Cold gas efficiency	73.2	82.6	82.6	80.2	80.2

- Higher efficiency and less coal consumption for pulverized gasifier than coal-water slurry gasifier
- If we have to choose coal gasification to produce hydrogen, use the pulverized gasifier as much as possible



Hydrogen from methane reforming in China

Product	Yearly prod. (mil. t/y)	Energy consumpt. (GJ/t)	Thermal LHV Practical (%)	Efficiency Ideal (%)	CO ₂ (t/t)	Main technology
Ammonia	124	29	65	89	16 ^a	Syngas/synthesis
Ethylene	75	15 ^b	62	93	0.65	Steam cracking C ₂ H ₆
Propylene	53	-	-			Steam cracking C ₂ H ₆
Methanol	32	28	72	84	0.28	Syngas/synthesis
Hydrogen	20	12.6	84 ^c	92	0.9	Steam reforming
Synfuels	18 ^d	67	60	78	1.18	Syngas/synthesis

a) incl. CO₂ converted into urea

b) data kindly provided by F. Dautzenberg, ABB Lummus, 2005

c) CH₄ used for reaction heat; no steam export

d) excl. 3 million tonnes per year under construction

- Currently, reforming process is mainly focus on using the tail gas, coke gas etc.
- Shale gas and unconventional gas reforming is expected to produce hydrogen in the future



Catalysts, products and processes in steam reforming

Design	H ₂ O/ CH ₄	P (bar)	T _{inlet} (°C)	T _{exit} (°C)	H ₂	CO	CO ₂	CH ₄	Process duty MW
Previous	4.5	30	500	850	75.19	11.07	10.49	3.24	97.8
Modern	1.8	30	650	920	71.08	17.61	4.56	6.75	85.4

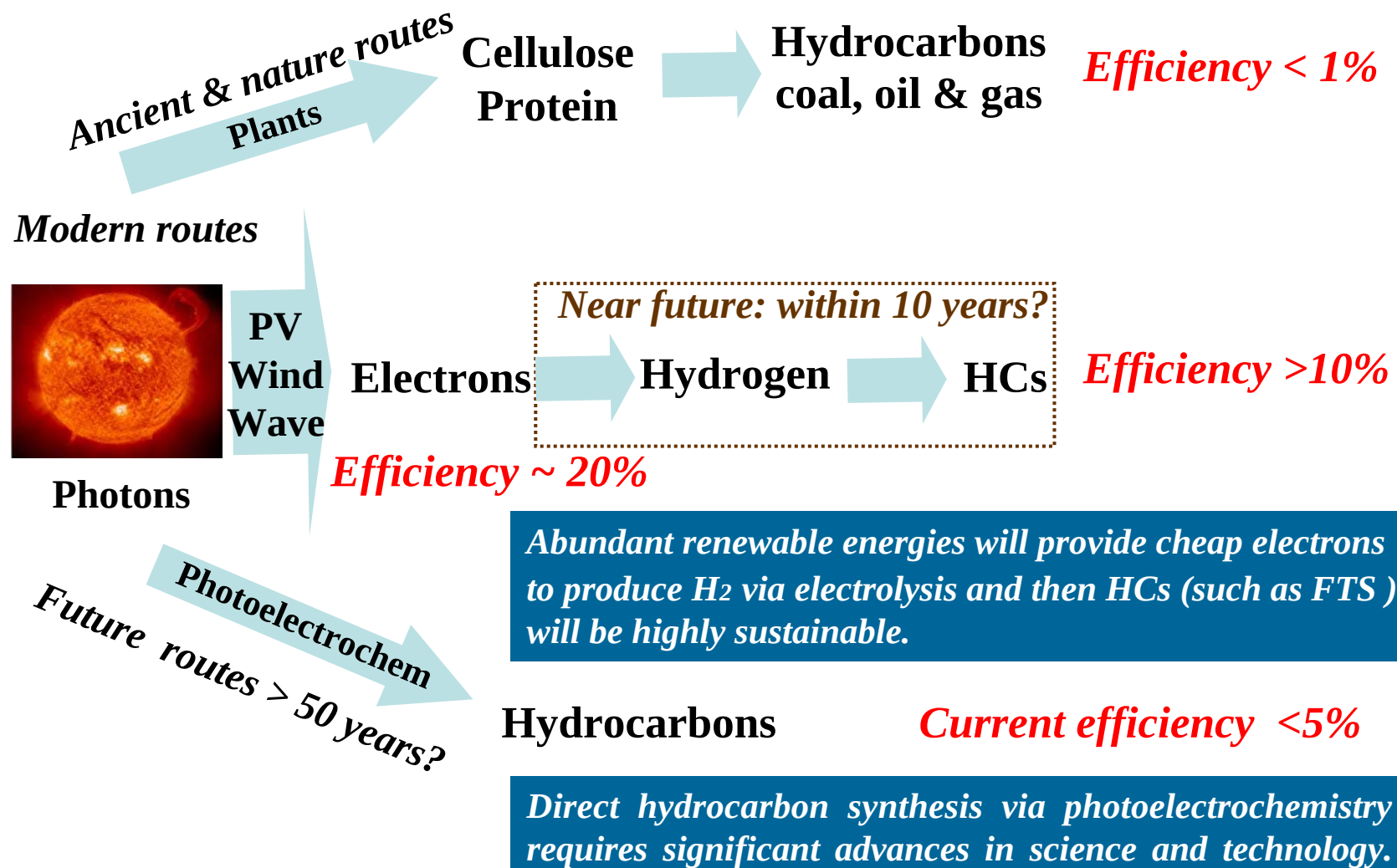
Production costs for hydrogen with/without CO₂ capture/storage.
Data from IEA 2005

	Large	Large with CCS	Small
H ₂ pressure (bar)	78	78	Liq. 340
LHV efficiency (%)	73.2	61.1	46 46.7
Investment (USD/GJ/y)	9.4	11.9	21 42
H ₂ costs (USD/GJ)	5.5	6.7	9.6 13.5

Hydrogen from non-fossil fuels

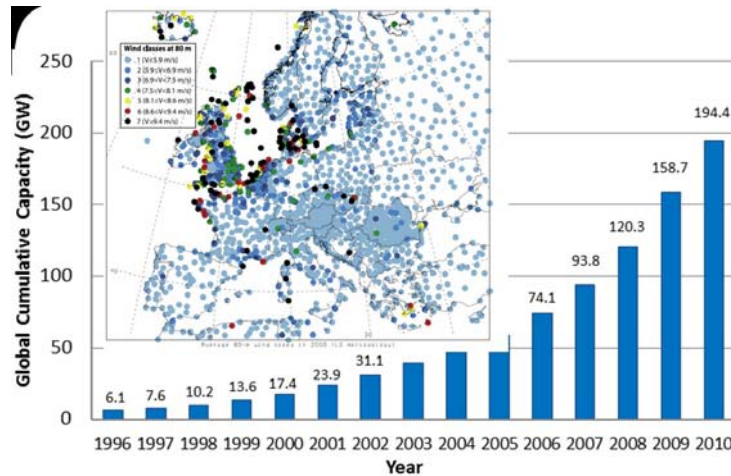


Routes to Harvest Photon Energy

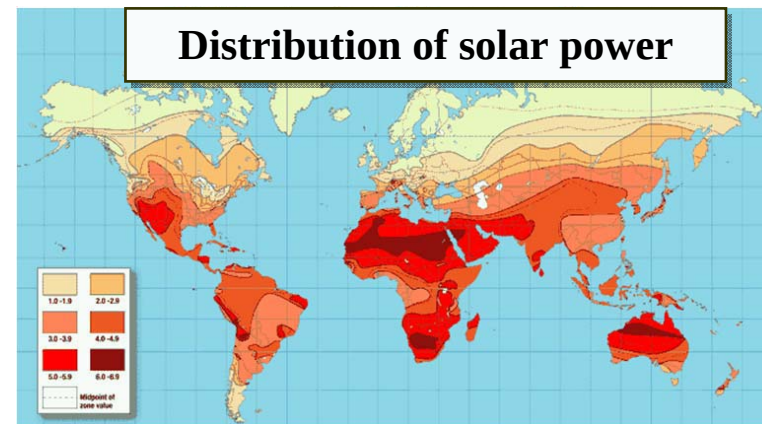




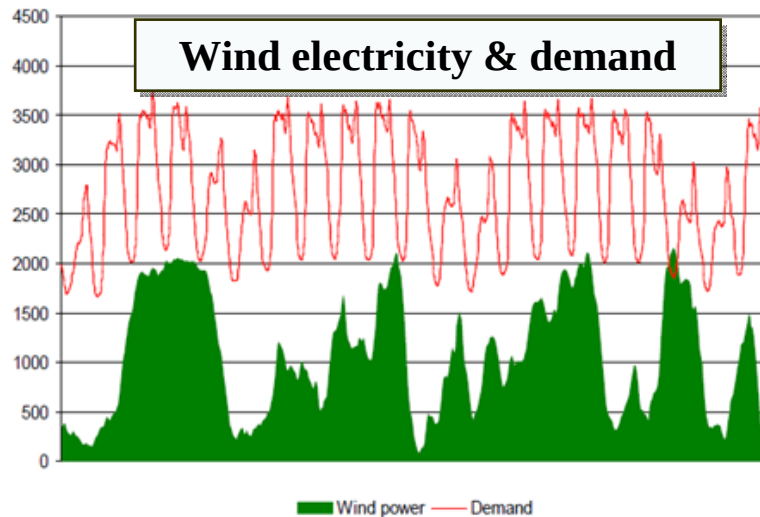
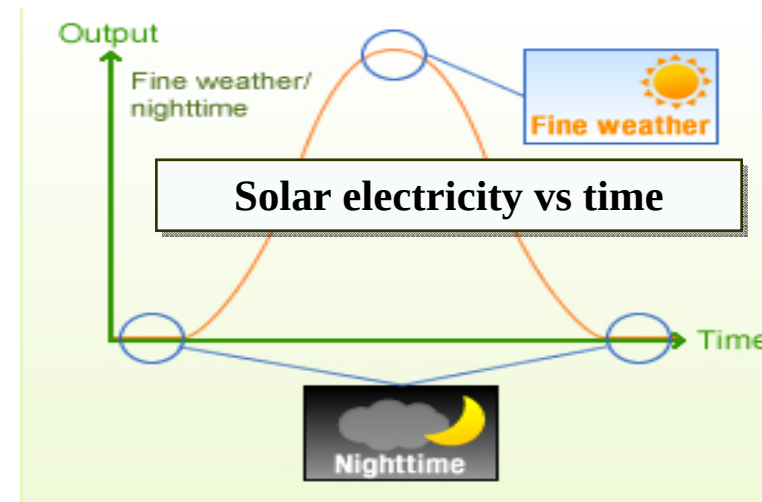
What if electricity is abundant but non-balanced?



Estimated wind potential 70 TW (land only)

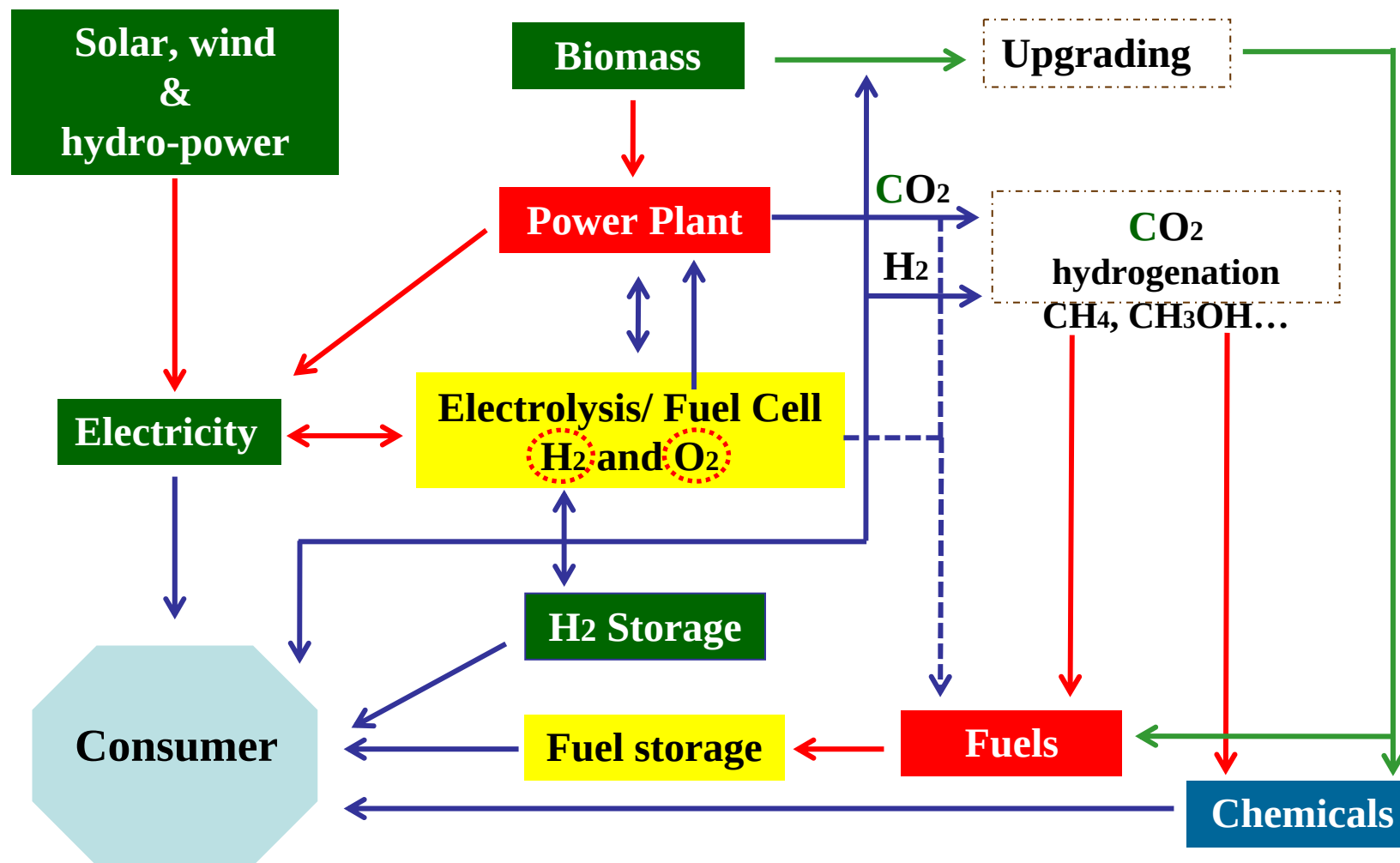


Theoretical 1.2×10^5 TW solar energy



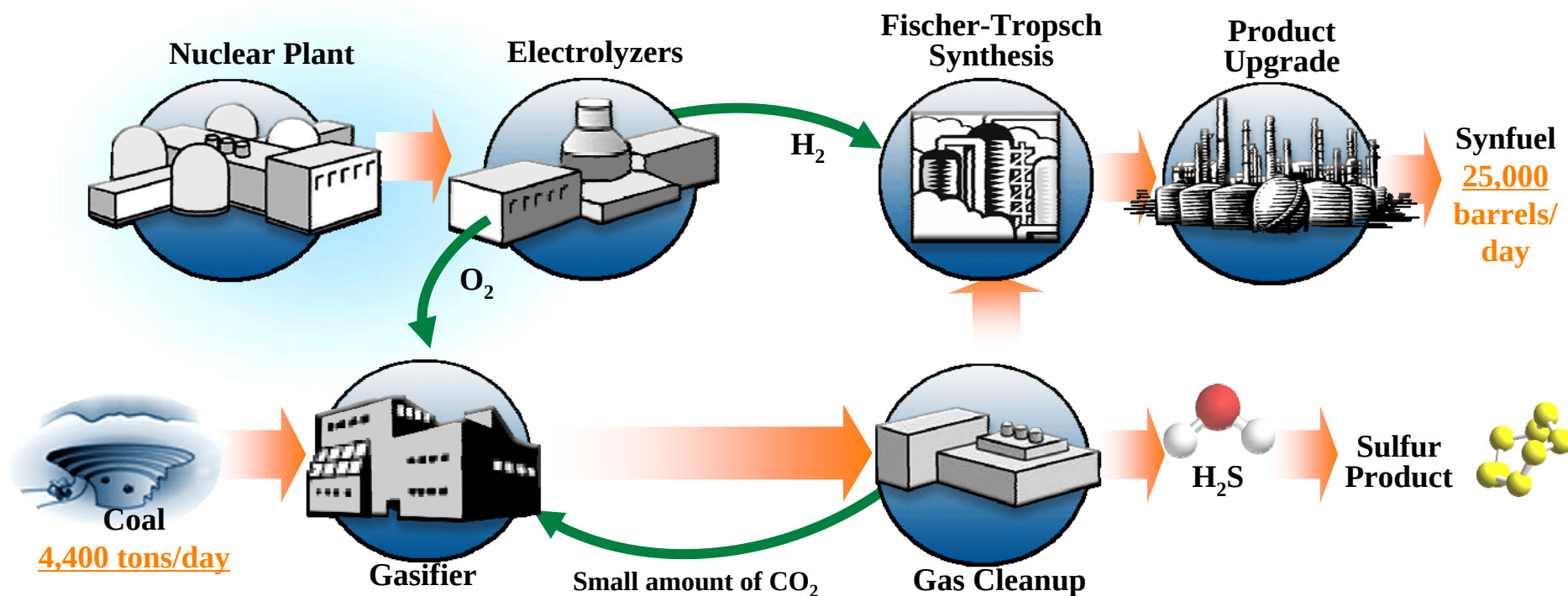


What if electrolysis plays a central role?





Converting available carbon to fuels, not by-product CO₂

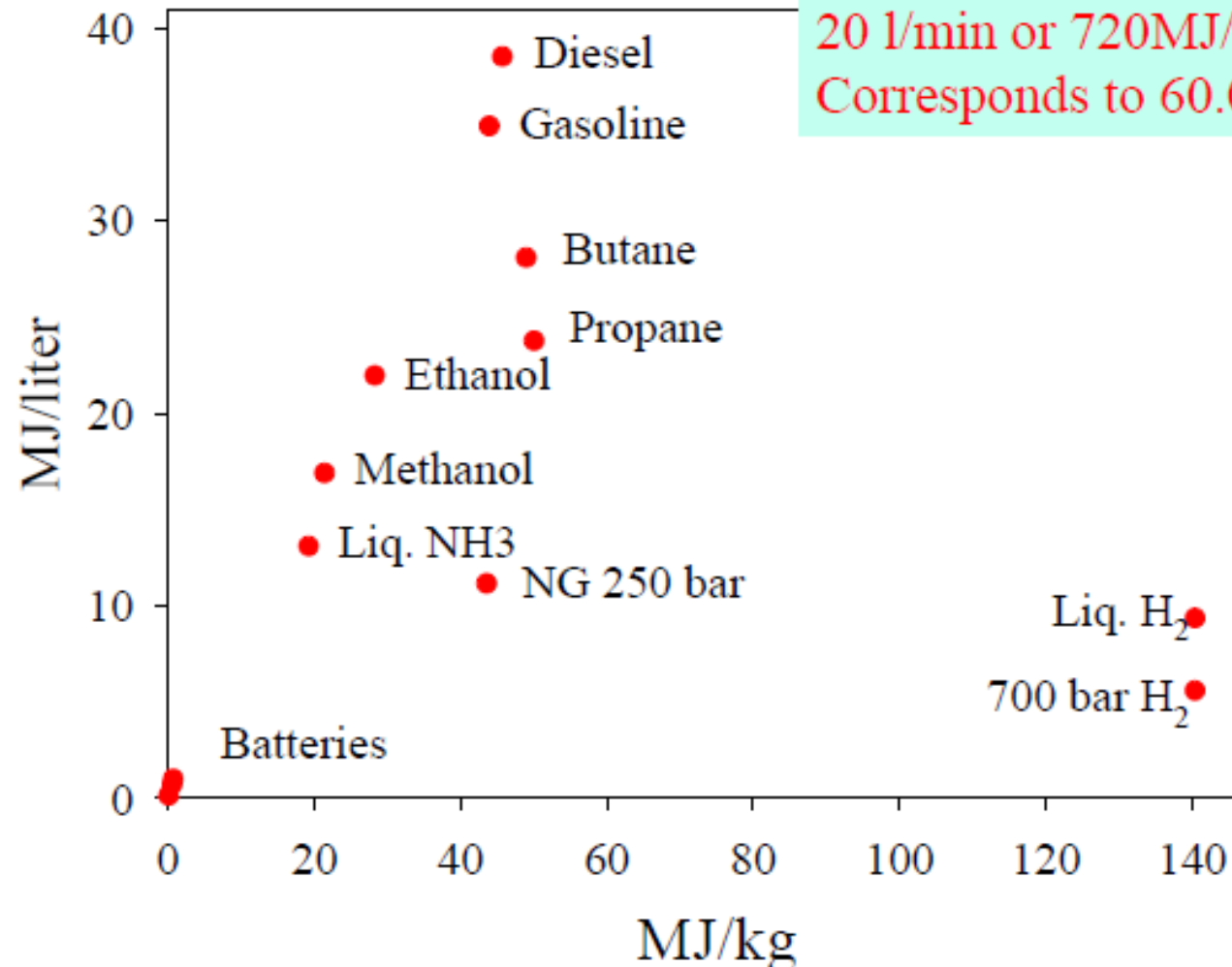


- ✓ No shift reaction $\text{CO} + \text{H}_2\text{O} \rightarrow \text{CO}_2 + \text{H}_2$
- ✓ Effectively no CO₂ emissions

- ✓ Hybrid system uses 70% less coal
- ✓ Product fuel's energy is 20% from nuclear



Energy content of fuels



Fill up the tank with gasoline!
20 l/min or 720MJ/min
Corresponds to 60.000A @ 200V



Challenges in the Transport Sector

Probably electricity will be the major form of sustainable energy, but it is impractical to store (in particular in the transport sector- require long cables?). **Who much energy is used in the transport sector??**

Brint Fuel Cells

- Electrolyse 70%
- Compression 90%
- Distribution 90%
- Fuel cell 45%
- Can be improved

Total efficiency

$$0,7*0,9*0,9*0,45= 25\%$$

Hard to store Hydrogen

No Infrastructure

Batteries

- Distribution 90%
- Local transformation 90%
- charging/decharging 80%

Total effektivitet

$$0,9*0,9*0,8 = 65\%$$

Capacitet is a problem

Charging is slow



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Thank you very much !

