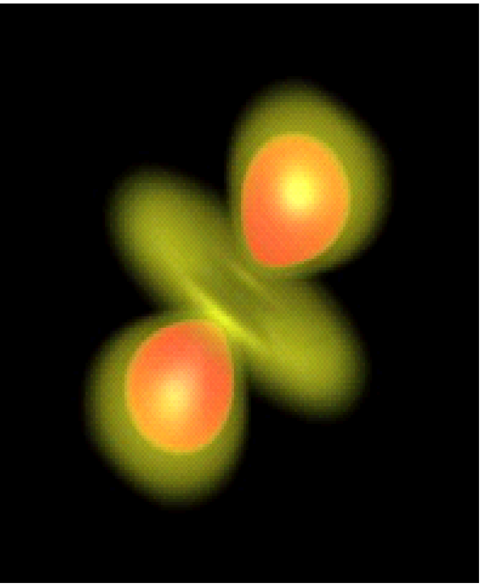
Hydrogen
2012
Production of hydrogen

Introduction

Hydrogen can be produced by a variety of methods. Hydrogen has ideal characteristics as an energy carrier. It can be transported for long distance with less transportation loss than electricity. It can be stored in the forms of compressed gas, liquid, or hydrogenated compounds using hydrogen-absorbing alloys. It can not only be used as a fuel in a wide variety of industrial sectors, but also be transformed into electricity by fuel cells. Also, it is very clean in the sense that water is the only waste material after burning. Therefore, hydrogen is a promising candidate of alternative energy carriers in our future energy system.

Własności fizyczne wodoru



Wizualizacja wodoru

Stan skupienia	gazowy
Gęstość	0,0899 kg/m3
Barwa	bezbarwny
Zapach	bez zapachu
Temperatura topnienia	-259,13 st. Celsjusza
Temperatura wrzenia	-252,88 st. Celsjusza
Temperatura krytyczna	-239,9 st. Celsjusza
Ciśnienie krytyczne	1,3 MPa
Ciepło parowania	0,44936 kJ/mol
Ciepło topnienia	0,05868 kJ/mol
Ciśnienie pary nasyconej	209 Pa (23 K)
Prędkość dźwięku	1270 m/s (298,15 K)

Fact box

Group	1	Melting point	[illegible] –434.49°F, 13.99 K
Period	1	Boiling point	–252.879°C, –423.182°F, 20.271 K
Block	s	Density (g cm^{-3})	0.000082
Atomic number	1	Relative atomic mass	1.008
State at 20°C	Gas	Key isotopes	^{1}H, ^{2}H
Electron configuration	$1s^1$	CAS number	133-74-0
Sound velocity	1270 ms		

Key plant types

Olefin Plants

Products:

- Ethylene
- Propylene
- Butadiene
- Aromatics
- Polymers

Natural Gas Plants

- Products:
- LNG
- NGL
- LPG
- Helium

Hydrogen and Synthesis Gas Plants

- Products:
- H_2/CO/Syngas
- Ammonia
- Gas removal
- Gas purification

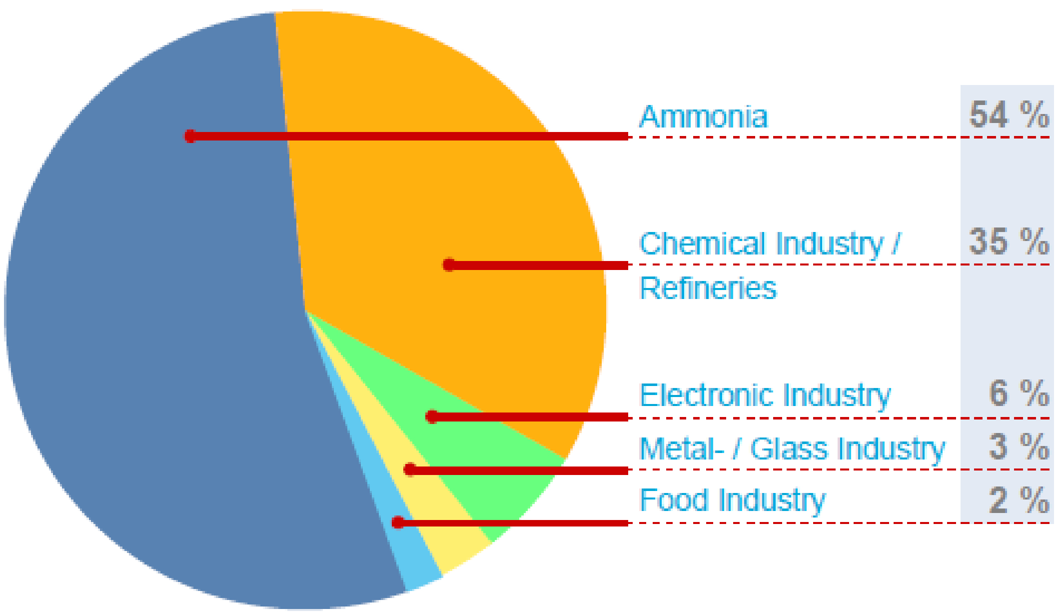
Air Separation Plants

- Products:
- Oxygen
- Nitrogen
- Rare gases

Industrial Hydrogen Market

Installed capacity worldwide: **600 Billion Nm^3/year**

Hydrogen Consumers:



Trends shaping future Hydrogen demand:

- Increase of World Oil Consumption
- Decline of Overall Crude Oil Quality
- More Stringent Environmental Standards
- New Applications (Automotive fuel, Fuel cell)

Reactions

Non Oxygen Consuming:

- **Steam Methane Reforming (SMR)**

  $CH4 + H_2O \rightarrow CO + 3\ H_2$ endothermal

- **Carbon Monoxide Conversion (CO-Shift)**

  $CO + H_2O \rightarrow CO_2 + H_2$ exothermal

Steam reforming

Oxygen Consuming

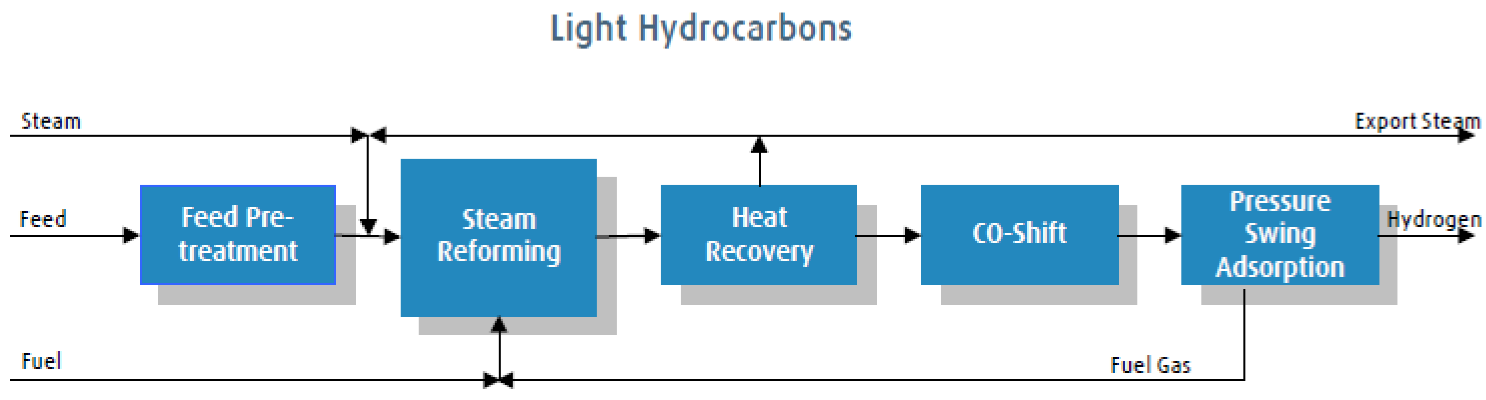
- **Hydrocarbon Conversion**

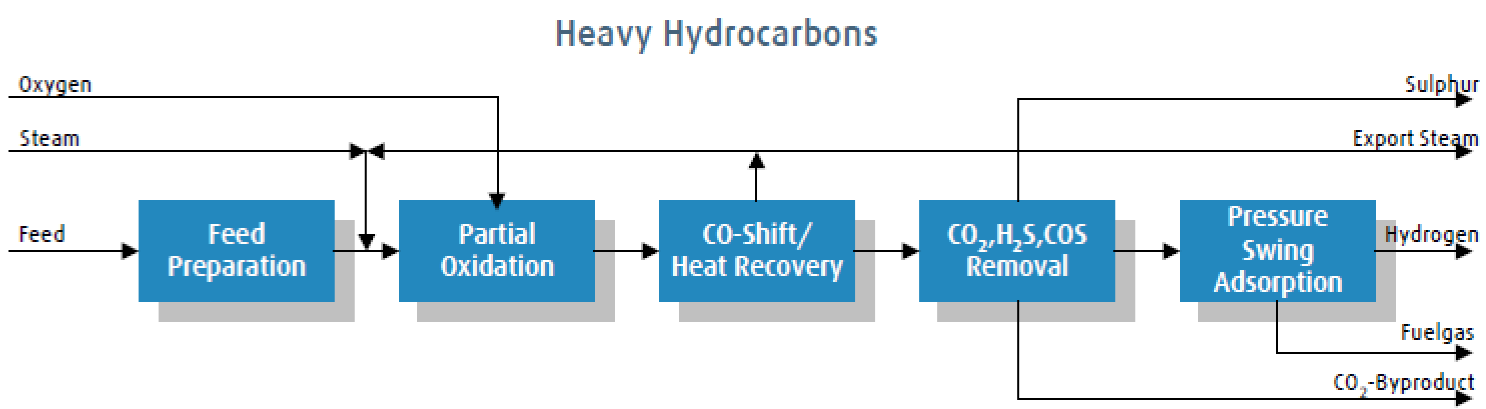
  $CnHm + n/2\ O_2 \rightarrow nCO + m/2\ H_2$ exothermal

Partial Oxidation, Autothermal Reforming

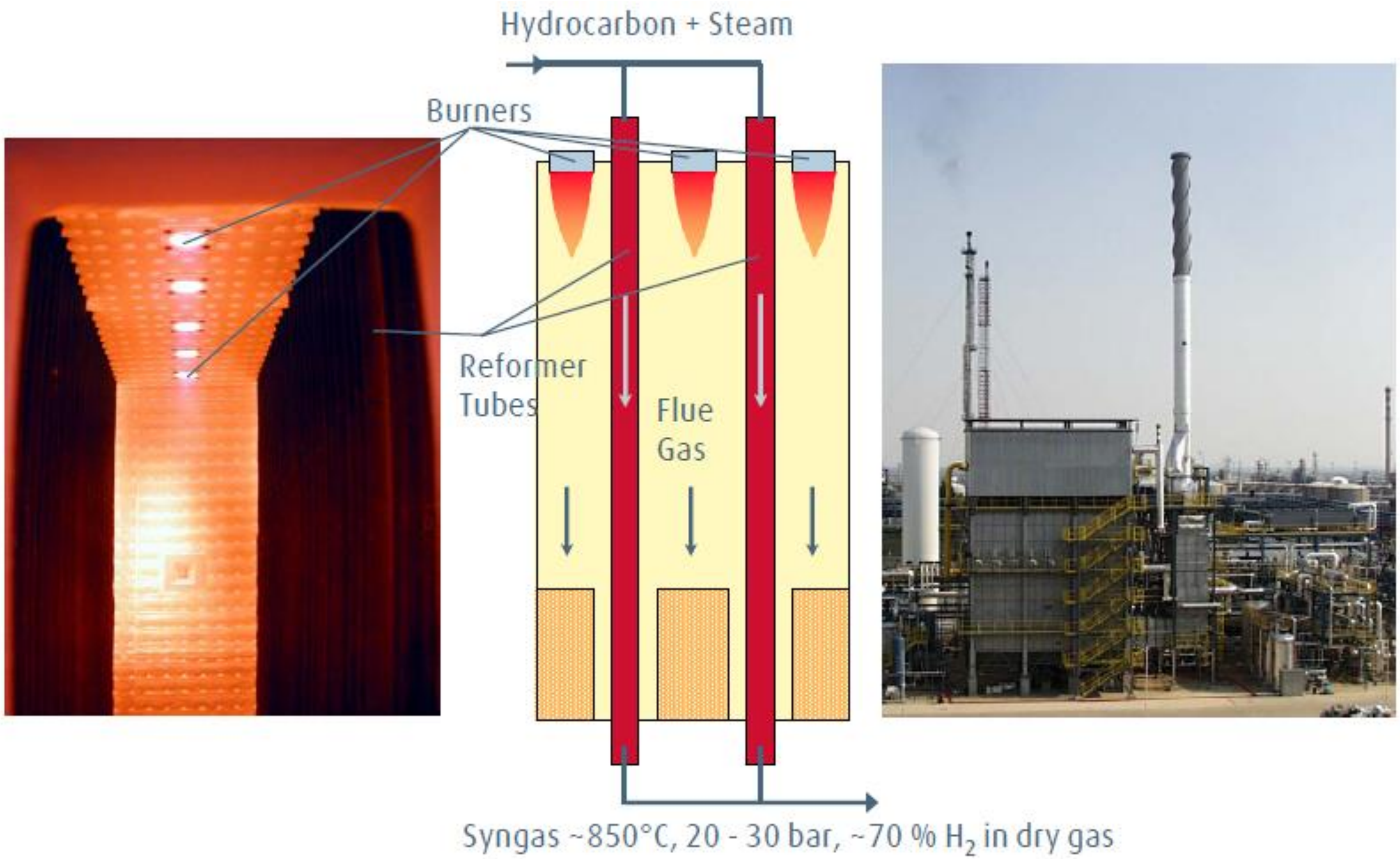
Requested Products is H_2
H_2 Separation + Purification required

Typical Basic Block Diagrams for H_2 Production



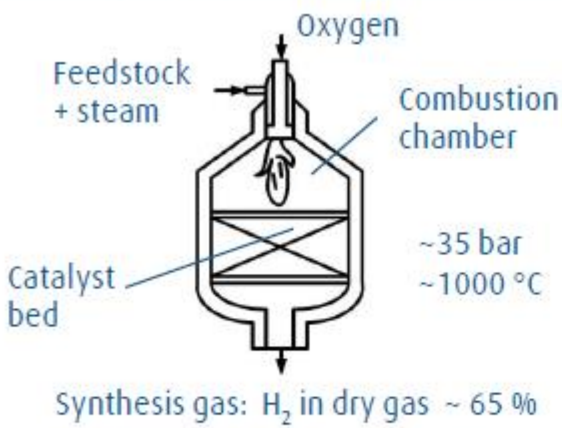


Steam Reformer

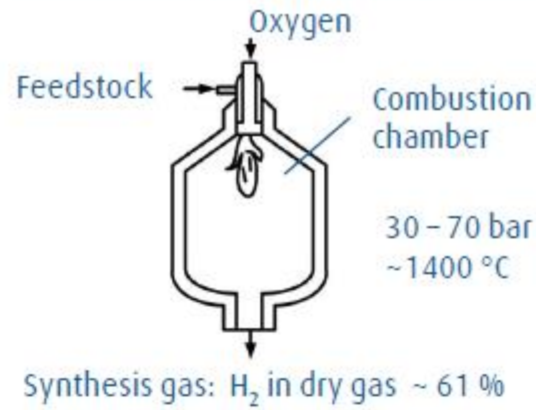


Autothermal Reforming Reactors/Partial Oxidation

ATR (Natural Gas)



POX (All Feedstocks)



CO-Shift Reactor

- Shifts undesired CO to H_2
  $CO + H_2O \rightarrow CO_2 + H_2$ exothermal
- Simple catalytic reactor
- CO conversion depends on Temperature
  High Temperature Shift: ~ 75 %
  Low Temperature Shift: ~ 90%
- H_2 in dry gas ~ 75 %

Wash Unit for POX Synthesis Gas

- e.g. for Syngas from Coal Gasification
- Methanol as washing solvent
- Rectisol® process separates CO_2, H_2S, COS
- H_2 Purity ~ 98 %

H_2 Purification: Pressure Swing Adsorption

- **Pressure Swing Adsorption for high Purity H_2**

  based on selective adsorption using different kinds of adsorption materials (e.g. molecular sieves)

- **H_2 Purity up to 99.9999 %**
- **H_2 Recovery up to 90 %**

Introduction to the IS process

Thermochemical hydrogen production process produces hydrogen from water by absorbing high temperature nuclear heat supplied by High Temperature Gas-cooled Reactors. Production by IS (Iodine-Sulfur) hydrogen and oxygen could be produced with stable rate and with molar ratio of 2 to 1, the stoichiometric ratio of water splitting. Thermochemical water-splitting cycle is a method for the large-scale production of hydrogen.

Closed-cycle H_2 production by thermochemical water-splitting IS process

This cycle is named IS process after the elements used in the process, iodine and sulfur. It has attractive features such that all the chemicals are used in the fluid phase and the endothermic sulfuric acid decomposition reaction proceeds stoichiometrically with large entropy change.

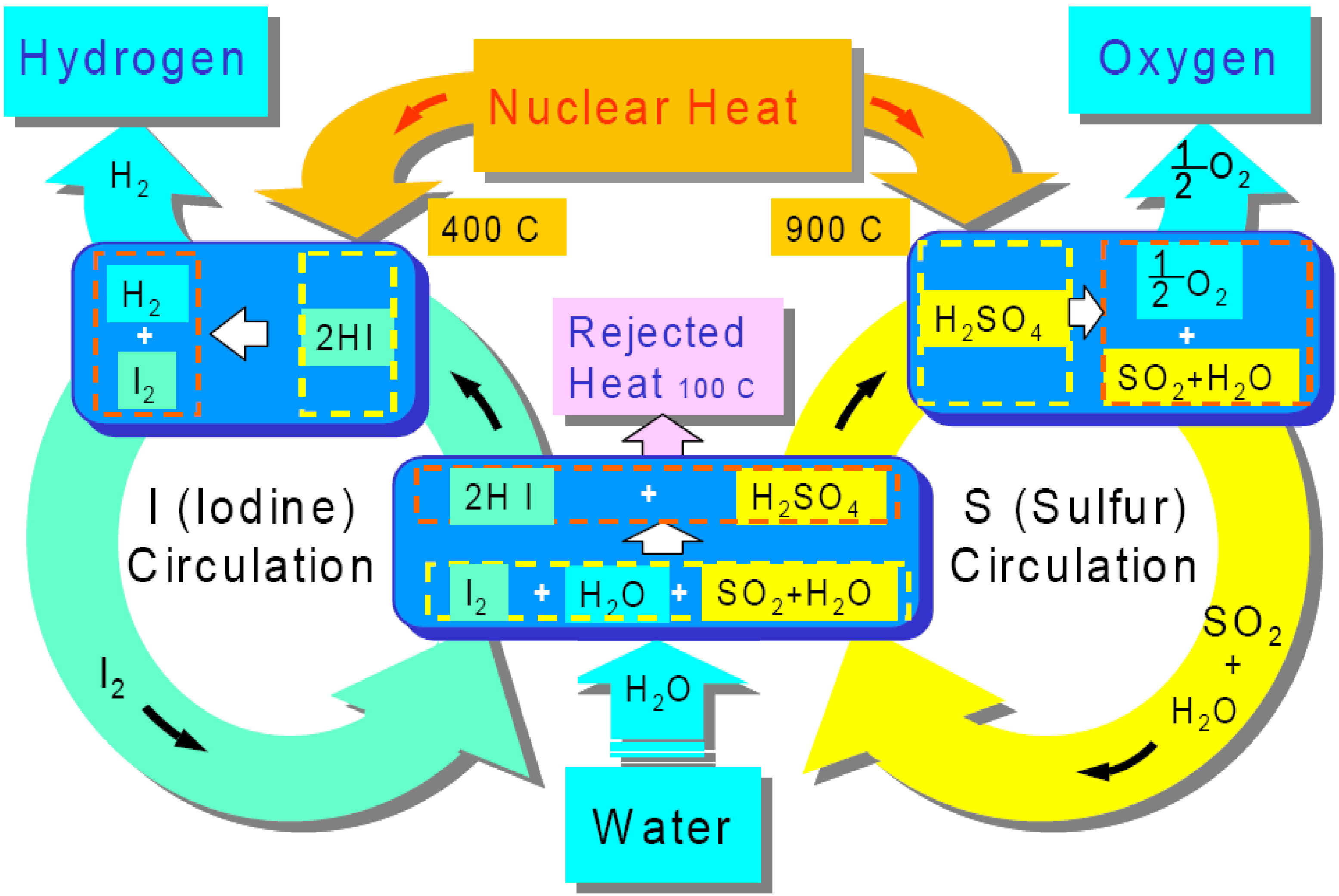
$$2H_2O + SO_4 + I_2 \rightarrow H_2SO_4 + 2HI$$

$$H_2SO_4 \rightarrow H_2O + SO_2 + (1/2)O_2$$

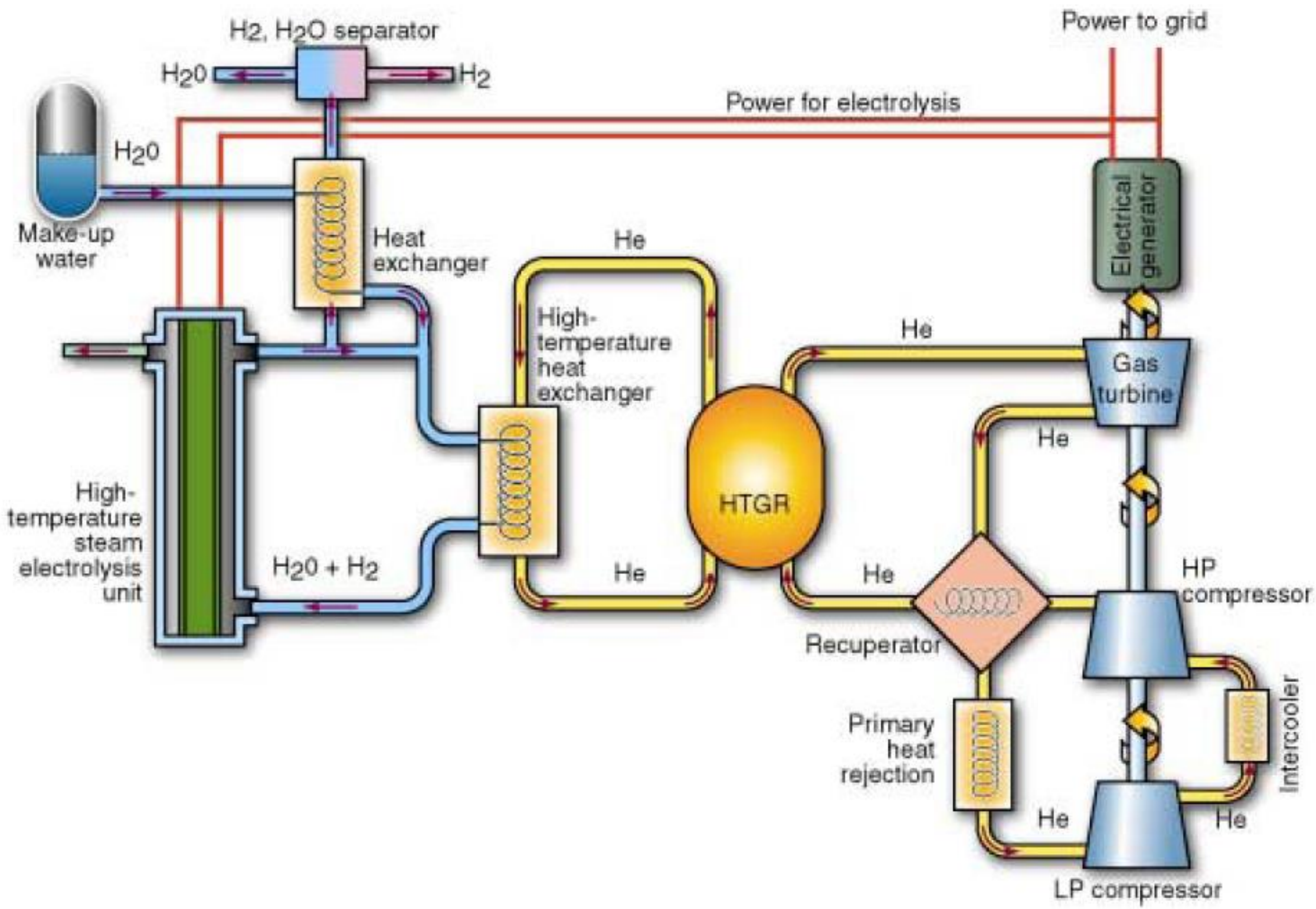
$$2HI \rightarrow H_2 + I_2$$

$$H_2O \rightarrow H_2 + (1/2)O_2$$

Thermochemical Water Splitting



High Temperature Electrolysis using a Nuclear Reactor Heat Source



The characteristics of the S-I process can be described as follows:

All fluid (liquids, gases) process, therefore well suited for continuous operation;

High utilization of heat predicted (about 50%), but very high temperatures required (at least 850 deg C);

Completely closed system without byproducts or effluents;

Corrosive reagents used as intermediaries; therefore, advanced materials needed for construction of process apparatus;

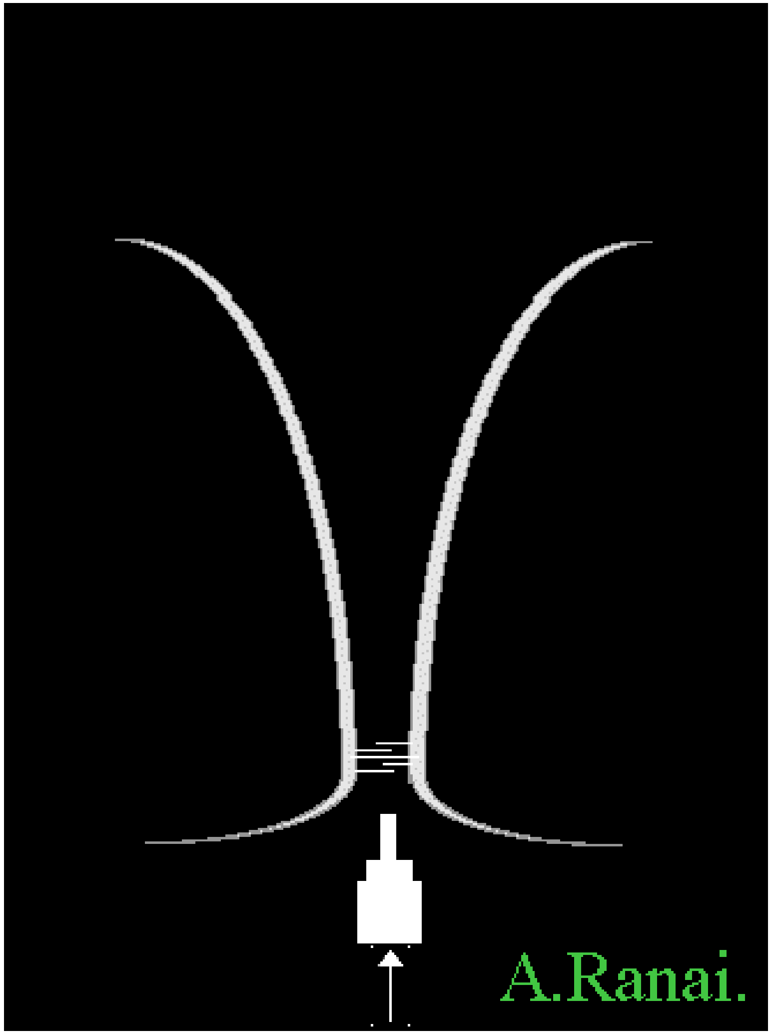
Suitable for application with solar, nuclear, and hybrid sources of heat;

More developed than competitive thermochemical processes.

H_2S is therefore an abundant source for potentially the cheapest Hydrogen

We can obtain hydrogen using method called GlidArc.

How does it work??



GlidArc

cold electric discharge, 5 – 25 kV, < 5 A, DC or AC,

power from 0.05 to 50 kW 0.03 - 12 bar

enhances and stabilises exothermic processes

via active catalytic species

bring active energy to endothermic processes

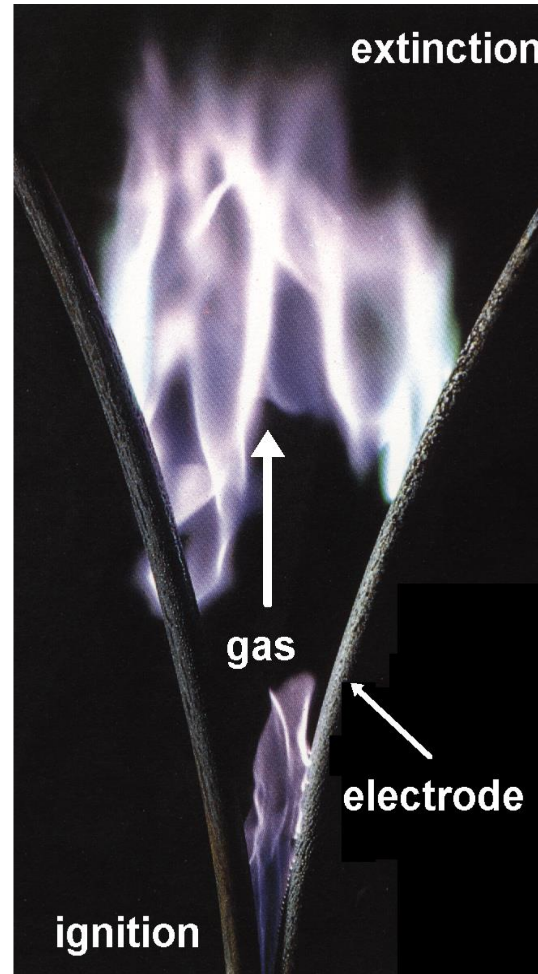
not cooled electrodes

any gas, vapour, droplets or dust accepted

any initial feed temperature accepted

multiple-discharge/electrode system can be

installed for a large scale



GlidArc reformer

Schematic view of 1.4-L GlidArc I reformer for H_2S or sour gas processing

1- cold gas entry,

2 - preheat chamber,

3 – preheated gas exit,

4 – injector of the preheated

gas into the plasma chamber,

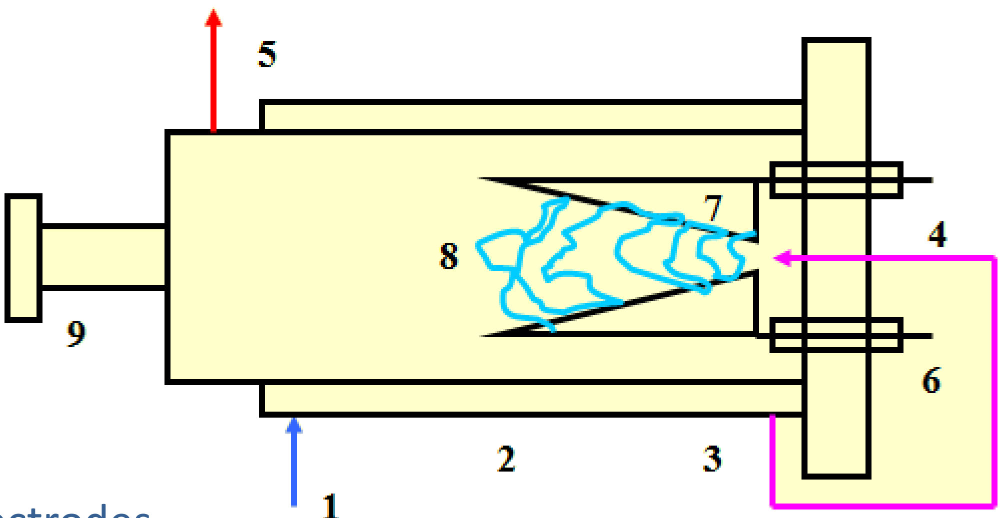
5 – exit of the product,

6 – high-voltage connectors to the electrodes,

7 – electrodes (six),

8 – gliding discharges,

9 – observation window



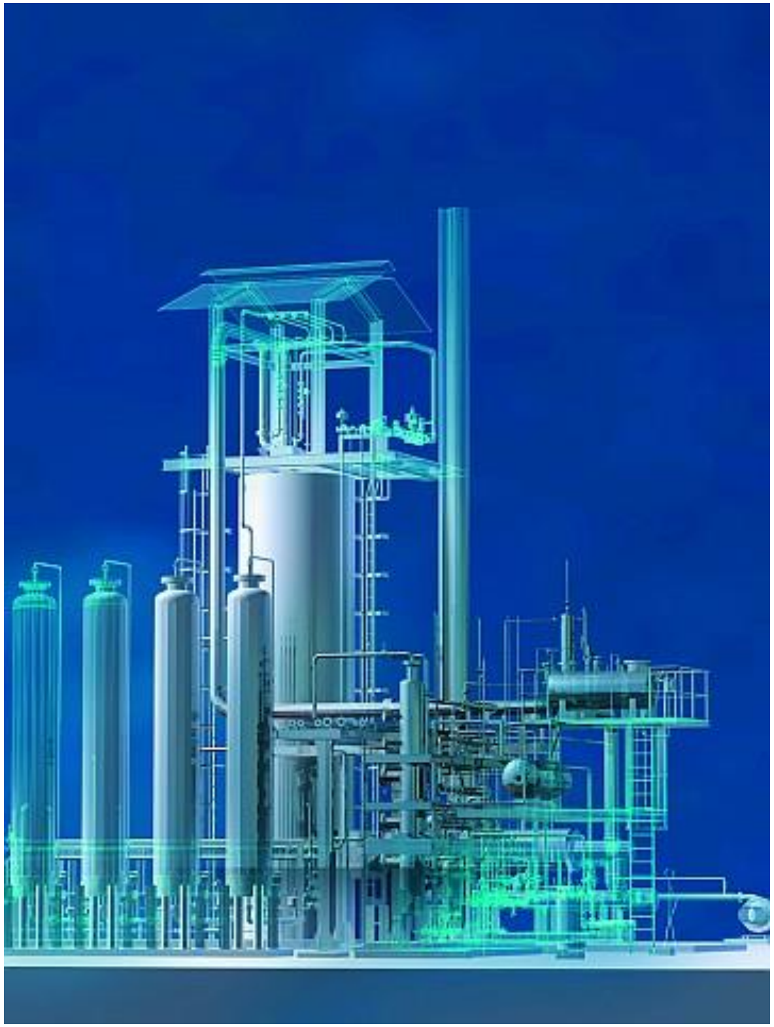
SulfArc advantages

- Products do not contain ballast of added reactants
- No catalyst
- Process does not depend on the chemical composition of effluents
- One can process small quantities of H_2S or sour gas produced by small industrial units
- Energy expense is quite low
- No thermal inertia, good resistance to corrosion…

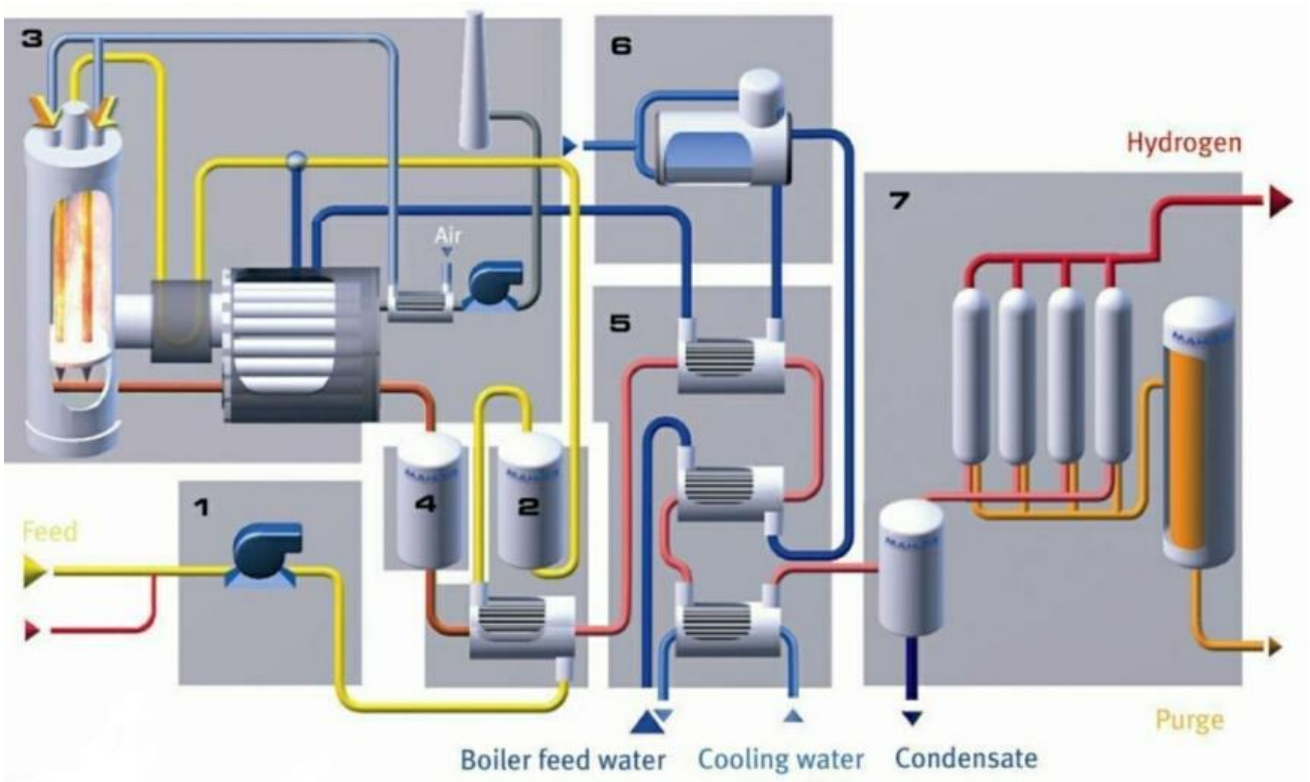
Mahler technologies I

The HYDROFORM-C system is based on steam reforming of natural gas, LPG or naphtha.

These processes offer customers a maximum of quality and security, as well as the capability of efficiently meeting hydrogen requirements from 100 to 10.000 Nm^3/h at purities of up to 99.999+ per cent by volume.



Mahler technologies I

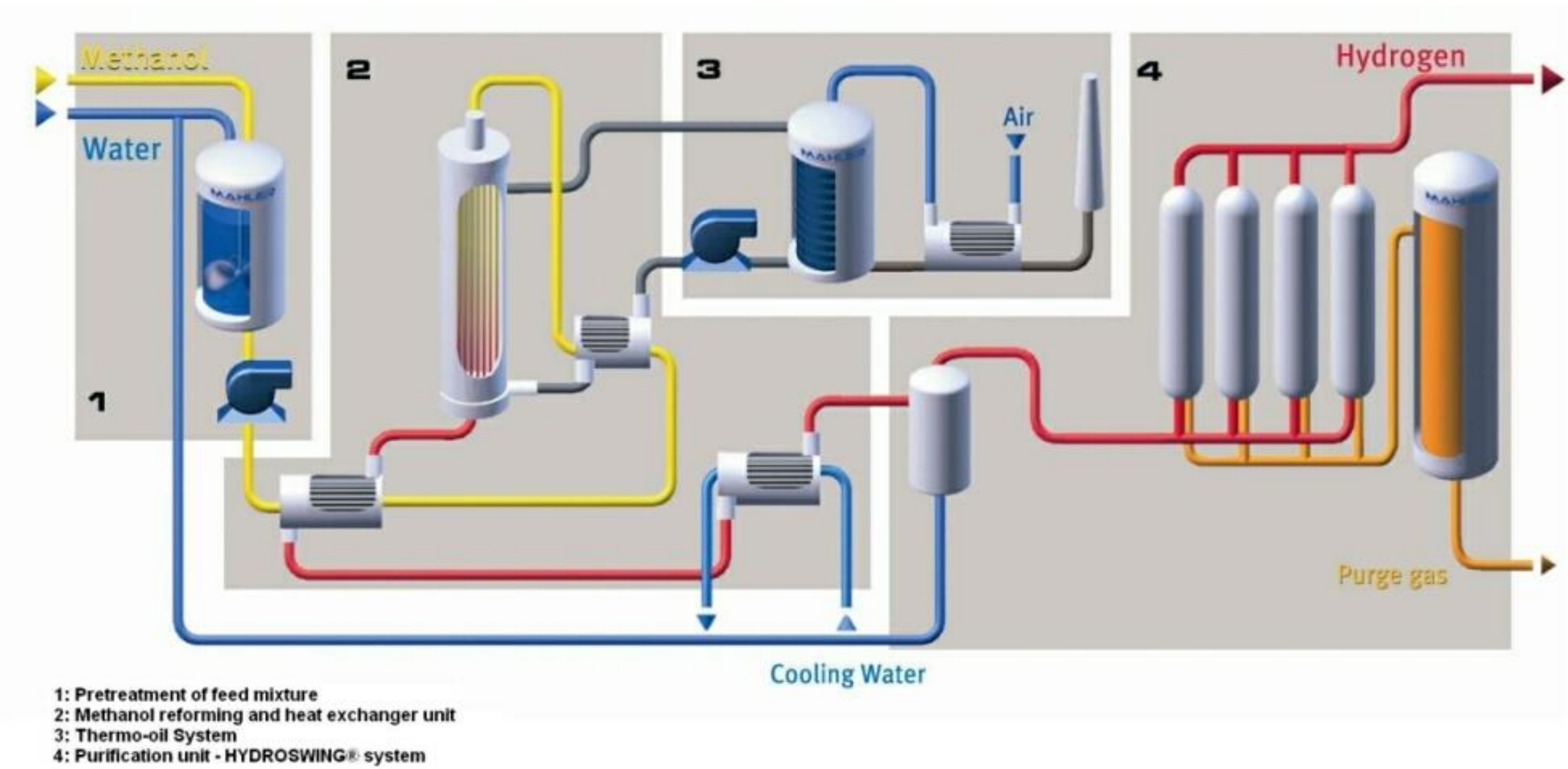


1: Feed compression unit
2: Feed pretreatment
3: Reforming and steam generation
4: High temperature conversion
5: Heat exchanger unit
6: Pretreatment of boiler feed water
7: Purification unit – HYDROSWING® system

Mahler technologies II

The HYDROFORM-M system is based on the reforming process of methanol to cover hydrogen requirements from 100 to 4.000 Nm³/h at purities of up to 99.999+ per cent by volume.

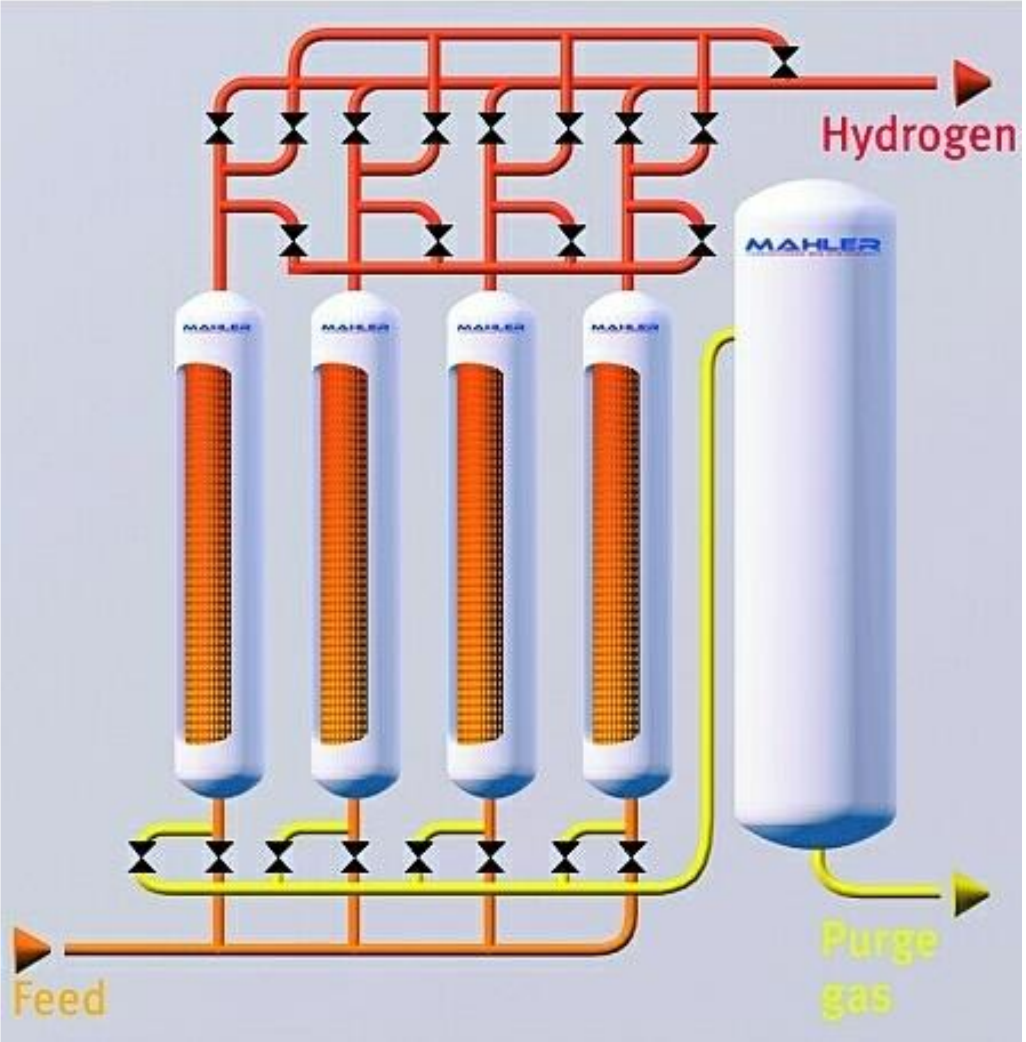
Mahler technologies II



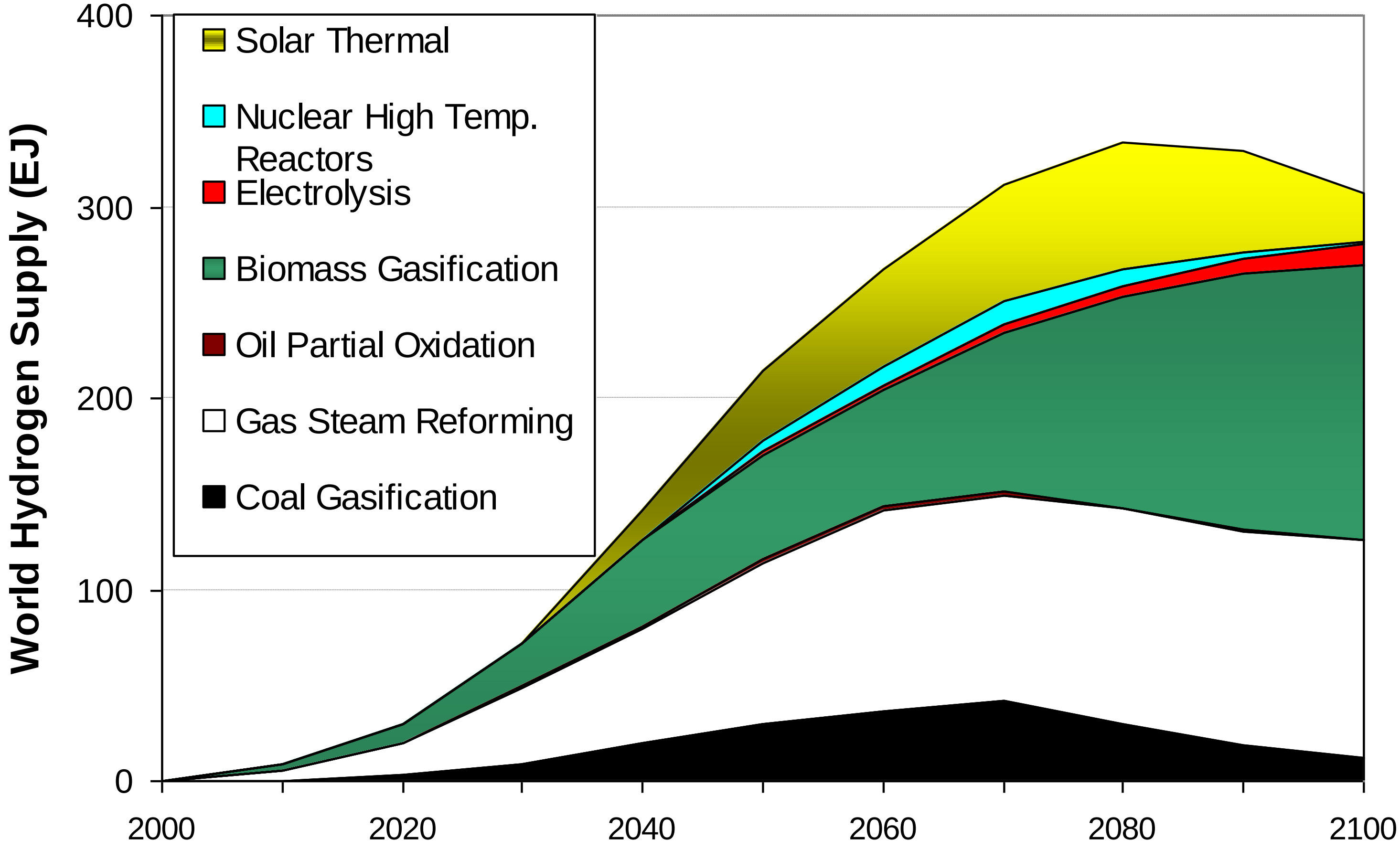
Mahler technologies III

The HYDROSWING® system is based on the pressure swing adsorption process of hydrogen-rich gases to cover hydrogen requirements from 100 to 10.000 Nm^3/h at purities of up to 99.999+ per cent by volume.

Mahler technologies III



Predicted delivery of H_2 in the future



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K. Wawrzinek/ HDV / Nov. 21, 2007 /Industrial H2 Production & Technology.ppt

Thank you
for your attention