

> How can we create the sustainable hydrogen society?

Hydrogen Vision:

- 1) Hydrogen has to become a common commodity
- 2) Hydrogen has to be produced free of pollution and losses
- 3) Hydrogen has to be traded locally, based on supply and demand
- 4) Hydrogen has to be used for electrification, transportation and convenience

Fuel Cells Vision:

Fuel Cells have to utilize their advantages in connecting the markets for:

→ 1. **Electricity** → 2. **Heat** → 3. **(clean) water**

Fuel Cells have to be used as decentralised, personal power systems

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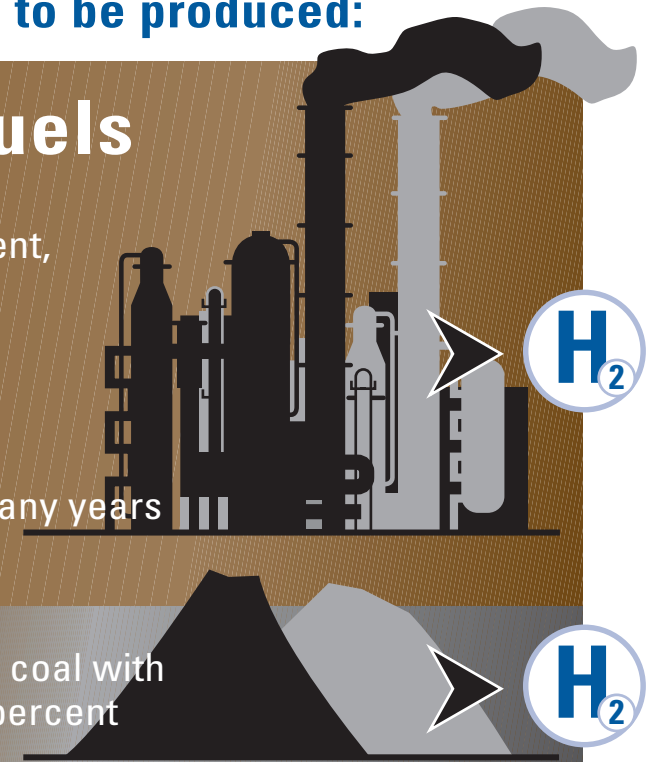
First released: May 2008

> The existing methods to produce hydrogen (1) (Conventional)

Hydrogen is the most abundant element in the universe, most of it occurs in chemical combination with oxygen in water, so it has to be produced:

1. Hydrogen production from fossil fuels

- 1.1. **Steam reforming of natural gas** at this time the most efficient, economical and widely used process for hydrogen production
- 1.2. **Partial oxidation** converts hydrocarbons heavier than naphtha, using natural gas, ethanol or even gasoline as feedstock
- 1.3. **Thermal cracking of natural gas** has been practised for many years using a methane-air flame in tandem furnances or fixed bed reactors
- 1.4. **Coal gasification** (Koppers-Totzek process) oxidizes pulverized coal with oxygen and steam, to produce hydrogen with purity higher than 97.5 percent



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Source: T. Nejat Veziroğlu and Frano Barbir, UNIDO (Vienna 1998)



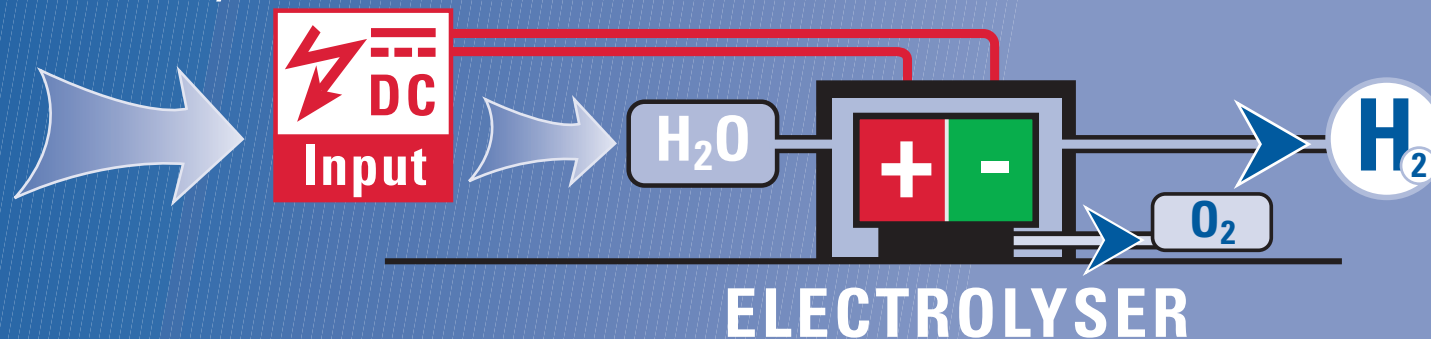
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> The existing methods to produce hydrogen (2) (Conventional)

Hydrogen is the most abundant element in the universe, most of it occurs in chemical combination with oxygen in water, so it has to be produced:

2. Hydrogen production with electrolyser

Electrolysis seems still to be the best method used for large-scale hydrogen production in a post-fossil-fuel era, however has very bad efficiency



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> The future role of hydrogen as energy carrier (1)

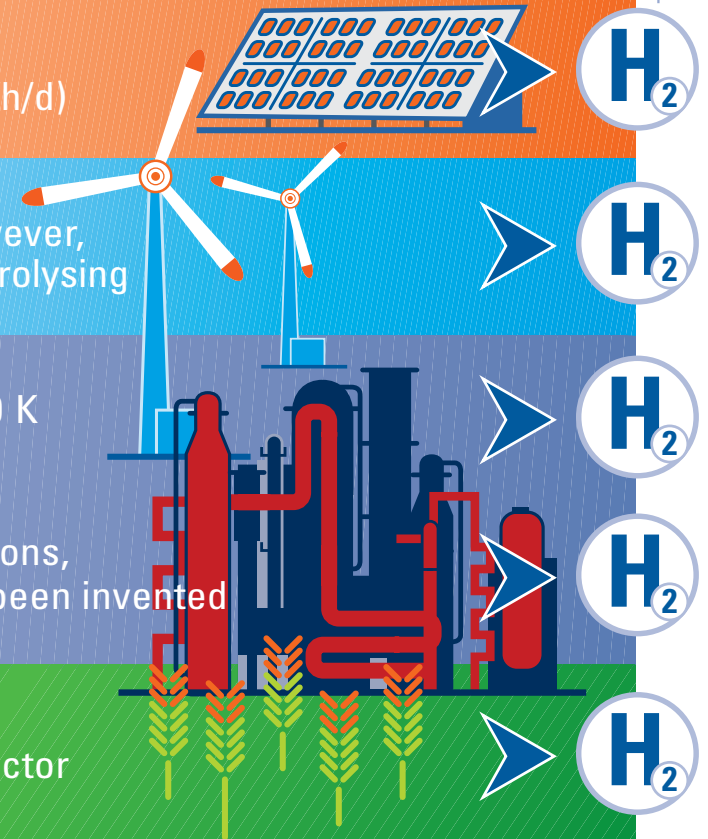
1. **Photo Voltaic** has the highest potential with solar insolation of up to 6,5 kWh per square meter per day (Avg. in the U.S. 3,0 kWh/d)

2. **Wind Power** can already produce electricity up to 6 MW, however, the electricity generated is intermittent and not very suitable for electrolysis

3.1 **Thermolysis** splits water thermally at temperatures up to 3000 K raising problems with the material resistance to high temperatures

3.2 **Thermochemical** produces hydrogen through cyclical reactions, on trial since the mid-1960, with thousands of cycles which have been invented

4. **Biomass** can produce hydrogen by a pyrolysis/gasification process, heating the biomass/water slurry under pressure in a reactor



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I M P L E M E N T I N G N E W I D E A S

Source: T. Nejat Veziroğlu and Frano Barbir, UNIDO (Vienna 1998)

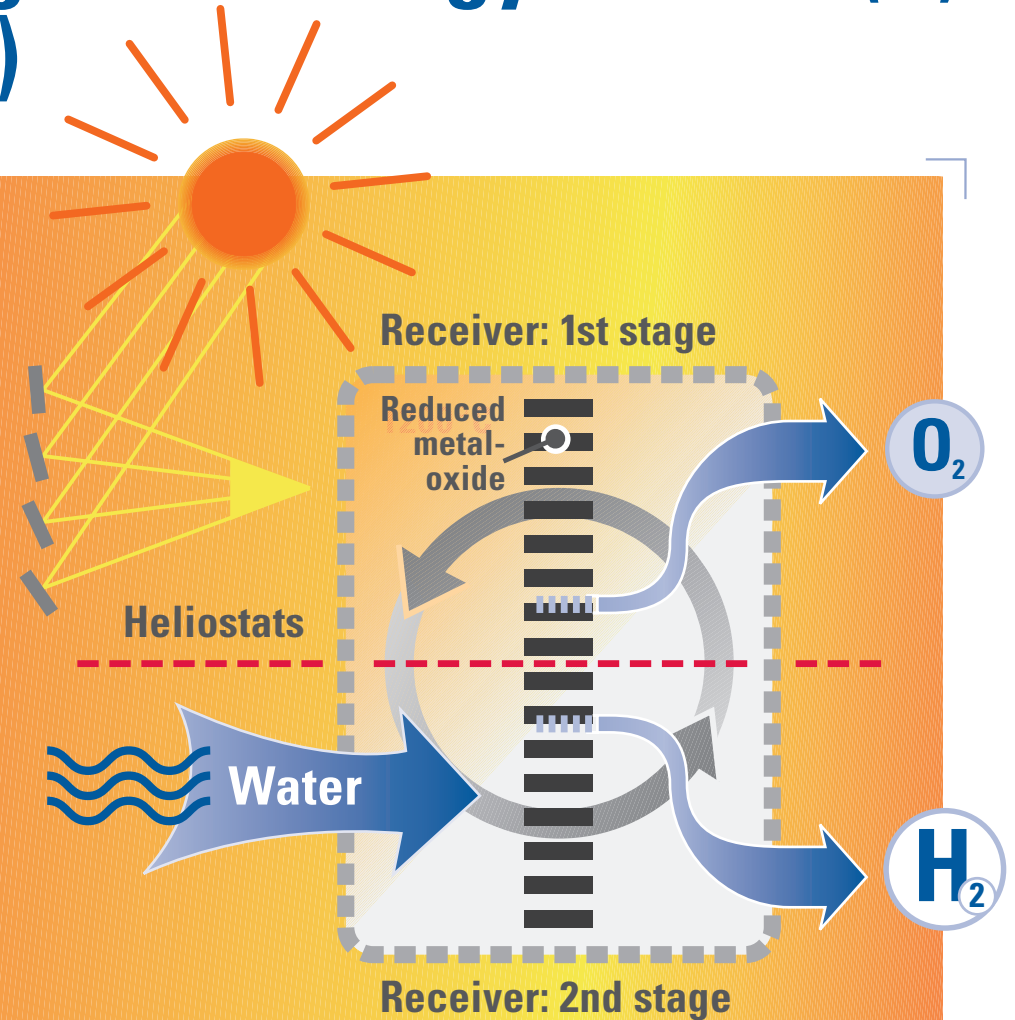


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> The future role of hydrogen as energy carrier (2) (direct solar production)

5. Photolysis direct extraction of hydrogen from water. Uses only sunlight in photobiological, photochemical or photo-electro-chemical conversions

All processes have to be developed and complemented with novel methods. Down-scaled to be used in decentralised mass-markets, the user of hydrogen and electricity will become their producer!



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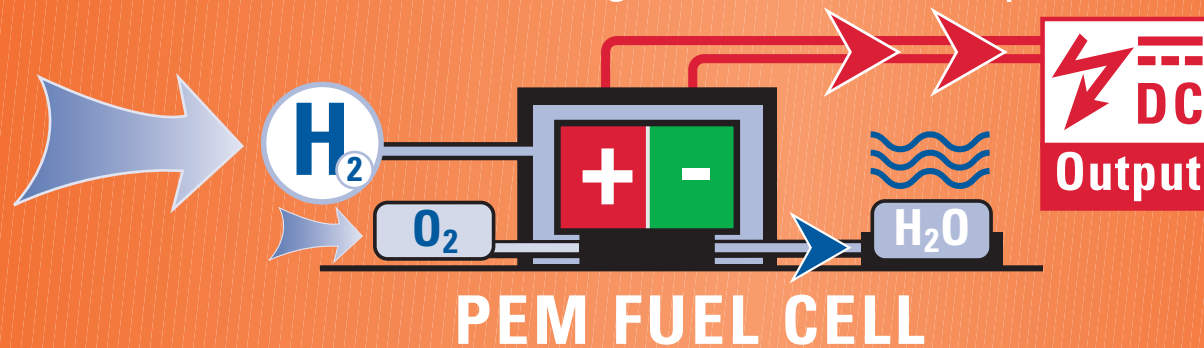
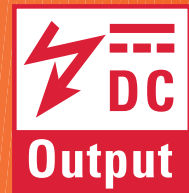


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> The future roles of fuel cells in decentralised power centers

Fuel Cells have the ability to work for three tasks:

1. **Electricity** will be utilized in buildings like hospitals, offices and houses as DC (Direct Current), as nearly all home and office appliances require DC
2. **Heat** is not being wasted or flared, but captured in the process and used for heating (in winter) or cooling (during summer)
3. **(clean) Water** is produced while making electricity and used in/externally or sold on the local market at the highest achievable price



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