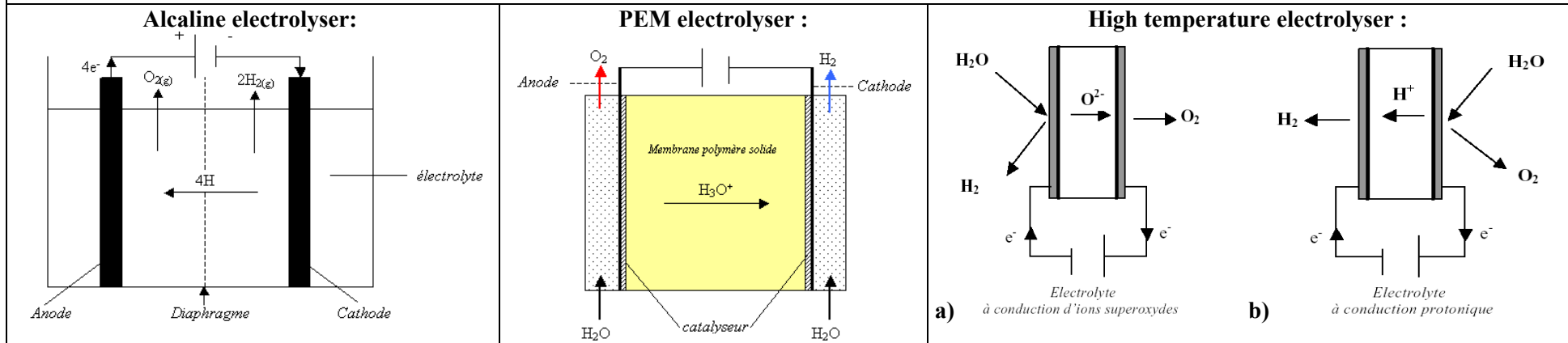


Electrolyser

Different types

type	Electrolyte / Membrane	Electrodes / Catalysers	global reaction
Alcaline	KOH/NiO, IMET™ (Inorganic Membrane Electrolysis Tech.)	Anode : Ni, Fer / Ni alloys, metal oxides Cathode : steel + Ni / Ni-Co	Anode : $4\text{HO}^-_{(l)} \Rightarrow \text{O}_{2(g)} + 2\text{H}_2\text{O}_{(l)} + 4e^-$ Cathode: $4\text{H}_2\text{O}_{(l)} + 4e^- \Rightarrow 2\text{H}_{2(g)} + 4\text{HO}^-_{(l)}$
Acid PEM	Solid, proton exchange polymer membrane (Nafion®)	Anode : Graphite-PTFE + Ti / RuO ₂ , IrO ₂ Cathode : Graphite + Pt / Pt	Anode : $6\text{H}_2\text{O}_{(l)} \Rightarrow \text{O}_{2(g)} + 4\text{H}_3\text{O}^+_{(l)} + 4e^-$ Cathode: $4\text{H}_3\text{O}^+_{(l)} + 4e^- \Rightarrow 4\text{H}_{2(g)} + 4\text{H}_2\text{O}_{(l)}$
High temp. steam	a) Zirconia ceramics (0,91ZrO ₂ -0,09Y ₂ O ₃) b) Zirconia oxide ceramics	Anode : ceramics (Mn, La, Cr) / Ni Cathode : Zr & Ni cermets / CeOx	a) Cathode: $2\text{H}_2\text{O}_{(g)} + 4e^- \Rightarrow 2\text{O}_2^- + 2\text{H}_{2(g)}$ Anode : $2\text{O}_2^- \Rightarrow \text{O}_{2(g)} + 4e^-$ b) Anode : $2\text{H}_2\text{O} \Rightarrow 4\text{H}^+ + \text{O}_{2(g)} + 4e^-$ Cathode: $4\text{H}^+ + 4e^- \Rightarrow 2\text{H}_{2(g)}$

Principle of operation



Technical data

type	Temperature of operation	Pressure of operation	Electric consumption	Energy Efficiency	Life duration	State of development
Alcaline	50 - 100 °C	3 - 30 bars	4-5 kWh / Nm ³ of H ₂	75 - 90 %	15 - 20 years	marketed
PEM	80 - 100 °C	1- 70 bars	6 kWh / Nm ³ of H ₂	80 - 90 %	150 000 hours (≅17 years)	development
High temp. steam	800 - 1000 °C	??	3-3.5 kWh / Nm ³ of H ₂	80 - 90 %	??	research

Electrolyser

Environmental impact

- fluor present in nafion membranes
- material & electrolyte recycling is required
- If the electrolyser is supplied by an IRE (wind, sun) the environmental balance is then interesting.

Safety

- Explosion threshold : H₂ in air concentration not to exceed 4% in mass

Applications

Type and site	H ₂ production rate	Cell efficiency	H ₂ O consumed	Power supplied
alkaline electrolyser Tokamatsu, Japan	30 Nm ³ /h (max.)	90% (1.0A/cm ²)	30kg/h	160 kW
PEM Electrolyser Reykjavik, Iceland	60 Nm ³ /h		60kg/h	300 kW

R&D Perspectives

Most fuel cells developments can be applied to electrolysers development..

- **Cost** : to decrease material costs (membranes, electrodes, bipolar plates, catalysers...)
- to develop auxiliaries technology to decrease energy losses occurring in the peripheral system supply.
- to store O₂ produced by electrolysers to increase the global energy efficiency.
- to develop unitized regenerative fuel cells

Economical data

Current costs:

Whatever the type of electrolysis is considered, the electricity cost represents 70 to 80% of the produced H₂ cost.

Maintenance cost estimated to 5% per year of the investment cost.

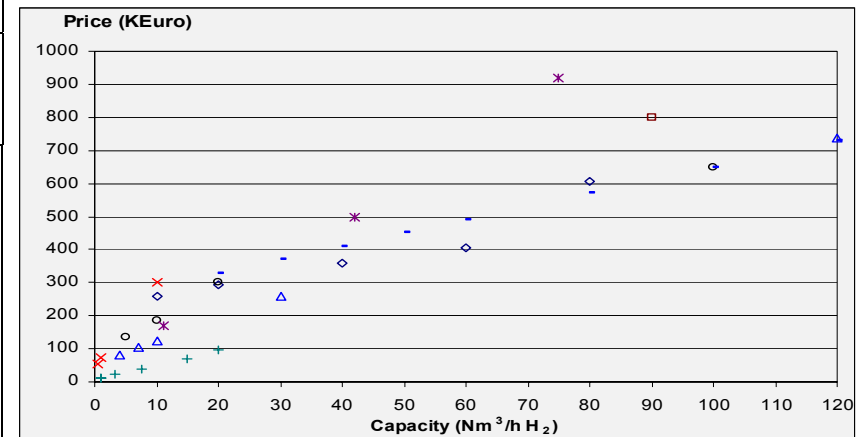
In 1991, small alkaline or membrane units (100 kW) had approximately same prices as well as energy consumption : 6 000 € / kW

30 000 €/kW for a membrane electrolyser "Hogen 20" from Diamond Lite (global efficiency : 21%)

15 000 €/kW for an alkaline electrolyser from Hydrogen Systems; 7 000 € / kW for the cells only (no auxiliary)

Targeted costs:

For Proton Energy Systems : 1000 €/kW (2010)



Prics based on manufacturers offers(2000-2002)

Manufacturers active on the market:

Nitrocraft, Stuart energy systems, Teledyne Energy Systems, Hydrogen systems (Vandenborre Technologies N. V.), Norsk Hydro, Packard, Peak scientific, Whatman, Giovanola, ELWATEC GmbH Grimma, MTU, Proton Energy System, Schmidlin / Piel, ErreDue, Casale Chemicals SA (& Metkon-Alyzer)

R&D Institutes involved in the field:

CNRS, CEA, CENERG, LPICM, CETH, LI2C, ZSW, ...