PERFORMANCES AND ECONOMIC COMPETITIVENESS COMPARISON OF ADVANCED HYDROGEN PRODUCTION PROCESSES COUPLED TO A NUCLEAR REACTOR


Christine Mansilla : christine.mansilla@cea.fr
Camille Cany : camille.cany@cea.fr

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A context of increasing needs for hydrogen

Efficiency is commonly used to compare processes.

However, advanced processes often imply high investments. The energy consumption may not be the first cost item.

Even if the efficiency of a given process can give some insights about its performances, ultimately, decisions will be made on production cost grounds.

3 processes are examined, with a view to identify the main cost drivers:
- S/I cycle
- HyS cycle
- HTSE
The investment is not restricted to the equipment price.
Energy:
- electricity: 40 €/MWh
- heat: 20 €/MWh when supplied by a HTR

Maintenance: 7%/year of the installed real equipment cost

Other items:
- Taxes and insurance
- Plant overhead costs
- Iodine losses when relevant
- Platinum regeneration when relevant
- Replacement of electrolysers (specific maintenance)
Calculation of a levelized production cost

Selected assumptions:

- Construction period: 3 years
- Equally-distributed investment over the construction period
- Plant life: 30 years with no replacement during the operation
- Load factor: 80%
- Discount rate: 8%
SULPHUR-IODINE CYCLE (S/I)

3 step cycle

High temperature heat provided by a HTR

$\rightarrow 600 \text{ MW}_{\text{th}}, 66 \text{ MW}_{\text{e}}$ to produce 2 kg$_{\text{H}_2}$/s
HYBRID-SULPHUR CYCLE (HYS)

2 step cycle

High temperature heat provided by a HTR

→ 410 MW_{th}, 118 MW_e to produce 2 kg_{H2}/s
Steam electrolysis + high temperature → reduction of the energy need
Heat supply for the vaporisation step: high T reactor is not mandatory
To produce 2 kg$_{H_2}$/s

**S/I cycle**
- 600 MWth
- 66 MWe
- 2.0 €/kg$_{H_2}$

**HyS cycle**
- 410 MWth
- 118 MWe
- 1.8 €/kg$_{H_2}$

**HTSE**
- 79 MWth
- 255 MWe
- 1.6 €/kg$_{H_2}$

- with degradation of the electrolyser performances
HTSE demonstrates a higher competitiveness
→ CEA's choice in 2009
S/I CYCLE COST DRIVERS

High investment

- impact of learning, maintenance, load factor, discount rate

High temperature process

- impact of thermal energy cost

CEA/DEN/DANS/I-tésé | 4-5 April 2013 | PAGE 13
Impact of the electrolyser

- uncertainty about its cost
- potential high impact of its life expectancy

High temperature process

- impact of thermal energy cost
Electrolysis process

- High impact of electricity consumption
  
  \(1.4 \, \text{€/kg}_\text{H}_2\) without performance degradation

High temperature electrolysis

- Electrolyser lifespan
  
  \(\text{e.g.} \, 1000 \, \text{€/m}^2 \text{ - 3yrs} \# \, 0.4 \, \text{€/kg}_\text{H}_2\)
Very different specificities and cost drivers:
- **S/I**: high investment
- **HyS**: electrolyser performance and lifespan
- **HTSE**: electrolyser performance and durability

Beware of the cost assumptions and uncertainties when comparing economic competitiveness of several processes

Technological breakthroughs to come?
The assessment that was carried out by the CEA in 2009 led to promote HTSE as the most competitive advanced process.

Major challenger in a CO₂ mitigation context: alkaline electrolysis (~ 3 €/kg\textsubscript{H₂} based on similar assumptions).

R&D is still needed.

2009 – 2013 studies focused on HTSE durability, cell performance, system integration
→ a production cost < 3 €/kg\textsubscript{H₂} seems achievable based on recent studies.

In an increasing electricity price context: the relative advantage is stronger for HTSE.
Thank you for your attention

Christine Mansilla : christine.mansilla@cea.fr

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