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STATE-OF-THE-ART CAPEX DATA FOR WATER ELECTROLYSERS, AND THEIR IMPACT ON RENEWABLE HYDROGEN PRICE SETTINGS

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***Abstract* - Within the framework of the Hydrogen Implementing Agreement (HIA) of the International Energy Agency (IEA), a new Task 38 was started early 2016, entitled *"Power-to-Hydrogen and Hydrogen-to-X : System Analysis of techno-economic, legal and regulatory conditions"*. Within this framework, a specific task force was set-up for the compilation of state-of-the-art technical and economical data on large-scale water electrolyser systems, both based on PEM and alkaline technology. The objectives set forward have been twofold. Firstly, to offer policy makers and industry with comprehensive trends and guidelines for further electrolyser cost reduction (CAPEX, in Euro/kW) into the MW-scale. Secondly, to provide objective technological & economic arguments for converging towards a realistic electrolytic (and hence renewable) H_2 market price (in Euro/kg). This should help water electrolysis to become competitive with SMR technology for (local) H_2 production, and hence to start making H_2 a competitive fuel.**

***Index Terms* - electrolyser, CAPEX, H_2 price, alkaline, PEM**

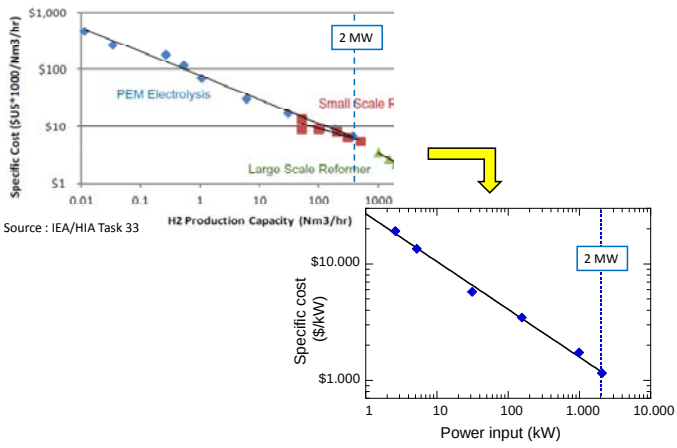

Fig. 1. CAPEX data for PEM electrolysers, collected from Task 33, as a function of H_2 production capacity (top) and replotted as a function of equivalent power input (bottom).

I. Introduction

As a starting point for setting up a specific task force on electrolyser data within IEA/HIA Task 38, published data from previous Task 33 have been (re-)considered, as shown in Figure 1. This plot shows on the one hand the actual CAPEX evolution of PEM electrolyser systems, both as a function of H_2 production capacity (top) and equivalent electrolyser power input (bottom). It also superimposes on the same graph data collected for both small and large scale steam methane reformer systems (SMR), the main H_2 production technology used today. Based on these data, it can be recognised that in order for water electrolysis to be a viable technological choice for H_2 production, a process intensification into the MW-range is absolutely mandatory. This is not only a necessary condition to become competitive, in terms of CAPEX, to SMR H_2 technology, but also a prerequisite to be able to couple to >MW-scale renewable electricity production capacities, as is typical for today's on-shore wind mills. The latter is an absolute boundary condition for any water electrolyser technology in order to produce fully renewable, green and clean H_2.

II. Results & Discussion

A. Comparing CAPEX for PEM and alkaline electrolysers

In a first stage, an attempt was made to complement the previous compilation effort of Task 33 with CAPEX data for alkaline water electrolyser, as the latter are today still considered to be the most mature and durable technology, especially for large-scale and long-term renewable H_2 production. CAPEX data are shown in Figure 2 as a function of power input, on a full electrolysis system level including the following components :

• Transformer(s), rectifier(s), control panel with PLC ;

• Water demineralizer/deionizer ;
• Electrolyser stack(s) ;
• Gas analysers, separators and separating vessels ;
• Scrubber or gas purifier system & recirculating pump ;
• Dry piston compressor @ 15 bar (note that PEM systems are typically self-pressurising upto 20/50 bar).

From this graph, it is easily seen that alkaline electrolyzers are (much) more susceptible to CAPEX reduction upon scaling than PEM, especially for single stack systems. In particular, for alkaline systems, a CAPEX of 750 Euro/kW, considered to be critical for storage purposes, is already realistic today for a single stack 2 MW system. For PEM, such a cricital CAPEX value should become within reach for 5 MW systems, probably requiring multi-stack systems as will be shown further below.

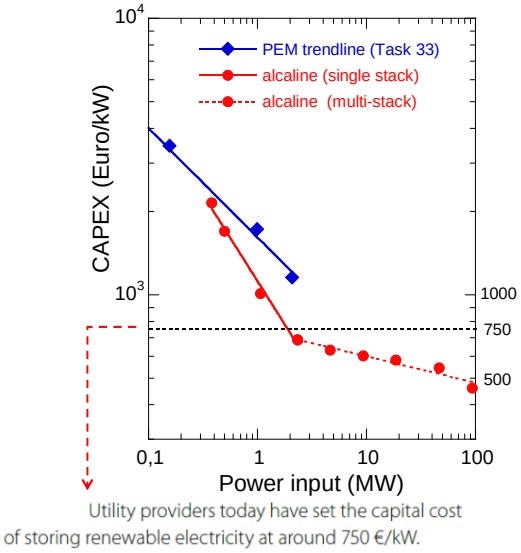

Fig. 2. CAPEX data for both PEM and alkaline electrolysers, plotted as a function of power input. Data for alkaline systems are based on a single stack of 2.13 MW consisting of 230 cells, 2.6 m² in size. Note that the change in slope for alkaline electrolysers corresponds to the use of multi-stack systems.

B. *Perspectives for further reduction in CAPEX (in Euro/kW)*

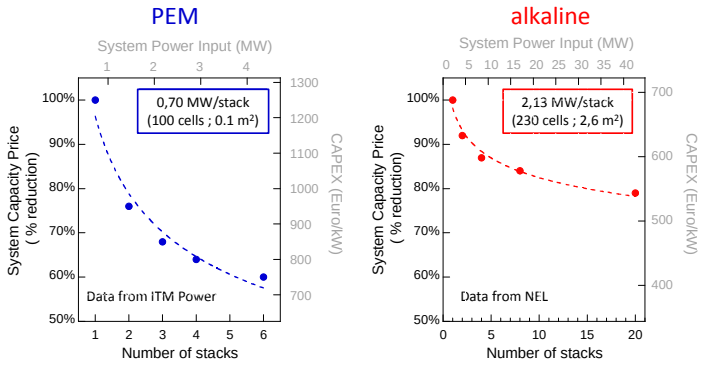

Fig. 3. Reduction in CAPEX upon use of multi-stack systems, both for PEM (left) and alkaline (right) electrolysers.

Figure 3 gives some perspectives for further CAPEX reduction based on multi-stack systems, both for PEM (left) and alkaline (right). It is clearly observed that such a further reduction upon scaling is much more pronounced (on a relative % scale) for a multi-stack PEM design than for alkaline. However, in absolute terms, CAPEX values below 500 Euro/kW can be expected for alkaline systems when scaling up to 100 MW, based on an intelligent engineering design of a 40 stack system.

C. *Impact of CAPEX on electrolytic H_2 price (in Euro/kg)*

Finally, based on the above CAPEX data, some projections can be made regarding price settings for electrolytic (i.e. renewable) H_2. To this end, some simulations from the literature have been gathered in Table I. As can be expected, for setting a realistic H_2 price, other parameters beyond simply electrolyser CAPEX values intervene as well, including operating hours and (renewable) electricity cost. Nonetheless, it seems that an electrolytic H_2 price of less than 4 Euro/kg is very realistic by 2020, very much comparable to SMR H_2.

TABLE I
ELECTROLYTIC H_2 PRODUCTION COSTS ACCORDING TO VARIOUS SCENARIO'S

Scenario	1	2	3	4	5
CAPEX electrolyser (Euro/kW)	2000	800	800	800	800
Efficiency electrolyser	60%	80%	80%	80%	80%
Annual operating hours	7000	2000	1000	500	7000
Electricity cost (Euro/MWh)	70	70	140	0	60
Electrolytic H_2 price (Euro/kg)	7.0	6.1	12.2	10.5	3.7

source : AFHYPAC Fiche 3.2.1 (2015)

III. CONCLUSIONS

At this stage of the IEA/HIA Task 38, the following major conclusions have been reached :

- For alkaline systems, a CAPEX of 750 Euro/kW, considered to be critical for storage purposes, is already realistic today for a single stack, 2 MW system ;
- For PEM, such CAPEX should become within reach for 5 MW systems, requiring multi-stack systems ;
- CAPEX values below 400 Euro/kW have been projected for alkaline systems, but this will require further upscaling upto 100 MW ;

Moreover, from the CAPEX data collected, it seems that a H_2 price of less than 4 Euro/kg is very realistic by 2020, very much comparable to SMR H_2.

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