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MELY: Market model for water ELectrolYsis

Electrolysis' Economic Potential given its Technological Feasibility

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Motivation and Purpose

Power-to-Gas (PtG) is a technology that has the potential to be a system solution to the fluctuating energy production due to the rising share of renewable energies. Despite the fact that the technology is mature, it has not penetrated the market, yet. Financial resources are, among others, often blamed for. To investigate the economics behind the first step of PtG, Power-to-Hydrogen (PtH_2), we derive a microeconomic partial equilibrium Market model for water ELectrolYsis, MELY, with a temporal horizon up to 2040.

Introduction

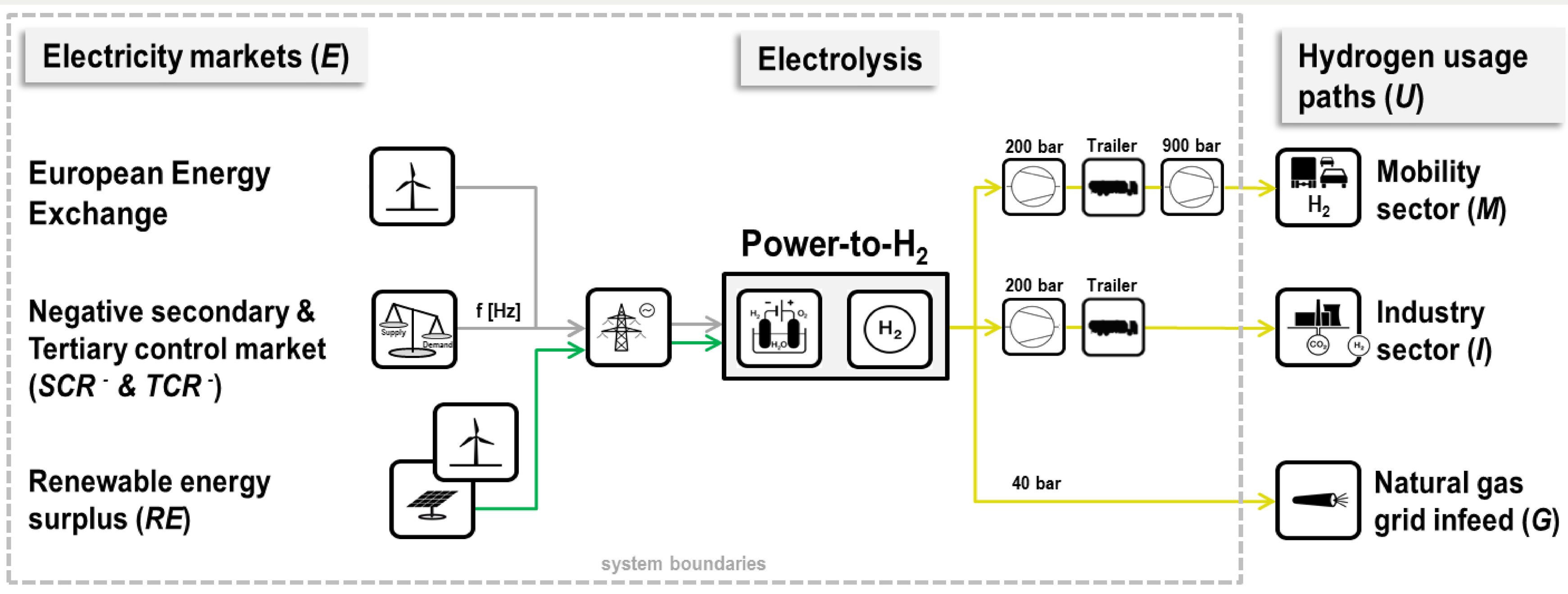
Our techno-economic analysis aims at investigating the economics behind electrolysis, which is also referred to as Power-to-Hydrogen (PtH_2). Our model incorporates multiple hydrogen as well as various electricity markets. We examine:

- Cost components of hydrogen production,
- Profits of hydrogen production,
- The point in time PtH_2 will generate positive unit profits for electrolysis' operators,
- Hydrogen usage paths and electricity markets that will play a major role in electrolysis' market penetration.

Methodology and Input Parameters

Figure 1 gives an overview on the 12 subsectors, that are constituted by combining an electricity market *E* with a hydrogen usage path *U*. Furthermore, the flow of the input factor electricity to vending the production output hydrogen in its usage paths is indicated. The system boundaries of the usage paths are crucial assumptions for the cost calculations.

Figure 1: Overview on MELY's subsectors and system boundaries, own representation.



The subsectors compete for the limited quantities. To determine which subsector will use the limited electricity and serve the limited demand, we assume a call sequence that proceeds according to the subsectors' marginal profits. If the maximal available electricity is depleted and/or the hydrogen demand is satisfied, the subsector *E-U* will stay inactive.

Additional input factors for hydrogen production are water, labour and physical capital. Values of selected input parameters are shown in **Table 1** and **Table 2**.

After ascertaining the level of production, costs and discounted profits are computed. We further apply a profitability condition and carry out an OFAT sensitivity analysis.

Table 1: Selection of chosen input parameters w.r.t. the electricity and hydrogen market.

Input parameter	Unit	2020	2030	2040	Source
Electricity price *EEX*	€/kWh_{el}	0.0349	0.0409	0.0469	[1], [2], own data fitting
Electricity price SCR^-	€/kWh_{el}	0.007	0.0105	0.0129	[3], own calculation and data fitting
Electricity price TCR^-	€/kWh_{el}	0.0009	0.0023	0.0033	[3], [4], own calculation and data fitting
Electricity price *RE*	€/kWh_{el}	0	0	0	[5]
Hydrogen price in *M*	€/kWh_{H2} (LHV)	0.2536	0.2972	0.3409	[6], own calculation
Hydrogen price in *I*	€/kWh_{H2} (LHV)	0.0676	0.1051	0.1426	[7], [8], [9], own data fitting
Hydrogen price in *G*	€/kWh_{H2} (LHV)	0.0434	0.0706	0.0978	[7], [8], own data fitting
Regulation charges	€/kWh_{el}	0.0412	0.0023	0.0023	[3], [7], [8], [10], own data fitting

Table 2: Selection of chosen input parameters w.r.t. capital input and technical input parameters.

Input parameter	Unit	2020	2030	2040	Source
Investment into electrolyser	€/kW_{el}	851	706	561	[7], own data fitting
Investment specific to *M*	€/2,000 kW_{el}	$1.59 \cdot 10^6$	$1.3 \cdot 10^6$	$1.17 \cdot 10^6$	[7], [8], own calculation
Investment specific to *M*	€/$kg_{Capacity}$ p.a. [1]	8.32	5.59	2.85	[8], own calculation and data fitting
Investment specific to *I*	€/2,000 kW_{el}	$1.59 \cdot 10^6$	$1.3 \cdot 10^6$	$1.17 \cdot 10^6$	[7], [8], own calculation
Investment specific to *G*	€/2,000 kW_{el}	$2.87 \cdot 10^5$	$2.35 \cdot 10^5$	$2.11 \cdot 10^5$	[7], [8], own calculation
Interest rate / discount rate	% p.a.	6	6	6	[11], [12], [13]
Efficiency factor of electrolyser	% (LHV)	63.25	70	74.25	[7], [11], own data fitting
Full load hours	h p.a.	2,500	2,500	2,500	[7]

1) This unit refers to the investment into the capacity of a refuelling station, which is measured by the hydrogen quantity a refuelling station can theoretically provide.

Results

Only the demand from the mobility sector *M* will be satisfied with positive unit profits for electrolysers' operators (cf. **Figure 2**). Renewable energies *RE* and the control markets TCR^- and SCR^- will serve the demand partially from 2027 until 2029. From 2030 on, the subsector *EEX-M* will achieve positive unit profits and will supply additional hydrogen such that total demand in the mobility sector *M* is met.

Figure 2: Hydrogen unit profits, own calculation.

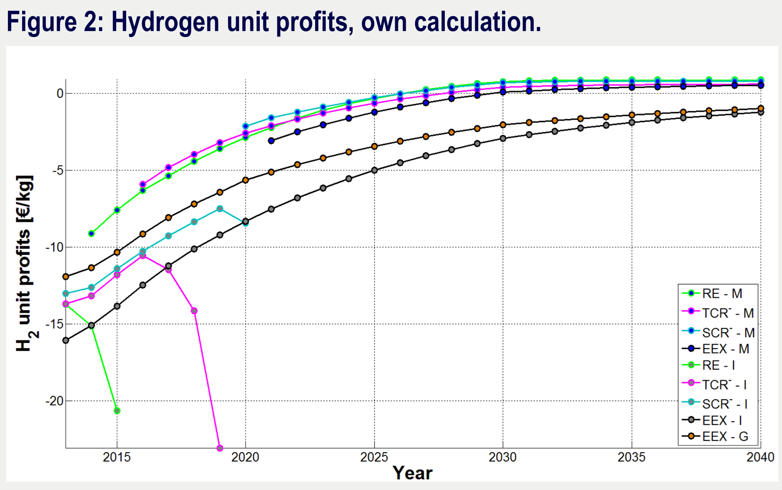


Figure 3: Capacities in the mobility sector, [14], own calculation.

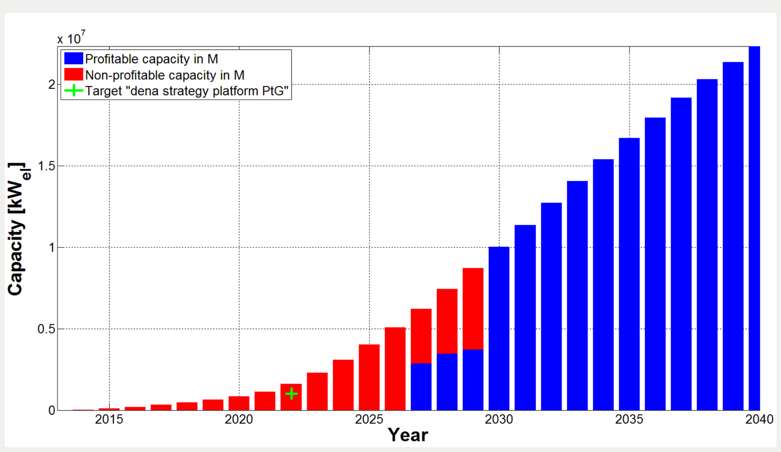


Figure 3 portrays capacities that are required to serve the entire demand in the mobility sector *M* and capacities that will be installed given the profitability condition.

The OFAT sensitivity analysis displayed in **Figure 4** refers to the subsector *RE-M* as this subsector turns out to be most attractive. Our analysis comes to the conclusion that unit profits react most sensitive to a variation in the hydrogen price, capital costs and full load hours. Note that the latter two parameters have repercussions on the effectiveness of the factor input capital, thus indirectly impacting the effectivity of capital costs.

Figure 4: Sensitivities, subsecetor *RE-M*, 2030, own calculation.

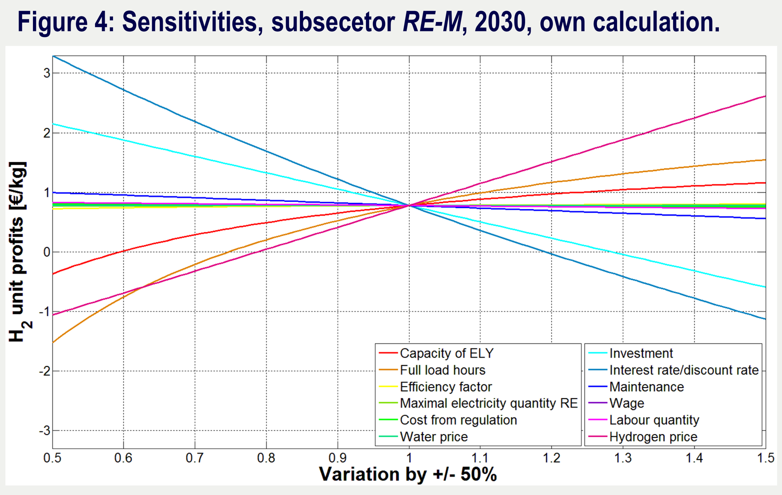


Figure 5: Unit cost decomposition, subsector *RE-M*, own calculation.

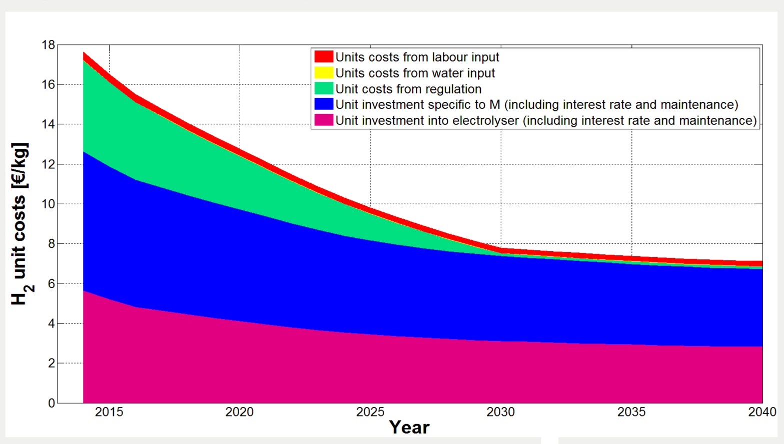


Figure 5 provides the explanation for the result of the sensitivity analysis: fix costs play a major role while variable costs take up a relatively small portion.

Discussion and Sources

Further research, especially endogenising certain variables, would provide a deeper insight into PtH_2's prospective evolution. Learning-by-doing effects as well as inclusion of CO_2-abatement costs would enhance the demand for green hydrogen. An upward spiral might set: increased demand would lead to a rise in production, degrading the costs of production and the price for hydrogen, in turn, enhancing the demand. The truthful potential of PtH_2 would be revealed.

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Conclusion

MELY negates the general assertion PtH_2 is not economical. The subsector *RE-M* yields positive unit profits in 2027 and further subsectors involving the mobility sector *M* follow up. Consequently, hydrogen is able to substitute fossil fuels but for PtH_2 to function as energy storage, improvements especially regarding the sensitive parameters hydrogen price, capital costs and full load hours are required.