REFHYNE
CLEAN REFINERY HYDROGEN FOR EUROPE

Policy implications of initial techno-economic modelling

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Michael Joos, michael.joos@element-energy.co.uk

ITM POWER Energy Storage | Clean Fuel sphera elementenergy SINTEF

FUEL CELLS AND HYDROGEN JOINT UNDERTAKING

Policy implications of initial large scale electrolyser modelling

Context

- Summary of report submitted to FCHJU by project[1]

Key modelling results

- High impact of **levies** on electricity and subsequently hydrogen price
- Electrolysis **not yet able to compete** with reforming of natural gas
- Currently **high load factor** rather than flexible operation of electrolyser leads to lowest hydrogen cost

Policy options to promote electrolytic hydrogen

- Support hydrogen as **low carbon feedstock** for refineries
- Enable hydrogen in **high value end uses** such as mobility

1) Full report, titled *Brief summary report on initial policy implications of the bulk electrolyser model* available on REFHYNE project webpage: https://refhyne.eu/

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Deployment of large scale electrolyser at refineries could enable cost reduction of electrolytic hydrogen

Role of hydrogen in future energy systems

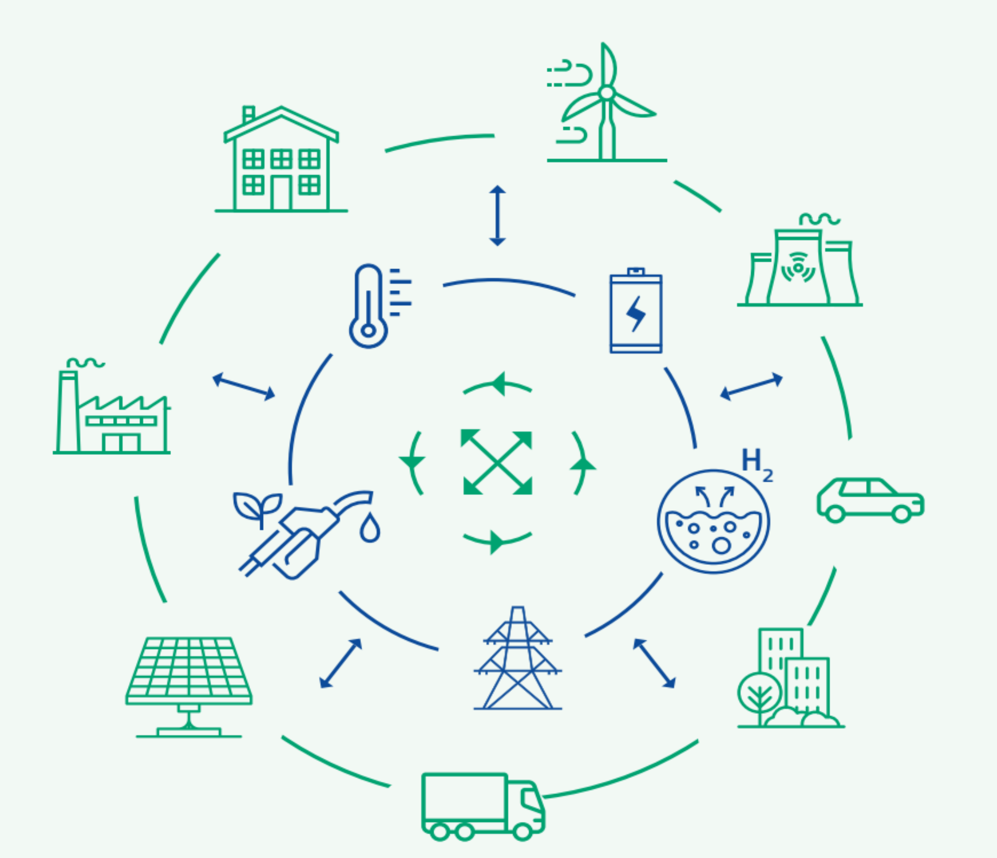
- Hydrogen could become a vital carrier of decarbonized energy
- Key role for hydrogen in sectors where electrification not an option
- Electrolytic hydrogen can provide flexibility over long time scales to electricity system with high renewable penetration (cp. right graph[1])

Current challenges

- High CAPEX of electrolysers
- Nascent demand in potential future end uses

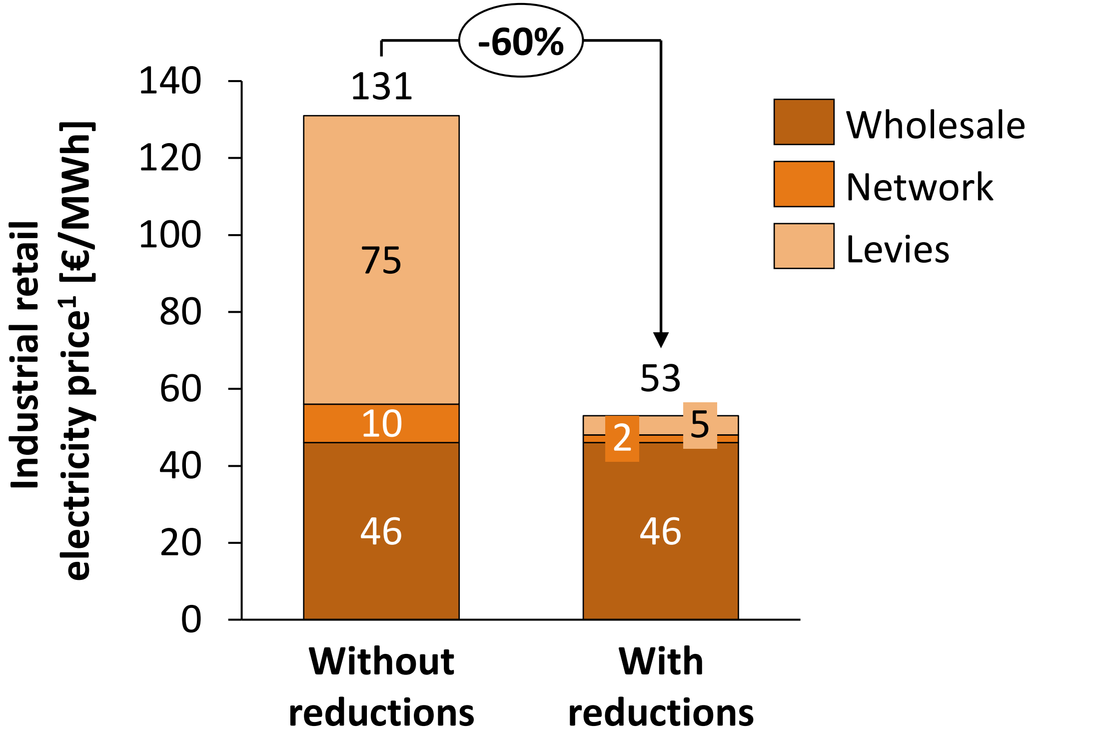
Why hydrogen in refineries

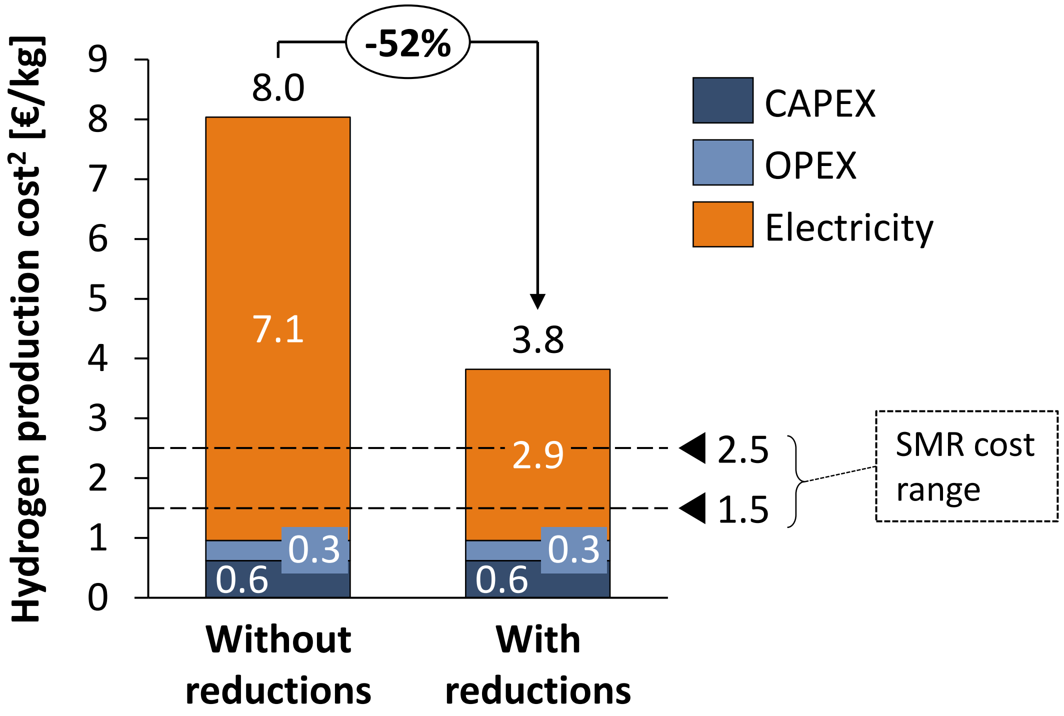
- Stable demand allows high electrolyser utilisation
- Large scale deployment can enable cost reduction
- Access to relatively cheap electricity



1) EU Energy System Integration Strategy Factsheet

Despite advantageous conditions at the refinery, electrolysis is not yet competitive with natural gas reforming



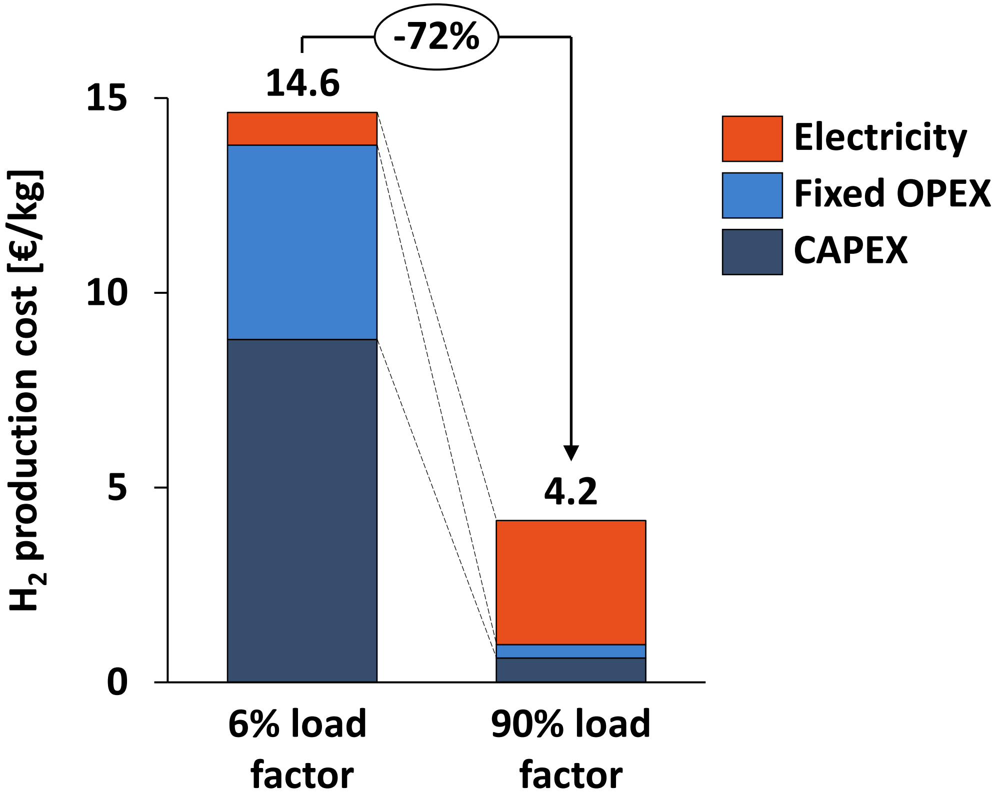


Even with access to cheap electricity, currently electrolysis cannot compete with SMR

- Access to levy exemptions and low grid fees reduces electricity cost by 60% (left) and hydrogen cost by more than 50% (right).
- Including grid fee and levy exemptions, H2 production cost is still higher for electrolysis than for SMR (right).
- Current CO2 prices not sufficient to close the gap between electrolytic and SMR based hydrogen.

1) Note that grid fees and levies differ significantly across countries in Europe, and grid connection cost can be significant component in certain jurisdictions.
2) Assuming a 90% load factor of the electrolyser; compare appendix for further techno economic assumptions.

Electrolysers face a trade off between high fixed cost at low load factors and high electricity cost at high load factors



Low load factor

- Low electricity cost
- High fixed cost (CAPEX + fixed OPEX)

High load factor

- High electricity cost
- Low fixed cost

High load factor more economic

- 70%+ cost reduction cp. to low load factor in this example
- Electricity price volatility, and frequency of negative price events not sufficient yet to offset higher CAPEX per kg of hydrogen at lower load factors.

Several scenarios have been investigated to identify levers which could help make green hydrogen viable (1/2)

Nr.	Scenario	Main implications
1	Run only in profitable hours	**Reduced electricity cost** per kg H_2 at low load factors more than **offset by higher CAPEX and fixed OPEX** per kg H_2.
2	Higher H_2 prices paid to electrolyser	Given policy levy and network fee exemptions, electrolysis could become **profitable above H_2 prices of €4/kg** (covering production cost only, not distribution and retail infrastructure)
3	Impact of price variability and negative prices across Europe	Explored wholesale electricity markets **in 5 countries** (DE, DK, NO, FR, ES). Higher variability and negative price periods occurring in DE , DK, leading to marginally better conditions for electrolysers. **Higher future VRE penetrations** will improve the opportunities for **flexibly operated electrolysers**.
4	Provision of balancing services	**Balancing services** could **support electrolyser business models** by providing valuable additional revenues. They are however not expected to be a core pillar of any business model.

Several scenarios have been investigated to identify levers which could help make green hydrogen viable (2/2)

Nr.	Scenario	Main implications
5	CO_2 adjusted electricity price	**Carbon intensity** of electrolytic hydrogen can be **reduced by 17%** compared to average grid mix. Higher VRE penetration will make grid carbon intensity more volatile.
6	Reduced network fees	**Network fees** per MWh for large industrial consumers are **already comparably low** so removal of network fees has **limited impact** on the electrolyser business model.
7	Reduced policy levies	Exemption from **renewable energy surcharge** in Germany (€64/MWh) has by far the **biggest impact**. At high load factor this can reduce electricity cost by more than 50% and hydrogen cost by more than 40%.
8	Internal load balancing	Helping to reduce grid fees of industrial sites by achieving an overall higher load factor could be a **niche business model** providing **early opportunities** for electrolysers.

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Policy recommendations (1/2): green hydrogen as low carbon feedstock in industry

Policy option 1: Support green hydrogen as a low carbon feedstock for refineries

- If renewable "green" H2 in refineries is accepted under RED II, the economic counterfactual could be equivalent to penalties of €470/tCO_2.
- Grid average carbon intensity is currently too high; electrolysers will need close links with sources of green electricity.

➢ *Clear definitions and rules are required for implementation of REDII; these are to be aligned across Member States; ensure production of green H2 is more cost-effective than non-compliance with directive.*

➢ *Rules should not be too restrictive to ensure viability of electrolyser projects and subsequent scale up.*

➢ *Consider exempting renewable electricity used to produce hydrogen from fees and levies for a limited time to foster the market uptake of green hydrogen.*

Policy recommendations (2/2): high value end uses for hydrogen

Policy option 2: Enabling hydrogen in high value end uses such as mobility

- Given sufficient demand for hydrogen for mobility, production of electrolytic hydrogen @ refineries could break even at hydrogen selling prices of up to €4/kg (this excludes cost of H2 distribution and retail)

➢ *Support for H2 mobility should focus on segments in which electrification is challenging due to requirements in terms of range, refuelling times, payload, etc. Examples include buses, coaches, taxis, vans, heavy duty trucks, trains, and ships.*

➢ *Positive returns on investment in hydrogen refuelling infrastructure require relatively large, well-utilised stations. Mechanisms to underwrite risks of underutilisation required.*

➢ *Local governments can play crucial role in catalysing uptake of hydrogen for transport, e.g. by implementing supportive policies (such as zero emission zones) and adopting fuel cell vehicles in their own fleets, thus creating anchor demands for refuelling stations.*

➢ *Capital grants for vehicles likely to be required in the short to medium term but may not bridge total cost of ownership (TCO) gap with traditional vehicles. Access to subsidies (e.g. arising from the implementation of RED II) will allow hydrogen refuelling infrastructure operators to sell hydrogen at price providing acceptable TCO.*

EU regulation on grid connected electrolysers to be adopted by end of 2021

Sustainability criteria for renewable H2

- Defining sustainability criteria for renewable hydrogen a priority of national and EU policy in 2021
- Criteria relatively straight forward in case of electrolysers with direct connection to renewables, less so for grid connected electrolysers.

National and EU policy

- EU Commission will adopt regulation on sustainability criteria for grid connected electrolysers producing RFNBIO[1] for the transport sector by end of 2021[1].
- German government has adopted regulation in May 2021 with sustainability criteria for green hydrogen but will align those with those of the EU Commission once they are adopted

European Commission

Bundesministerium für Wirtschaft und Energie

1) Renewable liquid and gaseous transport fuels of non-biological origin (cp. EU Commission 2018, RED II)
2) EU Commission 2018, RED II, Art. 27
2) BMWi, 2021

Conclusions

- High impact of **levies** on electricity and subsequently hydrogen price
- Electrolysis **not yet able to compete** with reforming of natural gas on production cost of hydrogen
- Currently **high load factor** rather than flexible operation of electrolyser leads to lowest hydrogen cost
- Supporting hydrogen as **low carbon feedstock** for refineries through the Renewable Energy Directive is a key policy option to scale up electrolytic hydrogen in the short term
- **Sustainability criteria** for renewable hydrogen from grid connected electrolysers to be adopted by EU COM by end of 2021; these could have significant impact on the scale up of electrolytic hydrogen

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References

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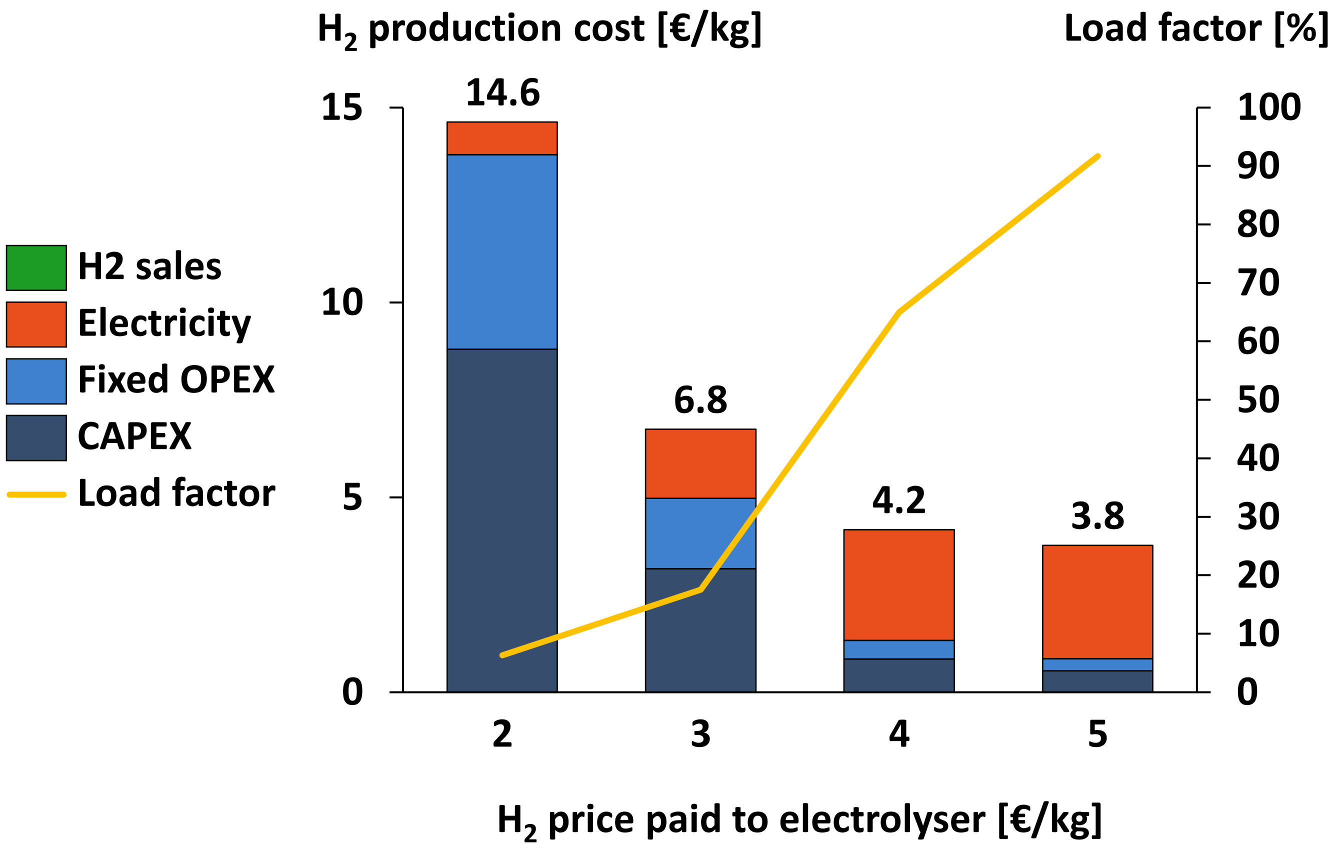
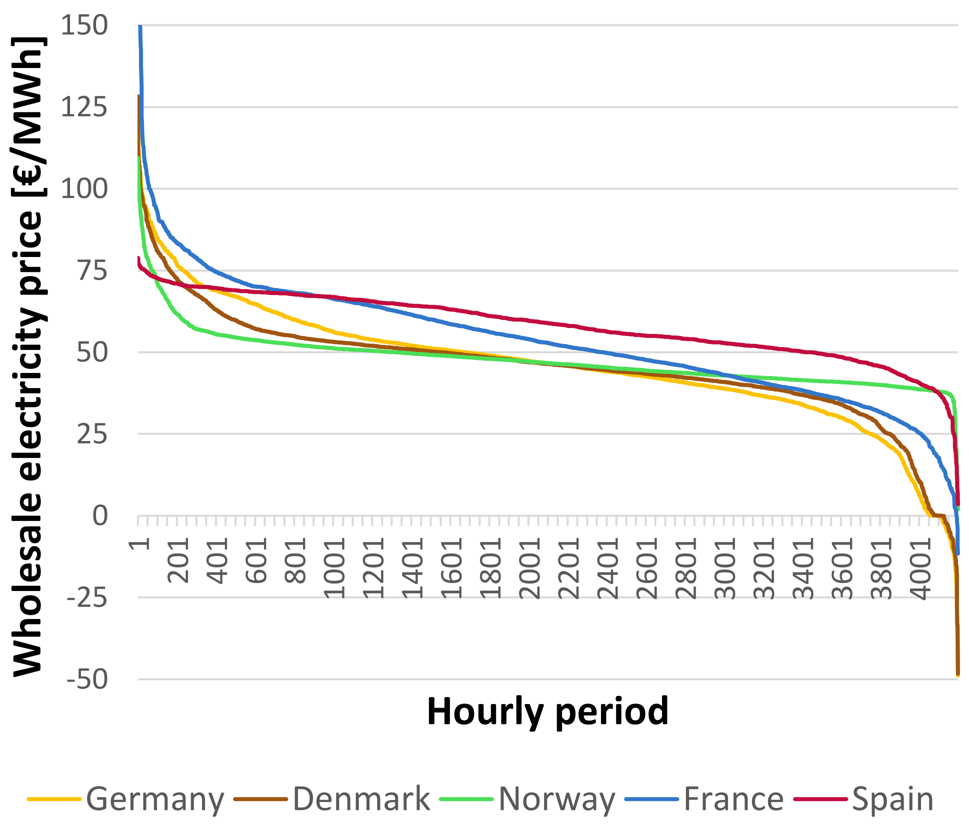
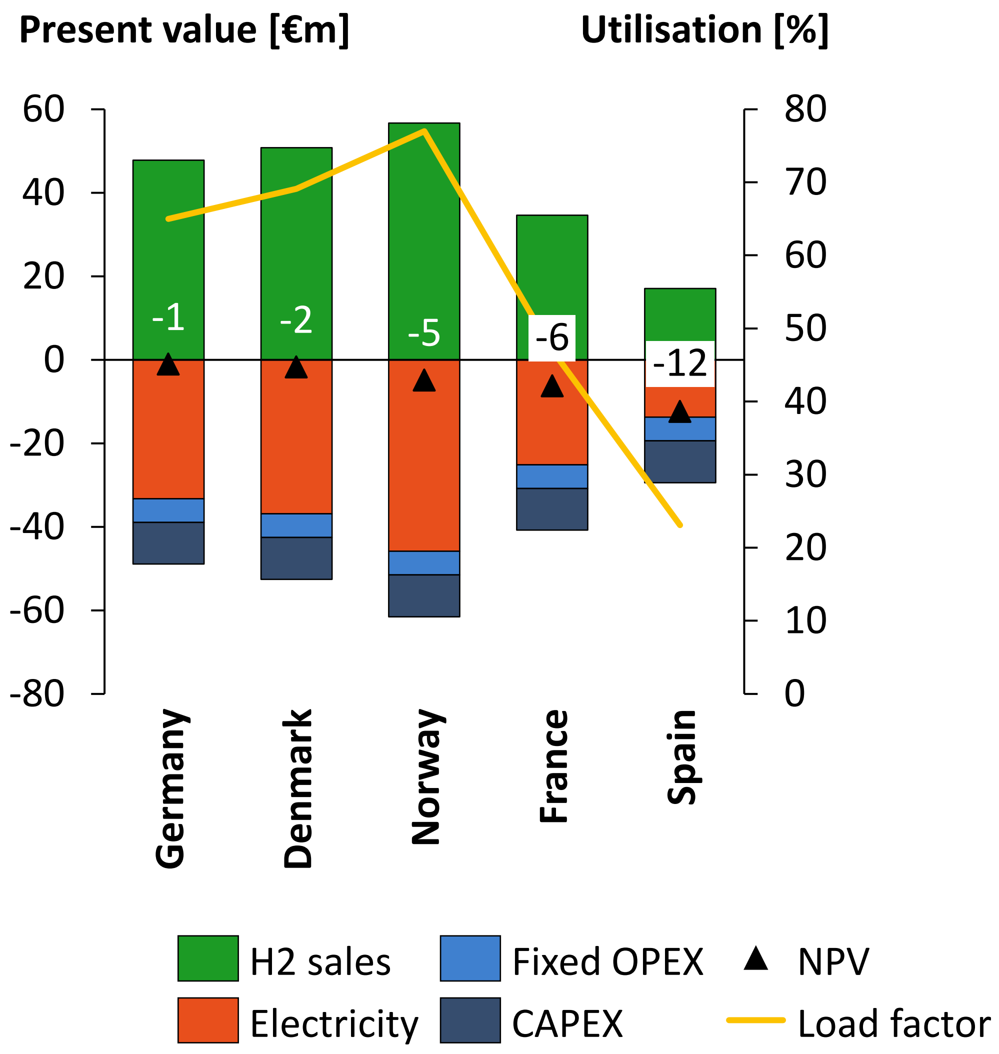


Scenario: Electrolyser operate when electricity costs are lower than H2 price.

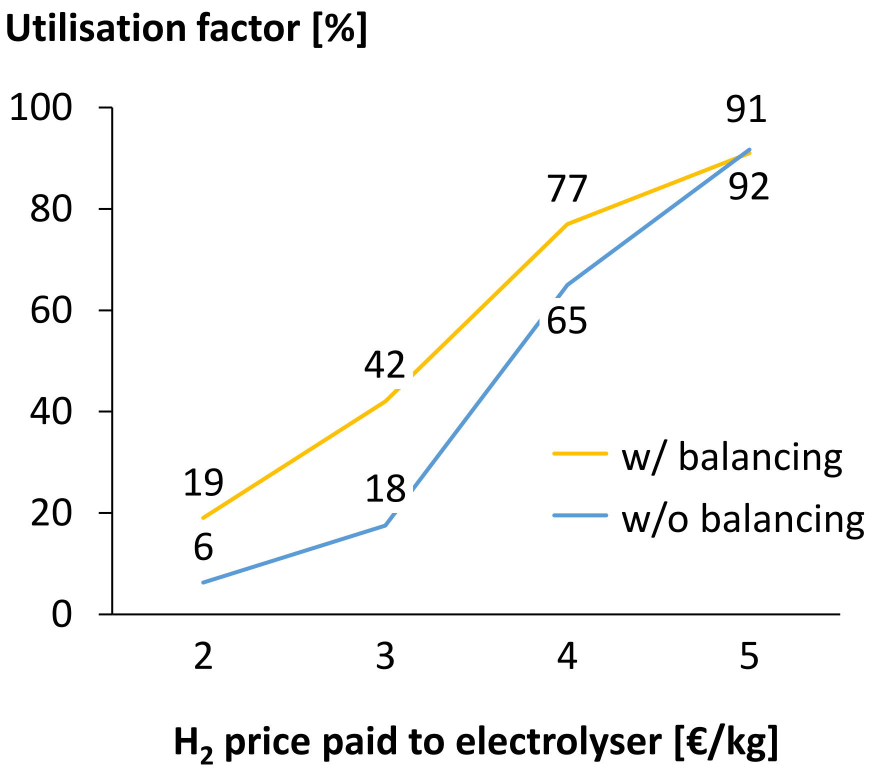
- This leads to low load factors where capex related costs dominate and production is uneconomic
- If revenues exceed 4€/kg this kind of "grid responsive" operation becomes economic.

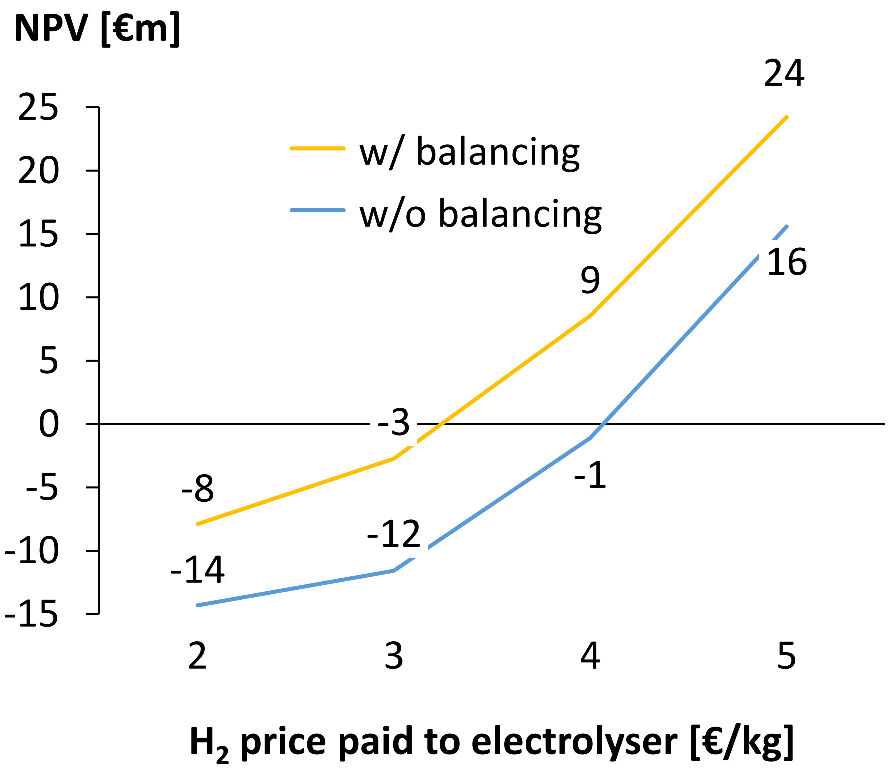
Higher wholesale price volatility and occurrence of negative price periods offer an opportunity for electrolysers





Provision of balancing services can improve the business case @ intermediate load factors





Exemption from the renewable energy surcharge has the biggest impact on electricity cost