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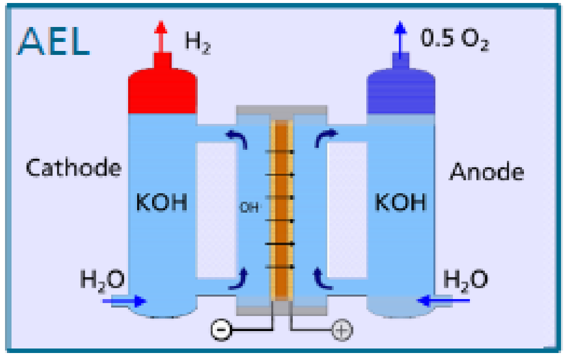
# LARGE-SCALE WATER ELECTROLYSIS

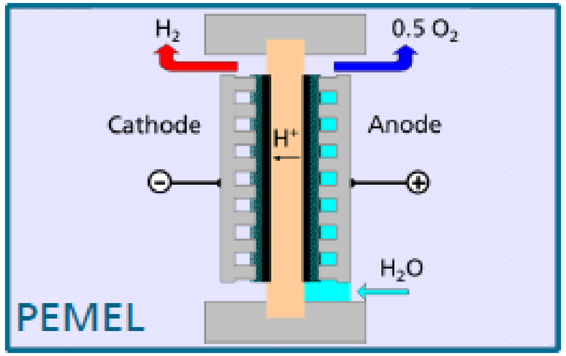
## TECHNOLOGY ASSESSMENT AND OUTLOOK TOWARDS 2030

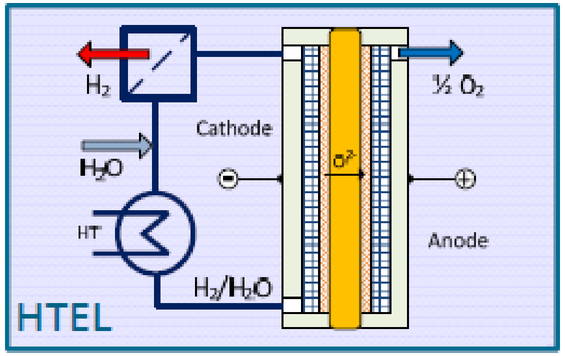
*Magnus Thomassen*

# Approaches for water electrolysis

| Technology | Temp. Range | Cathodic Reaction (HER) | Charge Carrier | Anodic Reaction (OER) |
|---|---|---|---|---|
| Alkaline electrolysis | 40 - 90 °C | $2H_2O + 2e^- \Rightarrow H_2 + 2OH^-$ | $OH^-$ | $2OH^- \Rightarrow \frac{1}{2}O_2 + H_2O + 2e^-$ |
| Membrane electrolysis | 20 - 100 °C | $2H^+ + 2e^- \Rightarrow H_2$ | $H^+$ | $H_2O \Rightarrow \frac{1}{2}O_2 + 2H^+ + 2e^-$ |
| High temp. electrolysis | 700 - 1000 °C | $H_2O + 2e^- \Rightarrow H_2 + O^{2-}$ | $O^{2-}$ | $O^{2-} \Rightarrow \frac{1}{2}O_2 + 2e^-$ |



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Source: Fraunhofer ISE

# A SELECTION OF KEY PERFORMANCE INDICATORS FOR ELECTROLYSIS TECHNOLOGIES

# Performance as a function of current density

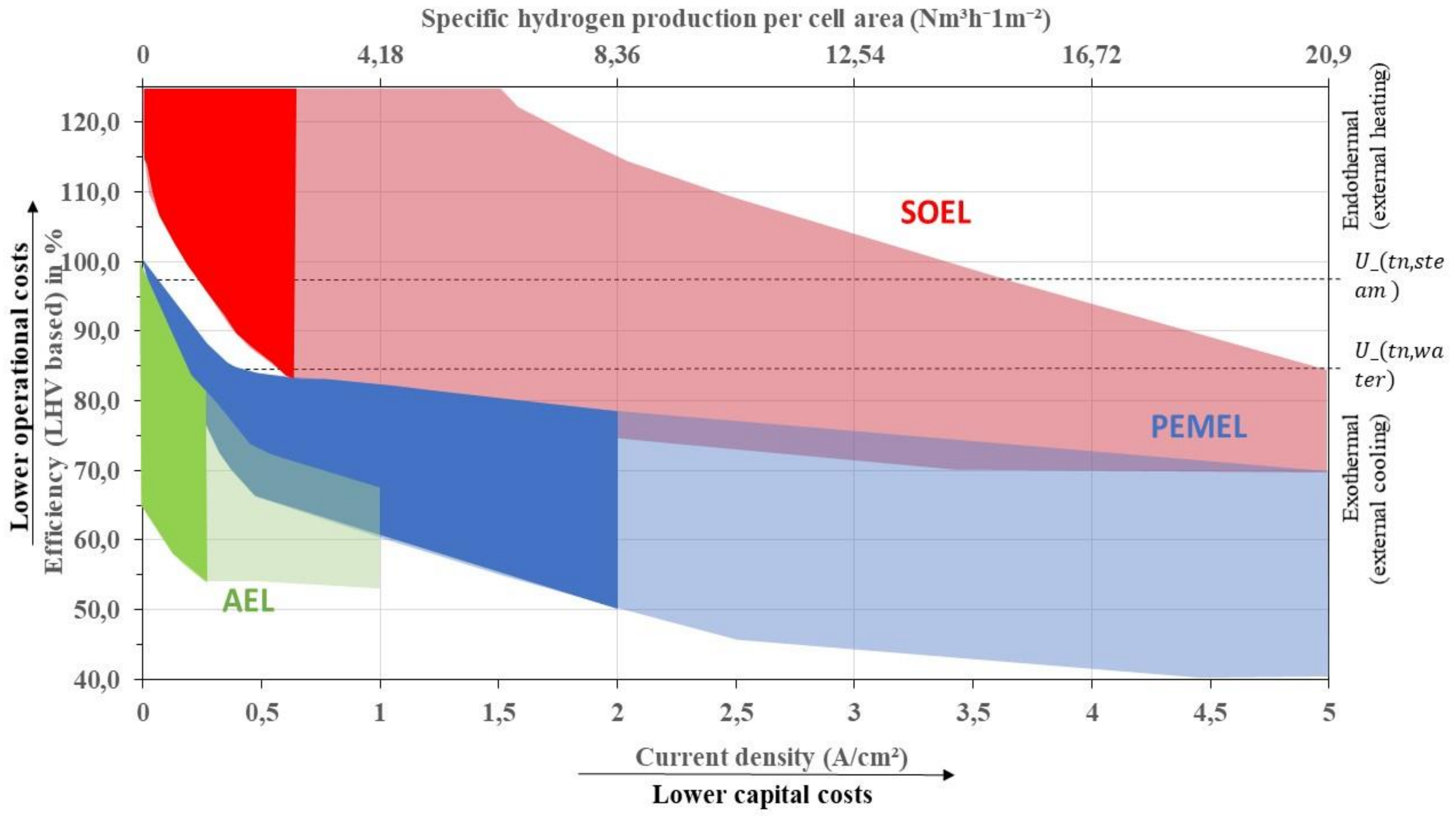
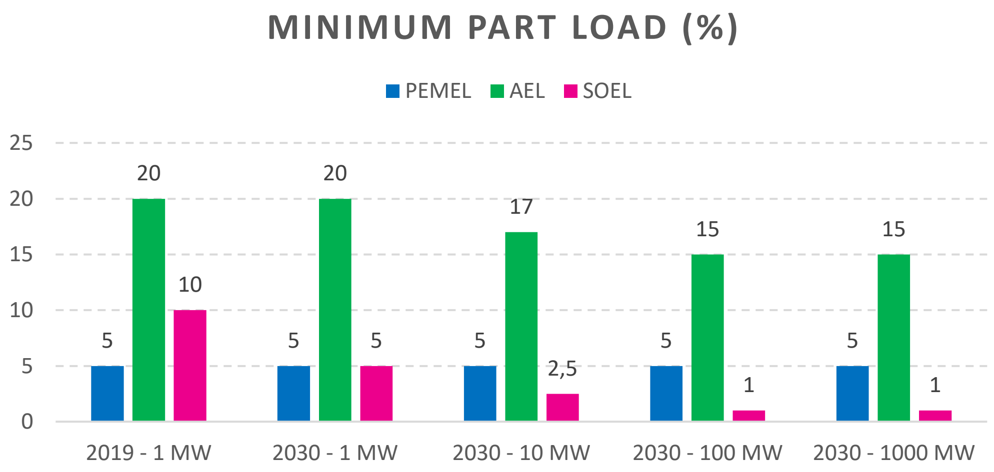
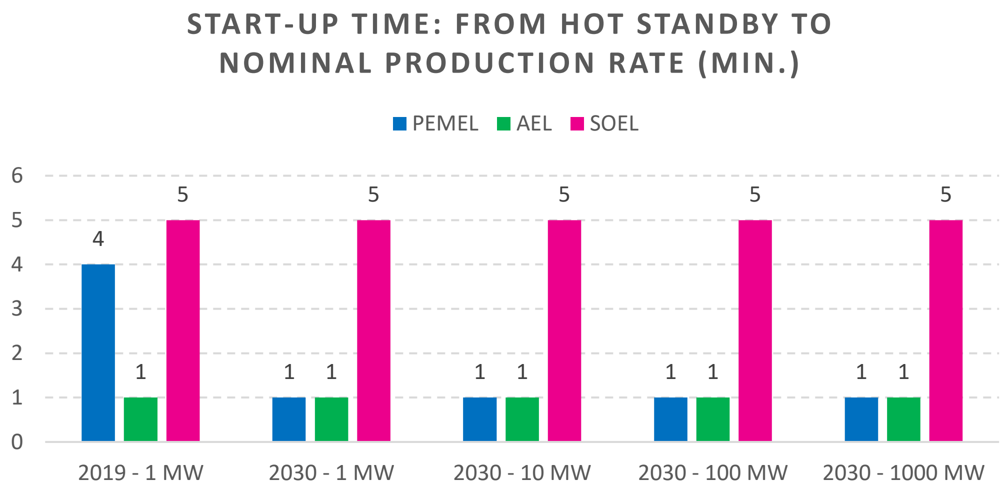


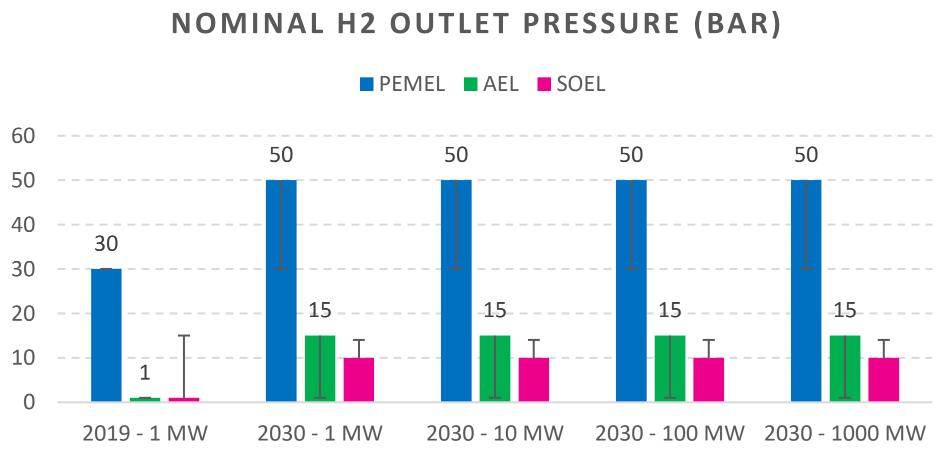

Figure: Overview of efficiency and operational range of AEL, PEM and SOE electrolyser stacks (illustration modified by SINTEF based on information from literature and the electrolyser suppliers).

# Minimum part load and start-up time







# ELECTROLYSER COST DEVELOPMENT

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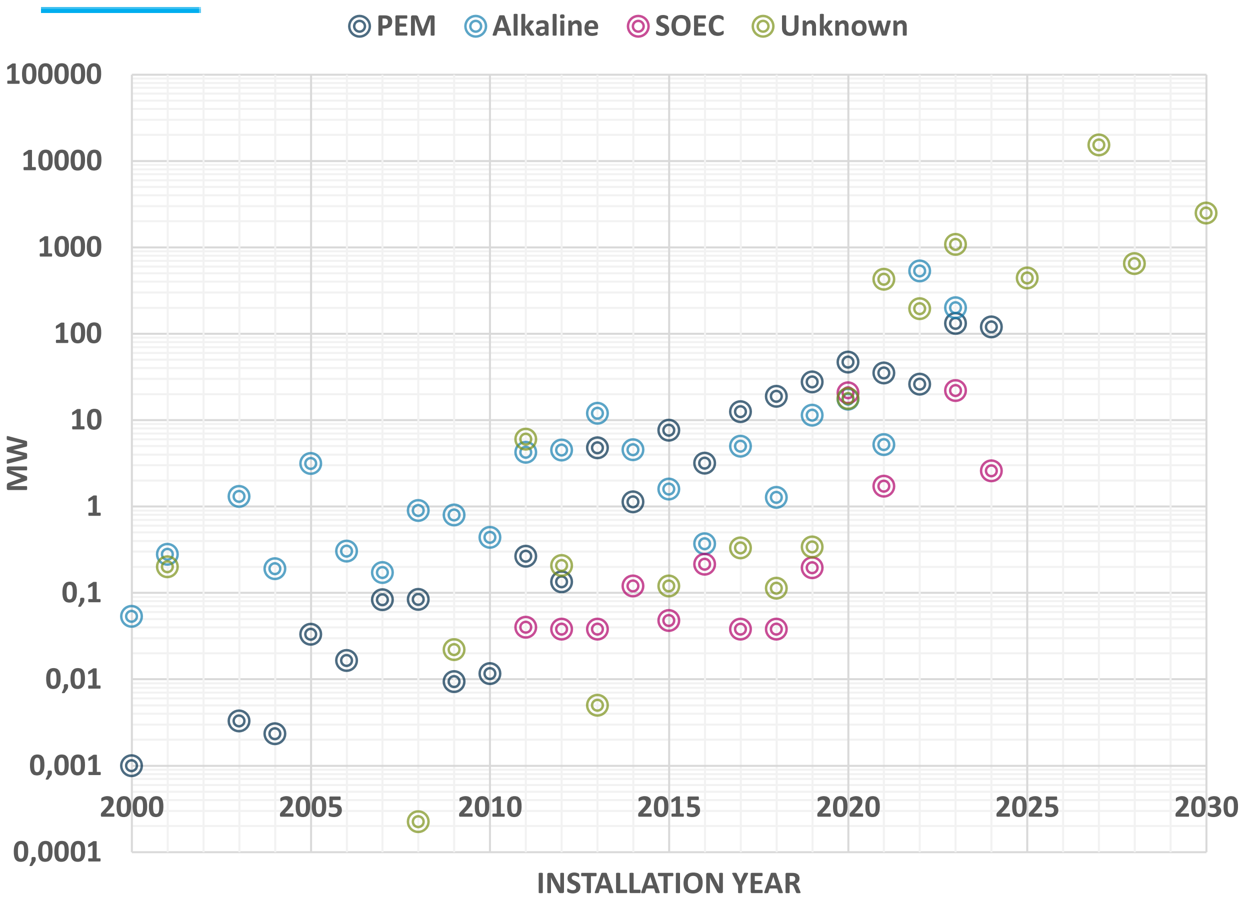
# Installed capacity – flexible electrolyser plants




**Source: IEA Hydrogen project database**

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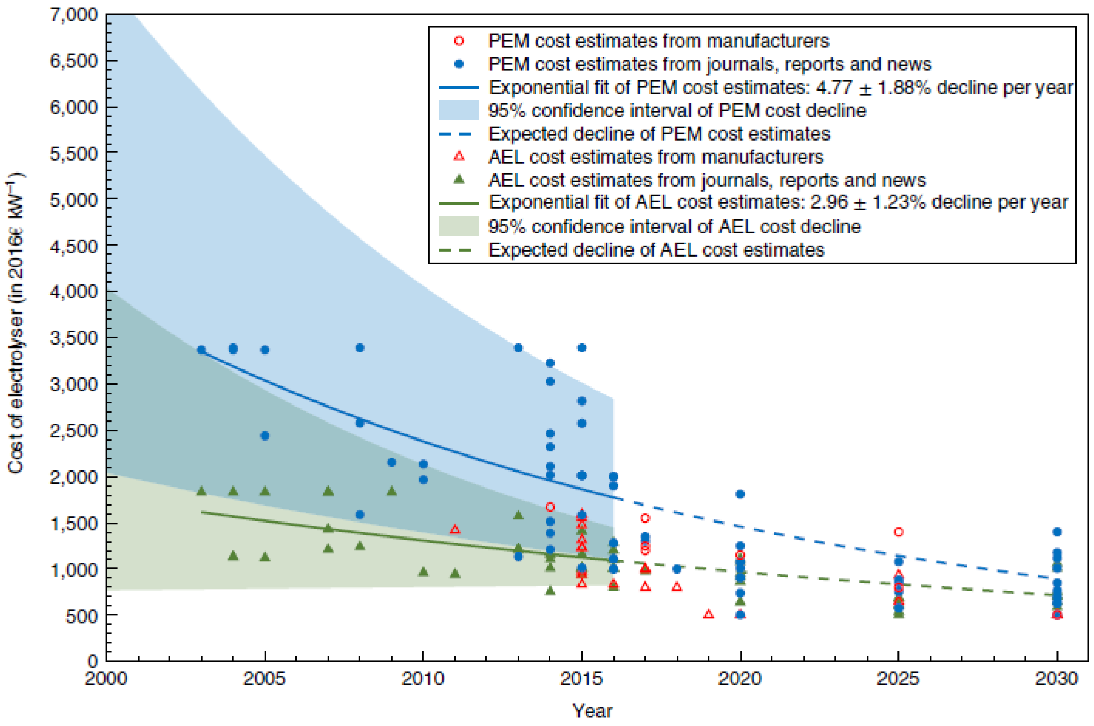
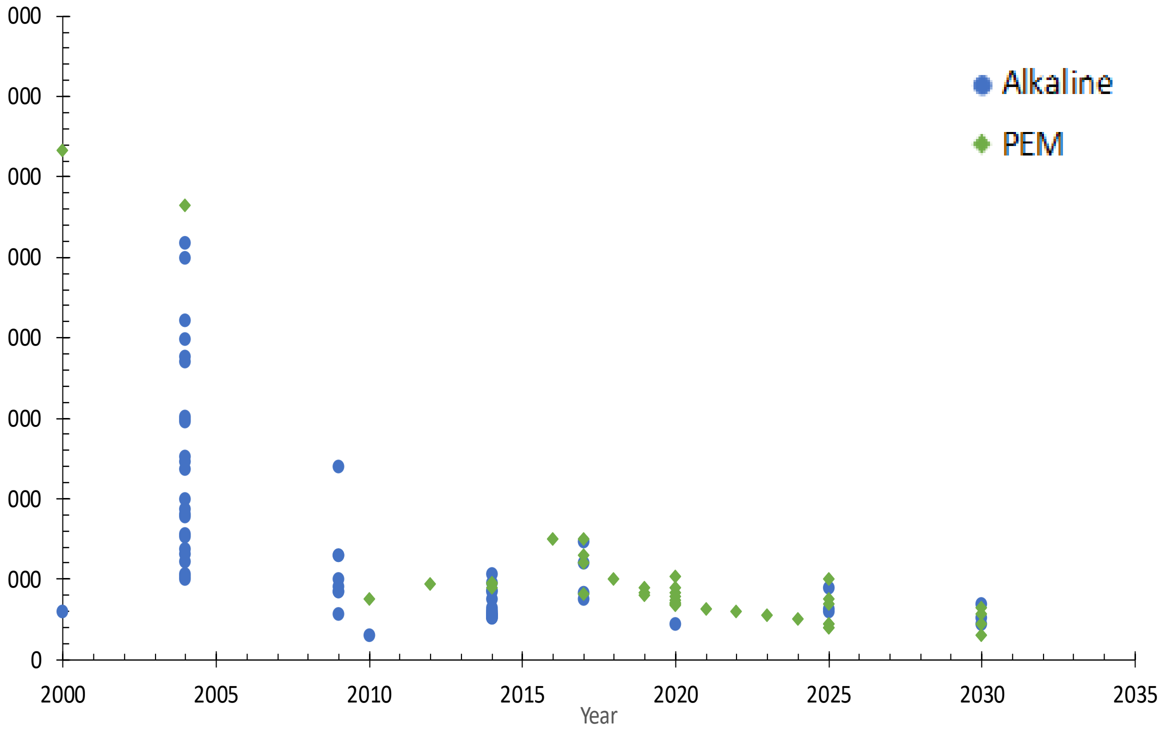
# Historic data and future projections




Glenck et al. Economics of converting renewable power to hydrogen. Nature Energy 2019



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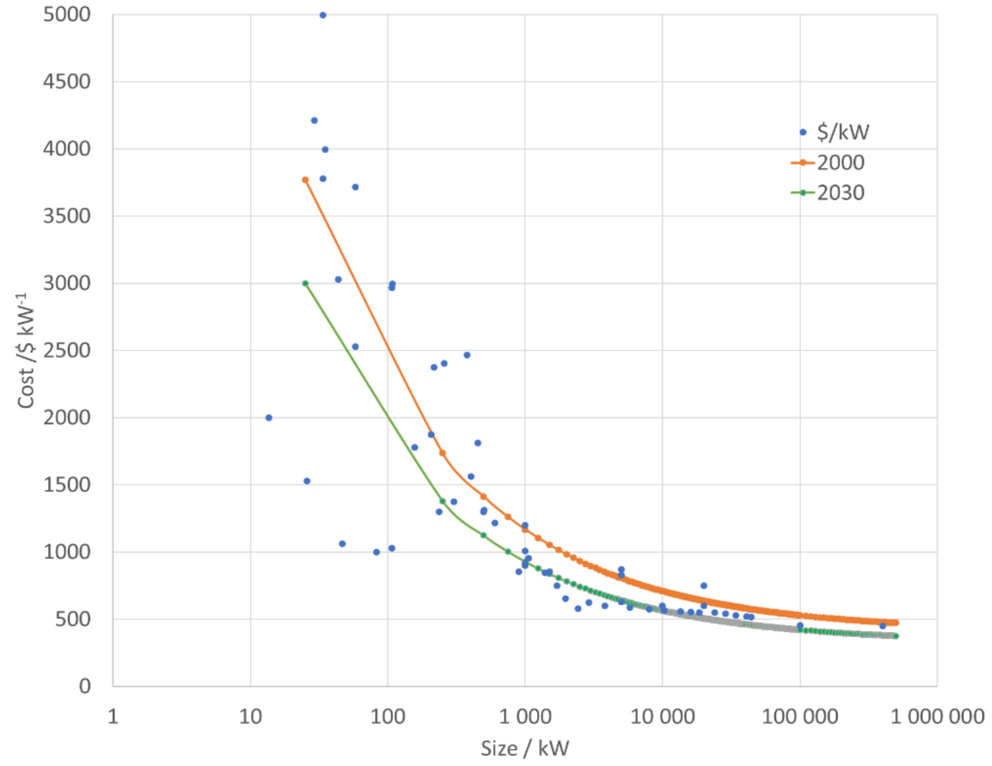
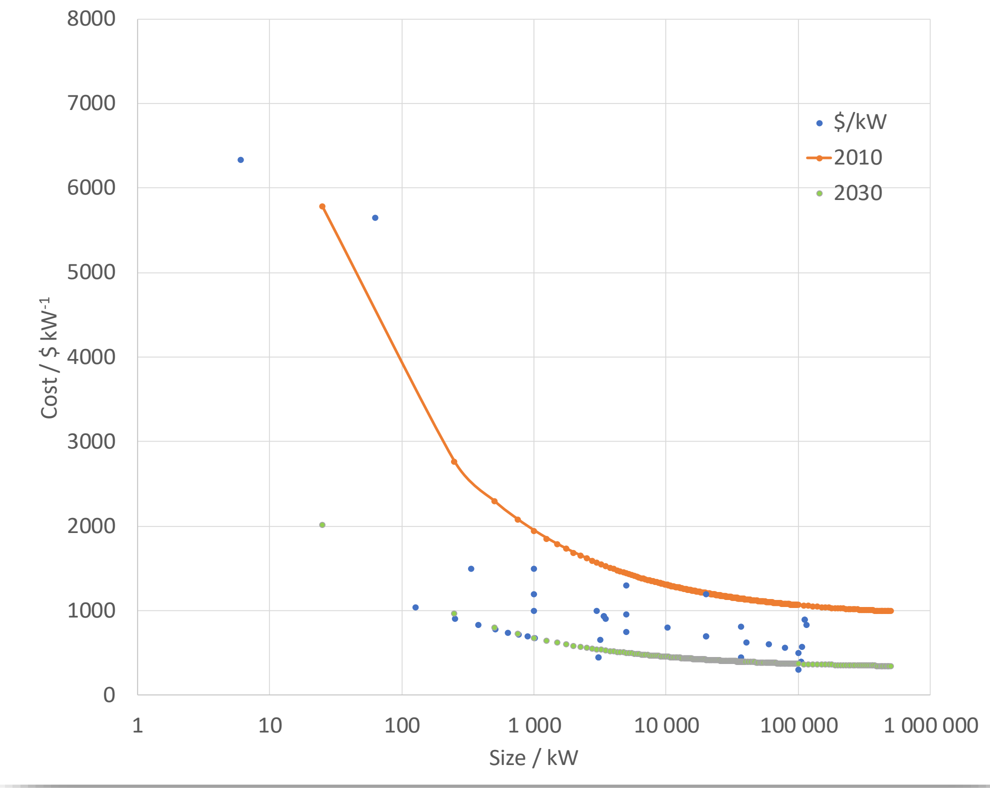
# Cost development




**Alkaline**

$$C = \left(k_0 + \frac{k}{Q} Q^{\alpha}\right)\left(\frac{V}{V_0}\right)^{\beta}$$




**PEM**

*C* - electrolyser plant cost / kW,
$k_0$ and *k* - fitting constants,
*Q* - electrolyser plant capacity
*V* and $V_0$ - plant installation year and reference year respectively. α and β are fitting constants and usually referred to as a scaling factor and learning factor, respectively.



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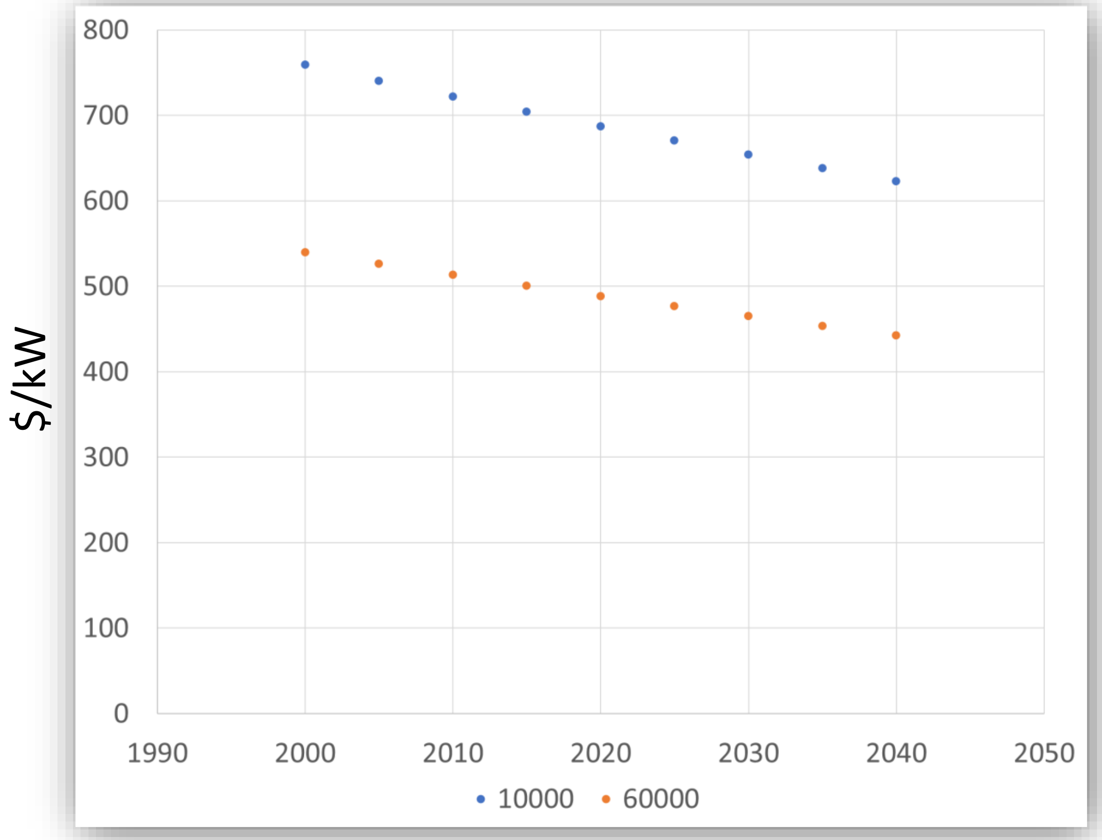
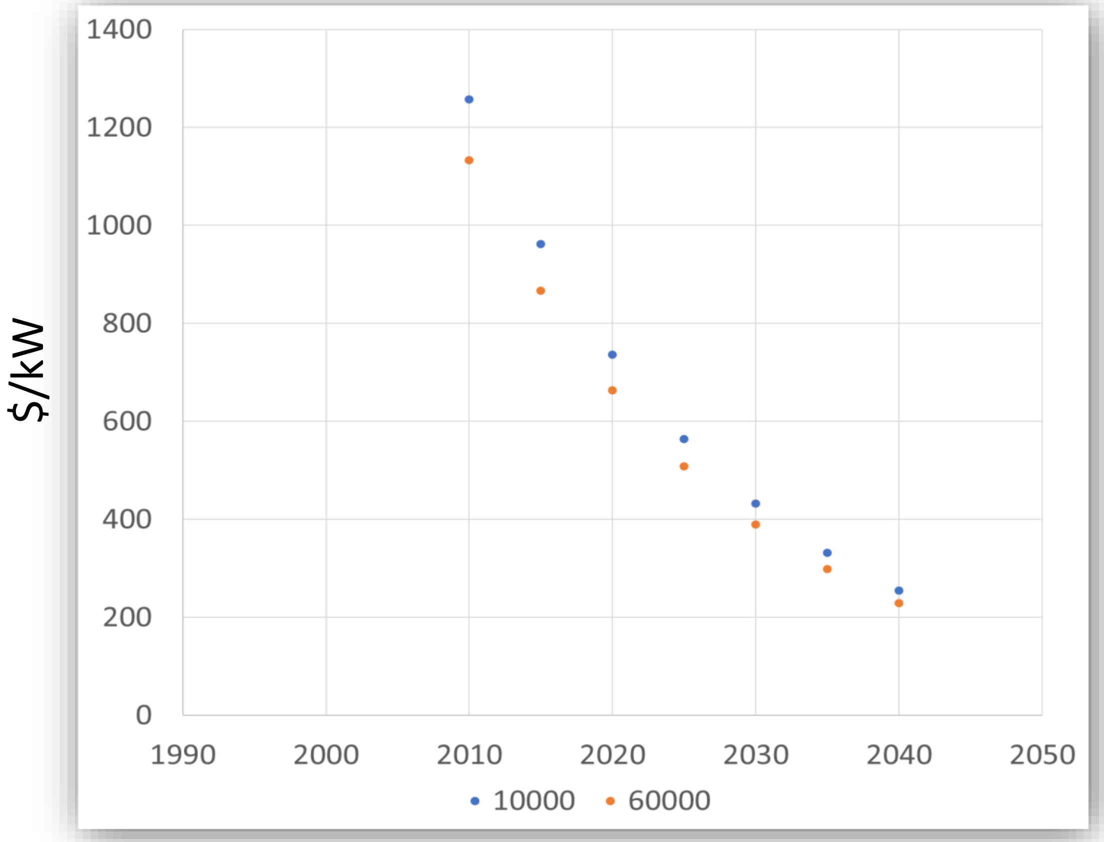
# Cost development

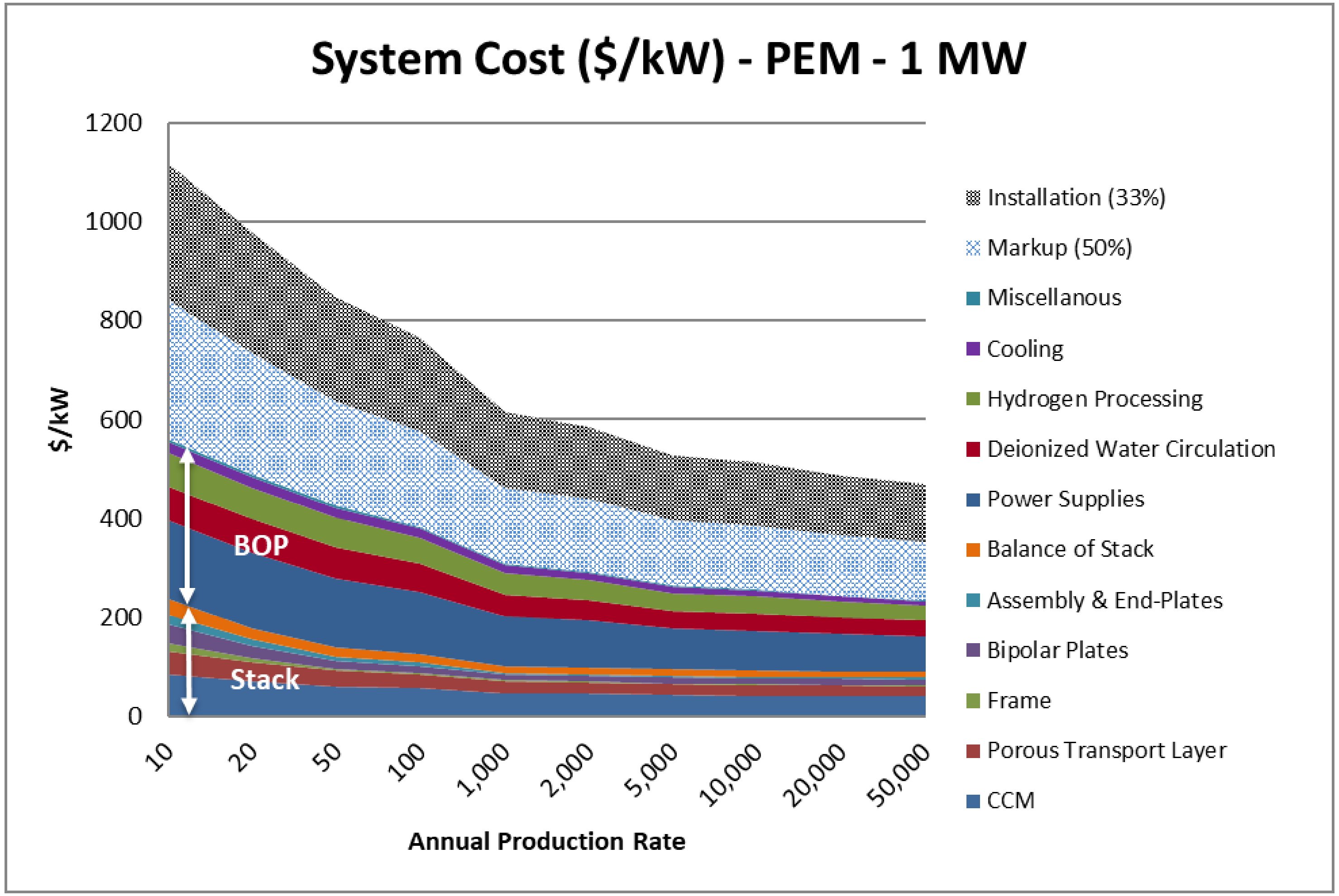



Alkaline




PEM

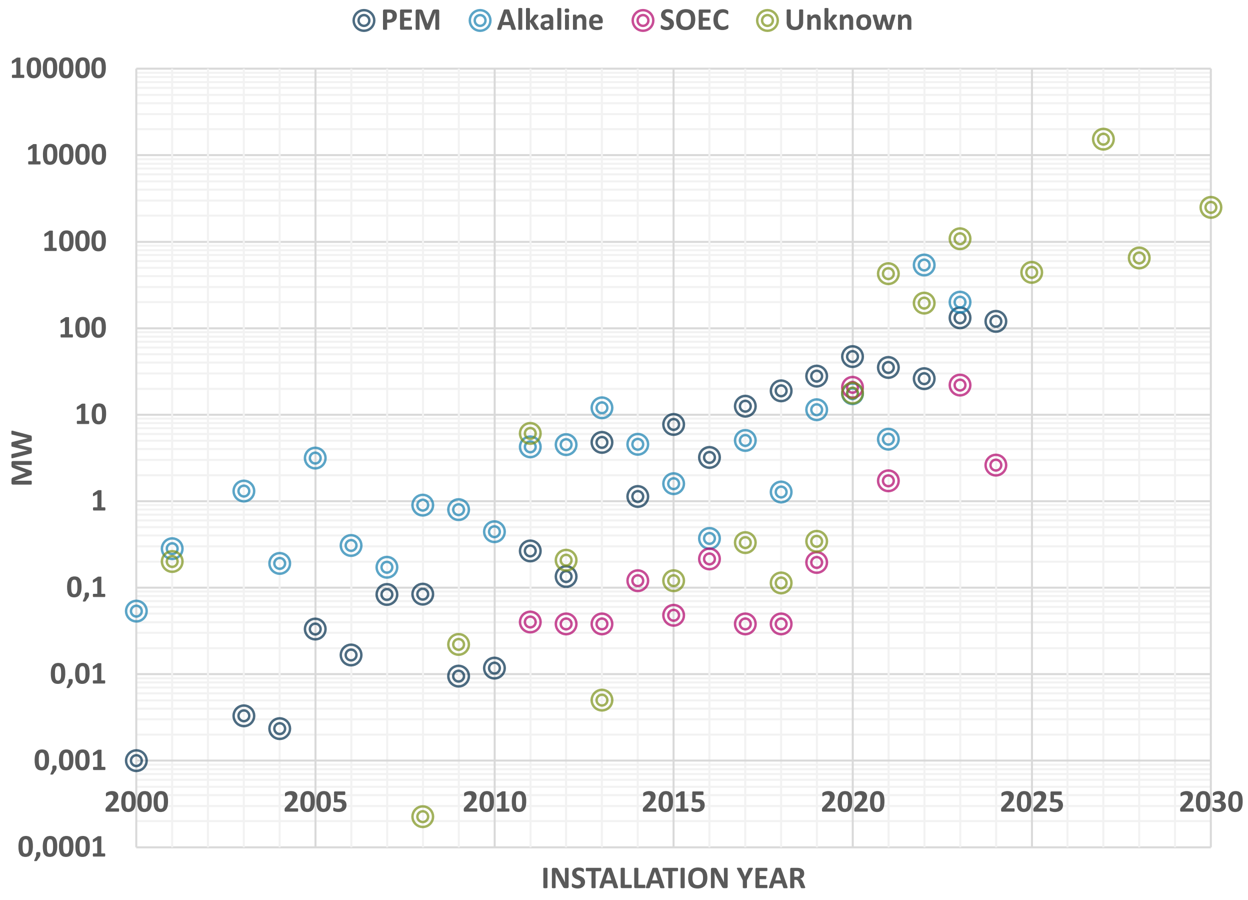
# Capital cost (CAPEX) break down




NREL: Manufacturing Cost Analysis for Proton Exchange Membrane Water Electrolyzers, Aug. 2019

# Summary

- Exponential growth of electrolyser installations
- Announced plans for >30 GW installed capacity in 2030
- CAPEX below $500/kW for both PEM and Alkaline in the 2025-2030 timeframe



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