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Green hydrogen production using low temperature water electrolysis

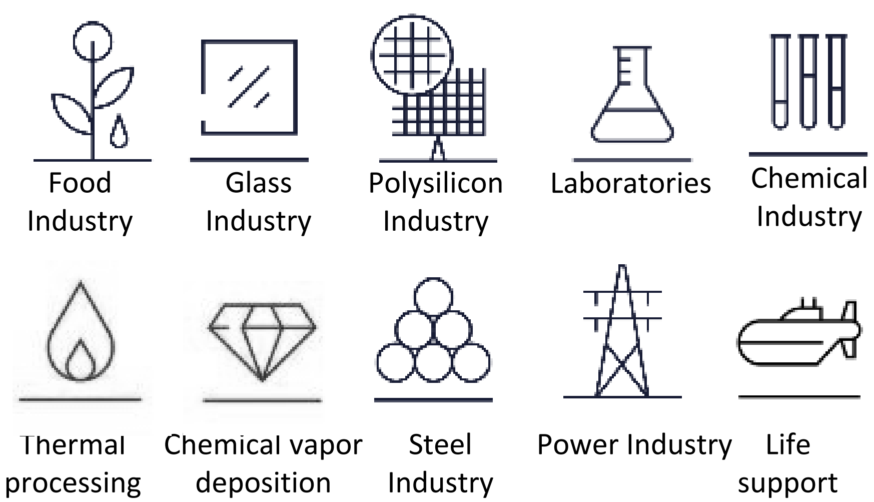
E Anderson Vice President, Advanced Product Development

Greening High-Temperature Manufacturing
BU-ISE/ITIF Workshop
27 January 2021

Hydrogen is expanding its areas of application

The H2 opportunity

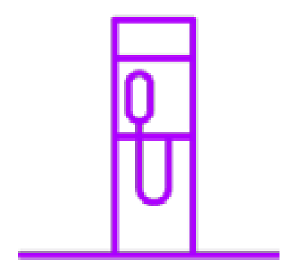
CONVENTIONAL INDUSTRY



- Conventional industries represents “traditional” hydrogen markets
- Steady demand for hydrogen

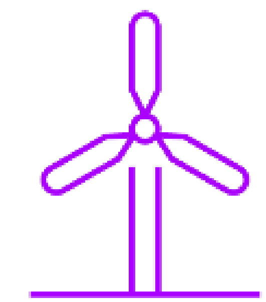
Steady growing market

MOBILITY



- Key market going forward – both within hydrogen production and fueling
- Heavy duty sector developing faster than anticipated – hydrogen now relevant fuel for all forms of mobility

POWER-TO-X



- Decreasing cost of renewables & electrolysers is accelerating market
- Vast opportunities within existing & new sectors

Markets expected to see fast growth going forward

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Nel Hydrogen

Pure Play Hydrogen Company Providing Entire Production/Delivery Value Chain

- Strong technology, field experience & manufacturing capacity

PEM electrolysers

Wallingford, USA

Systems delivered: **2,700+**

Nameplate capacity: **~40MW/year**

Alkaline electrolysers

Notodden/Herøya, Norway

Systems delivered: **800+**

Nameplate capacity: **~40MW/year**
→ ~500 MW/year in 2021
→ ~2GW/year if fully expanded

Hydrogen refuelling stations

Herning, Denmark

Stations delivered: **80+**

Nameplate capacity: **~300 HRS/year**

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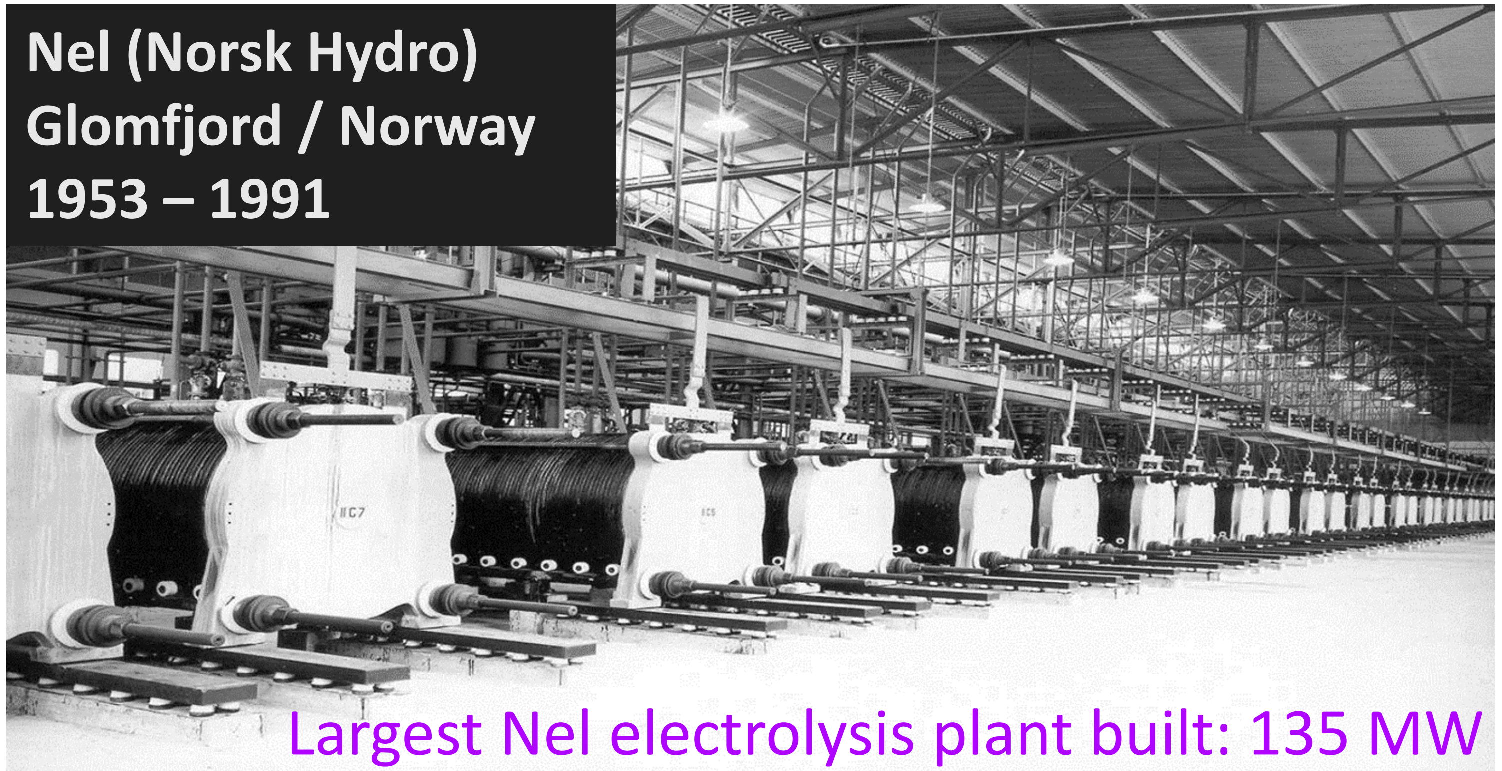
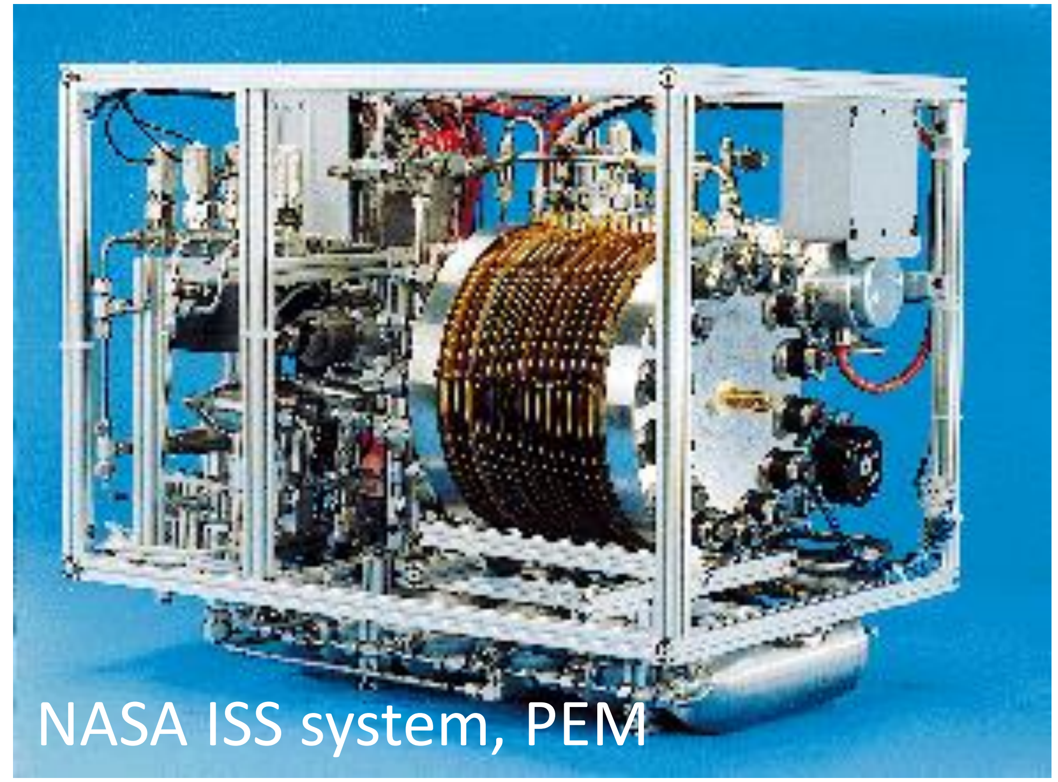
Electrolyzer History

Cost & Product Context





KOH developed at scale for industrial applications **from the beginning**

Designed for efficiency and low operating cost

Drove low current densities (passive atmospheric system also limits bubble removal)

PEM originally used for **life support** (O_2) in closed environments: Optimized for **very high reliability**

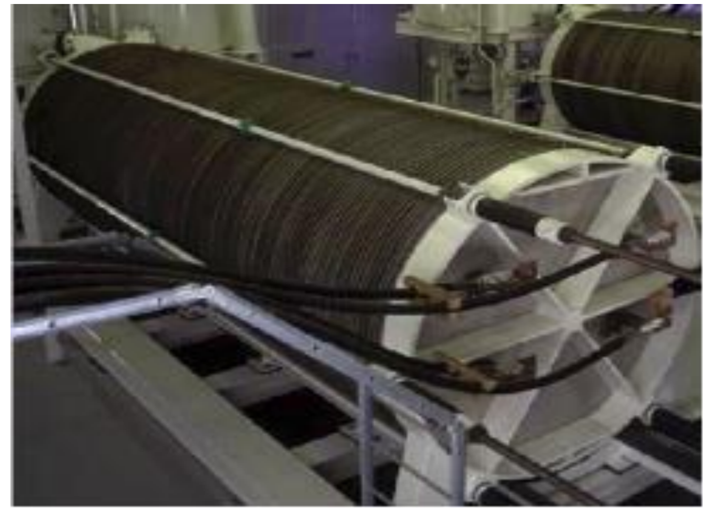
Initial commercial products at small scale
<200kW capacity until 2014

Drove high current densities for low capital cost

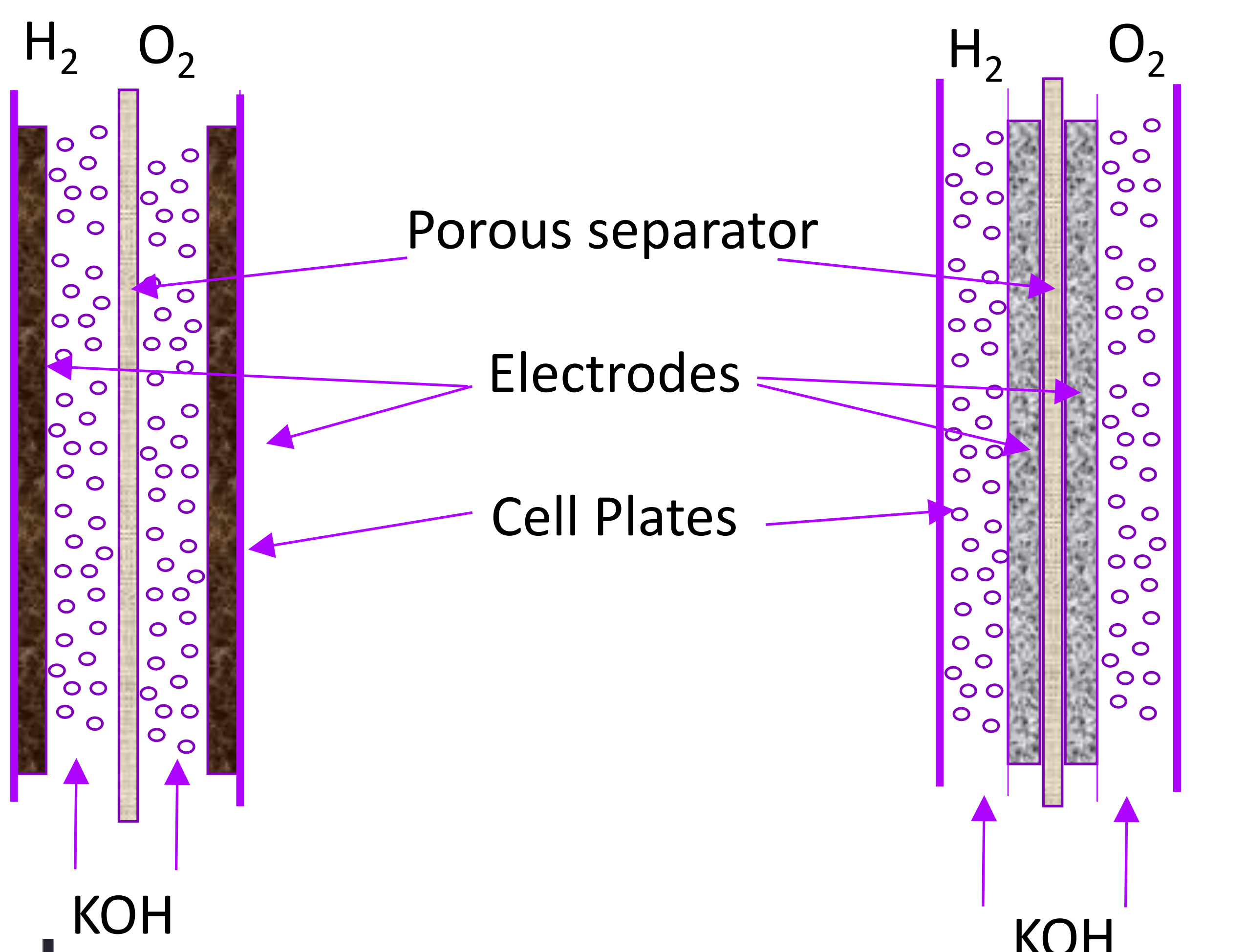
Commercial Electrolysis Comparisons

How They Work

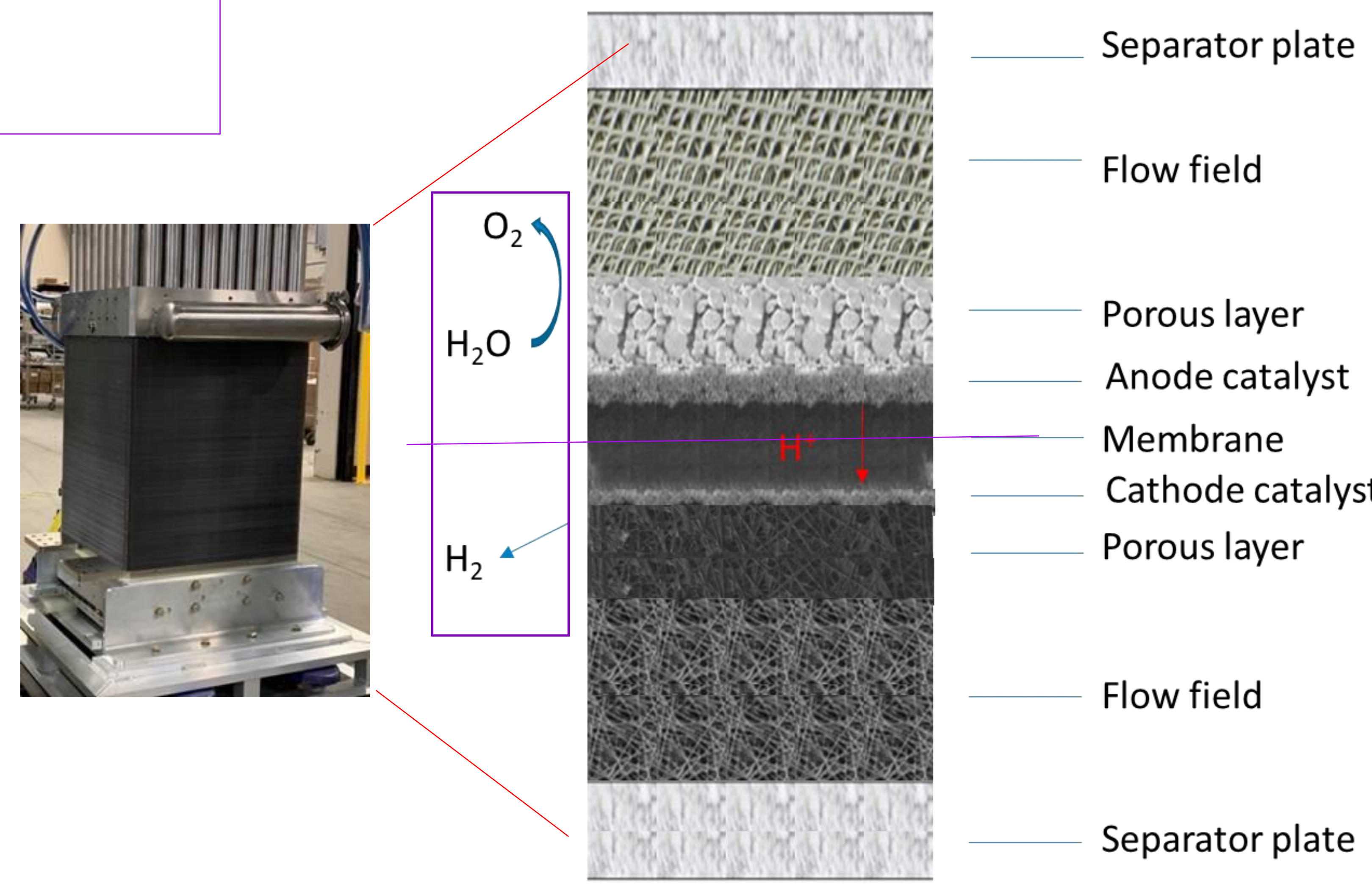
- Liquid Alkaline:
  - Liquid electrolyte
  - Enables non-noble metals
  - Lower current density
  - 1 MW stack = ~20 m^3



Traditional Cell | **“Zero Gap” Cell**



- PEM-based:
  - Solid electrolyte enables H_2 at pressure
  - Reliability at scale = KOH
  - Room for cost/efficiency growth
  - 1 MW stack < ~0.5 m^3



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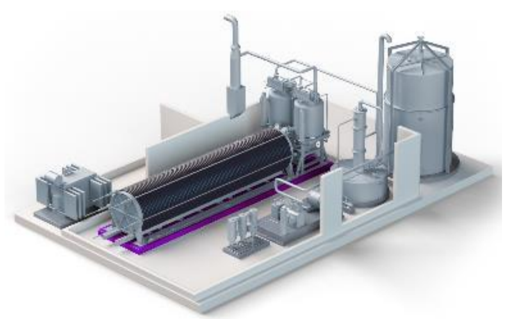
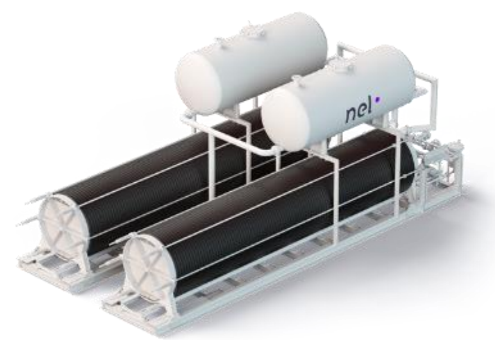
Scaling of Low Temperature Electrolysis

Cost Reduction through Product Design Scale

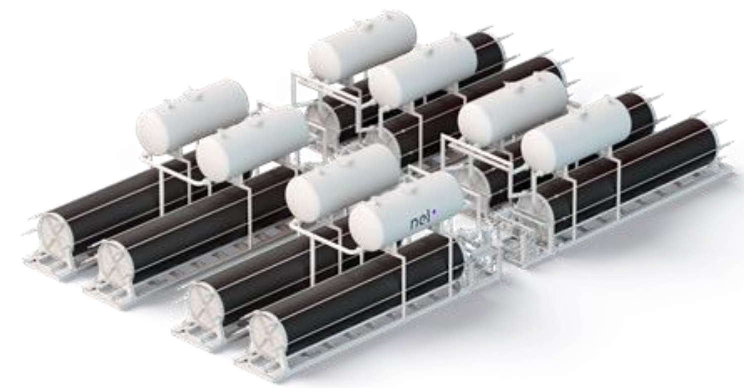
Alkaline



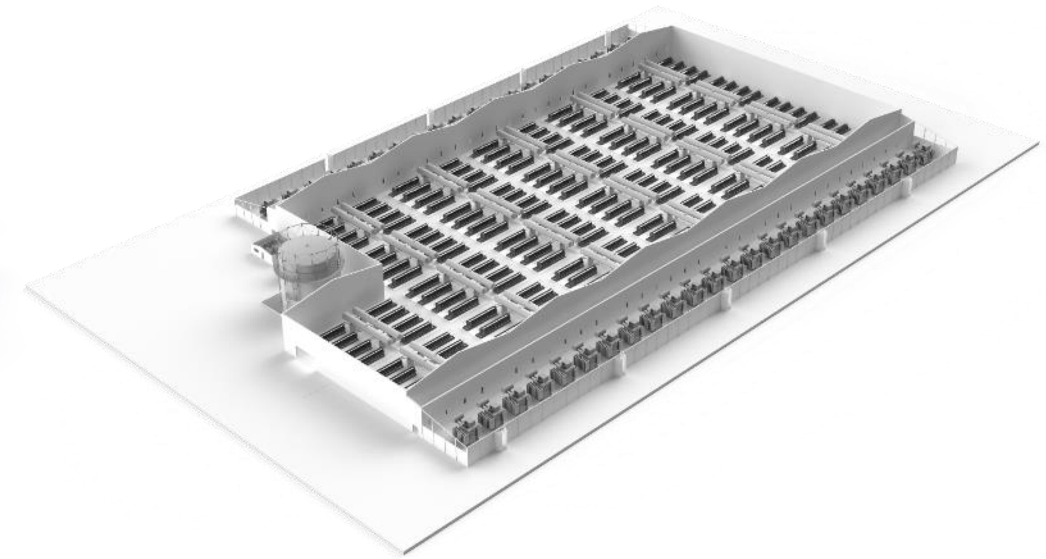
2.5 MW



5 MW



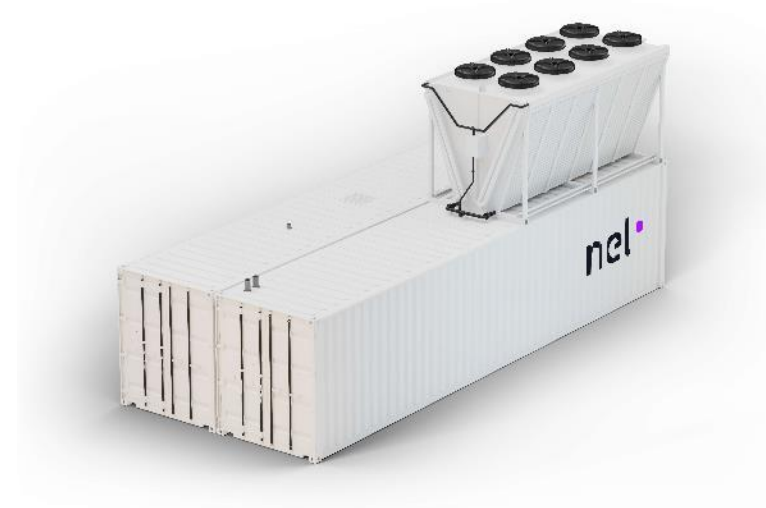
20 MW



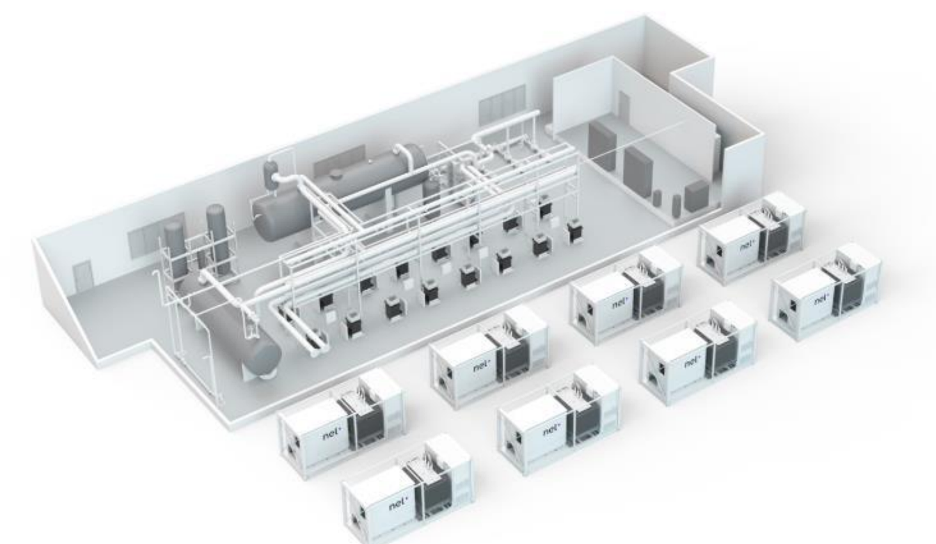
100's of MW

PEM

< 10 kW to 0.2 MW



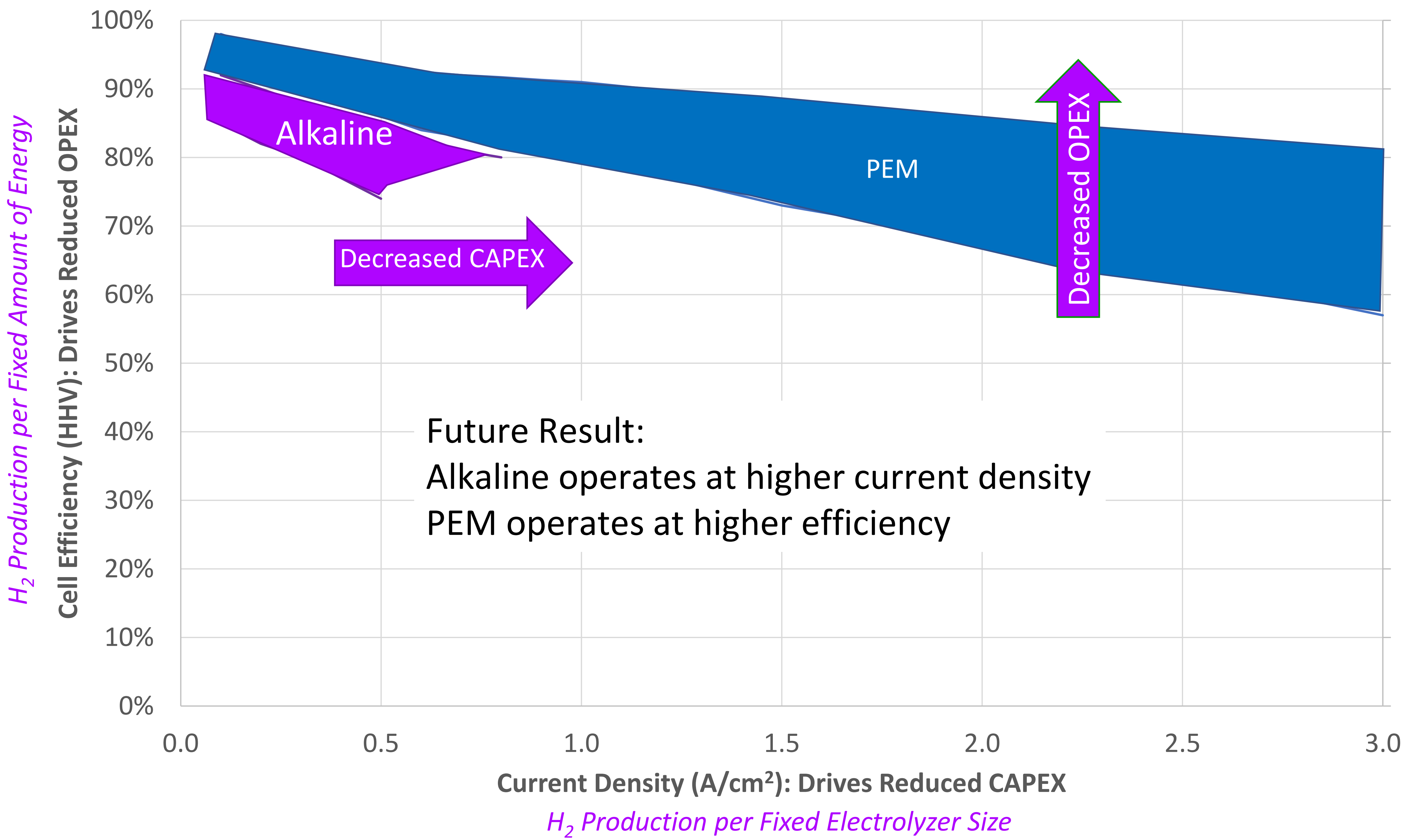
2.5 MW



10 to 25 MW

Technology directions

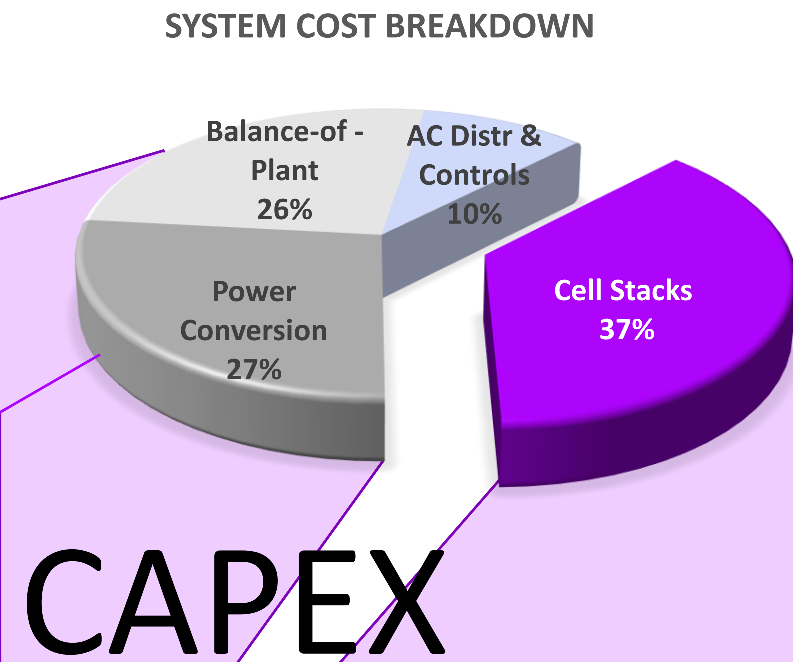
Historical CAPEX/OPEX relationship between ALK and PEM technology

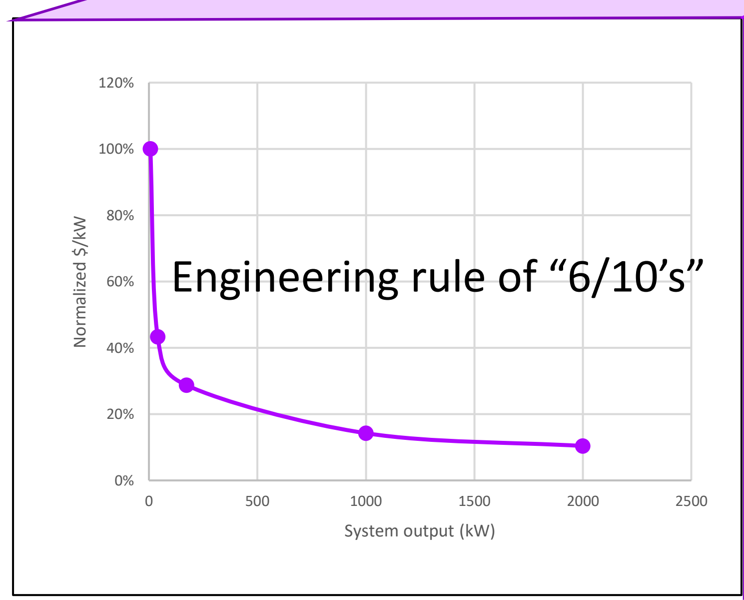


- PEM more efficient than alkaline at equivalent current density (CD)
  - PEM CAPEX too high low CD
  - Potential for lower OPEX
  - Reduction in CAPEX through technology development
- Alkaline strategy: increase output, maintain efficiency
  - Leverage chlor-alkali industry knowledge for higher rate
- PEM strategy: increase efficiency, maintain output
  - Leverage fuel cell industry knowledge

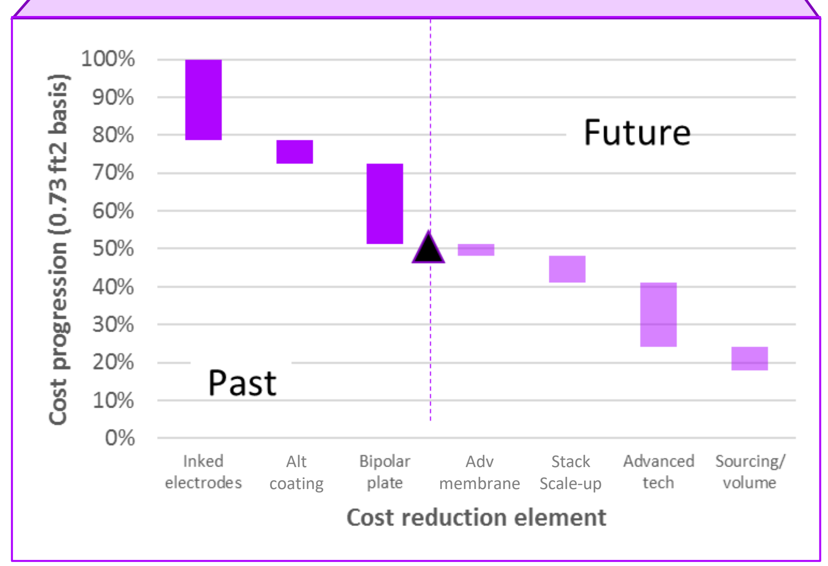
Cost and Efficiency Tradeoffs*

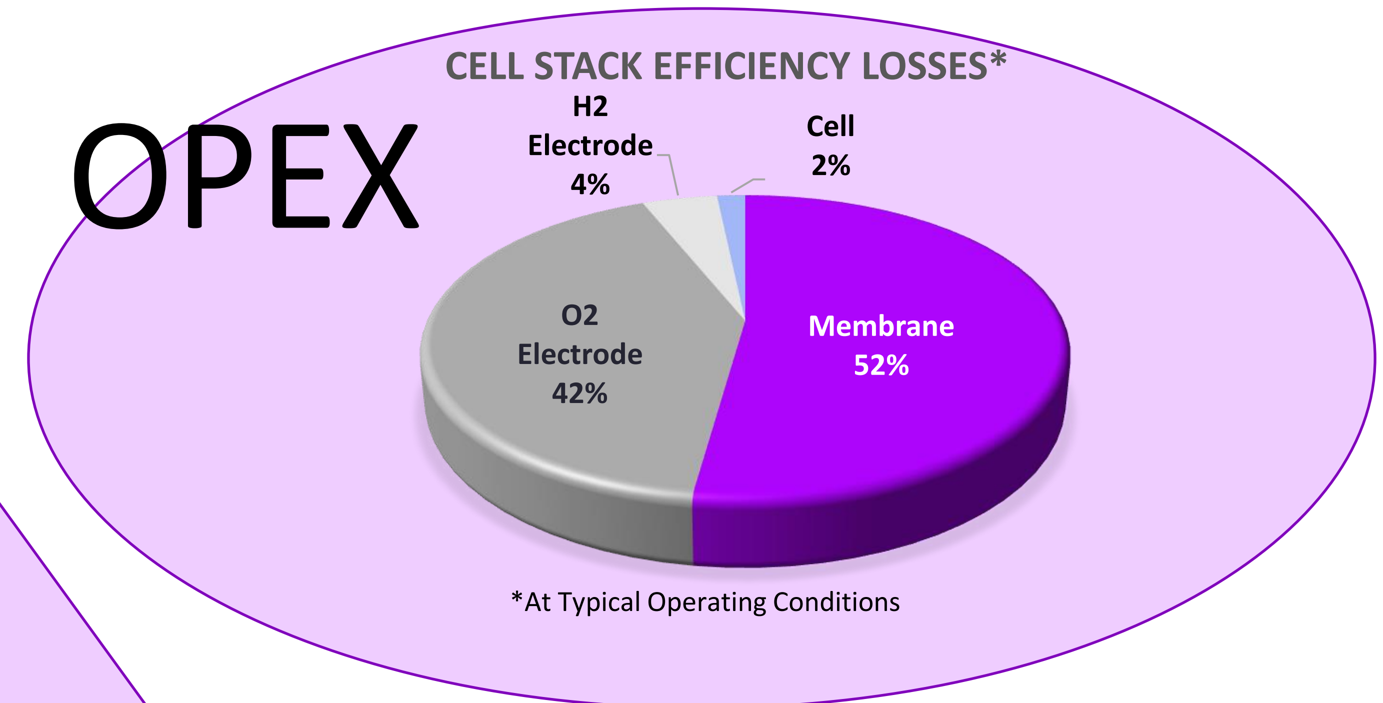
- Balance-of-plant sourced from standard industries and cost reduction addressed through scale





- Cell stack cost reductions being addressed through roadmap activities



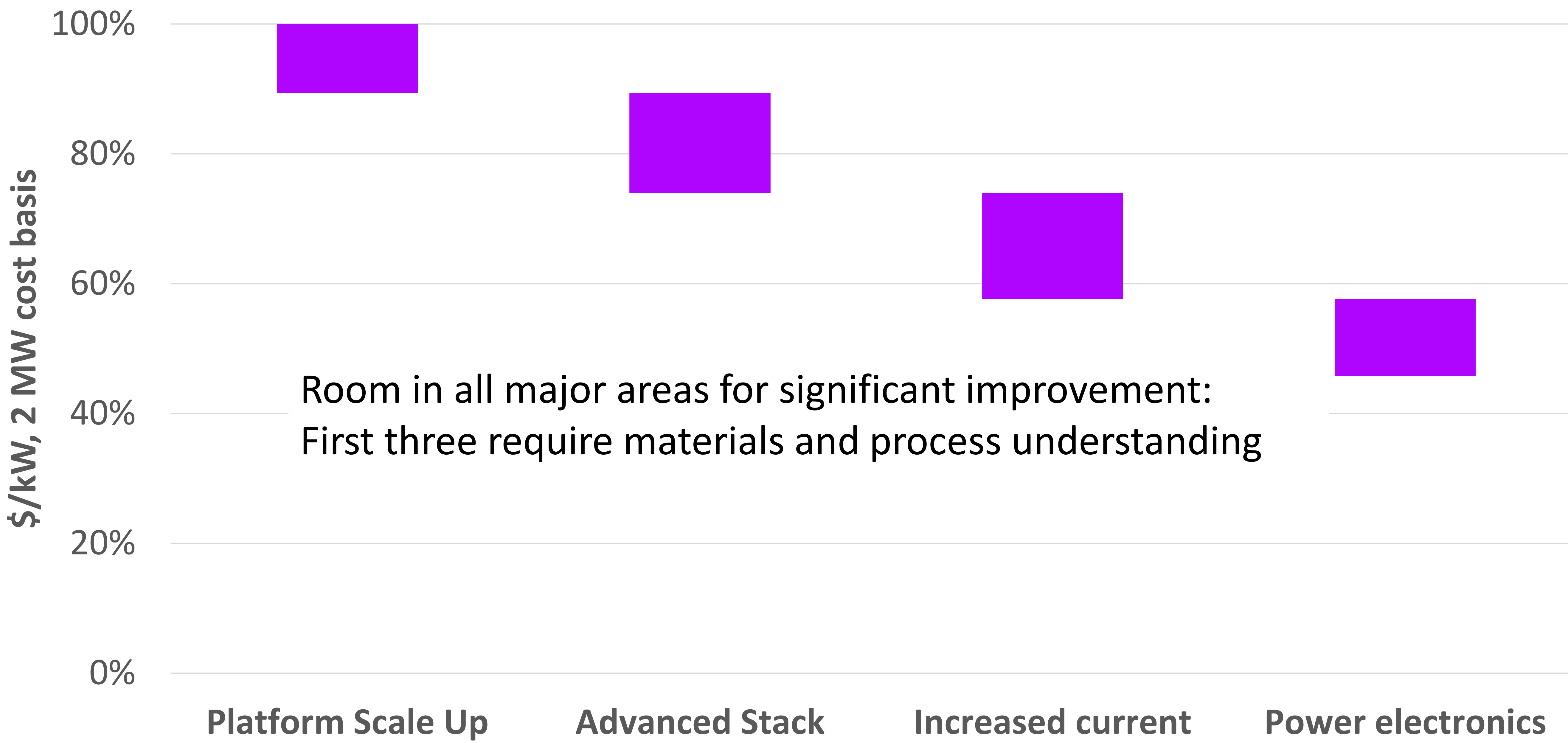


- Largest efficiency losses due to membrane
- Addressed through:
  - Advanced materials (thinner, higher strength)
  - Higher operating temperatures
- ***These efficiency improvement approaches can have inverse effect on operating lifetime***

*Values are illustrative only

Electrolysis Cost Reduction Opportunities

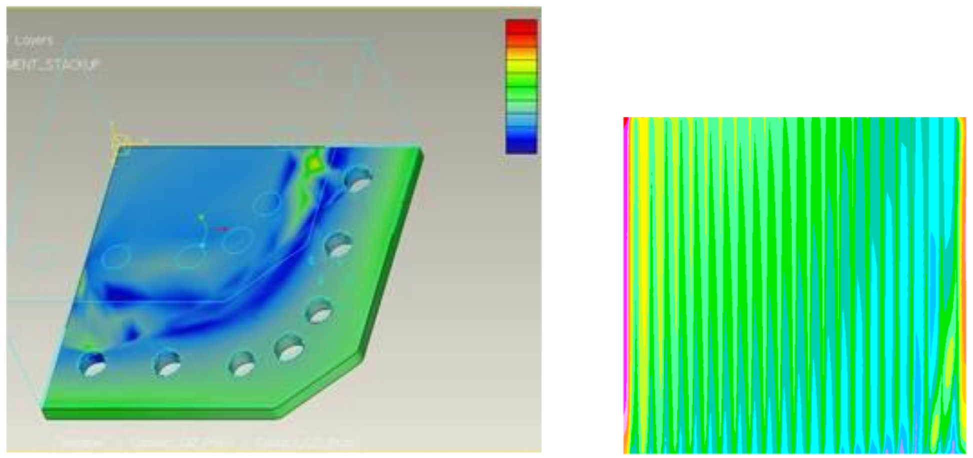
PEM Electrolysis Example



Analogous Technology Cost Reduction Roadmap Defined for ALK as well

Example of 80% Component Cost Reduction

Fundamental R&D to Prototyping



Component modeling

Accelerated embrittlement

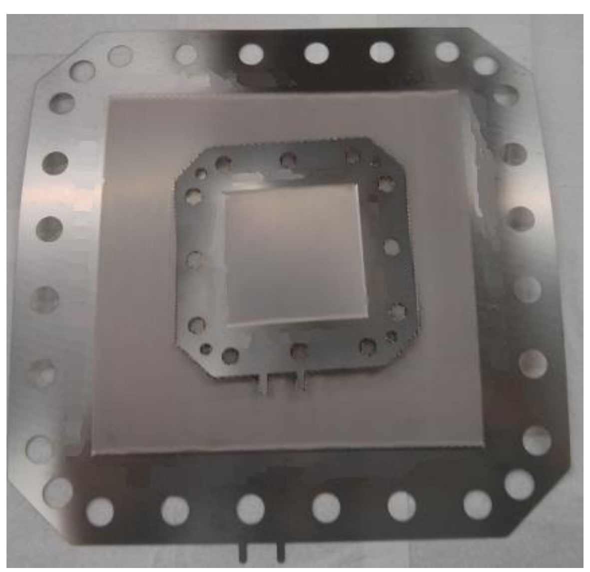
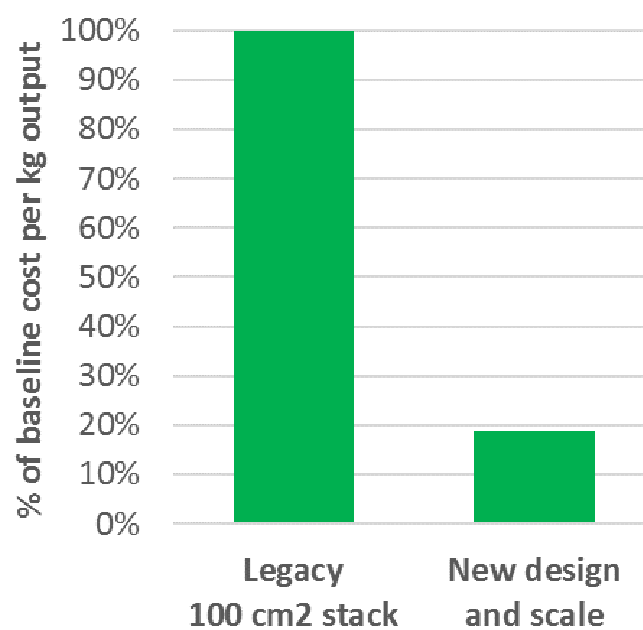
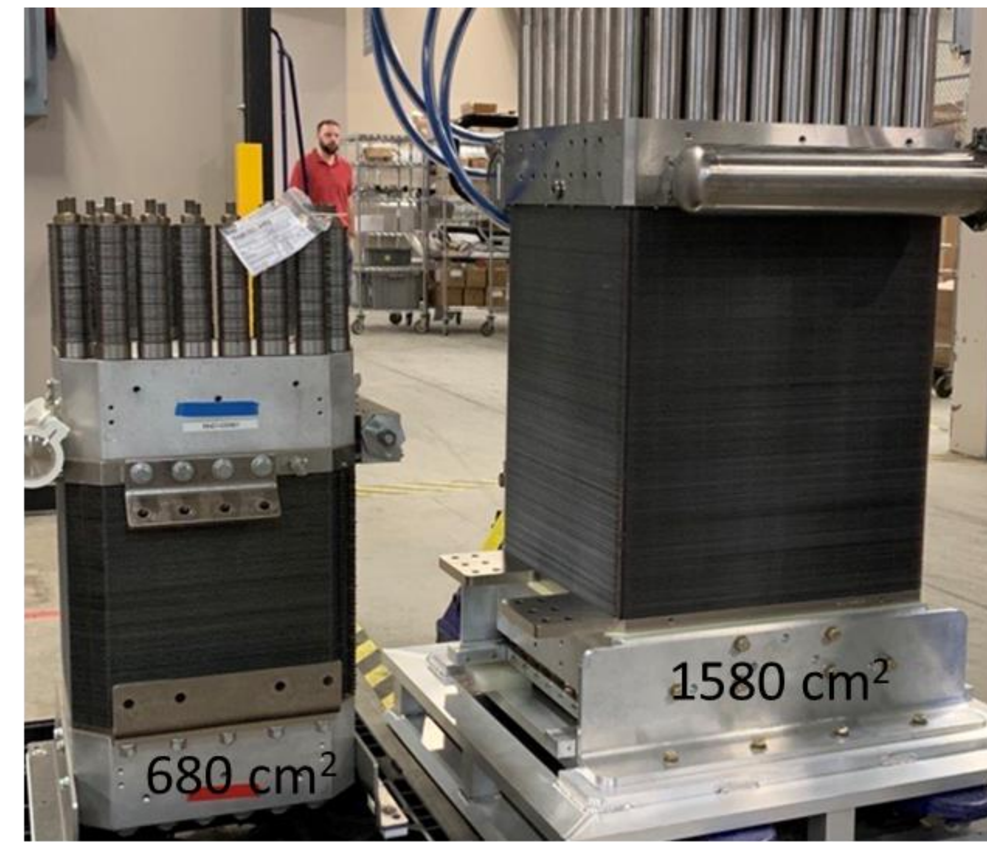


Plate manufacturing



Products from kW to MW scale

90 cm²



Nel scale up and commercialization:
MW stack based on same platform

Cost Reduction through Higher Volume Manufacturing

Taking Technology Advancements to Large Scale

- Planned capacity expansion at Herøya
- Fully automated and designed according to lean manufacturing principles
- Large production line improvements already identified, name plate capacity up from ~360 to ~500 MW/year, with further potential
- Test production in new line Q2 2021, start of ramp up Q3 2021
- Room to expand to ~2 GW/ yr

- Similar plant capacity plans being contemplated for PEM

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Low Temperature Electrolysis Cost Reduction

- PEM
  - Significant cell stack cost reduction achievable through advanced materials and process development
  - Leveraging fuel cell R&D and supply chain
  - Balance-of-Plant (BoP) reductions through product design/scale
- Alkaline
  - Incremental cell stack design improvements to drive output/unit area
  - Investments in manufacturing volume scale up including advanced manufacturing processed & automation
- Power matching
  - Optimization of cell stack size (current & voltage) versus power rectifier specs
  - Interfacing with variable renewable sources
- Supply chain still underdeveloped/immature
  - Not optimized for electrolyzer material requirements
  - Products driven/developed largely by small companies

- U.S. funding programs mainly small and focused ($1-2.5 million/project)
- Have made great progress but not sufficient for integration
- Components must work together to function in the device
- EU making much more investment in supply chain and prototypes

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number one by nature

Extra Slides

Already engaged in key projects for the major, future markets

Selected by Iberdrola as preferred supplier for a 20 MW green fertilizer project in Spain

In final negotiations to deliver a 20 MW PEM electrolyser solution to Iberdrola

- Iberdrola, one of the largest electricity utilities in the world, has together with a world-leading fertilizer manufacturer Fertiberia launched a project to establish the largest green hydrogen plant in Europe
  - Project includes 100 MW photovoltaic plant, a 20 MWh battery and a 20 MW electrolyser
  - Will use hydrogen to produce green fertilizer commencing in 2021
- Nel in final negotiations to deliver a 20 MW PEM solution for the first phase
  - Contract award is subject to mutual agreement on the final terms and conditions, technical details, and board approval

Signed letter of intent (LoI) with Statkraft for green hydrogen project in Norway

Up to 50 MW electrolysis to support fossil free recycling steel production

- Statkraft, the largest renewable energy company in Europe partnered up with Celsa Armeringsstål (Celsa), a leading steel producer
- Facility in Mo i Rana which produces reinforced steel from recycling of scrap metal
  - Current production: 700,000 tons/year (equal to two Eiffel towers per week)
  - By exchanging natural gas with hydrogen, CO_2-emissions can be reduced by >60%
- Nel and Statkraft has entered into a LoI for 40 – 50 MW of electrolyser capacity

Supplying electrolysers to HYBRIT, the fossil-free steel project in Sweden

Supplying electrolysers to the currently most advanced fossil free steel project

- Nel has received a purchase order for a 4.5 megawatt alkaline electrolyser which will be used in a pilot plant for fossil free steel production
- Hybrit Development AB (HYBRIT) is a joint venture owned equally by SSAB, LKAB and Vattenfall
- The steel industry accounts for 7% of global and 10% of Swedish CO2-emissions
- Pilot plant will operate in Luleå, Sweden from 2021 – 2024, with target of full-scale implementation by 2035

Photo: Vattenfall