

Nel Hydrogen Introduction

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Anthony Borski - PMO Director Americas

DISCLAIMER

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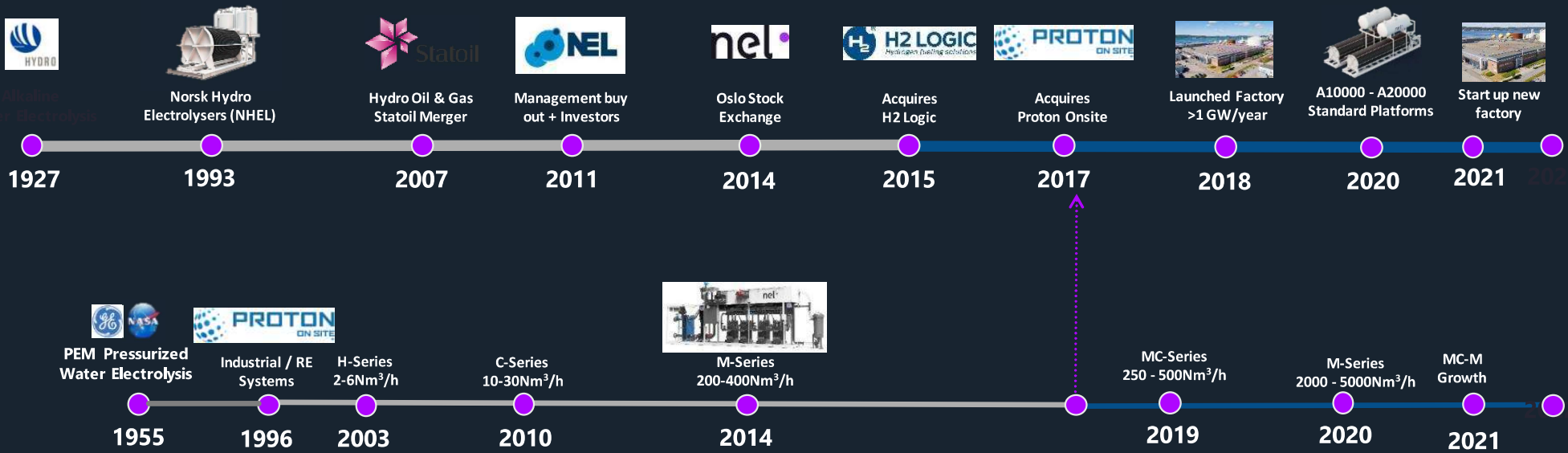
Anthony Borski Background



Company Overview

THIS IS NEL: PEM & ALKALINE ELECTROLYSIS

>95 Year Experience / Extended Field Know-How



THIS IS NEL: MANUFACTURING LOCATIONS

Strong field know-how and manufacturing capacity

PEM water electrolyzers



Wallingford, USA



Systems delivered: **2,700+**
Nameplate capacity: **100 MW/year**
Experience: **≈25+ years**

~300 MW/y in 2024
Expandable to 500 MW/y

Alkaline water electrolyzers



Notodden/Herøya, Norway



850+
500MW/year
≈ 95+ years

Approved 2nd line: + 500MW/y
→ 1GW by 2025, Expandable to 2GW/y

Hydrogen refuelling stations



Herning, Denmark



120+
300 HRS/year
≈ 20+ years

LARGE SCALE DEMAND

Industrializing our PEM platform

<0.005 MW



<1 Nm³/h



<0.03 MW



<6 Nm³/h



<0.15 MW



30 Nm³/h



<2.5 MW



<500 Nm³/h



<20 MW



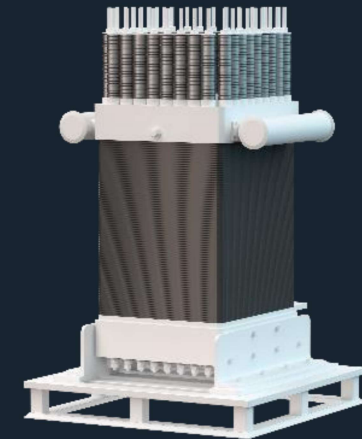
<4000 Nm³/h



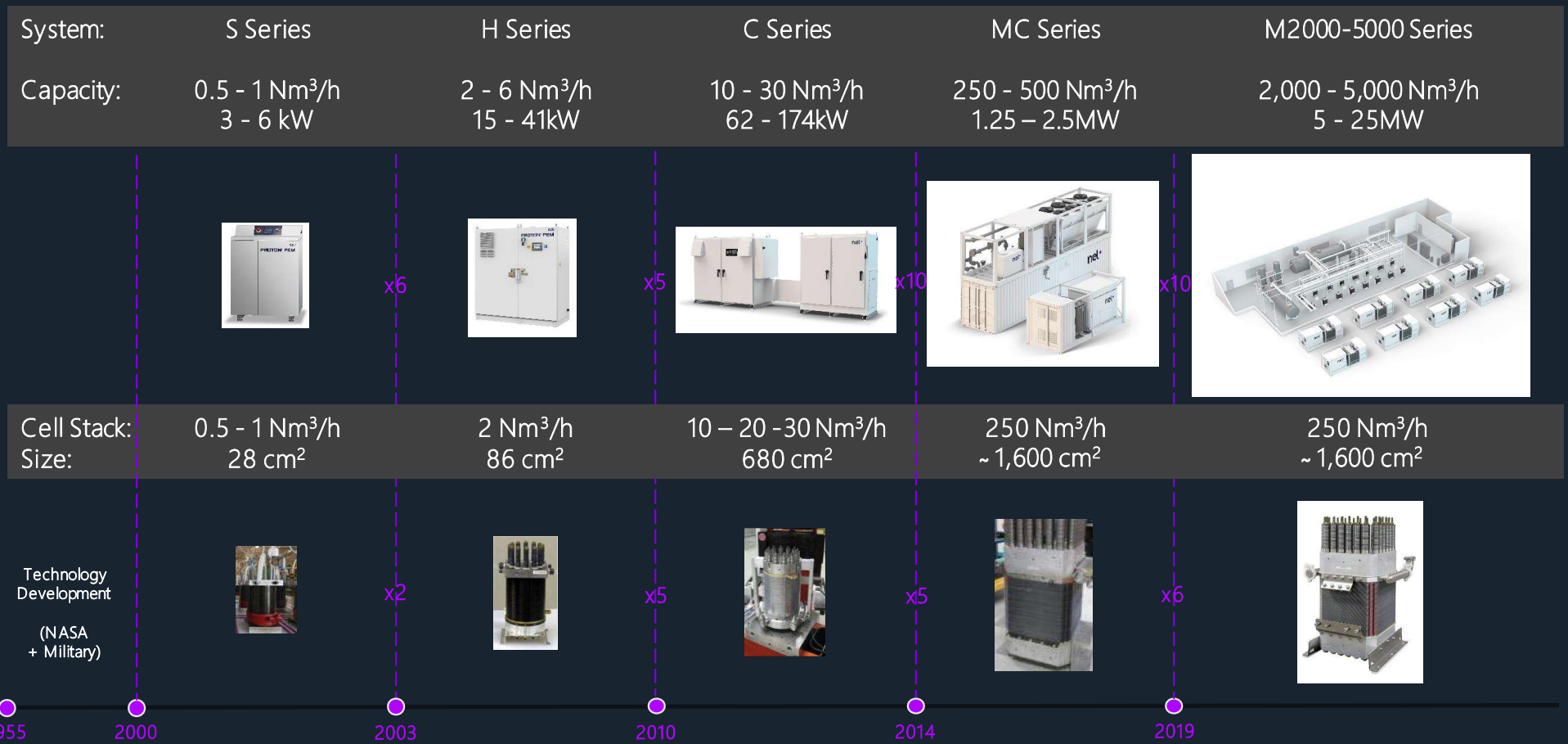
100MW+



- Scaling up and automation will drive down cost
- Reducing overall material usage
- Driving energy savings
- Reducing dependence on exotic materials such as iridium and platinum



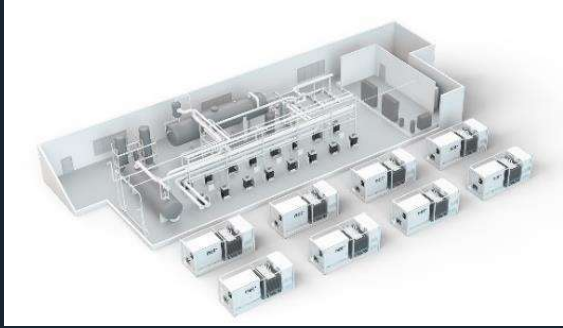
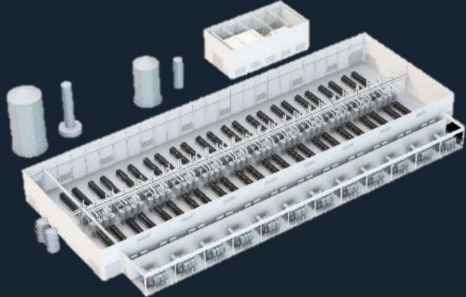

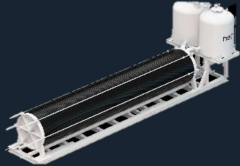


PEM Electrolyzer Systems Range



246 TO 38,800NM³ / 1.3 TO 200MW

Nel Systems Large Scale Platforms

PEM		Alkaline	
<p>Platforms</p> <p>MC250-500</p> <p>246 - 492 Nm³/H</p> <p>0.53 - 1.06 T/d</p> <p>1.3 – 2.6 all-in MW</p>		<p>Platforms</p> <p>A150 - 485</p> <p>150 - 485 Nm³/H</p> <p>0.32 - 1.05 T/d</p> <p>0.71 - 2.3 MW*</p>	
<p>M2000-5000</p> <p>1,968 - 4,920 Nm³/h</p> <p>4.25 - 10.6 T/d</p> <p>10 – 25 MW*</p>		<p>A1000-4000</p> <p>970 - 3,880 Nm³/h</p> <p>2.1 - 8.37 T/d</p> <p>4.6 - 18.2 MW*</p> <p>A10000-40000</p> <p>9,700 - 38,800 Nm³/h</p> <p>21 - 83.8 T/d</p> <p>45.6 - 182.4 MW*</p>	
<p>Cell Stack</p> <p>246 Nm³/h / 1.25 MW</p> <p>1,600 cm²</p> <p>*: depending on scope</p>		<p>Cell Stack</p> <p>485 Nm³/h / 2.04 MW</p> <p>*: depending on scope</p>	

M Series MW-scale PEM electrolyzer (Series 2, MC500)

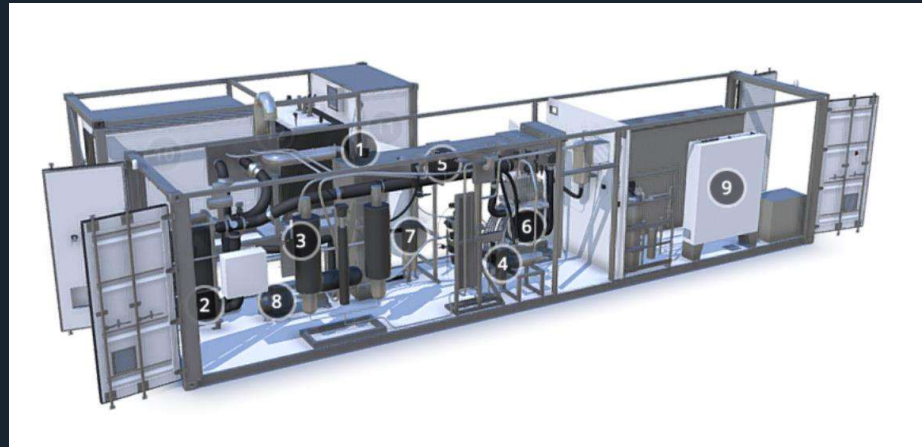
500Nm³/h – 30 barg (no compressor) for Outdoor Installation

Electrolyzer (Ely) container

- HX (process)
- Pump (x1), O₂ Phase Separator, DI polisher (x1)
- Cell Stack, Z200 (x2)
- Hydrogen Gas Management System (HGMS)
- Dryer (optional)

Non-classified room

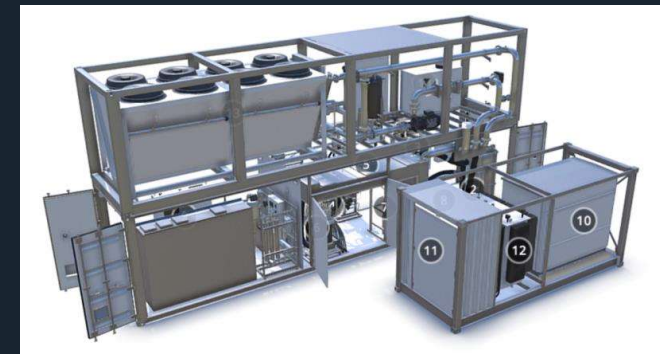
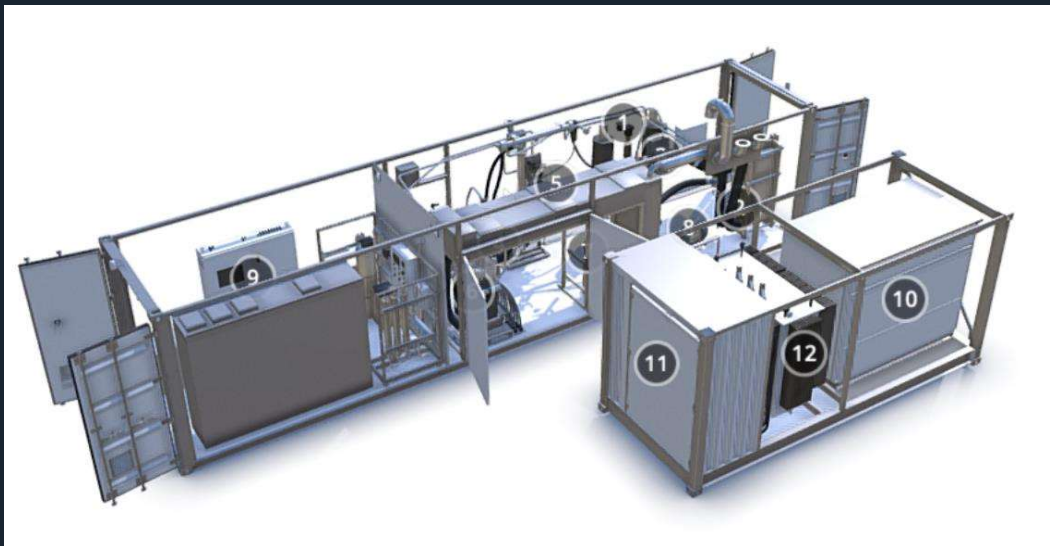
- Control Cabinet
- MCC
- Air compressor
- RO/DI



Power Supply (PS) container (20')

- MV Switchgear
- Transformer
- Rectifier
- DC Busbar (to stack)

Rooftop cooler (optional)



THIS IS NEL: PEM INSTALL BASE

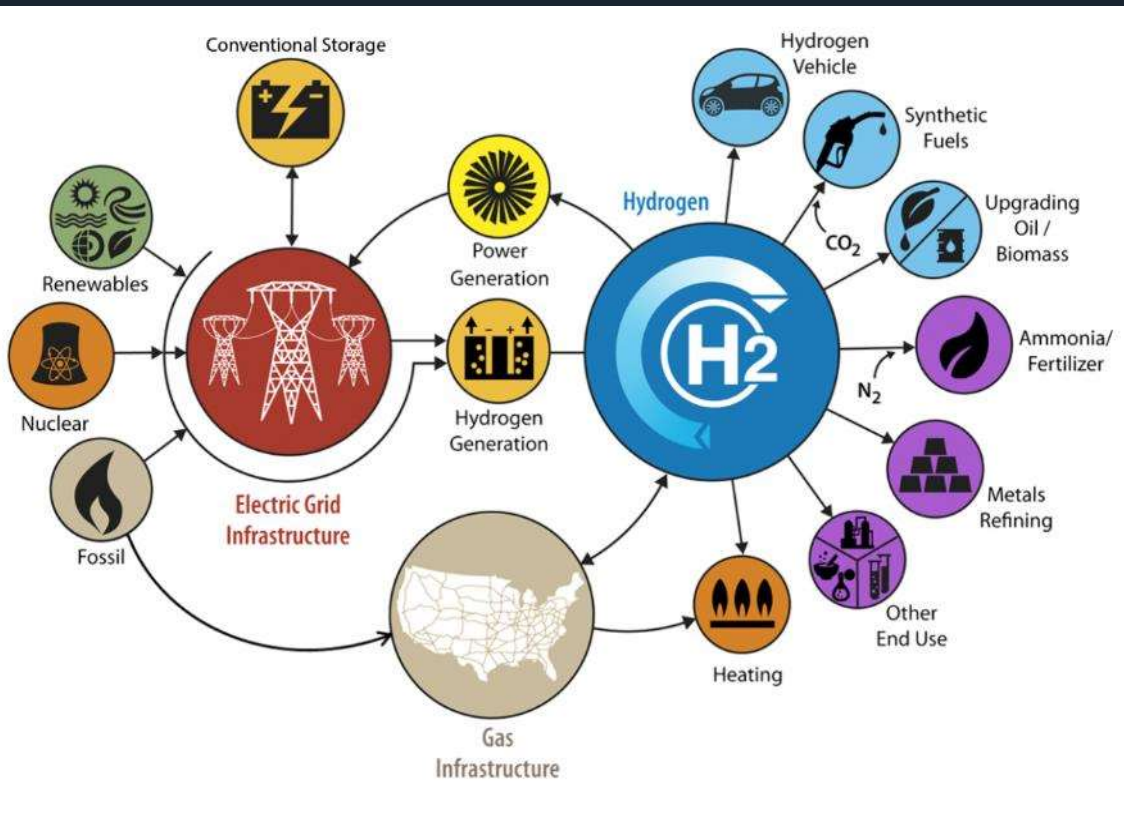
2024 MC and M-Series Fleet Sites and Locations



A person is silhouetted against a starry night sky, holding a flashlight that illuminates the text "Commercial Methodology of Scaling Growth". The background is a deep purple and blue night sky filled with stars. The person is standing on a dark horizon line, and the flashlight beam is directed towards the text.

Commercial Methodology of Scaling Growth

Electrolysis at scale needed for decarbonization



- Hydrogen can connect commercial sectors (industrial, transportation, energy)
- Majority of energy and CO₂ in NH₃ production is reforming CH₄ to produce H₂
 - 4% of US natural gas usage
- Conversion of CO₂ to useful fuels requires "green" proton source

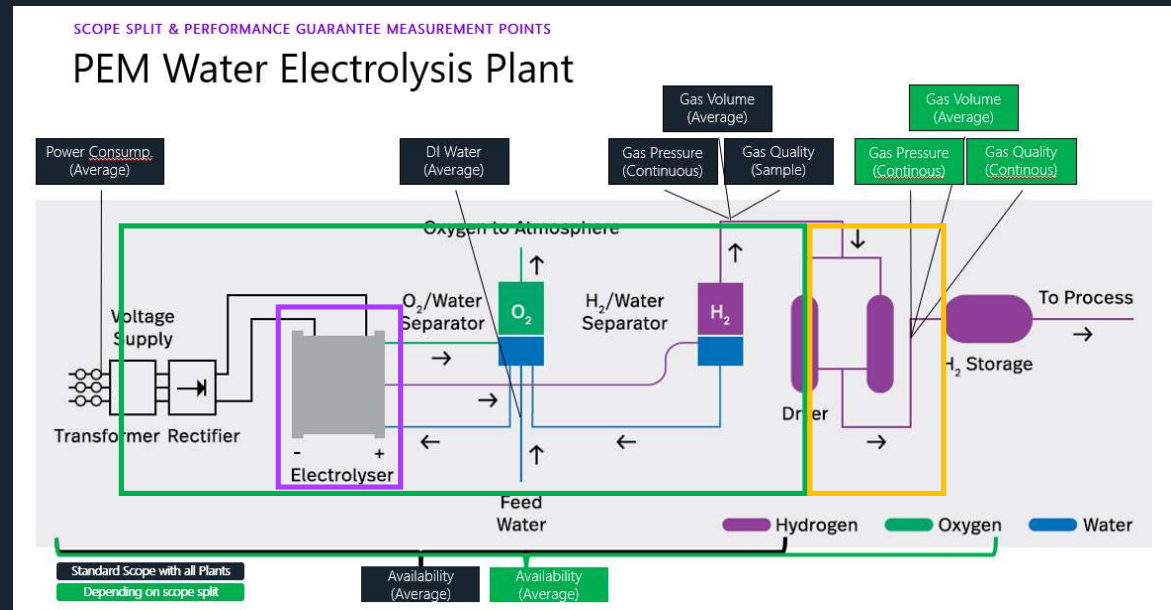
DOE H2@Scale Initiative: Connection of Various Infrastructures

Electrolyzer cost (capex and opex) needs to be reduced to make this happen

PEM Electrolysis System

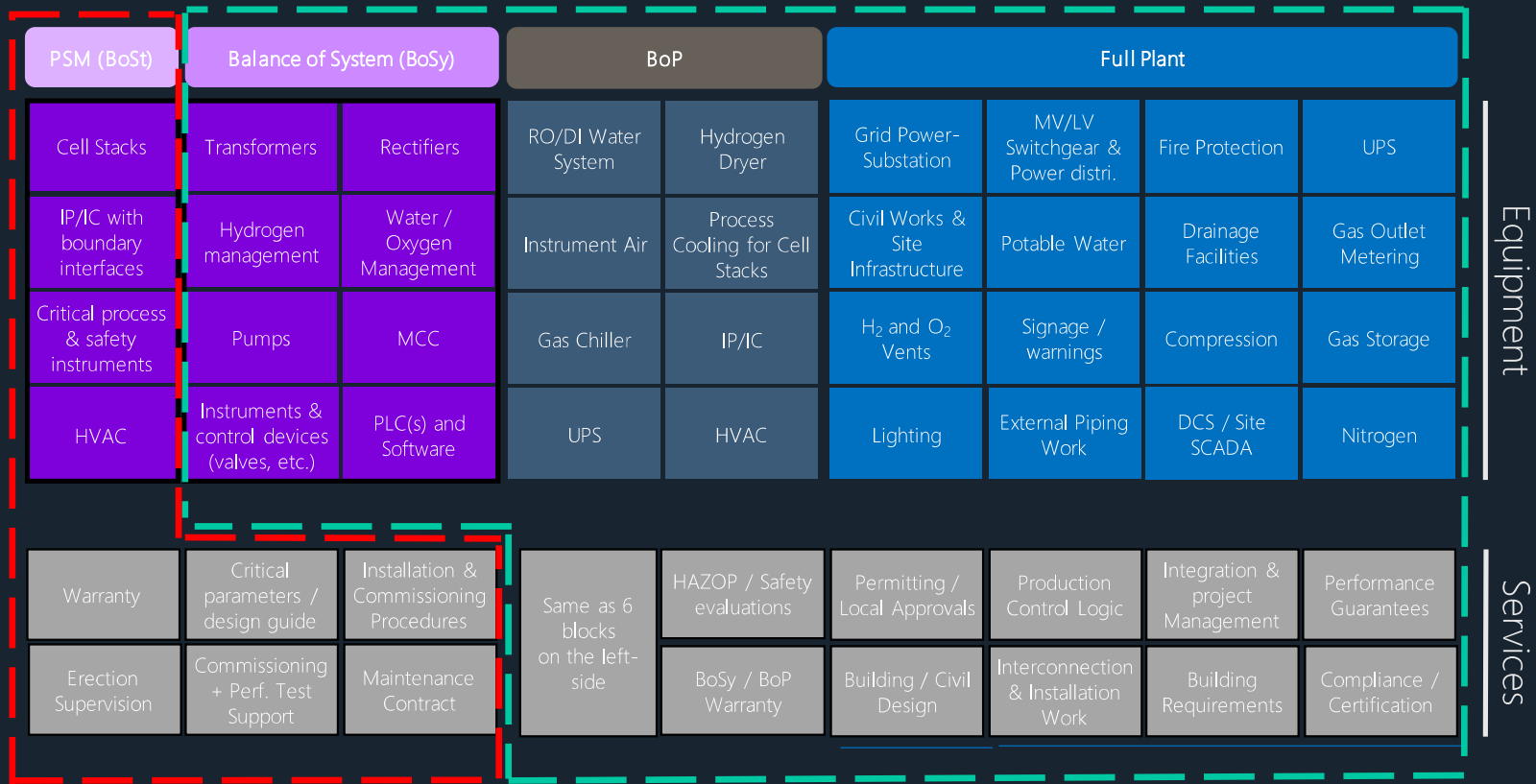
Typical PEM System

- Cell Stack Module (PSM)
- Water / Oxygen Management (WOMS)
 - Includes O₂/water separator
- Hydrogen Gas Management (HGMS)
 - Includes H₂/Water separator
- Power conversion (Transformer/Rectifier)
- BOP (Air Compressor, Water Purification, Gas Chiller)
- LV Distribution and controls
- Environmental conditioning (HVAC)
- Boundary interfaces
 - Water supply
 - Hydrogen product
 - Signal output
 - AC Power In (multiple feeds)
- Nel Guarantee: Power Consumption, Hydrogen Production, Hydrogen Purity



SCOPE SPLIT (FOR ALL NEL SYSTEMS >10 MW CAPACITY)

PEM Stack Module Scope Split



■ Nel
■ Customer / Customer EPC

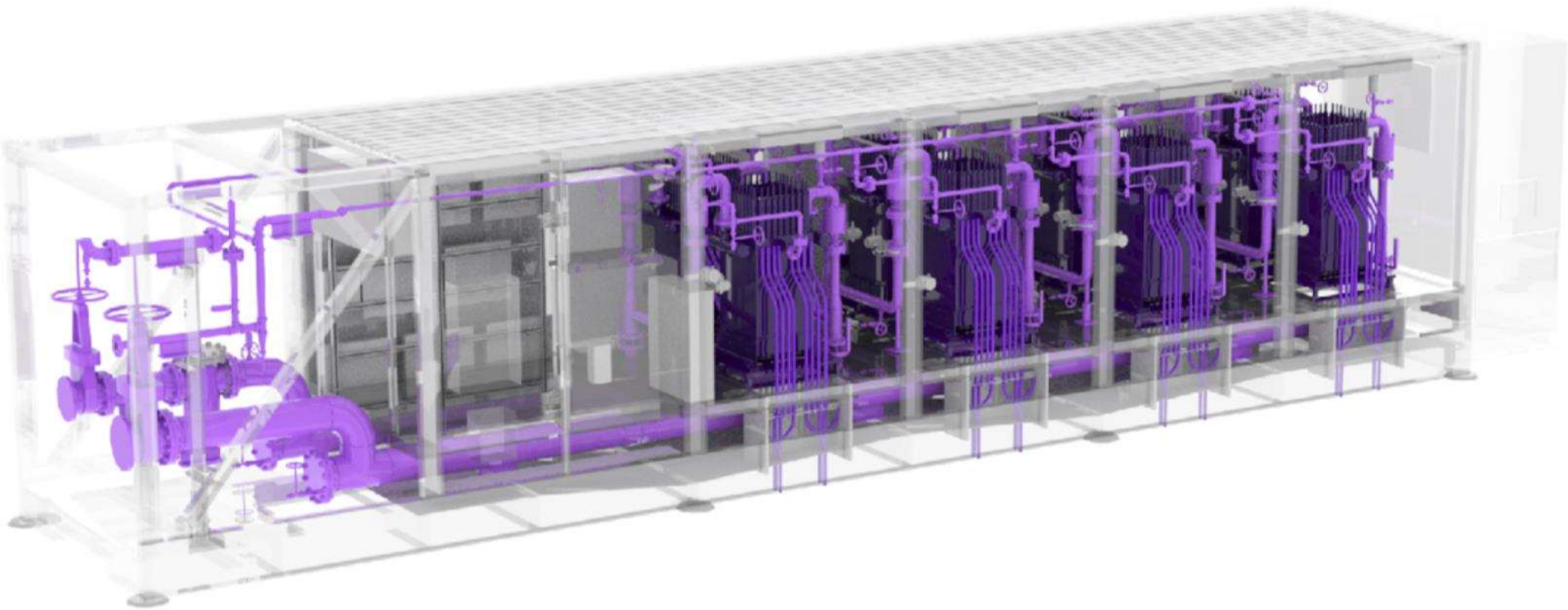
*(EP)(C)/EPC: Engineering Procurement, Construction

Strictly private & confidential. Cannot be distributed without Nel's prior approval.

PEM Stack Module (PSM)

PSM UPDATE

NeI 10MW PEM Stack Module



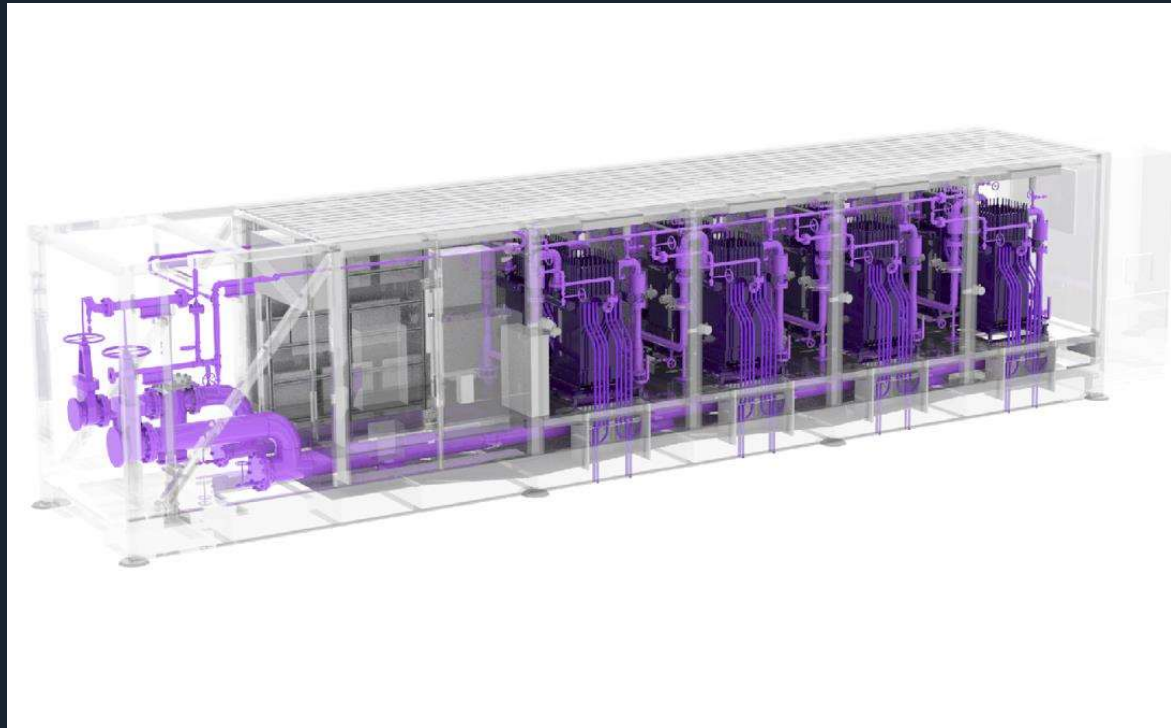
PEM Stack Module (PSM)

Scope

- 8 x 1.25 MW Cell Stack Arrangement (10MW)
- Outdoor design
- Safety monitoring instrumentation
- Critical process instrumentation

Key Features

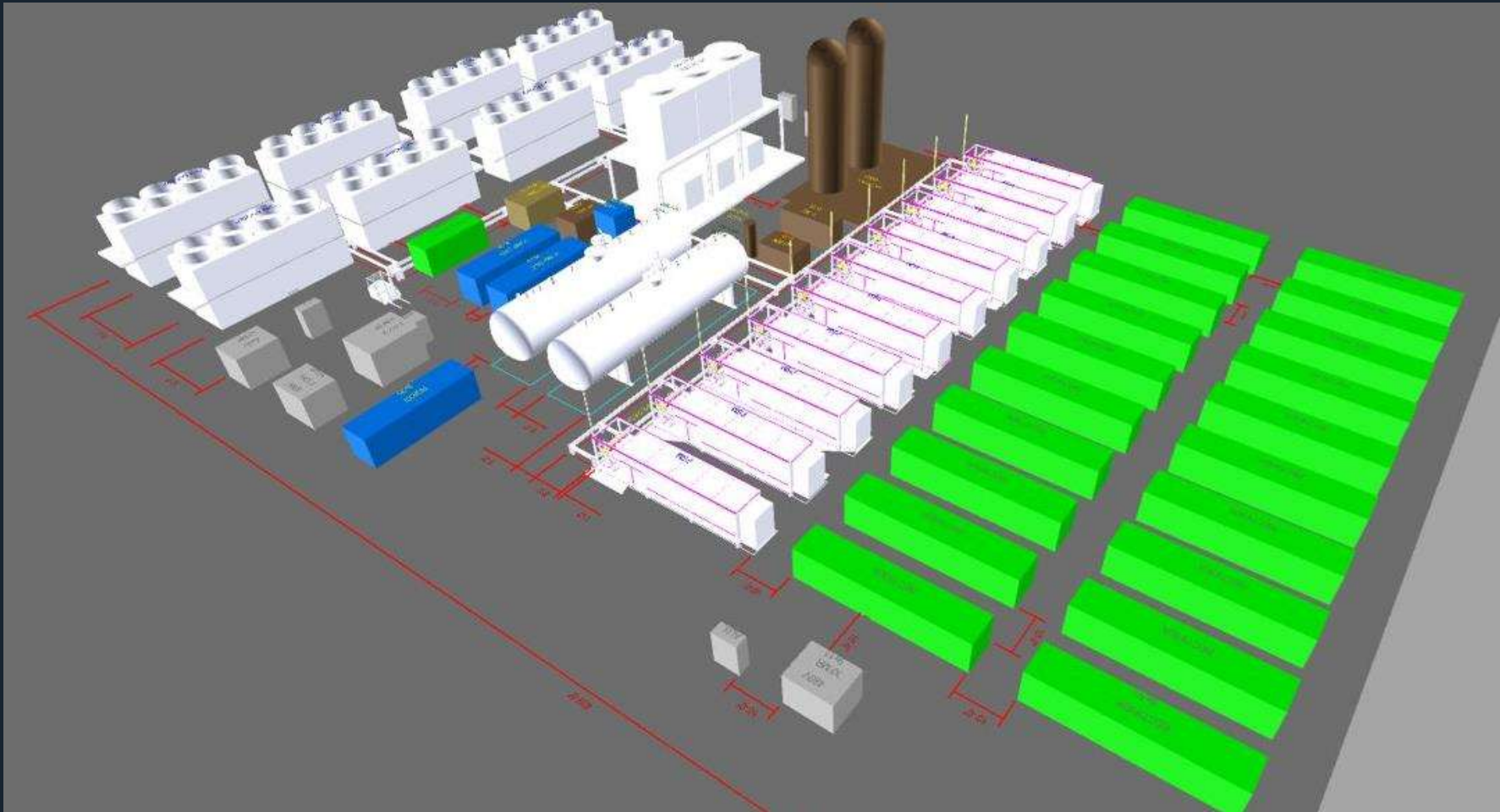
- Pre-assembled at factory
 - Connected and tested
 - Consideration to ship with stacks installed
- Scalable
- Interfaces located at boundary
 - Fluids
 - Electrical, including DC to stacks
 - Signals





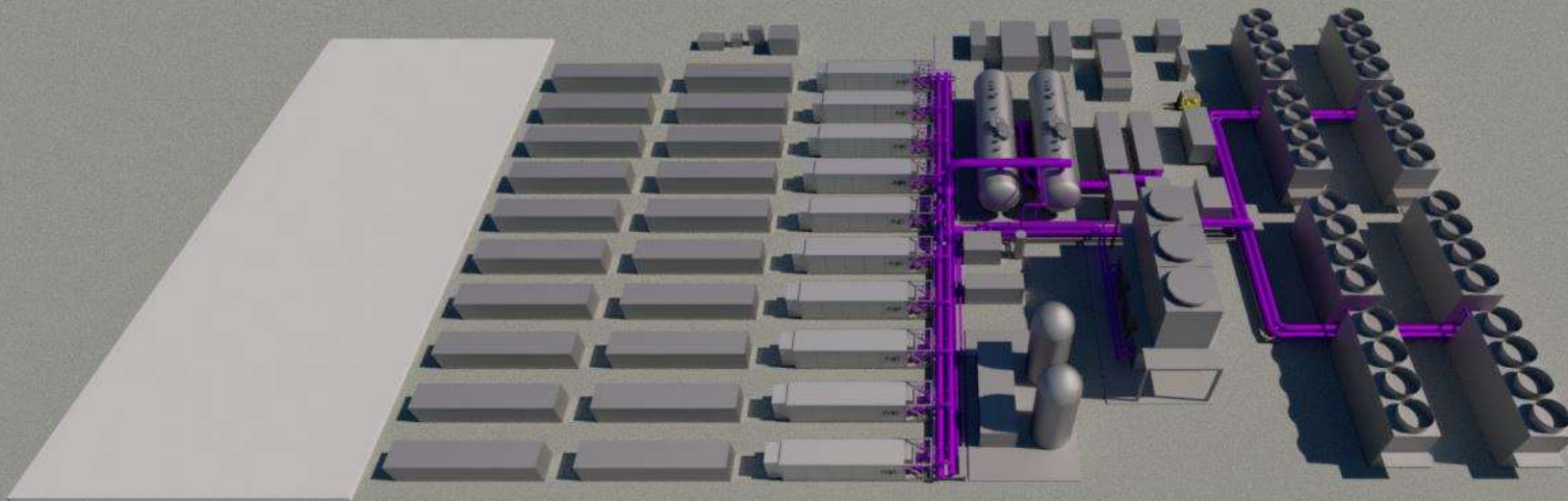
100MW Concept

Product Development 2024 – 100MW Design



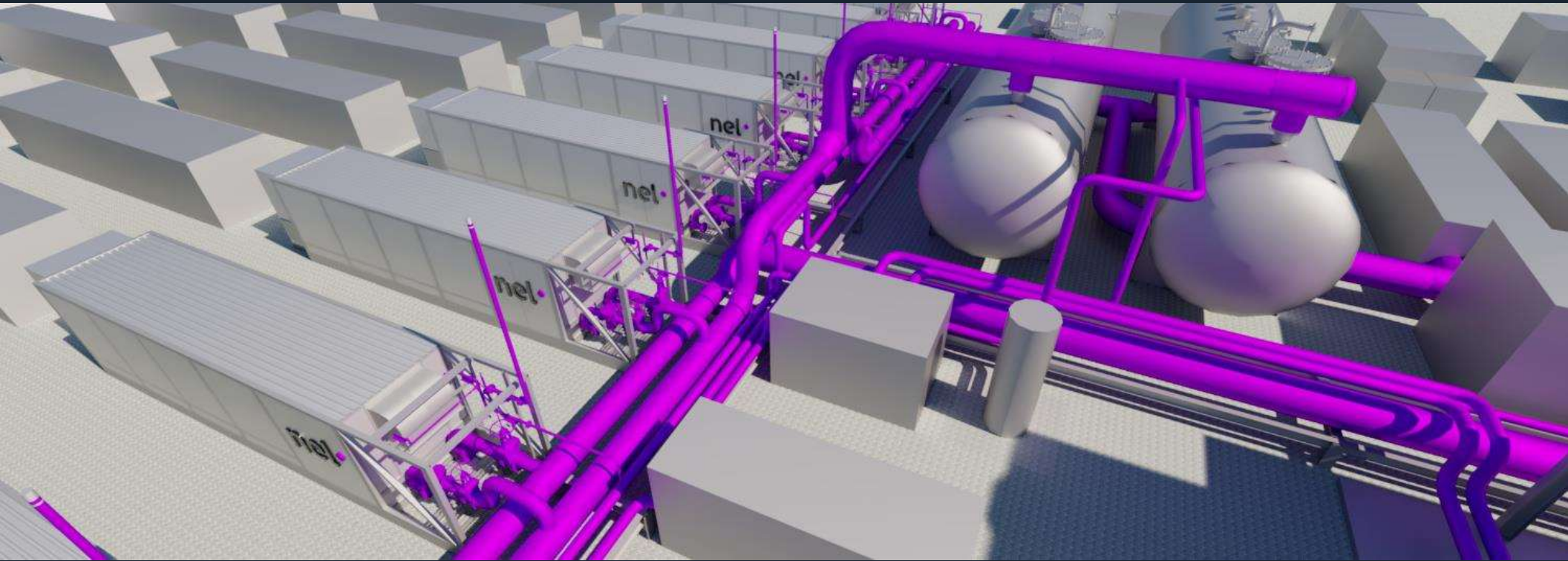
PRODUCT DEVELOPMENT

Product Development 2024 – 100MW Design



PRODUCT DEVELOPMENT

Product Development 2024 – 100MW Design



PRODUCT DEVELOPMENT

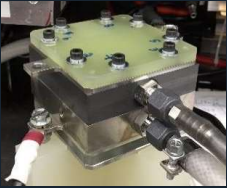
Product Development 2024 – 100MW Design



A person is silhouetted against a starry night sky, holding a flashlight that illuminates the text. The background is a deep purple and blue night sky filled with stars. The person is standing on a dark horizon line, and the flashlight beam is directed towards the center of the slide.

Technical Hurdles in PEM Electrolysis

Translation from Lab to Product at Scale



Test cell: 25 cm² active area



1 MW PEM electrolyzer: 272,000 cm²
11,000x test cell



20 MW KOH plant: 5,000,000 cm²
200,000x test cell

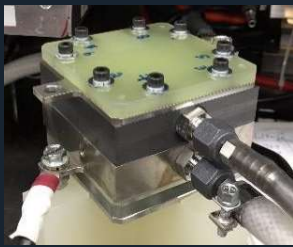
Challenges to implementing new designs based on promising materials

- Must be able to do the same thing millions of times
- Lifetime expectations of 7-10 years (>50,000 hours)
- How to ensure process is robust enough to field product?

99% accuracy is not enough at scale

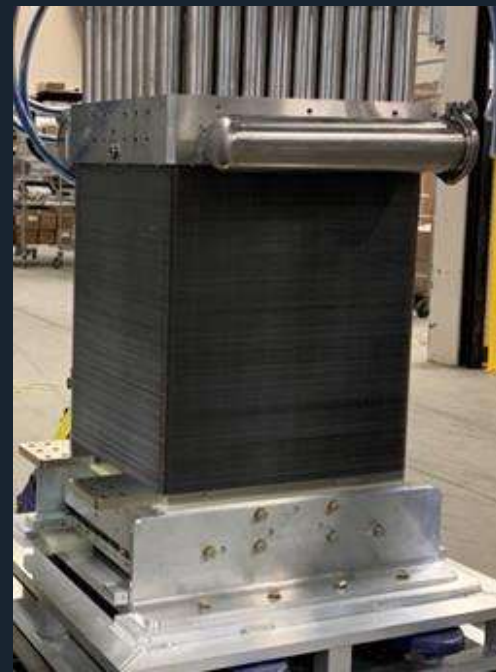
- 99/100 successful experiments would be considered great

High likelihood of successful result at this scale



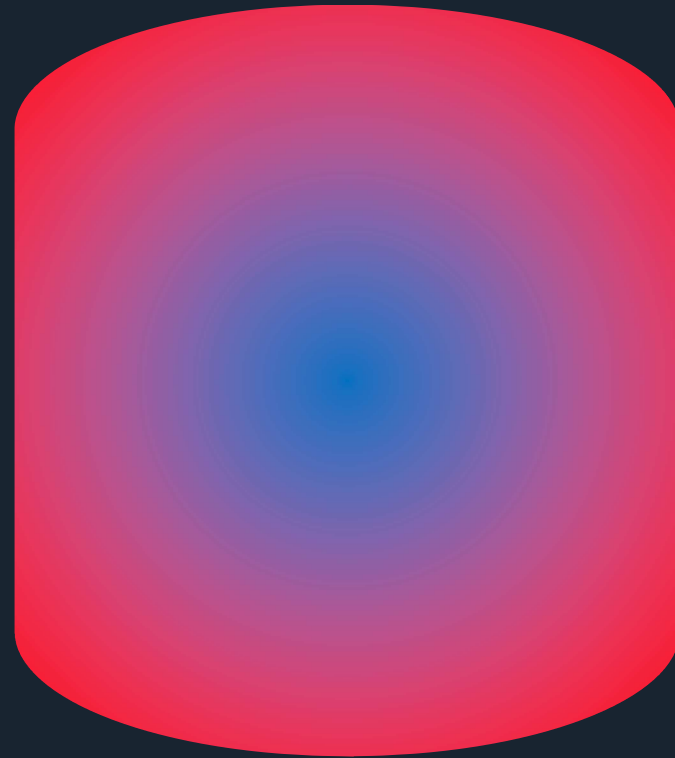
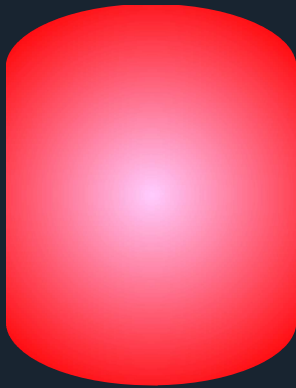
- 99/100 good cells would be a manufacturing disaster

High likelihood of failing every stack at this scale



Scaling impacts the whole supply chain - catalyst

- Reaction vessel scaling can change thermal distribution



Scaling impacts the whole supply chain - membrane

- Small sheets, small batches of ionomer
 - Can be hand cast
 - Even drying
 - Beaker chemistry



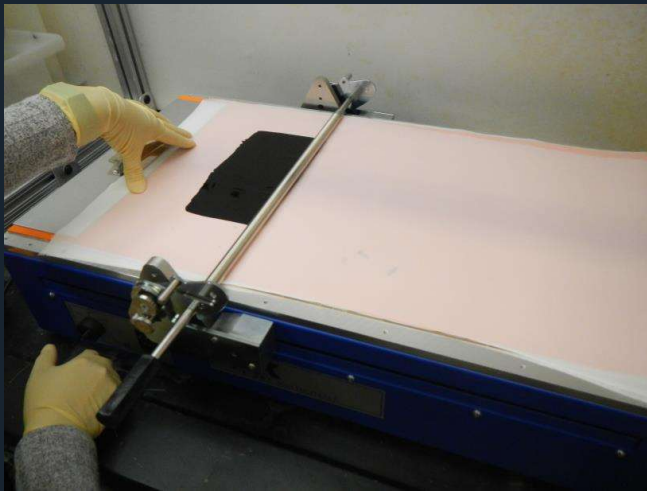
- Large Rolls
 - Subject to inclusions, uneven hydrolysis
 - Huge areas that need to be +/- microns in thickness



<https://www.nature.com/articles/s41467-023-38350-7/figures/1>

Scaling fundamentals – electrode production

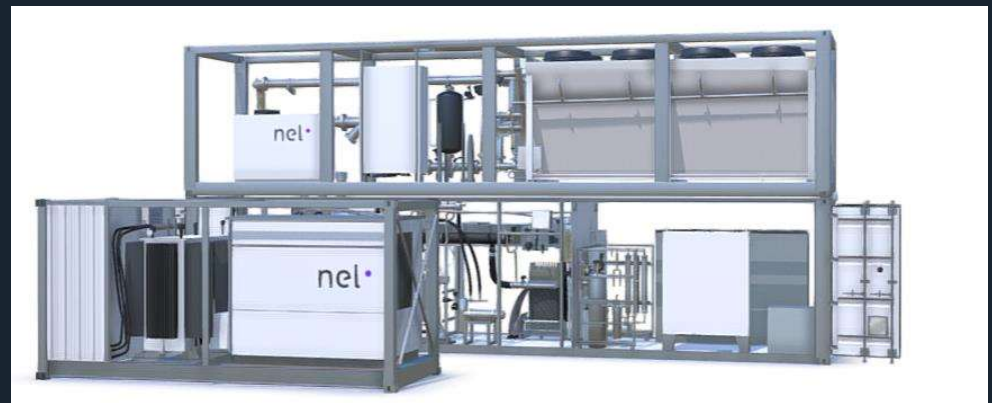
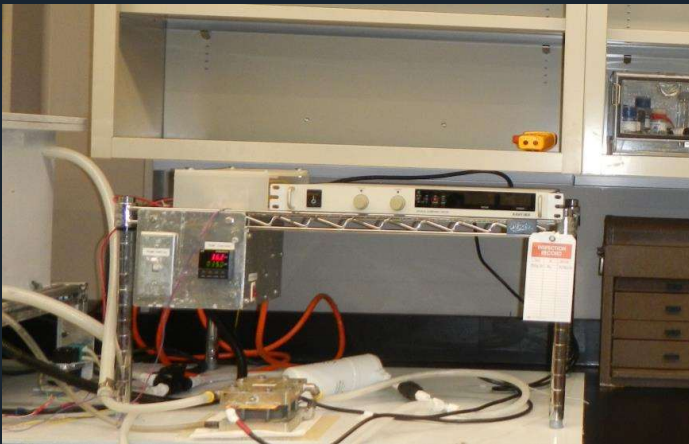
- Bench coating can simulate process to a degree
 - Rough estimate of viscosity and loading required
- Roll to roll at scale involves different fluid dynamics
 - Also generate a lot of scrap really quickly if wrong



TESTING INFRASTRUCTURE IS COSTLY AND LIMITED

Design verification

- Bench test:
 - Fast setup
 - \$\$ to build
 - \$ to operate
- Full scale test:
 - Days to set up
 - \$\$\$\$\$\$ to build
 - \$\$\$\$\$\$ to operate



Performance and Reliability



- Each Electrolyzer technology has its own tradeoffs
- PEM is much more reactive and available
- Alkaline has a longer track record
- The degradation rates for each consider normal operation and defined start stops.
- When the system is operational, it is important to monitor the power intake and gas output
- Cleanliness of the system is paramount for continual operation.
 - Filtration
 - Proper flushing of the system in commissioning
 - Water quality monitoring
 - Regular maintenance
 - Selecting correct climate and geographic options (temperature / coastal proximity)

Common issues in the Electrolyzer industry

- Permitting and licensing takes much longer than anticipated
- Getting Water and Power on site can take ~1 yr
- Ex Rated Buildings can significantly increase cost and drive delays
- Pre-Testing equipment prior to getting it onsite
 - Factory Acceptance and integration testing offsite can save valuable time and money
- Treat the site and system cleanliness as important as safety
- Involve the local government engineers as early as possible
- Have qualified electricians and plumbers ready onsite
- Work with the OEM service managers to ensure “reality” in your I&C schedule
- Start on the Controls Integration in FEED



number one by nature