PROTON

THE LEADER IN ON SITE GAS GENERATION.

Commercial Electrolysis: Setting the Stage for H2@Scale

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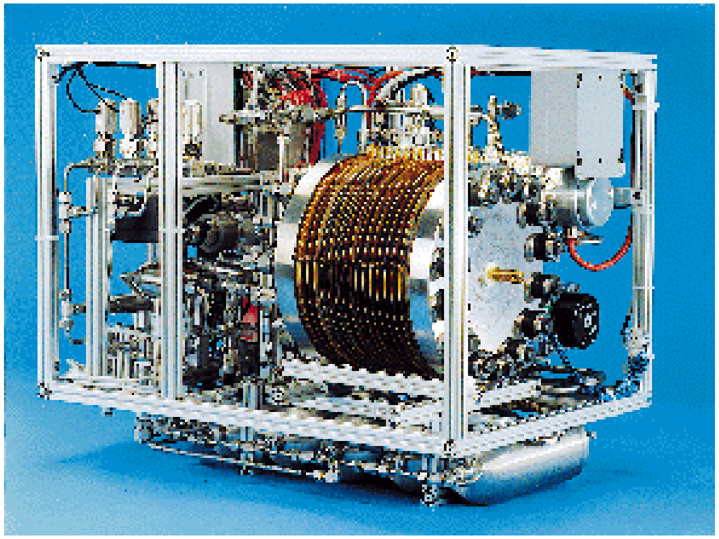
PEM Electrolysis: Product History

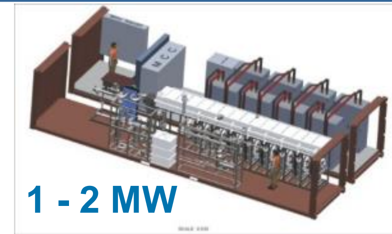
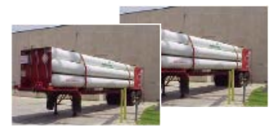
- Designed for life support in closed environments
  - Replaced caustic KOH systems
  - Qualified for O_2 generation in space and underwater
- Optimized for high reliability
  - Shock and vibration mil specs
  - Cost and efficiency not factors

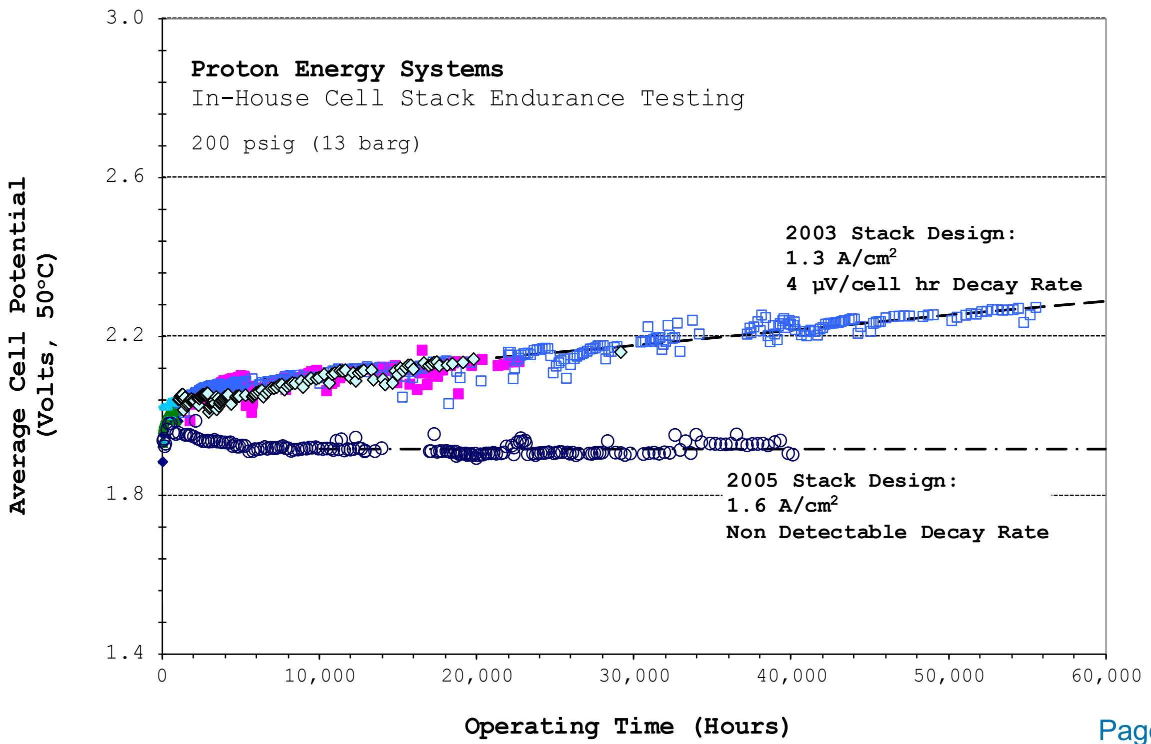


NASA OGA system: ISS

- Early lab scale products also replaced KOH systems
  - Pure water as circulating fluid eliminated need for customer to handle hazardous materials

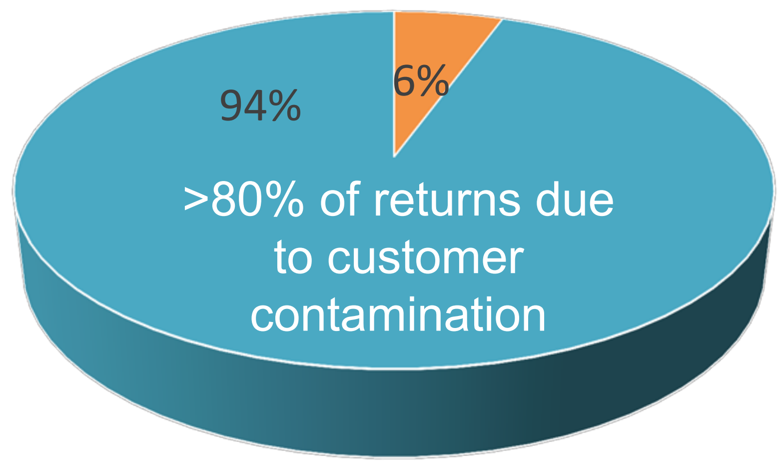
Evolution: 20 Years of Maturity and Scale

Product Type Input Power	 300 W	 6 kW	 36 kW	 180 kW	 1 - 2 MW
Year Introduced	1999	2000	2004	2012	2014
H2 output (Nm^3/hr)	0.04	1	6	30	200–400
Replaces	 Cylinder	 Six Pack	 Tube Trailer	 Jumbo Tube Trailer	 Jumbo Tube Trailers



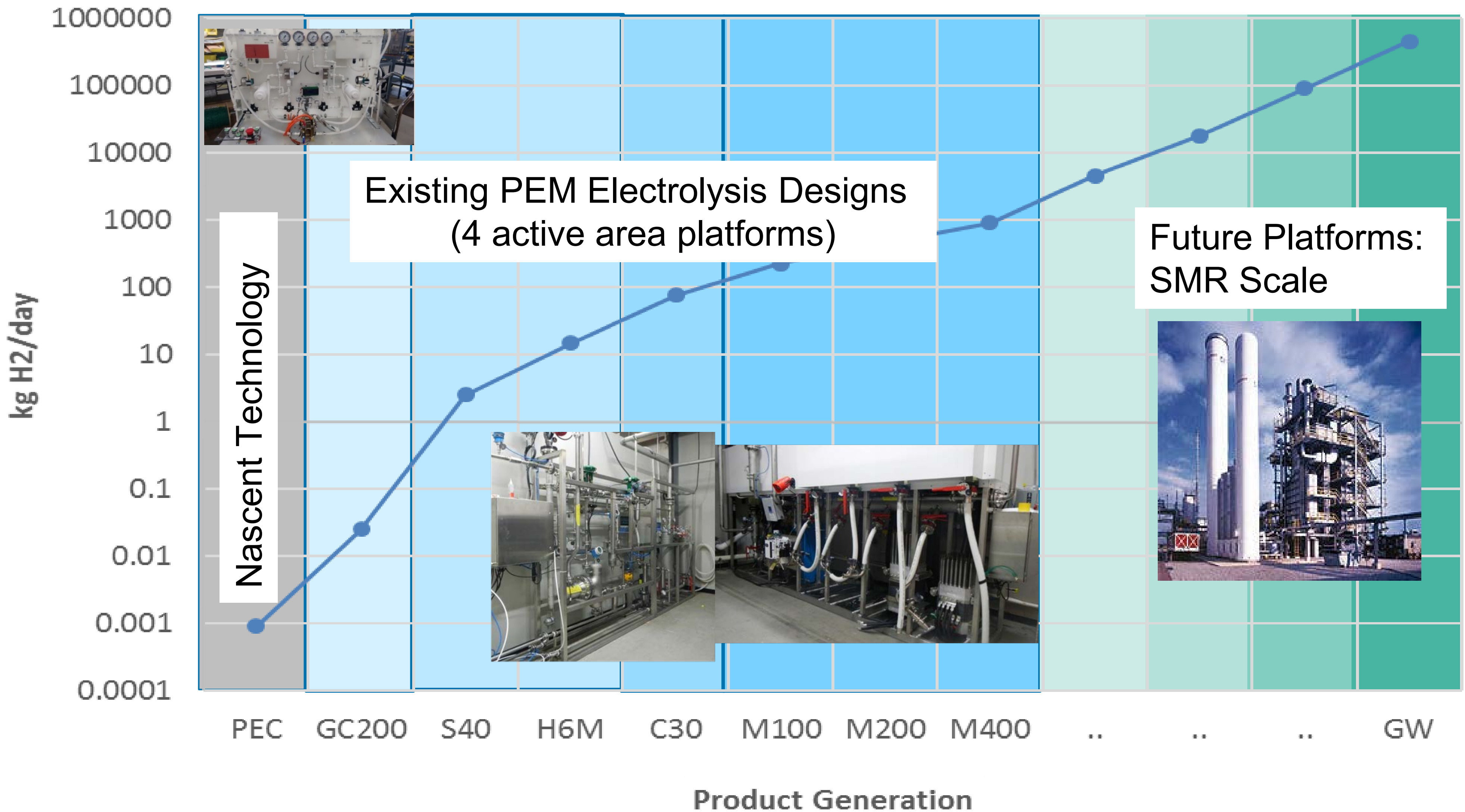
Proton Testing and Field History

Cell Rework Summary, 2006 - 2015



■ Total Cells Replaced
■ Original Cells in Operation

Platform Iterations: Electrolysis



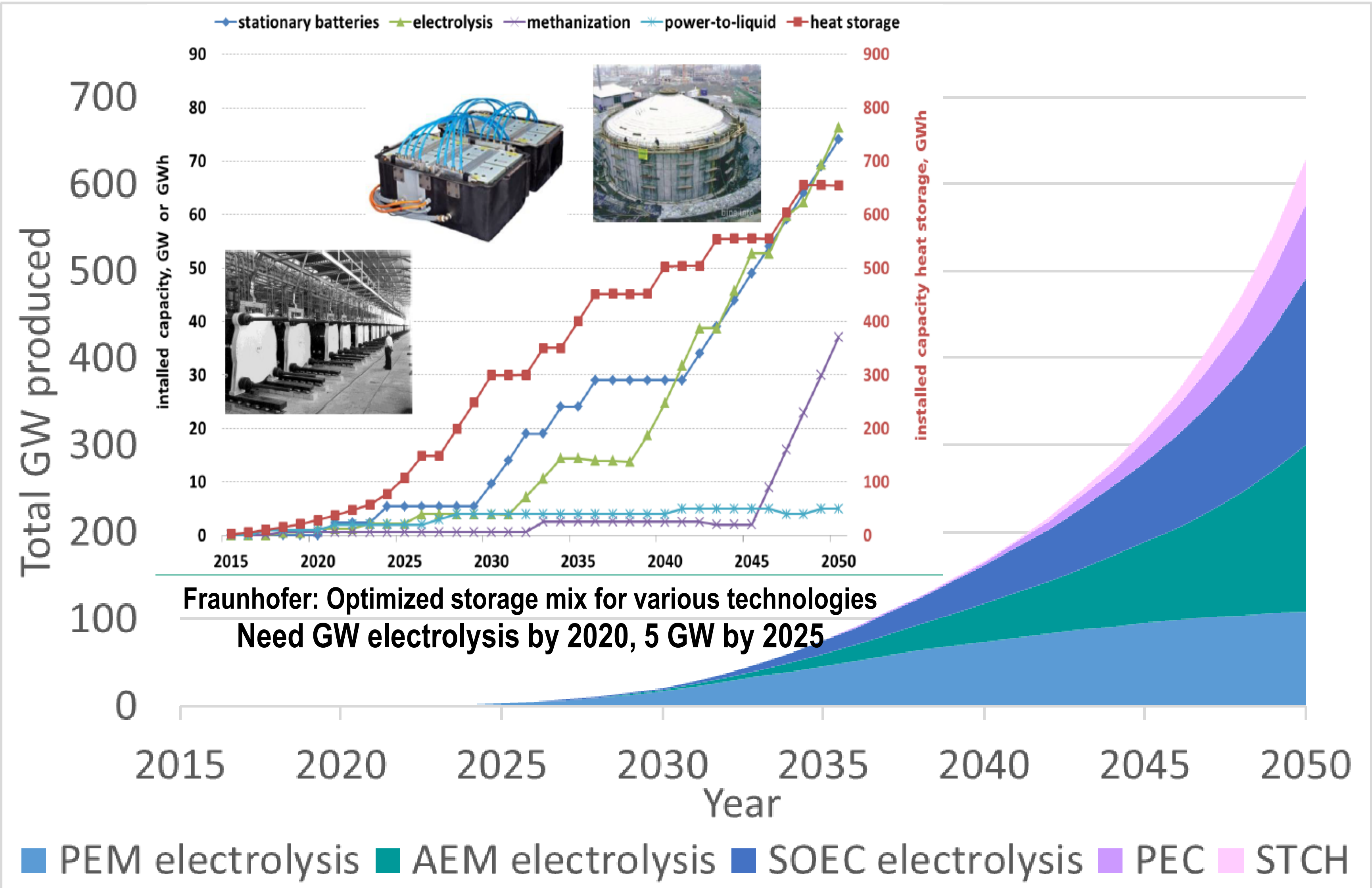
- 4 major platform changes over ~5 orders of magnitude
- New technology has to go through similar progression

Projections for H2@Scale

Let's assume:

- PEM systems at 100 MW scale w/in 10 yrs
  - Pt/Ir can support 10's of GW production
- Membrane based electrolysis = some mix of PEM and AEM (aggressive AEM)
- SOEC matches aggressive AEM assumptions
- PEC reaches 100 kW scale by 2026 and 5 MW by 2036
  - 100 kW = ~1000 m^2 electrode area
- STCH lags PEC by 2 years

Resulting Timeline for Energy Storage



New technology 20-25 years from impact even with aggressive assumptions

Need focus on near term technology to accelerate 1st 10 years

Electrolysis Markets

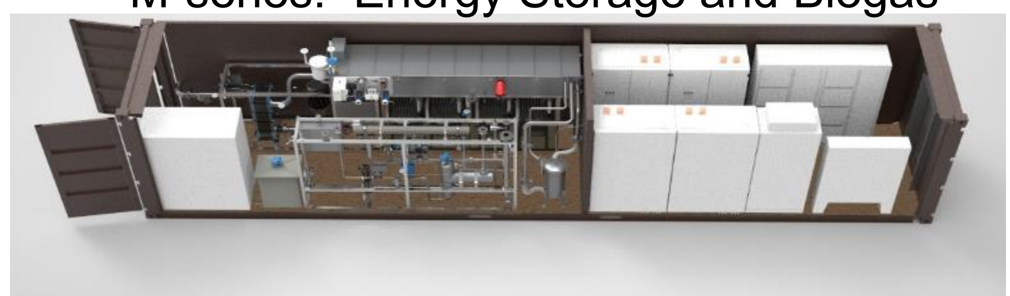
- Each new platform has had an identified market

H and C-series: Power Plants/ Industrial

Lab line: Instrumentation

S-series: Weather Balloons

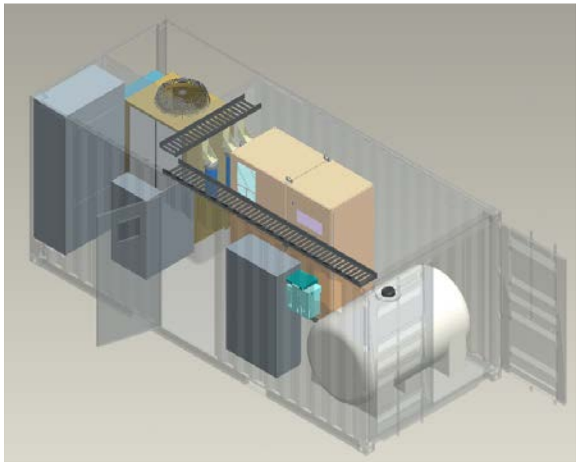
M-series: Energy Storage and Biogas



- Required to maintain sustainability and profitability

Power Plant Market

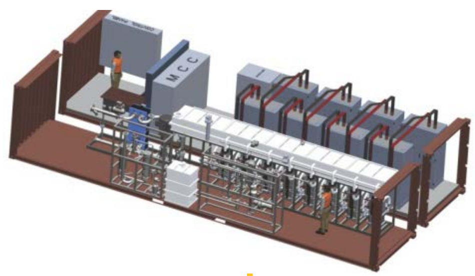
- Over 18,000 hydrogen-cooled electric power generators world-wide
  - 25% North America, 75% ROW
- Addressable market estimated at over $2.5 billion
- Value proposition
  - Improved plant efficiency
  - Increased plant output
  - Reduced greenhouse gas emissions
  - Payback typically less than one year
- Primarily H- and C-series, often integrated solutions (containerized)



Renewable Energy Storage: Stranded Wind & Solar

Wind and solar production mismatch can cause up to **30%** of electricity to become stranded

Value of this stranded renewable energy represents a TAM of over **$12B**[(1)]



- H_2 to Gas
- Industrial
- H_2 to Energy Storage
- Transportation Infrastructure
- Synthetic Methane

(1) Addressable market size based on management's internal estimates for Germany.

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Finding the Value Proposition

- Markets are large but customers want solutions: not a set of discrete technologies.
- Creative entrepreneurs are finding ways that hydrogen fits and provides an investment return
- Opportunities vary in size from <10MW to >> 100 MW
- Successful product strategy will need to scale to accommodate
- Gaps in technology / cost need to be addressed to enable

Demonstrations

- Many larger European projects in progress
- MW scale and larger: >20 MW awarded
- Projects include R&D elements

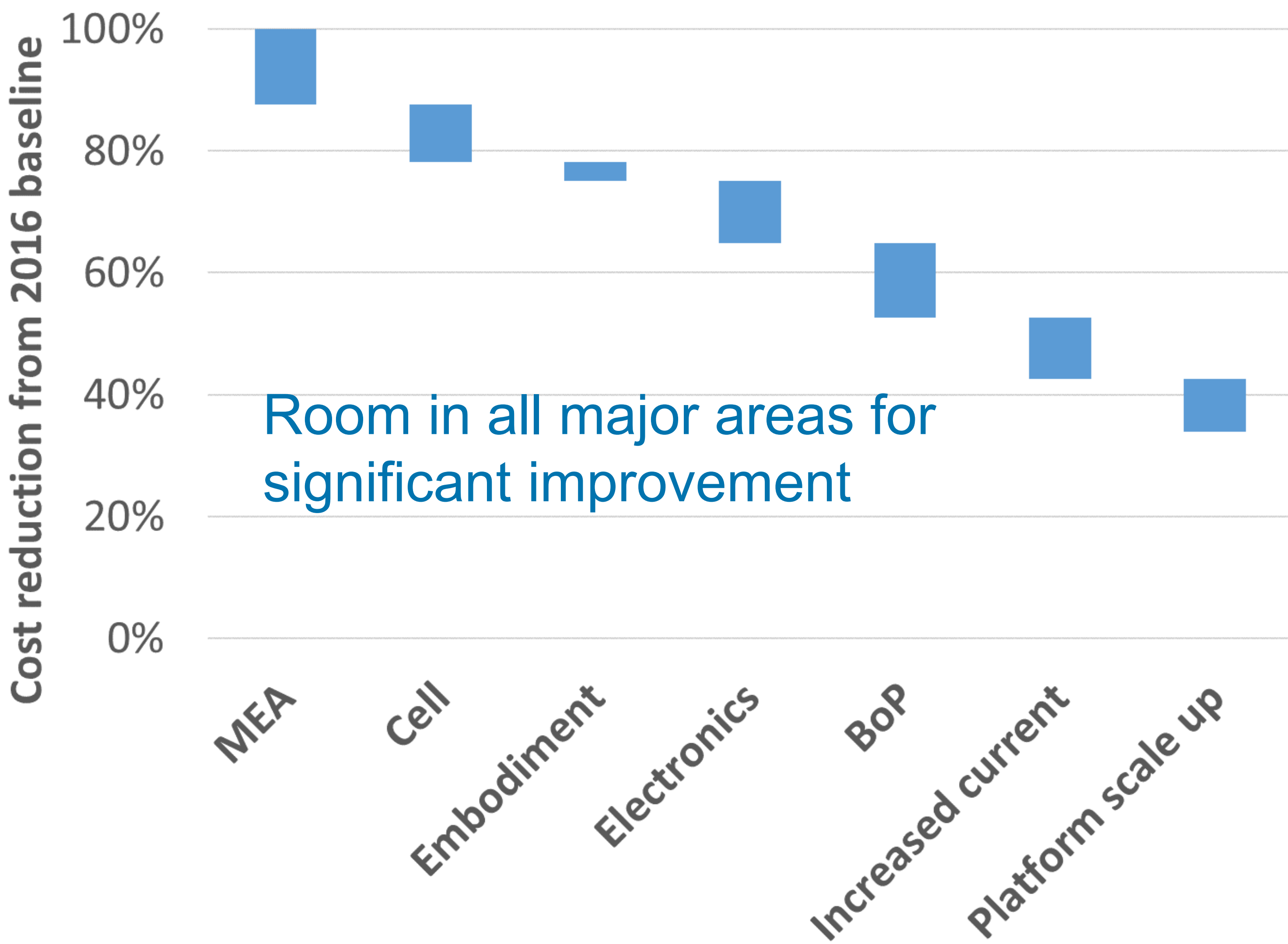
Viessmann (MicrobEnergy), Schwandorf, Germany

- 200 kW Proton electrolyzer + methanization
- H_2 combined with biogas CO_2 to produce bio-methane ($4H_2 + CO_2 \rightarrow CH_4 + H_2O$).
- Injected in gas grid → Carbon neutral process.

- Synthetic Energy, Idaho, USA
- Wind to H_2

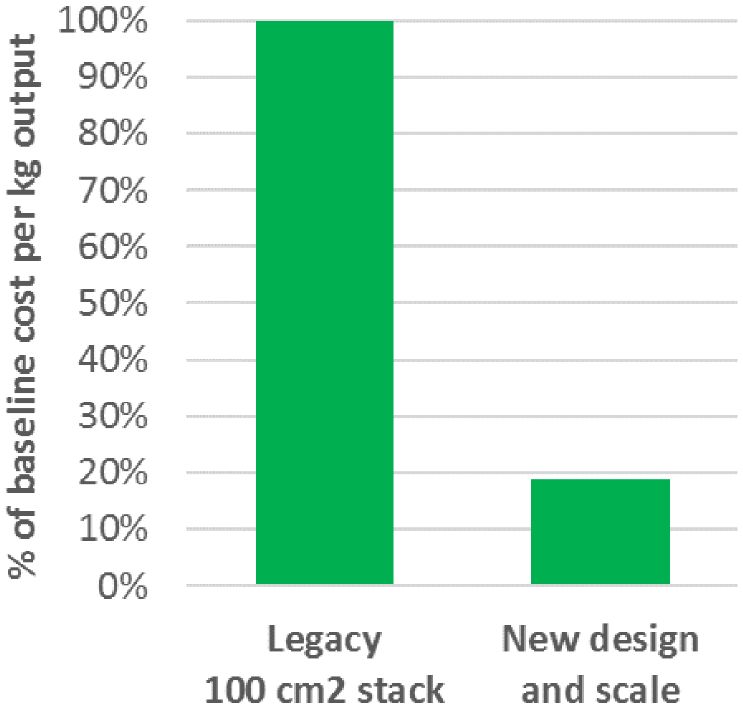
- Wind to H_2 to ammonia (NH_3): UMM
- Combining N_2 and H_2 to produce NH_3 onsite.

Cost Reduction Opportunities

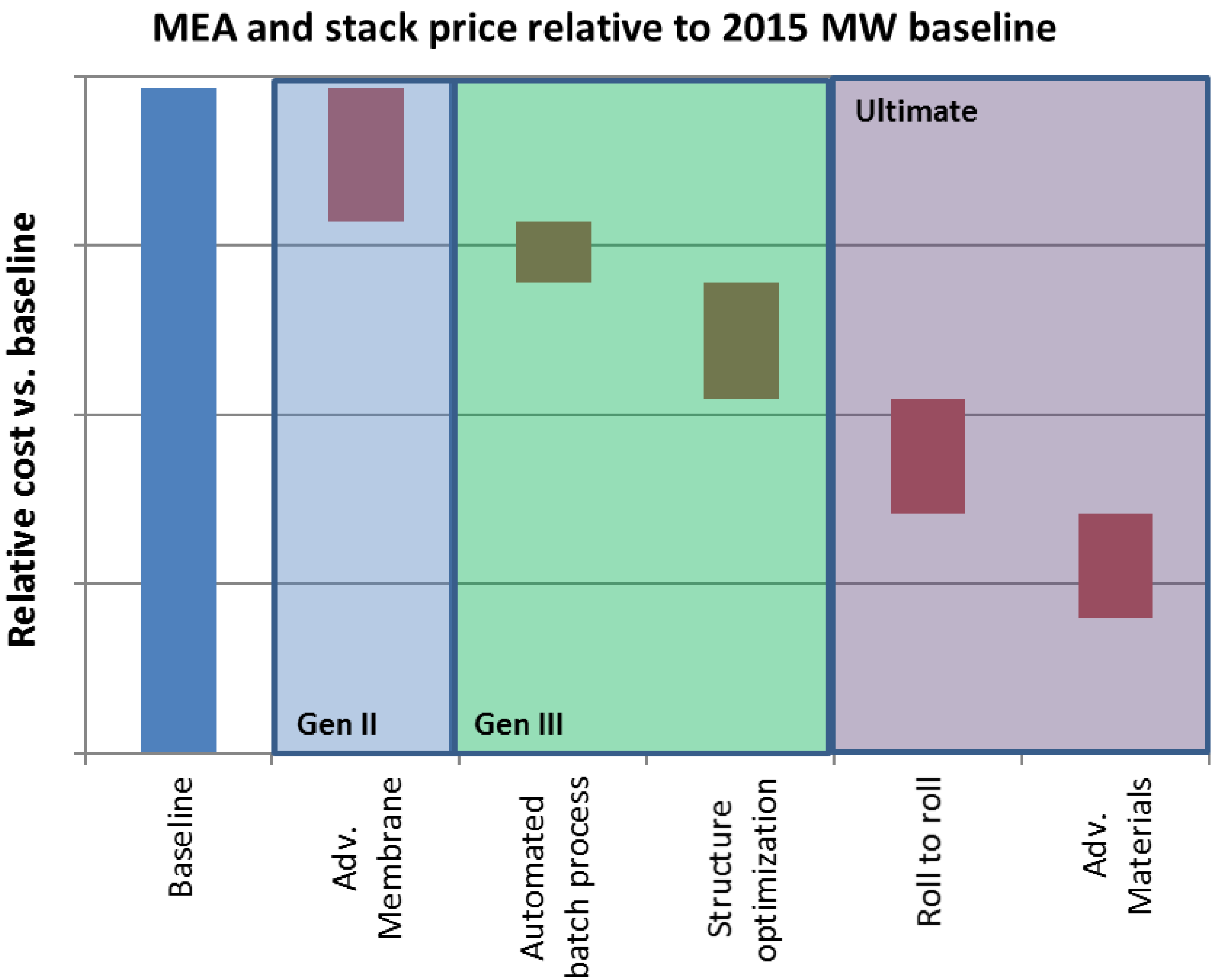


Bipolar Plate Project Success

- Surveyed and selected manufacturing techniques
- Modeled fluid flow and mechanical strength
- Prototyped parts and qualified alternate coating for improved resistance to environment and lower cost
- Scaled by 6X in active area and 3X in cell count vs. prototype
- Realized expected savings and achieved >500,000 cell hours
- Establishes credibility of cost reduction opportunities

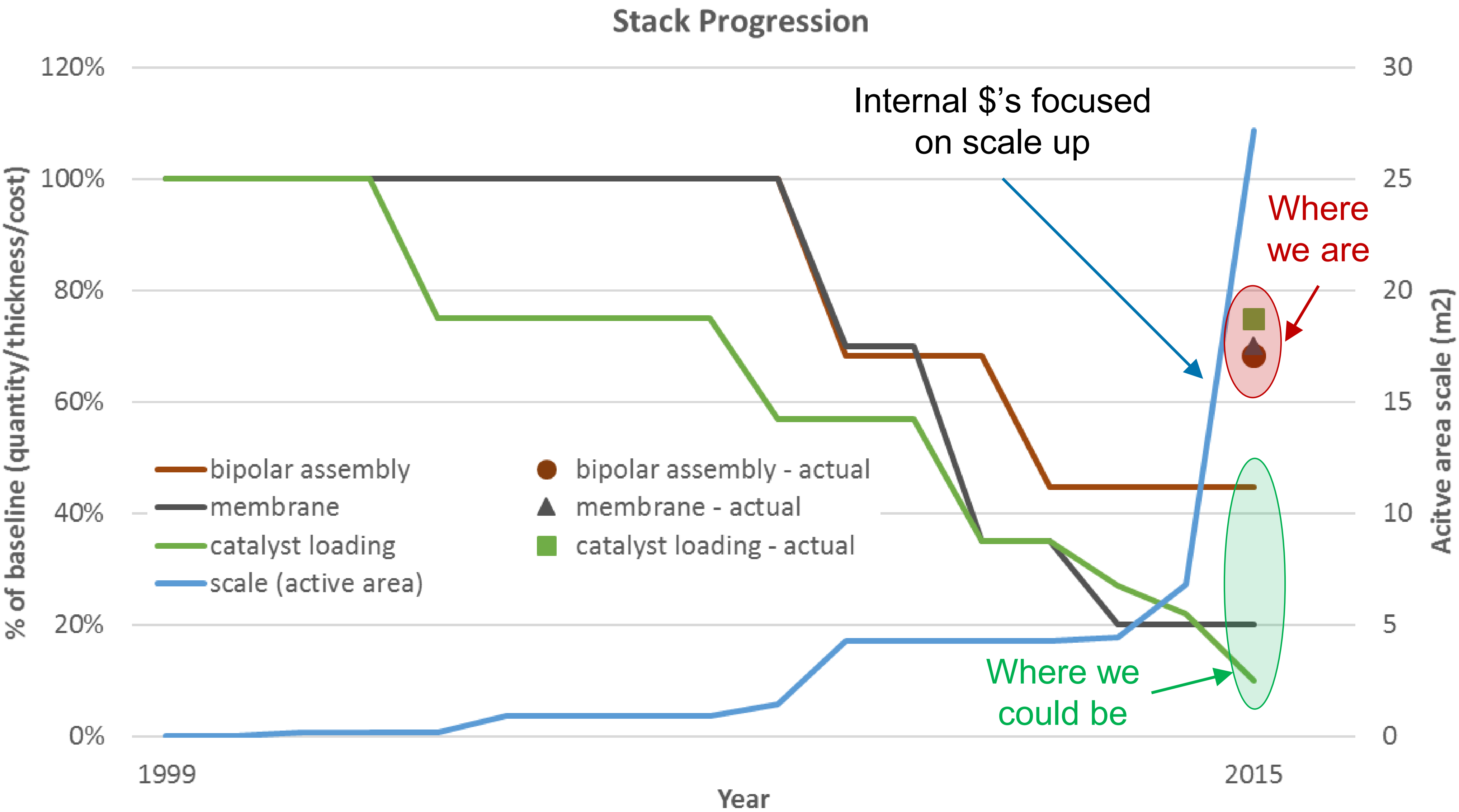


MEA Improvement Pathway



- Similar opportunity as bipolar plate
- Higher material utilization and automation
- Demonstrated feasibility for manual/small batch processes
- Interactions with other components

Implementation lags R&D considerably



Opportunities and Challenges

- Pathway defined to cost targets
  - Opportunities/needs in several areas
  - No single area that contributes majority
  - Lag in proof of concept to commercialization
- Interactions and integration are essential
  - Adjacent cell components
  - Matching of stack and power supply I-V
- Fundamental need is next scale
  - Manufacturing processes and product output
- Requires investment and focus
  - Materials understanding for manufacturing development

Questions to be Answered

- Need additional market input on:
  - How the system needs to interact with the grid
  - Optimal building block size – distributed vs. centralized
  - Preferences for hydrogen usage solutions (can we develop "typical" scenarios?)
  - Standard parametric cost/performance model for business case development
  - Regulatory position / constraints to scaled applications (no different from large scale industrial process plants??)