PROTON
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MW Electrolysis Scale Up

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Motivation – MW Electrolysis Markets

- Renewable energy storage
  - 10's of GW's of wind/solar energy capture
  - Power-to-gas
- Biogas market
  - Methanization
- Transportation market
  - H_2 infrastructure plans in US, Europe, Asia
- Multi-billion dollar opportunity in each
- MW-scale electrolysis needed
  - Targeting multi-MW product scale-up

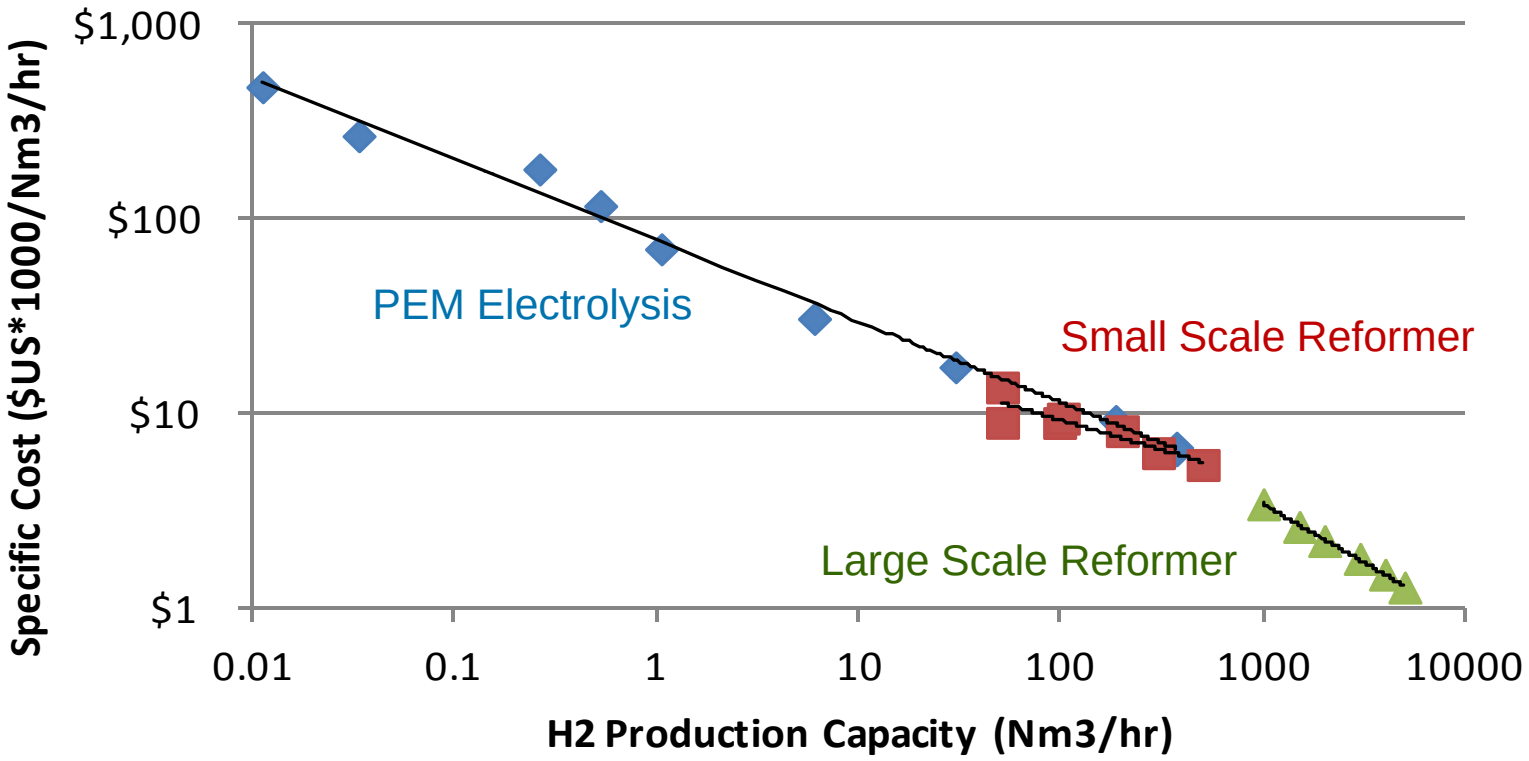
Scale-up/Cost Reduction Experience

Product Type	HOGEN S-Series	HOGEN H-Series	HOGEN C-Series
			
Product Launch	2000	2004	2011
Cells/stack	10-20	34	65
Stacks/system	1	1-3	1-3
H_2 Output (Nm^3/hr)	1.05	6	30
$/kW vs. S-series	100%	43%	28%
Input Power	7kW	40 kW	175 kW

- Order-of-magnitude scale up resulted in greater than 70% cost reduction ($/kW basis)

Development Cost Curve

- Maintain trajectory to meet MW targets
- Initial projections validated with actual quotes



Source: IEA-HIA Task 33

MW Scale-up Needs: Overview

- Cost reduction areas defined for both stack and system
  - Over 50% decrease achievable
- Opportunities in material substitution, automation, and scale up
  - Collaborations established with key partners
- Roadmap developed for technology
  - Have shown cell scale feasibility
  - Need investment in manufacturing implementation:
    - Within company and also with rest of supply chain
- High capital intensity
  - Resources needed >50% of company annual revenues

Cell Stack Needs

- 50% reduction in bipolar assembly cost - funded
  - Reduction of materials & assembly process time
  - Still have issues finding US-based suppliers
- Electrolysis-specific MEA manufacturing development
  - No US-based 3rd party electrolysis MEA source
  - Process improvement pacing material advancements
- Online quality control measurements
- Increased yield from component suppliers

Manufacturing Scale-up Examples:

Part	Current	End Goal
MEA	Manual CCM process	Roll-to-roll coating
Flow Field	Multi-piece manual assembly	Single piece high speed manufacture
Gaskets	Single piece die cut	oll stamping
Quality control	Individual part measurement	In-line measurement
Bipolar assembly	Metal plate	Laminate or composite

System Needs

- Better utilization of off the shelf components (COTS)
  - Electronics and enclosures have high customization cost vs. standard
  - COTS components often do not meet all needs – adds expense to modify system to adapt
  - Standardization to drive volumes
- Investment in high speed tooling/molds
- Increased production volumes through strategic/subsidized deployment
- Investment in larger scale balance-of-plant
- Product design/sourcing for world-wide markets
- Optimization of grid and/or DC interface

Gaps and DOE Assistance

- Energy policy and outside investment are inter-related
  - Lack of long term commitments like in EU
- Government role/needs:
  - Pre-commercial market support of technology innovation and manufacturing
  - Benefits: high tech job creation and international competitiveness
- Critical tipping point for PEM electrolysis
  - Large markets are materializing
  - US holds leadership position but European developers have strong national investment
    - Research consortiums to technology demonstration projects
    - US companies unable to compete for EU funding directly