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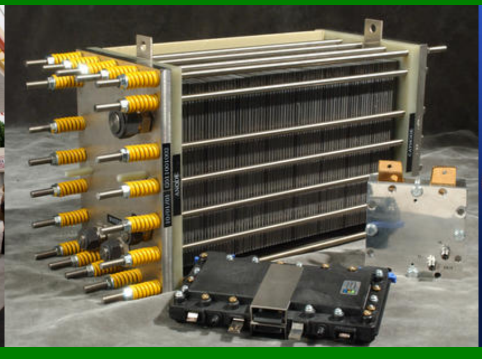

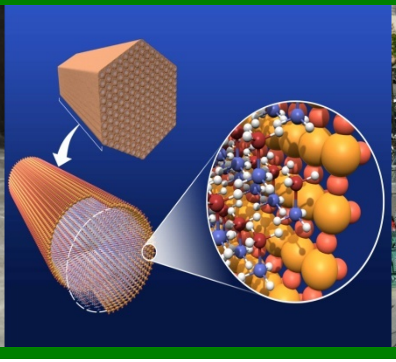

HYDROGEN PRODUCTION BY PEM ELECTROLYSIS:

SPOTLIGHT ON GINER AND PROTON

US DOE WEBINAR

(May 23, 2011)

Webinar Outline

- **Water Electrolysis H_2 Production Overview**
  - *DOE-EERE-FCT: Eric L. Miller*
- **Spotlight: PEM Electrolysis R&D at *Giner***
  - *Giner Electrochemical Systems: Monjid Hamdan*
- **Spotlight: PEM Electrolysis R&D at *Proton***
  - *Proton OnSite: Kathy Ayers*
- **Q&A**

DOE EERE-FCT Goals and Objectives

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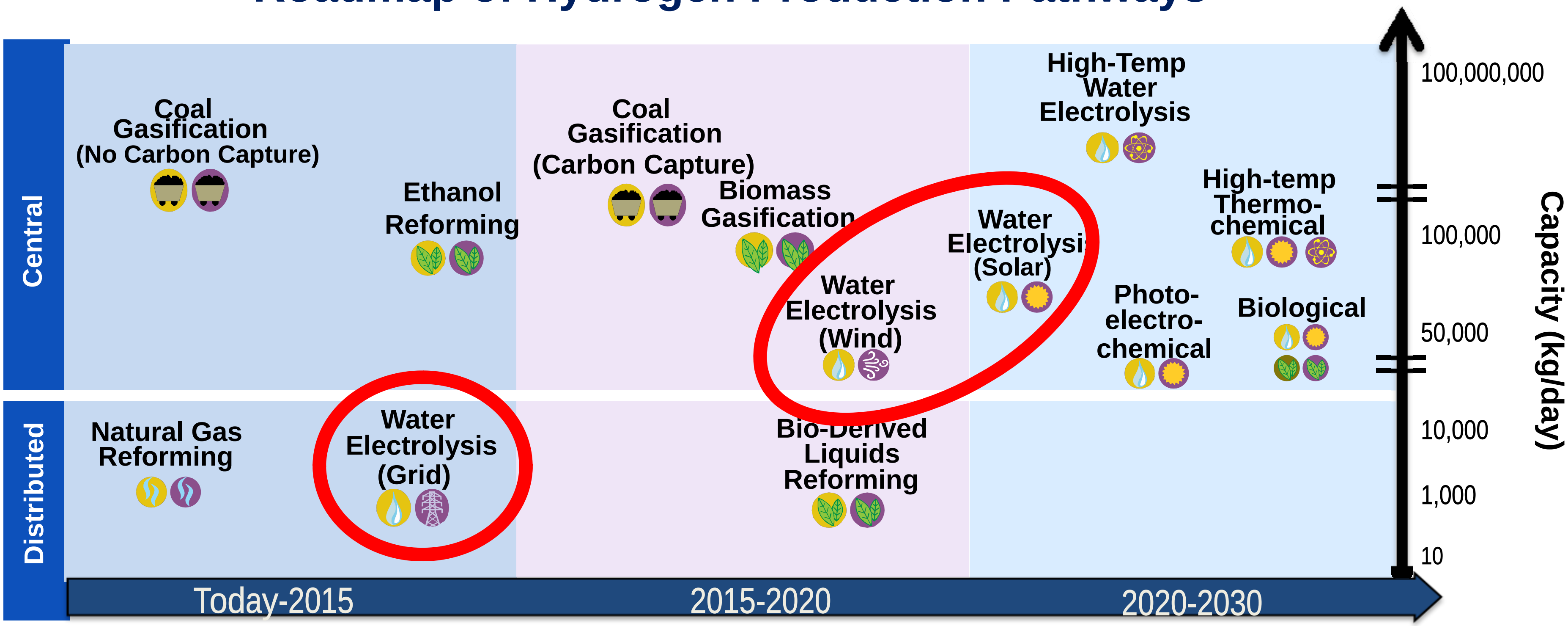
Develop technologies to produce hydrogen from clean, domestic resources at a delivered and dispensed cost of $2-$4/gge

Roadmap of Hydrogen Production Pathways



- ➢Central Production (50,000-750,000 kg/day H_2)
- ➢Distributed Production (up to 1,500 kg/day H_2)

electrolysis integral to both central and distributed pathways

Electrolysis: Splitting Water for Clean H_2

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Potential for clean and renewable hydrogen production at all scales

•Central Production

–*Commercial plants using alkaline electrolysis have operated at capacities over 60,000 kg /day for industrial chemical processing*

–*Renewable plants using renewable feedstocks (wind, solar, etc.) are envisioned in longer term*

•Distributed Production

–*Produced at station to enable low-cost delivery*

–*Currently available using grid electricity*

–*Renewable demonstration systems using PEM electrolysis already in place at select locations*

The atmospheric series Norsk alkaline electrolyzers with a unit production capacity of 1000 kg/day, with larger volumes produced by stacking multiple units .http://www.electrolysers.com/

The Las Vegas Nevada renewable hydrogen generation/distribution system is composed utilizing 13 kg/day PEM electrolyzers http://www.protononsite.com/technology/hydrogen-fueling-systems.html

Electrolysis: Benefits and Challenges

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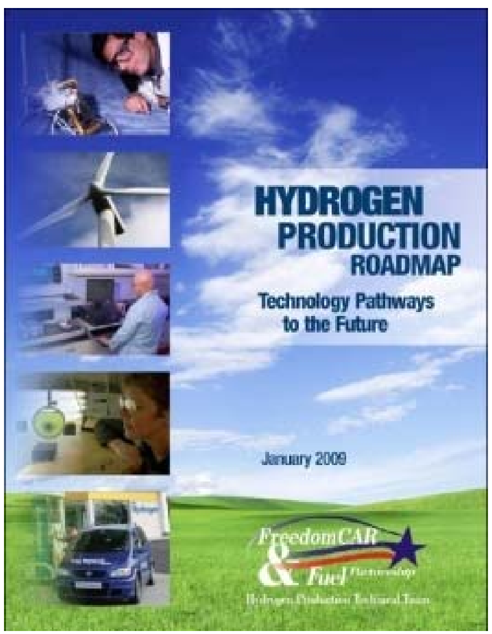
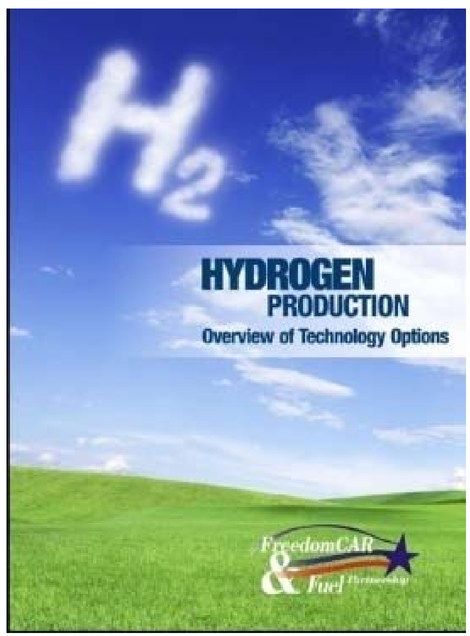
Key Benefits

- Produces virtually no pollution with renewable energy sources
- Uses existing infrastructure
- Uses fuel cell advances

Critical Challenges

- **System efficiency and capital and feedstock costs**
- **Integration with renewable energy sources**
- **Design for manufacturing**





http://www1.eere.energy.gov/hydrogenandfuelcells/pdfs/h2_production_roadmap.pdf

Major R&D Needs

- Develop more durable and less expensive membranes
- Develop long-lasting membranes and corrosion-resistant interconnects
- Develop durable, low-cost, and active catalysts
- Design novel architectures for large-scale production
- Balance storage and production rate capacity for variable demand
- Develop flexible, scalable systems using lower-cost materials
- Increase reliability for high-temperature units
- Develop novel, more efficient drier technologies
- Develop efficient water conditioning systems

Cost Reductions Needed

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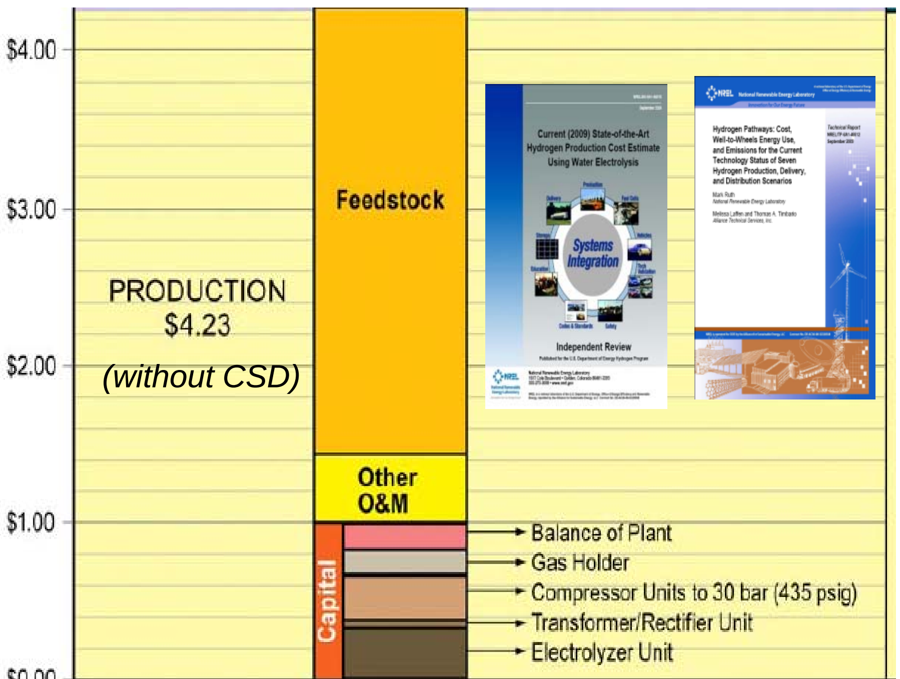
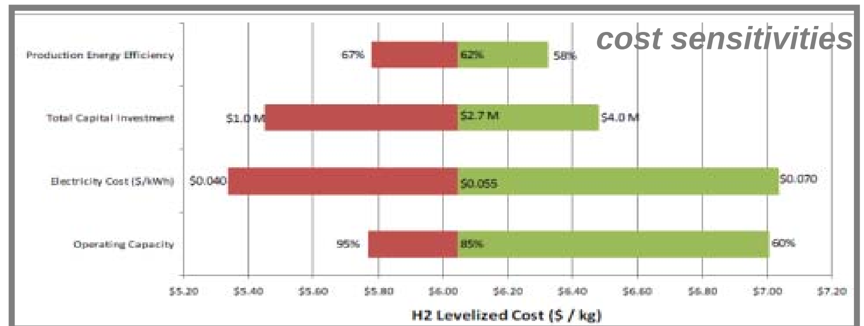
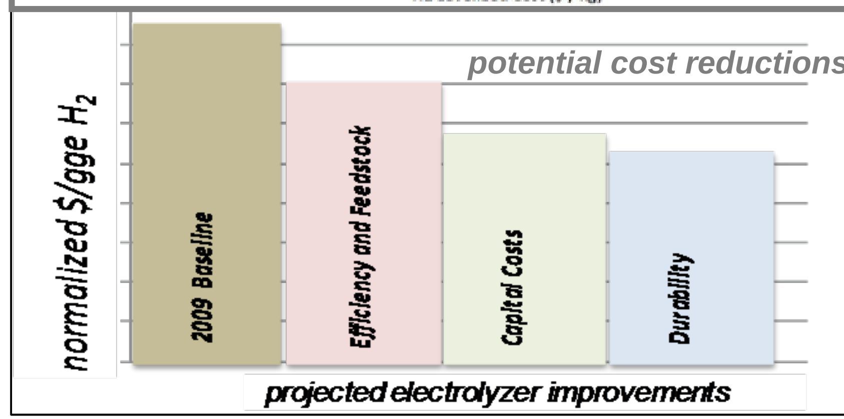
2009 analyses[1,2] evaluated at-volume costs of H_2 from electrolysis

$4.90 – $5.70/gge (*distributed baseline - with compression, storage, dispensing*)
$2.70 – $3.50/gge (*central baseline- excluding compression, storage, dispensing*)



2009 baseline costs (distributed case)





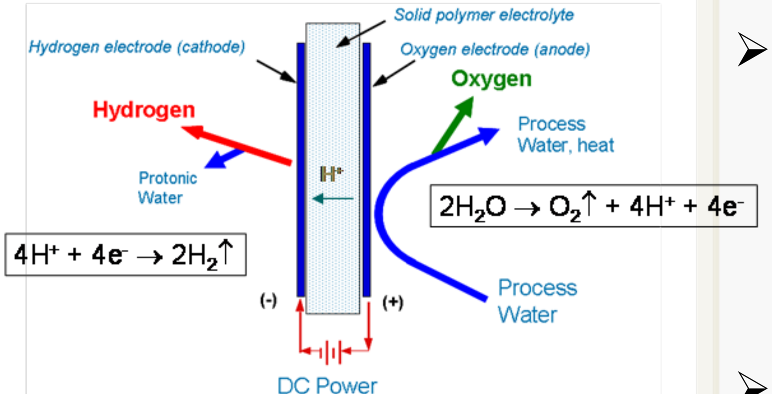
R&D continues to reduce cost through electricity feedstock and capital costs reduction, and efficiency and durability improvements

[1] http://www.hydrogen.energy.gov/pdfs/46676.pdf
[2] https://www1.eere.energy.gov/hydrogenandfuelcells/pdfs/46612.pdf

PEM Electrolysis: Motivation

Leverages advances in PEM fuel cell R&D for clean, renewable H_2

PEM Electrolysis Basics



produces high purity H_2 (~99.999%)

NREL Wind2H_2

- **Advantages over alkaline technology**
  - *No corrosive electrolytes*
  - *Enables differential pressure operation*
  - *Direct leveraging of PEM fuel cell advances*
- **Commercial technology compatible with renewable inputs for zero carbon footprint**
  - *PEM technology can be integrated with solar and wind power*
- **Cost competitive with current commercial delivered hydrogen costs**
  - *Currently producing at <$10/kg*
  - *Price, reductions expected with technical advancements and with economies of scale*

PEM Electrolysis: Current Directions

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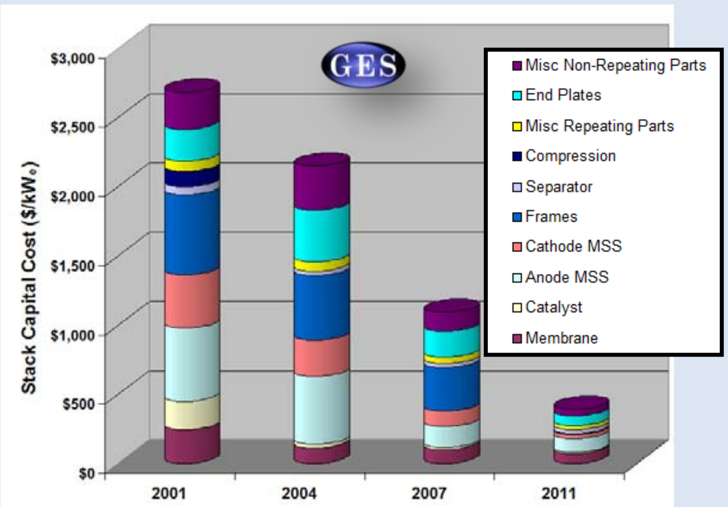
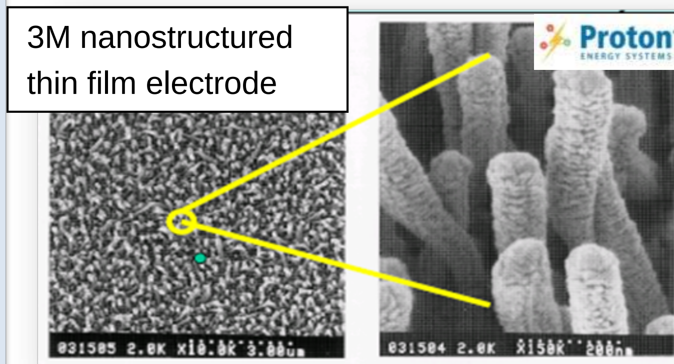
Costs being reduced through collaborative design and manufacturing innovations



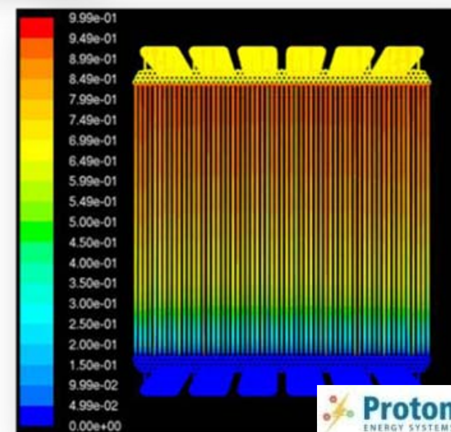
Historical capital cost reduction

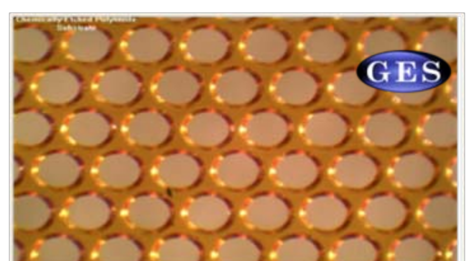
- **Stack capital cost reductions have been achieved with optimized component and system designs *(Proton, Giner)*:**
  - ***80% reduction since 2001***
  - ***15% reduction in past year***



Catalyst optimization:
- 50% loading reduction on anode
- >90% reduction on cathode

Design of electrolyzer cell model for more accurate performance prediction





90% cost reduction of the MEAs by fabricating chemically etched supports

Giner Presentation

Proton Presentation