Insights from Hydrogen Refueling Station Manufacturing Competitiveness Analysis

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NREL is a national laboratory of the U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, operated by the Alliance for Sustainable Energy, LLC.
I. Background
II. Current Analyses at CEMAC
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1. Background
The Clean Energy Manufacturing Analysis Center (CEMAC) provides unique and high-impact analysis, benchmarking, and insights of supply chains and manufacturing for clean energy technologies that can be leveraged by decision makers to inform research and development strategies, and other policy and investment decisions. Housed at the National Renewable Energy Laboratory and operated by the Joint Institute for Strategic Energy Analysis, CEMAC engages the DOE national lab complex, DOE offices, U.S. federal agencies, universities, and industry to promote economic growth and competitiveness in the transition to a clean energy economy.

CEMAC was established in 2015 by the U.S. Department of Energy’s Clean Energy Manufacturing Initiative.
DOE’s Clean Energy Manufacturing Institute recognizes value of capability:

- DOE and National Laboratories: uniquely suited to unsolved analysis challenges in clean energy manufacturing
- To date, DOE National Labs have:
  - pioneered manufacturing analysis for specific energy technologies
  - developed models and methodologies
  - curated substantial input data
  - housed and trained the world’s experts in clean energy technology and associated costs structures
  - earned trust as honest brokers for individual corporations and diverse decision and policy makers
  - become equipped to house sensitive information

“Therefore, DOE has established an analysis organization within DOE national laboratories and centered at the National Renewable Energy Laboratory (NREL) dedicated to the analysis of clean energy manufacturing.”
Creating Partnerships, Bridging Strategic Gaps

**Key questions**

- What is the global & regional supply chain?
- What drives competitiveness?
- How is competitiveness changing?
- How does competitiveness align with roadmaps?

**Clean Energy Manufacturing Analysis Center**

- Transparent, consistent, validated methods
- Regular update process
- Widely available reports and insights
- Protection of proprietary data

**Key partners**

- DOE Offices
- F500 Firms
- Startups
- State & local gov’t
- National Labs
- Federal officials
- Academics

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Current Analyses at CEMAC
## Current CEMAC Portfolio

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International HRS Status
1. Hydrogen station with gaseous hydrogen delivery

- Truck delivery
- Compressed H₂
- Tube storage
- Compressor
- High pressure hydrogen storage/cooling
- Dispenser

2. Hydrogen station with liquid hydrogen delivery

- Truck delivery
- Liquid H₂ Tank
- Cryogenic Pump
- Evaporator
Main Focus

- More focus on large capacity HRS’s >50 kg H₂ per day
- Demonstration and small size HRS’s dominate the past 10 years installations
FCV Sales 2015-2030

- 2020 estimates >30,000 FCEV
- 2030 estimates >250,000 FCEV
- Is hydrogen infrastructure ready to deal with this number of FCEV?

FCV Numbers between 2014-2028

Pratt et al., 2015

UKH2Mobility
International HRS Rollout

- **California Republic**
  - 2015 ➔ 51 HRS
  - 2020 ➔ 87 HRS
  - 2030 ➔ >500 HRS

- **Germany**
  - 2015 ➔ 50 HRS
  - 2020 ➔ 300 HRS
  - 2030 ➔ 1,000 HRS

- **Japan**
  - 2015 ➔ 100 HRS
  - 2020 ➔ 187 HRS
  - 2030 ➔ >500 HRS

- **UK**
  - 2015 ➔ ~5 HRS
  - 2020 ➔ 65 HRS
  - 2030 ➔ 330 HRS

- **South Korea**
  - 2015 ➔ ~15 HRS
  - 2020 ➔ 168 HRS
  - 2030 ➔ 500 HRS
HRS Trade Flow Map

- HRS’s trade flow by number of stations
- Germany is leading European countries in production and installation of HRS’s
- Japan has a strategic plan for Hydrogen infrastructure (~100 HRS’s by end of 2015)
HRS Trade Flow by Capacity
IV Manufacturing Competitiveness of the HRS
HRS Capital Cost

Maeda, 2013

Elgowainy et al., 2013

Pratt et al., 2015
H₂ Compressor Manufacturing Cost Analysis

Process Flow

- Crank case
- Casting (Cast iron, ASTM class 40 or 50)
- Crank shaft
- Forging (Carbon steel AISI 1020)
- Bearings
- Sheet Forming (Carbon steel AISI 1020)
- Connecting Rod
- Forging (Carbon steel AISI 1020)
- Crosshead
- Visual Inspection
- Machining
- Cylinder
- Casting (Cast iron, ASTM class 40)
- Liner
- Forging (Carbon steel AISI 1020)
- Piston
- Visual Inspection
- Machining
- Piston Rod
- Hardening
- Casting (Low carbon steel, AISI 1037)
- Valve Seat & Guard
- Cleaning
- Machining
- Valve Poppets
- Forging (Low carbon steel, AISI 1037)
- Cleaning
- Machining
- Spring

Assembly → Testing

Compressor Cost (compressor capacity 100 kg H₂/day = 46 Nm³/hr)

Hydrogen Compressor Manufacturing Cost (for 100 kg/day HRS)
Minimum Sustainable Price

- Mexico’s advantage relative to the U.S. is driven by lower labor, building and energy costs
- China’s advantage relative to the U.S. is driven by low material cost, lower labor, building and energy costs
V Conclusions and Future Work
Conclusions and Future Work

- HRS capital cost is still high
- Lack of standardization results in higher capital cost
- Cost of HRS in Japan is ~2x the cost of HRS in Europe and United States, partially as a result of size and materials restrictions in Japan
- Future technologies and economies of scale will have great impact on the HRS cost and hydrogen prices

- **CEMAC is seeking collaborations with experts from academia, industry, and national labs.**
Thank You

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Twitter: @CleanEnergyMFG

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