CEMAC
Clean Energy Manufacturing Analysis Center

Insights from Hydrogen Refueling Station Manufacturing Competitiveness Analysis

Fuel Cell Seminar and Energy Expo. 2015

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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.

Agenda

I. Background

II. Current Analyses at CEMAC

III. International HRS Status

IV. Manufacturing Competitiveness of the HRS

V. Conclusions and Future Work

I Background

CEMAC Clean Energy Manufacturing Analysis Center

Operated by the Joint Institute for Strategic Energy Analysis

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.

CEMAC Responds to DOE Request

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

CLEAN ENERGY MANUFACTURING INITIATIVE
U.S. DEPARTMENT OF ENERGY

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

II Current Analyses at CEMAC

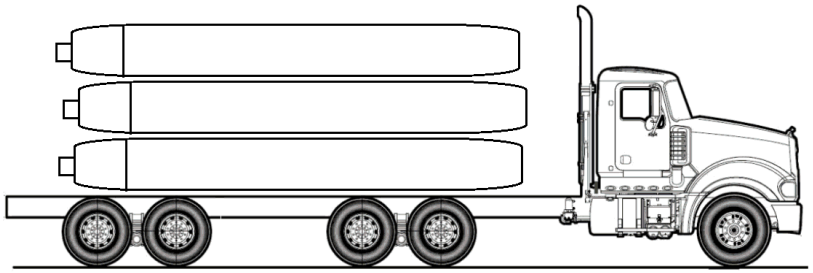
Current CEMAC Portfolio

TECHNOLOGY	DOE TECH OFFICE
WBG Devices for Industrial Motors	Advanced Manufacturing
Carbon Fiber for Lightweighting	Advanced Manufacturing
Biomass-Derived Chemicals & Products	BioEnergy
Conventional and Advanced Heat Pumps	Buildings
Energy-Efficient Insulated Windows	Buildings
LED Commercial Lighting	Buildings
Hydrogen Refueling Stations	**Fuel Cells Technology Office (FCTO)**
Geothermal Binary Power Plants	Geothermal
Solar PV	Solar Energy
Vehicle Li-ion Batteries	Vehicles
Wind Components via Additive Mfg	Wind and Water
Hydro Components via Additive Mfg	Wind and Water

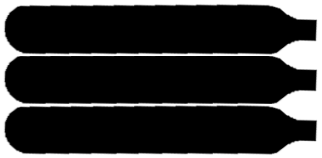
III International HRS Status

Hydrogen Delivery: Station Configurations

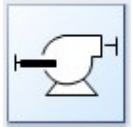
1. Hydrogen station with gaseous hydrogen delivery



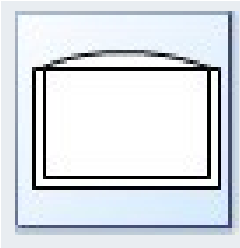
Truck delivery



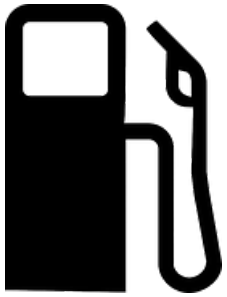
Compressed H_2 Tube storage



Compressor

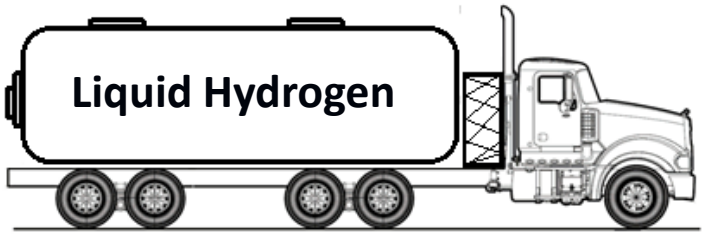


High pressure hydrogen storage/cooling



Dispenser

2. Hydrogen station with liquid hydrogen delivery



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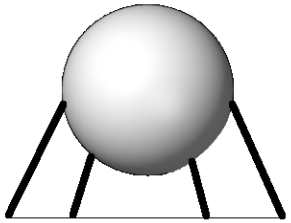
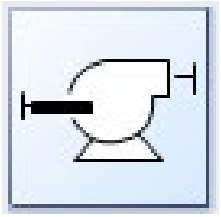
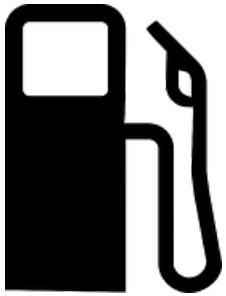


Liquid H_2 Tank

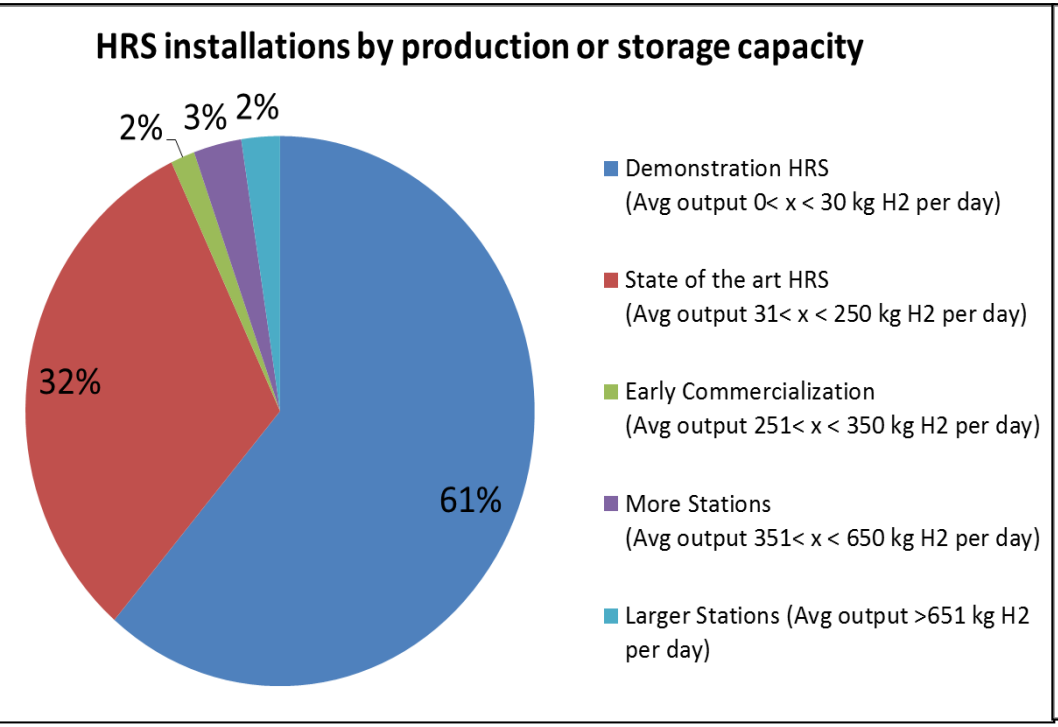


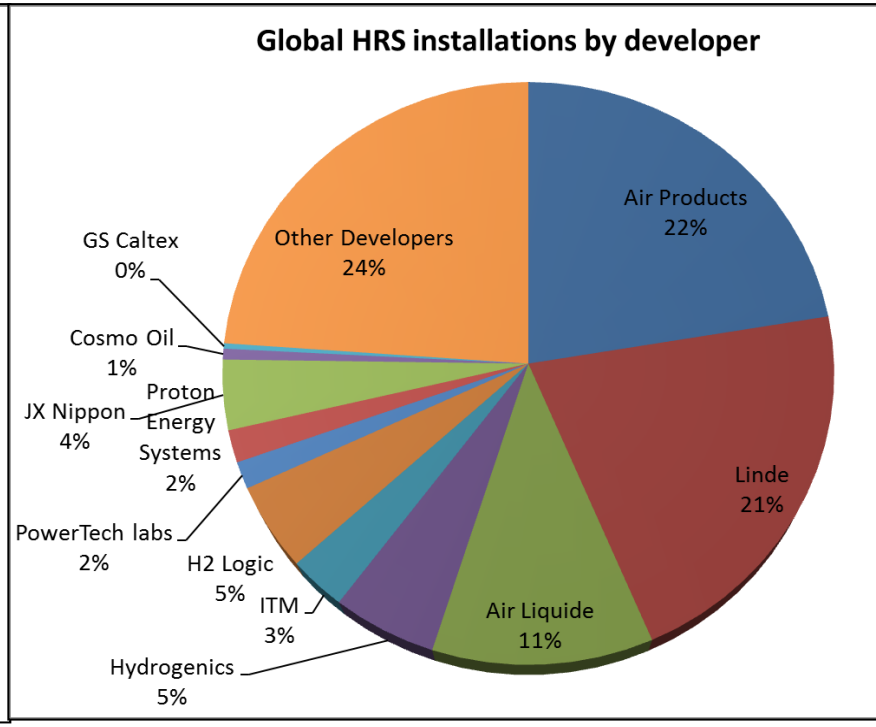
Cryogenic Pump

Evaporator



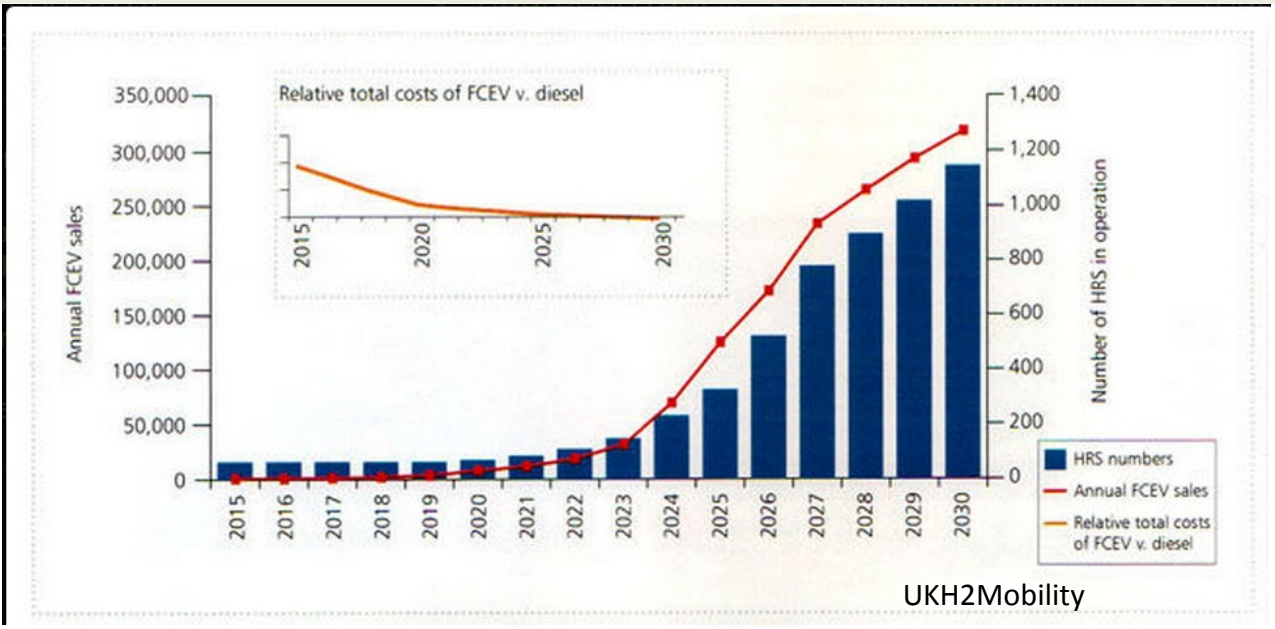
Main Focus





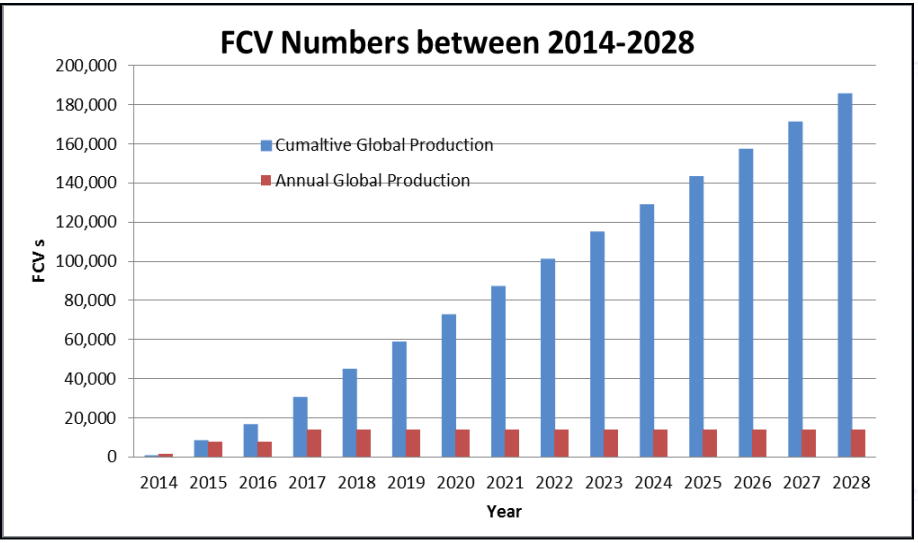
- More focus on large capacity HRS's >50 kg H_2 per day
- Demonstration and small size HRS's dominate the past 10 years installations

FCV Sales 2015-2030

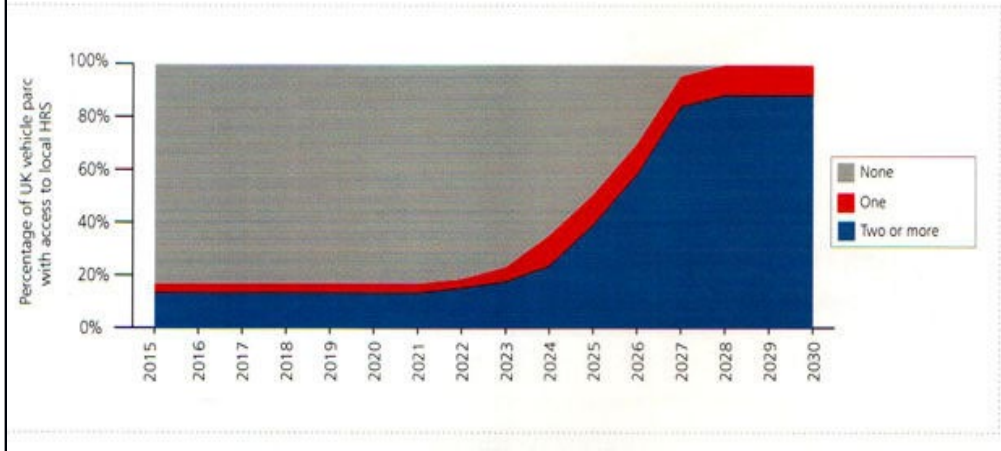


UKH2Mobility

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

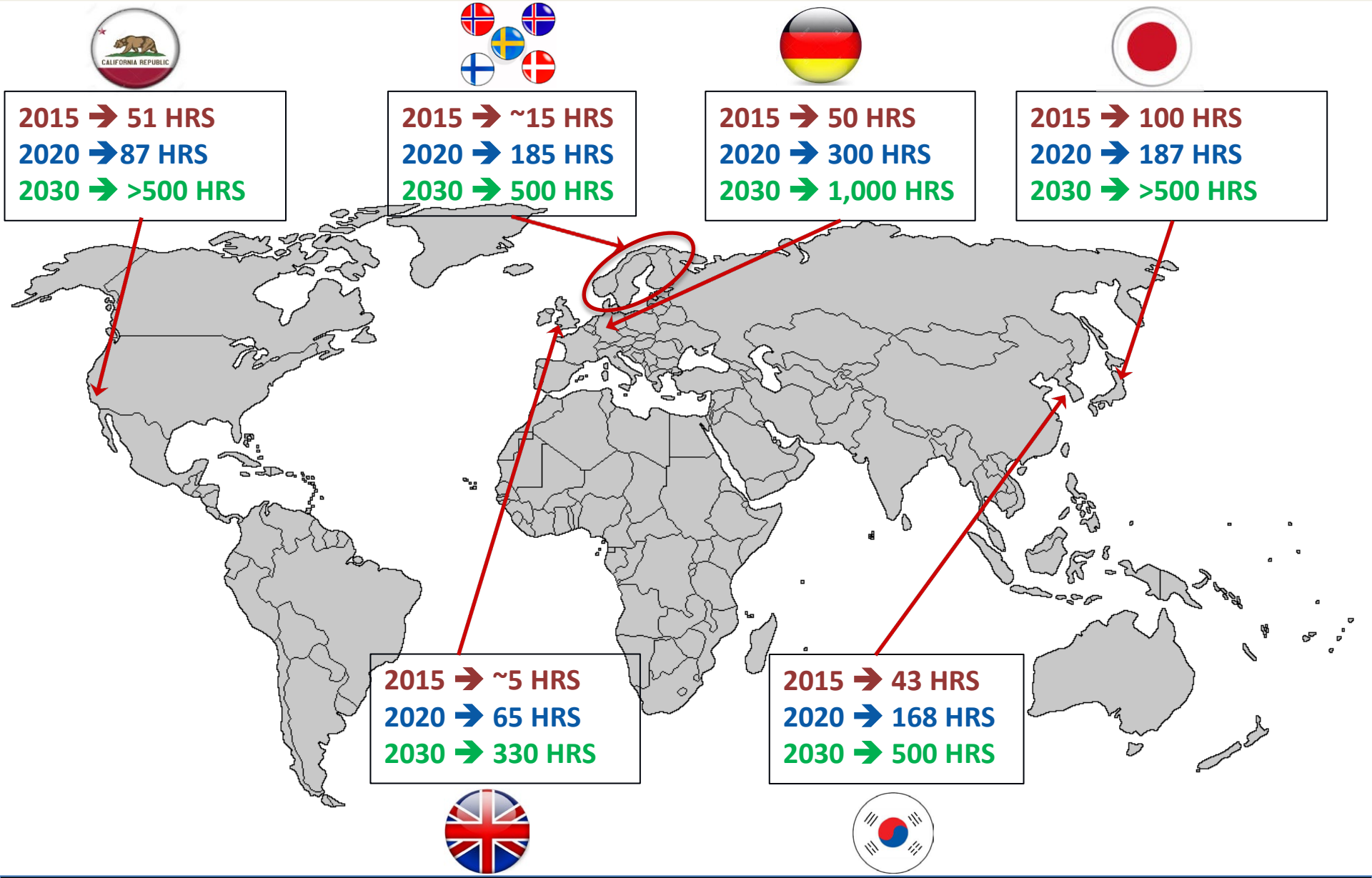


Pratt et al., 2015

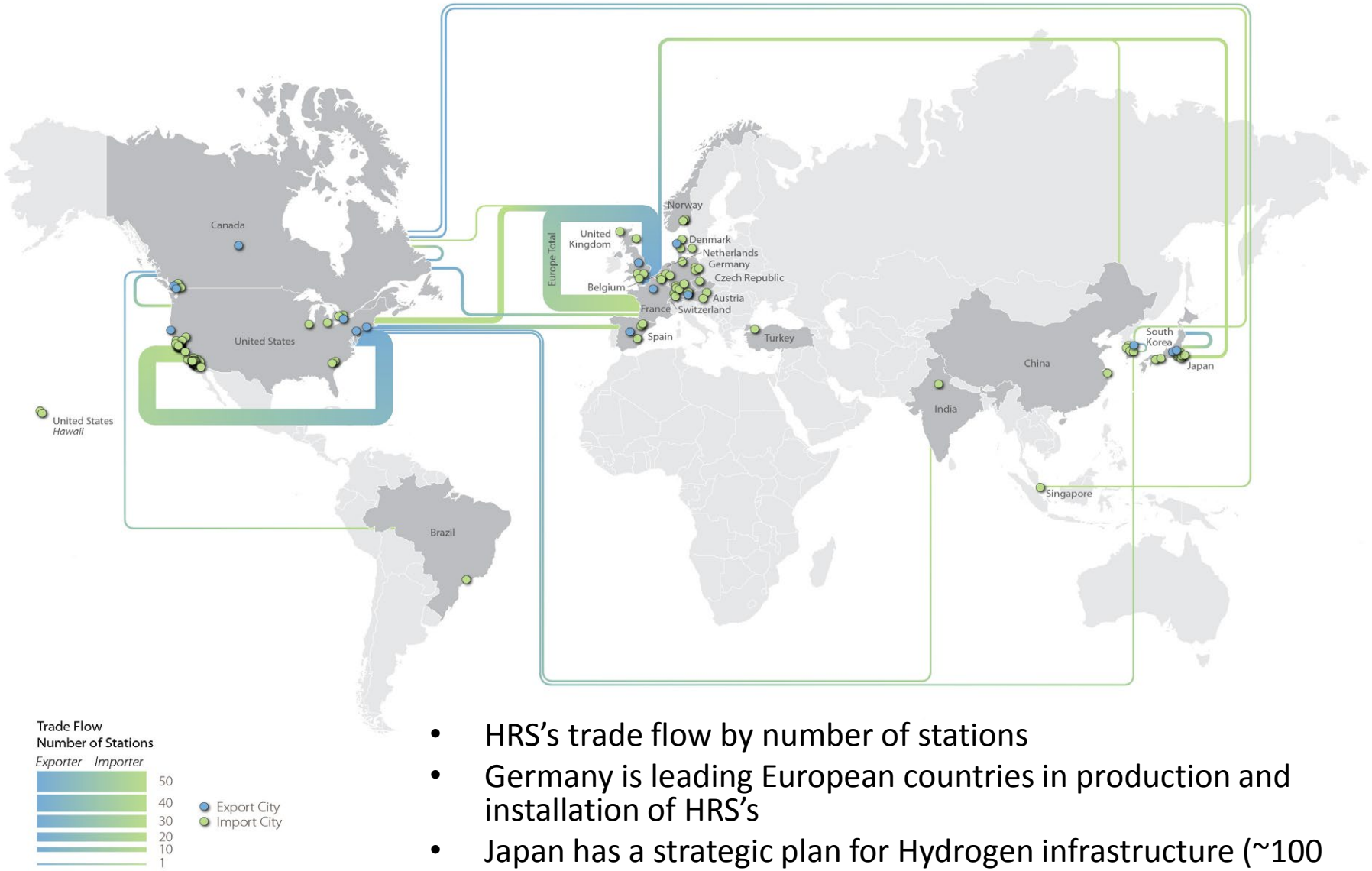


UKH2Mobility

International HRS Rollout

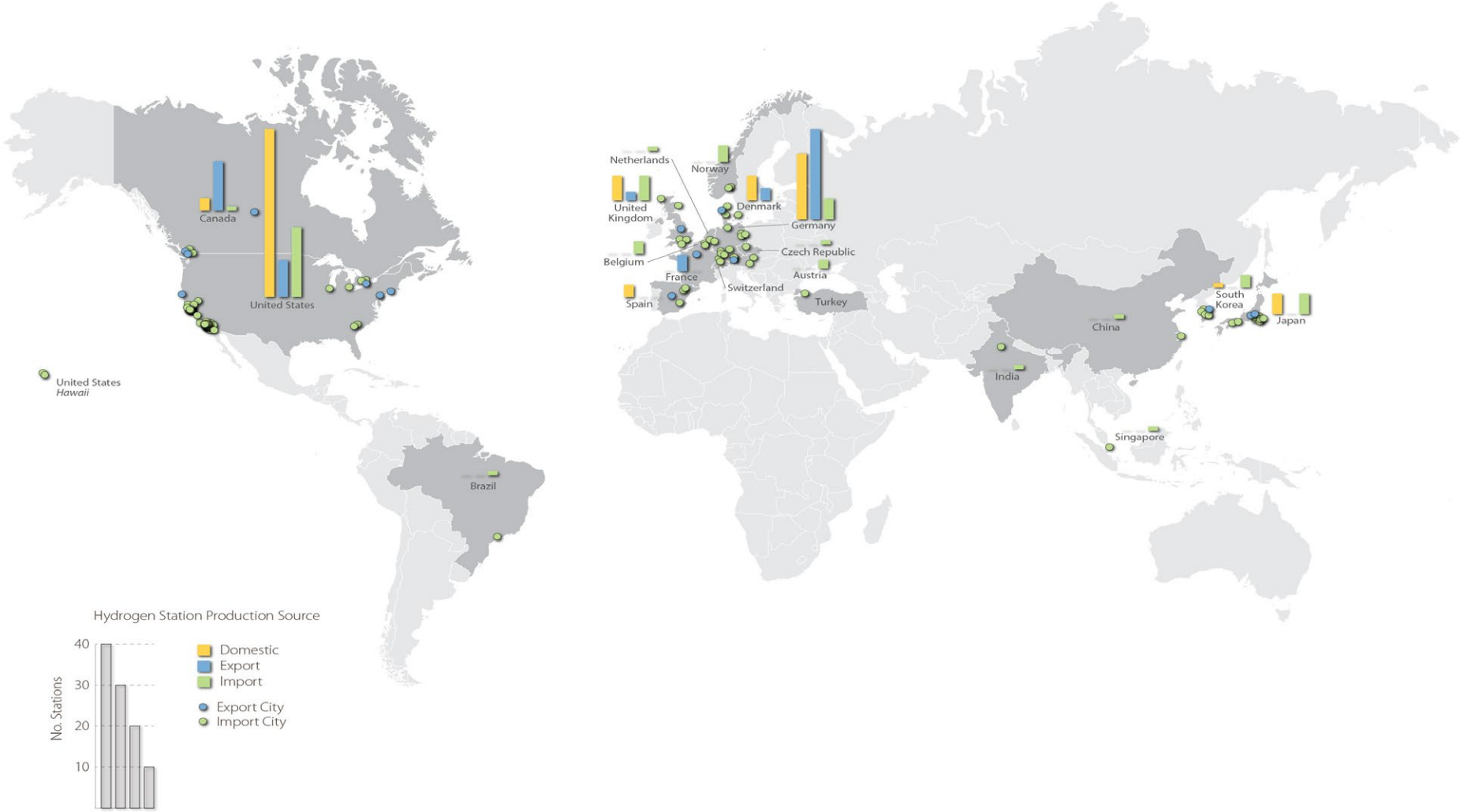


HRS Trade Flow Map

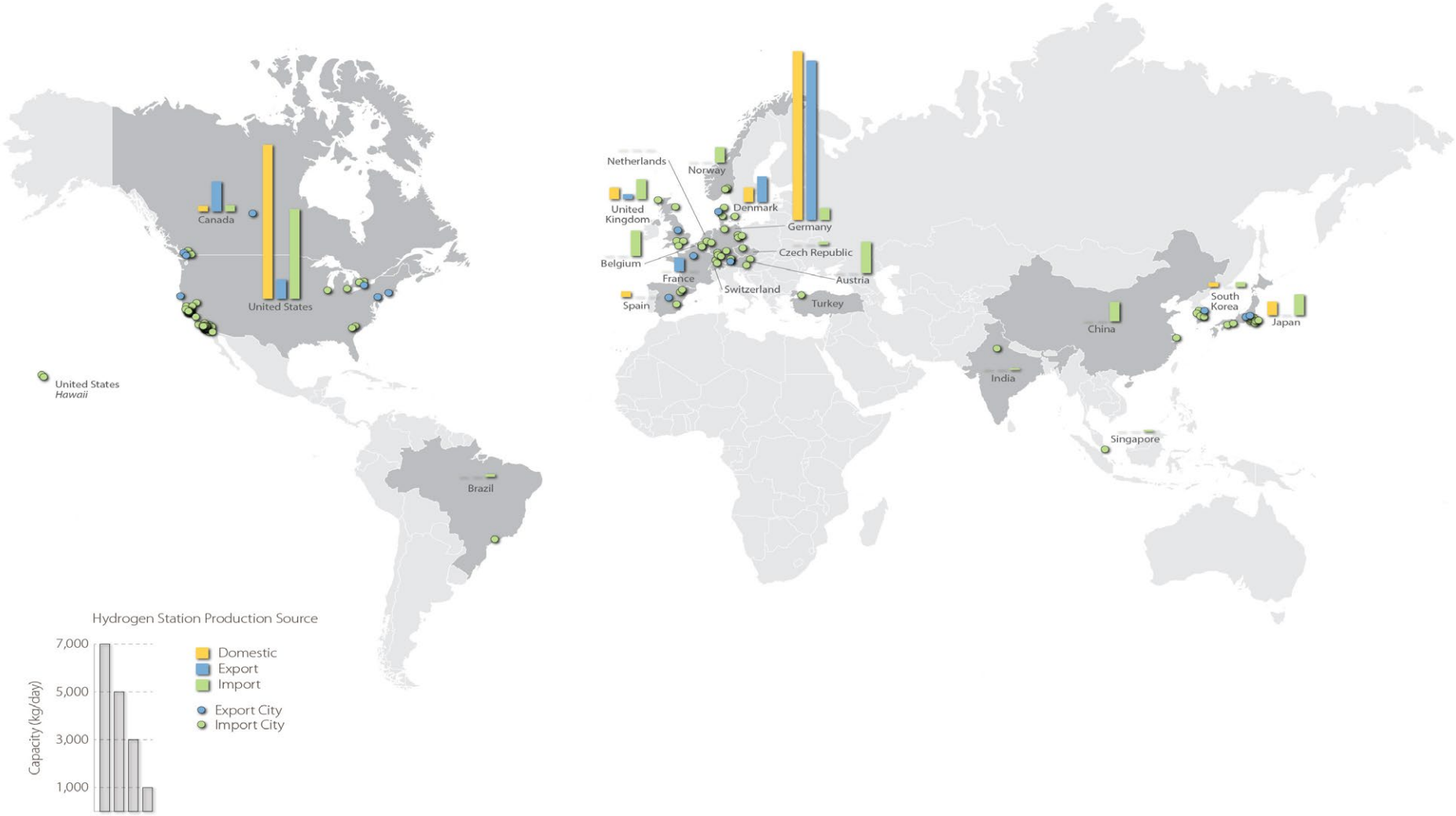


- HRS's trade flow by number of stations
- Germany is leading European countries in production and installation of HRS's
- Japan has a strategic plan for Hydrogen infrastructure (~100 HRS's by end of 2015)

HRS Trade Flow by Number

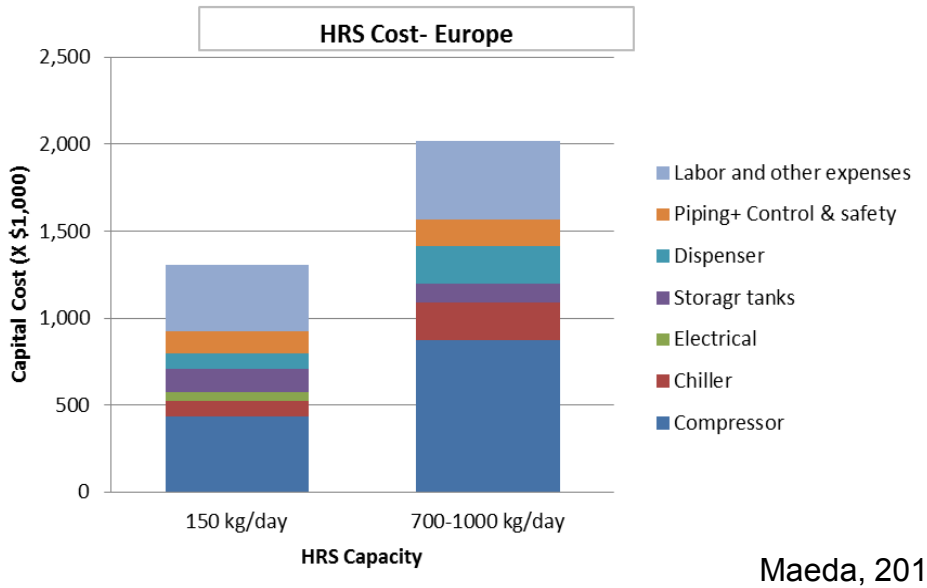


HRS Trade Flow by Capacity

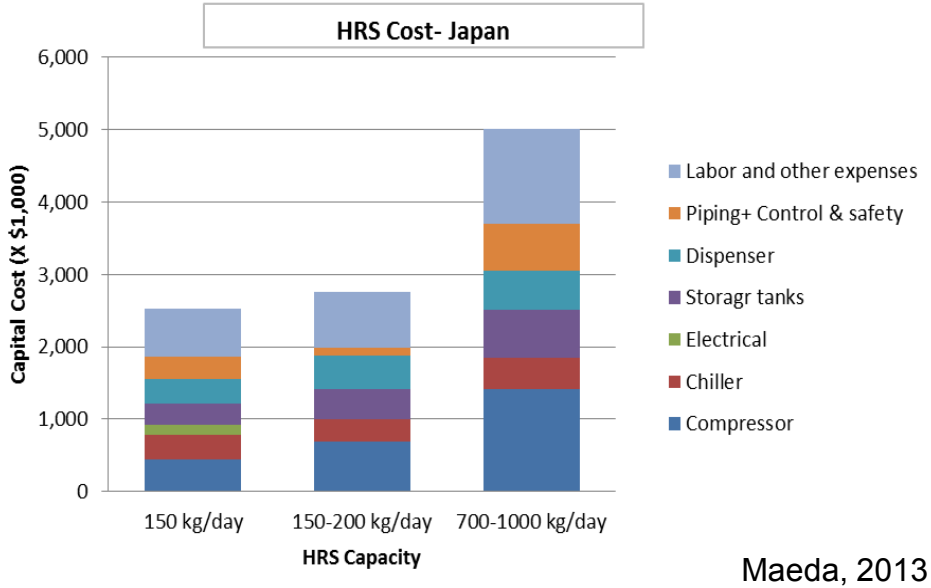


IV Manufacturing Competitiveness of the HRS

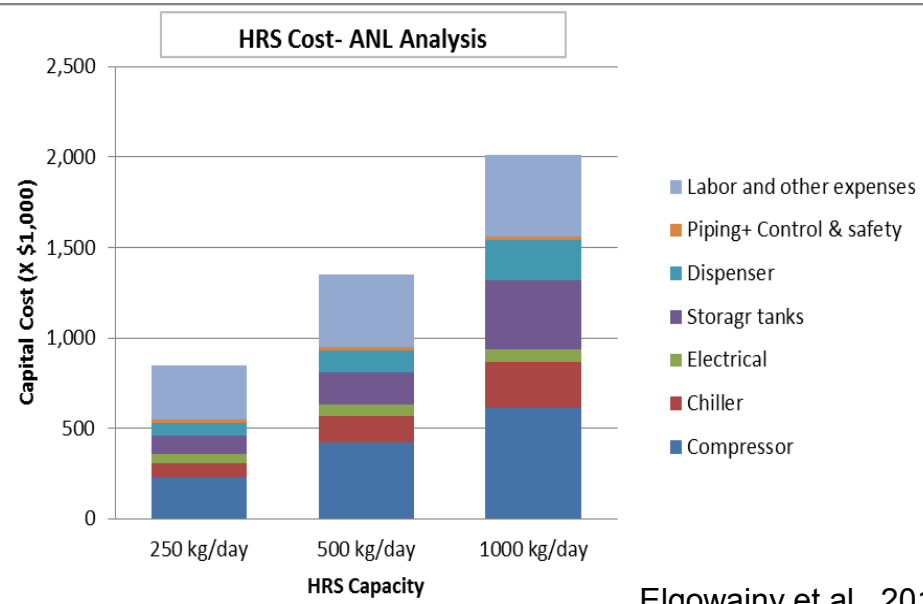
HRS Capital Cost



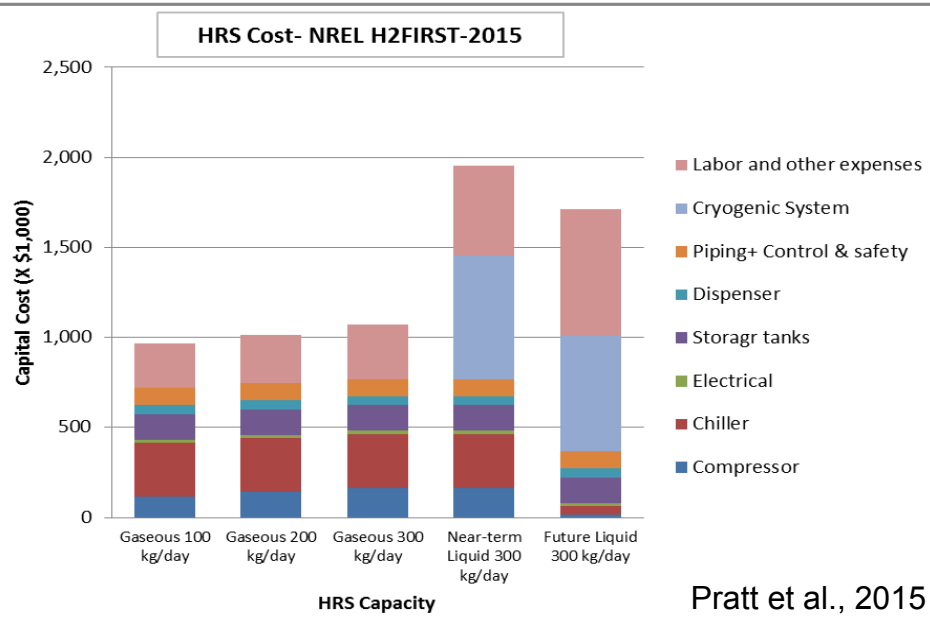
Maeda, 2013



Maeda, 2013

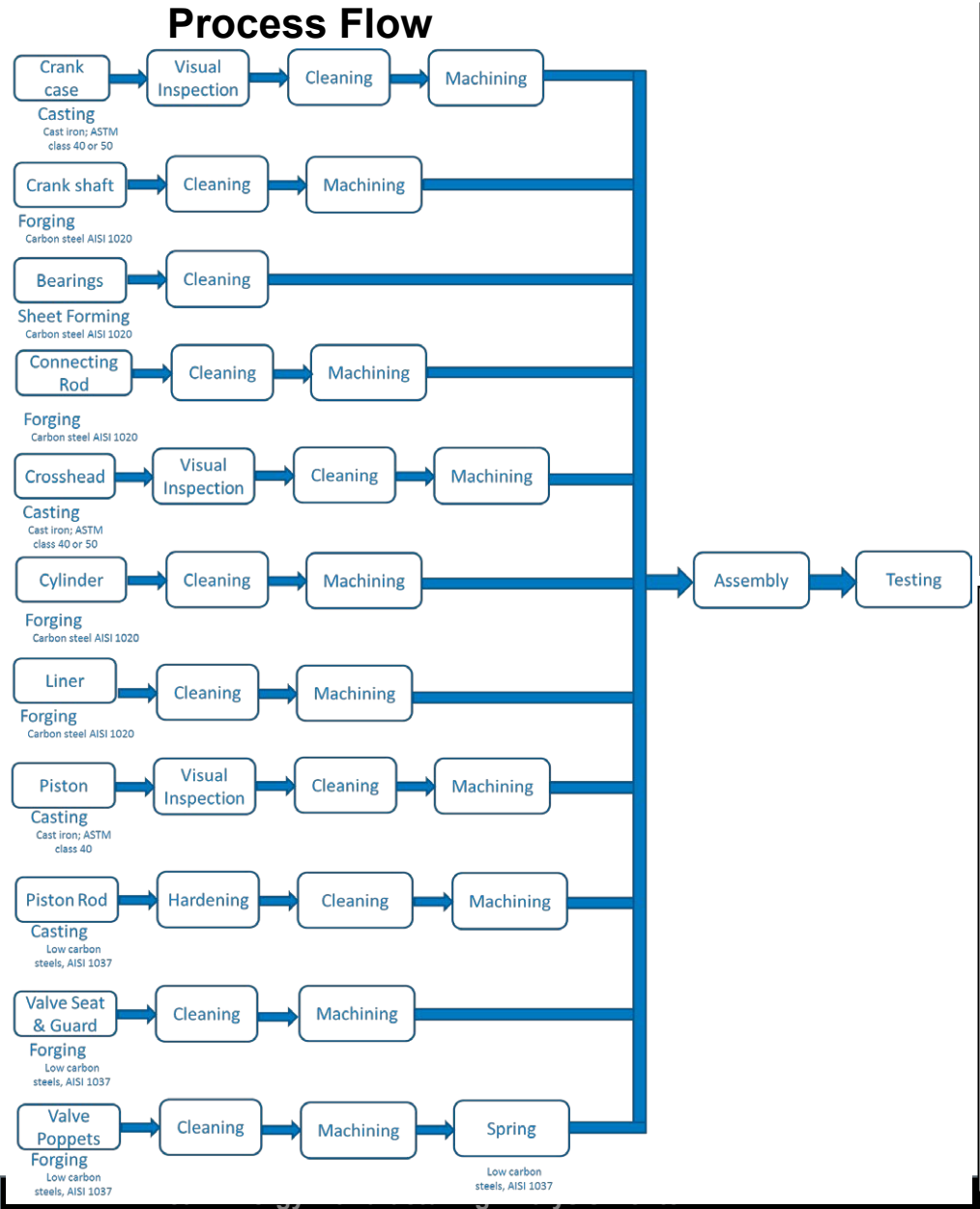


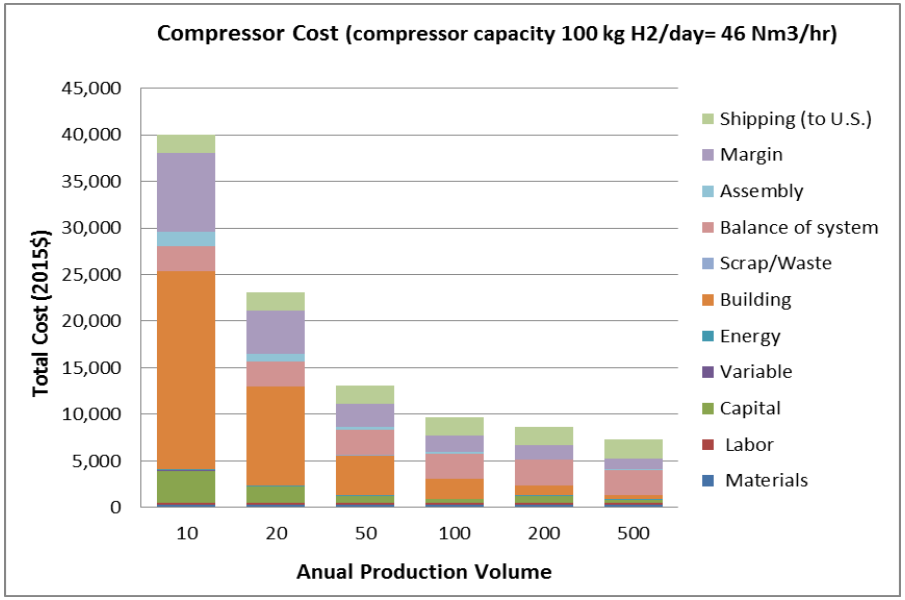
Elgowainy et al., 2013

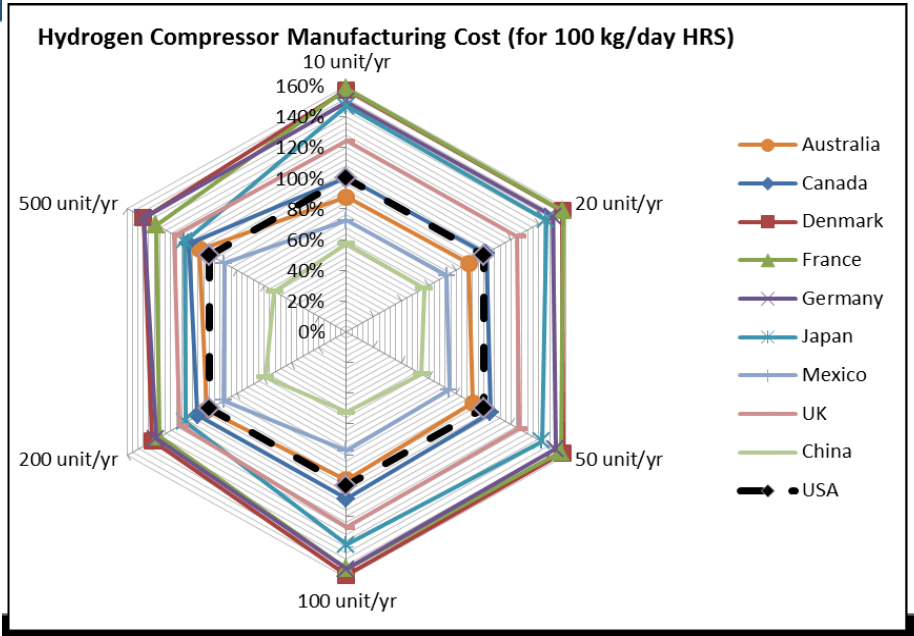


Pratt et al., 2015

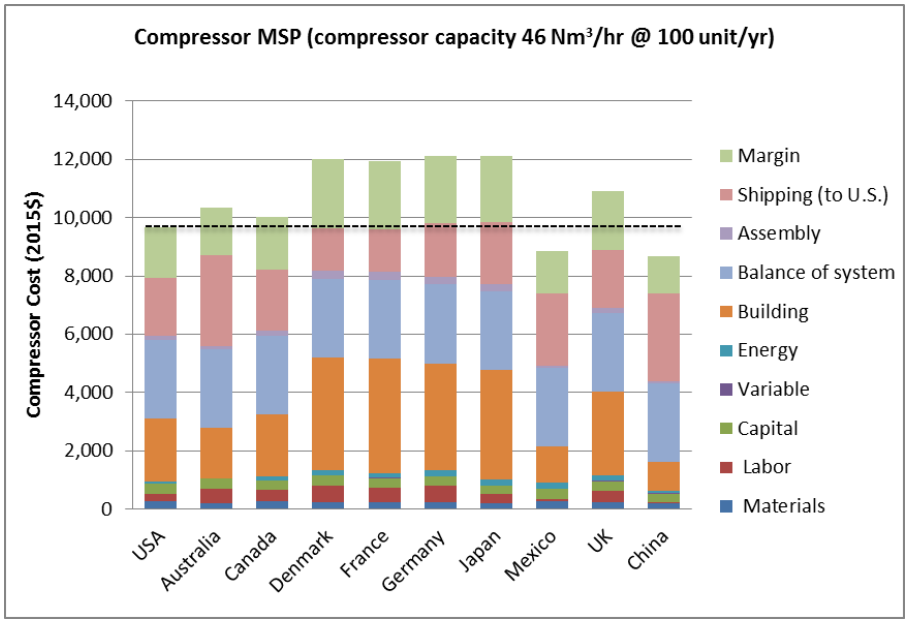
H_2 Compressor Manufacturing Cost Analysis

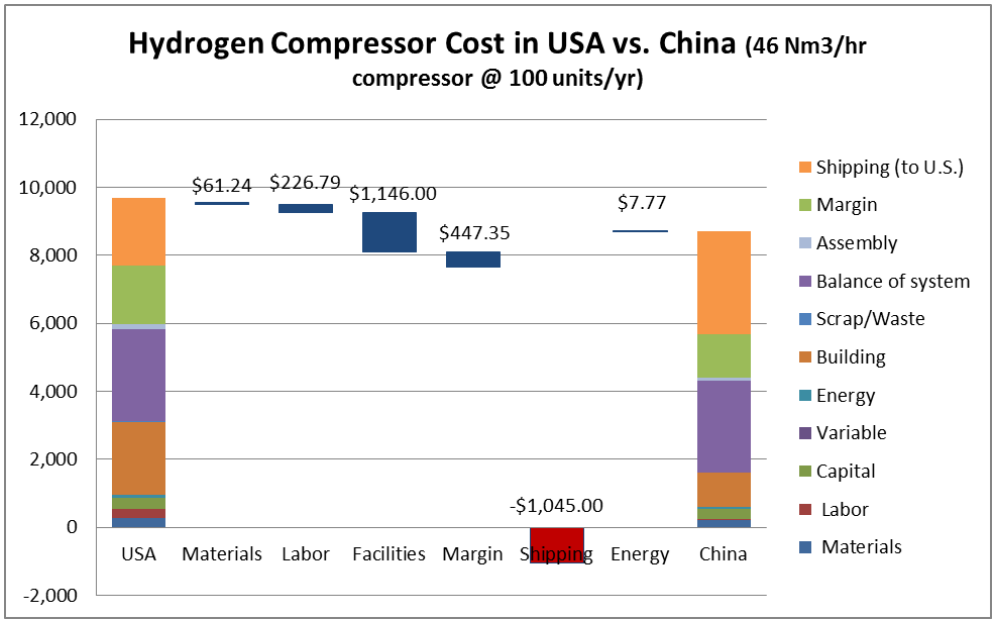






Minimum Sustainable Price





- 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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