VI.7 Manufacturing Competitiveness Analysis for Hydrogen Refueling Stations

Ahmad Mayyas (Primary Contact), Margaret Mann
National Renewable Energy Laboratory
15013 Denver West Parkway
Golden, CO 80401
Phone: (303) 384-7446
Email: Ahmad.Mayyas@nrel.gov

DOE Manager: Nancy L. Garland
Phone: (202) 586-5673
Email: Nancy.Garland@ee.doe.gov

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Overall Objectives

- Develop manufacturing cost models for major components in hydrogen refueling stations including compressors, storage system, dispenser, chiller and heat exchanger.
- Identify cost drivers associated with manufacturing hydrogen station parts and systems and highlight potential cost reduction opportunities through economies of scale and standardization.

Fiscal Year (FY) 2016 Objectives

- Develop analytical models to estimate capital costs for hydrogen refueling stations.
- Provide a platform for a manufacturing cost analysis for major hydrogen refueling station (HRS) systems and components.
- Identify cost drivers of hydrogen compressors which constitute approximately 40%–60% of the total HRS capital cost.
- Identify cost drivers of various storage tank technologies and configurations.
- Investigate the effect of learning experience on the chiller, heat exchanger, and dispenser costs.

Technical Barriers

This project addresses the following technical barriers from the Hydrogen Delivery section of the Fuel Cell Technologies Office Multi-Year Research, Development, and Demonstration Plan.

(A) Lack of Hydrogen/Carrier and Infrastructure Options Analysis

(B) Reliability and Costs of Gaseous Hydrogen Compression

(E) Gaseous Hydrogen Storage and Tube Trailer Delivery Costs

Contribution to Achievement of DOE Hydrogen Delivery Milestones

This project will contribute to achievement of the following DOE milestones from the Hydrogen Delivery section of the Fuel Cell Technologies Office Multi-Year Research, Development, and Demonstration Plan.

- Milestone 6.1: Define potential research, development, and demonstration activities for other long-term market fueling/terminal needs. (4Q 2015)
- Milestone 6.3: By 2020, reduce the cost of hydrogen delivery from the point of production to the point of use in consumer vehicles to less than $2/gge of hydrogen for the gaseous delivery pathway. (4Q 2020).

FY 2016 Accomplishments

In FY 2016 we have:

- Developed a regression analysis to estimate capital and installation costs for hydrogen stations in different regions in North America, Europe, and Asia.
- Developed manufacturing cost models for hydrogen piston compressors with different compression capacities.
- Developed manufacturing cost models for Type I hydrogen pressure vessels, dispensers, heat exchangers, and chillers.
- Developed a set of supply chain and international trade flows for installed hydrogen stations in the past 11 years (2005–2016).

INTRODUCTION

This study has two main goals: (1) develop manufacturing competiveness analysis for hydrogen stations by evaluating manufacturing cost of principal components in the hydrogen stations in some countries in North America, Europe, and Asia; and (2) develop supply chain and

international trade flow maps to help decision makers visualize the primary trade flows in the international markets and to spot the main markets for hydrogen station components.

APPROACH

This study includes three major analyses: manufacturing competiveness, supply chain analysis, and an assessment of the effect of qualitative factors on selection of the factory locations for manufacturing hydrogen compressors and other parts in the hydrogen refueling stations.

Manufacturing competiveness analysis is used to evaluate relative manufacturing cost in selected countries in North America, Europe, and Asia, for the principal components in the hydrogen stations including compressors, storage vessels, chillers, heat exchangers, and dispensers. Supply chain analysis was conducted with the aid of trade flow maps which show main trade flows between international markets from country of production to the installation locations. This study also seeks to address major factors that play a role in selecting manufacturing locations in the United States and other countries and considers how these factors can act as measures of competitiveness in these countries. Examples of these qualitative factors include manufacturing experience, product quality, skilled labor requirements and availability, tax policy, and currency fluctuations.

RESULTS

Hydrogen Refueling Station Capital Cost

Knowing that the United States, Germany, Japan, and South Korea are the leading countries in terms of fuel cell vehicles and required hydrogen refueling infrastructure, we collected data to evaluate relative capital cost in these countries and to investigate the effect of governmental and safety regulations on the overall hydrogen station equipment and installation costs (Figure 1). We found that hydrogen station cost is increasing with the capacity of the station (expressed in dispensed kg H_2 per day) in all countries. In Japan, the relative cost of hydrogen stations doubled as a result of safety and standard regulations enacted due to seismic activity and recent earthquakes (Figure 1c).

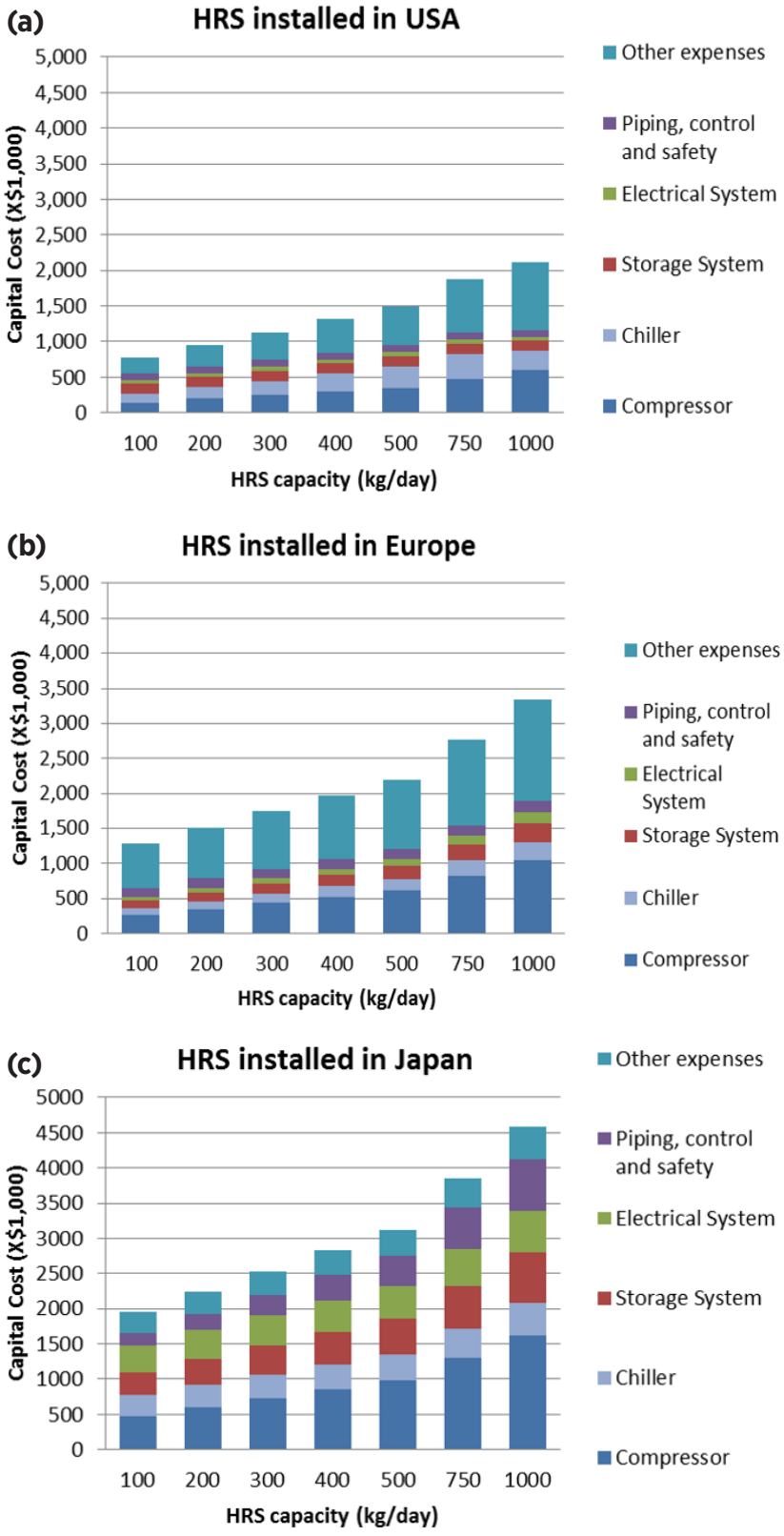

FIGURE 1. Capital and installation costs for HRS installed in: (a) United States; (b) Europe; and (c) Japan

Manufacturing Competitiveness Analysis

This analysis dives deeper into cost drivers associated with manufacturing of some systems and major parts in the hydrogen stations such as hydrogen compressors, Type I storage tanks, dispensers, chillers, and heat exchangers. Taking an example for piston compressors, manufacturing cost analysis starts with a process flow diagram, which shows a series of individual casting and hot forging steps, followed by cleaning and machining steps for individual components, and then assembly of these components into one structural unit to form the compressor housing and its internal parts (Figure 2a). After that, other components that make the balance of system such as the motor, control unit, valves, and sensors, can be added to get the final product. Once we get the direct manufacturing cost (Figure 2b) and balance of system cost with the required assembly cost, we can add a profit margin and shipping cost to estimate the minimum sustainable price (MSP) which is defined as the minimum price that sustains a manufacturer's business (Figure 2c). The MSP curve indicates potential cost reductions from producing more units in a manufacturing facility as direct results of better resource utilizations.

A comparative cost analysis using minimum sustainable prices was performed for piston compressors in some countries (Figure 3a). Figure 3b shows a comparison between Chinese- and United States-based manufacturing facilities. Both figures show that Chinese- and Mexican-based manufacturers have advantages of lower labor cost, lower building cost, lower materials cost, and lower energy cost (China only).

Supply Chain and Trade Flow Maps

This analysis is used as a qualitative measure to assess manufacturing competiveness in selected countries and investigate level of specialization in manufacturing certain components used in HRS.

CONCLUSIONS AND FUTURE DIRECTIONS

This project provides a set of manufacturing competitiveness and supply chain analyses that can help in understanding cost associated with manufacturing major components used in hydrogen stations. Bottom up cost analysis using design for manufacturing and assembly

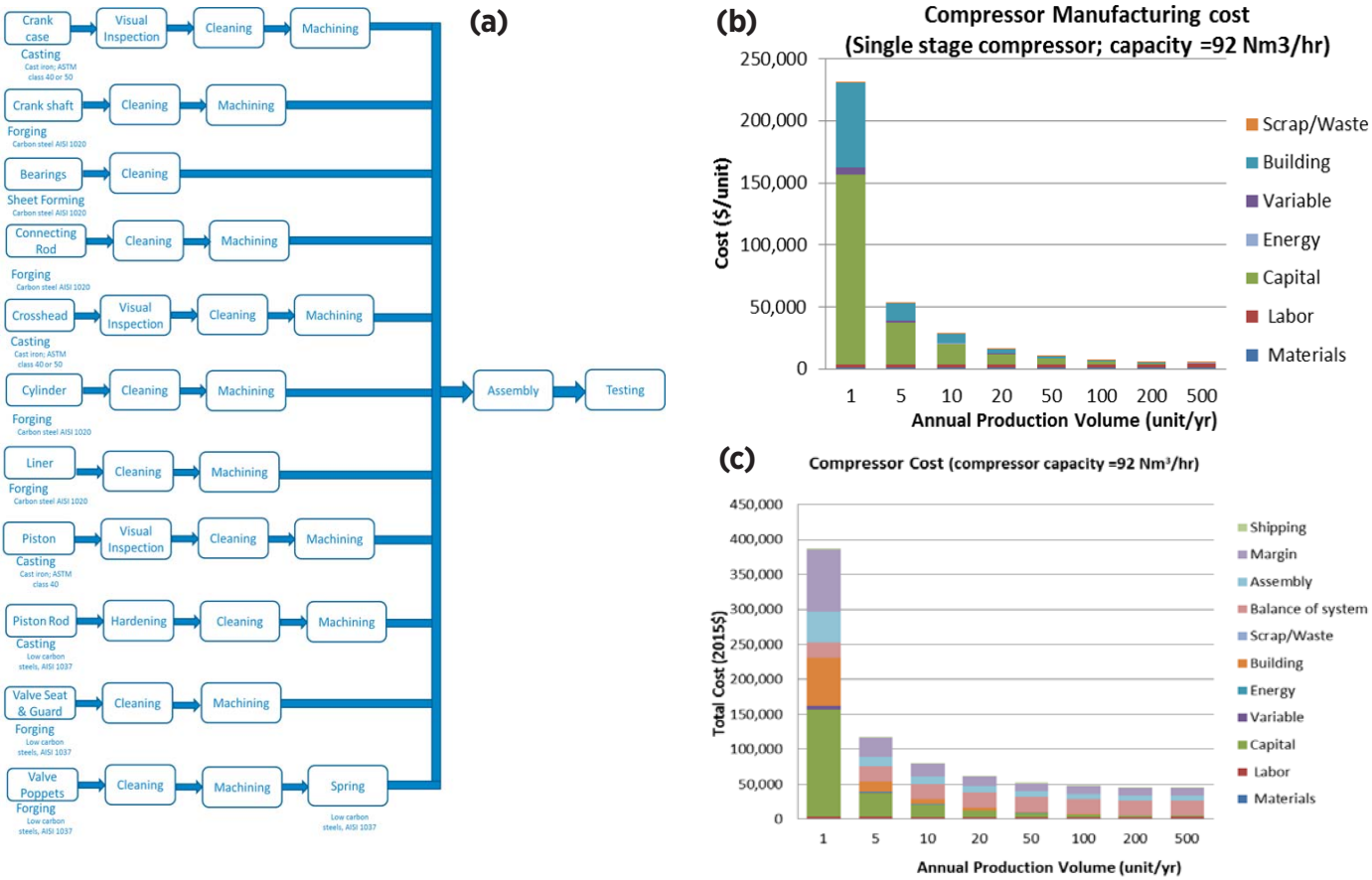

FIGURE 2. (a) Process flow diagram for making piston compressors; (b) direct manufacturing cost for compressor housing and internal parts as function of annual production rate (units/yr); (c) minimum sustainable price for piston compressors as function of annual production rate (units/yr)

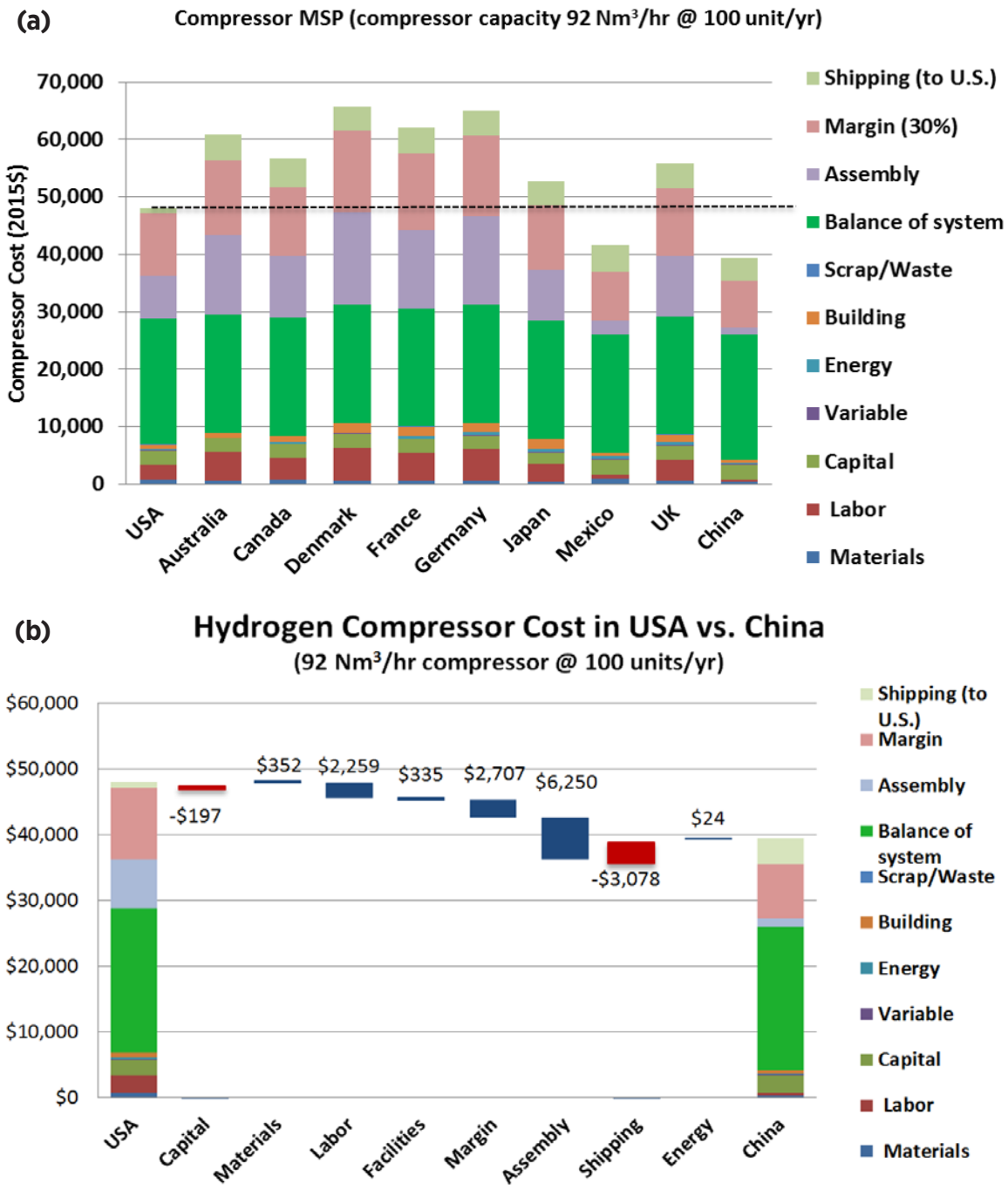

FIGURE 3. (a) Minimum sustainable prices for hydrogen piston compressors in some countries; (b) comparative cost analysis using MSP between United States- and Chinese-based manufacturers

methodology was used to develop a manufacturing cost model and was added to the balance of system and assembly costs to get equipment cost. This cost then was added to the profit margin and shipping cost to estimate MSP for several systems in the hydrogen station such as compressors, dispensers, storage vessels, chillers, and heat exchangers. Cost curves using MSP values for piston compressors indicate that cost reductions of 50% or more can be achieved if 100 units/yr are manufactured, relative to costs at production levels of 10 units/yr.

Based on international trade flow maps shown in Figure 4, we can say that that the United States and Germany, followed by Canada and Japan, are the leading countries in the number of manufactured hydrogen stations and number of installations.

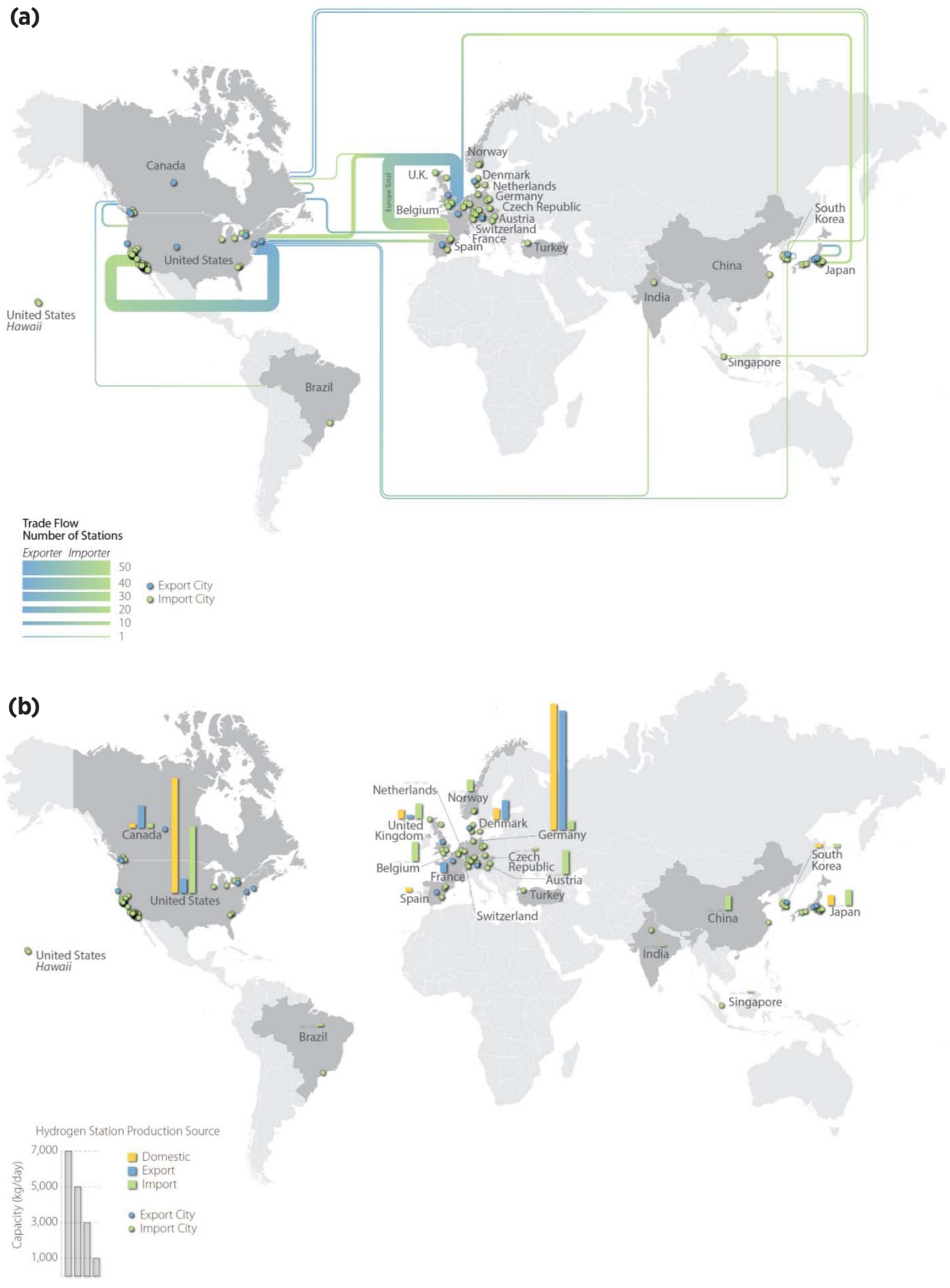

FIGURE 4. (a) International trade flows for hydrogen refueling stations; and (b) hydrogen refueling stations classified by countries of production and countries of installations

For FY 2017, manufacturing cost models and minimum sustainable price curves will be developed for other systems in hydrogen stations such as Type I storage tanks, dispensers, heat exchangers, and chillers. Then, the estimated MSP values will be summed to estimate the capital cost of HRS in different regions, followed by an analysis of the effect of cost reductions on hydrogen prices.

FY 2016 PUBLICATIONS/PRESENTATIONS

1. Ahmad Mayyas, "Clean Energy Manufacturing Analysis Center: A Case Study of the Fuel Cell Manufacturing Supply Chain Analysis." Fuel Cell Seminar and Energy Exposition. November 19, 2015, Los Angeles, CA.

2. Ahmad Mayyas, "Manufacturing Competitiveness Analysis for Hydrogen Refueling Stations." Presentation at the Annual Merit Review, June 8, 2016. Washington, DC.

3. Ahmad Mayyas, "Analysis of Current and Future Technologies for Hydrogen Refueling Stations From Manufacturing Competitiveness and Supply Chain Perspectives." Advanced Automotive Batteries Conference, June 17, 2016. Detroit, MI.