U.S. DEPARTMENT OF ENERGY

Office of ENERGY EFFICIENCY & RENEWABLE ENERGY

Hydrogen and Fuel Cells Overview: Opportunities for Ports & Maritime Applications

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U.S. Department of Energy

H2@Ports Workshop

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Energy Policy Act (2005) Title VIII on Hydrogen

Authorizes U.S. DOE to lead a comprehensive program to enable commercialization of hydrogen and fuel cells with industry.

Includes broad applications: Transportation, utility, industrial, portable, stationary, etc.

Program To-Date

- ~ $150M to $250M/year
- ~ 100 to 200+ Projects/year
- >100 Organizations

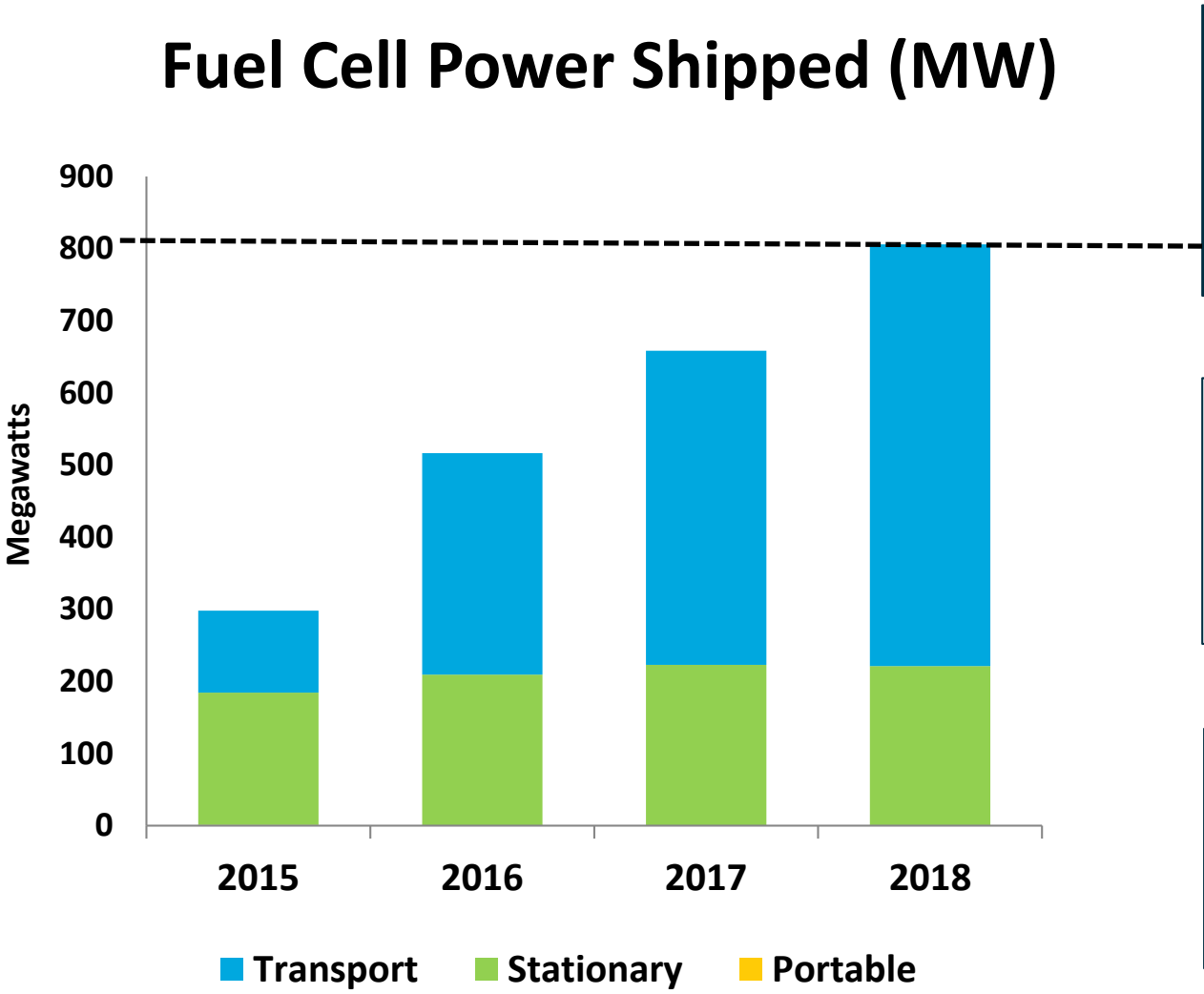
Includes RD&D on:

- H_2 production, delivery, storage, utilization (including fuel cells)
- Crosscutting: Analysis, systems development/integration, safety, codes and standards, education & outreach

Collaboration

- Federal and State Agencies
- Industry
- Regional partnerships, associations, trade organizations, codes and standards development organizations, etc.
- National labs, institutes, universities
- International

Fuel Cell Shipments - Growth by Application



800 MW
fuel cell power
shipped worldwide

68,500
fuel cell units
shipped worldwide

Approximately
$2.3 Billion
fuel cell revenue*

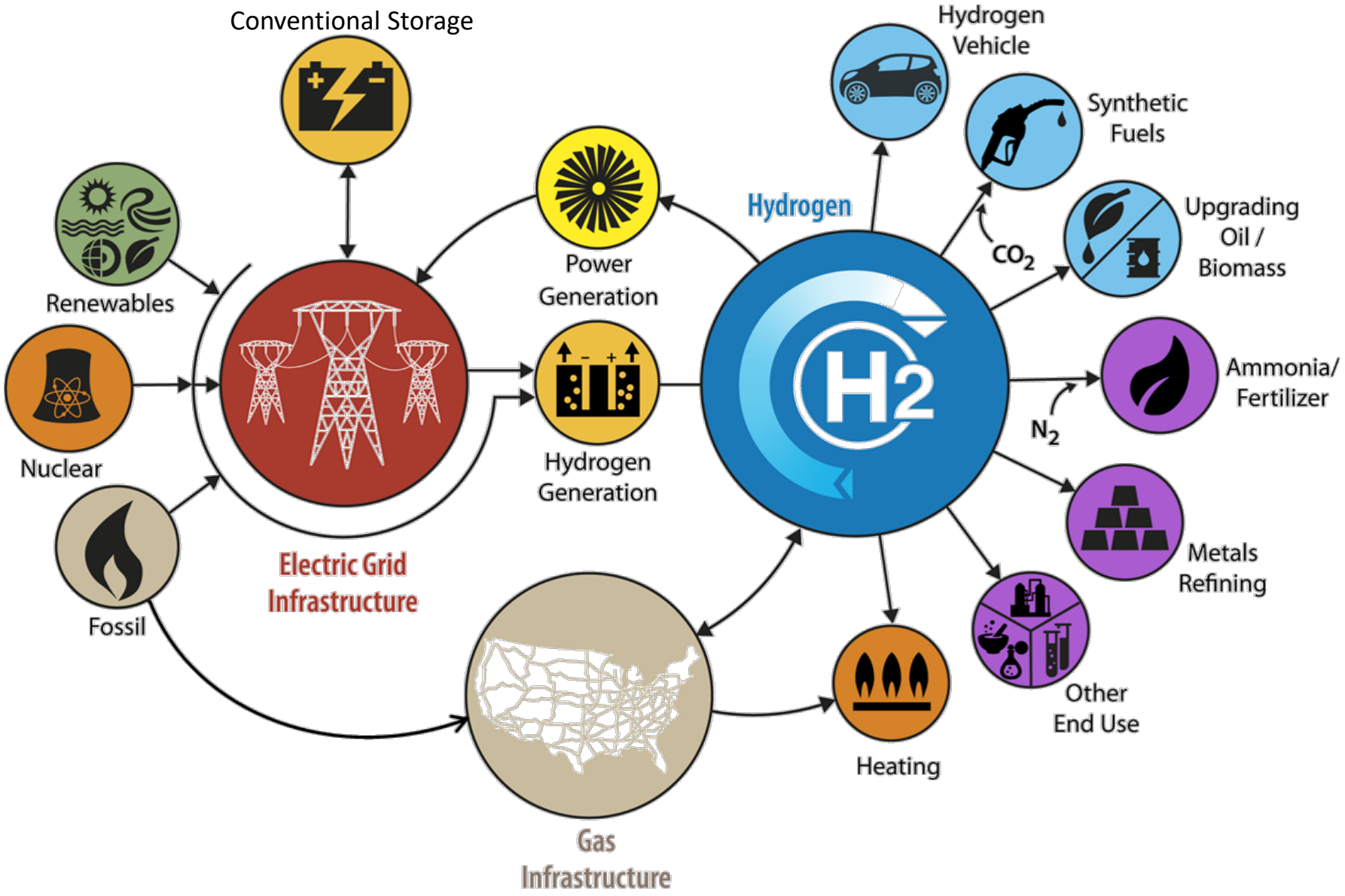
* Revenue from publicly available

Source: DOE and E4Tech

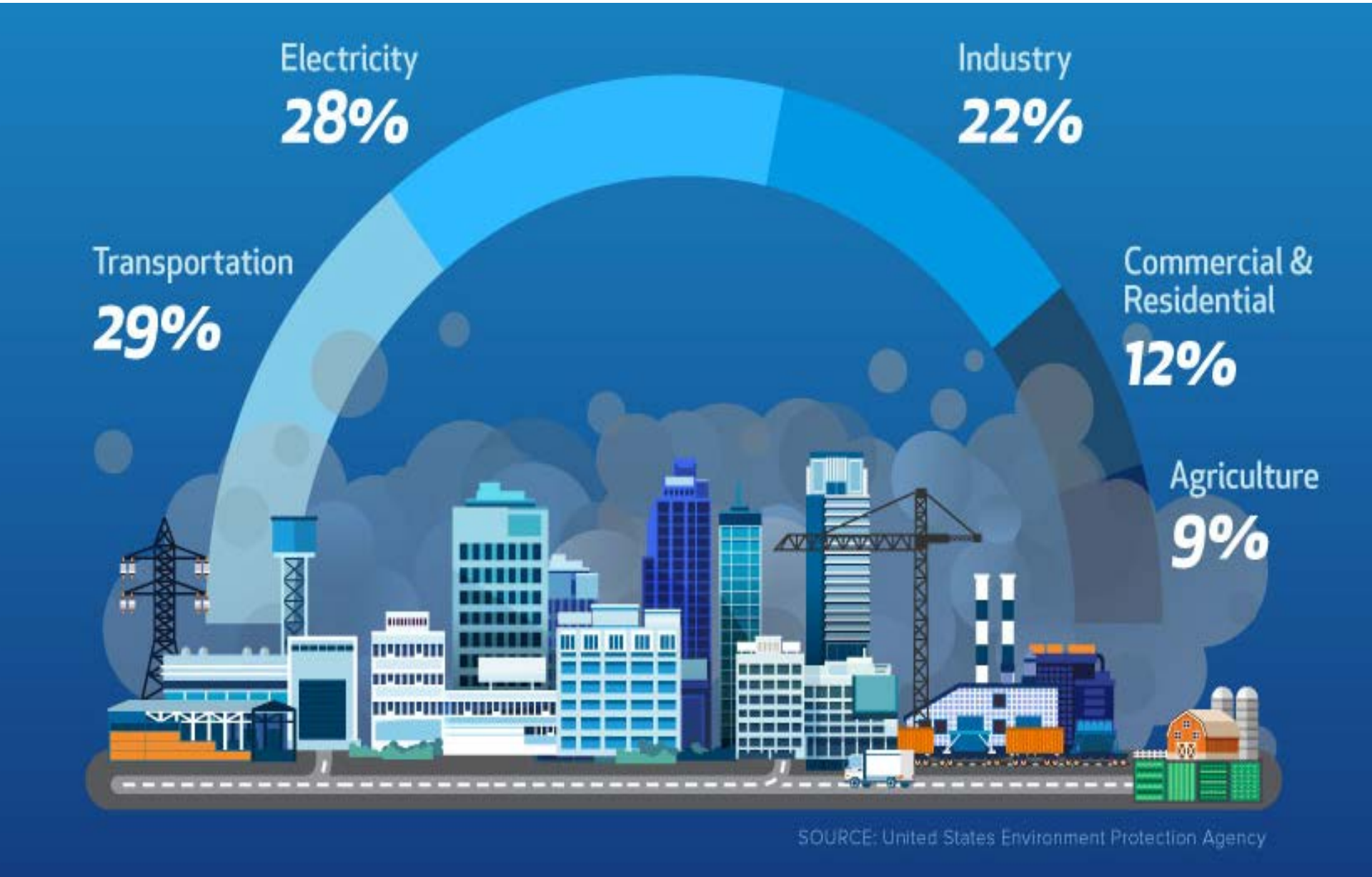
Commercial Hydrogen and Fuel Cell Technologies are now Available

Over 300,000 stationary fuel cells, 12,000 fuel cell cars, 300 stations worldwide. Heavy duty, rail, marine, aviation emerging.

Hydrogen is part of a Comprehensive Energy Strategy

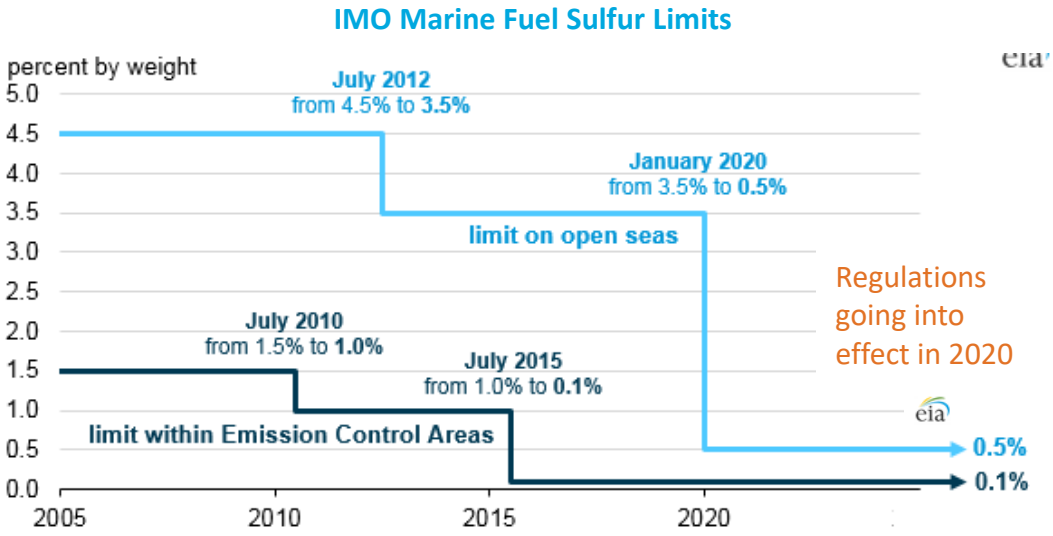


Transportation Is Now #1 Emissions Contributor



Hydrogen Fuel Cell Technologies for Marine Applications

Hydrogen can be used as a zero-emission fuel for marine & port applications



Source: Zhen, L., Li, M., Hu, Z., Lv, W., & Zhao, X. (2018). The effects of emission control area regulations on cruise shipping. *Transportation Research Part D: Transport and Environment*, *62*, 47-63.

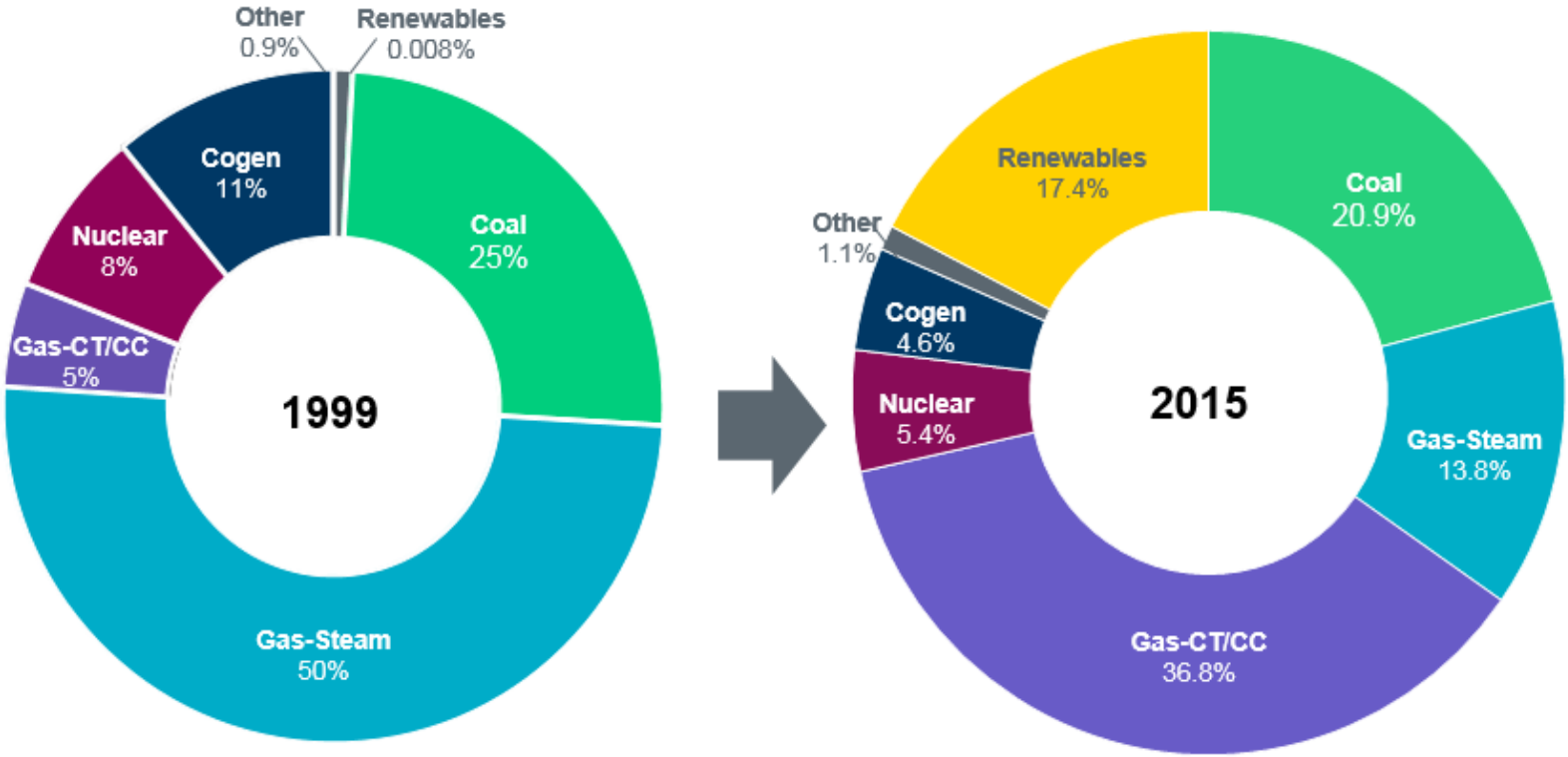
Today's maritime industry:

- Consists of about 2 million marine vessels worldwide
- Transports >90% of goods
- Consumes over 300 million tonnes of fuel consumed/year
- Produces 3% of global CO_2 emissions
- Constitutes the largest source of SO_x emissions

Hydrogen and ammonia are being pursued internationally as potential renewable, zero-emission marine fuels

Electricity Mix is Changing

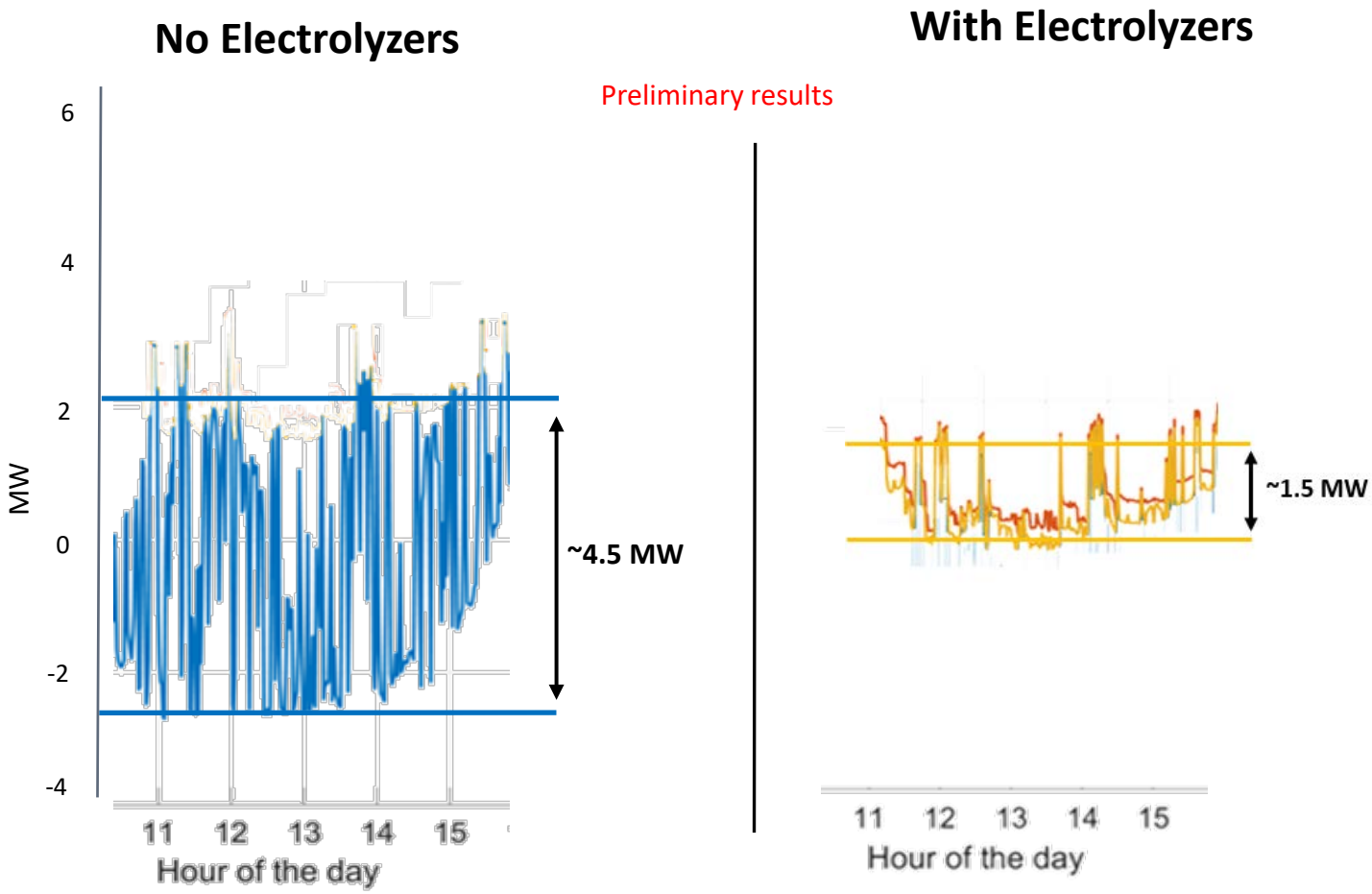
Example: Installed Capacity in Texas



Source: ERCOT, DOE H2@Scale Workshop, TX

Example: Hydrogen can help address grid needs

Preliminary study shows electrolyzers can reduce amplitude of power fluctuations in a grid with high renewables



Source: D. Murphy, et al, NREL and INL. Specific case with high solar penetration and electrolyzers used to compensate for power fluctuations

Hydrogen can enable long term energy storage and grid services

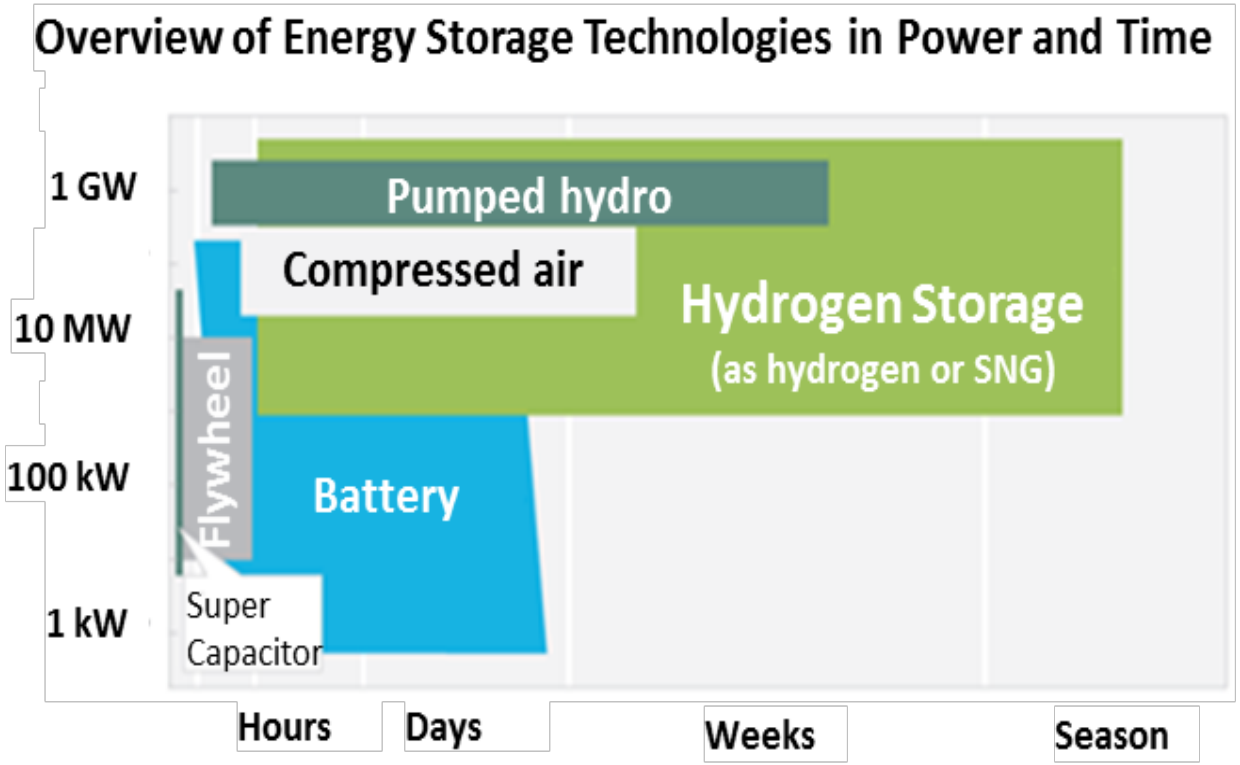


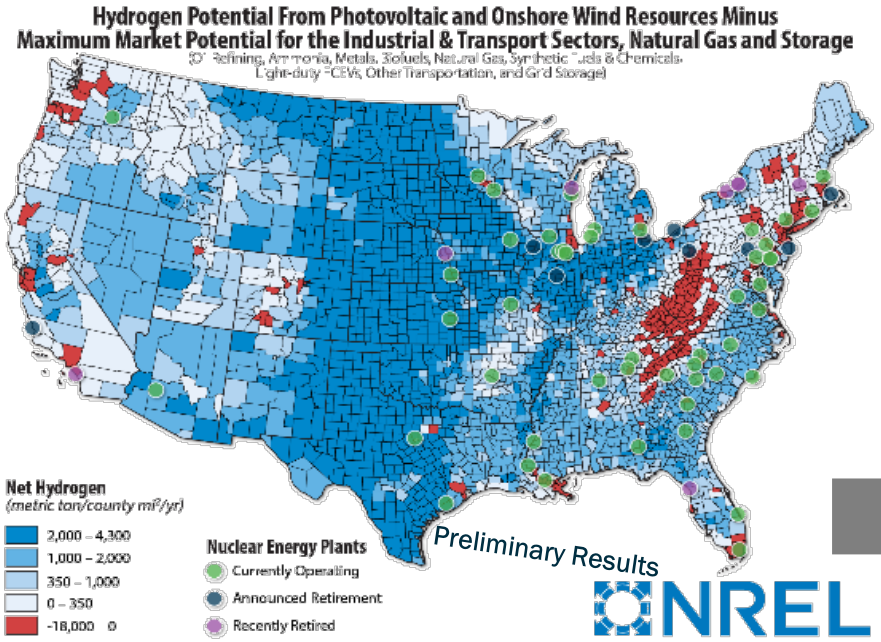
Image: Hydrogen Council

One hydrogen cavern could provide ~ 100 GWh energy storage

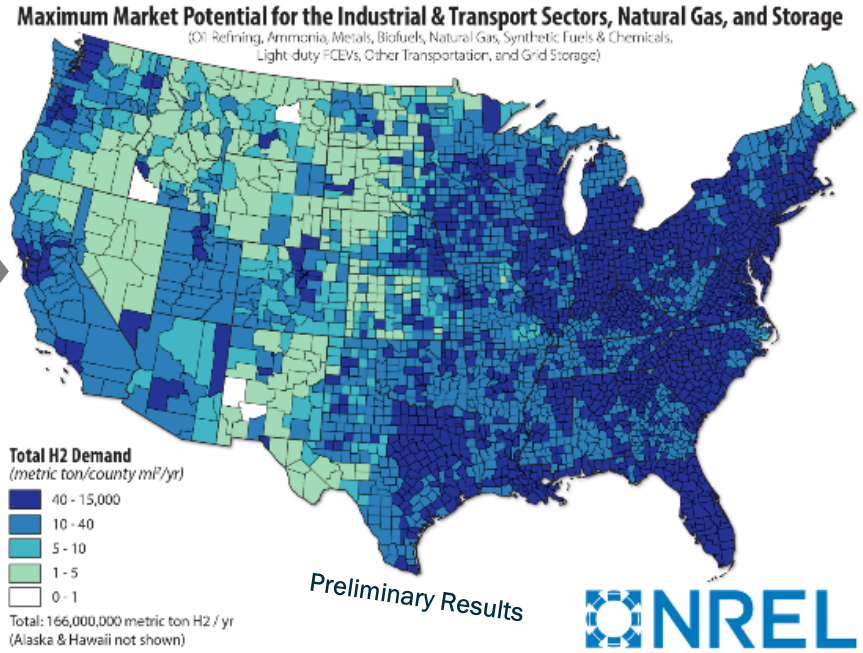
Hydrogen can be used to monetize surplus electricity from the grid, or remote, off-grid energy feedstock(e.g. solar, wind) for days to months.

Co-location of production and use can address delivery cost roadblock

Where hydrogen is available



Where potential hydrogen users are



H_2@Rail and H_2@Ports Initiatives

U.S. DOE in collaboration with:

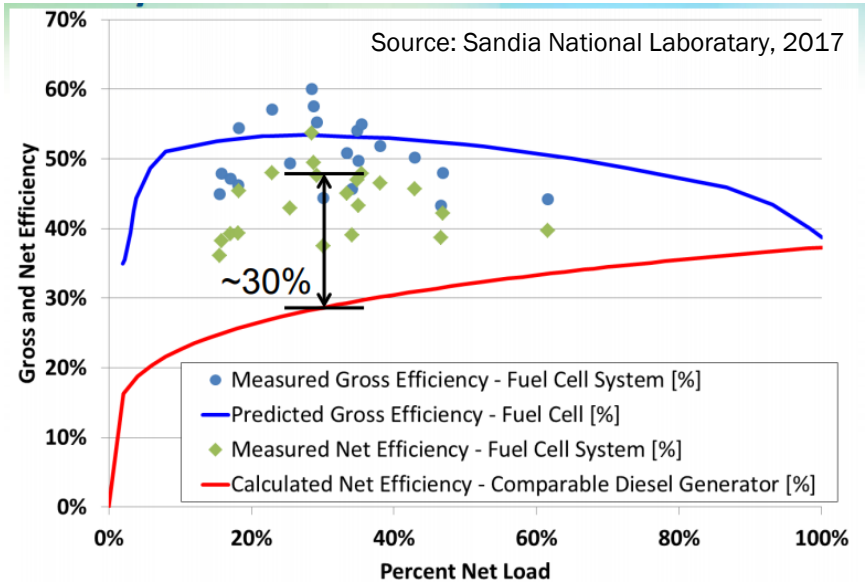
- Dept. of Transportation (DOT)-Federal Railroad Administration
- DOT-Maritime Administration

Source: DOT-FRA (top) & SNL (bottom)

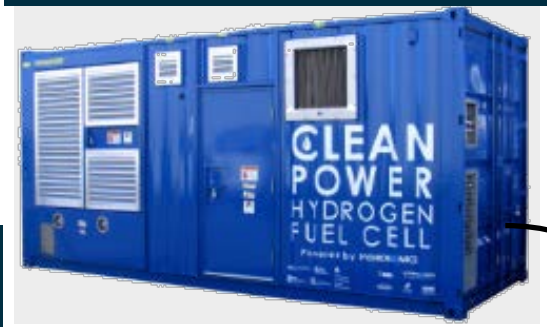
Data Centers and Energy Storage Applications

Source: EPA National Port Strategy Assessment, 2016; http://ad.apta.com/mc/rail/previous/2010/Papers/Demonstration-of-a-Hydrogen-Fuel-Cell-Locomotive.pdf

In collaboration with U.S. MARAD, developed and tested hydrogen fuel cell power generator



Model analysis validated in field experiment testing: ~30% energy efficiency gain over diesel engine at part loads



100kW fuel cell power system

Refrigerated containers

Next Step

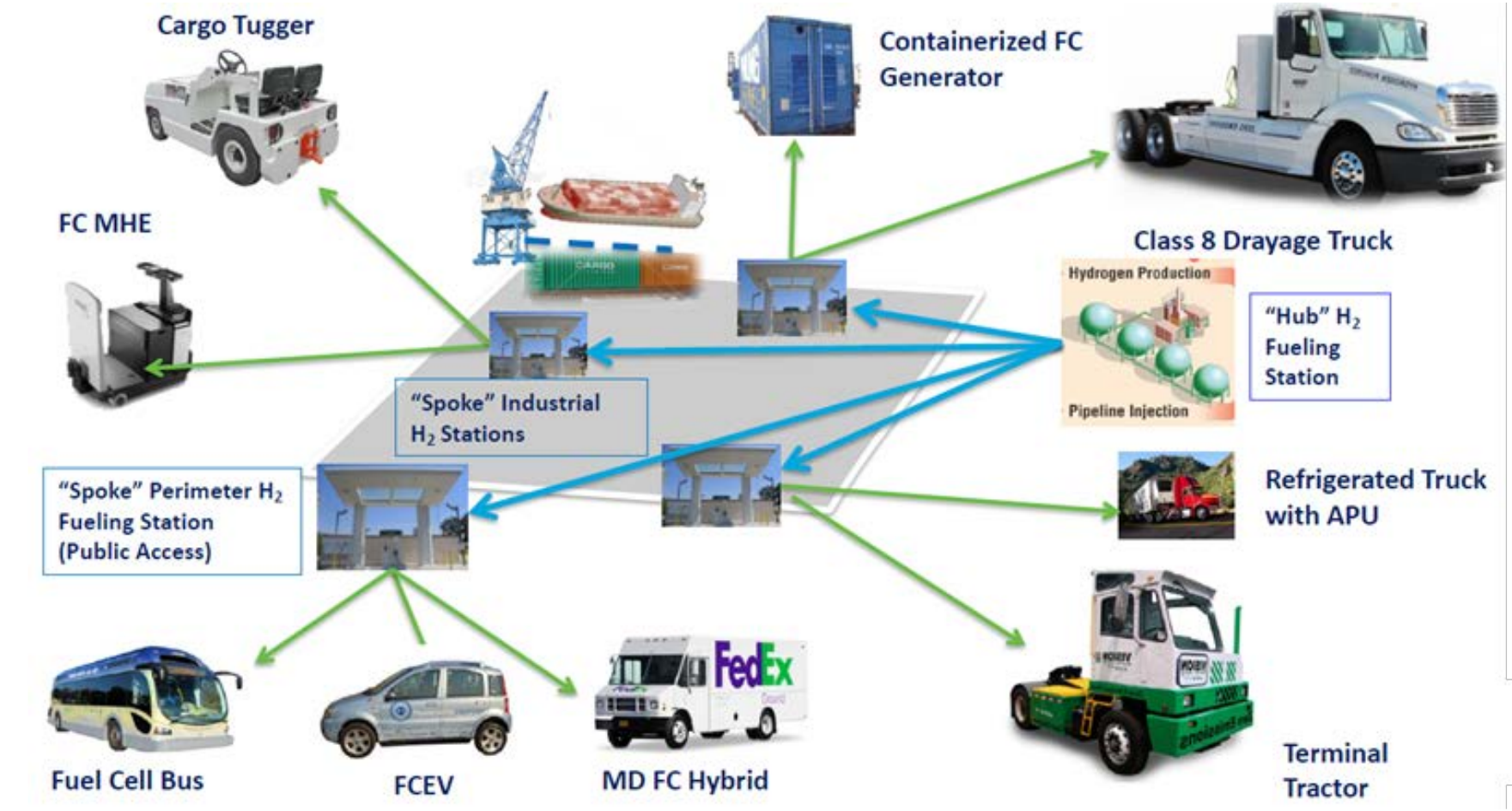
Maritime fuel cell generator will be field tested at Scripps Institution of Oceanography in San Diego for cold ironing application

Full report available at:
https://www.energy.gov/sites/prod/files/2017/07/f35/fcto_maritime_fc_generator_2017.pdf

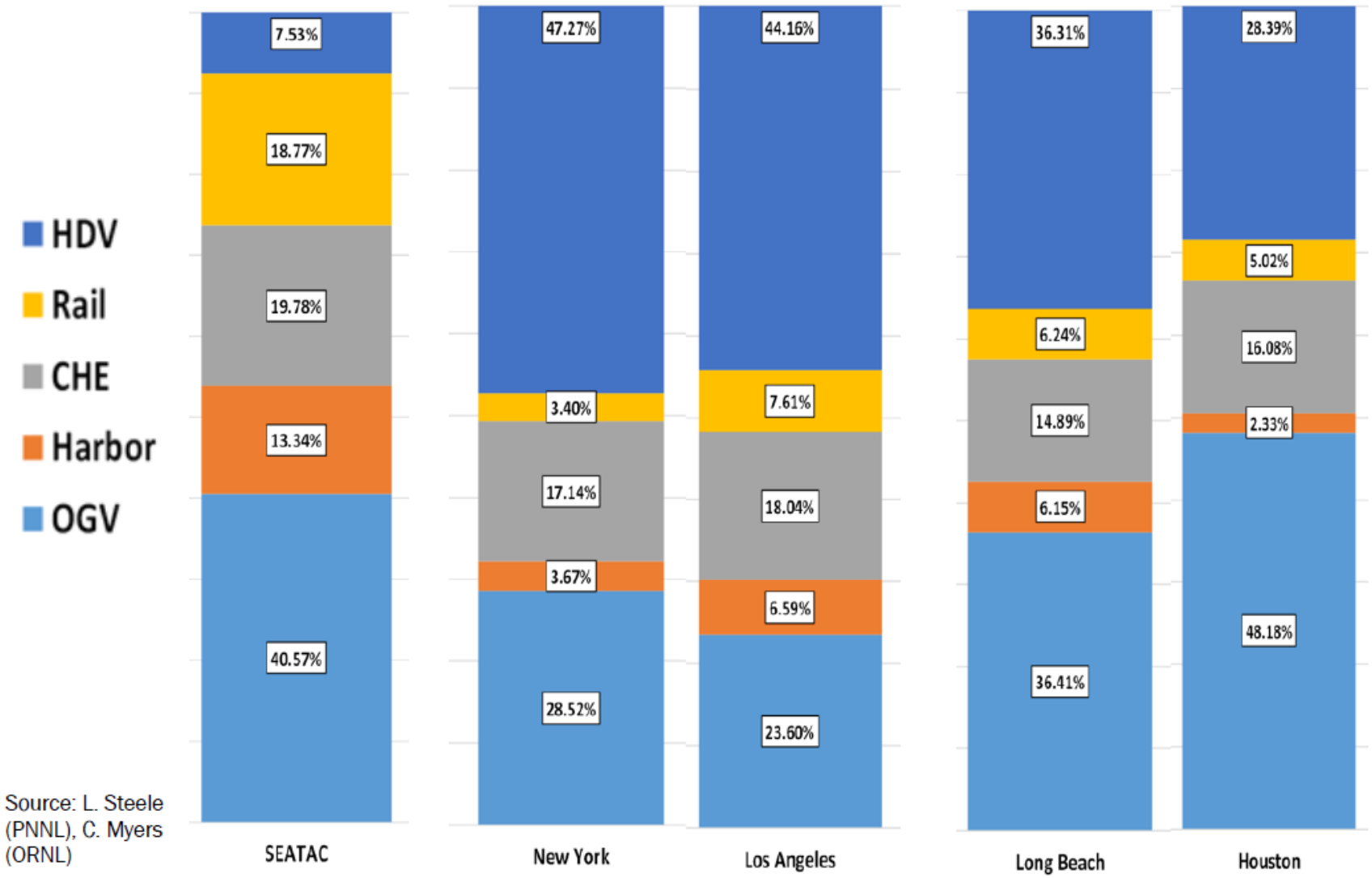
Scripps location for MarFC generator

"Clustering" FCEVs Can Drive H2 Demand in Port-Based Distribution Complexes

Representative Port-Based Industrial Complex with Hydrogen Cost < $6/kg
"Hub and Spoke" H2 Fueling Stations Connected by Pipelines

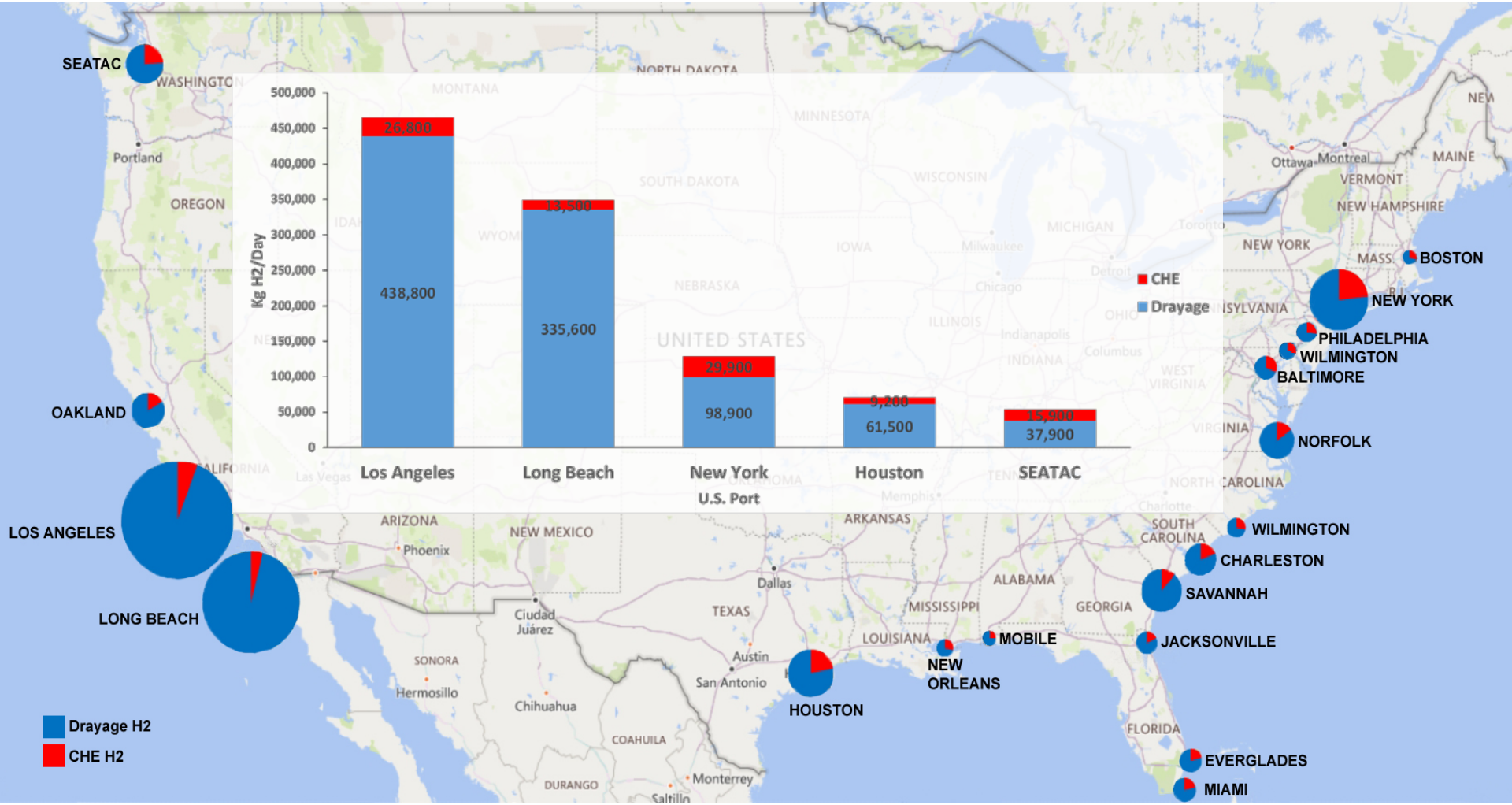


Fuel Consumption at Ports based on Application



Source: L. Steele (PNNL), C. Myers (ORNL)

Potential Hydrogen Demand at U.S. Ports




Collaboration
&
Resources

International Collaborations

The International Partnership for Hydrogen and Fuel Cells in the Economy

Enabling the global adoption of hydrogen and fuel cells in the economy

Working Groups: Education & Outreach
Regulations, Codes, Standards & Safety

Top Priorities	SHARE INFORMATION	INFORM FUTURE GOVERNMENT RD&D	FOSTER COLLABORATION

Find IPHE on Facebook, Twitter and Linkedin
Follow IPHE **@The_IPHE**

www.iphe.net

Formed 2003
19 Countries and EC

Mission Innovation Hydrogen Challenge 2017

Clean Energy Ministerial New Hydrogen Initiative Launched 2019

Hydrogen Energy Ministerial (HEM)

International Energy Agency (IEA)

New Global Safety Partnership: Center for H2 Safety launched 2019

IPHE Steering Committee emphasized need to increase visibility of CHS

AIChE

Pacific Northwest NATIONAL LABORATORY

Hydrogen Council

U.S. DEPARTMENT OF ENERGY
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hySafe

Over 20 partners
Access to 110 countries and
60,000 members- modeled after
industrial process safety center

CENTER FOR Hydrogen SAFETY

Connecting a Global Community

HYDROGEN Safety Panel

HYDROGEN Emergency Response Training Resources

See www.aiche.org/CHS to join

Summary and Next Steps

Maritime applications can enable large scale use of H_2.

This aligns with H2@Scale and can enable energy security, economic value and environmental benefits.

Next Steps

- Conduct analysis on H_2 and fuel cells maritime applications.
  - TCO *(underway),* impact potential (petroleum, emissions reductions, etc.)
- Develop technical and cost targets.
- Identify barriers and opportunities for RD&D and addressing regulations, codes and standards
- Focus on global collaborations to accelerate progress.

Workshop's Objectives

Identify R&D needs to accelerate technology development, address barriers to commercialization, identify opportunities for collaboration.

Goals:

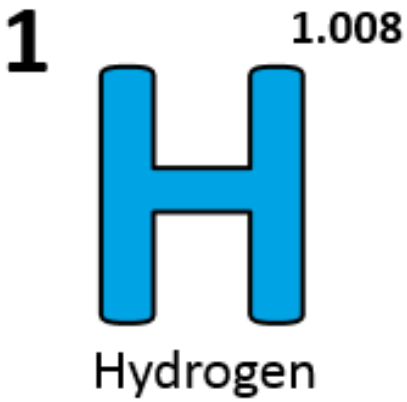
- Assess the state of the art for maritime applications using hydrogen fuel cells
- Discuss operational requirements and lessons learned on early fuel cell maritime projects
- Understand current technology gaps and identify collaborative R&D opportunities
- Identify regulatory, and safety, codes and standards issues to develop path forward to address them

Opportunities for outreach and to increase awareness

Celebrate National Hydrogen & Fuel Cell Day

October 8 or 10/08

(Held on its very own atomic- weight-day)



Information and Training Resources to Increase Awareness

H2tools.org

INCREASE YOUR H2IQ

Save the Date: May 19-22, 2020
Annual Merit Review
Washington DC

Learn more at: energy.gov/eere/fuelcells

Thank You!

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www.hydrogen.energy.gov