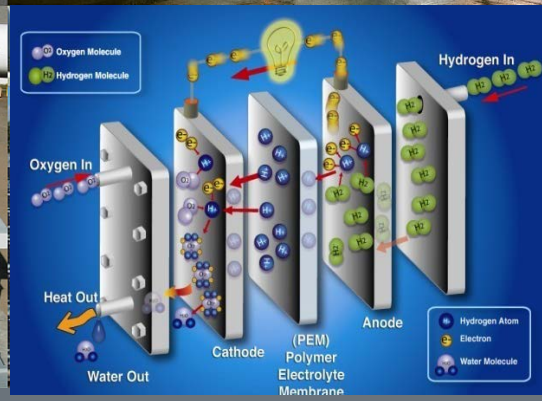
Fuel Cell Technologies Office Webinar

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



International Hydrogen Infrastructure Status

August 30, 2016

Will James

Project Manager

Safety, Codes and Standards Program

Fuel Cell Technologies Office

U.S. Department of Energy

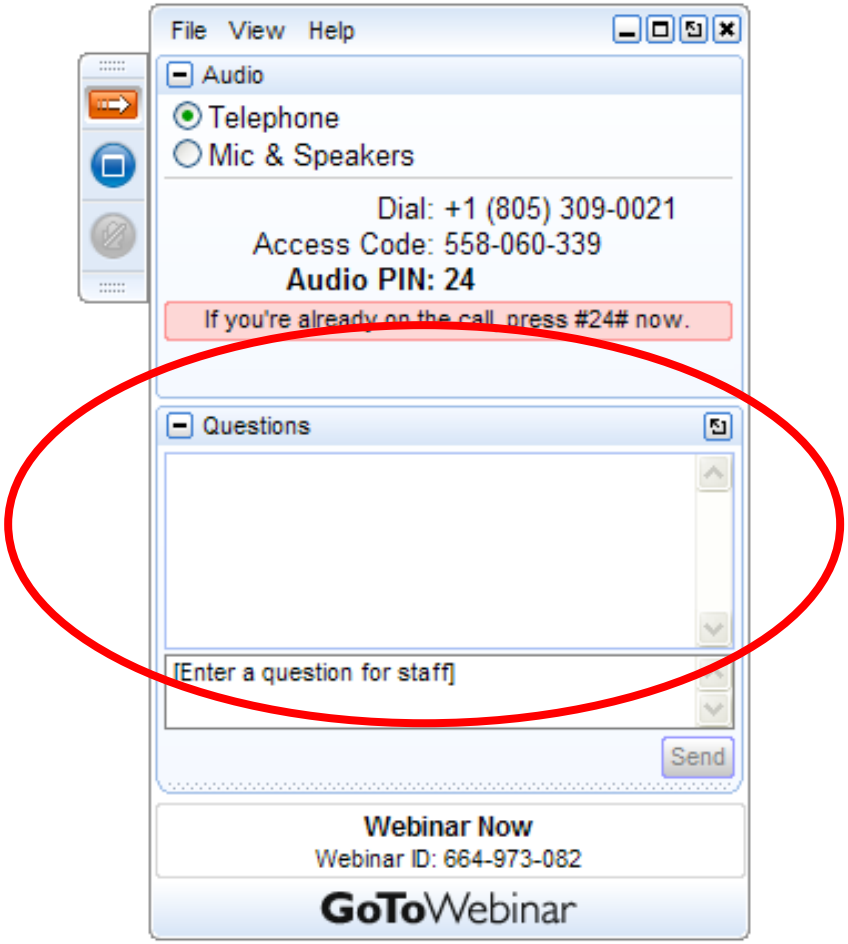
Tim Karlsson

Executive Director

International Partnership for Hydrogen and Fuel Cells in the Economy

Question and Answer

- Please type your questions into the question box



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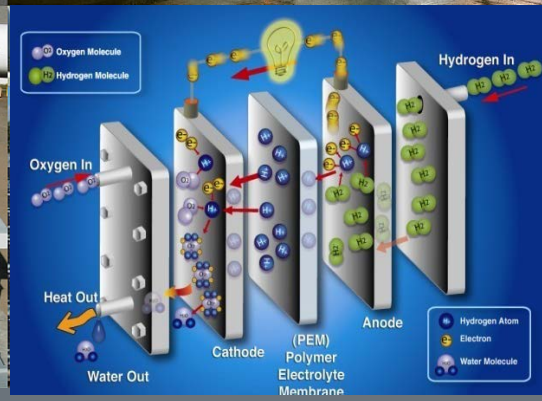

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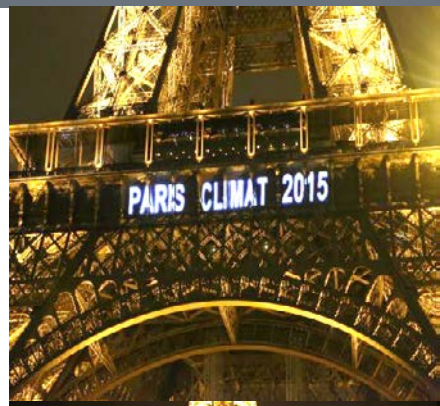
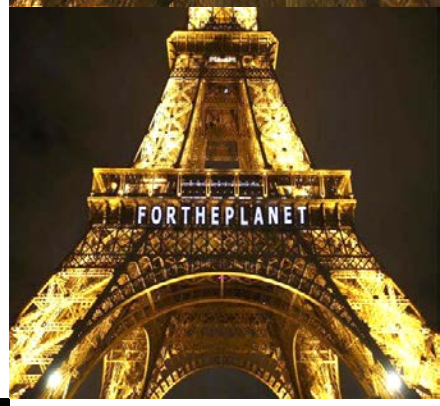
Key Driver- Paris Agreement at COP 21

"Let that be the common purpose here in Paris. A world that is worthy of our children. A world that is marked not by conflict, but **by cooperation**; and not by human suffering, but by human progress. A world that's safer, and more prosperous, and more secure, and more free than the one that we inherited. **Let's get to work**."

- President Barack Obama at the launch of COP21





PARIS2015
UN CLIMATE CHANGE CONFERENCE
COP21·CMP11

Mission Innovation

Mission Innovation Clean Energy R&D Focus Areas

	AUSTRALIA	BRAZIL	CANADA	CHILE	CHINA	DENMARK	EUROPEAN UNION	FRANCE	GERMANY	INDIA	INDONESIA	ITALY	JAPAN	KINGDOM OF SAUDI ARABIA	MEXICO	NORWAY	REPUBLIC OF KOREA	SWEDEN	UNITED ARAB EMIRATES	UNITED KINGDOM	UNITED STATES
INDUSTRY & BUILDINGS	●	●	●	●		●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
VEHICLES & OTHER TRANSPORTATION	●	●	●	●	●	●	●	●	●	●	●		●	●	●	●	●	●	●		●
BIO-BASED FUELS & ENERGY	●	●	●		●	●	●	●	●	●	●	●			●	●	●	●	●	●	●
SOLAR, WIND & OTHER RENEWABLES	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
NUCLEAR ENERGY	●	●	●		●												●		●	●	●
HYDROGEN & FUEL CELLS	●	●	●			●	●	●	●	●			●	●		●	●			●	●
CLEANER FOSSIL ENERGY		●	●		●	●			●	●	●			●			●				●
CO_2 CAPTURE, UTILIZATION & STORAGE	●	●	●		●	●	●	●	●				●	●	●	●	●		●	●	●
ELECTRICTY GRID	●	●	●	●	●	●	●	●	●	●	●	●	●		●	●	●	●	●	●	●
ENERGY STORAGE	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●		●	●	●
BASIC ENERGY RESEARCH	●		●			●	●	●	●	●	●	●	●	●		●		●	●		●

Indicators are for key areas of R&D investment, but do not imply a comprehensive representation of a country's full R&D portfolio.

Major U.S. Administration Energy Goals

Reduce GHG emissions by 17% by 2020, 26-28% by 2025 and 83% by 2050 from 2005 baseline Climate Action Plan

By 2035, generate 80% of electricity from a diverse set of clean energy resources Blueprint Secure Energy Future

Double energy productivity by 2030 Department of Energy

Reduce net oil imports by half by 2020 from a 2008 baseline Blueprint Secure

Reduce CO_2 emissions by **3 billion metric tons** cumulatively by 2030 through efficiency standards set between 2009 and 2016
CAP Progress Report

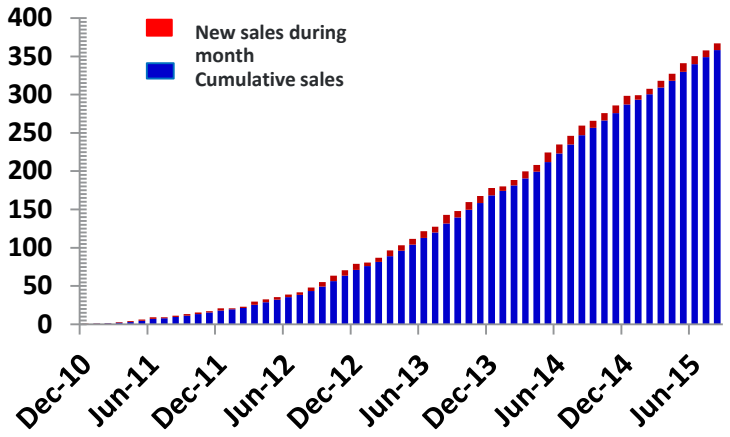
Policy can drive Innovation & Deployment

Policies
Examples

- **Climate Action Plan**
  - **>80% GHG reduction** by 2050
  - **Net oil imports cut by half** by 2020
- **Zero Emission Vehicle (ZEV) Mandate, 8 State agreement**
  - **3.3M ZEVs** by 2025
- **CAFE Standards**
  - **~55 mpg** by 2025

Innovation & Deployment

U.S. PEV Sales Growing
(in thousands)



> 420,000 PEVs on US roads

Oil Dependency is Dominated by Vehicles

- Transportation is responsible for:
  - **66%** of U.S. petroleum usage
  - **27%** of GHG emissions
- On-Road vehicles responsible for **85%** of transportation petroleum usage

- **17.4M LDVs** sold in 2015.
- **240 million light-duty vehicles** on the road in the U.S
- **10-15 years** for annual sales penetration
- **10-15 years** to turn over fleet

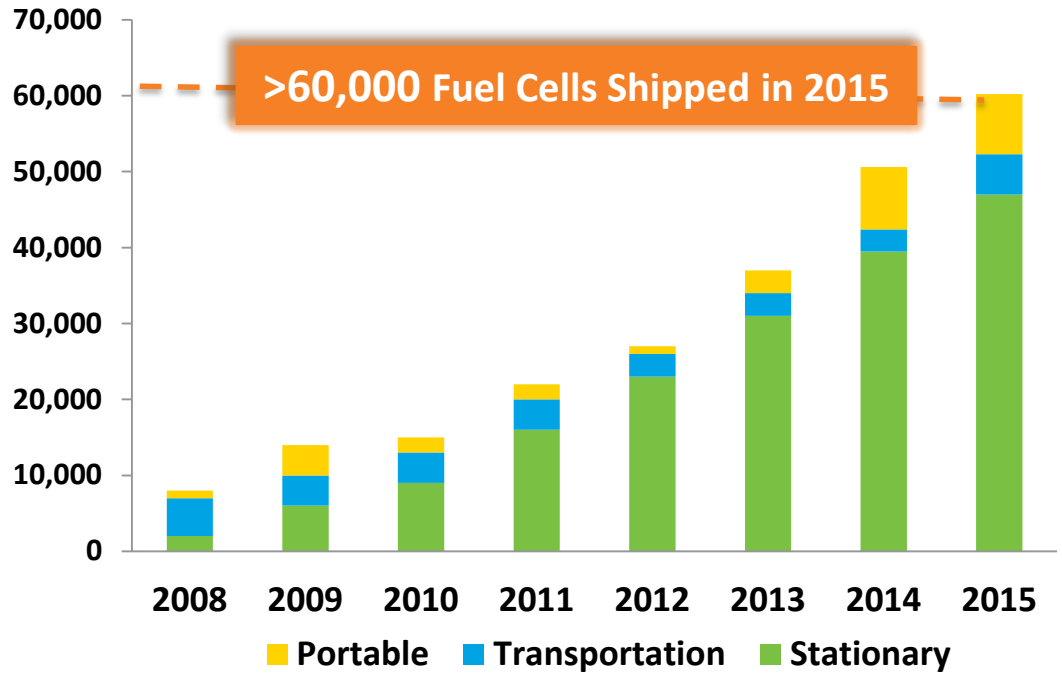
Poses significant economic, energy and environmental risks to U.S.

Photos courtesy of Spc. Jordan Huettl, U.S. Army; U.S. Environmental Protection Agency; and M. Studinger, NASA

It takes decades of sustained effort to turn over the fleet

Fuel Cells Market Overview

Fuel Cell Systems Shipped Worldwide by Application



Source: Navigant Research (2008-2013) & E4tech (2014, 2015)

- Consistent **~30% annual growth** since 2010
- Global Market Potential in 10- 20 years*

$14B – $31B/yr for stationary power
$11B /yr for portable power
$18B – $97B/yr for transportation

*Fuel Cell Economic Development Plan, Connecticut Center for Advanced Technology, Inc. January 2008

Fuel Cell Electric Vehicles (FCEVs) are here

Honda Clarity Fuel Cell Vehicle

FCEVs Reduce Greenhouse Gas Emissions

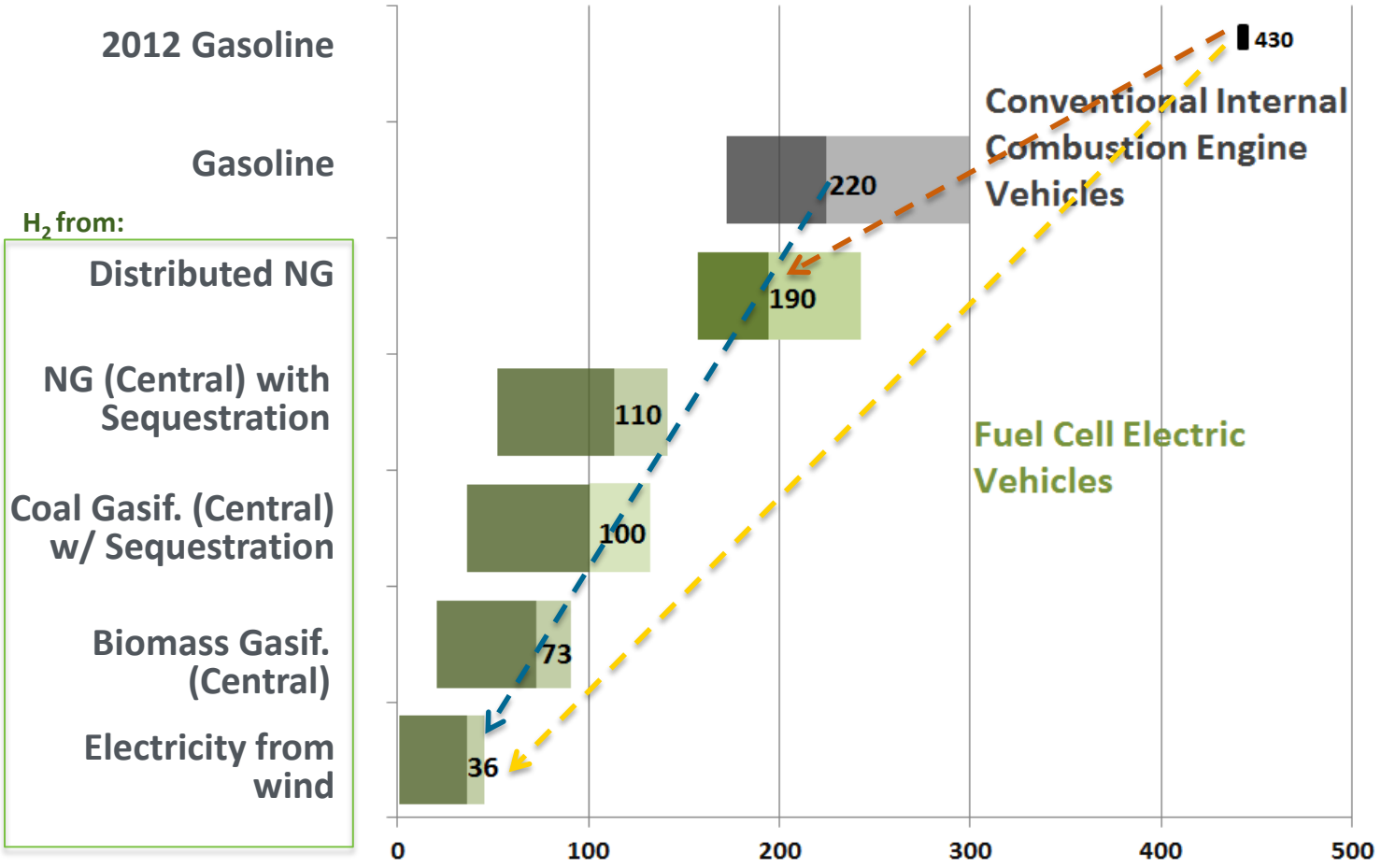
>50%
with H_2 from Distributed Natural Gas*

>80%
with H_2 from Renewables* **(Wind)**

>90%
with H_2 from Renewables** **(Wind)**

*Compared to 2035 gasoline vehicle
**Compared to 2012 gasoline vehicle

Well-to-Wheels CO_2 Emissions (in grams per mile) **for 2035 Vehicles Technologies,** *except were indicated*



Advanced 2035 technologies

Substantial GHG reductions with H_2 produced from renewables

Global Snapshot on Hydrogen Infrastructure

Tim Karlsson

Executive Director, IPHE Secretariat

e-mail: tim.karlsson@iphe.net
web: www.iphe.net

Introduction to the IPHE

The IPHE is an inter-governmental partnership that provides a forum to share information and advance collaborative initiatives to accelerate the cost-effective transition to the integrated use of fuel cell and hydrogen (FCHs) in the economy.

Member partners are undertaking significant research, development, demonstration and/or implementing policy initiatives to increase the use of FCHs in the economy.

- Australia
- Austria
- Brazil
- Canada
- China
- European Commission
- France
- Germany
- Iceland
- India
- Italy
- Japan
- Republic of Korea
- Netherlands
- Norway
- Russian Federation
- South Africa
- United Kingdom
- United States

Approach by the IPHE

- **IPHE Steering Committee**: National delegates review research, development, and deployment developments

- **Working Groups:**
  - Regulations, Codes, and Standards
  - Outreach and Education

- **Workshops and Policy Forum Examples**:
  - **Hydrogen – A Competitive Energy Storage Medium for Large Scale Integration of Renewable Electricity**; Seville, Spain , 15-16 November 2012
  - **Smart Cities**; Rome, Italy, 4 December 2014
  - **Fuel Cell Backup Power for Telecommunication Base Stations**; Wuhan, China, 29 May 2015
  - **Energy and Transportation Systems – A 2020 Perspective**; Grenoble, France, 3 December 2015
  - **Fuel Cell & Hydrogen Pathways to Clean Cities: A Stakeholder–Government Engagement**; Hotel Shattuck Plaza, Berkeley, US, Friday, May 20, 2016

For details see: http://www.iphe.net/events/workshops.html

International Drivers: Sustainability

National Circumstances for Member Countries Drive Actions:

- **Energy Security Concerns**
- **Energy Efficiency**
  - Trends: Need more effective use of variable generation, and move from centralized to distributed energy generation.
- **Economic Growth**
- **Environmental Performance**
  - Includes climate change goals for energy and transportation systems and Clean Air obligations

International Drivers: Policies

- **COP 21 Decisions**

  "Main aim is to keep a global temperature rise this century well below 2°C."
  Source: UNFCCC Statement Paris, 12/12/2015

- **Mission Innovation**

  "Mission Innovation aims to reinvigorate and accelerate global clean energy innovation with the objective to make clean energy widely affordable."
  Source: http://mission-innovation.net/

- **The "Break-though Energy" Coalition**

  "The world needs widely available energy that is reliable, affordable, and does not produce carbon. The only way to accomplish that goal is by developing new tools to power the world. That innovation will result from a dramatically scaled up public research pipeline linked to truly patient, flexible investments committed to developing the technologies that will create a new energy mix."
  Source: http://www.breakthroughenergycoalition.com/en/index.html

- **Clean Energy Ministerial**

  "Reduce emissions, improve energy security, provide energy access, and sustain economic growth."
  Source: http://www.cleanenergyministerial.org/

International Drivers: Political Commitment

Recognition of FCHs in future energy & transportation systems:

- **China:** *The Energy Development Strategy Action Plan (2014-2020)*
  Source: Country Update, 23rd IPHE SC Meeting Wuhan, China

- **Japan:** *"[Prime Minister] Abe has declared hydrogen-powered fuel cell vehicles "the ultimate eco-car," praising their promise for the environment and the nation's automakers, which are ahead of the pack."*
  Source: Japan Times Nov 30, 2015

- **Korea:** *President Park Geun-hye asked Hyundai to develop HFC buses to showcase South Korea's technological prowess at the 2018 Winter Olympics*
  Source: Yonhap News Agency March 18, 2016

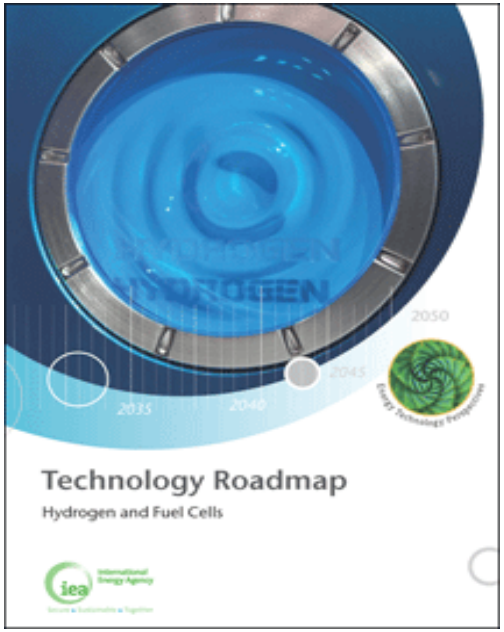
- **European Commission:** *"Hydrogen and fuel cells, by enabling the so-called hydrogen economy, hold great promise for meeting in a quite unique way, our concerns over security of supply and climate change.*
  Source: Hydrogen Energy & Fuel Cells: A Vision For Our Future, European Commission Report 2003

- **U.S.:** *"As part of an all-of-the-above energy approach, fuel cell technologies are paving the way to competitiveness in the global clean energy market and to new jobs and business creation across the country."*
  Secretary Moniz, U.S. Department of Energy, Dec 19, 2013

Energy & Transportation System Integration

Hydrogen offers a longer-term opportunity as an integrator.

- Technical research and economic analysis is necessary to understand the efficient and effective integration of the systems and the business cases to make it happen.



"... In a future energy system largely based on renewable energies, hydrogen could play a pivotal role by connecting different layers of infrastructure to link energy supply and demand. ***Hydrogen can enable new energy vectors used to supply transport, buildings and industry by bridging surplus renewable power into the energy demand sectors****"*

Source: IEA Roadmap Insights, 2015
https://www.iea.org/media/freepublications/technologyroadmaps/foldout/FoldoutTechnologyRoadmapHydrogenandFuelCells.pdf

Country Update Summary

IPHE Country Updates, 2016 Status

Country	# of Cars	# of Buses	# of Fork Lifts	# of Stations	# of <5 kW Stationary Units
United States	225	25	>8300	>50	
Germany	103	14	16	22	~1000
Japan	573	Demo only	4	86	156,017
France	110	-	60	5	9
United Kingdom	37	8		7	Demo only
Scandinavia	40	5		10	
TOTAL	**867**	**52**	**>8316**	**~215**	**~142,303**

~300 MW fuel cells installed worldwide in 2015

Member statements from: http://www.iphe.net/partners.html

National Approach: United States

Infrastructure Deployments:

- 1600 mi. of H2 pipeline
- ~10M metric tons produced/yr
- ~50+ stations (~20 public)

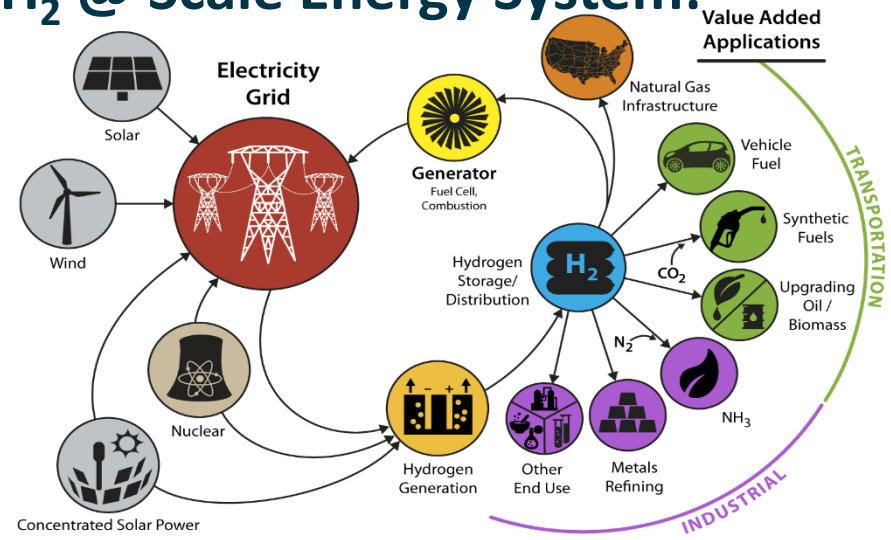
R&D Initiatives and Partnerships:

- **H2USA**, a public-private collaboration, and the H2FIRST project
- **U.S. DOE Program:** RD&D funding
- **H2 @ Scale Concept** – Three focus areas:
  - Advanced Generation
  - Storage and Distribution
  - End use market transformation and systems integration

(State) Government Investments & Incentives:

- CA- 100 stations, ~$100M planned through 2023
- Northeast States & Hawaii
- 8 State MOU- 3.3M ZEVs by 2025

H_2 @ Scale Energy System:



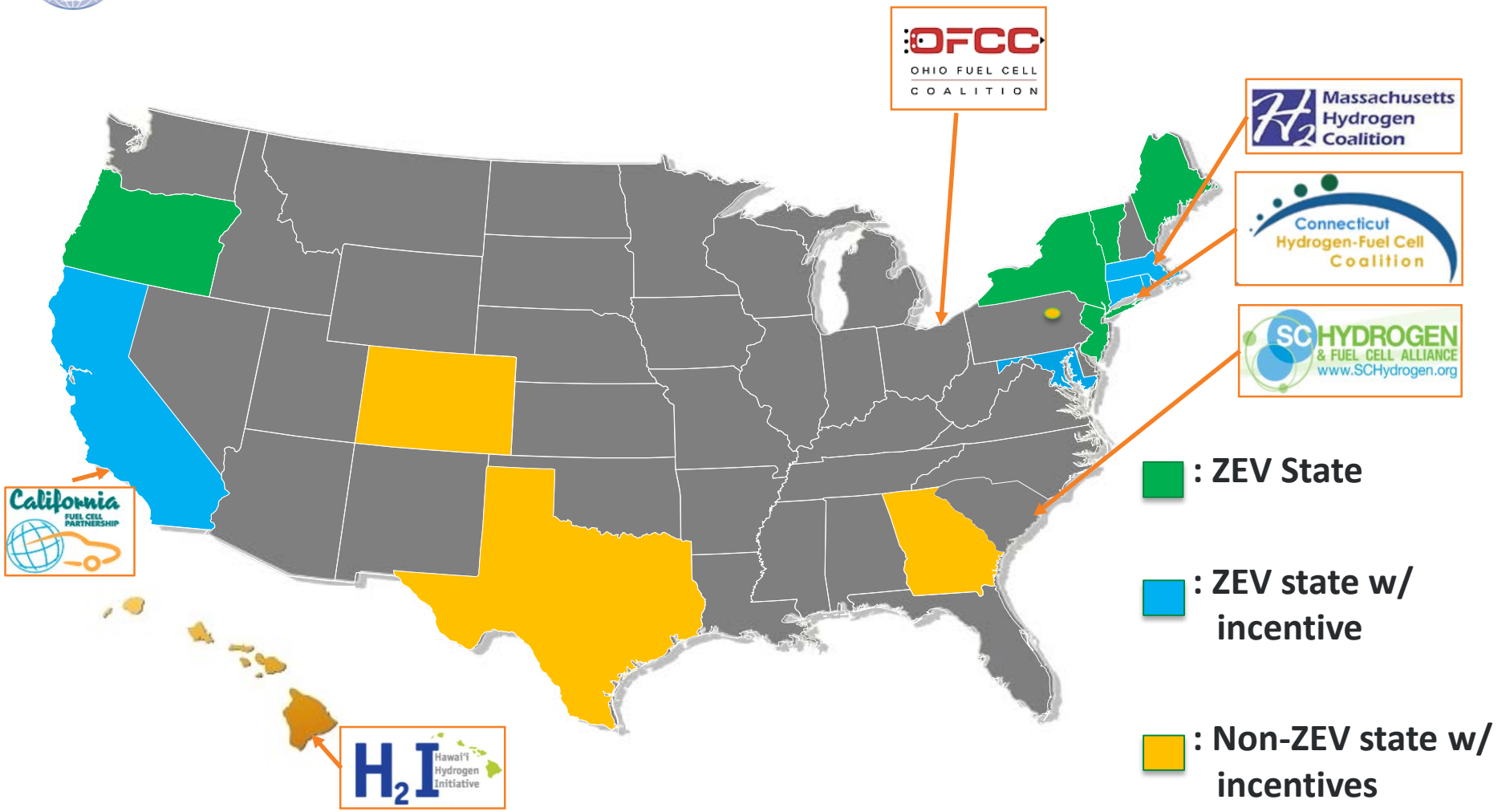
California
Connecticut
Massachusetts
Maryland
New York
Oregon
Rhode Island
Vermont

National Approach: United States

KEY CHALLENGES	DOE ACTIVITIES	EXAMPLES
1 Station Cost	✓ Components R&D ✓ Systems R&D	H2FIRST ▪ HySTEP ▪ Reference Station Design ▪ Contaminant Report
2 Station Reliability	✓ Contaminant Detection ✓ Sensors Testing	**SHOWCASE STATION** (HyTEST)
3 Station Rollout	✓ Safety Awareness ✓ Codes and Standards Harmonization ✓ Training & Education	**TOOLS** (HyRAM- Hydrogen Risk Assessment Models)

DOE efforts support public-private partnership: H2USA

State & Regional Incentives: United States

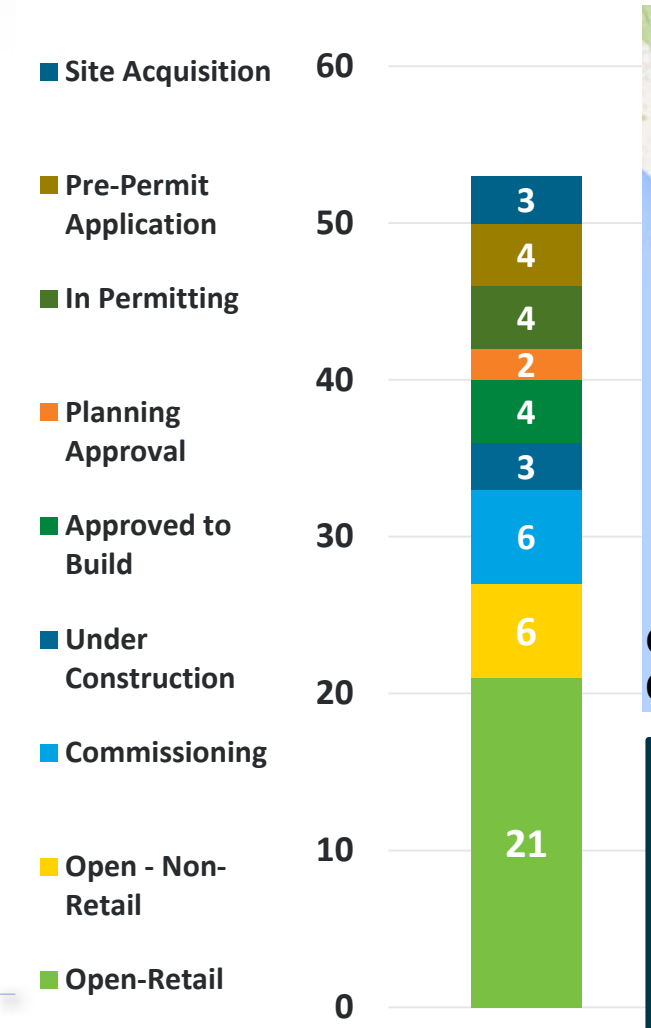


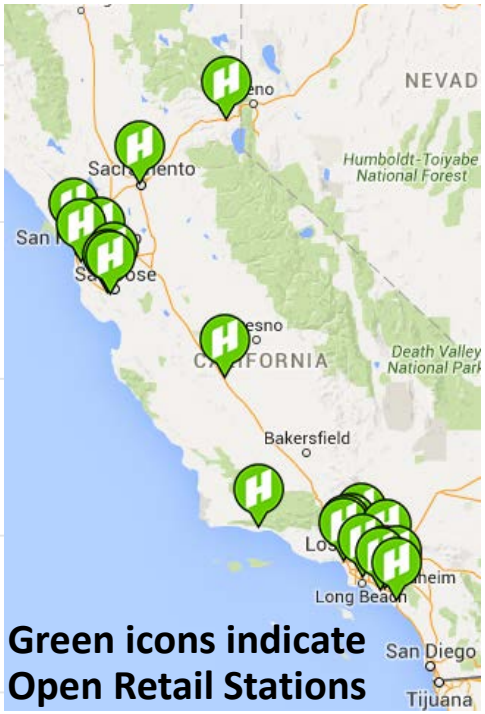
Source: NCSL

9 states (4 ZEV states) offering incentives for FCEVs and H_2 station deployments

Regional Status: United States

California





Green icons indicate Open Retail Stations

H_2 Stations

~50 underway

Goal: 100

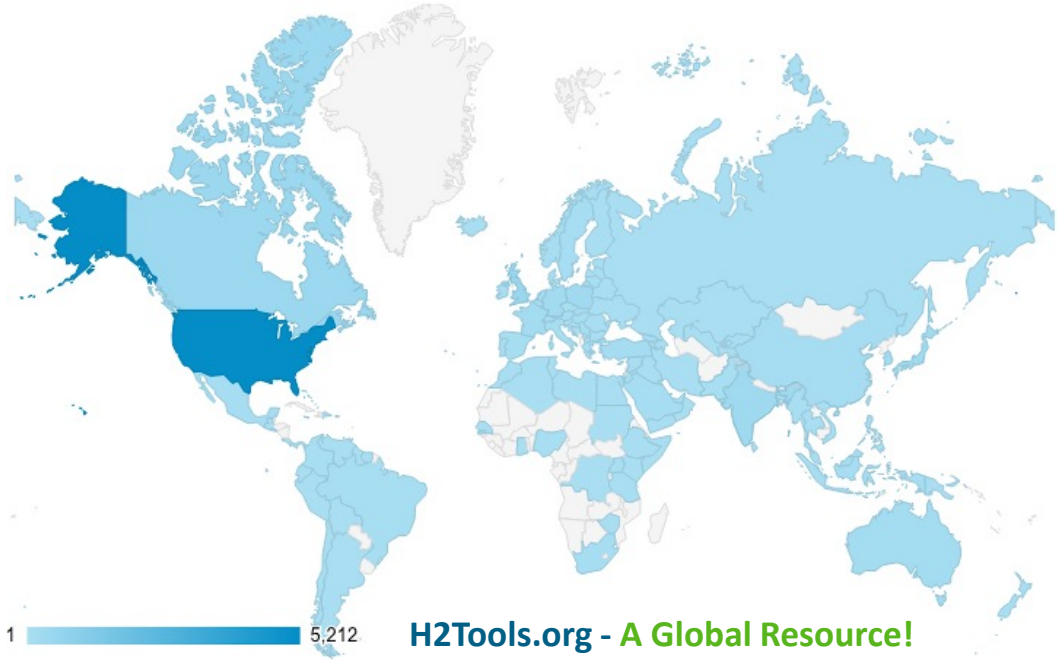
As of August 2016 (Data from CaFCP Aug. 24, 2016 status report- http://cafcp.org/sites/default/files/h2_station_list.pdf)

Northeast

12 Planned Retail H_2 Stations

- California
- Connecticut
- Massachusetts
- Maryland
- New York
- Oregon
- Rhode Island
- Vermont

United States Safety Collaboration



- Includes resources on **safety** best practices, **first responder training**, and **H_2 codes & standards**

- Tracked downloads from **Europe and Japan**
- Resource **translated in Japanese**
- **50%** of visits are **international!**

Enabling dissemination of safety information around the world

Europe

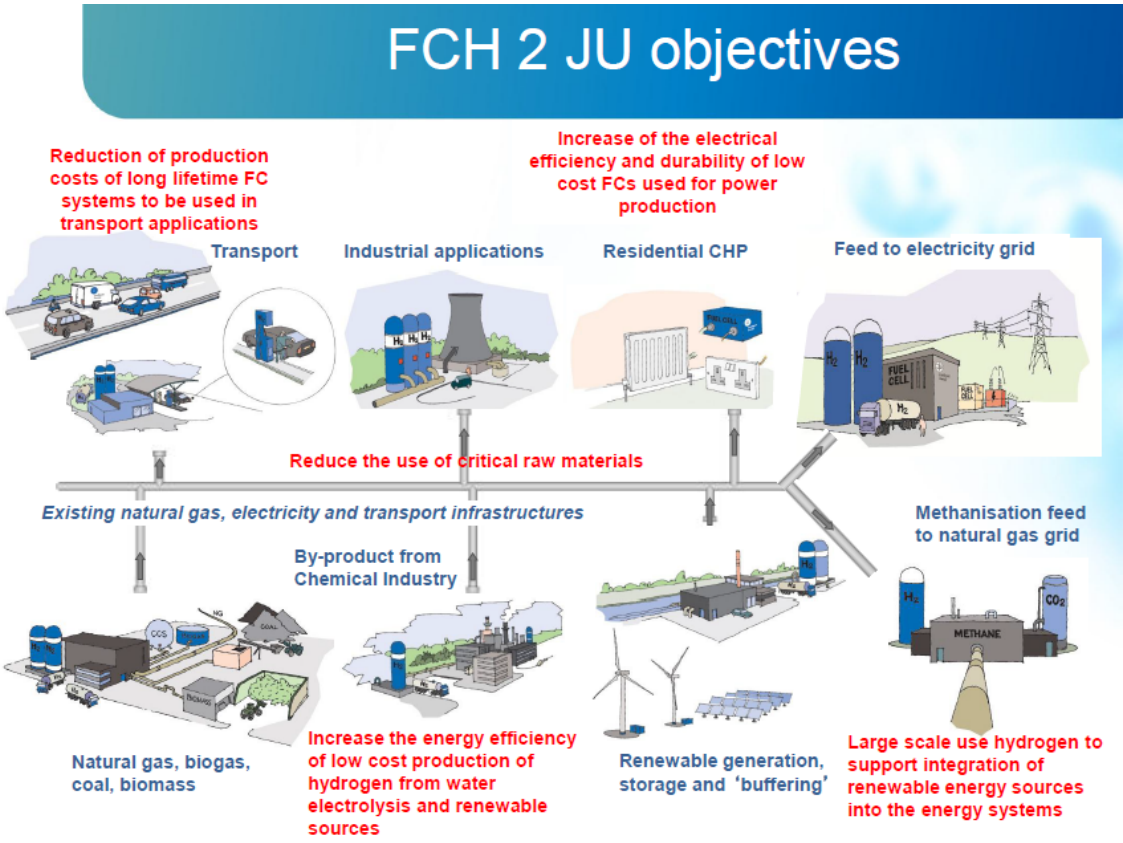
Fuel Cell & Hydrogen 2 Joint Undertaking (FCH2 JU)

Budget: 1.3B from gov't and industry contribution

Objective: demonstrate role of FCH technology in Europe's future energy and transport systems

1. **Transport:** vehicles, train, maritime, & aviation
2. **Energy:** H_2 production for energy storage & grid balancing from renewable electricity, FC systems for combined heat and powe
3. **Crosscutting Research:** Standards, consumer awareness, manufacturing methods

(See: http://www.fch.europa.eu/page/vision-objectives)

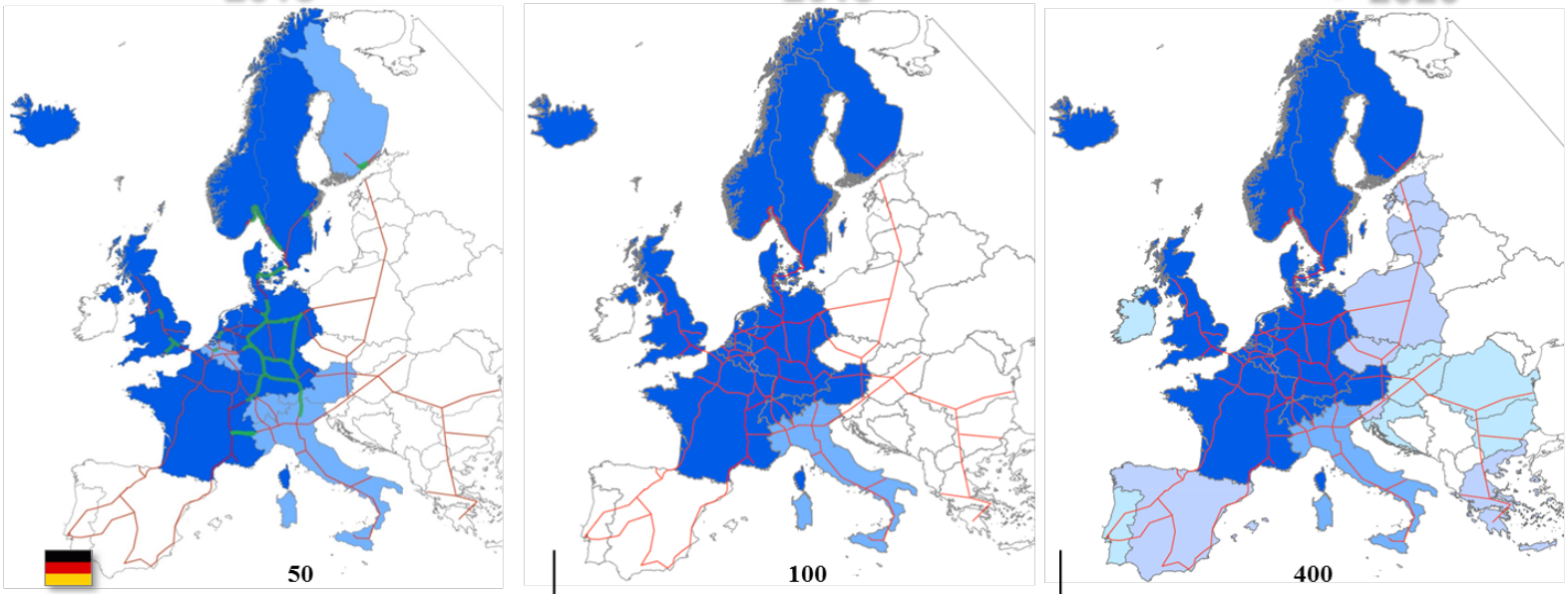


Directive 2014/94/EU on Deployment of Alternative Fuel Infrastructure:
Establishes a common framework of measures for the deployment of alternative fuels infrastructure in the EU

Source http://www.iphe.net/events/meetings/SC_24.html

Europe

Scenario for EU Hydrogen Refueling Infrastructure



	2015	2018	> 2020
	50	100	400
	2 – 4	10	20
	9	100	355
	9	30	70
	10	30	40

Source: NOW GmbH
Source: Hydrogen Mobility France

- Nations with H_2Mobility initiatives
- Nations with some activity and/or H2Mobility initiatives starting
- Nations without H_2Mobility initiatives

Mobilité Hydrogène France
H_2 Mobility
UK H_2 Mobility
Scandinavian Hydrogen Highway Partnership
Hydrogen mobility grouping in Benelux
Hydrogen mobility grouping in Austria
Hydrogen Europe

Germany

Infrastructure Deployment:

- H2Mobility: Public-private initiative
  - **2016 Status: >40 stations & >100 FCEVs**
  - **Goals: 100 HRS by 2018-2019, and 400 by 2023**

Government Investment and Incentives:

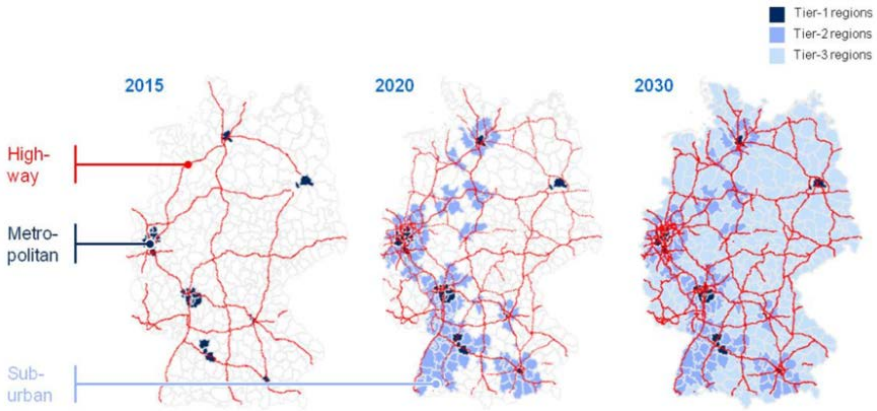
- €161M until 2018 (the Ministry of Transport and Digital Infrastructure, BMV)

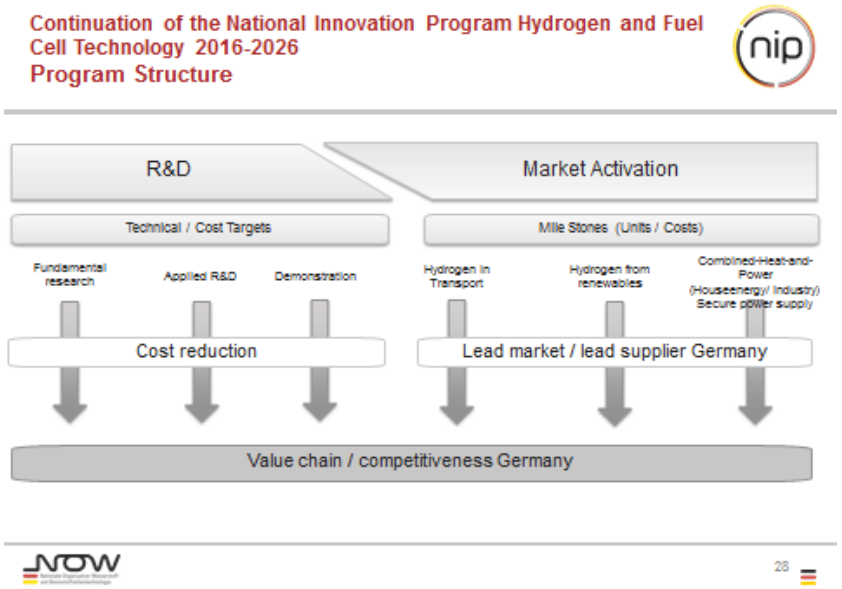
Initiatives:

- NOW (National Organization for Hydrogen and Fuel Cell Technology): developing national strategy framework for the deployment of AFI
- New directives consider renewable electricity and renewable hydrogen as transportation fuels
  - Required to implement into national law within next few years

Research and Development Examples:

- Power-to-gas (PtG) system aims to be the world's most efficient and compact PtG system
  - Recently launched, facilitates supply of hydrogen generated by wind electricity into Hamburg gas network





Source: http://www.iphe.net/partners.html

France

Deployment:

- **HYPE**: 1st FC Taxi Fleet (Hyundai FCEVs) in Paris, with 5 FCEV taxis (up to 70 through 2016)
- **HYWAY**: 1st fleet deployment of 50 RE-FCEVs in Grenoble and Lyon area.
- **H2ME** (FCH JU): Funded by FCH JU, will deploy 3 new HRS in France

Government Investment and Incentives:

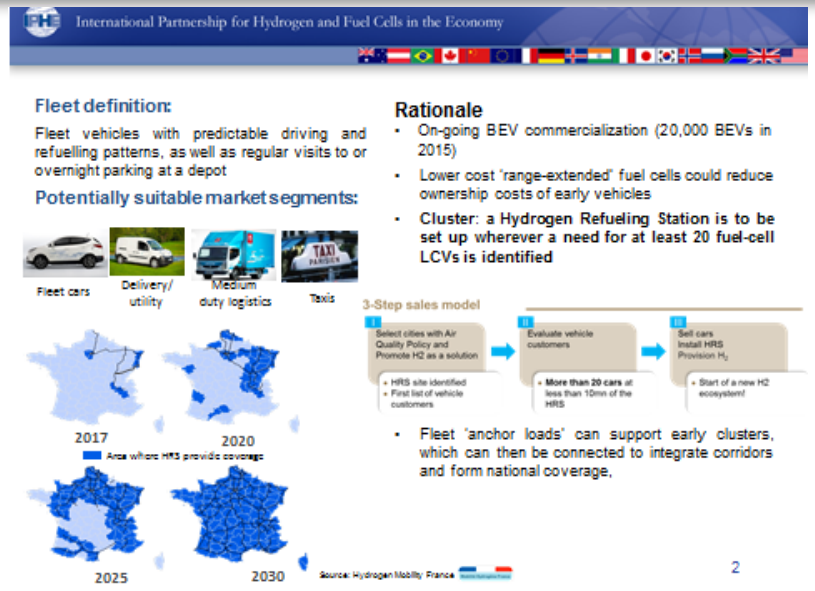
- Call for proposal by Ministries of Environment and Economy on "hydrogen in the territories" launched May 2016.
  See: http://www.developpement-durable.gouv.fr/IMG/pdf/AAP-territoires-hydrogene.pdf

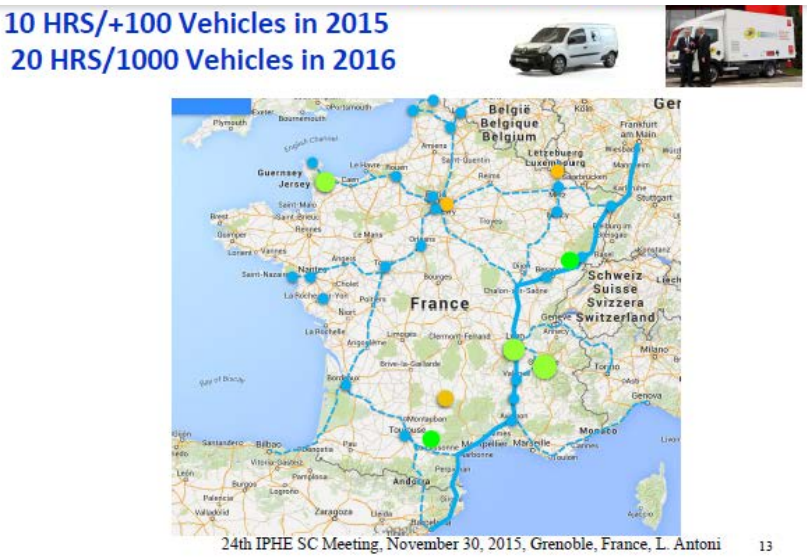
Initiatives:

- Legislation related to the energy transition includes hydrogen technologies in the areas of Energy and Transport

Research and Development Examples:

- CEA has developed a small-scale integrated High Temperature Electrolysis System (SOEC)





Source: http://www.iphe.net/partners.html

United Kingdom

Deployment:

- 2016 Status: 7 HRS, approx. 40 FCEV, 20 FCE Buses
- **UK H2 Mobility program:** initial network of 65 HRS in place by 2020
  - Long-term vision is for 1,150 HRS by 2030

Government Investment and Incentives:

- Award of a €5M EU grant for the BIG HIT (Building Innovative Green Hydrogen systems in an Isolated Territory) project (funded by FCH-JU)
  - to demonstrate use of constrained wind power to generate hydrogen for vehicle and heating in the Scottish Orkney Islands

Initiatives:

- UK Secretary of State for Energy and Climate Change announced a new direction for UK energy policy in November 2015
  - The UK's approach to meet its carbon budgets will be set out in 2016

Leeds City Gate Study

Project Team: Northern Gas Network, Wales & West Utilities, Kiwa, and Amec Foster Wheeler all of the UK

Objective: Determine the technical and economic feasibility of converting the existing natural gas system to pure hydrogen.

Rationale:

- Pipeline upgrade underway with funding in place
- Addresses Climate Change Policy driver
- Have done conversion like this in past (manufactured town gas to natural gas in 1960/70s)
- Significant access to natural gas and natural storage allowing for steam methane reforming with Carbon Capture and Storage

Findings:

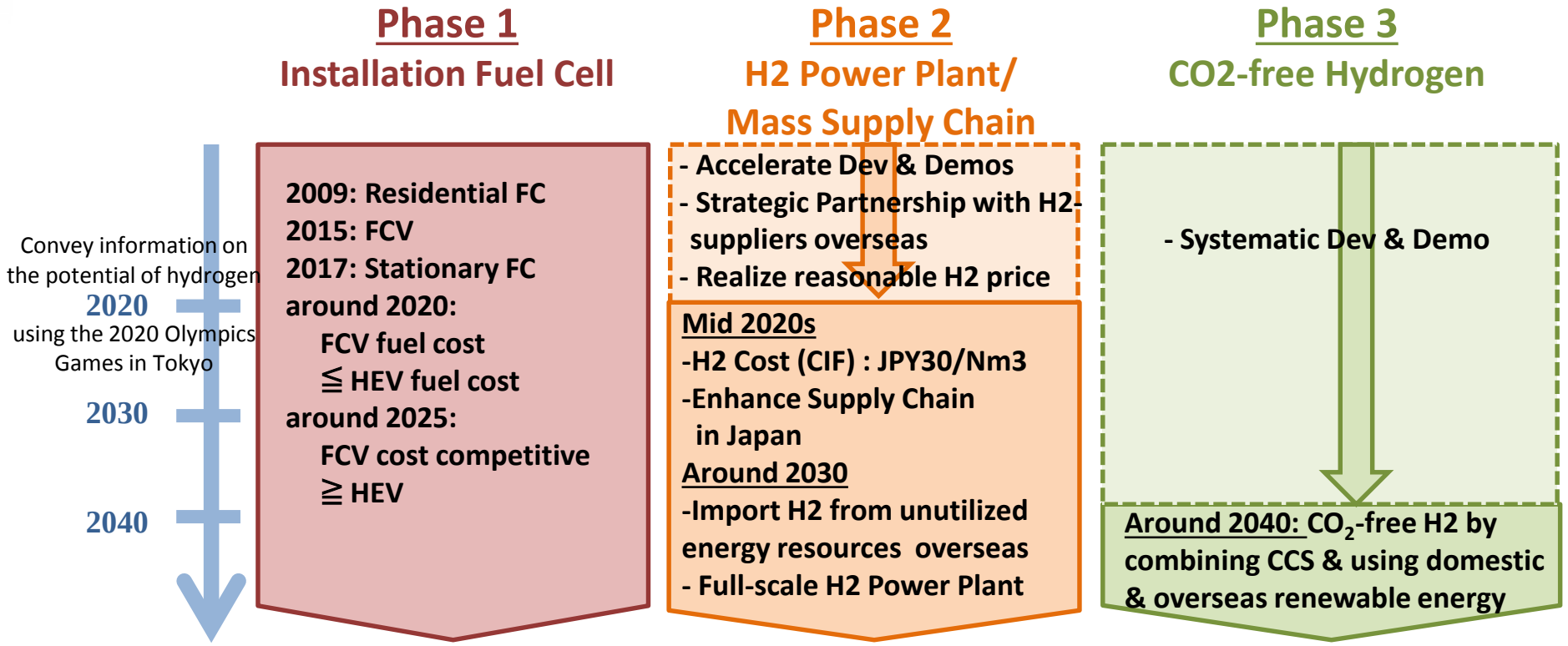
- Gas network has correct capacity for conversion
- Can be converted incrementally with minimal disruption
- Minimal new energy infrastructure required

Source: http://www.iphe.net/partners.html

See full report: www.northerngasnetworks.co.uk/wp-content/.../Energising-the-North-report-final.pdf

Japan's Approach to a Hydrogen Society

Step-by-Step approach to realize Hydrogen Society



Market scale of the equipment & infrastructure businesses related to FCH in Japan
Approx. 1 trillion yen in 2030 → Approx. 8 trillion yen in 2050

Japan

Deployments (as of March-April, 2016):

- **573 FCEVs**
- **78 HRS** (70 MPa) are in operation
- 156,000 units of ENE-FARM, residential micro-CHP fuel cell sold

Government Investment and Incentives:

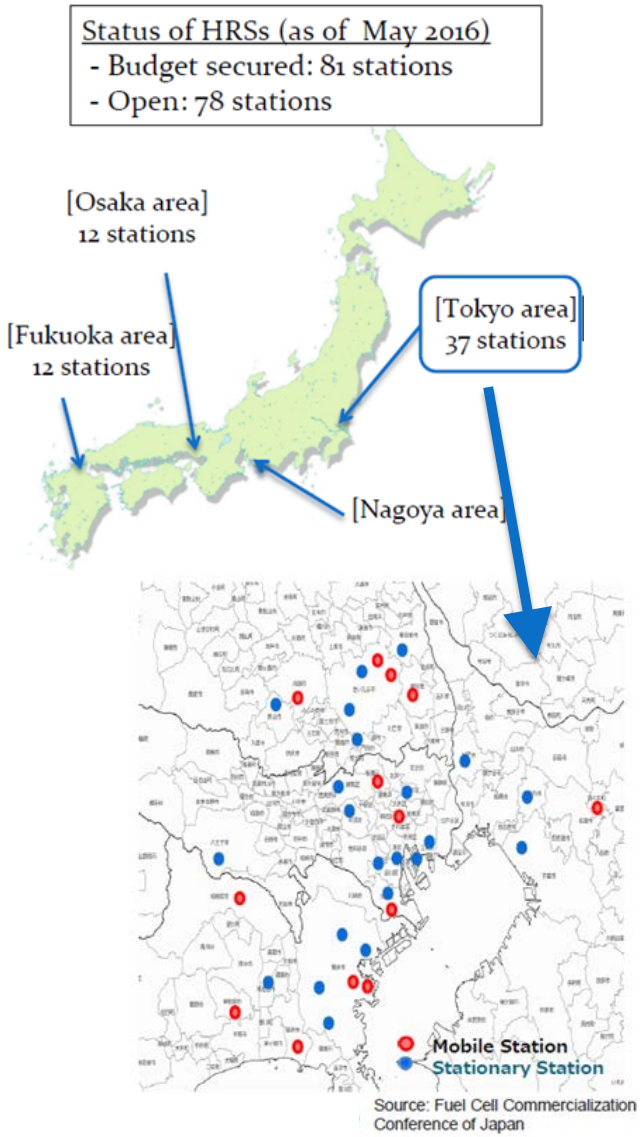
- Fiscal Year 2016: Budget of more than US$375M investment in FCH

Initiatives:

- Ministry of Economy, Trade, and Industry (METI) released revised "Strategic Road Map for Hydrogen and Fuel Cells" in March 2016.
  - FCV targets: ~40,000 by 2020, ~200,000 by 2025, ~800,000 by 2030
  - HRS site targets: ~160 by 2020, ~320 by 2025

Research and Development Examples:

- New NEDO RD&D projects:
  - Development of type-2 composite hydrogen cylinders to lower hydrogen refueling station construction cost
  - Regulation review to allow self-refilling to lower the operation cost of stations.



Source: http://www.iphe.net/partners.html

Korea

Deployments

- Status 2016: 10 HRS, 42 FCEV
- Total installed Stationary FC capacity: 177MW as of 2014

Government Investment and Incentives:

- *2016 Investment:*
  - US$5.4M investment in FCEVs and HRS
  - US$5.3M on household and building applications
- *2016 R&D budget*: US$26M.
- Incentives offered for FCEV purchase and installation of HRS

Initiatives:

- Renewable Portfolio Standard: obligation on power suppliers with capacity > 500 MW to produce a percentage of power (3.5% in 2016) from new & renewable sources
- The 3rd Eco-friendly Vehicle Development & Deployment Scheme:
  - Transform the auto landscape to be more eco-friendly
  - Aims to deploy 9,000 FCEV and 80 HRS by 2020

Research and Development Examples:

- Focused on cost reduction and improving durability of fuel cell systems for residential power generation, vehicles, and hydrogen refueling infrastructure

Source: http://www.iphe.net/partners.html

Other Countries

The Netherlands:

- 2 HRS in operation: one pipeline-fed station, one using on-site electrolysis
- Up to 15 additional stations in planning phase with target of 20 in total by 2020
- National Hydrogen Platform, a public-private partnership, being formed

China:

- The National Development and Reform Commission and China's National Energy Administration issued the energy technology revolution Innovation Action Plan (2016-2030), and the energy technology revolution innovation roadmap for action in April 2016.
  - Hydrogen & fuel cell technology innovation is one of 15 Key Tasks listed in Action Plan
- Fleet of 33 fuel cell powered buses launched in 2015 in Guangdong province, with more buses planned for other regions

India:

- Ministry of New & Renewable Energy has provided funding for Rs.59.5 Million ($US 0.89 M) for R&D related activities in the area of hydrogen energy & fuel cells for FY 2015-16
  - *FY 2016-17 funding:* Rs.200 Million ($US2.985Million) for hydrogen energy and fuel cell related activities
- 5 HRS are in operation; stationary PEM Fuel Cells being deployed to provide backup power for telecommunications towers; transportation focus on 3 wheelers

South Africa:

- HySA Programme received funding of R81.4 million (~USD5.4 million) from government through the Department of Science and Technology. An additional amount of R34 million (USD2.2 million) was leveraged from other Programmes within the Department; combined total of USD7.6 million.
- First fuel cell powered forklift deployed in 2016.
- A multi-stakeholder forum involving government, industry, and the mining sector has been set up to develop a fuel cell roadmap for South Africa.

Sources: **http://www.iphe.net/partners.html**; http://www.nationaalwaterstofplatform.nl

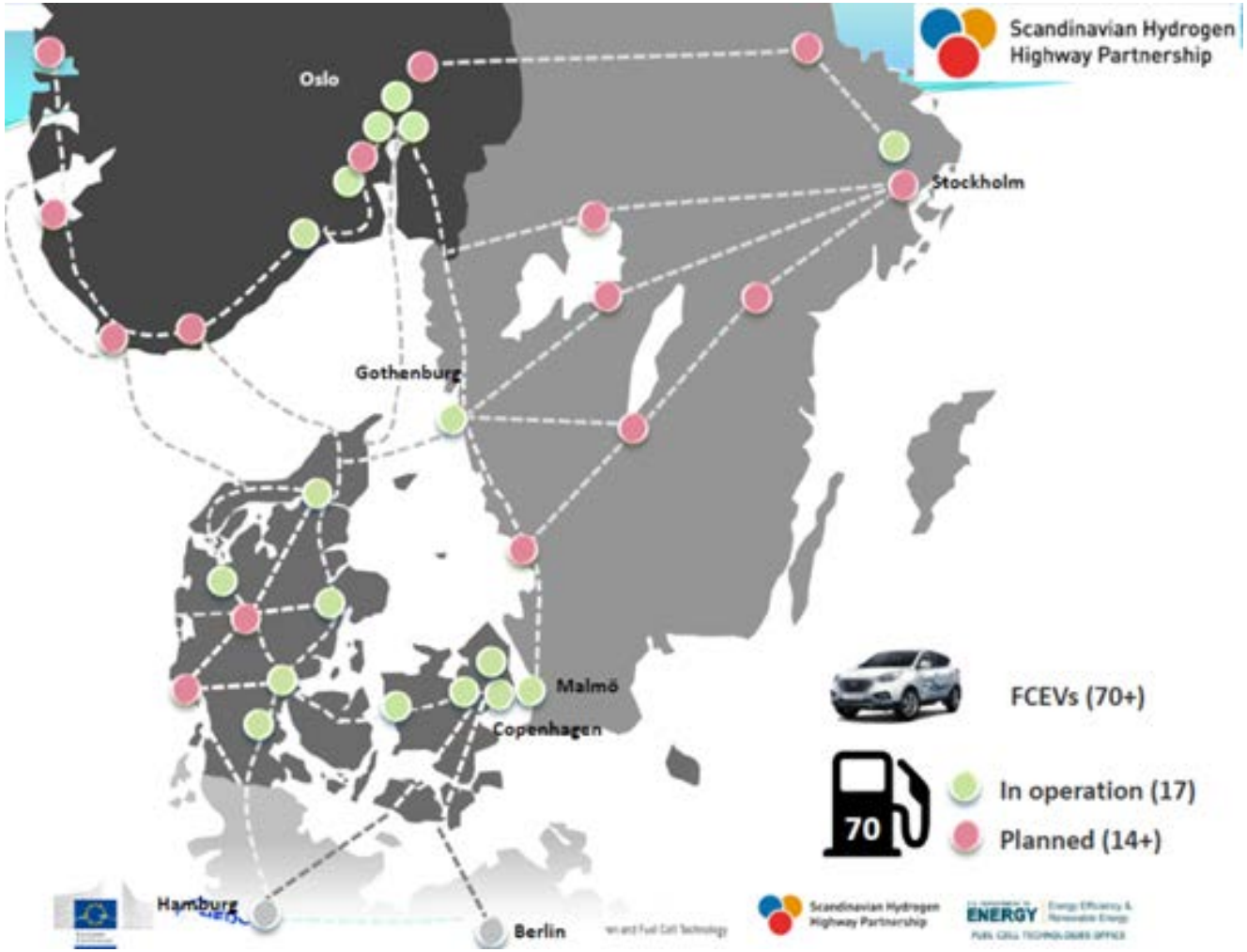
Scandinavia

Initiatives:

- Scandinavian H2 Highway Partnership (SHHP)
  - 2012 MOU with industry and NGOs for FCEVs and H2 infrastructure

Deployments:

- 2016 Status: ~20 stations, >70 FCEVs
- 45 H2 stations and a fleet of ~1K vehicles. Projects include H2Moves Scandinavia and Next Move



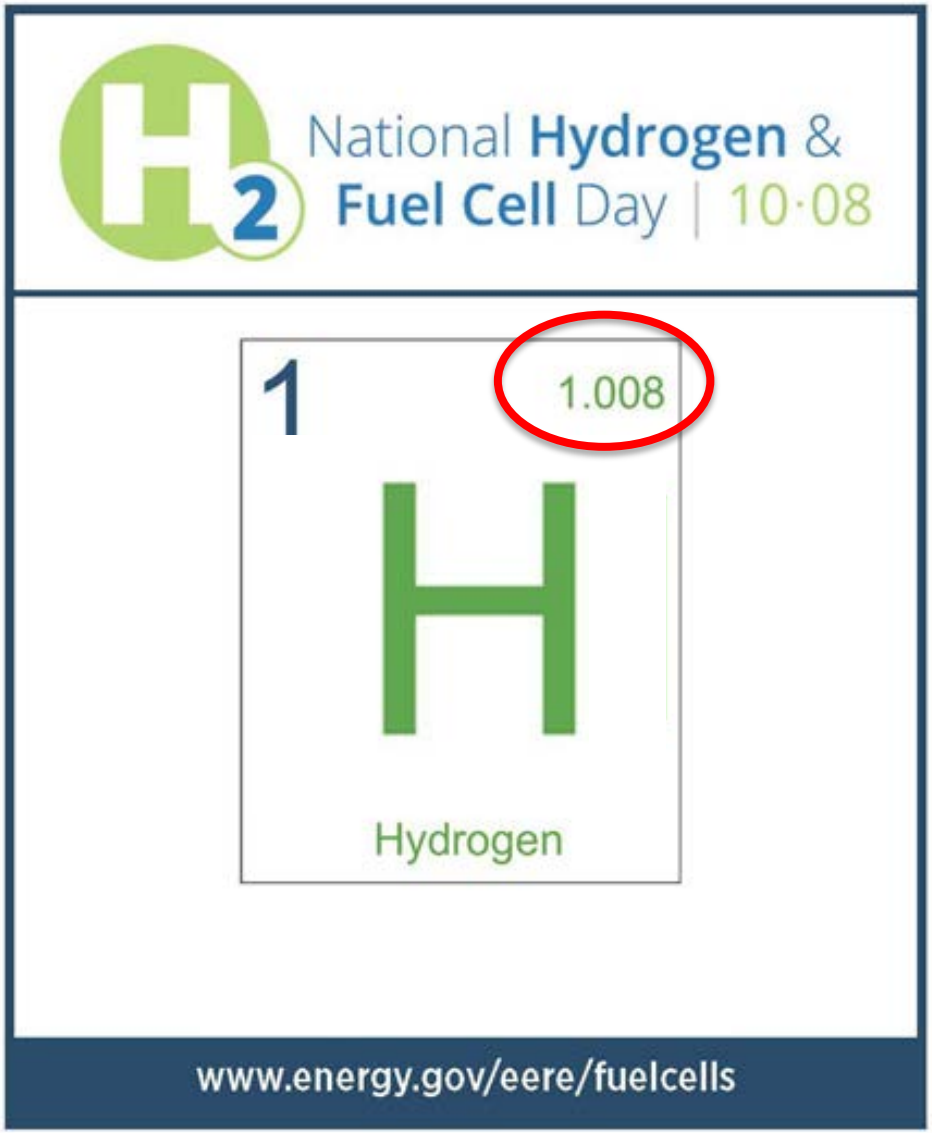
Source: http://www.iphe.net/partners.html

Barriers and Challenges

- Harmonization of International Regulations, Codes and Standards
- Policies at all government levels
- Incentives to support FCEV and hydrogen infrastructure deployment
- Broader Awareness and Acceptance, including on policy and for the general public

International Hydrogen & Fuel Cell Day!

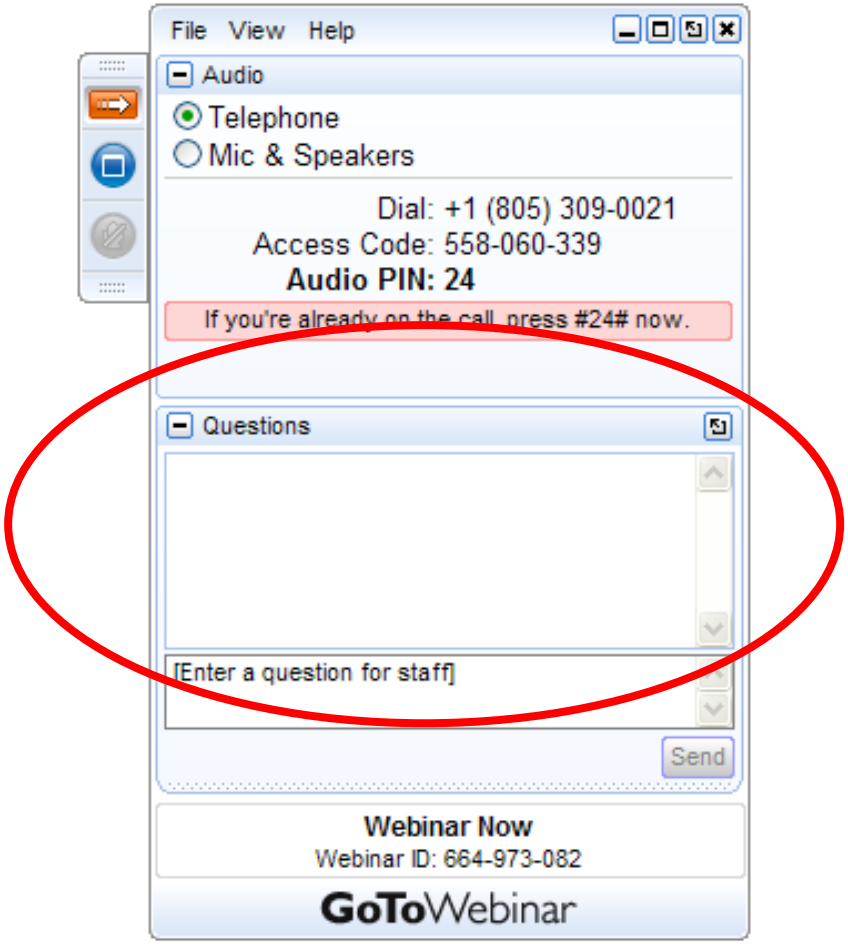
The U.S. will celebrate the <u>second ever</u> Hydrogen and Fuel Cells Day



<u>Upcoming</u>:
26th IPHE Steering Committee Meeting:
November 1-4, Gwangju, Republic of Korea

Question and Answer

- Please type your questions into the question box



Thank you

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