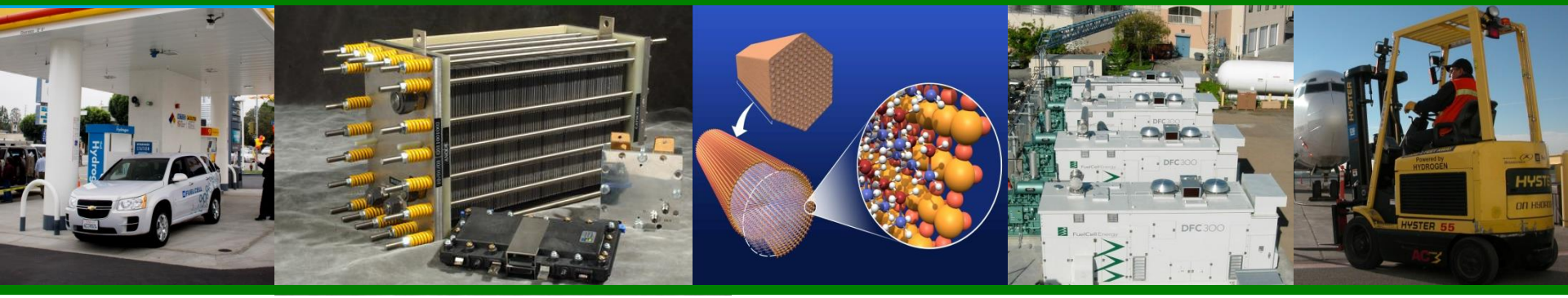
U.S. DEPARTMENT OF ENERGY



Annual Merit Review: Hydrogen Fueling Station Activities

Dr. Sunita Satyapal

Director, Fuel Cell Technologies Office

2016 Annual Merit Review and Peer Evaluation Meeting

June 6 - 10, 2016

Objectives and Key Outcome

Overall Objective

- **To review FCTO's priorities** related to **hydrogen station infrastructure**

Outcome

- **Feedback to inform FCTO strategies** on RD&D needs for hydrogen station infrastructure
- **RFI on station infrastructure topics** for future activities

First H_2 Station Infrastructure Feedback Session at an Annual Merit Review (AMR)

We welcome your feedback!

Hydrogen & Fuel Cells Budget

Key Activity	FY 15	FY 16	FY17
	($ in thousands)		
	Approp.	Approp.	Request
Fuel Cell R&D	33,000	35,000	35,000
Hydrogen Fuel R&D[1]	35,200	41,050	44,500
Manufacturing R&D	3,000	3,000	3,000
Systems Analysis	3,000	3,000	3,000
Technology Validation	11,000	7,000	7,000
Safety, Codes and Standards	7,000	7,000	10,000
Market Transformation	3,000	3,000	3,000
Technology Acceleration	0	0	13,000[2]
NREL Site-wide Facilities Support	1,800	1,900	N/A
Total	97,000	100,950	105,500

Office	FY 2016*
EERE	$101.0M
Basic Science	$18.5M
Fossil Energy, SOFC	$30.0M

FY 2016 DOE Total: ~$150M

*Estimated for BES funding (based on FY15)

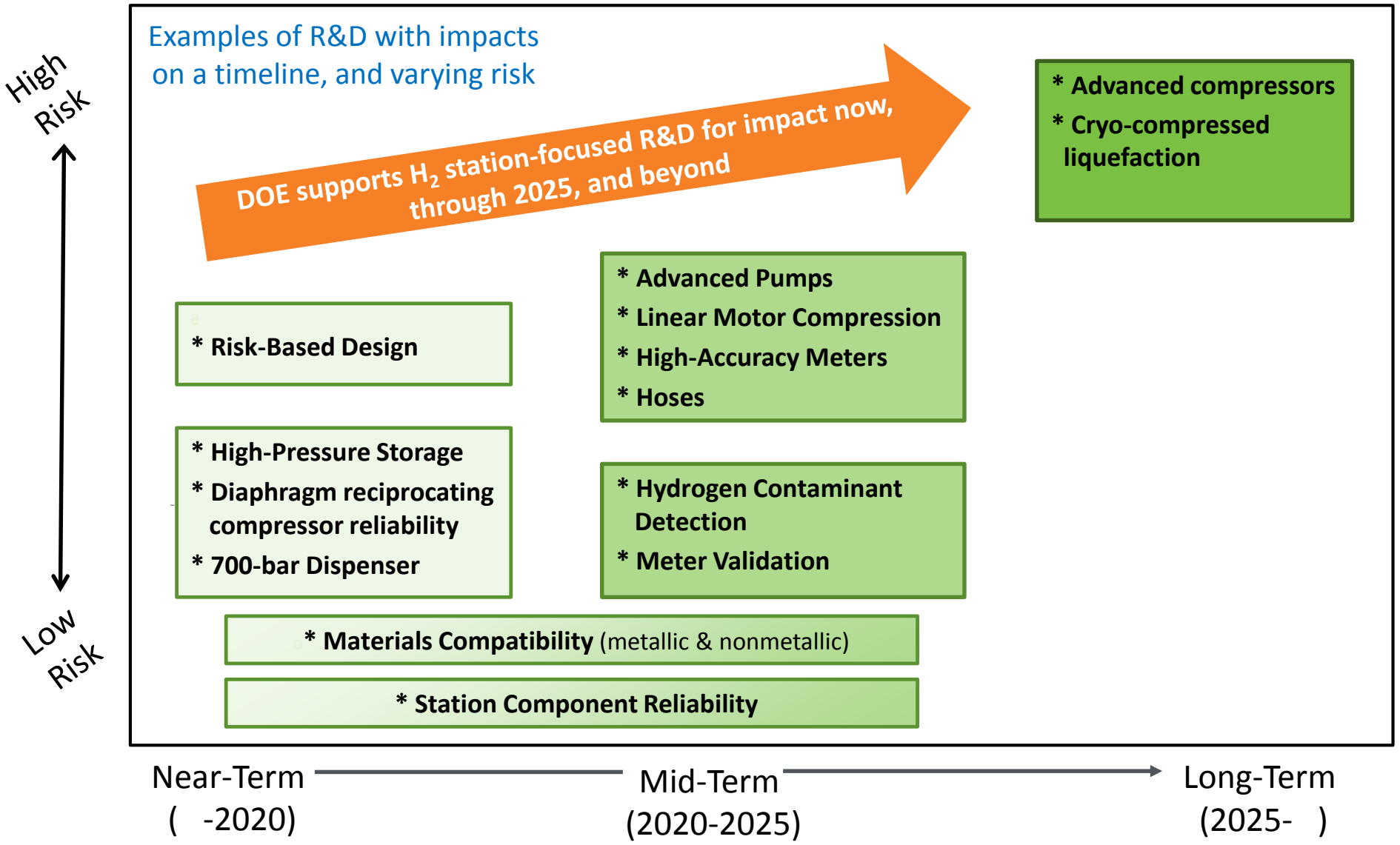
New in FY17 Request

[1]Hydrogen Fuel R&D includes Hydrogen Production & Delivery R&D and Hydrogen Storage R&D

[2]Combines Manufacturing R&D, Technology Validation, Market Transformation.

Sustained, stable funding requests and appropriations

Hydrogen Station Deployment R&D



Strategy addressing near, mid and long term challenges

Global Landscape- Infrastructure Activities

Japan

Hydrogen Supply/Utilization Technology (HySUT)

- 18 companies (3 car companies)
- **2016 Status: ~80 stations & >570 FCEVs**
- **Goals: FCEVs and stations- 40K & 160 by 2020, 200K and 320 by 2025 and 800K & 900 by 2030**

Germany

H2Mobility

- Public-private initiative for nationwide H_2 infrastructure
- **2016 Status: >40 stations & >100 FCEVs**
- **Goals: Stations- 100 by 2018-2019 and 400 by 2023**

UK

UKH2Mobility

- Will develop action plan to make UK a leading market for FCEVs
- **2016 Status: 16 stations and 12 fuel cell electric buses (FCEBs)**
- **Goals: 65 H2 Stations by 2020**

Denmark
Norway
Sweden

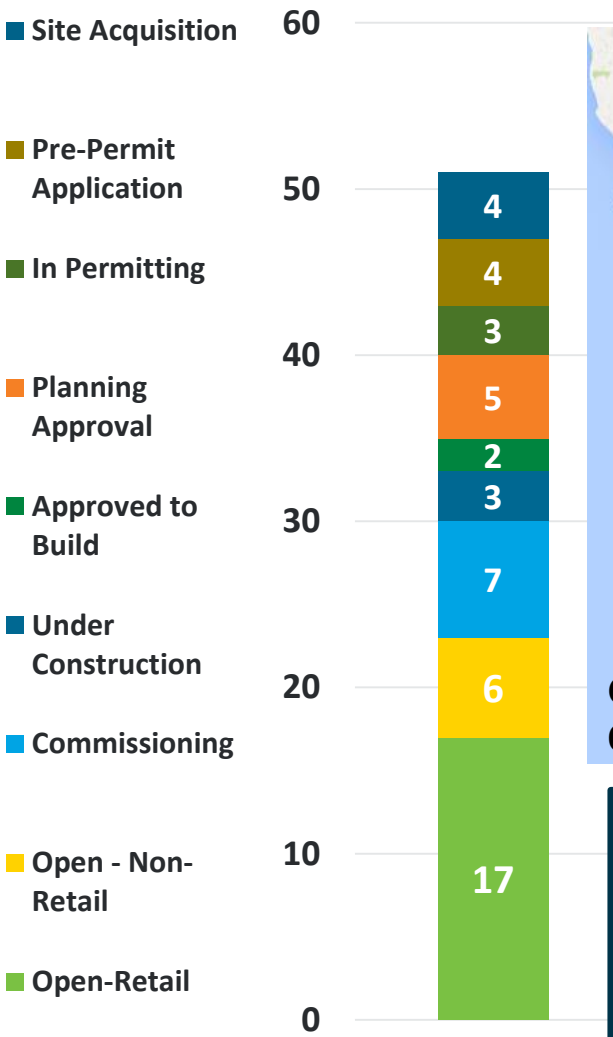
Scandinavian H2 Highway Partnership (SHHP)

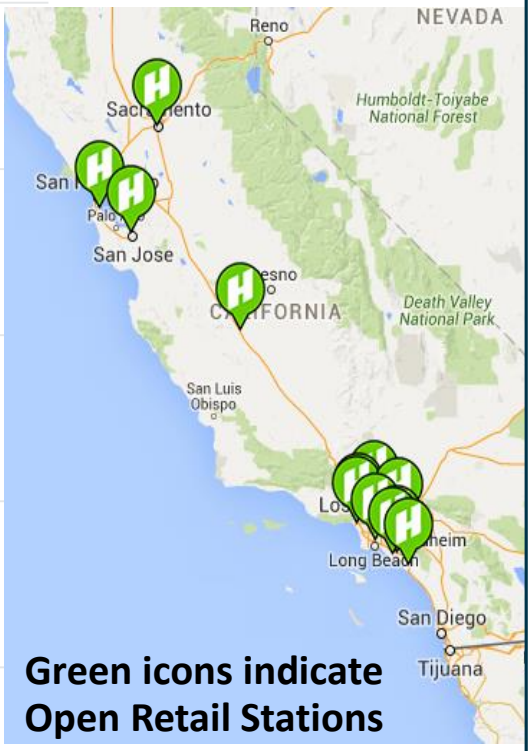
- 2012 MOU with industry and NGOs for FCEVs and H_2 infrastructure
- **2016 Status: ~20 stations, >70 FCEVs**
- **45 H_2 stations** and a fleet of **~1K vehicles.** Projects include H2Moves Scandinavia and Next Move

International partnerships established to accelerate hydrogen infrastructure

Regional Landscape- Infrastructure Activities

California





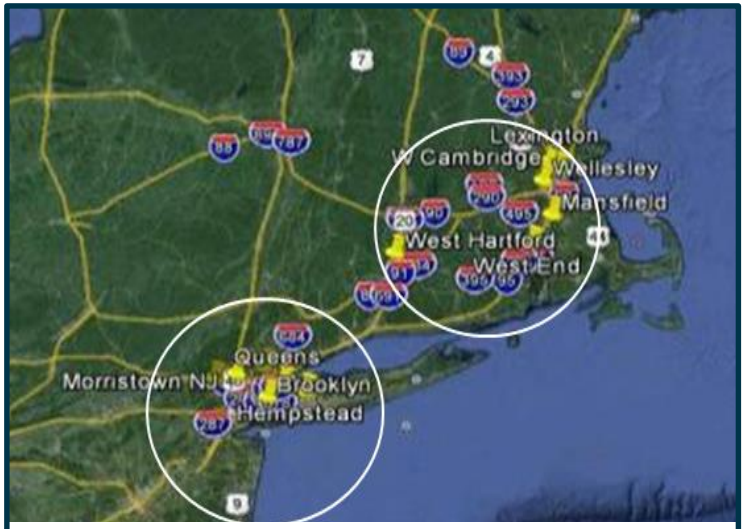
H_2 Stations

50 underway

Goal: 100

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

Northeast



12 Planned Retail H_2 Stations

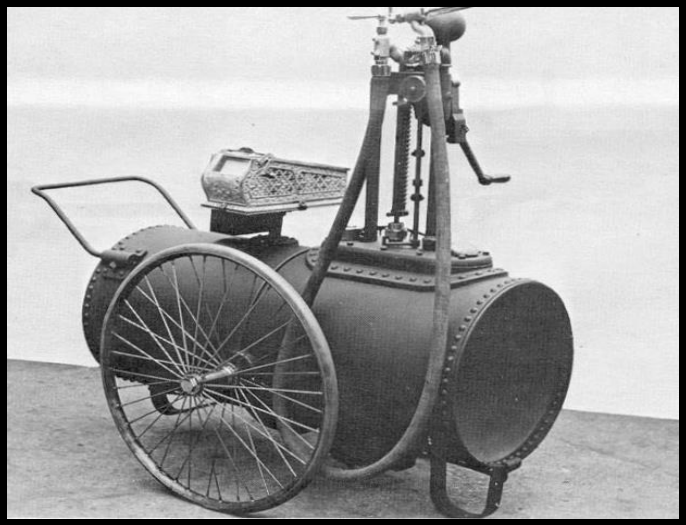
- California
- Connecticut
- Massachusetts
- Maryland
- New York
- Oregon
- Rhode Island
- Vermont

Many diverse options

Cans, barrels, home models, mobile refuelers

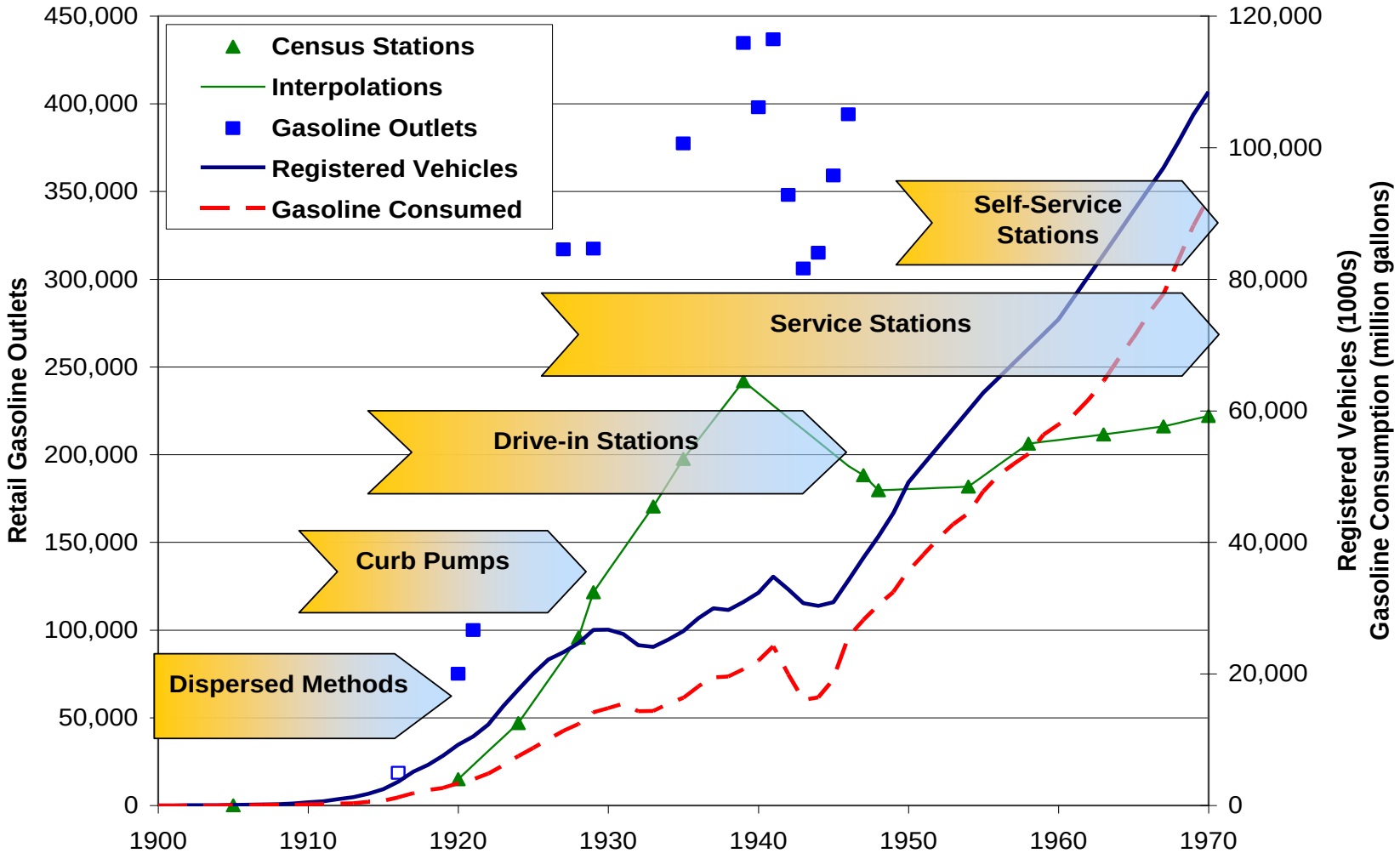
Source: M. Melaina 2008.

Source: Vieyra, 1979



Source: Milkues, 1978

Refueling Methods Evolved Over Time



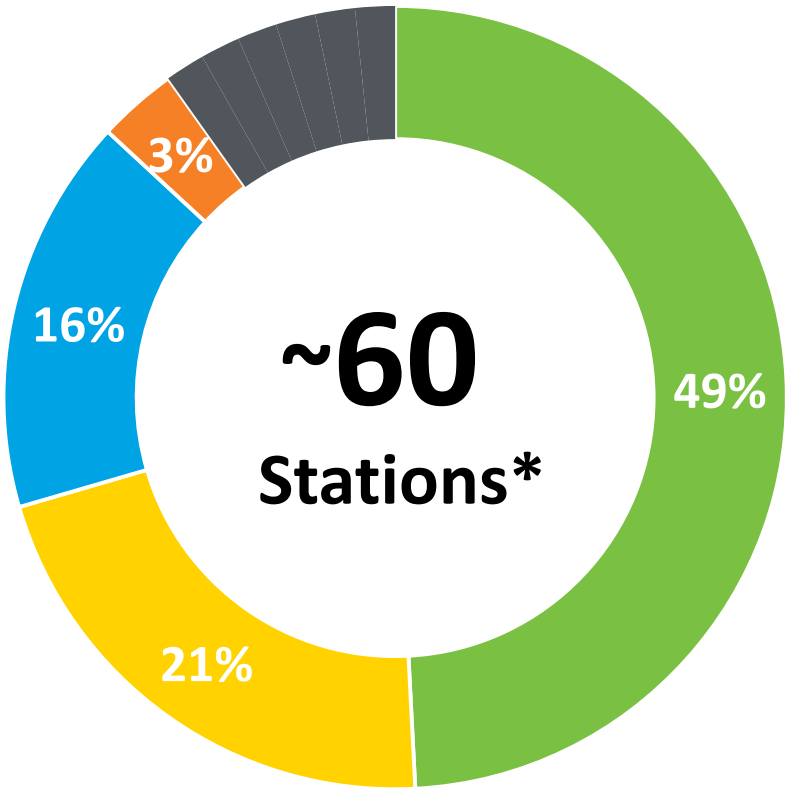
Source: Turn of the Century Refueling: A Review of Innovations in Early Gasoline Refueling Methods and Analogies for Hydrogen (Melaina 2007)

History shows phased introduction of different refueling methods

A Variety of H_2 Stations Demonstrated To Date

CA: ~ 20 stations now, up to 100 planned

Northeast: 12 stations planned



*Includes current (21), future (38) and retired (2) stations

NREL cdp_infr_11
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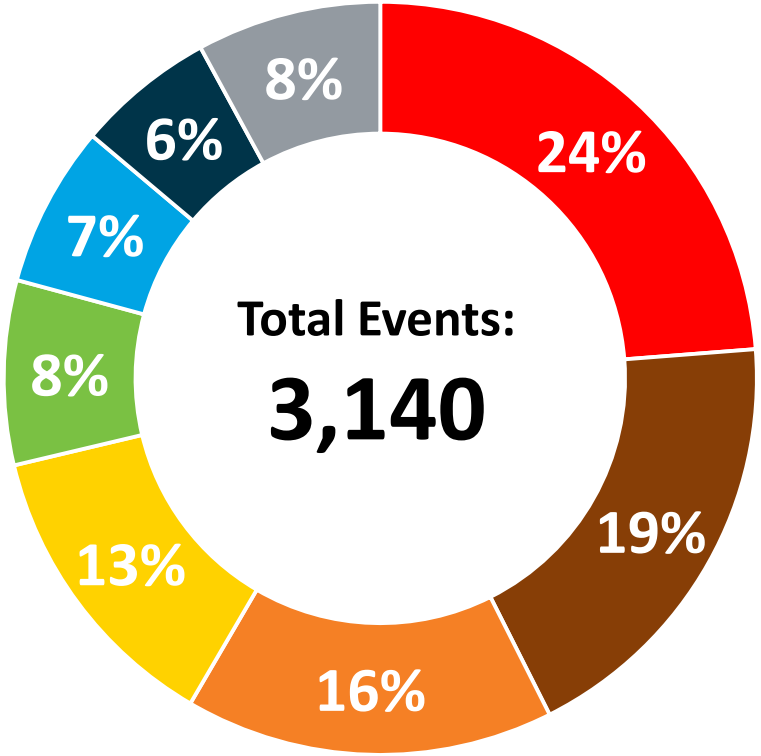
Type of Station

- Delivered Compressed SMR
- On-Site Electrolysis
- Delivered Liquid SMR
- On-Site SMR
- Other
  - Delivered Pipeline
  - Delivered Liquid By-Product
  - Delivered Compressed By-Product
  - On-Site Tri-Gen
  - Mobile Fueler
  - Trailers

SMR= Steam methane reforming

Real World Operation Data- H_2 Infrastructure

Example: **Sources of H_2 Infrastructure Maintenance**



Compressor
Dispenser
Entire
Safety
Storage
Reformer
Thermal Management
Other Chiller, Feedwater

Most maintenance related to compressors and dispensers

Contamination is a key issue: See Database *www.nrel.gov/hydrogen/system_contaminants_data/*

To participate: techval@nrel.gov

Providing insights to guide H_2 infrastructure activities and to maximize impact

Complementing Retail Stations: H_2 Refuel H-Prize

H2refuel
U.S. Department of Energy

$1M Competition: On-site H_2 fueling

Finalist Team Announced!
More at hydrogenprize.org

simple.fuel.™

Innovative packaging concepts
Electrolysis 350 and 700 bar

Email your Feedback
info@teamsimplefuel.com

Future: Renewable Hydrogen Consortium

Supporting

Will be led by NREL with SNL and LBNL on core team: Multiple partners to be added in FY17

Focus: **Materials for Renewable H_2 Production** including:

Advanced Electrolysis	**Photoelectrochemical**	**Solar Thermochemical**

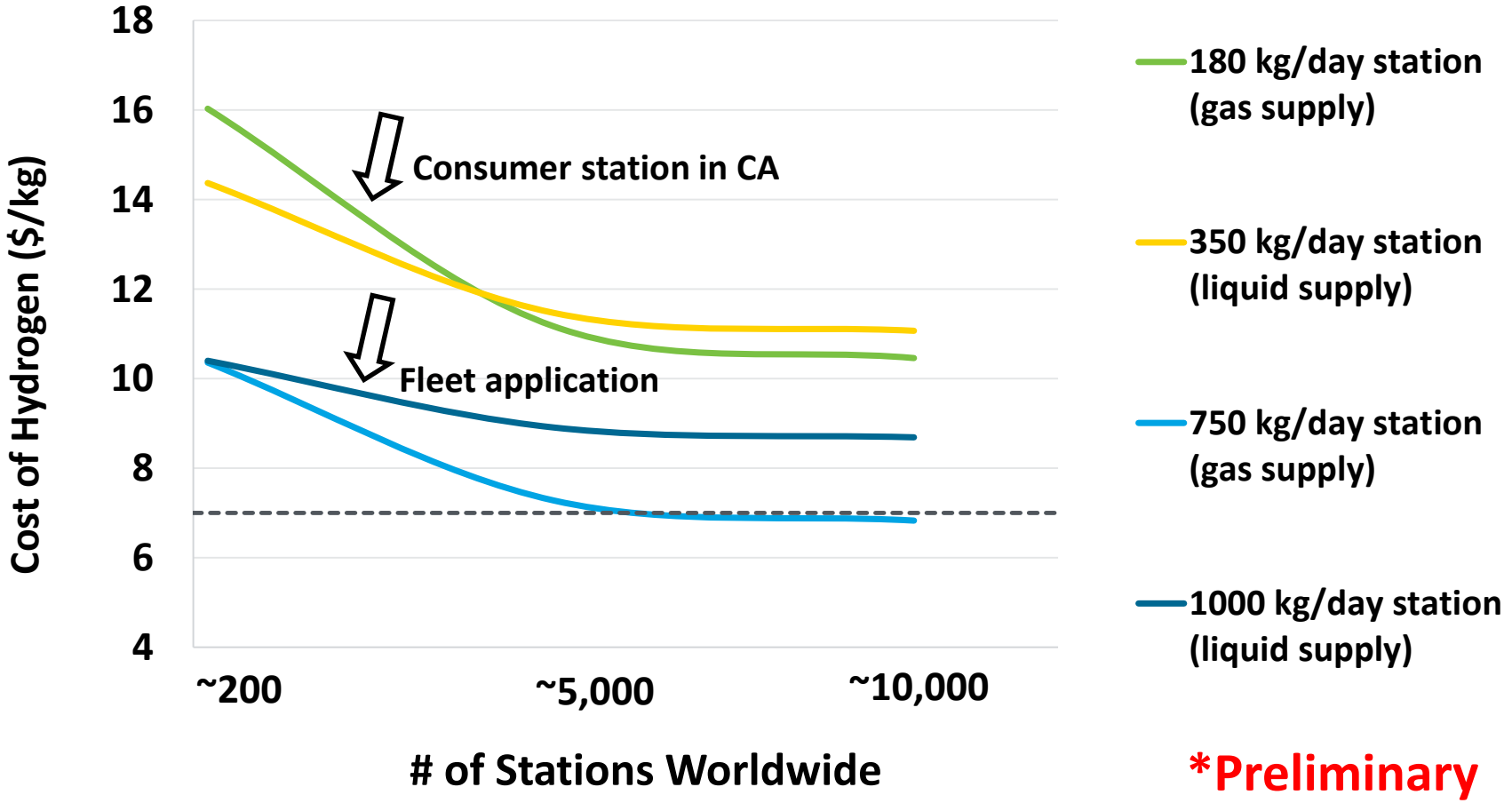
DOE H_2 Infrastructure Strategy

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)

What do YOU think are the main H_2 infrastructure barriers?

H_2 Infrastructure- Near-term Projections

Impact of Market Penetration on Hydrogen Cost (Production, Delivery, Dispensing)*



*Preliminary

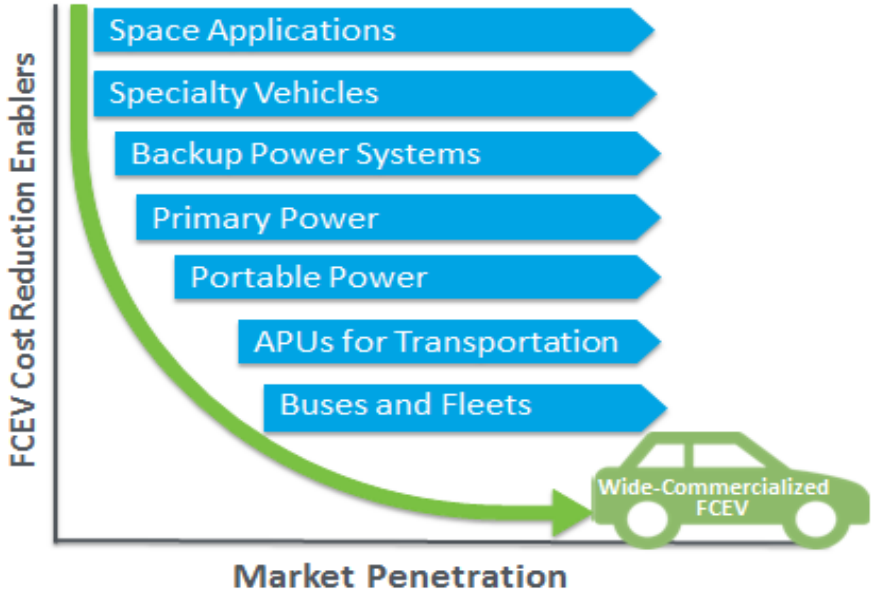
Based on near-term deployment scenario assumptions

Economies of scale and technological advancements are necessary

Early Market Strategies Increase Volume

Early Markets enable:

- Fuel cell cost reduction
- Robust supply base
- Emerging infrastructure
- Customer acceptance



Early Markets Applications Recently Deployed in the U.S.

Fuel Cell Tow Trucks

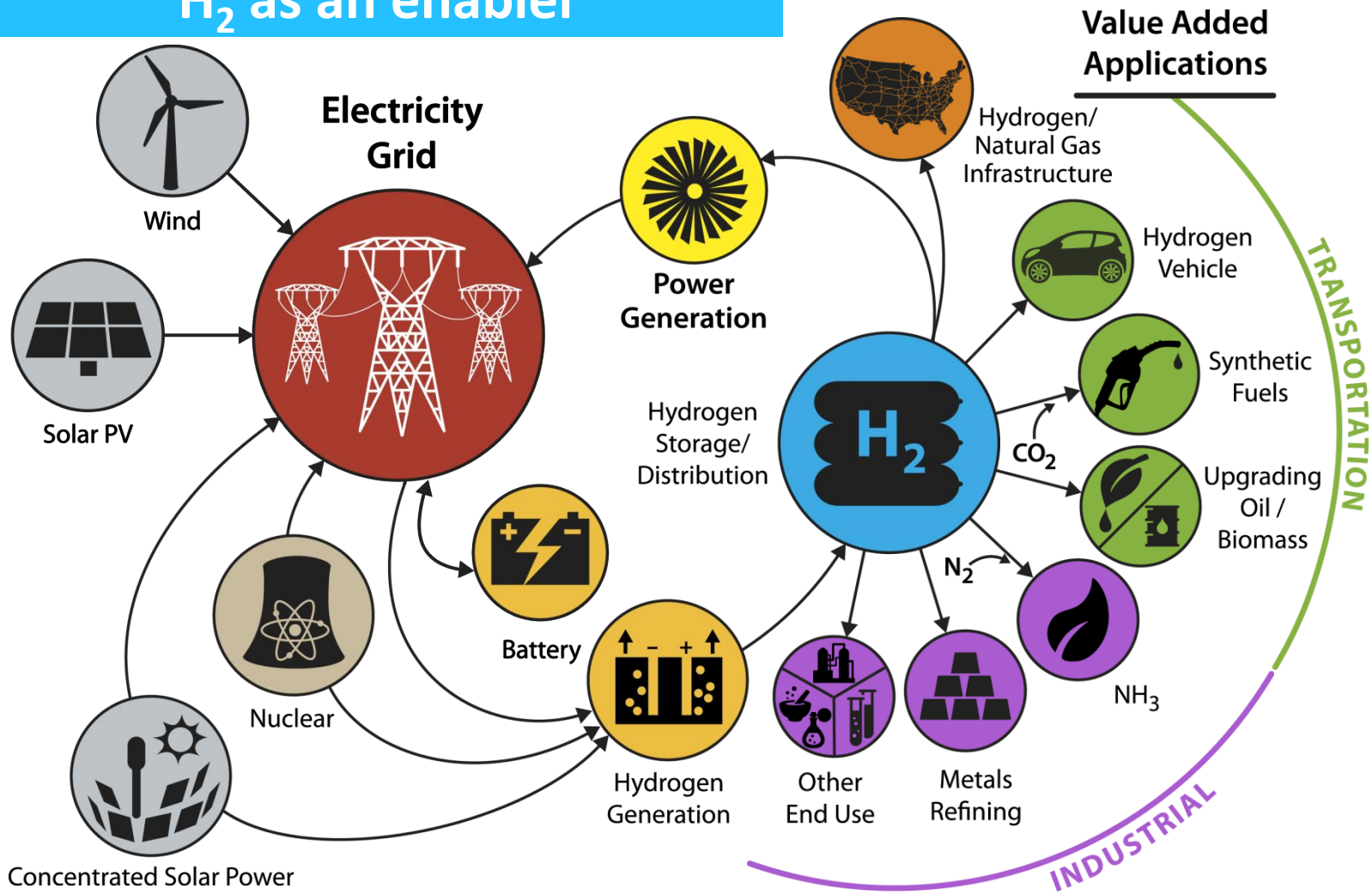
Fuel Cell Bus Fleets

Forklifts

Backup Power

H_2@Scale: Vision for the Future

H_2 as an enabler



Looking for your online feedback
Visit display by registration desk
https://www.surveymonkey.com/r/h2atscale

*Illustrative example, not comprehensive
Source: NREL; Lab Big Idea Summit

Thank You

Dr. Sunita Satyapal

Director

Fuel Cell Technologies Office

Sunita.Satyapal@ee.doe.gov

hydrogenandfuelcells.energy.gov