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California Energy Commission Integrated Energy Policy Report Workshop

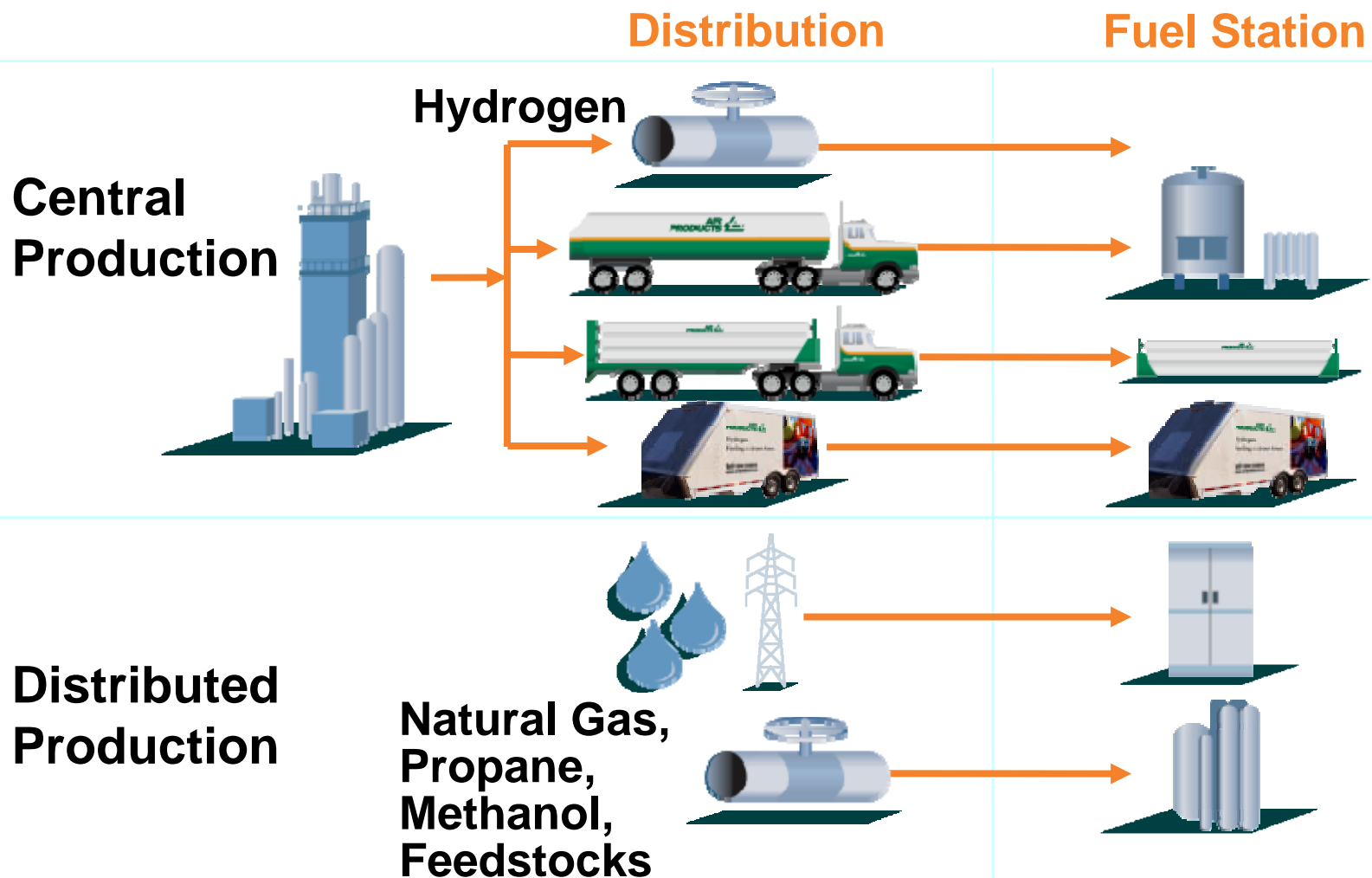
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Topics

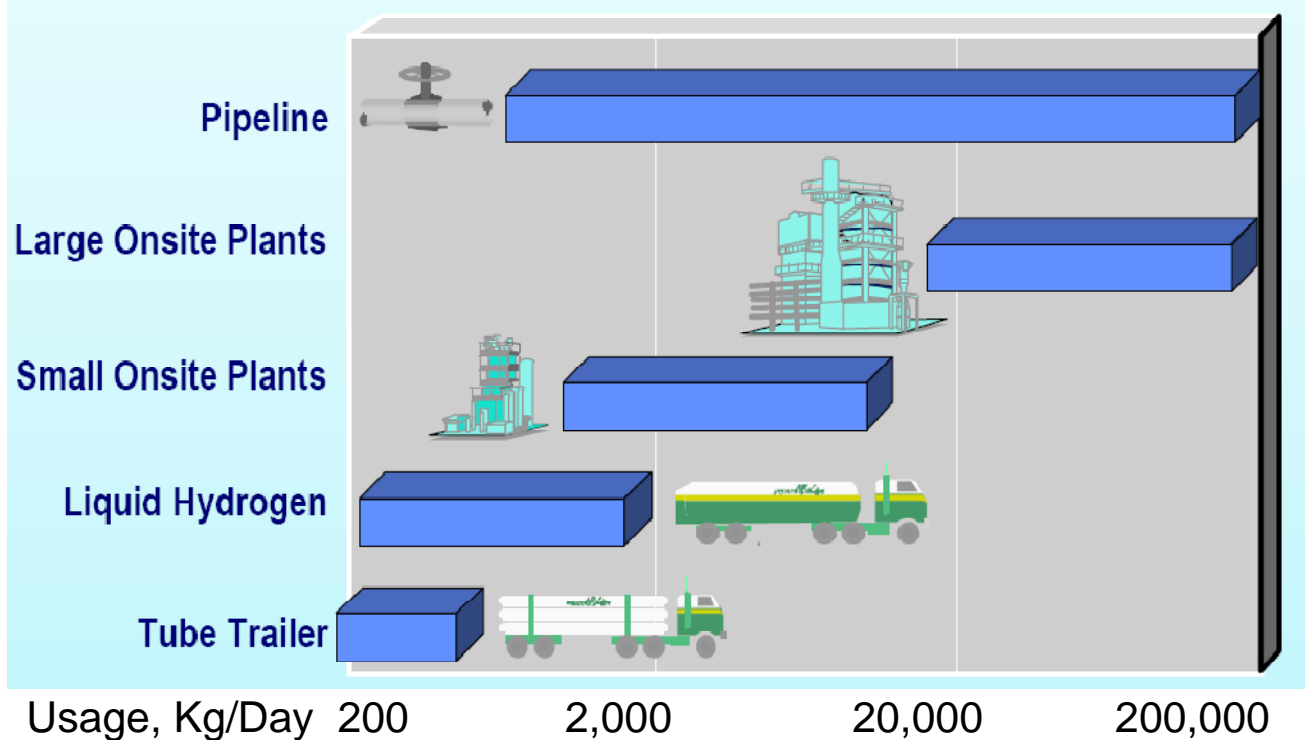
- Hydrogen Supply Chain
 - Production
 - Distribution
 - Dispensing
- Station Deployment Strategies
- Vehicle Information
- Other Issues
 - Quality
 - Codes and Standards

Hydrogen Sourcing



Hydrogen Means of Production

Hydrogen Distribution Modes



Overview of Hydrogen Production Economics

- Hydrogen is a volume business
- Lowest-cost production methods exist at large central facilities, and can meet targets for H₂ pricing to consumer transportation market
 - NREL Study (2009) shows H₂ cost of \$1.33 per kilogram produced at large volumes
- 10 May 2011: Opening of hydrogen fueling station supplied directly from industrial pipeline



Current Supply Chain for Delivered Hydrogen to Refueling Stations



Produce
And
Purify

Prepare
for
Transport

Distribution

Site
Storage

Prepare
For
Fueling

Dispense

- Need different approach to distribute low-cost H₂ from central production facilities to point of use
- Lowest cost of deployment utilizes excess capacity from existing sources

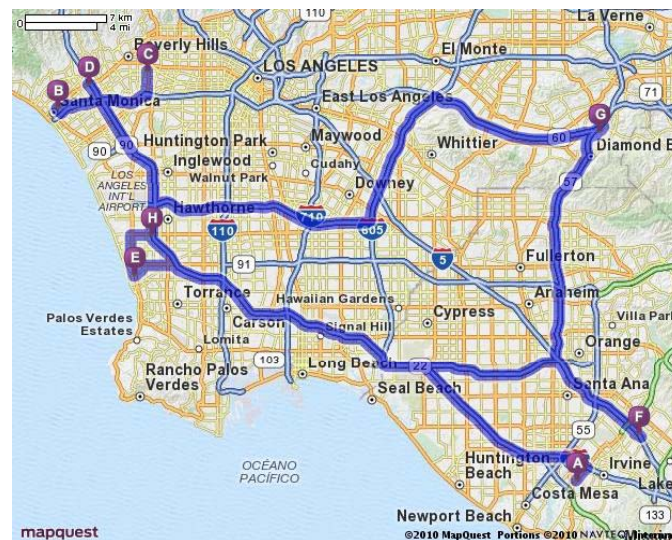
Hydrogen Fueling Station Considerations

- Stations can be built today for large throughputs
 - Example: liquid H_2 supply with liquid compression systems and multiple dispensers
 - Material handling
 - Mass transit
 - Issues for light duty vehicles:
 - High H_2 price at low station utilization
 - Station footprint - number of amenable existing retail gasoline stations?
 - Future innovations

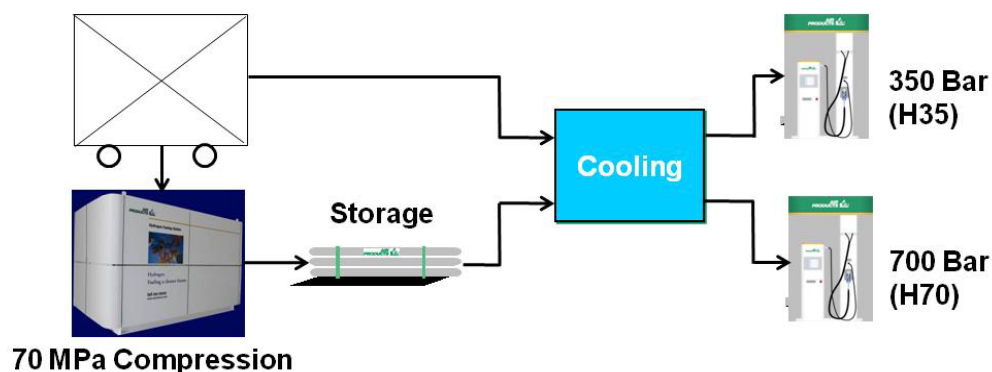


Hydrogen Fueling Station Deployment Strategy

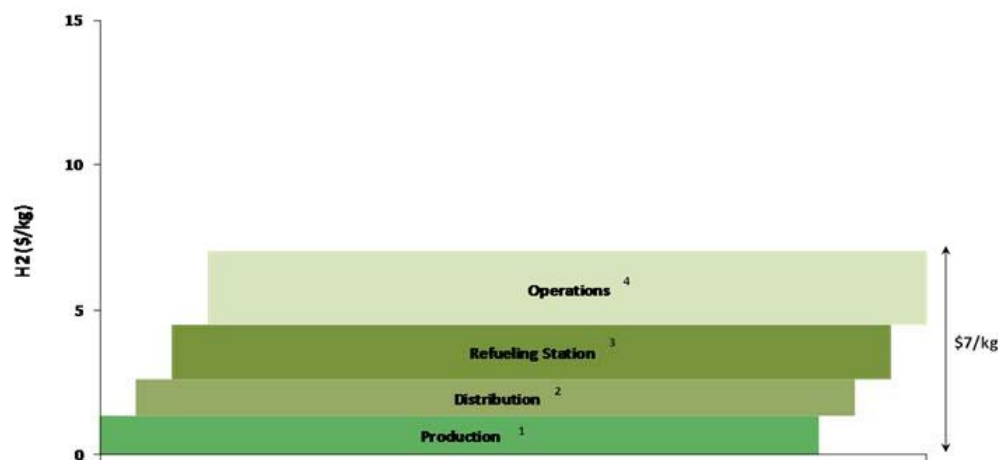
- For every \$10MM of infrastructure investment, stakeholders can deploy:
 - 3 stations at \$3MM each
 - 5 stations at \$2MM each
 - 10 stations at \$1MM each
- OEMs seeking market coverage ahead of vehicle rollout
 - Take full advantage of driving range of FCV's
- Modeling (ex.: UCI) along with OEM market data can target infrastructure deployment
 - Clusters
 - Destination stations (future cluster)



Air Products' Low-Cost Fueling Station



- Station cost: around \$1 million
- Ease of expansion, or deploy new additional station (market forces)



1- NREL, Ruth et al 2009. Central SMR production
 2- USDOE 10/2010. Infrastructure (Station with Tube Trailer Delivery)
 3- APCI 2011. (Hydrogen refueling station under CEC 2010 program)
 4- \$250k/yr. Based on UCD 2011 Hydrogen Station Analysis plus CA Excise Tax

- Price of H₂ attractive at higher throughputs
- Can operate within similar tax structure as other fuels
- Fixed operating costs for stations (insurance, property taxes, etc.)

Fuel cell vehicles in California



2010 CaFCP survey of automaker passenger fuel cell vehicles

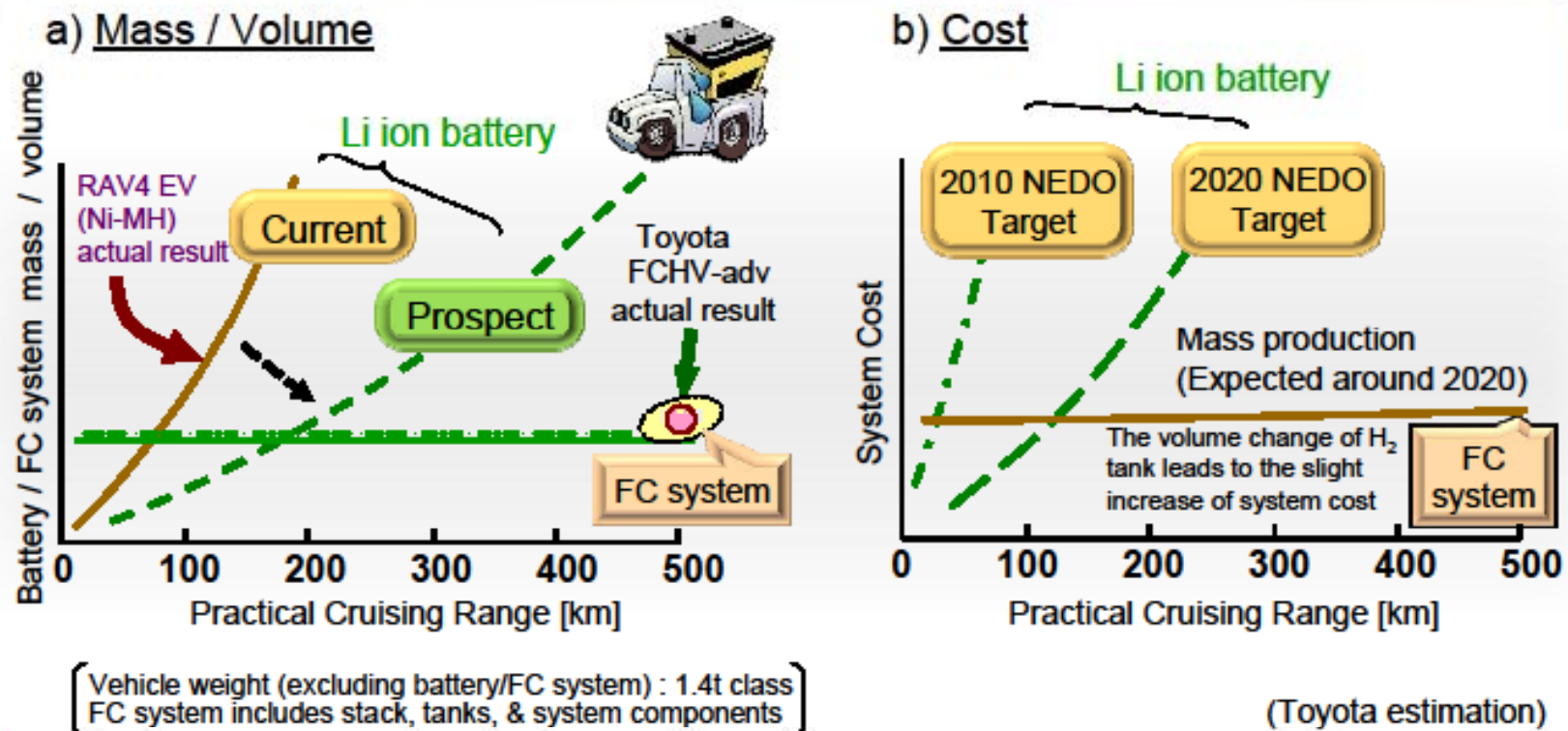
	Hundreds	Thousands	Tens of thousands
	Through 2013	2014	2015-2017
Total Passenger Vehicles	430	1,400	53,000



To date:

- 404 FCVs/FCBs since 1999
- >167 operating now
- Over 4 million road miles
- Over one million transit riders

FC and EV System Comparison



For long-distance driving, the data shows potentially dramatic savings in mass, volume, and cost for FC systems in mass production.

TOYOTA

Hydrogen Quality

- Hydrogen can be made from a number of sources, including byproducts from chemical manufacturing
 - Purity specifications for certain components (for example, helium) are difficult from a purification perspective and might disqualify these low-cost sources as potential fuels for FCVs
- Development and validation of testing methods to meet proposed specifications
 - Adds costs (analyzers, O&M)
 - Certain test methods still require validation
 - Lower unit cost for analytical at large central production plants vs. distributed production systems
- Hydrogen is made today at ultra high purity, costs are higher as purity tolerances are tightened

Codes and Standards

- Air Products participates in organizations that develop codes and standards for hydrogen fueling
- AHJs have different interpretations, which lead to different results at different locations
- It has been more difficult for smaller stations where there are hundreds of station configurations
 - As stations get larger, options will be fewer → this may lead to a more uniform interpretation of codes



Thank You