

### Hydrogen Infrastructure Analysis in Early Markets of FCEVs

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### **Regulations drive deployment of FCEVs**

California requires automobile OEMs to achieve specific sales volume of zero emissions vehicles (ZEVs). Others states are following suit.

|  | Category | Vehicle Acronym   | Vehicle Examples                                                    |  |  |
|--|----------|-------------------|---------------------------------------------------------------------|--|--|
|  | Gold     | ZEV               | hydrogen fuel cell electric (FCEV), battery electric vehicles (BEV) |  |  |
|  | Silver+  | Enhanced AT-PZEV* | Plug-in hybrids or hydrogen-ICE                                     |  |  |
|  | Silver   | AT-PZEV           | Hybrid, compressed natural gas                                      |  |  |
|  | Bronze   | PZEV              | Extremely clean conventional vehicle                                |  |  |

\*Advanced Technology Partial Zero Emissions Vehicle

| ZEV Type | Definition                                 | Example               | Credits (2009-2017) |
|----------|--------------------------------------------|-----------------------|---------------------|
| Туре І   | 50-75 mile Electric Range (ER)             | Limited Range BEV     | 2                   |
| Type I.5 | 75-100 mile ER                             | City Electric Vehicle | 2.5                 |
| Type II  | 100-200 mile ER                            | Full function BEV     | 3                   |
| Type III | 200 mile ER, or 100+ER with fast refueling | FCEV or BEV           | 4                   |
| Type IV  | 200+ mile ER with fast refueling           | FCEV                  | 5                   |
| Туре V   | 300+ mile ER with fast refueling           | FCEV                  | 7                   |

http://arbis.arb.ca.gov/msprog/zevprog/factsheets/2008zevfacts.pdf



# Refueling stations rollout faces several major challenges in early markets

- □ High capital investment at low manufacture volume of components
- Underutilization of the capital in early markets
- $\Box$  High investment risk  $\rightarrow$  requires high rate of return



### Refueling station underutilization poses significant burden on refueling cost in early markets

• Initial HRS network density is needed before FCEV deployment (e.g., 68 stations in California by 2015)

 $\rightarrow$  Major underutilization of initial network

- The next biggest question for HRS underutilization is vehicle ramp rate?
  - ➢ For slow FCEV ramp rate → long period of underutilization
    → build small HRS (loses benefits of economies of scale)
  - ➢ For fast FCEV ramp rate → short period of underutilization
    → build large HRS (benefits from economies of scale)
- But the vehicle ramp rate is very uncertain for many reasons, including customer acceptance

# Thus, HRS roll out initiatives with public support are needed to overcome challenges of early markets

| Market Phase                | Public<br>Support? | HRS<br>Profitable? | HRS<br>Reliable? | HRS<br>Sustainable?   |
|-----------------------------|--------------------|--------------------|------------------|-----------------------|
| [1] Demonstration           | Yes                | No                 | No               | No                    |
| [2] Early/<br>Precommercial | Yes                | Yes                | No               | Pseudo<br>Sustainable |
| [3] Commercial              | No                 | Yes                | Yes              | Self<br>Sustainable   |

# Pipeline delivery is not a likely option for the demand levels in early markets





#### Liquid vs. gaseous delivery: Each has unique advantages



# Station footprint impact on cost of H2 could be significant





#### IEA-HIA Task 28 Evaluation of H2 delivery concepts

| HRS size<br>Distribution option | e Very small<br>≤ 80 kg/day                                                                | Small<br>~ 200 kg/day                                                                       | Medium<br>~ 400 kg day | Large<br>~1000 kg/day | Very large<br>≥ 1000 kg/day |  |
|---------------------------------|--------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------|------------------------|-----------------------|-----------------------------|--|
| On-site electrolysis            | On-site power requirement may become an issue: 400 kg/day ≈ 1 MW                           |                                                                                             |                        |                       |                             |  |
| On-site reforming               | Difficult to c                                                                             | Difficult to capture CO <sub>2</sub> Required footprint for production facility is an issue |                        |                       |                             |  |
| CGH2 truck                      | Delivery of 300 kg up to potential maximum of 1000 kg per truck                            |                                                                                             |                        |                       |                             |  |
| LH2 truck                       | Relatively large boil-off for demand levels in early markets                               |                                                                                             |                        |                       |                             |  |
| CGH2 pipeline                   | Due to high investments pipelines are not likely in early markets unless already available |                                                                                             |                        |                       |                             |  |
| Color coding:                   | Very likely                                                                                |                                                                                             | Possible               |                       | Less likely                 |  |

- Differences in general applicability based on main differentiating characteristics, or the most demanding or challenging requirements
- Examples: CAPEX, amount of hydrogen load per delivery, footprint (setback distances), CO<sub>2</sub> emissions, ...

## Thank you!

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