# Lessons and Challenges for Early Hydrogen Refueling Infrastructure

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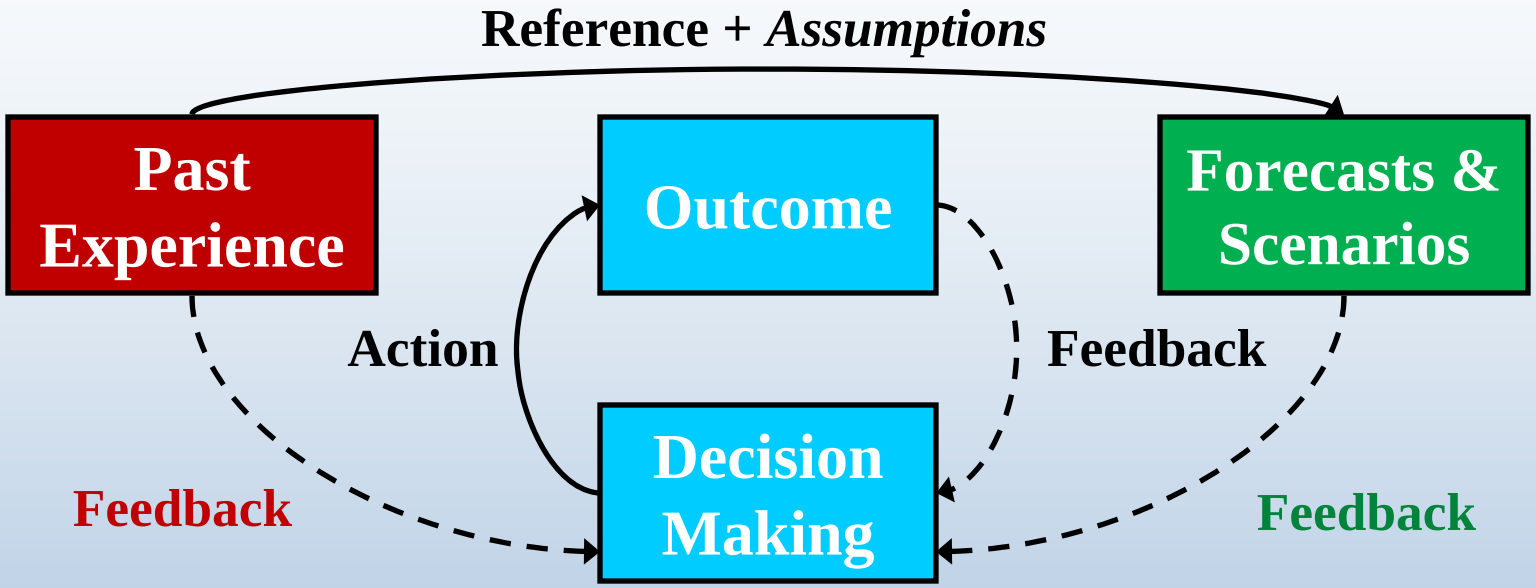
# Presentation Overview

- Learning from Past Alternative Fuel Vehicle Experiences
    - Lessons from the previous NREL Workshop (July 2006)
- Lessons and Challenges for Hydrogen Infrastructure
  - How many stations?
  - How many vehicles per station?
  - Early gasoline faced no chicken-and-egg problem
- Timing, Geography and Risks

# Introduction: Learning from the Past

**The learning process involves interpreting feedback to improve decision making**




- New context today
  - Technology has improved
  - Oil is above $100 a barrel
  - Peak Oil and Climate Change drivers overshadow Air Quality
  - Regulatory agencies are taking on greenhouse gas emissions

# AFVs have an Extensive History

- Alternative Fuel Vehicle Policy Initiatives
  - Nixon (1973) Domestic Oil & Nuclear: Zero imports in a decade
  - Carter (1977) Efficiency & Synfuels: Cut imports in half by 1985
  - Bush (2007) Alt fuels & CAFE: 20% gasoline reduction in 10 years
- Various policy strategies have been pursued
  - Mandates, tax credits, grants, renewable fuel content, etc.
- Waves of Enthusiasm
  - Ethanol
  - Methanol
  - Natural Gas
  - Electric Vehicles
  - Hydrogen
  - Biofuels
  - Plug-in Hybrids

**Porsche HEV - 1901**

# Recommendations from NREL's previous Lessons Learned Workshop (July 20th, 2006)

1) Set realistic deployment goals. Don't let deployment get out ahead of research and development.
2) Educate policy makers, OEMS, vehicle dealers, fleets and consumers.
3) Address both vehicle and infrastructure costs.
4) Create and maintain a cohesive, consistent national policy.
5) Use local efforts for deployment.
6) Use fleets for initial deployment, but create a strategy to leap to the individual consumer market.

**Focus of this workshop:**

- **Adequate refueling infrastructure is fundamental to near-term vehicle commercialization**

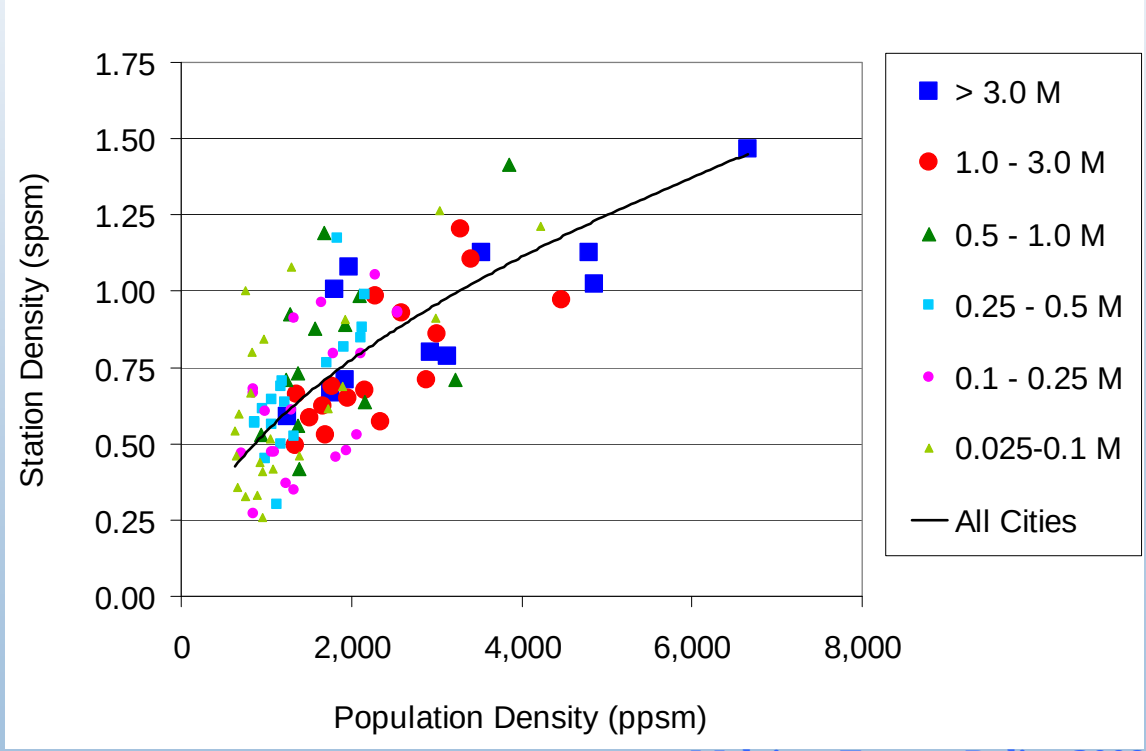
# Lessons from the “Fleets” Strategy

- In theory, fleets are an ideal niche market
- In reality, fleets are troublesome as ideal early adopters
  - Many fleet vehicles refuel at public refueling infrastructure
  - Fleet facilities are not always appropriate locations for public refueling stations
  - Fleet operators are relatively conservative in terms of accepting technological risks
  - Many fleets require a diverse set of specialized vehicles

# Lessons for Hydrogen Infrastructure

# Significant Refueling Infrastructure must Precede Vehicle Mass Production

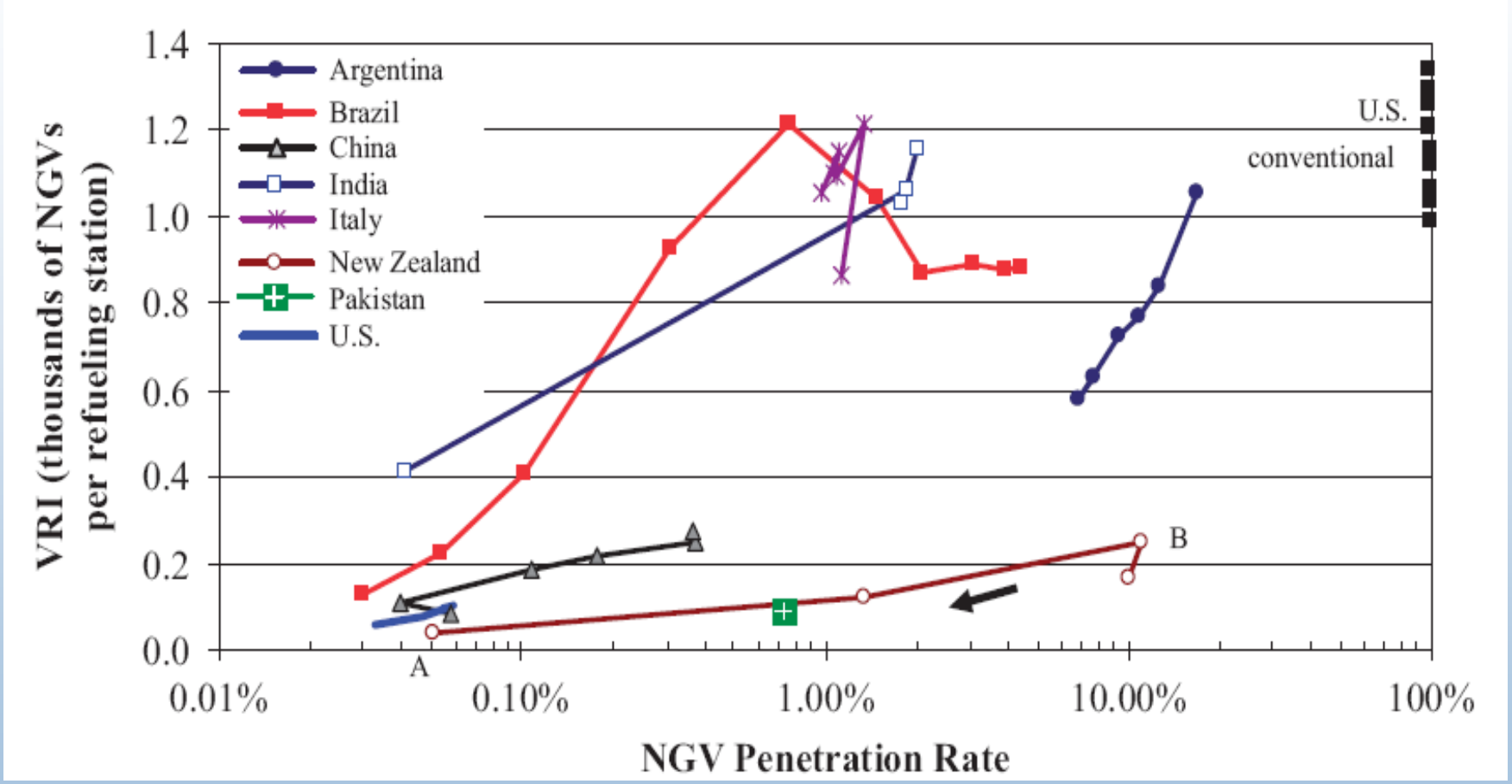
- **Refueling availability at 10% of existing stations satisfied most early diesel and natural gas vehicle adopters**
  - Surveys: New Zealand (CNG), Southern CA (diesel)
  - But 10% of what? 25% station reduction from 1991 to 2006




**Station densities vary significantly among cites**

Melaina, Energy Policy 2008

# CNG Success stories have achieved a ratio of about 1000 - 1300 vehicles per Station




Yeh, Energy Policy 2007

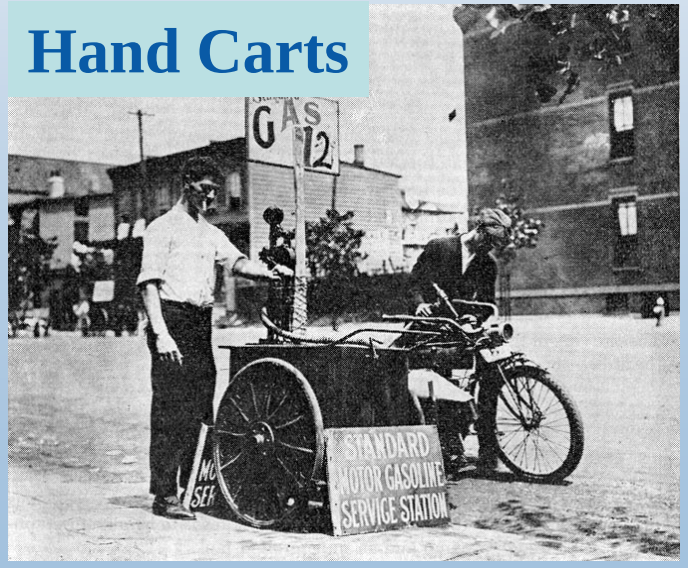
VRI = Vehicle-to-Refueling Station Index (1000s vehicles/station)

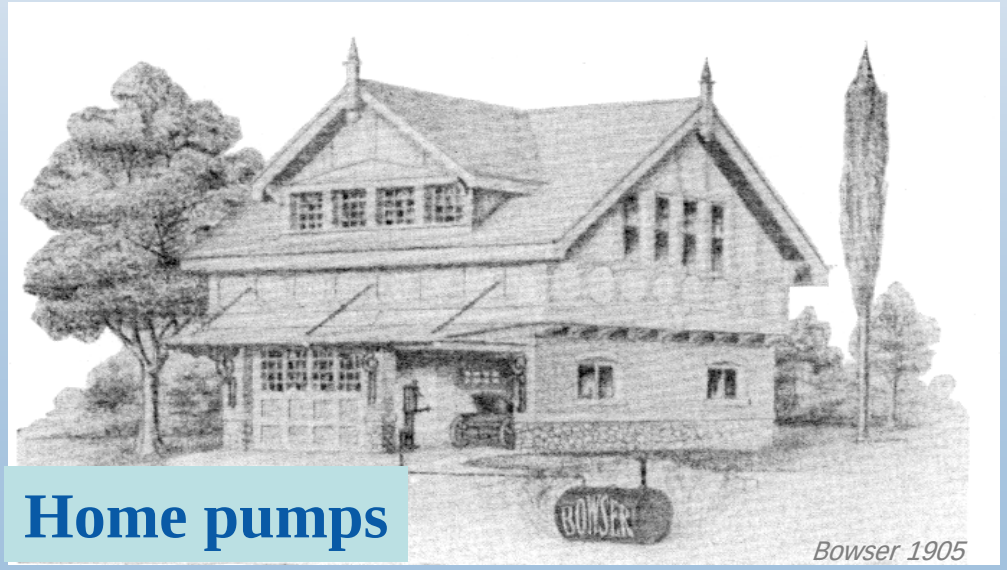
# Early "Non-Station" Refueling Methods


**Barrels**

- Gasoline had limited markets in urban and rural areas before gasoline vehicles (cans)
- "Non-station" methods preceded stations around 1900-1920
- 10s of thousands of non-station outlets were in place ~1910

**Hand Carts**




**Home pumps**

*Bowser 1905*

# Timing and Geography

# Geography is Key

## ORNL Scenarios Study

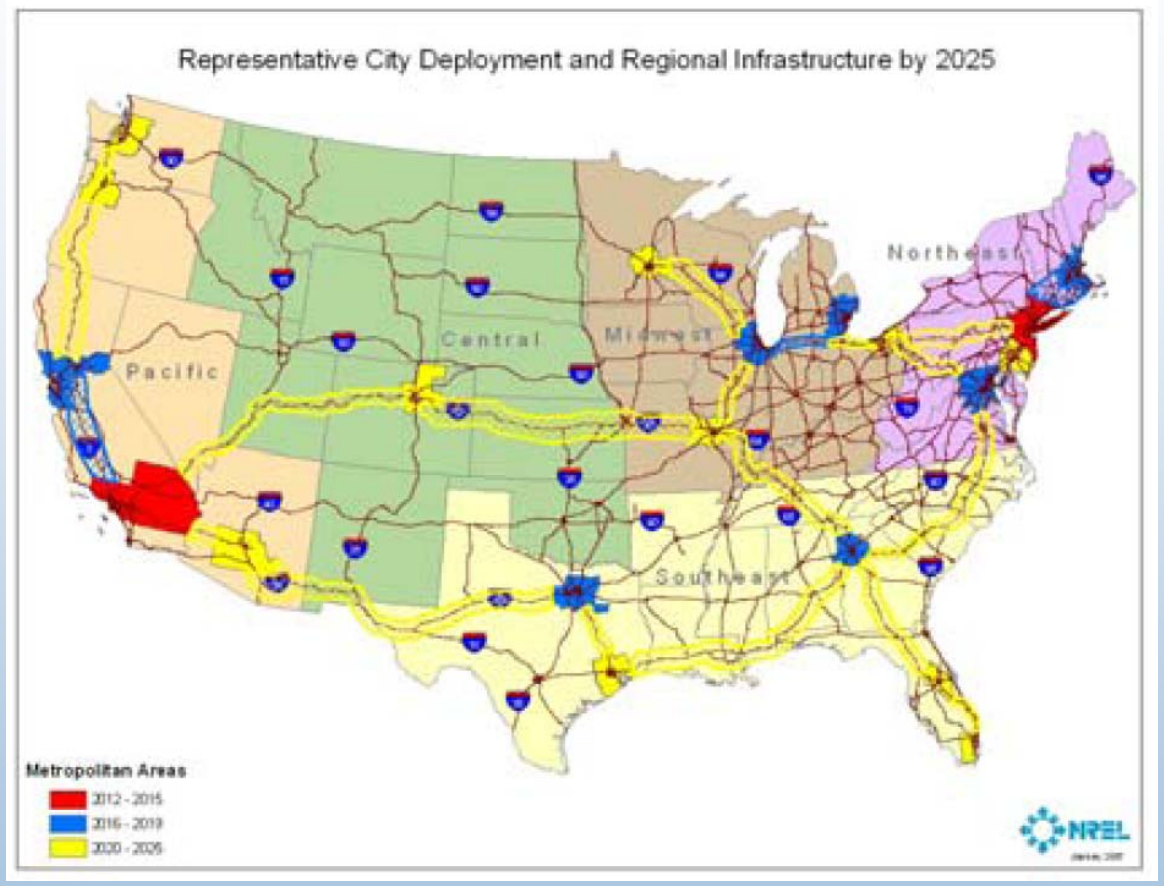
Developed through DOE Workshops

(Sig Gronich)

Phase I (2012-2015)

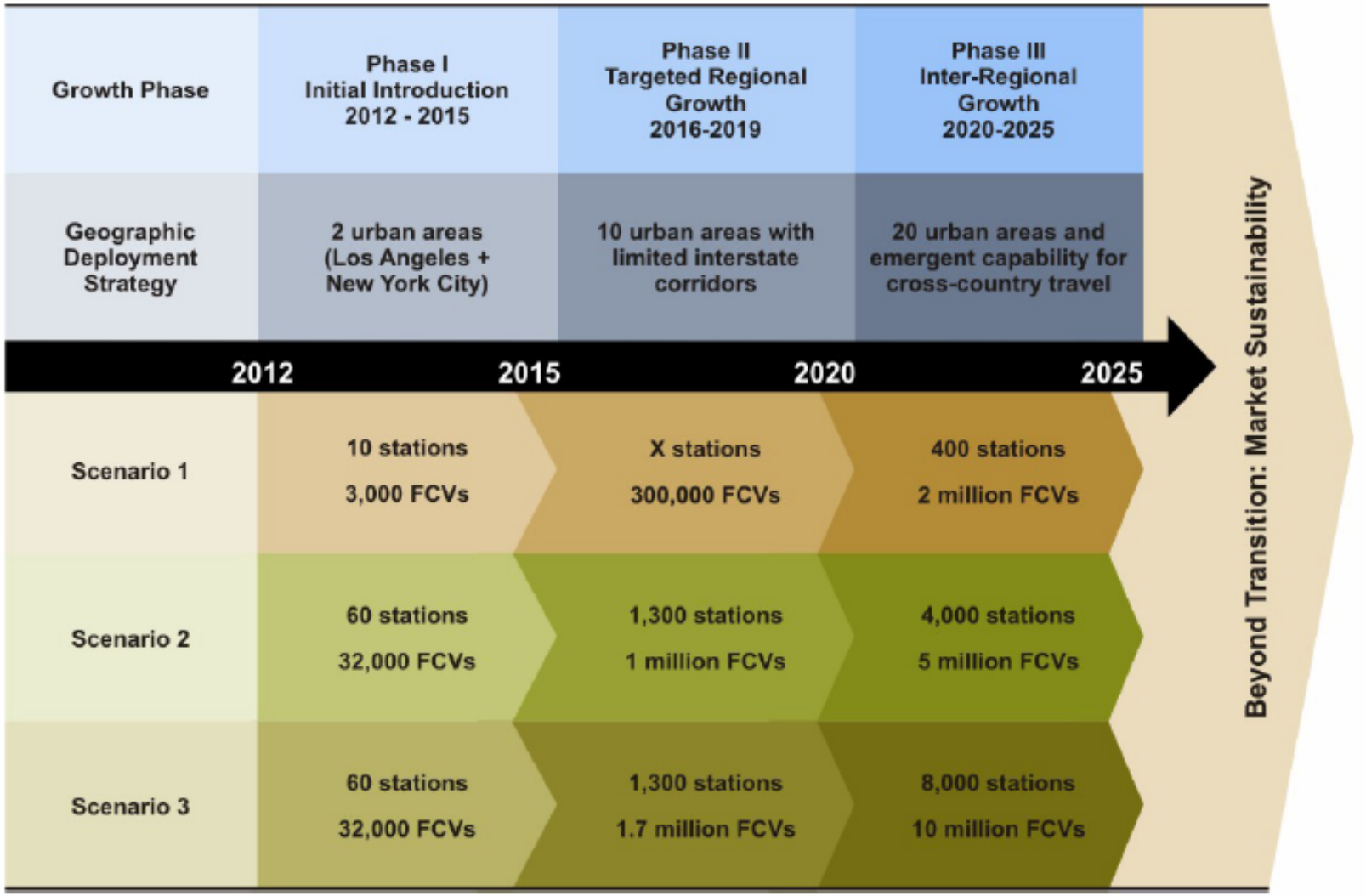
Phase II (2016-2019)

Phase III (2020-2025)



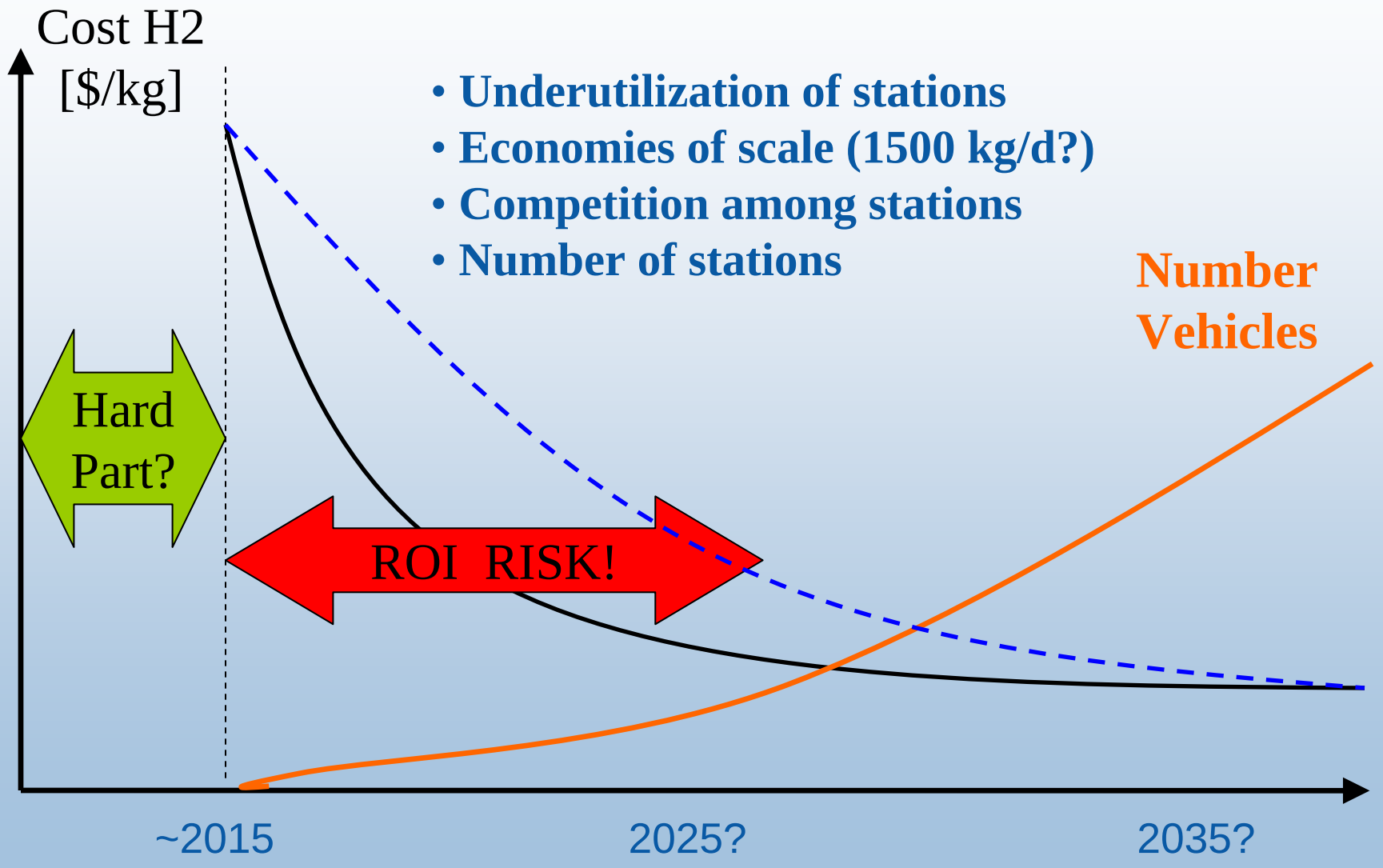

ORNL Scenarios Study 2008

# Timing is Key




ORNL Scenarios Study 2008

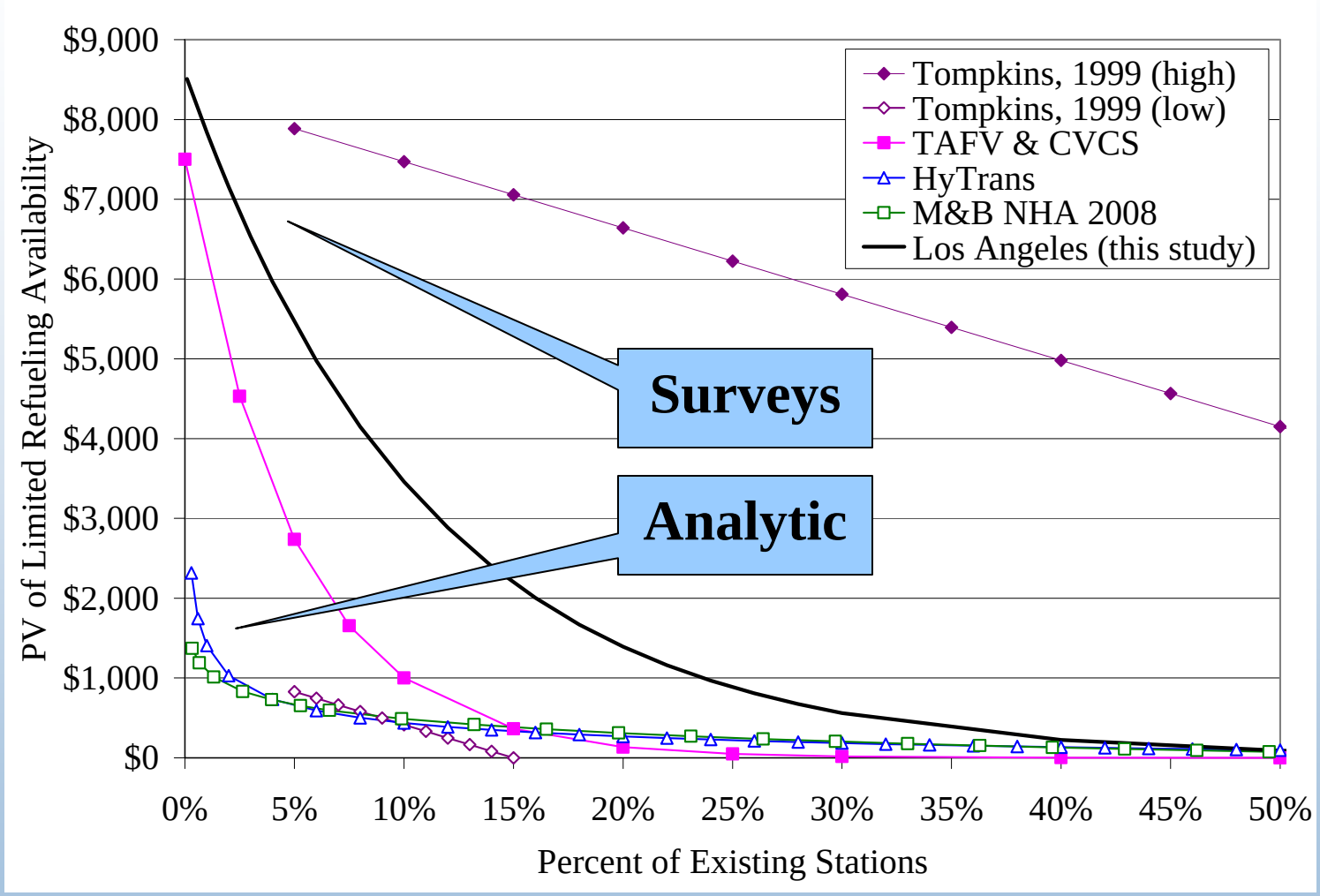
# The Early Transition Period: Managing Risk



# Thank You!

# Backup slides

# Metro cost penalties are relatively high




At 10% of existing stations, cost penalty is $3000 - $4000

# ORNL Scenarios Study

| | Phase I | Phase II | Phase III | |
|---|---|---|---|---|
| Urban Area* | 2012-2015 Stations | 2016-2019 Stations | Scenario 2 2020-2025 Stations | Scenario 3 2020-2025 Stations |
| New York | 20 | 200 | 554 | 1,227 |
| Los Angeles | 40 | 400 | 751 | 965 |
| Chicago | | 135 | 316 | 699 |
| Washington | | | 265 | 586 |
| San Francisco/ Sacramento | | 78 | 181 | 401 |
| Philadelphia** | | 58 | 136 | 302 |
| Boston | | 127 | 296 | 656 |
| Detroit | | 90 | 210 | 465 |
| Dallas | | 92 | 215 | 477 |
| Houston | | | 192 | 425 |
| Atlanta** | | 74 | 173 | 382 |
| Miami | | | 50 | 111 |
| Seattle | | 27 | 63 | 140 |
| Phoenix | | | 99 | 219 |
| Minneapolis/ St. Paul | | | 98 | 217 |
| Cleveland | | | 83 | 183 |
| Denver | | | 88 | 196 |
| St. Louis | | | 85 | 188 |
| Portland | | | 55 | 123 |
| Orlando | | | 35 | 77 |
| **Total** | **60** | **1,281** | **3,945** | **8,039** |