

*OPERATION OF A FUELCELL-HYBRID SWITCH
LOCOMOTIVE FOR THE LOS ANGELES BASIN: The Largest
Fuel-cell Land Vehicle*



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HYBRID-FUELCELL SWITCH LOCOMOTIVE



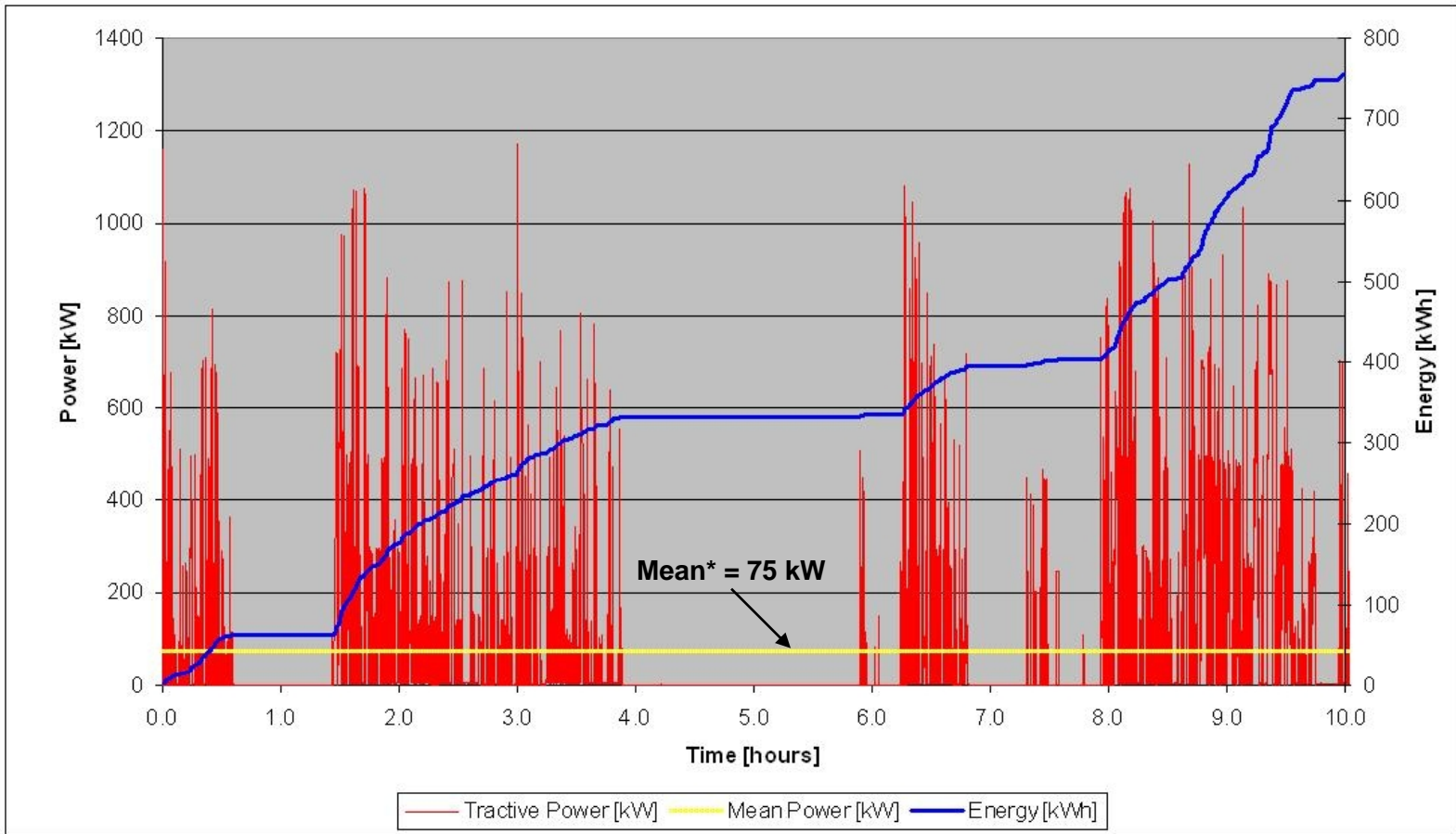
Completed locomotive at unveiling to press on 29 June 2009



WHY FUELCELL RAIL?

- **Marries best features of conventional locos (electric and diesel) but avoids their disadvantages:**
 - Zero chemical and low acoustic emissions at the vehicle (like electric loco)
 - Relatively low infrastructure cost (*linear* infrastructure and like diesel fuel)
 - Zero total CO₂ emissions if primary energy is renewable or nuclear
 - More efficient overall than diesel or electric
- **Current issues:**
 - Relative high cost of fuelcells
 - Entrenched competing technologies and fuels
 - Hydrogen storage

WHY HYBRID? DUTY CYCLE OF SWITCH LOCO



*Mean power computed over 20-h interval

HIGH-POWER FUELCELL VEHICLE DEVELOPMENT

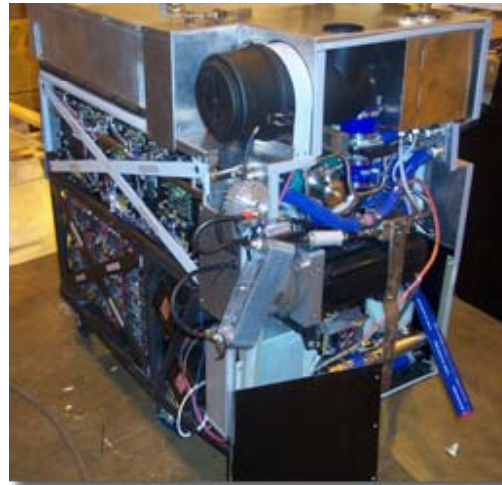
Vehicle Projects Inc has a unique history (since 1998) of developing large fuelcell vehicles



FC coalmine locomotive (project in progress)



Coal loco metal-hydride storage



Coal fuelcell-hybrid powerplant (to be repackaged)



Fuelcell mine locomotive, a non-hybrid





SWITCH LOCOMOTIVE PROJECT OBJECTIVES

An industry-government partnership has developed a prototype fuelcell-hybrid switch locomotive that will:

- Reduce air and noise pollution in urban rail applications, including seaports. (To be demonstrated in the Los Angeles Basin)
- Serve as a mobile backup power source (“power-to-grid”) for military bases and civilian disaster relief efforts.

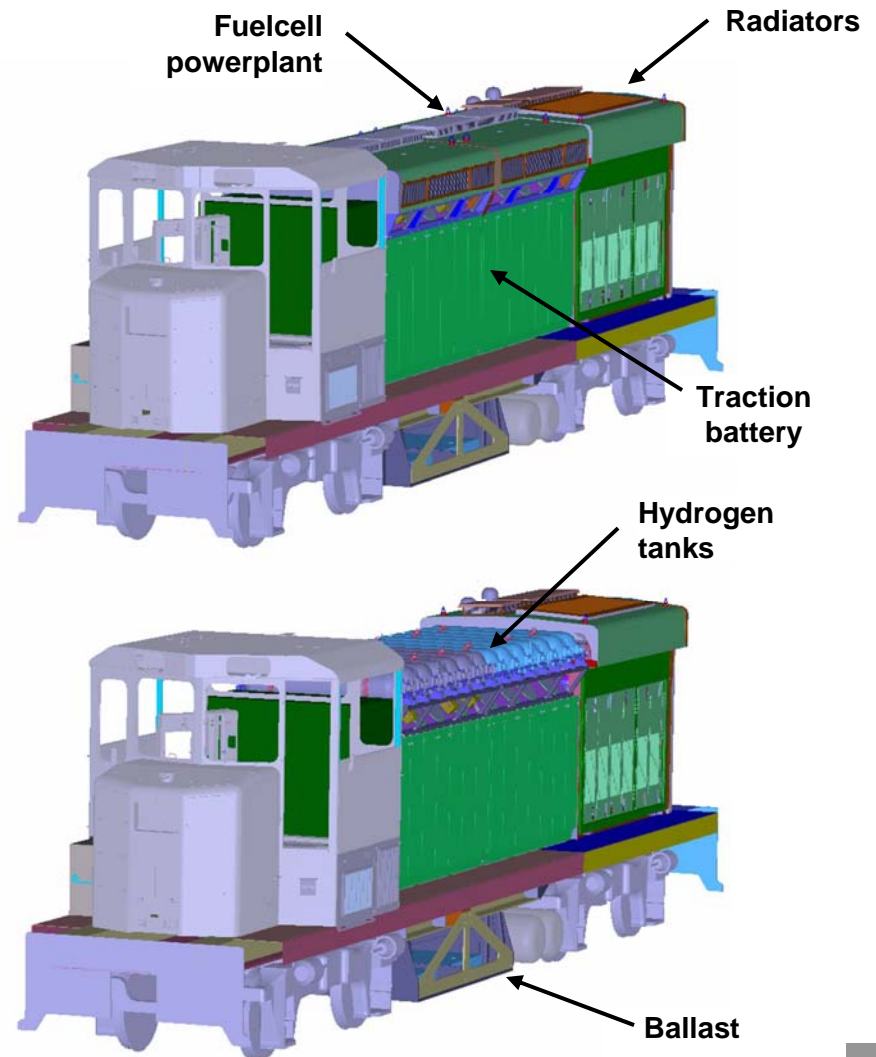
FUELCELL LOCOMOTIVE UNDER CONSTRUCTION



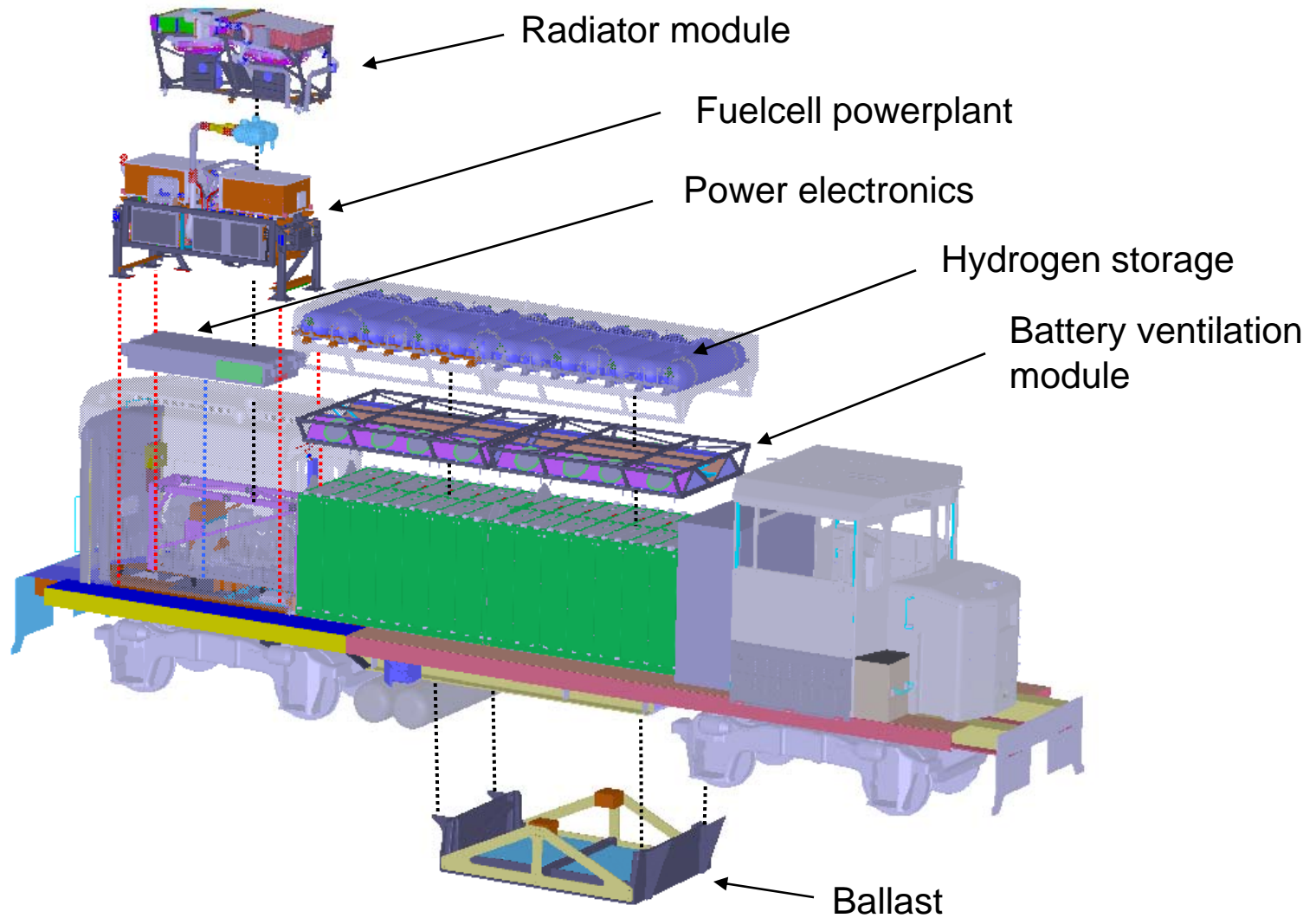
31 July 2008, BNSF Topeka System Maintenance Terminal

CAD MODEL OF FUELCELL-HYBRID SWITCHER

- 240 kW (continuous net) fuelcell prime mover
- 70 kg hydrogen at 350 bar at roofline
- Traction battery allows transients above 1 MW
- 9 thousand kg extra ballast to bring to 130 tonne (287 thousand lb)



EXPANDED VIEW OF VEHICLE



IMPACT TESTING

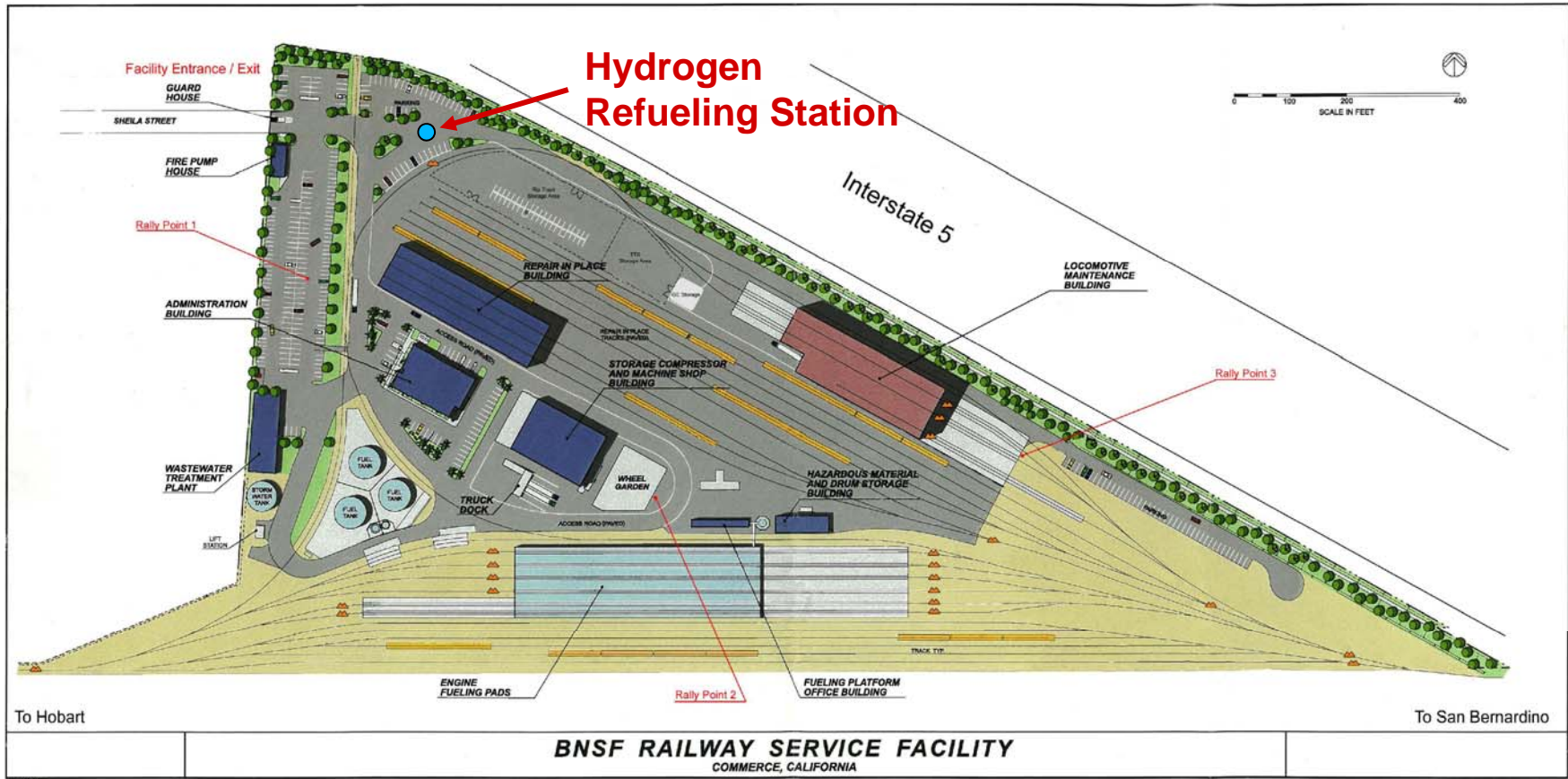


- Test conducted by Transportation Technology Center, Inc, in Pueblo, CO
- Tested at 5.1 mph at full gas pressure (3.8 mph with fuelcell operating)

HYDROGEN REFUELING STATION AT TTCI



DEMONSTRATION AT BNSF COMMERCE YARD





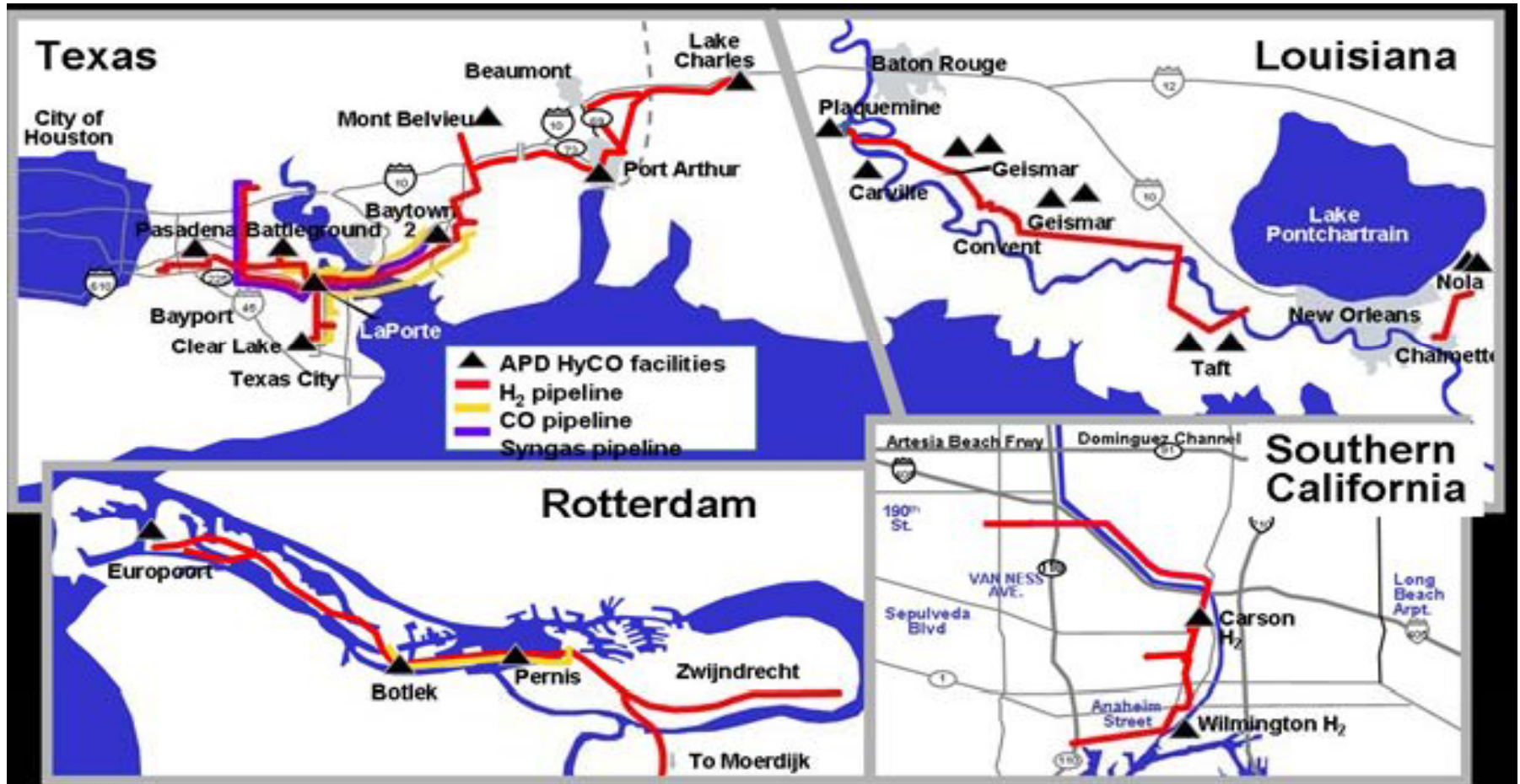
COSTS



Fuelcell costs must be compared to total costs – capital, operating, maintenance, & social – of conventional technologies

- **“Clean diesels” with exhaust after-treatment have many issues to resolve: space claim, complexity, reliability, efficacy**
- **Catenary-electric locos**
 - Having heat-engine prime movers, are energy inefficient
 - Usually are a large GHG emitters
 - Have very high infrastructure costs (US\$6-8 million/mile)

AIR PRODUCTS' HYDROGEN PIPELINES



- Serves 7 gasoline refineries in LA
- 26 km length
- 400 thousand kg/day of H₂



FUEL COSTS (HYDROGEN FROM LA PIPELINE)

- **Mean cost of diesel fuel currently is around \$2.60/gal**
- **1 kg hydrogen is equivalent to approx. 1 gal of fossil fuel in energy content**
- **Hydrogen from the Air Products' LA pipeline costs \$2-3/kg**
- **Based on energy content, hydrogen fuel cost today is equiv to diesel fuel (\$2-3/gal)**



SOCIAL COSTS (US EPA, 2030)

If the US EPA Tier Program were not implemented, the annual social costs of diesel rail by 2030 would be:

- **1,100 PM-related annual premature deaths**
- **Elevated diesel-PM cancer risk near urban railyards (concentrated bubbles of PM emissions)**
- **120,000 lost work days (all emissions)**
- ***Annual social costs: \$9.2 - \$11 billion***



RESULTS

- **Locomotive is complete and has approx. 40 hours operating time**
- **Zero emissions in the urban railyard**
- **Silent in cab; allows unstrained conversation beside power compartment**
- **The current social costs of diesels may exceed the cost premium of fuelcell locomotives**
- **With hydrogen from LA pipeline, energy cost would be comparable to or lower than diesel: ~ \$2-3/gal equivalent**



CONCLUSIONS



- **Considering fuel and social costs, hydrogen-fuelcell switch locomotives are a commercially viable niche market**
- **Vehicle Projects Inc and its partner BNSF Railway are working toward near-term commercialization**



FINANCIAL SUPPORT (ALL PROJECTS MENTIONED)

US Department of Energy, Hydrogen Program

US Department of Energy, Office of Industrial Technologies

Natural Resources Canada, Emerging Technologies Program

US Department of Defense, Defense Logistics Agency

BNSF Railway Company

National Institute for Occupational Safety and Health (NIOSH)

Fuelcell Propulsion Institute

Corporate cost-share contributors