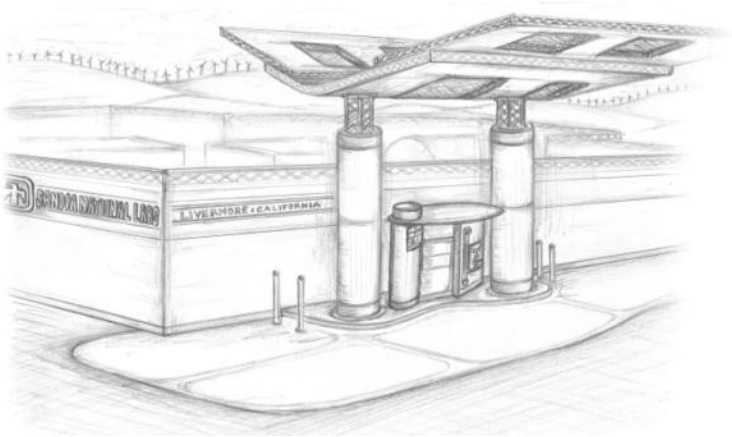
SAND2012-9162P

Considerations for an Industrial Gas Company to become a Partner in CIRI



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  - Facility concept
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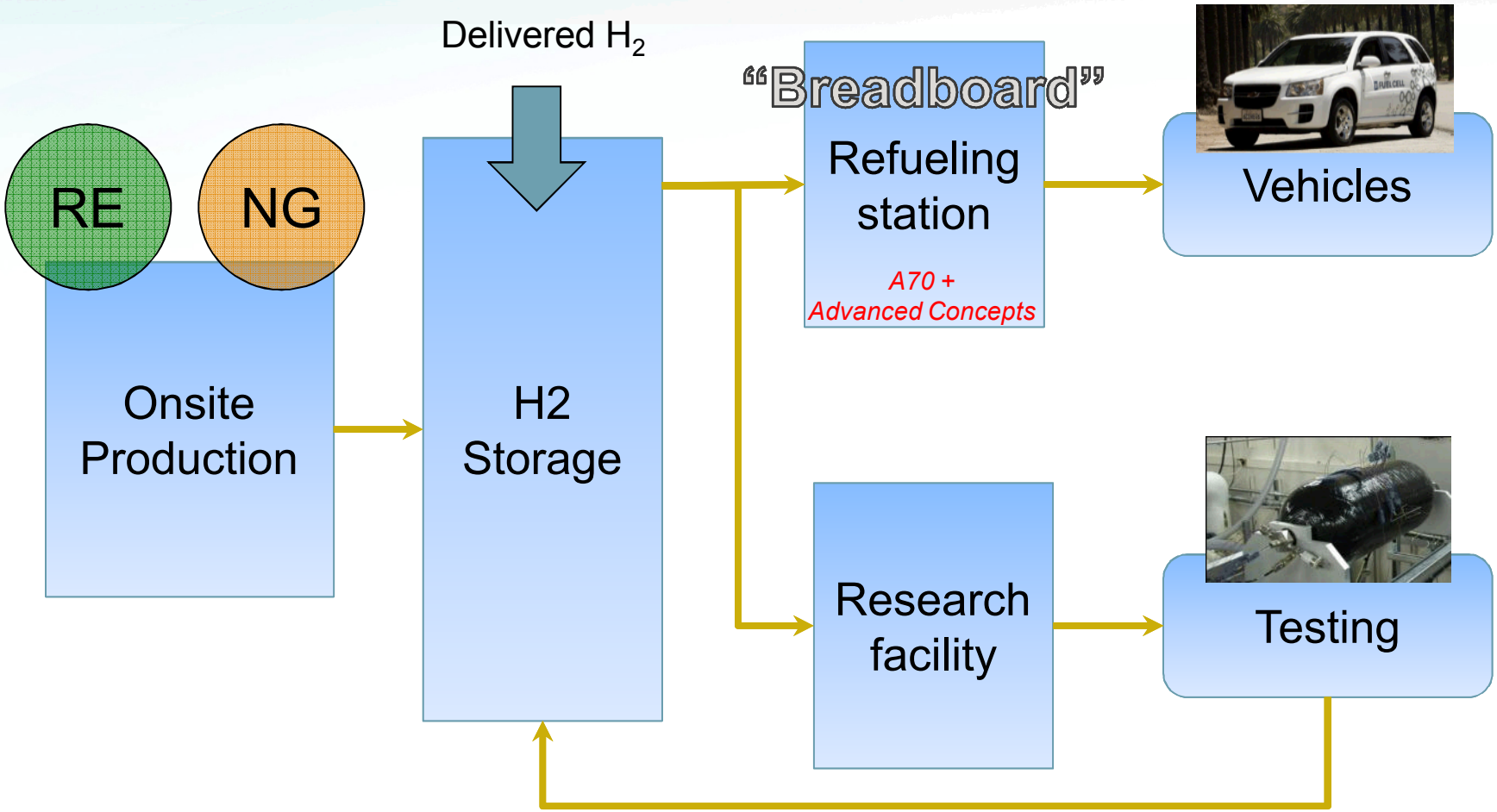
  - Conceptual financial model

Center for Infrastructure Research and Innovation

- WHY: Accelerate FC-EV vehicle fueling infrastructure in California, the US and beyond. There is no similar capability in the US.
- WHAT: A combined research/innovation and "breadboard" H_2 fueling facility
- WHO: Industrial gas company(s), Sandia, State of California, US Department of Energy, other public and private sector partners
- WHERE: The Livermore Valley Open Campus (LVOC), located at Sandia National Laboratories/Lawrence Livermore National Laboratory in Livermore, California

Engineering the Customer Experience



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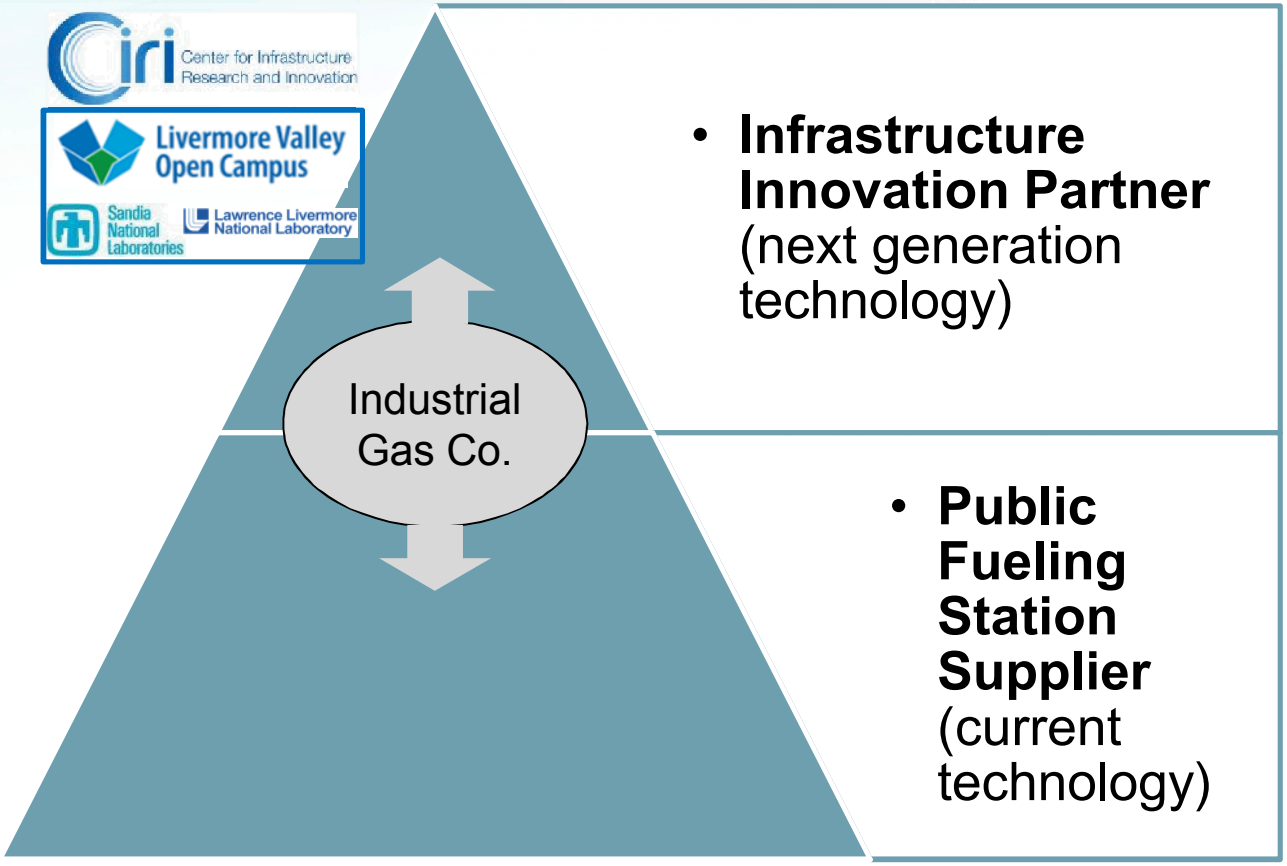
Market Presence in California and Beyond



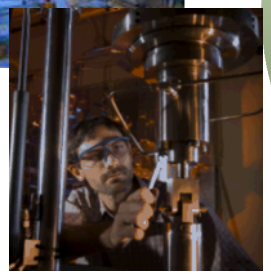
DEPARTMENT OF ENERGY · UNITED STATES OF AMERICA

STATE OF CALIFORNIA · ENERGY COMMISSION

California Environmental Protection Agency
AIR RESOURCES BOARD

Sandia's hydrogen program capitalizes on 50 years of investment from the DOE

People
(50 yrs of experience)



Unique Tools
(labs, diagnostics, software)

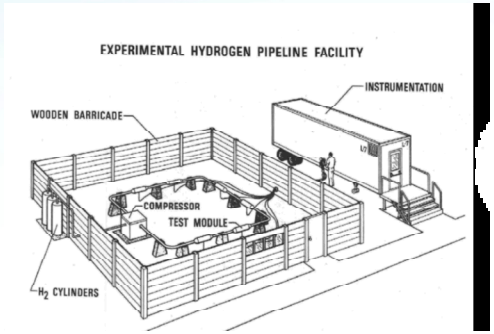
Key Partnerships
(the who's-who of H2)

SRNL
California Fuel Cell Partnership
I²CNER
NFPA
Ford
NASA
SAE
GM
ICC
ISO
ASME

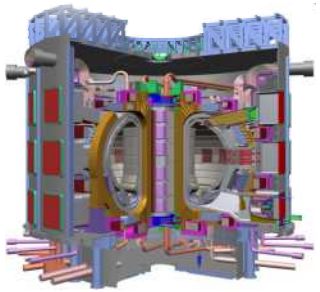
U.S. DEPARTMENT OF ENERGY
NASA
Energy Efficiency & Renewable Energy

Sandia provides hydrogen science and engineering for the Nation

- decades of complementary missions
- predictive understanding reduces risk

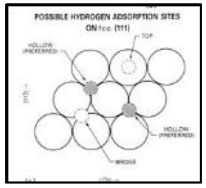


FUSION ENERGY

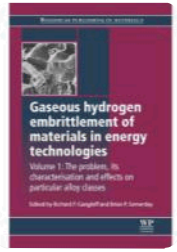


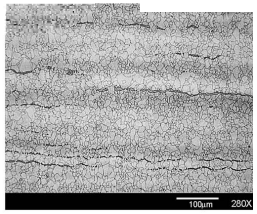
METAL HYDRIDE CENTER OF EXCELLENCE

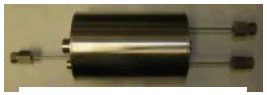
Lift-Truck Lifecycle Requirements



Embedded Atom Method







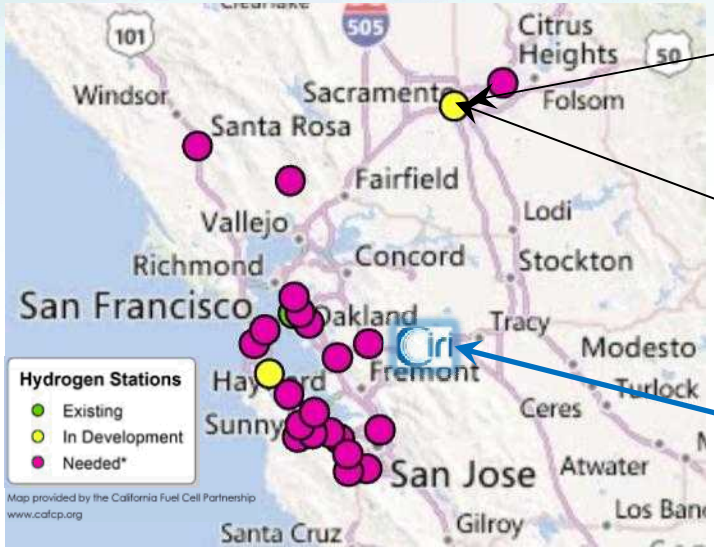
Power Harvester

B83 ALT353

GTS for W38, W41, W45, W47, W55, W56, W58, W62, W68, W70, W71, W79, B83, W84, W87

1960 1970 1980 1990 2000 2010 2012

CIRI is Ideally Located for Connecting to California's Hydrogen FCEV Future



California FUEL CELL PARTNERSHIP
DRIVING FOR THE FUTURE

Livermore Valley Open Campus
Sandia National Laboratories
Lawrence Livermore National Laboratory

- Co-located with two US Dept. of Energy National Labs
- Regional proximity to proposed fueling stations in Northern California
- 90-minutes to Sacramento: State of California government offices and the California Fuel Cell Partnership
- 45-minutes to Silicon Valley
- Close to world-class universities, four international airports, etc.

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Phase 1 (0-3yr) of CIRI addresses gaps and barriers facing H_2 infrastructure

Perform critical R&D to reduce the barriers to the wide-spread adoption of clean FCEVs

Materials/Components

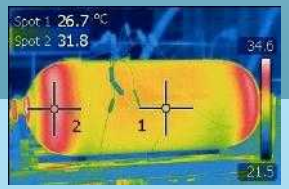
Understanding behavior at service conditions

- Embrittlement, corrosion, stress corrosion cracking
- Tank testing – fatigue, fiber rupture
- Pipeline testing – welds, fatigue
- Component materials – regulators, valves, etc.
- Non-metal materials: temperature, decompression
- Accelerated qualification method development

Fueling System Performance and Controls

Understanding of fluid dynamics and thermal effects

- Develop validated engineering models
- Fueling protocols
- Flow control/metering development and accuracy
- Dynamic behavior (Thermal Mass, Pressure Pulse)



Phase I

Innovation Breadboard

Develop and validate advanced system architectures

- System efficiency
- Station capacity (back-to-back fills)
- Dispenser and gas cooler technology
- Compressor innovation
- Priority & sequence system optimization

Hydrogen Workforce Development/Training

A quality workforce for an expanding market

- Provide a test-bed for system designers/developers
- Develop the next generation of innovative scientists, engineers, technicians

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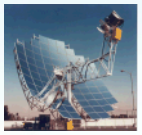
CIRI provides the framework for tri-generation and grid integration technology advancements

Green H_2 Production



HT cycles

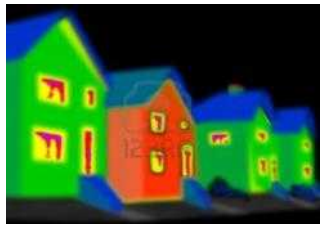
H_2 Storage

Fuel

Natural Gas

Electrochemical Systems

Heat



Low-carbon Electricity

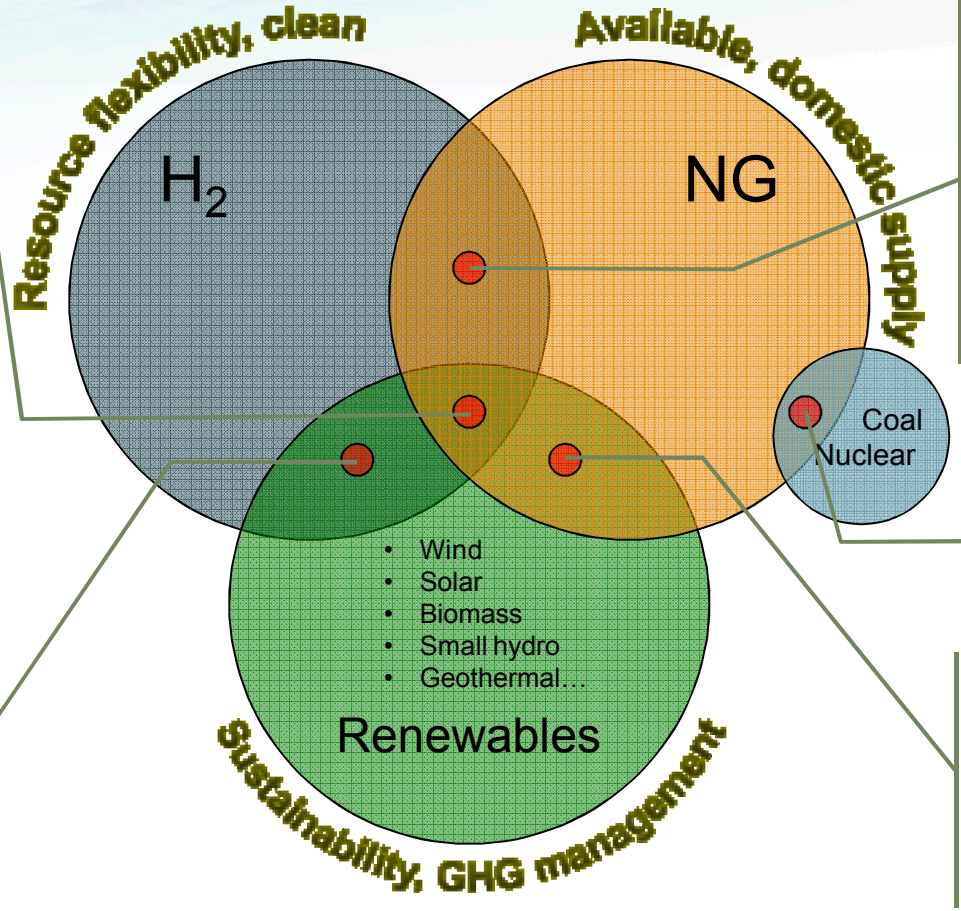
IGCC CCS

Electric Grid

Power

Phase 2 (3-20yr) vision for CIRI focuses on the nexus between NG, H_2, and Renewables

H2/NG/Renewable Nexus
- Distributed power
- Tri-generation RD&D (combined heat, power, & fuel)
- Power to gas
- Grid stabilization, supply security research
- Energy independence
- Biogas RD&D
- Synthetic fuels production (e.g. "Solar fuels")



NG/H2 Interface
- Distributed Generation
  - Reformer RD&D
- Codes and Standards and siting requirements
- Component technology RD&D
  - Tanks (on board)
  - Pipelines
  - Compressors
- Materials R&D
  - H2 effects in materials (Hythane)
  - Corrosion
- Combustion Research

NG/Coal/Nuclear Nexus
- Base-load power mgmt
- CCS
- Hybrid Coal IGCC / NG plants
- Combustion Research

H2/Renewables Nexus
- Energy Storage RD&D
  - Reversible FCs
  - Geologic storage
  - Batteries
- Biofuels RD&D

NG/Renewable Interface
- Hybridization
  - CSP/NG
  - Renewables balancing and stabilization technologies
- Solar reforming

Provide leadership during changes in global resource availability, technology, and policy

CIRI can provide a platform for Future Collaboration

- Systems analysis to inform R&D and technology decisions
- Green H2 production
- Advanced fuel cell technologies
- Oxycombustion
- CCS
- Advanced biofuels and biogas

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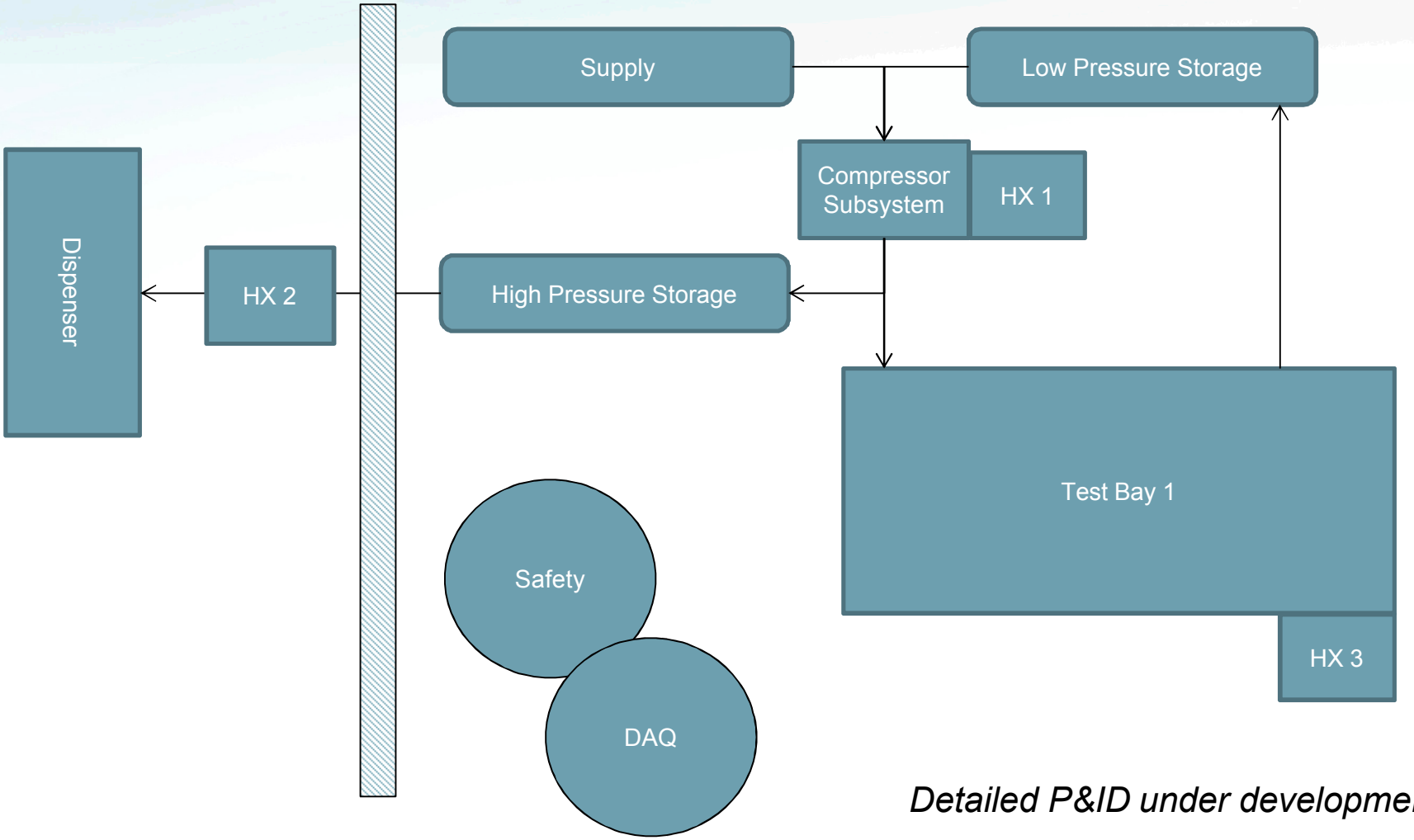
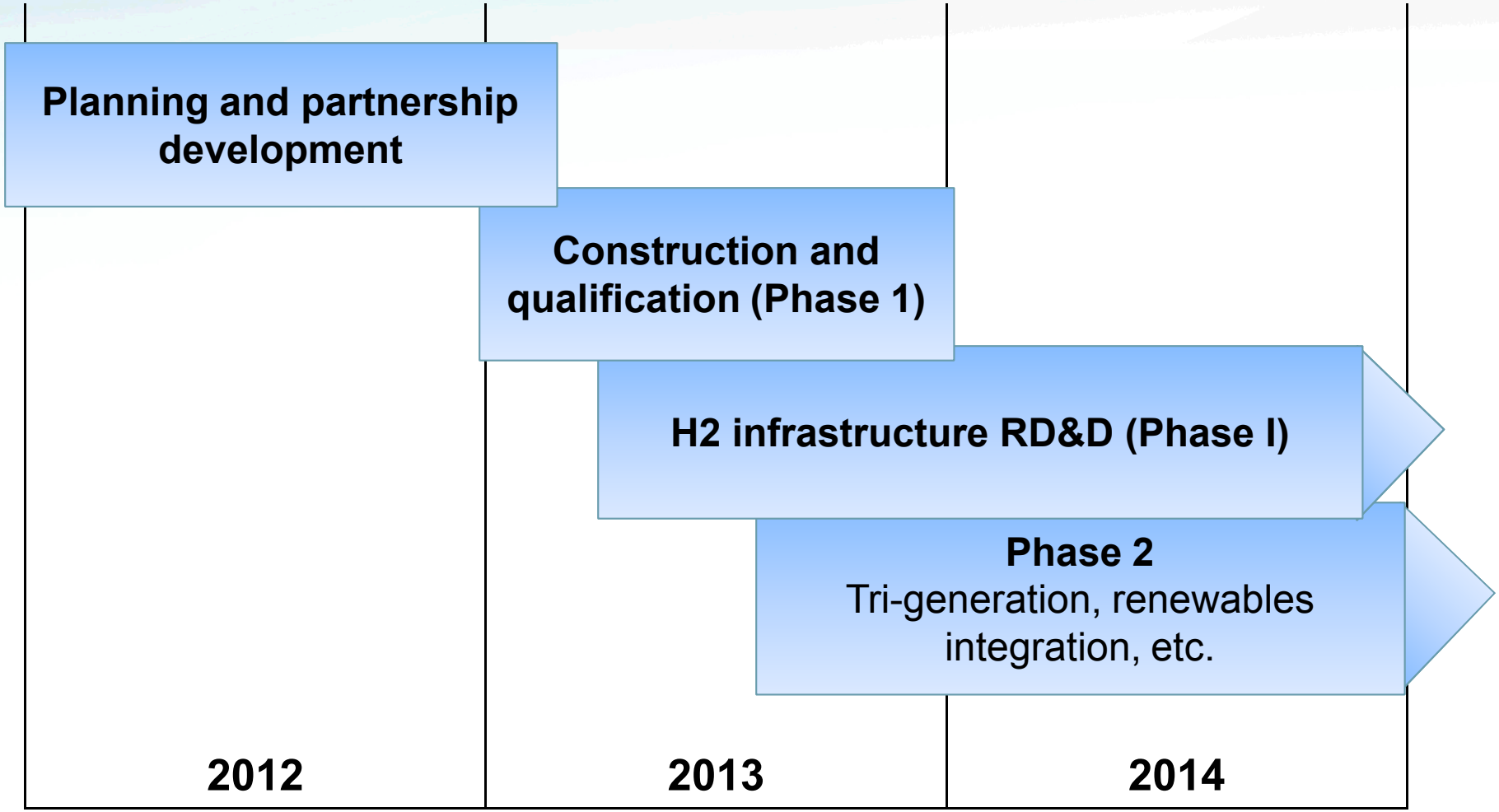
Phase 1 Block Diagram Major Components

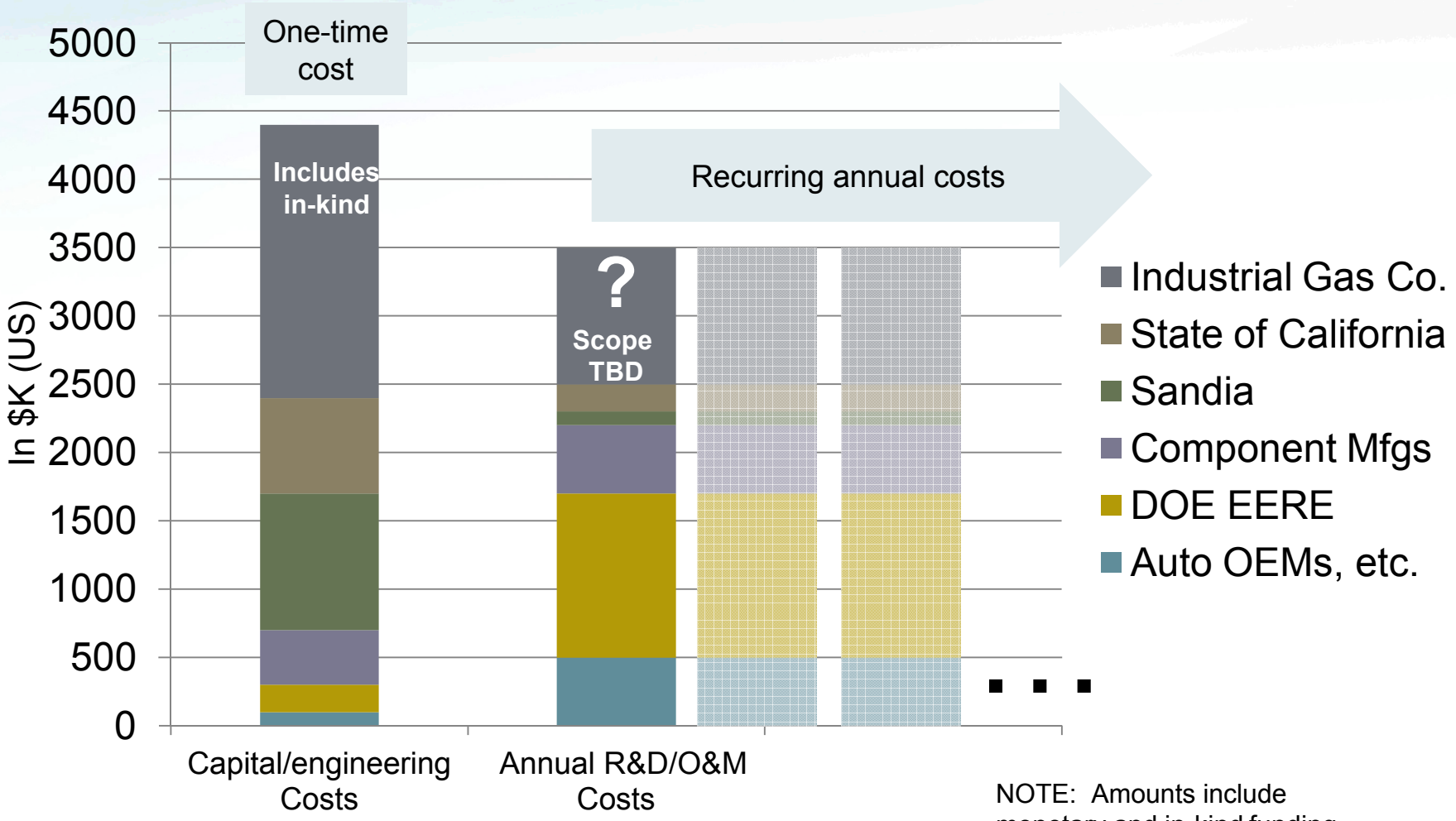


Detailed P&ID under development

Proposed Timeline



Sample Financial Model for Full Scope (Phase I & 2)



NOTE: Amounts include monetary and in-kind funding


Center for Infrastructure
Research and Innovation