Technical And Economic Studies of Regional Transition Strategies Toward Widespread Use of Hydrogen Energy

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Project Objectives

- **Assist the DOE in identifying promising paths for developing hydrogen infrastructure.**
  - Develop new simulation tools to evaluate alternative pathways toward widespread use of hydrogen under various demand scenarios and regional conditions.
    - Understand which factors are most important in finding viable transition strategies.
    - Develop “rules of thumb” for future regional hydrogen infrastructure development.
    - Conduct regional case studies of H2 infrastructure transitions
  - Work with H2A core group to develop models of hydrogen delivery systems.

Budget FY'04

$130,000

DOE Technical Barriers and Targets for H_2 Delivery Systems

- **Technical Barrier:**
  - *Lack of Hydrogen Carrier and Infrastructure Options Analysis.* "Analysis is needed to understand the advantages and disadvantages of various approaches."
- **Technical Target:**
  - "Perform delivery infrastructure analysis to define cost-effective, energy efficient, and safe infrastructure..for introduction and long term use of hydrogen for transportation and stationary power."

Technical Approach

- ***Develop new simulation tools to assess alternative transition strategies toward widespread use of H_2 under various demand scenarios and regional conditions.***
  - Develop engineering/economic models of hydrogen energy system components: H_2 demand, H_2 production systems, H_2 transmission and distribution, H_2 refueling stations, CO_2 sequestration.
  - Use Geographic Information System (GIS) data to study spatial relationships between H_2 demand, supply, primary resources, CO_2 sequestration sites, and existing infrastructure in particular region.
  - Explore use of various techniques (GIS analysis, mathematical programming) to find the lowest cost strategy for building a widespread H_2 energy system. Given a specified H_2 demand and resources for H_2 production, design a system to deliver H_2 to users at the lowest cost. Examine which transition paths give the lowest overall cost over time.
  - Carry out regionally specific case studies of H_2 infrastructure development, involving multiple H_2 plants, multiple H_2 demand sites, using GIS data.
- ***H2A: Work with DOE's team of hydrogen system analysts to develop "base case" data for hydrogen delivery systems***

Project Safety

- N.A. This project does not involve experimental work or hardware demonstrations.

Project Timeline

7/02 - 8/03; 4/04-9/04 10/04-4/06

Phase I	Phase II

Phase I :

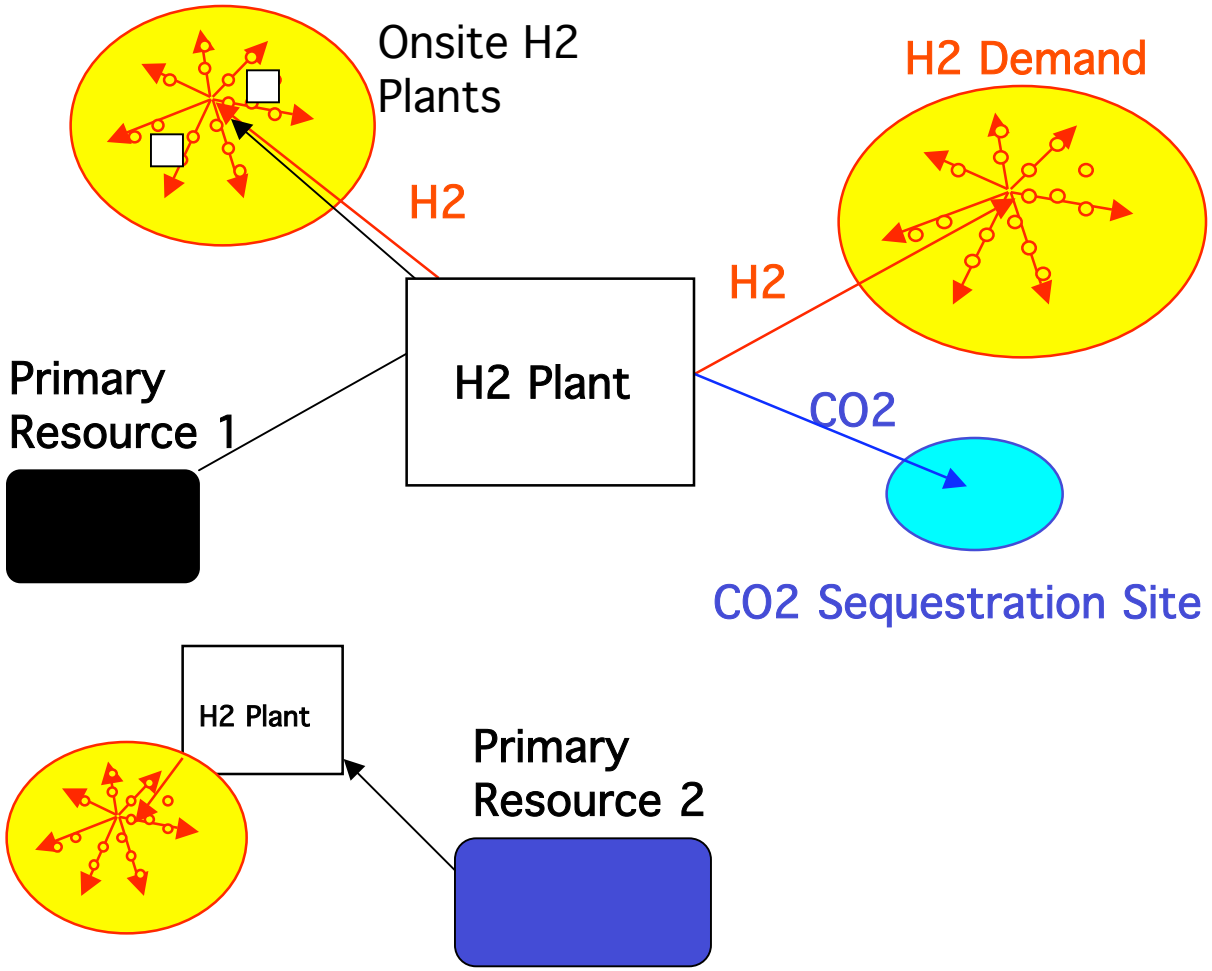
- Develop simulation tools to study regional hydrogen transitions
  - -Model H_2 demand spatially and over time
  - -Implement Engineering/economic models of H_2 technologies
  - -Develop GIS Maps of potential resources for H_2 production
  - -Develop GIS Data base for studying hydrogen supply and demand
  - -Develop optimization methods to design lowest cost system connecting supply and demand, and find lowest cost transitions
- Work with H2A group on delivery analysis

Phase II:

- Conduct case studies of regional transitions

Modeling Regional Hydrogen Infrastructure Development

What is the best system for producing and delivering H_2 to serve a growing regional demand?



H_2 Supply Cases to be Analyzed

- Centralized, large-scale production of H_2 from:
  - Coal gasification w/ and w/o CO_2 sequestration
  - Natural gas w/ and w/o CO_2 sequestration
  - Biomass gasification
- Distributed production of H_2 at refueling sites from:
  - Natural gas reforming
  - Electrolysis using off-peak power
- Delivery via truck (compressed gas or liquid); gas pipeline.
- For fossil H_2, consider disposal system for CO_2.

Technical Accomplishments (1)

Model H_2 demand spatially over time

Implement simple method using GIS data

Yr 1

Yr 5

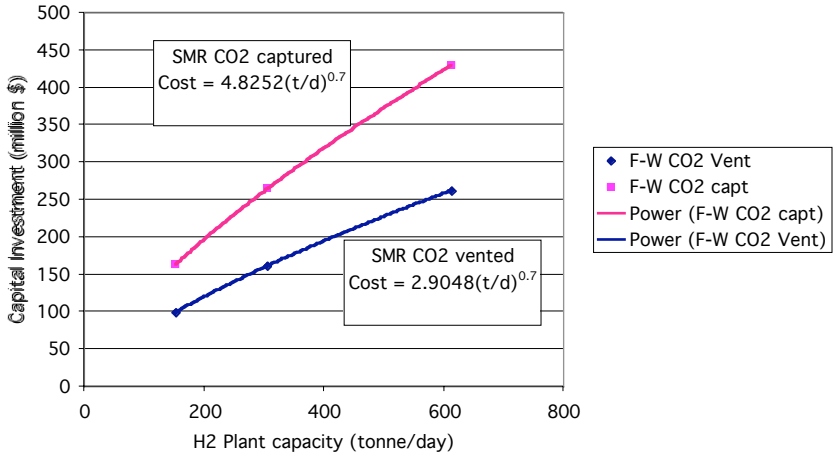
Yr 10

Highlights where concentrated H_2 demands grow first, magnitude and geographic density of the demand => best supply option

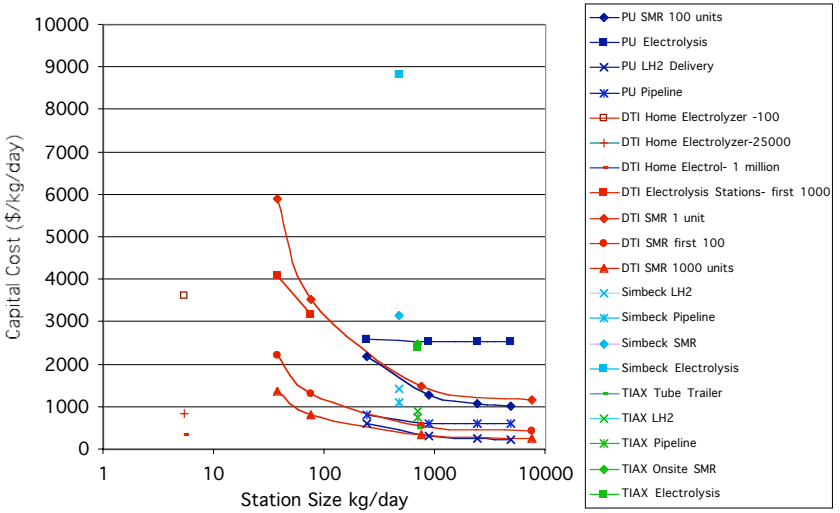
Technical Accomplishments (2)

Implement Engineering/economic models of H_2 technologies (production, storage, distribution and refueling systems) vs. scale & energy prices

Capital Cost of H2 Plants Using Steam Methane Reforming with and without CO2 sequestration versus plant capacity



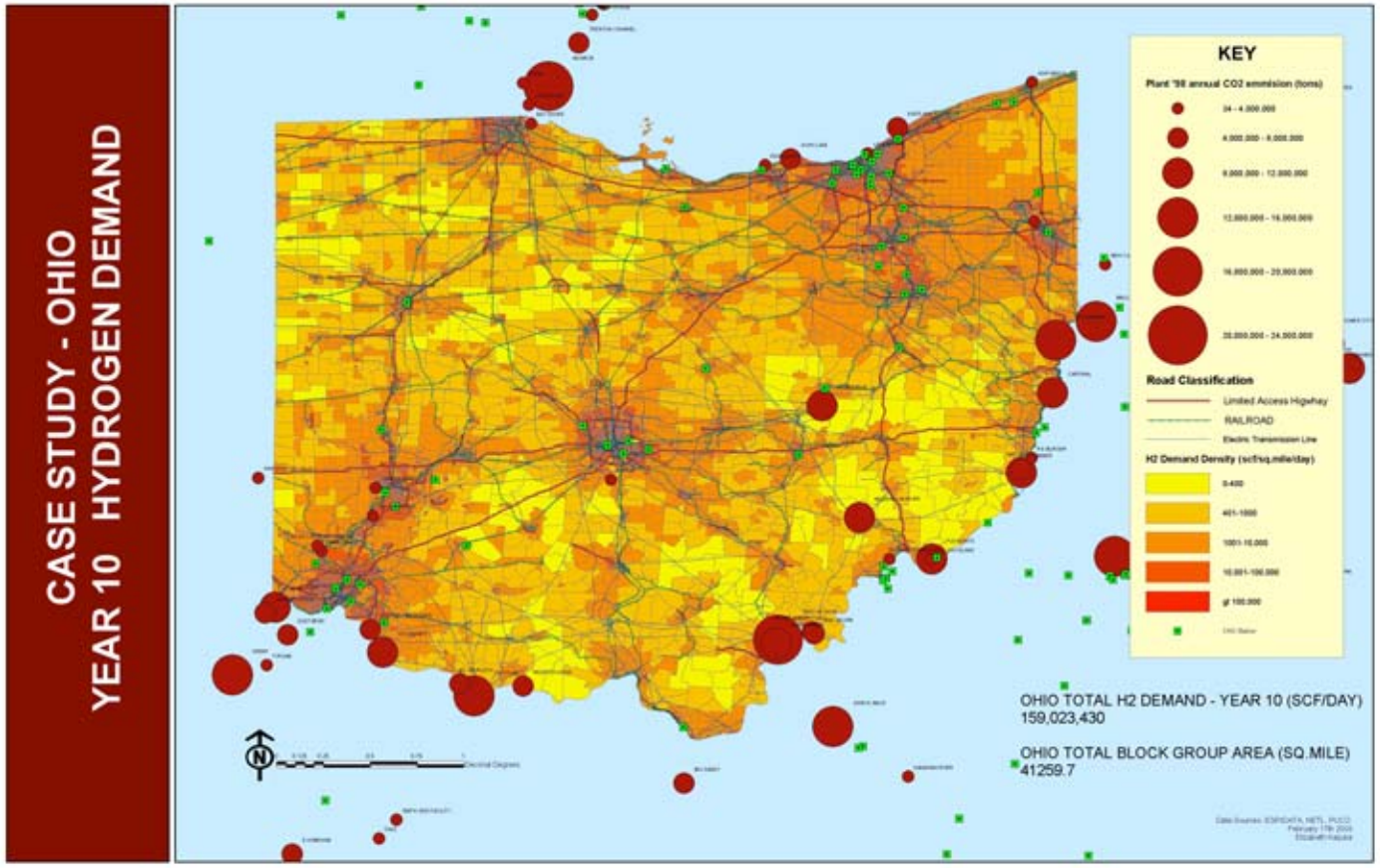
Capital Cost of Hydrogen refueling Stations v. Size



These estimates are being updated to reflect new estimates from the H2A project and the NAS study

Technical Accomplishments (3)

Develop GIS Maps of potential resources for H_2 production, existing infrastructure; GIS Data base for studying H_2 supply and demand



Technical Accomplishments (4)

Explore optimization methods to design lowest cost system connecting supply and demand, and find lowest cost transitions

First step: simple, analytic model to design supply to meet a specified demand (steady-state)

- Estimate infrastructure costs as a function of a small number of variables embodying averaged and/or simplified information about:
  - **H2 markets** (fraction of H2 vehicles in fleet, station size and coverage)
  - **Geographic factors** (idealized model of city, size and geog. density of demand)
  - **Cost and performance of H2 technologies** (vehicles and infrastructure)
- Compare H_2 infrastructure cost ($), levelized H_2 cost ($/kg) **for various supply options**

Technical Accomplishments (5)

Participation in H2A group

- Recently, DOE and NREL convened H2A, a group of analysts studying hydrogen energy systems. Their goal is to produce a credible, well-documented set of information on hydrogen production, delivery and forecourt refueling technologies and options.
- FY'04 Accomplishments
  - Lead role in H2A team analyzing hydrogen delivery infrastructure
  - Developed information on alternative pathways for delivering hydrogen to consumers
  - Developed base case scenarios for hydrogen delivery.
  - Close collaboration with researchers at DOE, NREL, Argonne on analyzing delivery options
  - Presentation at the NHA Analysis symposium on delivery team's work, April 2004.

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Interactions and Collaborations

- UC Davis Hydrogen Pathways Program (multi-disciplinary research program with 15 industry and government co-sponsors)
- NETL (fossil H_2 systems w/CO_2 sequestration)
- Princeton University (H_2 systems)
- H2A Delivery Group
  - DOE
  - NREL
  - Argonne National Laboratory
  - TIAX
  - DTI
  - H2A Key Industrial Collaborators: (Praxair, Air Products and Chemicals, BOC, Chevron Texaco, Exxon Mobil, BP)

Responses to Previous Year's Reviewers

- This project was not reviewed last year

Future Work

- Remainder of Phase I (5/04-9/04)
  - Develop simulation tools to study regional H2 transitions
    - Update hydrogen energy system component cost and performance models to reflect new data available from H2A
    - Compare hydrogen demand models with other work in the literature and ongoing within DOE
    - Further develop mathematical optimization methods to find lowest cost infrastructure solutions.
    - Develop GIS data base for studying H2 infrastructure in the Mid-west including natural gas steam reforming and coal power plant supply options
  - Continue work with H2A group on delivery analysis
- Phase II (10/04-4/06)
  - Add capability to model renewable hydrogen
  - Conduct geographic specific case studies of hydrogen infrastructure development

CREATING A H_2 DEMAND MAP

Vehicle Population Density (veh/km^2)

X Fraction H_2 vehicles (time) =

H_2 Vehicle Population Density (veh/km^2)

X Energy Use per Vehicle (kg H_2/veh/day) =

H_2 Demand Density (kg H_2 /d/km^2)

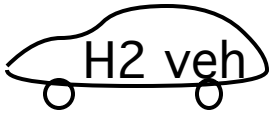
Census Data on vehicles by type and location

Market Penetration rate

Technical progress,

Economic competitiveness,

Policy



H_2 Vehicle characteristics,

drive cycle and mileage

Customer convenience

Refueling pattern

End-user req. H_2 pressure purity

Number, Size and Location of H_2 refueling stations

“Base Case” H2A Delivery Scenarios

Market Type	Early Fleet Market (1%)	General Light Duty Vehicles: Market Penetration		
		Small (10%)	Medium (30%)	Large (70%)
Metro	X	X	X	X
Rural			X	
Interstate			X	