

Global Assessment of Hydrogen Based Technologies

University of Alabama at Birmingham
in partnership with
Argonne National Lab
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UAB THE UNIVERSITY OF
ALABAMA AT BIRMINGHAM

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Project Objectives

- Evaluate performance and emissions characteristics of hydrogen-fueled vehicles.
- Assess impacts of hydrogen vehicle deployment on Southeast regional air quality.
- Evaluate the use of hydrogen fuel cells for stationary power generation.
- Assess infrastructure needs and costs for production and distribution of hydrogen in the Southeast.

Budget

- Total Project Funding (FY '03): \$ 939,996
- Project performance period: S8/2003 - 2/2005

Project Safety

- ANL staff have redesigned their vehicle testing facility to allow hydrogen to be stored outside and pumped inside as needed.
- Controls have been implemented to limit hydrogen concentrations in the facility to less than 1% (1/4 the lower explosive limit).

Approach

Task 1: Technology Evaluation of Hydrogen Light Duty Vehicles (LDV's).

Task 2: Comparison of Performance and Emissions from Hydrogen LDV's.

Task 3: Hydrogen Infrastructure Assessment and Deployment Needs.

Approach (continued)

Task 4: Deployment Potential for Hydrogen LDV's.

Task 5: Use of Fuel Cell Technology for Electric Power Generation.

Task 6: Establish Southeastern Hydrogen Technology Consortium.

Technical Targets and Barriers

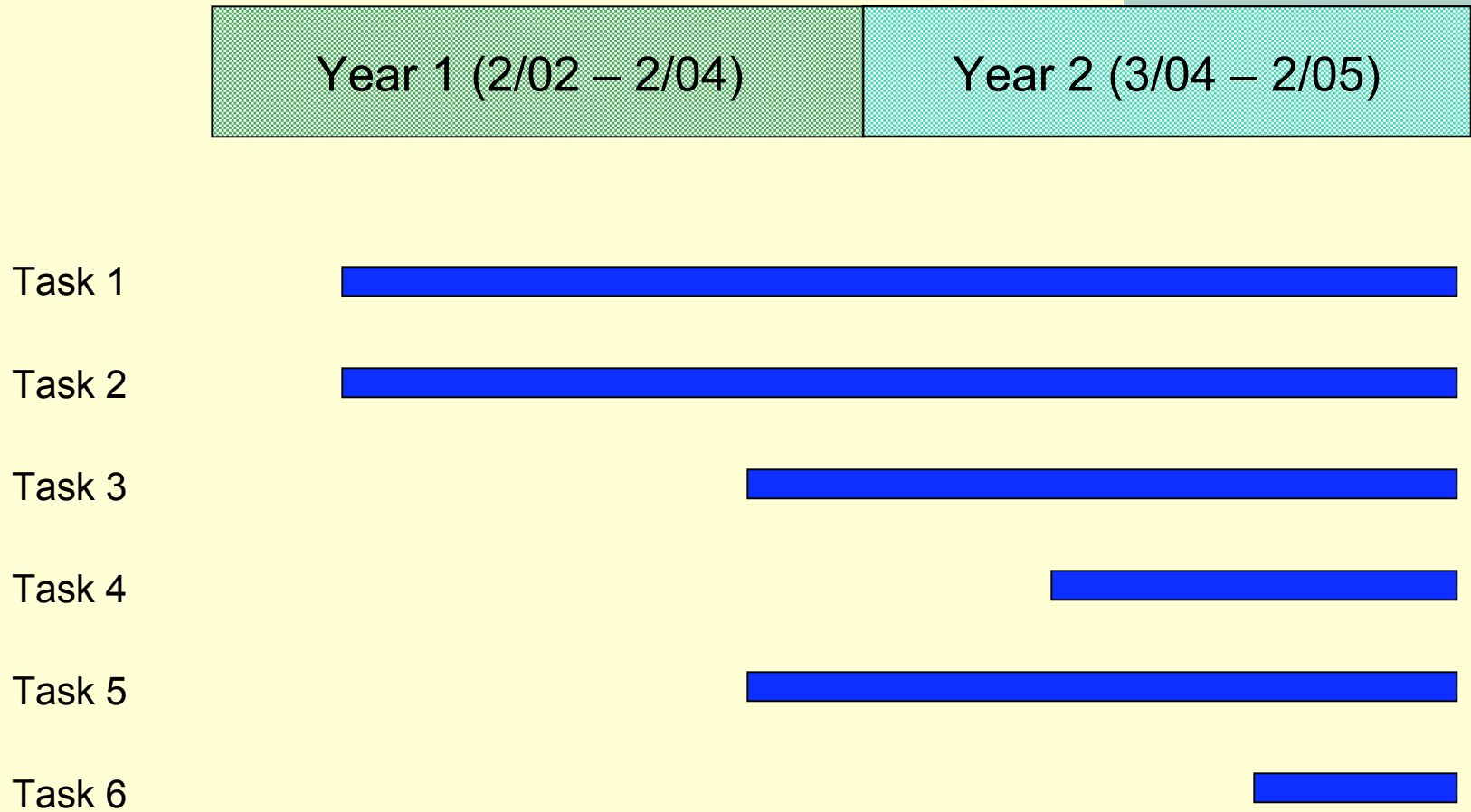
Technology Validation

- Performance of various hydrogen LDV's
- Performance and emissions profiles as functions of operating conditions and time
- Hydrogen refueling infrastructure
- Well to tank pathways and emissions
- Life-cycle costs of distribution infrastructure

Hydrogen Codes and Standards

- Document national and local codes for storing and dispensing hydrogen

Project Timeline



Interactions & Collaborations

- Argonne National Laboratory – Center for Transportation Research

- Tasks 1, 2, 3, 4, and 5.



- US DoE – Atlanta Regional Office

- Task 6

- Center for Transportation & the Environment

- Task 6



Task 1. Technology Evaluation of Hydrogen Light-Duty Vehicles

Objectives:

- Use simulation modeling to analyze a variety of hydrogen-fueled light truck configurations and assess their efficiency and performance as functions of operating conditions on standard cycles
- Compare emissions and performance from the simulated hydrogen-fueled vehicles to baseline conventional vehicles
- Compare results from simulation and field testing to validate the simulation model for future applications

Task 1: Approach

- Hydrogen-fueled light-duty vehicles for near and long-term use in the Southeastern U.S. are assessed through simulation modeling
- Candidate technologies include: Hythane-fueled engines (CNG); Hydrogen-fueled internal combustion engines (ICE); Hydrogen-fueled hybrid electric vehicles (HEV), and Hydrogen-fueled fuel cell vehicles (FCV)
- Modeling and simulation are performed using the PSAT NP 5.2 model
- A pre-transmission HEV was simulated and a parametric study was performed for a variety of cycles where vehicle mass, frontal area and drag coefficient were varied in steps
- Additional analysis is scheduled for the summer of 2004 during which trucks with 100% compressed natural gas, 15% hydrogen, and 30% hydrogen will be simulated as well as tested in the field
- Summary results will be documented on vehicle characteristics, efficiency, performance, and emissions profiles as functions of operating conditions on standard cycles

Task 1 - Accomplishments

- Performed extensive literature review in support of the Task 1 objectives
- Obtained and installed MATLAB and PSAT software
- Received training on PSAT at Argonne Laboratories
- Developed plan to initiate parametric analysis and developed data processing spreadsheets

Task 1 - Accomplishments

- Performed experimental parametric analysis on a pre-transmission HEV using PSAT
 - With and without modification of component power
 - Varying vehicle mass; frontal area; and drag coefficient in pre-selected steps
 - Run cycles include FUDS, FHDS, US06, NEDC, Japan1015 & Performance

Task 1 - Future Work

- Obtain new version of PSAT. New release (PSAT NP2) is scheduled for Spring 2004
- Obtain engine map and perform simulation runs for various types of hydrogen-fueled light-duty vehicles
- Analyze and tabulate the results from the simulations and compare with results obtained from field testing performed as part of Task 2
- Develop and submit for publication a research paper summarizing the analysis results

Task 2: Comparison of Performance and Emissions from Near-Term Hydrogen-Fueled Light-Duty Vehicles

Objective:

To determine and evaluate emissions performance of light-duty vehicles using compressed natural gas and hydrogen blends in internal combustion engines.

Task 2 - Approach

- Performance and Exhaust Emissions Testing of Hydrogen-CNG Fuel Mixtures (15-50% hydrogen, 50-85% CNG) in ICE Vehicles
- Performance and Exhaust Emissions Testing of Hydrogen-Powered ICE Vehicle
- Performance and Exhaust Emissions Testing of Hydrogen-Powered Fuel Cell Vehicle

Task 2 - Accomplishments

- A Ford F-150 was tested at Argonne National Laboratory using the dynamometer facility in their Transportation Technology R&D Center during May, 2003.
- The Ford F-150 was run on a fuel mixture (hythane) of ~50% hydrogen and ~50% compressed natural gas. During the testing, the hydrogen gas was supplied using seven hydrogen compressed gas cylinders.
- Emissions data were collected for carbon monoxide (CO), carbon dioxide (CO₂), total hydrocarbons (THC), nitrous oxides (NO_x), and particulate matter. The equivalent miles per gallon fuel consumption was also monitored.

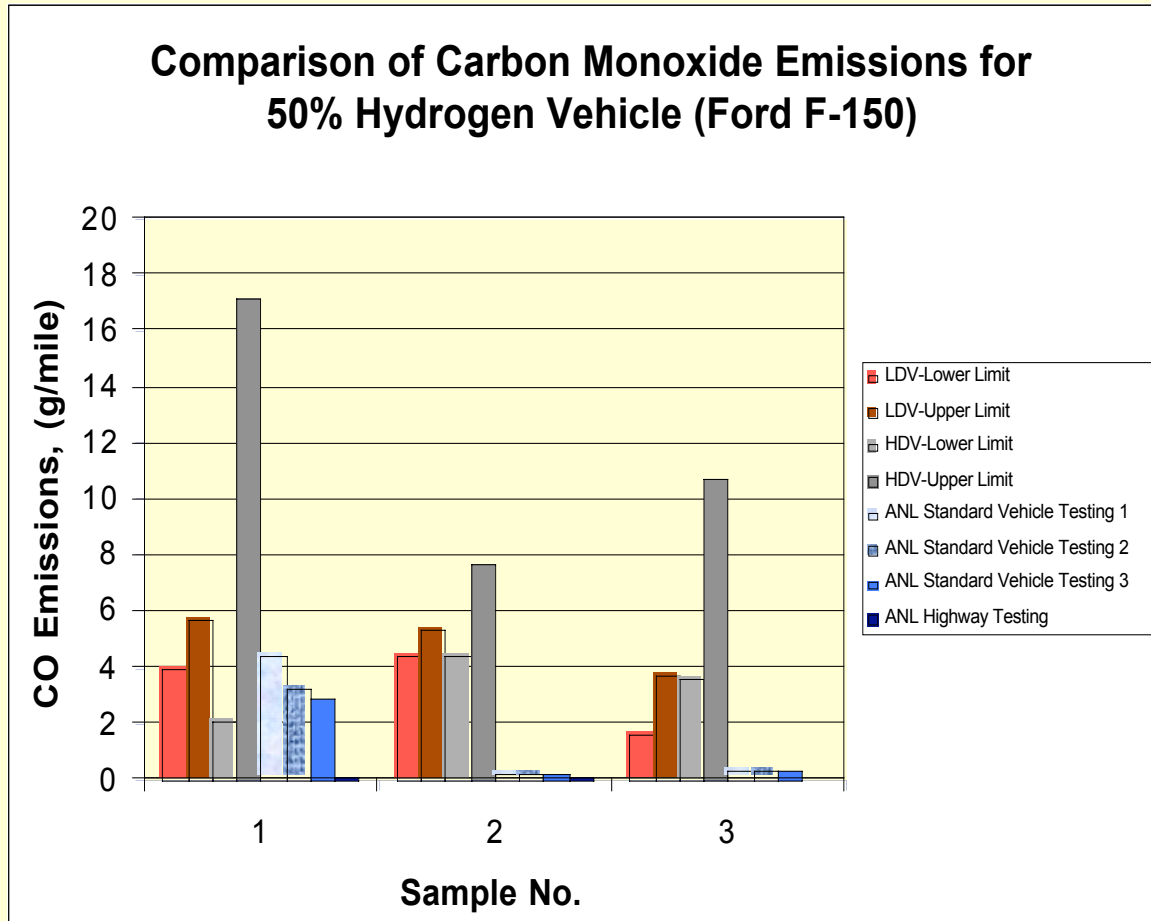
Task 2 - Accomplishments

- Results were obtained using cold starts, hot starts, standard vehicle testing, and highway testing. UAB compared the results with typical (high and low) emissions performance for CO, THC, and NO_x, for light-duty and heavy-duty vehicles.
- The results indicated for using the 50% hythane fuel mixture, reductions in CO, THC, and NO_x, exceeded 97%, 95%, and 94%, respectively, indicating that the emissions were reduced by more than an order of magnitude.

Emissions Testing of Ford F-150 at Argonne's PowerTrain Facility



Results of Emissions Testing Using 50% CNG/50% H₂ in Ford F-150s



Task 2: Future Work

- Tests on highway performance, cold start operation, and hot start operation using various blends of compressed natural gas (CNG) & hydrogen (100/0, 85/15, and 70/30) in a Ford F-150 will be performed at Argonne's PowerTrain facility in early May.
- Analysis and modeling of the emissions results for the blends of CNG/H₂.
- A fuel cell-powered Ford Explorer from the FutureTruck competition will be tested in the four wheel drive chassis dynamometer test facility of ANL.

Task 3: Hydrogen Infrastructure Assessment and Deployment Needs

Objectives:

- Develop estimates of costs and resource requirements for the infrastructure needed to deliver hydrogen fuels to advanced technology vehicles in the Southeast.
- Document codes and standards relating to the siting, production, transport, and handling of hydrogen.

Task 3 - Approach

- H₂ Infrastructure Assessment
 - Identify hydrogen pathways for Southeast
 - Use CHAIN model to estimate for each pathway:
 - Infrastructure requirements
 - Energy consumption
 - Life-cycle costs
 - Pollutant and greenhouse gas emissions
- Document local/national codes and standards for storing and dispensing H₂

Task 3 - Progress

- Inventory of production facilities underway. Currently identifying:
 - Hydrogen, NG, and electricity production
 - Current capacities
 - Delivery infrastructure
 - Pipeline networks and storage facilities
 - Historical rates/prices
- Argonne National Lab is modifying the CHAIN model for the Southeast Region.

Task 3 - Future Work

- Complete inventory of hydrogen, natural gas, and electricity production and distribution in the Southeast region (June 2004).
- Complete regionalization of CHAIN model (June 2004).
- Begin CHAIN assessment of hydrogen pathways, infrastructure costs, and well-to-tank emissions.

Task 4: Comparison of Deployment Potential of Four Hydrogen-Fueled Light-Duty Vehicle Technologies

Objectives:

- Examine potential benefits of large-scale deployment of hydrogen-fueled vehicle technologies in the Southeast.
- Focus on NOX reduction potential of hydrogen-based AFV's.
- Particular attention will be paid to the Birmingham metropolitan area.
- Adapt ANL's AirCred model for use in Birmingham.
- Provide support for the DOE Clean Cities activities of the *Central Alabama Clean Cities Coalition*.

Task 4 - Approach

- Collect Birmingham-specific data for input into AirCred.
- Validate AirCred application to Birmingham.
- Incorporate emission rate estimates for hydrogen-based AFV's into AirCred – these will be developed in UAB/ANL Tasks 1 & 2.
- Develop hydrogen-based AFV deployment scenarios for Birmingham.
- Select optimal deployment scenarios for fuel cycle analysis using ANL's GREET model.

Task 5. Use of Fuel Cell Technology for Stationary Electric Power Generation

Objectives:

- Assess the ability of hydrogen production and utilization to be competitive with other forms of energy generation.
- Review various case histories involving the use of hydrogen-based fuel cells for electric power generation.

Task 5 - Approach

- Evaluate the use of hydrogen-based fuel cell technology for electric power generation.
- Conduct studies to compare fuel cell operation and performance with other power generation systems or other new low emission technologies.
- Compare alternate power generation systems from economic and environmental perspectives.
- Conduct best practice and benchmarking studies.

Task 5 - Accomplishments

- Potential applications of fuel cells in the stationary power generation, particularly using phosphoric acid fuel cells, were investigated. Several case studies highlighted their wide spread applications in the medium to large scale category.
- The major areas where the fuel cells could be used were identified as being in the co-generation (combined heat and power), distributed generation, and residential fields areas.
- Considerable work has been performed in the market research area which provided information about different companies associated with fuel cells such as Ballard, Plug Power, International Fuel Cells, etc. This provided feed back on the latest commercial applications of fuel cells with their respective costs.

Task 5 - Future Work

- In support of analysis and assessments, an extensive fuel cell system model (called GCTool) developed by Argonne will be used.
- Using GCTool, the system will be modeled, to evaluate potential changes in components or trade-offs in operating parameters, and thereby optimize the fuel cell system for maximum performance.