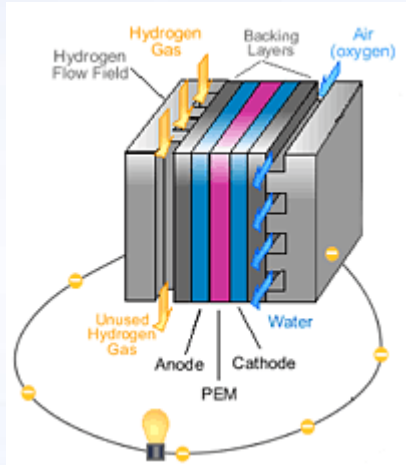
U.S. Department of Energy
Energy Efficiency and Renewable Energy

2006 Annual DOE Hydrogen Program Review

Systems Analysis

Fred Joseck, Technology Analyst



Office of Hydrogen, Fuel Cells and Infrastructure Technologies

Outline

- Goals and Objectives
- Strategy
- Barriers
- Planning and Implementation
- Budget
- 2005 Accomplishments
  - Program Applications
- Future Plans

Systems Analysis Goals & Objectives

Provide system-level analysis to support transition-strategy development and the 2015 technology readiness decision by evaluating technologies and pathways, guiding the selection of RD&D technology approaches/options, and estimating the potential value of RD&D efforts.

By 2008:

- Develop a Macro-System Model for the analysis of the hydrogen fuel and vehicle infrastructure.

By 2009:

- Identify and evaluate feasible transition scenarios consistent with infrastructure and hydrogen resources.

By 2011:

- Enhance the Macro-System Model to include the stationary electrical generation and infrastructure for a full hydrogen economy.

By 2014:

- Complete environmental studies that are necessary for the 2015 Technology Readiness Decision.

Annually:

- Update the Well-to-Wheels analysis for technologies and pathways for the Hydrogen Program to include technological advances and changes.

Continuously:

- Support the integration of the Hydrogen Program within a balanced, overall DOE national energy R&D effort.
- Provide and coordinate analysis of environmental and technoeconomic issues.
- Support a spectrum of analyses, including financial and environmental assessments.

Systems Analysis Strategy

Expected Outputs and Deliverables
- Recommendations
- Reports
- Inputs to Plans
- Validated Results
- Supporting Data

Studies and Analysis
- Transitional Analysis
- Long Term Analysis
- Environmental Analysis
- Collaborative Analysis
- **Report for 2015 Technology Readiness**

Models and Tools
- Macro-System Model
- Component Models
- Integrated Models

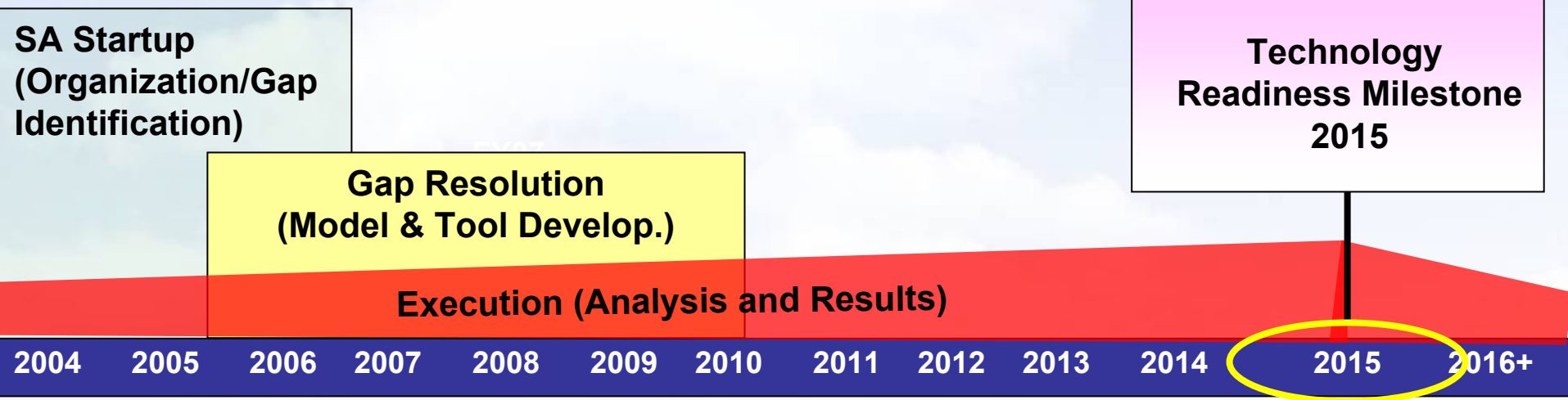
Systems Analysis Framework
- Systems Analysis Plan
- Hydrogen Analysis Resource Center
- Analysis repository

- Support Program decision-making processes and milestones.
- Ensure objective inputs.
- Provide direction, planning and resources/tools.
- Provide ongoing and planned studies and tasks.
- Provide independent analysis when required to validate decisions.
- Provide value-added products.
- Measure progress through a regular peer review process.
  - Respond to external review recommendations.

Systems Analysis Key Barriers

Barriers	
Stove-piped/Siloed Analytical Capability	• Each group and element perform separate analysis for similar subjects. • Segmented and inconsistent analysis
Inconsistent Data, Assumptions and Guidelines	• Current data sources inconsistent • Input assumptions vary for different tasks • No guidelines for modeling and analysis
Suite of Models and Tools	• Current modeling architecture for overarching transitional and infrastructure analysis does not exist. • Need to link wide range of models in order to analyze the hydrogen fuel infrastructure.
Unplanned Studies and Analysis	• Analysis not coordinated and on ad hoc basis • Major demand for analysis work and projects will be forthcoming
Future Market Behavior	• Need to understand behavior and drivers of fuels markets for a viable hydrogen economy. • Long-term hydrogen infrastructure and the evolution is not well understood. • Numerous economic, social, political and technical influences involved in the transition.

Systems Analysis Planning



Planning Step Descriptions

SA Startup

- ✓ Systems Analysis function established
- ✓ Systems Analysis sect. for RD&D Plan
- • Systems Analysis Plan
- ✓ Identify analytical gaps and "missing pieces"

Gap Resolution

- ✓ Hydrogen Analysis Resource Center
- ✓ Analysis Portfolio
- ✓ Macro-System Model (test version)
- ✓ H2A Production Model
- • Macro-System Model (final version)
- • Transition Models
- ✓ HyTrans
- ✓ Incorporate H2A into PBA NEMS and Markal Models
- • Macro-System Model with stationary electrical gen.

Execution (Analysis and Results)

- ✓ Individual Technology analysis
- ✓ WTW analysis
- ✓ Transition and infrastructure analysis
- • Hydrogen Economy Analysis
- • Environmental analysis
- • Policy analysis
- • Energy efficiency analysis

Legend:

- • Ongoing projects and activities
- ✓ Completed activities and projects by 2005

Planning and Implementation

Complete 1st edition of the Hydrogen Analysis Resource Center (2Q, 2006)

Complete 1st test version of Macro-System Model (2Q, 2006) [Linkage of H2A Prod., H2A Delivery and GREET Models]

Complete final version of Macro-System Model (2008)

Enhance the Macro-System Model to include electrical generation (1Q, 2011)

2004 2005 2006 2007 2008 2009 2010 2011

Public release of the H2A models (2005)

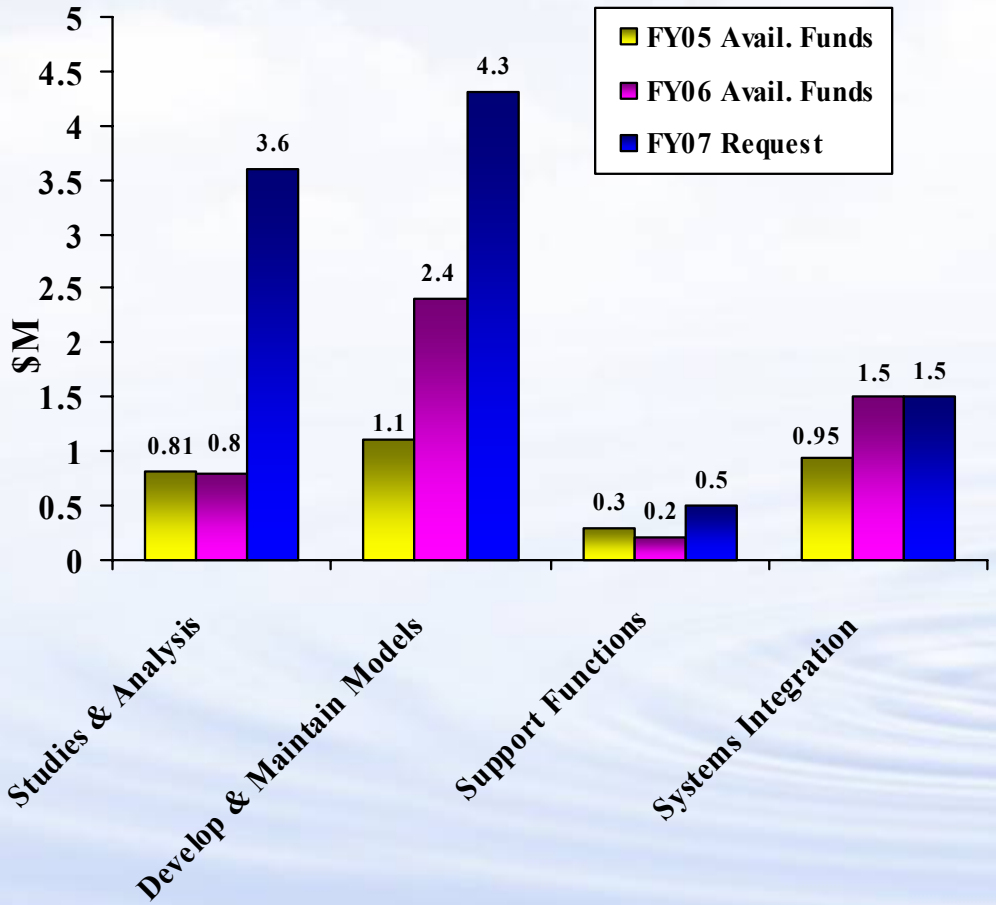
Complete transition models (2007)

Complete study for transitioning scenarios (2009)

Complete assessment of hydrogen quality requirements for Production, Delivery, Storage and Fuel Cell Pathway (2010)

Systems Analysis Budget

FY 2007 Budget Request = $9.90M
FY 2006 Available Funds = $4.90M
FY 2005 Available Funds = $3.16M



FY07 Systems Analysis Budget Details

- **Studies & Analysis ($3.6 million)**
  - WTW analysis (ANL & NREL)
  - Transition Analysis (NREL)
  - Infrastructure & Resource Analysis (TBD)
  - Environmental Analysis (ANL)
- **Develop & Maintain Models ($4.3 million)**
  - Macro-System Model Develop. (Systems Integration and Sandia NL)
  - H2A Production Model (NREL)
  - HyTrans Model (ORNL)
  - HyDS Model (NREL)
  - DTI Project
  - EEA Project
  - RCF Project
- **Support Functions ($0.5 million)**
  - FPITT (NREL)
  - Hydrogen Analysis Resource Center (PNNL)
  - External Studies
- **Systems Integration ($1.5 million)**
  - Independent Assessments
  - Risk Analysis
  - Analysis Portfolio
  - Program support
  - Analysis Repository

Accomplishments/ Progress

Hydrogen Analysis Resource Center

- Peer reviewed by industry, NIST, DOT, DOE and national labs.
- Completed and issued 1st version to the website 4/1/06.
- **In one month, over 25,000 visits to the website.**

http://hydrogen.energy.gov

Modeling and Model Development

Macro-System Model

- Systems Integration and Sandia NL accomplished the key task of linking various modeling systems.
- Completed first version of the model.

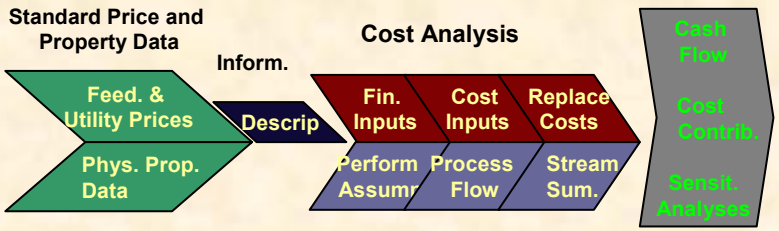
Accomplishments/ Progress

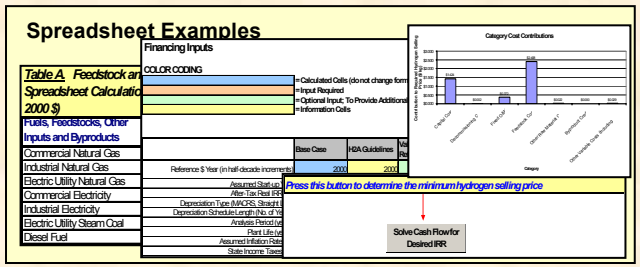
Modeling and Model Development

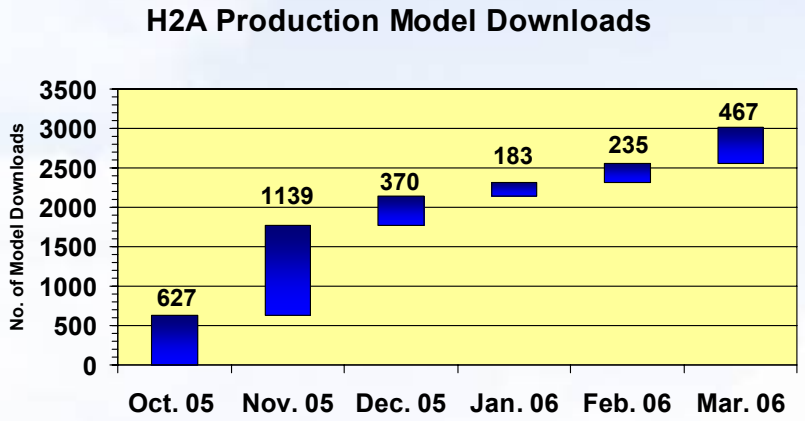
H2A Production Model

- Issued the H2A Production model to the website in October 2005.

H2A Cash Flow Modeling Tool







Key Points

- Over 3000 model downloads since H2A Production Model posted October 2005.
- Modeling community acquiring tool for consistent and transparent analysis.

Accomplishments/ Progress

Systems Analysis

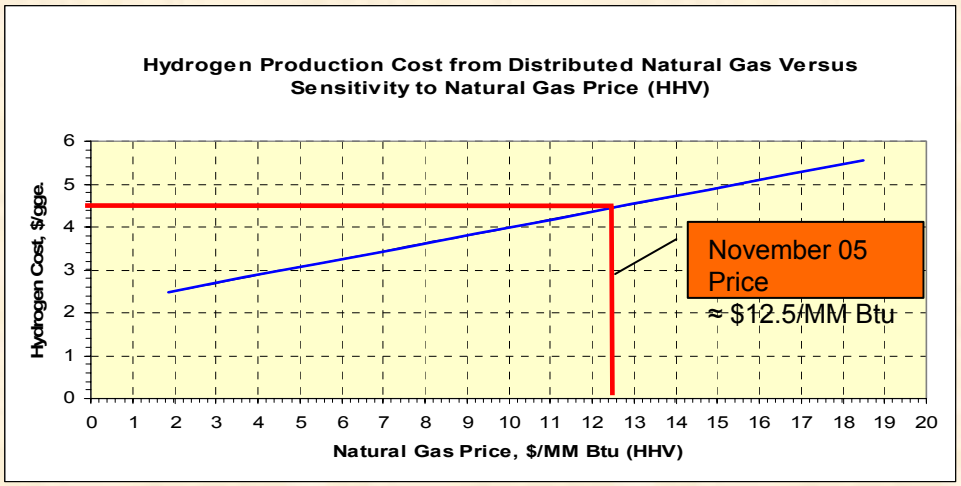
Program Analysis

Risk Analysis

- Draft "Risk Management Plan" developed for Hydrogen Program
- Started risk evaluation of Program elements with subject matter experts

Technology Analysis

- Feedstock pricing volatility impact



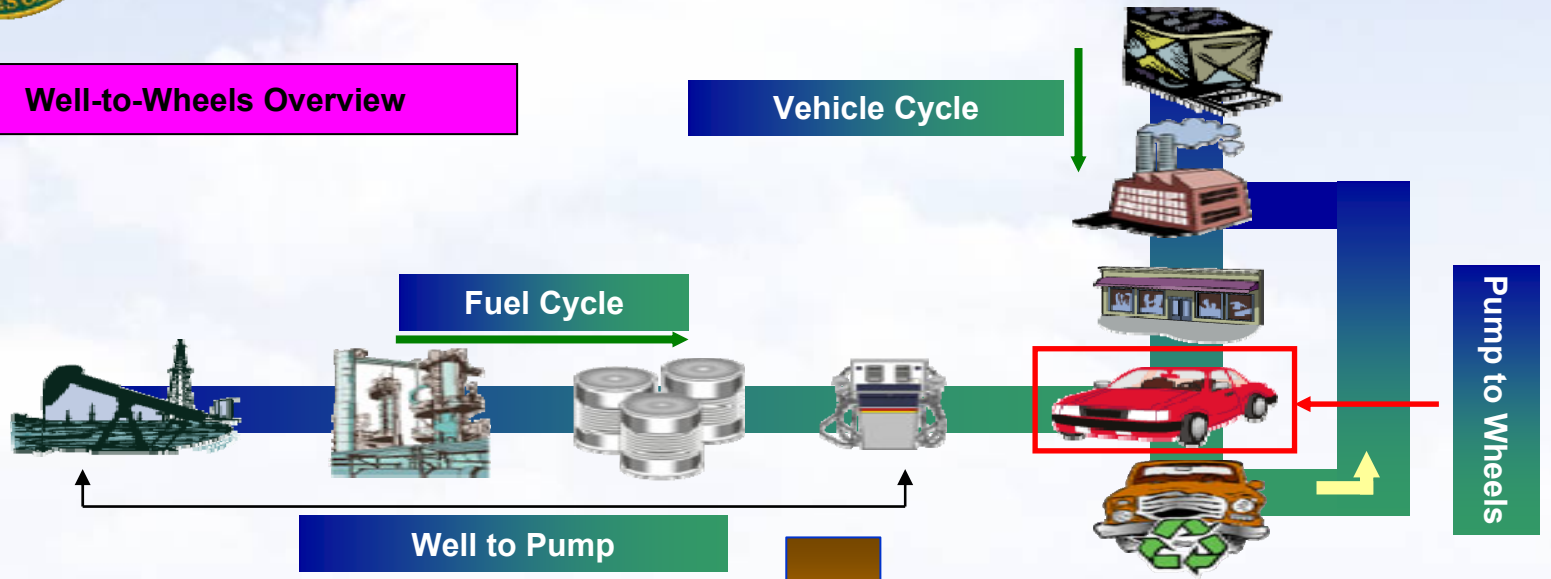
Well-to-Wheels Analysis

- Technology impact on Petroleum Use and GHG

DOE Well-to-Wheels Analysis Methodology

A "Systems" Approach

Well-to-Wheels Overview



Source: ANL

Well-to-Wheels Modeling Process

Vehicle Analysis (PSAT Model) (Output: Vehicle Fuel Economy)

Energy & Raw Materials Data Inputs (Hydrogen Analysis Resource Center)

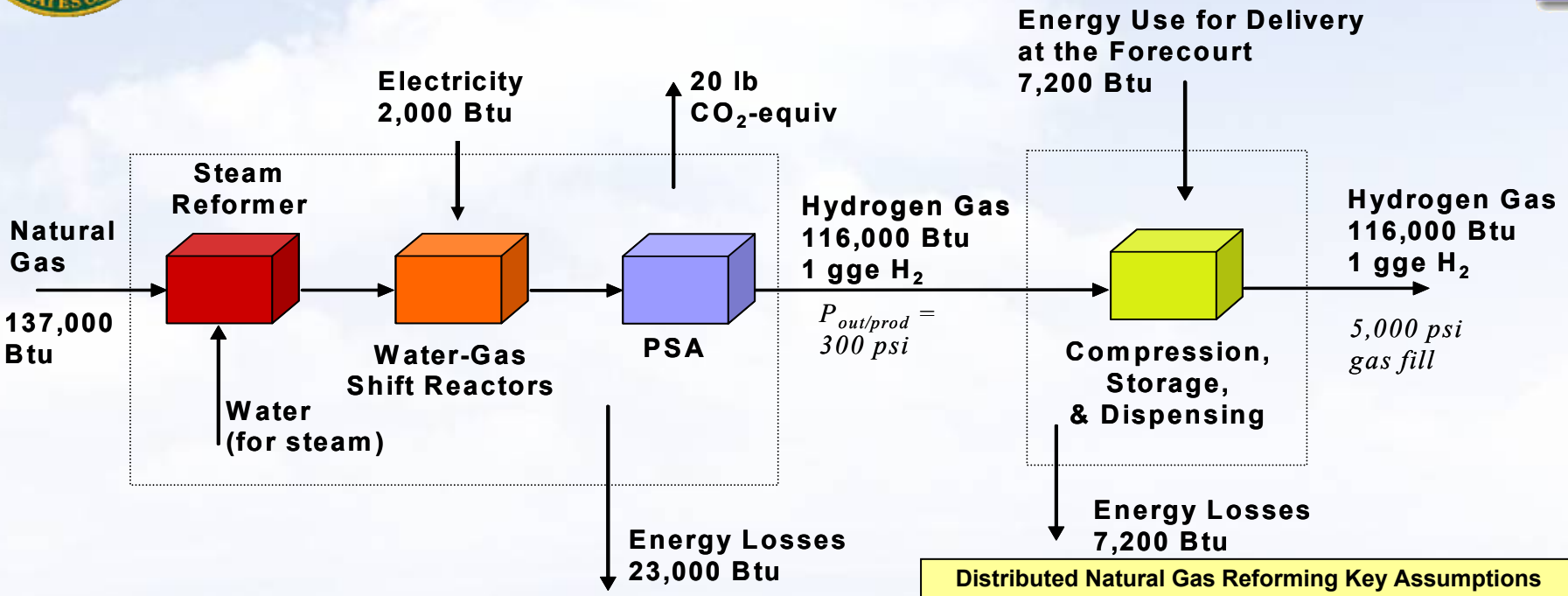
H2 Production & Delivery (H2A Model) (Output: Fuel Pathway Efficiency)

Well - to - Wheels Analysis *(GREET Model)*

Analysis Output

- Greenhouse Gas Emissions, Total Energy Use and Petroleum Energy Use for WTT, TTW and WTW for pathways.
- Comparison of Hydrogen FCVs, Gasoline and alternative fueled ICE & HEVs, Electric and other vehicle platforms on a WTW basis.

Well-to-Wheels Analysis: Hydrogen Pathways
Distributed Natural Gas: Transition Strategy



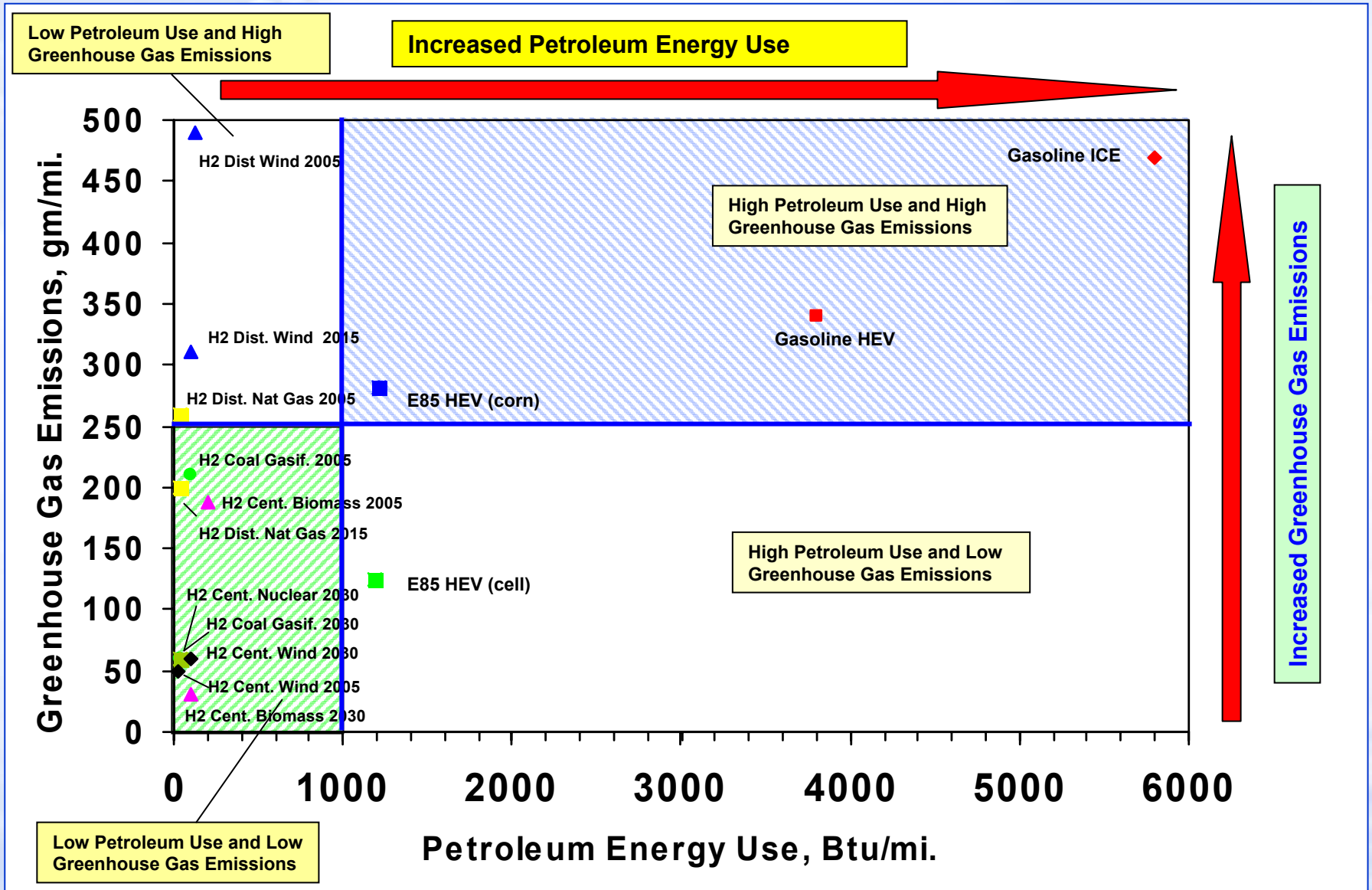
Well-to-Wheels Energy and Greenhouse Gas Emissions Data				
	Gasoline ICE Vehicle	Gasoline Hybrid Electric Vehicle	Current Distributed SMR - FCV	Future (2015) Distributed SMR - FCV
Well-to-Wheels Total Energy Use (Btu/mile)	5,900	4,200	3,700	2,800
Well-to-Wheels Petroleum Energy Use (Btu/mile)	5,300	3,800	40	40
Well-to-Wheels Greenhouse Gas Emissions (g/mile)	470	340	260	200
Cost of Hydrogen ($/gge, Delivered)			3.10	2.00

Source: NREL and ANL

Distributed Natural Gas Reforming Key Assumptions

1. Well-to-Wheels energy, petroleum and greenhouse gas emissions from Argonne Nat. Lab. GREET model.
2. Cost, resource requirements, energy requirements, fuel and feedstock energy content and efficiency values from H2A 1,500 kg/day Forecourt SMR.
3. Costs include hydrogen production, compression, storage and dispensing to the vehicle.
4. Natural gas feedstock price for current and future cases based on 2015 industrial gas ($5.24/MM Btu LHV) by DOE's EIA Energy Outlook 2005 High A case. Price is in 2005$.
5. Electricity prices for current and future cases based on 2015 commercial rate($0.08/kWh) electricity by EIA Energy Outlook Hi A case. Price is in 2005$.
6. Operating capacity factor is 70%.
7. Capital costs are $1.40/kg (Current) and $0.60/kg (Future).

GHGs vs. Petroleum Energy Use for Technologies



Future Directions

- Focused on continued resolution of known “gaps”
  - Macro-System Model development
  - Transition and Infrastructure analysis
- Continue with the model development required to cover the future analytical tasks.
- Complete the transition projects with DTI, EEA, RCF, NREL and ORNL.
- Begin detailed infrastructure and resource analysis and studies.
- Form a Cross-cut Analysis Team to address key analysis issues, insure analysis consistency and engage in cross-cutting analysis such as WTW, infrastructure development, etc.

Systems Analysis Partners

Program Analysis
NREL
Argonne Nat. Lab.
Oak Ridge Nat. Lab.
Pacific Northwest Nat. Lab.

Models
NREL
Sandia Nat. Lab.
Oak Ridge Nat. Lab.

Systems Integration
NREL

Transition and Infrastructure
Direct Technologies, Inc (DTI)
Energy and Environmental Analysis, Inc (EEA)
NREL
Oak Ridge Nat. Lab.
RCF
Brookhaven Nat. Lab.
UC Davis
Argonne Nat. Lab.

Environmental Analysis
Argonne Nat. Lab.
NREL

Fuels Analysis
TIAX