Moving Toward Consistent Analysis in the HFC&IT Program: *H2A*

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H2A Team

Objectives

- Overall goal: Bring consistency and transparency to hydrogen analysis
- Phase I goals:
  - Production and delivery analysis
  - Consistent cost methodology & critical cost analyses
  - R&D portfolio analysis
  - Tool for providing R&D direction
  - Current effort is not designed to pick winners

Funding

- Project inception February 2003
- Total funding approximately $800k
- FY04 funding approximately $600k
  - $350k to National Labs
  - $250k to expert contractors

Technical Barriers and Targets

- Section 4.3.3 of Program's MYPP
- Provide consistency in analysis
- Perform analysis needed to:
  - Provide direction, focus, and support to the development and introduction of hydrogen production, storage, and end-use technologies
- Types of analysis:
  - Resource
  - Technology feasibility and cost
  - Environmental
  - Delivery
  - Infrastructure development
  - Energy market

Approach

- Cash flow analysis tool
  - Estimates levelized price of hydrogen for desired internal rate of return
  - Take into account capital costs, construction time, taxes, depreciation, O&M, inflation, and projected feedstock prices
- Production costs estimated
  - Current, mid- (~2015), and long-term (~2030) technologies
    - Natural gas, coal, biomass, nuclear, electrolysis
  - Current delivery components
  - Data from published studies and industry design
- Refined inputs and results based on peer review and input from key industrial collaborators (KIC)
- Identified key cost drivers using sensitivity analyses

Project Safety

- Current effort is analysis of cost of production and delivery
- Subsequent phase will incorporate standardized reporting of project safety

Example

PROCESS ENERGY EFFICIENCY ASSUMPTIONS (Analysis Inputs):			
These are assumptions (i.e. single-step conversion efficiencies) that are input into the analysis			
Efficiency results should be given in terms of the lower heating values of the hydrogen and all fuels and feedstocks			
Energy efficiencies for individual process steps (add rows as appropriate)		**Basis**	**Reference**
HYDROGEN PRODUCT CONDITIONS		**Comments**	**PEMFC Spec. (1)**
Pressure (psig)			
% Hydrogen			98 minimum
$C0_2$ (ppm)			< 100
CO (ppm)			< 10
Sulfer (ppb)			< 10
Ammonia (ppm)			< 1
Non-methane hydrocarbons (ppm)			< 100
Total of Oxygen, Nitrogen and Argon (%)			< 2
Water (%)			
Other (*specify*)			

Project Timeline

- FY03: Definition
  - 1. Assess state-of-the-art
  - 2. Assemble team
  - 3. Define H2A objective
  - 4. Define first phase
- Phase I: Production and delivery cost analysis
  - 5. Assemble key industrial collaborators (KIC) group
  - 6. Develop cash flow tool
  - 7. Develop approach for feedstock and utility costs
  - 8. Perform critical analyses, including sensitivities
  - 9. Roll-out initial results at NHA
  - 10. Make model available on web
  - 11. Publish paper on Phase I results

Phase II possibilities:

-Environmental analysis

-Transition analysis

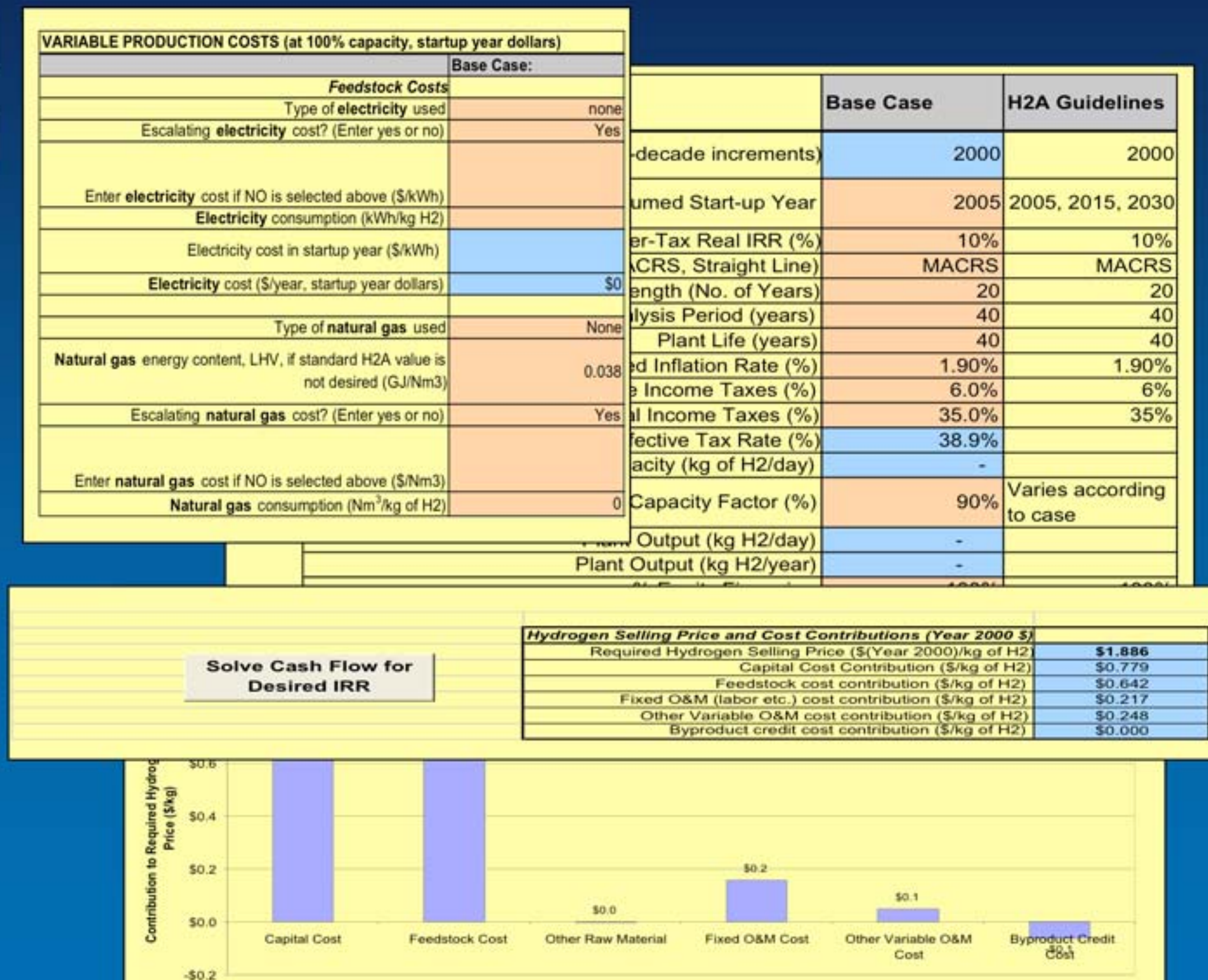
-End-point analysis

Technical Accomplishments

- Developed central and forecourt standard reporting spreadsheets
  - Documents assumptions, inputs, and results
- Completed base cases with sensitivity analysis for current, mid-term, and long-term technologies
  - Natural gas reforming: central and forecourt
  - Coal
  - Biomass
  - Nuclear
  - Central wind / electrolysis
  - Distributed electroysis
  - LH_2 and cH_2 (Tube Trailer and Pipeline) Delivery
- Worked with key industry collaborators (KIC) to establish parameters, process designs, and technology assumptions
- Demonstrated ability to calculate levelized hydrogen price and document a consistent set of assumptions

H2A Cash Flow Analysis Tool

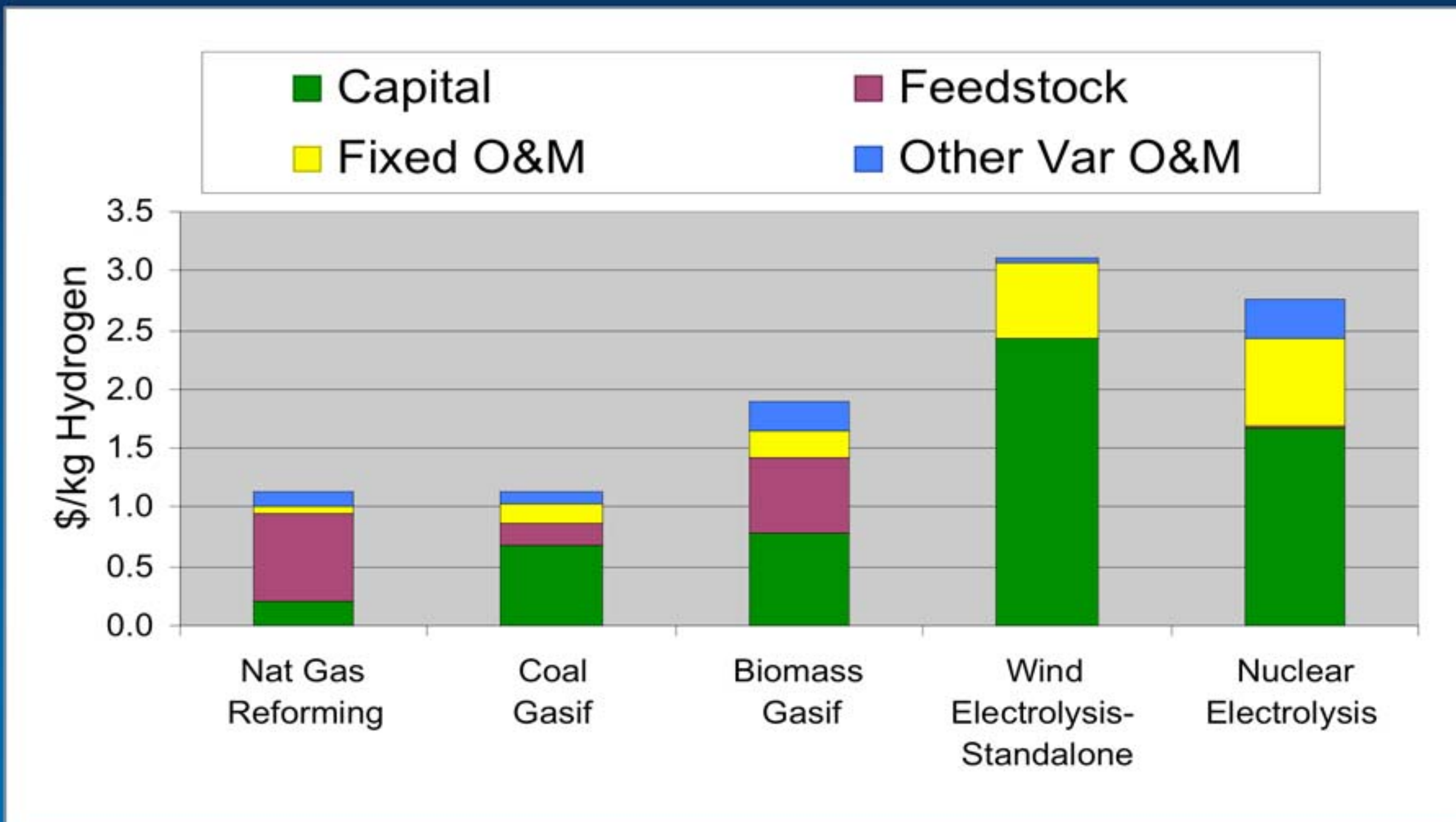
- Process Description
- Feedstock & Utility Prices
- Technology Performance Assumptions
- Process Flowsheet & Stream Summary
- Financing Inputs
- Cost Inputs
- Replacement Capital
- Cash Flow Analysis
- Results - Price of H2



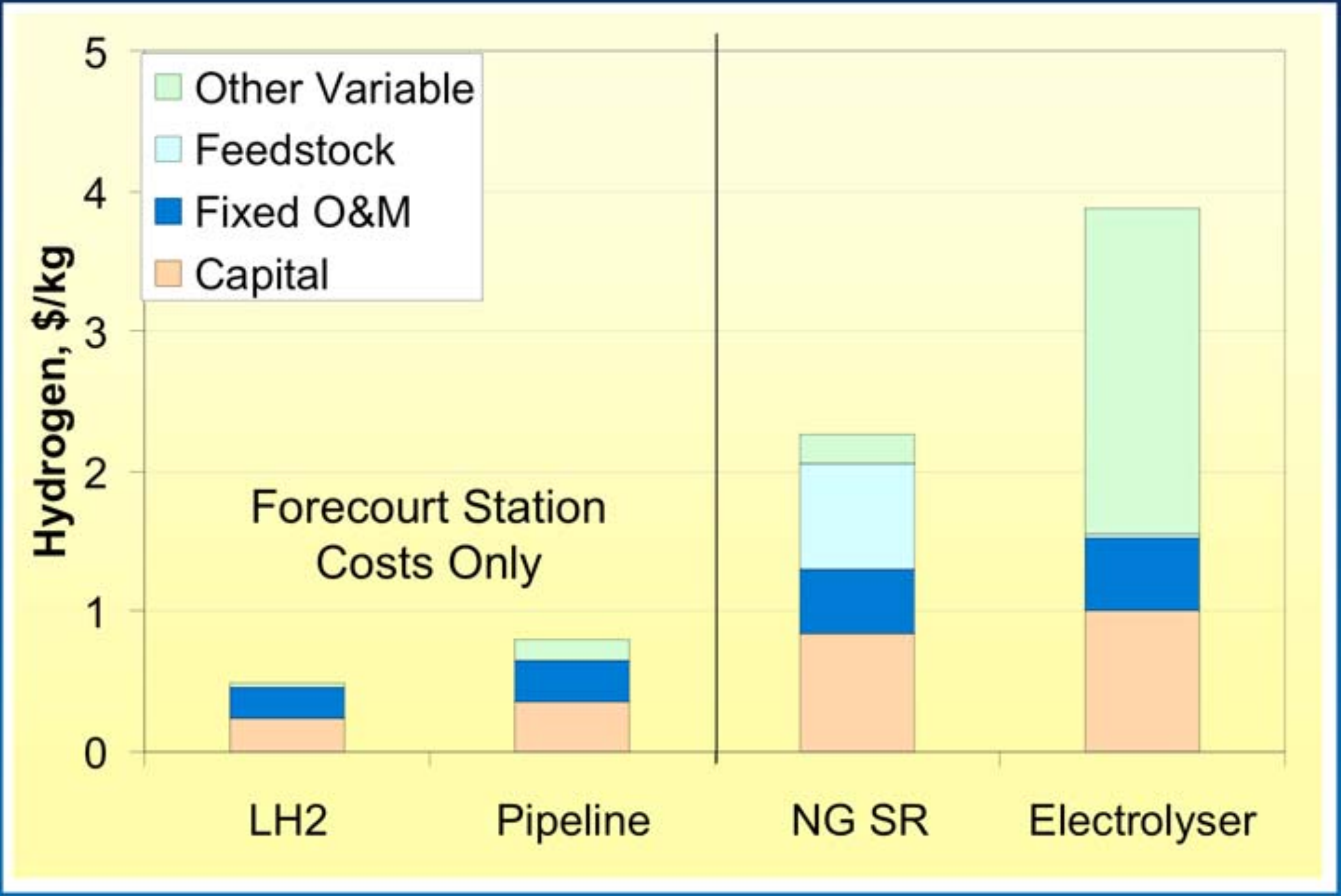
Key Financial Parameters Forecourt and Central

- + Reference year (2000 $)
- + Debt versus equity financing (100% equity)
- + After-tax internal rate of return (10% real)
- + Inflation rate (1.9%)
- Effective total tax rate (38.9%)
- Design capacity (varies)
- Capacity factor (90% for central (exc. wind); 70% for forecourt)
- Length of construction period (0.5 – 3 years for central; 0 for forecourt)
- Production ramp up schedule (varies according to case)
- Depreciation period and schedule (MACRS -- 20 yrs for central; 7 yrs for forecourt)
- Plant life and economic analysis period (40 yrs for central; 20 yrs for forecourt)
- Cost of land ($5,000/acre for central; land is rented in forecourt)
- Burdened labor cost ($50/hour central; $15/hour forecourt)
- G&A rate as % of labor (20%)

Mid Term Central Technology Options
- $/kg Components -

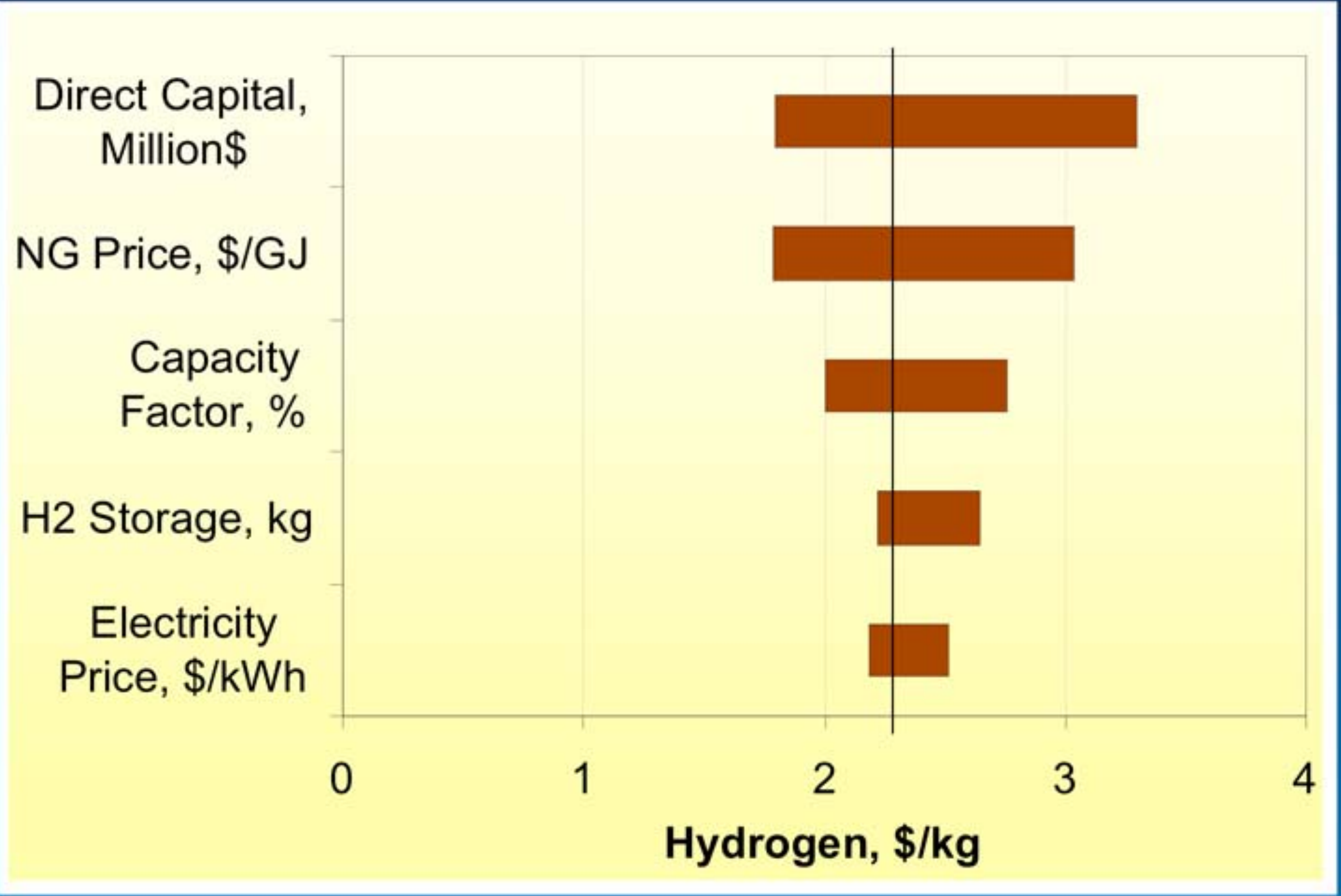


Mid-term Forecourt Technology Summary



Note: For side by side comparison, central plant and delivery costs must be added to the Pipeline and LH_2 cases.

Sensitivity Results: Mid-term Technology - Large NG SR



Low	Base	High
0.9	1.8	3.1
1.85	~4.15	8.58
90	70	50
375	525	1,500
0.025	~0.048	0.12

H2A Delivery Analysis

- Develop delivery component cost and performance database
- Develop delivery scenarios for major markets and demand levels
- Estimate the cost of H_2 delivery for scenarios

Assume 2005 delivery technologies

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	

Delivery costs are based on component combinations that meet the demands of the market

3 Delivery Modes: Compressed Gas Truck; Liquid H2 Truck; Gas Pipeline

Interactions & Collaborations

- H2A team:
  - Central: Johanna Ivy (NREL), Maggie Mann (NREL), Dan Mears (Technology Insights), Mike Rutkowski (Parsons Engineering)
  - Forecourt: Brian James (Directed Technologies, Inc.), Steve Lasher (TIAX), Matt Ringer (NREL)
  - Delivery: Marianne Mintz (ANL), Joan Ogden (UC Davis), Matt Ringer (NREL)
  - Finance, feedstocks, and methodology: Marylynn Placet (PNNL), Maggie Mann (NREL), Matt Ringer (NREL)
  - Environmental assessment: Michael Wang (ANL)
  - DOE: Mark Paster, Roxanne Danz, Pete Devlin
- Key Industrial Collaborators: AEP, Air Products, Areva, BOC, BP, ChevronTexaco, Conoco Phillips, Eastman Chemical, Entergy, Exxon Mobil, FERCO, GE, Praxair, Shell, Stuart Energy, Thermochem
- Other: Systems Integration, Program Tech Teams, efforts by H2A team member organizations

Future Work

- Remainder of FY03:
  - Incorporate energy efficiency and environmental measures (Summer '04)
  - Website with spreadsheet tool, results, and detailed documentation (Summer '04)
  - Complete delivery component and scenario cost analysis (Fall '04)
  - Complete remaining cases (Fall '04)
  - Peer-reviewed paper (Fall '04)
  - Plan for next phase of H2A
    - Transition analysis
    - End-point analysis