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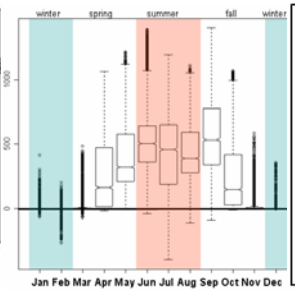
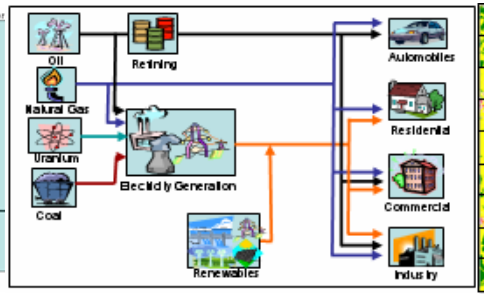
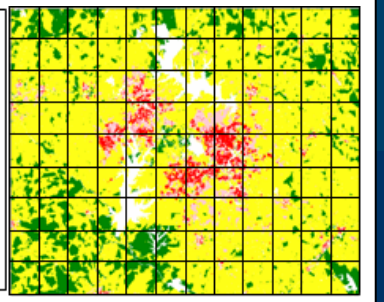
Environmental Protection
Agency

Tools and Methodology for Sensitivity and Risk Analysis with MARKAL

Dan Loughlin





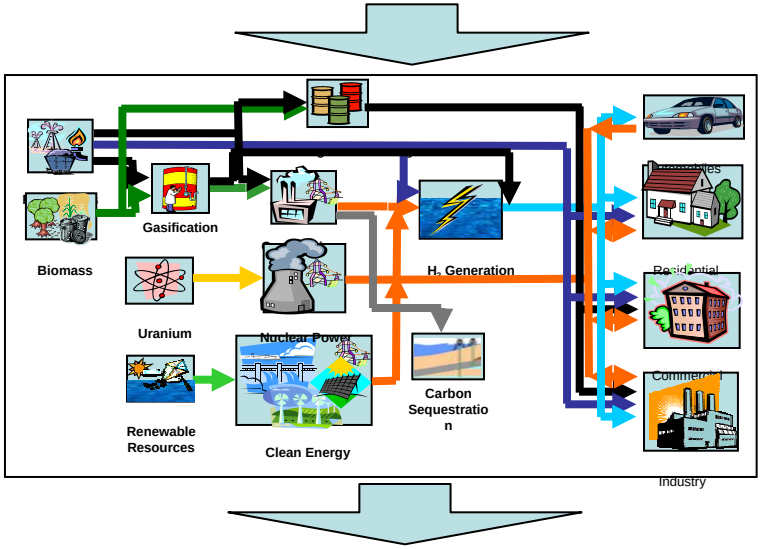


Office of Research and Development
National Risk Management Research Laboratory, RTP, NC

Technology Change Modeling: MARKAL

MARKAL Inputs:

- energy service demands
- resource supply cost curves
- current and future technology characteristics
- emissions regulations



MARKAL Outputs (5-yr increments, 2000-2050):

- technology penetrations by demand
- fuel use by type and region
- emissions by technology, sector, region, and system

Details

Resolution:

NM: 1 - US

9R: 9 - census

Runtime:

NM: 3 min

9R: 45 min

Status:

NM: public now

9R: public in 08?

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Technology Assessment with MARKAL

- Is the technology cost-competitive?
- What are the conditions that would make the technology competitive?
  - Technology breakthroughs in cost or efficiency
  - Changes in fuel availability and prices
- Are there technological pathways by which the technology is competitive, just not least cost?
- What are the technology's competitors and what are the tipping points by which one is selected over the others?
- What are the sectoral and system-wide energy and environmental impacts associated with penetration of the technology?

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Modeling Methodologies and Tools

Modeling Methodologies

- Least Cost Optimization
- What-If Analysis
- Sensitivity Analysis
- Uncertainty Analysis
- Alternative Generation
- Decision-Making Under Uncertainty:
  2-stage decision-making

Software Tools

- Graphics and Visualization software (R)
- Statistical and data-mining software (R & Weka)
- Modeling framework supporting sensitivity and uncertainty analysis (MIMS)

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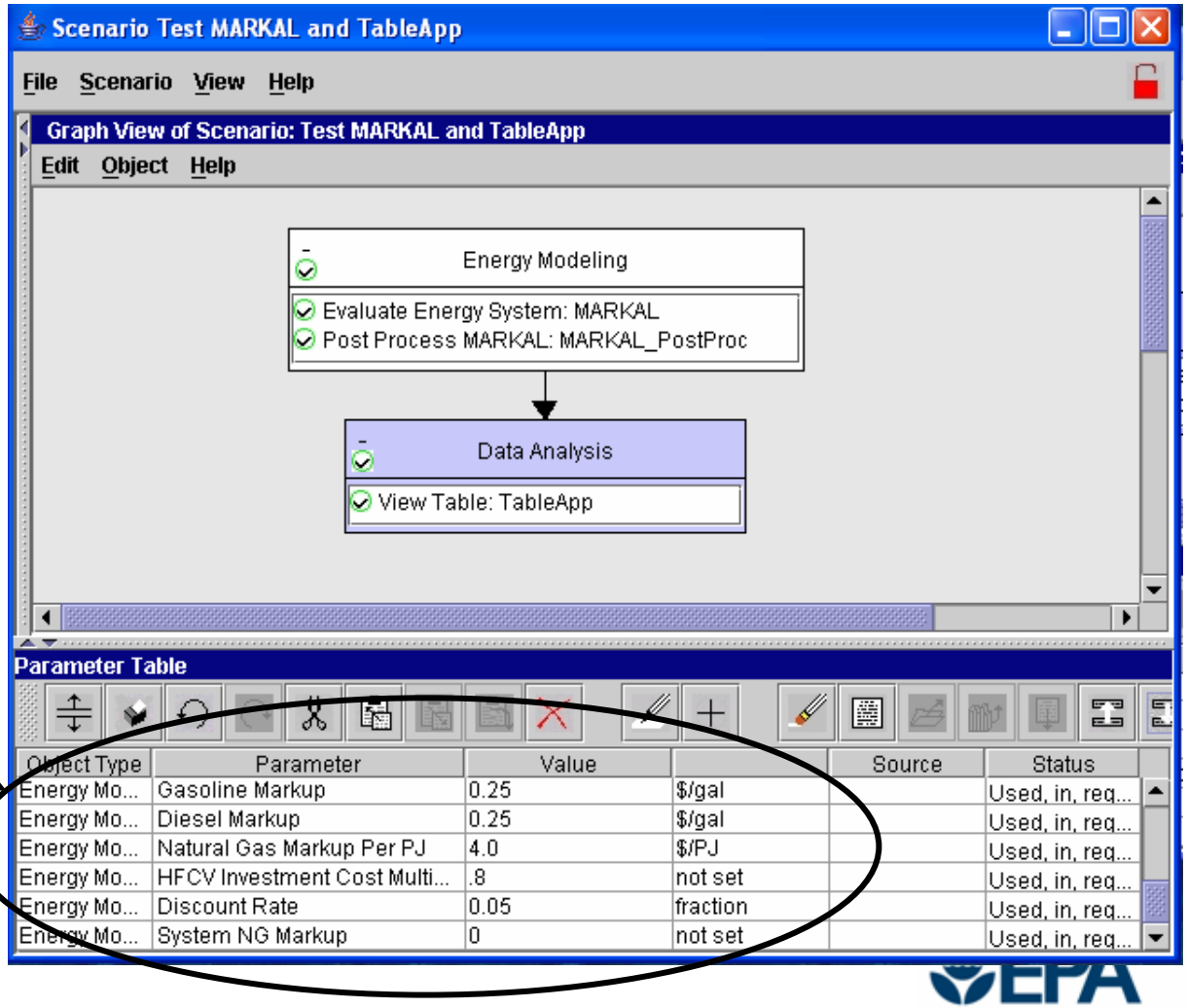
MARKAL Integrated into MIMS

Facilitates sensitivity analysis and linkage of MARKAL to other models and tools

Access to relevant parameters



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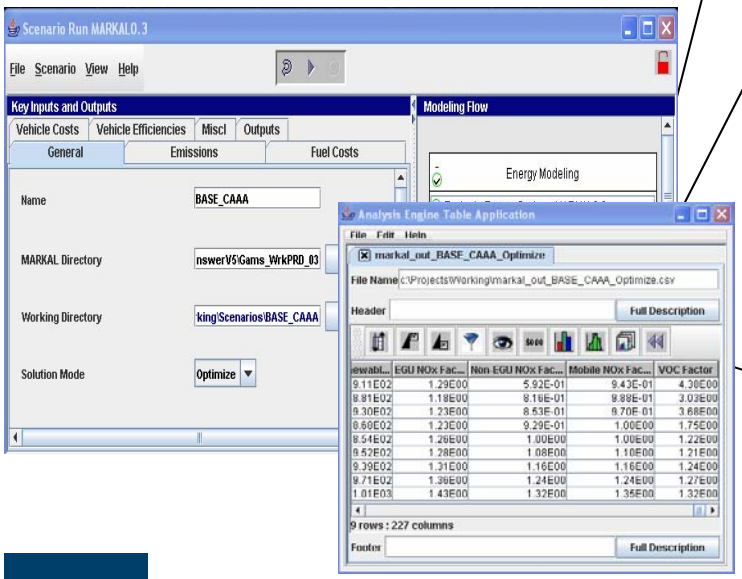
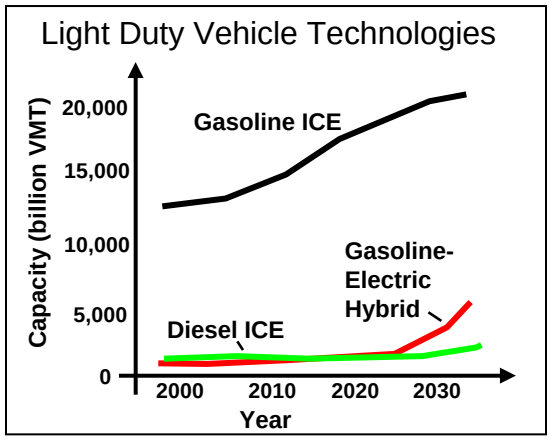
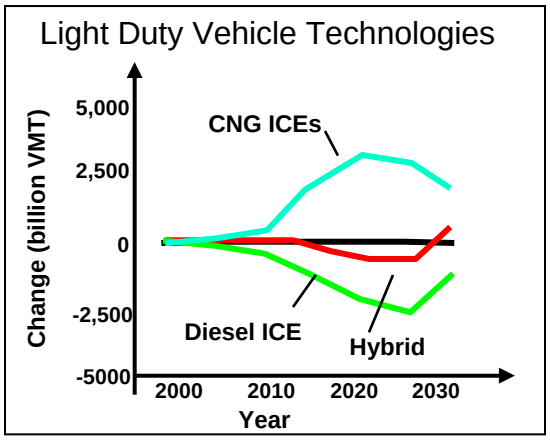
What-If Analysis

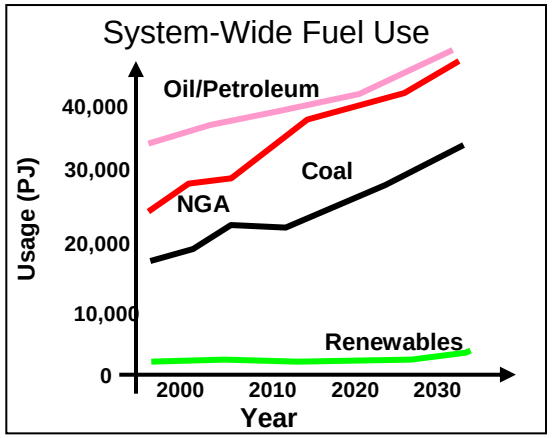
Support iterative exploration:

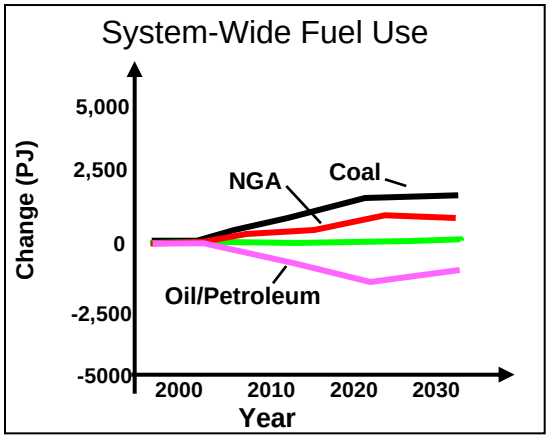
* facilitate input of assumptions
* automate execution
* manage results
* visualize results
* identify changes

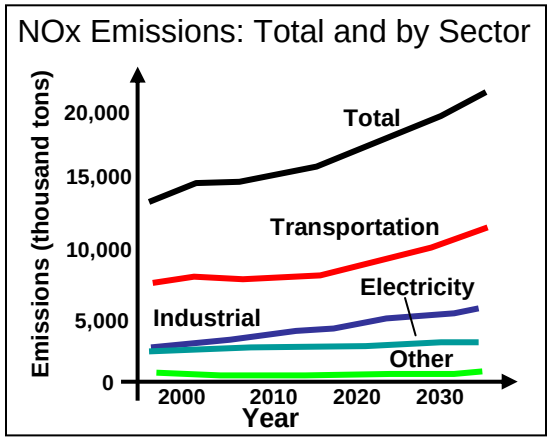


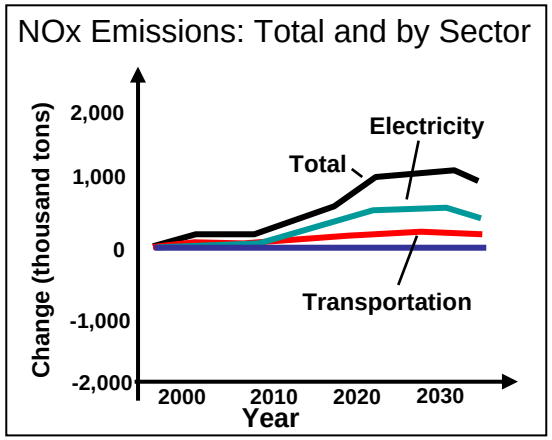










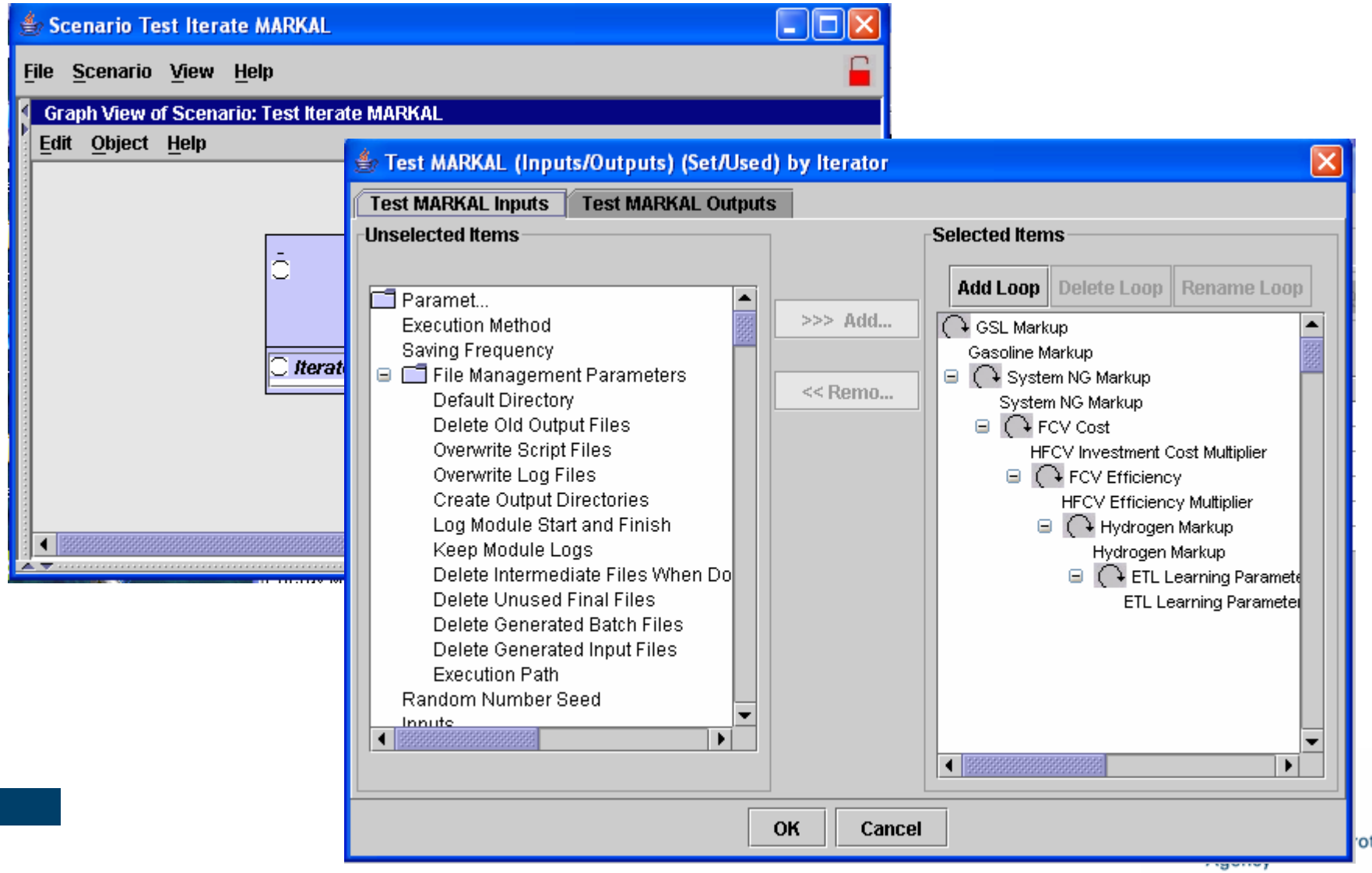


Illustrative Results

Visualize Output

Difference from Baseline

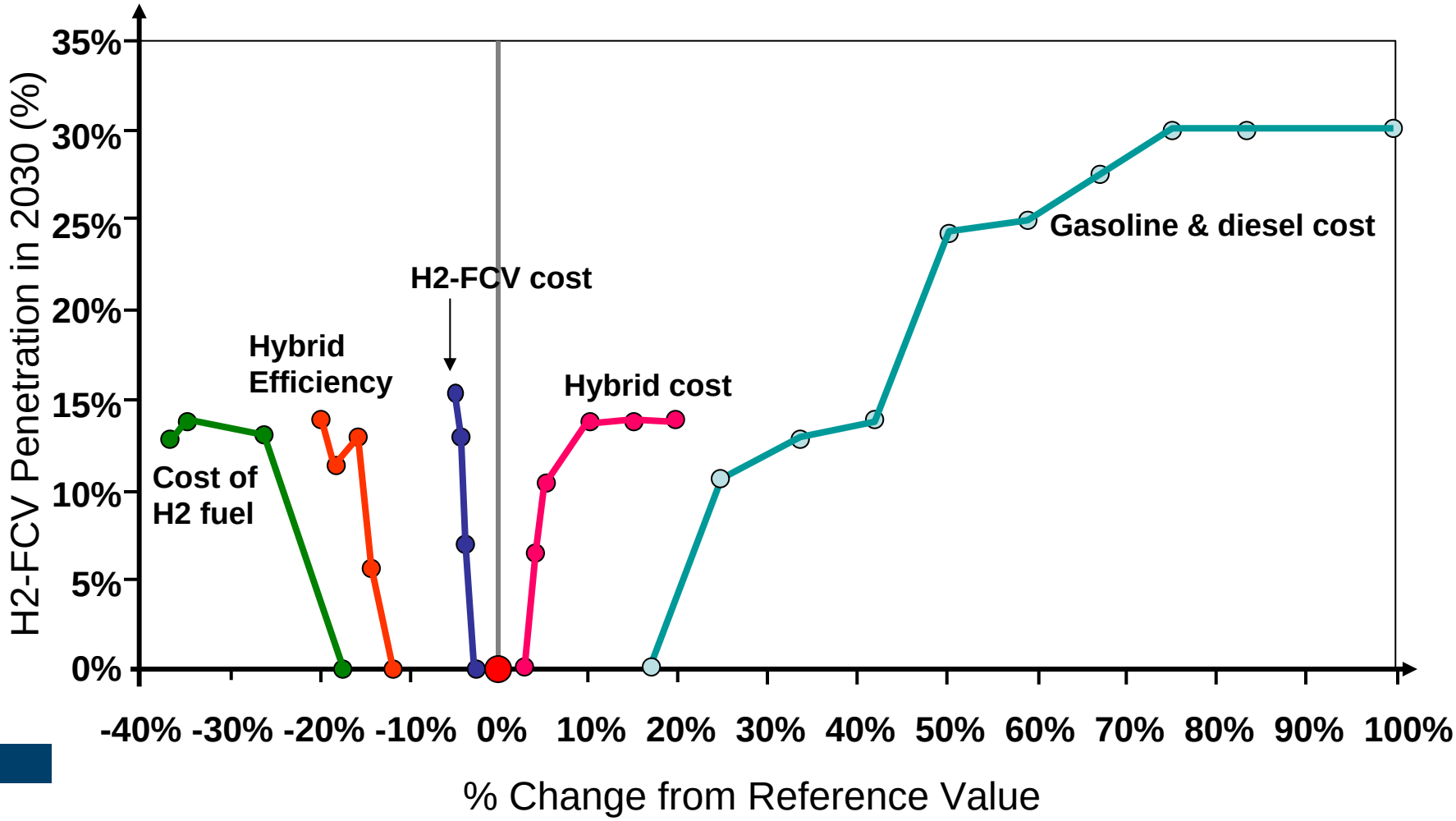
Automating Sensitivity Analysis



Parametric Sensitivity Analysis

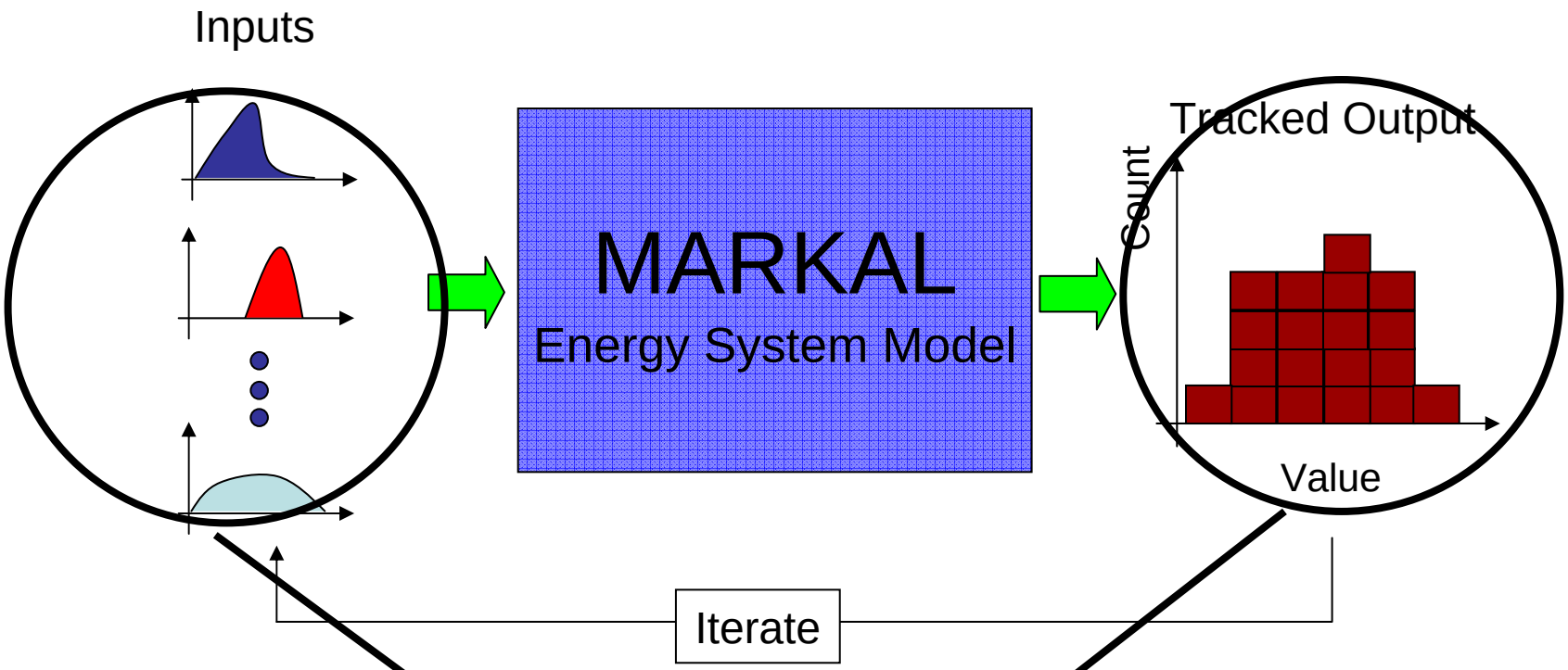
Illustrative Results

* Understand model responses to changes in individual inputs



Global Sensitivity Analysis

Monte Carlo Simulation



Analyze the relationships Between inputs and outputs

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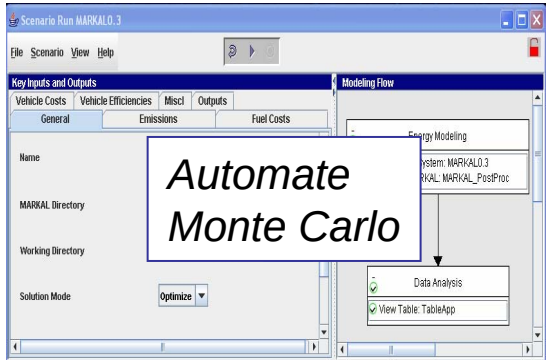
Global Sensitivity Analysis

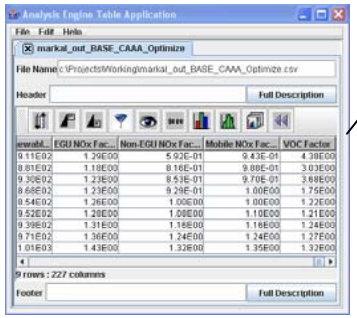
Illustrative Results

Specify Input Assumptions



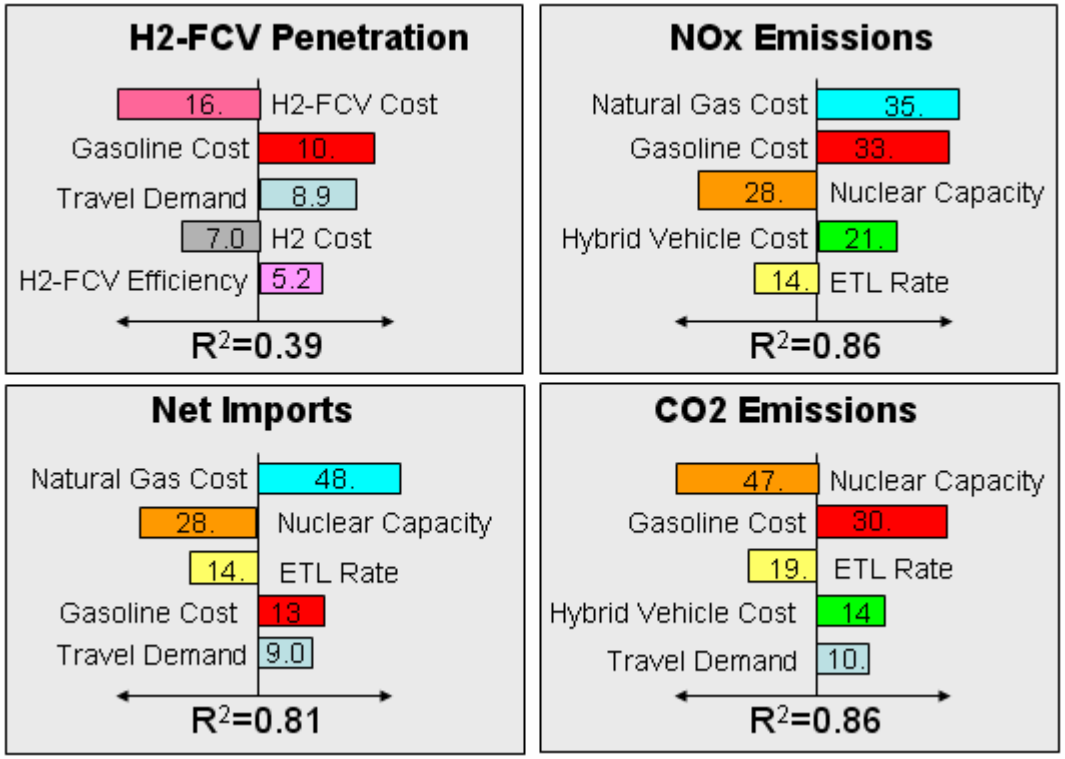
Automate Monte Carlo

Concatenate & Process Results



Analyze Data

Normalized Linear Regression Results



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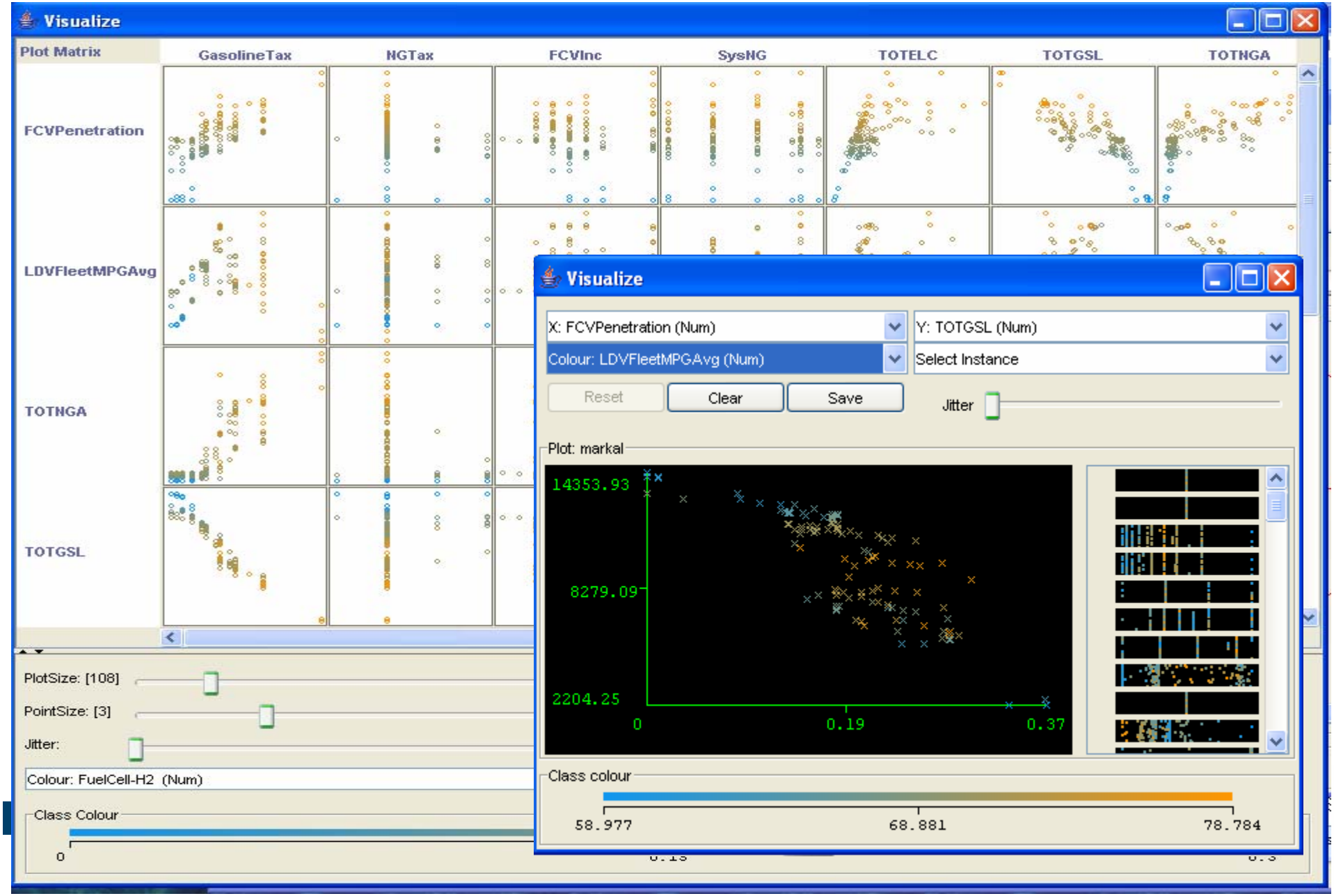
Exploratory Data Analysis

Illustrative Results



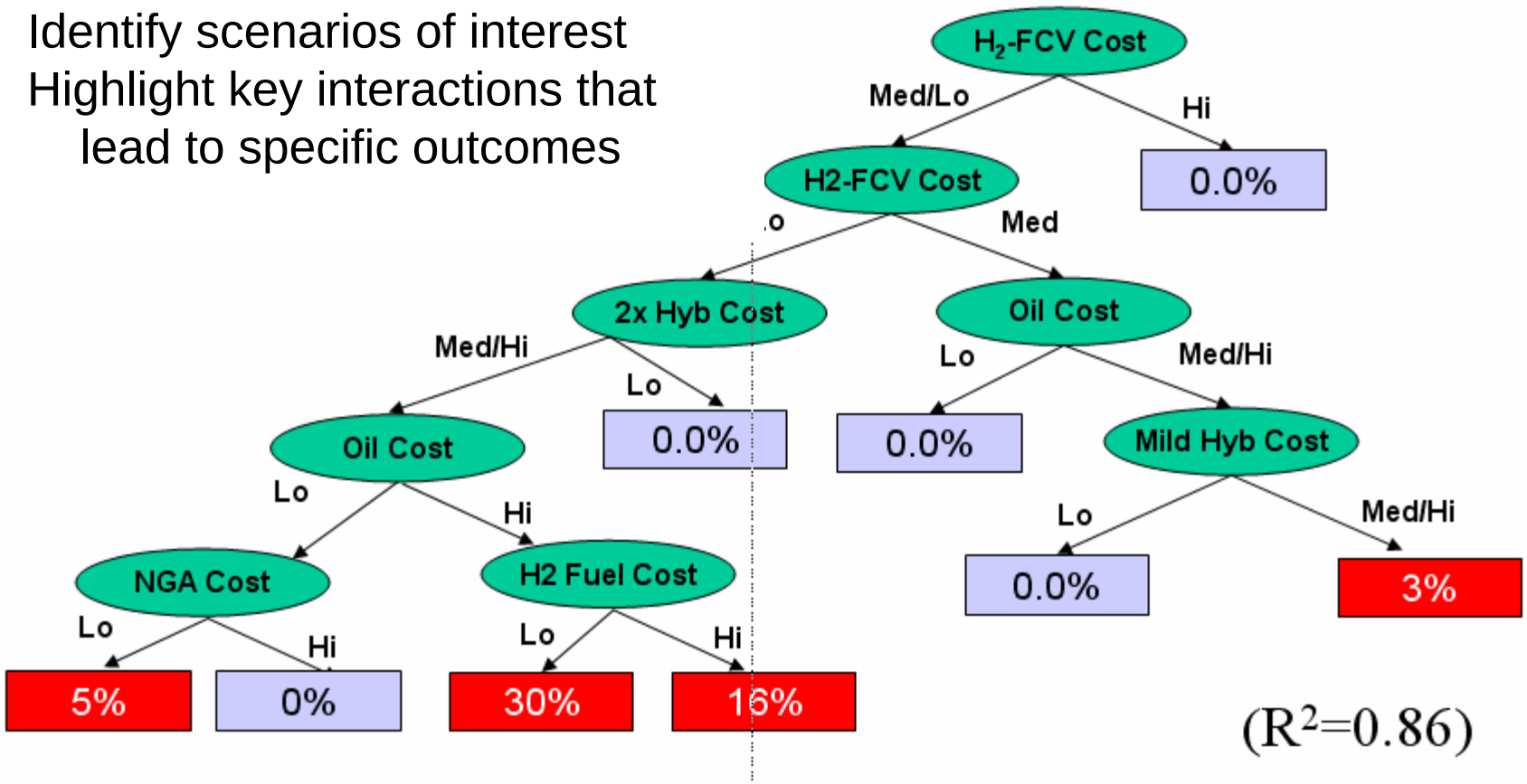
Illustrative Results

Sensitivity and Uncertainty Analysis

Data-Mining Monte Carlo Results

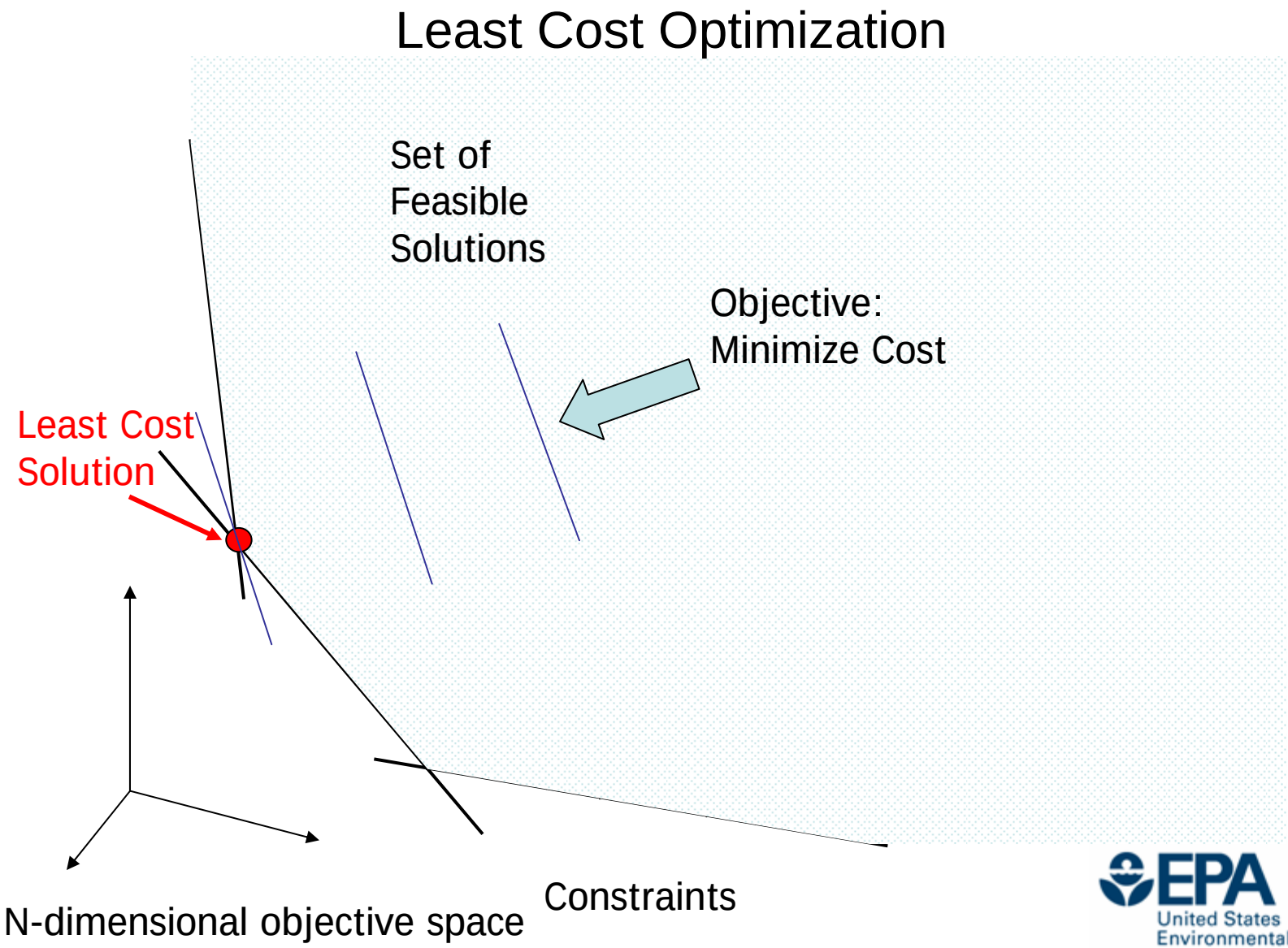
Goals:

- Identify scenarios of interest
- Highlight key interactions that lead to specific outcomes



(R^2=0.86)

Modeling to Generate Alternatives



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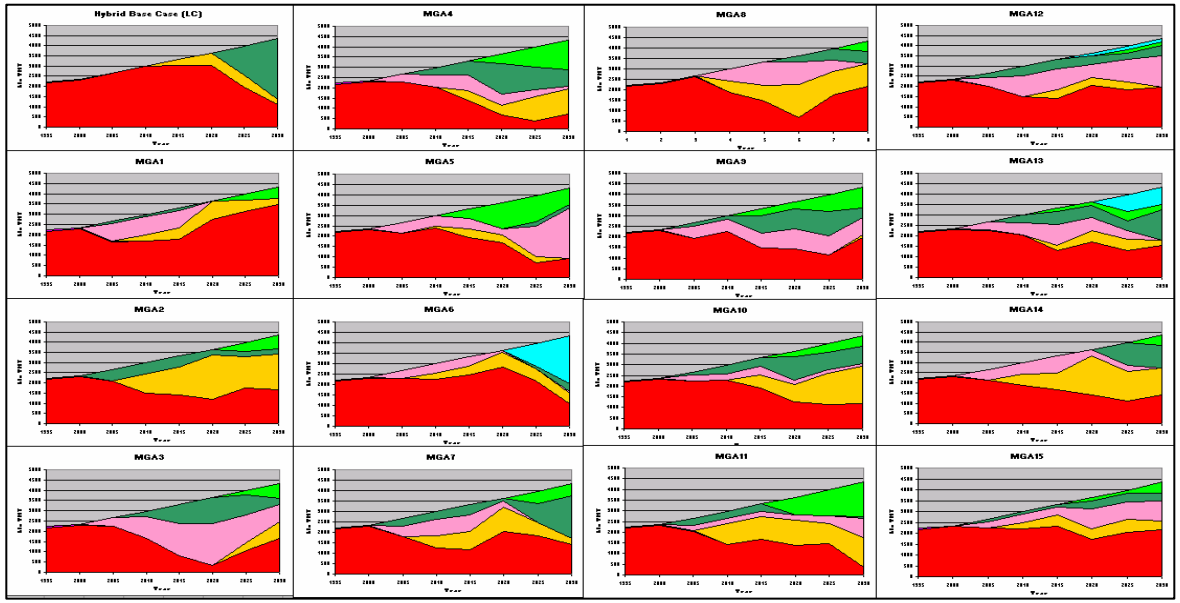
Modeling to Generate Alternatives

MGA Alternatives



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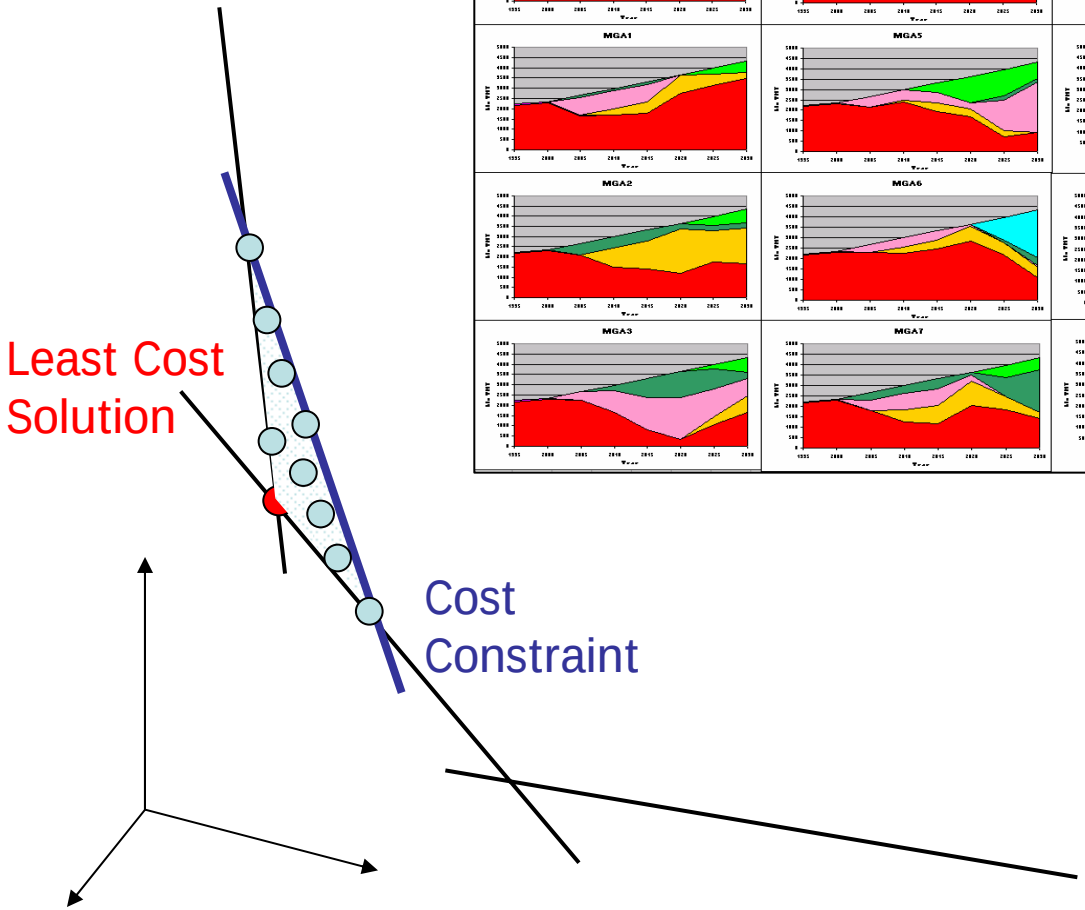

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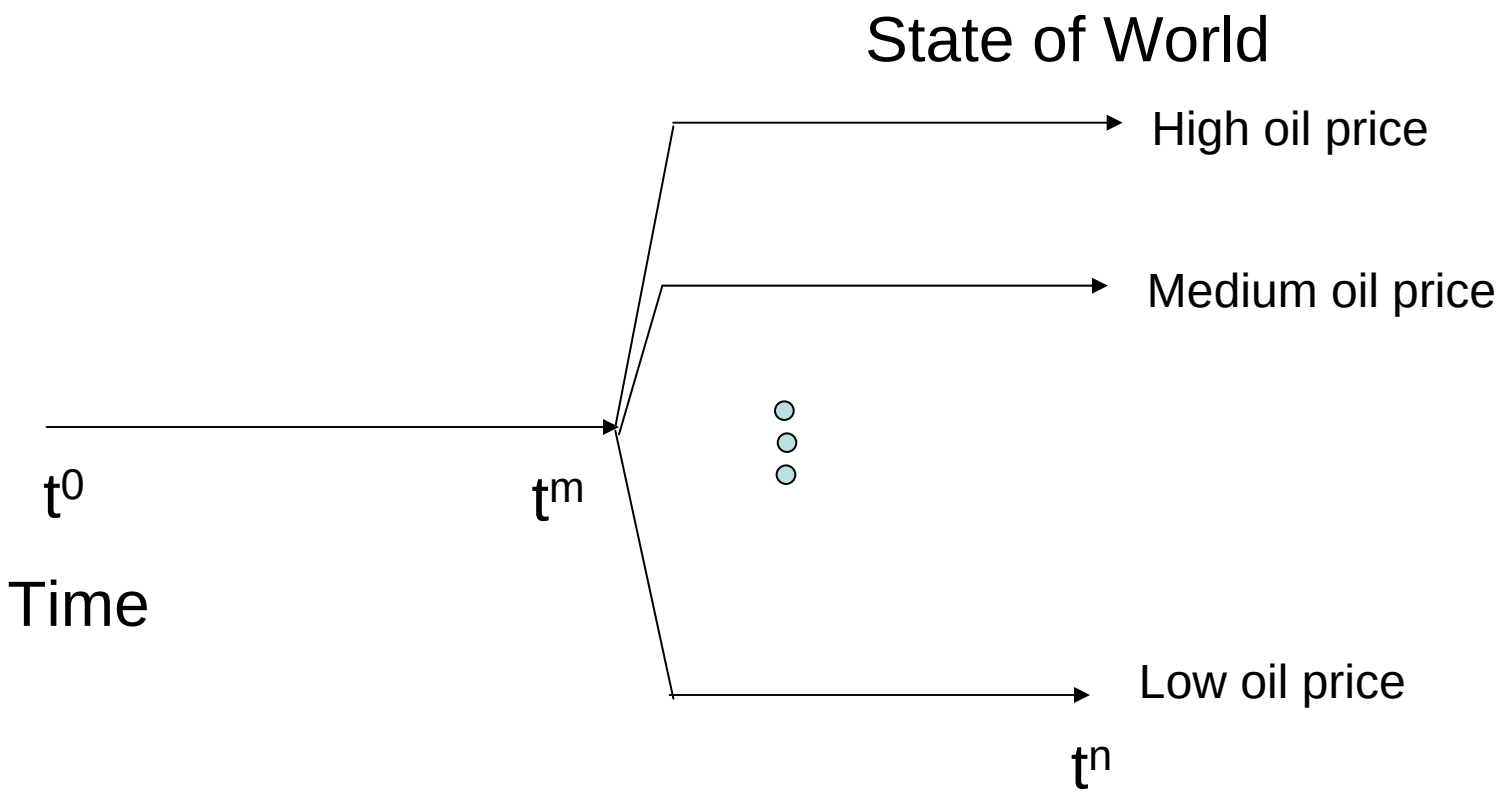
Decision-Making Under Uncertainty



MARKAL can find the optimal solution for each path and the optimal solution through t^m for all paths

Illustrative Graphic

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