Generation and Analysis of Alternative Technology Scenarios Using MARKAL-MGA:

Application to the Transportation Sector

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International Energy Workshop, Paris, France, June 24th, 2004

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Presentation Outline

- Context
  - US EPA's Global Change Air Quality Assessment
- MARKAL and Simulation
  - Simulation versus Optimization
  - Can MARKAL be used for simulation?
- Modeling to Generate Alternatives (MGA)
  - Theory
  - Initial application to the transportation sector
- Critique of MGA & MARKAL
- Next steps

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Global Change Air Quality Assessment

Primary Assessment Goal

For 2050, explore the relationships among:

- Meteorological change
- Land use change
- Technology change
- Economic growth
- Emissions growth
- *Air quality*

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Global Change Air Quality Assessment

Evolving Secondary Assessment Goals

- Advance the state-of-the-art in USEPA air quality modeling of future scenarios
  - Harmonize assumptions
  - Improve growth forecasts
  - Facilitate QA & uncertainty analysis
- Develop an integrated modeling framework that can be distributed to internal and external clients

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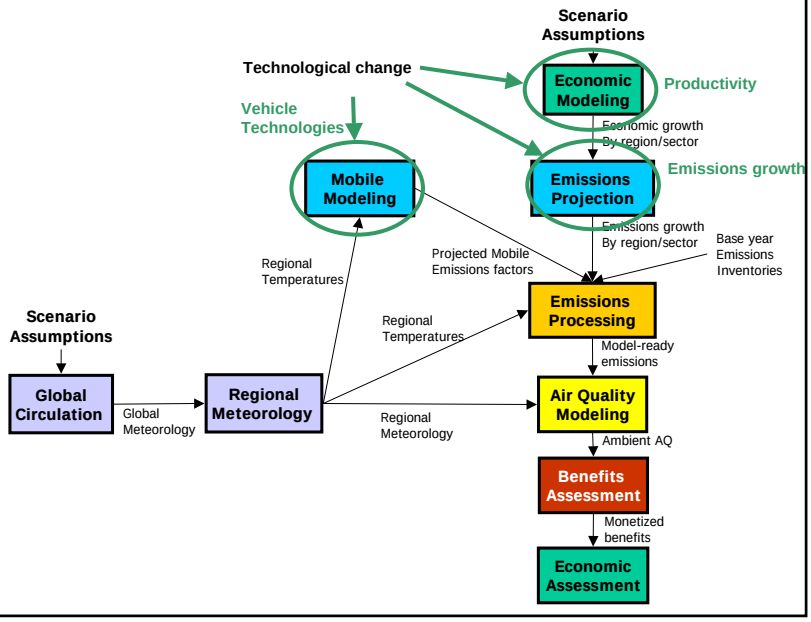
Global Change Air Quality Assessment



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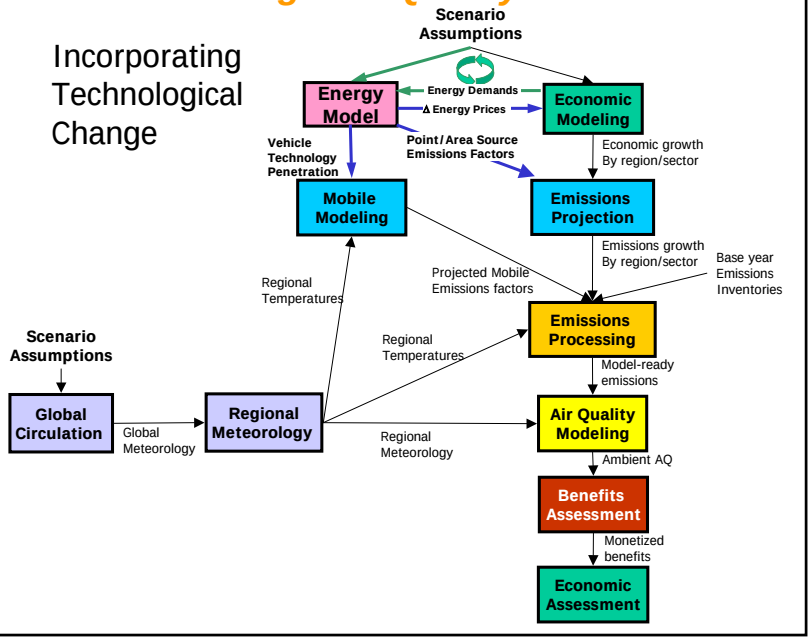
Incorporating Technological Change



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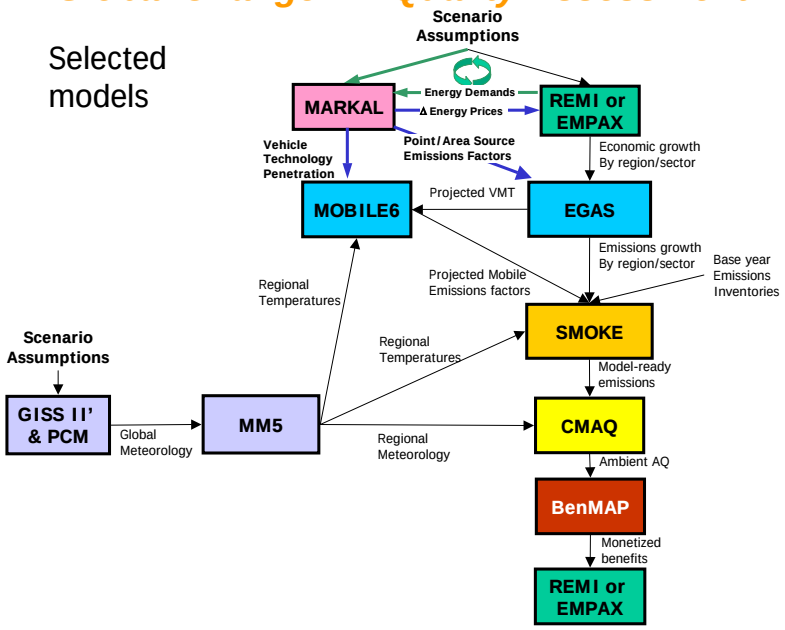
Global Change Air Quality Assessment

Selected models



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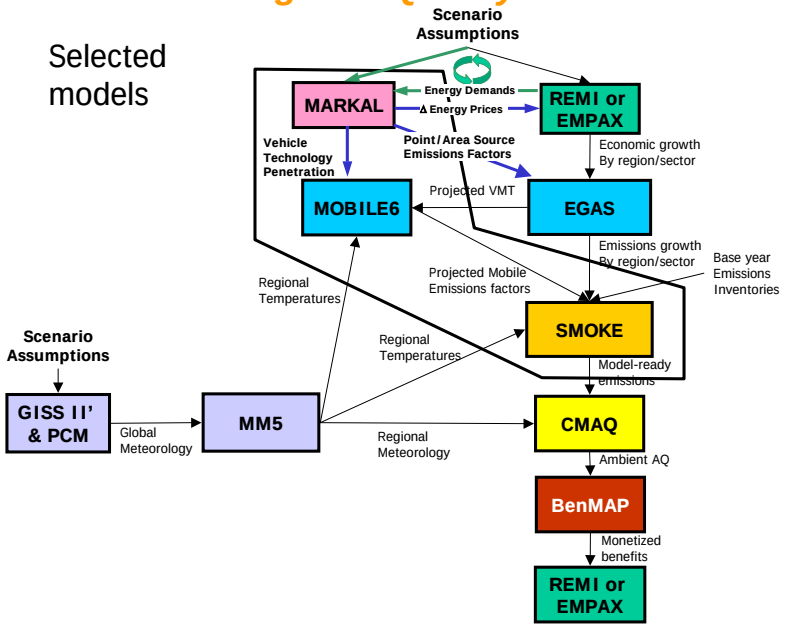

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Potential Roles of Technological Modeling

Simulation: How will things turn out?

- What set of technologies are expected to be adopted, given various policies and the respective cost-effectiveness of technology options?

Optimization: What should I do?

- What set of technologies most cost-effectively meets energy demands and emissions constraints?
- What policy options most cost-effectively meet energy demands and emissions constraints?

Q: MARKAL is an optimization model. Can it be used for simulation?

A: Yes, but carefully.

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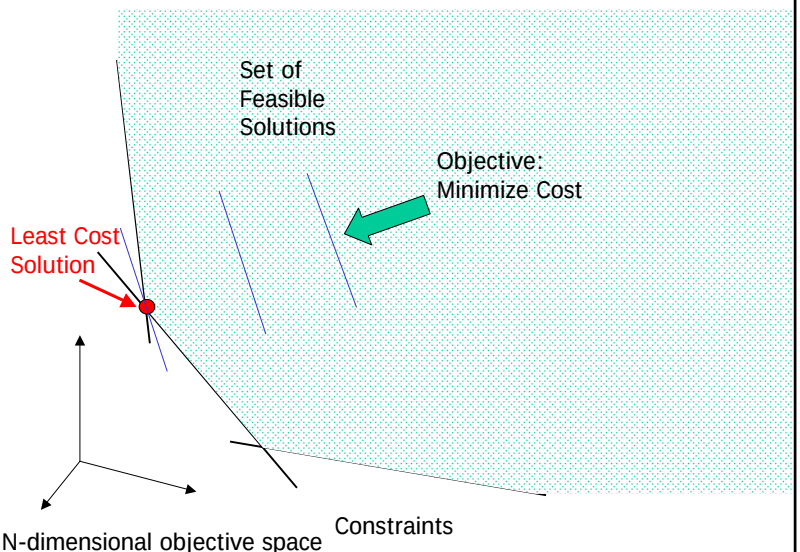
Least Cost Optimization



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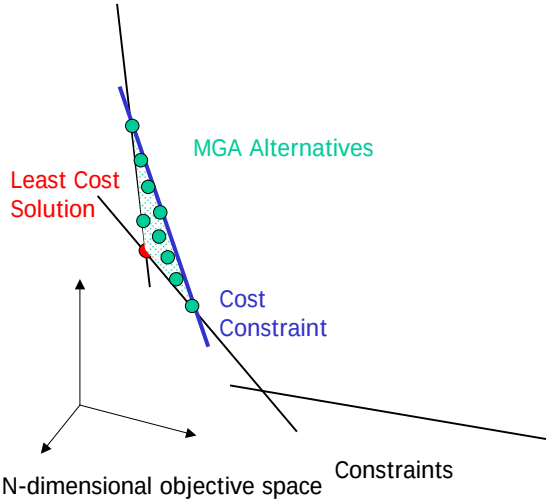
Modeling to Generate Alternatives (MGA)



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MGA Implementation

- Solve the LC formulation
- Set total system cost <= (1 + δ) * LC
- Set the objective to maximize some metric of distance from the LC solution
  - For example, minimize the occurrence of all technologies from the LC solution
- Generate MGA alternative 1
- Repeat iterative, each time maximizing the difference from the LC & all previous MGA solutions
- Terminate when a target number of MGA solutions have been reached or where difference is small

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Illustrative Example Application

- Examining US personal automobile technology penetration through 2030
- Considering:
  - Conventional vehicles
  - Advanced gasoline-fueled internal combustion engines
  - Advanced diesel engines
  - Hybrid vehicles
  - Advanced hybrid vehicles
  - Hydrogen fuel cell vehicles

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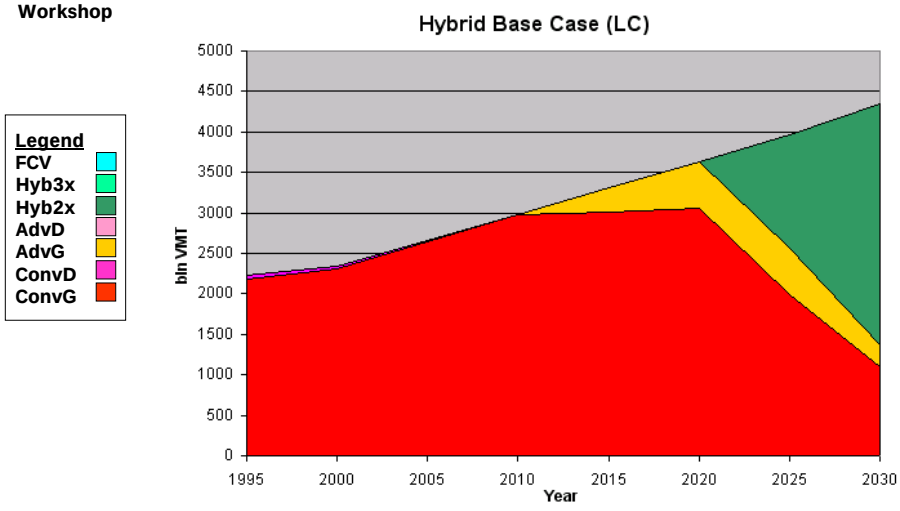
Least Cost Solution



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Note: These are illustrative results only.

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Application of MGA

- Set total system cost <= 1.01 * LC
- Maximize difference in:
  - Personal vehicle transportation technologies capacity
  - Hydrogen generation infrastructure
- Generate LC and 25 alternatives

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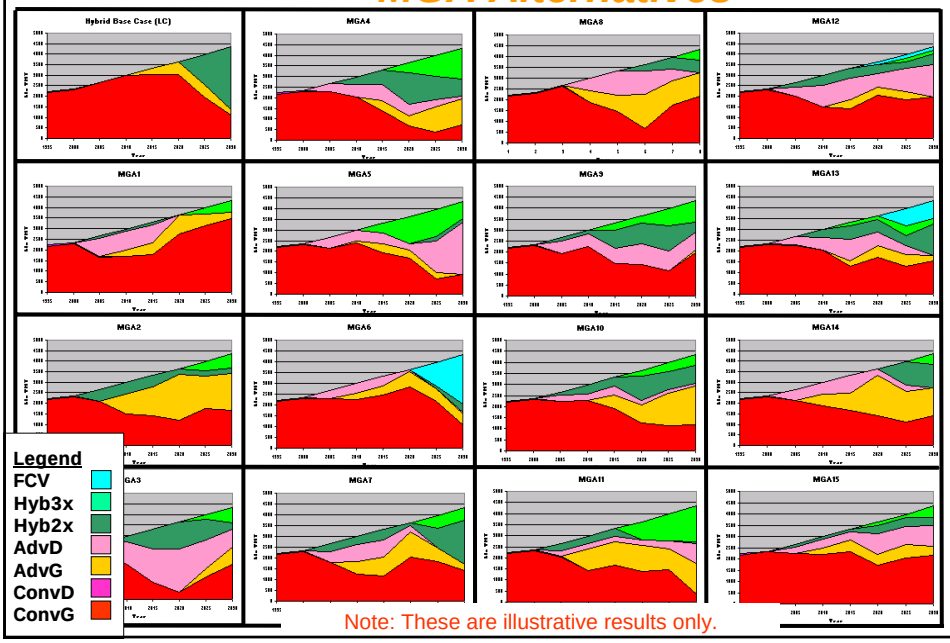
MGA Alternatives



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MGA Alternatives

Fuel Cell Vehicle (FCV) Penetration

- Fraction of scenarios with FCV penetration: 23%
- When FCV penetration occurred:
  - Maximum: 53%
  - Minimum: 1%
  - Average: 16%
  - Std. Dev: 19%
- Generation of Hydrogen
  - Primarily centralized generation
  - Wide range of possible technologies (e.g., SMR, CG, with and without carbon sequestration)
  - Typically comes online in 2025 or 2030

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Other Potential Applications

- Alternative pathways to achieve a target FCV penetration level
- Alternative trading outcomes in an emissions trading program
- Uncertainty analysis

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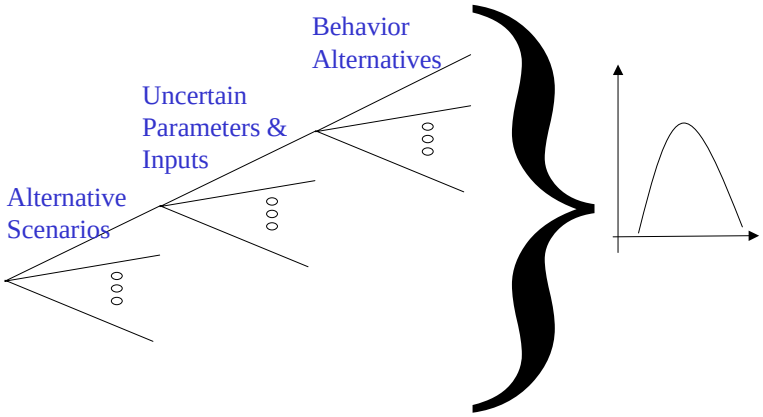
MGA in Uncertainty Analysis

Realizations of consumer & corporate behavior



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Critique of Experience

Advantages

- Easily integrated into MARKAL
- Readily applied
- Interesting results

Challenges and Issues

- What should cost relaxation be?
- How should results be interpreted?
- Is 'expected value' result meaningful?
- What are appropriate distance metrics?
- With overall cost relaxation, small players can behave oddly

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Next Steps

- Add sector-level cost constraints
- Application and testing
- Explore questions on previous slide

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