MAVRIC: Modeling Analysis, Verification, Regulatory and International Compliance

Modeling to Support Policy Analysis
What do energy-economic-environmental models and cross-comparison of models tell us about the future of energy system that include transportation?

Key Research Questions:

• What do existing models at the California, U.S. and international levels tell us about different possible energy and transportation futures and the paths to those futures?

• How have the forecasts and models of market adoption of new vehicle and fuel technologies developed during the STEPS 2007–2010 and NextSTEPS 2011–2014 programs performed relative to their actual market penetration? What lessons can be learned and applied to improve our future models and forecasts?

• How do model projections and scenarios compare and what can we learn from each?

• How can a wide range of diverse and divergent scenarios/modeling outcomes be used to help inform decision-making and policy design in the face of significant uncertainty? Are there robust strategies that we can identify?

• What assumptions are being made and which ones matter most? What metrics of change over time are required to assess the comparative likelihood of alternative energy pathways, including one dominated by shale oil and gas, meeting sustainability goals and timelines?

• How can we improve our own scenario making and use our own models in a better fashion to help us assess policies?
## STEPS 2015 Projects: MAVRIC - Modeling, Analysis, Verification, and Regional and International Comparisons

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Models

• California
  – CA-TIMES: Energy System Model for California
• Global
  – GCAM: Global Change Assessment Model
  – MoMo: Global Transport Energy Model (IEA)
  – Global Oil Model and Global Gas Model
• Transition model
  – GBSM: Geospatial Biorefinery Siting
  – Natural Gas Infrastructure model
  – Hydrogen station siting and rollout models
  – EV charger siting & rollout models
  – CCS system model
  – COCHIN-TIMES (COConsumer CHoice INtegration in TIMES)
• Environment and sustainability
  – LEM: Life cycle emissions models
  – AVCEM: Advanced Vehicle Cost & Energy Use Model
  – Water, land, materials & energy modeling
• Modeling Comparison
  – CCPM: CA Climate Policy Modeling dialogue project (December 2013, March 2015)
  – iTEM: International Transport/Energy Model Comparison Project (December 2014)
Highlights

• Climate policies in California and the role of academic modeling efforts in supporting policy analysis
  – California Climate Policy Modeling Dialogue
  – California energy system model: CA-TIMES
  – Adapting Consumer Choice Modeling to analyze non-regulatory policies

• Uncertainty Analysis and Robust Decision Making
Since 2007, California gov has started a series of legislations/regulations to mitigate GHG emissions
Governor’s 2030 Climate Goals

• If we have any chance at all of achieving reductions needed to limit global warming to 2 degrees by 2050 “California must show the way”

• 2030 goals
  – Increase to 50% electricity derived from electricity
  – Reduce petroleum use in cars & trucks by up to 50%
  – Double energy efficiency achieved at existing buildings & make heat fuels cleaner

Source: CCPM (March 2015)
Business As Usual (BAU) Scenarios
CCPM1 (December 2013)

Annual GHG Emissions (MMT CO2e/yr)

Historic
CCST
ARB Scoping Plan, 2008
PATHWAYS
BEAR
LEAP/SWITCH
CA-TIMES
CALGAPS
ARB Scoping Plan, 2014
80% Reduction

All Models in CCPM2 (2015)

2000 2010 2020 2030 2040 2050
Annual vs. Cumulative Emissions?
(December 2013)

Annual Emissions = Economy-wide emissions each year (e.g. all emissions in 2010)
Cumulative Emissions = The sum of annual emissions since the year 2010
(e.g. emissions in 2010 + emissions in 2011 +... emissions in year X)

interim target is important to drive early actions to lower cumulative emissions (and achieve learning & scale)
Observations from first CCPM forum
(December 2013)

• Future modeling efforts should focus on the:
  – economic impacts and logistical feasibility of given scenarios,
  – interactive effects between two or more climate policies,
  – role of uncertainty in the state’s long-term energy planning, and
  – identification of pathways that achieve the dual goals of criteria pollutant and GHG emission reduction.

• Modelers need to work with policy makers more closely to represent the details of the policy design

• Data availability and data/model transparency is absolutely essential.

• Identifying ways to make the models and model findings more useful and accessible to policy-makers and stakeholders.
Key Observations: CCPM2
(March 2015)

• More models show **cost impacts: $/HH, $/kWh**
• More discussion about **jobs and heterogeneity of impacts**
• **Forks in the road:** Studies illustrate major paradigm shifts necessary for 2050 goals
  – Massive expansion of biogas production/use
  – OR large scale electrification of vehicles as well as industrial and home heat usages
  – Each fork will eventually requires irreversible investments by *someone*.
• Are these really forks at the state policy level?
  – Individuals must choose, but don’t all have to make same choice
  – Can’t there be a mix of electric heating and biogas?

**INDUSTRIES WANT MAXIMUM FLEXIBILITY!**
The Big Gap between Scenario Analysis and Consumer Preferences

**PATHWAYS:** If we do everything technically feasible...

6-7 million ZEVs and PHEVs on the road by 2030

**CA-TIMES:** If we need to meet the policy objective, the least cost pathway is....

2.4 million vehicles (~1.1M BEV/PHEV, 1.3MFCV) in 2030

**CGEs:** If we achieve climate policy goals, what would be the direct and indirect economic impacts...

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**UC DAVIS INSTITUTE OF TRANSPORTATION STUDIES**
Overview of Model Approach

- Energy Systems Models
  - Technology rich on the supply side, but lack behavioral details
- Consumer Choice Models
  - Detail choices on the demand side but lack supply sector details
- Our focus: ‘Marrying’ these two types of models

\[ \text{Supply-rich} \quad \text{Consumer Choice Model} \quad \text{Demand-rich} \]
\[ \text{Supply-rich} \quad \text{TIMES model} \quad \text{Minimal behavior rep.} \]
\[ \text{Supply-rich} \quad \text{COCHIN-TIMES} \quad \text{Demand-rich} \]

COCHIN: COnsumer CChoice INtegration
Motivation for Consumer Choice

• System-engineering models typically assume society is homogenous, i.e. there is only one decision-maker at the societal level
• Consumer behavior cannot be ignored in system-wide modeling!
• One objective of this project is to develop a bridging approach to bring in consumer behavioral parameters, to the linear programming framework of TIMES
Consumers make decisions based on monetary costs, such as vehicle price, fuel cost, as well as the ‘disutility’ costs, such as their perception of a technology on various issues, and the infrastructure support available.
Components of Disutility Cost in the year 2020

- Model Availability Cost
- Risk Premium
- Refueling Inconvenience Cost
- Charger Refueler Cost
- Towing Cost
- Range Anxiety Cost

Urban Early Adopter
Moderate driver

Rural Late Majority
Frequent driver
CA-TIMES Model Improvements (2015)

Reviewing and updating model input assumptions

Enhancing and improving model output capabilities

Mitigation Options
Cost Effectiveness

Interactive Effects of Policies

Demand Response

Uncertainty Analysis

Together, Building a Better California

Heterogeneity and consumer choice in transportation

Parameter uncertainty (Monte Carlo simulations)

Technology forcing policies (learning-by-doing)

Electricity demand response for load shaping and peak reduction

Water demand/supply technology

Energy supply and delivery (storage)
Model infrastructure for Addressing Uncertainty

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STEPS Spring Symposium
May 13, 2015
“Failure to engage in systematic sensitivity and uncertainty analysis leaves both analysts and users unable to judge the adequacy of the analysis, and the conclusions reached.”

Morgan & Henrion (1990)

“Deterministic point estimates sometimes enjoy a precise and/or accurate appearance, and inspire a misleading sense of confidence.”

(Cullen & Frey p. 7)
BACKGROUND: MONTE CARLO SIMULATION

- Describe input parameters using probability distributions
- Run model numerous times and save results
- For each run, values are selected from each input distribution
- Accumulated outputs describe a frequency distribution

Figure: JGCM 101:2008
WHY NOT UNCERTAINTY ANALYSIS?

Barriers to addressing uncertainty

1. Limited technical know-how
2. Increased complexity
3. Long run-times preclude Monte Carlo analysis
4. Unknown parameter distributions
5. Scenario uncertainty dominates parametric uncertainty
APPROACHES TO ADDRESSING UNCERTAINTY

Monte Carlo Simulation

- Variability
  - Heterogeneity across time, space, or individuals

- Lack of knowledge
  - Parameter Uncertainty
    - Measurement error
      - Unpredictability
      - Conflicting data
      - Extrapolation error
      - Insufficient data
  - Model Uncertainty
    - Structural choices
      - Simplification
      - Incompleteness
      - Choice of distributions
    - Correlations and dependencies
    - System resolution

Non-stochastic methods

- Decision Uncertainty
  - Choice of metric
    - Discount rate
    - Risk tolerance
    - Utility functions
  - Distributional considerations
  - Scope of analysis
  - Timeframe
  - Scenarios chosen
Features in common with MCS

- Generate input parameters
- Run on computing cluster
- Collect results into database
- Analyze results

Additional requirements

- Non-probabilistic methods
- PRIM or similar analysis
- Visualization features
ROBUST DECISION-MAKING

- Addresses “deep” uncertainties
  - Disagreement about model form, probabilities, value-based judgments
- Focus is robustness rather than optimization or prediction
- Model is used to explore the parameter space
ROBUST DECISION-MAKING: “XLRM” Framework

Uncertain Factors (X)
- Well-defined distributions
- Deep uncertainties

Policy Levers (L)
- Actions that modify the system
- Potential strategies to explore

Model relationships (R)
- Links among Xs, Ls, and Ms
- Model equations

Performance metrics (M)
- Gauge policy performance
- Single or multiple-attribute

Alternative Futures → Strategies

Iterate
Strategies that might be compared in RDM:

- Treatment of biofuels
  - Indirect effects
  - Risk penalty for fuel with uncertain GHG effects
  - Feedstock restrictions (waste and residues only)
- Sectoral or economy-wide (e.g., C tax, cap & trade)
- Foresight about ramping cost or targets
  - Address path dependence
- Encourage faster behavioral change
- Emphasize RD&D of zero-carbon solutions
GLOBAL CHANGE ANALYSIS MODEL (GCAM)

- Long Term Shifts in Life Cycle Energy Efficiency and Carbon Intensity Mitigating
- Climate Change: **Decomposing** the Relative Roles of Energy Conservation, Technological Change and Structural Shift
- **Transportation** forecasts in various scenarios from IPCC’s SSPs and RCPs (Representative Concentration Pathways or Target Climate Goals)
- International Transportation Modeling Comparison (**ITEM**)