Applications of MARKAL to Economic Impact Analyses

Julia Gamas, U.S. EPA Office of Air Quality Planning and Standards
Dan Loughlin, U.S. EPA Office of Research and Development

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Objective:

Show planned MARKAL applications to Economic Impact Analyses in ABCG and elicit your comments, suggestions and ideas.

Outline:

I. Background

II. MARKAL stand-alone applications

III. MARKAL used with other models

I. Background

Who is ABCG and why does it need MARKAL?

U.S EPA
(Protects the environment)

→ Office of Research & Development
(Science to support policy → **Develop MARKAL database**)

→ Office of Air and Radiation
(Establish goals and policies for air quality and strategies to achieve them)

→ Office of Air Quality Planning and Standards
(Protects air quality)

→ Health and Environmental Impacts Division
(Health, ecological and economic impacts of HAPs and CAPs; Sets NAAQS - CAA)

→ Air Benefit & Cost Group
(Conducts Economic Impact Analyses (**Regulatory Impact Analyses**) of AQ standards)

Why use MARKAL in RIAs?

- high level of technological detail and representation of large sources of criteria and greenhouse gas emissions

Economic models alone do not capture emissions or technological detail. Air quality models alone do not capture economic behavior.

- ability to capture sectoral and cross-sector interactions

Single energy sector models cannot do this. Multi-sector models are too aggregated.

- ability to conduct multipollutant analyses

Is important given Climate Change and given a push to conduct multipollutant SIPs. Potential to find strategies that address more than one pollutant reduction at lower cost than several strategies targeted at a single pollutant individually.

II. Stand-Alone Applications

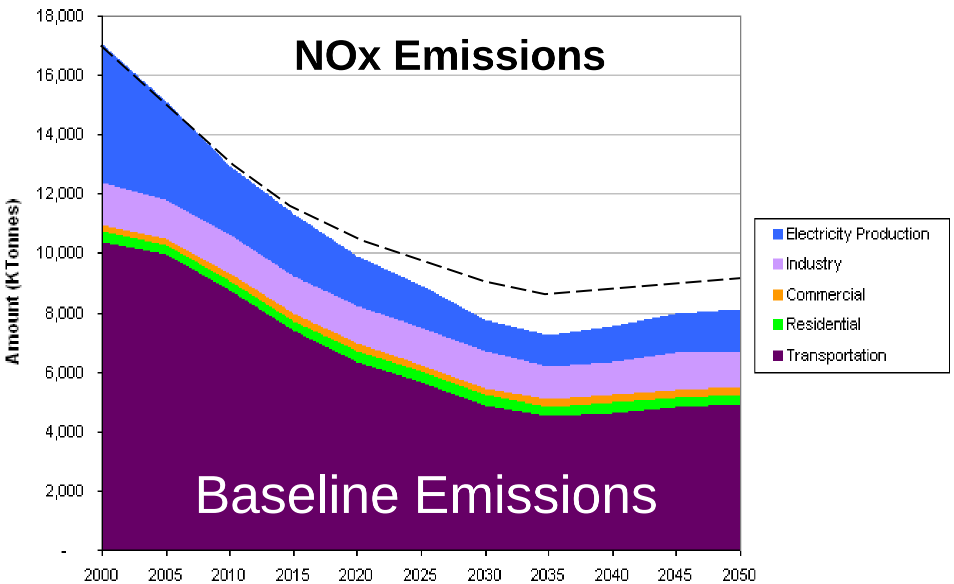
Stand-alone applications include using MARKAL scenarios to:

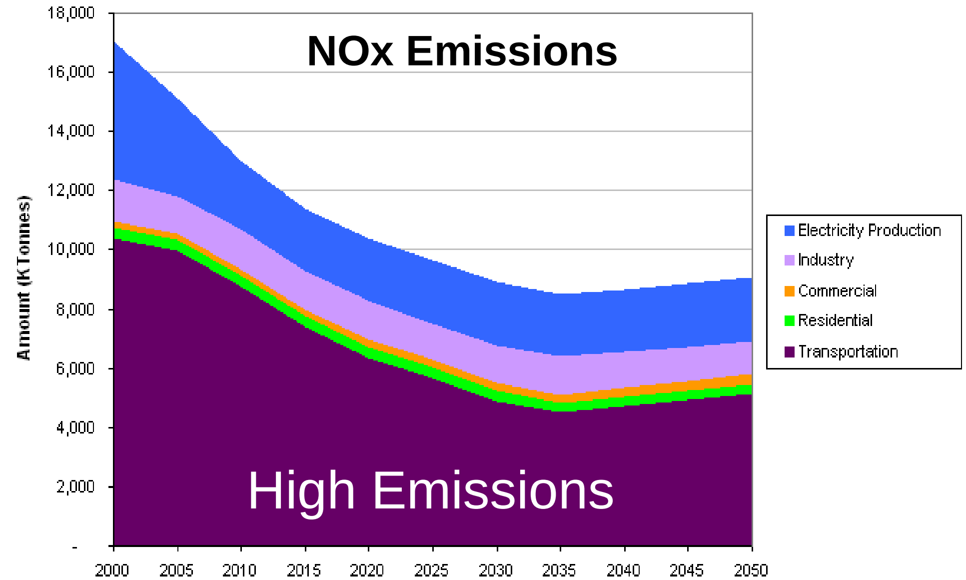
- **bound** the economic impacts RIAs
- **screening tool** to identify key influential parameters and assumptions under different future scenarios,

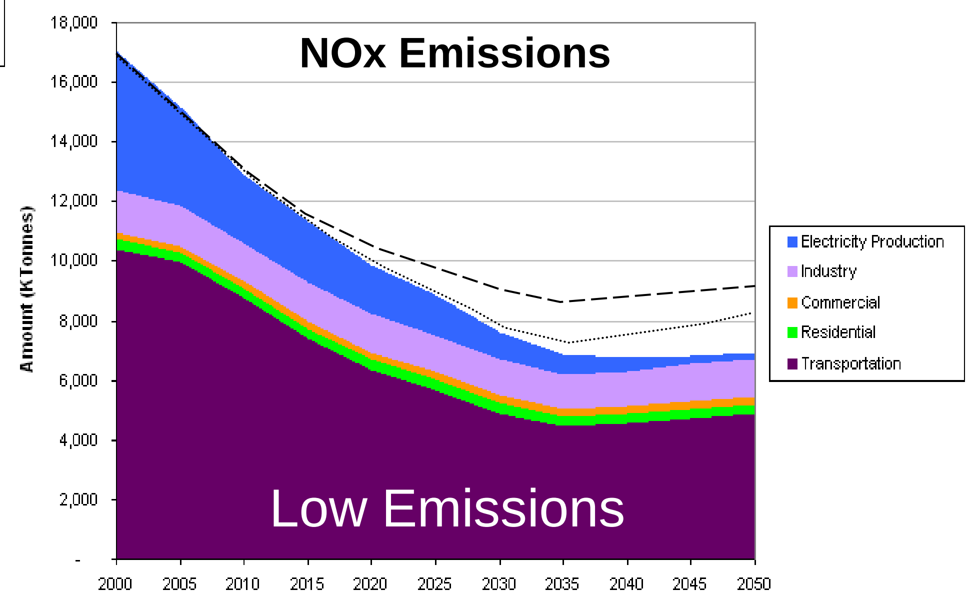
Bounding RIA Results

	MARKAL Results	ABCG Analysis for RIA
Scenario 1	High Emissions	Higher health impacts of emissions and benefit from emissions reduction. Higher costs of achieving emissions reductions.
Scenario 2	Baseline Emissions	Baseline costs and benefits.
Scenario 3	Low Emissions	Lower health impacts of emissions and benefit from emissions reduction. Lower costs of achieving emissions reductions.

Example of bounding scenarios







MARKAL as a Screening Tool

- There is considerable uncertainty about many of the factors identified as potentially affecting the ability to achieve emissions reduction goals

- Each could be examined individually, but their interactions are perhaps more important

- Approach:
  - use MARKAL within a nested parametric analysis, examining all combinations of discrete values for the critical factors.
  - analyze the results using tools such as pivot tables, visualization, and data-mining to identify key insights

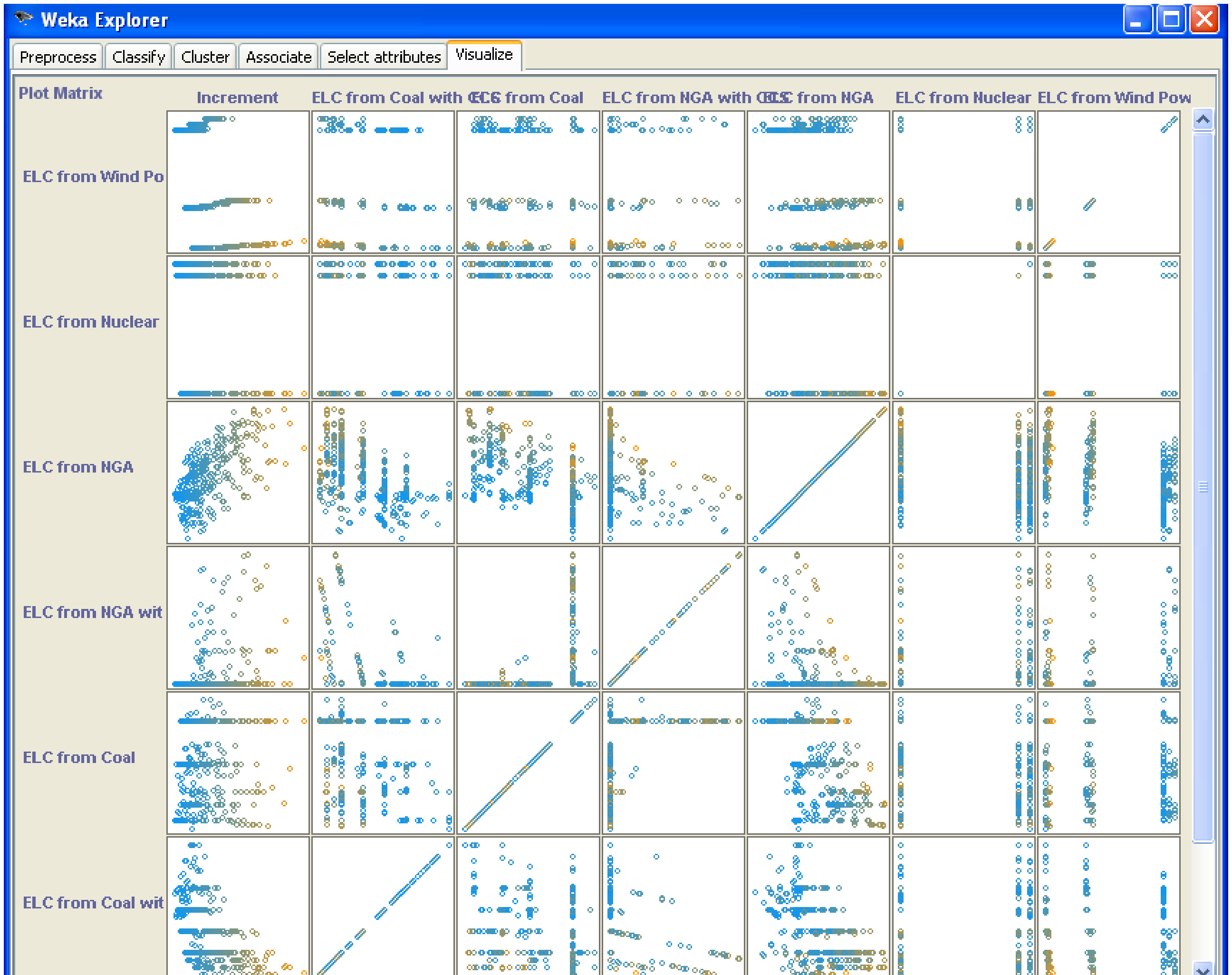
- Insights are obtained from analyzing the entire set of results
  - Important interactions
  - Co-benefits
  - Unintended consequences
- Scenarios are screened and interesting ones selected for further investigation
- Status: ORD has been exploring this type of analysis and will be presenting on their ongoing parametric analysis tomorrow

Example of Nested Runs

- Nuclear Capacity (Base+100%, Base, Base-50%)
  - Renewables Capacity (Base+100%, Base, Base-50%)
    - CCS Availability (2020, 2025, 2030)
      - CCS Growth Rate (High, Moderate, Low)
        - Policy Option (1, 2, 3, 4, 5)

Total Runs: 405
Runtime: 8 hours

Example Results



Tradeoffs between electricity production technologies.

Points colored by cost.

III. MARKAL Used with Other Models

- with Applied Dynamic Analysis of the Global Economy (**ADAGE**) and air quality modeling for carbon cap scenario representation.
- with the Control Strategy Tool (**CoST**)
- with Economic Model for Environmental Policy Analysis (**EMPAX**) computable general equilibrium model and the **Multi-Market Model**.

Analysis of Impacts of Climate Policy Using ADAGE and MARKAL

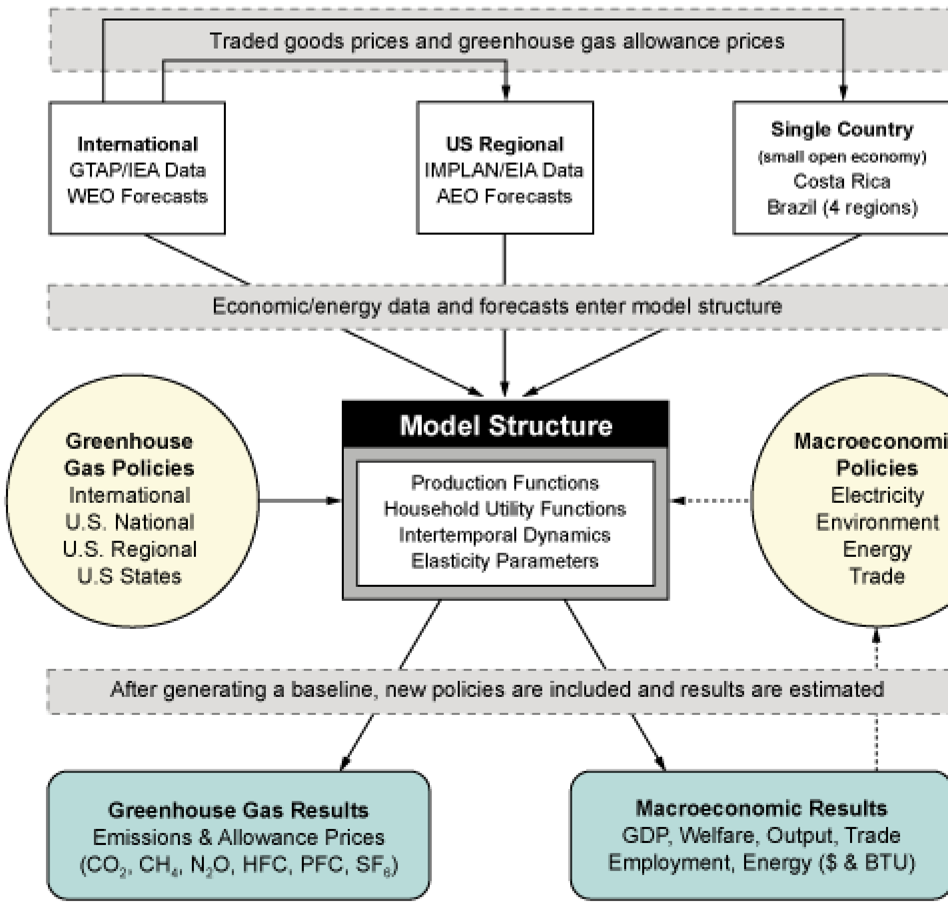
ADAGE is a dynamic computable general equilibrium (CGE) economic model:

• dynamic effects of many types of policies: economic, energy, environment, climate change mitigation (carbon pricing), trade

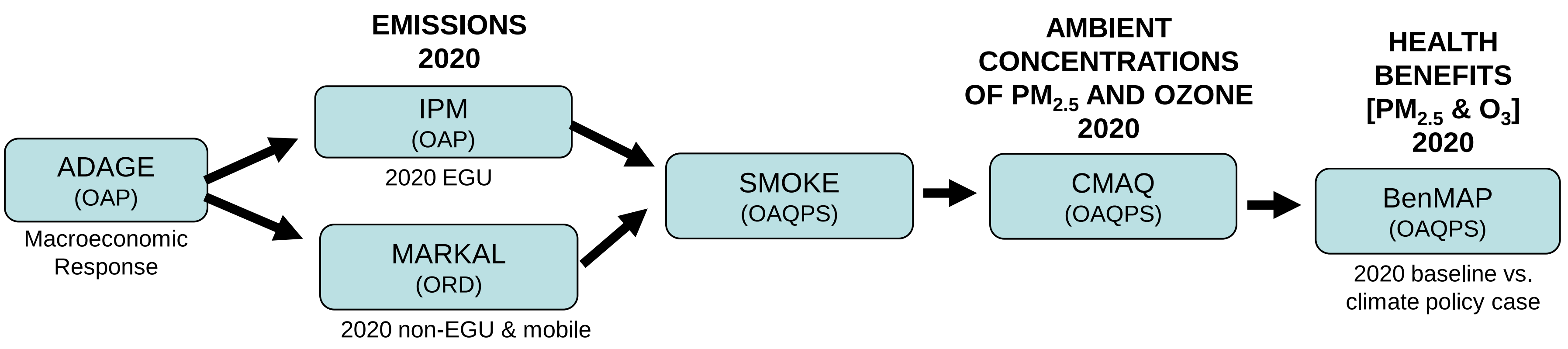
• consistent theoretical structure with economic data covering all interactions among businesses and households.

• includes International, US Regional, and Single Country modules: allows for detailed regional and state-level results that incorporate international impacts of policies.

ADAGE Integrated Model Structure



- Analyze air quality implications of illustrative climate policy, using nested set of economic and air quality models
  - For the year 2020, estimate (for example):
    - Changes in NOx, SO2, PM_{10} & $PM_{2.5}$ emissions by sector (mobile, EGU, industrial) and by region
    - Resulting changes in ambient ozone and $PM_{2.5}$
    - Associated monetized health benefits & control costs



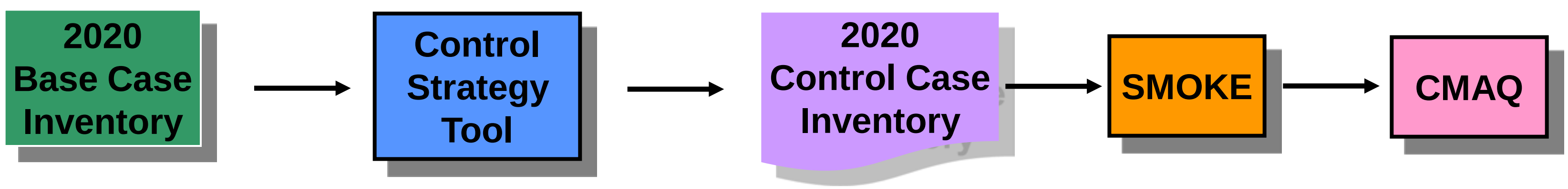
MARKAL and CoST

What is CoST?

CoST (Control Strategy Tool) is a model developed by the ABCG to for the assessment of emissions reductions and engineering costs for control strategies.

What does CoST do?

- Supports preparation and analysis of future year emission control strategies for point, area, and mobile sources



- Reports on the emissions reductions and costs associated with control strategies for:
  - the **target pollutant** (e.g., NOx or VOC for Ozone NAAQS Analyses)
  - **co-impacts** on other criteria pollutants

What questions are we trying to answer with CoST?

- Example Goal: reduce NOx emissions in 2020 for the Southeast by 100,000 tons/yr
- Use CoST to answer control questions for criteria air pollutants (CAPs) like:
  - What is the **maximum emissions reduction** achievable for NOx and what set of controls will achieve this reduction? (i.e., is my goal < maximum?)
  - What set of control measures can achieve the emissions reduction goal at the **least cost**?
  - What does the **cost curve** look like for other levels of reduction? Could also use COST to characterize the costs of criteria and greenhouse gas control technologies (or mitigation cost curves) for input into MARKAL.

- What **emission reductions** for the target pollutant would be achieved?
- What are the emission reductions **or increases** for **other pollutants** of interest?
- What are the **engineering costs** of applying the controls for a specific strategy?
- What **control measures** are available for specific source categories and pollutants; how much reduction do they provide and for what cost?
- Future goal: What is the optimum method for achieving simultaneous reductions of **multiple pollutants** (e.g., PM and toxics)? – target multiple pollutants simultaneously

Challenge # 1: Data exchange between models:

MARKAL

Emissions inventory for future scenario and year

MARKAL technology => SCC

CoST

Cost of applying strategies to reduce emissions to a given level in that future scenario and year

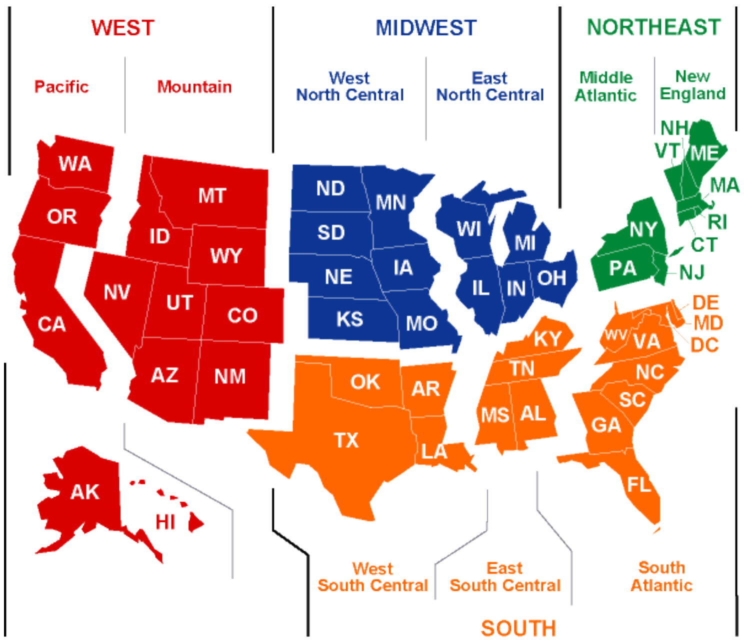
MARKAL_Tech	MARKAL_Description	Matching_SCC_Code	DATA_Category	SCC_L1	SCC_L2	SCC_L3	SCC_L4
PCOADSU	Coal to Liquids (Existing)	20100301	POINT	Internal Combus	Electric Generation	Gasified Coal	Turbine
PCOADSU30	Coal to Liquids (Future)	20100301	POINT	Internal Combus	Electric Generation	Process Gas	Reciprocating
PCOADSU	Coal to Liquids (Existing)	2306000000	NONPOINT	Industrial Proces	Petroleum Refining: SIC 29	All Processes	Total
PCOADSU30	Coal to Liquids (Future)	2306000000	NONPOINT	Industrial Proces	Petroleum Refining: SIC 29	All Processes	Total
PCOASNG30	Coal to Synthetic Natural Gas (Future)	20100301	POINT	Internal Combus	Electric Generation	Gasified Coal	Turbine
PCOASNGR	Coal to Synthetic Natural Gas (Existing)	20100301	POINT	Internal Combus	Electric Generation	Process Gas	Reciprocating
PCOADSU	Coal to Liquids (Existing)	20COALTOLIQUID	POINT	Fischer Trops - New Technology Not Classified Yet		All Processes	Total
PCOADSU30	Coal to Liquids (Future)	20COALTOLIQUID	POINT	Fischer Trops - New Technology Not Classified Yet		All Processes	Total
PCOADSU	Coal to Liquids (Existing)	20COALTOLIQUID	POINT	Fischer Trops - New Technology Not Classified Yet		All Processes	Total
PCOADSU30	Coal to Liquids (Future)	20COALTOLIQUID	POINT	Fischer Trops - New Technology Not Classified Yet		All Processes	Total
PCOASNG30	Coal to Synthetic Natural Gas (Future)	20COALTOLIQUID	POINT	Fischer Trops - New Technology Not Classified Yet		All Processes	Total
PCOASNGR	Coal to Synthetic Natural Gas (Existing)	20COALTOLIQUID	POINT	Fischer Trops - New Technology Not Classified Yet		All Processes	Total
PREFE	Refinery - Existing Conversion	2306000000	NONPOINT	Industrial Proces	Petroleum Refining: SIC 29	All Processes	Total
PREFE	Refinery - Existing Conversion	2306010000	NONPOINT	Industrial Proces	Petroleum Refining: SIC 29	Asphalt Paving/Roofing Materials	Total
PREFE	Refinery - Existing Conversion	30600901	POINT	Industrial Proces	Petroleum Industry	Flares	Distillate Oil
PREFE	Refinery - Existing Conversion	30600902	POINT	Industrial Proces	Petroleum Industry	Flares	Residual Oil
PREFE	Refinery - Existing Conversion	30600903	POINT	Industrial Proces	Petroleum Industry	Flares	Natural Gas
PREFE	Refinery - Existing Conversion	30600904	POINT	Industrial Proces	Petroleum Industry	Flares	Process Gas
PREFE	Refinery - Existing Conversion	30600905	POINT	Industrial Proces	Petroleum Industry	Flares	Liquified Petroleum Gas
PREFE	Refinery - Existing Conversion	30600906	POINT	Industrial Proces	Petroleum Industry	Flares	Hydrogen Sulfide
PREFE	Refinery - Existing Conversion	30600999	POINT	Industrial Proces	Petroleum Industry	Flares	Not Classified **
PREFN	Refinery - New Conversion	2306000000	NONPOINT	Industrial Proces	Petroleum Refining: SIC 29	All Processes	Total
PREFN	Refinery - New Conversion	2306010000	NONPOINT	Industrial Proces	Petroleum Refining: SIC 29	Asphalt Paving/Roofing Materials	Total
PREFN	Refinery - New Conversion	30600901	POINT	Industrial Proces	Petroleum Industry	Process Heaters	Oil-fired **
PREFN	Refinery - New Conversion	30600902	POINT	Industrial Proces	Petroleum Industry	Process Heaters	Gas-fired **
PREFN	Refinery - New Conversion	30600903	POINT	Industrial Proces	Petroleum Industry	Process Heaters	Oil-fired
PREFN	Refinery - New Conversion	30600904	POINT	Industrial Proces	Petroleum Industry	Process Heaters	Gas-fired
PREFN	Refinery - New Conversion	30600905	POINT	Industrial Proces	Petroleum Industry	Process Heaters	Natural Gas-fired
PREFN	Refinery - New Conversion	30600906	POINT	Industrial Proces	Petroleum Industry	Process Heaters	Process Gas-fired
PREFN	Refinery - New Conversion	30600999	POINT	Industrial Proces	Petroleum Industry	Flares	Not Classified **
SEBAGR	CO2 Uptake for Agricultural Production	28CO2UPTAKEAGR	NONPOINT	Agriculture Prod	Agriculture Production-Crops	CO2 Uptake from growth	Unspecified
SEBCRN	CO2 Uptake for Corn Production	28CO2UPTAKEAGR	NONPOINT	Agriculture Prod	Agriculture Production-Crops	CO2 Uptake from growth	NATURAL (Native American Fire Use)
SEBECG	CO2 Uptake for ECG Production	28CO2UPTAKEAGR	NONPOINT	Agriculture Prod	Agriculture Production-Crops	CO2 Uptake from growth	ANTHROPOGENIC
SEBFSR	CO2 Uptake for FSR Production	28CO2UPTAKEAGR	NONPOINT	Agriculture Prod	Agriculture Production-Crops	CO2 Uptake from growth	Field Crops Unspecified
SEBFSR	CO2 Uptake for FSR Production	28CO2UPTAKEAGR	NONPOINT	Agriculture Prod	Agriculture Production-Crops	CO2 Uptake from growth	Field Crop is Alfalfa : Headfire Burning
SEBFSR	CO2 Uptake for FSR Production	28CO2UPTAKEAGR	NONPOINT	Agriculture Prod	Agriculture Production-Crops	CO2 Uptake from growth	Field Crop is Alfalfa: Backfire Burning
SEBPMR	CO2 Uptake for PMR Production	28CO2UPTAKEAGR	NONPOINT	Agriculture Prod	Agriculture Production-Crops	CO2 Uptake from growth	Field Crop is Asparagus: Burning Techniques Not Significant
SEBPMR	CO2 Uptake for PMR Production	28CO2UPTAKEAGR	NONPOINT	Agriculture Prod	Agriculture Production-Crops	CO2 Uptake from growth	Field Crop is Barley: Burning Techniques Not Significant
SEBPMR	CO2 Uptake for PMR Production	28CO2UPTAKEAGR	NONPOINT	Agriculture Prod	Agriculture Production-Crops	CO2 Uptake from growth	Field Crop is Bean (red): Headfire Burning
SEBSTMECG	ECG to Biomass for ELC STM -- CO2 and S	10101206	POINT	External Combu	Electric Generation	Solid Waste	Agricultural Byproducts (rice or peanut hulls, shells, cow manure, etc
SEBSTMFSR	FSR to Biomass for ELC STM -- CO2 and S	10100902	POINT	External Combu	Electric Generation	Wood/Bark Waste	Wood/Bark Fired Boiler
SEBSTMFSR	FSR to Biomass for ELC STM -- CO2 and S	10100903	POINT	External Combu	Electric Generation	Wood/Bark Waste	Wood-fired Boiler - Wet Wood (>=20% moisture)
SEBSTMFSR	FSR to Biomass for ELC STM -- CO2 and S	10100908	POINT	External Combu	Electric Generation	Wood/Bark Waste	Wood-fired Boiler - Dry Wood (<20% moisture)
SEBSTMFSR	FSR to Biomass for ELC STM -- CO2 and S	10101308	POINT	External Combu	Electric Generation	Liquid Waste	Wood/Wood Waste Liquid

New technologies without SCC codes

One MARKAL technology emissions allocation to many SCC codes

Challenge # 2: Geographic pairing between models:

MARKAL



National

9 Region (US Census Division)

State

County

Plant

Example of CoST Outputs: 45% NOx Reduction

MARKAL and EMPAX

EMPAX

- general equilibrium economic model
- dynamic
- provides national and regional-level outputs
- does not have international modules like ADAGE but has more sectors (35 vs. 10)
- may provide a better breakout of impacts on industries than ADAGE if policy other than cap and trade is being considered, due to greater sectoral detail

MARKAL and the Multi-market Model

- Partial Equilibrium, Single Period – Static economic model
- Industry specific detail for a large number of industries – exact number of sectors depends on ability to collect and/or estimate elasticities
- Output Produced:
  - Price and Quantity changes per industry
  - Employment changes can be estimated using output change and data on output per worker for sector
  - Estimates of regional impacts on sectors
- can link to ADAGE (to assess impacts of climate scenarios) and CoST for multi-pollutant analyses)

Question	EMPAX	M^3	Off the Shelf	Input-Output
Price and quantity changes	✓ Moderate Industry Detail	✓ More Industry Detail	✓ Industry-Specific Detail	✓ Most Industry Detail
Distribution of impacts across sectors and areas	✓ Moderate Detail	✓ More Detail		✓
Ripple effects	✓ Moderate Industry Detail	✓ More Industry Detail		✓
Employment impacts	✓ Broad Analysis	✓	✓	✓
Intermediate term impacts	✓	✓		
Short term impacts		✓	✓	✓
Effect on industry competitiveness		?		?
Impact on technological change and adoption across industries	Through linkages with MARKAL?	Through linkages with MARKAL?		
Can programs be designed that are mutually beneficial				
Models Cap & Trade				

Questions, Comments and Suggestions.

Contact:

Julia Gamas (919) 541-7915,
gamas.julia@epa.gov

Dan Loughlin (919) 541-3928,
loughlin.dan@epa.gov