



Use of MARKAL to Assist Regional Energy Decision-Making

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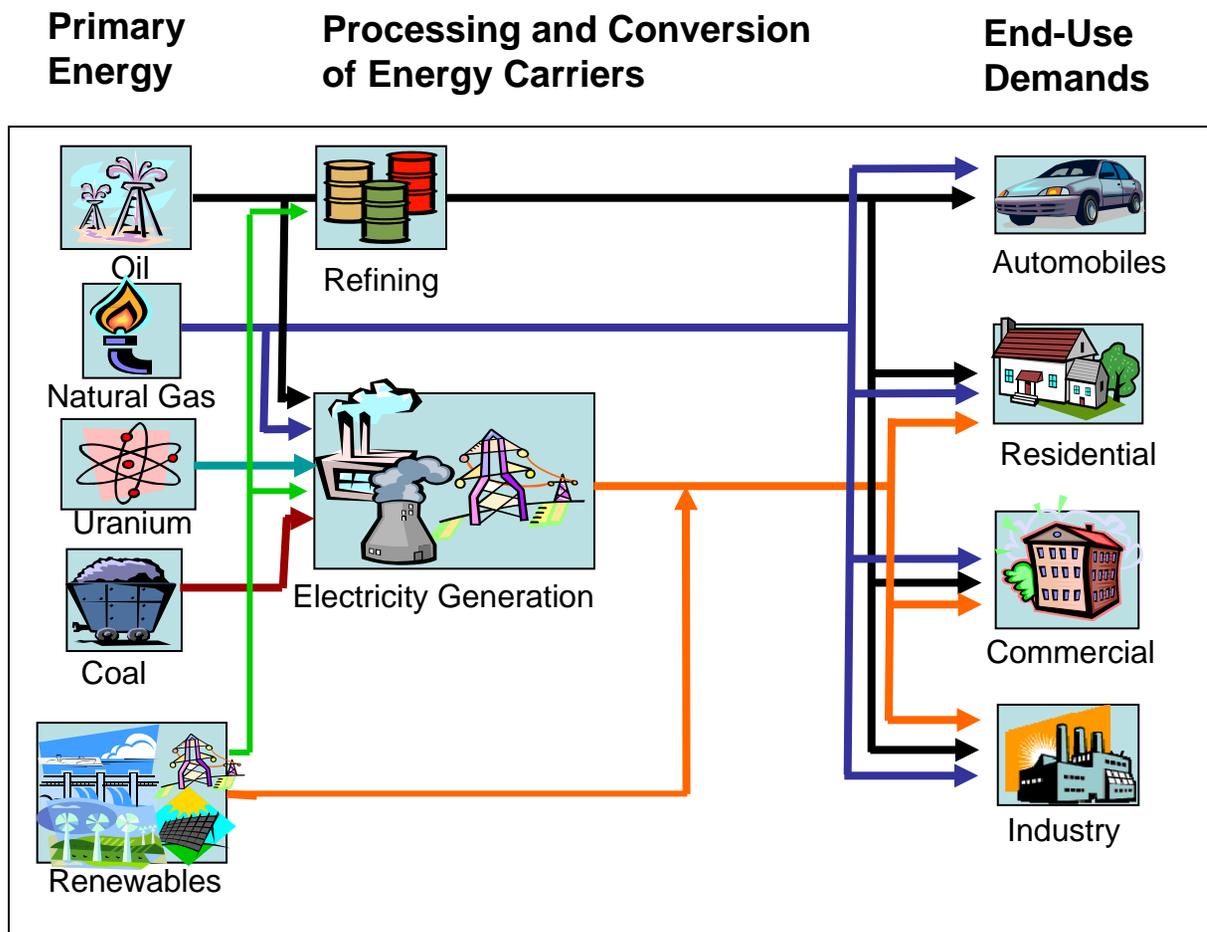
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Today's Energy System



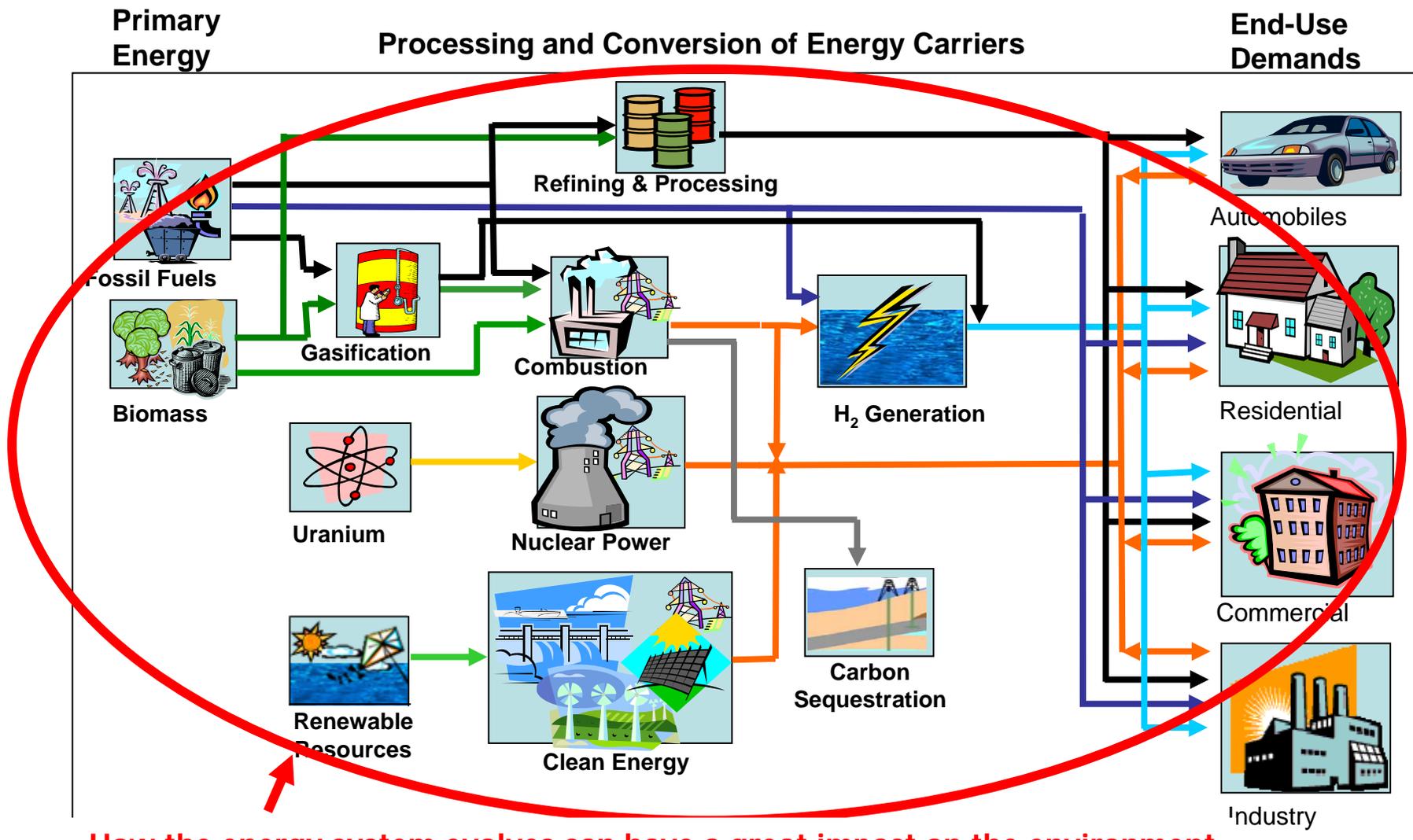
Emissions Contribution to anthropogenic emissions:

CO₂ ~ 94%
NO_x ~ 95%
SO₂ ~ 89%
CO ~ 95%
Hg ~ 87%

Environmental Concerns

Climate change
Tropospheric ozone
PM_{2.5}
Acid deposition
Toxics
Water use & quality
Solid & hazardous waste

Tomorrow's Energy System?



How the energy system evolves can have a great impact on the environment

Drivers Affecting Energy System Evolution

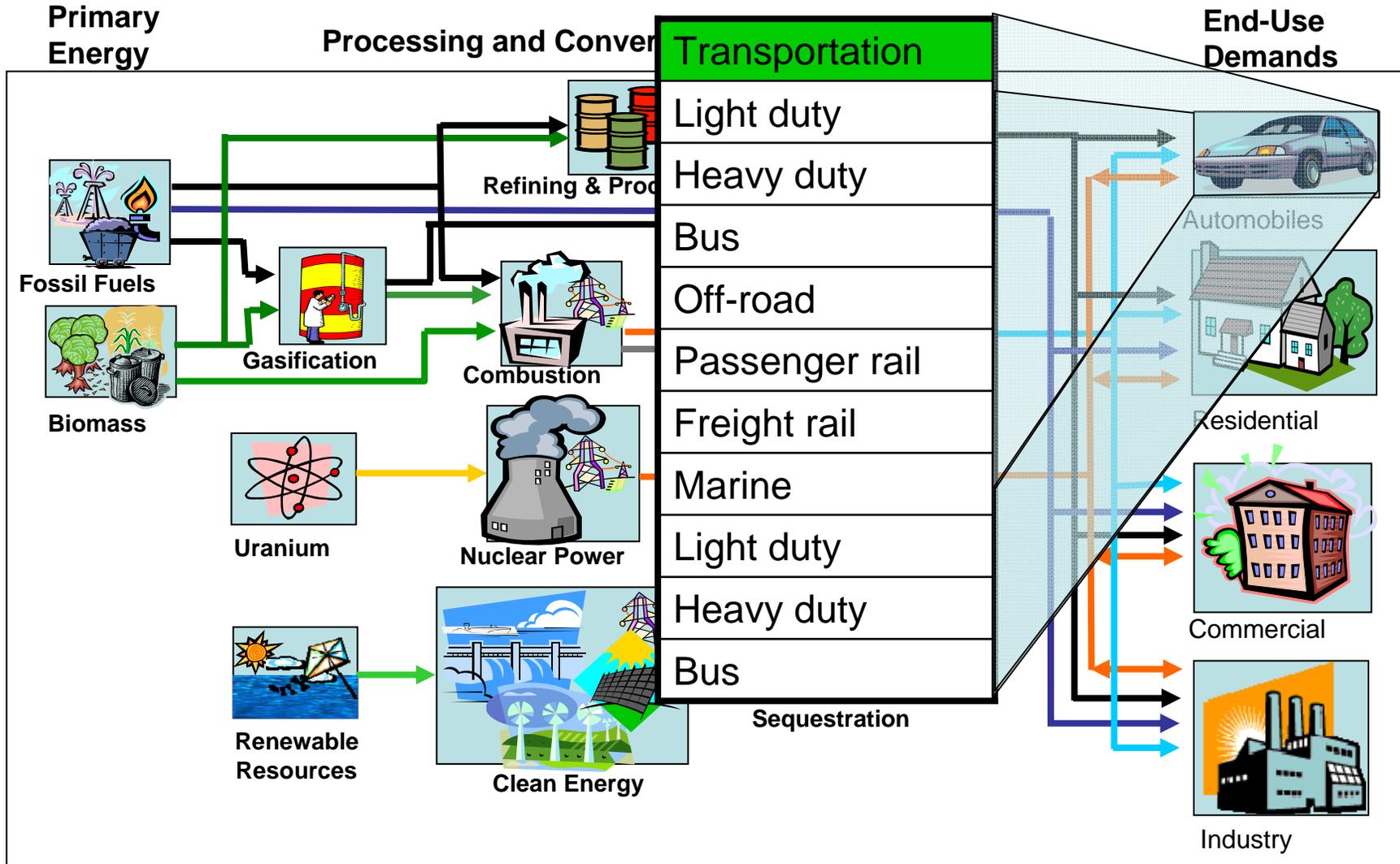
- Population
 - Growth, migration, affluence
- Economic
 - Growth and transformation
- Land use
 - (Sub)urbanization, transit
- Resources
 - Availability, cost
- Behavior
 - Willingness to pay
- Policy
 - Energy, environmental, smart growth



U.S. EPA MARKAL 9R Database & Model

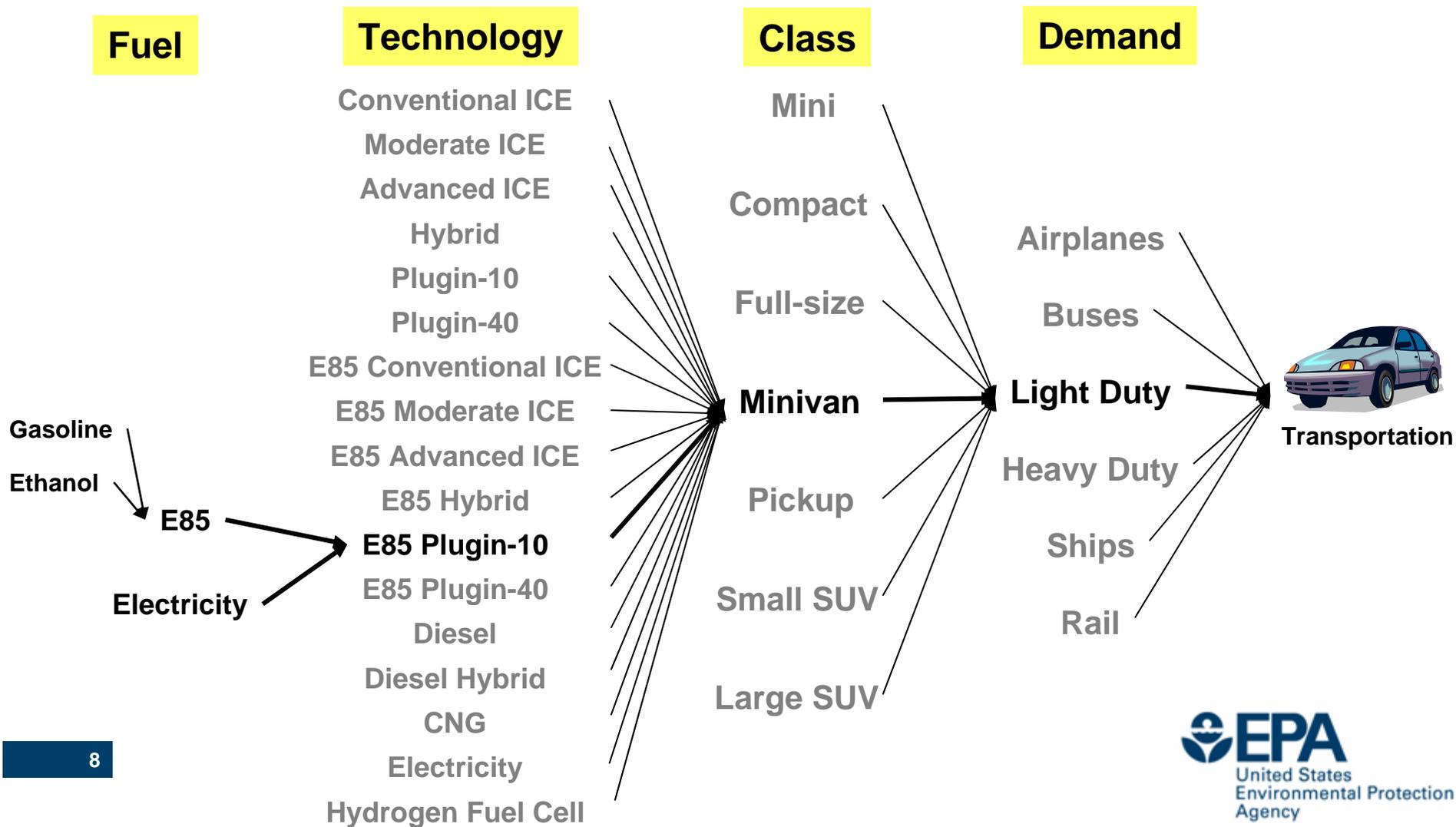
- **Type:** Bottom-up mixed-integer linear programming
- **Coverage:** U.S. energy system
- **Spatial resolution:** 9 U.S. Census Divisions
- **Modeling horizon:** 2000 to 2050 in 5-yr increments
- **Sectors:**
 - Electricity production
 - Transportation
 - Industrial
 - Residential
 - Commercial
 - Resource supply
- **Pollutants:** CO₂, NO_x, SO₂, PM₁₀
- **Outputs:** technology penetrations; fuel use; emissions; marginal costs for fuels, technologies and emissions

U.S. EPA MARKAL 9-Region Database



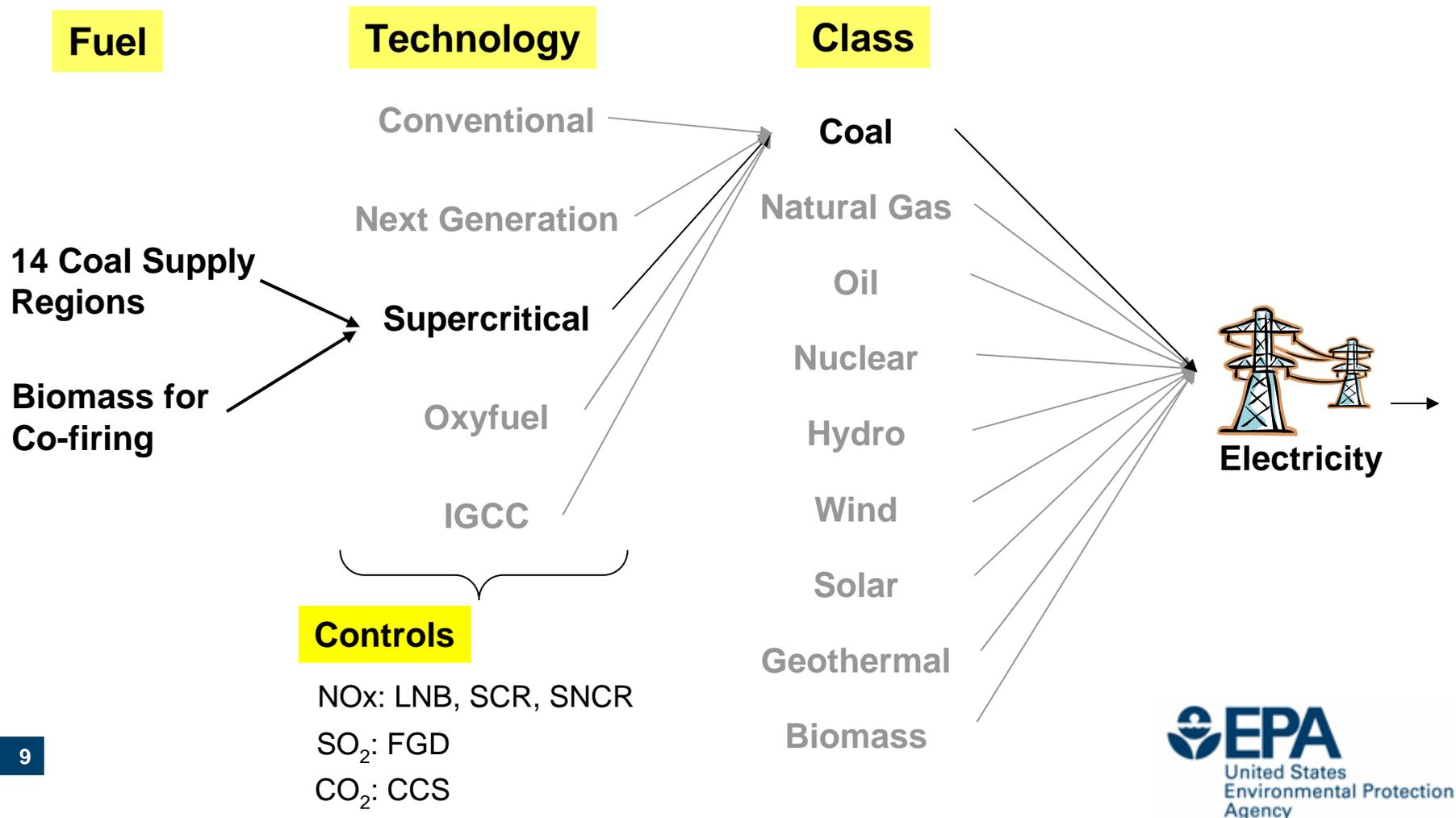
U.S. EPA MARKAL 9-Region Database

Technology Detail: Light Duty Vehicles



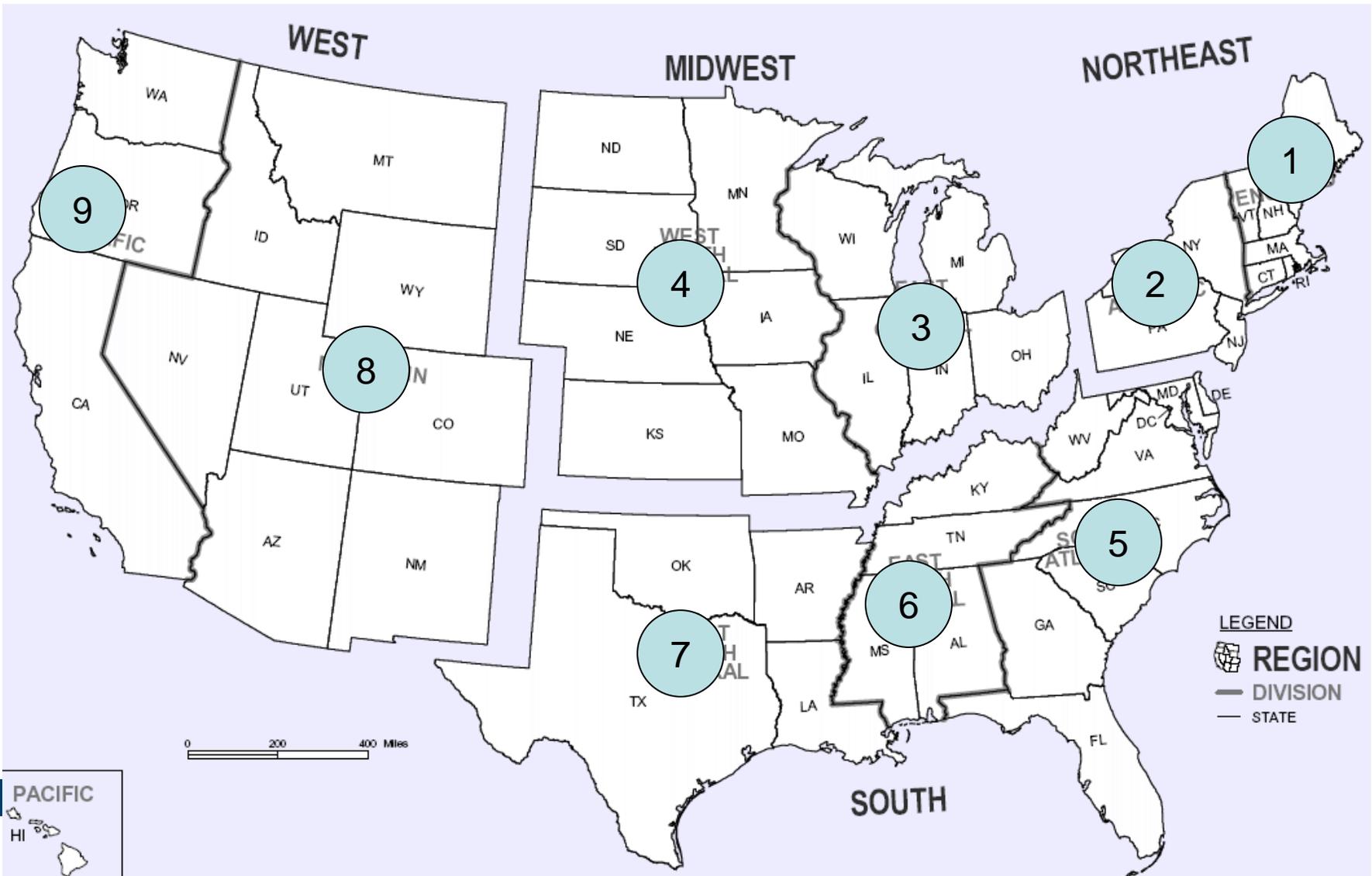
U.S. EPA MARKAL 9-Region Database

Technology Detail: Electricity Production



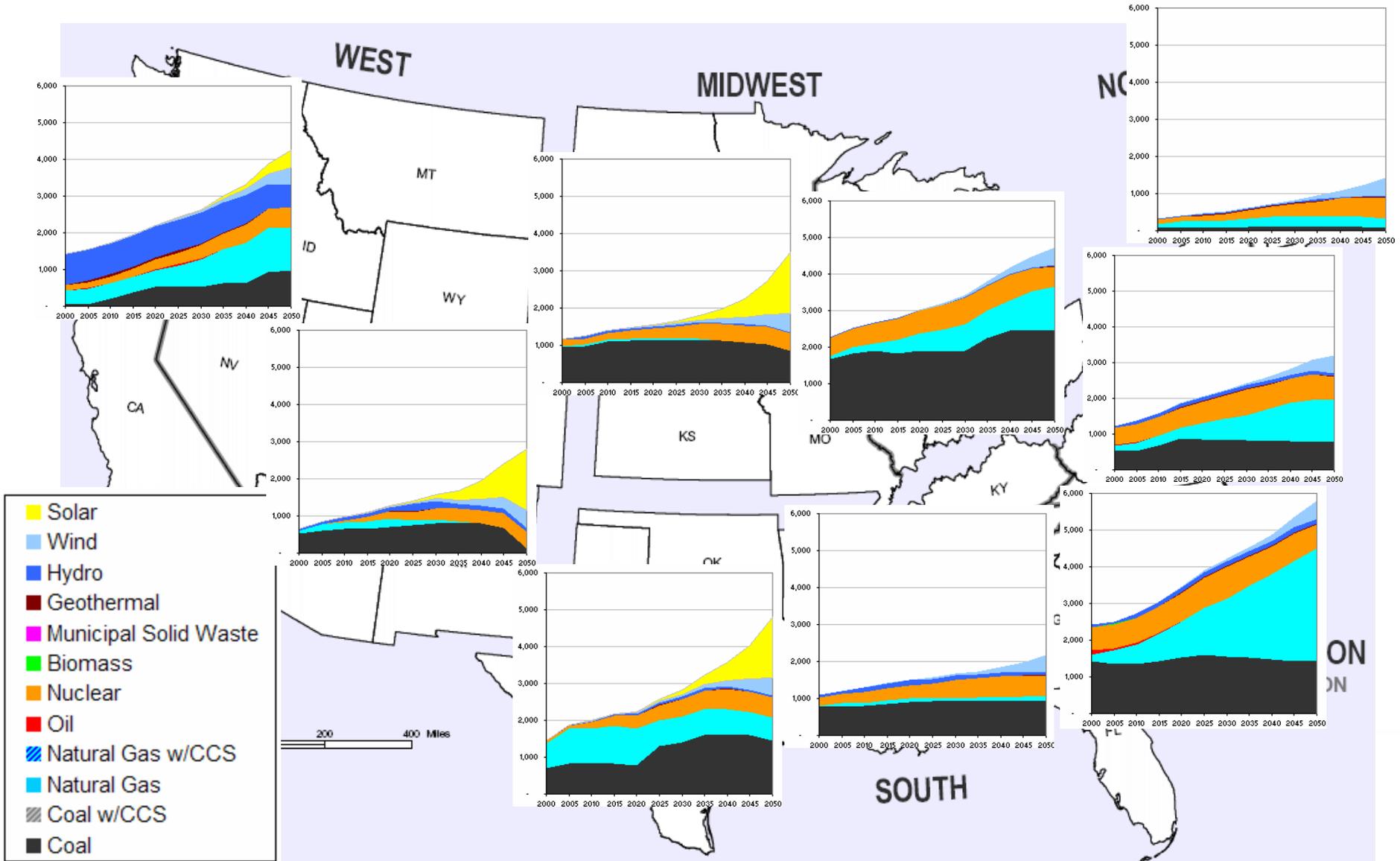
A Scenario of the Future

US EPA MARKAL 9R Regions



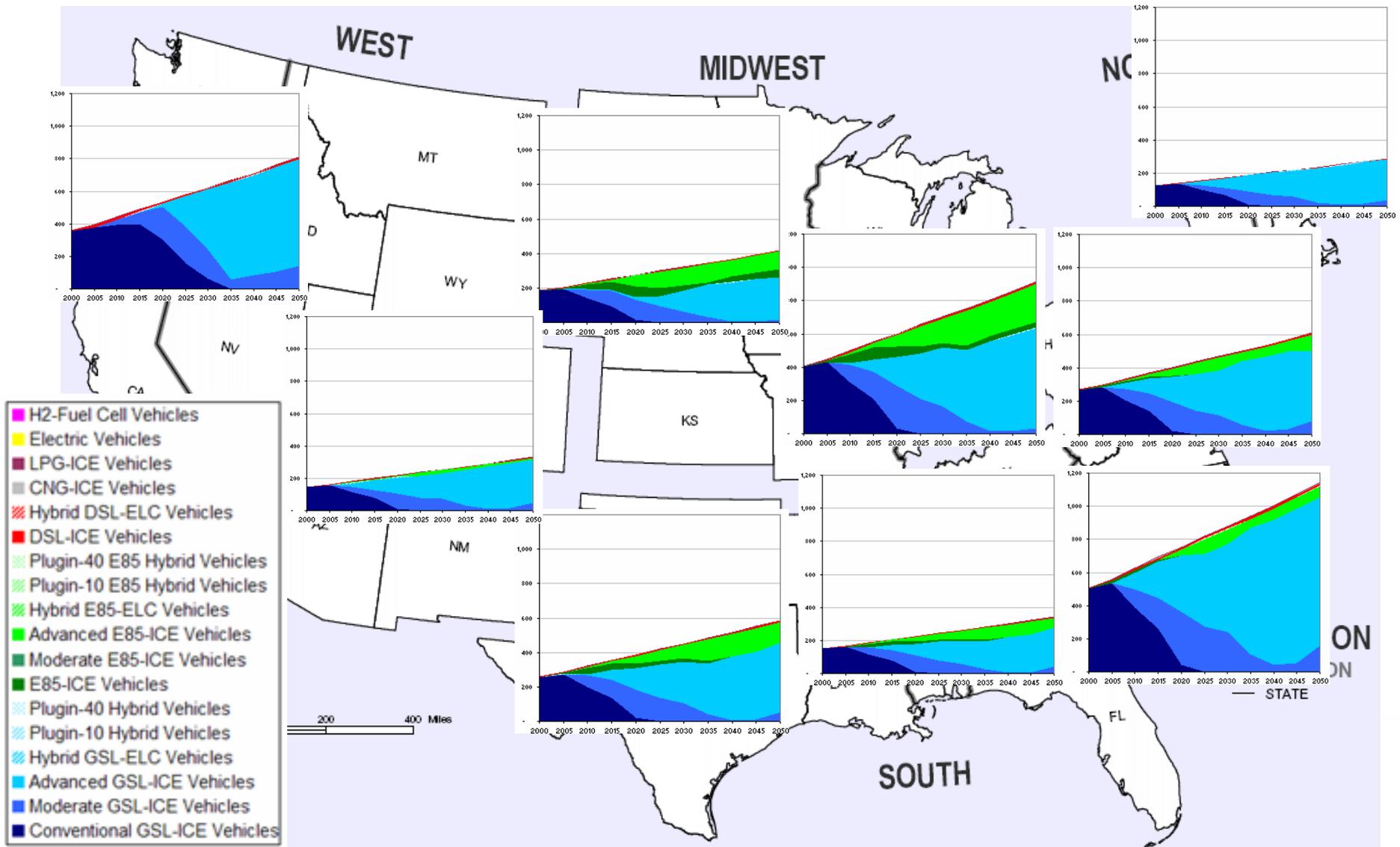
A Scenario of the Future

Regional Electricity Production



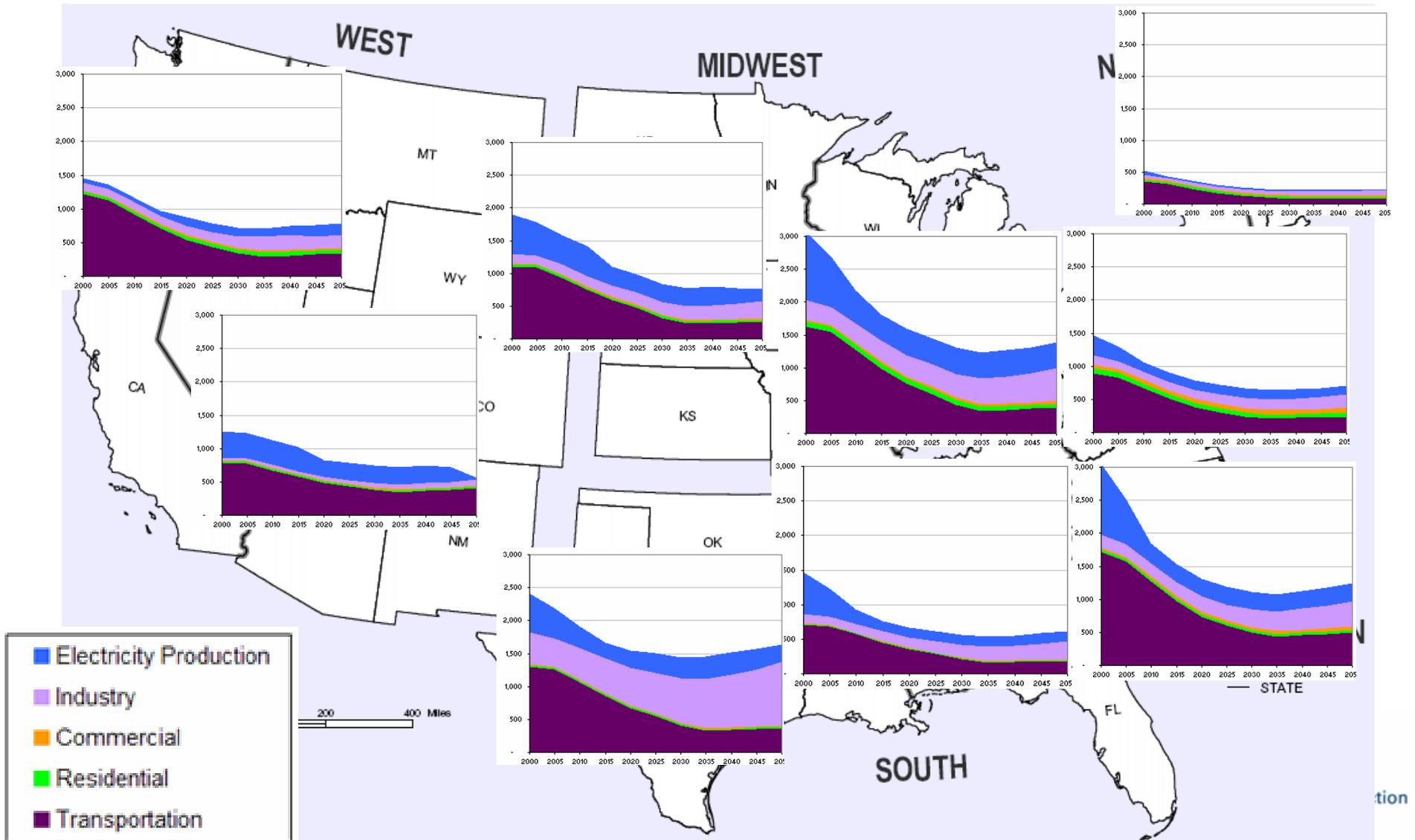
A Scenario of the Future

Regional Light Duty Vehicle Technologies & Fuels

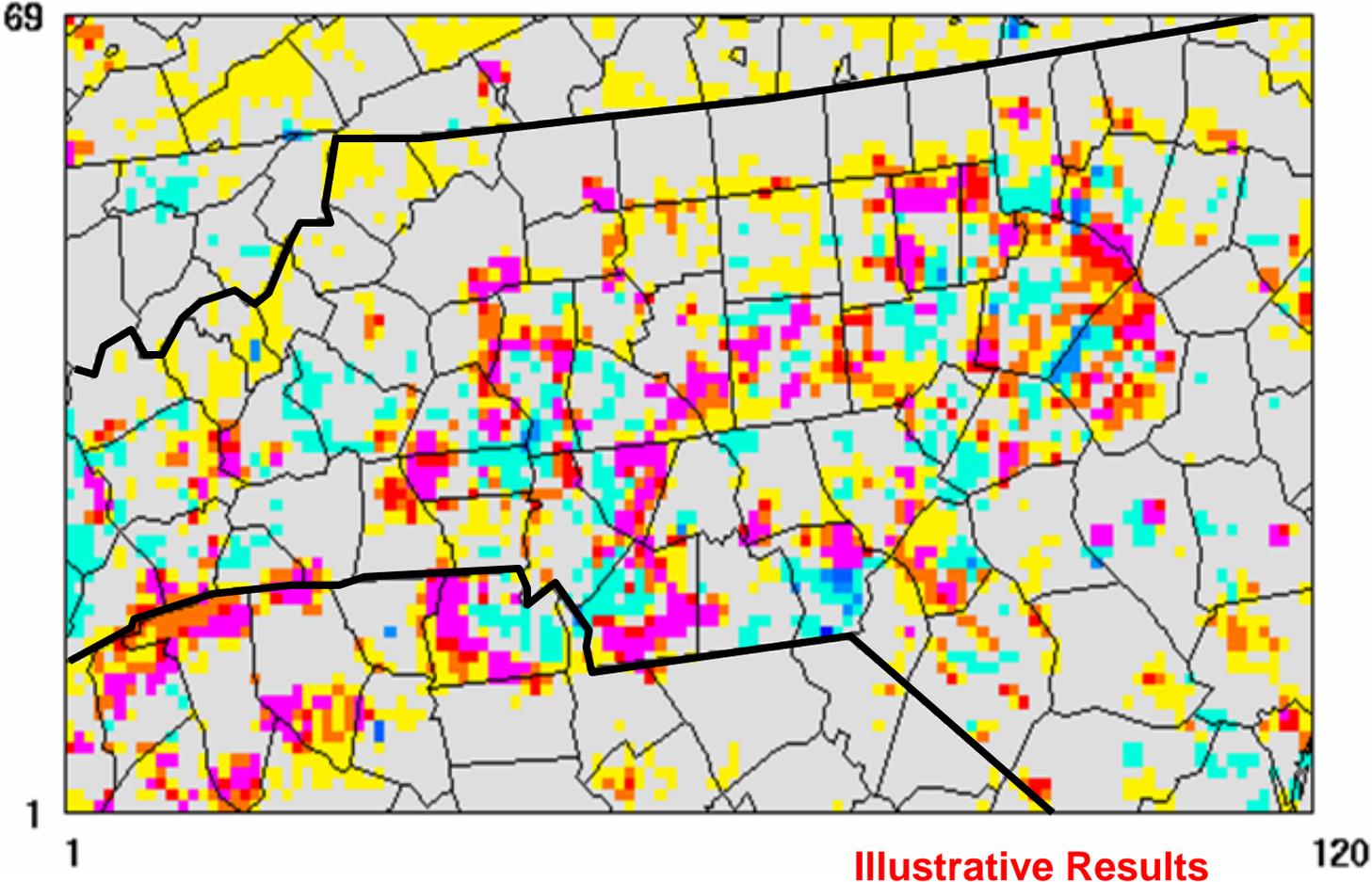


A Scenario of the Future

Regional NOx Emissions



Spatial Allocation of Future-Year Emissions for use in Emissions & Air Quality Models



Modeling Future Scenarios with MARKAL

- **There are an infinite number of possible futures**
- **Goal in Scenario Analysis**
 - Identify interesting futures
 - Plausible
 - Bounding
 - Represent either side of key tipping points
 - Yield insights into the system response to important drivers

Drivers, e.g.:

- High prices for oil and natural gas
- Energy efficiency and energy security policies
- Subsidies or other technology-specific actions
- Renewable portfolio standards
- Smart growth policies
- Emissions limits or taxes

Scenario Comparison

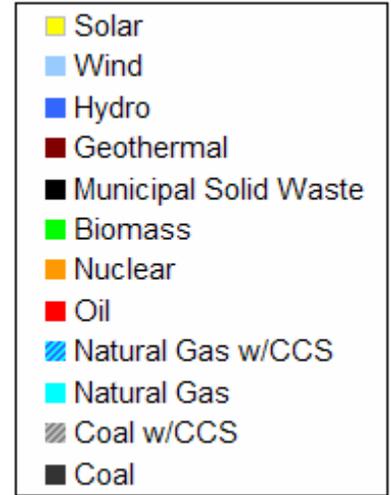
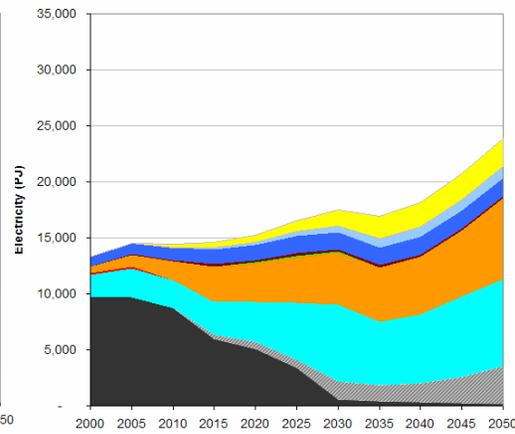
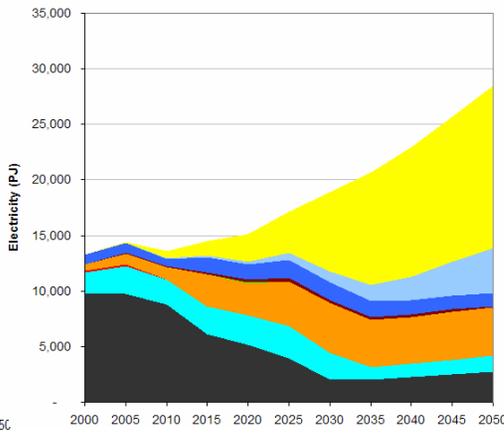
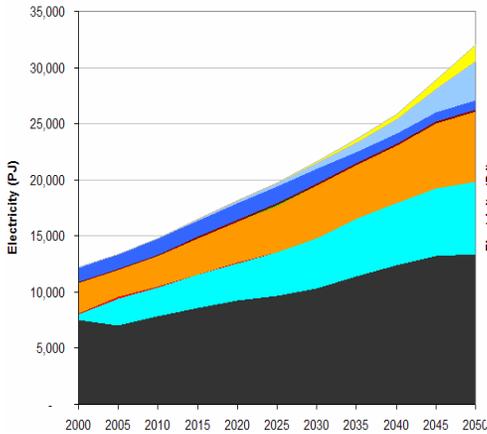
Illustrative Results

1. Hold the Course

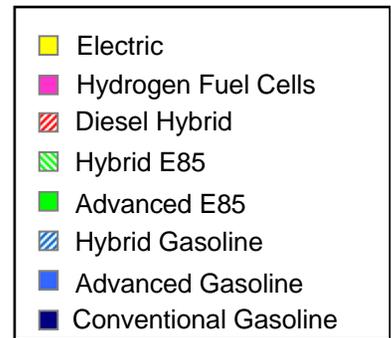
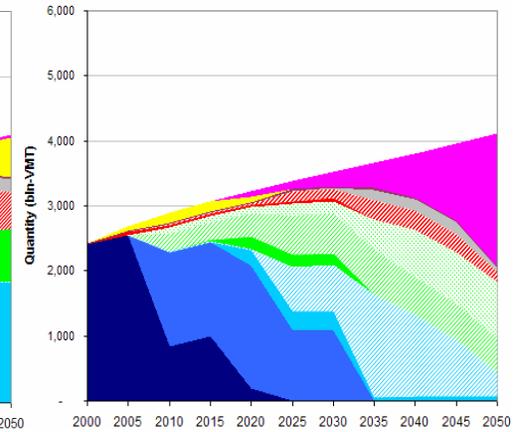
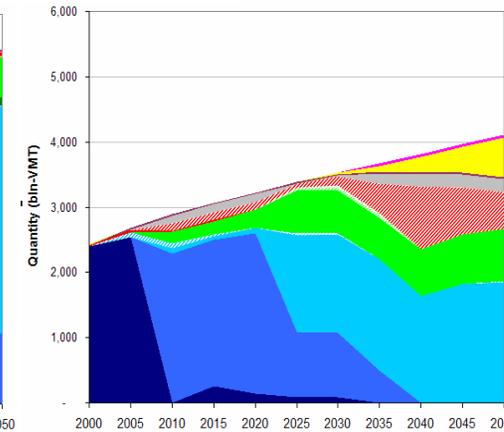
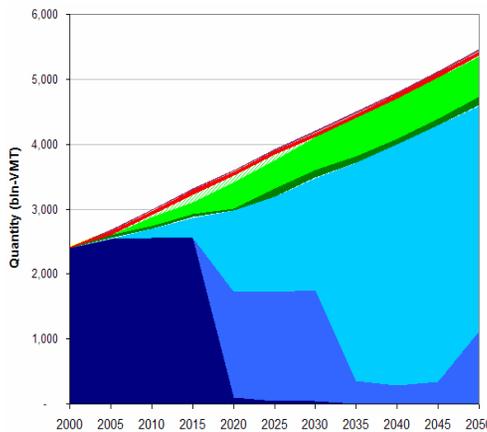
2. A Bright Future

3. Don't Worry, Be Happy!

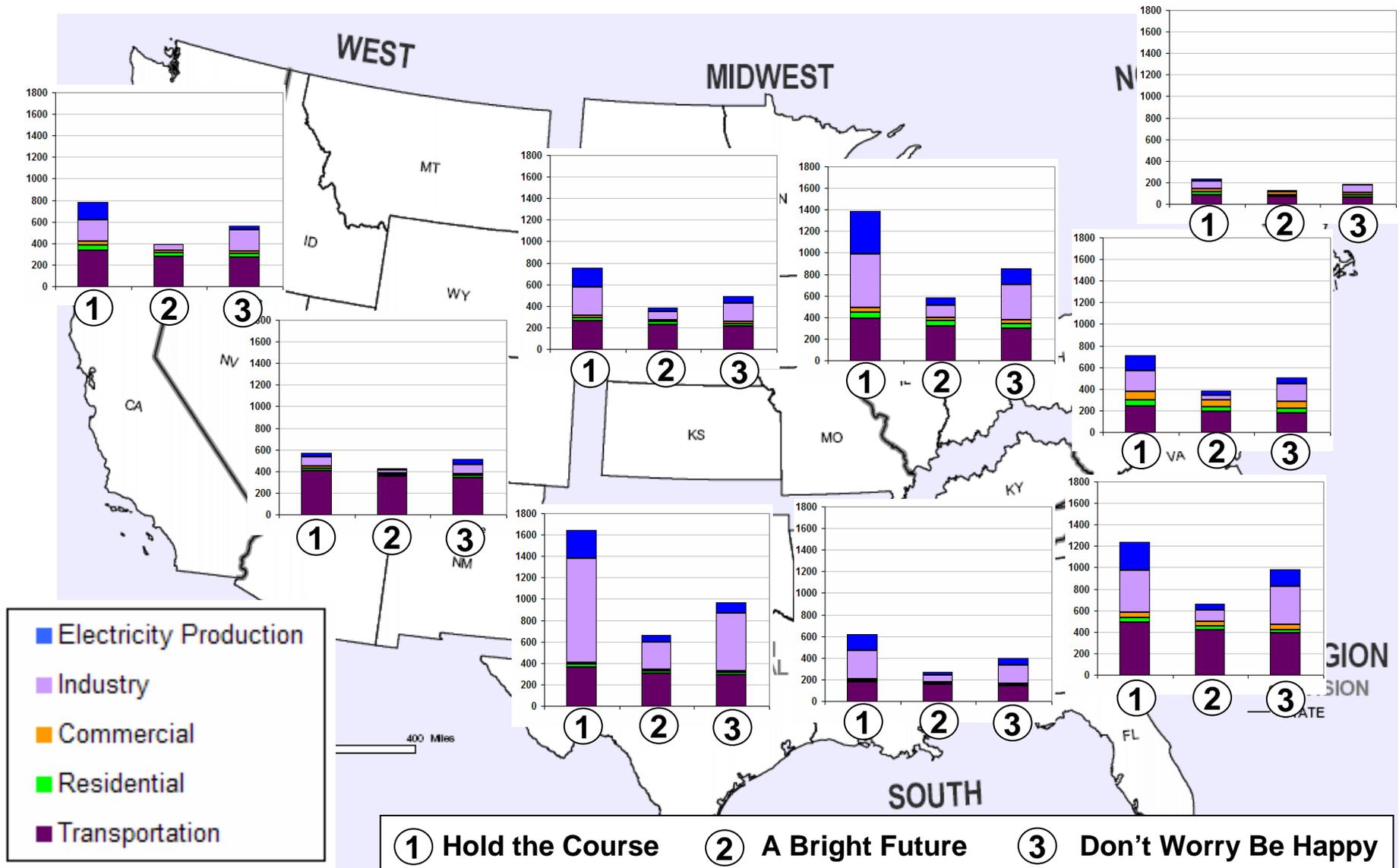
National Electricity Production



National Light Duty Vehicle Mix



Regional-Scale NOx in 2050





Regional Application

US EPA 9-Region MARKAL

- Characterize regional scenarios
 - Identify potential regional technology and emissions trends
 - Analysis of regional offsets achievable by energy efficiency improvements and new technologies
 - Technology mix data for life cycle assessments
 - ...

NESCAUM NE-MARKAL Model

- EPA cooperative agreement with NESCAUM for development of state-level MARKAL model
 - State-level resolution
 - Greater ability to model state and regional responses to drivers
 - ...