Climate Action for Sustained Growth

Analysis of ARB's Scoping Plan

David Roland-Holst
Department of Agricultural and Resource Economics, UC Berkeley
dwrh@are.berkeley.edu

19 April 2010

Acknowledgements

This work was performed at the invitation of the California Air Resources Board and in consultation with the California Environmental Protection Agency (CalEPA).

We wish particularly to thank the following staff for their time and insights:

Michael Gibbs and William Dean, CalEPA

We also thank the ARB and CalEPA staff for their data, insight, and advice on scenario development.

The lead author wishes to thank many research assistants for dedicated support during this project: Drew Behnke, Billie Chow, Melissa Chung, Joanna Copley, Elliot Deal , Sam Heft-Neal, Shelley Jiang, Fredrick Kahrl, Adrian Li, Tom Lueker, Jennifer Ly, Adrian Li, and Mehmet Seflek.

Financial commitments from the Energy Foundation and the Richard and Rhoda Goldman Fund are gratefully acknowledged.

For media enquiries, please contact Morrow Cater, Cater Communications, at 415-453-0430.

Objectives

1. Estimate direct and economywide indirect impacts and identify adjustment patterns.
2. Inform stakeholders and improve visibility for policy makers.
3. Promote empirical standards for policy research and dialogue.

Summary of Findings

- Aggregate direct effects of AB32 on the economy are negligible or positive
- Innovation responses could leverage climate policy for significant growth dividends
- Participation in a national climate program will increase benefits for California
- Individual sector demand, output, and employment can change significantly
- No significant leakage is observed

Primary Components

The Berkeley Energy And Resource (BEAR) modeling facility stands on two legs:

1. Detailed economic and emissions data
2. A dynamic GE forecasting model

The BEAR model has been peer reviewed and its structure is summarized in an annex below and fully documented elsewhere: http://are.berkeley.edu/~dwrh/CERES_Web/Docs/BEAR_Tech_2.0.pdf

Economic Data

California Social Accounting Matrix (2006)

An economy-wide accounting device that captures detailed income-expenditure linkages between economic institutions. An extension of input-output analysis.

- 170 sectors/commodities
- Three factor types
  - Labor (2+ occupational categories)
  - Capital
  - Land
- Households (10 by tax bracket)
- Fed, State, and Local Government (very detailed fiscal instruments, 45 currently)
- Consolidated capital account
- US and ROW trading partners

Other Data

- Employment
- Technical data (MACs, emission rates, etc.)
- Estimated structural parameters
- Trends for calibration
  - Population and other labor force composition
  - Independent macro trends (CA, US, ROW, etc.)
  - Productivity growth trends
  - Exogenous prices (energy and other commodities)
  - Baseline ("business as usual") emissions trends

Pollution Data 1

Our primary source of activity based pollution are California and US EPA emissions inventories, with detailed (ISIC-3) pollution coefficients per unit of output for:

1. SO_2
2. NO_2
3. CO_2
4. VOC – volatile organic compounds
5. PART – suspended particulate intensity index
6. BOD – water pollution measured by biological oxygen demand
7. TSS – total suspended solids TOXAIR – airborne toxic index
8. TOXWAT – waterborne toxic index
9. TOXSOL – soil retentive toxic index
10. BIOAIR – bioaccumulative toxic metals - airborne
11. BIOWAT – bioaccumulative toxic metals - waterborne
12. BIOSOL – bioaccumulative toxic metals – soil retentive

Motivation – Why use an economic model?

- Most human-induced environmental change originates in economic activity.
- Environmental effects of policy will largely result from economic responses.
- Thus, to understand environmental incidence, we need to understand economic behavior.

Why a state model?

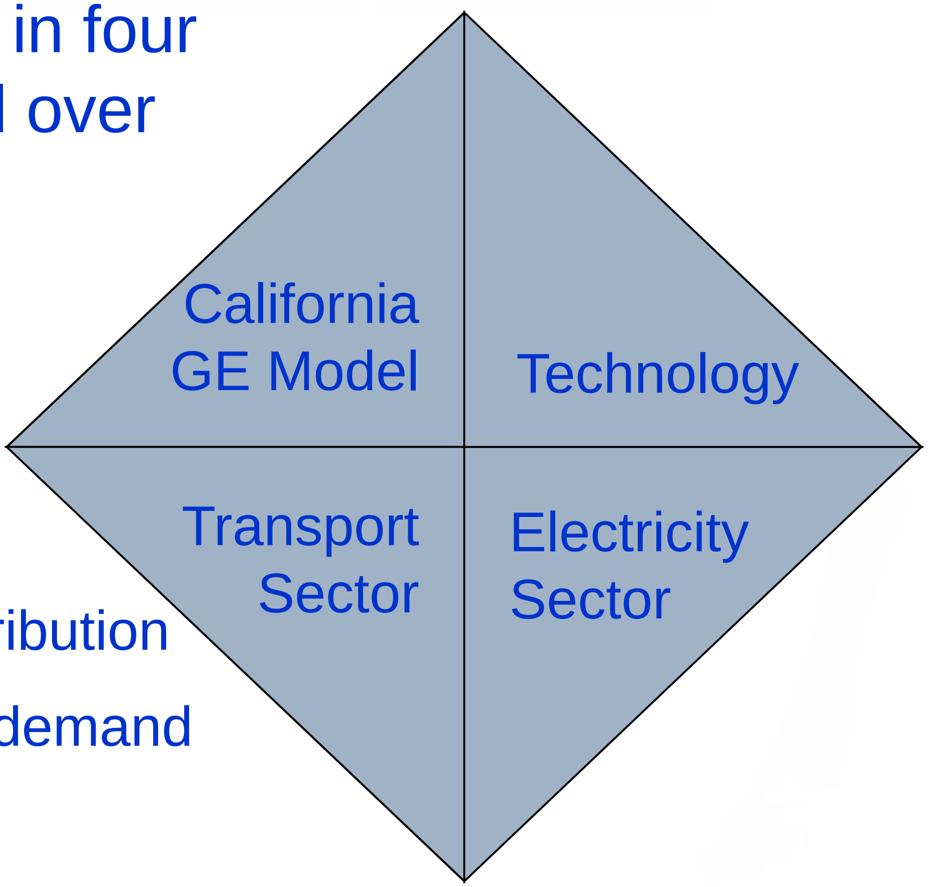
1. California needs research capacity to support its own policies
   - A first-tier world economy
2. California is unique
   - Both economic structure and emissions patterns differ from national averages
3. California stakeholders need more accurate information about the adjustment process
   - National assessment masks interstate spillovers and trade-offs

How we Forecast

BEAR is being developed in four areas and implemented over two time horizons.

Components:

1. Core GE model
2. Technology module
3. Electricity generation/distribution
4. Transportation services/demand



Why a General Equilibrium Model?

1. *Complexity* - Given the complexity of today's economy, policy makers relying on intuition and rules-of-thumb alone are assuming substantial risks.
2. *Linkage* - Indirect effects of policies often outweigh direct effects.
3. *Political sustainability* - Economic policy may be made from the top down, but political consequences are often felt from the bottom up. These models identify stakes and stakeholders *before* policies are implemented.

What is a General Equilibrium Model?

- Detailed market and non-market interactions in a consistent empirical framework.
- Linkages between behavior, incentives, and policies reveal detailed demand, supply, and resource use responses to external shocks and policy changes.

Technology

- Technology is a primary determinant of resource use patterns
- Currently, all technical efficiency is exogenously specified (share, elasticity, and productivity parameters)
- Future versions of the model will incorporate endogenous technological change

Electricity Sector Modeling

Power generation accounts for a significant percentage of GHG emissions within California.

To understand how this sector will adjust to policy changes, it is essential to capture its economic and technical heterogeneity

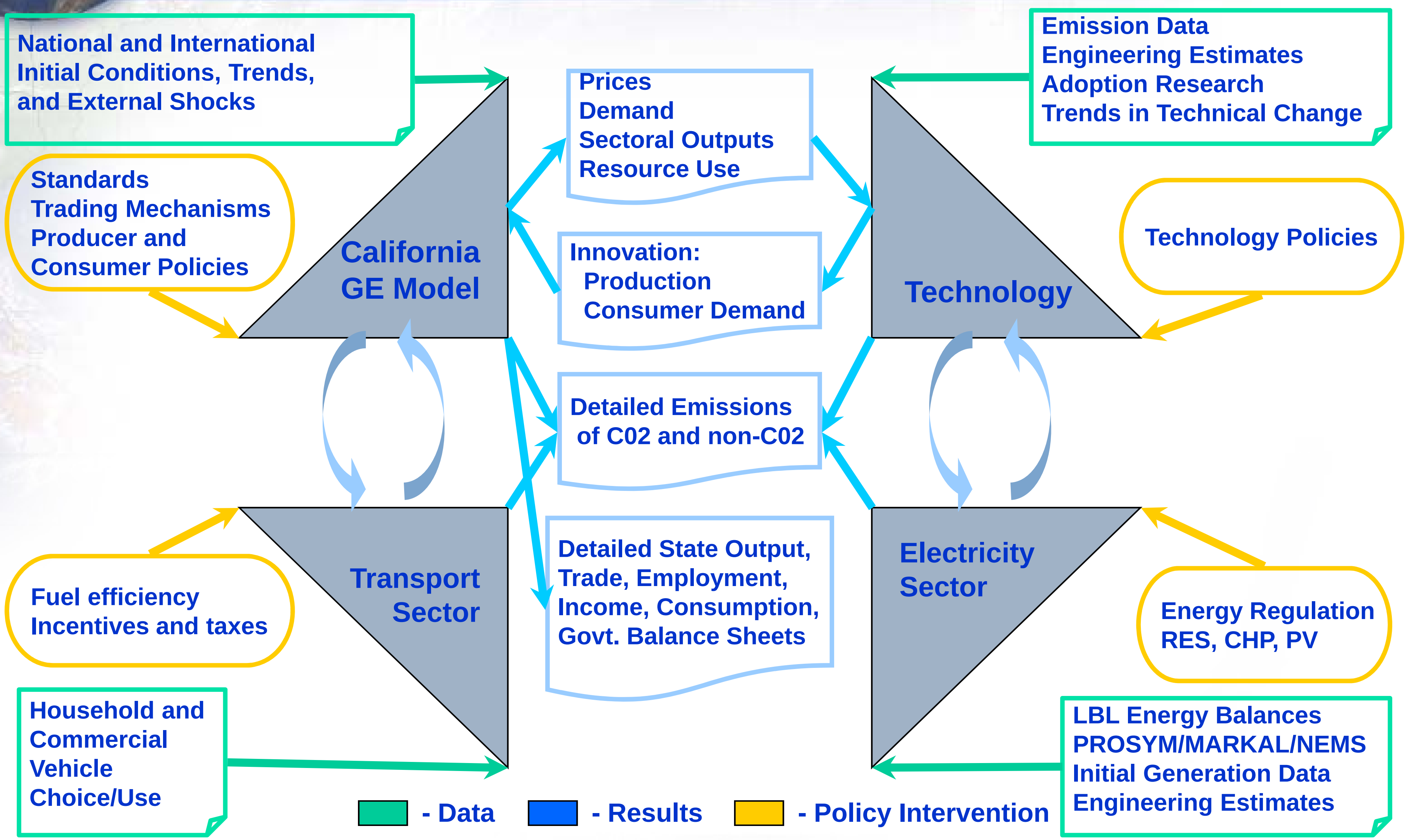
Based on detailed producer data from US EPA, CalEPA, CEC/PIER/PROSYM, we model technology and emissions in California's electricity sector

- Eight generation technologies
- Eleven fuels

Transportation Modeling

- The transport sector accounts for over 40% of California GHG emissions
- To elucidate the path to our emission goals, patterns of vehicle use and adoption need to be better understood
- We model the state's vehicle and transport services policies individually

Detailed Framework



Model Structure: Berkeley Environment And Resource (BEAR) Model

The core CGE model represents statewide patterns of market interaction between households, enterprises, and the government, as well as trade with economies outside the state.

Beyond general policy simulation, the BEAR model will also act as an integrating platform for extensions to apply other CEC research initiatives.

Time Horizons

BEAR is being developed for scenario analysis over two time horizons:

1. **Policy horizon**: 2005-2050

   Detailed structural change:

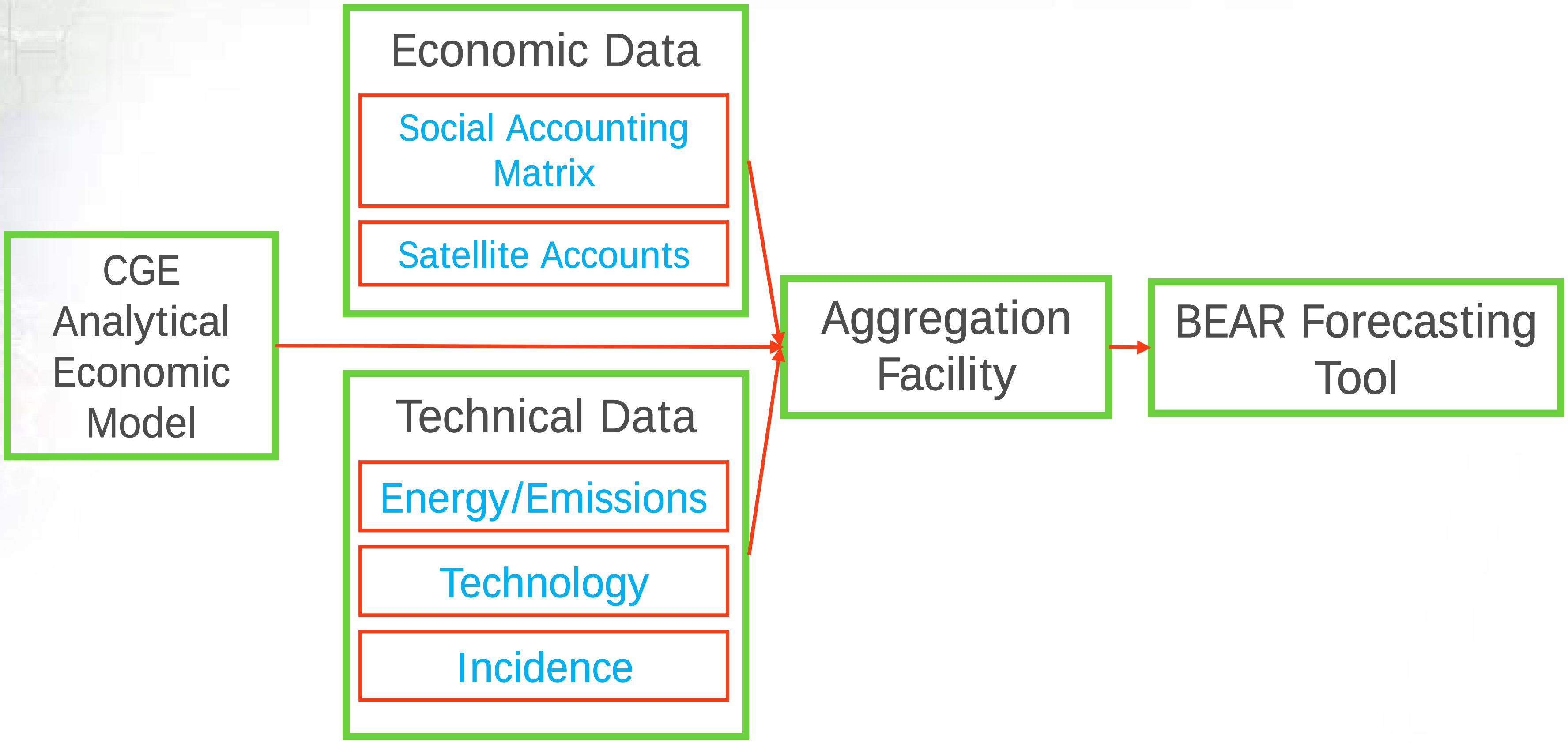
   1. 170 sectors
   2. 10 household income groups
   3. Labor by occupation, land, and capital by vintage

2. **Climate horizon**: 2005-2100

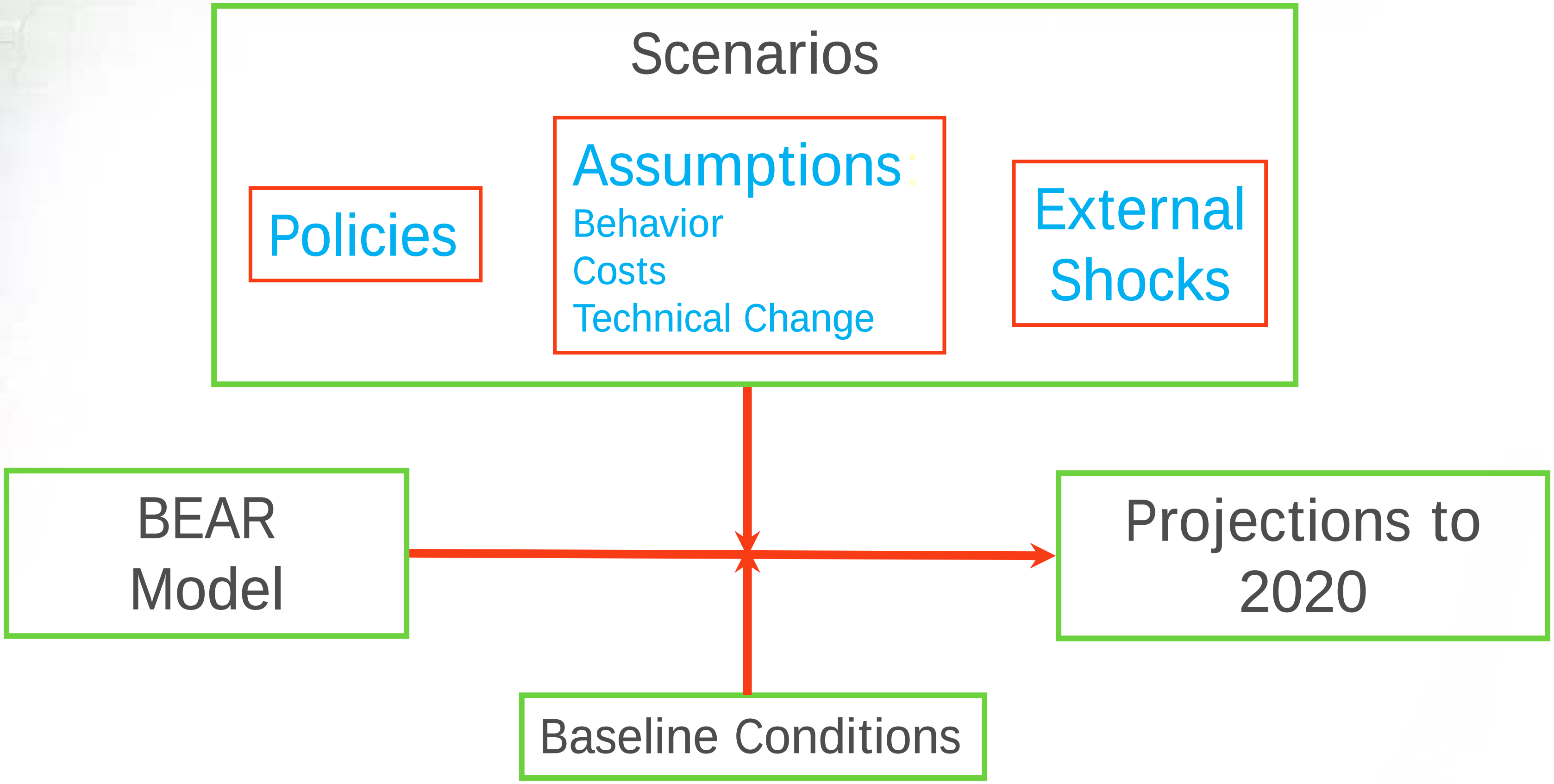
   Aggregated:

   1. 10 sectors
   2. 3 income groups
   3. labor, land, and capital

General Structure of the Forecasting Tool



Forward-looking Medium Term Policy Analysis



Modeling Economy-Environment Linkage

Economic activity affects pollution in three ways:

1. *Growth* – aggregate growth increases resource use
2. *Composition* – changing sectoral composition of economic activity can change aggregate pollution intensity
3. *Technology* – any activity can change its pollution intensity with technological change

All three components interact to determine the ultimate effect of the economy on environment.

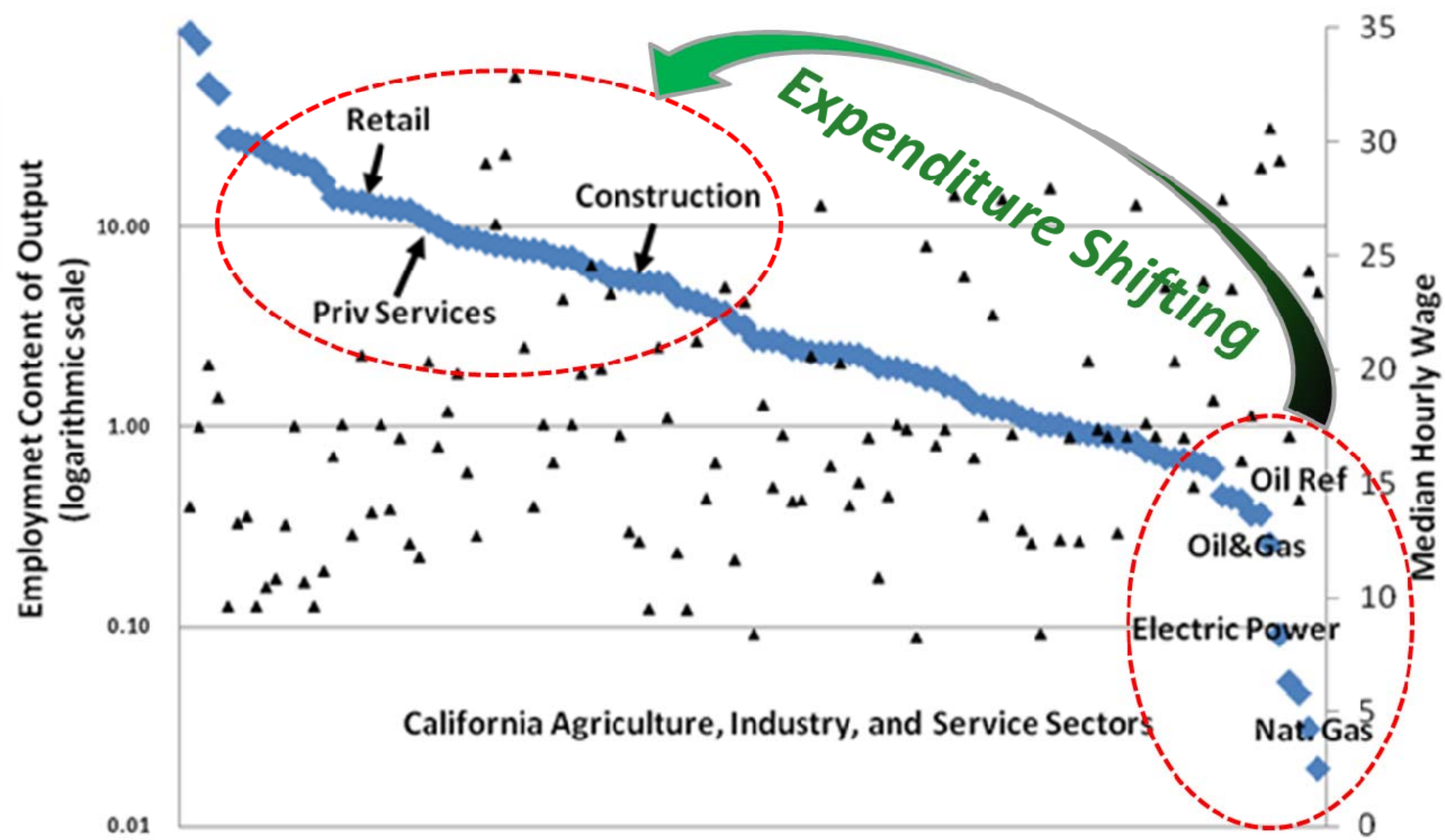
Salient Energy-Environment Features

- Production
  - Input based pollution coefficients
  - Nested CES for energy sources
  - Extensively parameterized for efficiency/productivity
- Consumption
  - 'technology" of consumption/pollution
  - detailed residential and transport modules
- Energy
  - differentiated and flexible generation technologies
  - CES fuel substitution and vintage capital
  - energy trading

The Role of Innovation

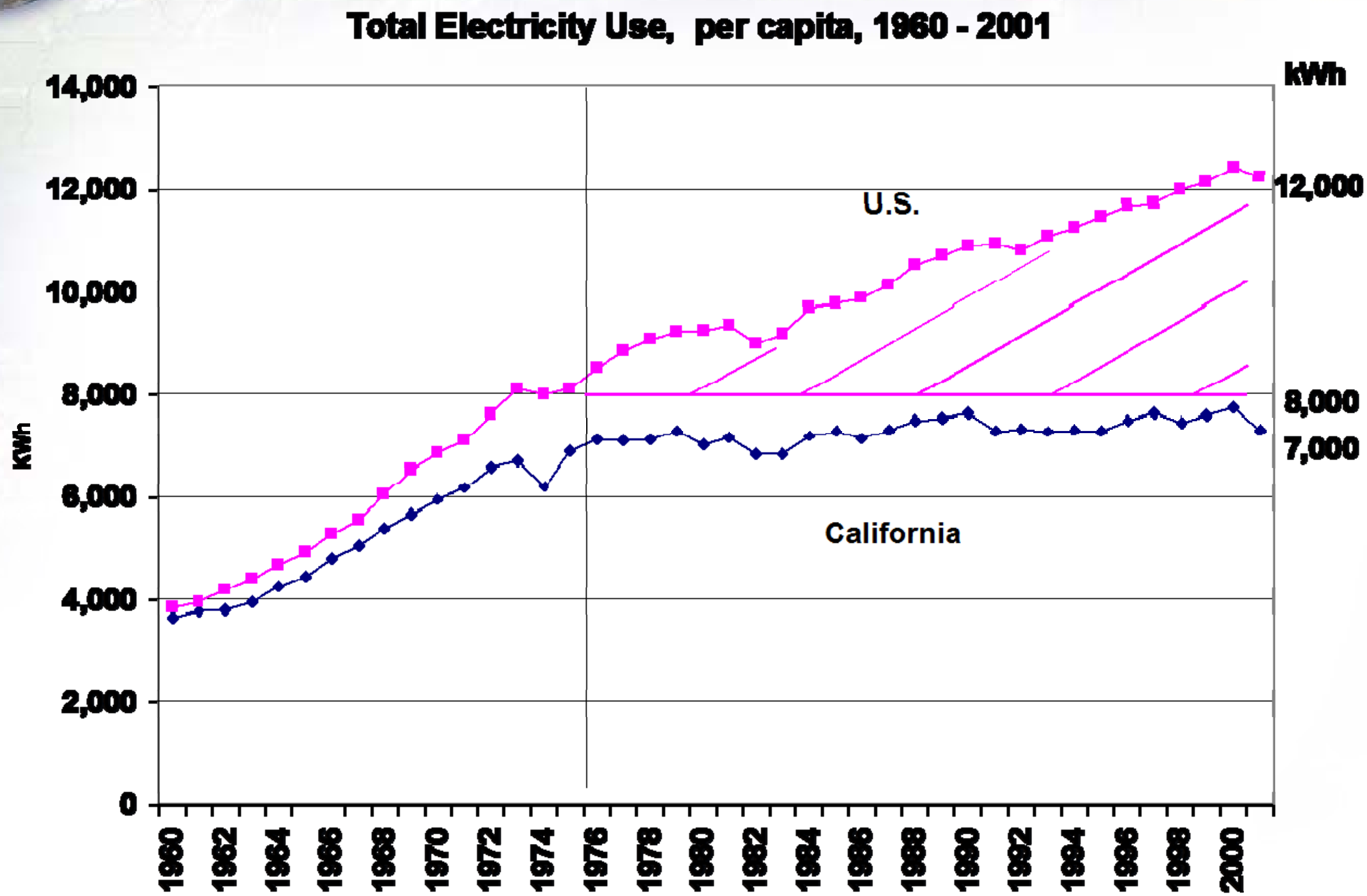
- Innovation is the hallmark of California's superior growth experience.
- This is particularly the case with energy efficiency improvements, which have induced innovation at home and nationally, saving households over $50 billion and creating 1.46 million additional jobs over three decades.
- To give an indication of the contribution of innovation potential, we assume California responds to AB32 with 0.4% additional energy efficiency improvements, very modest by historical standards.

Why this works



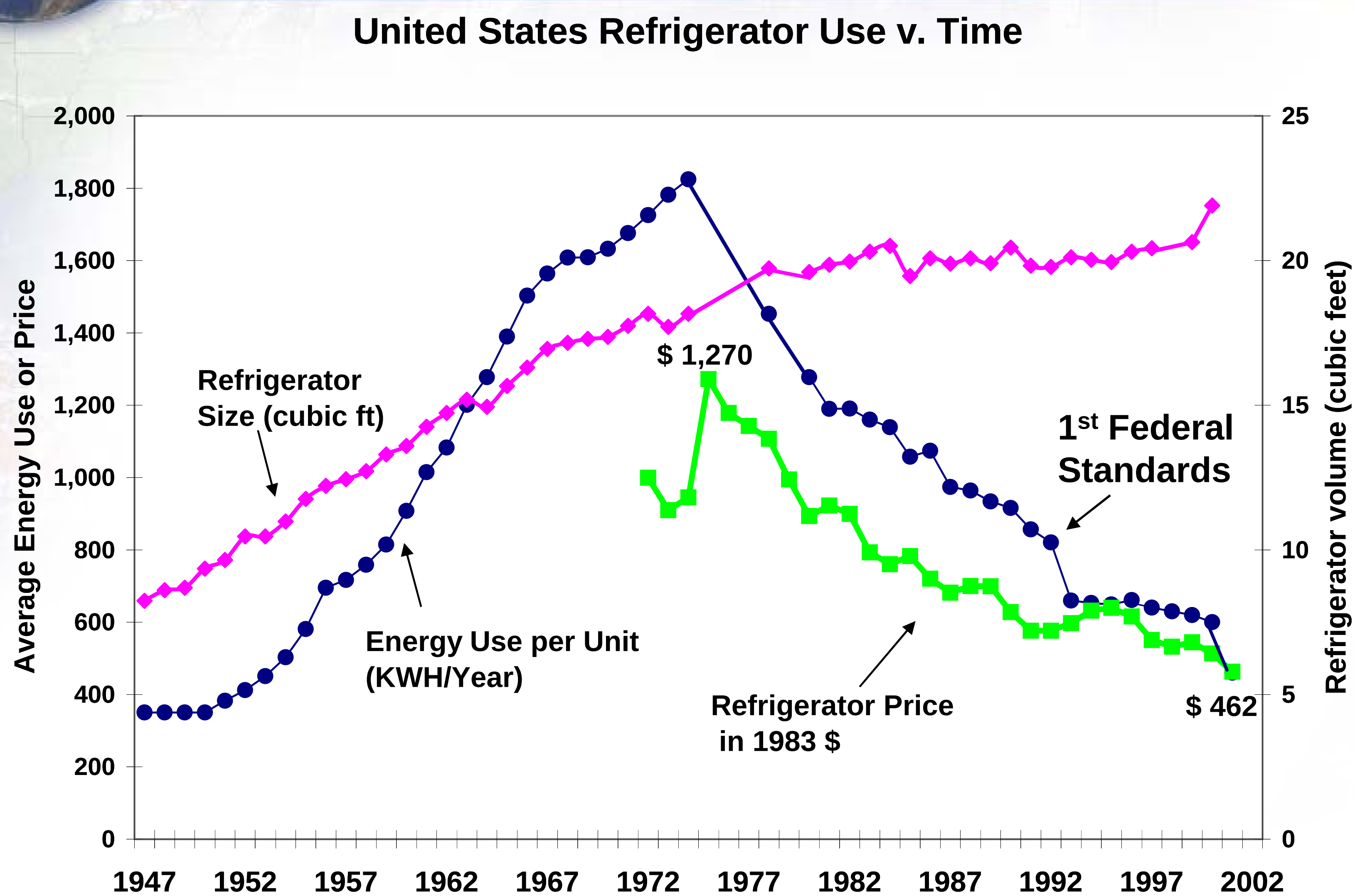
Source: Roland-Holst, David "Energy Prices and California's Economic Security," Next10.org, October, 2009

How it has worked before - I



Source: A. Rosenfeld, private communication.

How it has worked before - II



Source: A. Rosenfeld, private communication.

California in a National Climate Program

- Because of its past accomplishments, California's marginal cost of abatement exceeds most states
- For this reason, it would be cheaper for the state to promote efficiency elsewhere through an emissions trading mechanism
- A national program would also enlarge the market for our own energy use and emission technologies

National Climate Assessment – the EAGLE Model

- The Environmental Assessment in GeneraL Equilibrium (EAGLE) model is a national GE model that captures economy/climate interactions in each of the 50 states.
- In support of policy dialogue at the national level, we conducted an assessment of the Waxman-Markey or ACES climate legislation
- Using the EAGLE model, we found California gains from participation in a national program, but still has incentives for unilateral climate action.

AB32 and Related Scenarios

	Offsets	LCFS	Pavley II	VMT Reduction	EE Standards	33% RES	CHP	Annual EE Response
ARB1	4%	Full	Full	Full	Full	Full	Full	None
ARB2	No	Full	Full	Full	Full	Full	Full	None
ARB3	4%	Half	Half	Excluded	Full	Full	Full	None
ARB4	4%	Full	Full	Full	Half	Excluded	Half	None
ARB5	4%	Half	Half	Excluded	Half	Excluded	Half	None
ARB_Cap	4%	Excluded	Excluded	Excluded	Excluded	Excluded	Excluded	None
EE1	4%	Full	Full	Full	Full	Full	Full	0.40%
WM1	Full	Full	Full	Full	Full	Full	Full	None

Results

	1	2	3	4	5	6	7	8
	ARB1	ARB2	ARB3	ARB4	ARB5	ARB_Cap	EE1	WM1
Total GHG	-14	-19	-14	-14	-14	-14	-14	-9
Household GHG	-13	-13	0	-13	0	1	-13	-8
Industry GHG	-15	-23	-24	-15	-24	-24	-15	-10
Annual GSP Growth	-0.1	-0.2	-0.3	-0.5	-0.7	-0.9	3.0	0.7
Employment	-0.1	-0.1	-0.2	-0.3	-0.4	-0.5	2.2	0.9
Permit Price	$ 18	$ 74	$ 97	$ 83	$ 108	$ 132	$ 16	$ 34
Income Per Capita ($/yr)	-65	-72	-129	-252	-317	-417	1,389	327
Jobs (thousands)	-16	-18	-40	-56	-81	-101	397	73

Results expressed as percentage changes from year 2020 reference case levels unless otherwise indicated.

Sources of Bias in Results

- Assumptions regarding initial conditions – market failures
- No foregone damages considered – the costs of doing nothing
- Treatment of innovation potential

Conclusions

- The macroeconomic impact of AB32 will be negligible, unless
- Climate action triggers innovation responses, a potent catalyst for growth
- By creating a market to incubate the next generation of energy use and emission control technologies, California can capture national and global growth opportunities

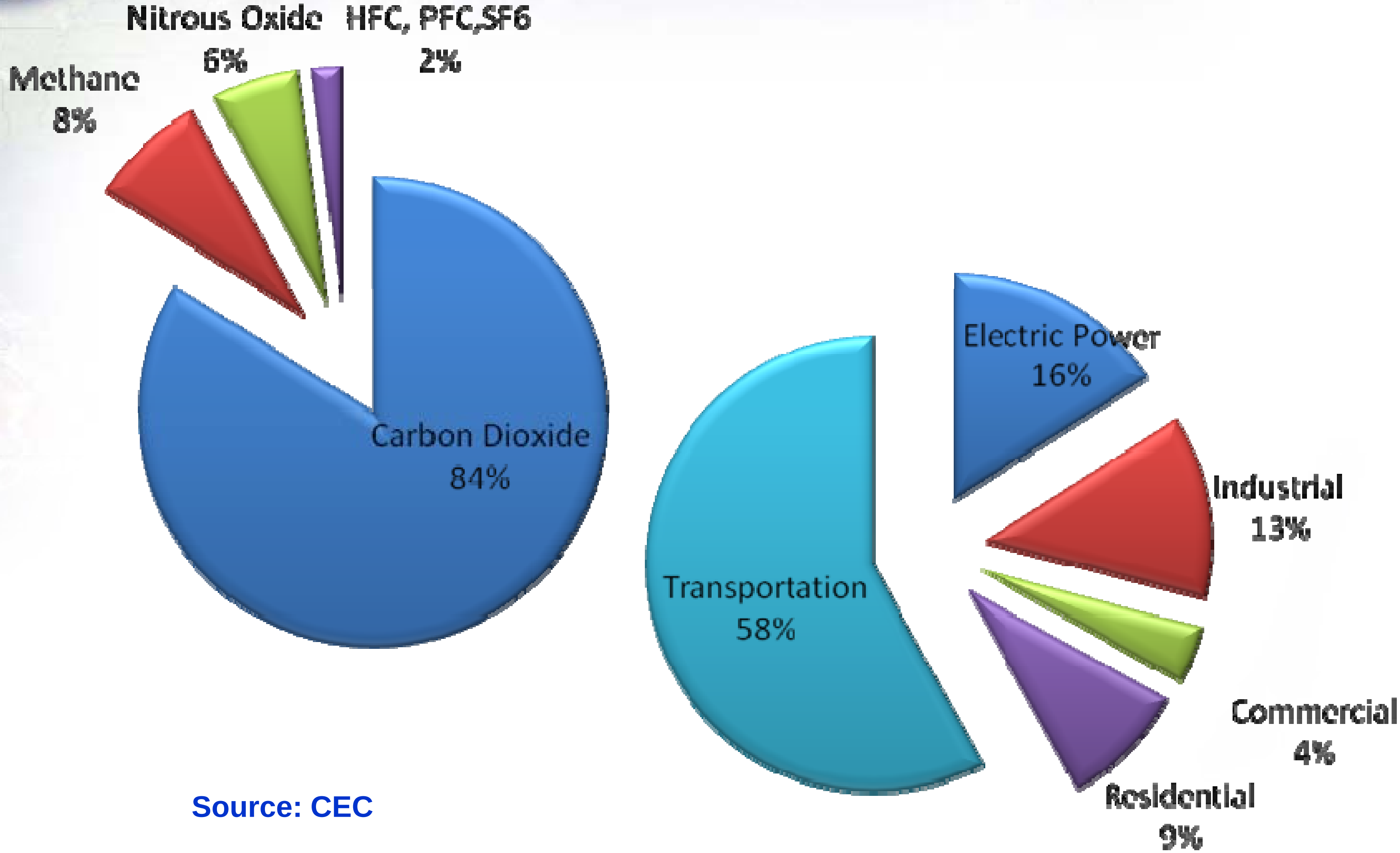
Annex 1

Supporting Data and Scenario Information

Data overview

- All economic data used in this study were obtained from official sources.
- CalEPA kindly provided a large share of technical data, an in those cases BEAR calibration is identical to EDRAM.
- For many emissions and renewable cost data, we obtained independent data.

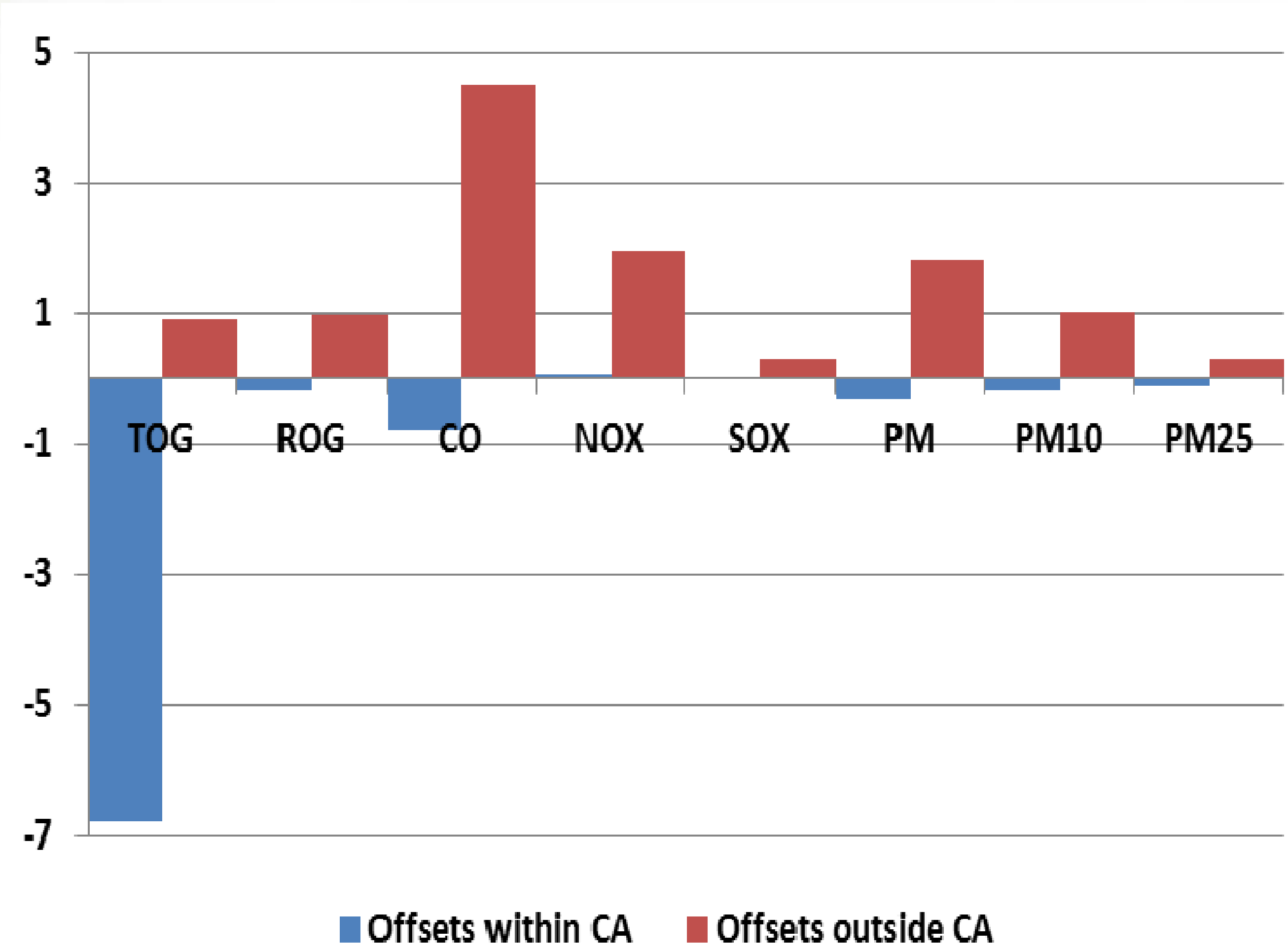
Climate Change and Carbon Fuel



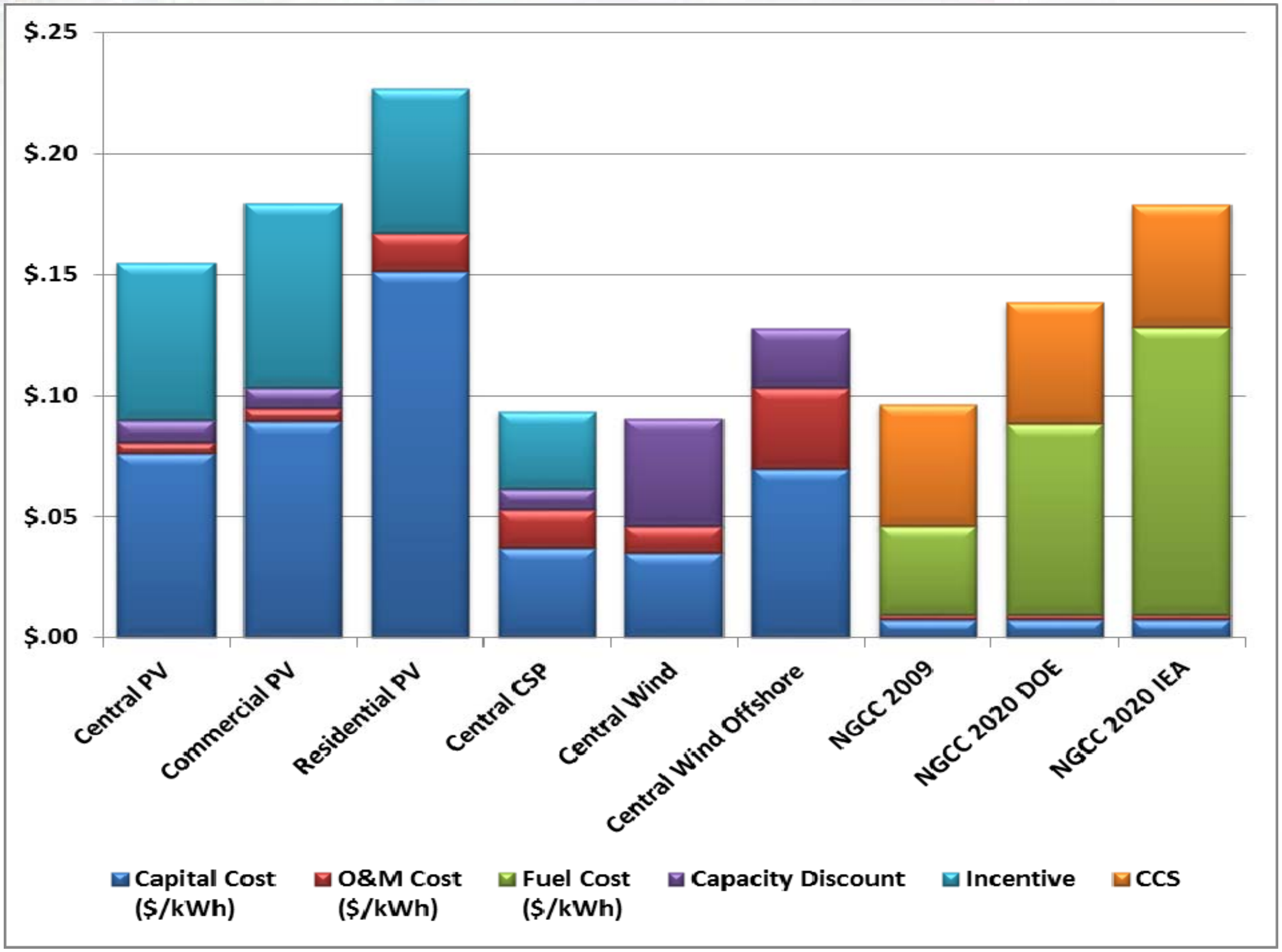
Source: CEC

A32 Criteria Emissions from Offsets

(metric kiloton change from 2020 baseline)

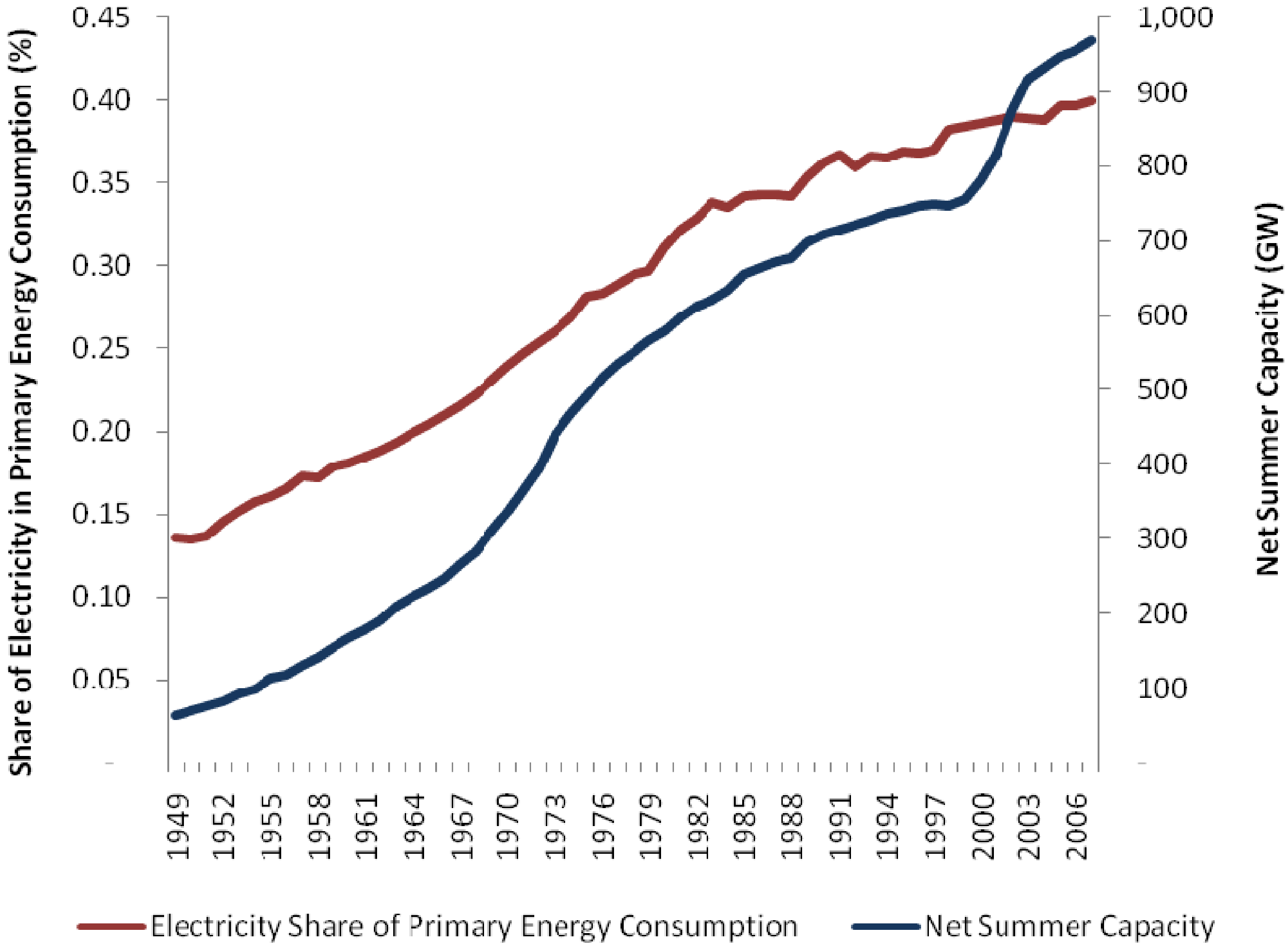


Renewable and Conventional Energy Cost Estimates

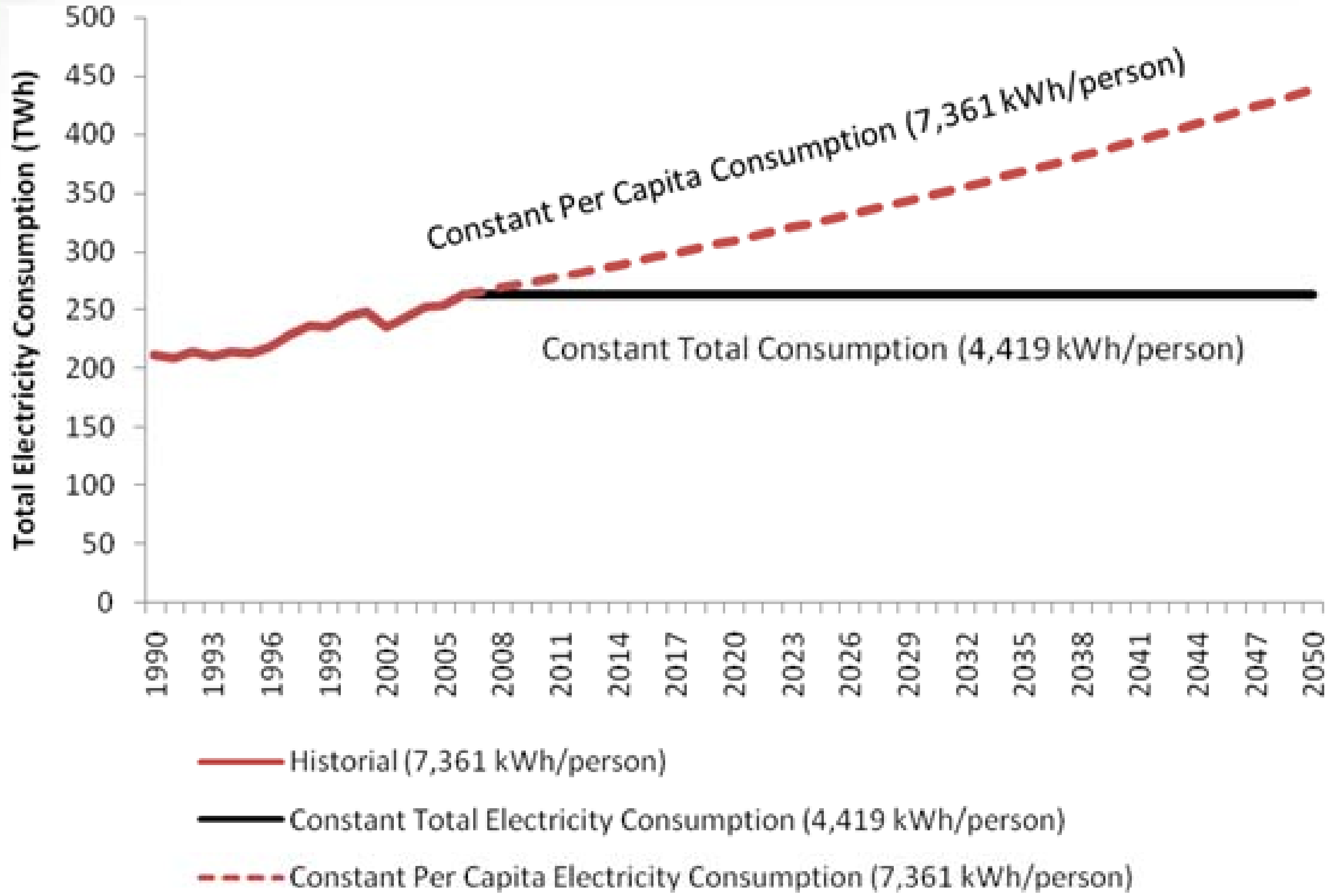


Source: Roland-Holst, David "Energy Prices and California's Economic Security," Next10.org, October, 2009

Vehicle Electrification Capacity



Population is Expected to Double by 2050



Annex 2

BEAR
Model Structure

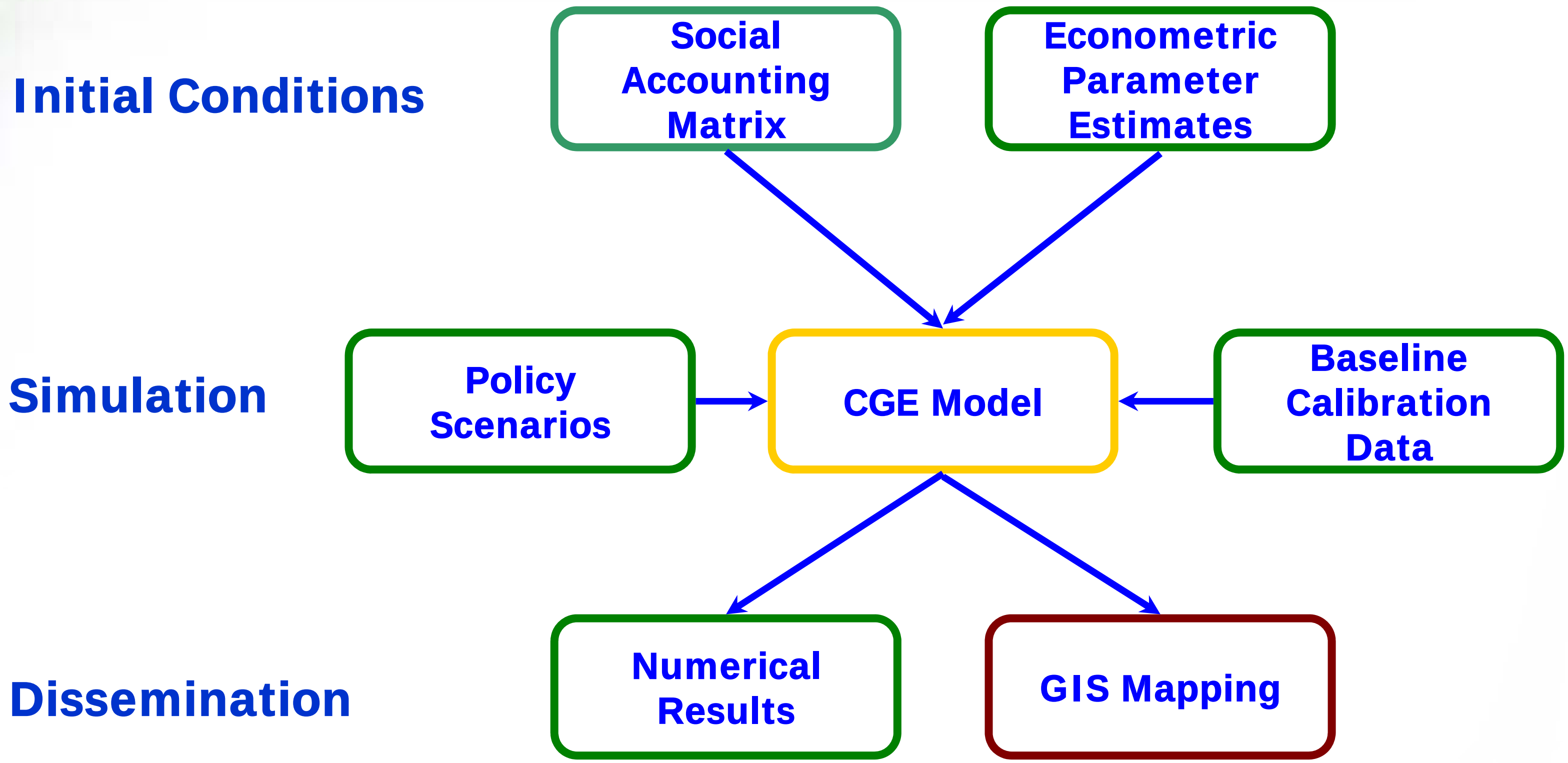
Basic Modeling Tenets

Policy makers need visibility about trends and linkages. Economic models can make a significant contribution to this provided:

1. They incorporate detailed and up-to-date data and methods.
2. Their results must be transparent.
3. They are locally implemented.

In order to achieve these three goals, BEAR uses a three tier modeling facility.

Schematic Modeling Facility



Software Implementation:
Excel GAMS ArcGIS

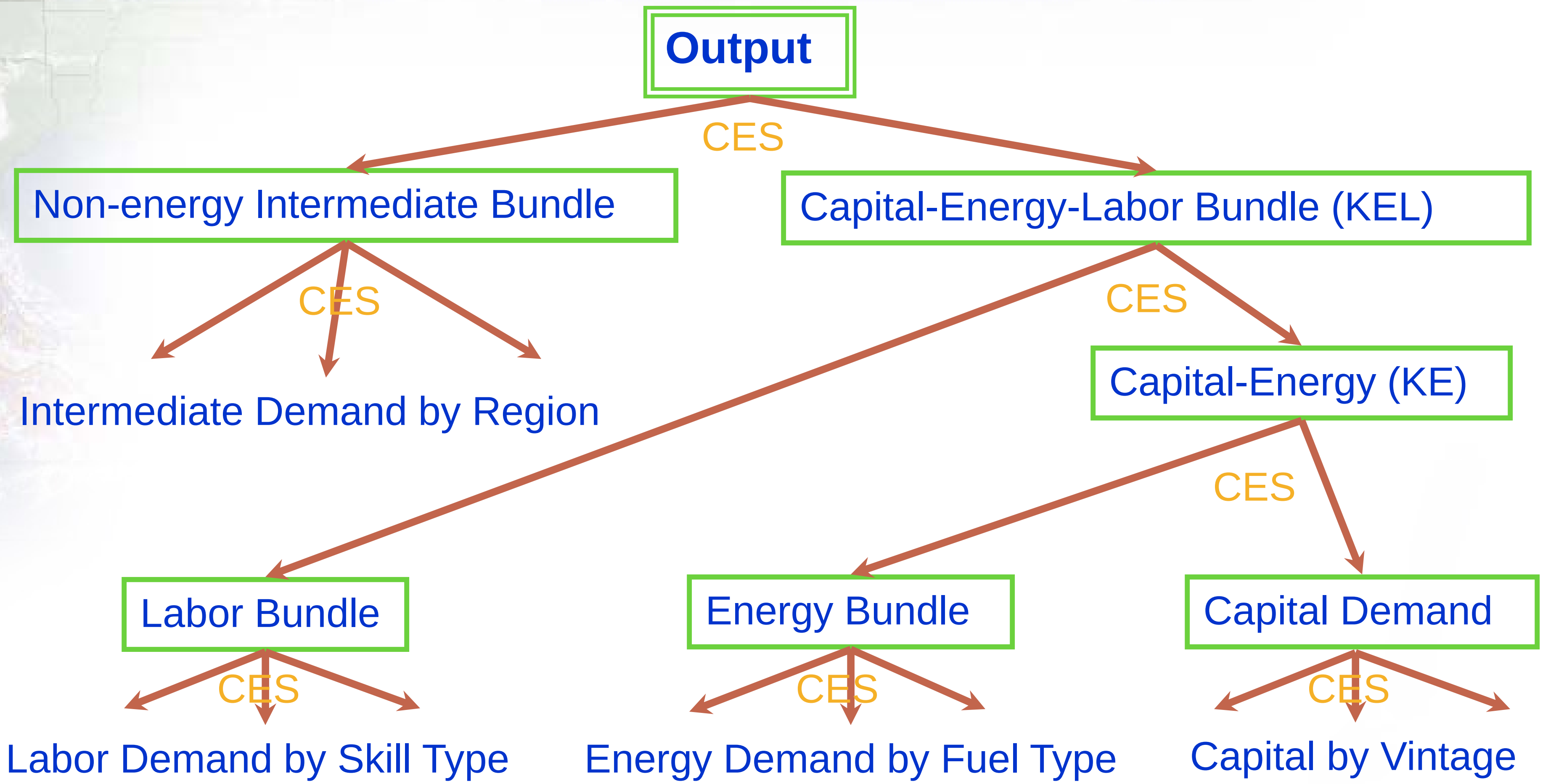
I. Overview

- Multi-sectoral and possibly multi-regional
- Constant-returns-to-scale and perfect competition
- Recursive dynamic
- Ten representative households
- Government and investment activities
- Detailed emissions

II. Production

- Supply – Firm-level production technology with Leontief intermediate use.
- Two production archetypes:
  - Agriculture (extensive vs. intensive), including land, energy and agricultural chemicals as substitutable inputs
  - Other (standard capital-labor substitution)
- Labor, Capital, Land, and Energy (by fuel type) are factors of production

Nested Production Structure



III. Capital and Land

- Two vintages of capital, old (sector specific) and new (mobile), each with its own productivity and relative price
- Land is specific to agriculture, but “mobile” between agricultural products

IV. Labor

- Supplied by households in response to a labor-leisure choice
- Employed by sector and occupation, with perfect mobility between the former and none (currently) between the latter
- Labor markets are perfectly competitive
- Migration is not currently modeled

V. Households

- Ten representative household categories, but state income tax bracket
- Income from all factors, enterprises, public and private transfers
- Consumption modeled with the Extended Linear Expenditure System
- Extensive tax and transfer mechanisms
- Demographic dynamics (population, labor force participation)

VI. Other Final Demand

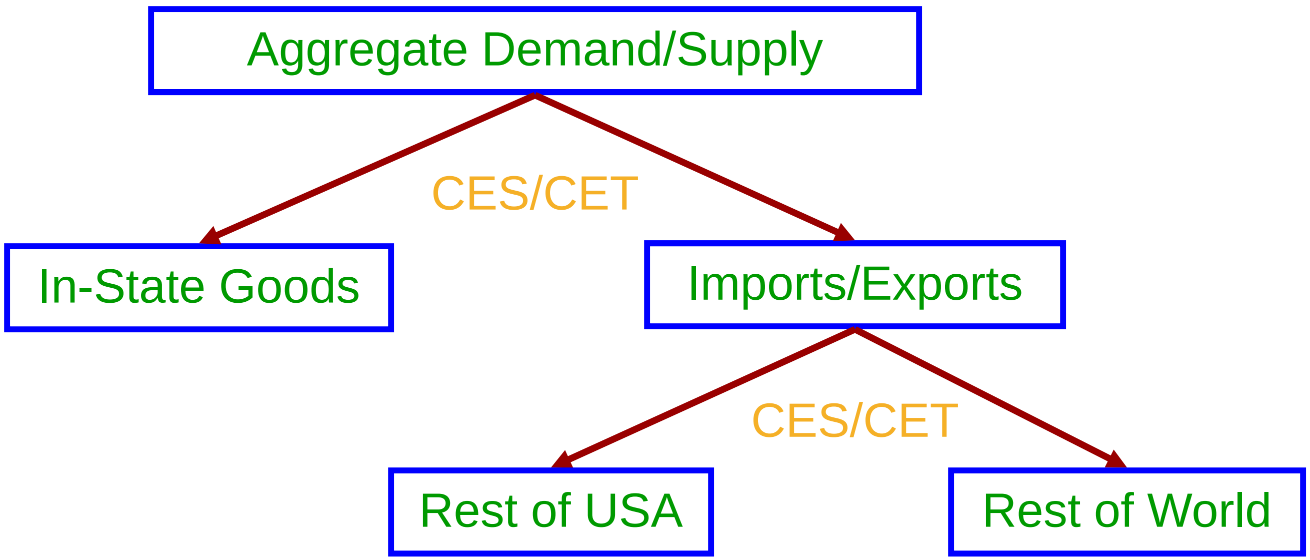
- Other final demand accounts are represented by a single demand matrix.
- Examples are
  - government current spending
  - government capital spending
  - private capital spending
  - trade and transport margins for domestic and imported goods
- All these final demand vectors are presently assumed to have fixed expenditure shares .

VII. Government

- Government is a passive actor in the baseline, adhering to established expenditure patterns and fiscal programs
- The model details extensive accounting for transfer relationships between institutions (fiscal, capital flows, remittances, etc.).
- Government behavior is a primary driver of scenarios, but this behavior remains largely exogenous (subject to fiscal closure)

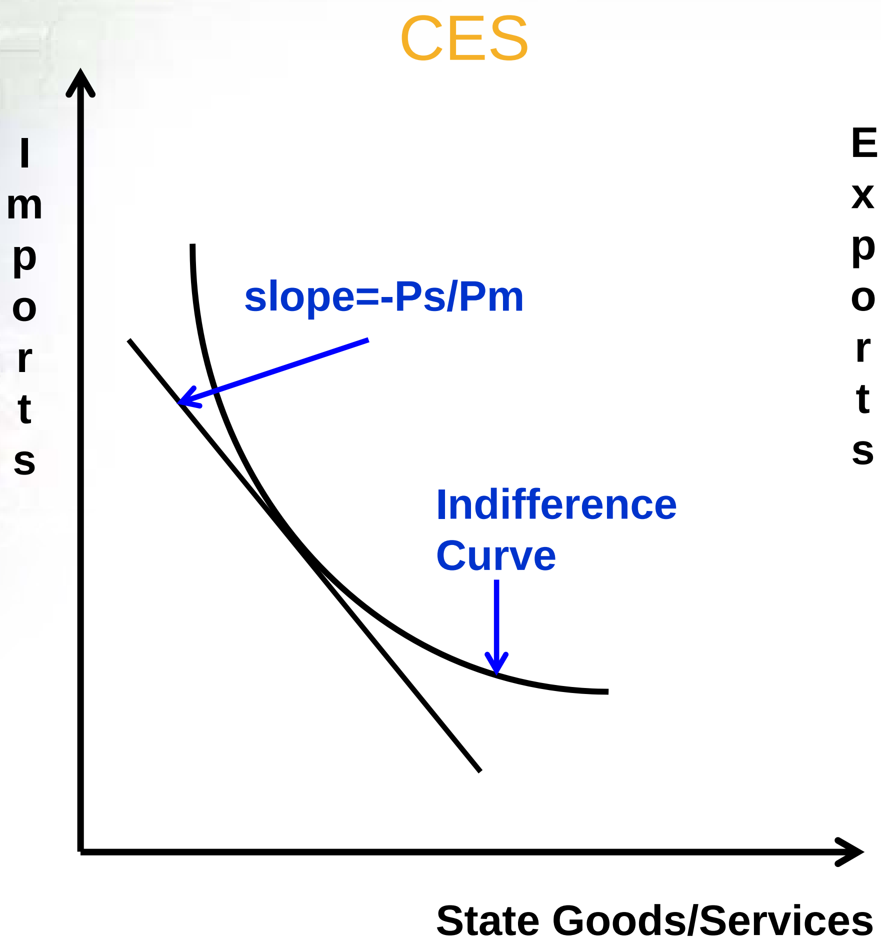
VIII. Trade

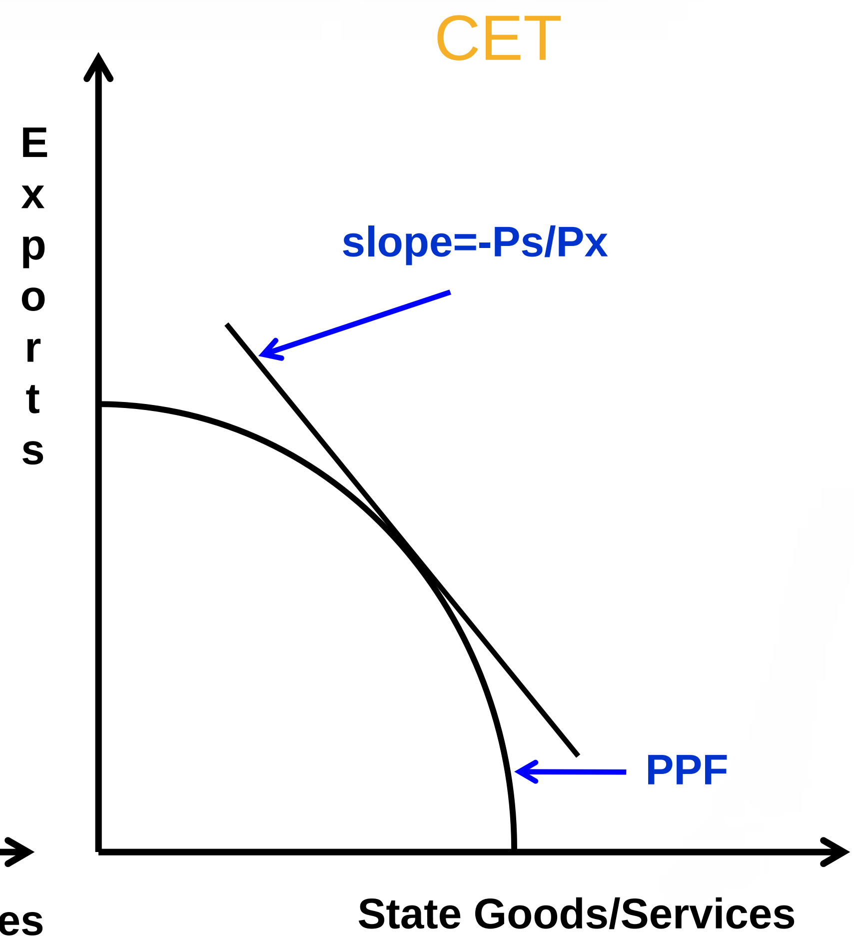
- Demand is thought to combine in-state and imported goods in each product category with a nested CES aggregation



- Output is modeled symmetrically with a dual nested CET structure

Trade Schematically





Trade Prices

- A single domestic price equilibrates demand and supply of each domestic good.
- Each trade node clears with a market-clearing price. The model thus has (nxr)(r+1) trade prices, for n goods and r trading partners.
- FOB/CIF wedges are modeled using trade and transport margins.

IX. Equilibrium Conditions

- Combined in-state and external demand equal supply for every good and service
- In-state factor (labor, land, capital) supply equals in-state factor demand
- California's net outflow of goods and services equals its net claims on external financial assets

X. Macroeconomic Closure

- Taxes on intermediate inputs and final demand, factors of production, output, trade, and households.
- All taxes are exogenous save household direct taxes. The latter are endogenous to hit a given fiscal balance.
- Investment is driven by savings (private, public and foreign).
- Net external savings are exogenous.
- The model numéraire is in-state manufacturing value added.

XI. Dynamics

- Labor force and population growth are currently exogenous.
- Capital stock is driven by past investments and depreciation.
- Total factor productivity is calibrated in baseline to achieve a GDP growth target.
- Productivity is currently exogenous.

XII. Emissions

Emissions are modeled as a composite of pollution in use and in process

1. *Pollution in Use* arises from per unit, intermediate and final consumption of goods and services
2. *Pollution in Process* is residual pollution, ascribed to production on a per unit of output basis

Non-CO2 Emission Categories

Air	1 Suspended particulates
	2 Sulfur dioxide (SO2)
	3 Nitrogen dioxide (NO2)
	4 Volatile organic compounds
	5 Carbon monoxide (CO)
	6 Toxic air index
	7 Biological air index
Water	8 Biochemical oxygen demand
	9 Total suspended solids
	10 Toxic water index
	11 Biological water index
Land	12 Toxic land index
	13 Biological land index

Economy-Environment Linkage

Economic activity affects pollution in three ways:

1. *Growth* – aggregate growth increases resource use
2. *Composition* – changing sectoral composition of economic activity can change aggregate pollution intensity
3. *Technology* – any activity can change its pollution intensity with technological change

All three components interact to determine the ultimate effect of the economy on environment.

Model Development Priorities

- Cap and Trade
- Electricity sector build-out
- Better modeling of vehicle and durable adoption behavior
- Renewable Energy Alternatives
- Combined Heat and Power – Moderate gains in statewide efficiency, benefits outweigh costs

XIV. Model Extensions

- Carbon sequestration – A complex portfolio choice among alternative storage media, but significant potential benefits
- Conservation – The biggest energy "resource," but technology adoption needs to be better understood
- Location/mapping
- Biofuels – ag. sector linkage

Annex 3

The
EAGLE
Model

EAGLE Overview

Environmental Assessment in GeneraL Equilibrium (EAGLE)

- Lineal Descendant of the BEAR California assessment model
- Extended to Western Climate Initiative
- Now extended to the national level, detailed each of 50 states
- Much more detailed information on economic adjustments than ADAGE, IGEM, NEMS, MARKAL, MRN, NEEM, etc.
- An economy-wide general equilibrium *forecasting* model, 2050 time horizon, forecasting annually
- Assessment including, for every state, but not limited to:
  - Economic growth projections
  - Household income deciles
  - Federal, state, and local government accounts (detailed fiscal instruments)
  - Up to 170 sectors/commodities
  - Employment by occupation
  - Tracks more non-CO2 emission categories (14)

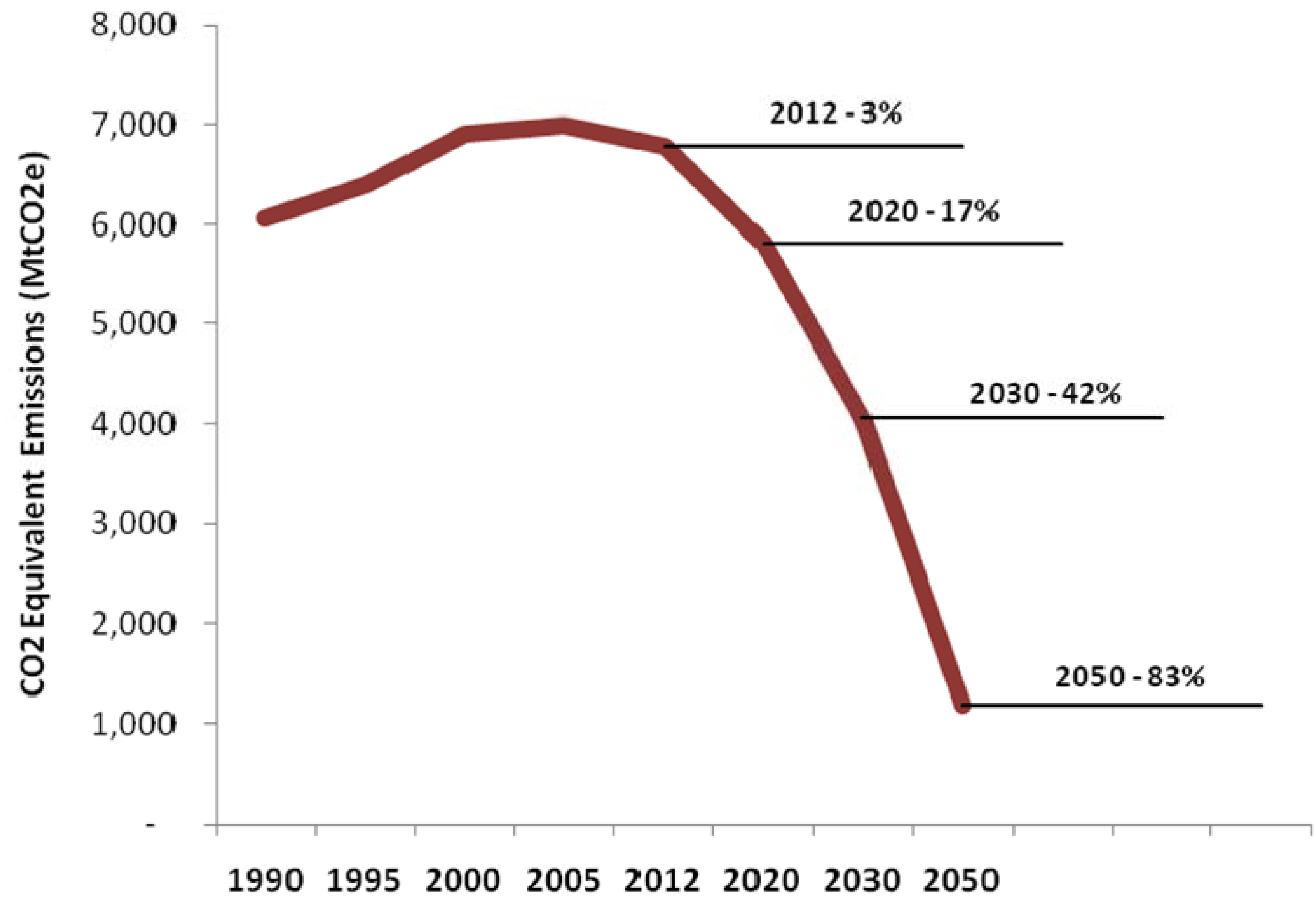
EAGLE Modeling Process

- An economy-wide accounting framework that captures detailed income-expenditure linkages between economic institutions and agents (e.g. government, consumer, and firm spending, and imports and exports)
- A large set of supply and demand equations iterate until they simultaneously reach equilibrium
- The initial conditions are calibrated to detailed input-output accounts and a reference dynamic baseline
- Other inputs:
- Population and other labor force composition
  - Independent baseline macro trends (States, U.S., Rest of World)
  - Productivity growth trends
  - Exogenous world prices (energy and other commodities)
  - Baseline emission intensities

How do we use EAGLE?

- Run the same policy scenarios as those developed in the MARKAL and NEMS analyses
- Compare economic predictions between the policy scenarios run in EAGLE to the EAGLE basseline (no-carbon-constraint) scenario
- Compare economic predictions at the national level between NEMS and EAGLE; analyze similarities and differences
- Compare the technology paths between MARKAL, NEMS, and EAGLE
- EAGLE is particularly suited to elucidating the role of technological change, a primary source adaptation capacity and growth potential

WM Emission Reduction Targets



Main EAGLE Findings for WM

- All 50 states can gain economically from strong federal energy and climate policy, despite the diversity of their economies and energy mixes. The states may differ on the supply side, but on the demand side they all have substantial opportunities to grow their economies by promoting energy saving and domestic renewable energy alternatives.
- Contrary to what is commonly assumed, comprehensive national climate policy does not benefit the coasts at the expense of the heartland states. In fact, heartland states will gain more by reducing imported fossil fuel dependence because they are generally spending a higher proportion of their income on this low employment, high price risk supply chain. Demand side policies make a bigger difference for more carbon-dependent states, and carbon reduction opportunities represent riper and lower hanging fruit.
- The country as a whole can gain 918,000 to 1.9 million jobs, and household income can grow by $488 to $1,176, by 2020 under comprehensive energy and climate policy. By aggressively promoting efficiency on the demand side of energy markets, alternative fuel and renewable technology development on the supply side can be combined with carbon pollution reduction to yield economic growth and net job creation. Indeed, a central finding of this research is that **the stronger the federal climate policy, the greater the economic reward.**

Source: http://are.berkeley.edu/~dwrh/CERES_Web/Docs/ES_DRHFK091025.pdf

State Initial Emission Intensity and Employment Impact in 2020