Application of EMPAX-CGE As Economic Driver for Emission Growth Projections

(Presented for 2007 International Emission Inventory Conference)

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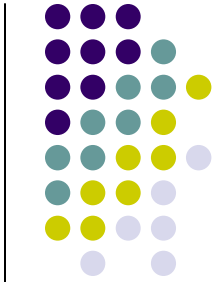
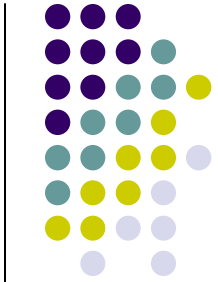
EMPAX-CGE: Presentation Summary



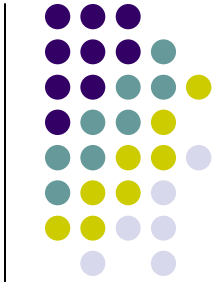
- Emission Projections
- EGAS 5.0:
  - REMI Economic Driver Data
  - Disconnect with Emission Projections for NonEGU Point and Area Sources and Historical Record
- Dynamic Computable General Equilibrium Model
- EMPAX-CGE
  - Baseline Data
  - Sector and Regional Detail
  - Structure and Calibration
  - Intertemporal Dynamics
    - Savings
    - Sources of Growth and Technology Change
    - Capital Accumulation and Mobility

Emission Projections Estimates and their Role in Regulatory Impact Analysis



- EPA generates emission forecasts for all relevant source categories in order to conduct Regulatory Impact Analyses (RIAs) to assess the benefits and costs of air regulations.
- EPA estimates the future-year emissions by forecasting changes in the various activities that generate emissions and using this forecasted activity to generate an emissions growth factor which increases (or decreases) emissions.
  - MOBILE 6.0 and NONROAD model provide mobile sector growth factors
  - Integrated Planning Model (IPM) provide future year output forecasts for Electrical Generating Units
  - Economic Activity Forecast Stationary NonEGU Point and Area Sources Using EGAS 5.0

Economic Growth Analysis System (EGAS 5.0)

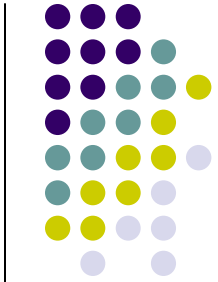


- EGAS 5.0 is a projection tool designed by EPA to generate emissions growth factors used in the development of grown emissions inventories for NonEGU Point and Area sources
- The tool is intended for use by States, Regional Planning Organizations, local governments, and the EPA so that these entities may project air pollution emissions and design appropriate policies to control them
- EGAS 5.0 produces these emission growth factors by linking emissions output to industry-level activity through a series of tables which contain future year industry economic variables by state
  - REMI Policy Insight provides the majority of the economic activity data
  - US Department of Energy, EIA

Disconnect Between Emission Projections and Observed Trend Data

- EPA has observed a disconnect between emissions forecasts for certain stationary non-EGU source categories and the historical record
  - Not apparent with the mobile sector and electrical generating units (EGU)
- Discrepancy appears to have led to over-prediction of NonEGU point and area source future year emissions in longer-forecast periods required for the National Ambient Air Quality Standard (NAAQS) and other programs
- The choice of economic activity driver data for energy-intensive manufacturing sectors in EGAS may be part of the cause of this disparity
  - Economic activity is a primary component of emission projections but data source (REMI) may not be specified for industries most impacted by EPA regulation.
  - REMI
    - Provides economic activity for 70 sectors for future years but does not focus on the interconnections of the energy and energy intensive sectors
    - Does not incorporate compliance costs of future EPA regulations and standards which would likely temper the growth path of the energy-intensive sectors
    - Consequently, REMI-based emissions forecasts for these industries may be inflated
- Alternative Economic Driver: EMPAX-CGE
  - EPA's Dynamic Computable General Equilibrium Model
  - Focus on Energy-Intensive Sectors most affected by EPA Regulations

Dynamic Computable General Equilibrium Model (CGE)

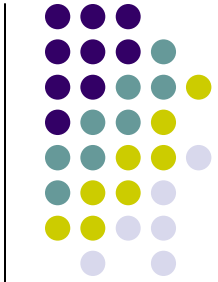


- Solves for changes in Quantity and Price simultaneously in multiple markets taking into account household behavior
- Designed to capture market interactions and industry response from Quantity and Price changes in multiple industries
- Captures the ripple effect on the economy resulting from changes in equilibrium prices and quantities due to various policies
- Dynamic component: Does not expect markets to react and clear in one year. Allows for intermediate and long run impact analysis
- Frequently is a bottom up model
- Ideal for high cost regulations, regional impact analysis, and multiple industry impact analysis

EMPAX-CGE: Overview

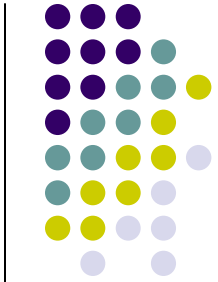
- Dynamic regional economic model of US economy
- 5 Regions (Currently)
  - Aggregation of 10 NERC regions along state lines
- 17 Sectors (Currently)
  - 6 energy sectors (e.g., coal, electricity (fossil & nonfossil), natural gas, etc.)
  - 8 manufacturing sectors (7 energy intensive & 1 non-energy intensive)
  - 3 non-manufacturing sectors (e.g., services, agriculture, etc.)
- Baseline conditions characterized by:
  - IMPLAN state-level economic data
  - DOE/EIA energy data and forecasts
- Intertemporal optimization with perfect foresight

EMPAX-CGE: Baseline Data Summary



- Economic and energy data sources:
  - IMPLAN state-level economic data (information on 528 industries and 9 household types)
  - Energy Information Agency at Department of Energy (AEO, MECS, State Reports, Industry Annuals)
- AEO energy and industrial output forecasts
  - Production and consumption by industry and fuel
  - Incorporate baseline energy efficiency improvements
- Natural resources (coal, crude oil, natural gas)
  - Match resource prices to AEO forecast (as feasible)
  - Set supply elasticity (from MIT) around resulting price path

EMPAX-CGE: Sectoral Detail



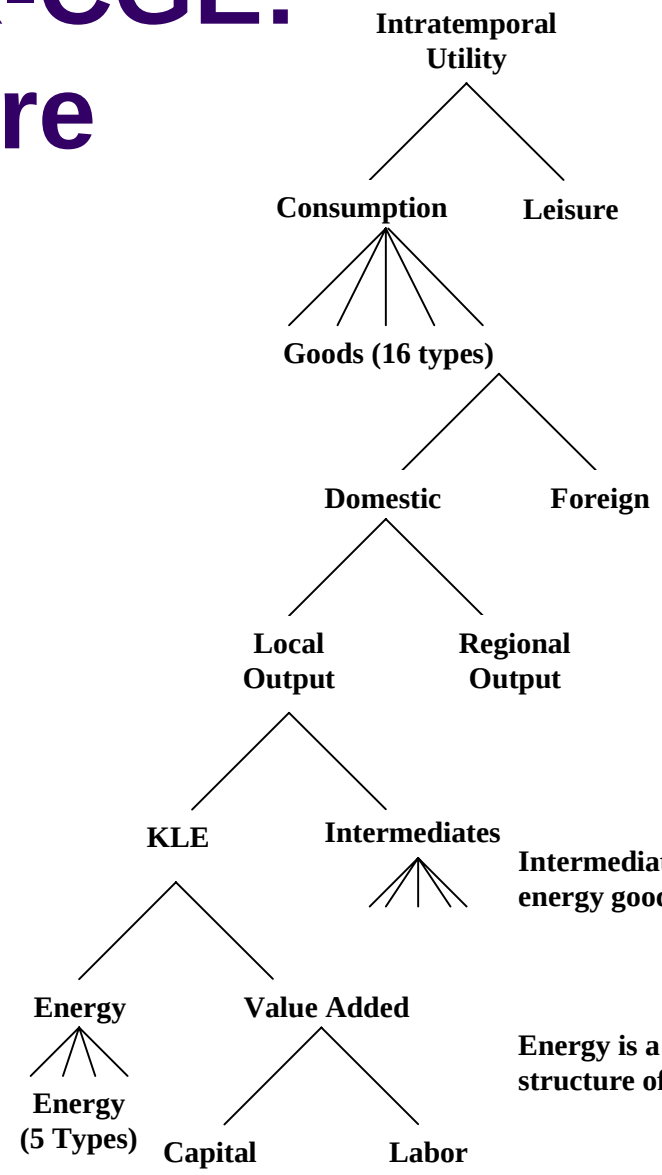
- 17 Sectors in each of 5 Regions:

Energy Production	**Energy-Intensive Sectors**	**Others**
Coal	Food	Agriculture
Crude oil	Paper	Other Manufacturing
Electricity *(fossil and nonfossil)*	Chemicals	Services
Natural Gas	Glass	Transportation
Refined Petroleum	Cement	
	Iron and Steel	
	Aluminum	

- All sectors are interconnected
- Model distinguishes between fossil and nonfossil electricity so costs can be applied separately

EMPAX-CGE:
Current Regional Detail

EMPAX-CGE: Structure



Household utility within a time period is a CES function of consumption and leisure.

Consumption is a Cobb-Douglas composite of the 16 types of goods.

Each consumption good is a CES composite of foreign and domestically produced goods.

Domestic goods are a CES composite of locally produced goods and goods from other regions.

Most producer goods use fixed proportions of intermediate inputs and a capital-labor-energy (KLE) composite.

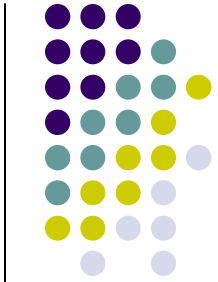
Intermediate materials inputs are the 11 types of non-energy goods, in fixed proportion for each industry.

The KLE composite is a CES function of energy and value-added (KL).

Energy is a CES composite of 5 types of fuel. The structure of this function varies across industries.

Value added is a Cobb-Douglas composite of capital and labor.

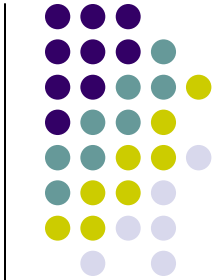
EMPAX-CGE: Calibration & Intertemporal Dynamics



- Model uses nested constant elasticity of substitution (CES) equations
  - Data show inputs currently used to produce output
  - CES functions show options for and ease of substitutions

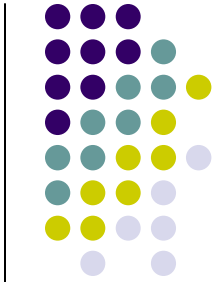
- Calibrated to production functions & elasticities of MIT's CGE model, EPPA (engineering estimates)
- Initial model year of 2005 - AEO forecasts (regional GDP, energy production, industrial output & energy consumption, energy prices)
- Initial year of 2005, usually solves to 2050
- Time periods at 5-year intervals connected by savings-investment decisions of households

EMPAX-CGE: Intertemporal Dynamics



- Sources of Growth:
  - Technology change
    - Technological progress & energy efficiency improvements from AEO forecasts
    - Increases in energy prices encourage industrial efficiency and substitution to K/L as well as household substitution to out of energy goods
  - Increases in natural resources (stocks are modeled)
  - Capital accumulation
  - Labor supply and productivity (regional GDP forecasts)
- Includes capital installation costs that determine adjustment dynamics over time
  - Capital stock levels do not adjust instantly or costlessly
  - Quadratic costs control how fast economy responds (Goulder, McKibbin/Wilcoxen)

EMPAX-CGE: Policy Evaluation



- Environmental expenditures (e.g., compliance costs from the IPM electricity model or AirControlNet) must be allocated to purchases of inputs from other industries within CGE model
  - In absence of other data, Nestor and Pasurka (1995) information on environmental protection expenditures forms basis of this allocation
- Allows model to capture ripple effect to other sectors associated with environmental expenditures by linking them to purchases of their goods and services (and factors of production)

EMPAX-CGE Energy Detail

Baseline Energy Use: Northeast

Sector	Fuel (Quad BTU)	2005	2010	2015	2020	2025	Growth Rate
Household	Electricity	0.64	0.68	0.69	0.71	0.74	0.8%
	Natural Gas	1.27	1.32	1.36	1.43	1.49	0.8%
	Oil	3.59	3.99	4.33	4.61	4.91	1.6%
	Total	**5.49**	**5.98**	**6.38**	**6.75**	**7.15**	**1.3%**
Electricity	Coal	1.69	1.89	1.91	1.96	1.99	0.8%
	Natural Gas	0.97	1.14	1.32	1.50	1.72	2.9%
	Oil	0.49	0.52	0.54	0.55	0.52	0.3%
	Total	**3.15**	**3.54**	**3.77**	**4.00**	**4.23**	**1.5%**
Agriculture	Coal	0.00	0.00	0.00	0.00	0.00	0.0%
	Electricity	0.01	0.01	0.01	0.01	0.01	0.9%
	Natural Gas	0.03	0.03	0.03	0.03	0.03	1.3%
	Oil	0.08	0.09	0.09	0.10	0.10	1.2%
	Total	**0.12**	**0.13**	**0.13**	**0.14**	**0.15**	**1.2%**
Energy-Intensive Manufacturing	Coal	0.34	0.35	0.35	0.34	0.34	0.0%
	Electricity	0.16	0.17	0.18	0.18	0.18	0.6%
	Natural Gas	1.15	1.25	1.33	1.41	1.50	1.3%
	Oil	1.28	1.43	1.57	1.69	1.81	1.8%
	Total	**2.93**	**3.20**	**3.43**	**3.62**	**3.84**	**1.4%**
Other Manufacturing	Coal	0.05	0.06	0.06	0.06	0.06	0.6%
	Electricity	0.16	0.19	0.22	0.24	0.26	2.4%
	Natural Gas	0.44	0.48	0.54	0.60	0.67	2.2%
	Oil	0.41	0.45	0.49	0.52	0.55	1.6%
	Total	**1.05**	**1.18**	**1.30**	**1.40**	**1.54**	**1.9%**
Services	Coal	0.01	0.01	0.01	0.01	0.01	0.9%
	Electricity	0.66	0.73	0.78	0.82	0.88	1.4%
	Natural Gas	0.80	0.84	0.88	0.95	1.01	1.2%
	Oil	0.24	0.25	0.25	0.26	0.26	0.3%
	Total	**1.71**	**1.83**	**1.93**	**2.04**	**2.15**	**1.2%**
Transportation	Coal	0.00	0.00	0.00	0.00	0.00	0.0%
	Electricity	0.01	0.02	0.02	0.02	0.02	1.3%
	Natural Gas	0.05	0.06	0.07	0.07	0.08	2.4%
	Oil	1.68	1.68	1.68	1.68	1.68	0.0%
	Total	**1.75**	**1.76**	**1.77**	**1.77**	**1.79**	**0.1%**
Total	Coal	2.11	2.32	2.34	2.39	2.42	0.7%
	Electricity	1.71	1.87	1.97	2.06	2.17	1.2%
	Natural Gas	4.87	5.30	5.73	6.18	6.73	1.6%
	Oil	7.98	8.88	9.67	10.31	10.98	1.6%
	Total	**16.67**	**18.37**	**19.71**	**20.94**	**22.30**	**1.5%**

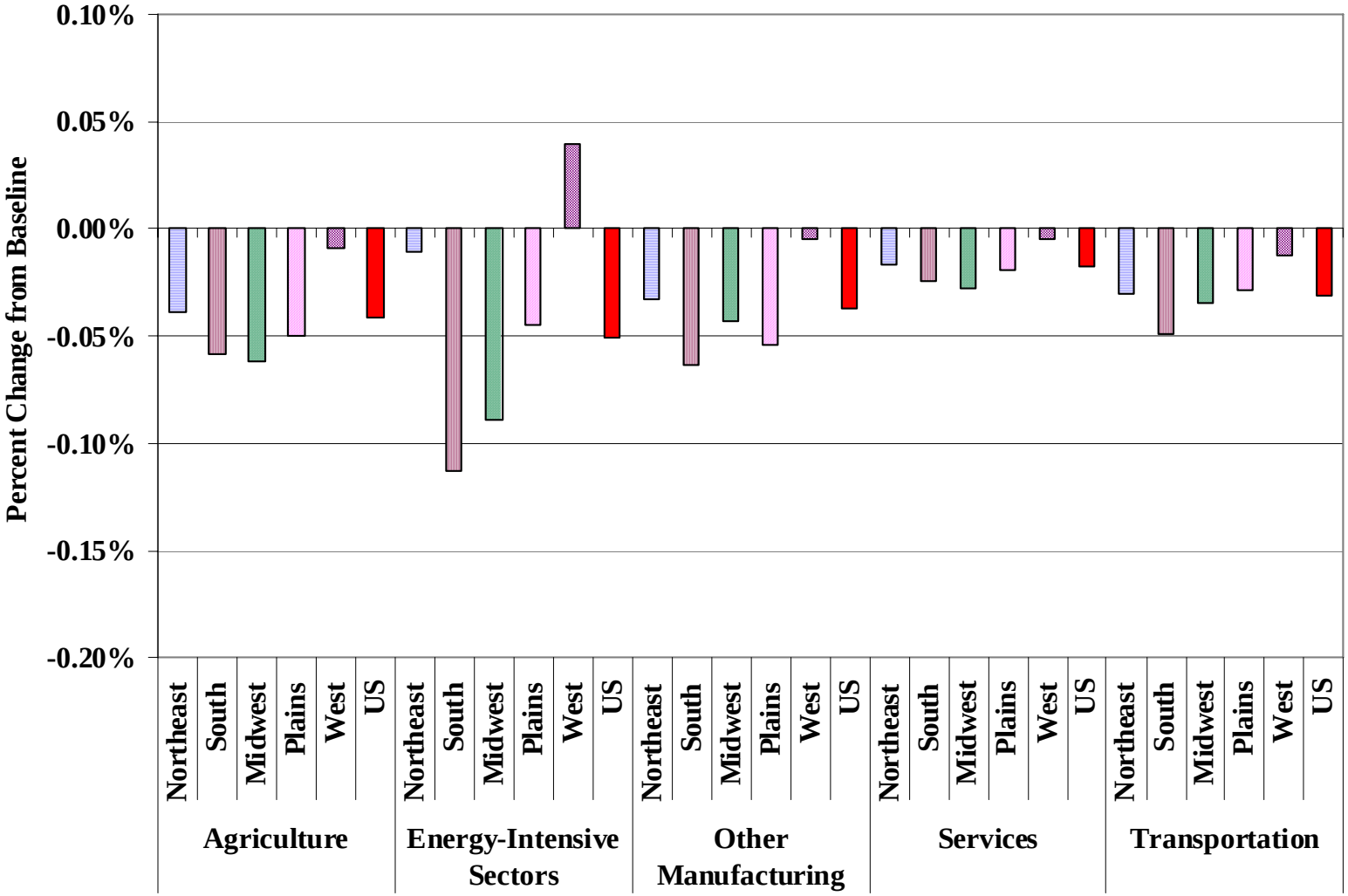
EMPAX-CGE Output

(Ex: Energy Intensive Production - US)

Model Run	Industry	2005	2010	2015	2020	2025	Growth Rate / Average Effect
Baseline Revenue ($ million)	Food and Kindred	$428,137	$460,434	$494,433	$529,365	$563,832	1.4%
	Paper and Allied	$168,599	$186,194	$205,503	$221,028	$236,642	1.7%
	Chemicals	$437,013	$514,623	$593,712	$670,607	$747,446	2.7%
	Glass	$22,082	$26,330	$29,489	$32,245	$35,979	2.5%
	Cement	$6,829	$7,776	$8,571	$8,952	$9,270	1.5%
	Iron and Steel	$83,072	$94,430	$100,583	$101,146	$103,321	1.1%
	Aluminum	$41,747	$46,458	$50,889	$53,445	$56,737	1.5%
Scenario Revenue ($ million)	Food and Kindred	$428,048	$460,237	$494,181	$529,018	$563,478	1.4%
	Paper and Allied	$168,607	$186,125	$205,393	$220,861	$236,472	1.7%
	Chemicals	$436,961	$514,426	$593,398	$670,049	$746,859	2.7%
	Glass	$22,087	$26,318	$29,470	$32,214	$35,947	2.5%
	Cement	$6,827	$7,775	$8,568	$8,946	$9,264	1.5%
	Iron and Steel	$83,089	$94,396	$100,526	$101,056	$103,235	1.1%
	Aluminum	$41,770	$46,460	$50,878	$53,424	$56,713	1.5%
Difference in Revenue ($ million)	Food and Kindred	-$90	-$197	-$252	-$347	-$354	-$248
	Paper and Allied	$8	-$69	-$110	-$168	-$170	-$102
	Chemicals	-$51	-$197	-$314	-$558	-$588	-$341
	Glass	$5	-$12	-$19	-$31	-$32	-$18
	Cement	-$2	-$1	-$3	-$5	-$5	-$3
	Iron and Steel	$17	-$34	-$57	-$89	-$85	-$50
	Aluminum	$23	$1	-$11	-$22	-$24	-$6
Percentage Change in Revenue (%)	Food and Kindred	-0.02%	-0.04%	-0.05%	-0.07%	-0.06%	-0.05%
	Paper and Allied	0.00%	-0.04%	-0.05%	-0.08%	-0.07%	-0.05%
	Chemicals	-0.01%	-0.04%	-0.05%	-0.08%	-0.08%	-0.05%
	Glass	0.02%	-0.04%	-0.06%	-0.10%	-0.09%	-0.05%
	Cement	-0.03%	-0.02%	-0.03%	-0.06%	-0.05%	-0.04%
	Iron and Steel	0.02%	-0.04%	-0.06%	-0.09%	-0.08%	-0.05%
Percentage Change in Quantity (%)	Food and Kindred	-0.01%	-0.03%	-0.04%	-0.05%	-0.05%	-0.04%
	Paper and Allied	0.00%	-0.04%	-0.05%	-0.08%	-0.07%	-0.05%
	Chemicals	-0.02%	-0.04%	-0.05%	-0.08%	-0.08%	-0.05%
	Glass	0.00%	-0.06%	-0.08%	-0.12%	-0.12%	-0.08%
	Cement	0.06%	-0.04%	-0.07%	-0.09%	-0.09%	-0.05%
	Iron and Steel	0.05%	-0.04%	-0.07%	-0.10%	-0.10%	-0.05%
	Aluminum	-0.02%	-0.12%	-0.14%	-0.19%	-0.17%	-0.13%

EMPAX-CGE Output

(Ex: Regional Production Changes)



EMPAX-CGE Output

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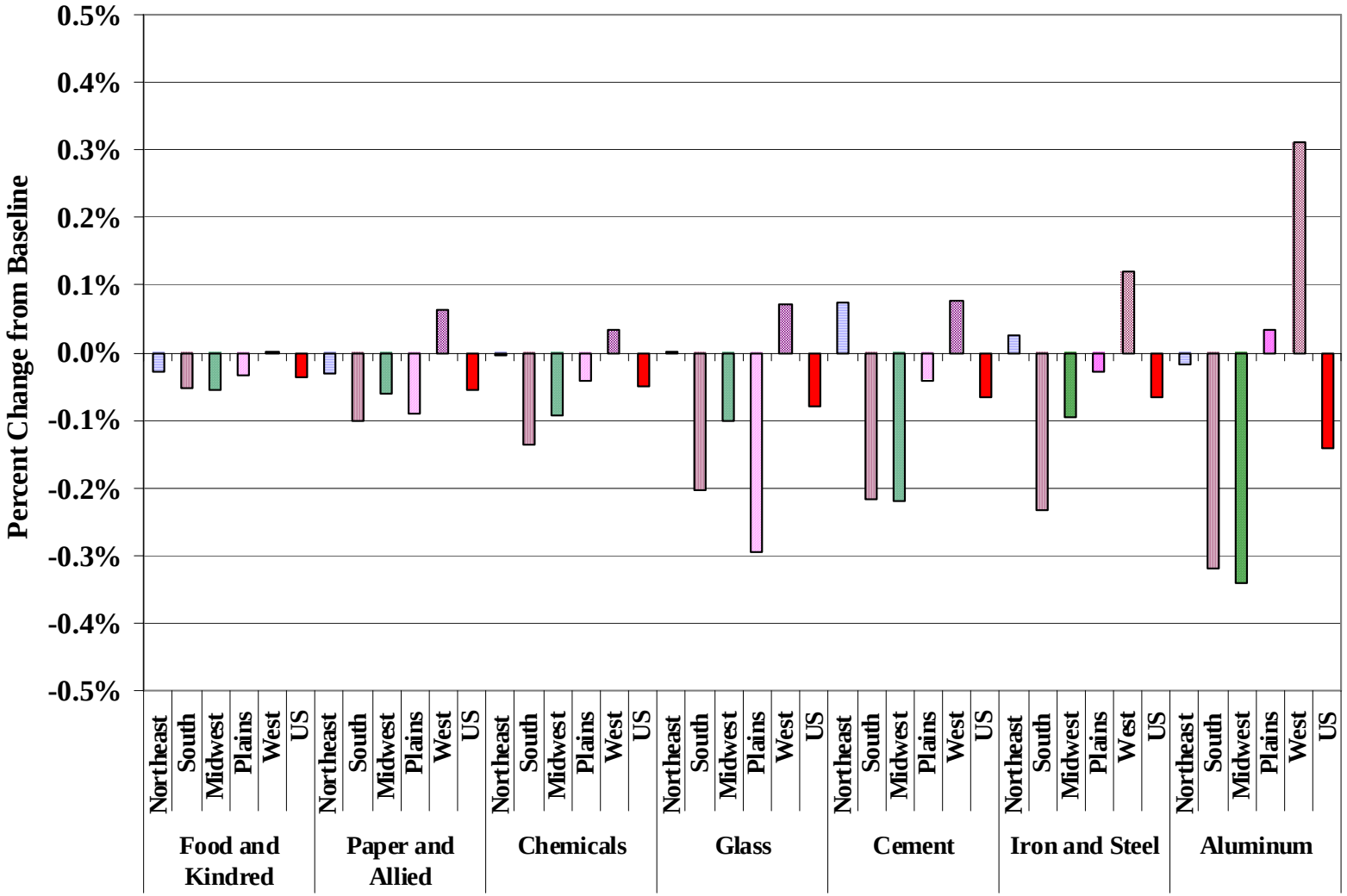
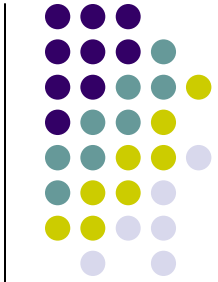


Summary of EMPAX Advantages

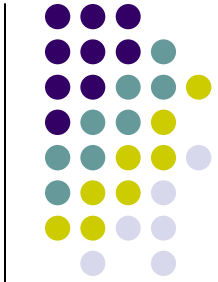
- Captures economic impacts from environmental policy on the US economy focusing on the energy-intensive sectors and taking into account the industries' interconnections
  - The augmentation of EMPAX-CGE to a state level model will improve its ability to generate credible regional and industry level output for EGAS 5.0
- Growth path has incorporated compliance costs for RIAs that impact energy intensive sectors output
- It is the Agency's dynamic computable general equilibrium model
  - Detailed analysis or refinements of industry growth which may be required can be completed in a timely manner

EMPAX-CGE: External Peer Review



- Dr. Charles Ballard, Economics Professor, Michigan State University
  - In many ways, the model described there is an impressive piece of work… generally speaking, I believe that this model is capable of providing insights into the effects of environmental policy changes.
- Dr. Christoph Bohringer, Professor, Center for European Economic Research
  - Overall, the model documentation conveys the impression of solid competent work.
- Dr. Hillard Huntington, Stanford Energy Modeling Forum
  - The model will be very useful for deriving regional and sectoral impacts of environmental policies that use economic instruments that directly affect the costs of using different energy types.
- Suggestions for Improvement:
  - Provide results from analyses – at the time, there were no publicly available findings.
  - Conduct sensitivity analyses to illustrate model reactions.
  - Consider adjusting some of the elasticity parameters
  - Add additional descriptions of policy evaluation techniques.

Concluding Remarks and Other Variables Affecting Emissions Projections



- Incorporation of EMPAX into EGAS 5.0 will improve the economic data used to drive emission projections and likely result in improved projections
- Economic driver data would be based on a model designed to estimate economic output for important portion of all stationary NonEGU sources in the emissions inventory
- Other variables affecting emissions projections that need to be analyzed in addition to aggregate industry economic activity
  - Changes in vintages of capital equipment
  - Changes in population and land use along with their impact on motor vehicle miles traveled and energy use
  - Emission controls implemented to satisfy CAA regulations, voluntary programs and other initiatives expected to reduce air emissions
  - Technological innovation or changes altering:
    - Production processes for emission sources
    - Control technologies available