Modeling a Technology-Based Climate Strategy within an Equilibrium Framework

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Three Paths of GHG Reductions

- ***Trading Path*** which has received the widest level of interest and analysis among analysts
- ***Technology Path*** which may offer large domestic benefit from greenhouse gas reductions
- But a *Practical* ***Path*** will likely be a mix of the two
- Moreover, all of the reductions will driven by some ***mix of policies, tax shift and/or price changes***

Overview of Major Topics

- The “Top-Down/Bottom-Up” Debate
- The Clean Energy Futures (CEF) study
- Sketch of the AMIGA model
- AMIGA applied to the CEF

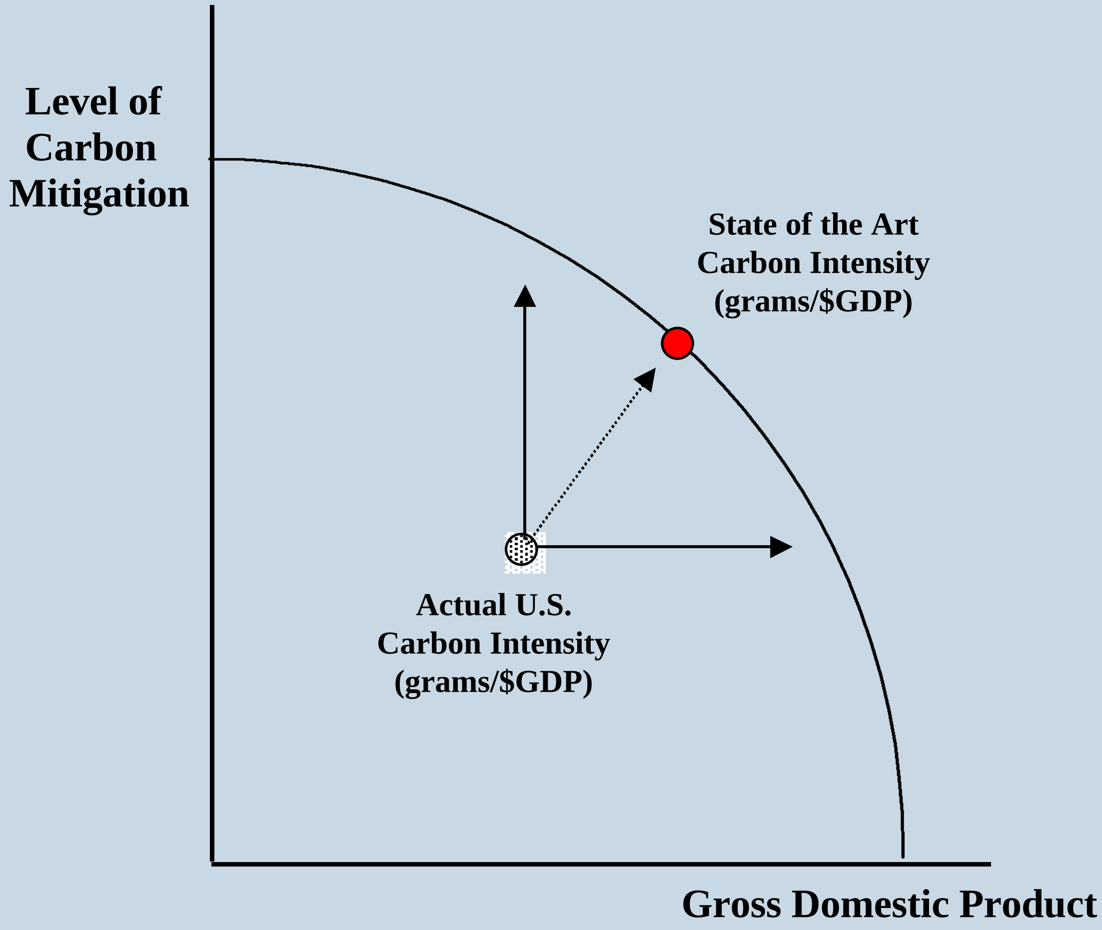
The "Top-Down/Bottom-Up" Debate (from an American perspective)

- Two Interpretations of "Bottom-up:"
  - Increased detail on technology, but baseline equilibria optimal (exclusive of environmental externalities).
  - Increased detail on technology, but baseline equilibria embody systematic inefficiency in market allocations of energy efficiency.
- The second interpretation is generally rejected by energy-economic modelers.

However...

- A 40+ year theoretical and empirical literature in the fields of economics and operations research.
- The basic notion of technical efficiency dates back to Koopmans (1951), Debreu (1951), and Farrell (1957), and more recently by Boyd, Färe, and S. Grosskopf (1998), Sanstad, DeCanio, and Boyd (2000), and Laitner, DeCanio and Peters (2001).
- The bibliography published by Cooper et al. (1999) contains over 1,500 references to inefficiency.
- This literature goes beyond the ‘bottom up’ engineering estimates of energy saving technology.

Trade-Offs Between Environment and Economy: Interpreting the Production Possibilities Frontier



Background on
Clean Energy Futures study

- Initiated by the U.S. Department of Energy (DOE) in Nov. 1998; conducted by a consortium of DOE National Laboratories.
- Undertaken to address key criticisms of the previous "5-lab Study": *Scenarios of U.S. Carbon Reductions* (1997).
- **Goal:** to identify and analyze policies that promote efficient and clean energy technologies to reduce carbon emissions and improve oil security and air quality
- Published in Nov. 200

Two Scenarios

- Defined by policies that reflect increased levels of national commitment to energy and environmental goals.

(1) **Moderate Scenario:** relatively non-intrusive, no-regrets or low-cost policies.

- assumes some shift in political will & public opinion
- excludes fiscal policies that involve taxing energy

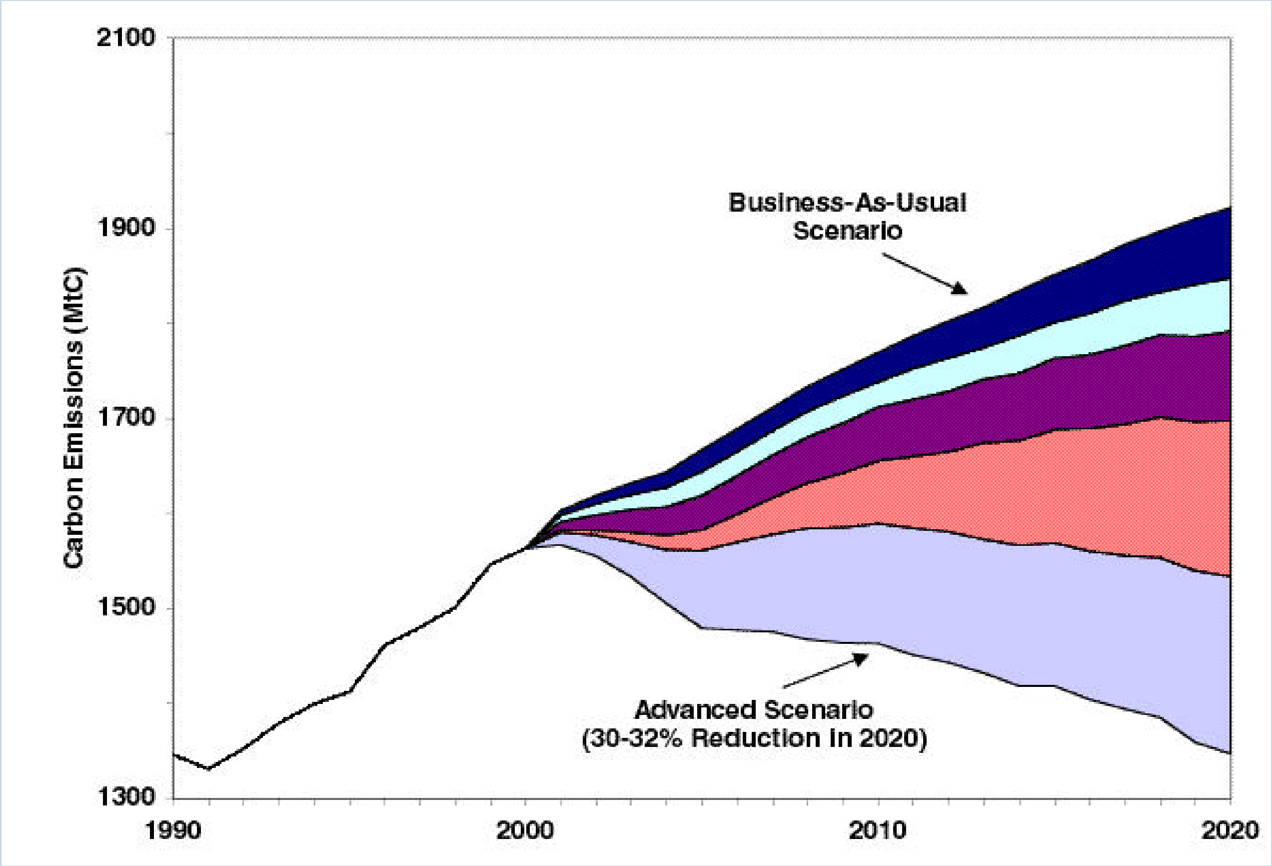
(2) **Advanced Scenario:** more vigorous policies.

- assumes a nationwide sense of urgency to address energy-related challenges
- includes a domestic carbon trading system with assumed permit price of $50/tC.

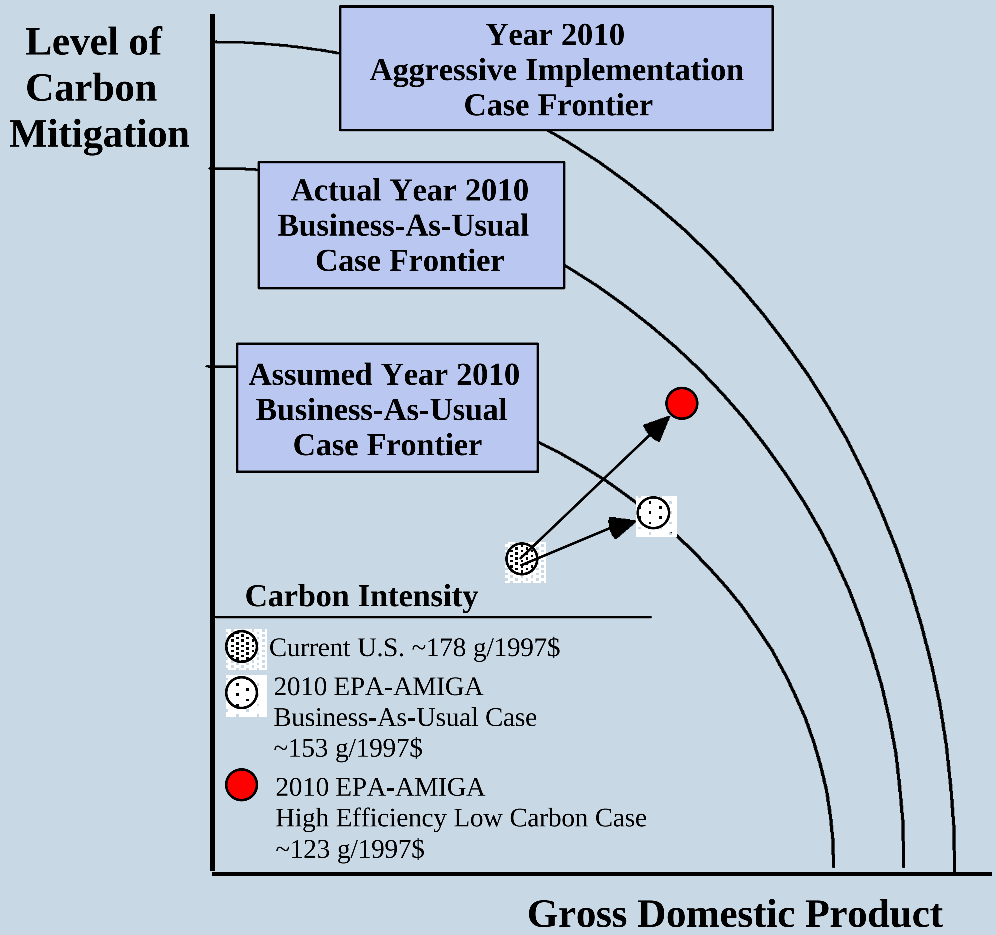
Key Policies – CEF Advanced Scenario

Buildings	Industry
–Efficiency standards for equipment –Voluntary labeling and deployment programs	–Voluntary programs –Voluntary agreements with individual industries and trade associations
Transportation	**Electric Utilities**
–Voluntary fuel economy agreements with auto manufacturers –"Pay-at-the-pump" auto insurance	–Renewable energy portfolio standards and production tax credits –Electric industry restructuring
Cross-Sector Policies	
– Doubled federal R&D	–Domestic carbon trading system

Carbon Emission Reductions Clean Energy Future Advanced Scenario, by Sector



Opportunities for Climate Change Actions by Reducing Carbon Inefficiencies in the United States



Source: EPA-AMIGA Policy Scenario Analysis, Fall 2000

AMIGA is a General Equilibrium Model Designed to Incorporate Key Elements of the "Bottom-Up" Perspective

- Allows for reference equilibrium inside production frontier.
- Models effects of informational programs, etc., through reductions in "hurdle rates" for energy efficiency.
- AMIGA can evaluate a variety of policy alternatives for
  - energy service demands
  - investment and capital stock implications
  - patterns of purchased energy
  - sectoral shifts and impacts
  - labor allocations
  - gross domestic product
  - personal consumption
  - trade balance
- Early support for the development of AMIGA was provided by the DOE Office of Energy Efficiency and Renewable Energy, recent support by the EPA Office of Atmospheric Programs.

Understanding AMIGA Results

A basic accounting identity:

GDP = Investment + Personal Consumption +
Government Spending + Net Exports

In AMIGA, an “investment-led” energy efficiency strategy can lead to:

(1) greater investment in efficient/low-carbon technologies;
(2) increased spending as a result of energy bill savings;
(3) R&D, incentives, and market development programs; and
(4) reduced oil imports

Therefore, an investment-led climate strategy can lead to a small but net positive gain for the economy

Summary of an AMIGA Analysis of the Clean Energy Future Study

- An advanced or High Efficiency/Low Carbon (HELC) scenario based upon an approximate doubling of current program expenditures and R&D activities. The work was done in cooperation with EPA/OAP and the Argonne National Laboratory (ANL)
- With carbon at $50 per tonne, domestic energy-related carbon emissions are projected to be reduced by ~289 MtC by 2010, or about 52 percent of the Kyoto Protocol (with emissions reduced by 7 percent of 1990 levels).
- The carbon reductions are made possible by a combination of energy efficiency improvements (~65%) and fuel switching and renewable energy technologies (~35%).
- Under these assumptions, GDP is largely unchanged in 2010 (+$55 billion out of an $11.6 trillion economy); and despite slightly higher energy prices, total energy expenditures are down (-$17 billion).

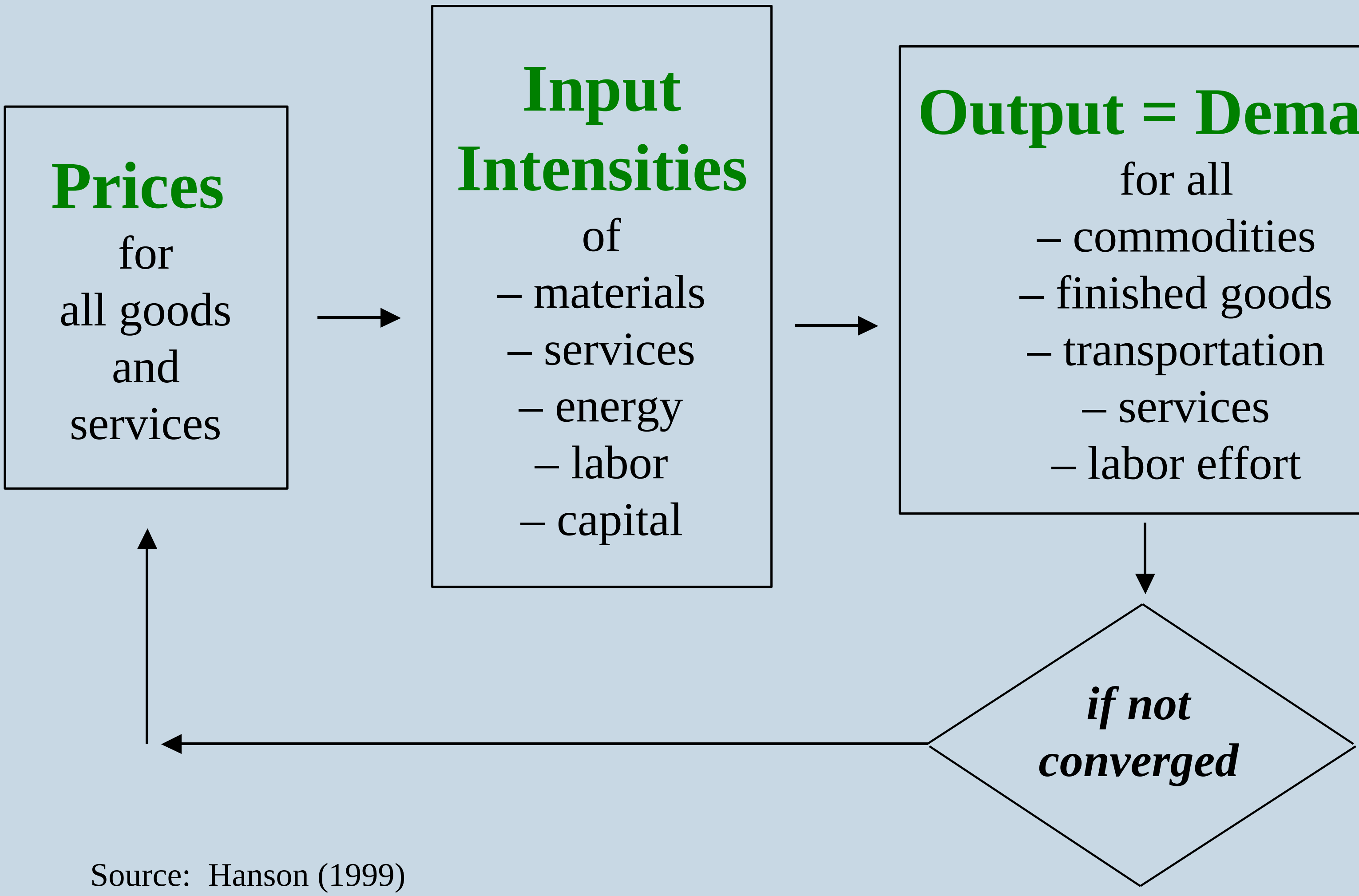
Cost of Energy Services in 2010

(Billions of 1997 Dollars)

Gross Energy Bill Savings:	+$91.3
Carbon Permit Costs:	-$74.5
Investment Costs:	-$39.7
Program Costs:	-$6.7
Recycle Carbon Revenues:	+67.8
Net Savings:	***+$38.2***

Source: EPA-AMIGA Policy Scenario Analysis, forthcoming, Fall 2000

AMIGA Uses a CGE Formulation



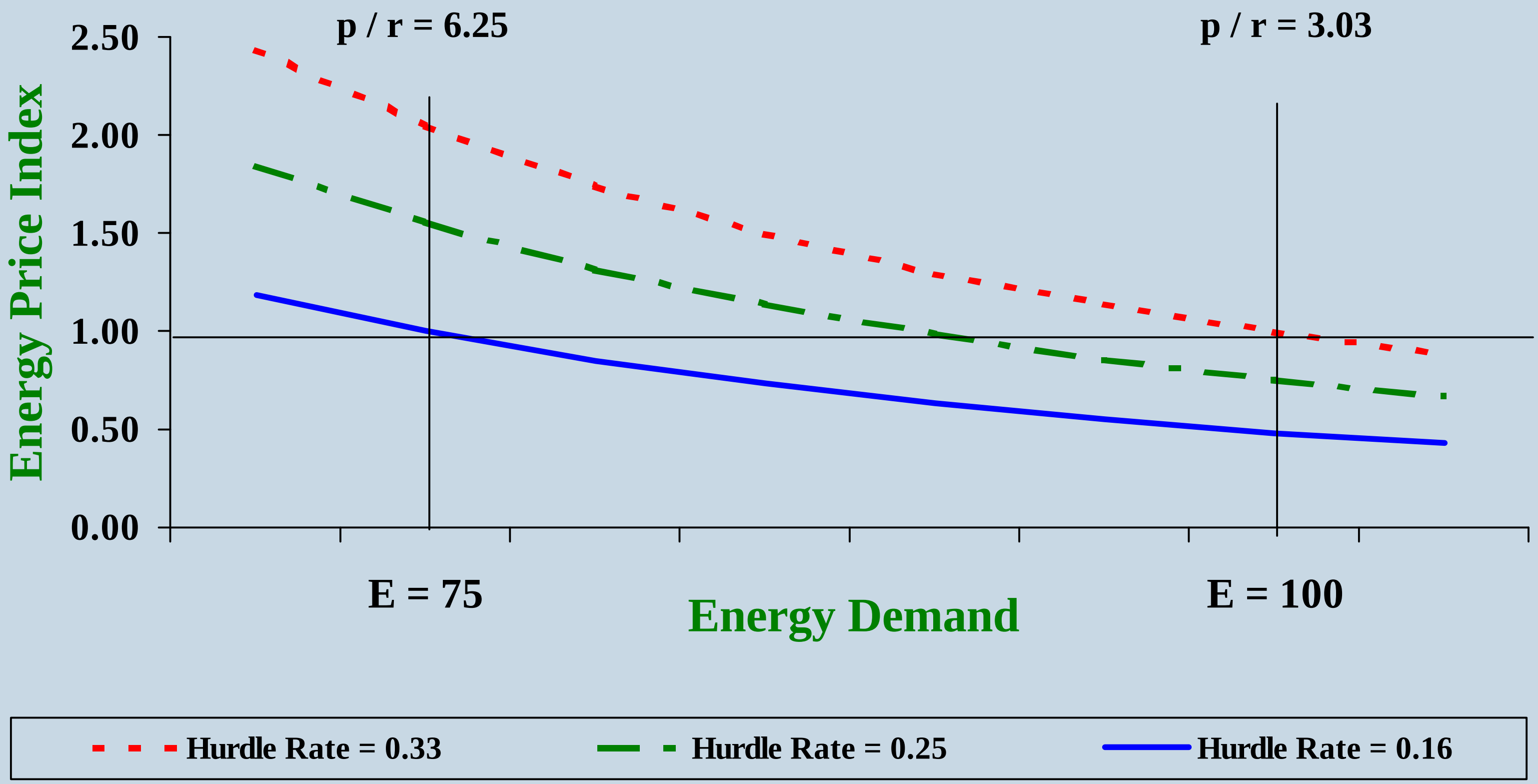
Source: Hanson (1999)

Representation of Factor Demands

- Product outputs, material inputs, labor, capital, and energy are all related though production processes and technology. Expansion of labor input, investment, and technical advances drive economic growth over time.
- The basic representation for the model of factor demands is obtained from the following CES nested production structure for each sector *i* :
  - *Sector Output = f (Utilized Capital, Labor Input)*
  - *Utilized Capital = f (Production Capital, Energy Services)*
  - *Energy Services$_j$ = f$_j$ (Energy-Saving Capital, Energy Input)*

  where *Energy Services* can be provided by multiple energy forms, denoted by *j*.

Complementary Effects of Price and Carbon-Related Policies on Energy Demand

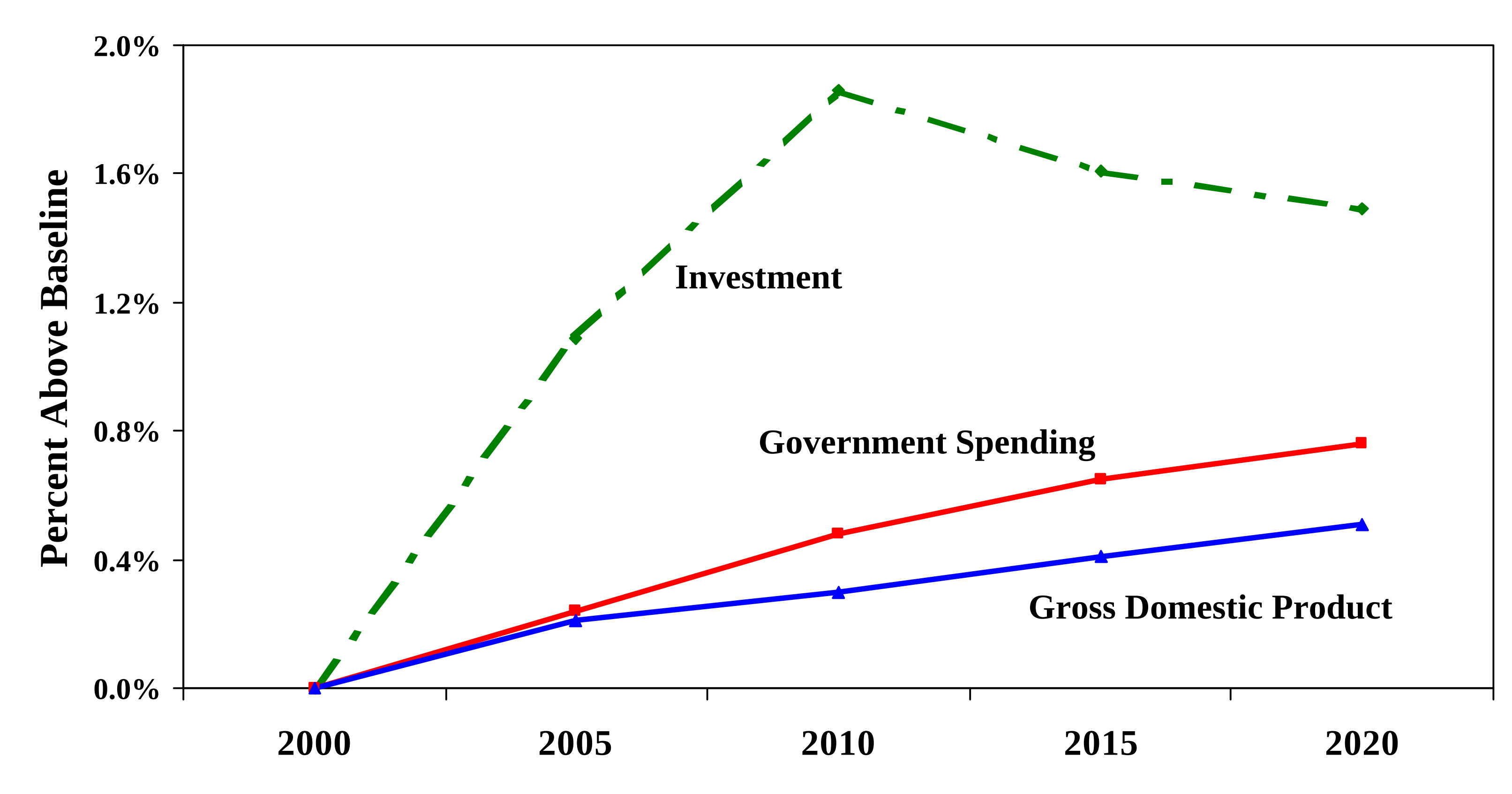


Note: This illustration assumes a price elasticity of -0.40.

Steps in the CEF Analysis

- Generate the CEF Reference Case
- Read NEMS files for Advanced Case scenario
- Adjust inputs to reflect
  - $50 per tonne carbon charge
  - Increased R&D and other program expenditures funded by the carbon charge
  - Unused carbon revenues to offset a portion of payroll taxes

AMIGA Evaluation of CEF Advanced Scenario



Policy and Program Expenditures:
Comparing Impacts in the Reference and Advanced Cases

Impact Category	**2010**	**2020**
R&D	2.8	2.8
Program	3.9	8.8
Residential Investment	11.0	12.2
Commercial Investment	8.0	8.8
Industrial Investment	5.1	5.1
Transportation Investment	19.0	21.0
Coal Mining Investment	-1.2	-2.6
Oil Field Investment	-2.0	-3.2
Electric Power Investment	-0.2	-3.3
Total Investment	39.7	38.0
Carbon Revenue	74.5	69.4
Recycled Revenue	67.8	57.8
Primary Energy (Quads)	-11.04	-22.89
Carbon (MtC)	-288.8	-542.4
Energy Prices (% change)	9%	1%
Energy Expenditures	(16.8)	(135.7)

Note: All values in 1997 billions of dollars, except where otherwise noted.

Changes in Sectoral Output and Jobs:
Comparing the 2010 Reference and Advanced Cases

Sector	Output (Million 97$)	Labor (1000 Jobs)
Agriculture	433	5
Mining, excl fuels	(75)	(1)
Fuel Mining - coal, oil, gas	(15,507)	(53)
Construction	4,827	44
Pulp and Paper	(361)	(1)
Chemicals	(5,983)	(11)
Petroleum refining & products	(8,895)	(3)
Rubber and Plastic Products	883	5
Printing and Publishing	354	4
Other Nondurable Mfg	2,963	14
Iron and Steel	(3,418)	(11)
Durable Manufacturing	23,666	98
Purchased Electricity & Services	(32,612)	(83)
Gas transport & distribution	(7,620)	(24)
Transport, Commun, Water	(4,470)	(39)
Wholesale/Retail trade	3,444	64
Finance, Ins, Real Estate	5,385	13
Services	10,115	73
All Other	3,454	52
Total	(23,417)	146

Net GDP Impacts:

Changes in the Reference and Advanced Cases

GDP Category	2010	2020
Personal Consumption	20.2	44.2
Government	5.3	9.9
Investment	42.9	42.6
Exports	-2.1	6
Imports	11.1	-4.8
Total GDP	55.2	107.5

Caveats to this Policy Impact Analysis

- Items that may reduce economic benefits:
  - Only an initial evaluation of policy effectiveness
  - No specific R&D outcome or focus
  - Tentative assumptions about capital stock turnover
- Items that may increase economic benefits:
  - No significant cross cutting policies (not easily modeled in this approach): full utility restructuring, integration of air and climate policies and/or technologies, and multigas assessments
  - Complementary benefits omitted as international flexibility mechanisms, air quality co-benefits, and productivity gains

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