

Sector Impacts and Industrial Energy Reductions In the Clean Energy Futures Study

by

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ABSTRACT

This paper examines the impacts of the Clean Energy Futures (CEF) Study on industrial energy consumption, and considers separately price effects, based on the \$50 per tonne carbon charge, from expanded energy efficiency programs, such as *Energy Star*. The price projections used in this analysis are calculated using the NEMS model developed by EIA and modified and ran by LBNL for CEF.

In this paper, the industrial energy demand projections are based on ANL's *All Modular Industry Growth Assessment* (AMIGA) system. The Reference and Full Policy cases track the corresponding projections from the LBNL NEMS model fairly closely. But the AMIGA model also produces (1) Decomposition of price and program effects on energy demand, (2) sector output changes and their effects on energy demand, and (3) cost, benefits and macroeconomic impact estimates.

INTRODUCTION

This paper examines the impacts of the Clean Energy Future (CEF) study, discussed in a companion paper in this A&WMA session¹, on industrial energy consumption. We consider price effects (i.e., the \$50 per tonne carbon charge) separately from expanded energy efficiency programs, such as *Energy Star*.

The price projections used in this analysis are calculated using the NEMS model developed by EIA and modified and ran by LBNL for the CEF study.

In this paper, the industrial energy demand projections are based on the AMIGA model, which is described in a companion paper in this A&WMA session¹. The Reference and Full Policy cases track the corresponding projections from the LBNL NEMS model fairly closely. But the AMIGA model produces several kinds of outputs not easily obtainable from NEMS:

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- Decomposing price and program effects on energy demand,
- Inclusion of sector output changes and those effects on energy demand,
- Estimation of the costs, benefits and macroeconomic impacts.

The changing composition of sector outputs has a relatively small effect on overall industrial energy demand. Estimates of sector output changes are available from the first author.

METHODOLOGY

This section describes a portion of the AMIGA model; that part which forecasts industrial energy demand. For each industrial sector or sub-sector process, the model accounts for capital stock vintages by year. In this sense it is a putty-clay representation of capital, although short run price elasticities are based on increased labor input to manage and control the use of energy in operations. Each capital vintage has specific technology characteristics. Energy-related services are provided as a sum over all the capital vintages. The energy use is also summed over vintages. A retirement rate is applied to older vintages based on the retirement functional form used in NEMS. Electricity-related services are modeled separately from direct gas and other fossil fuel use.

Each year the model evaluates investments in new energy-related capital. In many (but not all cases) a premium is paid for more energy efficient equipment. This premium is captured by the model and added to incremental investment expenditures for energy efficiency.

The effects of an industry installing additional gas-fired cogeneration (combined heat and power, CHP) equipment is to increase purchased gas and to reduce purchased electricity while supplying direct heat service demand and self-generated electricity with heat rates (efficiencies) depending on the performance of the CHP equipment.

AMIGA is programmed in C. C code is organized into structures. The AMIGA energy demand modules have four types of programming structures:

- Data by vintage and sector/equipment-type,
- Sums over vintages by sector/equipment-type and stored by forecast year,
- Variety of intermediate sector calculations in each year,
- Industrial sums for the output report writer.

This portion of the AMIGA model follows in the tradition of the LIEF model in many ways². Parameters adapted from the LIEF model for AMIGA are as follows:

- Price elasticities for ideal long-run factor intensities,
- Historical energy efficiency gap by industry and energy type,
- Behavioral parameters related to adoption of efficient technologies.

LIEF develops these parameters for 18 industrial sector groups for both electricity and fossil fuels.

Energy prices and efficiency programs have effects primarily on new capital being installed, but also some effects on the management of all operating equipment. In this paragraph we discuss the effects due to new capital being installed. Higher energy prices from a carbon charge reduce the ideal energy intensity of new equipment. Further, they increase the "long run equilibrium" market share of efficient technologies relative to less efficient technologies. As such, higher prices increase the adoption rate of efficient technologies. In the LIEF model and in AMIGA, increased effort on efficiency programs is represented as reducing the hurdle rate that industry managers use in adopting efficient technologies. If management includes cost-effective energy saving among the firm's priorities, hurdle rates on evaluating energy-related equipment purchases (and other efficiency measures) can be reduced toward, but not equal to, the marginal cost of capital facing the firm. Lower hurdle rates have the same effects as higher energy prices, except price changes yield external income transfers. (A carbon charge transfers income from the energy user to the revenue collector). Lower hurdle rates also reduce the ideal energy intensities of new equipment. Further, they also increase the "long run equilibrium" market share of efficient technologies relative to less efficient technologies. But because efficiency programs can directly influence adoption decisions, these programs may be able to accelerate penetration faster than with price incentives. Price incentives drive adjustment processes toward long run equilibrium.

The AMIGA model routinely handles hundreds of economic sectors, each with demands for electricity and natural gas. The AMIGA model output report writer presents these sectors and production processes at three levels of aggregation: 14 aggregate sectors, 73 sector groups, and selected, more specific sub-sectors or production processes of particular interest. (See Table 1 in the Appendix. Also included in Table 1 are indications of the relative size of the sectors as measured by 1992 BEA value of shipments in 1992 dollars.)

INDUSTRIAL ENERGY DEMAND

We use the industrial electricity and gas price paths, shown in Figures 1 and 2 for the reference and policy cases, for our analysis of industrial energy demand and resulting energy expenditures.

Figure 1 shows the industrial electricity price projections in the reference case and with the \$50 per metric tonne carbon charge. The carbon charge increases the cost of fossil-fuel-fired generation (depending on the carbon content of the fuels) and these increased costs are passed on to end-use sectors (in this case, industrial customers). The carbon charge is assumed to be announced in advance (to avoid price surprises which could trigger adjustment costs) and phased in over four years from 2002 to 2005.

Figure 2 shows the industrial natural gas price projections in the reference case and with the \$50 per metric tonne carbon charge. Gas has a lower carbon content than oil or coal and hence the price increment from the carbon charge is less with gas than with oil or coal. The gas supply model in NEMS forecasts lower gas prices (pre carbon charge) under the Full Policy Scenario because of reduced gas demand from energy efficiency measures. Hence the price projected to be paid by industry, shown in Figure 2, shows offsetting effects of the charge and lower gas production costs, particularly later in the forecast horizon.

Fig. 1. Industrial Electricity Price Projections

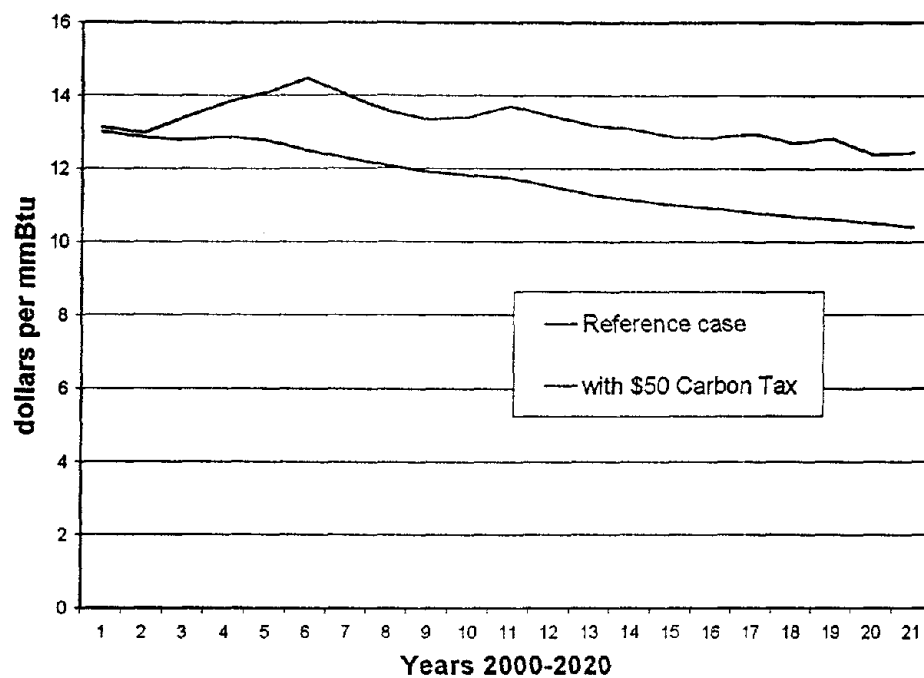
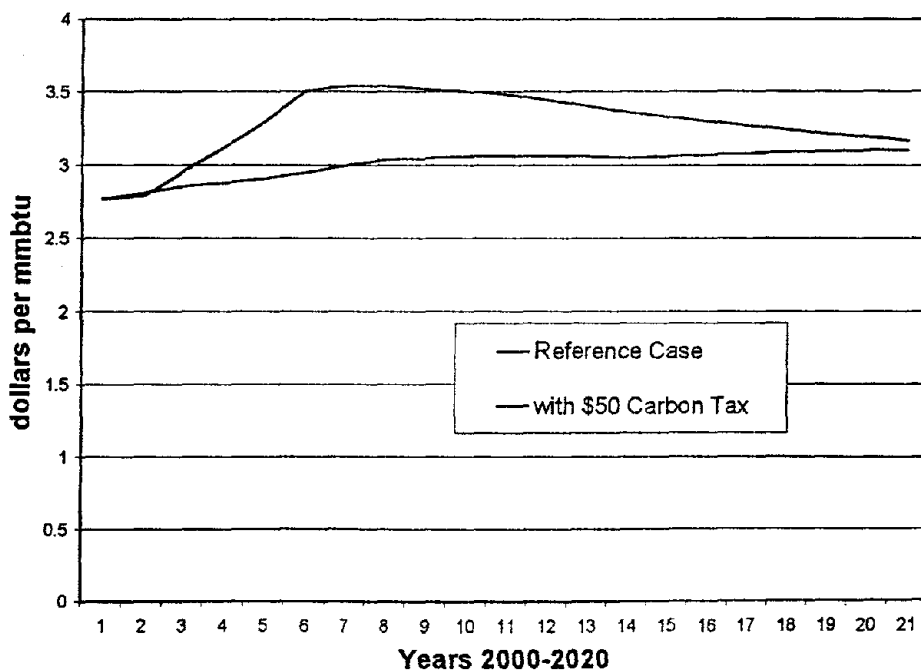


Fig. 2. Industrial Natural Gas Price Projections



The industrial energy demand results depend on the size of the carbon charge and the amount of programmatic effort. Industrial end-use electricity and gas demands (Quads) are shown in Figures 3 and 4, respectively, over the forecast horizon of year 2000 to 2020. These are forecasts using the AMIGA model¹. The Reference and Full Policy cases track the corresponding projections from the LBNL NEMS model fairly closely. That is, the total energy savings (Full Policy Case – Reference Case) shown in these Figures are close to the energy savings in the CEF.

The AMIGA model has been used to decompose the price and program related effects on energy demand. We apply the price changes with no programs, and also apply the programs with no price changes, to get the shown sensitivity cases. It is seen that both the carbon charge and the programs contribute to energy use reductions. Further, the projected effects are almost linear, i.e., the difference between the Full Policy simulation and the Reference simulation, in any given year, is approximately equal to the sum of the price impacts taken alone and the program impacts taken alone.

The approximately linear response that we see in this case can be interpreted as follows. Programs and prices are both complements and substitutes. As complements, some more-involved efficiency measures would only be taken in the presence of both increased price incentives and voluntary programs on the part of companies' managements. Also some measures may be program-responsive but not price-responsive, and some measures may be price-responsive but not program-responsive. As substitutes, some simple, high-payback measures could likely be induced either by higher prices or efficiency programs.

Fig. 3. Industrial Electricity Projections

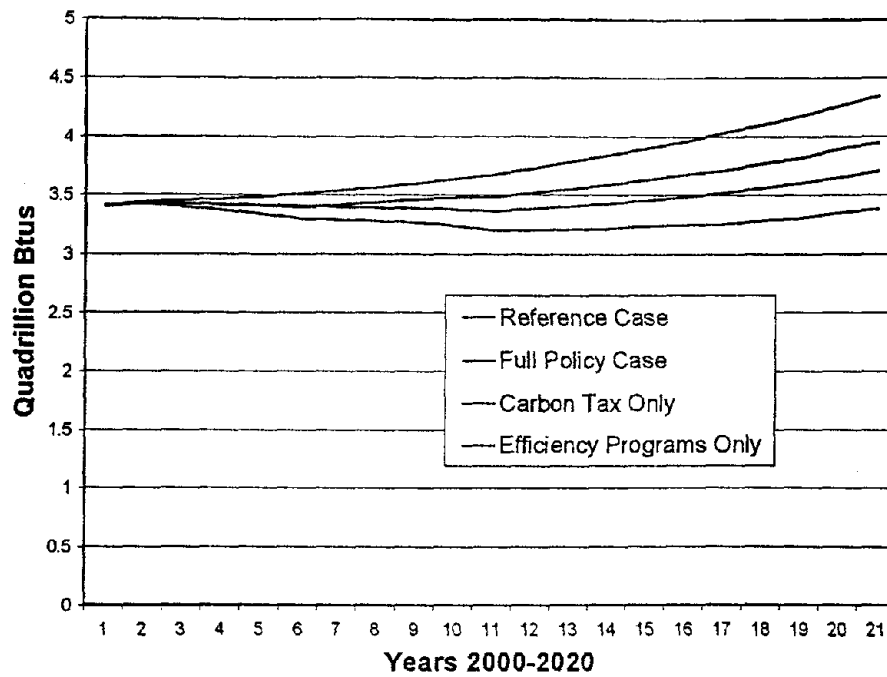
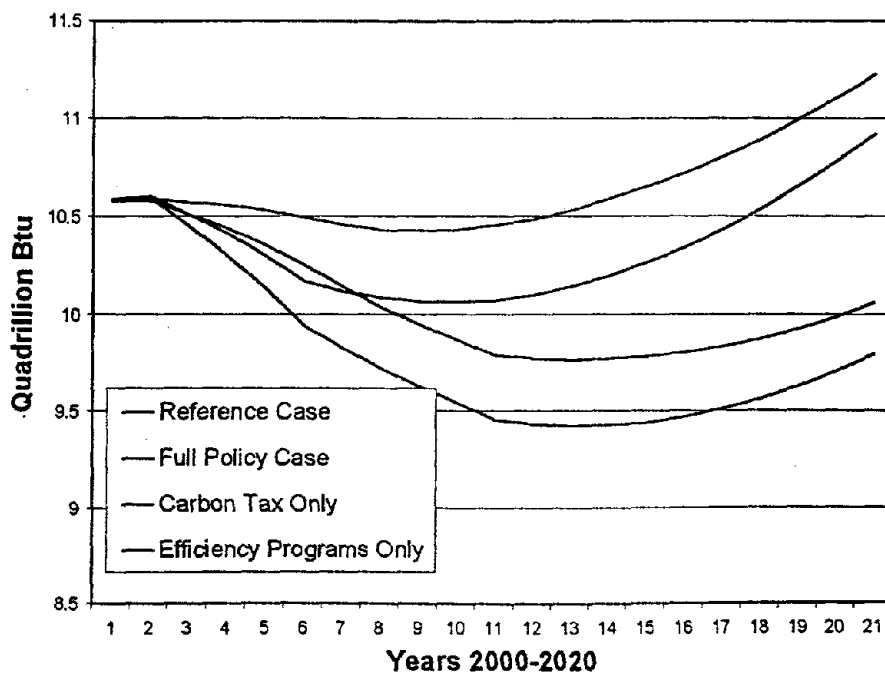


Fig. 4. Industrial Natural Gas Projections

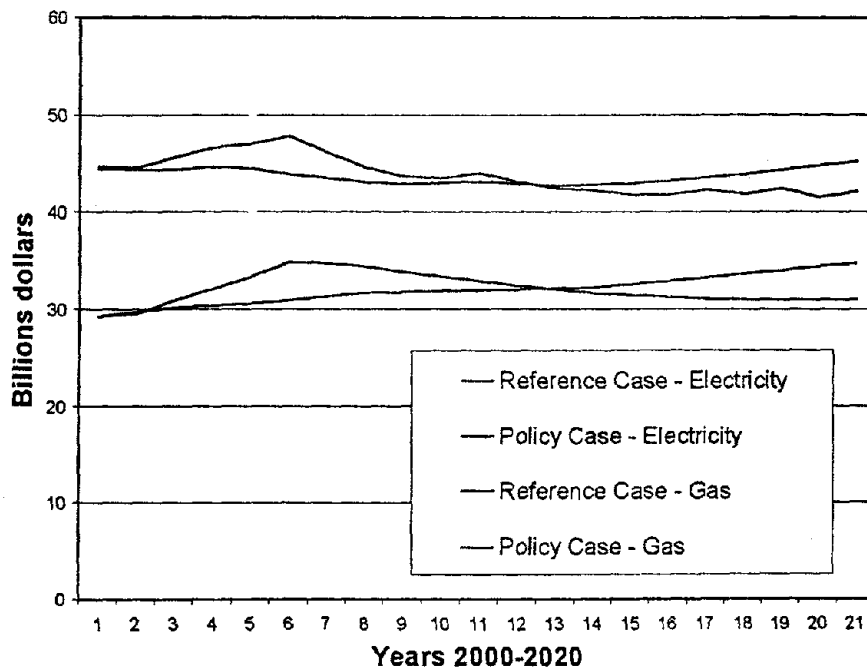


NET REAL SAVINGS

Figure 5 shows the energy expenditures for electricity and gas in both the Reference Case and the Full Policy Case. Energy expenditures initially rise as the carbon charge is phased in to the price of gas and of electricity. However, over time, induced energy efficiency measures offset higher prices by reducing demand. Note that energy expenditures in the policy case include charge revenues collected. Even so, total energy expenditures eventually go down.

It should be noted that the change in energy expenditures, less the carbon charge revenue drawn from industry, less the public and private incremental efficiency program investments and other expenditures equals the real resources savings in a given year. As discussed in our other paper¹, these real resources saved translate into increased future consumption levels in the aggregate economy.

Fig. 5. Expenditures on Purchased Energy



SECTOR OUTPUT EFFECTS

The Full Policy effects on sector activities are obtained from the general equilibrium AMIGA runs, available from the first author. Some sector outputs that are shown in Table 1 are directly impacted by the CEF scenarios. The most directly affected sectors are as follows:

- Coal mining,
- Crude oil and gas production,
- Construction related to energy efficiency projects on structures,
- Petroleum refining,
- Motor vehicle manufacturing,
- Manufacturers of efficient equipment,
- Oil pipelines,
- Purchased electricity,
- Energy service providers,
- Gas pipeline transport,
- Gas distribution,
- Engineering R&D Labs, and
- Government efficiency programs.

In addition to the sectors listed above that are most directly affected in the Full Policy Case, many other sectors of the economy would experience small effects working through price and demand channels. Energy prices would change for all sectors of the economy. Demands for sector outputs could shift due to changing composition of the demand for various goods and services in the economy. Finally the aggregate economy could further expand or contract. As presented in our other paper, the more efficient utilization of real resources in the economy, by implementing cost-effective energy efficiency measures, would expand the production capacity of the macro economy.

In our forecasts, the sectoral shift terms and the aggregate economic expansion are small in relative terms (although significant in absolute dollars). Therefore the feedback from the economy to industrial energy demand is relatively small. For example, what is called the "rebound effect" in the energy efficiency literature is relatively small. The main effects on energy consumption and carbon emissions are due to the price and efficiency program effects with relatively small effects on energy consumption from changes in industrial output.

REFERENCES

¹Donald Hanson and John A. "Skip" Laitner, *An Economic Growth Model of Investment, Energy Savings, and CO₂ Reductions*, for presentation at the Air and Waste Management Association, June 2000 Annual Meeting.

²Ross, M., et.al., *Long-Term Industrial Energy Forecasting (LIEF) Model (18-Sector Version)*, ANL/EAIS/TM-95, Argonne National Laboratory, May 1993.

KEY WORDS

Energy Efficiency, Industrial Energy, Electricity Demand, Gas Demand, Efficiency Programs, Energy Star

APPENDIX TABLE

Table 1. Sector Groups Presented in the AMIGA Model Report Writer

	1992 BEA data
Domestic Industry Output: 14 Sectors	
Totals	10772784
* Agriculture	235591
* Mining, excl fuels	23022
* Fuel Mining - coal, oil, gas	124540
* Construction	679330
* Nondurable Mfg, excl petro refining	1398364
* Petroleum refining & products	149831
* Durable Manufacturing	1342283
* Purchased Electricity & Services	195695
* Gas transport & distribution	96155
* Transp, commun, water	637506
* Wholesale/retail trade	1095148
* Finance, Ins, Real estate	1583705
* Services	2356776
* other (i.e., 78-85)	854838
Domestic Industry Output: 73 Sectors	
Totals	10772784
1 Agri - livestock	89375
2&3 Agri - crops, forest, fishing	116411
4 Agri services & landscaping	29805
5&6 Mining - metals	10739
7 Coal mining	26917
8 Crude oil & gas production	97623
9&10 Mining - minerals	12283
11M Construction - mining	16086
11- Construction - new	442582
12- Maintenance & Repair Construction	220662
14 Food	408757
15 Tobacco	40147
16 Textile mills	37528
17-19 Textile products	107641
20&21 Wood products	87127
22&23 Furniture	42849
24&25 Paper	130240
26 Printing & publishing	101097
27 Chemicals	131209
28 Synthetic materials	50944
29A Drugs	62321
29&30 Paint & cleaning	54936
31- Petroleum refining	134555
31oth Petroleum products	15276
32 Rubber, Plastic products	111813
33&34 Leather products	9538
35-36 Glass, stone & clay products	60272
37 Iron & steel	73919

Table 1. Sector Groups Presented in the AMIGA Model Report Writer

	1992 BEA data
Domestic Industry Output: 14 Sectors	
38 Nonferrous metals	64856
39-42 Fabricated metal products	153370
43 Engines & turbines	17895
44-50 Machinery	141124
51 Computers, etc	62088
52 Serv ind machinery	25801
53 Electrical equipment	28574
54 Household appliances	16833
55-58 Electronic items	164437
59A Motor vehicles	149684
59B MV parts	75202
59C Truck bodies & trailers	6056
60 Aircraft	102154
61 Transportation other equipment	29907
62&63 Instruments & photographic	130660
64 Miscellaneous manufacturing	39450
13 Ordinance	22217
65A Rail transportation	62058
65B Trucking & warehousing	157110
65C Water transportation	34347
65D Air transportation	98819
65E1 Pipelines, petro (excl gas)	7315
65E2 Transport services	21651
66&67 Communications	205941
68A1 Purchased electricity	189433
68A2 Energy service providers	6262
68B1 Gas pipeline transport	15778
68B2 Gas distribution	80377
68C Water & sanitary	50265
69A Wholesale trade	568970
69B Retail trade	526178
70 Finance & insurance	622428
71A Owner occupied dwellings	457250
71B Real estate & royalties	504027
72 Personal services	150952
73A Business services	731953
73B Engineering R&D labs	112271
74 Restaurants	282017
75 Auto repair & services	164408
76 Amusements	122937
77 Health, education & social services	792238
78 U.S. postal & other enterprises	50200
79 State&Local gov enterprises	30162
82 Govt industry (employee payroll)	764389
84 Household industry	10087
Domestic Output in Selected Detailed Sectors	
*** Paper mills	54439