Peabody

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FREDRICK D. PALMER
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February 17, 2004

Mr. Mark Friedrichs, PL-40
Office of Policy and International Affairs
U.S. Department of Energy
Room 1E190
1000 Independence Avenue, S.W.
Washington, D.C. 20585

Dear Mr. Friedrichs:

Re: Comments of Peabody Energy Corporation on General Guidelines for Voluntary Greenhouse Gas Reporting

Peabody Energy Corporation ("Peabody") presents these comments on the Department of Energy's ("DOE's") proposal with respect to General Guidelines for Voluntary Greenhouse Gas Reporting (the "Guidelines") as published in the Federal Register at 68 Fed. Reg. 68024 (December 5, 2003).

Peabody is the world's largest privately owned coal company. In 2003, we produced 200 million tons of coal, supplying more than 270 power plants in 11 countries, fueling 9.8 percent of U.S. electricity and nearly 2.5 percent of the world's electricity. In the United States, we produce coal from every major coalfield, and we serve power plants in all parts of the country.

Because Peabody is such an important part of the electricity market in the United States, we take seriously our environmental and societal responsibilities. Peabody believes:

- Coal-based electricity generation should be preserved to ensure a diversity of fuel supply, produce affordable and reliable electricity, maintain a strong U.S. economy, and help stabilize the balance of payments

- Coal is the nation's most abundant energy source and an option to use coal and other fuels to generate electricity should be preserved

- The improvements in emissions from coal-based generating plants will continue and development of more efficient clean coal technologies should be encouraged and deployed.

Today's energy situation is too similar to the energy problems the country confronted in the 1970s and early 1980s. During that period, we experienced two major oil shocks, and our reliance on foreign oil put in place a number of new policies that served us well for two decades.

Under President Jimmy Carter, Project Energy Independence resulted in a massive investment in new coal-based electric generating units. The capacity and associated energy of those power plants fueled economic growth for 20 years even while emissions of pollutants from those same power plants declined dramatically. During that same period, U.S. coal consumption rose from 700 million tons per year to 1 billion tons per year.

Today the excess capacity from those coal plants has been used up. Compounding the problem, the federal government pursued policies in the late 1990s designed to move the country away from coal-based generation to natural gas. The result of these misguided policies is scarce and expensive natural gas that has cost consumers billions of dollars in excess electricity and fuel costs while decimating large parts of American industry, which have moved overseas. Our dependence on foreign oil remains high, and we now are moving to further dependence on imported energy as activity flourishes to bring online new liquefied natural gas projects.

The country's recent focus on greenhouse gas emissions and particularly carbon dioxide (CO_2) has the very real potential to make a bad situation worse. In DOE's proposed guidelines, for example, there is specific focus on electric generating stations and industrial power plants and an implicit direction from the government to reduce CO_2 emissions at those plants by switching from coal to natural gas and other fuels with lower carbon content. Discouraging the use of coal to generate electricity or in other industrial applications is both misguided and unwise.

The energy reality facing the country today is that we will have to use more coal and not less if we are to continue to grow the economy while providing the American people with always available, affordable electric energy. Ironically, by using more coal, we will encourage a trend that has been in place since Project Energy Independence, which is robust economic growth and an ongoing reduction of carbon intensity per unit of economic growth. President Bush, to his credit, has recognized the importance of this trend and is committed to policies that will enhance it.

We are submitting a study by Mark Mills of the Digital Power Group, which documents this phenomenon and identifies the importance of increased penetration of electricity into our economy. Mr. Mills' conclusions should be used by DOE in modifying the proposed guidelines to take the focus away from power plants and consider CO_2 emissions on a full "fuel cycle" basis. By doing so, DOE will bring its guidelines into harmony with the President's policy on energy efficiency and greenhouse gas emissions.

Sincerely,

PEABODY ENERGY

Fredrick D. Palmer
Executive Vice President
Legal and External Affairs

FDP:rw

Enclosure

Comments on:
U.S. DOE General Guidelines for Voluntary Greenhouse Gas Reporting
Federal Register Vol. 68, No. 234/ Friday, December 5, 2003/Proposed Rules

By: Mark P. Mills
Partner, Digital Power Group
www.digitalpowergroup.com

Premise & Context

Greenhouse Gas policies and proposals are, at their core, primarily about making changes in society's overall basic energy supply and consumption patterns.

For all practical purposes, in the 12 years since the non-binding Rio Treaty started the vast global industry of greenhouse analyses and meetings, the main focus of Greenhouse Gas initiatives has been on carbon dioxide arising from energy consumption. While there are a variety of other targeted greenhouse gases (e.g., methane and CFCs), CO2 alone accounts for over 80 percent of the weighted anthropogenic emissions of greenhouse gases.

Thus, from the inception, nearly all policies and proposed actions, voluntary and otherwise, there have been two near universal, either implicit or explicit, objectives;

- discourage the use of carbon-based fuels, especially carbon-dense coal
- discourage the use of electricity, because it is, in the U.S., dominantly coal-based, and an ostensibly inefficient use of primary fuel resources.

There is no way around concluding that Greenhouse Gas proposals are consequently surrogates for energy policies. And to say energy is fundamental to society's survival and growth borders on tautological. No life, no industry, no society itself is possible without energy – vast quantities of energy. The availability of energy, in the right form, at the right time – and especially at the right price -- simply underpins everything.

The current DOE approach to Greenhouse Gases appears to move, laudably, away from proposals that create mandatory caps on carbon emissions. Such caps and targets would be very thinly disguised ways to force primary fuel policies, and would demonstrably result in constraining fuel supply while raising energy costs. A voluntary program on greenhouse emissions, such as the greenhouse gas registry administered by DOE, while inherently preferable, also has risk in unintentionally tinkering with the energy system that has so ably supported U.S. economic growth.

> "Underpinning our approach to climate change is an understanding that meeting this long-term [Greenhouse Gas] challenge requires policies that recognize that sustained economic growth is an essential part of the solution. Policies that undermine the health of our economy would only hamper America's ability to develop and deploy new energy technologies and invest in energy efficiency and productivity improvements. The United States is the world's leader in technological development,

industrial productivity, and environmental quality. These strengths make possible the initiatives that have been announced today to reduce or capture and store greenhouse gas emissions."

Statement by the President, February 12, 2003
http://www.climatevision.gov/statements_021203.html

The over-riding "long term" characteristic of this issue, and the core long-term economic and energy trends are frequently lost in a pre-occupation with the minutiae of near-term greenhouse proposals, whether mandatory or voluntary. Energy policies should not result in -- even when ostensibly "voluntary" -- overt or covert outcomes that lead to either fuel price control, or economic behavioral controls that negatively impact core economic and technology trends. Wealth, as President Bush's statement properly notes, matters in environmental pursuits, since poorer nations cannot and do not have the environmental record of richer ones.

A rich nation, one might suppose then, would therefore be able to accommodate more expensive energy, were that a means to address Greenhouse Gases. Yet, proposals that would nakedly use price 'signals' (i.e., increasing energy costs) as a policy tool to influence energy behavior nearly always fail to gain political support (except where they're disguised or hidden). The ignominious and near unanimous rejection of a pure energy tax, the so-called "BTU tax," was typical of the fate of such direct approaches. The environmentally-motivated BTU tax was proposed by the Clinton Administration in 1993, and defeated by the then Democrat-controlled Congress. Most constituencies oppose overt policies to increase costs of basic commodities, especially energy. And where price control has failed, so too generally have attempts at direct controls of energy consumption behavior. (The godfather of modern energy controls, the 55 mph speed limit, lasted for a while, while the archetype of such controls, CAFE standards and similar appliance standards, still continue). There has thus evolved a broad array of Greenhouse 'tools' to variously encourage "voluntary" changes in behavior, most frequently directed at energy-consuming equipment rather than just energy production or price, through standards and mandates, rebates and incentives. The goal is generally the same as with price "signals" or mandated "standards:" persuade citizens and businesses to avoid energy use -- electricity in particular – and to drive slower or less, buy less, keep cooler or hotter, live smaller, slower or more generally abstemiously.

The concepts in "voluntary" actions, incentives, standards and "best practices" are all means to influence energy purchases, and more specifically, equipment purchases, and technology R&D decisions. The core premise is that "voluntary" activities are less objectionable and may not be harmful to the economy. However, it is not possible to know if voluntary proposals are economically harmless, and thus consistent with current Federal policy, without first considering the macro-economic and macro-energy context of the core trends in the U.S. economy.

Recent historical trends provide an essential starting point for future policies, and for considering whether policies may be ineffective or counter-productive. By and large, since nearly all historic trends relevant to Greenhouse Gas issues can be reasonably seen as voluntary (in the U.S. at least), these trends reveal what will be easiest, indeed possible, to encourage or accelerate in future "voluntary" programs.

We should begin by considering the central objective of DOE's proposals to modify the Greenhouse Gas reporting system and other voluntary Greenhouse Gas emissions programs advanced by the Administration, which is to reduce the carbon intensity of the U.S. economy.

> "On February 14, 2002, the President announced a series of programs and initiatives to address the issue of global climate change, including a greenhouse gas intensity reduction goal, energy technology research programs, targeted tax incentives to advance the development and adoption of new technologies, voluntary programs promote actions to reduce greenhouse gases, and international initiatives."
> *Federal Register Vol. 68, No. 234/ Friday, December 5, 2003/Proposed Rules*

Let us then focus on the recent voluntary record to determine whether energy decisions made voluntarily by industry and consumers have advanced the goal of improved carbon intensity, while helping, or holding harmless, economic growth. Such a focus reveals two important facts for voluntary Greenhouse Gas programs. First, the key to improving Greenhouse Gas intensity is to focus on consumption of energy, not production. Second, even voluntary efforts that encourage fuel switching in electric generation will have the counterproductive effect of increasing greenhouse intensity by increasing the price, and therefore discouraging the use, of electricity.

Voluntary Programs – accelerating the 'voluntary' history

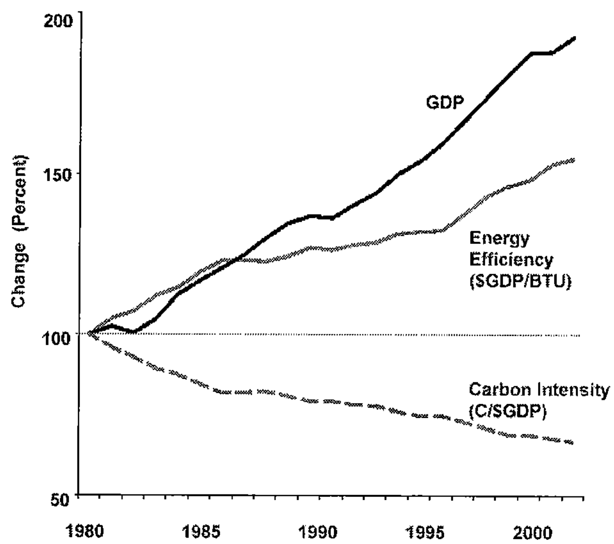
There are clear statistical trends that demonstrate what the U.S. market has "voluntarily" achieved in terms of carbon intensity, and thus where one might productively direct incentives to encourage more of the same. That the Greenhouse Gas challenge is long-term is widely accepted. While the 20-year trends discussed here are, by geophysical standards, hardly long-term, two decades are by economic policy standards, unequivocally "long-term" as they supercede election/policy cycles. In two decades, most policy fads begin to separate from physical and economic reality.

Over the past two decades the carbon intensity on the U.S. economy has decreased while the economy has grown. As we shall illustrate, the former is dominantly a surrogate measure of rising energy efficiency, and both are largely a consequence of technology progress. In unraveling the interstices of energy trends, it will become clear that both rising energy efficiency and technology progress are rooted primarily in the increased use of electricity-consuming devices and systems. **Furthermore, history reveals that these trends are firmly anchored in 'voluntary' decisions made in the marketplace where energy is consumed, not in the primary fuel markets.** These historic energy realities provide a clear basis for evaluating Greenhouse Gas policies, voluntary or otherwise.

Benchmarked from 1980, the economy (GDP) has nearly doubled in size, and overall U.S. carbon intensity has declined 30 percent (tons carbon/$GDP). See Figure 1.

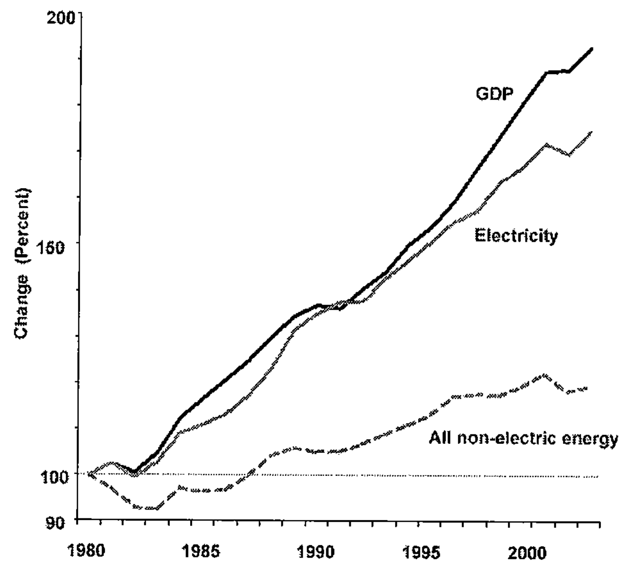
The nation's reduction in overall carbon intensity cannot be attributed to either lower electricity consumption, or to reduced coal use (fuel switching). It has long been a tenet of disciples of energy efficiency policies (and collateral greenhouse gas avoidance) that electricity generation is inherently inefficient, leading to a vast array of proposed programs (many implemented over the past several decades) to discourage kilowatt-hour consumption. Similarly, and usually in the same proposed greenhouse gas programs, sustained coal use is viewed as antithetical because of the fact coal is the most carbon-rich fossil fuel.

Figure 1: Carbon Intensity and Economic Growth



Index = 1980

Figure 2: Economic Growth & Electricity Consumption



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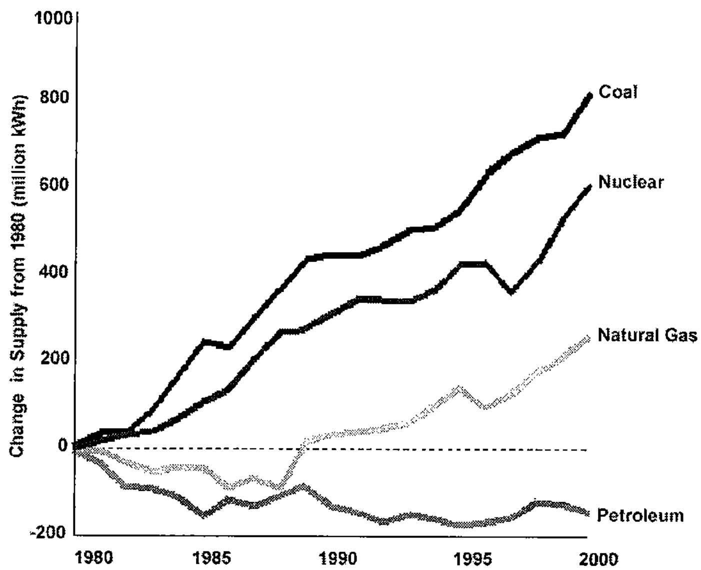
Yet, the salutary history of greenhouse gas intensity has occurred while electricity use grew substantially (roughly equal to GDP growth – see Fig 2), and coal use grew by some 400 million tons/year (see Fig 3). Coal supplied about the same share (55 percent) of total electric generation 20 years ago as it does now. Oil and natural gas have largely swapped position as primary sources of electric power. Nuclear generation has grown, occupying second place as the source of additional power to fuel growth. With the combined rise of both coal and nuclear energy, and the essentially carbon-neutral change in oil & gas electric generation, there has been no net change in the average carbon intensity (carbon/kWh) of electric supplied to the marketplace (actually decreasing only very slightly, about 3 percent). In short, the economy's dramatic 30 percent decrease in overall carbon intensity cannot be attributed to a change in how electricity is produced. Nor can it be attributed to a change, i.e., a decrease, in the use of our carbon-dominated electricity supply.

The historic trends clearly show some explicit forces encouraging growth in electric use, and collateral rising coal use, while greenhouse gas intensity has declined. **No other conclusion is possible: primary fuel use patterns in electric generation have not been a factor in overall reduction in national greenhouse gas intensity.**

Figure 3: Electric Sector: Primary Fuel Consumption

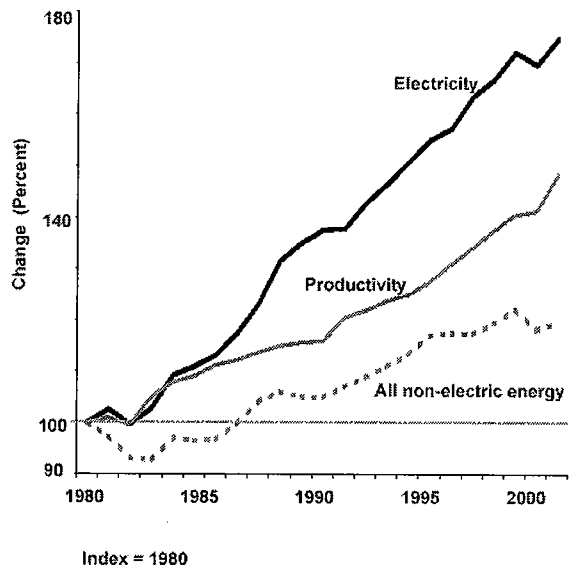


Source: EIA *Annual Energy Review 2000.*

Answers to how such an apparent conundrum could occur are not found in transportation sector trends either. Transportation fuel use is the main non-electric part of the U.S. economy, and remains essentially 100 percent fueled by oil. The average transportation sector fuel efficiency – directly symmetrical to transportation carbon intensity – for the nation's vehicles has certainly improved. Overall fuel efficiency has increased by nearly 30 percent in the two decades considered here. However, given the transportation sector's roughly 30 percent share of total primary energy use, and roughly 10 percent share of total GDP, this means that the transportation sector is responsible, overall, for well under 10 percentage points of the 30 percent reduction in society's carbon intensity. This is an interesting contribution, but hardly the core driving force in the overall national decline in carbon intensity.

At the macro-economic level, the only explanation for the lion's share of the reduction in carbon intensity is improved energy efficiency everywhere else. The nation has made remarkable progress in producing more goods and services – has become much more productive – using less largely carbon-based energy per dollar of GDP – without significantly changing the carbon mix of primary fuels. The two core trends have substantially improved. Energy efficiency ($GDP per unit of energy) has improved over 40 percent (see Figure 1). And the overall economic productivity ($GDP per worker) of the U.S. economy has risen nearly 50 percent (see Figure 4).

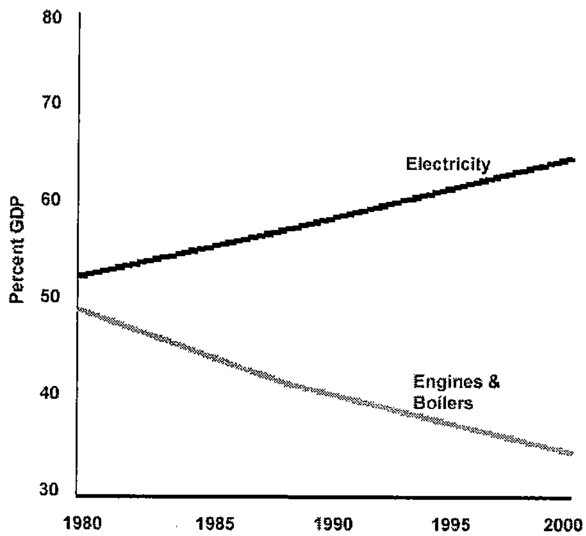
Figure 4: U.S. Productivity and Energy Trends



The rising productivity and energy efficiency trends are entirely anchored in changes in the nature and mix of the energy-consuming hardware in the market place. Here, the market's preference for the type of equipment is abundantly clear. Both in absolute and relative terms, the economy has clearly migrated to increased use of electric technologies.

In absolute terms (see Fig 4), there has been very little change in end-use consumption of combustible fuel, yet end-use electricity consumption has risen 70 percent. In relative terms (see Figure 5), the GDP's dependence on electric and non-electric energy continues a trend that began at the start of the 20th century, and will continue well in to 21st century. Since the GDP is a direct measure of marketplace activity, it is similarly a direct measure of marketplace equipment preferences used to generate the GDP – preferences driven almost entirely by economic and behavioral factors. Businesses seek to improve profits, productivity, viability and competitiveness – fuel choice is in nearly all applications, at most, a tertiary factor, a consequence of equipment choice decisions.

Figure 5: GDP dependence on electricity



* Excludes residential energy: counts only fuels used by GDP-producing sectors; transportation, industry (incl. mining, agriculture) and services.

Source: EIA Annual Energy Review 2000; Bureau of Economic Analysis.

Most businesses make indirect fuel choices – purchasing decisions are equipment and service oriented. The preferential use of electric technologies highlights the overwhelming policy importance then of the indirect emissions aspect of greenhouse gases. At the macro-energy consumption level, the unequivocal primary driving force is simply that we've used more electricity, and more coal and uranium, both in absolute terms and relative terms. That this has indirectly caused greater carbon efficiency is no accident – it is a consequence of solid, observable and verifiable economic decisions. There is thus clear risk in policies that implicitly or explicitly run counter to this historic 'voluntary' trend.

These trends also point to the "boundary" challenge in greenhouse gas policies – or in reality, the close interconnected nature of technology, energy-form, price, supply and reliability.

Counter intuitive as it may seem, but clear from the foregoing trends -- greater use of electric technologies improves carbon efficiency, and improves productivity, and energy efficiency, even as we increase our overall use of and relative dependence on carbon-rich primary fuels. **The collateral conclusion – greenhouse gas activities should focus, not on primary fuel (fuel switching), but on market technology choices.**[1]

[1] Primary fuel choice of course does matter at some level, most especially with regard to fuel commodity prices, availability and assurance of supply.

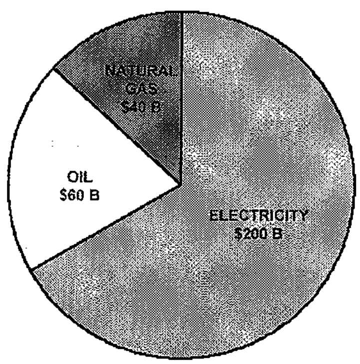
Capital Spending – revealing the electric factor

Thus far, the data shown are for the economy's annual purchase of what is essentially the 'raw' delivered energy commodity consumed by end-use consumers – the oil, natural gas and electricity delivered to factories, offices, and homes. Another important measure, and validation, of energy preferences and 'voluntary' behavior is the capital spending on energy conversion equipment – the hardware purchased and installed each year in the manufacturing, commercial and residential sectors; the boilers and heaters, turbines and engines, or electric motors, electric power supplies, even lasers and microwaves.

The capital equipment metric reflects the technology or hardware component of energy choices – the same technologies that are targeted by financial and tax incentives, and R&D programs.

Annual capital spending on all types of energy conversion hardware substantially exceeds annual purchases of raw fuel. The U.S. economy buys roughly $300 billion of primary fuels per year (see Figure 6), divided approximately as $200 billion on electricity, $60B on oil and $40B on natural gas.

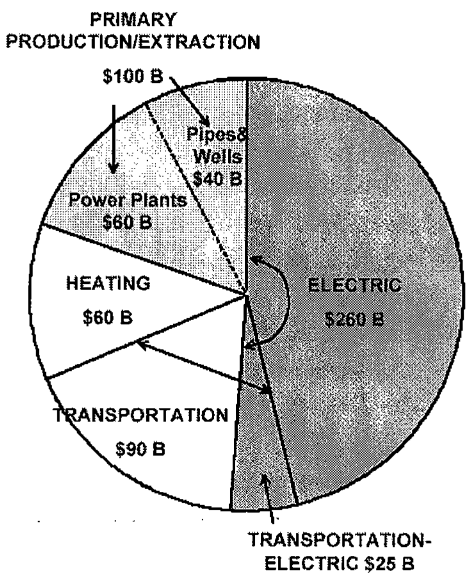
Figure 6. Fuel Purchases



Meanwhile, over $400 billion per year is spent on all forms of capital equipment that converts raw delivered energy into useful forms. (See Figure 7)

Note that this $400 billion does not include the roughly $100 billion/yr in capital spending on the equipment used to extract and provide primary energy – e.g., power plants, pipelines, oil wells, refineries. Even in the primary energy part of the capital equation, the electric sector dominates, as illustrated in Figure 7. About two-thirds of capital spending on primary energy hardware is for electric generation, the balance for primary raw fuel extraction from mining to oil wells, and processing from refineries to uranium enrichment, and delivery from pipelines to tankers.

Figure 7. Capital Spending



While most policy and technology explorations focus on primary fuel purchases or capital requirements for primary energy production – it is the vast array of specific types of end-use energy conversion hardware that dominates society's annual expenditures. End-use energy conversion hardware can be grouped into just three basic categories;

- those that burn fuel to provide heat,
- burn fuel to move things (transportation),
- those which can convert electricity into different forms.

Annual capital spending for these three types of energy conversion equipment breaks down roughly as follows: (see Figure 7):

- $60B on thermal technologies to heat air, water and fluids, heat materials to dry, join or convert -- in all sectors from homes and businesses, to chemical refineries.
- $90B on thermal-based engines and related thermo-mechanical drive trains that burn fuel to directly create thrust and motion, from car and truck engines, to aircraft turbines
- $260B on all types of electric and electronic power conversion, from motors, and light bulbs, to microwave tubes and computer power supplies (including $25 billion/yr of electric conversion hardware that is increasingly appearing under the hood of cars and trucks).

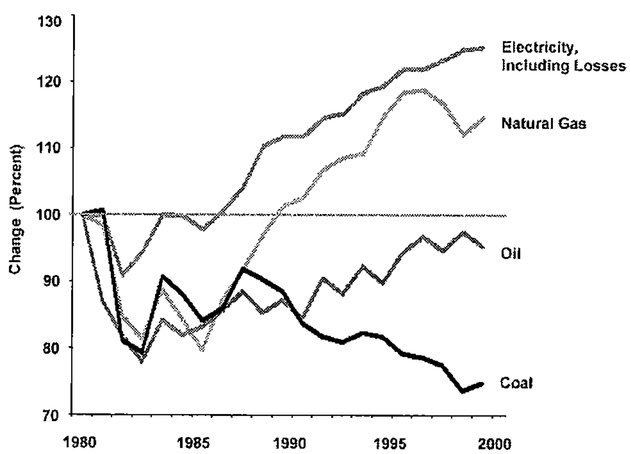
In all three sectors of power conversion technology, the ascendant trend is the growth in new kinds of electric-to-electric power conversion, not only expanding the electric component, but also permitting electric power conversion to invade the two thermally dominated power conversion domains. The semiconductor revolution is the central driving force in this new, and now accelerating, trend of electrification of non-electric power conversion.

Core sector trends in electrification

The impact of semiconductors is seen in both direct and indirect ways, and at both high and low power levels. When (electric-powered) information systems are used to add control and efficiency to thermal and mechanical power conversion systems, the result is usually a modest new source of electric demand, added to what remains a dominantly thermal or mechanical process. The additional electricity use, used to drive systems that increase control, leads to improved economic and energy efficiency. Overall energy use goes down, electric use goes up. The additional new uses of electricity, while individually modest, begins to add up across millions of applications, and often occur where no electricity was previously used (to power sensors, electric valves and CPU-control, in refineries for example).

The net result of this trend is the widely recognized and frequently dramatic improvements in productivity, operational control and overall energy (and collaterally carbon) efficiency. Combustion-based hardware and systems simply become much, much more efficient with an associated relatively modest increase in electric use. This has, in fact, been the central dynamic of the industrial sector over the past two decades. (See Figure 8 – note that these trends understate the industrial electrification trend, since a significant share of industrial natural gas consumption is used to provide on-site electricity.)

Figure 8. Industrial Primary Energy Consumption by Fuel



Index = 1980

http://www.eia.doe.gov/oiaf/aeo/demand.html

The addition of (electricity-consuming) digital logic to conventional thermal and mechanical systems is the first and continuing phase of industrial electrification. The next stage in industrial electrification is now underway, with the advent of affordable semiconductor technologies that move beyond the realm of logic, and in to high power, including even heating.

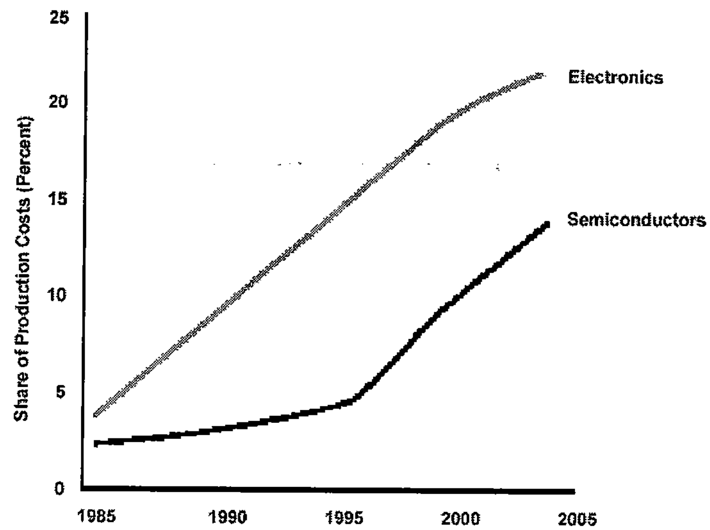
Some two-thirds of industrial energy use is in the form of raw heat – heat used to melt, convert and process fluids, gases and solids. Until now, industrial and manufacturing processes produce heat almost exclusively by simply burning fuel, and as efficiently as possible, controlling the resulting (largely chaotic, difficult-to-control) hot air, gas or fluid. Engineers have long recognized the profound improvement in control and efficiency possible using electric-based technologies for heat-related processes – whether with microwaves and electric-plasmas, or with magnetic field or lasers. But until very recently, electric heating technologies have had only specialized application, where the precision and control greatly outweigh the cost of early electric-heating systems, and in many cases the associated hardware's fragility in harsh industrial environments. Lasers are a prime example of an electric technology, long in use at very low power levels for telecommunications and consumer products, and only recently migrating to medical applications with higher power and reliability at reasonable costs – the next power migration is in the industrial markets.

Producing high-power laser and microwave energy is almost entirely dominated by high cost, high-maintenance, fragile tube-based technologies. Power semiconductors are just now emerging to replace this last domain where vacuum tubes still dominate. Riding the coat-tails of the materials, technology and processes of the digital age, engineers are just now able to produce, or envision producing, extremely high power semiconductor based systems to create and control heat and motion. Chemical and process engineers eagerly embrace the advantages of precisely focused and digitally controlled beams of microwave and optical energy that can selectively heat and catalyze reactions.

On the horizon now are the necessary semiconductors to replace microwave tubes with a new class of power semiconductors -- think of these as the same type of RF chips that power a cell phone, but some ten-thousand fold higher in power output. High power microwave energy will penetrate the industrial market as successfully as much lower power microwaves have penetrated the residential market. Similarly, while expensive high-power gas-tube type carbon-dioxide lasers are used (sparingly) in industry for heat treating metals, new semiconductor laser-based systems have emerged which are cheaper, smaller, more reliable, and now hold the potential to replace a vast array of metal heat treatments that are now completely dominated by relatively crude combustion processes. While the new photon heating technologies closely resemble the millions of lasers embedded in CD and DVD players that can 'burn' plastic with milliwatts, burning metal with kilowatts requires a non-trivial (but now achievable) million-fold increase in power.

The transportation sector is undergoing a similar and closely related migration in energy conversion technology that, in most respects leads that in the industrial sector. Microprocessors combined with electric sensors and actuators (motors) are already improving the automotive driven train – yielding improvements in safety, convenience, comfort and efficiency. Total spending on electric and electronic components is now north of 20 percent of the cost to manufacture a car, and has for some time exceeded spending on steel. Soon it will become the primary cost component of manufacturing automobiles, and trucks. A typical car has a dozen or so microprocessors, and the average trend is towards dozens more (which luxury cars already possess). There is as well the progressive replacement of thermal and thermal-mechanical systems with silicon power systems. The average car already contains 50 to 100 special high-power silicon transistors (called MOSFETS) used, not for logic, but to switch and control electric power flows. Where transistors used for logic handle, individually, billionths of a watt – transistors used for controlling power flows to drive shafts and wheels must handle hundreds and even thousands of watts. The power transistor industry also rides the coattails of the silicon logic industry, but has taken longer to mature in large measure because of the inherent engineering and material challenges that high power creates.

Figure 9. Silicon and Electronics in the Automobile



Source: Bosch, courtesy DaimlerChrysler

The advantages of digital power control are abundantly obvious to auto engineers; a single $100 module containing the power electronics that allow a car to be steered electrically–as some aircraft are flown now–can deliver far more responsive, accurate steering than existing hydraulic systems, and also add a half a mile per gallon of fuel efficiency. An electromagnetically activated valve train, replacing the standard mechanical systems, delivers more performance in less space and boosts fuel efficiency. Electric-hydraulic braking systems are already standard on some cars; all-electric brakes arrive next – adding safety, reliability and reducing both weight and fuel use.

Shafts, pulleys, gears and hydraulics will all give way to silicon logic, silicon power and wires, controlled by microprocessors and local-area-networks. This is the real "hybrid" automobile that is emerging under the hood of every car, not just the much-touted Toyota Prius -- hybrid because it is a largely seamless combination of the old internal combustion with the new silicon-controlled electric drive train. The hybrid vehicle as epitomized by the Prius, and emerging Ford Escape and others, does represent the next stage in electrification – where the combustion-engine is relegated almost entirely, and eventually entirely, to electric-power generation and the drive train is fully electrified.[2]

The electrification and siliconization of the automobile has both near- and long-term relevance to other energy conversion sectors. The first impact will be to drive down the cost of high-power silicon power conversion technologies. The size of the auto sector market has enormous impact in driving economies of scale; it is second to none in power. The auto industry puts more kilowatts of power plants on the road per year than exists to power the entire U.S. electric grid. As the auto industry qualifies, perfects and then drives the cost of high-power conversion technologies down, these new technologies will rapidly invade the smaller, but still large, industrial thermal-mechanical power conversion business. The transportation sector today accounts for only 10 percent of the $260 billion in electric power conversion technology spending. In the near future, the transportation market alone is likely to match total capital spending in all other markets on silicon power conversion.

In the longer term, once the hybrid transformation of transportation is firmly underway, we are likely to see interesting and heretofore unlinked energy arbitrage. The now oil-dominated auto sector will be able to share with the coal-dominated electric grid. Some have proposed that a nation with millions of power-plants-on-wheels (hybrid cars) will be able to opportunistically connect to the grid to displace central station generated power – thereby presaging the end of the central power plant. It is equally possible, and indeed much more likely, that the opportunistic activity will be the reverse – vehicles will start sipping from the grid. Hybrid vehicles can be viewed as big generator-battery systems on wheels, with the batteries the other necessary half of the hybrid electric equation (linked together via high-power silicon). In the evenings, using on-board logic that will 'know' the prevailing net cost per mile of burning gasoline that day, or tapping the coal-fired grid that night, such vehicles may 'chose' to opportunistically charge their batteries from low-cost off-peak central station power. For a very large share of the daily driving needs, hybrid batteries could store enough energy to relegate the on-board gasoline-fired generator to back-up status.[3]

Even though electric technologies are poised to invade the combined $150 billion/year in capital spending on power conversion in industrial and transportation markets, the electric-to-electric market for power conversion is already a $260B/yr enterprise, and growing.

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[2] Much of the gains from automotive electrification, thus far, have permitted primarily bigger, faster, more comfortable and safer cars – not necessarily more efficient cars if measured only in mpg (or carbon emitted) per car. Consumers have, instead, been eagerly purchasing the other economic metrics that the new technologies create; safety, comfort and convenience.

[3] While seemingly counter-intuitive, it bears noting that the net carbon emissions from a coal-dominated grid charging a hybrid's batteries will be comparable to, even lower than, charging the same batteries from an on-board gasoline engine. The much higher inherent efficiencies of central electric generation more than offset the lower carbon intensity of gasoline used in inherently less efficient small combustion engines. It is impossible to consider hybrids without noting the fuel-cell option; while intriguing, fuel cells are not relevant to near-term transportation policies, they are only relevant to longer-term R&D funding.

There is a broad range of technologies that fall in the electric-to-electric; refrigerators, lights, motors, entertainment, and computer power supplies that run on electric power, along with the entire class of related power conditioning technologies used to energize everything from medical to research equipment, from factory motor controls to uninterruptible power systems, from home entertainment to cellular towers.

The relatively recent emergence, and dominance, of this new class of power conversion technologies is evident in the poorly disaggregated statistical information the Energy Information Administration (EIA) collects for the commercial and residential sectors. In the commercial sector, EIA data shows that office PCs and related equipment already exceed the total electric consumption for all office cooling. But more tellingly, most of the commercial sector demand, today and tomorrow, is buried in an undifferentiated statistical catch-all "all other" category. While EIA is careful to parse the use of the 20^{th} century's dominant class of electric technologies (relatively recently adding PCs to the differentiated mix), all the rest of new commercial technologies show up lumped together as "all other." The EIA hints at what this category includes - - the largest source of existing and new commercial electric demand:

> "New telecommunications technologies and medical imaging equipment are projected to increase electricity demand in the "all other" end-use category..."

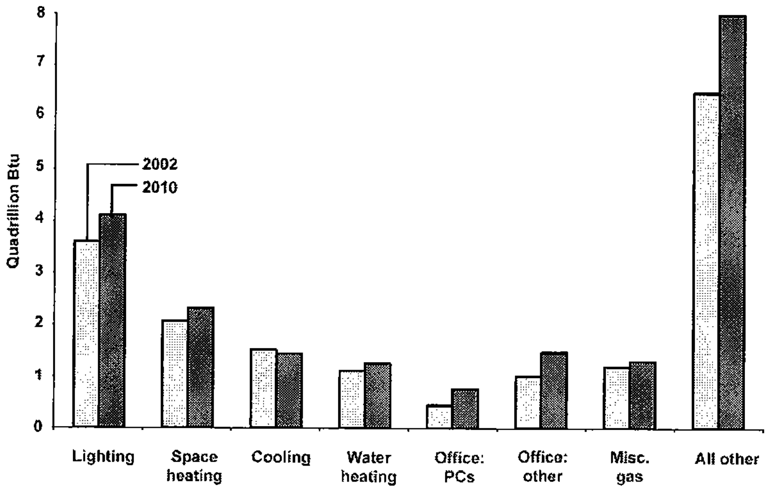
More serious analysis of this grouping is called for given that the "all other" category accounts for nearly twice as much energy as commercial lighting – the ostensible "largest source of commercial electric demand." The "all other" category will be the main source of growth in energy demand in the commercial sector, followed electric-fueled PCs and related "office" hardware.

A similar picture emerges in Residential sector data – where careful tracking of energy data continues for traditional technologies, but the fastest growing source of demand (and use of power conversion technologies) also falls in to an undifferentiated "all other" category. Here too the EIA notes:

> "The 'all other' category (including small appliances such as personal computers, dishwashers, clothes washers, and dryers) … accounted for 29 percent of residential primary energy use in 2002, is projected to account for 37 percent in 2025."

As with the commercial sector, this "all other" comprises the largest and fastest growing source of energy-technology demand in the residential sector. No one seriously expects electric demand for conventional technologies of dishwashers, clothes washers and dryers to increase. Even with population growth, net demand from this class of technologies will continue to follow the same downward trajectory as the other conventional energy-consuming technologies. The net new demand arises from the net new class of electricity-consuming, productivity-driving, lifestyle-enhancing technologies.

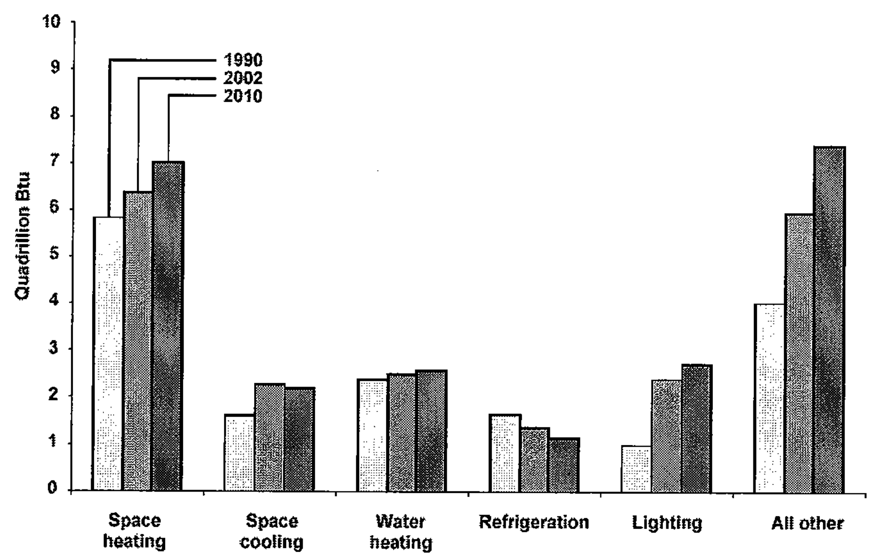
Figure 10. Commercial Primary Energy Consumption by End Use



http://www.eia.doe.gov/oiaf/aeo/demand.html

Residential Energy Consumption

Figure 11. Annual Energy Outlook 2004 with Projections to 2025



For those who study these trends, it is clear that there is now underway a deep, broad-based change in how the economy uses energy. The changes are visible whether measured in terms of equipment purchases, technology trends or fuel purchases. Electric-based technologies continue, and are now accelerating, their penetration of every facet of the U.S. economy. It is a trend so fundamental, and so important to the U.S. economy that it should be (but generally is not) considered and understood first and foremost in any energy policy deliberations, especially including those that are de facto 'stealth' energy policies arising from Greenhouse Gas programs.

The important central role of electric technologies has been almost entirely abandoned as a field of extensive and deep analysis over the past 15 years. A vital next step in considering future energy and Greenhouse Gas policies would be for the President to request the National Academy of Sciences (NAS) to revisit and update their seminal research and 1986 report, Electricity in Economic Growth. The NAS carefully studied the nature and impact of electric technologies, not how electricity is produced, as the core focus on the macro-economic relationship between electricity and the U.S. economy. The NAS was prescient in forecasting continued growth in electric technologies, and electric demand, and noted that:

"Our first and important conclusion is that electricity plays a very important role in productivity growth."

The same NAS report also concluded in 1986:

"These [electric] price increases play an important role in explaining the decline in U.S. productivity growth since 1973."

Does Price Matter?

Which brings us, briefly, to the issue of price. It is often suggested that, if the rising use of electric technologies has improved carbon intensity, wouldn't carbon intensity be improved even more if the country switched from carbon-rich fuels, such as coal, in generating electricity to other less carbon-intensive fuels? Such suggestions ignore the fundamental role that the price of electricity plays in consumer and business decisions.

The NAS study devoted considerable effort to unraveling the broad economic impacts of the price of electricity. There is, at first blush, a conundrum. Given the powerful economic benefits of electric technologies, why does it matter how the electricity is produced, and thus how much it costs? In effect, don't all electrons, once delivered, look alike from the perspective of the end-use? The fact is price remains a very important characteristic, setting aside the other substantive physical metrics of electric supply -- issues of reliability and quality, where in purely physical terms all electron flows are no more equal than all types of calories in food.

End-users select equipment on the basis of many metrics, initial capital cost of course, and a host of related benefits the equipment provides. Also considered are the constellation of operational costs for a piece of equipment, where the cost of energy is relevant, but rarely primary. This secondary, even tertiary position of operational energy costs as a deciding factor in initial purchases would seem to argue against the relevance of electric prices as a pivotal issue. Yet the NAS found, at the macro-economic level, high and rising electricity prices depressed economic growth by, overall, depressing the migration to productivity-enhancing electric technologies.

The NAS document eloquently addresses this apparent conundrum, put simply; there are practical differences between capital and operational expenses. Once a piece of equipment is purchased, the cost is in effect "sunk," so any future increase in the cost to own/operate that equipment simply takes away from the "bottom line" -- comes out of profits. At the most basic level, revenue taken from business through higher operating (fuel) costs simply reduces the ability to grow capital to then buy yet more productivity-enhancing equipment. Homeowner's buy homes considering many factors, where energy costs are only one and rarely primary - - but residential consumers are notoriously intolerant of fuel price increases once the home is owned. It is true for businesses as well. The effect, the NAS found in 1986, is far from subtle. There is no reason to expect the effect to be less today; indeed there is every reason to expect the effect to be more important now given the increased dependence of the GDP on electricity (see Figure 5).

One proposed solution to the consequence of tinkering with primary price is to have the federal government enact equipment efficiency standards; i.e., if end-use equipment is required to be more efficient, higher cost electricity can be offset by reduced consumption. It's a nice theory, and frequently proffered, but capital formation is a zero sum game – capital consumed to make equipment more efficient reduces capital available to make it more productive. When, however, new technologies are pursued first for productivity benefits, and are then found to be more efficient as well, there is the positive net outcome of economic/productivity growth along with rising energy efficiency. This is precisely the trend that has occurred in the marketplace over the past two decades.

Conclusions

As the foregoing data show, the current state of affairs on the energy demand side of the equation is quite different from what it was two decades ago. The energy supply side is largely the same. Yet most policies and even most data collection remain locked in 20th century metrics that have their roots in post WWII technologies and trends, rather than post Cold-War trends.

All serious Greenhouse Gas proponents/proposals either aggressively seek, or at least genuflect to the proposition that policies should complement the goal of economic growth, or at least not cause serious damage. The historic trends shown here illustrate an unequivocal trajectory.

- Carbon efficiency has improved coincident with rising GDP, rising electrification, and rising coal use.
- Reduced carbon intensity is a direct consequence of improved energy efficiency, arising directly from technology purchase decisions in the marketplace.
- More money is spent each year on the technologies of power conversion than on raw fuel, and
- Electric technologies are the overwhelming favored form of power conversion hardware (thus driving an increased preference for electricity as the primary fuel).

Efforts to encourage and accelerate market behavior, including R&D, and to understand "boundaries" should thus follow the firmly established and productive history of the past two decades. **While there are many technologies deserving of focus and**

encouragement, electric-based power conversion technologies are the utterly dominant factor. Every one of the five activities contemplated in the DOE proposals should encourage and reflect the core historic trends - - and equally importantly, not contemplate actions that impede these trends.

1. greenhouse gas intensity reduction goal
2. energy technology research programs
3. targeted tax incentives to advance the development and adoption of new technologies
4. voluntary programs promote actions to reduce greenhouse gases
5. international initiatives.

In addition, DOE/EIA should initiate programs directed at collecting and assimilating data to accommodate the realities of new technologies that have entered the energy-consuming market, specifically to unbundled the large and growing "all other" categories in energy accounting. Furthermore, the National Academy of Sciences should be called upon to revisit its economic research into the role of electric technology and electricity prices.

In general, any efforts directed at manipulating primary energy markets – whether through price/tax signals, or "voluntary" programs/credits for fuel switching -- should be carefully evaluated for their potential to, unintentionally, but negatively impact core productivity (and carbon intensity) trends. DOE's voluntary Greenhouse Gas reporting program should focus on energy consumption rather than production and should not encourage fuel switching in electric generation.