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Pew Center/NCEP 10-50 Workshop

Energy Efficiency Overview Paper

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I. Introduction

The purpose of this paper is to assess the possibilities for energy efficiency improvements in the United States over the next ten to fifty years. Energy use is the major contributor to greenhouse gas (GHG) emissions and any effort to bring GHG emissions under control will require considerable improvements in energy efficiency. In addition to reducing GHG emissions, energy efficiency can reduce peak electricity demands thereby reducing the need for new electrical capacity, contribute to reduced air pollution, and contribute to energy security to the extent that it reduces our reliance on foreign energy imports. Economic savings would also offset some of the costs of energy efficiency investments.

Business as usual scenarios suggest that U.S. carbon emissions will grow at an annual rate of 1.5 percent in the period between now and 2025. While predictions going out 50 years are risky and subject to considerable adjustment, a standard reference case is the 1.5 percent growth rate contained in the Energy Information Administration’s *Annual Energy Outlook 2004*.

In this overview, I provide a “good news – bad news” story. The good news is that there is enormous technological potential for energy efficiency, and that energy use responds to changes in energy prices and policies such as efficiency standards. The bad news is that although technological potential is high, it is unclear how high prices will have to rise (or other institutional reforms will need to be undertaken) to bring about these changes. Therefore, it will likely require some combination of significant energy price increases, efficiency standards, efficiency labeling and other information campaigns, and institutional reforms in order to bring about large-scale improvements in energy efficiency.

II. Background

I begin by noting some trends in energy use over the past fifty years. Energy consumption in the United States has nearly tripled over that time period (see Figure 1). Declines in aggregate energy consumption are closely tied to the recessions of 1953-54, 1957-58, 1973-75, 1980, 1981-82, 1990-91, and 2001. Sharp reductions over short time periods occurred during the energy crises brought on by the Arab oil embargo in 1973 and the Iran-Iraq War of the early 1980s. In nearly all cases, energy use has quickly rebounded.

Figure 2 presents data on per capita energy consumption and real energy prices in the United States over this same period. The solid line is per capita energy consumption (legend on the left hand axis) while the dotted line graphs a real fossil fuel composite production price in dollars per million BTUs (legend on right hand axis). Rising energy use per capita peaked in 1978-79 and has stayed relatively constant since then. The large run up in energy prices in the 1970s blunted the upward momentum of per capita energy use and—despite the sharp fall-off in real energy prices since 1980—per capita energy use has not resumed its upward trajectory.

The most striking story is told in Figure 3 which graphs energy consumption per dollar of real GDP (together with the same overlay of the composite real energy price) from 1949 through to the present. Energy consumption per dollar of real GDP has fallen by over 50 percent since 1949. While it was falling prior to the first oil price shock, the decline in energy consumption relative to real GDP accelerated in the 1970s and has continued in the 1990s during a time of falling energy prices. An important question for research—and one which will critically inform recommendations for future enhanced energy efficiency—is the source of the dramatic improvement in energy use per dollar of GDP. The background paper on building energy efficiency for this conference (Loftness, 2004) hints at one possible answer to the question. Loftness cites work by Rosenfeld, Romm, Akbari and Lloyd (2004) that argues that California and national standards for equipment and appliance efficiency reduced overall energy consumption for heating, cooling, and refrigeration by from 25 to 75 percent. Figure 3 hints at another source of the gains. Energy consumption began its steady drop in 1971 just as energy prices stopped falling and began to rise—first slowly and then sharply. It may be that some of the efficiency gains that are attributed to efficiency standards would have occurred anyway in the higher energy price environment following the first oil price shock. A further complication arises from studies that emphasize the importance of structural shifts in demands for energy services (e.g., Schipper et al, 2001).

Last I note the large number of regulatory and informational initiatives that have been undertaken to encourage energy efficiency. Loftness notes the Leadership in Environmental and Energy Design (LEED) program of the U.S. Green Building Council. To obtain a LEED certification, a building project must satisfy a certain number of prerequisites related to site sustainability, energy efficiency, material and resource conservation, and indoor environmental quality. In addition to the building certification program, LEED provides resources to educate builders about constructing environmentally friendly and energy efficient buildings.

The U.S. EPA's Energy Star Program began in 1992 as a voluntary program to provide information to consumers about energy consumption of computers and other office equipment. It has expanded to include home appliances and other equipment. The logic behind the Energy Star Program is to provide information so that consumers can make educated appliance and equipment purchase decisions to trade off the (possible) increased purchase costs of energy efficient equipment against the lower energy costs of usage (see U.S. Environmental Protection Agency (2003)). The Energy Star Program subsumed the EPA's Green Lights Program in 1995. This program had been formed to work with the industrial and commercial sector to encourage energy efficient lighting in these two sectors. One component of the Green Lights Program was a contract between Green Lights Partners and the EPA by which partners agreed to install specified energy efficient lighting if the rate of return on the energy efficient investment exceeded a given rate of return.

Another initiative to encourage energy efficiency is described in the background paper on industrial energy efficiency for this conference (Price and Worrell, 2004). This is the U.S. Department of Energy's Industrial Assessment Centers, run by a number of universities across the country. The IAC database (housed at Rutgers University) contains data from some 12,000 assessments with over 82,000 recommendations for improvement.

In addition to the initiatives described above to encourage energy conservation and efficiency, Jaffe, Newell and Stavins (2001) report public-private partnerships in the area of housing (Partnership for Advancing Technology in Housing), schools (Energy Smart Schools), vehicles (FreedomCAR), and industrial processes (Best Practice, and the Office of Industrial Technology's Industries of the Future).

Finally, an important area in which the government has moved to limit energy consumption has been the development of mandatory appliance energy efficiency standards. The first standards were implemented in 1988 for clothes washers and dryers and dishwashers (see Table 1 in Jaffe, Newell and Stavins (2001) for a detailed listing through 2001).

III. The Energy Paradox

Two of the background papers for this conference are quite upbeat about the potential for long-run energy efficiency improvements. Price and Worrell cite studies suggesting long-term potential reductions in energy use in the industrial sector of between 30 and 65 percent. Loftness concludes that various initiatives "could trigger dramatic improvements in energy and environmental quality in the built environment." The background paper on the economics of energy efficiency (Newell, 2004), on the other hand, is less sanguine about the potential for large-scale energy efficiency improvements, noting that the benefits of any such gains must be weighed against the costs of achieving these gains. The difference in outlook reflects a long-standing difference in outlook between energy economists and energy technologists. As noted by Jaffe, Newell and Stavins (2001), this difference is well documented in the 1995 *Second Assessment Report of the Intergovernmental Panel on Climate Change*. Jaffe et al. note that "[o]ne part of this report states that energy efficiency improvements on the order of 10 to 30 percent might be possible at little cost or even with net benefits (ignoring climate benefits), while another part highlights the fact that most economic models indicate a significant cost for stabilizing or cutting OECD emissions below 1990 levels."

The difference in outlook between economists and technologists can be summed up in the concept of the "energy paradox." The energy paradox is the seeming anomaly that consumers pass up attractive energy efficiency investments with high *ex ante* rates of return (see Hassett and Metcalf (1993) for more discussion of this idea). But observing that people pass up what appear to be high return investments does not necessarily imply that there is a paradox. Part of the explanation comes down to differences in definition. Technologists often focus on technologies that have been proven in the laboratory. As Newell points out in his background piece, the process of technology acceptance involves three steps: *invention, innovation,* and *diffusion*. Each step is critically important to the acceptance of a new technology. According to Newell, invention "involves the development of a new idea, process, or piece of equipment." Technologists are often at the center of invention-related activity. Innovation is the step "in which new processes or products are brought to market." Innovation is the key step of making an invention commercially viable and may involve significant modification of the underlying technology. Note too that the commercialization aspect of innovation is such that the firm that spurs the technical breakthrough may not be the best skilled at taking it into the marketplace. The final step is diffusion, which is from Newell's explanation "the gradual adoption of new processes or products by firms and individuals, who then also decide how intensively to *use* new products or processes."

The innovation and diffusion processes can lead to significantly different efficiency gains than can be achieved in the laboratory. One study that illustrates this point (Metcalf and Hassett, 1999), used DOE data on energy consumption to measure empirically the returns to various home energy efficiency investments. This study found that realized returns were on the order of 10 percent—roughly one-fifth the estimated returns. One explanation for the lower returns is the difference in installation and utilization of energy efficiency capital between test houses and houses lived in by families. Insulation, for example, might not be installed optimally, and its benefits may be undermined by other characteristics of the house or family (ineffective windows or weather-stripping elsewhere, family inattention to open doors and thermostats, etc). This study suggests that additional measures such as consumer education should be considered when arguing for research investments in new technologies as a key tool for improving energy efficiency.

Studies of the diffusion of new technology find that adoption rates follow an S-shaped pattern with adoption beginning slowly, then rapidly increasing, and finally diminishing as the market becomes saturated. Newell's background piece alludes to a curious finding in a number of studies concerning the role of prices and the role of the upfront cost of the investment in efficiency in affecting adoption rates. Jaffe and Stavins (1995) studied the effects of energy prices and adoption costs on the adoption of new technology that increases the R-value in new home construction. R-value is a measure of the insulating properties of building materials. A house with a high R-value will use less energy than a house with a low R-value, other things held constant. While rising energy prices positively impacted the average R-value in new home construction, they found that equivalent cost subsidies were roughly three times as effective as price increases. This importance to consumers of reducing these upfront costs of energy efficiency is surprising given standard financial theory suggesting that a 10 percent permanent increase in energy prices should have the same effect on a cost-benefit analysis of an energy efficiency investment as a 10 percent reduction in the price of the investment.[1] Jaffe and Stavins's result is consistent with the view that consumers discount the future "too heavily." It is also consistent with other explanations. Hassett and Metcalf (1995) also found that tax credits that reduce the purchase price of new energy efficiency investments are roughly eight times more effective as equivalent increases in energy prices. The researchers speculate in that study that consumers may view the energy price increases as temporary in which case it is not surprising that one-time up-front cost savings are more effective than future (and risky) price savings.[2]

In addition to measurement problems (temporary versus permanent energy price increases, over-optimistic energy efficiency gains), other possible explanations of the Energy Paradox have been proposed. These include myopia, imperfect information, and capital market imperfections. To the extent that short-sighted behavior and imperfect or insufficient information are significant, information programs may be very helpful. As Newell points out, information is a public good and—like all public goods—will be under-produced in a competitive market. The government can play a key role with programs like energy labeling on appliances or office products.

One instrument that is not unambiguously welfare improving is energy standards. Energy standards have the effect of forcing consumers to purchase a minimal level of energy efficiency capital. In return for an increased upfront cost, the consumer receives future benefits in the form of energy savings. Let's say that the internal return on this investment is r^*. For consumers with a discount rate below r^*, this is a welfare enhancing investment. For consumers with discount rates above r^*, however, this is welfare reducing. Consumers with high discount rates are being forced to invest more than is optimal for them in energy efficiency. To the extent that high discount rates are disproportionately found among the poor, an appliance standards program will be regressive.[3] That standards may be regressive should not deter us from considering them. But we may wish to consider them as part of a larger package that combines progressive elements with this potentially regressive initiative (see Metcalf (1999) for a discussion of distributionally neutral green tax reforms).

Energy price fluctuations were noted above as one possible explanation for the dominance of purchase cost subsidies over energy price taxes as an instrument to induce greater energy efficiency investments. Energy price fluctuations raise the issue of uncertainty and sunk costs. An investment in energy efficiency is a risky investment given the uncertainty inherent in future energy prices. In addition, the investment involves sunk costs. Sunk costs are costs that cannot be recovered if a project is abandoned. Consider a factory manager considering investing in a new energy-efficient furnace. To the extent that the furnace is custom-designed for the specific factory, there is little resale value should the factory decide to "undo" the investment.[4] In the presence of return uncertainty and sunk costs of an irreversible investment, it is straightforward to show that the hurdle rate for investment rises with the risk. Hassett and Metcalf (1993) show some illustrations to demonstrate that diffusion of a new technology that has the properties of an irreversible investment and uncertain return can be dramatically slowed relative to a world with no uncertainty in the return to the investment. Metcalf and Rosenthal (1995) apply this methodology to investments in energy-efficient refrigerators and commercial fluorescent lighting. Given historic price variation in refrigerators and electricity, we estimated that the hurdle rate for new energy-efficient refrigerators is roughly 2.5 times what it would be in the absence of price uncertainty.

Summing up, there may be exciting technological developments that augur well for reducing energy use in the future. But there also exist a number of critical economic issues that suggest that the gains will not come as quickly or at as low a cost as we might otherwise think. I turn next to a brief discussion of the policy implications of this discussion.

IV. Policy Implications

Enhancements in energy efficiency can only be viewed as one piece of the puzzle for a plan to reduce carbon emissions in the United States. Given the uncertainties and difficulties attendant to many carbon reducing technologies, energy efficiency will be particularly important as one of the short to medium term contributors to reduced carbon emissions. As a general matter, any policy (whether it apply to energy efficiency or to other technologies) should be designed to be policy neutral between new energy supplies and efficiency. In other words, we should treat efficiency improvements as an energy source. A carbon tax or cap-and-trade system is an example of a policy that is neutral between efficiency and clean carbon sources. A subsidy to renewables and/or nuclear only is not.

The Energy Information Agency's Annual Energy Outlook 2004 projects carbon emissions to grow from 1,563 million metric tons per year in 2002 to 2,221 million metric tons in 2025, an annual growth rate of +1.50 percent. Consider as an example, a target for the United States to reduce its emissions to 1990 levels by 2015. Taking 2002 as the reference point for future emission reductions, emissions would have to decrease by -1.04 percent per year over the 13 year period (see Figure 4). Sutherland (2000) reports that the high technology assumptions contained in the "Five Lab" Study would only reduce the growth rate of emissions from +1.50 percent from the Annual Energy Outlook 1998 prediction to +0.56 percent. Therefore, even an optimistic assessment of energy efficiency options, finds that in the near-term technology alone will not stabilize carbon emissions in absolute terms.

My reading of the historic improvements in energy efficiency over the past 30 years leads me to conclude that a combination of price based instruments along with quantity based instruments (e.g. standards) will provide the most effective gains in energy efficiency in the near-term. In both cases, a key component of the policy is that carbon is priced. Let me discuss these in turn.

Taxes are the most obvious price-based instrument. One rationale for moving to a greater reliance on carbon or energy taxes is that the United States taxes energy much more lightly than other developed countries. The possibilities include a carbon tax, a BTU tax, as well as more specific fuel taxes, for example, an increased federal excise tax on gasoline. A tax on carbon is the most efficient way to bring about reduced carbon emissions as the tax is precisely targeted to the externality of concern (GHG emissions).[5] A carbon tax has the disadvantage, however, that it raises the price of coal significantly relative to other fuels. While desirable from an environmental perspective, this price differential has adverse political and distributional implications that serve as a barrier to the use of carbon taxes.

The current political climate, in my view, is not likely to look favorably on *any* form of energy taxation in the United States. This despite the fact that energy taxes could offset some of the revenue losses from recent changes to the tax laws (see Metcalf (1999) for a discussion of revenue neutral green tax reforms).[6] This suggests that we should look at quantity based instruments.

Quantity instruments include non-tradable pollution quotas, tradable emissions permits (like the SO_2 permit program under the Clean Air Act Amendments of 1990), and performance standards (appliance standards, CAFE, etc.) In choosing how to design an effective and politically viable permit system, two questions must be answered. First, will the permits be given away (as under the electric utility SO_2 program) or will they be sold? In a world with pre-existing tax distortions, there are large efficiency losses resulting from giving away permits rather than selling them.[7] In brief, the revenues from selling the permits can be used to lower other distortionary taxes. Bovenberg and Goulder (2001) show that only a small fraction of the permits need be given to the energy producing industry to compensate for the loss in equity value for the firms following a decision to restrict carbon emissions. This follows because permits create barriers to entry (since you need a permit in order to operate if your firm emits pollution) and barriers to entry in turn create economic profits (or rents).

Second, will be permits be tradable? The primary benefit of trading is that a given level of pollution reduction can be achieved at lowest cost given the ability of heterogeneous firms to trade with high cost firms purchasing permits from low cost firms. Trading is counter-indicated when pollution can lead to "hotspots," areas of intense pollution. While an important issue for air pollutants in urban areas, this is not a relevant concern for carbon emissions given the mixing of carbon and other GHGs in the atmosphere. Thus a permit program should allow trading.

Starting with a modest cap (low price) and a consistent, pre-announced commitment to tighten the cap over 10-20 years (thereby raising the price) would give industry time to prepare for it while minimizing short-term resistance. Prior to its implementation, support for voluntary programs (like the Chicago Climate Exchange) should be provided. Also, it is worth studying whether a U.S. cap and trade system should allow for international buy-in on some level. This might simply allow firms to substitute foreign carbon reductions for domestic carbon reductions. For this to be feasible, firms would have to agree to more extensive measurement activities to create more comprehensive baselines for carbon emissions. This has the benefit for multinational firms to encourage them to engage in world-wide carbon audit measurement activities.

Performance standards in the industrial, transportation and building sectors that mandate a level of energy efficiency are politically attractive given the resistance to taxes or to programs that might require firms to purchase pollution permits. Loftness (2004) argues that due to a historic lack of policy attention and the diffuse nature of energy use in buildings, targeted standards (e.g., cool roofs, daylighting and natural ventilation) could provide significant reductions in national energy use. Performance standards in the industrial sector would likely have to be fine-tuned for individual industries. Strengthened CAFE standards are an attractive option for the transportation sector. Despite the fact that CAFE standards only apply to new vehicles (while gasoline taxes apply to new and used vehicles), research suggests that CAFE standards are much more effective at reducing fuel consumption than gasoline taxes (see Goldberg (1998) for evidence on this point).

In addition to the above policies, simple policies to raise awareness of energy consumption and carbon emissions would be low-cost but valuable policy instruments. Labeling the embodied carbon content in consumer products (or buildings) is an example of a policy to raise awareness. Promoting research to develop consistent measures of taxes and subsidies to energy production is another way to promote awareness. A federal policy requiring firms to engage in carbon audits (as some states do now in the environmental area) is a third low-cost policy. Interestingly, research in environmental economics suggests that state laws that mandate waste audits (with no requirement for remedial action) lead to waste reduction in the production process. The information gained through the audits is a valuable input used in production to bring about reductions in environmental waste (see Snyder, 2003).

In the longer-term, price increases have the potential to induce technological innovation that brings about further energy improvements. Using data from 1960-1990, Newell, Jaffe and Stavins (1999) found substantial evidence for price-induced technological change for a variety of appliances. Popp (2002) has found that energy-efficiency patent applications are positively correlated with energy prices. To strengthen the importance of induced technological change as we move forward in time, one approach promoted in the Loftness and the Price-Worrell background papers is to invest more money in R&D for energy-efficiency technologies. As a cautionary note, however, it should be noted that rate of speed of technology diffusion is retarded as capital stock service lives lengthen. Jaffe, Newell and Stavins (2001) note that the typical service life of commercial and industrial buildings is 40 to 80 years. While many efficiency opportunities are achievable through retrofit (and debate continues over the overall potential for retrofitted efficiency measures), even greater efficiency gains occur as the capital stock turns over (i.e., new construction, new equipment offer greatest opportunity vs. retrofitting). The background paper by Loftness provides exciting examples in the longer-term of potential reductions in energy use in buildings, and even the use of buildings as power plants in a distributed system.

V. Conclusion

Significant price changes, combined with regulatory and information policies to overcome market failures, will likely be required to bring about large-scale reductions in carbon emissions through improved energy efficiency. Price increases for energy or price reductions for energy efficient capital investment will bring about reductions in energy use;

whether these can be brought about at a low cost to the economy, however, remains to be seen. Evidence to date suggests that this will be unlikely at least in the short term.

Over the longer term, price signals have the potential to induce innovation that speeds up technological change. Even with significant technological change, however, we must recognize that it will be a slow process to replace the current energy inefficient capital stock, particularly for long-lived assets like buildings. Over the fifty year horizon we can expect to see significant efficiency improvements. In the near term, a combination of taxes, tradable permit schemes, and performance standards are the best options for bringing about increases in energy efficiency. Over the longer term, induced innovation resulting from price increases combined with strategic research and development investments can bring about greater energy savings and improvements in energy efficiency.

Note: Data source for figures: EIA (2003), *Annual Energy Review 2002*, Energy Information Administration, U.S. Department of Energy, Washington DC.

Figure 1. U. S. Energy Consumption

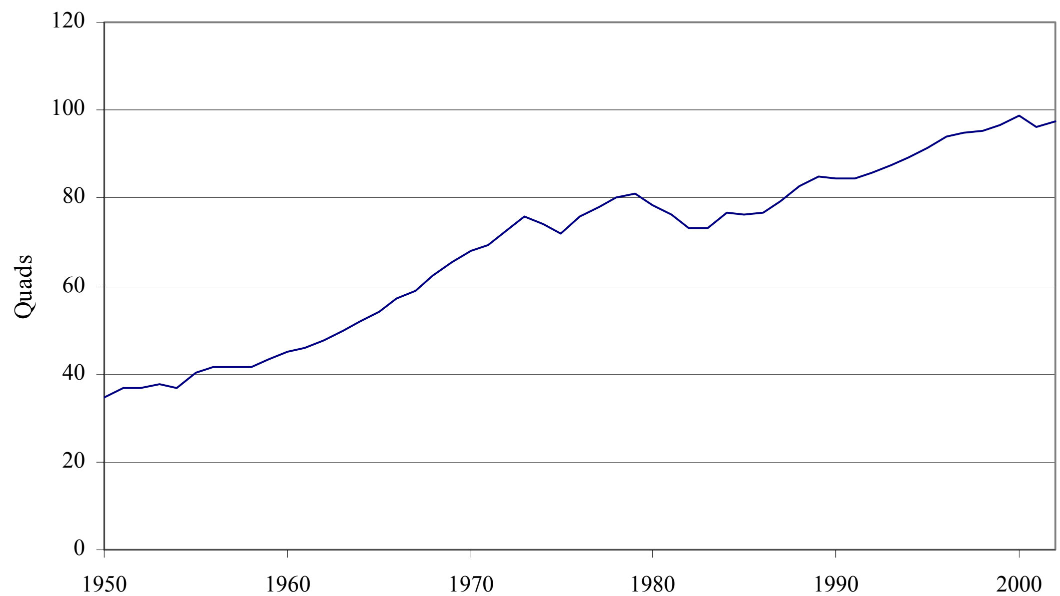


Figure 2. U. S. Energy Consumption Per Capita and Real Energy Prices

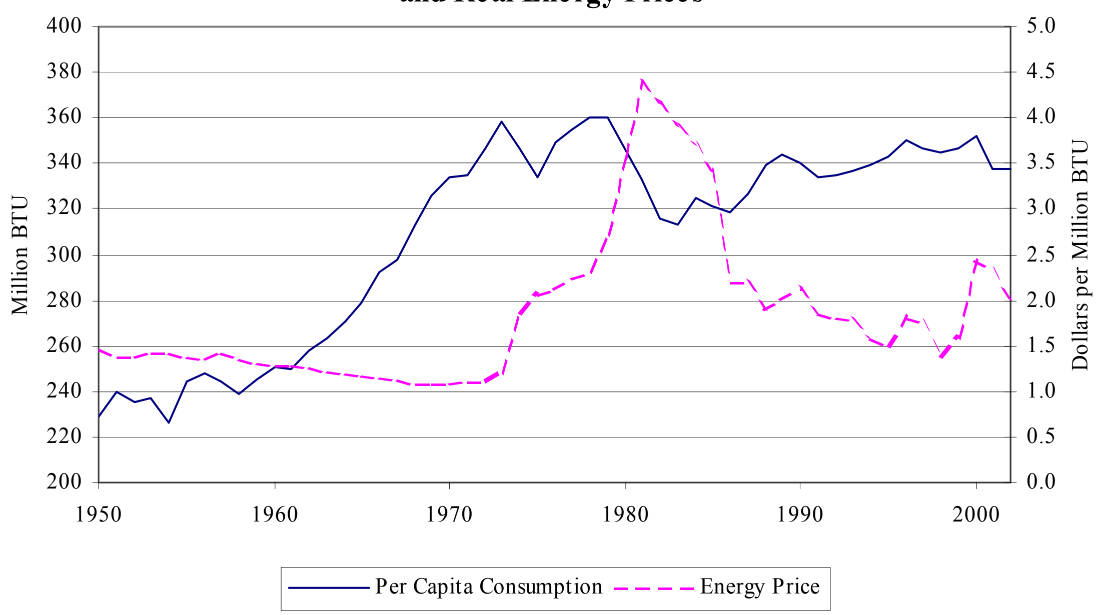


Figure 3. U. S. Energy Consumption per GDP and Real Energy Prices

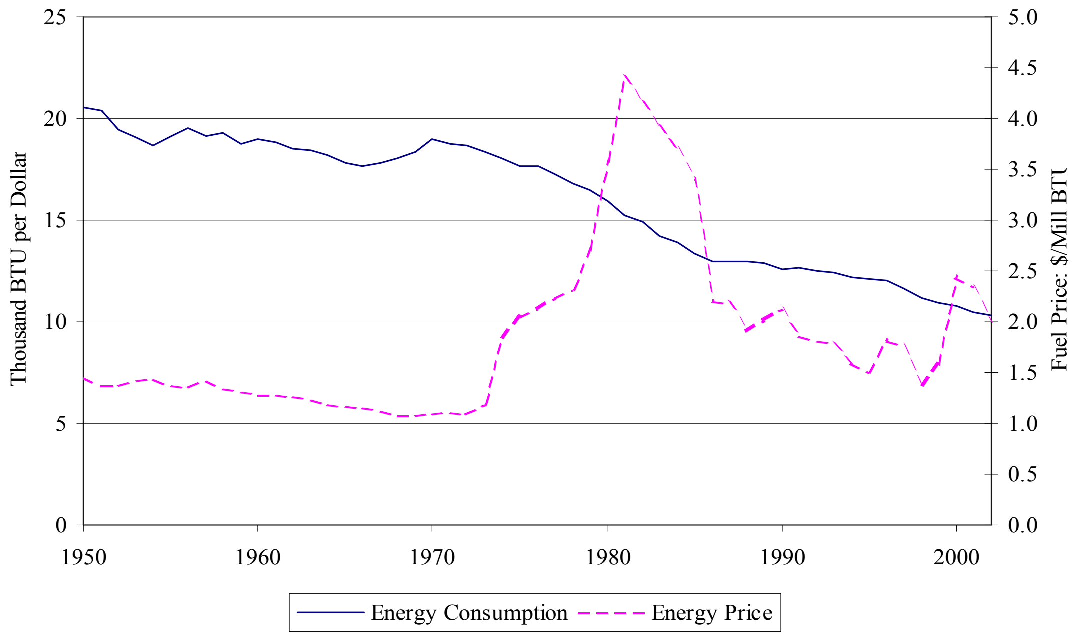
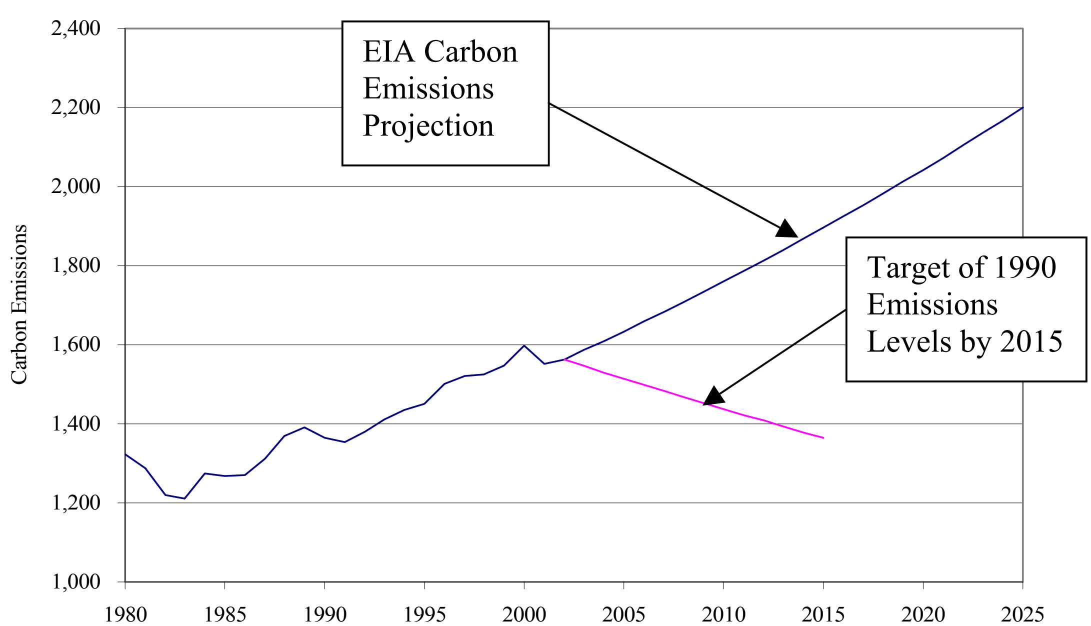


Figure 4. U.S. Carbon Emissions



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[1] This is true as a first-order approximation.

[2] While providing subsidies to energy efficient capital investments may have a greater bang for the buck to induce investment, it does not provide any incentive to reduce energy use with existing capital.

[3] Train (1985) documents the long-standing finding for higher discount rates among low-income people. Poorer access to capital markets and lower levels of education are two oft-cited reasons for this finding. Sutherland (1991) provides a CAPM analysis for why the poor might exhibit a high discount rate for energy efficiency investments.

[4] This is exacerbated by costs of customization and installation over and above the capital cost of the furnace itself.

[5] Fullerton, Hong and Metcalf (2001) discuss the welfare costs of imperfectly targeted environmental taxes.

[6] With estimates of the ten year budget deficit now approaching $2.4 trillion (Congressional Budget Office (2004)), there may be a softening of the opposition to energy taxes.

[7] See the discussion in Goulder, Parry and Burtraw (1997) and Fullerton and Metcalf (2001) on this point.