Forecasting an Increasing Role for Energy Efficiency in Meeting Global Climate Goals

David B. Goldstein, Natural Resources Defense Council
Marc G. Hoffman, Consortium for Energy Efficiency

ABSTRACT

A number of studies over the past decade and longer have shown how energy efficiency can achieve a large fraction, or all, of the greenhouse gas emissions reductions necessary to meet the goals of the Kyoto Protocol in the United States. But few studies suggest that we can go significantly beyond these goals, particularly on a global basis, as is required for climate stabilization. If energy models show that cost effective measures such as energy efficiency are not sufficient to meet climate goals, then economic models will show that the costs of climate policies are unnecessarily high.

This paper focuses on the potential for continuous improvement in energy efficiency based on voluntary efficiency programs' ability to use demand pull strategies such as market transformation to introduce more efficient technology into the marketplace and mandatory policies such as minimum efficiency standards that are upgraded regularly to eliminate the obsolete models. These two policies are interrelated: both efficiency advocates and manufacturers are recognizing the advantages to having "premium" levels of energy efficiency induced by market transformation programs as well as mandatory standards and have recognized that the market demonstration of these higher levels of efficiency often leads to upgrades in the minimum standards. But even after the upgrade, continued existence of market transformation programs provides manufacturers with an incentive to redesign, not just to meet the standards, but to go beyond them, at least for a fraction of their products. As manufacturers strive to take advantage of this dynamic, even higher levels of energy efficiency are achieved. These new technologies are almost never included in forecasts.

We will document the dynamic process of encouraging continuous technological improvement through a combination of research, market transformation, incentives, standards, and market forces, and suggest options for forecasting and scenario planning based on these observations. We will compare forecasting assumptions used in analysis of future appliance standards for the base case to energy models used in analyses of global warming scenarios. Both will be contrasted to our analyses of the dynamic voluntary/mandatory piggybacking of demand pull and higher minimum standards policies on efficiency forecasts for common technologies in the residential and commercial sectors.

Introduction and Overview

Policy discussions concerning how to deal with the problem of anthropogenic climate change focus heavily on energy forecasts that can be used to project whether the economic consequences of complying with a given level of climate pollution emissions reduction--for example, that required by the Kyoto Protocol--is economically beneficial or harmful, and by what amount. Thus, energy forecasts play an important role in the view of policymakers throughout the world concerning the feasibility of adopting or ratifying such agreements, and the accuracy and realism of these forecasts is of considerable interest.

Energy models do not provide absolute forecasts of energy use, but rather scenarios that respond to specific policy questions. Often, the very structure of the model determines – that is, limits – the types of questions that the model can answer.

Different models utilized by different organizations have yielded strikingly opposing conclusions on what it would take to comply with the goals of the Kyoto Protocol. Most of this difference is because they are asking very different policy question. This issue is discussed in Section II.

U.S. Energy Models

Econometric Models

Models that are primarily top-down and econometric in their structure, such as those generally used by the U.S. Energy Information Administration (EIA), focus on simulating price effects, and, in the case of the more sophisticated models, balancing supply and demand through the price mechanism. While such models often have end-use detail, the level of detail falls far short of what would be necessary to simulate the effects of policies that are not primarily based on price.[1]

These models, when applied to the case of climate change, answer the question: "If we limit climate emissions to a predetermined level using only emissions taxes (or equivalent cap-and-trade systems) as the policy mechanisms, what are the likely effects?" Not surprisingly, if the question is framed this way, the relevant answer will be: an extent to which the limitation costs the economy extra money. This is because the models assume an economic equilibrium at market prices for energy, and any deviation of prices from the market level, by, for example, carbon taxes, reduces economic value. Policies such as efficiency standards, which can have large and favorable effects on the economy, are generally difficult or impossible to simulate using such models.

End-use Based Models

Another set of models looks primarily at policies affecting end uses of energy, such as efficiency standards or incentives, and pays less attention to price effects. These types of models consistently have shown that it is relatively easy and, overall, profitable for the U.S. economy to meet goals such as the Kyoto Protocol target. Studies performed by non-governmental organizations typically have shown that all of the savings necessary to meet the Kyoto Protocol can be produced by measures that are cost-effective even without considering the climate problem. In some cases, *all* measures included in the policy case meet this test; in other cases, the *package* of measures is economically profitable but includes some individual measures where the private costs exceed the private benefits.

But even the most optimistic studies fail to show the ability to go dramatically further than the Kyoto Protocol. This is particularly true if the goal is climate stabilization globally,

---

[1] Examples of such policies include: energy efficiency standards on new construction or new equipment, utility regulatory changes to make energy efficiency programs profitable to utilities, and the provision of economic incentives for higher levels of energy efficiency.

rather than just the U.S. This paper finds that this is an artifact of the current structure for these models and analyzes why it is so difficult to get them to can show emissions declining continuously over time, particularly globally.

Policies That Have Achieved Energy Efficiency and Their Consequence for Selection of Models.

The United States has improved its gross energy efficiency, measured by the ratio of GDP to energy consumption, by some 75% since 1973, and some one-half to three-quarters of this improvement is attributed to technical energy efficiency measures at the end use level. But this increase has not been a steady trend for all thirty years in all places; rather, there is considerable temporal and regional variation.

Of particular importance for this discussion is the fact that many states have improved energy efficiency dramatically faster than the rest of the country. For example, California's electricity use per capita has remained constant for the past 30 years while the average electricity consumption in the United States as a whole grew by 50%. California Energy Commission estimates show very large savings coming from two types of policies: efficiency standards for buildings and appliances, and incentive programs for energy efficiency, operated in California by utilities. The California Energy Commission and several California Governors have claimed that these policies also enhance economic growth, and several studies support the claim.

On the national level, a substantial portion of the gains in energy efficiency have come from the increase in fuel economy of automobiles, an increase that was concentrated during a one-decade timeframe when mandatory standards on fuel economy were in effect.

These differences illustrate that models that are incapable of dealing with these types of policies are not suitable for forecasting the impact of climate policies whose implementation mechanism focuses heavily on end-use efficiency standards and economic incentives.

Models that do allow this type of analysis tend to have a relatively transparent structure: they are based on spreadsheets that look at the efficiency of individual devices of buildings as they're purchased or constructed and track their numbers in energy consumption until they are retired or demolished. Energy efficiencies can change during the lifespan due to retrofits or changes in operation that may be related to energy price. Programs can be disaggregated into their impact on new construction or retrofit and folded into the spreadsheet.

These types of models have been in use since the early 1970's.[2] These studies differ primarily in their level of disaggregation and detail and in the ambitiousness of energy efficiency policies that they are simulating. The national laboratory studies tend to be more technically

[2] Examples include: L. King et al., Moving California Toward a Renewable Energy Future, NRDC, San Francisco, 1980; D. Goldstein, A. Rosenfeld, "Projecting and Energy Efficient California," 1975; Solar Energy Research Institute: "A New Prosperity: Building a Sustainable Energy Future – The SERI Solar/Conservation Study," Brickhouse Publishing, Handover, MA 1981; "America's Energy Choices: Investing in a Strong Economy and a Clean Environment," ASE, ACEEE, NRDC, Tellus Institute, UCS, 1991; S. Bernow, et al., "Energy Innovations: A Prosperous Path to a Clean Environment," ASE, ACEEE, NRDC, Tellus Institute, UCS, 1997; Inter-Laboratory Working Group on Energy Efficient and Low-Carbon Technologies, "Potential Impacts of Energy Efficient and Low-Carbon Technologies by 2010 and Beyond," U.S. Department of Energy, Sept. 1997; "Clean Energy Futures," Department of Energy, 2000.

conservative, limiting the efficiency measures to those that appear politically acceptable as well as economically feasible.[3, 4]

Perhaps the most optimistic, as well as the most transparent, model was developed for *America's Energy Choices*. It provides extensive documentation down to the level of supply curves for saved energy for virtually all of its end uses. America's Energy Choices forecast a reduction of 70% in CO_2 emissions over a 40-year time span using measures that cumulatively cost US $2.5 trillion but save US $5 trillion.

But even this level of efficiency improvement would not lead to climate stabilization: such a goal requires that net emissions are cut to near zero. Structurally, the assumptions in the end-use models generally were that higher levels of efficiency were imposed on new construction or equipment purchases in one or two cycles, going to the perceived limit of feasible, practical, and cost-effective technology, and then efficiency stayed at that level. In many cases, existing stocks were retrofit. But ultimately, under this scenario, there is a limit to how much efficiency can occur; and after that limit is achieved, energy use grows inexorably with GDP.

Thus, on the scales relevant to climate change – 30 years, 50 years, or 100 years – emissions growth transitions from a high base to a lower base, but continuing emissions growth is inevitable: stabilization cannot be achieved without large and growing amounts of renewable energy sources, which may present their own environmental problems at those levels of exploitation.

Fortunately, real world experience is beginning to show that much further progress can be made in energy efficiency over the long run, this is because as technologies expand, new opportunities are discovered; and as markets for the first level of improvement in energy efficiency are developed, processes by which second generation improvements can be profitable are brought into play. Section III discusses the practical experience with "continuous improvement" in energy efficiency policies.

Market Transformation Programs and Continuous Efficiency Improvement

Let us examine the dynamics of efficiency improvements in refrigerators to see how American voluntary programs, minimum standards, and competition have driven their energy consumption and resultant emissions of GHG below most expectations. Refrigerators are the classic example of multiple cycles of competitive markets induced by voluntary efficiency programs continuing to drive improved efficiency, with minimum standards coming behind to prohibit the least efficient models.

Standards were first promulgated in 1976; these standards and their subsequent revisions became effective in 1977, 1979, 1987, 1990, 1993, and 2001. Efficiency programs began in the early eighties with direct consumer rebates for high efficiency units. In the mid- and late-eighties, voluntary efficiency programs pooled their resources for a winner-take-all competition to support R&D and marketing of a super-efficient refrigerator (30 percent more efficient than current models) without using CFC refrigerants.

---

[3] For example, the "Clean Energy Futures" study did not include, even in its advanced technology scenario, the possibility that an air conditioner standard at SEER 13 could be enacted. Yet, that is exactly what DOE did in 2001.

[4] These studies were also highly conservative in that they used a high discount rate to evaluate economic cost effectiveness and tended to look at individual measures rather than whole systems (particularly important for commercial buildings, which consume 15% of the nation's energy).

Some rebates programs continued in the nineties and starting in 1997 efficiency programs embraced the ENERGY STAR label as a marketing platform and began increasing their support for ENERGY STAR qualified refrigerators. This renewed support and attention to high efficiency refrigerators allowed manufacturers and efficiency advocates to agree on the latest minimum standards, which took effect in 2001.

Today, ENERGY STAR qualifying models are at least 10 percent more efficient than the minimum requirement and tiers supported by the Consortium for Energy Efficiency which call for units 20, 25 and 30 percent above the federal minimum. As of January 2004 there are 621 models under 25 brand names qualifying for ENERGY STAR with 72 models at CEE tier 1, 8 models at CEE tier 2 and even 9 models at CEE tier 3.

The combination of policies cumulatively led to ~80% lower energy consumption of new units compared to the 1970s. These reductions were achieved in the face of a market in which refrigerator size and features were growing. While all this was happening, the price of the refrigerator declined almost continuously throughout the period.

We compare this history with some of the more aggressive forecasts, scenarios, and planning documents. The NRDC *Scenario* of 1980, which was considered quite aggressive at the time, forecast that the energy consumption of refrigerators post-1985 could be reduced to 600 kWh/yr for a top freezer model. This level compares with the actual sales weighted average of 660 kWh achieved when the industry complied with the 1993 standard. Today, there are many models available at 430 kWh/yr and at a larger size than predicted in the scenario. The federal standard is about 500.

The study “A New Prosperity” projected a potential for reducing energy use to 750 kWh after 1990 and 500 after 2000. This tracks pretty decently what actually happened; but significantly, it forecast no further savings beyond that.

The Northwest Power Planning Council’s 1989 supplement to its “Power Plan” limits the realistic potential at the level of a forthcoming 1993 federal standard, but notes a technical potential that it felt was not realizable through policy means for reductions to 520 kWh/yr.

America’s Energy Choices is the only one that forecasts continuing levels of improvement for refrigerators; but interestingly, this is the *only end use* in which continuous improvements are projected. Going from the 1990 standards level of about 955 kWh/yr, this study suggests a further reduction to 620 kWh in 1993, 438 in 1998 (which is within about 10 percent of the level of the 2001 standards that were originally agreed by manufacturers and DOE to become effective in 1998) and then forecast further reductions of 25%-30% for the next two five-year cycles. When refrigerator use finally reaches 228 kWh/yr in 2008, no further improvements are assumed, but probably because the absolute magnitude of energy use for the product was approaching insignificance. Today there are 9 models that exceed the minimum standards by 30 percent and the ENERGY STAR criterion by 20 percent.

Another end use in which standards, voluntary programs, and market transformation efforts have interacted to drive continuous efficiency improvements over the years is the clothes washer. For clothes washers, most of the studies suggested that a 40%-50% savings in hot water with associated gas or electricity savings was possible; except for *America’s Energy Choices* suggestion that savings up to two-thirds were possible after 2003. None of these studies distinguished between pre-1980 energy use; thus they missed a reduction of over 30% in energy use in new clothes washers that occurred between 1972 and 1981. In reality, following the modest energy efficiency standards of 1994, energy use was already down by 50% while the market transformation goals, adopted by ENERGY STAR®, produced a reduction of about 60% from that level, or about 80% compared to the 1972 baseline.

Interestingly, since the adoption of mandatory standards in 2000, effective 2007 at the previous ENERGY STAR level, the maximum efficiency available has continued to increase, corresponding with ever-higher tiers of market transformation programs. In 2003, the Consortium for Energy Efficiency adjusted its performance specifications and raised its highest tier to 43 percent above the 2007 minimum standard. By early 2004, there are already 49 models that meet or exceed this highest efficiency level.

Dishwashers followed a similar pattern, with the energy forecast/scenario studies suggesting savings of about 50%; savings which had already been achieved when the 1994 mandatory standards went into effect. New developments in dishwashers include soil sensing features whose effects are just beginning to be incorporated into tested results, but which promise substantial energy savings beyond the standards.

For residential heating and cooling, all of the studies focused on improvements in insulation of the major building envelope components and improving fenestration up to a level of triple glazing. *America's Energy Choices* was more aggressive, suggesting specific targets in the long run for U-value and solar heat gain coefficient of the windows. In the case of the other studies, codes were established requiring the projected levels of efficiency, but new technologies such as reduced-conductivity framing and low-emissivity coatings allowed the state-of-the-art to progress far beyond the projected efficiency for windows. The forecast in *America's Energy Choices* is consistent with (but slightly more stringent than) today's ENERGY STAR levels, which command a significant market share. Much higher levels of efficiency are available and cost-effective today.

For commercial lighting, one of the largest uses of energy, virtually all of the studies projected today's higher efficiency luminaires and the use of dimmable electronic ballasts with T-8 lamps and controls as the optimum technologies. Utility programs promoted these technologies aggressively in the 1990's; leading to the adoption of mandatory ballast standards in 2000, effective 2005. As market transformation programs focused on lower lighting power densities, unforeseen improvements were made in the underlying products. Today's generation of super T-8s with programmable start electronic ballasts reduce energy consumption by an additional 17% while improving color rendition, lighting quality, and lamp life.

Conclusions

We have examined how, for many significant end uses, even the most aggressive forecasts were unable to predict how far industry could go with efficiency over the mid to long term. For these uses, we have shown how the interaction of minimum standards, normative labeling, and market transformation programs have been able to establish a dynamic that rewards innovations in energy efficiency, and industry had responded by introducing higher levels of cost-effective efficiency than had been considered possible with previously known technologies.

This conclusion implies that there is a systematic error in energy forecasting models that consistently overstates the difficulty of meeting a specific energy reduction goal. The structure of this systematic error is particularly troubling: the more aggressive the energy efficiency goal, the greater the extent to which the model overstates the difficulty of achieving it.

This systematic error is the result of the "once-through" assumption for the incorporation of efficiency measures that underlies most of the models that we have examined. That is, the models assume that a given set of measures (perhaps on a supply curve of conserved energy) can be implemented up to a certain extent, but then further progress towards efficiency stops. This paper has demonstrated numerous examples where, after the economy achieves a given predicted level of energy efficiency, manufacturers and designers find even more opportunities for savings, particularly when there are policy instruments pushing in that direction.

To correct this problem, models could assume that continued progress in efficiency for each end use can be made in future years at approximately the same rate (the same percent savings from the new base case) as was achieved over the number of years in the direct forecast. This scenario should at least be available in models as a sensitivity case.

References

Alliance to Save Energy, American Council for an Energy-Efficient Economy, Natural Resources Defense Council, Tellus Institute, and Union of Concerned Scientists. 1991. *America's Energy Choices: Investing in a Strong Economy and a Clean Environment*. Washington, D.C.: American Council for an Energy-Efficient Economy.

Alliance to Save Energy, American Council for an Energy-Efficient Economy, Natural Resources Defense Council, Tellus Institute, and Union of Concerned Scientists. 1997. *Energy Innovations, A Prosperous Path to a Clean Environment*. Washington, D.C.: American Council for an Energy-Efficient Economy.

Bush/Cheney Administration. 2001. *National Energy Policy Development Group Report*.

Consortium for Energy Efficiency. 1993. *Residential High Efficiency Clothes Washer Initiative, Performance Specifications*.

Department of Energy (DOE). 1997. *Potential Impacts of Energy Efficient and Low-Carbon Technologies by 2010 and Beyond.* Inter-Laboratory Working Group on Energy Efficient and Low-Carbon Technologies. U.S. Department of Energy.

Department of Energy (DOE). 2000. *Clean Energy Futures.* U.S. Department of Energy.

Goldstein, David and Art Rosenfeld, 1975. *Projecting an Energy Efficient California*.

King, Laura, et al. 1980. *Moving California Toward a Renewable Energy Future.* Natural Resources Defense Council

Solar Energy Research Institute. 1981. *A New Prosperity: Building a Sustainable Energy Future – The SERI Solar/Conservation Study.* Brickhouse Publishing, Hanover.