Improving the Contribution of Economic Models in Evaluating Energy and Climate Change Mitigation Policies

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1. INTRODUCTION

There are expanding national discussions on a critical number of energy-related issues. Among these issues is the need to understand the inevitable transition from a petroleum-based economy and the need to identify a smart set of climate change mitigation and adaptation policies. The complex interactions surrounding all of these issues have motivated the development of a relatively large number of energy-economic models to assist decision makers in the framing of appropriate energy and climate policy directions.

But how much do these models really inform the debate? The record of U.S. model-based energy forecasting holds evidence that such models provide biased estimates that tend to reinforce the status quo, inadequately inform policy-makers about new market potential, and serve to constrain the development of innovative policies. At the same time, there is a growing critique that may lend insights into many of the modeling discrepancies (see, for example, Koomey 2005, Worrell et al 2004, Laitner et al 2003, and DeCanio 2003, Craig et al 2002, among others). At the same time, Munson (2004) adds that there is also a disconnect between the questions policy makers want answered and the results provided by modeling exercises. This paper examines some of the analytical reviews that underpin these critiques. It then explores four specific areas of improvement based on a consistent set of modeling exercises carried out by analysts at the Argonne National Laboratory.[1] The hope is that this paper will be among the positive contributions that might highlight potential improvements for the policy community so that the models better reflect a dynamic technological characterization and diffusion process; and which, in turn, can encourage a more robust policy development to the benefit of both the economy and the environment.

2. BACKGROUND

Even a cursory review of recent model projections suggests a critical disconnect with real world outcomes. With some exceptions the majority of standard policy models suggest that high energy prices from carbon charges would negatively (and in some cases significantly) contribute to large GDP losses.[2] In contrast, world oil prices are now up prices now up to \$75 per barrel compared to an average \$28 per barrel in 2003. That price increase is roughly the same as a carbon charge of about \$370 per ton of carbon (in constant 2000 dollars). Yet, the economy grew by a very healthy 3.7 percent annually over that same period. That level of economic expansion despite these higher prices may be an indication of an economy that has a greater capacity to respond to price changes than is usually suggested.

This point was brought home in a 1999 *Energy Journal* article by Kydes (1999). The analysis in that article, based on a series of runs from the Energy Information Administration's (EIA) *Annual Energy Outlook 1997* (AEO 1997), suggested that in the period 1996 through 2015, the annual rate of decline in the nation's energy intensity appeared to be "bounded by 1.25 percent when real energy prices are relatively stable." Yet in the period 1996 through 2000 when prices were, in fact, relatively stable, the rate of decline in energy intensity averaged 2.85 percent (EIA 2006a), more than double the responsiveness in the economy that was otherwise anticipated. Although it has tapered off in the most recent years, the average rate of decline continues to be a steady 2.41 percent annually (in the period 2000 through 2005). This is still nearly double the limit suggested by the EIA in 1999.

Finally, the modeling community in recent years has been reasonably on target in getting the energy quantities approximately right; but at the wrong set of energy prices. For example, the EIA annual evaluation of past energy forecasts since the AEO 1982 (EIA 2006b) shows that total primary energy are typically forecast to be within 3-5 percent of the actual value for a given year. However, the coal, oil and natural gas prices are typically 40-80 percent too high. Sanstad et al (2006) suggest that this continual result of "the right quantities-wrong price" indicates a significant understatement of the nation's capacity for productivity improvements and technological change. This and other evidence suggests a need for an in-depth review of critical model shortcomings as they might impact the evaluation of different oil/energy transition scenarios.[3] In this paper I highlight four important areas with suggestions for improvement based on how they are now handled in the AMIGA modeling system. The four areas are:

(1) Technology characterization that is often limited or even inappropriate – for both the demand and the supply-side of the equation;

(2) Capital flows that are not sufficiently disaggregated to provide meaningful policy assessments;

(3) Modeling assumptions about consumers and firms which may be unrealistic and which may also give misleading insights about policy options; and

(4) An economic accounting of investments and technology choices that are limited or poorly represented.

Given a body of evidence that points to a clear "room for improvement" (Laitner et al 2003), the question might then be asked: "How might we address these potential shortcomings or weaknesses in a way that provides a satisfying (if imperfect) response?" It is not enough to outline these shortcomings with some detailed comment; rather it will be more useful to provide a suggested set of remedies that might be mapped into the existing and into the new family of policy models. Toward that end, I first offer a brief description of the AMIGA modeling system (Hanson and Laitner 2006); and then highlight several of the key problem areas with an overview of how each of these problems are currently handled within the model. I finally close with some brief suggested areas of improvement beyond those discussed in this paper.

3. AMIGA MODELING SYSTEM

The AMIGA Modeling System is a hybrid general equilibrium model that incorporates detailed energy end use and energy supply characterization within computable general equilibrium (CGE) framework. It is supported by the Argonne National Laboratory with funds from both the U.S. Department of Energy and the U.S. Environmental Protection Agency (Hanson and Laitner 2006). Although AMIGA is used to analyze a variety of worldwide energy and climate policy scenarios as they might be implemented throughout 21 regions of the world, its strength is the detailed energy market characterization of the U.S. economy.

AMIGA can evaluate the impact of energy-related technology investments in more than 200 individual sectors (in terms of both dollar measures and physical units). In short, it integrates a detailed energy market specification within a structural economic model. Within its CGE framework, AMIGA allows firms to maximize net wealth and consumers to maximize intertemporal utility. In the absence of perfect foresight, agents act on approximate intertemporal rules. As it evaluates a wide variety of energy and climate policies, it calculates both prices and macroeconomic variables such as consumption, investment, government spending, real GDP, and employment. The model provides annual results from the present through the year 2050, with the capability of extending the time horizon out to 2100. As part of the various scenarios that might be explored, AMIGA (in turn) uses the MAGICC model (Wigley 2003) to estimate greenhouse gas concentrations and temperatures. The model has been used in a variety of assessments, including the Clean Energy Future study (Interlaboratory Working Group 2000), an analysis for the Pew Climate Center (Mintzer et al 2003), the International Energy Agency's (IEA) *World Energy Outlook 2004* (IEA 2004) and *World Energy Outlook 2006* (IEA 2004), as well as contributions to the EMF-21 and EMF-22 multi-gas emission scenario exercises.

In evaluating the various energy and climate policy scenarios, AMIGA integrates a number of modules that describe the various economic interactions among twenty-one world regions, including the United States. This modular approach facilitates a detailed accounting of the major goods, services, and technologies demanded by households and the various production sectors of the economy that lead to changes in energy production and consumption, greenhouse gas emissions, and resulting temperature changes.

4. CRITICAL PROBLEM AREAS

The section that follows provides a review of the four critical problem areas that, if not appropriately reflected within energy and climate policy models will tend to provide misleading insights for policy and decision makers. Following a short description of the problem, the paper discusses ways that can resolve the problem as it is done within the AMIGA modeling system.

4.1 Limited Technology and Energy Efficiency Characterization

Compared to the year 1970, both technology and changes in market structure accelerated the rate of decline in the nation's energy intensity such that energy efficiency now provides 75 percent of all U.S. energy service demands (Laitner 2006).[4] Despite the significant contributions from past efficiency gains, there is a tendency in economic models and conventional policy analyses to assume that new energy efficiency investments can make only a limited — and "not always cost-effective" — contribution to our nation's energy future. The operative assumption is that we've pushed the efficiency frontier as far and as fast as it can reasonably go. The good news, however, is that the evidence points to the very real prospect for new and substantially greater gains in energy efficiency — especially when one explores the role of industry as innovator and champion of new and more productive technologies. Hence, the mere assumption that there are near-term "practical limits" to further efficiency gains is not defensible (Lovins 2006; Laitner 2004; and Laitner 2005a).

At the same time, other research demonstrates that improvements in energy services may actually turn out to be the critical factor in the growth of an economy — perhaps one of the primary drivers that underpin "technological progress" (Ayres and Warr 2005). From a longer term perspective, if sustainable economic activity is to continue — but without proportional increases in emissions and waste, it is essential to reduce energy use per unit of work or dollar of economic activity. In other words, increased energy efficiency may be the key to long-term sustainable development; and, one might add, the key to long-term global development and international security.

In effect, energy efficiency improvements do not have to be about ratcheting down the economy. Instead, they can be all about providing new services, making new products, and providing new ways to both work and play (Hanson et al 2004). Moreover, the evidence suggests – that despite the impressive efficiency gains following the oil crises in the 1970s and early 1980s, energy efficiency resources still remain an impressive investment opportunity (Lovins 2006, Elliott et al 2006, Shipley and Elliott 2006, and Laitner 2004). So the question is posed as we model or evaluate policy scenarios: why is it that we always gravitate toward supply-side solutions with the implied assumption that efficiency reserves are either already used up? Or that they cannot be deployed quickly or cost-effectively?

To more fully explore this question, the AMIGA Modeling System offers a detailed technology representation within a CGE framework. The model tracks a detailed accounting of major goods and services demanded by households and the various production sectors of the economy that lead to changes in energy use and production, greenhouse gas emissions, and temperature changes. In short, AMIGA combines a bottom-up, discrete technology representation of the demand for energy and the many other goods and services available with regional markets, together with a detailed interaction among the sectors and among the regions of the world. Various choices within these sectors are modeled through nested constant elasticity of substitution (CES) production functions. This, in turn, determines how economic output is supported through inputs of capital, labor, materials, and electric and non-electric energy.

The model allows for autonomous improvements in technologies as well as both price and other policy-induced improvements which can lead to cost-effective reductions in both energy use and the full complement of greenhouse gas emissions. AMIGA also incorporates macroeconomic feedbacks. Higher energy and other resource costs lead to the substitution of capital and labor for energy.

The business and household production functions are conveniently represented by a three parameter Constant Elasticity of Substitution (CES) production function (Hanson and Laitner 2006). The three parameters are denoted by *alpha* and *beta* which are scale parameters related to cost shares of the capital and energy factors, respectively, and *sigma* which is the elasticity of substitution that governs the ease of substituting capital for energy. Because of mathematical properties of the CES production function, *sigma* is often expressed as a function of another parameter denoted by *rho*. In addition to these first three parameters, we also have base capital costs and expected minimum efficiency parameters to describe actual technologies and their associated investment and energy costs. (Note: the next part of the paper, section 4.2, provides a discussion on the importance of a more disaggregated capital stock with respect to energy-related capital services and other productive capital.) Drawing from a series of data on commercial lighting, for example, we can use these five parameters to describe the array of discrete lighting technologies using the CES function as shown in Figure 1.

Figure 1. Illustration of an Isoquant for Commercial Lighting in 2010 and 2030

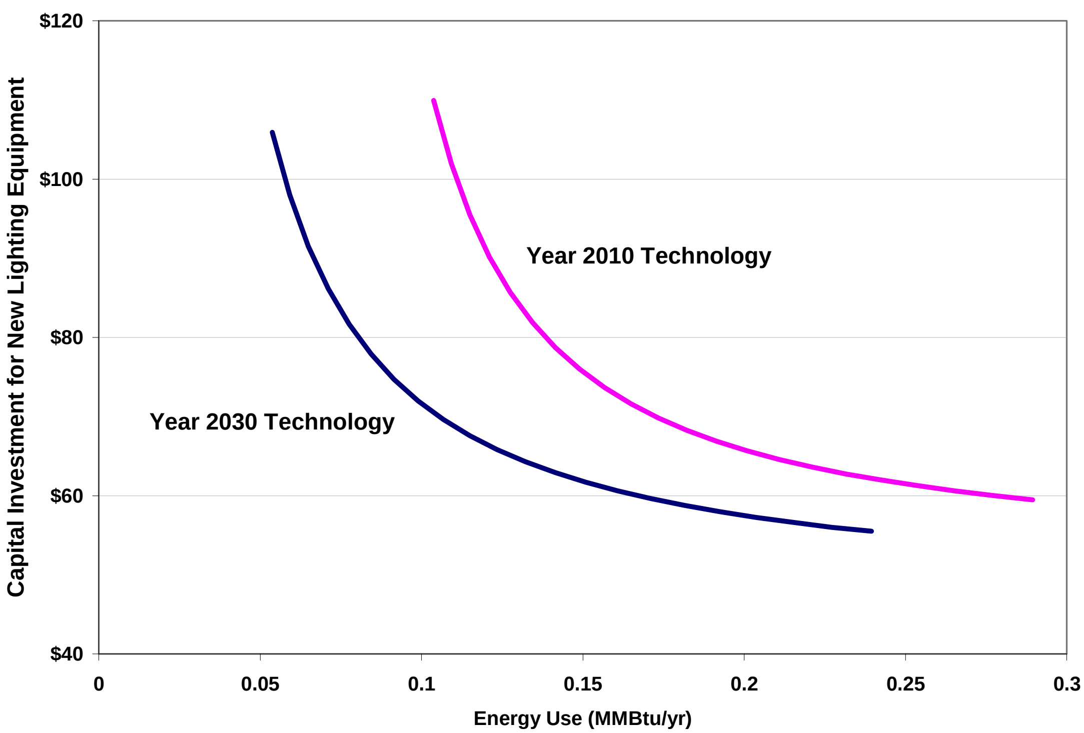


Figure 1, shows illustrative technology "cost curves" for actual commercial lighting technologies which have been adapted from data files provided by the Energy Information Administration.[5] Additional information can be obtained from research by the U.S. Department of Energy's various national laboratories, university engineering laboratories, and research groups such as the American Council for an

Energy-Efficient Economy, among others. In effect, the isoquant represents the opportunity set facing the consumer or business for a particular demand for energy services. The decision-maker must select a point from this opportunity set. The point selected will reflect the relative weight that the decision maker places on "first costs" incurred when equipment is purchased or the project is being constructed compared to future operating costs.[6]

For future years beyond (say) 2010, technical progress and learning from experience will increase the substitution possibilities between capital and energy. We model this as technological progress and cumulative learning having the effect of increasing the parameter sigma, the elasticity of substitution in the CES function prior to normalization. The other parameters alpha and beta are then adjusted accordingly to represent any expected change for the minimum efficiency of the equipment.

The two curves in Figure 1 for the years 2010 and 2030 represent and contrast the potential for incremental energy-efficiency investment for a single "lighting system" as an alternative to higher electricity consumption. In this example, both electricity and incremental capital are inputs to a production function intended to satisfy a demand for effective lighting of a commercial building. Holding the demand for energy services at a fixed level (in this case the providing of about 1000 lumens of light over the normal operating hours of an office building), the different technologies that might satisfy the demand for lighting can be represented as a production isoquant that describes the combinations of capital and energy which can produce the same level of the desired energy service.

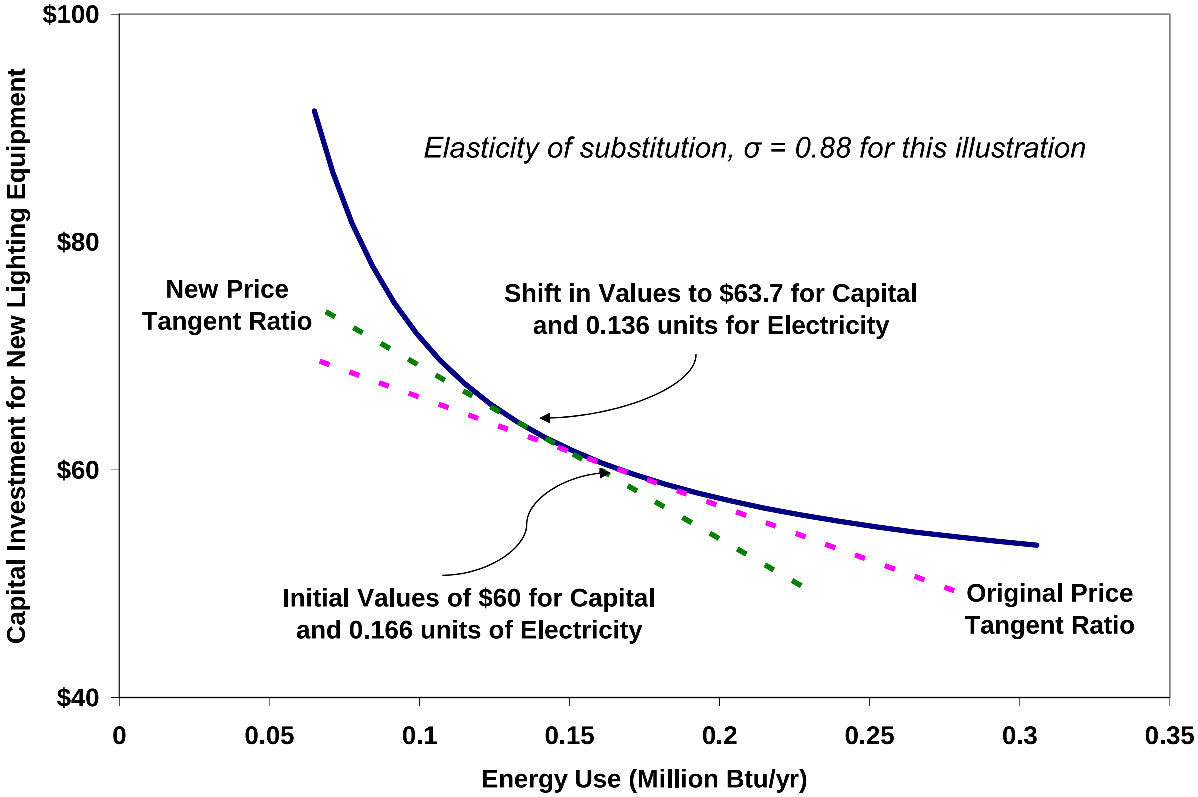
In the year 2010 the technologies available at that time are shown both to cost more and to have less potential to reduce overall energy use compared to those which might be available in 2030. By 2030, however, there will be some combination of technical progress, scale economies, and learning-by-doing which is likely to shift the isoquant both lower and more to the left. This suggests that the technologies in 2030 year can be expected to generally cost less and achieve a slightly larger reduction in the amount of electricity needed to satisfy the service demand in that year. It will also enhance the competitiveness between end-use and supply-side technologies (Laitner and Sanstad 2004).

In AMIGA the actual decision to choose from a given set of technologies – each with its own cost and level of efficiency – is a function of both energy price, *Pe*, and the individual preferences of a consumer or firm as they might be reflected in a hurdle rate, *r*. This produces a price ratio, *Pe/r*, which influences the ultimate choice from among the available technologies. Given a specified mix of price and preferences, the rate at which capital is substituted for energy is governed by the production function's isoquant as shown in Figure 2 on the following page. (Note that section 4.3 of this paper will explore the implications of the price-preference ratio, *Pe/r*, in more detail).

In this case, and drawing from an actual set of discrete lighting technologies that might be available in 2030, we show how changes in consumer preferences might drive changes in the mix of capital and energy – assuming an elasticity of substitution of 0.88.[7] Assuming an electricity price of \$24.29 per million Btu (~\$0.083 per kilowatt-hour), a starting hurdle rate of 25 percent, and a *Pe/r* ratio of 97.2, a commercial building manager might have selected a lighting technology that costs \$60 and consumes 0.166 million Btus (~49 kWh) per year. In some future policy case electricity prices might rise by some amount and preferences might shift as a result of promotional efforts mounted by the EPA Energy Star program.

In this case, we assume that electricity rates increase by 30 percent and the 25 percent hurdle rate is reduced by to perhaps 20 percent as a result of some small set of programs. In this case the price ratio would increase by ~63 percent. Governed by a 0.88 elasticity of substitution, this change in preferences moves the optimal mix of capital and energy up the isoquant so that the new values are shown as \$63.7 and 0.136 million Btus (~40 kWh). In other words, with the lower hurdle rate, a commercial property manager is willing to increase capital expenditures by \$3.7 per lighting unit to save 0.03 million Btus (9 kWh). With new electricity prices of \$31.58 per million Btu (\$0.108/kWh), the expected payback on this incremental investment is less than 4 years.

Figure 2. The Increased Electricity Savings from Commercial Lighting in 2030



There are a large number of technologies that can be similarly characterized. For example, vehicle technology has been undergoing relatively continuous technical change. AMIGA represents what might be called evolutionary technical change as improvements in the characteristics of conventional and advanced gasoline and diesel vehicle types. Practical, economic fuel cell technology and hydrogen storage technology would represent engineering breakthroughs. The model takes as an input assumption the dates for availability of breakthrough technologies. Their importance can be examined through sensitivity testing. Hybrid vehicles with advanced power electrics and controls represent a mid-case. This is foreseeable technology that is developing very quickly.[8] Similar discrete technology characterizations are provided for other transportation (e.g., heavy duty vehicles), building (e.g., space conditioning, appliances, and office equipment), industrial processes (including petroleum refineries and combined heat and power systems), and energy conversion and power generation technologies (ranging from petroleum coking and gasification systems to a diverse array of renewable energy resources).

4.2. Disaggregating Energy and Non-Energy Capital Flows

The experience with the AMIGA modeling system suggests that disaggregating energy-related capital from other productive capital is a critical distinction in determining optimal allocation of all capital resources. Unfortunately, most of the U.S. based models participating in the Energy Modeling Forum exercises, for example (with the exception of AMIGA), provide little or no distinction between the different energy-using capital stocks or between energy and non-energy productive capital – especially with respect to energy end-use details. Those models typically employ some form of an autonomous energy efficiency index (AEEI) to represent change in energy demand over time, or in response to changing energy prices.[9]

The net effect of employing a highly aggregated capital stock is to produce a suboptimal competition within the mix of capital resources. This, in turn, tends to create downward pressure on sector output as energy prices rise. The reason is that there is less effective substitution of capital for energy to maintain a level of energy services that can satisfy the demand for sector output. For example, a highly aggregate capital stock that shows a consistent return of only 8-10 percent may obscure a significant 20-40 percent return on new end-use efficiency investments, and which in turn can improve a sector's bottom line if the substitution is allowed. This often is the case even if that substitution is only a small part of the overall capital stock. This would be especially true when the economy confronts higher energy prices, improved technology performance (either with respect to cost or performance), or shifting preferences that may lower hurdles rates (see section 4.3 that follows for an elaboration of this point). Certainly the recent programs to promote greater end-use efficiencies announced major corporations like Wal-Mart or Dow Chemical underscore this last point.

As a step toward providing a more satisfying competition among the different forms of capital, AMIGA applies a stock-flow approach in modeling end-use energy demand. Flows are additions of equipment necessary to meet growing service demands. Additions must also account for replacements due to retirements. Within the AMIGA modeling system, the allocation of capital and energy resources involves six key dimensions: time, region, sector, service demand, energy form, and consumer or customer group. The model evaluates the need for decisions in a given simulation year and the implications for energy demands and investment spending over all six of these dimensions.

Figure 3. Hierarchical Structure of Output within the AMIGA Modeling System

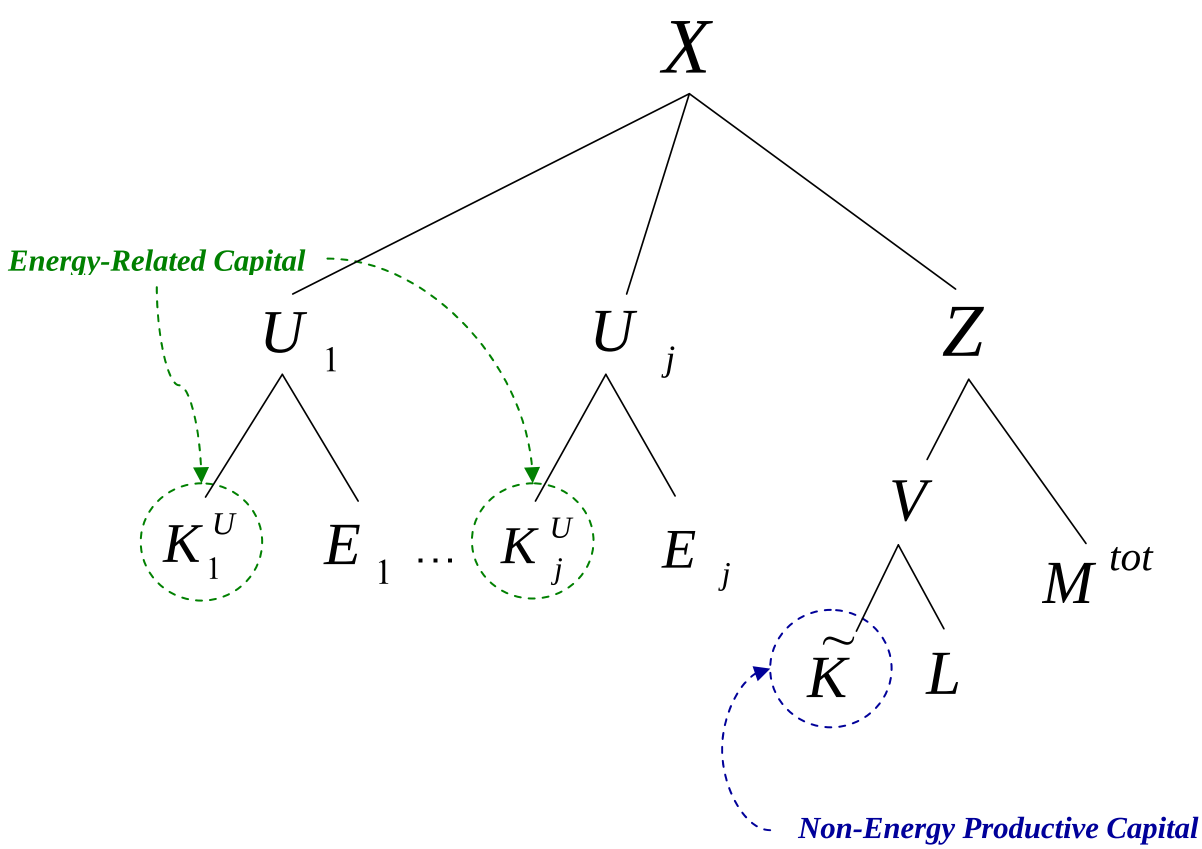


Figure 3, above, shows both the hierarchical structure of a typical commercial or industrial sector within the model together with the different forms of energy and non-energy capital needed to provide both utilized energy services and the value-added aggregate, both of which are necessary in maintaining sector output. In this arrangement shown in Figure 3, sector output X is supported by a variety of utilized energy services, U, ranging from subscripts *1* through j (which might include such services as spacing conditioning and lighting as well as motor drive requirements and process heat). This, is turn, is sustained by some mix of energy-related capital, *K*, and energy flows, *E*. As the necessary complement to energy services is the value-added aggregate, *Z*, which consists of materials, *M*, and pure value-added, *V*, that depends on contributions from non-energy productive capital, *Tilde K*, and labor, *L*.[10]

In this structure, the return on energy-related capital – for instance, a set of lighting improvements with a four-year payback (in effect, technologies that would have a 25 percent return on investment) – would compete with other capital in some combination that allows the overall sector returns to be maintained so that sector outputs can continue despite some increase in energy prices. This arrangement in the model structure also allows policy makers to understand that energy or climate policies might benefit from an emerging investment strategy that is more productive than the nation's existing capital stock.

To assist policy makers in understanding the new investment pattern, such changes in the capital stock can be reported out as shown in the example highlighted in Table 1 adapted from Hanson et al (2004). Note that all values reported as billions of 2000 U.S. dollars.

Table 1. Example of U.S. Investment Patterns Needed to Achieve a ~25 Percent Reduction in Total Primary Energy Use by the Year 2020

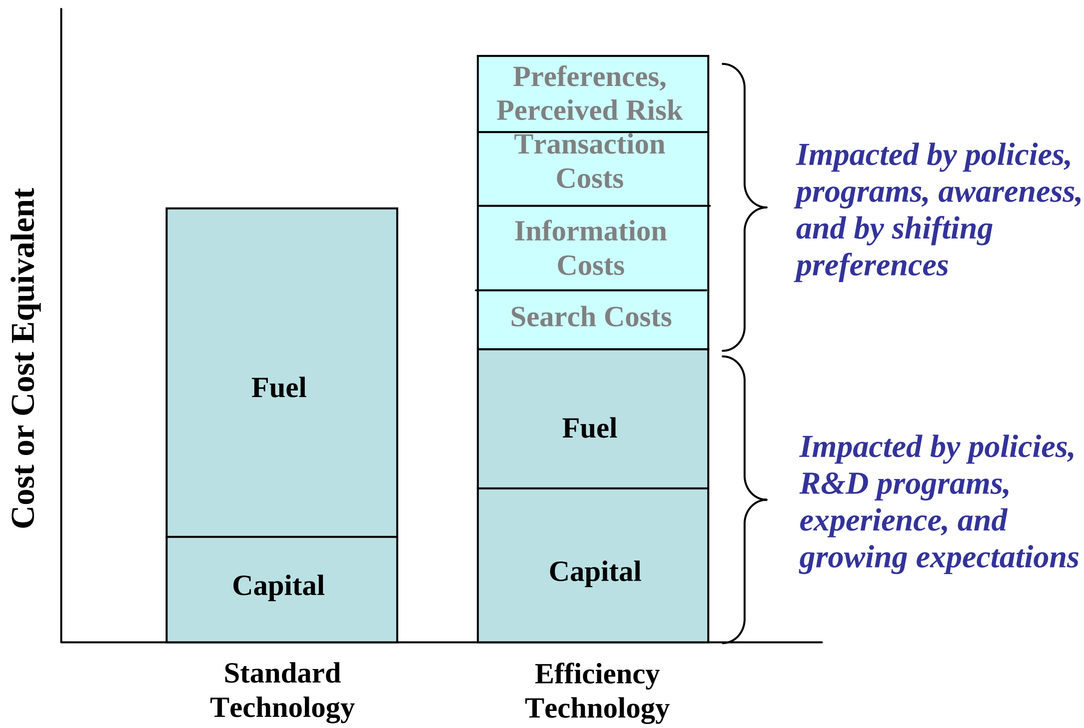
Category of Investment	Reference Case	Tech Policy Case	Percent Change
Electric Utility Plant	22	25	13.0%
Distributed Generation	4	11	189.5%
Hydrogen Infrastructure	0	31	n/a
Fuel Supply	24	20	-18.2%
Residential Efficiency Equipment	122	138	12.6%
Commercial Efficient Equipment	113	136	20.8%
Industrial Efficient Equipment	100	132	31.3%
Transportation Equipment	507	579	14.2%
Total Energy-Related Investment	892	1,071	20.1%
Non-Energy Investments	3,413	3,958	16.0%
Total Economy-wide Investments	4,305	5,029	16.8%

In this particular example, the technology-based policy scenario assumes a start year of 2002 in which policies are implemented such that a (roughly) 25 percent reduction in energy consumption is achieved in 2020 (compared to the reference case forecast for that same year). The energy savings are driven by sizeable increases in sector investments for energy efficiency improvements as well as the increased deployment of distributed generation resources. Investment in conventional fuel supply resources are reduced somewhat compared to the reference case. Overall energy-related investments are up by 20 percent in the year 2020 while non-energy related investments are up 16 percent. Combined economy-wide investments are increased by about 16.8 percent.[11] In this example, then, the positive results that flow from this particular scenario can be traced to the more productive deployment of capital compared to the reference case assumptions.

4.3. Assumptions about Consumer and Firms Behavior

UK economist Joan Robinson (1947) commented almost 60 years ago that "economics science has not solved its first problem – namely, what determines the price of a commodity?" Both common sense and growing evidence from the fields of both experimental and behavioral economics suggests that among the things that can influence commodity prices are belief, values, habit, alternatives, necessity, and income. All of these items can be shaped by changed perceptions, clear and persistent policy signals, as well as new or expanding programs (Brown 2001, and Nadel and Geller 2001). Highly imperfect markets are burdened with an array of search, information, and other transaction costs. Moreover, all choices within the market are impacted by perceived risks and existing preferences and beliefs. They are similarly affected to the extent that these perceived risks and preferences are changed in response to programs such as the Environmental Protection Agency's Energy Star activities and the U.S. Department of Energy's Industrial Assessment Centers and similar programs. Figure 4, adapted from a presentation by Koomey (2006) on the following page, illustrates the comparison between the reasonably known capital and fuel costs and the "harder-to-estimate-or-evaluate" softer costs such as search and transaction costs. Yet, many programs such as Energy Star and the Industrial Assessment Centers successfully address these costs in many different ways so as to highlight the overall attractiveness of the more energy efficient technologies and to encourage a greater rate of adoption.

Figure 4. Comparing Hardware and Energy Costs with "Soft" Search and Transaction Costs



In AMIGA the energy-efficient investment decision, and again referencing the example discussion in section 4.1 earlier in the paper, is determined by the condition:

$$dK / dE = - Pe / r.$$

That is, the change in capital and the change in energy are influenced both by the price of energy and the expected hurdle rate which becomes a proxy for many of the soft costs which might otherwise prevent the adoption of a cost-effective technology. At the point at which both sides of the equation are equal, we would expect to find the tangent point. A high value for the hurdle rate, r, implies that only energy-efficiency investments with a short payback will be undertaken. For example, a hurdle rate of 40 percent implies that the efficiency investment will not be adopted even if it has a five-year payback – despite the possibility of an investment that might otherwise generate return that is higher than expected from normal productive investments (e.g., a 20 percent return compared to a normal 10 percent return). In AMIGA we allow r to be impacted by program expenditures that we track; and under specific scenarios which we might explore, by changing consumer preferences as households and businesses become more aware of pending energy shortages and/or climate change. At the same time, we can also incorporate equipment and appliance performance standards as well as flexible and/or tradable CAFE permits and similar policies.

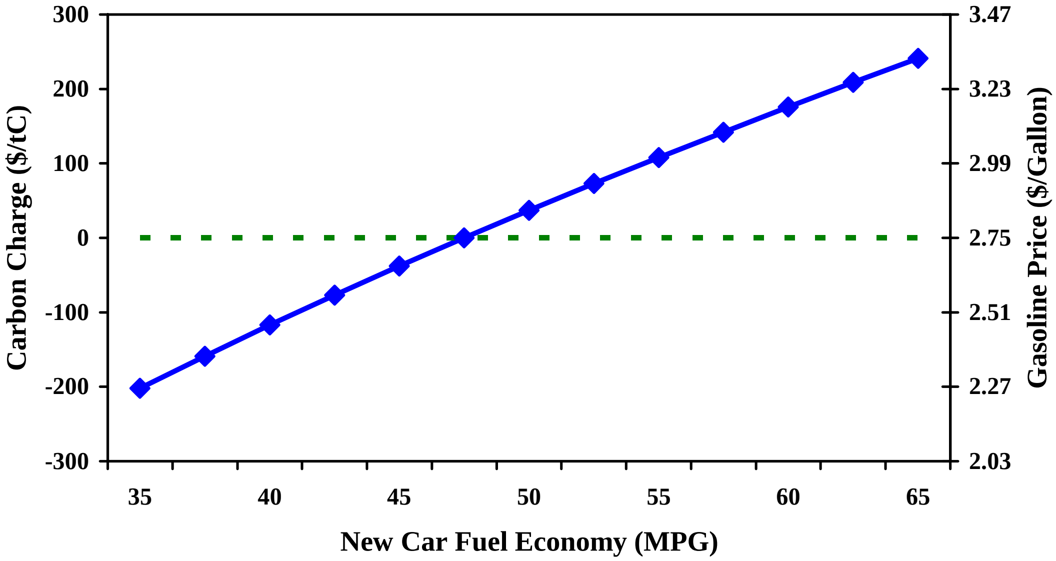
Some of the policy drivers in AMIGA that now influence investment decisions include voluntary and information programs that impact both service demands as vehicle or ton-miles traveled, or technology characterization as Energy Star products. They also include research and development programs, renewable portfolio standards, appliance, equipment and CAFE standards (including tradable permits for standards), as well as the more familiar system of tradable emission permits (including banking, borrowing, and interpollutant trading). In effect, the AMIGA modeling structure incorporates both changes in energy and non-energy prices as well as changes in consumer preferences and expectations which are not expected to remain static over some long time horizon; and which, in turn, are affected by a wide variety of perceptions and unexpected outcomes.

4.4. A Limited Economic Accounting of Technology Choices and Investment Patterns

Depending on their knowledge of alternatives, their existing or changing preferences, and their current financial position, consumers may alter travel patterns or purchase a different vehicle when confronted by changes in prices, changes in non-price policies, or changes in preferences. Models should reflect this full array of choices. Moreover, a change in relative prices should be viewed more as a decision signal than as an indication of resource cost. If the cost of gasoline at today's prices, for example, rose by (say) $100 per metric ton of carbon ($/tC), or 24 cents/gallon, it might require the purchase of 4 new cars to save one ton of carbon. Many would think of the resulting carbon charge as a $100 resource cost. But if we "follow the money," the possibility emerges for a small but net positive economic gain despite the price increase. To illustrate this point, let us map out a more complete accounting to reveal the larger array of changes in economic activity which might be stimulated by the $100 price signal.

Under this scenario, spending for consumer durables would first might increase by some amount (roughly equal to the higher cost of the four new cars and depending what else might be purchased as a result). Additional business in the banking sector might also increase with the additional level of annual loan payments (although there may be less investment elsewhere in the energy production sector). Gasoline savings will clearly benefit consumers and provide a return on the higher cost of the new car. Moreover, gasoline prices might actually decrease for all drivers as a result of the lower. And some fraction of that gasoline savings will reduce the national oil import bill. In addition, the $100 carbon charge might become a transfer payment that can offset the need for other governmental revenue – in effect, providing a neutral source of tax revenues that can reduce taxes elsewhere. All of these impacts are likely to add up to something completely different than an assumed $100 resource cost. This detailing of the changed expenditure pattern offers a significantly different result than many of the models now portray, especially as the savings continue over the life of the cars. Perhaps even more interesting, the full accounting of the consumer investment might reveal a net negative cost, something that has been steadily overlooked by many familiar models. Figure 5 explores this perspective.

Figure 5. Fuel Economy Cost Curve for Medium-Size Cars in 2020



Most energy and climate modelers assume that if there is no change in prices, there will be no reduction in energy use or carbon emissions. Thus, as the carbon signal begins to rise, prompting energy prices to increase in turn, consumers are given a sufficient incentive to begin reducing energy use. Yet, the left-most Y-axis in Figure 5 suggests a negative carbon cost which seems difficult to reconcile within many policy models. The explanation for this apparent discrepancy emerges by examining the second and right-most Y-axis. Here the higher investment in the car is amortized against the fuel savings. If the cost of the car per gallon of gasoline saved (because of a higher fuel economy) is less than the current price of gasoline (which is the equivalent of a zero carbon charge), the consumer saves money. So it only appears to be a negative cost of carbon since: (a) the focus was on the cost of carbon as a proxy for a resource cost; and (b) the failure to explore what is really happening in the market place – in this case a carbon price that behaves more like a signal but one that drives a changed pattern of investment. Both have clear implications for understanding the avoided costs of energy as a negative cost of carbon.

4.5. Other Areas of Future Mapping

With this level of detailed accounting AMIGA is now able to reasonably reflect the costs and benefits of reduced energy expenditures which frees up resources and income that can be spent on goods and services in other sectors of the economy. At the same time, as the reduced demand for energy us tracked, it can generate additional gains in the form of lower world oil prices which would benefit most countries in the world. And the cost-effective reduction in energy demand can decrease the aggregate price index for both domestic and imported goods throughout the U.S. At the same time, there are a number of critical areas that might be carefully reflected and mapped into both AMIGA and other models. For example, evidence is emerging on the value of non-energy benefits that follow from what is often thought to be only an efficiency investment. But a number of researchers (for example, Worrell et al 2003, and Lung et al 2005) are suggesting that there may be significant additional productivity gains that can impact both the decision to invest in new equipment or processes (if the plant or building manager knows about them), and that may underpin a further reduction in the level of real resources necessary to satisfy an existing or expanding service demand. Other areas of potential improvement within models include increased energy and national security, possibly reduced military expenditures, the value of fuel diversity, the improved trade balance with the prospect of less foreign debt, and the impact of reduced health care expenditures as they might result from fewer air pollutants being emitted.

5. CONCLUSION: THE REALLY "NOT SO BIG" INSIGHTS

Even when the appropriate technology characterizations, consumer behaviors, and market structures are properly mapped into an economic policy model, it will remain the case that low energy prices can sustain a higher level of economic growth. But as the evidence clearly suggests, so can a smart investment path also support a more robust economy – especially one that emphasizes a balanced portfolio of both energy efficiency and advanced energy supply or energy conversion technologies (Hanson et al 2004, and Laitner et al 2005). Moreover, there is little question that today's public and private choices will affect the cost of managing the oil transition and responding to the unexpected climate future. Using the framework of the AMIGA modeling system we have consistently found that a productive technology investment strategy – begun early – will better position the economy and the environment to respond to unexpected challenges ahead (for a particularly useful discussion on this point, see Lempert et al 2003; and also see Hanson et al 2005). Hence, one task of near-term modeling exercises will be to identify the mix of early technology investments that will satisfy multiple social goals (national security, environmental quality, equity, and a robust economy) — given conditions of deep uncertainty. To accommodate these scenario evaluations, the pressing need is to complete an assessment of model shortcomings. The improved model performance can provide useful rather than misleading policy insights.

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[1] The author spent almost a decade as an EPA senior economist working with the Argonne National Laboratory in the development of the AMIGA Modeling System, both in support of and in concert with Dr. Donald Hanson who has been the primary developer of the model. Since leaving EPA, however, I am pleased to say that collaboration continues – although at a somewhat reduced level of participation.

[2] See, for example, a comparison of different modeling results in Laitner et al (2003).

[3] In fact, there is already a significant level of work to re-examine the technology characterization and assumptions embedded within many of the past modeling exercises. EPA, for example, sponsored a workshop this past July by Syracuse University's Drs. Peter Wilcoxen and David Popp. The intent was to explore the link between technology and climate change policies as they might be modeled in a variety of different contexts. The National Renewable Energy Laboratory convened an Energy Analysis Collaborative Workshop on behalf of the U.S. Department of Energy in June 2006. With funding from both the Energy Foundation and the EPA, the American Council for an Energy-Efficient Economy and the University of California are planning to convene a two-day workshop in November 2006 to further examine a number of critical issues and assess what might be called "best modeling

practices." The intent of this forthcoming effort is to build a network in support of appropriate changes that might be made within policy models. For more information on this forthcoming effort, contact the author as listed.

[4] According the latest data from the Energy Information Administration, U.S. energy consumption in 2005 is estimated at about 100 quads. Total energy use in 1970 was about 68 quads. Based on 1970 "frozen technology characterization" and 1970 market shares, and given the expansion of the economy over that time, energy consumption would have been nearly 200 quads by 2005. The 1970 energy demand was about 68 quads (Laitner 2006). Following the logic of Ayres and Warr (2005) we might suggest that the demand energy services grew by 194 percent. Actual energy use, however, grew only 47 percent. If we do the simple calculation of subtracting 47 percent from 194 percent, and then dividing that result by the 194 indicates that energy efficiency (broadly speaking a combination of both structural change and reduced energy intensity) has met 76 percent of the new demand for energy services since 1970.

[5] For more detail on the transformation of specific technology characterization into capital-energy production isoquants see, for example, Hanson and Laitner (2006) and Laitner and Hanson (2006).

[6] Some regions or sub-sectors may have special circumstances that would suggest using separate curves to represent the special cases or special technology applications or niches. In the case of both commercial and industrial lighting, for example, there may be a significant difference between ambient lighting and task lighting. And in the industrial sector different applications of combined heat and power systems (a potentially large source of near-term and future energy savings) may have to be represented in substantially different ways. Petroleum coking which also yields hydrogen as a chemical feedstock may be significantly different than gasification systems within the pulp and paper industries.

[7] Some analysts may be used to seeing smaller elasticities. The reason is that when they use this functional form they apply an elasticity against total productive capital. In AMIGA, however, we estimate elasticities for a much smaller "energy-related" capital or a mix of energy technologies. A smaller capital base against the same level of reduction, by definition, would generate larger elasticities. Readers should be cautioned in this regard not to apply the elasticities reported here to any other model since they were estimated directly for this purpose, using specific estimates of capital and energy.

[8] While AMIGA does maintain "default assumptions" about all technology attributes within its standard reference case, its highly modular database allows any of these attributes to be changed or modified to enable users to explore a variety of scenarios and policy tools.

[9] A number of models do use vintaging in their capital stock but this continues to miss the critical differences between energy-using capital and other non-energy productive capital.

[10] Readers who wish to see more detail and the range of substitution elasticities should read Hanson and Laitner (2006) and Laitner and Hanson (2006).

[11] Note that the AMIGA report writer can provide a much greater level of sectoral and end-use use detail than summarized here. Indeed, the model could report out the anticipated capital requirements for a scenario in each sector as it might be subscripted across each of the six dimensions discussed in the main text of the paper.