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### **Developing an “Energy Sustainability Index” to Evaluate American Energy Policy**

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**Abstract:**

This paper proposes the creation of an energy sustainability index (ESI) to inform policymakers, investors, and analysts about the status of energy conditions, and to help educate the public about energy issues. The proposed ESI builds on the substantial body of literature on “sustainability” and also draws on past efforts to measure environmental and energy progress – both of which are reviewed below. The index covers four dimensions (oil security, electricity reliability, energy efficiency, and environmental quality) and includes twelve individual indicators. Comparing these indicators in 1970 with 2004, nine have trended in an unfavorable direction, two have moved in a favorable direction, and one has been essentially unchanged. Clearly, the “energy problem” fretted about in the 1970s has not been fully addressed. While the proposed ESI is preliminary and requires further refinement, it takes an important step toward creating a set of indicators that can easily assess and communicate the condition of the U.S. energy system

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# Developing an ‘energy sustainability index’ to evaluate energy policy

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How well are industrialised nations doing in terms of energy policy? Without a standardised set of metrics to evaluate national energy systems, it is difficult to determine the extent to which energy resources, technologies and infrastructure are truly keeping up with emerging challenges related to climate change, the environment, population growth and economic wellbeing. In response, we propose the creation of an energy sustainability index (ESI) to inform policymakers, investors and analysts about the status of energy conditions. Using the United States as an example, the ESI shows that the country has failed to truly progress on solving some of its most pressing energy problems, and that in many respects conditions have deteriorated. The proposed ESI builds on the substantial body of literature on ‘sustainability’, and draws on past efforts to measure progress in environmental and energy systems.

To hear it from politicians and government spokespeople, one could easily be persuaded that the quality of the environment in the United States – as well as the health of the nation’s energy sector – has improved significantly since the energy crisis of the 1970s. Jeffrey R. Holmstead of the US Environmental Protection Agency recently suggested that the country ‘made the connection between polluted air and public health decades ago, and has worked steadily to reduce harmful emissions . . . As science has revealed more about the risks of various pollutants, efforts to monitor, control, and even eliminate these substances have grown ever more ambitious’.<sup>1</sup> Paula Dobriansky from the US Department of State put it even more succinctly: ‘the US record of achievement in addressing environmental issues over the past 30 years is impressive’.<sup>2</sup>

We hear almost the same commentary coming from utility executives and self-proclaimed ‘conservative’ energy policy analysts. Michael Lynch, a former executive at Chevron, recently argued that the tight oil market, warm weather, rising natural gas prices, and the ‘great majority’ of other factors are ‘obviously transient in nature, and do not require any major policy revisions’.<sup>3</sup> Paul L. Joscow argues in his assessment of American energy markets that ‘considerable progress has been made and many useful lessons have been learned’.<sup>4</sup> And Bjorn Lomborg suggests ‘the evidence clearly shows that we are not headed for a major energy crisis’.<sup>5</sup>

Indeed, numerous other experts around the world have been quick to dispel claims of impending domestic and international energy crises as fabricated, exaggerated and untrue.<sup>6</sup> Analysts have explained away energy price spikes as simply marketplace manipulation, as in the Californian electricity crisis of 2001 and the record-breaking gasoline prices of

2006–07. Others have characterised talk about an energy crisis as a ruse to advance pro-industry policies and a way of relieving pressure on environmental issues. Still other technology champions belittle ‘hype’ about energy problems by emphasising the ability of science to produce solutions, and energy resource analysts calm fears by pointing to abundant unconventional fossil resources such as tar sands, oil shale and methane hydrates.

The evidence seemingly points both ways. On the one hand, the world energy crisis of 1973/4 culminated in the establishment of the International Energy Agency, the creation of strategic petroleum reserves among its members, and the diversification of the fuel base for electricity as most countries moved away from their use of oil to produce electricity. In the US, the crisis forced sweeping energy legislation through Congress, resulted in the establishment of the US Department of Energy, and even provoked President Jimmy Carter to cite the energy challenge as ‘the moral equivalent of war’ on 18 April 1977. Since those times, the international community has seen advances in low-income energy services, efficiency and demand reduction programmes, renewable resources initiatives, and market restructuring of the various energy industries. In the US, many individual states have implemented aggressive renewable portfolio standards and systems benefits funds, started emissions trading schemes, and invested heavily in alternative fuels such as hydrogen, ethanol and biodiesel.

On the other hand, a great disparity exists in the degree to which different countries have improved their energy sectors. As of January 2007, eighteen members of the European Union had set some type of national, mandatory target for promoting renewable energy, and on climate policy the EU Greenhouse Gas Emission Trading Scheme (EUETS) calls for mandatory reductions in greenhouse gas emissions and allows countries to trade carbon credits. In the past five years even Brazil, China, Indonesia, Nicaragua, Sri Lanka and Turkey have adopted mandatory renewable energy or climate change targets.<sup>7</sup> Meanwhile, in the US, the federal government has failed to set a national target for renewable energy among regulated utilities, rejected a national cap on greenhouse gas emissions, and refused to create a nationwide trading system for carbon credits. As a result, there is growing evidence that the country’s lakes, rivers, streams, air and land continue to face rising levels of pollution, and the country’s power grid remains centralised, vulnerable and carbon dioxide-intensive.

Amidst the cacophony of rhetoric, posturing and lobbying, we seek to ask a simple question with a somewhat more complicated answer: How well are industrialised countries *really* doing in terms of energy policy? Without a standardised set of metrics to evaluate the state of national energy systems, it is difficult to determine the extent to which energy resources, technologies and infrastructure are truly keeping pace with the growing demands of an expanding world economy. Though considerable effort in the US has been dedicated, for example, to the development of composite indicators of transportation productivity, environmental quality and educational effectiveness, there are no standard composite metrics to evaluate the condition of the US energy system. Thus, the enduring question – are our energy systems progressing or regressing? – remains difficult to answer.

In response, we propose the creation of an energy sustainability index (ESI) to inform policymakers, investors and analysts about the state of energy conditions. Using the United States as an example, the ESI shows that the country has failed to make real progress on solving some of its most pressing energy problems, and that in many cases conditions

have deteriorated. The proposed ESI builds on the substantial body of literature on 'sustainability', and draws on past efforts to measure environmental and energy progress, both of which are reviewed below.

While policymakers might use our ESI to assess the relative vitality of any country's energy system, why have we decided to focus on the US? By any standard, the United States is the largest consumer of energy. In 2004, it consumed twenty-three per cent of the world's total primary energy production, and its per capita consumption of energy is also one of the highest in the world.<sup>8</sup> The country constitutes the world's largest market for power equipment. It has more automobiles, nuclear reactors, pipelines, refineries, power producers and electricity customers than any other state. In 2004, for example, the US possessed twenty-five per cent of the world's installed electricity capacity.<sup>9</sup> Since the US remains the world leader in the extraction, consumption and use of oil, uranium, coal and natural gas, its decisions affect the global energy marketplace. The size of its energy system suggests that trends occurring in the United States may occur elsewhere, and that knowledge of its energy policy problems may help policymakers all over the world better understand how to promote more sustainable forms of energy use.

## OF INDEXES AND INDICATORS

A variety of experts have long used quantitative data to measure all types of conditions. In particular, much progress has been made in developing better tools for environmental impact assessments and cost-benefit analyses. Over the past three decades, quantities such as levels of food production, trends in plant growth, and the movement of nitrogen across the US have been carefully tracked, monitored and recorded.<sup>10</sup> The US Environmental Protection Agency's 2007 report on the environment, for instance, will have chapters addressing outdoor and indoor air quality, water, land, human health and the condition of ecosystems.<sup>11</sup>

Moreover, practitioners in the field of environmental impact assessment seem to have abandoned their classical approach of narrowly analysing the 'environmental impacts' of technologies, in favour of a more holistic methodology assessing the ways technologies influence a panoply of social, economic, cultural and ecological forces.<sup>12</sup> What would once have been an examination of, say, the effects of a large dam on local salmon populations would now investigate that dam's influence on property rights, the expansion of local agriculture, community employment, tax structure, disturbance of view-scape, educational potential and a whole host of other 'sustainability concerns'.<sup>13</sup> Such efforts often result in immense checklists full of data, ranging from the ecological integrity of wetlands to catalogues of endangered species in the Arctic.

In other aspects of our daily lives, cholesterol and blood pressure reflect the extent of our physical health; the Dow Jones index, unemployment rate, inflation and GDP indicate the comparative health of the economy; literacy, infant mortality, crime and life expectancy rates are used to measure the inherent progress of a given society; the United Nations uses its Human Development Index to rank entire countries based on sophisticated economic, health and educational attainment measures. In his *Introduction to the Principles of Morals and Legislation*, radical philosopher Jeremy Bentham (1748–1832) even created numerical indicators to quantify happiness – hedons – that he believed could be used to assist people trying to calculate whether their decisions would bring them pleasure.<sup>14</sup>

This is not to say that such quantitative measures are perfect, or that reducing complex situations to numbers is without problems. Numerical indices often measure not what is most significant or meaningful, but merely what is measurable. Quantitative measurements, especially those taken out of context, can also conceal important nuances and variability. Does a reduction in pedestrian casualties mean that roads are getting safer, or that they have merely become so dangerous that no one dares to cross the streets?<sup>15</sup> Or does a reduction in the energy intensity of a given country mean that its economy is becoming more energy efficient, or that instead more energy-intense products are being imported from elsewhere? As Kevin D. Haggerty put it, ‘numbers are like people; torture them enough and they’ll tell you anything’.<sup>16</sup>

Yet while they have their flaws, such indicators – with perhaps the exception of Bentham’s – help condense voluminous data into usable form. They can be useful for shaping public attitudes regarding air or water quality or the extent of biodiversity loss. Indicators provide a necessary baseline for measuring progress, and can illustrate the complexity and interconnectedness of pressing problems. They make it easier for scientists to understand and devise research strategies, and can help focus on important interactions between different issues and data measurements.<sup>17</sup>

However, despite the obvious utility of numerical indicators, none has been proposed that measures the sustainability of a country’s *energy* decisions. We find this puzzling, as energy is one of the ubiquitous components of our modern lifestyles. It powers our vehicles, lights our workplaces, is essential for producing food, enables the manufacture and distribution of products, cools and warms our homes. Energy is, according to economist E. F. Schumacher, ‘not just another commodity, but the precondition of all commodities, a basic factor equal with air, water, and earth’.<sup>18</sup> Thus, energy is something used, directly and indirectly, by every living person.

#### FOUR HISTORICAL MODES OF ENERGY POLICY ANALYSIS

This is not to say that there has not been much talk – both recently and historically – about energy in modern society. Our brief assessment of energy policy distinguishes at least four distinct modes of energy analysis to date. From the 1940s to the early 1970s, energy discussions were primarily dominated by economists emphasising the importance of energy to economic performance. Studies frequently measured economic performance and growth – using indicators such as GNP (Gross National Product) – and compared these to the amount of energy a given country consumed. These assessments found strong parallelism between energy use and economic growth, and perpetuated the uncontested idea that increases in energy consumption were essential to the continued growth of industrialised economies. Energy policy analysis, then, consisted of calibrating economic performance against energy consumption, and of devising strategies to ensure adequate supply to guarantee economic expansion.<sup>19</sup>

A more refined type of energy analysis emerged with the energy crises of the 1970s, challenging the assumption that energy consumption and economic wellbeing were destined to grow in a lock-step relationship. New studies suggested that advanced societies differed greatly in their per capita energy consumption. Longitudinal studies of energy use patterns and cross-national surveys comparing countries with similar standards of living all seemed to point in the same direction: a threshold level of high energy consumption had

to be met for a society to achieve industrialisation, but after that threshold had been crossed a wide latitude in the amount of energy needed to sustain standards of living existed. Energy analysis became a means of finding out how much efficiency could be achieved and of exploring alternatives for those countries that had already crossed the consumption threshold.

A third type of analysis started to take hold near the end of the 1970s and continues to the present. Such studies are predominately concerned with producing forecasts of the future and characterising scenarios of alternative futures. Reports from the US Energy Information Administration (EIA), Environmental Protection Agency (EPA) and International Energy Agency (IEA) typically focus on estimating generation capacities, projecting fuel costs and predicting the environmental impacts of particular energy technologies. For example, the paragon of excellence among these types of reports, the EIA's 'Annual energy outlook', predicts the current and future technical potential for energy technologies, but does not anticipate expected policy changes or provide policy recommendations.<sup>20</sup> This type of analysis focuses on different technological options, and provides insight into how supply and demand should be managed. Analysis frequently extrapolates current trends, creates a picture of a future world, and informs policymakers of the different options for accomplishing such a vision.

A fourth type of analysis concerns technology assessment, or focuses on how to diffuse a particular technology into the marketplace. The Edison Electric Institute (EEI) and Electric Power Research Institute (EPRI) tend to centre purely on the economics of electricity supply and demand, while reports from groups like the Pew Center on Global Climate Change and the Natural Resources Defense Council emphasise the environmental dimensions of energy consumption. The US National Academies of Science and Union of Concerned Scientists have produced insightful analysis of the security and infrastructure challenges facing the energy sector, while groups like the Alliance to Save Energy and the American Council for an Energy Efficient Economy remain principally concerned with conservation and energy efficiency. Other groups – including the Nuclear Energy Institute, American Wind Energy Association, the American Solar Energy Society, and the Combined Heat and Power Association – focus on particular types of technologies. Energy analysis, in this light, involves picking optimal technologies and then attempting to integrate them into society.

## **THE TREATMENT OF SUSTAINABILITY IN MODERN ENERGY POLICY**

While the bulk of energy policy analyses have thus avoided talking about sustainability in a coherent or comprehensive fashion, the idea has slowly begun to take hold – albeit in more of an *ad hoc* fashion. In its classic sense, the concept of sustainability encompasses the notion of balancing current resource consumption with the resource requirements of future generations. For example, the landmark 1987 Brundtland report of the World Commission on Environment and Development (published under the title *Our Common Future*) defined sustainable development as meeting 'the needs of the present without compromising the ability of future generations to meet their own needs'.<sup>21</sup> Historically, sustainability has meant balancing two sets of equally tenuous concerns: the present with the future, and energy consumption and economic growth with ecological integrity.



Sustainability is frequently theorised as having two forms: ‘weak’ and ‘strong’. The notion of ‘weak’ sustainability – predicated on neoclassical economic theory – assumes that manufactured and natural capital are close substitutes, so that environmental damage can be measured in monetary units. An optimal strategy for attaining sustainability, then, centres on finding the best way to allocate such resources.<sup>22</sup> Pearce and Atkinson, for instance, argue that damage to the environment can be calculated economically through concepts such as capital, interest, savings and depreciation.<sup>23</sup> Similarly, Hueting and Bosch suggest that water, soil, forest, air and other natural resources should be assigned monetary value so that society can better assess what would be needed to reach a sustainable level of consumption.<sup>24</sup>

The idea of ‘strong’ sustainability recognises that environmental problems expand beyond mere questions of allocation to include notions of distribution and scale. Resources should be distributed justly, and their distribution and consumption must achieve a state where economic activity does not compromise global ecological carrying capacity. Strong sustainability attempts to incorporate scale, equity and efficiency into the weak model. The most important task of economic policy, following the logic of the strong model, is to ensure that the economic system does not grow to a size that endangers the global ecological system.<sup>25</sup> Popular measurements and indices for ‘strong’ sustainability include the notions of eco-capacity (ensuring that economic growth and development do not compromise the integrity of ecosystems), eco-intensity (measuring the material intensity or eco-efficiency of products), and eco-space (measuring the spatial and land impacts of a given technology).<sup>26</sup>

In practice, when applied to energy policy, sustainability has meant pursuing one of three management rules: ensuring that the harvest rates of natural resources do not exceed regeneration rates; making sure that waste emissions do not exceed relevant assimilative capacities of ecosystems; and guaranteeing that non-renewable resources are only depleted at a rate equal to the creation of renewable ones.<sup>27</sup> Thus, any index of energy sustainability must reflect the resources consumed to meet current energy demands while also including the ability of future generations to meet their requirements. This can be measured as the total energy consumed by a given country in a given year (e.g. approximately thirty trillion kilowatt-hours for the United States). Alternatively, it can be quantified in terms of total energy consumption per capita or energy use per GDP, which are measures of energy intensity or energy productivity. These measures are often emphasised because they recognise the correlation between energy use and level of economic activity.

Many similarly discrete indicators reflect the ability of future generations to meet their needs, such as measures of reliance on renewable energy *v.* fossil fuels, consumption of domestic *v.* imported fuels, as well as price trends and levels of investment in new energy infrastructure. Ideally, these indicators should be reduced to a single metric, so that all dimensions of the question can be reflected in a single index value. This is done, for instance, in the notion of ecological footprint, an index that converts, for comparative purposes, all energy, materials and other resources associated with different built environments into equivalent land area requirements. The appeal of this metric is its ability to take account more fully of the resource implications of different policies and outcomes such as different built environments. Ecological footprint studies by Wackernagel and Rees, Walker and Rees, Merkel, and others are especially useful because they assess energy consumption at the *micro*-level, often at the scale of the community or household.<sup>28</sup> For

instance, Walker and Rees note that almost half a given Canadian household's impact on the environment has more to do with associated travel requirements than with the home itself.

Other aggregate indicators with energy dimensions have been developed, notably the Leadership in Energy and Environmental Design (LEED) index developed by the US Green Buildings Council to help commercial building developers evaluate a variety of green building designs in the early stages of development.<sup>29</sup> Under LEED, building projects are awarded points in six categories: sustainable sites, water efficiency, energy and atmosphere, incorporation of local and recycled materials and resources, indoor environmental quality, and innovation and design process.

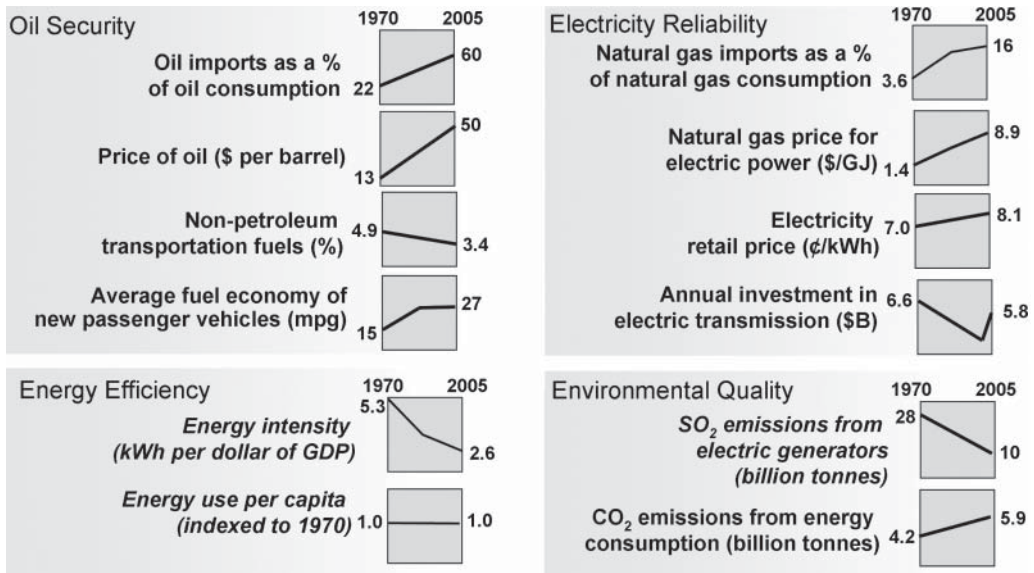
While each of the historical modes of energy analysis can be very useful – measuring the consumption of energy within and between countries provides a key baseline for future comparisons; forecasts offer a dynamic tool for projecting the consequences of a society's energy choices; assessments of individual technologies help track their diffusion into society – none provides a holistic account of energy *sustainability*. Early calculations of energy consumption were typically ethnocentric and distinguished between industrialised and underdeveloped nations. Energy forecasts often take for granted the existing configuration of the industry and thus restrict their consideration to a very narrow range of alternatives. Technology assessment frequently narrows energy analysis, meaning that integrative concepts that combine systems and cut across technologies, disciplines and sectors of the economy are difficult to pursue.

Moreover, in their current incarnations, the concepts of sustainability, ecological footprint and LEED ignore some dimensions – such as fuel diversity, energy prices and infrastructure investments – of the energy system. Furthermore, such concepts vary greatly and often lack integrated and consistent meanings. The term sustainability, for instance, can simultaneously mean finding sustainable *use* of natural resources or sustainable *distribution* of natural resources; maximising the quality of life for *present* or *future* generations; protecting the *biosphere* or safeguarding *humanity*.

### PROPOSING AN ENERGY SUSTAINABILITY INDEX (ESI)

Rather than merely assessing energy intensity, forecasting the future, assessing an individual technology, or promoting some abstract idea of sustainability, we propose to look more critically and comprehensively at energy sustainability. We have developed an energy sustainability index (ESI) covering four dimensions of the US energy system: oil security, electricity reliability, energy efficiency and environmental quality. It is based on twelve indicators corresponding to these four dimensions as shown in the figure below: oil imports, petroleum prices, availability of non-petroleum fuels, fuel economy of vehicles, energy intensity, energy use per capita, natural gas imports, natural gas prices, retail electricity prices, annual investment in transmission and distribution, sulphur dioxide emissions, and carbon dioxide emissions. Metrics such as 'oil imports' and 'natural gas imports' help measure the availability of some key natural resources; metrics such as 'petroleum prices' and 'natural gas prices' assess their economic cost and equity for lower income households; metrics such as 'energy intensity' and 'energy use per capita' reflect levels of consumption; and metrics such as 'sulphur dioxide emissions' and 'carbon dioxide emissions' take into account the state of the natural environment and a level of futurity.





An energy sustainability index for the US energy system: financial metrics are for 2005 and in US dollars unless otherwise indicated; the metrics shown in italics represent favourable or neutral trends, all other metrics suggest deteriorating conditions

The four indicators of *oil security* suggest worsening or at best stagnant conditions. The rapid growth of US oil consumption, combined with shrinking domestic oil production, has resulted in increased dependence on imported oil, which now accounts for sixty per cent of total US oil consumption – up from twenty-two per cent in 1970.<sup>30</sup> Recent trends in world oil markets, including the emergence of China and India as major contributors to global demand, continuing instability in the Middle East, and refinery outages from Gulf Coast hurricanes have caused the price of oil to rise from its historic average of US\$12 per barrel in 1990 to \$45 per barrel in 2005 and more than \$70 per barrel during much of 2005 and 2006.<sup>31</sup>

Fuel diversity is an important long-term strategy for coping with oil dependence, price volatility and the dwindling supply of oil, but it has not improved: non-petroleum fuels (mostly natural gas, corn ethanol and electricity) actually represent a smaller fraction of the energy consumed by the US transportation sector in 2005 (at 3.4 per cent) than in 1970 (when it was 4.9 per cent).<sup>32</sup> Cellulosic ethanol shows great promise because it is made from fibrous or woody plant material, rather than from corn and other starches that are both energy-intensive to produce and important sources of food. Similarly, diesel from biomass and wastes could displace a large fraction of US oil consumption without constraining food production. Such fuels, however, are still primarily used only in niche markets.

Problems associated with the dominance of petroleum-based transportation fuels in the United States are exacerbated by the fact that the fuel economy of cars has been essentially unchanged for more than two decades. Corporate Average Fuel Economy (CAFE) standards for cars peaked in 1985 at 27.5 miles per gallon. Improvements in front-wheel

drive transmissions, electronic fuel injection, enhanced power-train configurations and computer-controlled engines have been negated by consumer preferences for larger and more powerful vehicles. In addition, a greater number of cars populate the roads, and they are driven further each year. The consequence of these trends has been growing demand for oil in the transportation sector and greater imports to meet that demand.<sup>33</sup>

*Electricity reliability* is also threatened. Volatility in natural gas markets, sustained price increases and increasing natural gas imports are prompting concerns about this environmentally friendly fuel, which has become a preferred choice for new power plants over the past decade. Natural gas imports have grown from 3.6 per cent of US natural gas consumption in 1970 to 15.9 per cent in 2005, placing US demand for natural gas increasingly under the control of unstable world markets.<sup>34</sup>

Natural gas prices have been rising as well, partly in response to its increased use for electric power generation. Between 1970 and 2005, the price of natural gas for power production in the US experienced a sixfold increase.<sup>35</sup> This fuel price upsurge has produced economic downturns in industries that are heavily reliant on natural gas for power production or feedstocks, with chemical manufacturers, paper and pulp mills, and refineries being particularly hard hit. Continued natural gas price spikes may reverse the trend away from coal use in power production, raising concerns for carbon dioxide emissions and air pollution. The environmental consequences of such an outcome would be aggravated if today's nuclear power plants are retired over the next fifty years as their licences expire.<sup>36</sup> Renewable sources of electricity show great promise, but their current market penetration is limited to only two per cent of electricity generation (excluding hydropower).

As a result of increasing demand for electricity, environmental regulations and rising fuel prices, the cost of electricity is rising. The average retail price of electricity for all customers rose in real terms from 6.2 cents per kilowatt-hour in 1970 to 7.2 cents in 2005.<sup>37</sup> Proportionately, twenty-two utilities increased rates for their customers in 2005, and at least forty-one did so in 2007. The end of June 2006 saw Delmarva Power business customers in Delaware experiencing rate increases as high as 118 per cent. Baltimore Gas and Electric Residential have announced rate increases of 72 per cent. Other customers in New Jersey will likely see rate increases of 28 per cent, those in Florida 29 per cent, those in Wisconsin 14.4 per cent.<sup>38</sup>

Compounding these price and fuel reliability issues, the US transmission system continues to experience stress from the combination of increasing power flows and declining grid investments. US expenditures in transmission infrastructure peaked at almost seven billion dollars in 1970, but then declined to less than half that amount annually over the last two decades, although recently the amount has risen again to \$5.8 billion.<sup>39</sup> Patrick Lanning, the president of a mid-size utility serving eighty-three thousand customers in Oregon, recently told investors that his electricity grid was so underfunded that eighty-five per cent of his transmission and distribution poles were at least thirty years old. Lanning cautioned that: 'Wires, circuit breakers, substations and other equipment are nearing or have reached the end of their useful life and are in need of replacement or upgrading. If we don't start taking care of these needs now, reliability will slip below acceptable levels.'<sup>40</sup> The shortfall in electric transmission investments is contributing to a dramatic increase

in transmission congestion. Requests from system operators for transmission loading relief in the eastern part of the US, for example, rose from around fifty in July 1998 to 180 in July 2002 and more than 275 in July 2004.<sup>41</sup>

Similar infrastructure issues pervade the whole US energy system, which is much more extensive and varied today compared with the 1970s. Communities are increasingly unwilling to host new energy facilities, as evidenced by the Cape Wind project off the Massachusetts coast, the liquid natural gas terminals proposed for Maine and New Jersey, and the Yucca Mountain nuclear repository. As a result, today's energy infrastructure is in great need of modernisation and expansion.<sup>42</sup>

The two indicators of *energy efficiency* are inconsistent in their directional trends. On the positive side, the consumption of energy has not been expanding as rapidly as the economy has been growing. In 1970 the US consumed approximately 5.3 kilowatt-hours (16 kBtu) per dollar of GDP, while by 2005 this measure of energy intensity had dropped to around 2.6 kilowatt-hours (8 kBtu) per dollar.<sup>43</sup> Were it not for this change, the United States would be consuming twice as much energy today, and its energy bill would be a billion dollars per day higher.<sup>44</sup> This energy productivity improvement reflects structural shifts in the economy, away from energy-intensive industry and toward service and information-based jobs. In addition, it reflects the fact that the country has learned to get more for the energy it consumes by investing in more efficient end-use technologies – better appliances, more home insulation, variable speed motor and drive systems in industry, and more efficient lighting. The potential for energy efficiency to continue to stretch the nation's energy resources remains vast, but whether this potential will be tapped is unclear.<sup>45</sup>

In contrast to the improving trend in energy productivity, energy use per capita has remained relatively static. Based on a metric indexed to 1.0 in 1970, energy use per capita remains at about that same level today. Hidden within this index are several balancing trends. On the one hand, industrial energy use per capita has declined by more than thirty per cent, largely due to the shift toward a more service-oriented economy. At the same time, industry has moved away from direct combustion of fossil fuels toward greater electrification, including increased use of electric and electronic equipment such as digital controls, telecommunications, computers and peripheral devices, microwave heating and imaging devices.

Because of these industrial trends and increased plug loads in residential and commercial buildings, US electricity consumption per capita has increased more than sixty per cent since 1970, placing greater stress on the power grid. Recent data indicate that this growth continues unabated. The EEI, for instance, estimated that 1.1 million new residential and 184,000 new commercial customers were added to the national power grid in 2005, and that the kilowatt-hours consumed per customer grew by 5.95 per cent between 2004 and 2005.<sup>46</sup>

While it is true that remarkable improvements in energy efficiency have contributed greatly to reducing the growth in energy consumption, the historical record suggests that energy efficiency practices and demand-side reduction programmes in most US regions have been unable to offset steady increases in demand. For example, on-site electricity consumption per household in the United States dropped twenty-seven per cent between 1978 and 1997, yet the number of households grew by a third. Over the same period,

electricity's share of household energy consumption actually increased from twenty-three to thirty-five per cent.<sup>47</sup> John Wilson, a staff member for the California Energy Commission, put it this way: 'New Californian homes use one sixth of the energy per square foot for air conditioning that they did 20 years ago. The bad news is that homes are almost twice as big as they were 30 years ago. We are making things more efficient, but making more of them.'<sup>48</sup> Many states have demonstrated the potential for aggressive and sustained energy efficiency programmes, such as California where electricity consumption per capita has remained flat while the state's economy has grown significantly.<sup>49</sup> The challenge is to translate this energy efficiency 'best practice' to the rest of the country.

Similarly, the two indicators of *environmental quality* are mixed. Electricity production and passenger cars and trucks are the largest sources of air pollution (including sulphur dioxide) and greenhouse gas emissions (including carbon dioxide) in the United States. Thus, the US energy enterprise has significant impacts on human and ecosystem health.

On the one hand, the country has made great progress in reducing air pollution from electricity production as a result of three decades of 'clean air' legislation. Between 1970 and 2004, sulphur dioxide emissions from electricity generation and combined heat and power systems have decreased dramatically from 28.3 million tons in 1970 to 10.3 million in 2004.<sup>50</sup> These reductions were accomplished by installing pollution control devices at coal plants and industrial facilities, relying more on low-sulphur coal, and transitioning to cleaner fuels such as natural gas. Similar reductions are now needed to curb particulate matter and nitrogen dioxide emissions and to improve visibility.

On the other hand, total US emissions of carbon dioxide from energy consumption have increased significantly from 4.2 billion metric tons in 1970 to 5.9 billion in 2005.<sup>51</sup> Put another way, since the US emits a quarter of the world's greenhouse gases and power plants are responsible for forty per cent of those emissions, American power plants alone today account for a tenth of *total world* greenhouse gas emissions.<sup>52</sup> While scientists are still refining their knowledge about the link between anthropogenic emissions of greenhouse gases and global climate change, it appears likely that a cause-and-effect relationship is intimately tied to the ways in which we consume energy. Clearly, the last thirty years have not produced the low-carbon energy technologies needed for low-cost stabilisation of atmospheric greenhouse gas concentrations.

## CONCLUSIONS

First – and contrary to many prevailing views – the United States has backslid in terms of energy sustainability. Even during the 1970s, at the height of the energy crisis and the pinnacle of public awareness concerning energy, Americans increased their energy use. From 1970–79, electricity consumption increased by a half, and the consumption of gasoline and total number of miles driven by automobiles increased by a fifth.<sup>53</sup> The price per barrel of oil and the amount of oil the country imports have grown exponentially. The nation's electricity transmission and distribution networks remain strained and near collapse, and the price of natural gas and retail electricity rates have begun to rise. People consume more energy per capita today than in 1970, and consequently carbon dioxide emissions continue to grow.

Second, because energy progress is always based on what one measures, we need to develop better ways of conceptualising energy sustainability. We caution that our

ESI (energy sustainability index) is just a start, a preliminary effort to quantify energy sustainability – although our hope is that it will become as important as other often used indicators relating to the quality of the environment, life, health and the economy. Given the interrelated nature of energy to each of these activities, a case can be made that energy sustainability is even more fundamentally important. We need better tools to assess the nexus between energy, society and the environment.

Third and finally, the somewhat bleak outlook for the US underscores the urgency of decisive action regarding energy policy – for both the US and the international community. Energy consumption in developed countries now rises in lock-step with population growth. From 1990–2000, for instance, total consumption of energy in the United States grew 13.1 per cent, and the total population of the US grew 13.1 per cent.<sup>54</sup> Over the next forty years, the United Nations estimates that the population of the world will grow at a rate of 1.2 per cent each year – more than seventy-five million more people annually – from 6.4 billion in 2005 to 9.4 billion in 2050.<sup>55</sup> If the global demand for energy continues to grow at an analogous rate, then capital investment in energy technologies will need to triple from twelve trillion dollars today to thirty-six trillion by 2100.

This means, for better or for worse, that the ‘energy problem’ fretted about in the 1970s has by no means been fully addressed – and that we need to start more coherently talking about energy sustainability. Trying to measure the complex interactions between energy and society by using contemporary methods – such as energy intensity or electricity consumption – is akin to trying to drive a car with only a fuel gauge, or to seeing a doctor who only checks your cholesterol. Whether we decide to metaphorically tap the accelerator, eat more chocolate, or heed the challenge is entirely up to us.

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