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Competing Dimensions of Energy Security: An International Perspective

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Measuring Energy Security Performance in the OECD

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Introduction

This chapter measures and assesses energy security for 22 countries in the Organization for Economic Cooperation and Development. It begins by discussing ten metrics that comprise an Energy Security Index. We then use our Energy Security Index to measure and track progress on energy security within the OECD from 1970 to 2007. The third section analyzes the relative performance of four countries: Denmark (one of the top performers), Japan (which performed well), the United States (which performed poorly), and Spain (the worst performer). The chapter concludes by offering implications for energy policy and security.[1]

In attempting to tackle a concept as complicated as energy security, we could have focused on almost any scale and any group of countries. Instead of emphasizing smaller scales (such as the individual and enterprises) or international organizations (such as the World Bank or Organization of Petroleum Exporting Countries), we have focused exclusively on nation states. And instead of looking at countries in a single region such as the European Union, Asia, the Caspian Sea, or the Black Sea, we have investigated energy security for 22 geographically dispersed countries that belong to the OECD. The first reason for this focus is practical: data on patterns of energy production and use have been collected and compiled for OECD countries since the 1950s, and these countries compose a number of multilateral organizations dealing with energy issues such as the United Nations and the International Energy Agency. The next reason is more theoretical: OECD countries offer a representative sample of different types of energy markets and cultures. The United Kingdom and New Zealand are examples of liberalized and privatized energy markets while other countries such as Denmark and parts of the United States remain highly regulated. The OECD countries we selected also include cultures as diverse as Australia, Greece, Japan, and Turkey. The final reason is pragmatic: because OECD countries are the most industrialized, they also possess the technical and financial capacity to implement policy changes that can improve their energy security. The OECD countries include many of the world's largest consumers of energy, so their decisions affect the global energy marketplace

Creating an Energy Security Index

[1] This chapter is based on Benjamin K. Sovacool and Marilyn A. Brown, "Competing Dimensions of Energy Security: An International Perspective," *Georgia Tech Ivan Allen College School of Public Policy Working Paper Series, Working Paper #45* (Atlanta, Georgia, January 13, 2009), as well as Benjamin K. Sovacool and Marilyn A. Brown, "Competing Dimensions of Energy Security: An International Perspective," *Annual Review of Environment and Natural Resources* (in press 2010).

Chapter One of this book argued that energy security consists of four interconnected criteria or dimensions: availability, affordability, efficiency, and environmental stewardship. Availability refers to diversifying the fuels used to provide energy services as well as the location of facilities using those fuels, promoting energy systems that can recover quickly from attack or disruption, and minimizing dependence on foreign suppliers. Affordability refers to providing energy services that are affordable for consumers and minimizing price volatility. Efficiency involves improving the performance of energy equipment and altering consumer attitudes. Stewardship consists of protecting the natural environment, communities and future generations. Recognizing that each criterion does not exist in a vacuum, and that each is of comparable importance, Table 1 presents 10 indicators that comprise an Energy Security Index. Note that in each case, the indicator is an inverse measure of security; that is, the higher the value, the lower energy security.

Table 1: Defining and Measuring Energy Security

Criteria	**Underlying Values**	**Explanation**	**Indicators**
Availability	Independence, diversification, reliability	Diversifying the fuels used to provide energy services as well as the location of facilities using those fuels, promoting energy systems that can recover quickly from attack or disruption, and minimizing dependence on foreign suppliers	Oil import dependence; Natural gas import dependence; Dependence on petroleum transport fuels
Affordability	Equity	Providing energy services that are affordable for consumers and minimizing price volatility	Retail electricity prices; Retail gasoline/petrol prices
Energy and Economic Efficiency	Innovation, resource custodianship, minimization of waste	Improving the performance of energy equipment and altering consumer attitudes	Energy intensity; Per capita electricity use; On-road fuel intensity of passenger vehicles

Environmental Stewardship	Sustainability	Protecting the natural environment and future generations	Sulfur dioxide emissions; Carbon dioxide emissions

To reflect *availability*, oil import dependence, natural gas import dependence, and dependence on petroleum transport fuels serve as useful indicators. Oil import dependence and natural gas import dependence reflect how dependent a country is on foreign supplies of petroleum (mostly used in transport) and natural gas (a feedstock for industrial activity and power generation), and also document changes in the supply mix for the world's first and third most used fuels (the second being coal). The presence of alternative fuels such as ethanol and bio-diesel also reveal how far countries have moved away from dependence on petroleum. To reflect *affordability*, the price of electricity and gasoline at the retail level serve as important metrics. We have decided to track residential prices for electricity and gasoline consumption rather than diesel or jet fuel because homes and passenger vehicles account for a majority of the energy used by ordinary people.[2] To reflect *energy and economic efficiency*, metrics such as energy intensity, per capita electricity use, and on-road fuel intensity of passenger vehicles show different but important dimensions. Perhaps the most important of these three is energy intensity, a measure that indicates the amount of energy used to produce a unit of GDP. By correlating energy use with economic output, the measure thus encompasses patterns of consumption and use for industries, government facilities, consumers, and multiple sectors all at once. Per capita electricity consumption and on-road fuel economy for passenger vehicles also show how efficient individual technologies have become at the end-user level. To reflect *environmental stewardship*, aggregate sulfur dioxide emissions and carbon dioxide emissions reveal how far countries have gone towards mitigating greenhouse gas emissions, acid rain, and noxious air pollution. These indicators also help show relative progress in how governments have implemented national climate change programs.

Evaluating Performance for the OECD

[2] For assessments of industrial electricity use, readers are invited to see Olutomi I. Adeyemi and Lester C. Hunt, "Modelling OECD industrial energy demand: Asymmetric price responses and energy-saving technical change," *Energy Economics* 29 (2007), pp. 693-709. The paper explores the issue of energy-saving technical change and asymmetric price responses for 15 OECD countries over the period 1962–2003. For assessments of fuel economy for freight, rather than passenger vehicles, see Lorna A. Greening, Mike Ting, and William B. Davis, "Decomposition of aggregate carbon intensity for freight: trends from 10 OECD countries for the period 1971 to 1993," *Energy Economics* 21 (1999), pp. 331-361; and Lee Schipper, Lynn Scholl, and Lynn Price, "Energy Use and Carbon Emissions from Freight in 10 Industrialized Countries: An Analysis of Trends from 1973 to 1992," *Transportation Research D* 2(1) (1997), pp. 57-76.

We collected data on these ten indicators and metrics for 22 OECD countries from 1970 to 2007, with a few exceptions and caveats. First, reliable data for energy intensity was only available for 1980 and 2005; fuel economy data for 2005 instead of 2007; and sulfur dioxide emissions data for 2000 instead of 2007. Second, our index is not meant to imply that quantitative measures of energy security are perfect, or that reducing complex situations to numbers is without problems. Numerical indices often highlight 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 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 and energy-intensive jobs outsourced?[3] Third, collecting the data for this study was tedious and difficult. Most of it was not available online and the data for 1970 involved much digging through libraries. Historical data from International Energy Agency publications and archives are inconsistent, and discrepancies found in data and reports published by different agencies (e.g., the Energy Information Administration, World Resources Institute, United Nations, and the World Bank) are even more troubling.

That said, we do believe that these ten metrics provide a reasonable sense for how well countries have provided energy services and promoted energy security, and the results may be surprising to some. Tables 2 and 3 present data for each of the 10 metrics for the 22 selected countries in 1970 and 2007.

To assess how a country has performed relative to other countries based on an array of indicators that use diverse units of measurement, we rely on z-scoring. Z-scores are “dimensionless” quantities that indicate how many standard deviations a country is above or below the mean of the 22 OECD countries. We created z-scores for each of the ten indicators in 1970 and 2007 by subtracting the mean value for each data point and dividing by the indicator’s standard deviation. The z-scores are then summed for 1970 and 2007, giving equal weight to each indicator and providing a total energy security score for each country in both years. This z-scoring exercise indicates that the United States had the lowest energy security of all 22 countries, both in 1970 and still in 2007. In contrast, Figure 1 depicts that the United Kingdom., New Zealand, and Denmark had high energy security scores in 2007.

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[3] Marilyn A. Brown and Benjamin K. Sovacool, “Developing an ‘Energy Sustainability Index’ to Evaluate Energy Policy,” *Interdisciplinary Science Reviews* 32(4) (December, 2007), pp. 335-349.

Table 2: Energy Security Performance Index for 22 OECD Countries, 1970 (in $2007)[4]

	Oil import dependence (%)	Dependence on petroleum transport fuels (%)	On-road fuel intensity (gpm)	Energy per GDP intensity (thousand BTU/US$GDP)*	Electricity use (kWh/capita)	Natural gas import dependence (%)	Nominal electricity retail prices (US¢/kWh)	Nominal gasoline prices (US$/liter)	SO_2 emissions (million tons)	CO_2 emissions (million tons)
Australia	67%	96.1%	0.059	10.3	3,919	0%	3.7	0.26	1.6	148
Austria	57%	94.3%	0.048	8.5	3,302	34%	18	1.32	0.4	51
Belgium	100%	98.4%	0.045	12.2	3,399	99%	18.5	1.74	1.2	126
Canada	46%	97.3%	0.071	18.7	9,529	1%	3.7	0.37	4.1	341
Denmark	99%	98.1%	0.042	8.8	3,211	0%	9.5	0.42	0.3	62

5. Data for energy intensity starts at 1980 instead of 1970. (See *58-68).* Specific values for fuel economy for Austria, Canada, Denmark, France, Germany, Italy, Japan, Netherlands, Spain, Sweden, United Kingdom, and United States taken from Lee Schipper and Lew Fulton, *Disappointed by Diesel? The Impact of the Shift to Diesels in Europe Through 2006* (2009 Presentation to the Transportation Research Board Annual Meeting, Washington, DC). Values for remaining countries taken from OECD averages. Values for population figures and Gross Domestic Product taken from U.S. Economic Research Service, *International Macroeconomic Data Set* (Washington, DC: U.S. Department of Agriculture, 2008). Figures for electricity consumption per capita exclude electricity exports, and were calculating by dividing IEA data in total national consumption (in GWh) by the reported national population. Figures for "energy intensity" taken from 1980 data compiled by the U.S. Energy Information Administration, *World Energy Intensity—Total Primary Energy Consumption per Dollar of Gross Domestic Product* (Washington, DC: U.S. Department of Energy, 2007), and presume market exchange rates adjusted for 2007 U.S. dollars. Values for retail gasoline prices presume premium gasoline, exclude taxes, have been adjusted to 2007 U.S. dollars, and are taken from Jan Bentzen, *An Empirical Analysis of Gasoline Price Convergence for 20 OECD Countries* (Denmark: Aarhus School of Business Working Paper 03-19), and adjusted according to the Organization of Economic Cooperation and Development's "Consumer Price Indices—Energy" from their *Main Economic Indicators* (Paris, France: OECD, 2008). Values for retail electricity prices have been adjusted to 2007 U.S. dollars, are taken from International Energy Agency, *Energy Prices & Taxes—Quarterly Statistics* (Paris, France: IEA, 2008), and adjusted according to the Organization of Economic Cooperation and Development's "Consumer Price Indices—Energy" from their *Main Economic Indicators* (Paris, France: OECD, 2008). Some sulfur dioxide emissions come from Peter A. Spiro, Daniel J. Jacob, and Jennifer A. Logan, "Global Inventory of Sulfur Emissions With 1x1 Resolution," *Journal of Geophysical Research* 97 (1992), pp. 6023-6036 and Peter Brimblecombe*, Historical Sulfur Emissions* (School of Environmental Sciences University of East Anglia Norwich, 1999). All remaining figures come from International Energy Agency, *Energy Statistics of OECD Countries, 1960 to 1979* (Paris, France: Organization for Economic Cooperation and Development, 1991); International Energy Agency, *Energy Balances of OECD Countries, 1970 to 1982* (Paris, France: Organization for Economic Cooperation and Development, 1984).

Finland	100%	97.7%	0.045	12.6	4,885	100%	5.3	0.53	0.4	40
France	98%	96.3%	0.036	8.7	2,882	35%	7.9	0.74	3.5	439
Germany	92%	96.4%	0.042	9.8	2,962	24%	15.9	1.16	6.9	1,027
Greece	99%	98.3%	0.048	6.0	1,118	0%	2.1	0.58	0.3	24
Ireland	98%	97.2%	0.045	9.0	1,956	0%	6.9	0.58	0.2	19
Italy	97%	98.7%	0.036	7.1	2,262	0%	6.3	0.42	2.6	297
Japan	100%	98.2%	0.050	7.8	3,445	32%	48.6	1.27	5.1	769
Netherlands	97%	98.0%	0.040	12.9	3,110	0%	15.3	1.00	1.4	142
New Zealand	100%	95.6%	0.053	11.0	4,941	0%	3.17	0.48	0.1	14
Norway	100%	97.5%	0.043	16.4	14,785	0%	2.6	0.42	0.2	28
Portugal	99%	98.0%	0.043	4.4	830	0%	20.6	1.59	0.1	15
Spain	99%	97.3%	0.037	7.0	1,623	85%	5.8	0.37	1.1	117
Sweden	100%	97.5%	0.050	13.7	8,048	0%	3.2	0.32	0.9	92
Switzerland	100%	96.9%	0.043	7.6	4,693	100%	4.0	1.59	0.1	40
Turkey	53%	97.7%	0.067	5.0	241	0%	21.1	0.11	0.8	43
UK	100%	97.7%	0.048	9.9	4,489	7%	5.3	0.58	8.6	653
United States	22%	95.1%	0.077	14.7	8,022	4%	7.0	0.42	31.2	4,413
Median	99%	97.5%	0.045	9.4	3,351	1%	6.6	0.56	1.0	105
Mean	87%	97.2%	0.049	10.1	4,257	24%	10.7	0.74	3.2	405

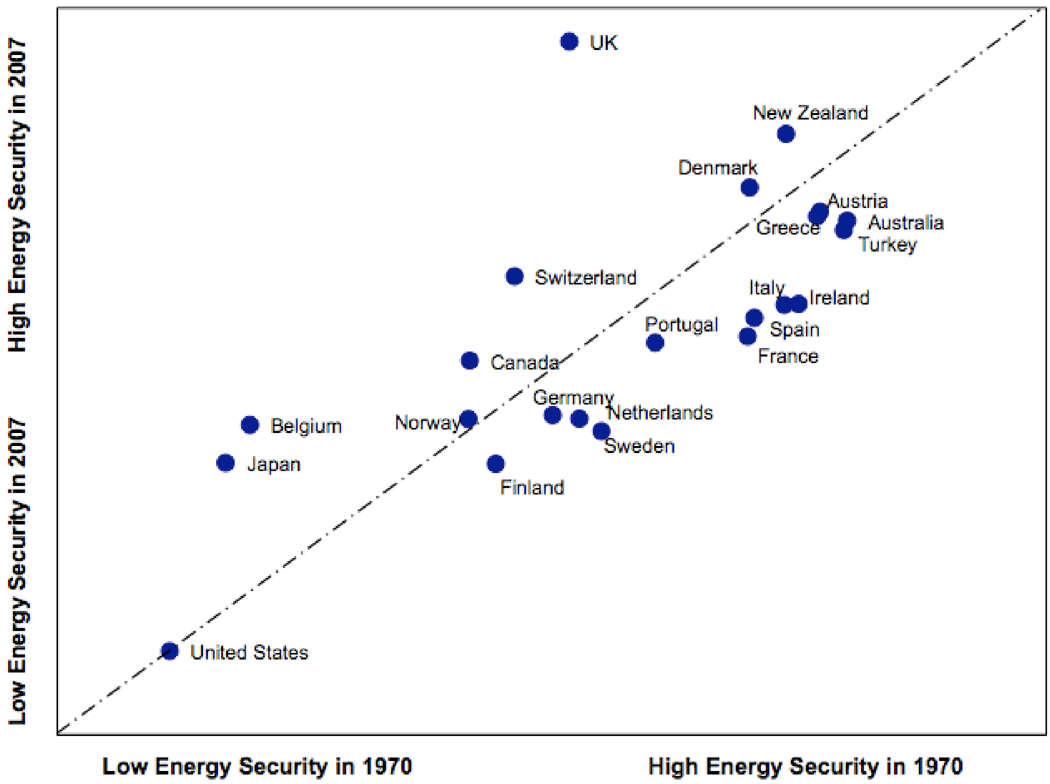
Table 3: Energy Security Performance Index for 22 OECD Countries, 2007[5]

	Oil import dependence (%)	Dependence on petroleum transport fuels (%)	On-road fuel intensity (gpm)	Energy per GDP intensity (thousand BTU/US$GDP)*	Electricity use (kWh/capita)	Natural gas import dependence (%)	Real electricity retail prices (US¢/kWh)	Real gasoline prices ($/liter)	SO_2 emissions (million tons)*	CO_2 emissions (million tons)
Australia	37%	98.3%	0.038	9.0	11,309	0%	12.5	1.24	2.6	394
Austria	91%	96.3%	0.032	7.0	8,090	95%	22.6	1.81	0.2	66
Belgium	99%	98.1%	0.034	9.2	8,688	100%	16.5	2.20	1.3	103
Canada	0%	98.8%	0.043	13.8	16,766	0%	7.6	1.08	2.9	573
Denmark	0%	97.7%	0.033	5.2	6,864	0%	38.2	2.05	0.1	50
Finland	96%	98.1%	0.034	8.8	17,178	93%	17.1	2.12	0.3	64
France	96%	98.1%	0.031	7.2	7,585	97%	17.3	2.03	1.3	353

6. Data for energy intensity and fuel economy is for 2005 instead of 2007. See (*67-71).* Energy intensity is taken from U.S. Energy Information Administration, *World Energy Intensity—Total Primary Energy Consumption per Dollar of Gross Domestic Product* (Washington, DC: U.S. Department of Energy, 2007), and adjusted for purchase power parity (PPP). Specific values for fuel economy for Austria, Canada, Denmark, France, Germany, Italy, Japan, Netherlands, Spain, Sweden, United Kingdom, and United States taken from Lee Schipper and Lew Fulton, *Disappointed by Diesel? The Impact of the Shift to Diesels in Europe Through 2006* (2009 Presentation to the Transportation Research Board Annual Meeting, Washington, DC). Values for remaining countries were taken from European and OECD averages. Data for sulfur dioxide emissions are from 2000 instead of 2007, and are taken from World Resources Institute, *Climate and Atmosphere Indicators: Sulfur Dioxide Emissions* (Washington, DC: WRI, 2007). Values for retail gasoline exclude taxes for the United States and presume unleaded premium or equivalent grade fuel. Data for alternative fuels includes only ethanol and biodiesel, reports EU targets for most European countries, and comes from the Organization for Economic Cooperation and Development, *Biofuel Support Policies: An Economic Assessment* (Paris: OECD, 2008). All remaining figures taken from U.S. Energy Information Administration, *Country Energy Profiles* (Washington, DC: U.S. Department of Energy, 2008) and International Energy Agency, *Key World Energy Statistics 2008* (Paris, France: International Energy Agency, 2008), with adjustments made according to the Organization of Economic Cooperation and Development's "Consumer Price Indices—Energy" from their *Main Economic Indicators* (Paris, France: OECD, 2008) when data was not available for 2007.

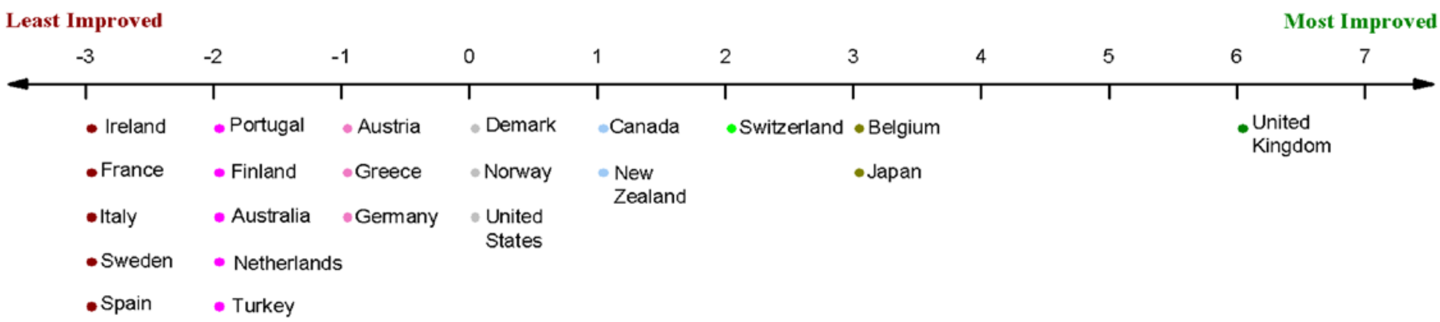
Germany	94%	98.1%	0.034	7.0	7,175	79%	23.1	2.10	2.4	790
Greece	99%	98.1%	0.034	6.8	5,372	99%	13.0	1.19	0.8	97
Ireland	100%	98.1%	0.034	4.9	6,500	86%	24.7	1.77	0.1	44
Italy	93%	97.5%	0.030	5.8	5,762	85%	27.2	2.06	1.5	430
Japan	97%	98.2%	0.045	6.5	8,220	93%	17.8	1.46	2.6	1,227
Netherlands	91%	98.1%	0.033	9.8	7,057	59%	24.2	2.28	1.0	179
New Zealand	69%	97.1%	0.034	9.1	9,746	0%	17.8	1.35	0.1	36
Norway	0%	98.1%	0.034	12.8	24,295	0%	17.5	2.32	0.6	36
Portugal	98%	98.1%	0.034	5.9	4,799	100%	23.3	2.07	0.2	55
Spain	98%	98.1%	0.032	7.1	6,213	100%	18.7	1.64	2.1	346
Sweden	99%	98.1%	0.036	9.1	15,230	100%	12.7	1.99	0.3	45
Switzerland	99%	98.1%	0.034	5.8	8,279	100%	15.6	1.65	0.1	38
Turkey	94%	96.3%	0.034	6.1	2,053	97%	15.8	2.60	2.1	266
UK	4%	96.3%	0.032	6.0	6,192	8%	22.7	2.07	1.6	524
United States	59%	97.1%	0.050	9.1	13,515	17%	10.3	0.82	17.8	5,725
Median	94%	98.1%	0.034	7.1	7,838	90%	17.7	2.01	1.2	141
Mean	73%	2.2%	0.036	7.8	9,404	64%	18.9	1.81	1.9	520

Figure 1: Energy Security "Z-Scores" in 1970 and 2007



We then assessed the relative progress of each country over time by comparing the sum of their Z-scores on the 10 indicators in 1970 and 2007. The results of our analysis indicate that the United Kingdom experienced the largest improvement in energy security over this time frame. Its energy security improved on six of the ten indicators, and was particularly strengthened with respect to oil import dependence, shifting from 100 percent oil imports in 1970 to only 4 percent in 2007. Figure 2 illustrates that Belgium, Japan, Switzerland, Canada, and New Zealand also experienced significant improvements in their energy security over this same timeframe. In contrast, Ireland, France, Italy, Sweden, and Spain experienced the largest declines in energy security over this same period.

Figure 2: Most to Least Improved Energy Security
(Based on Differences in Z-Scores: 1970 and 2007)

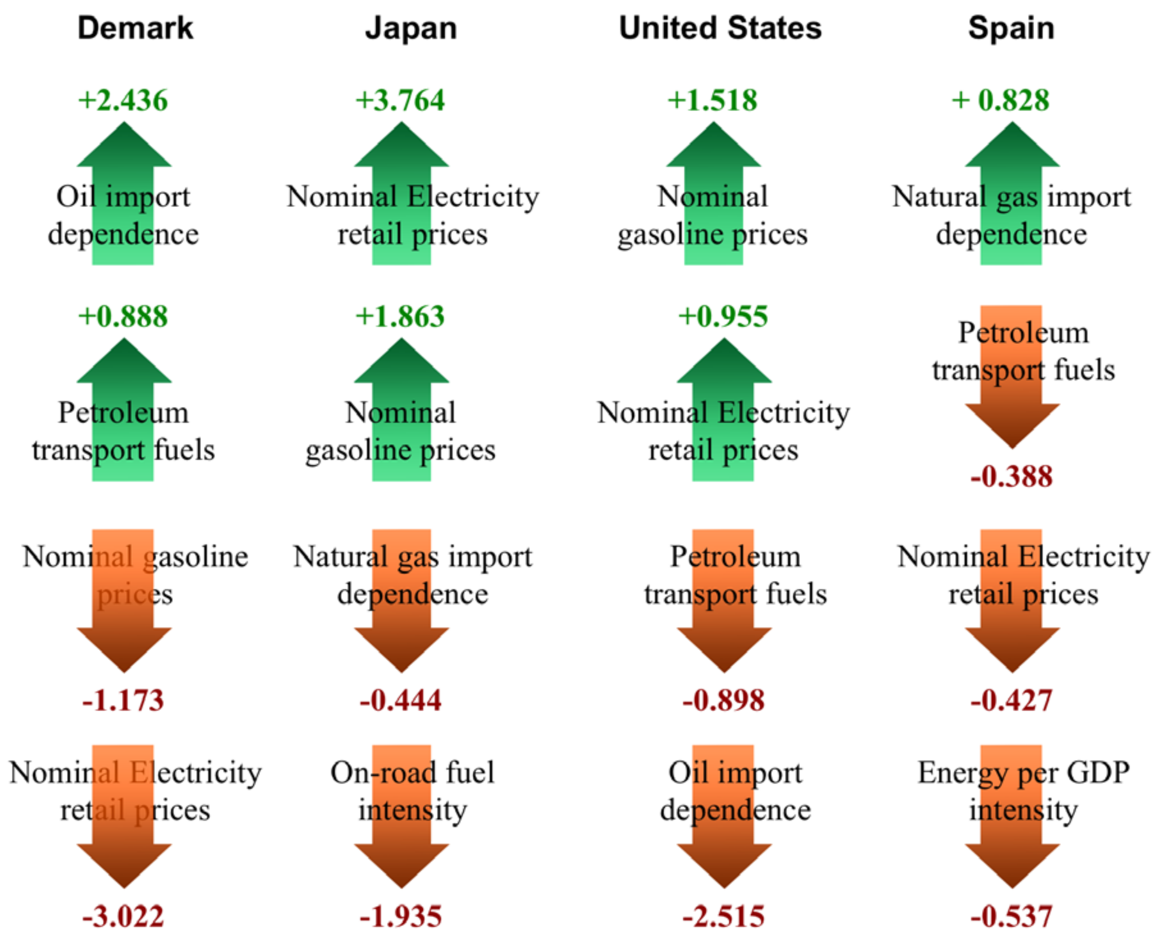


A few general trends are worth noting. First, changes in energy security scores over time have been highly variable within the OECD, implying that the countries examined have taken diverse and divergent paths towards energy policy and security, and also reflecting different natural resource endowments. Second, no country improved along all ten indicators of energy security. The United Kingdom and Denmark both scored better on six indicators over the past four decades, exhibiting the greatest breadth of improvement. Third, a majority of countries have experienced declines in energy security, with thirteen countries scoring worse on a majority of the ten indicators between 1970 to 2007. Fourth, some metrics, such as energy intensity and fuel economy for passenger vehicles, have almost universally improved, while others, such as electricity consumption per capita, electricity prices, and gasoline prices have almost universally deteriorated.

Explaining Energy Security Performance

Using the same statistical data, supplemented by a review of the published literature, we explore four countries in greater detail, focusing on their energy security scores and the strategic actions that have led to them. Figure 1 shows that Denmark had one of the highest Z-scores in 1970 and 2007 and the United States had the worst score; Figure 2 shows that Spain was one of the countries that improved the least in terms of its energy security from 1970 to 2007 whereas Japan was one of the countries that improved the most. We thus decided to explore these four case studies in greater detail: Denmark, Japan, the United States, and Spain—as they seem to represent two of the best and two of the worst countries in terms of their energy security trends over time. Figure 3 breaks down their performance among four particular indicators that saw the biggest changes from 1970 to 2007 within each country

Figure 3: Areas of Energy Security Improvement and Decline for Denmark, Japan, United States, and Spain, 1970 to 2007*



Denmark

Denmark has exhibited considerable success in improving its energy security compared to the other countries analyzed. Since 1970, Denmark has transitioned from being 99 percent dependent on foreign energy sources such as oil and coal to becoming a net exporter of natural gas, oil and electricity today. Over the same period, Denmark has improved its reliance on non-petroleum transportation fuel, decreased its energy intensity by almost a factor of two, and lowered its aggregate carbon dioxide and sulfur dioxide emissions. The only areas where Denmark did not improve were in electricity use per capita, electricity prices, and gasoline prices, and these latter three were areas where almost no country improved.

Denmark is now the unchallenged world leader in terms of wind energy, exporting $8 billion in wind turbine technology and equipment per year, and Denmark also boasts the lowest energy consumption per capita in the European Union.[6] Primary energy consumption nationally grew just 4 percent from 1980 to 2004, even though the economy grew more than 64 percent in fixed prices. At the same time, more renewable energy replaced fossil fuels, and total CO_2 emissions decreased by 16 percent. Therefore, the carbon dioxide emission intensity—the amount of CO_2 emitted per unit of Gross Domestic Product—was 48 percent lower in 2004 than it was in 1980.

The most obvious factor responsible for such improvement is strong political leadership and well-designed, consistent policy mechanisms aimed at improving energy efficiency and promoting renewable energy. Denmark implemented energy taxes in 1974 as a response to the energy crises, and used the billions in dollars of revenue to invest in wind power, biomass, and small-scale combined heat and power units. The taxes furthermore sent price signals that encouraged voluntary energy efficiency measures. Denmark mandated energy efficiency standards for new buildings, and tightened them over a period of 30 years. Danish regulators also designed investment subsidies and feed-in tariffs forcing utilities to buy all power produced from renewable energy technologies at a rate equal to 70 to 85 percent the consumer retail price of electricity in a given distribution area, and they later regulated that all renewable power providers be given priority access to the grid.[7] The government levied a general carbon tax on all forms of energy and set strict vehicle fuel economy standards, and later adopted European standards pledging to decrease carbon dioxide emissions from automobiles to 140 grams of carbon dioxide emitted per kilometer driven by 2008, which help explain Denmark's lowered emissions of greenhouse gases.

While these efforts have improved many aspects of energy security, they have also made energy more expensive. Denmark's taxes do mean that electricity prices are the highest in the European Union at about 38 cents per kWh, and the price of petrol is more expensive than 13 other OECD countries. Denmark's experience does suggest that improving availability, efficiency, and stewardship can tradeoff with affordability, but overall the country appears to be the most energy secure in the OECD.

Japan

A similar pattern of strong government support for energy security exists in Japan, although with less focus on renewable energy and some other notable differences. Since

[6] Benjamin K. Sovacool, Hans Henrik Lindboe and Ole Odgaard, "Is the Danish Wind Energy Model Replicable for Other Countries?" *Electricity Journal* 21(2) (March, 2008), pp. 27-38.
[7] P.E. Morthorst, "The Development of a Green Certificate Market," *Energy Policy* 28 (2000), pp. 1085-1094.

1970, Japan has lessened its dependence on oil and improved vehicle fuel economy slightly, but increased its dependence on natural gas and significantly increased its sulfur dioxide and carbon dioxide emissions despite its promises under the Kyoto Protocol. Electricity use per capita more than doubled and gasoline prices rose, but Japan was also one of only three countries where electricity prices decreased, and its energy intensity also improved.

Overall, Japan recorded unprecedented levels of economic growth between 1970 and 2007, closing the gap in per capita income, raising standards of living, and improving labor productivity compared to Western Europe and North America all while drastically improving energy efficiency.[8] Devastated after World War II, Japan's immediate problem was securing adequate supply of energy to fuel reconstruction and industrial growth, and the country's energy needs were met predominately by imported oil and domestic coal. Population density in major cities such as Tokyo, however, made the mounting costs of air and water pollution visible, and environmental awareness was starting to rise at the same time the Arab oil embargo hit. By 1973, the time of the oil crisis, petroleum accounted for nearly 80 percent of total energy demand, and the crisis precipitated nothing less than panic.[9]

Energy security was given highest priority, and from 1973 to 1975 the government announced a formal energy security strategy that consisted of reducing dependence on petroleum, diversifying domestic energy supply, aggressively promoting energy conservation, and pushing research and development. Japan's Ministry of International Trade and Industry (MITI) began their "Moonlight Project" in 1978 to develop more efficient power technologies and early fuel cells. In addition, the government offered free energy audits for smaller firms and issued standards for combustion and heating devices in industry to improve energy efficiency. These standards applied to more than 3,500 factories in the manufacturing mining and energy supply sectors, and the government also required these facilities to hire a certified energy manager and to publicly disclose their energy consumption annually.

The 1980s saw Japan pass an Alternative Energy Law with provisions forcing suppliers to adopt natural gas and renewable power sources, along with the creation of tax incentives and low-interest loans for industrial energy efficiency measures, emphasizing the

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[8] Yujiro Hayami, "Changes in the Source of Modern Economic Growth: Japan Compared with the United States," *Journal of Japanese International Economics* 13 (1999), pp. 1-21.
[9] Yukiko Fukasaku, "Energy and Environment Policy Integration: The Case of Energy Conservation Policies and Technologies in Japan," *Energy Policy* 23(12) (1995), pp. 1063-1076.

petrochemicals, refining, cement, and paper industries.[10] The first minimum energy performance standards came in 1983 for refrigerators and air conditioners, and were later expanded to virtually all appliances, including the underrated electric toilet seat warmer. The appliance standards were very successful at reducing electricity consumption. Average electricity use for refrigerators, for example, declined by 15 percent from 1979 to 1997 while average refrigerator size increased by 90 percent. Japanese regulators also applied their performance standards to imported technology ranging from automobiles and televisions to air conditioners and computers, and demanded that the efficiency level of new products had to meet the best performing product in the market, in some cases requiring energy efficiency improvements of more than 50 percent.[11]

Japanese progress, however, has been more tempered than Denmark. Energy use per capita increased from 1973 to 2005 for both Japanese households and passenger travel. While the government promoted strict performance standards for appliances, they set only voluntary standards for buildings, and did not ramp up financial incentives until the late 1990s. Japan did require efficiency standards and efficiency labeling for automobiles, and these led to a 12 percent increase in fuel economy from 1979 to 1985 and another 8.5 percent increase from 1990 to 2000. Such improvement, however, was offset by a doubling of transport energy use between 1973 and 2001 due to the growth in vehicle ownership and increases in vehicle size. Private automobile travel rose in Japan from a modest 42.5 percent in 1970 to 55.9 percent in 1987.[12] Moreover, cheap oil prices in mid-1980s encouraged energy consumption. Energy demand growth as a whole averaged only 0.2 percent between 1973 and 1986, but jumped to 4 percent between 1987 and 1991.[13]

United States

The United States fared poorly compared to almost all other countries—with only Greece, Portugal, and Spain performing worse. The country has improved in only three of the indicators from 1970 to 2007—energy intensity, fuel economy, and sulfur dioxide

[10] Shuji Yamamoto, "Japan's New Industrial Era—Restructuring Traditional Industries," *Long Range Planning* 19(1) (1986), pp. 61-66.

[11] Howard Geller, Philip Harrington, Arthur H. Rosenfeld, Satoshi Tanishima, Fridtjof Unander, "Policies for Increasing Energy Efficiency: Thirty Years of Experience in OECD Countries," *Energy Policy* 34 (2006), pp. 556-573.

[12] Lee Schipper, Ruth Steiner, Peter Duerr, Feng An, and Steinar Strom, "Energy Use in Passenger Transport in OECD Countries: Changes Since 1970," *Transportation* 19 (1992), pp. 25-42.

[13] Yukiko Fukasaku, "Energy and Environment Policy Integration: The Case of Energy Conservation Policies and Technologies in Japan," *Energy Policy* 23(12) (1995), pp. 1063-1076.

emissions. In contrast, the country has become significantly more dependent on foreign supplies of natural gas and oil and remains the world's leading emitter of greenhouse gases.

While progress in the adoption of more energy-efficient technologies has saved billions of dollars throughout the economy, most other indicators of energy autonomy demonstrate that the country has become less less energy secure over time. Even though energy efficiency has taken root in some sectors of the economy, it has not compensated for the growth in energy consumption that has occurred since 1973, nor will it (if current trends continue) accommodate the growth that forecasters anticipate in coming decades. Moreover, America's dependence on oil from insecure and politically unstable countries has required extensive diplomatic and military efforts that incur huge costs borne by energy users and taxpayers. The country's information economy also remains inextricably tied to reliable power and to just-in-time manufacturing and distribution processes that depend on fleets of petroleum-guzzling trucks and airplanes.[14]

The United States remains more susceptible today to oil supply disruptions and price spikes than at any time in the recent past. It has grown to become the world's largest oil consumer by a considerable margin while, at the same time, its domestic oil production has plummeted. Oil imports have filled the expanding gap, accounting for 59 percent of total U.S. oil consumption in 2007—up from 22 percent in 1970. The United States has so many automobiles that the number of cars exceeds the number of people with drivers' licenses.[15]

The United States also continues to see increasing demand for electricity in a way that threatens its ability to meet customer load requirements. The country consumed about 170 percent more electricity in 2007 than it did in 1970, with power usage growing from 25 percent of the nation's total energy use in 1970 to 40 percent today. Efforts resulting from three decades of clean air legislation have decreased sulfur dioxide emissions from electric generators in the United States. Nevertheless, air pollution remains a serious threat to human and ecosystem health. Americans have experienced a rise in respiratory illnesses, and visibility continues to degrade in formerly pristine areas as a result of pollution from vehicles and coal-burning power plants. Beyond air pollution issues, current energy trends will lead to expanded emissions of greenhouse gases, which appear to be contributing to increased global temperatures, recession of glaciers, and more frequent and powerful weather events such as hurricanes.

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[14] Marilyn A. Brown, Benjamin K. Sovacool, and Richard F. Hirsh, "Assessing U.S. Energy Policy," *Daedalus: Journal of the American Academy of Arts and Sciences* 135(3) (Summer, 2006), pp. 5-11.

[15] Lee Schipper, Ruth Steiner, Peter Duerr, Feng An, and Steinar Strom, "Energy Use in Passenger Transport in OECD Countries: Changes Since 1970," *Transportation* 19 (1992), pp. 25-42.

Because of its huge dependence on imported oil to fuel a transportation sector that has seen little improvement in energy efficiency, the nation could be ravaged by disruptions to oil supplies due to weather, war, or terrorist attacks. At the same time, growing electricity consumption and reliance on power plants employing natural gas (which increasingly comes from foreign sources) make the electric utility infrastructure more vulnerable to service disruptions. And while efficiency efforts have successfully stemmed the growth rate of fuel consumption in the last few decades, population increases and economic expansion have forced up the nation's overall use of energy, exacerbating the country's environmental problems.

Spain

Tied for last in our energy security index, Spain has shown improvement in only two indicators: a meager reduction in dependence on foreign sources of oil from 99 percent to 98 percent, and a modest improvement in on-road fuel economy from 27 to 31 miles per gallon. Spain has worsened in every other metric, including energy intensity. Total primary energy use per unit of GDP has fallen for 19 other OECD countries (two other exceptions being Greece and Portugal), and overall major OECD economies used a third less primary energy to generate a unit of GDP in 2006 than in the 1970s.[16]

Spain has defied this trend. The country lacks sufficient supplies of domestic coal, oil, gas, and uranium, has experienced ongoing industrialization, but made little improvement in energy efficiency. Thus, the Spanish energy sector is currently suffering from difficulty in controlling greenhouse gas emissions, high prices, increasing reliance on imported fuels, high levels of growth in energy demand, and stagnating energy efficiency and energy intensity, culminating in a situation even Spanish analysts consider unsustainable.[17] Spain's gradual transition to democracy left intact the prevailing economic structures that had existed during the Franco regime. Unlike the comparatively progressive governments implementing energy reforms in other OECD countries during the 1970s, bankers and industrial managers continued to play the primary role in Spanish energy policymaking. Rather than promote energy efficiency or diversification, these stakeholders sought ways to ensure a smooth political transition, maintain economic growth, and retain their political power. From 1975 to

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[16] Howard Geller, Philip Harrington, Arthur H. Rosenfeld, Satoshi Tanishima, Fridtjof Unander, "Policies for Increasing Energy Efficiency: Thirty Years of Experience in OECD Countries," *Energy Policy* 34 (2006), pp. 556-573.

[17] P. Linares, F.J. Santos, and I.J. Perez-Arriaga, "Scenarios for the Evolution of the Spanish Electricity Sector: Is it On the Right Path Towards Sustainability?" *Energy Policy*, forthcoming 2008/2009.

1982, alternative sources of policy such as left-wing parties, environmental groups, trade unions, and consumer advocates were able to exert little influence over Spanish energy policy. The country thus remained committed to developing conventional forms of supply and strengthening agreements to import energy fuels, but neglected energy efficiency and alternative energy.[18] When the Spanish Socialist Workers Party came to power in 1982, energy policy did not break significantly with past patterns.

Whereas energy intensity declined in almost every other OECD country, the late 1980s and most of the 1990s saw sustained growth in energy consumption per unit of GDP in Spain, which increased at an annual rate of 0.75 percent from 1990 to 1997. Per capita electricity consumption and carbon dioxide emissions also increased at rates between 2.3 and 2.8 percent annually over the same period.[19] Spanish regulators heavily focused on building nuclear plants in the early 1980s, but their plans were threatened by high costs and the Chernobyl disaster in 1986. Despite a few early policy documents and royal decrees, the country did not seriously consider energy efficiency and conservation until the early 1990s.[20] At this time, however, a significant number of mergers and acquisitions occurred in the energy sector, creating massive levels of concentration. The newly integrated energy companies, rather than focusing on the domestic Spanish market, initiated plans for international expansion, attempting to privatize and invest in emerging markets in Latin America.[21] Spanish companies established production, refining, and manufacturing centers in Argentina, Brazil, Columbia, and Mexico. The Spanish oil company REPSOL-YPF, the seventh largest in the world, expanded exploration and production to four Latin American countries. Endesa and Iberdrola, some of the world's largest electricity companies, became leading power suppliers for seven countries in South America and Central America. The Spanish company Gas Natural Group also became the largest single investor in Latin American gas markets.

The consolidation and concentration of Spanish energy companies, coupled with comparatively weak political oversight, lack of competition, and a focus on global markets

[18] Thomas D. Lancaster, *Policy Stability and Democratic Change: Energy in Spain's Transition* (London: Pennsylvania State University Press, 1989); Aad Correlje, "Spanish Energy Policy Overview," *Energy Policy* (November, 1991), pp. 901-902.

[19] Felix Hernandez, Miguel Gual, Pablo Rio, Alejandro Caparros, "Energy Sustainability and Global Warming in Spain," *Energy Policy* 32 (2004), pp. 383-493.

[20] Yannick Perez and Francisco Ramos-Real, "The Public Promotion of Wind Energy in Spain from the Transaction Costs Perspective, 1986 to 2007," *Renewable and Sustainable Energy Reviews* 2008, pp. 1-9; Pablo Gonzalez, "Ten Years of Renewable Electricity Policies in Spain: An Analysis of Success Feed-in Tariff Reforms," *Energy Policy* 36 (2008), pp. 2917-2929.

[21] Pablo Arocena, Ignacio Contin, and Emilio Huerta, "Price Regulation in Spanish Energy Sectors: Who Benefits?" *Energy Policy* 30 (2002), pp. 885-895.

left little space for consumer advocacy or environmental policy.[22] Throughout the late 1990s, Spanish customers had some of the highest electricity prices in all of Europe, and most consumers generally believed that such high prices reflected a pro-industry bias that allowed large cash flows to be funneled into the international expansion of Spanish firms. The consequence has been a deterioration of energy security in almost every metric. Spanish energy intensity increased from 1990 to 2000 by 5 percent while European intensity decreased by 10.4 percent.[23] The Spanish economy continues to be highly dependent on high-carbon fossil fuels such as oil and coal, which accounted for roughly 60 percent of energy use in 2007, and the situation is further compounded by the mismatch between state, territorial, and national energy policy, which has been very sporadic and irregular, with some regions aggressively pursuing renewables such as wind and solar while other regions have little penetration of renewable power supplies.

Conclusion

This chapter has created an Energy Security Index, utilizing ten metrics that encompass economic, social, political, and environmental aspects of energy security, and analyzed the status of energy conditions in 22 OECD countries from 1970 to 2007. At least four interconnected conclusions can be drawn from our exercise.

First, our Energy Security Index shows that a majority of countries analyzed have regressed in terms of their energy security. This conclusion is discouraging, especially considering that the oil shocks of 1973 and 1974 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 United States, the crisis forced sweeping energy legislation through Congress, resulted in the establishment of the Department of Energy, and even provoked President Jimmy Carter to cite the energy challenge as "the moral equivalent of war." Since those times, the international community has seen advances in low-income energy services, efficiency and demand reduction programs, renewable resources initiatives, and market restructuring of the various energy industries. Many individual states in Europe and the United States have implemented aggressive renewable portfolio standards, feed-in tariffs, and systems benefits funds, started

[22] Pablo Rio and Gregory Unruh, "Overcoming the Lock-Out of Renewable Energy Technologies in Spain: The Cases of Wind and Solar Electricity," *Renewable and Sustainable Energy Reviews* 11 (2007), pp. 1498-1513.
[23] Francisco Climent and Angel Pardo, "Decoupling Factors on the Energy-Output Linkage: The Spanish Case," *Energy Policy* 35 (2007), pp. 522-528.

emissions trading schemes, and invested heavily in alternative fuels such as hydrogen, ethanol and biodiesel. Despite all of this effort, our Index reveals that most countries have backslid in their efforts to improve energy security.

Second, despite the near universal deterioration of energy security, a great disparity exists between countries. Some clear leaders, such as Denmark and Japan, stand above the rest, and offer many lessons. Neither country left improving energy security to the marketplace, and their experience underscores the importance of government intervention through a progression of energy policy mechanisms. First came energy taxes, standards, and R&D, followed by mechanisms such as tariffs and quotas, demonstrating the necessity of using a variety of mechanisms at once to promote sound energy policy. The Danish strategy has promoted "triple diversification:" reliance on not just one type of technology, renewables, but also energy efficiency as well as combined heat and power and district heating to meet energy needs; not just one type of policy mechanism but a combination of taxes, subsidies, tariffs, and standards; and not just one type of renewable energy but a combination of biomass, wind, and biogas digestion. Diversification in all three forms—combining supply- and demand-side measures, utilizing a variety of policy mechanisms, and promoting a broad assortment of different types of renewable technologies—is essential. No one approach, no one technology, and no one policy is sufficient alone. Perhaps equally important, the overarching explanation for the success of Danish and Japanese energy policy lies in coordinated and consistent political support and policy. Unlike the United States and Spain, where lack of synchronization between state and federal policy, constant changes in authorization and appropriations, a focus on other priorities, and expiration of programs has impeded energy policy, Japan and Denmark stands as testaments to the importance of consistency.

Third, notwithstanding the progress made by Japan and Denmark (as well as Belgium and the United Kingdom), no nation scored perfectly. This is because efforts to promote energy security, even for the most successful nations, have tended to focus on energy efficiency or increased supply to meet consumer behavior. Strategies have involved increasing the energy efficiency of buildings, appliances, industrial operations, and vehicles, but not on changing consumer patterns, encouraging them to drive less, buy fewer vehicles, or own fewer appliances. Virtually none of the countries examined tax urban sprawl, heavily promote mass transit and limited personal vehicle ownership, attempted to change consumer awareness, provided feedback on energy consumption in the form of real time prices, or changed underlying values by encouraging people to value nature, community involvement, and conservation.[24] Thus, no country has successfully promoted true availability and affordability alongside efficiency and stewardship. Tradeoffs have often been involved between them, and most countries have seemingly pursued one or two of the criteria at the expense of the others.

Fourth and finally, the relative success of Denmark and Japan and the relative failure of the United States and Spain serve as an important reminder that creating energy security is as much a matter of policy from within as it is from without. Policymakers need not focus only on geopolitical power structures in energy resource producing states or draft new contracts with Nigeria and Russia for oil and gas supply. It is not sufficient to build trade alliances and share intellectual property, send more troops to Iraq or Saudi Arabia, or bolster naval deployments throughout the world's shipping lanes. Equally effective and important can be coordinated and robust domestic energy policy, aimed at changing consumer behavior, promoting energy efficiency, and lowering greenhouse gas emissions. Tools such as R&D expenditures, subsidies, tariffs, and standards can be just as important, possibly more, for achieving available, affordable, efficient, and responsible forms of energy supply and use.

[24] Geller et al. 2006, p. 571.