2017 EDITION

INDEX OF U.S. ENERGY SECURITY RISK®

ADDRESSING AMERICA'S VULNERABILITIES IN A GLOBAL ENERGY MARKET

GLOBAL ENERGY INSTITUTE
U.S. CHAMBER OF COMMERCE

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Foreword

This 2017 Edition of the Index of U.S. Energy Security Risk is the first that we are releasing as the Chamber's Global Energy Institute. GEI's original incarnation, the Institute for 21st Century Energy, was formed in 2007 at a time when gasoline prices were at an all-time high, America's dependence on foreign oil was growing, and our energy security was worsening alarmingly. Today, the situation is much different, which is reflected in our new name. American energy has changed our economy, and now it will change the world's.

The vast improvement in U.S. energy fortunes—from scarcity to abundance—over the last 10 years is one of the most remarkable turn of events in the energy space in decades. Since 2010, we have captured these tectonic changes in our U.S. Index, and the conclusion is inescapable: America is on an energy roll, and it shows no signs of slowing down.

The 2010 Edition of the Index was prepared during a time when energy security risks were comparable in magnitude if not necessarily in kind to those the country faced in the late 1970s and early 1980s. Energy consumption was rising worldwide, oil prices were soaring, and world financial markets saw massive flows of revenue from oil-importing countries to oil exporters. Then the global financial crisis struck in late 2008, which led to a severe contraction of economic activity worldwide and plummeting oil prices. By 2011, U.S. energy security risks were at their highest level ever. It is about that time that the shale revolution in the United States really began to take hold, and its beneficial impacts really began to ripple throughout the economy.

From the high point in 2011, overall U.S. energy security risk has plunged in 2016 to the fourth lowest level we have seen—from the record high to the fourth lowest score in just six years. Such a drop in risk is unprecedented in the Index. The single biggest factor in the U.S. improvement has been the widespread use of hydraulic fracturing, horizontal drilling, and advanced seismic imaging technologies to unlock vast quantities of oil and natural gas in shale formations. Because of the shale revolution, the United States has enjoyed greater energy self-sufficiency, lower costs, and reduced emissions, all of which have contributed greatly to lowering our energy security risks. The future looks pretty good, too, with recent forecasts suggesting much lower future risks than earlier forecasts did.

Indeed, as an already established major player on the demand side, the U.S. is becoming a major player on the supply side. In oil markets, for example, the ability of U.S. oil producers to adjust rapidly to new market conditions and exceed expectations continues to astound, even in the face of attempts by OPEC to drive U.S. frackers out of business. It has been said that in world crude oil markets, Saudi Arabia's excess production capacity made it the global "price maker" while the United States was a "price taker." No more. With its ability to respond rapidly to price increases and ramp up production almost instantly from large and growing inventories of untapped wells, America is now effectively the world's "price braker," able to restrain crude oil prices from spiking.

That is not all. Consider some of the major trends to have emerged in recent years that have improved our energy security:

- Domestic production of oil and natural gas, which had been declining or stagnant for decades, has grown tremendously, and the U.S. is now the world's largest combined producer of these fuels.

- The increased domestic production of oil and natural gas has led to fewer imports. Rather than earlier expectations of growing imports, the United States now is a net exporter of refined petroleum, is poised to become a net exporter of natural gas, and exports growing volumes of crude oil (though is still a net importer).

- The increased supply of oil and natural gas has had a downward effect on prices. Oil, a global commodity, is now priced less than half of what it was just a few years ago. Natural gas price tends to be more regional in its pricing, and the increased U.S. supply has brought down natural gas prices sharply within the U.S.

- For petroleum, the lower world price and lower need for U.S. imports has led to sharply lower energy import expenditures. In 2008, U.S. net imports for oil and natural gas approached $500 billion. In 2016, the import cost was less than $100 billion, and it is projected to remain well below $100 out to 2040.

- Energy efficiency continues to proceed apace, and strong gains have been made in all sectors of the economy.

- Total energy expenditures in the U.S. have similarly improved. Just in the 2014 to 2016 time frame, U.S. energy expenditures dropped by over $400 billion. This is an average cost savings of over $1,000 per person in the U.S.

- Comparatively low prices for coal, natural gas, and electricity for industrial users, often two to four times less than in other developed countries, are giving many U.S. manufacturers a competitive advantage over other countries facing higher prices.

- Low coal and natural gas prices have also resulted in lower electricity prices across much of the U.S.

- Generous production subsidies caused both wind generating capacity and generation to more than double since 2010, and wind provided nearly 6 % of U.S. power production in 2016. Subsidies also led to even more explosive growth for solar capacity and generation, but its share of power production remained below 1% in 2016.

- As more natural gas and renewables have entered the generation mix, carbon dioxide emissions from the electric power sector have fallen sharply. As of 2016, U.S. power sector emissions have declined 595 million metric tons from 2005 levels, far more than any other sector in the U.S. and any other country in the world.

Over the years since its inception, the U.S. Index along with its counterpart, the *International Index of Energy Security Risk,* have been able to capture these and other developments and have proven to be valuable tools in understanding our energy security risks and how they vary across types of risk, time, and countries.

Despite the comprehensive nature of the Index, it cannot take into account everything. The Index was designed to highlight and track annually important long-term trends. To achieve this goal, we determined that data we would use needed to be:

- Sensible;
- Credible;
- Accessible;
- Transparent;
- Complete; and
- Prospective.

Although we came up with 37 metrics, lots of potentially relevant risk factors also were considered but ultimately could not be included because they failed to fit these criteria. However, their absence from our metrics does not mean that they may be important risks, only that we cannot quantify them adequately for use in the Index.

These other risks are many and varied, and we note a few of them below:

Resilience of the Power Supply: Although the energy trends cited above have had a beneficial impact on security, there are other trends that, if left unchecked, could pose future risks. One risk that is getting increased attention is the loss of baseload power generators, primarily stream coal and nuclear power plants, and the effect this has on the reliability of the U.S. electricity system.

Baseload capacity normally runs at very high rates and is operated to meet normal load requirements. From 2010 to 2016, coal plant capacity declined about 42 gigawatts (GW)—almost 14%—and nuclear capacity by almost 2 GW. Within the next five years, it is expected that the United States will lose a further 18 GW and 6 GW, respectively, of coal and nuclear capacity. In addition to this lost baseload capacity, the large influx of intermittent renewable capacity, especially wind, also poses complications for grid operators and baseload power suppliers.

The Department of Energy recent *Staff Report to the Secretary on Electricity Markets and Reliability* examined this issue in some detail found four factors that contributed to the premature closure of baseload capacity: (1) low natural gas prices; (2) slowing growth n electricity demand; (3) dispatch of subsidized variable renewable electricity that has changed the economics of operating baseload plants; and (4) regulatory compliance costs.

"Ultimately," the report states, "the continued closure of traditional baseload power plants calls for a comprehensive strategy for long-term reliability and resilience."

The value of a resiliency, a broader concept than simply diversity, cannot be overstated. A just-released IHS Markit Research Report (which GEI co-sponsored), *Ensuring Resilient and Efficient Electricity Generation: The Value of the Current Diverse US Power Supply Portfolio,* found that while in 2016 U.S. consumers paid $381 billion for the reliable and resilient grid-based electricity that they consumed, an analysis of consumer purchasing decisions revealed that they "valued" the electricity at more than twice that amount. That is, consumers attach a large value to producing the reliable electricity available whenever needed at the lowest possible cost.

But, IHS warns, policy-driven market distortions are causing some power plants that are critical to a reliable, resilient, and efficient electric supply to retire prematurely, a trend that is creating an U.S. power generation mix that is less economic, resilient, and reliable.

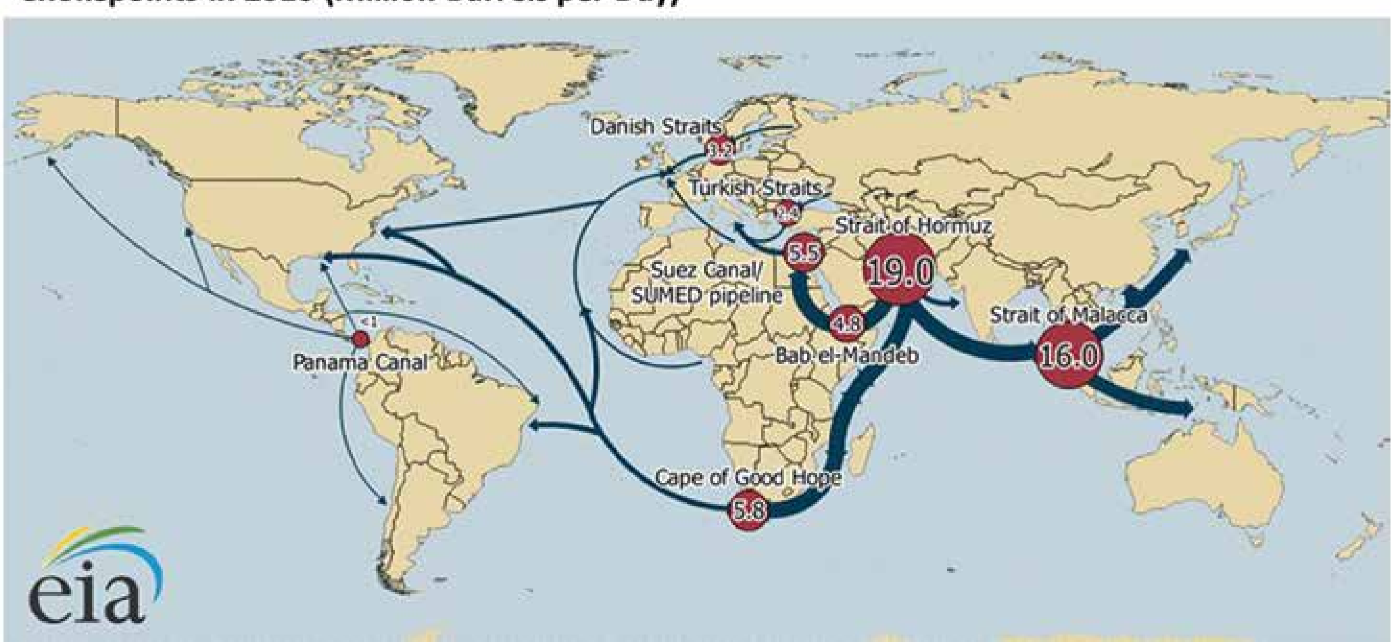
Moving towards less-reliable power mix could have real economic consequences. Among other findings, IHS estimates that, compared to a less divers generation mix, the current electric supply portfolio saves consumers $114 billion dollars per year and lowers he average retail price of electricity by 27%.

IHS concludes: "Growing awareness of the lack of harmonization with policy initiatives and market operations puts the U.S. power sector at a critical juncture. Doing nothing likely results in higher and more varied monthly power bills reflecting less reliable and less resilient power supply in the decades ahead compared to doing something that preserves the consumer net-benefits generated by a more reliable, resilient and cost-effective U.S. electric supply portfolio."

This is an issue that will be—and deserves to be—front and center in the energy debate over the next few years.

Shipping Choke Points: World trade and transportation of energy, particularly oil and natural gas but increasingly coal, too, presents security risks that are real

Daily Transit Volumes of Crude Oil and Petroleum Liquids through World Maritime Oil Chokepoints in 2016 (Million Barrels per Day)



but not so easily quantified and tracked. Most of the global trade in oil moves by sea, and much of that has to transit at least one if not more "choke points." These narrow channels along widely used global sea routes are a critical part of global energy security because of the high volume of petroleum and other liquids transported through them.

Data from the Energy Information Administration (EIA) show that over 60 percent of crude oil and petroleum products—about 59 million barrels per day—are transported through seven world chokepoints and the Cape of Good Hope (see the EIA map nearby). The Strait of Hormuz at the mouth of the Persian Gulf and the Strait of Malacca between Malaysia and Indonesia are, by volume of oil being transported through them, the most important strategic chokepoints.

At these locations, oil tankers are vulnerable to theft from pirates, terrorist attacks, political unrest, wars or hostilities, and shipping accidents that can lead to disastrous oil spills. A disruption in any one of these chokepoints, but especially the Straits of Hormuz and Malacca, could shoot crude oil costs higher. The same sorts of risks exist for shipments of liquefied natural gas and, potentially, coal (though this is less likely).

Pipelines: Energy delivered by pipelines can also be considered to transverse a kind "choke point." Many countries in Eastern Europe, for example, are linked almost exclusively by pipeline to Russia for their natural gas supplies, and some countries are almost entirely dependent on Russian gas, leaving them extremely vulnerable. Europe is looking to diversify its sources of natural gas, including by importing U.S. liquefied natural gas through new LNG terminals being built there.

It is not just geopolitical risks associated with pipelines, but also risks associated with aging or inadequate infrastructure. In the U.S., about half of the distribution pipes in the country are 50 years old or older, and increasingly subject to problems. In some regions of the country, like New England, shifts to natural gas for power generation have met with constraints on pipeline capacity. To prevent infrastructure limits could hold back America's energy production, we need to ensure that needed infrastructure is able to be built in a timely manner.

Rare Earth Minerals: New, advanced energy systems, especially renewable systems and batteries, require rare earth metals and materials. Electric vehicles, fluorescent lighting, photovoltaic cells, and wind turbines are all examples of technologies that use rare earths. Moreover, many U.S. defense and weapons systems are now totally dependent upon rare earth materials, almost all of which come from foreign sources.

The rapid growth in the commercial use of renewable technologies has increased demand for rare earth metals and compounds. While the United States has large reserves scattered across more than a dozen states, it is reliant largely on overseas providers, especially China, for supplies.

The term "rare earths" is misleading in the sense that they are not all that rare. They are not, however, as concentrated as other types of metal ores, which makes them more difficult and expensive to mine. Like many energy resources, mineable rare earth reserves are found in a few countries. China alone accounts for more than one-third of world reserves, and China, Brazil, Vietnam, and Russia account for nearly 90% of world reserves.

The dominance of China in production is starker still. In 2015, it produced an estimated four-fifths of the world's supply (the United States produced just about 5%). A major worry is that China has attempted to manipulate the markets for rare earths by withholding exports, which has highlighted the need for alternative sources of supplies.

Tapping domestic resources can be extremely time-consuming and involve meeting a variety of onerous regulations governing prospecting, exploration, process development, permitting, construction, and commissioning. Behre Dolbear found that permitting delays "are the most significant risk to mining projects in the United States," with waiting periods of seven to 10 years before mine development can begin. As a result, while the United States remains a good place for mining companies to invest in, it consistently ranks among worst countries for the time it takes to issue a mining permit. As a potentially large producer, this makes little sense either from an economic or from an energy security perspective to continue to rely on often-unreliable supplies of increasingly important rare earths.

U.S. policy must welcome the opportunity to produce more of these metals domestically and to come up with ways to recycle them to moderate demand.

These minerals have not always been as critical in our energy mix, and given technological change they may not be in the future. But they are critical now. The limited data for time series, as well as an ability to quantify the associated risks, make this a poor candidate for a metric in our Index, even though the risks associated with their production are very real.

Cyber Security: The world is much more interconnected today than ever before. This interconnectivity brings greater efficiency, reliability, and economic productivity, but it also brings new types of risk in the form of cyber incidents disrupting critical functions. Cyber threats pose new types of risks, and going forward, energy security and reliability must entail cyber-resilient energy delivery systems and infrastructure.

"WannaCry," "Petya," "Crash Override," and "Stuxnet" are examples of just a few of the emerging and significant cyber threats to America's energy security. While the energy sector has been able thus far to ward off attacks with significant impacts, the frequency of these attacks on the business operations and industrial control systems of America's energy providers is a daily occurrence. Neither legislation nor technological leaps will solve this issue, for it is unfortunately the new normal in an increasingly connected world.

With 90% of the nation's electricity grid operated by private entities, and countless pipelines and other forms of energy infrastructure owned by private entities, the nation's energy security is bifurcated between the public and private sectors. Federal agencies, such as the Department of Homeland Security, have the intelligence capabilities to identify potential threats, while the private-sector owners and operators of energy infrastructure stand as the last line of defense against a cyber intrusion.

Foreign nation-states are becoming the most prolific actors in this space, with an understanding that China, Russia, and the United States each have the capability to shut down another nation's power grid. Russia demonstrated this capability with two separate attacks on Ukraine in 2015 and 2016. While the impacts of these attacks were short-lived, and dated non-digital infrastructure enabled a quick recovery, a cyberattack that inflicts physical damage to electric grid hardware could cause long-term impacts that would harm the economy and public safety. While no successful cyberattacks have shut down power on U.S. soil, many experts view the future prospect for such an attack in terms of "when" rather than "if."

Fortunately, the U.S. power sector has taken great strides to raise its defenses to cyberattacks. Electric sector utilities are the only industry in America subject to mandatory, binding, and enforceable Critical Infrastructure Protection standards that aim to minimize the exposure of our power grid to cyberattack. Together with formalized information sharing mechanisms established between the intelligence community and the electric sector, via the Electricity Subsector Coordinating Council and the Electricity Information Sharing and Analysis Center, the electric power sector is engaged in a perpetual effort to adjust to and defend against an evolving cybersecurity threat landscape.

The gas and oil sector is also mobilizing to defend against the evolving cybersecurity threat, with the creation of its own information sharing and analysis center for the exchange of intelligence on cyber incidents, threats, and vulnerabilities, both among industry members and between the industry and the federal government. Together with their electric sector colleagues, this industry recognizes that as the electric sector becomes more dependent on natural gas as a feedstock, this dependency places a heightened responsibility on the oil and gas industry to guard its pipeline and pumping infrastructure against both physical and cyber intrusions.

A recent PricewaterhouseCoopers report identified a 140% jump in cyberattack incidents from nation-states over the past three years, along with increases of 83% and 24% associated with hacktivists and terrorists, respectively. These disturbing upward trends are unlikely to abate in the near future as nations increasingly look to strong cyber warfare capabilities as a complement to—or supplement for—traditional military might. This evolving threat environment requires constant vigilance on behalf of the owners and operators of our energy sectors, cooperation from federal agencies, and an understanding from state regulators that these activities merit appropriate compensation in rates. We have been lucky so far, but we cannot discount these risks to our critical energy infrastructure.

Regional Concentration of Energy Supplies: An old adage on risk reduction is to not put all of your eggs in one basket. This is reflected in several of the metrics for our Index, for example, those that measure international geographic diversity and the political risk attached to petroleum, natural gas, and coal production and reserves. We also measure electricity capacity margins at the national level, which could mask regional vulnerabilities.

While useful, these metrics leave out some regional details that reflect real-world risks. The recent experience with Harvey shows how the concentration a sizeable portion of U.S. oil and natural gas supply and infrastructure, including pipelines and refining capacity, in and along the Gulf of Mexico can be taken off-line by hurricanes. Preliminary reports as of this writing suggest Harvey resulted in the loss of about 20% of Gulf oil and natural gas production and greater than 2.4 million barrels per day of refining capacity. In addition, about 300,000 customers lost electric power in Texas and Louisiana, a number that could have been higher had it not been for investments made by energy companies in transmission infrastructure.

Our ability to compensate for supply disruptions has been helped by the shale revolution, which has increased domestic supplies of oil and natural gas in areas outside the Gulf Coast, and by strategic oil and gasoline reserves. Harvey does, however, highlight the need for more pipelines and other infrastructure to enhance resilience and move energy around to where it is needed in an emergency.

As the 2017 Edition of the Index documents, U.S. energy security continues to improve in dramatic fashion. But we cannot lose sight of these other types of risks that, while not amenable to measurement in our Index, nonetheless pose significant threats to our energy security. A strong U.S. energy sector, a strong U.S. economy, and a smart energy policy can go a long way to mitigating these risks and guaranteeing that the United States is a force for more open and secure global energy markets.

As our new name, the Global Energy Institute, implies, we are ready to help turn that vision into a reality.

Karen A. Harbert
President and CEO
Global Energy Institute
U.S. Chamber of Commerce

Introduction

The 2017 edition of the Global Energy Institute's (GEI) Index of U.S. Energy Security Risk (Index) employs the most recent historical and forecast data to measure U.S. energy security risks. The Index covers the period from 1970 to 2040, and it incorporates 37 different measures of energy security risk in nine categories: Global Fuels; Fuel Imports; Energy Expenditure; Price and Market Volatility; Energy Use Intensity; Electric Power Sector; Transportation Sector; Environmental; and Research & Development.[1]

These metrics are used to create four sub-indexes measuring geopolitical, economic, reliability, and environmental risks. Each of the 37 metrics is mapped to one or more of these four sub-indexes. These four sub-indexes are then combined into an overall Index, where the weighted average of the four sub-indexes constitutes the overall Index of U.S. Energy Security Risk.[2]

This year's edition reflects revisions to the historical data and the new forecast in the Energy Information Administration's (EIA) *Annual Energy Outlook (AEO) 2017*.

The Index is designed to convey the notion of risk, with a lower Index score indicating a lower risk and a higher score a higher risk. When evaluating the results, it is important to recognize that the Index necessarily moves along an open-ended scale. As a practical matter, however, the total Index general has moved between risk scores of 70 to 110. (The sub-indexes and individual metric indexes can and do move within larger, sometimes much larger, ranges.) To provide a relative sense of potential hazard, the Index score for 1980, a particularly bad year for U.S. (and global) energy security risks, was set at 100. Index scores approaching or surpassing 100, therefore, suggest a very high degree of risk.

Readers also should be aware that because revised historical data are used in each annual update—and these revisions can go back many years—the parts of the Index using historical data are not comparable across different editions. Each new edition supersedes previous edition. Forecasts of energy security risk, however, can be compared across different editions of the Index and can provide valuable insights into how our perceptions of these risks can change over time.

The average Index score for the 30-year period 1970 to 1999, a period that includes times with relatively very high (100 in 1980) and very low (74.8 in 1992) scores, is 83.7. When reviewing this year's results, the 1980 baseline score, the 30-year averages, and the historical high and low scores can be used as reference points against which to assess current and future risk scores. Unless noted otherwise, all dollar figures are in real 2015 dollars.

The Index discussed in this report is focused exclusively on the United States and how its energy security risks have moved over time and where they might be headed in the future. GEI also has developed an *International Index of Energy Security Risk* that puts the risks to the U.S. in an international context and provides comparisons with other large energy producing countries. Readers interested in how U.S. risks compare to those faced by other countries should consult the International Index, which is available on GEI's website.

1 Each of the 37 metrics is presented and discussed in Appendix 2.

2 Appendix 1 contains more information on the methods used to develop the Index.

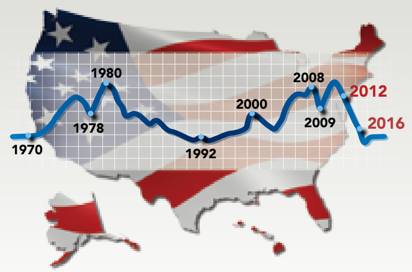
Highlights

The total U.S. energy security risk score in 2016 fell 1.2 points to 76.0. This is the fifth consecutive annual decline. The 2016 score is the fourth lowest since 1970, and U.S. energy security risks are now at their lowest level since 1995. Projections indicate that risks will rise slightly but stay below 80 through 2040, an extraordinarily low level compared to those of previous forecasts.

This 2017 edition of the Index of U.S. Energy Security Risk (U.S. Index) includes the most recent energy data available, including *AEO 2017* projections, to provide an up-to-date assessment of those energy supply and energy use metrics having the greatest impact on energy security over the past year. The U.S. Index is based on a combination of 37 different energy security metrics beginning in 1970 and ending in 2040.

Total energy security risk in 2016 fell for the fifth year in a row, dropping 1.2 points (about 1%) from 2015 to

76.0

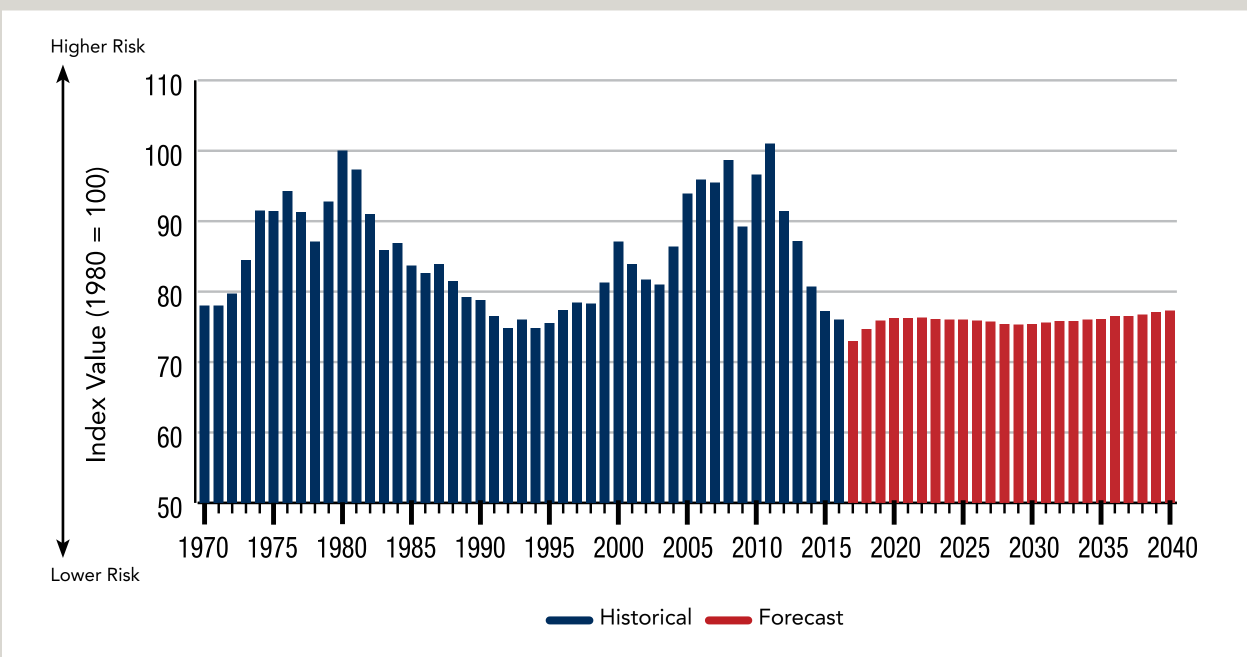


Overview

Total energy security risk in 2015 fell for the fifth year in a row, dropping 1.2 points (1.5%) from 2015 score to 76, its lowest level

Figure 1

U.S. Energy Security Risk Index, 1970-2040



since 1995 and the fourth lowest in the entire database. During these five years, the total risk fell a remarkable 25 points. Going back to 1970, there has been no five-year period during which the total U.S. risk score changed as rapidly, either up or down, not even during the oil crises of the 1970s.

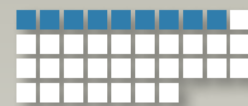
The 2016 score dipped 9.2% below the 30-year (1970-1999) average. Greater domestic unconventional oil and natural gas production from shale formations occurring against a backdrop of an increasingly efficient economy have been the biggest factors contributing to the improved U.S. energy security picture since 2011.

The decrease in risk was generally broad based. Of the 37 Index metrics, twice as many metrics showed a decrease in risk of 1% or more (18 versus 9), with 10 showing essentially no change in risk from 2015. Most of the 18 metrics showing improvement were in the Fuel Import, Energy Expenditure, Energy Use Intensity, and Environmental categories. The most significant metrics showing higher risk were in the Global Fuels grouping and those measuring price volatility.

Although decreasing risks were seen across about half of the energy security measures, most of the risk decrease in 2016 can be attributed to a half dozen oil and natural gas related measures that declined by very large amounts (±10% or more). Risk measures associated with imports of oil and natural gas and energy expenditures were the biggest drivers of the 1.2-point drop in overall energy security risks in 2016 (Table 2). No metric showed an increased risk exceeding 10%. The oil and natural

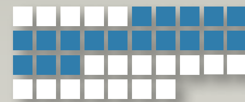
Of the 37 Index metrics,

9



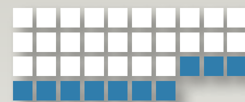
showed an increase in risk of 1% or more,

18



showed a decrease in risk of 1% or more, and

10



showed essentially no change in risk in 2014.

Table 1. U.S. Energy Security Risks from 1970 to 2016: Highest, Lowest and 30-Year (1970-1999) Average Index Scores

Indexes of U.S. Energy Security Risk	2016 Score	1980 Baseline Score	Highest Risk		Lowest Risk		30-Year Average (1970-1999)
			Year	Index Score	Year	Index Score	
Total Composite Index	76.0	100.0	2011	101.0	1992	74.8	83.7
Sub-Indexes:							
Geopolitical	74.9	100.0	2011	100.7	1970	71.9	82.5
Economic	65.5	100.0	2011	101.7	1998	61.0	73.2
Reliability	88.7	100.0	2011	114.7	1994	75.8	85.9
Environmental	80.8	100.0	1973	110.7	2016	80.8	99.2

gas metrics related to greater domestic production from shale resources, and their impacts on other metrics related to imports and expenditures, have been improving over the past several years and suggest a durable trend towards lower risk.

The sharp decline in the price of oil had an impact on domestic production of crude oil, but overall the volumes of crude oil and natural gas produced in 2016 were very high and have helped maintain record or near record low levels of risk for import-related metrics. Sharp downward price volatility, however, has raised questions about the ability of U.S. industry to maintain high levels of crude oil production. Because natural gas is produced in association with crude oil in many areas of the country, there is also the potential for lower natural gas production. The United States produces all the coal it needs, and in recent years has increased its export volumes, primarily to Asia but also to Europe and South America.

Although the risk score for the Security of U.S. Petroleum Imports metric increased by about 8% in 2016, its score is still the second best since 1970, and the scores for the three most recent years are all lower than at any time going back to 1970. The increase in import risk in 2016 is due a decline in domestic crude oil output that accompanied the large drop in the price of crude oil from more than $100 per barrel in 2014 to about $43 per barrel in 2016. After increasing steadily from 5.0 million barrels per day in 2008 to 9.4 million barrels per day in 2015, crude oil slipped 560,000 barrels per day in 2016 to a little less than 8.9 million barrels per day. As a result, the United States imported about 460,000 barrels per day more crude oil in 2016 than in 2015. The impact of this on the oil import risk score was muted somewhat by an increase of about 300,000 barrels per day of net refined product exports in 2016. Preliminary data for 2017 point to a recovery in domestic crude oil production in 2017, which if maintained could send future oil import risks lower still.

Because of domestic natural gas production that continues to roar ahead, risks associated with the Security of U.S. Natural Gas Imports continue to decline and will probably hit "0" by 2018. Since the risk score for this metric peaked at a record high of 181.9 in 2007, it decreased steadily and rapidly. Indeed, beginning in 2012, the risk score for this metric has set a new low score every consecutive year. Like for crude oil output, dry natural gas output—after climbing for 10 consecutive years—declined about 2% in 2016 to 26.5 trillion cubic feet. Because some natural gas is produced during the production of crude oil, and crude oil production declined in 2015, it is not surprising to see a corresponding dip in natural gas production. This decrease was not, however, sufficient to increase import risk In fact, net imports of natural gas continued to decline in 2016, buoyed not only by increasing pipeline

Table 2. Movers and Shakers: Energy Security Metrics Changing at Least ±10% in 2016

Declining Risk		Rising Risk	
Metric	% Change	Metric	% Change
Security of U.S. Natural Gas Imports	-26%	NA	
Crude Oil Prices	-18%		
Oil & Natural Gas Import Expenditures per GDP	-17%		
Oil & Natural Gas Import Expenditures	-16%		
Energy Expenditures per GDP	-12%		
Energy Expenditures per Household	-10%		
Energy-Related CO_2 Emissions	-11%		

shipments, but also by a large increase in liquefied natural gas shipments (from about 28.4 billion cubic feet of LNG in 2015 to 186.8 billion cubic feet in 2016).

Risks related to energy expenditures—including the metrics for Energy Expenditures, Energy Expenditures per GDP, Oil & Natural Gas Import Expenditures, and Oil & Natural Gas Import Expenditures per GDP—once again showed significant declines of between 10% and 20% in 2016 largely because of the continued, if more modest, decline in crude oil prices in 2016 after the very large drop in 2015.

- *Energy Expenditures:* Energy expenditures per household dropped nearly 10% in 2016, or almost $960. Energy expenditures as a share of GDP also fell 12% in 2016, and about 5.5% of GDP was spent on energy (which translates into about $55 for every $1,000 of GDP).
- *Oil and Gas Import Expenditures:* Expenditures on imports of petroleum and natural gas have dropped for five consecutive years. From $374 billion 2011, expenditures on imports of petroleum and natural gas fell to just $79 billion in 2016, a stunning decline of nearly 80% over the five-year period. These expenditures as a share of GDP, a gauge of the exposure of the United States to price shocks, also improved a similar amount (81%) over the same period. Preliminary data suggest the price for crude oil will increase somewhat in 2017, which may stop any further declines, at least temporarily.

At 87.1, the Retail Electricity Price risk metric in 2016 had the lowest score since 2005 thanks to lower costs for fuel used in the power sector, especially natural gas but also coal. There are broad variations in the retail price of electricity across the United States, and not all states experienced price declines in 2016. Twenty-seven states showed declines in their 2016 average retail electricity prices. Declines in perennial high-cost states such as California, New York, and many in New England occurred despite policies that put upward pressure on prices. Northeast states could further moderate their high prices if they expanded their currently limited natural gas pipeline infrastructure to take greater advantage of the natural gas being produced in Ohio and Pennsylvania. Another group of states that generally saw a decrease in rates were those that produce natural gas, such as Texas, Pennsylvania, and Oklahoma. In fact, eight of the top ten natural gas producing states saw a decline in their average electricity price. Even Hawaii, which produces a lot of its electricity using oil, saw its rates decline thanks to the lower price of crude oil.

On the flipside, 23 states witnessed an increase in electricity prices in 2016. Among these were many low-cost leaders, such as Iowa, Kentucky, Utah, Washington, West Virginia, and Wyoming. These specific states are traditionally reliant upon coal for a large share of their electricity mix, with the exception of Washington State which depends primarily upon hydroelectric resources. Despite the small 2016 increase, they continue to enjoy some of the lowest electricity prices in the nation thanks to the historically reliable and low-cost nature of the resources upon which they rely.

Energy efficiency, including in the transportation sector, continue to contribute to lower overall risk, with all metrics measuring energy use but one in 2016 realizing improvements compared to 2015. Declines in most of the energy use metrics—Energy Intensity, Petroleum Intensity, Commercial Energy Efficiency, Industrial Energy Efficiency, Motor Vehicle Average MPG, and Vehicles Miles Traveled (VMT) per GDP—are part of multi-decadal trends. The exception is Household Energy Efficiency, which from about 1980 to 2005 generally worsened, as people built bigger homes with more electronic gadgets and appliances. Still, since about 2005, Household Energy Efficiency has improved sporadically, and it is expected to continue to decline well into the future.

The only energy use or transportation metric that did not improve in 2016 was VMT intensity. In fact, this is the second consecutive year in which the risk scores for this metric have increased. Two years do not make a trend, but it is probably not a coincidence that the number of vehicle miles traveled per dollar of GDP rose during a period of rapidly declining fuel prices. Except for the odd year or two, however, the long-term improvement in VMT intensity is not likely to be reversed. Although lower energy costs can slow the pace of future improvements, the overall trends have a lot of inertia, and in many cases—such as vehicle efficiency standards—are supported by government policy. They will be difficult to reverse for any period of time beyond a few years.

Risks related to all metrics in the Environmental group declined in 2016, led by a 7% decline in associated with Energy-Related Carbon Dioxide Emissions. The decrease in risk for economy-wide emissions stemmed entirely from a reduction in power sector emissions related both to decarbonization and greater efficiency of electricity use. Decarbonization of the power supply accompanied the build-out of nuclear facilities in the 1980s and more recently has been the result of coal plant closures dues to a combination of regulation and competition from inexpensive shale gas and, to a lesser extent, greater generation from renewables.

The shift in the amount of electricity used to generate a dollar of GDP—electricity intensity—often has been overlooked but since 1970 has had as bigger impact lowering emissions. For decades after the Second World War, U.S. electricity intensity trended higher and did not start to decline until the mid- 1990s or so. As Figure 2 shows, when power sector emissions are broken down into their Kaya Identity[3] elements, the cumulative impacts of improvements in electricity intensity since 1970 have flipped from positive (adding to emissions) to negative. This is a huge switch and by 2020, cumulative emission declines from electricity intensity improvements since 1970 should exceed those from declining carbon intensity of generation.[4]

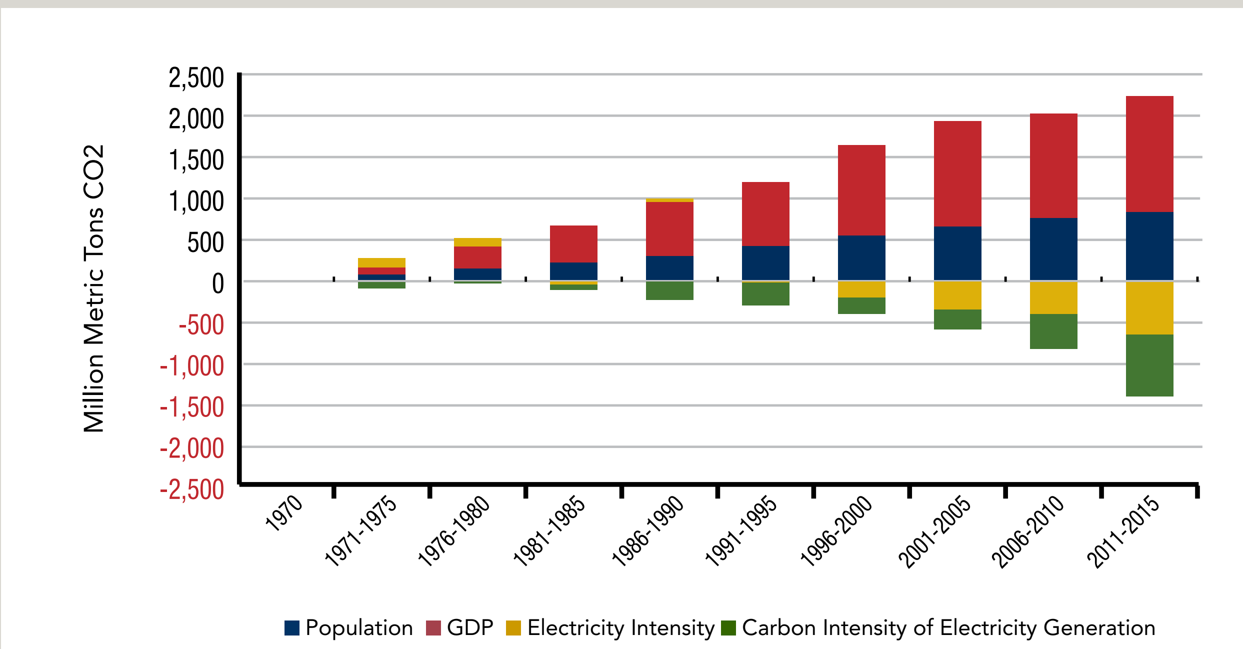
As expected, crude oil price volatility remained high in 2016, drifting up nearly nine points to 139.2. While the risk level is high, we saw a much smaller increase in this metric in 2016 compared to 2015. As a general rule, low prices are a good thing, but if achieved too rapidly can create increases in risk related to volatility, which is what we have seen over the past

3 The Kaya identity is a calculation whereby total emissions of energy-related carbon dioxide emissions can be expressed as the product of four factors: population, GDP per capita, the energy intensity of the economy, and the carbon intensity of the energy supply (emissions per unit of energy consumed).

4 An analysis such as this that uses cumulative changes is sensitive to the starting point. Because the Index begins in 1970, that was the year selected as the starting point to calculate cumulative emissions changes.

Figure 2

Cumulative Kaya Indenity Components of Power Sector CO2 Emissions: 1970-2015



two years. In 2015, volatility jumped 93 points (250%), an increase attributable to efforts by Saudi Arabia to capture greater market share by opening the spigots and increasing output and (it was hoped) drive some U.S. producers out of business. The Saudi move drove down the price of crude oil sharply, from more than $100 per barrel to less than $50 per barrel within a year. After falling further to the mid-$20 range in early 2016, prices for most of the year fluctuated between $40 to $55 per barrel and averaged $43 per barrel over the entire year. Even though prices stabilized somewhat in 2016 compared to 2015, our volatility metric is based on a three-year running average of annual differences in average prices. Therefore, we can expect high volatility risk for at least one more year and perhaps more if prices do not stabilize within a narrow range. If crude oil prices do settle at a price such that low volatility is paired with high domestic output, it is possible that we could see a record low U.S. risk in the near future.

Electricity capacity margin risk rose in 2016 for the second year in a row. This metric measures the average amount of unused available capability of the U.S. electric power system at peak load as a percentage of total capability. Preliminary data suggest a 7% increase in risk in 2016 coming on the heels of a similar increase in 2015. Since 2014, peak load—which can vary from year-to-year depending on many different factors—has outpaced capacity growth, shrinking size of the margin, causing the rise in risk. A special section devoted to this metric is included later in the report.

Of the 37 metrics, 15 have had their lowest risk scores in the past five years (2012 to 2016) while only one has had its lowest score during this period (Table 3). It is not surprising to find that most of those metrics with the lowest scores are in the Energy Use, Transportation, and Environmental groupings, as these metrics demonstrate long-term trends of consistently declining risks. (Indeed, of these 15 metrics, 10 register their *highest* scores in the first five years of the Index (1970 to 1974).) Growing domestic oil and natural gas production also has pushed down the risk score for the import metrics of these two fuels to record lows in 2015 and 2016 respectively.

Outlook to 2040

The historical data in the Index provides a look at where America's energy security risks are and where they have been. The forecast piece of the Index provides a look at where country's energy security risks might be headed. By comparing our current expectations to those in previous years, it is possible to see how our thinking about the future has changed over time.

Data from EIA's *AEO2017* was used to project Index risk scores out to 2040.[5] For 2017, EIA ran one Reference case with Clean Power Plan (CPP) implementation and one without it. When EIA runs the National Energy Modeling System each year, it updates the model by including, among other things, new regulations that have been finalized. Even though CPP implementation has been stayed by the Supreme Court, it is still on the books, and EIA's Reference case includes it. The Environmental Protection Agency, however, is planning to withdraw the rule (which could be replaced by another rule that does not have the legal vulnerabilities of the existing rule). Given these political dynamics, it makes more sense to use the Reference case that does not include CPP compliance in our base case Index forecast. At the end of this section, we take a look how the Reference case with CPP and other EIA side cases impact the risk scores.

Based on EIA's latest *AEO 2017*, the U.S. Index is projected to average 75.9 points from 2017 to 2040, a 2.3 point improvement over last year's Index projection based on the *AEO 2016 Reference* forecast (which included CPP). Risks are expected to stay below 78 points through 2040. These are remarkably low levels of risk and if maintained over the forecast period would be near the lowest Index risk scores (from the mid-1990s) going back to 1970. Indeed, preliminary numbers suggest that next year, 2017, will set a record for the lowest risk score in our record. From then, risks rise very slowly out to 2040. This would represent an unprecedented period—nearly 25 years—of energy security risk scores below 80.

Most metrics are expected to improve from 2016 to 2040. Of the 25 metrics for which forecast data are

5 EIA's model runs out to 2050, but only data through 2040 were used in this analysis.

Table 3. Highest and Lowest Energy Security Risks by Metric: 1970-2016				
Metric	Highest Risk		Lowest Risk	
	Year	Index Score	Year	Index Score
Global Fuels Metrics				
Security of World Oil Reserves	1993	133.6	2007	86.3
Security of World Oil Production	1976	114.7	2002	65.7
Security of World Natural Gas Reserves	1984	141.8	1970	57.5
Security of World Natural Gas Production	1986	155.8	1997	61.1
Security of World Coal Reserves	1976	108.6	1998	49.8
Security of World Coal Production	2013	161.4	1998	70.8
Fuel Import Metrics				
Security of U.S. Petroleum Imports	1977	132.7	2015	48.9
Security of U.S. Natural Gas Imports	2007	181.9	2016	30.2
Oil & Natural Gas Import Expenditures	2008	218.7	1970	7.4
Oil & Natural Gas Import Expenditures per GDP	1980	100.0	1970	10.1
Energy Expenditure Metrics				
Energy Expenditures per GDP	1981	101.9	2016	41.9
Energy Expenditures per Household	2008	120.3	1970	54.0
Retail Electricity Prices	1982	111.8	1970	70.4
Crude Oil Price	2011	131.4	1972	14.4
Price & Market Volatility Metrics				
Crude Oil Price Volatility	2011	182.5	1972	1.2
Energy Expenditure Volatility per GDP	2010	128.8	1995	2.8
World Oil Refinery Utilization	1970	159.9	1982	90.5
Petroleum Stock Levels	1973	140.1	2016	78.8
Energy Use Intensity Metrics				
Energy Consumption per Capita	1979	104.6	2012	87.5
Energy Intensity	1970	118.7	2016	48.3
Petroleum Intensity	1973	121.1	2016	40.7
Household Energy Efficiency	1972	112.2	2016	87.2
Commercial Energy Efficiency	1972	113.1	2016	66.9
Industrial Energy Efficiency	1970	124.1	2016	48.3
Electric Power Sector Metrics				
Electricity Capacity Diversity	1971	110.2	2000	77.0
Electricity Capacity Margins	1999	266.4	1982	81.1
Electricity Transmission Line Mileage	2006	134.3	1982	90.8
Transportation Sector Metrics				
Motor Vehicle Average MPG	1973	111.8	2016	72.2
Transportation VMT per $ GDP	1977	104.4	2014	79.9
Transportation Non-Petroleum Fuels	1978	101.4	2013	90.5
Environmental Metrics				
Energy-Related CO2 Emissions	2007	259.3	1970	33.8
Energy-Related CO2 Emissions per Capita	1973	113.2	2016	58.1
Energy-Related CO2 Emissions Intensity	1970	122.0	2016	42.0
Electricity Non-CO2 Generation Share	1970	131.3	2016	66.5
Research and Development Metrics				
Industrial Energy R&D Expenditures	1999	323.3	1980	100.0
Federal Energy & Science R&D Expenditures	2000	290.9	1978	95.2
Science & Engineering Degrees	2000	144.0	1971	79.0

available, 18 are expected to improve and seven are expected to worsen. Not surprisingly, Fuel Imports metrics show the biggest improvements, both because of greater domestic production of oil and natural gas on the supply side and greater efficiency on the demand side. Metrics in the, Energy Use, Transportation, and Environmental categories show, with one exception (Carbon Dioxide Emissions), much lower risk in 2040 compared to 2026. The Energy Expenditure metrics show the largest increases.

As a group, the combined Energy Use metrics (weighted) are expected to decline 23% from 2016 to 2040. As they have in the past, energy efficiency improvements expected across all sectors of the economy will continue to moderate future risks by decreasing upward pressure on demand, and therefore prices and imports. Metrics measuring energy and petroleum intensity (consumption per unit of dollar of economic output) and sector-specific energy efficiency, led by the industrial sector, all show considerable improvement. Both the economy-wide energy intensity and petroleum intensity are both expected to improve between 35% and 40% from 2016 to 2040. Over the same period, energy efficiency is expected to improve between 15% and 21% in the residential, commercial, and industrial sectors.

As a group, the combined Transportation metrics (weighted) are expected to decline 23% from 2016 to 2040. Much greater efficiency in the transportation sector combined with fewer vehicle miles being traveled are the main factors contributing to lower petroleum demand. By 2040, the Motor Vehicle Average MPG metric is anticipated to improve 32%, with average fuel economy of the U.S. automobile fleet moving from about 18 miles per gallon to a little more than 27 miles per gallon. While Vehicle Miles Traveled are expected to climb from 3.1 trillion miles in 2016 to almost 3.9 trillion miles in 2040—a 20% increase—this represents a much slower expected rate of growth than for the economy—68%—over the same period. This continues a long-term trend begun in the mid-1990s, when GDP growth and Vehicle Miles Traveled began to decouple. As a result, liquid fuel demand in the transportation sector, which peaked in 2007, is expected to decline nearly 10% by 2040, led by a projected 18% drop in gasoline demand. Demand for jet fuel, however, bucks the declining trend. It is expected to jump 45% by 2040. Together with greater domestic crude oil production, these trends should continue to dampen net U.S. demand for foreign crude oil.

As a group, the combined Environmental metrics (weighted) are expected to decline almost 5% from 2016 to 2040. The risk scores for all metrics in this group decline except for total Carbon Dioxide Emissions from Energy, which increase a very modest 2% between 2016 and 2040. Trends in emissions are discussed in greater detail in the section on the Environmental Sub-Index.

The primary source of upward pressure on future energy security risk came from the price of crude oil. As a group, the combined Energy Expenditure metrics (weighted) are expected to rise 65% from 2016 to 2040. The rising risk trend late in the forecast period is being driven primarily by a projected increase in the price of crude oil from $43 per barrel in 2016 to $108 per barrel in 2040, a jump of 150%. It is important to recognize that although crude oil prices are anticipated to increase, the size of that anticipated increase has gotten smaller over the past several years. There are many factors that come into play in the price of crude oil, but the higher level of production as a result of the shale revolution in the United States should make any increases in crude oil process much lower than they would have been otherwise. Flattening oil demand, especially in the transportation sector, also should help moderate the impact of higher prices on energy expenditures.

Energy Security Risks Under Alternate Future Scenarios

In addition its Reference case, EIA modelers ran a number of alternative cases using very different assumptions and policies, providing very different looks at what the future might hold. For 2017, EIA ran two references cases, one with CPP and one without CPP. The scenario we used as the base case for the Index was the EIA's Reference case without CPP, which remains stayed by the Supreme Court and is being withdrawn by the Environmental Protection Agency (EPA) (which may eventually replace it with an "inside the fence" alternative). EIA also ran an additional eight scenarios, six of which are pertinent to a discussion of energy security. (The high and low economic growth cases say very little about energy policy and do not impact energy security greatly at any event.) All of these side cases except one include CPP.

These alternate scenarios were plugged into the U.S. Index model to see their impact on future energy security risk as compared to the *AEO 2017* Reference case without CPP. The cases are ranked in Table 3 and described Table 4. In addition, the table contains the cumulative difference in GDP from 2018 to 2025 and from 2018 to 2040 for each case as a way to gauge the cost of the change in risk. (A negative change in the risk score indicates a decrease in risk compared to the base case while a negative change in GDP number indicates slower economic growth over the base case.)

The largest decreases in future risk are associated with those scenarios reflecting higher oil and gas resources and low oil and gas costs. These high-resource scenarios also yield large increases in GDP compared to the Reference case without CPP, the only scenarios examined here that result in greater economic growth.

Given this, it is not surprising that low resource and high price cases result in both higher energy security risks and lower levels of GDP growth compared to our base case.

Sub-Indexes of U.S. Energy Security Risk

The Sub-Indexes of Energy Security Risk provide different lenses through which to view energy security: geopolitical, economic, reliability, and environmental. There are no "bright lines" delineating these categories. In fact, many of the 37 individual metrics can affect more than one sub-Index. For example, the amount of oil we import is in part a measure of geopolitical risk, but also impacts reliability. The cost of our oil use has economic implications, and its consumption poses environmental risks. As another example, underinvestment in electricity transmission facilities can impose an economic cost when low-cost resources cannot reach their markets, and also reduce reliability of the grid.

In some instances, changes in a measure will be positive for some categories of risk, but negative for others. For instance, oil can be imported at a lower cost than domestic production, even while those imports affect geopolitical risks. Inexpensive energy also impacts economic and environmental risks in different ways. The methodology of having several metrics connected to the four categories of energy security risks allows us to see the impacts of this tension among some metrics.

Table 4. Energy Security Risk Measures: EIA AEO 2017 Side Cases vs. Reference Case without Clean Power Plan

EIA *AEO 2017* Side Case	Change in:			
	2025 Energy Risk Index Score	Cumulative GDP: 2018-2025 (Billion 2015$)	2040 Energy Risk Index Score	Cumulative GDP: 2018-2040 (Billion 2015$)
Reference Case with CPP	-1	-262	-2	-1,059
High Oil Price (with CPP)	13	-1,331	14	-3,059
Low Oil Price (with CPP)	-7	578	-7	-635
High Oil & Gas Resource & Technology (with CPP)	-4	304	-7	3,395
Low Oil & Gas Resource & Technology (with CPP)	2	-865	5	-4,788
High Resource (without CPP)	-3	518	-7	4,144

Table 5. Summary of Side Cases

EIA *AEO 2017* Case	Description
Reference without Clean Power Plan	Baseline assumptions for economic growth, oil prices, technology, and demographic trends. Brent spot prices rise to about $109 per barrel (2016 dollars) in 2040. Assumes the Clean Power Plan is not implemented.
Reference Case with Clean Power Plan	Baseline assumptions for economic growth (2.2% from 2016 to 2040), oil prices, technology, and demographic trends. Brent spot price rises to about $109 per barrel (2016 dollars) in 2040. Assumes compliance with the Clean Power Plan through mass-based standards modeled with cooperation across states at the regional level, with all allowance revenues rebated to taxpayers.
High Oil Price	Low oil prices result from a lack of global investment in the oil sector, eventually inducing higher production from non-OPEC producers. Higher economic growth relative to the Reference Case leads to increased demand, particularly in non-OECD nations. Brent spot price rises to $226 per barrel (2016$) in 2040. Assumes compliance with the Clean Power Plan.
Low Oil Price	Low oil prices result from a combination of lower demand for petroleum and other liquids in non-OECD nations and higher global supply. Producers face lower costs of production for both crude oil and other liquids technologies. OPEC increases its market share to 53% in 2040, and the costs of other liquids production technologies are lower than in the Reference case. Brent spot price falls $25 per barrel (2016$) in 2017, remains below $30/bbl through 2023, below $40/bbl through 2033, and below $50/bbl through 2040. Assumes compliance with the Clean Power Plan.
High Oil & Gas Resource & Technology	Estimated ultimate recovery per shale gas, tight gas, and tight oil in the United States, and undiscovered resources in Alaska and the offshore lower 48 states, are 50% higher than in the Reference case. Rates of technological improvement that reduce costs and increase productivity in the United States are also 50% higher than in the Reference case. In addition, tight oil and shale gas resource are added to reflect new plays or the expansion of known plays. Assumes compliance with the Clean Power Plan.
Low Oil & Gas Resource & Technology	Estimated ultimate recovery per shale gas, tight gas, and tight oil in the United States, and undiscovered resources in Alaska and the offshore lower 48 states, are 50% lower than in the Reference case. Rates of technological improvement that reduce costs and increase productivity in the United States are also 50% lower than in the Reference case. Assumes compliance with the Clean Power Plan.
High Resource without Clean Power Plan	Estimated ultimate recovery per shale gas, tight gas, and tight oil in the United States, and undiscovered resources in Alaska and the offshore lower 48 states, are 50% higher than in the Reference case. Rates of technological improvement that reduce costs and increase productivity in the United States are also 50% higher than in the Reference case. In addition, tight oil and shale gas resource are added to reflect new plays or the expansion of known plays. Assumes the Clean Power Plan is not implemented.

Sub-Index of U.S. Geopolitical Energy Security Risk

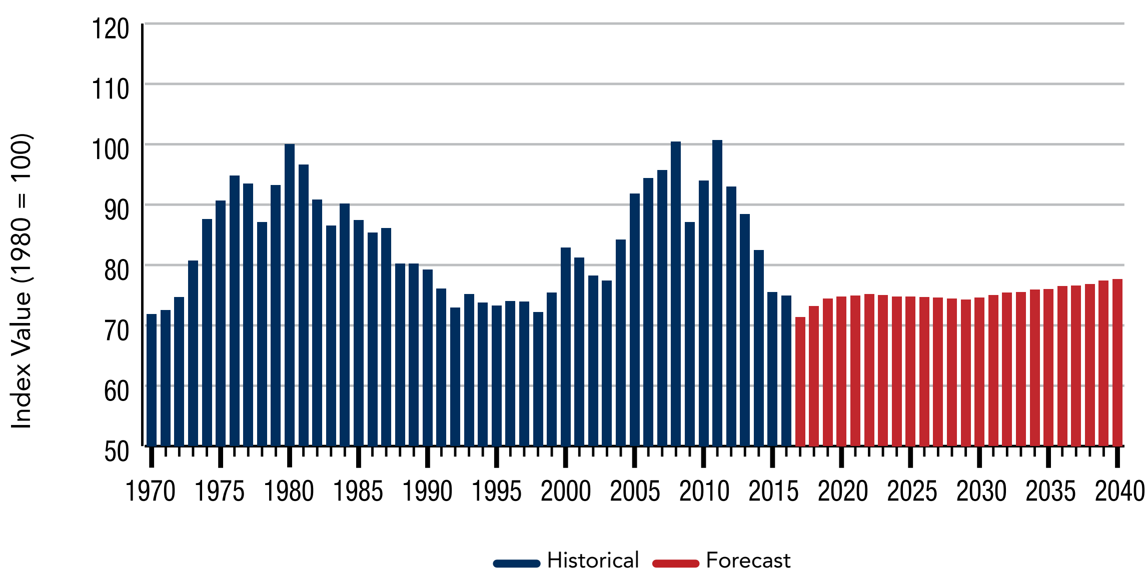
The Geopolitical Sub-Index measures the security of global oil, natural gas, and coal supplies and other factors that affect the ability of the U.S. economy to withstand supply disruptions from whatever causes.

Geopolitical energy security risks declined for the fifth consecutive year, dipping to 74.9 in 2016. This is the lowest risk score recorded for this sub-Index since 1998 (Figure 3), and well below the 30-year average of 82.5. Lower risks related to crude oil and natural gas imports and import expenditure were the main factors contributing to lower geopolitical risks in 2016. The only increases in risk of any note were from still-high crude oil price volatility (discussed earlier) and increases in global supply risks for crude oil and natural gas resulting from a higher share of global production of crude oil and, to a lesser extent, natural gas coming from higher-risk sources (e.g., Iran, Iraq, Saudi Arabia, and Russia). This underscores the importance of U.S. crude oil and natural gas production in lowering global supply risks.

EIA's 2016 forecast suggests that geopolitical risks will rise between 2016 and 2040 from 74.9 points to 77.7 points. This 2040 risk score is smaller than the comparable 2040 score forecast last year. Based on last year's *AEO2016*, we calculated a Geopolitical Index score of 81.1 in 2040. Using the AEO2017, that 2040 score is 77.7 points—still an increase (of about three points) compared to 2016 but lower than last year's projection. Increasing crude oil prices, propelled in part by growing demand in the large emerging economies like China, India, Brazil, and others, and potential price volatility may pull risks higher. Moreover, political turmoil like that being experienced in the Middle East today may lead to market instability and price volatility. It is also expected, however, that continued strong U.S. production of crude oil and natural gas will put the brakes on the some of these risks, making them less severe than they would be otherwise.

Figure 3

U.S. Energy Security Risk: Geopolitical Sub-Index, 1970-2040



Sub-Index of U.S. Economic Energy Security Risk

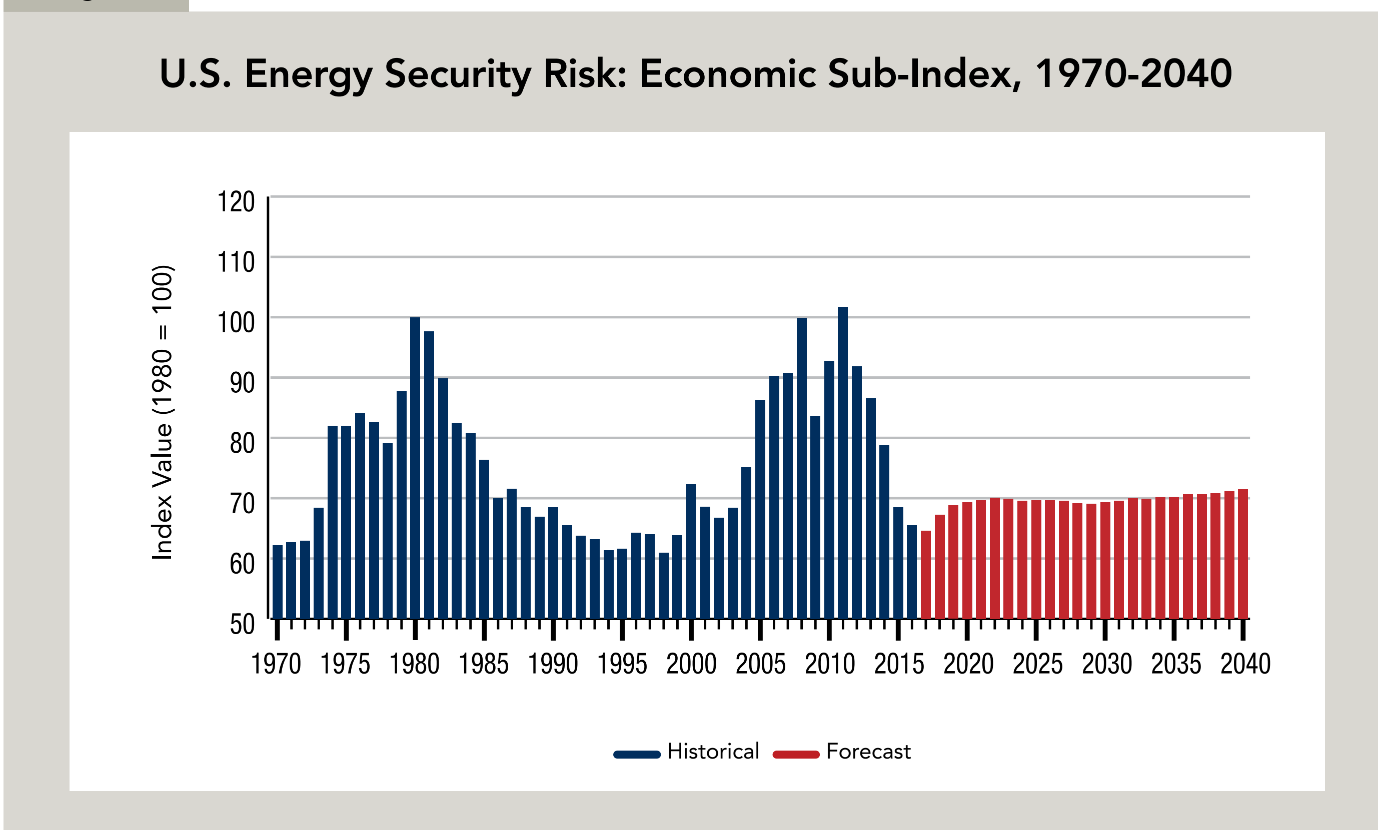
Energy costs are a significant portion of our overall economy. In 2016, roughly $1.0 trillion was spent for end-use energy in the residential, commercial, industrial, and transportation sectors, amounting to roughly 5.5% of GDP, the lowest level since the early 1970s. The Economic Sub-Index includes metrics measuring trends in the costs associated with energy, the intensity and efficiency of energy use, and international supply risks. Energy price volatility and high energy prices can have large impacts on the economy, the competitiveness of U.S. industries, and U.S. balance of trade.

Economic energy security risk fell 3 points in 2016 to 65.5, the lowest level since 1999 and lower than the 30-year average of 73.2 (Figure 4). Risks for this Sub-Index are approaching the lows seen in the mid-1990s. The biggest improvements were noted in the metrics covering energy expenditure and oil and gas import expenditures, which fell between 10% and 20% each.

Greater expenditures on imported fuels represent lost economic investment opportunities closer to home. Import expenditures both in total and as a share of GDP improved again in 2016, and both are well below their respective 30-year averages. These reductions in risk were offset somewhat by an increase, noted earlier, in crude oil price volatility. The increase in volatility risk in 2016, however, was much lower than in 2015. This is important because a large part of our energy supply still consists of fuel imports and market volatility can lead to sudden, and often unfavorable, shifts in international trade.

Economic risks are expected to rise six points to 71.5 by 2040, considerably lower than the comparable to Sub-Index score for 2040 based on last year's forecast (77.8 points). Most of that increase comes over the next few years and is related to expected increases in the price of crude oil and how that could affect energy expenditures and import costs. Still, future economic risks of around 70 points give or take a point of two is quite good by historical standards.

Figure 4



Sub-Index of U.S. Reliability Energy Security Risk

The metrics that make up the Reliability Sub-Index measure such things as global oil, natural gas, and coal production and imports, crude oil price and volatility, oil refining and stock levels, the power sector, and energy research and development.

After a very large 93-point jump in crude oil price volatility led to a 10.9 point rise in the Reliability Sub-Index in 2015, a much more modest increase in volatility risk in 2016 meant that risks for this Sub-Index rose just 1.1 points in 2016 to 88.7 (Figure 5). This is a little less than three points above the historical (1970-1999) baseline average score of 85.9—the only one of the four Sub-Indexes with a 2016 score above the 30-year average. In addition to the volatility-related risks, somewhat higher risks related to crude oil import, electricity capacity margins, and transmission also contributed to the rise in risk observed in 2016. The impact of these was offset largely by lower risks related to natural gas imports and crude oil prices.

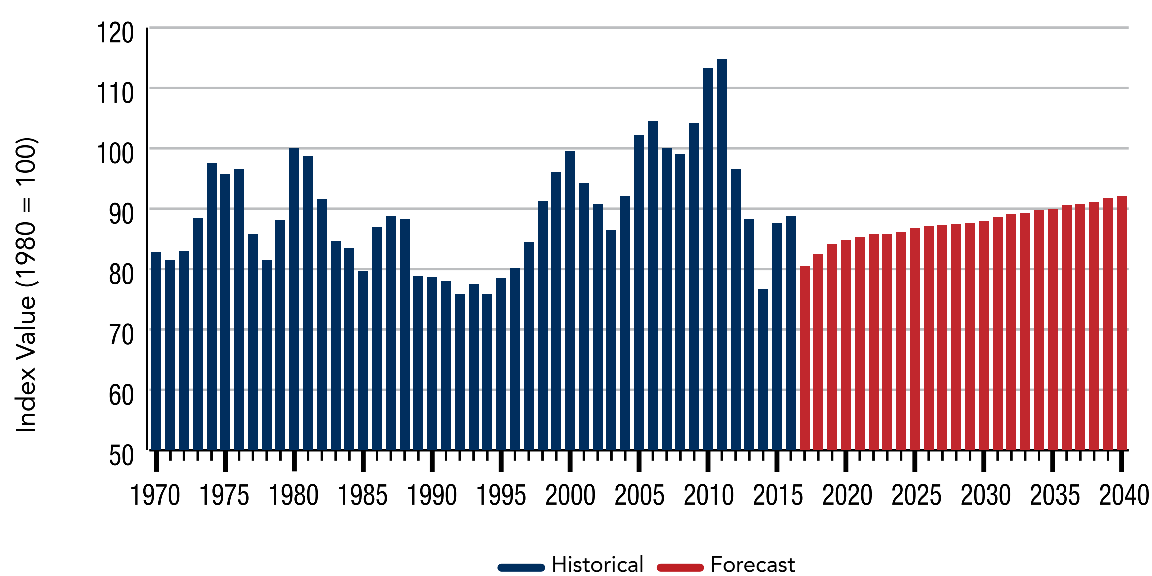
Forecast scores based on the *AEO2017* suggest that after falling sharply in 2017, the risk score for this sub-index will steadily rise out to 2040, reaching 92.0, five points below the comparable 2040 figure last based on the *AEO2016* (Figure 5). The increase in the price of crude oil is expected to be a significant factor going forward. (A slower trajectory in the crude oil price increase explains much of the difference between the 2040 Sub-Index scores based on the *AEO2016* and *AEO2017*.) There is also the potential for rising risks associated with capacity margins and transmission unless current trends change.

Sub-Index of U.S. Environmental Energy Security Risk

The Environmental Sub-Index includes metrics of energy intensity and efficiency, transportation, power, carbon dioxide emissions, and research and development.

Figure 5

U.S. Energy Security Risk: Reliability Sub-Index, 1970-2040

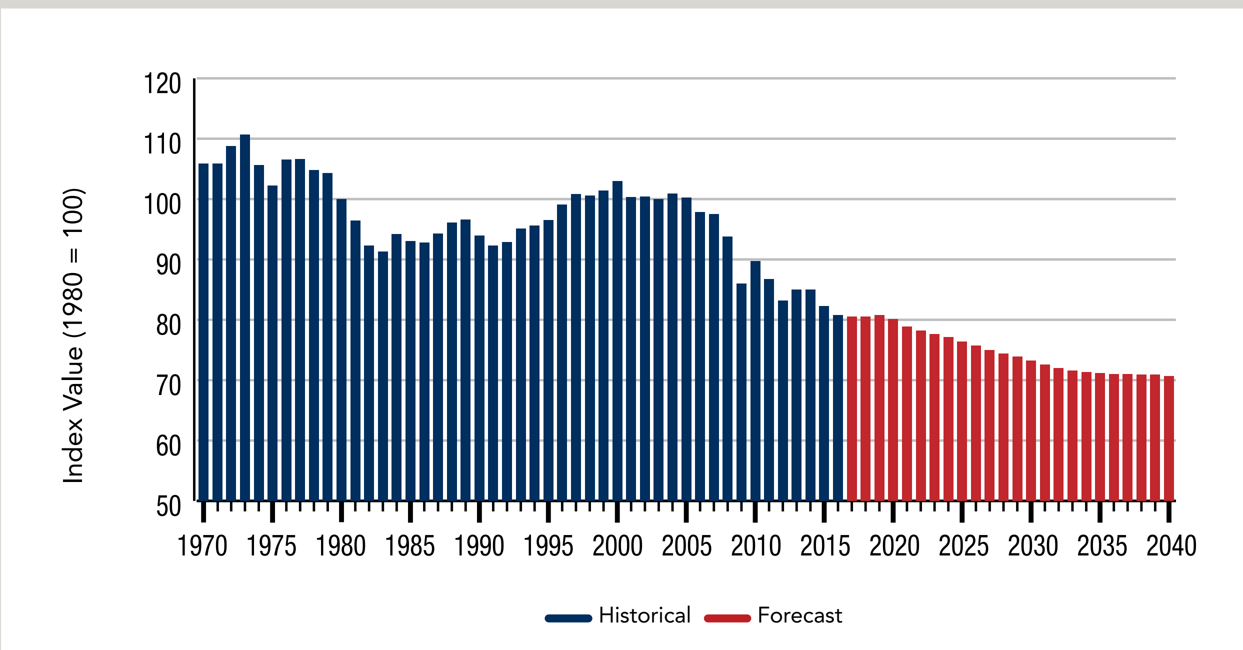


With a score of 80.8, total environmental energy security risks in 2016 declined to their lowest level since 1970 (Figure 6). This is nearly 20 points below the 30-year baseline average of 99.2. As Table 3 shows, with but a few exceptions the environmental metrics measuring energy use and carbon dioxide emissions had their record low scores in 2016 or within the last few years (the exception is Carbon Dioxide Emissions from Energy, which had its low score in 1970, the first year of the database).

Of the four sub-indexes, the Environmental Sub-Index is the only one showing steadily declining risk out to 2040, where it is forecast to hit 70.7. Both lower emission levels and improving efficiency contribute to lower future risks. By 2040, total carbon dioxide emissions are expected to be about 2.4% lower than in 2016. A Kaya Identity analysis shows that improvements in energy intensity are the main drivers of lower emissions, with fuel switching being a significant additional factor. Risk scores for emissions per capita emissions intensity are expected to decline 24% and 39%, respectively. Large improvements in the metrics measuring energy intensity (36%) and petroleum intensity (40%), and energy efficiency in all sectors—residential (-15%), commercial (-17%), industrial (-20%), and transportation (-32%)—all contribute.

Figure 6

U.S. Energy Security Risk: Environmental Sub-Index, 1970-2040



In Focus: Electricity Capacity Margins

Electricity Capacity Margins is one of four metrics used in the U.S. Index dealing directly with the power sector.[6]

Modern society has come to depend on reliable electricity as an essential resource for national security, health and welfare, communications, finance, transportation, food and water supply, heating and cooling, lighting, computers and electronics, commercial enterprise, and entertainment and leisure. Our society is becoming increasingly electrified, and the energy consumed for making electric power is becoming a larger portion of our total energy consumption. Net electricity generation as a share of total primary energy consumption (less the energy consumed in the power sector) grew from 10% in 1970 to 23% in 2016.[7]

In the electric power sector, system operators build in a margin of safety so that when generating units go offline—either due to an unexpected disruption or scheduled downtime for maintenance—there are enough other units available to pick up the slack and keep the juice flowing. Customers have grown to expect that electricity will almost always be available when needed at the flick of a switch. And while most users have experienced and do not find unexpected local outages related to bad storms, the occurrence of a massive outage on days when the weather is calm remains unexpected. Widespread electrical outages are rare, but they can happen if multiple reliability safeguards break down as we saw in the 2003 blackout affecting parts of the United States and Canada.[8]

Electricity is different from other energy resources in that it cannot readily be stored. For oil, gas, and coal, physical storage and stockpiles allow variations in both supply and demand to be managed, providing some cushion in the event of supply interruptions, demand surges, seasonal fluctuations, and other variances. However, the generation, distribution, and consumption of electricity occur together in real time. Ensuring a secure and reliable flow of power entails a host of activities along every step of the supply chain and over the short, intermediate, and long term.

Providing reliable electricity is an enormously complex technical challenge, even on the most routine of days. It involves real-time assessment, control, and coordination of electricity production across thousands of generators, moving electricity across an interconnected network of transmission lines, and ultimately delivering the electricity to millions of customers by means of a distribution network.

One of the key measures of electricity reliability is the electricity capacity margin, defined as the amount of unused operational capability of an electric power system (at peak summer load) as a percentage of total capability.[9] This metric provides an indication of the ability of the power sector to respond to the disruption or temporary loss of some production capacity without an uneconomic overhang of excess capacity. So while some excess capacity helps reduce risk, beyond a certain point it can be costly for relatively little additional benefit.

In practice, each electricity region or subregion may have its own specific minimum margin level—the Target Capacity Margin—based on load, generation, and transmission characteristics as well as regulatory requirements. When actual margins shrink and approach the Target Capacity Margin, the safety "cushion" is lost and reliability risks rise rapidly. In its reliability assessments, the North American Electric

6 The others are: Electricity Capacity Diversity; Electric Power Transmission Line Mileage; and Electricity Non-CO_2 Generating Share.

7 Overall, the amount of primary energy used to produce electricity rose from 24% in 1970 to 39% in 2016. This 2016 figure is off its peak of nearly 41% a few years ago. The declining share is due largely to the growth in renewable generation (which does not consume primary energy).

8 U.S.—Canada Power System Outage Task Force, Final Report on the August 14, 2003 Blackout in the United States and Canada: Causes and Recommendations, p. 5, April 2004. Available at: https://reports.energy.gov/BlackoutFinal-Web.pdf.

9 A related measure is "capacity reserve margin." Whereas capacity margin is defined as the net of capacity minus demand as a percentage of total generating capacity, reserve margin measures this net as a percentage of total electricity demand. These two measure track pretty well, but as intermittent generating capacity (e.g., from wind and solar plants) grows over time, it is likely that these two trends will begin to diverge.

Reliability Corporation (NERC) uses a default Target Capacity Margin of 13% for predominately thermal systems, unless otherwise specified in the regions' data submittals.

Developing this time series required many sources and assumptions because of data shortcomings. With many risks being local or regional rather than national, and with much of the desired data being incomplete over the decades of interest here, we needed to develop a metric that was both conceptually valid and capable of being implemented with actual data. Our approach has been never to let the perfect be the enemy of the good.

From 1990 to the present, capacity margin data reported by the Energy Information Administration (EIA) in its *Annual Energy Review (AER)* was used.[10] For data going back to 1970, we used older EIA data on nameplate capacity and total generation, detailed in *The Changing Structure of the Electric Power Industry, 1970-1991*, to develop a comparable proxy measure.[11]

Data on nameplate capacity and annual generation were compiled for the electric utility and non-utility sectors. Because non-utility data were not available for 1980-1985, they were estimated using linear interpolation. The average system capacity factor, which included both utility and non-utility data, was calculated for each year.

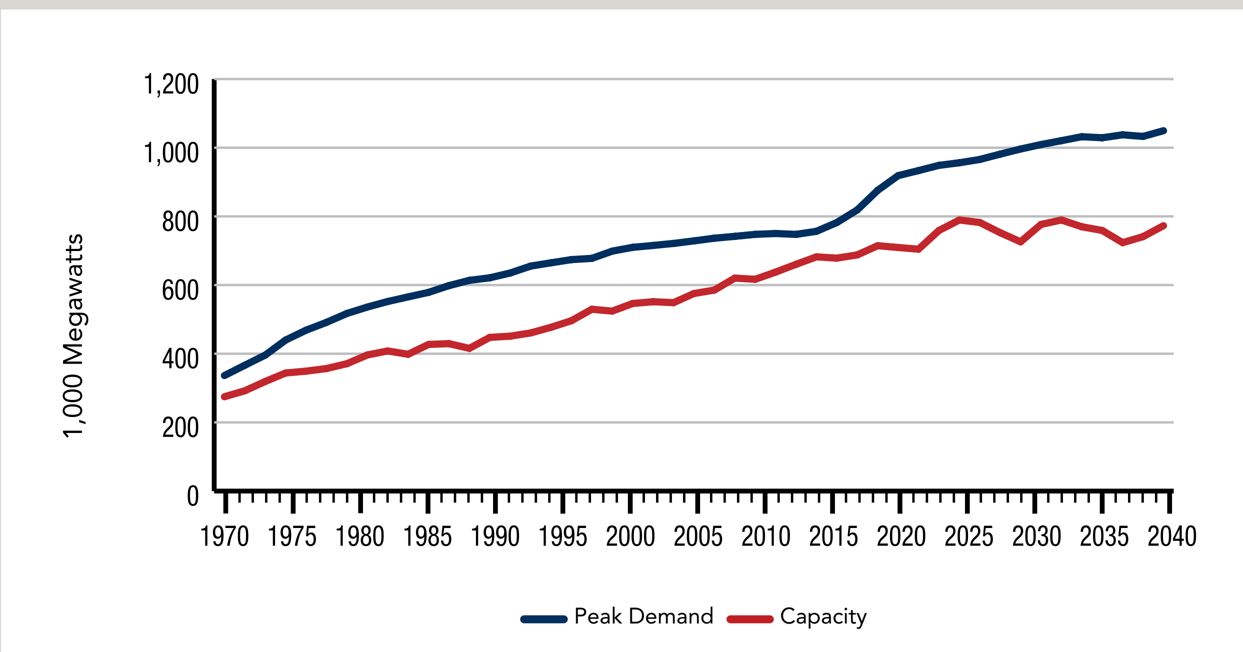
The estimated value for 1990 arrived at using this method of calculation was then pegged to the capacity margin value for 1990 as reported in EIA's *AER*. Estimates for all prior years were then adjusted to preserve each year's relative position, either higher or lower, to the 1990 value.

10 Available at: https://www.eia.gov/totalenergy/data/annual/index.php. Note that net internal demand does not include estimated demand for direct control load management and customers with interruptible service agreements. And that data are for the 48 contiguous States only.

11 See Tables C.6 and C.7. Available at: http://webapp1.dlib.indiana.edu/virtual_disk_library/index.cgi/4265704/FID3754/pdf/electric/0562.pdf.

Figure 7

Figure 7. Peak Summer Demand and Capacity: 1970-2016



EIA's *Coordinated Bulk Power Supply Program Report,* which collects information from the nation's power system planners about future electricity capacity and energy needs to meet expected growth, is used to project capacity margins five years into the future.[12] Although the full data extend for 10 years into the future, the capacity data show a steep drop-off in additions beyond about five years. We see this more as a reflection of limited planning horizons and less as a sign of impending shortages. Accordingly, capacity margin data derived from this source are used only for the first five-year period. Margin values beyond this are held at the last (the fifth) forecast value.

The following figures show the individual trends in capacity and peak summer demand (Figure 7) and the capacity margin as a percent (Figure 8).

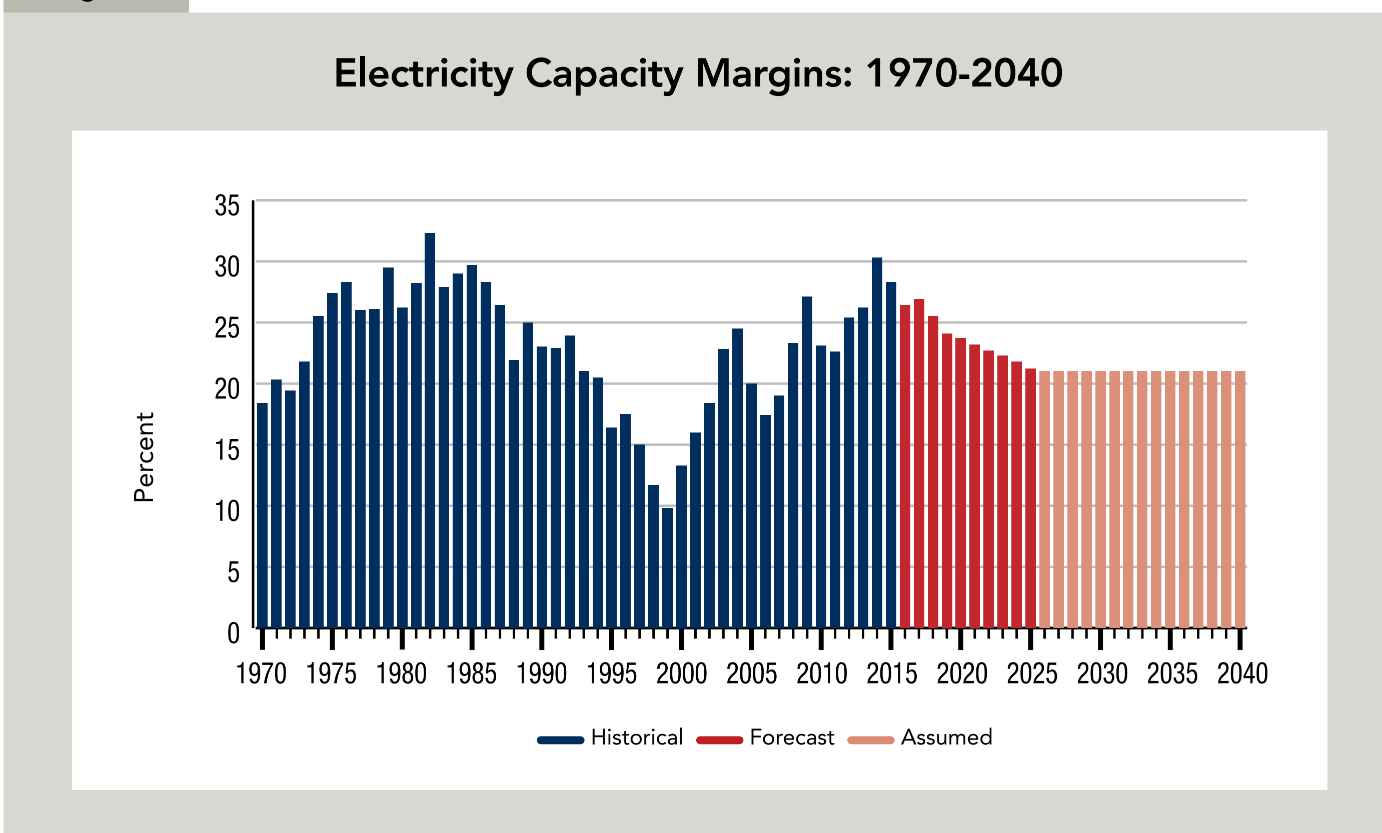
The historical data show clearly the ups and downs the industry has experienced over time. Construction of electricity generating capacity is generally a long-term process, typically requiring several years and often longer. With long lead times, demand changes from business cycles, changes in fuel markets, and regulatory uncertainty, the industry has moved back and forth between periods of relative excess capacity to periods of near under capacity.

In general, from 1970 to the early 1980s, capacity margins increased reflecting capacity additions and flatter demand in response to rising oil prices (remember, in the mid-1970s petroleum-fired plants were responsible for about 15% of electricity production).

From its peak of about 32% in 1982, capacity declined steadily to its lowest level—10%—in 1999, as capacity additions did not keep pace with rising peak demand, a reflection of the roaring economy over much of this period. From 2000 to about 2005, the capacity margin increased steadily, reflecting a spurt of natural gas-plant construction. Since then, peak load has shown

12 EIA compiles these electricity data in the spreadsheet "Net Internal Demand, Capacity Resources, and Capacity Margins" Available at: https://www.eia.gov/electricity/data/eia411/.

Figure 8



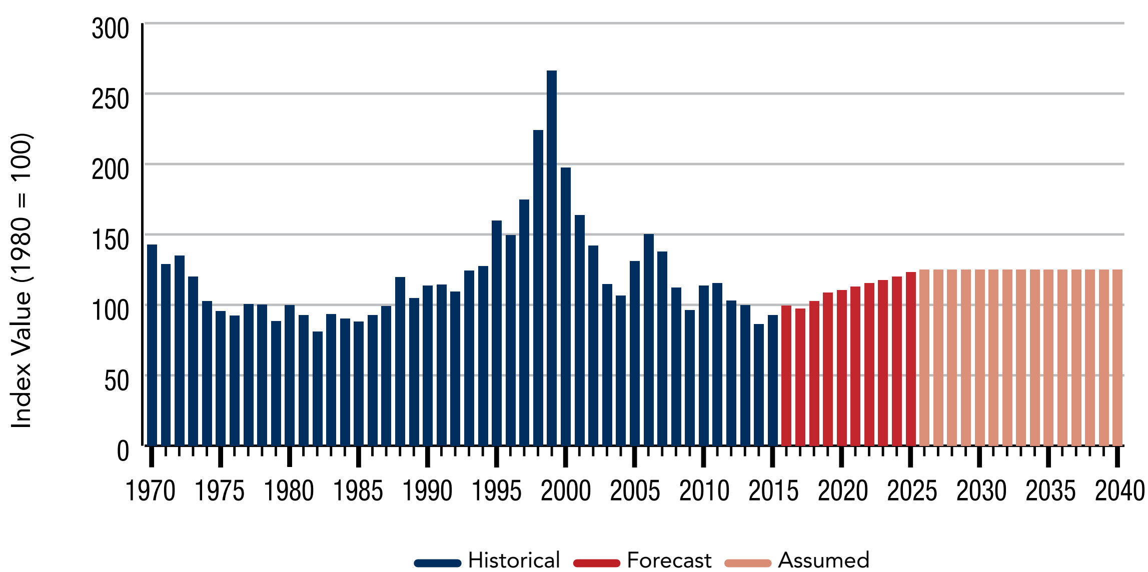
unusual volatility, being buffeted in particular by the Great Recession of late 2008 and 2009 and the uneven economic recovery from it. In 2014, the capacity margin reached 30% before slipping back down to about 25% in 2016, as coal plants closed in response to environmental regulations.

Looking ahead, the data show a bit more tightening of the capacity margin as peak demand recovers and as capacity additions slow. Since the mid-2010s, in particular, coal-plant closures related to low natural gas prices, subsidies for renewables, and new regulations targeting these plants have squeezed capacity margins, which nonetheless are still adequate and look to remain so through 2025.

Normalizing the Electricity Capacity Margin Metric: For the purposes of the Index, a higher index score represents greater risk and a lower score less risk. But for Electricity Capacity Margins, the higher the margin is, the smaller the risk. Accordingly, for using this metric, we took the reciprocals of the capacity margins and then normalized the time series to set the year 1980 equal 100. This produces the values graphed in Figure 9. The steep decline in capacity margins from the mid-1980s to around 2000, which increased risk sharply, is seen clearly, as is the subsequent decline in risk.

Figure 9

Electricity Capacity Margins Index: 1970-2040



In Focus: Electricity Transmission Line Mileage per Peak Summer Demand

A key component of the nation's electricity system is the transmission system. As we noted earlier, nearly all aspects of modern life run to one degree or another on electric power. Consumers expect that electricity will be available to them 24 hours a day, seven days a week, and 365 days a year.

The electricity transmission system—the grid—is rightly considered to be one of the greatest engineering achievements of the 20th century. It is an extensive system of interconnected high-voltage networks, and its electricity transmission lines provide the "highways" along which electrons flow from generating sources to demand centers. Providing reliable electricity is an extremely complicated undertaking, and while electrical outages are uncommon, they can and do occur, sometimes with significant local or regional economic impacts.

The importance of a reliable transmission system is apparent in the results of a 2007 North American Electric Reliability Corporation (NERC) Survey of Reliability Issues, which sought to identify and rank factors electrical power industry executives and professionals perceive may harm reliability. NERC asked industry respondents to consider 10 technical issues according to the likelihood and the severity of an occurrence. The three issues scoring high both for occurrence and impact were all related to, or impact in one way or another, transmission: (1) aging infrastructure and limited new construction; (2) transmission system congestion; and (3) operating closer to load limits.

A robust transmission system gives power users the ability to draw from a diverse set of power plants in different locations and with different operating characteristics. If the transmission system has a certain amount of redundancy built in, it can withstand the failure of its most critical lines or other components. Moreover, as electrification of our economy continues, and as intermittent renewable resources and load management grow in importance, the critical nature of the transmission grid comes increasingly into focus.

Growing electricity use and continued growth in wholesale power markets depend upon an adequate transmission system. The growth of more competitive wholesale electricity markets since 1996 has created new challenges for reliability management. The emergence of regional and interregional wholesale markets has had a significant impact on the use of power lines and the volatility of power flows. The transmission system is being subjected to flows in magnitudes and directions that were not contemplated when they were designed and for which there is minimal operating experience.

While overall use of the transmission system has been growing, capacity additions through new construction or upgrades have not always kept pace. While transmission lines support interstate commerce, their siting and approval are generally a state and local governmental responsibility.[13]

An analysis by the U.S. Department of Energy, the *National Transmission Grid Study*[14], asserted that without dramatic improvements and upgrades, the nation's transmission system will fall short of the reliability standards our economy requires and result in higher electricity costs to consumers.

There is abundant evidence that the U.S. transmission system is in urgent need of modernization. The system has become congested because growth in electricity demand and investment in new generation facilities have not been matched by investment in new transmission infrastructure.

Transmission problems have been compounded by the incomplete transition to fair and efficient competitive wholesale electricity markets. Because the existing transmission system was not designed to meet present demand, daily transmission constraints or "bottlenecks"

13 Energy Information Administration, "Electricity Transmission Fact Sheet." Available at: http://www.eia.doe.gov/cneaf/electricity/page/fact_sheets/transmission.html.

14 Available at: http://www.ferc.gov/industries/electric/gen-info/transmission-grid.pdf.

increase electricity costs to consumers and increase the risk of blackouts.

Improvements to our transmission grid also are essential if renewable resources are expected to produce a significant portion of our electric power. The United States is endowed with large resources of wind and solar energy, but these are often far away from demand centers and are effectively stranded unless and until new transmission capacity can bring them to market.

To measure the reliability of the transmission system and provide an indication of the transmission system's ability to meet increasing demand, we developed a metric, Electricity Transmission Line Mileage, that measures total circuit-miles of AC (230 kilovolts and above) and DC (250 kilovolts and above) transmission lines per gigawatt of peak demand.

The circuit-line data are from NERC and the peak demand data are from EIA. EIA planning projections for AC and DC lines and projected peak load are used to forecast five years into the future. After that, it is assumed that the last forecast value would remain unchanged.

Figure 10 shows the individual trends in peak summer demand and circuit mileage transmission for 1970 to 2016. Figure 11 shows these two measures combined as circuit mileage per peak summer demand.

Three distinct historical trends are evident in the chart:

1. A period of increasing transmission circuit line mileage per peak summer load from 1970 to the mid-1980s, where it recorded its highest (best) level of more than 300 miles. During this time, transmission circuit miles grew at a faster rate than peak summer load.
2. A period of decreasing mileage per peak load from the mid-1980s to the mid-2000s, where it recorded its lowest scores in the record (207 in 2006). During this time, transmission line construction did not keep pace with peak demand.
3. A period of generally increasing, though volatile, mileage per peak load since the mid-2000s. During this

■ Figure 10

Figure 10. Peak Summer Demand and Circuit Miles: 1970-2016

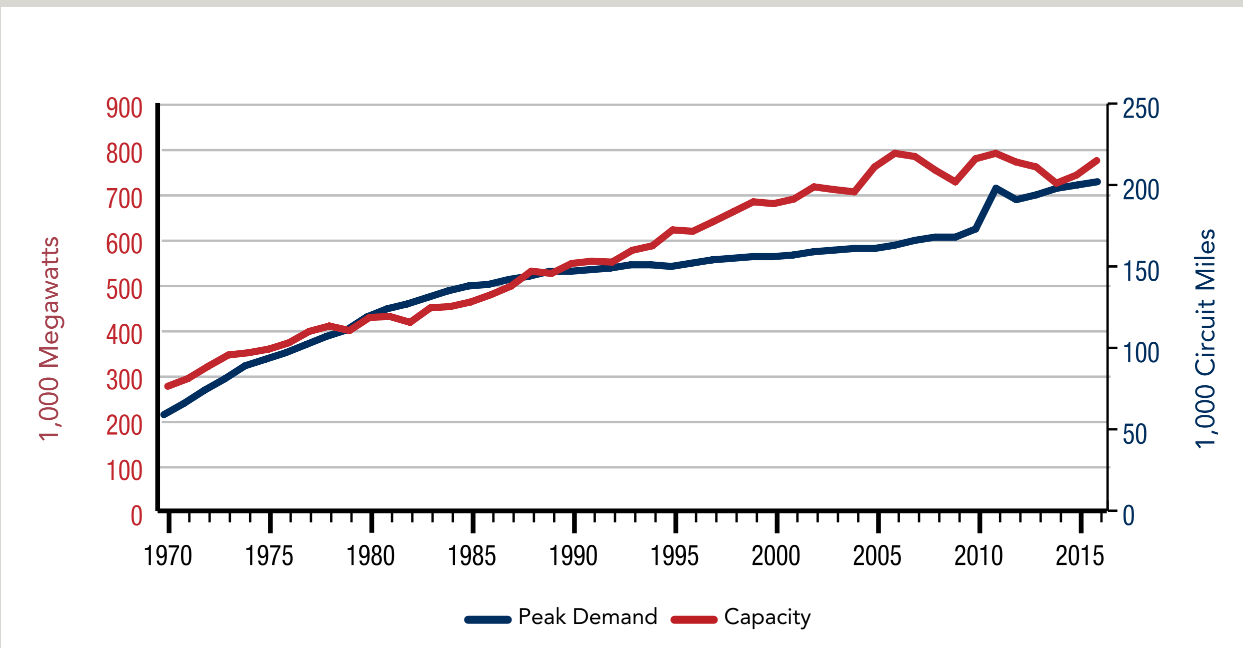


Figure 11

Electricity Transmission Line Mileage: 1970-2040

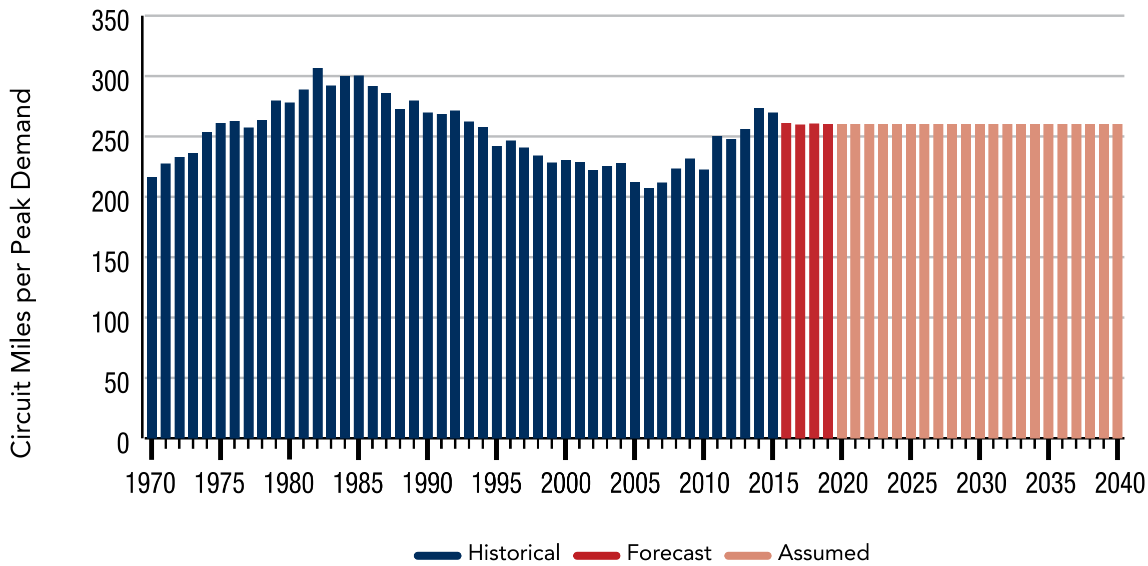
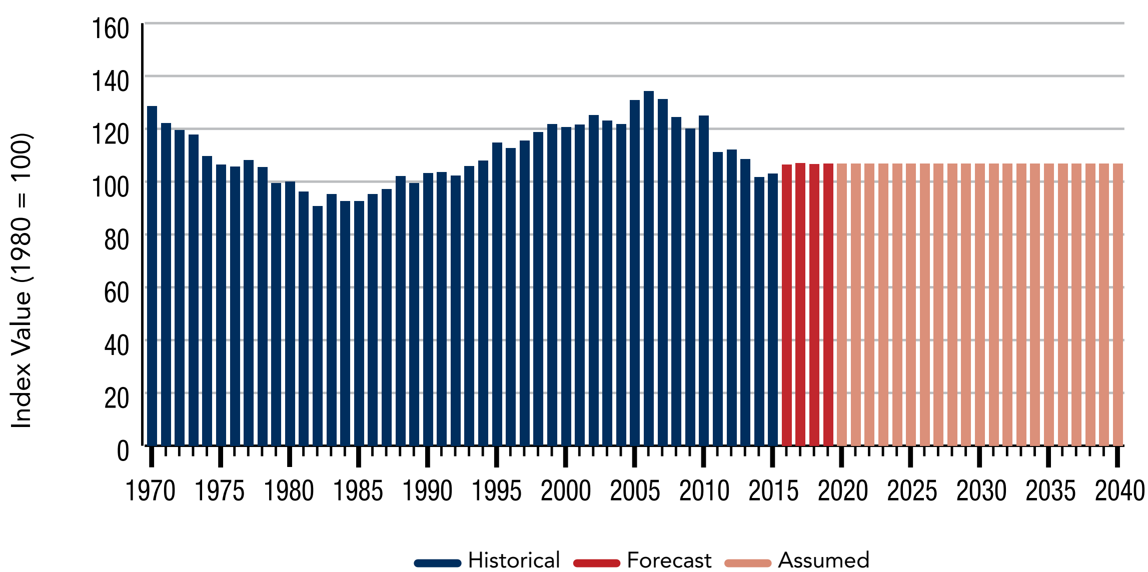


Figure 12

Electricity Transmission Line Mileage Index: 1970-2040



time, greater transmission line construction coupled with a somewhat slower rise in peak demand.

Normalizing the Transmission Mileage Metric: To use this metric as a component of the *Index of U.S. Energy Security Risk* requires inverting the data series because the *risks* described by this metric move in the opposite direction to the *value* of the metric. In other words, the lower the number of circuit-miles of transmission capacity for a given peak load, the higher the risks of congestion, uneconomic dispatch, and adverse events. The metric was inverted by taking the reciprocals and then normalizing the time series to an indexed value, where the year 1980 is set at 100. This produces the values graphed in Figure 12.

Our inability to site and construct interstate transmission lines in a predictable and timely way has become a growing problem. The U.S. energy sector writ large suffers from a lengthy, unpredictable, and needlessly complex regulatory maze that delays, if not halts entirely, construction of new energy infrastructure, including transmission. Federal and state environmental statutes—such as the National Environmental Policy Act—state siting and permitting rules, and a "BANANA syndrome" mentality (build absolutely nothing anywhere near anything)routinely have been used to block construction and expansion of everything from transmission lines to power plants. One result of this has been that capital has flowed to other investments offering quicker returns.

New transmission is essential to creating a robust electricity grid and accommodating demand growth, new facilities, and intermittent renewable power. Streamlining the regulatory and legal obstacles to transmission line construction could unleash investment, create jobs, improve grid operation and reliability, and enhance our energy security.

Appendix 1: Methodology Used to Develop the Index of U.S. Energy Security Risk

The Global Energy Institute's (GEI) ultimate goal in developing the Index of U.S. Energy Security Risk was to use available data and forecasts to develop the metrics that collectively describe the geopolitical, economic, reliability, and environmental risks that in turn combine to measure the risk to overall U.S. energy security in a single Index.

Boiling down something as multifaceted as U.S. energy security into a single number posed a significant challenge. The Index was built from a foundation of just over three dozen individual metrics measuring energy security in a variety of aspects. The Index uses historical and forecast data covering the period 1970, before the time when energy security first became a large concern with the American public, to 2040 using "business-as-usual" forecasts from the Energy Information Administration (EIA).

The process used to develop the Index is described below, and it is represented schematically in figure A1-1.

Selecting and Developing the Metrics

Before selecting the measures, the first task was to establish some criteria that would ensure the data used possessed several important characteristics. The data for each metric had to be:

- Sensible—The data had to relate to common- sense expectations.
- Credible—The data source had to be well-recognized and authoritative.
- Accessible—The data had to be readily and publicly available.
- Transparent—Data derivations and manipulations had to be clear.
- Complete—The data record had to extend back in history for a reasonable amount of time, preferably back to 1970.
- Prospective—The historical data had to dovetail cleanly with forecast data that extend to 2040 where these are available.
- Updatable—The historical data had to be revised each year, with a new historical year added and new forecast outlooks prepared.

In many cases, data from government agencies—primarily the EIA, Department of Commerce, and Department of Transportation—were tapped, but this was not always possible, especially for certain types of data extending back to the 1970s and 1980s. Where historical data from government sources were not available, other widely used and respected sources were employed.

The metrics selected were organized around nine broad types of metrics that represent and balance some key and often competing aspects of energy security. These are found in table A1-1.
Using these categories as guides, 37 individual metrics were selected and developed covering a wide range of energy supplies, energy end-uses, operations, and environmental emissions. Anywhere from three to six metrics were selected for each metric category.

GEI's Index of U.S. Energy Security Risk and the various metrics that support it are designed to convey the notion of risk, in which a lower Index number equates to a lower risk to energy security and a higher Index number relates to a higher risk. This notion of risk is conceptually different from the notion of outcome. Periods of high risk do not necessarily lead to bad outcomes just as periods of low risk do not necessarily lead to good outcomes.

More often than was preferred, the available historical data measured what actually happened, not what might have happened. In other words, much of the available data measure history, not risk.

In choosing which metrics to use, it was necessary to strike a balance between the desired "ideal" measure and the available measure. Where data for the preferred metric existed, they were used, but in many cases, proxies for the risks that could not be measured directly had to be developed.

Figure A1-1. Building the Index of U.S. Energy Security Risk

Table A1-1. Categories of Energy Security Metrics		
	Metric Category	General Description of the Metrics
1.	Global Fuels	Measure the reliability and diversity of global reserves and supplies of oil, natural gas, and coal. Higher reliability and diversity mean a lower risk to energy security.
2.	Fuel Imports	Measure the exposure of the U.S. economy to unreliable and concentrated supplies of oil and natural gas and import costs (not necessarily related to the amount of imports). Higher reliability and diversity and lower costs mean a lower risk to energy security.
3.	Energy Expenditures	Measure the magnitude of energy costs to the U.S. economy and the exposure of consumers to price shocks. Lower costs and exposure mean a lower risk to energy security.
4.	Price & Market Volatility	Measure the susceptibility of the U.S. economy and consumers to large swings in energy prices. Lower volatility means a lower risk to energy security.
5.	Energy Use Intensity	Measure energy use in relation to economic output and energy efficiency. Lower energy use by industry to produce goods and services and by commercial and residential consumers mean a lower risk to energy security.
6.	Electric Power Sector	Measure the diversity and reliability of electricity generating capacity. Higher diversity and reliability mean a lower risk to energy security.
7.	Transportation Sector	Measure efficiency of the vehicle fleet and diversity of fuels. Higher efficiency and diversity mean a lower risk to energy security.
8.	Environmental	Measure the exposure of the U.S. economy to national and international greenhouse gas emission reduction mandates. Lower emissions of carbon dioxide from energy mean a lower risk to energy security.
9.	Research & Development	Measure the prospects for new advanced energy technologies and development of intellectual capital. Higher R&D investments and technical graduates mean a lower risk to energy security.

Several of the metrics use similar data in different ways and many of these related metrics rise and fall at the same times in the historic record, a situation that could introduce a bias in the Index. However, it is important to note that seemingly related metrics can often diverge at some point in the historical record or future. Furthermore, a procedure for weighting each metric avoided giving undue influence in the overall Index to metrics that on the surface appear similar.

Because the metrics are measured in many different units, it was necessary to transform them into comparable "building blocks" that could be assembled into the composite Geopolitical, Economic, Reliability, and Environmental Sub-Indexes and, ultimately, a single comprehensive Index of U.S. Energy Security Risk. To achieve this, the 1970 to 2040 time series for each metric was normalized into an index by setting the value for the year 1980 at 100 and setting the values for all other years in proportional relation to 1980 value, either higher or lower so that the trend lines remains the same. This normalizing procedure simply places all the metrics into a common unit that it preserves the trend as well as the relative movement up or down of each metric over time.

Setting each individual metric so that 1980 equals 100 also means that the Geopolitical, Economic, Reliability, and Environmental Sub-Indexes as well as the overall Index built from them will have a 1980 value of 100. The year 1980 was selected because an initial analysis of the metrics suggested that it reflected the worst year overall for U.S. energy security since 1970.[1]

With some metrics, additional transformations were needed beyond this normalization procedure. The Index is designed so that a lower value represents an improvement in energy security while a higher value represents deterioration in energy security. This makes sense because for most of the metrics used, a declining trend is better for U.S. energy security than a rising trend. There are, however, some metrics where a rising trend signals a declining risk. When creating the normalized index for these metrics, various techniques were used to invert or "flip" the metric so that its index value moves in the opposite direction of its measured value, that is, increases became decreases and vice versa.[2] Additionally, some of the metrics required further transformations to reflect non-linearities in the scale.[3]

EIA's *Annual Energy Outlook (AEO)* is the primary source for metric forecasts. *AEO* projections, however, are not available for all of our metrics. In these cases, a neutral assumption was adopted and the last year of available data was extended over the forecast period.[4] All of these data transformations are discussed in detail in the documentation material available on the GEI's web site.

Using the Metrics to Create Four Sub-Indexes of Energy Security Risk

Within our broad definition of energy security, four areas of concern were identified: (1) geopolitical; (2) economic; (3) reliability; and (4) environmental. While there are no "bright lines" delineating these categories, they nonetheless provided a reasonable framework around which to develop Sub-Indexes that when combined create the overall Index of U.S. Energy Security Risk.

- **Geopolitical:** Petroleum is a globally-traded commodity with a supply that is concentrated in a relative handful of countries. Natural gas also is increasingly becoming a globally-traded commodity, and it too is fairly well concentrated, with about 70% of proven reserves located in the Middle East, Russia, and other former Soviet Union states. Trade in coal is more regional, but as China, India, and other large economies expand, it also may become a more international commodity. For both oil and gas, several of the top reserve-owning countries have uncertain political stability and are at best reluctant business partners with the United States. Dependence upon these fuel sources—for both the United States and the rest of the world—poses political and military risks. Because international disputes can quickly turn into energy problems, and vice versa, energy necessarily occupies a consequential role in U.S. foreign policy.

- **Economic:** With a large part of U.S. national income being spent on energy, price volatility and high prices can have large negative national impacts that crimp family budgets and idle factories. Over the longer-term, high energy prices can diminish our national wealth and provoke energy-intensive industries to migrate to other countries. Since much of U.S. petroleum consumption is supplied by imports, the nation's trade balance is affected by hundreds of billions of dollars each year spent on imported oil.

- **Reliability:** Disruptions to energy supplies—whether natural or man-made, accidental or deliberate—entail high costs. Long-distance supply chains, including tankers and pipelines, are vulnerable to accidents and sabotage. Oil and gas fields located in weather-sensitive areas can be knocked out of service. Inadequate and outdated electrical grids can overload and fail. Lack of adequate electricity generation or refinery capacity can cause shortages and outages. These reliability considerations, in turn, have economic and even geopolitical consequences.

- **Environmental:** Fossil fuels—coal, oil, and gas—

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1 This does not mean that 1980 necessarily represents the worst year for each individual metric or even for the Geopolitical, Economic, Reliability, and Environmental Sub-Indexes. Some metrics display higher (worse) values in years other than 1980, but in the composite Index for the United State, these are offset by lowers values for other metrics leading to an overall score of 100, the highest in the record for the composite Index.

2 For example, while a decline in energy use per unit of economic output would decrease energy security risks, a decline in energy R&D expenditures would increase risks.

3 For example, in cases where movement of a metric above or below a specific range of values does not change the risk in any meaningful way.

4 Similarly, on those few occasions where data for the metric did not extend all the way back to 1970, the last year of available data was "back cast" to 1970.

dominate the U.S. energy system. Combusting these fuels releases carbon dioxide, and these emissions comprise about four-fifths of total gross U.S. greenhouse gas emissions. Climate change poses risks related both to the actual impacts of climate change and to the economic and energy market impacts of taking actions to reduce GHG emissions. These risks and uncertainties are appropriately included as part of an assessment of energy security.

In determining the metrics that should be selected to build the Geopolitical, Economic, Reliability, and Environmental Sub-Indexes, the relevance of each metric to each of the four Sub-Indexes had to be established as well as the weight each metric should be accorded. In general, the aim was to develop a set of weightings that reflected not only each metric's intrinsic characteristics, but also provided a balance across sectors and within groups of metrics.

The weightings were applied as fixed values that remain unchanged over the 1970 to 2040 period. Both analysis and expert judgment were relied on in setting the appropriate weights. Those metrics considered of greater importance within a Sub-Index were given a greater weighting than those considered of lesser importance. It is also important to note that the importance of an individual metrics can differ across different Sub-Index categories, so when the same metric is used in two or more Sub-Indexes, its weighting might be different in one Sub-Index compared to another.

To arrive at the Sub-Indexes, the weightings were applied to each metric within each of the four areas to calculate essentially a weighted average of all the metrics selected for that group. The resulting weighted average is the energy security Sub-Index number.

As with the individual metric indexes, a lower Sub-Index number indicates a lower risk to U.S. energy security, a higher number a greater risk. Since each of the individual metrics has been normalized to a scale where its value for the year 1980 equals 100, all four Sub-Indexes also have a value for the year 1980 equaling 100.

Using the Four Sub-Indexes to Create an Index of U.S. Energy Security

The final step was to merge the four Sub-Indexes into an overall annual Index of U.S. Energy Security Risk for each year from 1970 to 2040. To do this, the input share of each of the four Sub-Indexes to the final overall Index was weighted and apportioned as follows:

- Geopolitical 30%
- Economic 30%
- Reliability 20%
- Environmental 20%

These values were used to arrive at a weighted average of the four Sub-Indexes.[5] The resulting number represents the overall Index of U.S. Energy Security Risk.

As with the weightings applied to the individual metrics in the Sub-Indexes, these weightings are unchanged over the entire 70-year period the Index covers. The weightings used to create the Energy Institute's Index are intended to give substantial weight to each of the four Sub-Indexes but to give slightly more weight to the geopolitical and economic risks that, for good reason, tend to dominate much of the public debate on energy security.

Like the individual metric indexes and the four Sub-Indexes, the year 1980 is set at 100. Although at 100, 1980 represents the worst year in historical record, this level is not a cap—the scale is open-ended. Whether future values approach or exceed this high point will be determined in large part by developments in U.S. policy, international politics, energy markets, technology, and many other factors.

5 To arrive at the Index, each Sub-Index was multiplied by its percentage weighting, and the products of these calculations were added together.

Appendix 2: Metrics and Data Tables

Appendix 2 presents and describes the individual metrics used to define, quantify, and construct the Sub-Indexes and Index of U.S. Energy Security Risk. Nine types of metrics were selected covering a wide range of energy supplies, energy end-uses, operations, and environmental emissions covering the years 1970 to 2040. The nine types of metrics categories are as follows:

1. Global Fuels
2. Fuel Imports
3. Energy Expenditures
4. Price & Market Volatility
5. Energy Use Intensity
6. Electric Power Sector
7. Transportation Sector
8. Environmental
9. Research & Development

The following information is provided for each metric:

- **Definition:** Describes what is being measured and the units of measurement.

- **Importance:** Describes the potential impact and risks associated with each metric.

- **Category of Metric:** Identifies the metric as one of nine broad types of metrics.

- **Historical and Forecast Values:** Provides two charts: one that shows the metric in its units of measurement and another that shows the metric as a normalized index in which 1980 equals 100. Historical values are in blue and forecast values are in red. Lighter shades of blue or red indicate assumed data or combined forecast/assumed data.

- **Observations:** Provides a brief overview of major trends, policies, and events that contributed to the observe trends in the metric.

- **Weighting and Average Historical Contribution of Metric to Energy Security Indexes:** Provides a table with: (1) the weight each metric was assigned in creating each of the four Sub-Indexes and its average weight for the total U.S. Index and (2) the average historical contribution of each metric to the resulting Sub-Index value. These weights are given as percentages. The weight assigned to each metric is an input measure, and it remains the same for each year over the entire period (both historical and forecast). The average historical contribution (1970-2016) of each metric to the Sub-Index and Index values is an output measure. It can and does change from year-to-year as the metric moves up or down in relation to other metrics.

- **Primary Data Sources:** Lists government and other sources used to compile the metric.

- **Data Issues:** Describes briefly how the metric data were manipulated, where necessary, to arrive at the annual metric values and metric indexes and how gaps and discontinuities in the data were resolved.

Additionally, the annual data for each metric as well as the four Sub-Indexes and Index are provided in two sets of tables that follow the metric summaries. The first set lists the values for each of the metrics in the units in which it was measured. The second set of tables lists the values for each of the metrics as an index, with the value for the year 1980 pegged at 100 and the values for all other years set in relation to 1980 value, either higher or lower.

Data references used to develop the metrics are listed at the end of this appendix.

METRIC #1

Security of World Oil Reserves

Definition

Global proved oil reserves in billions of barrels weighted by (1) each country's Freedom House freedom ranking and (2) a diversity index applied to global oil reserves.

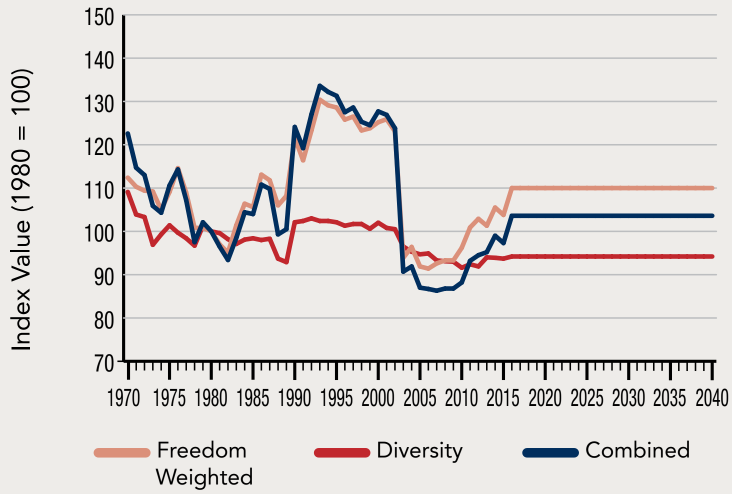
Importance

Indicates risk attached to the average barrel of global crude oil reserves. As a measure of reserves and not production, it largely reflects longer-term concerns.

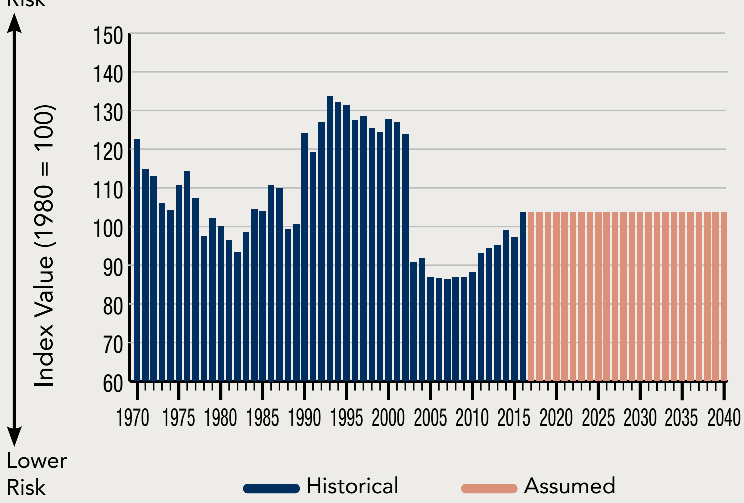
Category of Metric

Global Fuels

Historical and Forecast Values (1970-2040):
Security of World Oil Reserves Trends



Index (1970-2040):
Security of World Oil Reserves Index



Weighting and Average Historical Contribution of Metric to Energy Security Indexes (Percent):

	Geopolitical	Economic	Reliability	Environmental	Total Index
Weight	9.0	N/A	N/A	N/A	2.7
Average Contribution	11.7	N/A	N/A	N/A	3.4

METRIC #2

Security of World Oil Production

Definition

Global oil production weighted by (1) each country's Freedom House freedom ranking and (2) a diversity index applied to global oil production.

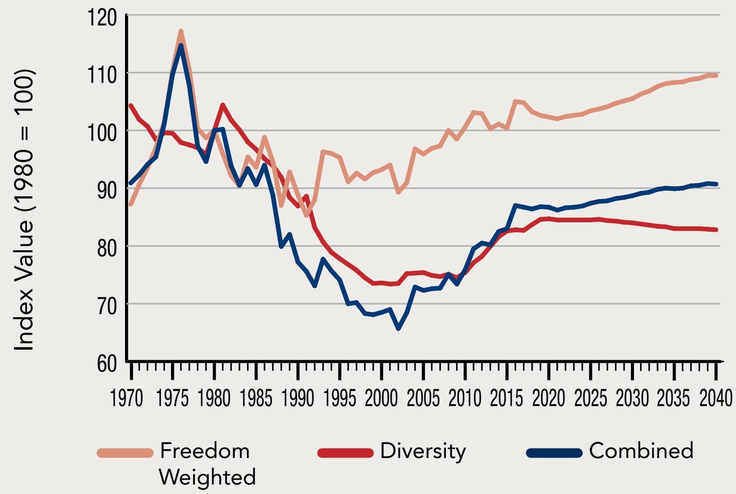
Importance

Indicates the level of risk attached to the average barrel of crude oil produced globally.

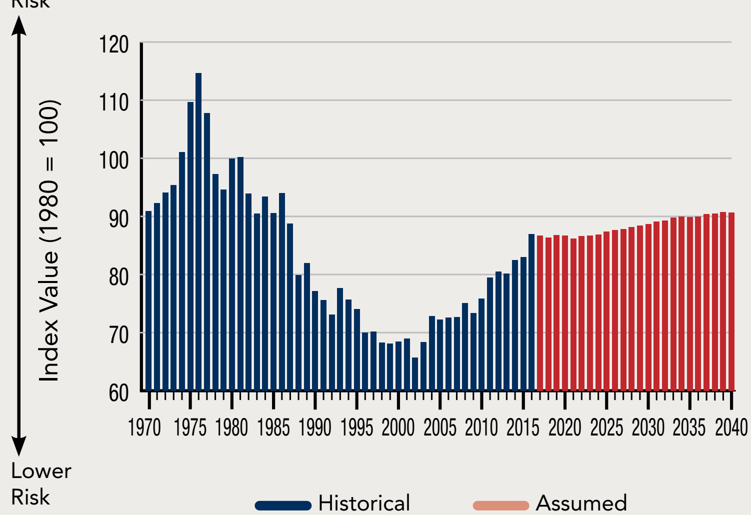
Category of Metric

Global Fuels

Historical and Forecast Values (1970-2040):
Security of World Oil Production Trends



Index (1970-2040):
Security of World Oil Production Index



Weighting and Average Historical Contribution of Metric to Energy Security Indexes (Percent):

	GEOPOLITICAL	ECONOMIC	RELIABILITY	ENVIRONMENTAL	TOTAL INDEX
Weight	7.0	5.0	6.0	N/A	4.8
Average Contribution	7.0	5.6	5.6	N/A	4.7

METRIC #3

Security of World Natural Gas Reserves

Definition

Global proved natural gas reserves weighted by (1) each country's Freedom House freedom ranking and (2) a diversity index applied to global gas reserves.

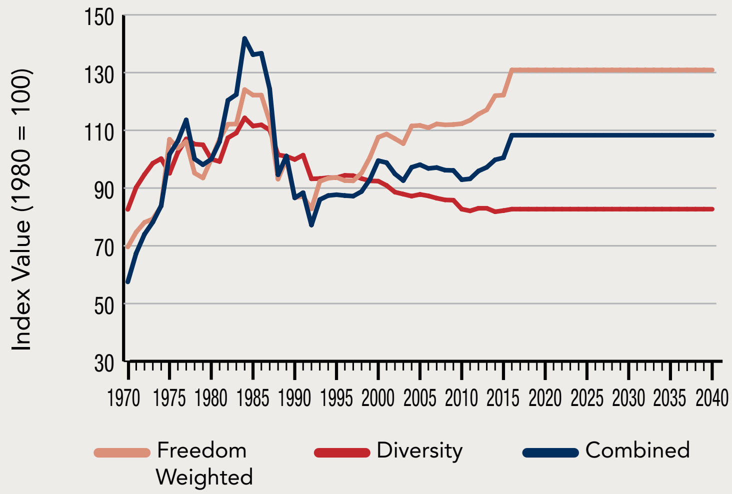
Importance

Indicates the risk attached to the average cubic foot of natural gas reserves globally. As a measure of reserves and not production, it largely reflects longer-term concerns.

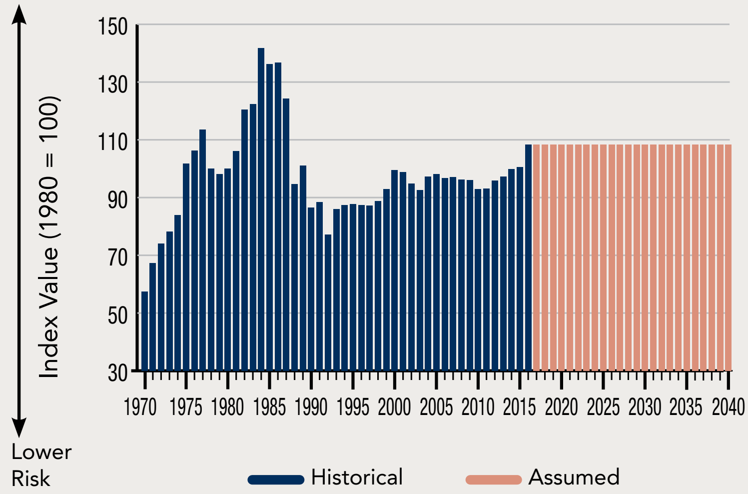
Category of Metric

Global Fuels

Historical and Forecast Values (1970-2040):
Security of World Natural Gas Reserves Trends



Index (1970-2040):
Security of World Natural Gas Reserves Index



Weighting and Average Historical Contribution of Metric to Energy Security Indexes (Percent):

	GEOPOLITICAL	ECONOMIC	RELIABILITY	ENVIRONMENTAL	TOTAL INDEX
Weight	6.0	N/A	N/A	2.0	2.2
Average Contribution	7.0	N/A	N/A	2.0	2.5

METRIC #4

Security of World Natural Gas Production

Definition

Global natural gas production weighted by (1) each country's Freedom House freedom ranking and (2) a diversity index applied to global natural gas production.

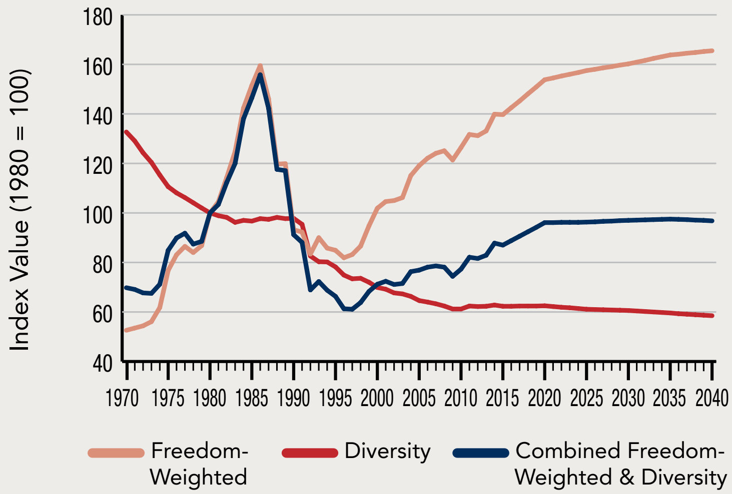
Importance

Indicates the level of risk attached to the average cubic foot of natural gas produced globally.

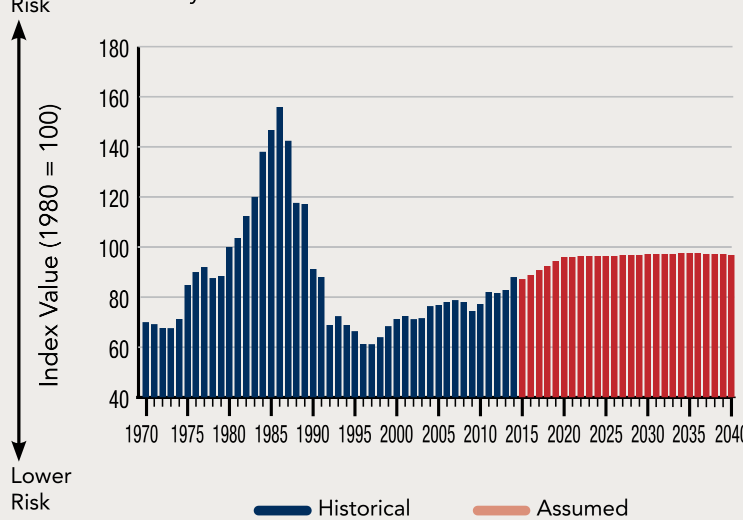
Category of Metric

Global Fuels

Historical and Forecast Values (1970-2040):
Security of World Natural Gas Production Trends



Index (1970-2040):
Security of World Natural Gas Production Index



Weighting and Average Historical Contribution of Metric to Energy Security Indexes (Percent):

	GEOPOLITICAL	ECONOMIC	RELIABILITY	ENVIRONMENTAL	TOTAL INDEX
Weight	5.0	2.0	3.0	2.0	3.1
Average Contribution	5.2	2.3	2.9	1.8	3.2

METRIC #5

Security of World Coal Reserves

Definition

Global proven coal reserves weighted by (1) each country's Freedom House freedom ranking and (2) a diversity index applied to global coal reserves.

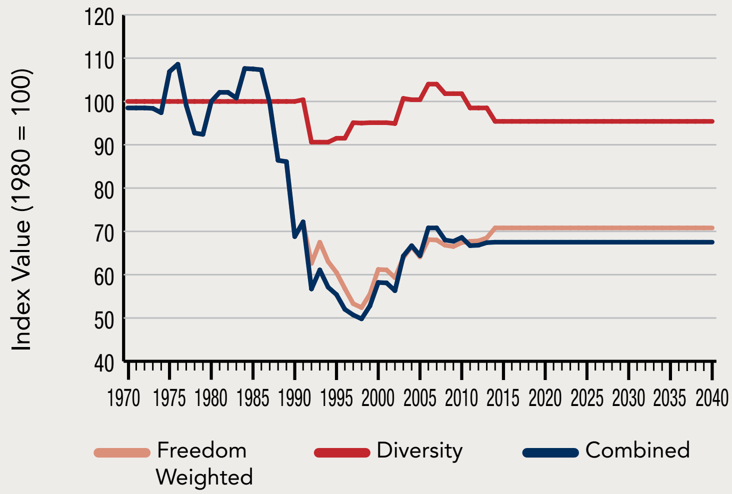
Importance

Indicates the risk attached to the average ton of coal reserves globally. As a measure of reserves, it largely reflects longer-term concerns.

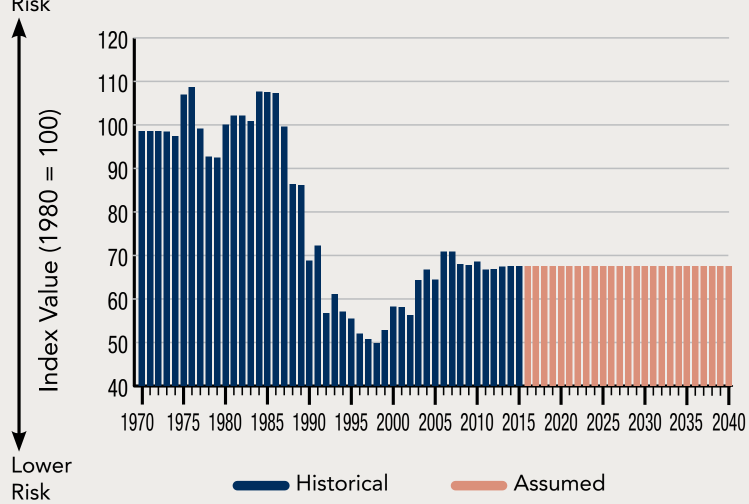
Category of Metric

Global Fuels

Historical and Forecast Values (1970-2040):
Security of World Coal Reserves Trends



Index (1970-2040):
Security of World Coal Reserves Index



Weighting and Average Historical Contribution of Metric to Energy Security Indexes (Percent):

	GEOPOLITICAL	ECONOMIC	RELIABILITY	ENVIRONMENTAL	TOTAL INDEX
Weight	4.0	N/A	N/A	N/A	1.2
Average Contribution	3.7	N/A	N/A	N/A	1.1

METRIC #6

Security of World Coal Production

Definition

Global coal production weighted by (1) each country's Freedom House freedom ranking and (2) a diversity index applied to global coal production.

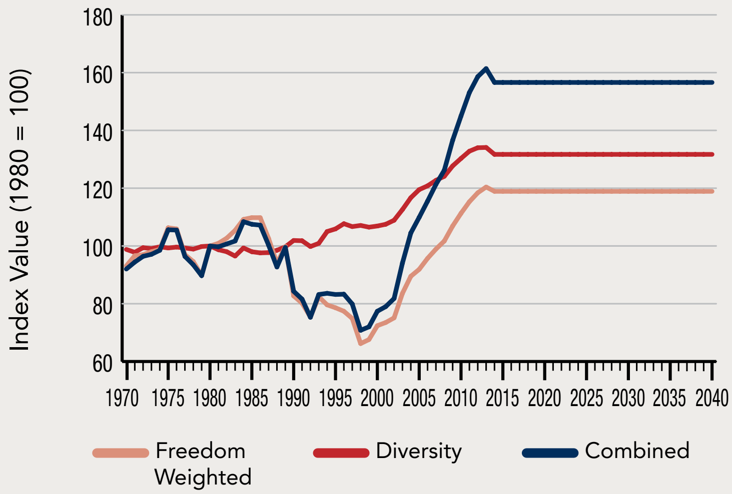
Importance

Indicates the level of risk attached to the average ton of coal production globally.

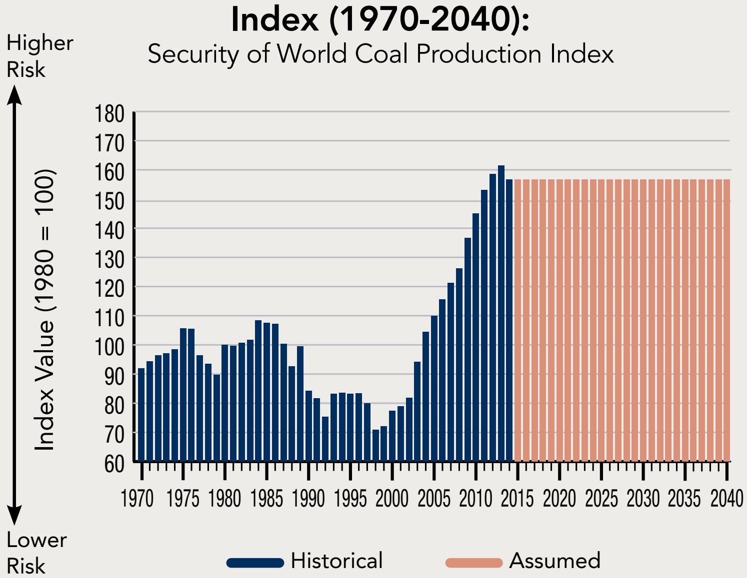
Category of Metric

Global Fuels

Historical and Forecast Values (1970-2040):
Security of World Coal Production Trends



Index (1970-2040):
Security of World Coal Production Index



Weighting and Average Historical Contribution of Metric to Energy Security Indexes (Percent):

	Geopolitical	Economic	Reliability	Environmental	Total Index
Weight	2.0	1.0	1.0	N/A	1.1
Average Contribution	2.5	1.4	1.2	N/A	1.3

METRIC #7

Security of U.S. Petroleum Imports

Definition

Net petroleum imports as a percentage of total U.S. petroleum supply adjusted to reflect (1) each country's Freedom House freedom ranking and (2) a diversity index applied to non-U.S. oil producing countries.

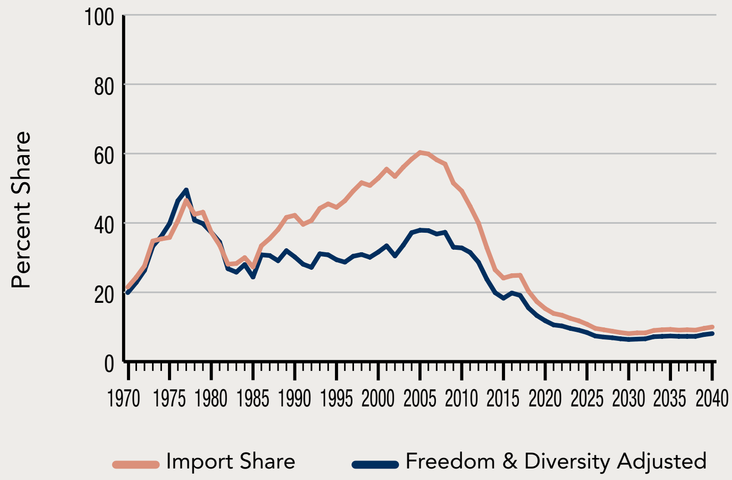
Importance

Indicates the degree to which changes in import levels expose the U.S. to potentially unreliable and/or concentrated supplies of crude and refined petroleum.

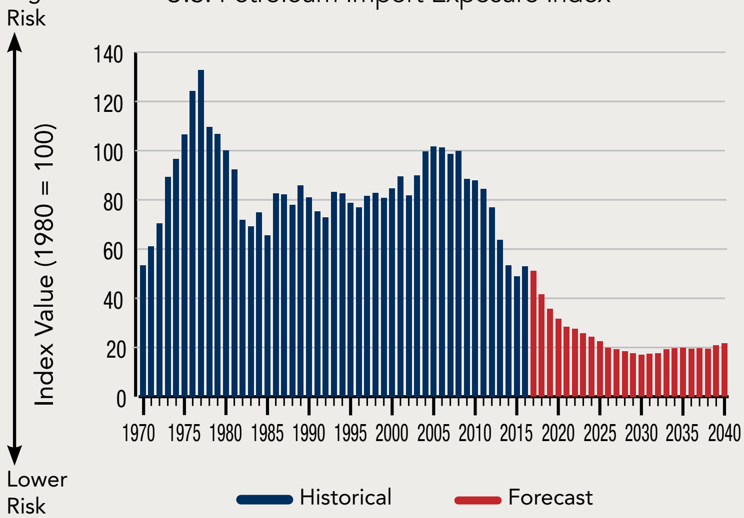
Category of Metric

Fuel Imports

Historical and Forecast Values (1970-2040):
U.S. Petroleum Import Exposure Trends



Index (1970-2040):
U.S. Petroleum Import Exposure Index



Weighting and Average Historical Contribution of Metric to Energy Security Indexes (Percent):

	GEOPOLITICAL	ECONOMIC	RELIABILITY	ENVIRONMENTAL	TOTAL INDEX
Weight	8.0	N/A	9.0	N/A	4.2
Average Contribution	8.0	N/A	8.5	N/A	4.1

METRIC #8

Security of U.S. Natural Gas Imports

Definition

Net natural gas imports as a percentage of total U.S. natural gas supply risk-adjusted to reflect (1) each country's Freedom House freedom ranking and (2) a diversity index applied to non-U.S. natural gas producing countries.

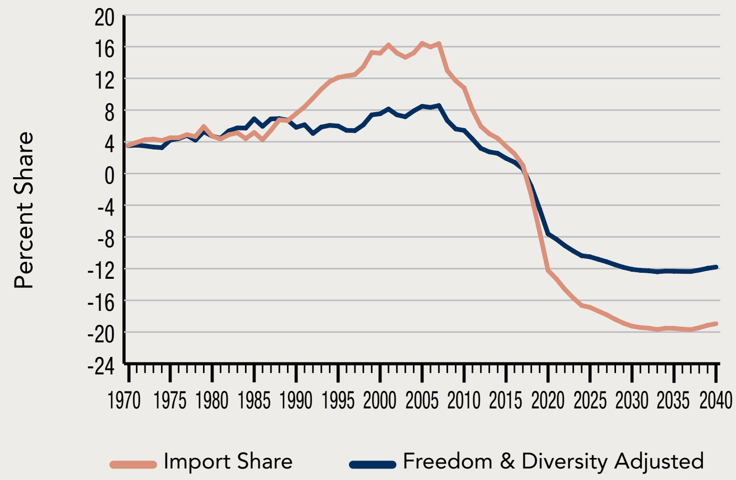
Importance

Indicates the degree to which changes in import levels expose the U.S. to potentially unreliable and/or concentrated supplies of natural gas.

Category of Metric

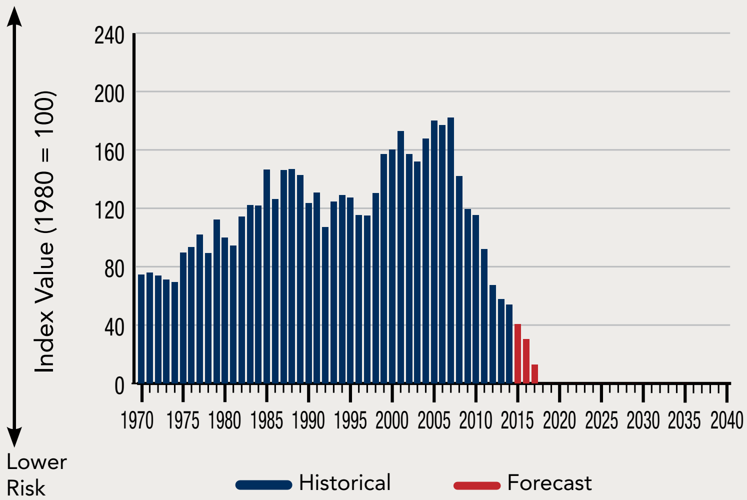
Fuel Imports

Historical and Forecast Values (1970-2040):
U.S. Natural Gas Import Exposure Trends



Index (1970-2040):
U.S. Natural Gas Import Exposure Index

Higher Risk



Weighting and Average Historical Contribution of Metric to Energy Security Indexes (Percent):

	GEOPOLITICAL	ECONOMIC	RELIABILITY	ENVIRONMENTAL	TOTAL INDEX
Weight	3.0	N/A	2.0	N/A	1.3
Average Contribution	4.2	N/A	2.6	N/A	1.8

METRIC #9

Oil & Natural Gas Import Expenditures

Definition

Value of net imports of crude oil, petroleum products, and natural gas in billions of real (2015) dollars.

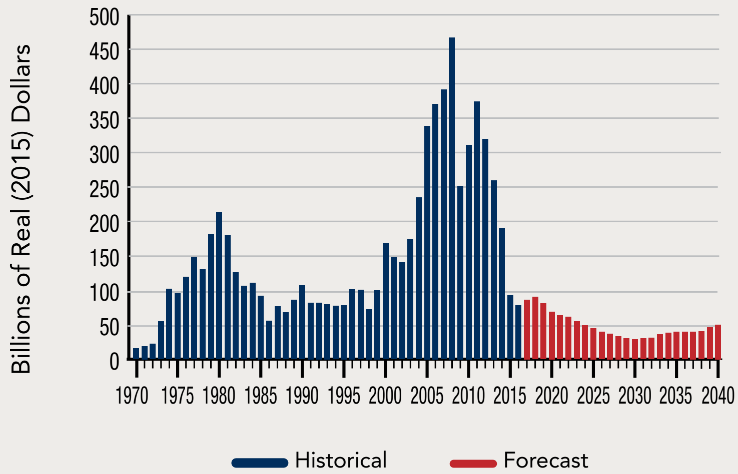
Importance

Indicates lost domestic economic investment and opportunity and the relative magnitude of revenues received by foreign suppliers.

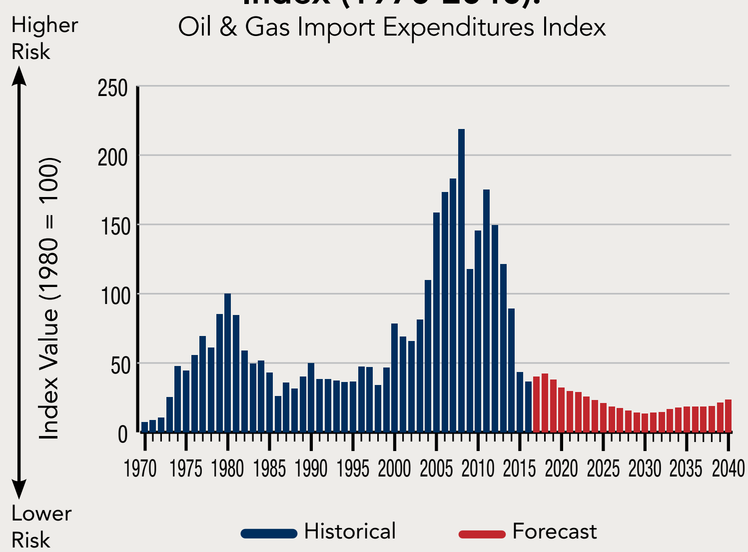
Category of Metric

Fuel Imports

Historical and Forecast Values (1970-2040):
Oil & Natural Gas Import Expenditures



Index (1970-2040):
Oil & Gas Import Expenditures Index



Weighting and Average Historical Contribution of Metric to Energy Security Indexes (Percent):

	GEOPOLITICAL	ECONOMIC	RELIABILITY	ENVIRONMENTAL	TOTAL INDEX
Weight	6.0	6.0	N/A	N/A	3.6
Average Contribution	4.9	5.3	N/A	N/A	2.9

METRIC #10

Oil & Natural Gas Import Expenditures per dollar of GDP

Definition

Value of net imports of crude oil, petroleum products, and natural gas as a percentage of GDP.

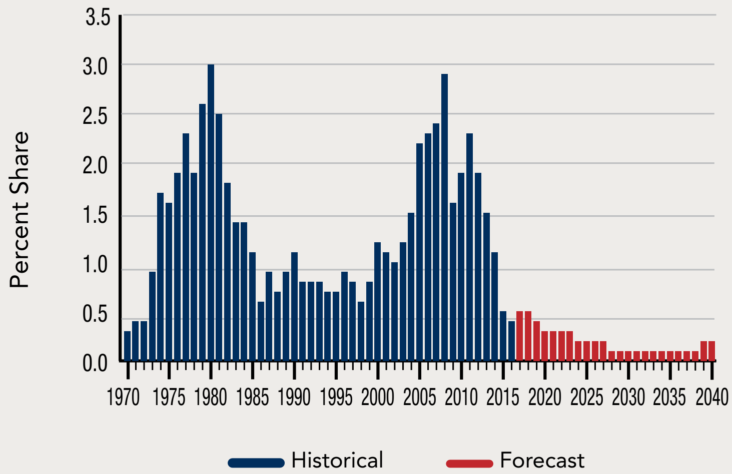
Importance

Indicates the susceptibility of the U.S. economy to imported oil and gas price shocks.

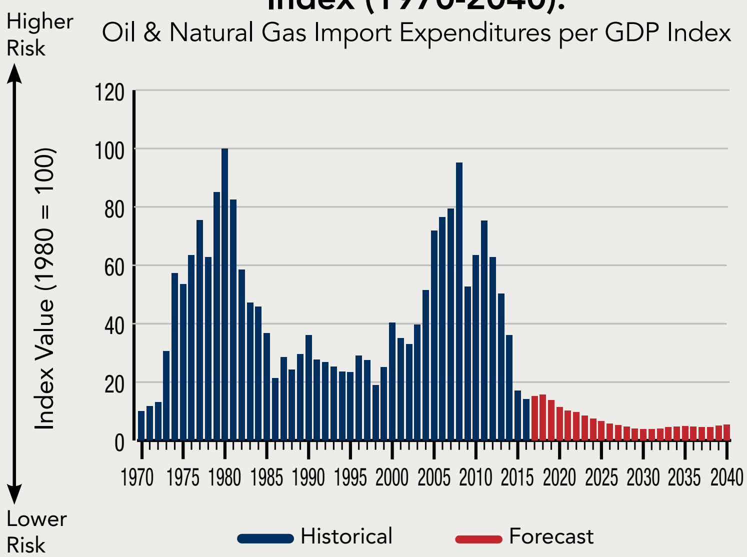
Category of Metric

Fuel Imports

Historical and Forecast Values (1970-2040):
Oil & Natural Gas Import Expenditures per GDP



Index (1970-2040):
Oil & Natural Gas Import Expenditures per GDP Index



Weighting and Average Historical Contribution of Metric to Energy Security Indexes (Percent):

	GEOPOLITICAL	ECONOMIC	RELIABILITY	ENVIRONMENTAL	TOTAL INDEX
Weight	N/A	9.0	N/A	N/A	2.7
Average Contribution	N/A	5.0	N/A	N/A	1.4

METRIC #11

Energy Expenditures per dollar of GDP

Definition

Total real (2015) dollar cost of energy consumed per $1,000 of GDP per year.

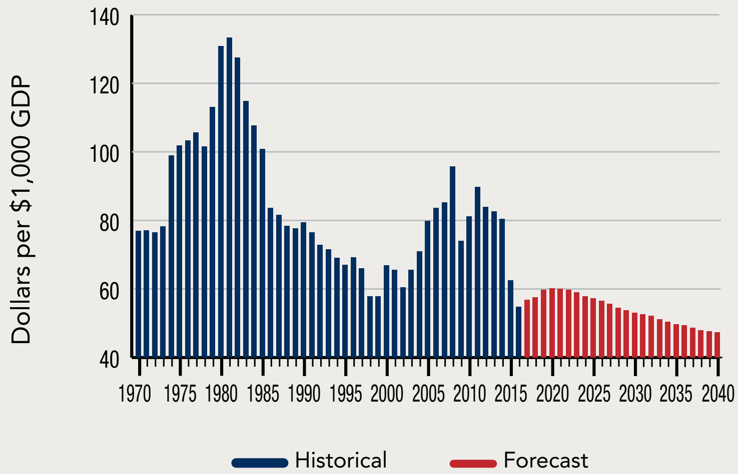
Importance

Indicates the magnitude of energy costs in the U.S. economy and its susceptibility to energy price shocks and exposure to price changes.

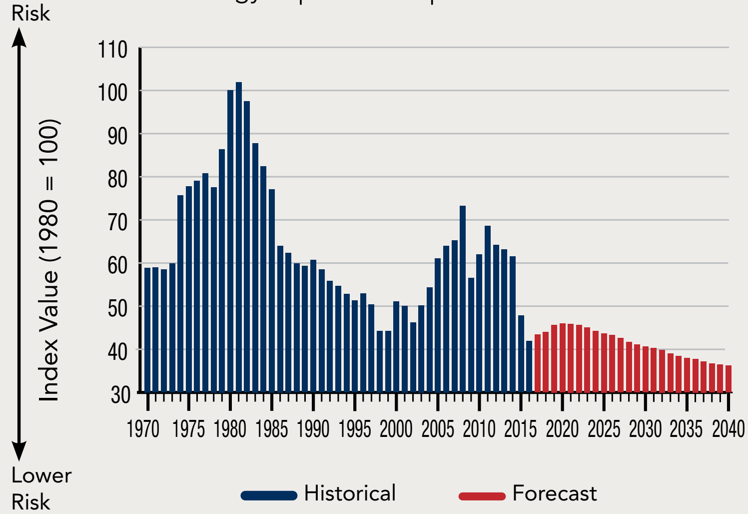
Category of Metric

Energy Expenditures

Historical and Forecast Values (1970-2040):
Energy Expenditures per GDP



Index (1970-2040):
Energy Expenditures per GDP Index



Weighting and Average Historical Contribution of Metric to Energy Security Indexes (Percent):

	GEOPOLITICAL	ECONOMIC	RELIABILITY	ENVIRONMENTAL	TOTAL INDEX
Weight	5.0	7.0	N/A	N/A	3.6
Average Contribution	3.8	5.9	N/A	N/A	2.7

METRIC #12

Energy Expenditures per Household

Definition

Total real (2015) dollar cost of the energy consumed per household per year.

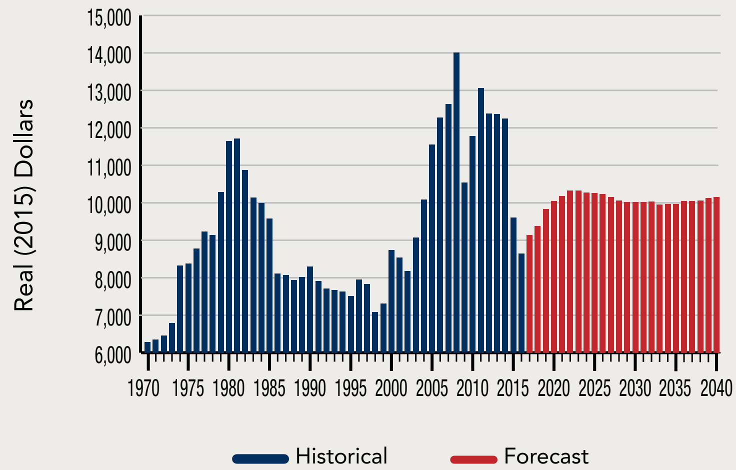
Importance

Indicates the importance of energy in household budgets and the susceptibility of U.S. households to energy price shocks.

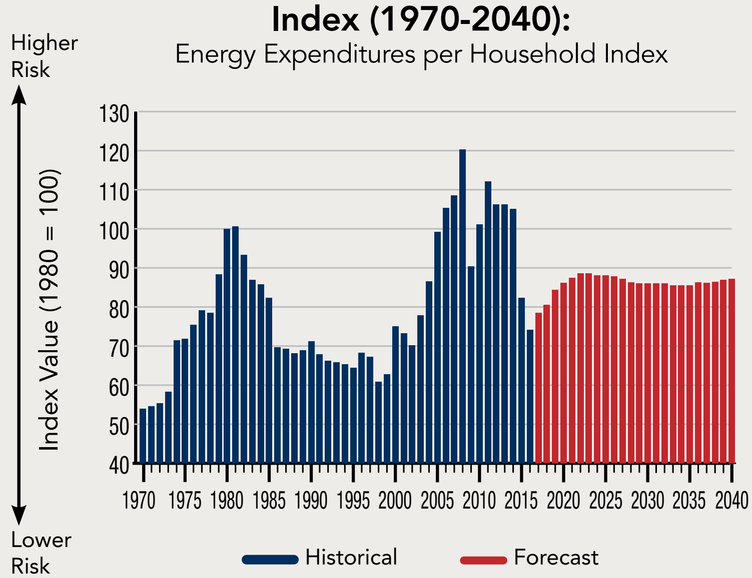
Category of Metric

Energy Expenditures

Historical and Forecast Values (1970-2040):
Energy Expenditures per Household



Index (1970-2040):
Energy Expenditures per Household Index



Weighting and Average Historical Contribution of Metric to Energy Security Indexes (Percent):

	GEOPOLITICAL	ECONOMIC	RELIABILITY	ENVIRONMENTAL	TOTAL INDEX
Weight	N/A	9.0	N/A	N/A	2.7
Average Contribution	N/A	9.4	N/A	N/A	2.5

METRIC #13

Retail Electricity Prices

Definition

Average electricity costs in the U.S. in cents per kWh in real (2015) dollars.

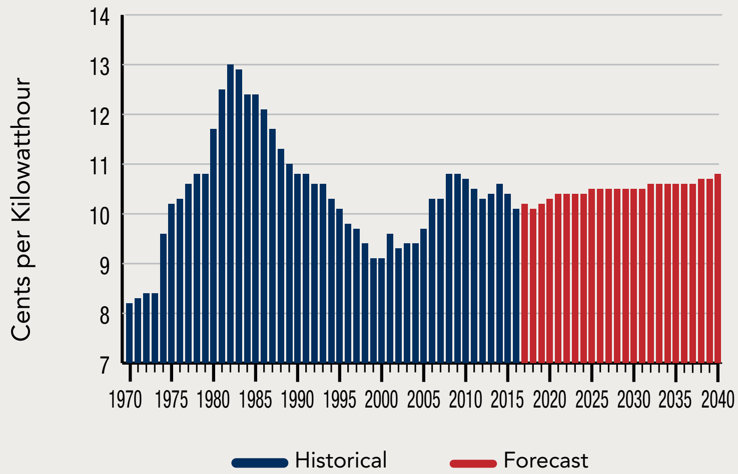
Importance

Indicates the availability of low-cost, reliable forms of power generation.

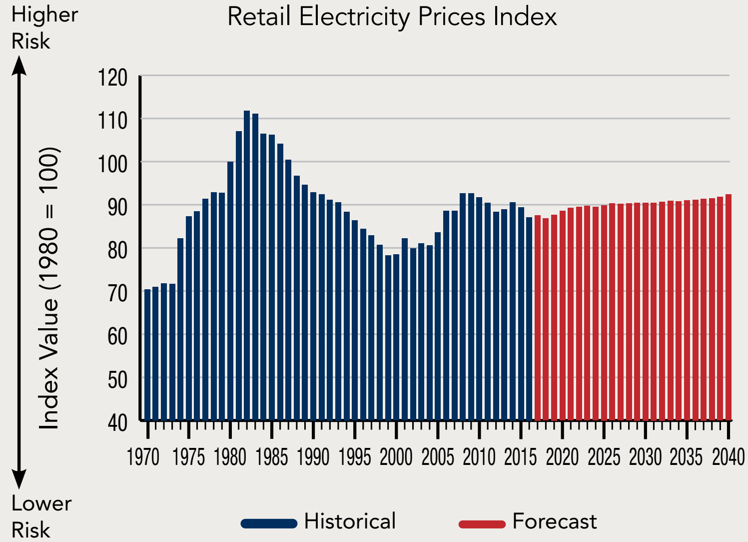
Category of Metric

Energy Expenditures

Historical and Forecast Values (1970-2040):
Retail Electricity Prices



Index (1970-2040):
Retail Electricity Prices Index



Weighting and Average Historical Contribution of Metric to Energy Security Indexes (Percent):

	GEOPOLITICAL	ECONOMIC	RELIABILITY	ENVIRONMENTAL	TOTAL INDEX
Weight	N/A	10.0	N/A	N/A	3.0
Average Contribution	N/A	11.9	N/A	N/A	3.2

METRIC #14

Crude Oil Prices

Definition

Cost per barrel of crude oil landed in the U.S. in real (2015) dollars.

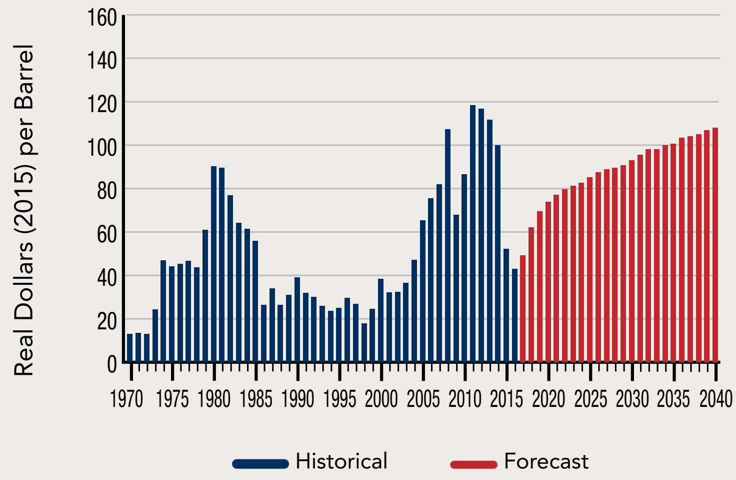
Importance

Indicates the susceptibility of the U.S. economy to high prices for petroleum, which supplies a significant portion of U.S. energy demand.

Category of Metric

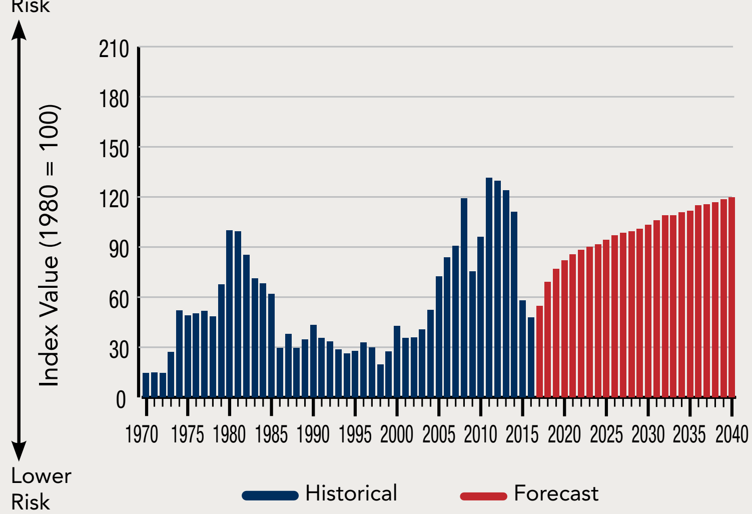
Energy Expenditures

Historical and Forecast Values (1970-2040):
Crude Oil Prices



Index (1970-2040):
Crude Oil Prices Index

Higher Risk



Weighting and Average Historical Contribution of Metric to Energy Security Indexes (Percent):

	GEOPOLITICAL	ECONOMIC	RELIABILITY	ENVIRONMENTAL	TOTAL INDEX
Weight	13.0	13.0	6.0	N/A	9.0
Average Contribution	8.4	9.1	3.7	N/A	5.8

METRIC #15

Crude Oil Price Volatility

Definition

Annual change in real (2015) crude oil prices averaged over a three-year period.

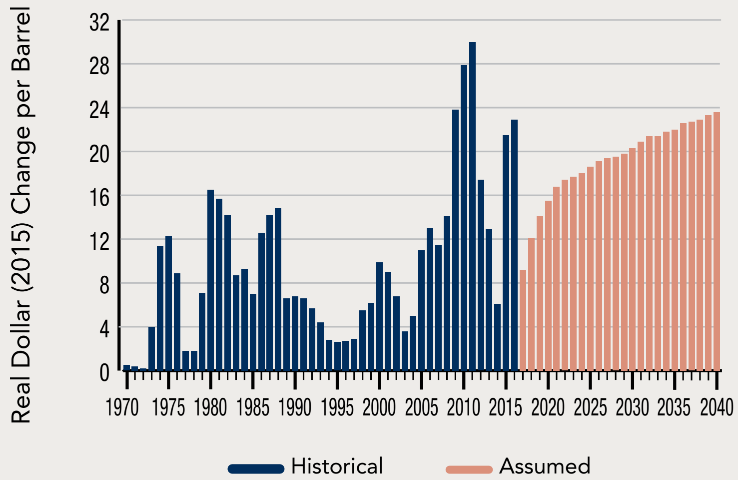
Importance

Indicates the susceptibility of the U.S. economy to large swings in the price of petroleum, which supplies a significant portion U.S. energy demand.

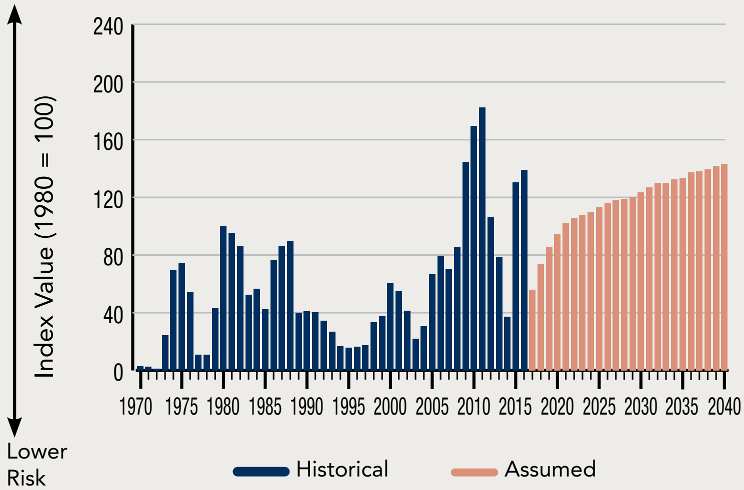
Category of Metric

Price Volatility

Historical and Forecast Values (1970-2040):
Crude Oil Price Volatility



Index (1970-2040):
Oil Price Volatility Index



Weighting and Average Historical Contribution of Metric to Energy Security Indexes (Percent):

	GEOPOLITICAL	ECONOMIC	RELIABILITY	ENVIRONMENTAL	TOTAL INDEX
Weight	5.0	3.0	10.0	N/A	4.4
Average Contribution	3.4	2.2	6.4	N/A	3.0

METRIC #16

Energy Expenditure Volatility

Definition

Average annual change in real (2015) U.S. energy expenditures per $1,000 of GDP.

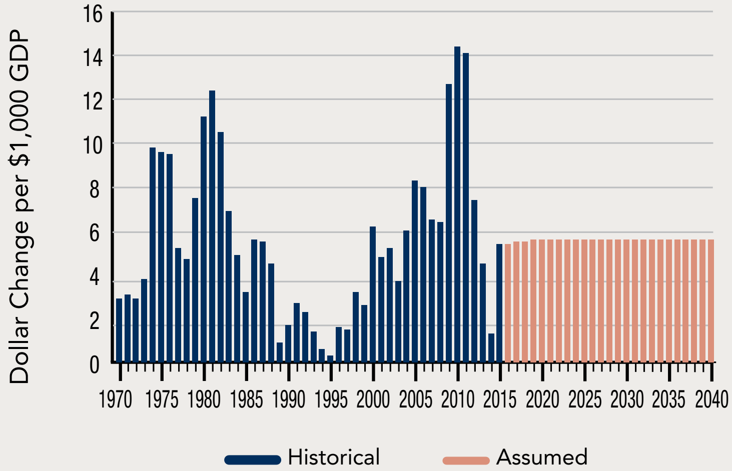
Importance

Indicates the susceptibility of the U.S. economy to large swings in expenditures for all forms of energy.

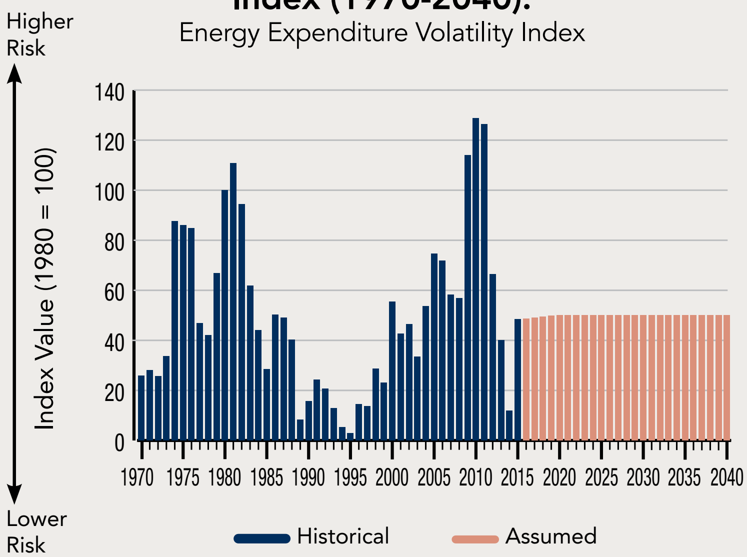
Category of Metric

Price Volatility

Historical and Forecast Values (1970-2040):
Energy Expenditure Volatility



Index (1970-2040):
Energy Expenditure Volatility Index



Weighting and Average Historical Contribution of Metric to Energy Security Indexes (Percent):

	GEOPOLITICAL	ECONOMIC	RELIABILITY	ENVIRONMENTAL	TOTAL INDEX
Weight	N/A	5.0	14.0	N/A	4.3
Average Contribution	N/A	3.1	7.5	N/A	2.4

METRIC #17

World Oil Refinery Utilization

Definition

Average percentage utilization of global petroleum refinery capacity.

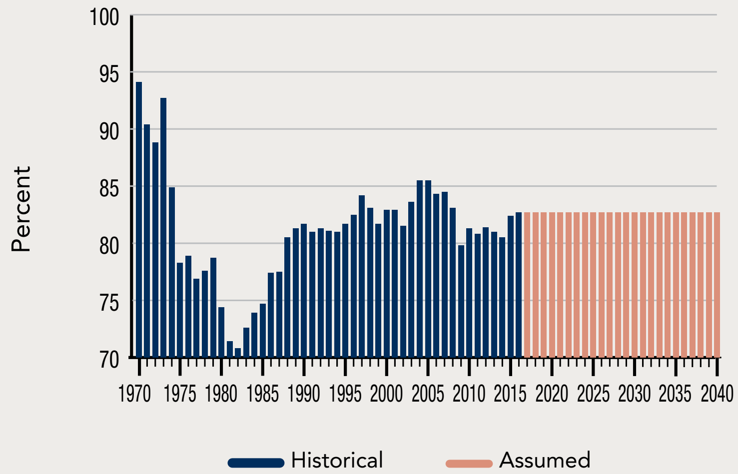
Importance

Indicates the likelihood of higher prices at high capacity utilization, and higher risk of supply limitations during refinery outages or disruptions.

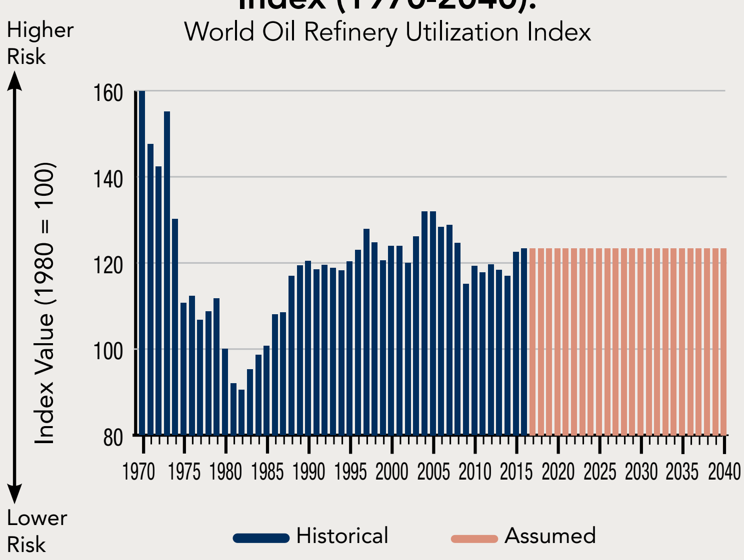
Category of Metric

Price Volatility

Historical and Forecast Values (1970-2040):
World Oil Refinery Utilization



Index (1970-2040):
World Oil Refinery Utilization Index



Weighting and Average Historical Contribution of Metric to Energy Security Indexes (Percent):

	GEOPOLITICAL	ECONOMIC	RELIABILITY	ENVIRONMENTAL	TOTAL INDEX
Weight	3.0	N/A	6.0	N/A	2.1
Average Contribution	4.3	N/A	8.1	N/A	3.0

METRIC #18

Petroleum Stock Levels

Definition

Average days supply of petroleum stocks, including strategic petroleum reserve (SPR), non-SPR crude, and petroleum products.

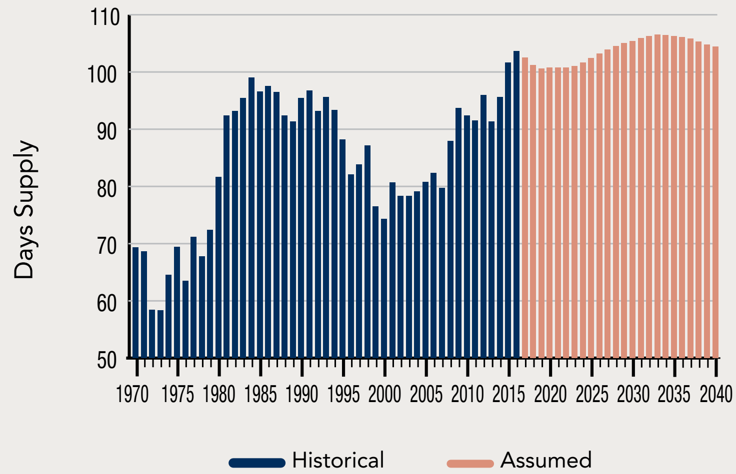
Importance

Indicates vulnerability of the U.S. to a supply disruption based on the quantity of oil stocks that are available domestically to be drawn down.

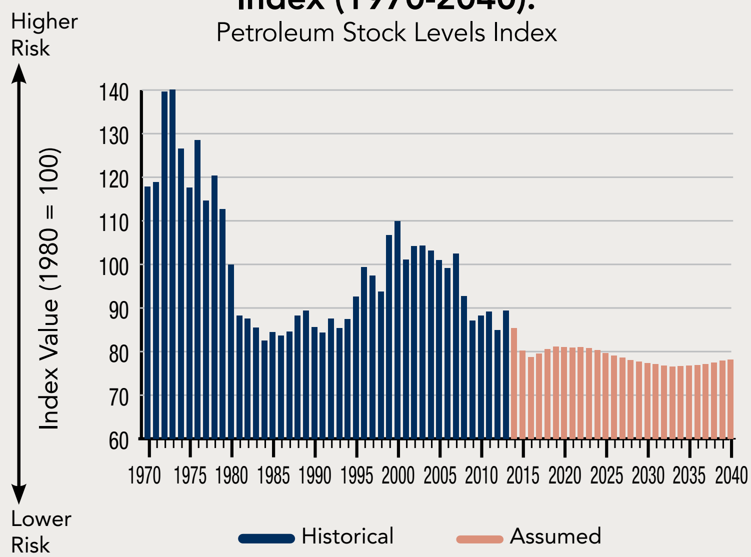
Category of Metric

Price Volatility

Historical and Forecast Values (1970-2040):
Petroleum Stock Levels



Index (1970-2040):
Petroleum Stock Levels Index



Weighting and Average Historical Contribution of Metric to Energy Security Indexes (Percent):

	GEOPOLITICAL	ECONOMIC	RELIABILITY	ENVIRONMENTAL	TOTAL INDEX
Weight	2.0	N/A	6.0	N/A	1.8
Average Contribution	2.4	N/A	6.7	N/A	2.1

METRIC #19

Energy Consumption per Capita

Definition

Million Btu consumed per person per year.

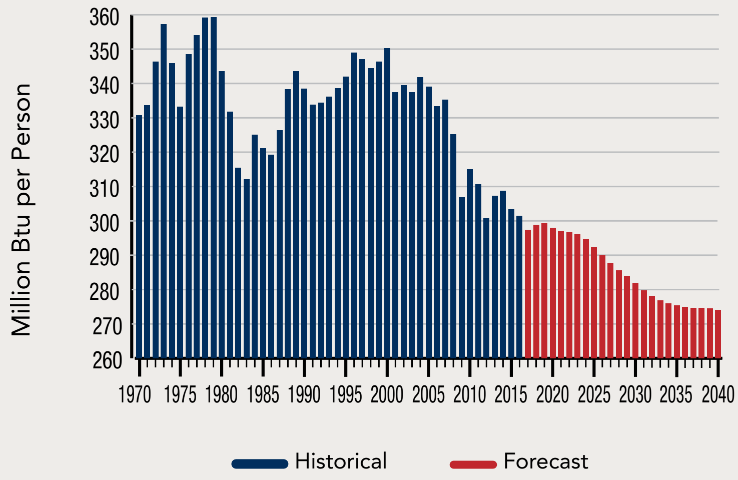
Importance

Indicates changes in both energy intensity and in per-capita GDP.

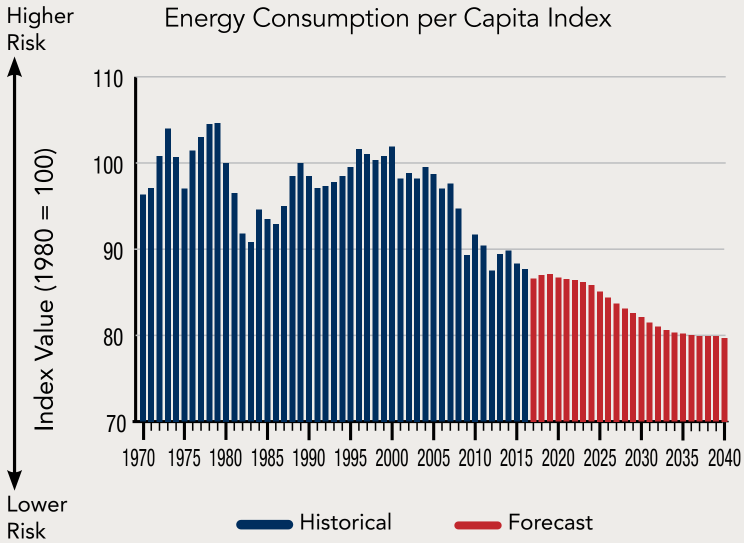
Category of Metric

Energy Use Intensity

Historical and Forecast Values (1970-2040):
Energy Consumption per Capita



Index (1970-2040):
Energy Consumption per Capita Index



Weighting and Average Historical Contribution of Metric to Energy Security Indexes (Percent):

	GEOPOLITICAL	ECONOMIC	RELIABILITY	ENVIRONMENTAL	TOTAL INDEX
Weight	N/A	3.0	N/A	8.0	2.5
Average Contribution	N/A	3.9	N/A	8.0	2.9

METRIC #20

Energy Intensity

Definition

Million Btu of primary energy used in the economy per $1,000 of real (2015) GDP.

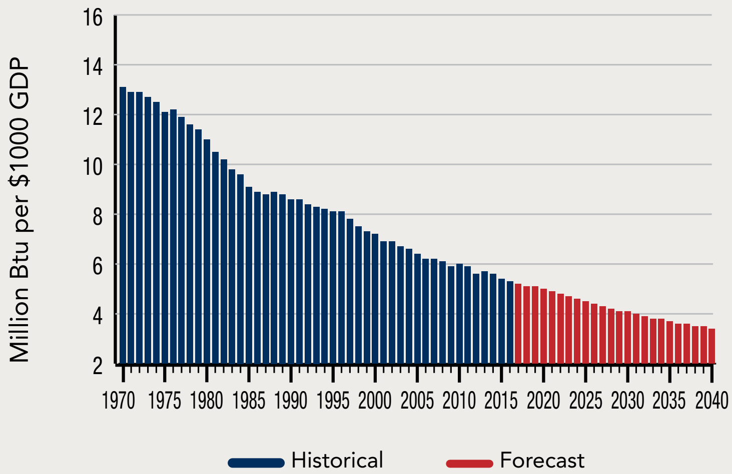
Importance

Indicates the importance of energy as a component of economic growth.

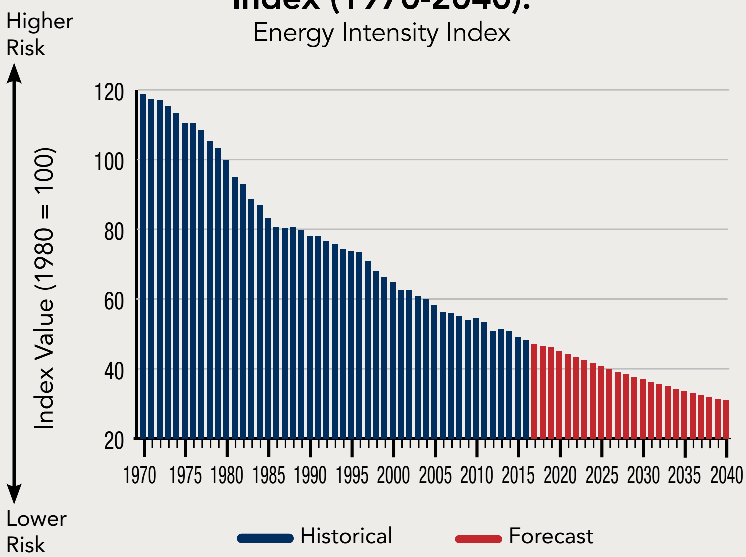
Category of Metric

Energy Use Intensity

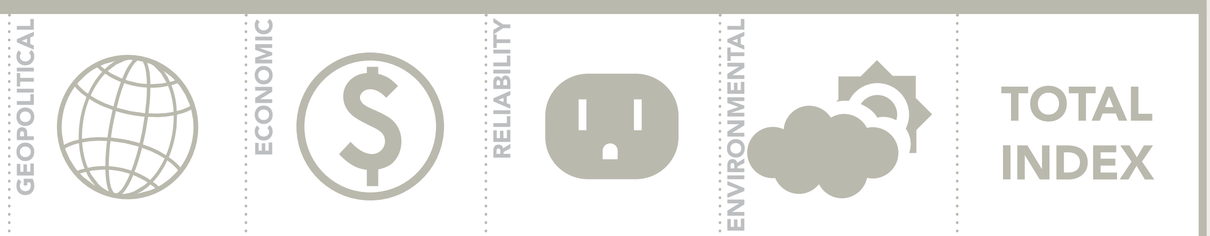
Historical and Forecast Values (1970-2040):
Energy Intensity



Index (1970-2040):
Energy Intensity Index



Weighting and Average Historical Contribution of Metric to Energy Security Indexes (Percent):



	GEOPOLITICAL	ECONOMIC	RELIABILITY	ENVIRONMENTAL	TOTAL INDEX
Weight	N/A	4.0	N/A	10.0	3.2
Average Contribution	N/A	4.2	N/A	8.0	2.9

METRIC #21

Petroleum Intensity

Definition

Million Btu of petroleum consumed per $1,000 GDP in real (2015) dollars.

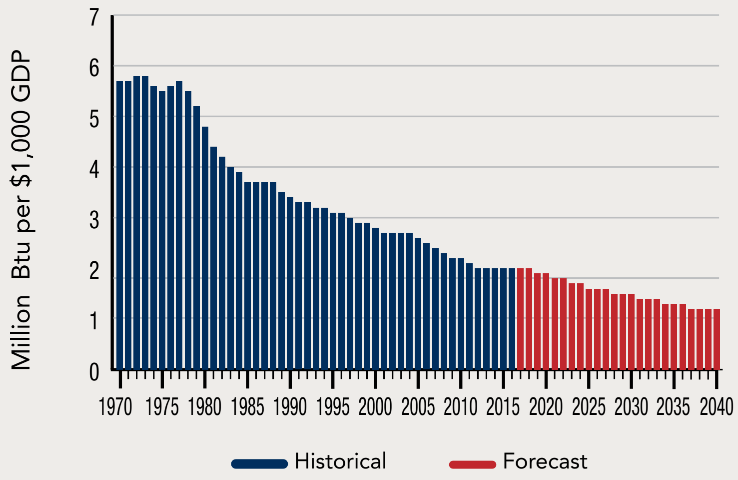
Importance

Indicates the importance of petroleum as a component of economic growth.

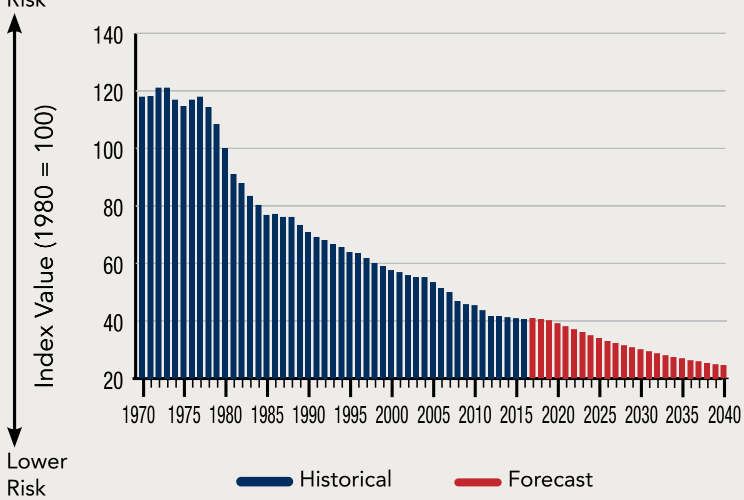
Category of Metric

Energy Use Intensity

Historical and Forecast Values (1970-2040):
Petroleum Intensity



Index (1970-2040):
Petroleum Intensity Index



Weighting and Average Historical Contribution of Metric to Energy Security Indexes (Percent):

	GEOPOLITICAL	ECONOMIC	RELIABILITY	ENVIRONMENTAL	TOTAL INDEX
Weight	8.0	3.0	N/A	6.0	4.5
Average Contribution	7.1	3.0	N/A	4.5	3.9

METRIC #22

Household Energy Efficiency

Definition

Million Btu of total energy consumed per household.

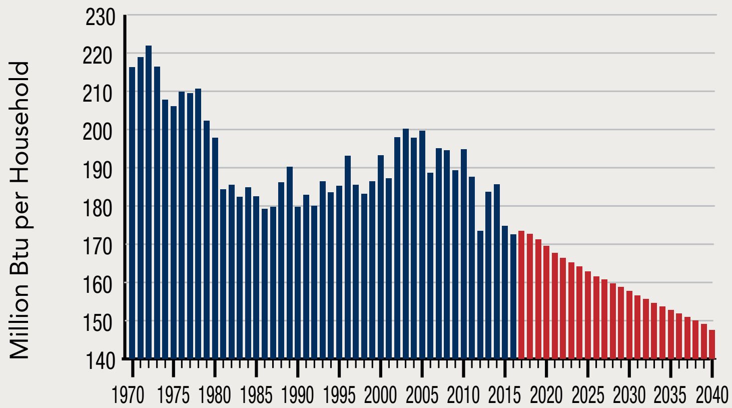
Importance

Indicates the degree to which the typical household uses energy efficiently.

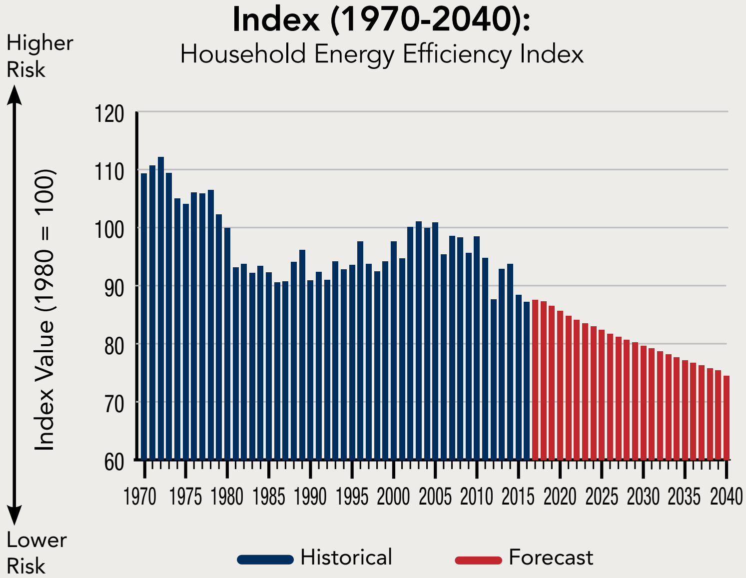
Category of Metric

Energy Use Intensity

Historical and Forecast Values (1970-2040):
Household Energy Efficiency



Index (1970-2040):
Household Energy Efficiency Index



Weighting and Average Historical Contribution of Metric to Energy Security Indexes (Percent):

	GEOPOLITICAL	ECONOMIC	RELIABILITY	ENVIRONMENTAL	TOTAL INDEX
Weight	N/A	3.0	N/A	4.0	1.7
Average Contribution	N/A	3.9	N/A	4.0	1.9

Commercial Energy Efficiency

Definition

Million Btu of total commercial energy consumed per 1,000 square feet of commercial floor space.

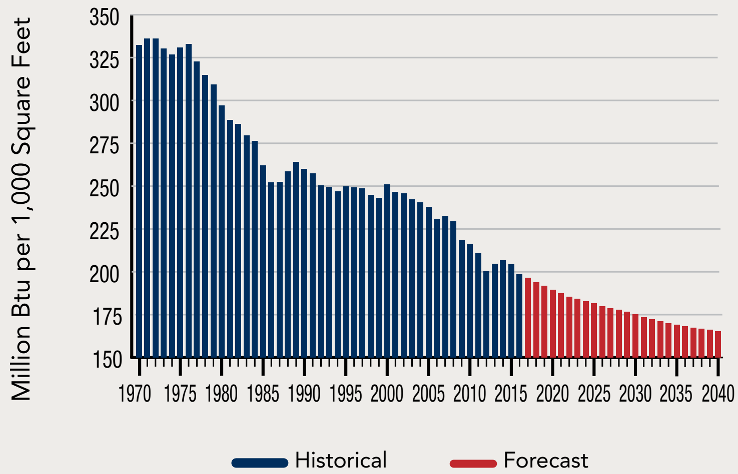
Importance

Indicates the degree to which commercial enterprises use energy efficiently.

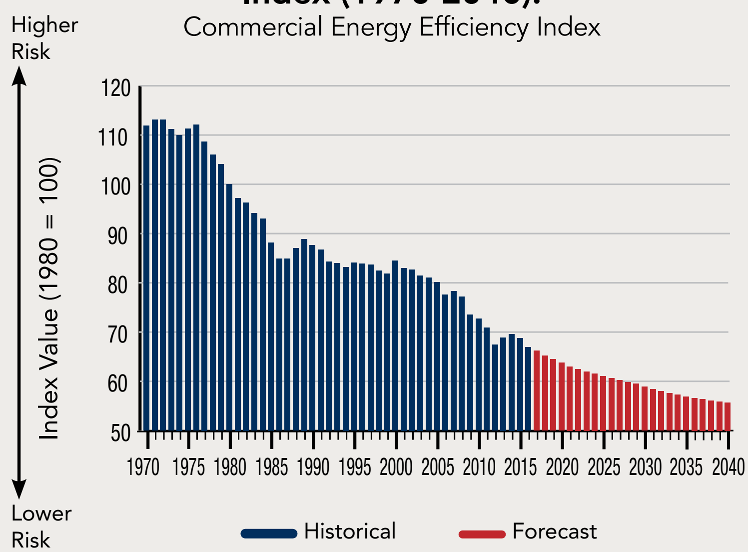
Category of Metric

Energy Use Intensity

Historical and Forecast Values (1970-2040):
Commercial Energy Efficiency



Index (1970-2040):
Commercial Energy Efficiency Index



Weighting and Average Historical Contribution of Metric to Energy Security Indexes (Percent):

	GEOPOLITICAL	ECONOMIC	RELIABILITY	ENVIRONMENTAL	TOTAL INDEX
Weight	N/A	3.0	N/A	4.0	1.7
Average Contribution	N/A	3.6	N/A	3.6	1.8

METRIC #24

Industrial Energy Efficiency

Definition

Trillion Btu of total Industrial energy consumed per unit of industrial production as measured by the Federal Reserve Bank's Industrial Production (IP) Index.

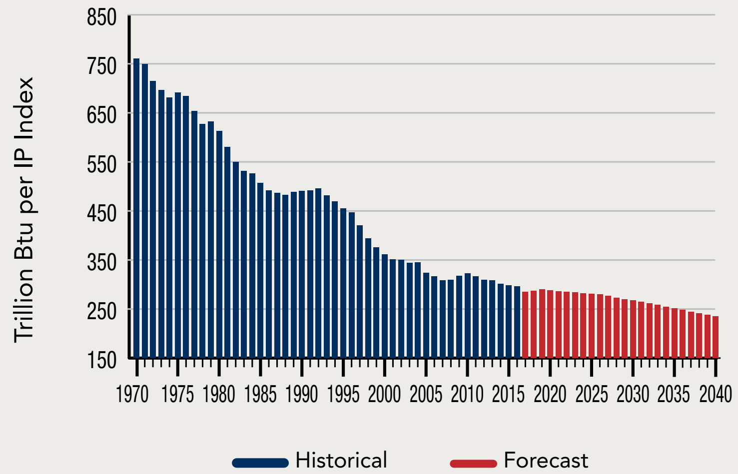
Importance

Indicates the degree to which the typical commercial enterprise uses energy efficiently.

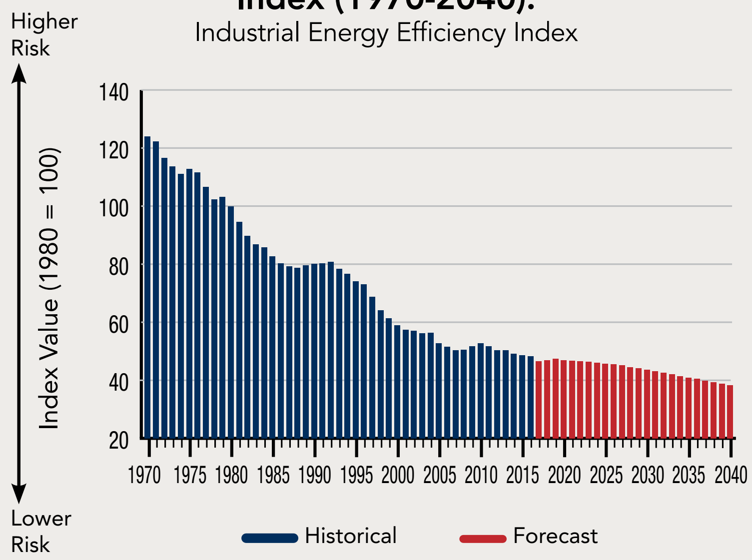
Category of Metric

Energy Use Intensity

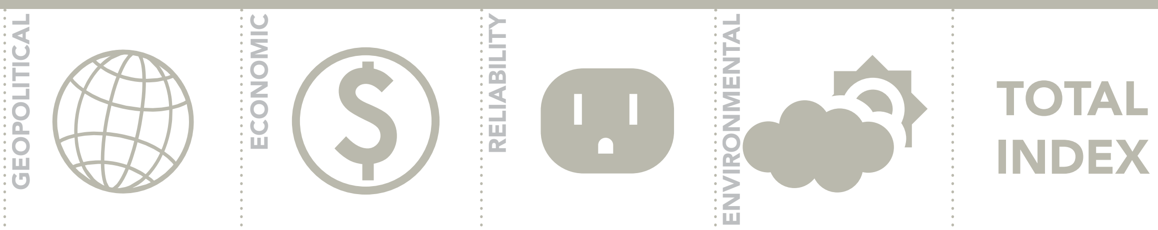
Historical and Forecast Values (1970-2040):
Industrial Energy Efficiency



Index (1970-2040):
Industrial Energy Efficiency Index



Weighting and Average Historical Contribution of Metric to Energy Security Indexes (Percent):



	GEOPOLITICAL	ECONOMIC	RELIABILITY	ENVIRONMENTAL	TOTAL INDEX
Weight	N/A	3.0	N/A	4.0	1.7
Average Contribution	N/A	3.1	N/A	3.1	1.5

METRIC #25

Electricity Capacity Diversity

Definition

Market share concentration index (HHI) of the primary categories of electric power generating capacity, adjusted for availability.

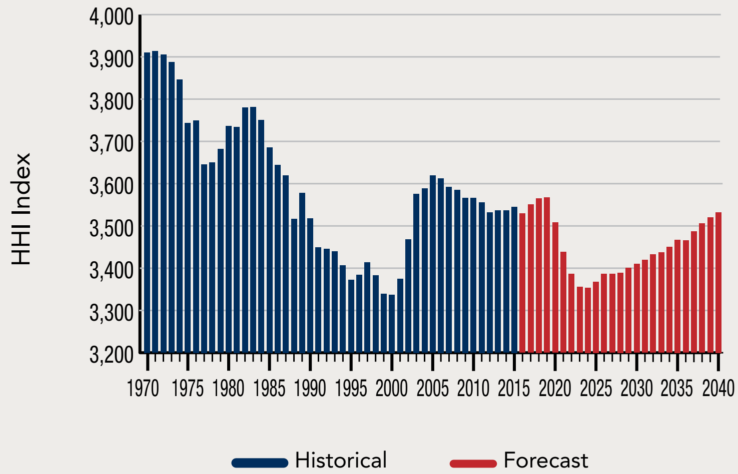
Importance

Indicates the flexibility of the power sector and its ability to dispatch electricity from a diverse range of sources.

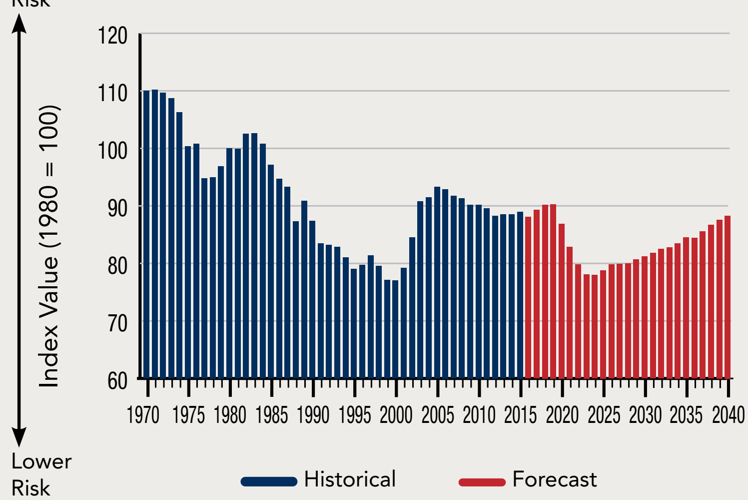
Category of Metric

Electric Power Sector

Historical and Forecast Values (1970-2040):
Electricity Capacity Diversity



Index (1970-2040):
Electricity Capacity Diversity Index



Weighting and Average Historical Contribution of Metric to Energy Security Indexes (Percent):

	GEOPOLITICAL	ECONOMIC	RELIABILITY	ENVIRONMENTAL	TOTAL INDEX
Weight	N/A	N/A	7.0	3.0	2.0
Average Contribution	N/A	N/A	7.2	2.9	2.2

METRIC #26

Electricity Capacity Margins

Definition

Unused available capability in the U.S. electric power system at peak load as a percentage of total peak capability.

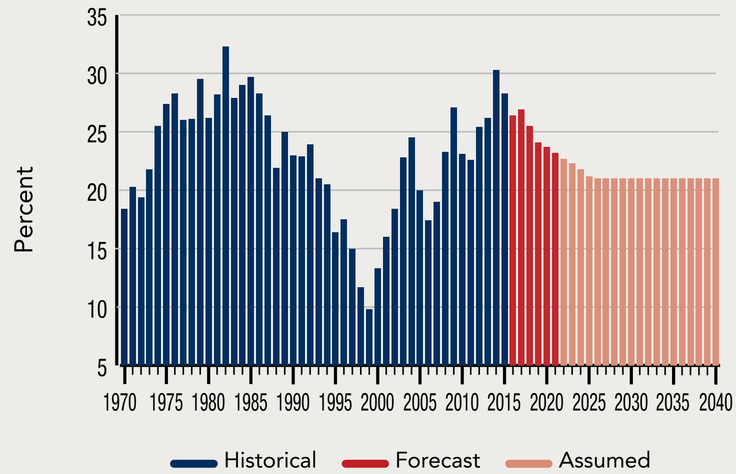
Importance

Indicates the ability of the power sector to respond to the disruption or temporary loss of some production capacity without an uneconomic overhang of excess capacity.

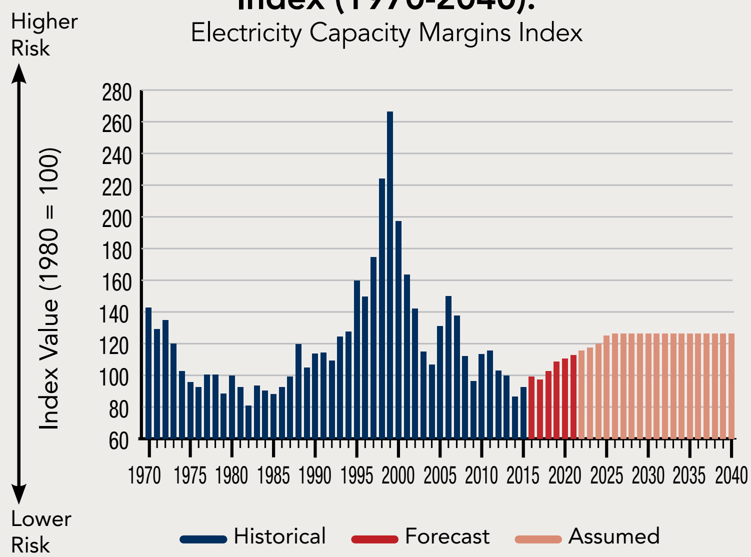
Category of Metric

Electric Power Sector

Historical and Forecast Values (1970-2040):
Electricity Capacity Margins



Index (1970-2040):
Electricity Capacity Margins Index



Weighting and Average Historical Contribution of Metric to Energy Security Indexes (Percent):

	GEOPOLITICAL	ECONOMIC	RELIABILITY	ENVIRONMENTAL	TOTAL INDEX
Weight	N/A	1.0	7.0	N/A	1.7
Average Contribution	N/A	1.7	9.5	N/A	2.4

METRIC #27

Electric Power Transmission Line Mileage

Definition

Circuit-miles of transmission lines per gigawatt of peak summer demand.

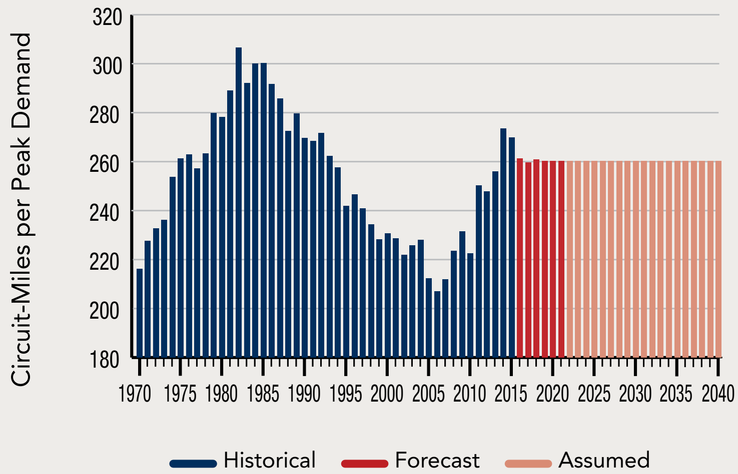
Importance

Indicates the integration of the transmission system and its ability to meet increasing demand reliably.

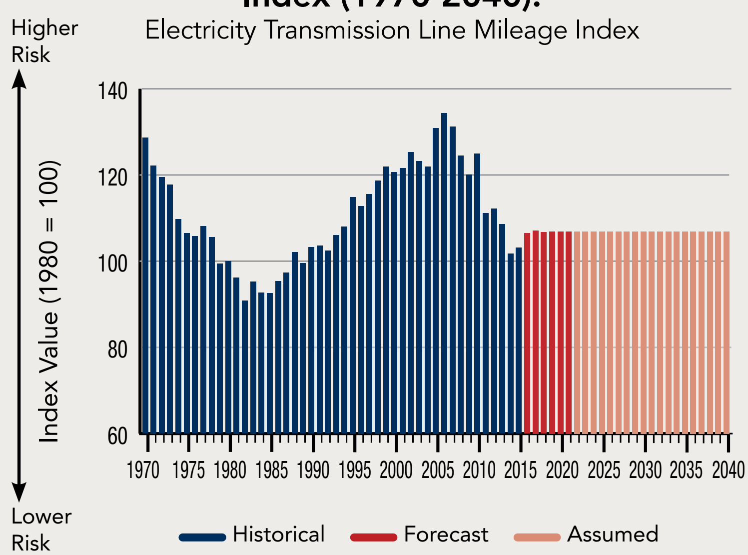
Category of Metric

Electric Power Sector

Historical and Forecast Values (1970-2040):
Electricity Transmission Line Mileage



Index (1970-2040):
Electricity Transmission Line Mileage Index



Weighting and Average Historical Contribution of Metric to Energy Security Indexes (Percent):

	GEOPOLITICAL	ECONOMIC	RELIABILITY	ENVIRONMENTAL	TOTAL INDEX
Weight	N/A	1.0	8.0	3.0	2.5
Average Contribution	N/A	1.5	10.0	3.5	3.3

METRIC #28

Motor Vehicle Average MPG

Definition

Average miles per gallon of passenger car fleet.

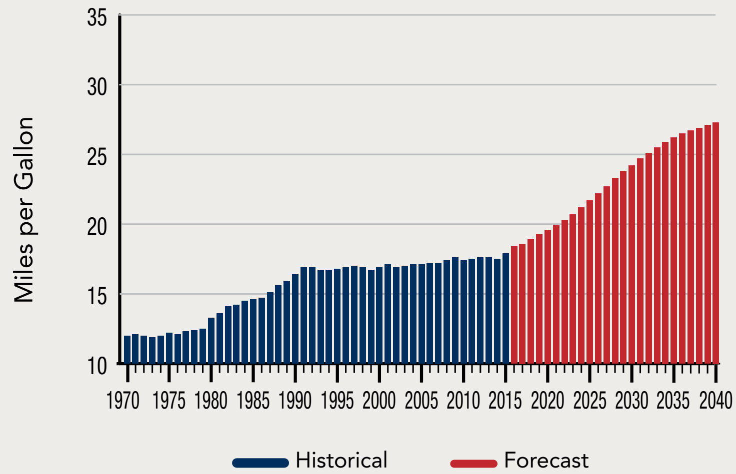
Importance

Indicates the degree to which the typical light vehicle uses energy efficiently (gasoline consumption accounts for about 16% of total U.S. energy demand).

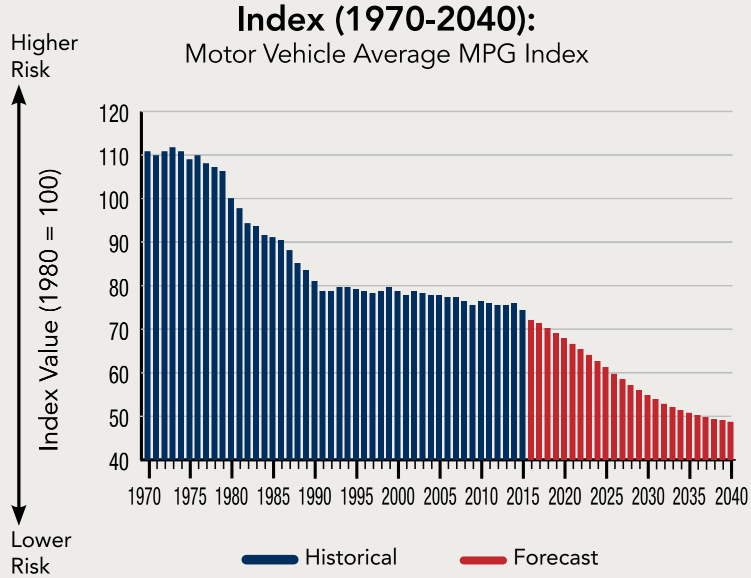
Category of Metric

Transportation Sector

Historical and Forecast Values (1970-2040):
Motor Vehicle Average MPG



Index (1970-2040):
Motor Vehicle Average MPG Index



Weighting and Average Historical Contribution of Metric to Energy Security Indexes (Percent):

	GEOPOLITICAL	ECONOMIC	RELIABILITY	ENVIRONMENTAL	TOTAL INDEX
Weight	3.0	4.0	N/A	12.0	4.5
Average Contribution	3.1	4.7	N/A	10.8	4.6

METRIC #29

Vehicle-Miles Traveled per GDP

Definition

Vehicle-miles traveled (VMT) per $1,000 of GDP in real (2015) dollars.

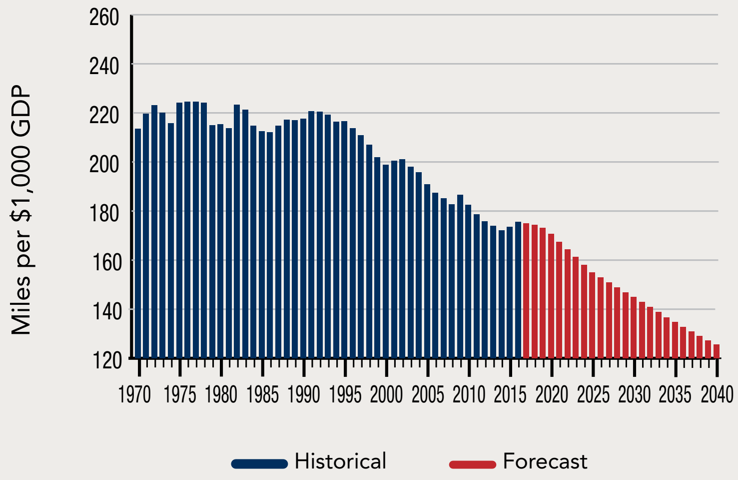
Importance

Indicates the importance of travel as a component of the economy.

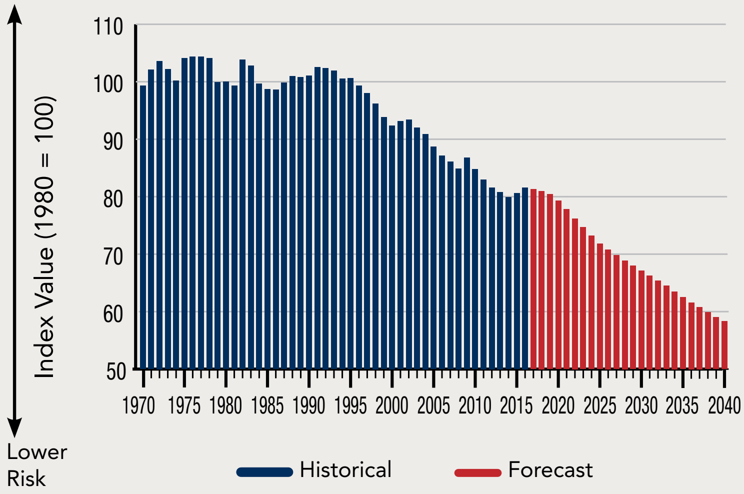
Category of Metric

Transportation Sector

Historical and Forecast Values (1970-2040):
Transportation Vehicle-Miles Traveled per GDP



Index (1970-2040):
Transportation Vehicle-Miles Traveled per GDP Index



Weighting and Average Historical Contribution of Metric to Energy Security Indexes (Percent):

	GEOPOLITICAL	ECONOMIC	RELIABILITY	ENVIRONMENTAL	TOTAL INDEX
Weight	2.0	2.0	N/A	8.0	2.8
Average Contribution	2.3	2.6	N/A	7.9	3.2

METRIC #30

Transportation Non-Petroleum Fuel Use

Definition

Non-petroleum fuels as a percentage of total U.S. transportation energy consumption.

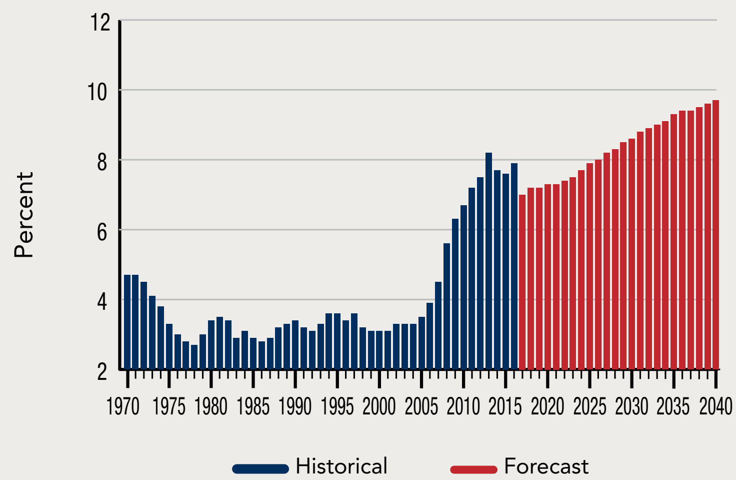
Importance

Indicates the diversity and flexibility of the fuel mix for transportation.

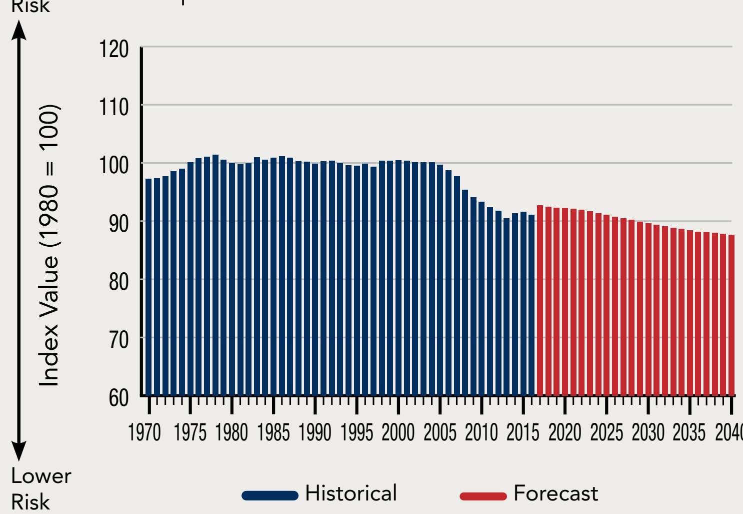
Category of Metric

Transportation Sector

Historical and Forecast Values (1970-2040):
Transportation Non-Petroleum Fuel Use



Index (1970-2040):
Transportation Non-Petroleum Fuel Use Index



Weighting and Average Historical Contribution of Metric to Energy Security Indexes (Percent):

	GEOPOLITICAL	ECONOMIC	RELIABILITY	ENVIRONMENTAL	TOTAL INDEX
Weight	3.0	N/A	4.0	4.0	2.5
Average Contribution	3.5	N/A	4.4	4.1	2.9

METRIC #31

Energy-Related Carbon Dioxide Emissions

Definition

Total U.S. energy-related CO_2 emissions in million metric tons.

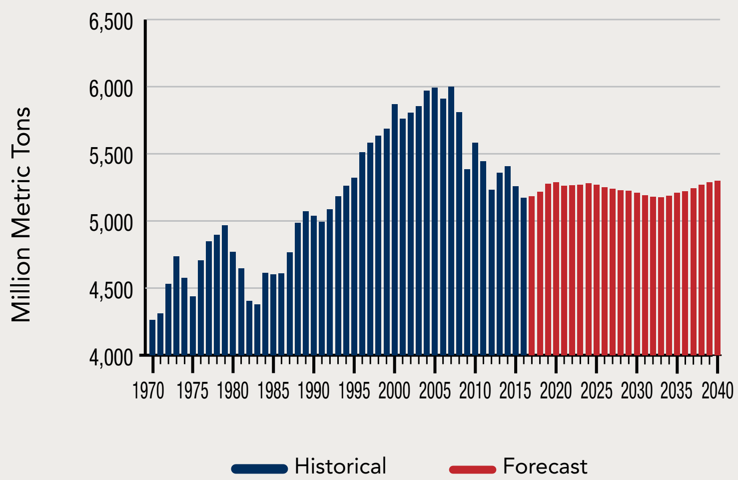
Importance

Indicates the exposure of the U.S. economy to domestic and international emissions reduction mandates.

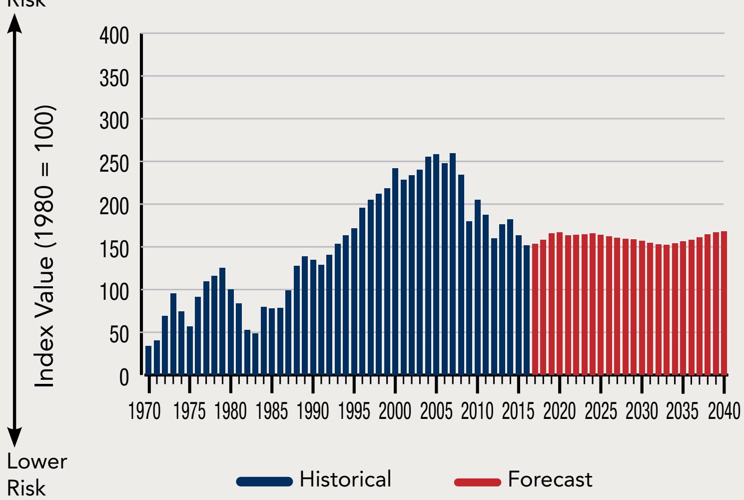
Category of Metric

Environmental

Historical and Forecast Values (1970-2040):
Energy-Related Carbon Dioxide Emissions



Index (1970-2040):
Energy-Related Carbon Dioxide Emissions Index



Weighting and Average Historical Contribution of Metric to Energy Security Indexes (Percent):

	GEOPOLITICAL	ECONOMIC	RELIABILITY	ENVIRONMENTAL	TOTAL INDEX
Weight	2.0	N/A	N/A	7.0	2.0
Average Contribution	3.6	N/A	N/A	10.9	3.5

METRIC #32

Energy-Related Carbon Dioxide Emissions per Capita

Definition

Million metric tons of CO_2 emissions from energy per capita.

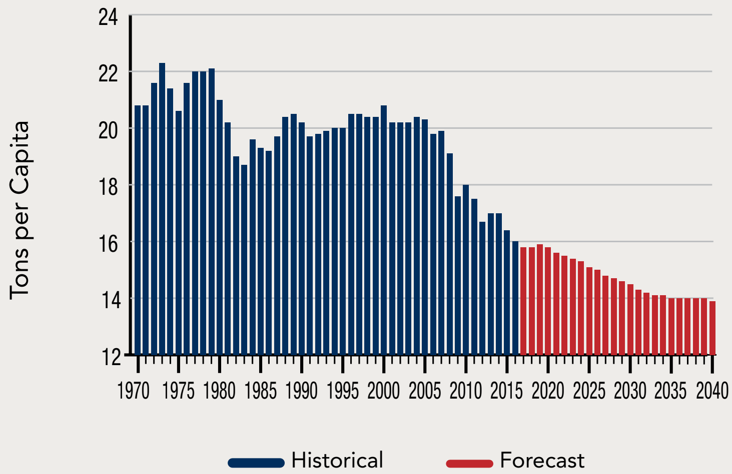
Importance

Indicates the joint effect of the amount of energy used per capita in the U.S. and the carbon intensity of that energy use.

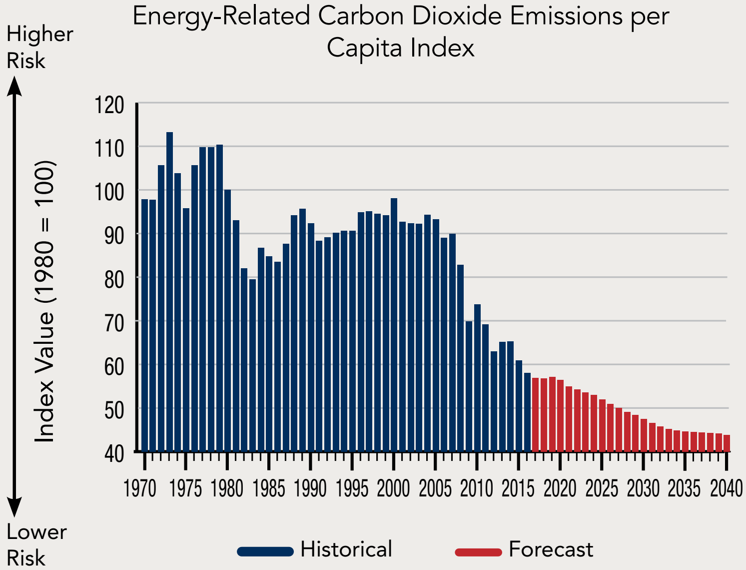
Category of Metric

Environmental

Historical and Forecast Values (1970-2040):
Energy-Related Carbon Dioxide Emissions per Capita



Index (1970-2040):
Energy-Related Carbon Dioxide Emissions per Capita Index



Weighting and Average Historical Contribution of Metric to Energy Security Indexes (Percent):

	GEOPOLITICAL	ECONOMIC	RELIABILITY	ENVIRONMENTAL	TOTAL INDEX
Weight	2.0	N/A	N/A	5.0	1.6
Average Contribution	2.2	N/A	N/A	4.6	1.7

METRIC #33

Energy-Related Carbon Dioxide Emissions Intensity

Definition

Metric tons of CO_2 from energy per $1,000 of GDP in real (2015) dollars.

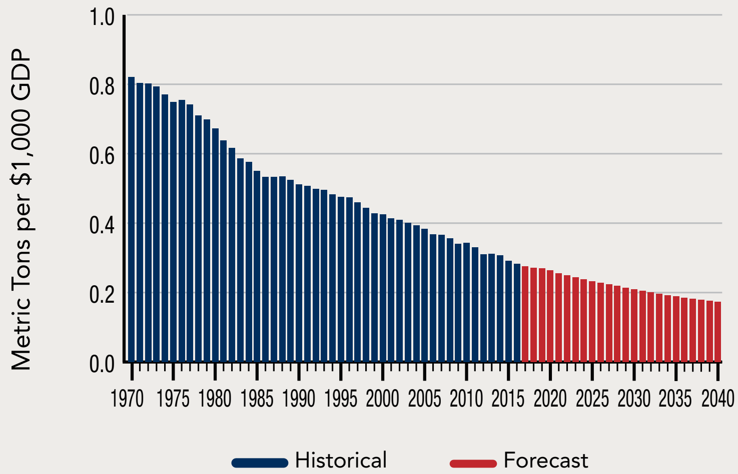
Importance

Indicates the importance of carbon-based fuels as a component of the economy.

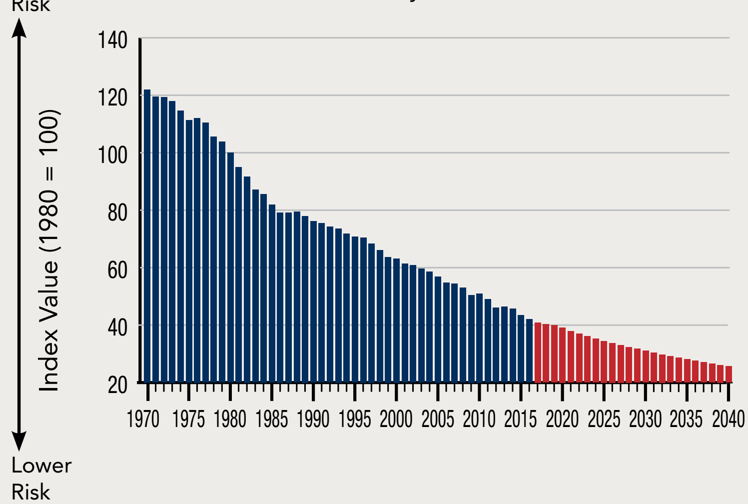
Category of Metric

Environmental

Historical and Forecast Values (1970-2040):
Energy-Related Carbon Dioxide Emissions Intensity



Index (1970-2040):
Energy-Related Carbon Dioxide Emissions Intensity Index



Weighting and Average Historical Contribution of Metric to Energy Security Indexes (Percent):

	GEOPOLITICAL	ECONOMIC	RELIABILITY	ENVIRONMENTAL	TOTAL INDEX
Weight	2.0	N/A	N/A	5.0	1.6
Average Contribution	1.8	N/A	N/A	3.9	1.4

METRIC #34

Electricity Non-CO_2 Generation Share

Definition

Percentage of total electric power generation contributed by renewables, hydroelectric, nuclear, and fossil-fired plants operating with carbon capture and storage (CCS) technology.

Importance

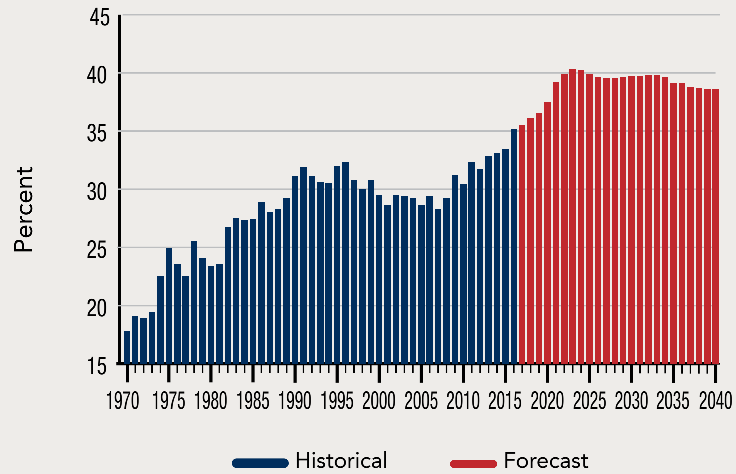
Indicates the degree to which the power sector is diversifying and employing non-CO_2 emitting generation.

Category of Metric

Environmental

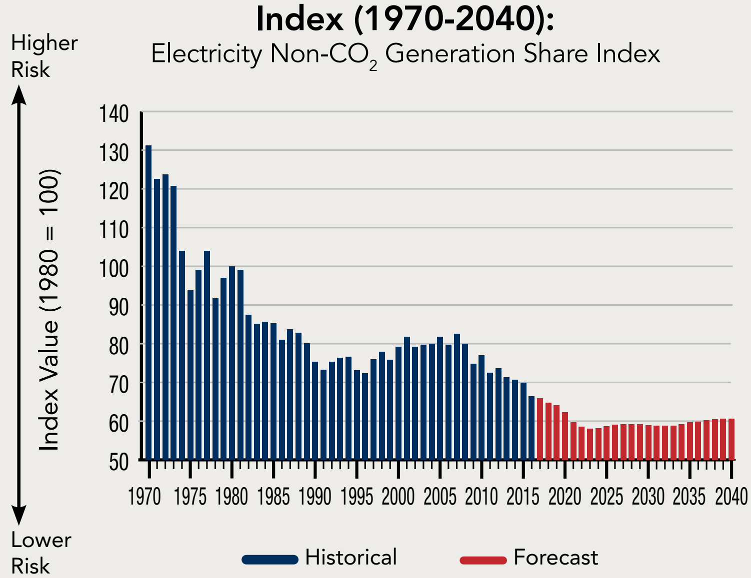
Historical and Forecast Values (1970-2040):

Electricity Non-CO_2 Generation Share



Index (1970-2040):

Electricity Non-CO_2 Generation Share Index



Weighting and Average Historical Contribution of Metric to Energy Security Indexes (Percent):

	GEOPOLITICAL	ECONOMIC	RELIABILITY	ENVIRONMENTAL	TOTAL INDEX
Weight	N/A	N/A	5.0	7.0	2.4
Average Contribution	N/A	N/A	4.8	6.2	2.4

Industrial Energy R&D Expenditures

Definition

Dollars of industrial energy-related R&D (non-Federal) per $1,000 of GDP in real (2015) dollars.

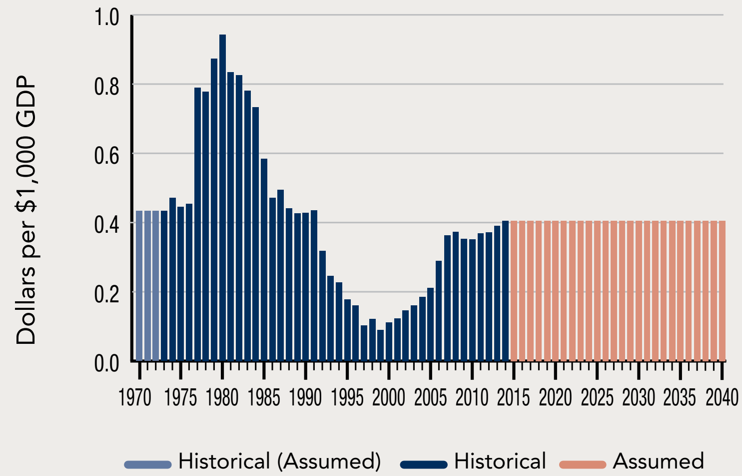
Importance

Indicates private industry engagement in improving performance and enabling new technological breakthroughs.

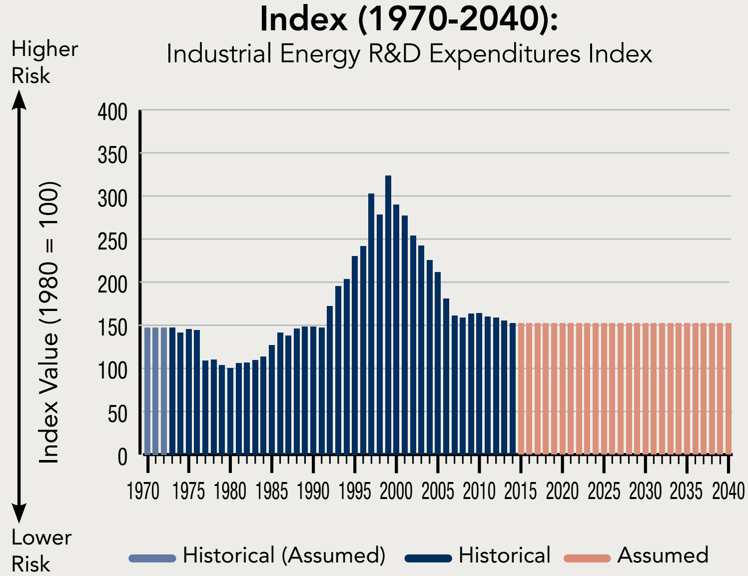
Category of Metric

Research & Development

Historical and Forecast Values (1970-2040):
Industrial Energy R&D Expenditures



Index (1970-2040):
Industrial Energy R&D Expenditures Index



Weighting and Average Historical Contribution of Metric to Energy Security Indexes (Percent):

	GEOPOLITICAL	ECONOMIC	RELIABILITY	ENVIRONMENTAL	TOTAL INDEX
Weight	N/A	1.0	2.0	2.0	1.1
Average Contribution	N/A	2.4	3.9	3.6	2.3

METRIC #36

Federal Energy & Science R&D Expenditures

Definition

Dollars of federal energy and science R&D per $1,000 of GDP in real (2015) dollars.

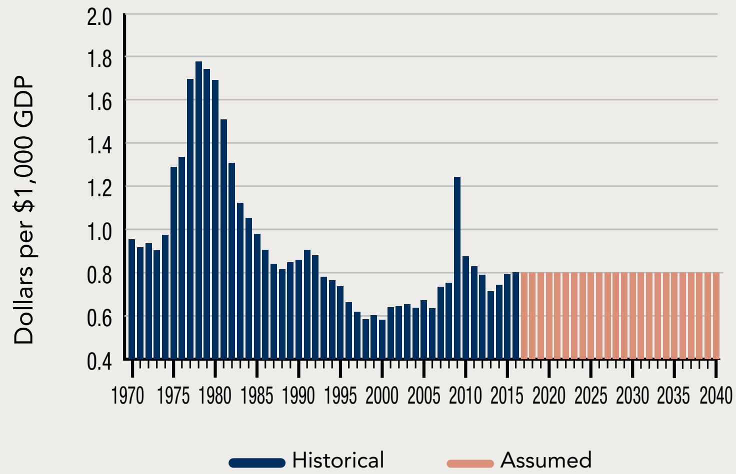
Importance

Indicates prospects for new scientific and technological breakthroughs through federally-supported public-private research.

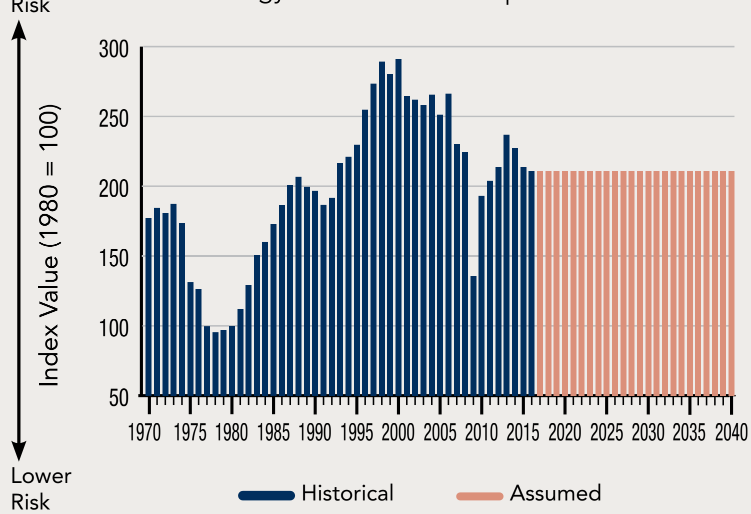
Category of Metric

Research & Development

Historical and Forecast Values (1970-2040):
Federal Energy & Science R&D Expenditures



Index (1970-2040):
Federal Energy & Science R&D Expenditures Index



Weighting and Average Historical Contribution of Metric to Energy Security Indexes (Percent):

	GEOPOLITICAL	ECONOMIC	RELIABILITY	ENVIRONMENTAL	TOTAL INDEX
Weight	N/A	1.0	2.0	2.0	1.1
Average Contribution	N/A	2.7	4.5	4.1	2.6

METRIC #37

Science & Engineering Degrees

Definition

Number of science and engineering degrees, per billion dollars of GDP in real (2015) dollars.

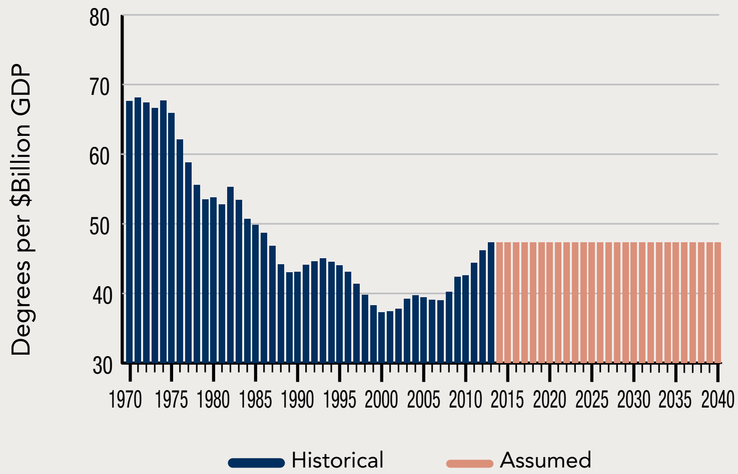
Importance

Indicates the degree to which human capital in high-tech science, technology, engineering, and mathematics fields will be available to the economy.

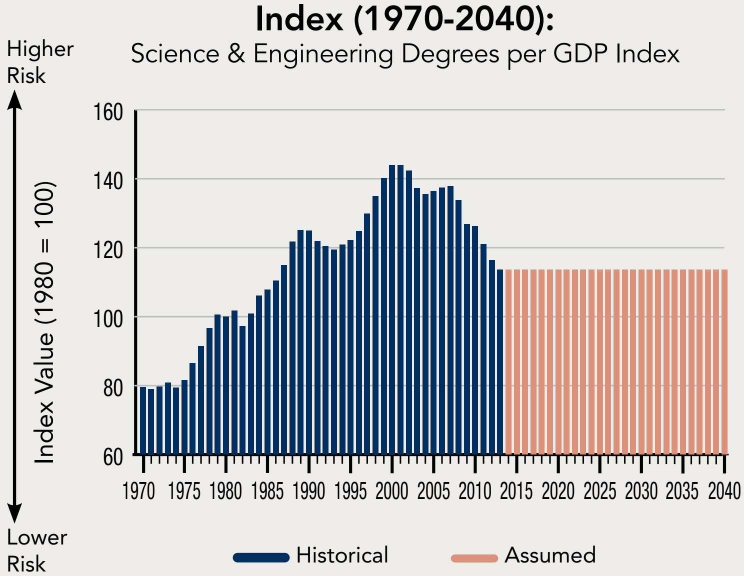
Category of Metric

Research & Development

Historical and Forecast Values (1970-2040):
Science & Engineering Degrees per GDP



Index (1970-2040):
Science & Engineering Degrees per GDP Index



Weighting and Average Historical Contribution of Metric to Energy Security Indexes (Percent):

	GEOPOLITICAL	ECONOMIC	RELIABILITY	ENVIRONMENTAL	TOTAL INDEX
Weight	N/A	1.0	2.0	2.0	1.1
Average Contribution	N/A	1.5	2.6	2.4	1.5

Summary Table 1: Energy Security Metrics (Values)

1970-1976

#	Metric	Units of Measurement	1970	1971	1972	1973	1974	1975	1976
Global Fuels Metrics									
1	Security of World Oil Reserves	reserves, freedom & diversity-weighted	122.6	114.7	113.0	105.9	104.3	110.6	114.3
2	Security of World Oil Production	production, freedom & diversity-weighted	90.9	92.3	94.1	95.4	101.1	109.7	114.7
3	Security of World Natural Gas Reserves	reserves, freedom & diversity-weighted	57.5	67.4	74.0	78.2	83.9	101.7	106.3
4	Security of World Natural Gas Production	production, freedom & diversity-weighted	69.8	69.1	67.7	67.5	71.2	84.9	89.9
5	Security of World Coal Reserves	reserves, freedom & diversity-weighted	98.5	98.5	98.5	98.4	97.4	106.9	108.6
6	Security of World Coal Production	production, freedom & diversity-weighted	92.0	94.4	96.4	97.1	98.5	105.6	105.5
Fuel Import Metrics									
7	Security of U.S. Petroleum Imports	oil imports, freedom & diversity-weighted	19.9	22.8	26.3	33.3	36.1	39.8	46.4
8	Security of U.S. Natural Gas Imports	gas imports, freedom & diversity-weighted	3.5	3.6	3.5	3.3	3.3	4.2	4.4
9	Oil & Natural Gas Import Expenditures	billions of 2015$	$15.8	$18.9	$22.4	$54.8	$102.2	$95.6	$119.4
10	Oil & Natural Gas Import Expenditures per GDP	percent	0.3%	0.4%	0.4%	0.9%	1.7%	1.6%	1.9%
Energy Expenditure Metrics									
11	Energy Expenditures per GDP	$ per $1,000 GDP (2015$)	$77.03	$77.10	$76.47	$78.33	$99.02	$101.75	$103.28
12	Energy Expenditures per Household	2015$/Household	$6,287	$6,356	$6,451	$6,788	$8,330	$8,381	$8,782
13	Retail Electricity Prices	cents/kWh (2015$)	8.2¢	8.3¢	8.4¢	8.4¢	9.6¢	10.2¢	10.3¢
14	Crude Oil Price	2015$/bbl	$13.11	$13.36	$13.01	$24.45	$46.98	$44.06	$45.39
Price & Market Volatility Metrics									
15	Crude Oil Price Volatility	$ change in year-to-year price	$0.51	$0.44	$0.20	$4.01	$11.44	$12.30	$8.93
16	Energy Expenditure Volatility	average yearly price change/$1,000 GDP (2015$)	$2.89	$3.12	$2.86	$3.76	$9.78	$9.62	$9.47
17	World Oil Refinery Utilization	percent utilization	94.1%	90.4%	88.8%	92.7%	84.9%	78.3%	78.9%
18	Petroleum Stock Levels	average days supply	69	69	58	58	64	69	63
Energy Use Intensity Metrics									
19	Energy Consumption per Capita	million Btu/Person	330.8	333.6	346.3	357.2	345.9	333.2	348.5
20	Energy Intensity	million Btu/$1,000 GDP (2015$)	13.1	12.9	12.9	12.7	12.5	12.1	12.2
21	Petroleum Intensity	million Btu/real $1,000 GDP (2015$)	5.68	5.70	5.83	5.84	5.64	5.53	5.63
22	Household Energy Efficiency	million Btu/household	216.3	218.9	221.9	216.4	207.7	206.0	209.9
23	Commercial Energy Efficiency	million Btu/1,000 sq.ft.	332.4	336.0	336.0	330.2	326.6	330.7	332.9
24	Industrial Energy Efficiency	trillion Btu/IP Index	761	749	715	697	681	691	684
Electric Power Sector Metrics									
25	Electricity Capacity Diversity	HHI Index	3,910	3,913	3,905	3,887	3,846	3,743	3,750
26	Electricity Capacity Margins	percent	18.4%	20.3%	19.4%	21.8%	25.5%	27.4%	28.3%
27	Electricity Transmission Line Mileage	circuit-miles/peak GW	216	228	233	236	254	261	263
Transportation Sector Metrics									
28	Motor Vehicle Average MPG	miles per gallon	12.0	12.1	12.0	11.9	12.0	12.2	12.1
29	Transportation VMT per $ GDP	vehicle miles traveled/$1,000 GDP (2015$)	214	220	223	220	216	224	225
30	Transportation Non-Petroleum Fuels	percent	4.7%	4.7%	4.5%	4.1%	3.8%	3.3%	3.0%
Environmental Metrics									
31	Energy-Related CO_2 Emissions	$MMTCO_2$	4,261	4,312	4,532	4,735	4,575	4,439	4,707
32	Energy-Related CO_2 Emissions per Capita	metric tons CO_2/Person	20.8	20.8	21.6	22.3	21.4	20.6	21.6
33	Energy-Related CO_2 Emissions Intensity	metric tons CO_2/$1,000 GDP (2015$)	0.82	0.80	0.80	0.79	0.77	0.75	0.75
34	Electricity Non-CO_2 Generation Share	percent of total generation	17.8%	19.1%	18.9%	19.4%	22.5%	24.9%	23.6%
Research and Development Metrics									
35	Industrial Energy R&D Expenditures	energy R&D $/$1,000 GDP (2015$)	$0.43	$0.43	$0.43	$0.43	$0.47	$0.45	$0.45
36	Federal Energy & Science R&D Expenditures	R&D $/$1,000 GDP (2015$)	$0.95	$0.92	$0.93	$0.90	$0.97	$1.29	$1.34
37	Science & Engineering Degrees	# degrees/$billion GDP (2015$)	67.6	68.1	67.4	66.6	67.7	65.9	62.1

Summary Table 1: Energy Security Metrics (Values)

1977-1994

1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994
107.2	97.5	102.1	100.0	96.5	93.4	98.5	104.4	104.0	110.8	109.8	99.3	100.5	124.1	119.2	127.0	133.6	132.2
107.8	97.3	94.6	100.0	100.2	93.9	90.5	93.4	90.6	94.0	88.8	79.9	82.0	77.2	75.6	73.1	77.7	75.7
113.6	100.1	98.1	100.0	106.1	120.4	122.4	141.8	136.2	136.7	124.3	94.6	101.1	86.6	88.4	77.2	86.0	87.4
91.8	87.4	88.5	100.0	103.4	112.3	120.0	138.0	146.5	155.8	142.3	117.6	117.1	91.2	88.1	68.9	72.3	68.8
99.1	92.7	92.4	100.0	102.1	102.1	100.8	107.6	107.5	107.3	99.6	86.4	86.1	68.8	72.2	56.7	61.1	57.1
96.4	93.5	89.7	100.0	99.7	100.7	101.7	108.4	107.5	107.2	100.3	92.7	99.5	84.3	81.6	75.3	83.2	83.6
49.5	40.8	39.8	37.3	34.5	26.8	25.8	28.0	24.4	30.8	30.6	29.1	32.0	30.2	28.1	27.2	31.1	30.8
4.8	4.2	5.3	4.7	4.4	5.4	5.8	5.7	6.9	5.9	6.9	6.9	6.7	5.8	6.1	5.1	5.9	6.1
$148.3	$130.3	$181.9	$213.6	$180.8	$125.8	$106.2	$110.6	$92.2	$55.5	$76.8	$67.8	$86.1	$106.9	$82.2	$82.2	$79.8	$77.2
2.3%	1.9%	2.6%	3.0%	2.5%	1.8%	1.4%	1.4%	1.1%	0.6%	0.9%	0.7%	0.9%	1.1%	0.8%	0.8%	0.8%	0.7%
$105.70	$101.54	$113.05	$130.78	$133.26	$127.50	$114.79	$107.73	$100.84	$83.68	$81.64	$78.35	$77.60	$79.38	$76.52	$72.92	$71.56	$69.08
$9,231	$9,144	$10,290	$11,652	$11,717	$10,873	$10,141	$9,998	$9,585	$8,116	$8,069	$7,937	$8,022	$8,298	$7,907	$7,711	$7,670	$7,626
10.6¢	10.8¢	10.8¢	11.7¢	12.5¢	13.0¢	12.9¢	12.4¢	12.4¢	12.1¢	11.7¢	11.3¢	11.0¢	10.8¢	10.8¢	10.6¢	10.6¢	10.3¢
$46.57	$43.68	$60.94	$90.15	$89.54	$76.80	$64.17	$61.50	$55.79	$26.50	$34.04	$26.46	$31.14	$39.14	$31.95	$30.11	$25.90	$23.64
$1.81	$1.80	$7.11	$16.45	$15.70	$14.19	$8.66	$9.35	$7.00	$12.56	$14.18	$14.80	$6.60	$6.75	$6.62	$5.68	$4.41	$2.77
$5.24	$4.70	$7.47	$11.16	$12.37	$10.53	$6.90	$4.92	$3.17	$5.61	$5.46	$4.50	$0.91	$1.74	$2.72	$2.31	$1.43	$0.59
76.9%	77.6%	78.7%	74.4%	71.4%	70.8%	72.6%	73.9%	74.7%	77.4%	77.5%	80.5%	81.3%	81.7%	81.0%	81.3%	81.1%	81.0%
71	68	72	82	92	93	95	99	97	98	96	92	91	95	97	93	96	93
354.0	359.2	359.3	343.6	331.7	315.5	312.1	325.0	321.1	319.2	326.3	338.3	343.5	338.4	333.8	334.4	336.1	338.6
11.9	11.6	11.4	11.0	10.5	10.2	9.8	9.6	9.1	8.9	8.8	8.9	8.8	8.6	8.6	8.4	8.3	8.2
5.68	5.51	5.22	4.82	4.39	4.23	4.02	3.88	3.70	3.72	3.67	3.67	3.54	3.41	3.34	3.29	3.22	3.17
209.4	210.7	202.3	197.8	184.3	185.5	182.4	184.8	182.5	179.2	179.7	186.2	190.2	179.8	182.9	180.0	186.4	183.5
322.8	314.8	309.2	297.0	288.6	286.1	279.6	276.2	261.9	252.1	252.3	258.5	264.0	260.1	257.4	250.4	249.5	247.0
653	627	632	613	580	550	532	526	507	492	486	482	488	491	492	496	481	470
3,646	3,650	3,682	3,736	3,734	3,780	3,781	3,751	3,686	3,645	3,620	3,516	3,578	3,518	3,449	3,445	3,440	3,406
26.0%	26.1%	29.5%	26.2%	28.2%	32.3%	27.9%	29.0%	29.7%	28.3%	26.4%	21.9%	25.0%	23.0%	22.9%	23.9%	21.0%	20.5%
257	263	280	278	289	307	292	300	300	292	286	273	280	270	269	272	262	258
12.3	12.4	12.5	13.3	13.6	14.1	14.2	14.5	14.6	14.7	15.1	15.6	15.9	16.4	16.9	16.9	16.7	16.7
225	224	215	215	214	223	221	215	212	212	215	217	217	218	221	220	219	216
2.8%	2.7%	3.0%	3.4%	3.5%	3.4%	2.9%	3.1%	2.9%	2.8%	2.9%	3.2%	3.3%	3.4%	3.2%	3.1%	3.3%	3.6%
4,847	4,897	4,966	4,771	4,646	4,405	4,377	4,614	4,600	4,608	4,766	4,984	5,070	5,039	4,993	5,087	5,185	5,261
22.0	22.0	22.1	21.0	20.2	19.0	18.7	19.6	19.3	19.2	19.7	20.4	20.5	20.2	19.7	19.8	19.9	20.0
0.74	0.71	0.70	0.67	0.64	0.62	0.59	0.58	0.55	0.53	0.53	0.53	0.52	0.51	0.51	0.50	0.50	0.48
22.5%	25.5%	24.1%	23.4%	23.6%	26.7%	27.5%	27.3%	27.4%	28.9%	28.0%	28.3%	29.2%	31.1%	31.9%	31.1%	30.6%	30.5%
$0.79	$0.78	$0.87	$0.94	$0.83	$0.83	$0.78	$0.73	$0.58	$0.47	$0.49	$0.44	$0.43	$0.43	$0.44	$0.32	$0.25	$0.23
$1.70	$1.78	$1.74	$1.69	$1.51	$1.31	$1.12	$1.05	$0.98	$0.91	$0.84	$0.82	$0.85	$0.86	$0.91	$0.88	$0.78	$0.76
58.8	55.6	53.5	53.8	52.8	55.3	53.4	50.7	49.8	48.7	46.8	44.2	43.0	43.1	44.1	44.6	45.0	44.5

Summary Table 1: Energy Security Metrics (Values)

1995-2001

#	Metric	Units of Measurement	1995	1996	1997	1998	1999	2000	2001
Global Fuels Metrics									
1	Security of World Oil Reserves	reserves, freedom & diversity-weighted	131.3	127.5	128.6	125.3	124.5	127.7	126.9
2	Security of World Oil Production	production, freedom & diversity-weighted	74.1	70.0	70.2	68.3	68.1	68.5	69.0
3	Security of World Natural Gas Reserves	reserves, freedom & diversity-weighted	87.7	87.4	87.2	88.8	93.0	99.5	98.8
4	Security of World Natural Gas Production	production, freedom & diversity-weighted	66.3	61.3	61.1	63.8	68.3	71.2	72.4
5	Security of World Coal Reserves	reserves, freedom & diversity-weighted	55.4	52.0	50.7	49.8	52.8	58.2	58.1
6	Security of World Coal Production	production, freedom & diversity-weighted	83.2	83.3	79.9	70.8	72.0	77.4	79.0
Fuel Import Metrics									
7	Security of U.S. Petroleum Imports	oil imports, freedom & diversity-weighted	29.4	28.7	30.4	30.9	30.1	31.6	33.4
8	Security of U.S. Natural Gas Imports	gas imports, freedom & diversity-weighted	6.0	5.4	5.4	6.1	7.4	7.5	8.1
9	Oil & Natural Gas Import Expenditures	billions of 2015$	$78.4	$101.6	$100.6	$72.7	$100.2	$167.9	$147.6
10	Oil & Natural Gas Import Expenditures per GDP	percent	0.7%	0.9%	0.8%	0.6%	0.8%	1.2%	1.1%
Energy Expenditure Metrics									
11	Energy Expenditures per GDP	$ per $1,000 GDP (2015$)	$67.15	$69.17	$65.98	$57.90	$57.83	$66.87	$65.55
12	Energy Expenditures per Household	2015$/Household	$7,516	$7,957	$7,836	$7,090	$7,314	$8,738	$8,545
13	Retail Electricity Prices	cents/kWh (2015$)	10.1¢	9.8¢	9.7¢	9.4¢	9.1¢	9.1¢	9.6¢
14	Crude Oil Price	2015$/bbl	$24.86	$29.60	$26.95	$17.80	$24.59	$38.50	$32.12
Price & Market Volatility Metrics									
15	Crude Oil Price Volatility	$ change in year-to-year price	$2.56	$2.74	$2.87	$5.52	$6.20	$9.95	$9.02
16	Energy Expenditure Volatility	average yearly price change/$1,000 GDP (2015$)	$0.31	$1.62	$1.53	$3.19	$2.58	$6.19	$4.76
17	World Oil Refinery Utilization	percent utilization	81.7%	82.5%	84.2%	83.1%	81.7%	82.9%	82.9%
18	Petroleum Stock Levels	average days supply	88	82	84	87	76	74	81
Energy Use Intensity Metrics									
19	Energy Consumption per Capita	million Btu/Person	341.9	349.0	347.0	344.4	346.4	350.2	337.5
20	Energy Intensity	million Btu/$1,000 GDP (2015$)	8.1	8.1	7.8	7.5	7.3	7.2	6.9
21	Petroleum Intensity	million Btu/real $1,000 GDP (2015$)	3.08	3.07	2.98	2.90	2.85	2.77	2.74
22	Household Energy Efficiency	million Btu/household	185.2	193.1	185.5	183.1	186.4	193.2	187.2
23	Commercial Energy Efficiency	million Btu/1,000 sq.ft.	249.9	249.1	248.7	244.9	243.2	251.0	246.6
24	Industrial Energy Efficiency	trillion Btu/IP Index	455	447	421	393	376	361	351
Electric Power Sector Metrics									
25	Electricity Capacity Diversity	HHI Index	3,372	3,384	3,414	3,383	3,339	3,337	3,374
26	Electricity Capacity Margins	percent	16.4%	17.5%	15.0%	11.7%	9.8%	13.3%	16.0%
27	Electricity Transmission Line Mileage	circuit-miles/peak GW	242	247	241	234	228	231	229
Transportation Sector Metrics									
28	Motor Vehicle Average MPG	miles per gallon	16.8	16.9	17.0	16.9	16.7	16.9	17.1
29	Transportation VMT per $ GDP	vehicle miles traveled/$1,000 GDP (2015$)	216	214	211	207	202	199	200
30	Transportation Non-Petroleum Fuels	percent	3.6%	3.4%	3.6%	3.2%	3.1%	3.1%	3.1%
Environmental Metrics									
31	Energy-Related CO_2 Emissions	$MMTCO_2$	5,323	5,510	5,584	5,635	5,688	5,868	5,761
32	Energy-Related CO_2 Emissions per Capita	metric tons CO_2/Person	20.0	20.5	20.5	20.4	20.4	20.8	20.2
33	Energy-Related CO_2 Emissions Intensity	metric tons CO_2/$1,000 GDP (2015$)	0.48	0.47	0.46	0.44	0.43	0.42	0.41
34	Electricity Non-CO_2 Generation Share	percent of total generation	32.0%	32.3%	30.8%	30.0%	30.8%	29.5%	28.6%
Research and Development Metrics									
35	Industrial Energy R&D Expenditures	energy R&D $/$1,000 GDP (2015$)	$0.18	$0.16	$0.10	$0.12	$0.09	$0.11	$0.12
36	Federal Energy & Science R&D Expenditures	R&D $/$1,000 GDP (2015$)	$0.74	$0.66	$0.62	$0.58	$0.60	$0.58	$0.64
37	Science & Engineering Degrees	# degrees/$billion GDP (2015$)	44.0	43.1	41.4	39.8	38.3	37.3	37.4

Summary Table 1: Energy Security Metrics (Values)

2002-2019

2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
123.8	90.7	91.9	87.0	86.7	86.3	86.8	86.8	88.2	93.2	94.5	95.2	99.0	97.3	103.6	103.6	103.6	103.6
65.7	68.4	72.9	72.3	72.6	72.7	75.1	73.4	75.9	79.5	80.5	80.2	82.5	83.0	87.0	86.7	86.4	86.8
94.9	92.6	97.2	98.1	96.8	97.1	96.2	96.1	92.9	93.2	95.9	97.2	99.8	100.5	108.3	108.3	108.3	108.3
71.1	71.5	76.3	76.9	78.1	78.6	78.1	74.4	77.3	82.1	81.6	82.9	87.8	87.0	88.8	90.6	92.4	94.2
56.3	64.3	66.7	64.4	70.8	70.8	68.0	67.7	68.6	66.7	66.8	67.4	67.5	67.5	67.5	67.5	67.5	67.5
81.8	94.1	104.5	109.9	115.5	121.3	126.2	136.6	145.0	153.1	158.6	161.4	156.6	156.6	156.6	156.6	156.6	156.6
30.5	33.6	37.2	37.9	37.8	36.8	37.3	33.0	32.8	31.5	28.7	23.8	19.9	18.3	19.8	19.1	15.5	13.3
7.4	7.2	7.9	8.5	8.3	8.6	6.7	5.6	5.4	4.3	3.2	2.7	2.5	1.9	1.4	0.6	-1.6	-4.5
$140.5	$174.0	$234.6	$338.6	$370.5	$391.1	$467.1	$251.8	$311.1	$374.1	$319.5	$259.6	$190.5	$92.6	$78.2	$86.3	$90.4	$81.1
1.0%	1.2%	1.5%	2.2%	2.3%	2.4%	2.9%	1.6%	1.9%	2.3%	1.9%	1.5%	1.1%	0.5%	0.4%	0.5%	0.5%	0.4%
$60.48	$65.60	$70.97	$79.86	$83.63	$85.23	$95.71	$73.95	$81.08	$89.76	$83.95	$82.61	$80.46	$62.49	$54.79	$56.80	$57.50	$59.72
$8,182	$9,072	$10,089	$11,554	$12,269	$12,641	$14,015	$10,534	$11,788	$13,063	$12,382	$12,372	$12,251	$9,605	$8,648	$9,144	$9,381	$9,830
9.3¢	9.4¢	9.4¢	9.7¢	10.3¢	10.3¢	10.8¢	10.8¢	10.7¢	10.5¢	10.3¢	10.4¢	10.6¢	10.4¢	10.1¢	10.2¢	10.1¢	10.2¢
$32.32	$36.59	$47.22	$65.25	$75.60	$81.86	$107.44	$67.91	$86.51	$118.46	$116.71	$111.69	$100.03	$52.32	$42.98	$49.27	$62.20	$69.45
$6.83	$3.61	$5.03	$10.98	$13.00	$11.55	$14.06	$23.79	$27.90	$30.03	$17.43	$12.91	$6.14	$21.46	$22.90	$9.19	$12.09	$14.06
$5.19	$3.74	$5.99	$8.34	$8.02	$6.50	$6.35	$12.72	$14.37	$14.10	$7.41	$4.48	$1.33	$5.40	$5.44	$5.48	$5.52	$5.56
81.5%	83.6%	85.5%	85.5%	84.3%	84.5%	83.1%	79.8%	81.3%	80.8%	81.4%	81.0%	80.5%	82.4%	82.7%	82.7%	82.7%	82.7%
78	78	79	81	82	80	88	94	92	91	96	91	96	102	104	103	101	101
339.5	337.5	341.8	339.0	333.4	335.3	325.2	306.8	315.0	310.7	300.7	307.3	308.7	303.4	301.4	297.4	298.9	299.3
6.9	6.7	6.6	6.4	6.2	6.2	6.1	5.9	6.0	5.9	5.6	5.7	5.6	5.4	5.3	5.2	5.1	5.1
2.69	2.66	2.66	2.57	2.48	2.41	2.26	2.20	2.18	2.11	2.01	2.02	1.98	1.97	1.96	1.98	1.96	1.94
198.0	200.1	197.8	199.7	188.6	195.1	194.5	189.3	194.8	187.6	173.4	183.7	185.6	174.8	172.6	173.4	172.7	171.2
245.8	242.1	240.6	237.8	230.6	232.5	229.4	218.4	215.9	210.7	200.2	204.6	206.8	204.3	198.6	196.6	193.8	191.7
350	344	346	324	316	308	309	318	323	317	309	308	302	298	296	285	287	290
3,468	3,576	3,588	3,619	3,613	3,593	3,585	3,566	3,566	3,556	3,532	3,537	3,537	3,545	3,529	3,550	3,565	3,567
18.4%	22.8%	24.5%	20.0%	17.4%	19.0%	23.3%	27.1%	23.1%	22.6%	25.4%	26.2%	30.3%	28.3%	26.4%	26.9%	25.5%	24.1%
222	226	228	212	207	212	223	232	223	250	248	256	273	270	261	260	261	260
16.9	17.0	17.1	17.1	17.2	17.2	17.4	17.6	17.4	17.5	17.6	17.6	17.5	17.9	18.4	18.6	18.9	19.3
201	198	196	191	188	185	183	187	183	179	176	174	172	174	176	175	174	173
3.3%	3.3%	3.3%	3.5%	3.9%	4.5%	5.6%	6.3%	6.7%	7.2%	7.5%	8.2%	7.7%	7.6%	7.9%	7.0%	7.2%	7.2%
5,804	5,853	5,970	5,993	5,910	6,000	5,809	5,386	5,582	5,445	5,232	5,360	5,406	5,259	5,171	5,183	5,218	5,277
20.2	20.2	20.4	20.3	19.8	19.9	19.1	17.6	18.0	17.5	16.7	17.0	17.0	16.4	16.0	15.8	15.8	15.9
0.41	0.40	0.39	0.38	0.37	0.37	0.36	0.34	0.34	0.33	0.31	0.31	0.31	0.29	0.28	0.28	0.27	0.27
29.5%	29.4%	29.2%	28.6%	29.4%	28.3%	29.2%	31.2%	30.4%	32.3%	31.7%	32.8%	33.1%	33.4%	35.2%	35.5%	36.1%	36.5%
$0.15	$0.16	$0.19	$0.21	$0.29	$0.36	$0.37	$0.35	$0.35	$0.37	$0.37	$0.39	$0.41	$0.41	$0.41	$0.41	$0.41	$0.41
$0.64	$0.65	$0.64	$0.67	$0.63	$0.73	$0.75	$1.24	$0.87	$0.83	$0.79	$0.71	$0.74	$0.79	$0.80	$0.80	$0.80	$0.80
37.8	39.2	39.7	39.4	39.1	39.0	40.2	42.4	42.6	44.4	46.2	47.3	47.3	47.3	47.3	47.3	47.3	47.3

Summary Table 1: Energy Security Metrics (Values)

2020-2026

#	Metric	Units of Measurement	2020	2021	2022	2023	2024	2025	2026
Global Fuels Metrics									
1	Security of World Oil Reserves	reserves, freedom & diversity-weighted	103.6	103.6	103.6	103.6	103.6	103.6	103.6
2	Security of World Oil Production	production, freedom & diversity-weighted	86.7	86.2	86.6	86.7	86.9	87.4	87.7
3	Security of World Natural Gas Reserves	reserves, freedom & diversity-weighted	108.3	108.3	108.3	108.3	108.3	108.3	108.3
4	Security of World Natural Gas Production	production, freedom & diversity-weighted	96.1	96.1	96.2	96.2	96.2	96.3	96.4
5	Security of World Coal Reserves	reserves, freedom & diversity-weighted	67.5	67.5	67.5	67.5	67.5	67.5	67.5
6	Security of World Coal Production	production, freedom & diversity-weighted	156.6	156.6	156.6	156.6	156.6	156.6	156.6
Fuel Import Metrics									
7	Security of U.S. Petroleum Imports	oil imports, freedom & diversity-weighted	11.8	10.6	10.3	9.6	9.1	8.4	7.4
8	Security of U.S. Natural Gas Imports	gas imports, freedom & diversity-weighted	-7.6	-8.3	-9.1	-9.8	-10.4	-10.5	-10.8
9	Oil & Natural Gas Import Expenditures	billions of 2015$	$68.9	$63.5	$61.7	$54.9	$49.4	$45.1	$39.6
10	Oil & Natural Gas Import Expenditures per GDP	percent	0.3%	0.3%	0.3%	0.3%	0.2%	0.2%	0.2%
Energy Expenditure Metrics									
11	Energy Expenditures per GDP	$ per $1,000 GDP (2015$)	$60.17	$59.97	$59.80	$58.98	$57.87	$57.20	$56.57
12	Energy Expenditures per Household	2015$/Household	$10,044	$10,186	$10,328	$10,326	$10,270	$10,264	$10,230
13	Retail Electricity Prices	cents/kWh (2015$)	10.3¢	10.4¢	10.4¢	10.4¢	10.4¢	10.5¢	10.5¢
14	Crude Oil Price	2015$/bbl	$73.86	$77.12	$79.65	$81.21	$82.68	$85.14	$87.40
Price & Market Volatility Metrics									
15	Crude Oil Price Volatility	$ change in year-to-year price	$15.54	$16.84	$17.39	$17.73	$18.05	$18.59	$19.08
16	Energy Expenditure Volatility	average yearly price change/$1,000 GDP (2015$)	$5.59	$5.59	$5.59	$5.59	$5.59	$5.59	$5.59
17	World Oil Refinery Utilization	percent utilization	82.7%	82.7%	82.7%	82.7%	82.7%	82.7%	82.7%
18	Petroleum Stock Levels	average days supply	101	101	101	101	102	102	103
Energy Use Intensity Metrics									
19	Energy Consumption per Capita	million Btu/Person	298.0	297.0	296.7	296.0	294.7	292.4	289.9
20	Energy Intensity	million Btu/$1,000 GDP (2015$)	5.0	4.9	4.8	4.7	4.6	4.5	4.4
21	Petroleum Intensity	million Btu/real $1,000 GDP (2015$)	1.89	1.84	1.79	1.74	1.69	1.64	1.60
22	Household Energy Efficiency	million Btu/household	169.5	167.7	166.4	165.2	164.2	162.9	161.6
23	Commercial Energy Efficiency	million Btu/1,000 sq.ft.	189.5	187.3	185.5	184.1	182.9	181.5	179.9
24	Industrial Energy Efficiency	trillion Btu/IP Index	288	286	285	284	282	280	280
Electric Power Sector Metrics									
25	Electricity Capacity Diversity	HHI Index	3,508	3,439	3,386	3,356	3,354	3,368	3,386
26	Electricity Capacity Margins	percent	23.7%	23.2%	22.7%	22.3%	21.8%	21.2%	21.0%
27	Electricity Transmission Line Mileage	circuit-miles/peak GW	260	260	260	260	260	260	260
Transportation Sector Metrics									
28	Motor Vehicle Average MPG	miles per gallon	19.6	19.9	20.3	20.7	21.2	21.7	22.2
29	Transportation VMT per $ GDP	vehicle miles traveled/$1,000 GDP (2015$)	171	168	164	161	158	155	153
30	Transportation Non-Petroleum Fuels	percent	7.3%	7.3%	7.4%	7.5%	7.7%	7.9%	8.0%
Environmental Metrics									
31	Energy-Related CO_2 Emissions	$MMTCO_2$	5,288	5,260	5,266	5,271	5,279	5,268	5,250
32	Energy-Related CO_2 Emissions per Capita	metric tons CO_2/Person	15.8	15.6	15.5	15.4	15.3	15.1	15.0
33	Energy-Related CO_2 Emissions Intensity	metric tons CO_2/$1,000 GDP (2015$)	0.26	0.26	0.25	0.24	0.24	0.23	0.23
34	Electricity Non-CO_2 Generation Share	percent of total generation	37.5%	39.2%	39.9%	40.3%	40.2%	39.9%	39.6%
Research and Development Metrics									
35	Industrial Energy R&D Expenditures	energy R&D $/$1,000 GDP (2015$)	$0.41	$0.41	$0.41	$0.41	$0.41	$0.41	$0.41
36	Federal Energy & Science R&D Expenditures	R&D $/$1,000 GDP (2015$)	$0.80	$0.80	$0.80	$0.80	$0.80	$0.80	$0.80
37	Science & Engineering Degrees	# degrees/$billion GDP (2015$)	47.3	47.3	47.3	47.3	47.3	47.3	47.3

Summary Table 1: Energy Security Metrics (Values)

2027-2040

2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040
103.6	103.6	103.6	103.6	103.6	103.6	103.6	103.6	103.6	103.6	103.6	103.6	103.6	103.6
87.8	88.2	88.4	88.7	89.1	89.3	89.8	90.0	89.9	90.0	90.4	90.5	90.8	90.7
108.3	108.3	108.3	108.3	108.3	108.3	108.3	108.3	108.3	108.3	108.3	108.3	108.3	108.3
96.6	96.7	96.9	97.0	97.1	97.2	97.3	97.4	97.5	97.4	97.3	97.1	97.0	96.8
67.5	67.5	67.5	67.5	67.5	67.5	67.5	67.5	67.5	67.5	67.5	67.5	67.5	67.5
156.6	156.6	156.6	156.6	156.6	156.6	156.6	156.6	156.6	156.6	156.6	156.6	156.6	156.6
7.1	6.9	6.6	6.4	6.5	6.6	7.2	7.3	7.4	7.3	7.3	7.3	7.8	8.1
-11.1	-11.5	-11.8	-12.1	-12.2	-12.3	-12.4	-12.3	-12.3	-12.4	-12.4	-12.2	-12.0	-11.8
$37.1	$33.6	$30.4	$28.9	$30.1	$31.1	$35.8	$38.4	$39.6	$39.7	$39.9	$40.4	$46.0	$50.2
0.2%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	0.2%	0.2%
$55.65	$54.47	$53.70	$53.15	$52.65	$52.14	$51.07	$50.35	$49.65	$49.40	$48.70	$48.01	$47.69	$47.28
$10,158	$10,060	$10,025	$10,018	$10,021	$10,032	$9,958	$9,968	$9,969	$10,053	$10,049	$10,062	$10,128	$10,155
10.5¢	10.5¢	10.5¢	10.5¢	10.5¢	10.6¢	10.6¢	10.6¢	10.6¢	10.6¢	10.6¢	10.7¢	10.7¢	10.8¢
$88.84	$89.51	$90.74	$93.10	$95.55	$98.17	$98.12	$99.89	$100.64	$103.54	$104.08	$105.12	$106.77	$107.88
$19.39	$19.54	$19.81	$20.32	$20.86	$21.43	$21.42	$21.81	$21.97	$22.60	$22.72	$22.95	$23.31	$23.55
$5.59	$5.59	$5.59	$5.59	$5.59	$5.59	$5.59	$5.59	$5.59	$5.59	$5.59	$5.59	$5.59	$5.59
82.7%	82.7%	82.7%	82.7%	82.7%	82.7%	82.7%	82.7%	82.7%	82.7%	82.7%	82.7%	82.7%	82.7%
104	105	105	105	106	106	107	106	106	106	106	105	105	104
287.7	285.6	283.9	281.9	279.8	278.2	276.8	276.0	275.4	274.9	274.6	274.6	274.5	274.0
4.3	4.2	4.1	4.1	4.0	3.9	3.8	3.8	3.7	3.6	3.6	3.5	3.5	3.4
1.56	1.52	1.48	1.45	1.42	1.39	1.35	1.32	1.30	1.27	1.25	1.22	1.20	1.19
160.7	159.7	158.8	157.7	156.6	155.6	154.6	153.7	152.7	151.8	150.9	150.0	149.1	147.5
178.8	177.7	176.6	175.1	173.6	172.3	171.2	170.1	169.1	168.2	167.4	166.7	166.1	165.4
277	273	270	267	264	262	258	255	251	248	245	241	238	235
3,387	3,389	3,401	3,410	3,419	3,432	3,437	3,450	3,467	3,466	3,487	3,506	3,520	3,532
21.0%	21.0%	21.0%	21.0%	21.0%	21.0%	21.0%	21.0%	21.0%	21.0%	21.0%	21.0%	21.0%	21.0%
260	260	260	260	260	260	260	260	260	260	260	260	260	260
22.7	23.3	23.8	24.2	24.7	25.1	25.5	25.9	26.2	26.5	26.7	26.9	27.1	27.3
151	149	147	145	143	141	139	137	135	133	131	129	127	126
8.2%	8.3%	8.5%	8.6%	8.8%	8.9%	9.0%	9.1%	9.3%	9.4%	9.4%	9.5%	9.6%	9.7%
5,238	5,228	5,224	5,210	5,192	5,181	5,176	5,188	5,208	5,221	5,244	5,270	5,288	5,297
14.8	14.7	14.6	14.5	14.3	14.2	14.1	14.1	14.0	14.0	14.0	14.0	14.0	13.9
0.22	0.22	0.21	0.21	0.21	0.20	0.20	0.19	0.19	0.19	0.18	0.18	0.18	0.17
39.5%	39.5%	39.6%	39.7%	39.7%	39.8%	39.8%	39.6%	39.1%	39.1%	38.8%	38.7%	38.6%	38.6%
$0.41	$0.41	$0.41	$0.41	$0.41	$0.41	$0.41	$0.41	$0.41	$0.41	$0.41	$0.41	$0.41	$0.41
$0.80	$0.80	$0.80	$0.80	$0.80	$0.80	$0.80	$0.80	$0.80	$0.80	$0.80	$0.80	$0.80	$0.80
47.3	47.3	47.3	47.3	47.3	47.3	47.3	47.3	47.3	47.3	47.3	47.3	47.3	47.3

Summary Table 2: Energy Security Indexes (1980 = 100)

1970-1981

#	Metric	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981
	Index of U.S. Energy Security Risk	78.0	78.0	79.7	84.5	91.5	91.4	94.3	91.3	87.1	92.8	100.0	97.3
	Sub-Indexes												
	Geopolitical	71.9	72.5	74.7	80.7	87.6	90.7	94.8	93.5	87.1	93.2	100.0	96.6
	Economic	62.2	62.7	63.0	68.4	82.0	82.0	84.1	82.6	79.1	87.8	100.0	97.7
	Reliability	82.8	81.4	82.9	88.4	97.5	95.8	96.6	85.8	81.5	88.1	100.0	98.7
	Environmental	105.9	105.9	108.8	110.7	105.6	102.2	106.5	106.6	104.8	104.3	100.0	96.4
Global Fuels Metrics													
1	Security of World Oil Reserves	122.6	114.7	113.0	105.9	104.3	110.6	114.3	107.2	97.5	102.1	100.0	96.5
2	Security of World Oil Production	90.9	92.3	94.1	95.4	101.1	109.7	114.7	107.8	97.3	94.6	100.0	100.2
3	Security of World Natural Gas Reserves	57.5	67.4	74.0	78.2	83.9	101.7	106.3	113.6	100.1	98.1	100.0	106.1
4	Security of World Natural Gas Production	69.8	69.1	67.7	67.5	71.2	84.9	89.9	91.8	87.4	88.5	100.0	103.4
5	Security of World Coal Reserves	98.5	98.5	98.5	98.4	97.4	106.9	108.6	99.1	92.7	92.4	100.0	102.1
6	Security of World Coal Production	92.0	94.4	96.4	97.1	98.5	105.6	105.5	96.4	93.5	89.7	100.0	99.7
Fuel Import Metrics													
7	Security of U.S. Petroleum Imports	53.4	61.0	70.5	89.2	96.7	106.6	124.3	132.7	109.5	106.7	100.0	92.4
8	Security of U.S. Natural Gas Imports	74.5	75.9	73.9	70.9	69.2	89.4	93.5	101.9	89.3	112.2	100.0	94.4
9	Oil & Natural Gas Import Expenditures	7.4	8.8	10.5	25.6	47.8	44.7	55.9	69.4	61.0	85.2	100.0	84.6
10	Oil & Natural Gas Import Expenditures per GDP	10.1	11.7	13.1	30.5	57.2	53.6	63.5	75.4	62.8	85.0	100.0	82.5
Energy Expenditure Metrics													
11	Energy Expenditures per GDP	58.9	59.0	58.5	59.9	75.7	77.8	79.0	80.8	77.6	86.4	100.0	101.9
12	Energy Expenditures per Household	54.0	54.6	55.4	58.3	71.5	71.9	75.4	79.2	78.5	88.3	100.0	100.6
13	Retail Electricity Prices	70.4	71.0	71.8	71.7	82.2	87.3	88.5	91.4	92.9	92.8	100.0	107.0
14	Crude Oil Price	14.5	14.8	14.4	27.1	52.1	48.9	50.3	51.7	48.5	67.6	100.0	99.3
Price & Market Volatility Metrics													
15	Crude Oil Price Volatility	3.1	2.6	1.2	24.4	69.5	74.7	54.2	11.0	10.9	43.2	100.0	95.4
16	Energy Expenditure Volatility	25.9	28.0	25.6	33.6	87.6	86.1	84.9	46.9	42.1	66.9	100.0	110.8
17	World Oil Refinery Utilization	159.9	147.6	142.4	155.2	130.2	110.7	112.4	106.8	108.7	111.8	100.0	92.1
18	Petroleum Stock Levels	117.9	118.9	139.7	140.1	126.6	117.6	128.5	114.7	120.4	112.7	100.0	88.3
Energy Use Intensity Metrics													
19	Energy Consumption per Capita	96.3	97.1	100.8	104.0	100.7	97.0	101.4	103.0	104.5	104.6	100.0	96.5
20	Energy Intensity	118.7	117.4	117.0	115.3	113.3	110.4	110.6	108.5	105.4	103.3	100.0	95.0
21	Petroleum Intensity	117.9	118.2	121.0	121.1	116.9	114.6	116.9	117.9	114.2	108.3	100.0	91.0
22	Household Energy Efficiency	109.3	110.7	112.2	109.4	105.0	104.1	106.1	105.9	106.5	102.3	100.0	93.2
23	Commercial Energy Efficiency	111.9	113.1	113.1	111.2	110.0	111.3	112.1	108.7	106.0	104.1	100.0	97.2
24	Industrial Energy Efficiency	124.1	122.3	116.6	113.7	111.1	112.8	111.6	106.6	102.4	103.2	100.0	94.6
Electric Power Sector Metrics													
25	Electricity Capacity Diversity	110.0	110.2	109.7	108.7	106.3	100.4	100.8	94.8	95.0	96.9	100.0	99.9
26	Electricity Capacity Margins	142.7	129.2	135.0	120.1	102.9	95.7	92.6	100.6	100.4	88.6	100.0	92.7
27	Electricity Transmission Line Mileage	128.6	122.2	119.5	117.8	109.7	106.5	105.8	108.1	105.6	99.4	100.0	96.2
Transportation Sector Metrics													
28	Motor Vehicle Average MPG	110.8	109.9	110.8	111.8	110.8	109.0	109.9	108.1	107.3	106.4	100.0	97.8
29	Transportation VMT per $ GDP	99.3	102.1	103.6	102.2	100.2	104.1	104.4	104.4	104.1	99.9	100.0	99.3
30	Transportation Non-Petroleum Fuels	97.3	97.4	97.7	98.6	99.0	100.1	100.8	101.1	101.4	100.6	100.0	99.8
Environmental Metrics													
31	Energy-Related CO_2 Emissions	33.8	40.4	69.0	95.3	74.5	56.9	91.6	109.8	116.3	125.2	100.0	83.7
32	Energy-Related CO_2 Emissions per Capita	97.9	97.8	105.7	113.2	103.8	95.8	105.7	109.8	109.8	110.4	100.0	93.0
33	Energy-Related CO_2 Emissions Intensity	122.0	119.5	119.3	118.0	114.6	111.4	112.1	110.4	105.6	103.8	100.0	94.9
34	Electricity non-CO_2 Generation Share	131.3	122.6	123.7	120.8	104.0	93.8	99.1	104.0	91.8	97.1	100.0	99.1
Research and Development Metrics													
35	Industrial Energy R&D Expenditures	147.5	147.5	147.5	147.5	141.3	145.5	144.1	109.2	110.1	103.9	100.0	106.2
36	Federal Energy & Science R&D Expenditures	177.2	184.5	180.7	187.4	173.5	131.1	126.5	99.7	95.2	97.1	100.0	112.1
37	Science & Engineering Degrees	79.5	79.0	79.7	80.8	79.4	81.6	86.5	91.4	96.7	100.6	100.0	101.8

Summary Table 2: Energy Security Indexes (1980 = 100)

1982-2000

1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
91.0	85.9	86.9	83.7	82.6	83.9	81.5	79.2	78.8	76.5	74.8	76.0	74.8	75.5	77.4	78.4	78.3	81.3	87.1
90.8	86.5	90.2	87.4	85.4	86.1	80.2	80.2	79.2	76.1	72.9	75.2	73.8	73.3	74.0	73.9	72.2	75.4	82.9
89.9	82.5	80.8	76.4	70.0	71.6	68.5	66.9	68.5	65.5	63.8	63.2	61.4	61.6	64.3	64.0	61.0	63.9	72.3
91.5	84.6	83.5	79.6	86.9	88.8	88.2	78.9	78.7	78.0	75.8	77.5	75.8	78.5	80.2	84.5	91.2	96.0	99.6
92.3	91.3	94.2	93.0	92.8	94.3	96.1	96.6	93.9	92.3	92.9	95.1	95.6	96.5	99.1	100.8	100.6	101.4	103.0
93.4	98.5	104.4	104.0	110.8	109.8	99.3	100.5	124.1	119.2	127.0	133.6	132.2	131.3	127.5	128.6	125.3	124.5	127.7
93.9	90.5	93.4	90.6	94.0	88.8	79.9	82.0	77.2	75.6	73.1	77.7	75.7	74.1	70.0	70.2	68.3	68.1	68.5
120.4	122.4	141.8	136.2	136.7	124.3	94.6	101.1	86.6	88.4	77.2	86.0	87.4	87.7	87.4	87.2	88.8	93.0	99.5
112.3	120.0	138.0	146.5	155.8	142.3	117.6	117.1	91.2	88.1	68.9	72.3	68.8	66.3	61.3	61.1	63.8	68.3	71.2
102.1	100.8	107.6	107.5	107.3	99.6	86.4	86.1	68.8	72.2	56.7	61.1	57.1	55.4	52.0	50.7	49.8	52.8	58.2
100.7	101.7	108.4	107.5	107.2	100.3	92.7	99.5	84.3	81.6	75.3	83.2	83.6	83.2	83.3	79.9	70.8	72.0	77.4
71.8	69.1	74.9	65.5	82.6	82.1	78.0	85.8	81.0	75.2	72.9	83.2	82.6	78.7	77.0	81.5	82.7	80.8	84.7
114.2	122.2	121.7	146.5	126.3	146.2	146.9	142.7	123.5	130.6	107.2	124.4	129.0	127.1	115.4	114.8	130.2	157.0	160.0
58.9	49.7	51.8	43.2	26.0	35.9	31.7	40.3	50.1	38.5	38.5	37.4	36.2	36.7	47.6	47.1	34.0	46.9	78.6
58.5	47.2	45.8	36.7	21.3	28.5	24.2	29.6	36.1	27.7	26.8	25.3	23.5	23.3	29.1	27.5	19.0	25.1	40.4
97.5	87.8	82.4	77.1	64.0	62.4	59.9	59.3	60.7	58.5	55.8	54.7	52.8	51.3	52.9	50.4	44.3	44.2	51.1
93.3	87.0	85.8	82.3	69.7	69.3	68.1	68.9	71.2	67.9	66.2	65.8	65.4	64.5	68.3	67.3	60.9	62.8	75.0
111.8	111.1	106.4	106.2	104.1	100.4	96.7	94.6	92.9	92.4	91.2	90.6	88.4	86.4	84.4	82.9	80.7	78.3	78.5
85.2	71.2	68.2	61.9	29.4	37.8	29.4	34.5	43.4	35.4	33.4	28.7	26.2	27.6	32.8	29.9	19.7	27.3	42.7
86.2	52.6	56.8	42.6	76.3	86.2	90.0	40.1	41.0	40.3	34.5	26.8	16.8	15.6	16.6	17.4	33.5	37.7	60.5
94.4	61.8	44.0	28.4	50.2	49.0	40.3	8.2	15.6	24.3	20.7	12.8	5.3	2.8	14.5	13.7	28.6	23.1	55.4
90.5	95.3	98.7	100.8	108.1	108.5	117.0	119.4	120.5	118.5	119.5	118.8	118.3	120.4	123.0	127.9	124.8	120.6	124.0
87.6	85.5	82.5	84.5	83.7	84.6	88.3	89.4	85.6	84.4	87.6	85.4	87.5	92.6	99.4	97.4	93.8	106.7	109.9
91.8	90.8	94.6	93.5	92.9	95.0	98.5	100.0	98.5	97.1	97.3	97.8	98.5	99.5	101.6	101.0	100.3	100.8	101.9
93.0	88.8	86.9	83.1	80.6	80.3	80.6	79.7	78.0	78.0	76.5	75.8	74.3	73.9	73.6	70.8	68.1	66.2	65.0
87.8	83.4	80.4	76.8	77.2	76.2	76.2	73.4	70.7	69.2	68.2	66.7	65.8	63.8	63.7	61.8	60.2	59.1	57.5
93.8	92.2	93.4	92.3	90.6	90.8	94.1	96.2	90.9	92.4	91.0	94.2	92.8	93.6	97.6	93.8	92.5	94.2	97.6
96.3	94.1	93.0	88.2	84.9	84.9	87.0	88.9	87.6	86.7	84.3	84.0	83.2	84.1	83.9	83.7	82.5	81.9	84.5
89.7	86.8	85.9	82.7	80.3	79.3	78.7	79.7	80.1	80.3	80.9	78.5	76.7	74.2	73.0	68.7	64.2	61.3	58.9
102.5	102.6	100.8	97.1	94.7	93.3	87.3	90.9	87.4	83.5	83.2	82.9	81.0	79.0	79.7	81.4	79.6	77.1	77.0
81.1	93.7	90.4	88.1	92.7	99.2	119.7	104.8	113.7	114.3	109.5	124.5	127.6	159.8	149.6	174.7	224.3	266.4	197.5
90.8	95.3	92.7	92.6	95.4	97.3	102.1	99.5	103.2	103.6	102.4	106.0	108.0	114.9	112.8	115.5	118.7	121.9	120.6
94.3	93.7	91.7	91.1	90.5	88.1	85.3	83.6	81.1	78.7	78.7	79.6	79.6	79.2	78.7	78.2	78.7	79.6	78.7
103.8	102.8	99.7	98.7	98.6	99.8	101.0	100.8	101.1	102.5	102.4	101.9	100.5	100.6	99.3	98.0	96.2	93.8	92.4
100.0	101.0	100.6	100.9	101.2	100.9	100.3	100.2	99.9	100.3	100.4	100.0	99.6	99.5	99.9	99.4	100.4	100.4	100.5
52.5	48.9	79.6	77.8	78.8	99.3	127.6	138.7	134.6	128.7	140.9	153.6	163.5	171.5	195.7	205.3	212.0	218.8	242.1
82.0	79.5	86.8	84.8	83.5	87.7	94.2	95.7	92.4	88.3	89.2	90.2	90.7	90.6	94.9	95.1	94.6	94.2	98.1
91.7	87.1	85.6	81.9	79.2	79.2	79.5	78.0	76.1	75.4	74.2	73.6	71.8	70.7	70.5	68.4	66.1	63.7	63.2
87.5	85.2	85.7	85.3	81.0	83.7	82.8	80.1	75.3	73.3	75.3	76.4	76.7	73.1	72.4	76.0	77.9	75.9	79.2
106.8	109.8	113.4	127.1	141.3	138.0	146.1	148.5	148.4	147.0	171.9	195.6	203.7	230.4	241.7	302.9	278.1	323.3	290.2
129.3	150.6	160.4	172.7	186.5	200.9	207.0	199.5	196.7	186.7	191.9	216.5	221.1	229.7	255.0	273.6	289.3	280.4	290.9
97.3	100.8	106.1	107.9	110.4	114.9	121.8	125.1	124.9	121.9	120.4	119.4	120.9	122.2	124.8	129.9	135.0	140.2	144.0

Summary Table 2: Energy Security Indexes (1980 = 100)

2001-2012

#	Metric	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
	Index of U.S. Energy Security Risk	83.9	81.7	81.0	86.4	93.9	95.9	95.5	98.7	89.2	96.6	101.0	91.4
	Sub-Indexes												
	Geopolitical	81.2	78.2	77.4	84.2	91.8	94.4	95.7	100.4	87.1	94.0	100.7	93.0
	Economic	68.6	66.8	68.4	75.1	86.3	90.3	90.8	99.9	83.6	92.8	101.7	91.9
	Reliability	94.3	90.7	86.5	92.0	102.2	104.5	100.1	99.0	104.1	113.2	114.7	96.6
	Environmental	100.3	100.4	100.0	100.9	100.2	97.8	97.5	93.8	86.0	89.7	86.7	83.2
Global Fuels Metrics													
1	Security of World Oil Reserves	126.9	123.8	90.7	91.9	87.0	86.7	86.3	86.8	86.8	88.2	93.2	94.5
2	Security of World Oil Production	69.0	65.7	68.4	72.9	72.3	72.6	72.7	75.1	73.4	75.9	79.5	80.5
3	Security of World Natural Gas Reserves	98.8	94.9	92.6	97.2	98.1	96.8	97.1	96.2	96.1	92.9	93.2	95.9
4	Security of World Natural Gas Production	72.4	71.1	71.5	76.3	76.9	78.1	78.6	78.1	74.4	77.3	82.1	81.6
5	Security of World Coal Reserves	58.1	56.3	64.3	66.7	64.4	70.8	70.8	68.0	67.7	68.6	66.7	66.8
6	Security of World Coal Production	79.0	81.8	94.1	104.5	109.9	115.5	121.3	126.2	136.6	145.0	153.1	158.6
Fuel Import Metrics													
7	Security of U.S. Petroleum Imports	89.4	81.8	90.0	99.6	101.7	101.2	98.6	99.9	88.5	87.8	84.4	77.0
8	Security of U.S. Natural Gas Imports	172.7	157.1	152.0	167.6	180.0	177.0	181.9	141.8	119.2	115.4	92.1	67.4
9	Oil & Natural Gas Import Expenditures	69.1	65.8	81.5	109.8	158.5	173.4	183.1	218.7	117.9	145.6	175.1	149.6
10	Oil & Natural Gas Import Expenditures per GDP	35.1	32.9	39.6	51.4	71.8	76.5	79.4	95.1	52.7	63.5	75.2	62.8
Energy Expenditure Metrics													
11	Energy Expenditures per GDP	50.1	46.2	50.2	54.3	61.1	64.0	65.2	73.2	56.5	62.0	68.6	64.2
12	Energy Expenditures per Household	73.3	70.2	77.9	86.6	99.2	105.3	108.5	120.3	90.4	101.2	112.1	106.3
13	Retail Electricity Prices	82.2	79.9	81.0	80.6	83.6	88.6	88.6	92.7	92.7	91.7	90.5	88.3
14	Crude Oil Price	35.6	35.9	40.6	52.4	72.4	83.9	90.8	119.2	75.3	96.0	131.4	129.5
Price & Market Volatility Metrics													
15	Crude Oil Price Volatility	54.8	41.5	22.0	30.6	66.7	79.0	70.2	85.5	144.6	169.6	182.5	106.0
16	Energy Expenditure Volatility	42.6	46.5	33.5	53.6	74.7	71.9	58.2	56.9	114.0	128.8	126.3	66.4
17	World Oil Refinery Utilization	124.0	120.0	126.2	132.0	132.0	128.4	128.8	124.6	115.1	119.3	117.8	119.6
18	Petroleum Stock Levels	101.1	104.2	104.3	103.2	101.0	99.2	102.5	92.8	87.1	88.3	89.2	85.0
Energy Use Intensity Metrics													
19	Energy Consumption per Capita	98.2	98.8	98.2	99.5	98.7	97.0	97.6	94.7	89.3	91.7	90.4	87.5
20	Energy Intensity	62.7	62.5	61.0	60.0	58.2	56.2	56.1	55.1	53.9	54.5	53.3	50.8
21	Petroleum Intensity	56.8	55.8	55.1	55.1	53.4	51.4	50.1	46.9	45.7	45.3	43.7	41.8
22	Household Energy Efficiency	94.7	100.1	101.1	100.0	100.9	95.4	98.6	98.3	95.7	98.5	94.8	87.7
23	Commercial Energy Efficiency	83.0	82.7	81.5	81.0	80.1	77.6	78.3	77.2	73.5	72.7	70.9	67.4
24	Industrial Energy Efficiency	57.4	57.1	56.2	56.4	52.8	51.6	50.3	50.5	51.8	52.7	51.7	50.4
Electric Power Sector Metrics													
25	Electricity Capacity Diversity	79.2	84.5	90.8	91.5	93.3	92.9	91.7	91.3	90.2	90.2	89.6	88.3
26	Electricity Capacity Margins	163.7	142.3	115.0	106.8	131.0	150.2	137.8	112.3	96.5	113.6	115.7	103.1
27	Electricity Transmission Line Mileage	121.6	125.3	123.2	121.9	130.9	134.3	131.2	124.5	120.1	125.0	111.2	112.2
Transportation Sector Metrics													
28	Motor Vehicle Average MPG	77.8	78.7	78.2	77.8	77.8	77.3	77.3	76.4	75.6	76.4	76.0	75.6
29	Transportation VMT per $ GDP	93.1	93.4	92.0	90.9	88.7	87.1	86.1	84.9	86.8	84.8	83.0	81.6
30	Transportation Non-Petroleum Fuels	100.4	100.1	100.1	100.1	99.7	98.8	97.7	95.4	94.1	93.3	92.4	91.8
Environmental Metrics													
31	Energy-Related CO_2 Emissions	228.3	233.9	240.3	255.4	258.4	247.6	259.3	234.5	179.6	205.1	187.3	159.7
32	Energy-Related CO_2 Emissions per Capita	92.7	92.4	92.3	94.3	93.3	89.0	90.0	82.8	69.9	73.8	69.2	63.0
33	Energy-Related CO_2 Emissions Intensity	61.4	60.8	59.6	58.6	56.9	54.7	54.5	53.0	50.5	51.0	49.0	46.1
34	Electricity non-CO_2 Generation Share	81.8	79.2	79.7	80.0	81.8	79.7	82.6	80.0	74.9	77.0	72.5	73.7
Research and Development Metrics													
35	Industrial Energy R&D Expenditures	277.2	254.0	242.3	225.3	211.4	180.6	161.0	159.0	163.3	163.8	159.8	159.1
36	Federal Energy & Science R&D Expenditures	264.6	261.9	258.2	265.6	251.3	266.5	230.0	224.4	135.9	193.3	204.1	213.8
37	Science & Engineering Degrees	143.9	142.4	137.2	135.6	136.4	137.4	137.8	133.8	126.9	126.2	121.1	116.4

Summary Table 2: Energy Security Indexes (1980 = 100)

2013-2031

2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
87.2	80.7	77.2	76.0	73.0	74.7	75.9	76.2	76.2	76.3	76.1	76.0	76.0	75.9	75.7	75.4	75.3	75.4	75.6
88.4	82.5	75.5	74.9	71.4	73.2	74.4	74.8	74.9	75.2	75.0	74.8	74.8	74.7	74.6	74.4	74.3	74.6	75.0
86.6	78.8	68.5	65.5	64.6	67.3	68.8	69.3	69.7	70.1	69.9	69.6	69.7	69.7	69.6	69.2	69.1	69.3	69.6
88.3	76.7	87.6	88.7	80.4	82.4	84.1	84.8	85.3	85.7	85.8	86.1	86.7	87.1	87.3	87.4	87.6	88.0	88.6
85.0	85.0	82.3	80.8	80.5	80.5	80.8	80.1	78.9	78.2	77.6	77.1	76.4	75.7	75.0	74.4	73.9	73.2	72.6
95.2	99.0	97.3	103.6	103.6	103.6	103.6	103.6	103.6	103.6	103.6	103.6	103.6	103.6	103.6	103.6	103.6	103.6	103.6
80.2	82.5	83.0	87.0	86.7	86.4	86.8	86.7	86.2	86.6	86.7	86.9	87.4	87.7	87.8	88.2	88.4	88.7	89.1
97.2	99.8	100.5	108.3	108.3	108.3	108.3	108.3	108.3	108.3	108.3	108.3	108.3	108.3	108.3	108.3	108.3	108.3	108.3
82.9	87.8	87.0	88.8	90.6	92.4	94.2	96.1	96.1	96.2	96.2	96.2	96.3	96.4	96.6	96.7	96.9	97.0	97.1
67.4	67.5	67.5	67.5	67.5	67.5	67.5	67.5	67.5	67.5	67.5	67.5	67.5	67.5	67.5	67.5	67.5	67.5	67.5
161.4	156.6	156.6	156.6	156.6	156.6	156.6	156.6	156.6	156.6	156.6	156.6	156.6	156.6	156.6	156.6	156.6	156.6	156.6
63.7	53.3	48.9	53.0	51.1	41.5	35.6	31.6	28.4	27.6	25.7	24.3	22.5	19.9	19.2	18.5	17.7	17.0	17.5
57.8	54.0	40.5	30.2	12.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
121.5	89.2	43.3	36.6	40.4	42.3	38.0	32.2	29.7	28.9	25.7	23.1	21.1	18.6	17.4	15.7	14.2	13.5	14.1
50.2	36.0	17.1	14.2	15.2	15.6	13.7	11.4	10.2	9.7	8.4	7.4	6.6	5.7	5.2	4.7	4.1	3.9	3.9
63.2	61.5	47.8	41.9	43.4	44.0	45.7	46.0	45.9	45.7	45.1	44.2	43.7	43.3	42.6	41.7	41.1	40.6	40.3
106.2	105.1	82.4	74.2	78.5	80.5	84.4	86.2	87.4	88.6	88.6	88.1	88.1	87.8	87.2	86.3	86.0	86.0	86.0
88.9	90.6	89.4	87.1	87.6	86.8	87.7	88.6	89.3	89.5	89.7	89.5	89.9	90.3	90.2	90.3	90.5	90.5	90.5
123.9	111.0	58.0	47.7	54.6	69.0	77.0	81.9	85.5	88.3	90.1	91.7	94.4	96.9	98.5	99.3	100.7	103.3	106.0
78.4	37.3	130.4	139.2	55.8	73.5	85.4	94.4	102.3	105.7	107.7	109.7	113.0	116.0	117.9	118.8	120.4	123.5	126.8
40.1	11.9	48.4	48.7	49.1	49.4	49.8	50.1	50.1	50.1	50.1	50.1	50.1	50.1	50.1	50.1	50.1	50.1	50.1
118.4	117.0	122.6	123.4	123.4	123.4	123.4	123.4	123.4	123.4	123.4	123.4	123.4	123.4	123.4	123.4	123.4	123.4	123.4
89.4	85.4	80.3	78.8	79.6	80.6	81.2	81.0	80.9	81.0	80.8	80.4	79.7	79.1	78.6	78.1	77.7	77.4	77.1
89.4	89.8	88.3	87.7	86.6	87.0	87.1	86.7	86.5	86.4	86.2	85.8	85.1	84.4	83.7	83.1	82.6	82.1	81.5
51.4	50.8	49.1	48.3	47.0	46.5	46.1	45.2	44.2	43.3	42.5	41.6	40.8	40.0	39.2	38.4	37.7	37.0	36.3
41.8	41.2	40.9	40.7	41.0	40.7	40.2	39.1	38.1	37.0	36.1	35.0	34.0	33.1	32.3	31.4	30.7	30.0	29.4
92.9	93.8	88.4	87.2	87.6	87.3	86.5	85.7	84.8	84.1	83.5	83.0	82.4	81.7	81.2	80.7	80.3	79.7	79.2
68.9	69.6	68.8	66.9	66.2	65.2	64.5	63.8	63.0	62.5	62.0	61.6	61.1	60.6	60.2	59.8	59.5	58.9	58.4
50.3	49.2	48.6	48.3	46.5	46.9	47.4	47.0	46.7	46.6	46.4	46.0	45.8	45.6	45.2	44.6	44.1	43.6	43.1
88.5	88.5	89.0	88.1	89.3	90.2	90.3	86.9	82.9	79.8	78.1	78.0	78.8	79.8	79.9	80.0	80.7	81.2	81.8
99.8	86.5	92.7	99.4	97.4	102.6	108.7	110.5	112.9	115.6	117.5	120.2	123.3	125.0	125.0	125.0	125.0	125.0	125.0
108.6	101.7	103.1	106.5	107.1	106.7	106.9	106.9	106.9	106.9	106.9	106.9	106.9	106.9	106.9	106.9	106.9	106.9	106.9
75.6	76.0	74.3	72.2	71.4	70.2	69.1	67.9	66.7	65.4	64.1	62.7	61.3	59.8	58.5	57.2	56.0	54.9	53.9
80.8	79.9	80.6	81.6	81.3	81.0	80.4	79.3	77.8	76.2	74.7	73.2	71.8	70.8	69.8	68.9	68.0	67.1	66.3
90.5	91.4	91.6	91.1	92.7	92.5	92.3	92.2	92.1	92.0	91.7	91.4	91.1	90.8	90.5	90.2	89.9	89.6	89.4
176.4	182.3	163.2	151.7	153.3	157.9	165.6	166.9	163.4	164.1	164.7	165.8	164.3	162.1	160.4	159.1	158.6	156.9	154.5
65.2	65.3	60.9	58.1	56.9	56.8	57.2	56.5	55.0	54.3	53.6	53.0	52.0	50.9	50.0	49.1	48.4	47.5	46.6
46.4	45.7	43.4	42.0	40.9	40.3	40.0	39.2	37.9	37.0	36.1	35.3	34.5	33.8	33.1	32.4	31.8	31.1	30.4
71.4	70.7	70.0	66.5	66.0	64.8	64.1	62.3	59.7	58.6	58.1	58.2	58.7	59.1	59.2	59.2	59.2	59.0	58.9
155.3	152.4	152.4	152.4	152.4	152.4	152.4	152.4	152.4	152.4	152.4	152.4	152.4	152.4	152.4	152.4	152.4	152.4	152.4
236.8	227.2	213.7	210.8	210.8	210.8	210.8	210.8	210.8	210.8	210.8	210.8	210.8	210.8	210.8	210.8	210.8	210.8	210.8
113.6	113.6	113.6	113.6	113.6	113.6	113.6	113.6	113.6	113.6	113.6	113.6	113.6	113.6	113.6	113.6	113.6	113.6	113.6

Summary Table 2: Energy Security Indexes (1980 = 100)

2032-2040

#	Metric	2032	2033	2034	2035	2036	2037	2038	2039	2040
	Index of U.S. Energy Security Risk	75.8	75.8	76.0	76.1	76.5	76.5	76.7	77.1	77.3
	Sub-Indexes									
	Geopolitical	75.4	75.5	75.9	76.0	76.5	76.6	76.8	77.4	77.7
	Economic	70.0	69.9	70.2	70.2	70.7	70.7	70.8	71.2	71.5
	Reliability	89.1	89.3	89.8	90.0	90.6	90.8	91.1	91.7	92.0
	Environmental	72.0	71.6	71.3	71.2	71.0	71.0	70.9	70.9	70.7
Global Fuels Metrics										
1	Security of World Oil Reserves	103.6	103.6	103.6	103.6	103.6	103.6	103.6	103.6	103.6
2	Security of World Oil Production	89.3	89.8	90.0	89.9	90.0	90.4	90.5	90.8	90.7
3	Security of World Natural Gas Reserves	108.3	108.3	108.3	108.3	108.3	108.3	108.3	108.3	108.3
4	Security of World Natural Gas Production	97.2	97.3	97.4	97.5	97.4	97.3	97.1	97.0	96.8
5	Security of World Coal Reserves	67.5	67.5	67.5	67.5	67.5	67.5	67.5	67.5	67.5
6	Security of World Coal Production	156.6	156.6	156.6	156.6	156.6	156.6	156.6	156.6	156.6
Fuel Import Metrics										
7	Security of U.S. Petroleum Imports	17.6	19.2	19.6	19.9	19.5	19.7	19.5	20.8	21.6
8	Security of U.S. Natural Gas Imports	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9	Oil & Natural Gas Import Expenditures	14.6	16.8	18.0	18.6	18.6	18.7	18.9	21.5	23.5
10	Oil & Natural Gas Import Expenditures per GDP	4.0	4.5	4.7	4.8	4.7	4.6	4.6	5.1	5.4
Energy Expenditure Metrics										
11	Energy Expenditures per GDP	39.9	39.0	38.5	38.0	37.8	37.2	36.7	36.5	36.2
12	Energy Expenditures per Household	86.1	85.5	85.6	85.6	86.3	86.2	86.4	86.9	87.2
13	Retail Electricity Prices	90.7	90.9	90.8	91.0	91.2	91.4	91.5	91.8	92.4
14	Crude Oil Price	108.9	108.8	110.8	111.6	114.9	115.4	116.6	118.4	119.7
Price & Market Volatility Metrics										
15	Crude Oil Price Volatility	130.2	130.2	132.5	133.5	137.4	138.1	139.5	141.7	143.1
16	Energy Expenditure Volatility	50.1	50.1	50.1	50.1	50.1	50.1	50.1	50.1	50.1
17	World Oil Refinery Utilization	123.4	123.4	123.4	123.4	123.4	123.4	123.4	123.4	123.4
18	Petroleum Stock Levels	76.8	76.6	76.7	76.8	76.9	77.2	77.5	77.9	78.2
Energy Use Intensity Metrics										
19	Energy Consumption per Capita	81.0	80.6	80.3	80.2	80.0	79.9	79.9	79.9	79.7
20	Energy Intensity	35.7	35.0	34.3	33.6	33.1	32.5	31.9	31.4	30.9
21	Petroleum Intensity	28.7	28.0	27.4	26.9	26.3	25.9	25.4	24.9	24.6
22	Household Energy Efficiency	78.7	78.2	77.7	77.2	76.7	76.3	75.8	75.4	74.5
23	Commercial Energy Efficiency	58.0	57.6	57.3	56.9	56.6	56.4	56.1	55.9	55.7
24	Industrial Energy Efficiency	42.7	42.1	41.5	40.9	40.5	39.9	39.3	38.9	38.4
Electric Power Sector Metrics										
25	Electricity Capacity Diversity	82.5	82.8	83.5	84.5	84.4	85.6	86.7	87.6	88.3
26	Electricity Capacity Margins	125.0	125.0	125.0	125.0	125.0	125.0	125.0	125.0	125.0
27	Electricity Transmission Line Mileage	106.9	106.9	106.9	106.9	106.9	106.9	106.9	106.9	106.9
Transportation Sector Metrics										
28	Motor Vehicle Average MPG	52.9	52.1	51.4	50.8	50.3	49.8	49.4	49.1	48.8
29	Transportation VMT per $ GDP	65.4	64.5	63.5	62.5	61.6	60.8	59.9	59.0	58.3
30	Transportation Non-Petroleum Fuels	89.1	88.9	88.7	88.4	88.2	88.1	88.0	87.8	87.7
Environmental Metrics										
31	Energy-Related CO_2 Emissions	153.1	152.5	154.0	156.6	158.3	161.2	164.6	166.9	168.2
32	Energy-Related CO_2 Emissions per Capita	45.8	45.2	44.9	44.7	44.5	44.4	44.3	44.2	43.9
33	Energy-Related CO_2 Emissions Intensity	29.8	29.2	28.6	28.1	27.6	27.1	26.6	26.1	25.7
34	Electricity non-CO_2 Generation Share	58.8	58.8	59.2	59.8	59.9	60.2	60.5	60.7	60.6
Research and Development Metrics										
35	Industrial Energy R&D Expenditures	152.4	152.4	152.4	152.4	152.4	152.4	152.4	152.4	152.4
36	Federal Energy & Science R&D Expenditures	210.8	210.8	210.8	210.8	210.8	210.8	210.8	210.8	210.8
37	Science & Engineering Degrees	113.6	113.6	113.6	113.6	113.6	113.6	113.6	113.6	113.6

Primary Data Sources

The Global Energy Institute relied primarily on government data from the Energy Information Administration (EIA), Department of Commerce, and Department of Transportation to develop its Index of U.S. Energy Security. Where historical data from government sources were not available (largely data before 1990 or so), other widely-used and respected sources were employed. EIA's Annual Energy Outlook 2017 (AEO 2017) was the primary source for metric forecasts out to 2040.

The following provides a list of the main sources of the data used to compile the metrics. Detailed information on these sources also is available on the Energy Institute's Index of U.S. Energy Security website at http://www.energyxxi.org/energysecurityindex.

American Petroleum Institute: For pre-1980 refinery utilization data.

BP:
BP Statistical Review of World Energy. Available at: http://www.bp.com/en/global/corporate/about-bp/energy-economics/statistical-review-of-world-energy.html. For pre-1980 international natural gas production and post-1980 refinery utilization data.

Department of Commerce:
- Bureau of the Census, Statistical Abstract. Available at: http://www.census.gov/compendia/statab/. For historical population data.
- Bureau of the Census, Housing, Housing Vacancies and Homeownership (CPS/HVS) - Historical Tables, Table 7. Annual Estimates of the Housing Inventory: 1965 to Present. Available at: https://www.census.gov/housing/hvs/data/histtabs.html. For historical household data.
- Bureau of Economic Analysis, National Economic Accounts: Current-Dollar and "Real" Gross Domestic Product. Available at: http://www.bea.gov/national/xls/gdplev.xls. For historical nominal and real GDP data.
- Bureau of the Census, Statistical Abstract, Energy & Utilities, Electric Power Industry - Capability, Peak Load, and Capacity Margin. Available at http://www.census.gov/compendia/statab/cats/energy_utilities.html. For pre-1989 summer peak load aggregates.

Department of Transportation:
Federal Highway Administration, Highway Statistics. Available at: http://www.fhwa.dot.gov/policyinformation/statistics.cfm. For historical vehicle miles traveled data.

Energy Information Administration:
- *Annual Energy Outlook* 2016. Available at: http://www.eia.gov/forecasts/aeo/. For forecast import, expenditure, cost, electricity price, generating capacity, production, consumption, stock, miles per gallon, and energy-related carbon dioxide emissions data.
- Annual Energy Review. Available at: http://www.eia.gov/totalenergy/data/annual/. For historical import, expenditure, cost, electricity price, generating capacity, production, consumption, stock, miles per gallon, and energy-related carbon dioxide emissions data
- International Energy Outlook. Available at: http://www.eia.gov/forecasts/ieo/index.cfm. For forecast world oil and natural gas production data.
- International Energy Statistics. Available at: http://www.eia.gov/countries/data.cfm. For historical international reserves and production data.
- Monthly Energy Review. Available at: http://www.eia.gov/totalenergy/data/monthly/. For historical energy expenditure data and preliminary energy and emissions data.

Federal Reserve Board:
Industrial Production Index. Available at: http://www.federalreserve.gov/releases/G17/download.htm. For historical industrial production data.

Freedom House:
Freedom in the World: Comparative and Historical Data. Available at: http://www.freedomhouse.org/report-types/freedom-world#.U_JVsqO5KiA. For

historical international political rights and civil liberties.
historical international political rights and civil liberties
data. Freedom House's annual index of political rights and civil liberties was used as a proxy for reliability of international trading partners.

International Energy Agency:
For pre-1980 international coal production data.

Oil & Gas Journal:
For pre-1980 international crude oil reserves and natural gas reserves data.

National Science Foundation:
Division of Science Resources Statistics, Science and Engineering Statistics. Available at: http://www.nsf.gov/statistics/. For historical industrial R&D expenditure, federal science and energy R&D expenditure, and science and engineering degree data.

North American Electric Reliability Council:
For historical transmission line mileage data.

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