2019

INDEX OF U.S. ENERGY SECURITY RISK®

10th Anniversary Edition

ADDRESSING AMERICA'S VULNERABILITIES IN A GLOBAL ENERGY MARKET

GLOBAL ENERGY INSTITUTE
U.S. CHAMBER OF COMMERCE

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CONTENTS

FOREWORD

This year, we are celebrating our tenth anniversary of the Global Energy Institute's first *Index of U.S. Energy Security Risk* (Index). What a difference a decade can make.

Since at least the early 1970s, when the Arab oil embargo disrupted America's energy supply, energy security has occupied the minds of policymakers on both sides of the aisle. In the nearly four decades since, we have experienced a series of supply disruptions, price spikes, blackouts, shortages, geopolitical market manipulation, and many other incidences that have continued to keep energy security a pressing national and economic and security priority.

While concerns about energy security have increased, that increase has not been matched with metrics that would allow for a dispassionate, data-driven assessment. More often than not, ideas about energy security boiled down to how much oil we import, the price of a gallon of gasoline, or whether the United States was "energy independent." These measures have a certain political potency, but they are a far cry from adequately explaining the security of something as complex as the U.S. energy system.

Given these shortcomings and the obvious importance of energy to the U.S. economy, we embarked on a project to fill an analytical hole and develop an index that would measure and combine the many facets of U.S. energy security. By developing a transparent and objective means for measuring the once elusive concept of energy security, it was GEI's hope to ensure that energy security considerations are more directly incorporated into the policy debates. Thus we developed the first-of-its-kind Index, a product that provides analysts, policymakers, and the public with a reliable tool to measure the energy security of the United States to answer the question: Is U.S. energy security getting better or worse, and why?

At its inception in 2010, the Index showed a dire energy security situation in the United States. From its most secure point in the mid-1990s, our Index showed energy security deteriorating, with total risks heading steadily higher through 2011, and every indication was that future risks would remain near the record high for decades. Indeed, we wrote at the time: "Looking ahead, the outlook for U.S. energy security is not bright, with decades of risks comparable to those experienced in 1980 and 1981 and again in 2008. When realized, these risks exacted a heavy toll in geopolitical, economic, and human terms. The prospect of extended periods of comparable risk in the future is unsettling."

Little did any of us realize at the time how the gathering Shale Gale—at the time a gentle breeze—would blow away this forecast and produce a period of dramatically lower energy security risks, reaching and eventually exceeding the low point of the mid-1990s. The combination of hydraulic fracturing, horizontal drilling, and advanced seismic imaging of shale formations has made America the world's largest oil and natural gas producer in the world, something unimaginable a decade ago. The U.S. is also among the largest producers of coal, renewables, and nuclear power generation, making us the world's single largest energy producing country, by far. The Index report that follows goes into much greater detail on these trends, but suffice it to say that the energy revolution in the United States has had profound economic and geopolitical implications we still have not fully appreciated.

Another thing the Index has shown over the last decade is how the nature of the risks to our energy security is constantly changing, often in unpredictable ways. The ultimate measure of energy security, therefore, is that our energy systems have the resilience needed to weather the crises of the future we know will crop up unexpectedly from time to time.

We also noted in the inaugural edition of the Index that we did not expect it to be the last word in measuring our energy security. Through the years, we have continually revised and improved the metrics we use, and we have considered the addition of new metrics to reflect a changing energy system.

A case in point is critical earth elements associated with the tremendous growth in the use of renewable technologies to generate electricity here and abroad. Specialty metals and materials such as cobalt graphite, lithium, and rare earths are essential components to advanced energy and other technologies, but their distribution and concentrated production has led to heightened concerns about their security of supply in Congress and the Trump Administration. Increasing the diversity and reliability of supply for these resources is no less important than doing the same for traditional sources of energy. This 2019 edition of the Index includes an initial examination of how risks connected to these critical earth elements could be incorporated in future U.S. Indexes, and we are asking readers to submit ideas on how this might be done.

GEI will continue to strive to keep the Index relevant in a rapidly changing energy market. Ten years from now, we hope the Index will be able to tell a story as compelling and encouraging as after the first 10 years.

Martin Durbin
President
Global Energy Institute
U.S. Chamber of Commerce

Acknowledgements

Developing and maintaining something as complex as the U.S. Index remains a very challenging task that could not happen without the remarkable efforts of many people. In particular, our thanks go to Daniel E. Klein, President of Twenty-First Strategies of Santa Fe, New Mexico for designing and compiling much of the data used, and Christopher Russell. Special thanks also to GEI intern and data cruncher extraordinaire Nick Mueller, a student at Washington University in St. Louis. The entire production team here at the U.S. Chamber of Commerce did their usual fine job designing clean graphics that make sense of complex issues and producing a publication under a tight deadline. We thank them all for their efforts in continuing to make this the world's premier energy security assessment.

Introduction

The 2019 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)* 2019.

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 score necessarily moves along an open-ended scale.) As a practical matter, however, the total Index generally has moved between risk scores of 70 to 105. (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 new edition of the Index—revisions that can and often do reach back many years—historical Index scores are not comparable across different editions. Each new edition of the Index supersedes previous editions. Although data revisions result in changes to Index scores, both total and for individual metrics, the trends identified in earlier editions are still evident. *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 change over time.

Also for purposes of discussion, an average "baseline" Index score for the 30-year period 1970 to 1999—83.8 points—is included as a representative reference point. This period was selected because it includes times with very high (100 in 1980) and very low (74.8 in 1992) scores. When reviewing this year's results, the 1980 baseline score and the 30-year average can be used along with the historical high and low scores to assess how current and future risk scores compare to past scores. Unless noted otherwise, all dollar figures are in real 2018 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 the 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 2018 fell 1.6 points (2%) to 75.8. Since total risk peaked in 2011 at 101.4 points, risk scores through 2018 have declined every year but 2017. The 2018 score is the fourth lowest since 1970,[3] and U.S. energy security risks are now at their lowest level since 1995. Future *U.S. Index* scores out to 2040 calculated using the *AEO2019* reference case suggest that after 2020, total U.S. risk scores will not exceed 74 points (an average of 73.4). This represents the lowest level of projected risk of the 10 EIA forecasts used since 2010.

Overview

Total energy security risk in 2018 fell 1.6 points, or 2.0%, to 75.8 points, the fourth lowest score since 1970 and the lowest since 1995 (Figure 1). During the seven years since the total risk score hit its peak of 101.4 in 2011, scores have fallen almost 26 points (25%). There has been no comparable period where scores have moved so rapidly, either up or down. To put this decline into perspective, consider that during the decade leading up to 1980, the Arab Oil Embargo, the Iranian Revolution and hostage crisis, the invasion of Afghanistan by the Soviet Union, two U.S. recessions, and much else occurred. The events of this decade had a large impact on U.S. energy security risk, which jumped up 22 points to a score of 100 in 1980. In just the seven years since 2011, the U.S. energy security risk score plunged 24 points from its record almost entirely because of the direct or indirect benefits of the U.S. shale revolution. In other words, the magnitude of the shale revolution on U.S. energy security (to the good) has been as big, if not bigger than the combined impact of tumultuous geopolitical events that shook world energy markets profoundly in the 1970s.

The 2018 score was well below (8 points) the 30-year (1970-1999) average (Table 1). 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 overall risk was driven by large shifts in a few metrics. Of the 37 Index metrics, 15 showed little change (±1%) in risk, 13 showed an increase in risk of 1% or more, and 9 showed a decrease in risk of 1% or more. Most of the risk decrease in 2018 can be attributed to crude oil price volatility and oil and natural gas import and import expenditure metrics that registered very large declines of ±

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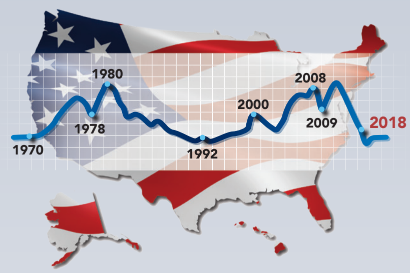

Of the 37 Index metrics,

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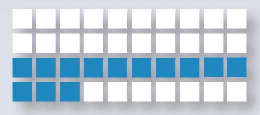

showed an increase in risk of 1% or more,

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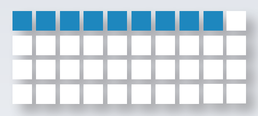

showed a decrease in risk of 1% or more, and

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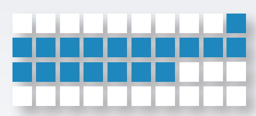


showed essentially no change in risk in 2018.

[3] Only 1992, 1994, and 1995 had lower scores.

Figure 1

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

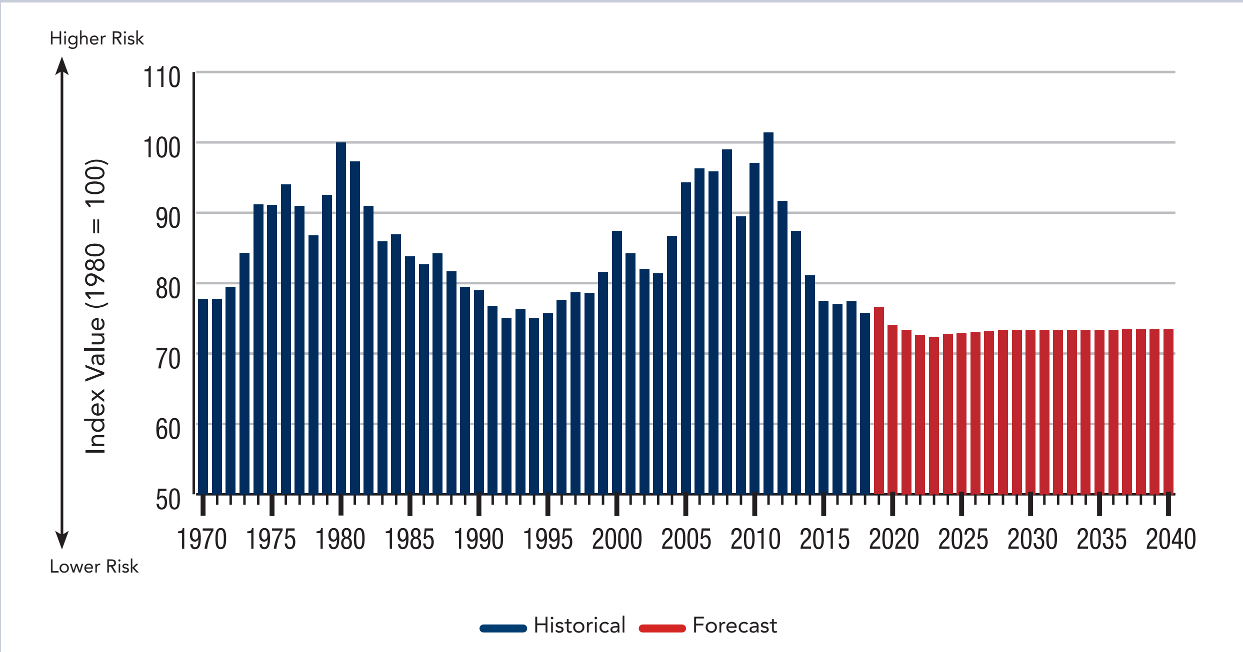


Table 1. U.S. Energy Security Risks from 1970 to 2018: Highest, Lowest and 30-Year (1970-1999) Average Index Scores							
Indexes of U.S Energy Security Risk	2019 Score	1980 Baseline Score	Highest Risk		Lowest Risk		30-Year Average (1970-1999)
			Year	Index Score	Year	Index Score	
Total Composite Index	75.8	100	2011	101.4	1992	75.0	83.8
Sub-Indexes:							
Geopolitical	73.0	100	2011	101.0	1970	71.6	82.6
Economic	68.8	100	2011	102.1	1998	61.1	73.1
Reliability	84.3	100	2011	115.3	1994	75.9	85.9
Environmental	81.9	100	1973	110.7	2017	80.3	99.4

10% or more from the previous year (Table 2). Metrics related to the price of crude oil and total emissions were the only two to register an increase of more than 10%.

The risk score for crude oil price volatility, as expected, plunged by half in 2018, the largest drop of any metric. Crude oil price volatility is measured as the absolute average change in price over three years (in this case, 2016, 2017, and 2018). We noted in last year's Index how the plunge in price in 2015—after the world price of crude oil tumbled from more than $100 per barrel in 2015 to less than $50 in 2016—would have no impact on this metric in 2018. Since 2015, the world price has recovered somewhat, and there have been no large swings comparable to what occurred in 2015.

Domestic crude oil production has increased rapidly and projections indicate continued growth for many years. From 2010 to 2018, crude oil production in the United States more than doubled to nearly 11 million barrels per day (MMbbl/d) from 5.5 MMbbl/d because of continuing development of shale plays, especially in the Permian Basin in West Texas and Southeast New Mexico. Texas was responsible for nearly 60% (+3.2 MMbbl/d) of that jump. Large production increases also were observed in North Dakota (+960 MMbbl/d), New Mexico (+500 MMbbl/d), Colorado (+400 MMbbl/d), and Oklahoma (+365 MMbbl/d). Even greater production is expected from these regions. EIA's *AEO2019* projects that by 2024, total U.S. crude oil production will exceed 14 MMbbl/d and stay above that level through 2040.

Largely as a result of the growing crude oil production, U.S. petroleum import risk fell 38% in 2018 to its lowest score going back to 1970. It is expected that by 2020, the United States will become a net exporter of total petroleum (crude oil and refined products) on an annual basis. The United States has been a net exporter of refined petroleum products since 2009. The anticipated increases in crude oil production coupled with greater efficiency means that by 2020 the country could be a net exporter of total oil. This is a remarkable development because just two years ago, EIA's *AEO2017* did not indicate that the United States would achieve status as a net oil exporter at least out to 2050. The changing expectation about domestic crude oil production, in particular, has been the main reason the United States almost surely will become a net oil exporter. Compared to the *AEO2017*, EIA's most recent *AEO2019* is projecting domestic crude oil production over the 2020 to 2040 period will average almost 4 MMbbl/d more, while refined product exports will average about 1 MMbbl/d more—an astonishing combined jump in the forecast of nearly 5 MMbbl/d in a mere two years.

Table 2. Movers and Shakers: Energy Security Metrics Changing at Least ±10% in 2018

Declining Risk		Rising Risk	
Metric	% Change	Metric	% Change
Crude Oil Price Volatility	-50%	Crude Oil Price	28%
Security of U.S. Petroleum Imports	-38%	Energy-Related CO_2 Emissions	12%
Oil & Natural Gas Import Expenditures per GDP	-25%		
Oil & Natural Gas Import Expenditures	-23%		

Domestic natural gas production continues to race ahead and is expected to set production records each year to 2040. The risks associated with the security of U.S. natural gas imports, therefore, will continue to remain there for the foreseeable future. Since the risk score for this metric peaked at a record high of 181 in 2007, it has declined rapidly, eventually reaching a score of 0 once the United States became a net exporter of natural gas in 2018. Dry natural gas production in the United States grew 43% from 2010 to 2018 to 30.4 trillion cubic feet. The amount being exported also increased over this period, especially as liquefied natural gas. Looking to the future, EIA's forecast indicates that by 2040 net LNG shipments of 5 trillion cubic feet will be more than twice as large as net pipeline shipments. Indeed, if current trends continue, the IEA reports that the United States could overtake Qatar and Australia to become the world's largest exporter of LNG within a decade.

With the United States already a net natural gas exporter and set to become net oil exporter by 2020, the risk scores for the metrics measuring oil and gas import expenditures and oil and gas import expenditures as a share of GDP also will move to zero. The U.S. also is expected to become an even larger exporter of coal, which will contribute to a positive balance of trade in energy as well. The risk score for oil & natural gas import expenditures per GDP is, at 9.5 points, at its lowest level in the record, and the risk score for nominal oil and natural gas import expenditures, at 26 points, is lower than at any time since 1974. By 2020, scores for both of these are expected to be 0. At that time, the balance of trade in oil and gas will favor the United States. These developments will set the four oil and natural gas import-related metrics at 0 going forward, which explains the very low projected total risk scores out to 2040. Over the 30-year baseline period from 1970 to 2009, these four metrics ranged from about 5% to 21% of the total U.S. risk score and averaged 11%. Eliminating these risks will therefore have a big and beneficial impact on future risk scores.

Crude oil prices rose 28% in 2018, from about $55 to $71 per barrel. The firming world price of crude oil in 2017 and 2018 after the big drop in price between 2014 and 2016 and greater production efficiency helped to spur increased production of crude oil and natural gas. Output of both fuels fell in 2016 after the world price of crude oil tumbled 57% between 2014 and 2016. The rising crude oil price in the past two years has been comparatively modest and was not enough to send the crude oil volatility metric higher. At $71 per barrel, the price of crude oil in 2018 was about 56% higher than the 30-year baseline average price. Despite much greater U.S. crude oil production in the EIA forecast, greater global demand and declines in production elsewhere create conditions where crude oil prices will rise in the future. By 2035, EIA expects the global price of crude oil to breech $100 per barrel. It is worthwhile to note, however, that the expected increase in price is much lower than the expected increase in forecasts from just a few years ago, when the per barrel price was forecast to exceed $150 in a couple of decades. Although a significant contributor of future risk, the price of crude oil is not expected to be as big a contributor as it once was.

The risk associated with energy-related carbon dioxide emissions increased by 12% and energy use per capita by 4% in 2018, resulting from largely increased economic growth and greater energy demand stemming from more heating and cooling degree days. Emissions from the residential and commercial sectors led the way, rising by 7.4% and 2.8%, respectively. A Kaya Identity[4] analysis suggests that while the economy (and the power sector) continued to decarbonize in 2018, it used slightly more energy to create a dollar of GDP. The contribution to emissions from GDP also was higher than it has been for some time because of faster growth. The same factors that led to a rise in economy-wide emissions also caused power sector emissions to increase, but by less than 2%. Nevertheless, decarbonization of the power supply continues. Figure 2 measures the contribution of the Kaya components to cumulative changes in power

[4] The Kaya Identity states that a country's total carbon dioxide emissions from energy is the product of four factors: per capita GDP, energy intensity, carbon intensity of the energy supply, and population.

sector emissions since 1970.[5] It shows how changes in electricity intensity and the carbon content of the energy supply used to generate electricity started to reduce emissions in this sector.

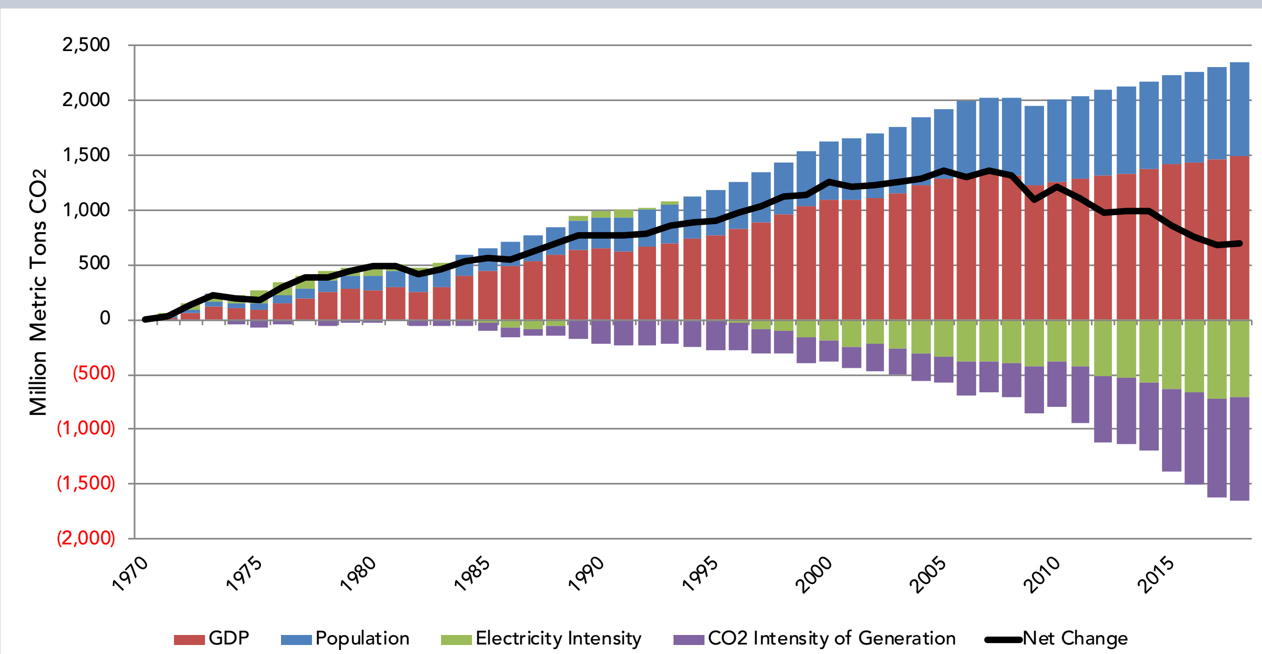
Although long-term trends in the risk scores for the six Energy Use Intensity metrics are declining—except for household energy efficiency, which has been doing so for decades—risk scores for four of the metrics in this category increased in 2018. Transportation Sector metrics, however, continued to improve in 2018. It is much too soon to determine if the reversals in household energy efficiency, energy use per capita, energy intensity, and commercial energy efficiency scores indicate a trend or are just one-offs that occur from time to time. As mentioned earlier, EIA reports that the United States experienced a relatively high number of both heating and cooling degree days in 2018, which increased energy use, particularly for households.

In the Transportation Sector, risks related to motor vehicle miles per gallon declined a healthy 5% in 2018, while those related to vehicle miles traveled intensity and petroleum fuel use declined only marginally. The long-term improvements in each of these metrics should proceed apace, supported by vehicle efficiency standards.

Record high and low risks scores tend to bunch at the beginning and end of the database. Of the 37 metrics, 12 had their highest risks scores from 1970 to 1973 while 16 had their highest risk scores from 2016 to 2018 (Table 3). Although the lowest total risk score for the entire United States was in 1994, only one metric had its lowest risk score in 1993 to 1995 period. Many risk scores around that time, especially those related to imports, expenditures, and price and volatility, were comparatively very low, if not at their record lows. Efficiency-related metrics were also much

Figure 2

Cumulative Kaya Indentity Components of Power Sector CO_2 Emissions: 1970-2018



[5] It should be noted that this kind of analysis measuring 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.

Table 3. Highest and Lowest Energy Security Risks by Metric: 1970-2018

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	110.9	2002	67.0
Security of World Natural Gas Reserves	1984	141.6	1970	57.4
Security of World Natural Gas Production	1986	155.8	1997	61.2
Security of World Coal Reserves	1976	108.6	1998	49.8
Security of World Coal Production	4035	166.3	1998	71.8
Fuel Import Metrics				
Security of U.S. Petroleum Imports	1977	130.1	2018	25.9
Security of U.S. Natural Gas Imports	2007	180.8	2017	0.0
Oil & Natural Gas Import Expenditures	2008	219.0	1970	7.4
Oil & Natural Gas Import Expenditures per GDP	1980	100.0	2018	9.5
Energy Expenditure Metrics				
Energy Expenditures per GDP	1981	101.8	2016	42.4
Energy Expenditures per Household	2008	120.6	1970	54.0
Retail Electricity Prices	1982	111.7	1970	70.5
Crude Oil Price	2011	131.8	1972	14.5
Price & Market Volatility Metrics				
Crude Oil Price Volatility	2011	183.1	1972	1.3
Energy Expenditure Volatility per GDP	2010	128.8	1995	2.8
World Oil Refinery Utilization	1970	160.0	1982	89.7
Petroleum Stock Levels	1973	140.1	2016	79.4
Energy Use Intensity Metrics				
Energy Consumption per Capita	1979	104.6	2017	87.6
Energy Intensity	1970	118.6	2017	46.9
Petroleum Intensity	1973	121.0	2018	39.3
Household Energy Efficiency	1972	112.2	2017	84.3
Commercial Energy Efficiency	1972	113.1	2017	66.4
Industrial Energy Efficiency	1970	124.2	2018	48.6
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	2018	69.5
Transportation VMT per $ GDP	1976	104.3	2018	78.4
Transportation Non-Petroleum Fuels	1978	101.4	2013	90.4
Environmental Metrics				
Energy-Related CO_2 Emissions	2007	267.0	1970	34.8
Energy-Related CO_2 Emissions per Capita	1973	113.3	2017	57.0
Energy-Related CO_2 Emissions Intensity	1970	122.5	2018	40.4
Electricity Non-CO_2 Generation Share	1970	131.3	2017	62.5
Research and Development Metrics				
Industrial Energy R&D Expenditures	1999	323.1	1980	100.0
Federal Energy & Science R&D Expenditures	2000	290.5	1978	95.1
Science & Engineering Degrees	2000	143.7	1971	79.0

lower compared to previous years. The very low score in 2018 was driven by steep declines in fuel import metrics and expenditures that occurred against a backdrop of continued improvements in efficiency, transportation, and, more recently, environmental metrics. Indeed, 14 metrics, almost all related to efficiency and emissions, had their highest score among the first three years for the record, and their lowest score among the last three years. Growing domestic oil and natural gas production also has pushed down the risk score for the four import metrics, three of which had their lowest score within the last three years.

Shifts in Sources of Energy Security Risk over Time

The 37 metrics used in the *U.S. Index* are sorted into nine categories (see more information on these in Appendix 1). A new feature of the 2018 edition of the Index shows how much the nine metric groups contribute to the total energy security risk score over time. Although the input weighting for each metric group does not change from year to year, the "output weighting" of each group—how much of the total risk score is accounted for—can change greatly over time.

Table 4 provides a list of the nine metric categories, the total input weighting of the metrics that make up that group, and the percent difference between the input and output share for each metric group for select years. In years where the output share for a particular metric group is higher than the input score, it means that metric group is a relatively more significant contributor to the total energy security score. That does not necessarily mean that the overall score for that metric group is getting worse. It could also mean that its score is improving more slowly than the scores for the other metric groups. The same dynamic in reverse applies when a metric group score is below its corresponding input value—its score could be improving more rapidly or worsening less rapidly than the scores for other groups.

The data in Table 4 show the difference, by metric group, of the output weight compared to the input weight. Consider the Power Sector as an example. It has an input weight of 6.2%. In 2018, the combined risk score for this group accounted for 8.0% of the total U.S. risk score. Therefore, the output weight for this metric was 1.8 percentage points greater than the input weight. Measuring these differences over time can provide insights into the relative contribution of these groups.

From the mid-1980s to the early 2000s, the Fuel Imports, Energy Expenditures, and Energy Use Intensity group scores were all below the assigned input weighting for that group, indicating that these groups were smaller contributors to the total *U.S. Index* score compared to the other groups. Over the same period

Table 4. Input and Output by Metric Group

Metric Category	Input Weighting %	Percentage Point Difference Between Input Weighting and Actual Output										
		1970	1975	1980	1985	1990	1995	2000	2005	2010	2015	2018
Global Fuels	15.1	1.7	1.7	0.0	5.4	2.1	1.7	(0.5)	(1.9)	(1.7)	3.2	5.2
Fuel Import	11.8	(7.0)	(2.3)	0.0	(3.1)	(1.8)	(2.6)	(0.8)	3.4	0.8	(5.8)	(8.8)
Energy Expenditure	18.3	(9.3)	(5.4)	0.0	(1.9)	(4.6)	(6.9)	(6.8)	(3.5)	(1.4)	(3.0)	(0.7)
Price & Volatility	12.6	(3.9)	(0.0)	0.0	(4.6)	(4.3)	(6.0)	(1.6)	(1.2)	5.0	2.7	0.7
Energy Use Intensity	15.3	7.0	3.0	0.0	0.1	0.6	0.6	(2.3)	(3.9)	(5.1)	(3.6)	(3.4)
Power Sector	6.2	3.9	0.7	0.0	0.7	1.7	3.3	2.9	1.6	0.9	1.5	1.8
Transportation Sector	9.8	3.3	1.5	0.0	1.4	1.6	1.9	0.1	(0.8)	(1.4)	0.3	0.2
Environmental	7.6	1.9	(0.3)	0.0	(0.1)	1.6	2.8	3.2	2.7	0.7	1.1	1.0
R&D	3.3	2.4	1.0	0.0	2.1	3.2	5.2	5.8	3.7	2.2	3.6	4.0

Power Sector, Transportation, and R&D were relatively bigger contributors to the total *U.S. Index* score.

As we have seen, risk scores in recent years have benefited greatly from a relatively low collective score in the Fuel Import category as well as Energy Use Intensity and (barely) Energy Expenditures. Moreover, even though Transportation Sector and Environmental categories accounted for a higher share of total risk, the scores for these metric groups have been declining, just at a slower rate than for some other groups (e.g., Fuel Imports). These trends help explain why recent total U.S. risk scores are approaching lows last seen in the mid-1990s.

Other ways to present how risks have shifted over time are presented in Figure 3, which shows the contribution of each metric group by nominal group score, and Figure 4, which shows the relative contribution of each metric group from 1970 to 2018.

- **Fuel Import:** These charts show how the relative contribution of the Fuel Import metrics has declined since the beginning of the shale revolution around 2005 or so. The combined risks of these metrics is smaller than it was in 1970, another period of very low Fuel Import risk.

- **Price and Volatility:** The Price and Volatility metrics category is, not unexpectedly, the most changeable of the groups. The gyrations of the scores in this group over the years reflects the wild swings in the price of crude oil and natural gas, many of which had their origins in geopolitical crises or attempted, and sometimes successful, market manipulation by OPEC (*e.g.*, such as its recent attempt in 2015 and 2016 to capture greater market share by driving the world price of crude oil lower).

- **Energy Expenditures:** The contribution of the Energy Expenditures group has been affected by the price of energy and the efficiency with which energy is used in the United States. The plunge in energy prices in the mid-1980s certainly had an impact in lowering the relative contribution of these metrics, but steady improvement in efficiency also has reduced its influence on the total *U.S. Index* score.

- **Energy Use:** The scores for the Energy Use group since 1970 have declined at a rate of about 0.6% per year, about the same rate as the decline in its share of the total U.S. score over the same period. The contribution of this group is now below the input weighting, meaning that, among other things, the United States has made quite a bit of progress in making its economy less energy intensive and more efficient.

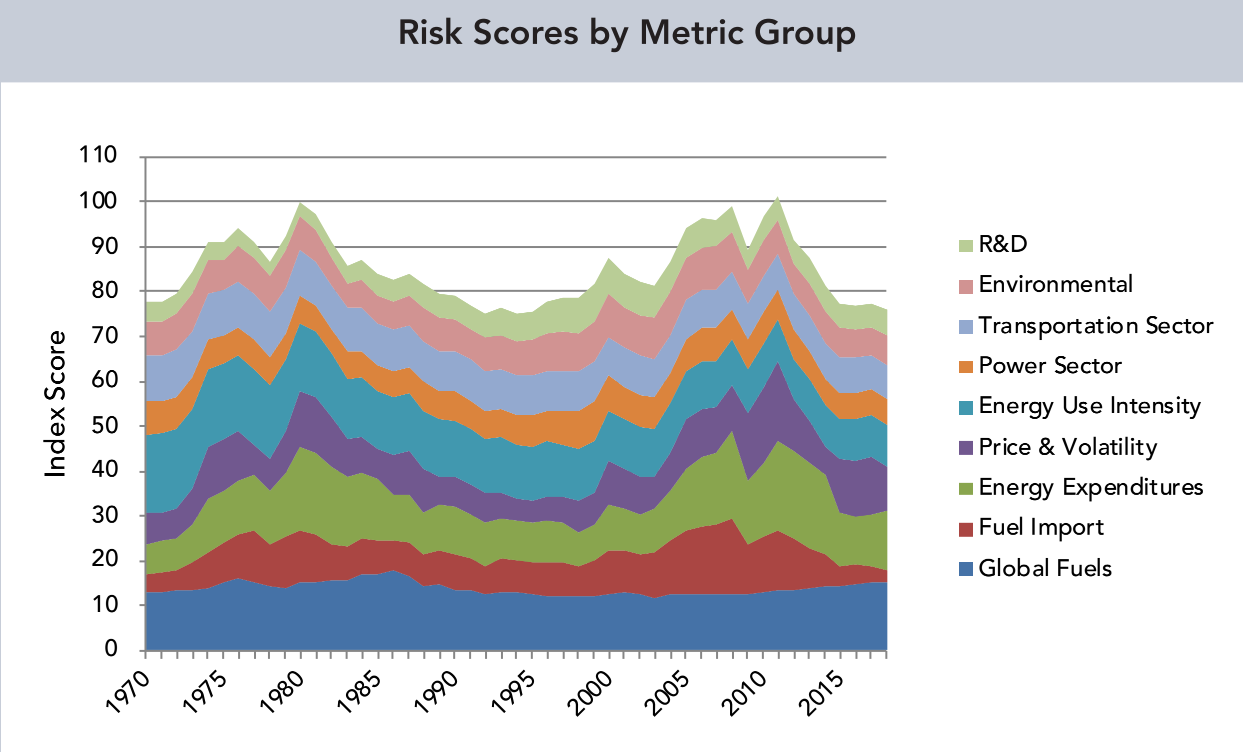
- **Global Fuels:** Risks connected to Global Fuels were less of a risk factor in the two decades following the break-up of the Soviet Union. Not only were reliability risks reduced as former Soviet Bloc countries moved to more representative forms of government, but the increase in the number of countries providing energy to world markets, and thus the diversity of sources, also lowered risk. After 2010, increased geopolitical turmoil and a retrenchment to more authoritarian forms of government in some large energy-producing countries have caused the contribution of this metric group to gain greater importance.

- **Power Sector:** Despite improving risks scores for this group of metrics. The Power Sector accounts for a greater share of total risk compared to its input weight, and it has for the entire period going back to 1970 even though the absolute contribution has not changed that much.

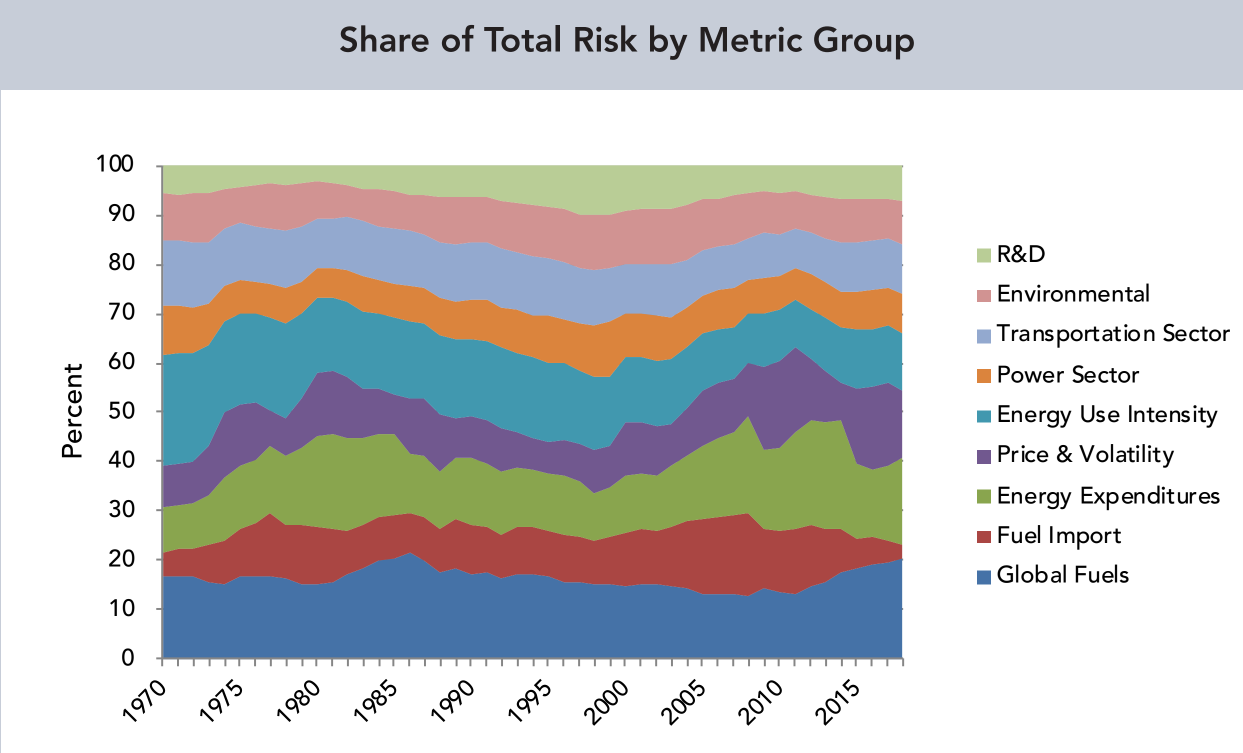
- **Transport and Environmental:** The input and output weighting for the Environmental and Transportation metric groups are about the same. The absolute contribution of both, however, has generally been trending down, if at a slower rate than for other metric groups.

- **R&D:** The Energy R&D metric group was at its lowest point shortly after the energy crises of 1973 and 1979/80. Since around 2010, risk scores for this group have increased both nominally and as a share of total risk.

■ Figure 3



■ Figure 4



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 the 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 *AEO2019* was used to project Index risk scores out to 2040.[6] 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. Not all metrics used in the *U.S. Index* are captured in the *AEO* model runs. For these metrics, a neutral assumption is adopted, and future scores are assumed to be equal to the last actual score.

Based on EIA's latest *AEO2019*, the *U.S. Index* is projected to average 73.4 points from 2019 to 2040—an average lower than the record of 75.0 reached in 1992. This average score represents a 1.1 point improvement over the average in last year's Index projection based on the *AEO0218*. Indeed, from 2020 to 2040, risk scores will be below the historical record going back to 1970. This would be a completely unprecedented level of energy security.

By 2020, each of the metrics in the Fuel Import group will reach risk scores of 0 and is expected to maintain that score throughout the forecast period to 2040. Crude oil production in excess of 14 MMbbl/d and continuously increasing natural gas output means that risks for crude oil imports, oil & gas expenditures, and oil & gas expenditures as a share of GDP will join the risk for natural gas imports at 0.

Efficiency-related metrics will see large improvements (typically 20% to 40%) between 2018 and 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 all show considerable improvement, as does the efficiency of the automotive fleet (measured as average miles per gallon and vehicle miles traveled per dollar of GDP).

Risks associated with the three Environmental metrics measuring aspects of carbon dioxide emissions are all expected to decline between 30% and 40%. The largest improvement is expected to come in the amount of emissions per dollar of GDP produced, a key measure of efficiency and decarbonization.

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 48% from 2018 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 $71 per barrel in 2018 to $105 per barrel in 2040. 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 the crude oil price 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.

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

Estimates of future risk continue to decline compared to the forecast of just a few years ago. The size and durability of the shale revolution continues to bode well for U.S. energy security to an extent not appreciated in past forecasts. Figure 5 illustrates how projections of total Index scores have changed over time. It is remarkable how in almost each subsequent AEO forecast since 2010, future risk scores have got much better of over time. The largest variables have been changing expectations about the price of crude oil and more significantly the changing views about the extent of domestic unconventional oil and natural gas production from shale formations.

Energy Security Risks Under Future Scenarios

In addition to 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 2019, EIA ran a reference case and an additional six scenarios. These alternate scenarios were plugged into the *U.S. Index* model to assess their impact on future energy security risk as compared to the *AEO2019* Reference case for 2030, 2040, and 2050.

The results are presented in Table 5 and each side case is described in Table 6. In addition, the table contains the cumulative difference in GDP from 2018 to 2030, 2040 and 2050 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. While high- and low-GDP growth side cases show the largest changes in GDP, they have very little relevance to energy security compared to the other side cases.

Figure 5

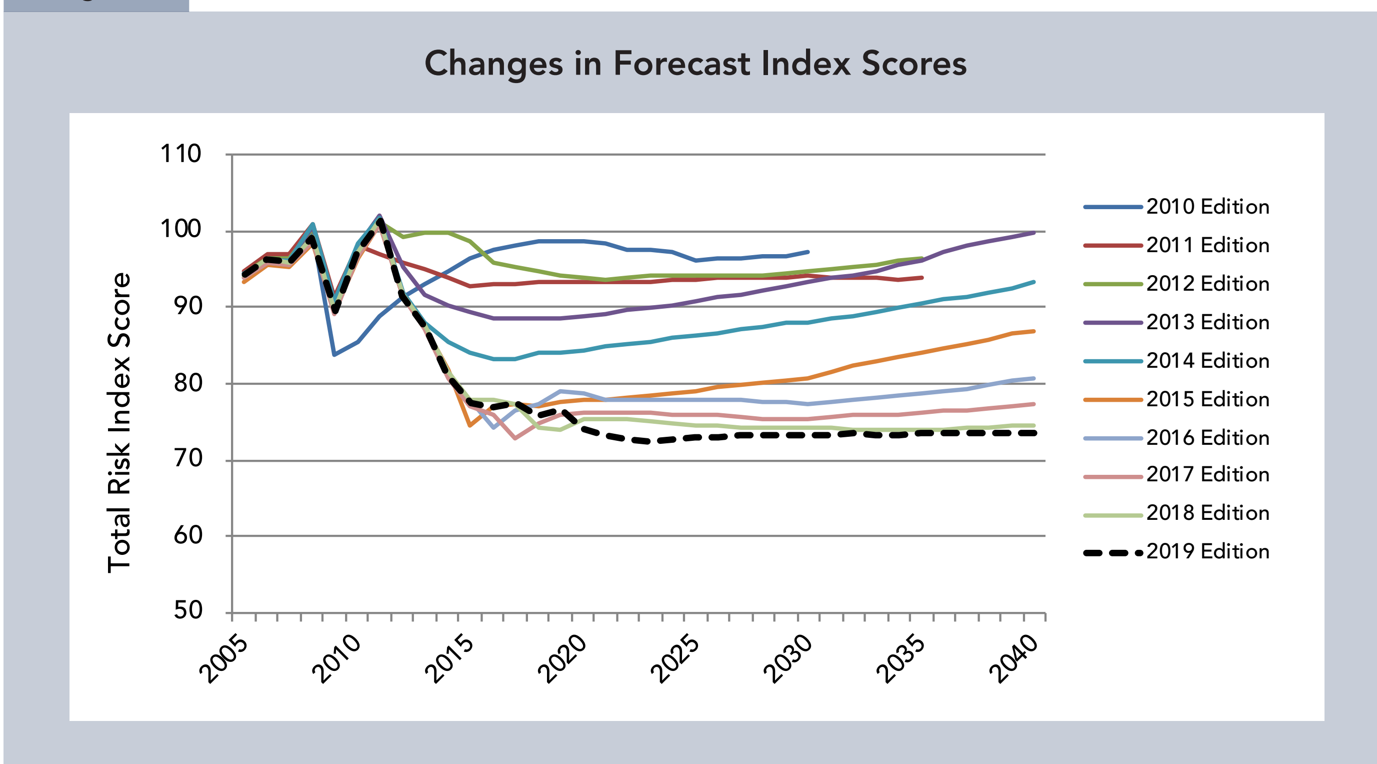


Table 5. Energy Security Risk Measures: Comparison of *EIA AEO* 2019 Reference and Side Cases

EIA *AEO Model Run*	Change In:					
	2030 Energy Risk Index Score	Cumulative GDP: 2020-2030 (Billion 2018$)	2040 Energy Risk Index Score	Cumulative GDP: 2020-2040 (Billion 2018$)	2050 Energy Risk Index Score	Cumulative GDP: 2019-2050 (Billion 2018$)
2019 Reference Case	NA	NA	NA	NA	NA	NA
2019 High economic growth	0.3	8,630	1.0	29,984	2.8	76,467
2019 Low economic growth	-0.3	-13,208	-0.9	-40,618	-1.8	-85,065
2019 High oil price	12.7	1,675	13.7	415	14.6	1,890
2019 Low oil price	-6.4	-1,165	-5.5	-302	-3.0	-193
2019 High oil and gas resource and technology	-0.3	1,201	-0.4	3,287	-0.4	6,246
2019 Low oil and gas resource and technology	0.7	-2,434	3.1	-4,262	6.7	-6,494
2018 Reference Case	0.8	1,180	1.0	6,792	2.1	18,060

Table 6. Summary of *AEO2019* Side Cases

EIA AEO 2019 Case	Description
Reference Case	Baseline assumptions for economic growth (1.9 percent from 2018 through 2050), oil prices, technology, and demographic trends. Brent spot price rises to about $108 per barrel (2018 dollars).
High economic growth	Real GDP grows at an average annual rate of 2.4 percent from 2018 to 2050.
Low economic growth	Real GDP grows at an average annual rate of 1.4 percent from 2018 to 2050.
High Oil Price	High oil prices result from a combination of higher global demand for petroleum and other liquids and lower global supply. Higher economic growth relative to the reference case leads to increased demand, particularly in non-OECD countries. Brent spot price rises to $212 per barrel (2018 dollars) in 2050.
Low Oil Price	Low oil prices result from a combination of lower demand for petroleum and other liquids in the non-OECD nations and higher global supply. Producers face lower costs of production for both crude oil and other liquids production technologies. Brent spot price falls below $44 per barrel (2018 dollars) in 2020 and rises slowly to almost $50 per barrel in 2050.
High Oil & Gas Resource & Technology	Estimated ultimate recovery per well for 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 resources are added to reflect new plays or the expansion of known plays.
Low Oil & Gas Resource & Technology	Estimated ultimate recovery per well for 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.

In Focus: Critical Earth Elements

The rapid growth in commercial use of many advanced technologies—especially renewable systems and rechargeable batteries—has increased demand for rare earth minerals[7] and other critical elements (which we will collectively call "critical earth elements"). Electric vehicles, fluorescent lighting, photovoltaic cells, and wind turbines are all examples of technologies that use these materials. Moreover, many U.S. defense and weapons systems are now totally dependent upon these types of materials, almost all of which come from foreign sources. So it is not just energy security that is at issue, but national security, too.

These key elements have not always been as critical in our energy mix, but they are much more significant now and, if expectations are borne out, will gain even more in importance in the future. Growing demand for these materials in the energy sector may lead to larger energy security risks.

Recently, the federal government took a look at U.S. vulnerabilities related to supplies of 35 critical minerals. According to an interagency report from the U.S. Department of Commerce (DOC), *A Federal Strategy to Ensure Secure and Reliable Supplies of Critical Minerals*,[8] the United States is import-reliant (importing more than 50% of annual consumption) on 31 of 35 of the critical minerals examined, making the U.S. economy susceptible to supply shocks. The report states: "Lack of domestic processing and manufacturing capabilities for critical materials makes the United States vulnerable to potential geo-economic and geo-political actions from foreign governments that may lead to price and demand volatility for specific minerals, as well as potential supply disruptions causing mineral shortfalls."

To address this, the DOC report recommends increasing domestic exploration and production, encouraging recycling and reprocessing, and research and development to develop new technologies that are less reliant on these materials.

Reserves of critical earth elements are highly concentrated geographically, with some rare earths and specialty metals markets are often nearly monopolistic. The potential market manipulation where critical earth element supplies are highly concentrated has highlighted the need for diversified sources of supplies. The DOC report warns that, "U.S. access to critical mineral resources abroad and the viability of industries producing these minerals in the United States can be negatively impacted by trade and investment restrictions, and by foreign conduct that distorts markets through various forms of unlawful or otherwise unfair competition."

These concerns are not unfounded. As we have seen with crude oil, concentration of supply can create vulnerabilities, especially when access to supplies is based as much on geopolitical advantage as on market forces. For example, in 2010 China issued what was for all intents and purposes a ban on the export of rare earth elements to Japan following a territorial dispute in the South China Sea, causing prices to spike. Although the incident was short-lived, it has raised concerns about potential supply risks from too great a concentration of supply.[9]

GEI has identified four critical earth elements that have become essential to a range of advanced energy technologies and for which data are adequate for an analysis of energy security risks:

[7] There are 17 rare earths elements: lanthanum, cerium, praseodymium, neodymium, promethium, samarium, europium, gadolinium, terbium, dysprosium, holmium, erbium, thulium, ytterbium, lutetium, yttrium, and scandium.

[8] Available at: https://www.commerce.gov/news/reports/2019/06/federal-strategy-ensure-secure-and-reliable-supplies-critical-minerals.

[9] See: 2016. Spring 2016 Industry Study, Final Report, *Strategic Materials*. The Dwight D. Eisenhower School for National Security and Resource Strategy. National Defense University. Available at: https://es.ndu.edu/Portals/75/Documents/industry-study/reports/2016/es-is-report-strategic-materials-2016.pdf.

- **Cobalt**—Cobalt is a key component of rechargeable lithium ion batteries, used in electric vehicles; permanent magnets in wind turbines; natural gas turbine generators; and catalysts to split water in solar energy technologies.

- **Graphite**—Graphite is a key component of lithium ion batteries. New applications using graphene, derived from graphite, hold promise in energy storage applications.

- **Lithium**—Lithium is used in rechargeable batteries that power electric vehicles and is also for storing energy produced by solar and wind power.

- **Rare Earths**—Rare earths are used in rechargeable batteries, permanent magnets in wind turbines, and host of consumer electronics.

Table 7 uses data from U.S. Geological Survey (USGS) to give an idea of how reserves of the four critical earth elements GEI identified are concentrated. It shows all countries with reserves of at least 10% of the global total plus the share of global reserves in the United States. It is readily apparent that reserves of these elements generally are highly concentrated in a few countries and that U.S. reserves make up a small share of the global total.[10]

Further, several of these countries rate poorly in terms of economic and political freedom, factors we have long used in assessing the global risks associated with conventional fossil fuel production and reserves. World Mining Data (WMD) includes in its database a breakdown of mining production in stable, fair, unstable, and extremely unstable countries (Table 8) that shows most production of these elements occurring in either unstable or extremely unstable countries.

Table 7. Share of Global Reserves of Critical Earth Elements by Country: 2018

Cobalt		Graphite		Lithium		Rare Earths	
Country	% Share	Country	% Share	Country	% Share	Country	% Share
Congo (Kinshasa)	49	Turkey	30	Chile	57	China	37
Australia	17	China	24	Australia	19	Brazil	18
U.S.	6	Brazil	24	Argentina	14	Vietnam	18
Other	28	U.S.	NA	U.S.	0.3	Russia	10
		Other	22	Other	9	U.S.	1
						Other	24

Table 8. Production of Critical Earth Elements & Political Stability: 2017

Political Stability	Cobalt	Graphite	Lithium	Rare Earths
Stable	0%	0%	0%	0%
Fair	17%	3%	93%	14%
Unstable	22%	95%	7%	86%
Extremely Unstable	61%	2%	0%	0%

[10] "Reserves" typically refers to a subset of a resource that is available economically and with a higher degree of geologic certainty. It is quite possible that these reserve figures for these materials will change dramatically as their price changes and as new geological surveys bring to light currently unknown deposits.

Similarly, Figures 6, 7, 8, and 9 use data from BP and Freedom House to show the shares of production for these four critical elements in Free, Partly Free, and Not Free counties. The concentration of production in countries with relatively poor civil and political liberties, a proxy for reliability, is readily apparent.

These four commodities are not only growing in importance, but their global distribution suggests risks comparable to those we have seen for other energy resources.

Despite the growing demand for these materials and potential supply risks, the United States has done comparatively little to develop known mineral resources or to assess what other alternative resources might be found. According to U.S. Geological Survey data, less than 18% of the U.S. land mass has been geologically mapped at the necessary scale. Even less of the country has been mapped using the aeromagnetic technology at a sufficient resolution to perform robust mineral resource assessments.

Domestic mining and trade agreements with friendly countries are ways to avoid vulnerability to critical minerals. There is, however, opposition to developing America's critical mineral resources required to manufacture, among other things, renewable energy technologies. In the United States, rare earth minerals are only produced at a mine in Mountain Pass, California—which sends ore to China for processing—while efforts to expand production in places like northern Minnesota have been met with stiff resistance from environmentalists.

The minerals industry advisor group Behre Dolbear's *Where to Invest 2015* report[11] found that permitting delays are the most significant risk to mining projects in the United States. While the United States remains a good place for mining companies to invest in, it takes a long time to get a mining permit. "The U.S. is a bit of a paradox. Its experienced governmental and financial sectors contribute to high investor confidence. However, the public's worry over environmental legacy, combined with the incremental concern that new production capacity represents, leads to an onerous permitting process that creates sufficient uncertainty to sometimes destroy the viability of new project."

The increased use of many of these elements in new energy technologies, especially but not exclusively in renewable technologies and batteries, and the potential supply issues that recall in many ways those experienced in the oil industry, means that critical earth elements have taken on greater prominence in the discussion about energy security.

GEI noted back in 2010 that we would continue to revise, improve, and expand the metrics we use, and would entertain including new metrics. The addition of risk factors linked to critical earth elements now is ripe for consideration.

Risks associated with global oil, natural gas, and coal reserves and production are already measured for the U.S. Index, and the same techniques could be applied to the critical earth elements identified earlier.[12] Data on production of these materials are much more comprehensive and seemingly more reliable than data on reserves, which are less detailed and geographically sparse than necessary to develop an adequate metric.

There are four sources of mining or refining production data for the critical earth elements we have selected to focus on: the USGS, British Geological Survey (BSG), WMD, and BP Statistical Review of World Energy (BP).[13]

[11] Available at: http://www.mining.com/wp-content/uploads/2015/08/WHERE_TO_INVEST_2015_08.pdf.

[12] We have less confidence in data that would be needed to measuring import risks for these critical materials, similar to the way metrics created for petroleum and natural gas imports.

[13] Available at:
USGS—https://www.usgs.gov/centers/nmic/mineral-commodity-summaries
BGS—http://www.bgs.ac.uk/mineralsuk/statistics/wms.cfc?method=searchWMS
WMD—https://www.world-mining-data.info/
BP—https://www.bp.com/en/global/corporate/energy-economics/statistical-review-of-world-energy.html

Figure 6

Share of World Cobalt Production in Free, Partly Free & Not Free Countries: 1995-2018

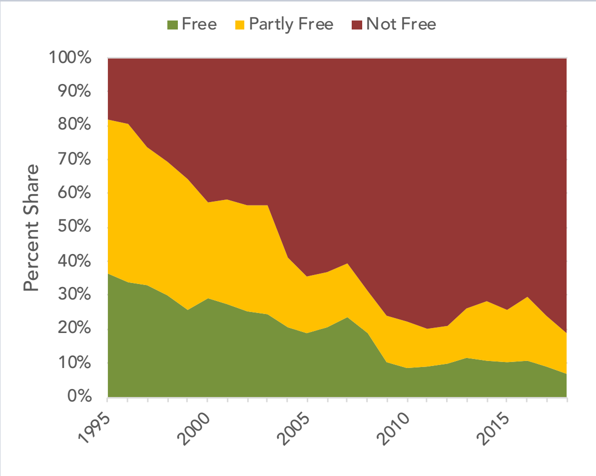


Figure 7

Share of World Graphite Production in Free, Partly Free & Not Free Countries: 1995-2018

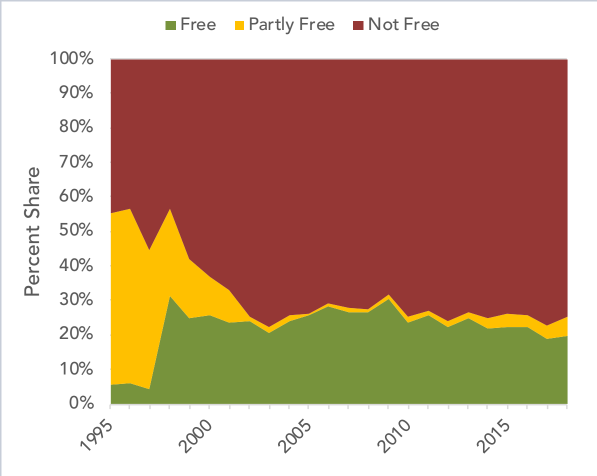


Figure 8

Share of World Lithium Production in Free, Partly Free & Not Free Countries: 1995-2018

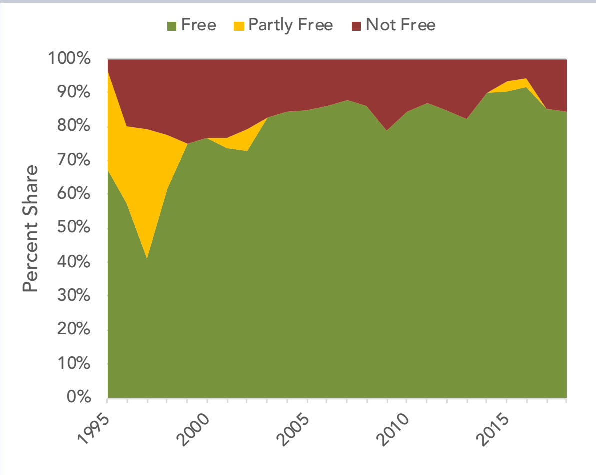
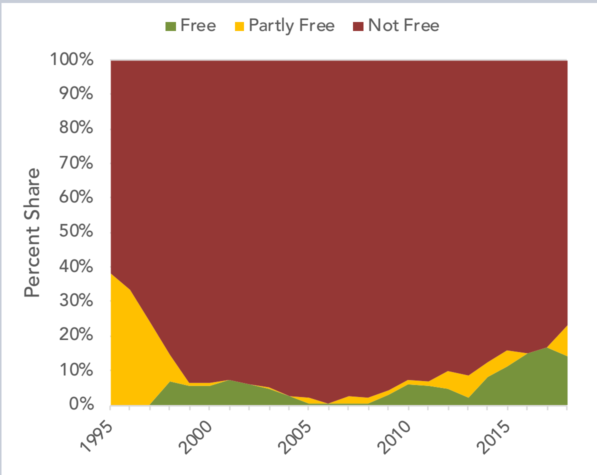


Figure 9

Share of World Rare Earths Production in Free, Partly Free & Not Free Countries: 1995-2018



It should come as no surprise that the data reported by these four sources vary, sometimes considerably. Some databases, for instance, list all the countries for which data are available while others list major producers and lump smaller producers into an "other" or "rest of world" category. Some also apparently measure slightly different things, such as ores, oxides, metals, refined products, carbonates, minerals, etc. There are also differences in the time span covered among the four databases, arranging from before 1970 to 2006. (Having historical data available that goes back to, or close to, 1980 is an advantage.)

Mine production data for the four commodities from each database are provided in Figures 10, 11, 12, and 13. The global production levels data reported by USGS, BGS, WMD, and BP are largely consistent with the notable exception of BGS data for graphite and lithium production. For graphite, BGS shows very high production from China from the early-1990s to the 2010s than the other databases, and for lithium BGS shows relatively high production from Australia, Chile, China, and Zimbabwe, from the mid-1990s and especially in 2017. The other three databases do not show anywhere near these production levels for these countries. Other than these outliers, the trends in total production match up fairly well even as there is variation among the data for individual countries.

Adopting the same methodology used for our Global Fuels metrics to these materials[14] yields the results presented in Figures 14, 15, 16, and 17 (with 1980=100). It is evident that some of the risk scores are, when calculated this way, extraordinarily high, with scores of hundreds and in one case thousands, especially later in the period after 2000. While such a high index score reflects the supply risks we are concerned with here, the extremely high scores may also reflect data beyond the range for which the metrics were formulated and calibrated. Such high scores are in part a result of: (1) data gaps for some countries (such as China) in the early years of the record; and (2) the fact that extensive in-filling with less accurate is needed at the beginning of the record to arrive at the 1980 baseline score of 100, which tends to skew much higher the scores for the years with actual data.

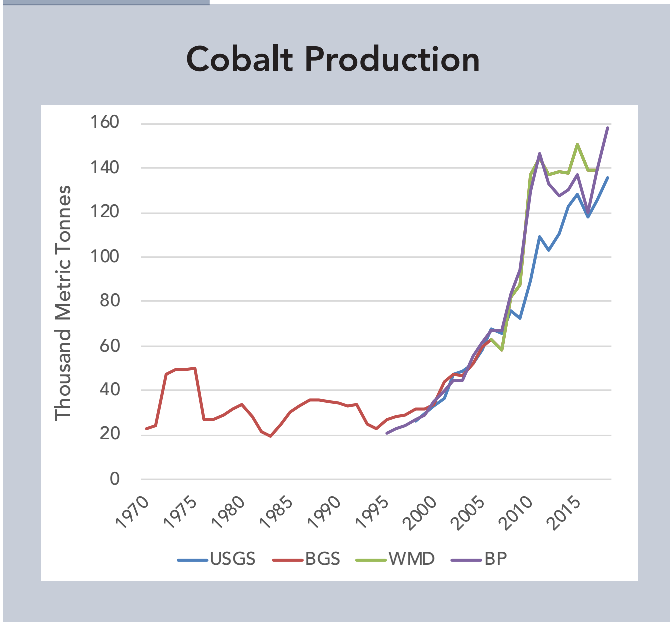
One way to get around this would be to change the base year for these metrics to a year for which actual critical earth element data are available. As an example, Figures 18, 19, 20, and 21 show global production risk scores using a base year of 2010=100 rather than 1980=100. These risks scores appear to be less extreme compared to those using 1980 as the base year, but some scores are probably higher than perhaps they ought to be. For example, the risk attached to global lithium production, while lower than in earlier years, is still too high for a commodity that is produced mostly in Australia and Chile, both stable democracies.

Should Critical Earth Elements be Included in the *U.S. Index*, and If So How?

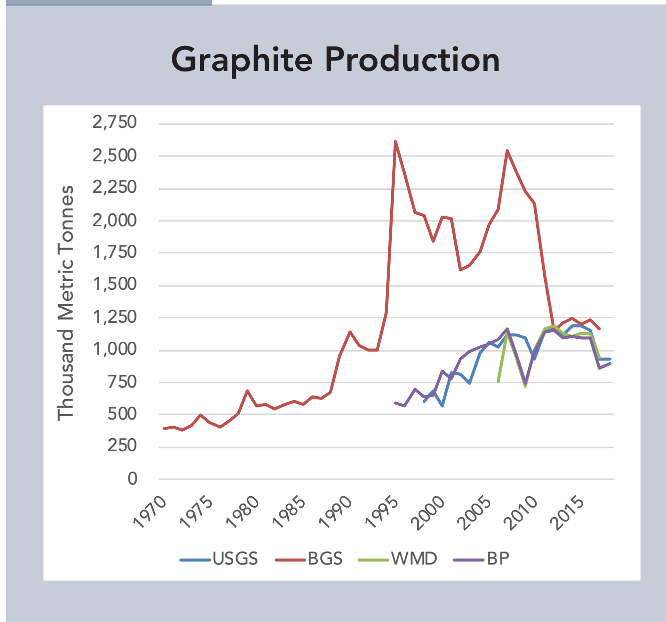
GEI's *U.S. Index* and its companion, the *International Index of Energy Security Risk* indexes were designed to measure energy security risk and how that risk varies across time and among countries. Energy security risk is the product of trends affecting a broad array of individual energy metrics measuring risks associated with global supplies, imports, prices and expenditures, efficiency, transportation, electricity, emissions, and research and development. GEI's aim was to use available data and forecasts to develop the metrics in these broad categories 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.

[14] Global Supply risks scores are calculated by: (1) weighting global production by each country's relative Freedom House index score (a proxy for reliability); (2) calculating the global diversity of production using the Herfindahl-Hirschman Index; and (3) multiplying product of the square of the Freedom rating and the square root of the HHI. This helps keep the effects proportionately similar.

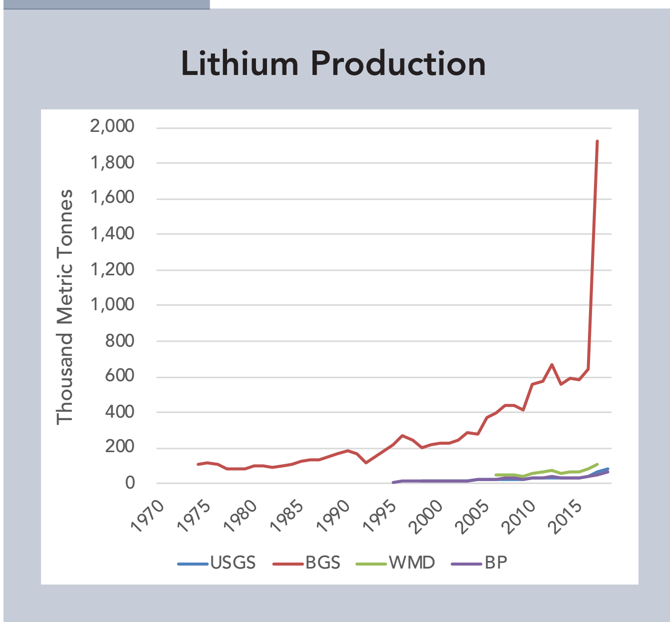
■ Figure 10



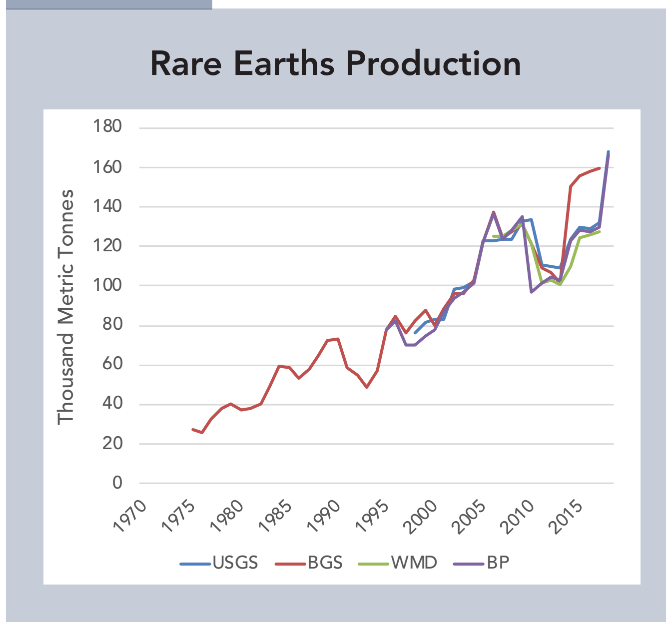
■ Figure 11



■ Figure 12



■ Figure 13



The metrics GEI selected for inclusion in the indexes were limited by the availability and quality of the data. We established criteria that would ensure the data we used possessed the important quality characteristics listed below (and discussed in more detail in Appendix 1: Methodology Used to Develop the Index of U.S. Energy Security Risk):

- Sensible
- Credible
- Accessible
- Transparent
- Complete
- Prospective
- Updatable

While these criteria help insure the data we use are as robust as possible, they also prevent consideration of potentially relevant risk factors that fail to fit these criteria. The absence of these risk factors—such as shipping choke points, for example—from our metrics does not mean they are not significant risks, only that we cannot quantify them adequately for use in the Index.

We have examined the availability and quality of the data available on the production and use of various key elements to determine if the risks associated with their use could be quantified and used in the Index. GEI is confident that data meeting the criteria outlined above are available for the four critical earth elements noted earlier—cobalt, graphite, lithium, and rare earths—from four reliable and authoritative sources.

Other increasingly important elements, such as indium, gallium, and tellurium (used in photovoltaic solar cells, among other things), were considered, but we have less confidence in the quality and extent of the data for these. Their suitability and use for this analysis will await future improvements in the available data.

The 37 metrics used in the U.S. Index all have the characteristic of being important to U.S. energy security over long periods, both historical and prospective. In contrast, the reliable availability of critical earth elements has not been a security concern in the energy sector until fairly recently, so incorporating the risk scores for these four elements all the way back to 1970 would not reflect this.

GEI will be investigating what is the appropriate year to begin phasing in the risk scores for these metrics. Seeing as these materials are critical mostly in renewable technologies, they could be phased in the historical data during, our current thinking is that these metrics could be ramped up over a period of five to 10 years during a time of rapid renewable capacity additions.

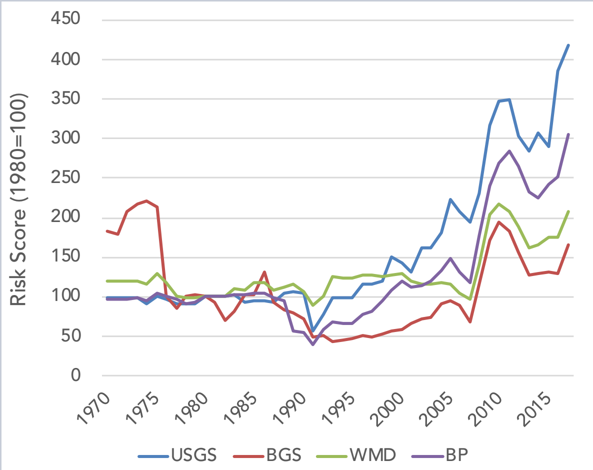
How heavily these metrics—whether individually or combined—ultimately will be weighted in the Index is another consideration. Metric weights now range from 1.1% (for R&D-related and global coal) to 9% (for the price of crude oil). Early thinking is that it is unlikely the total weight for these metrics would exceed 4% of the total risk index.

Then there is the question of how the weights of an existing metric or metrics should be lowered to accommodate the new metrics. The total weighting of all metrics necessarily sums to 100%, so the addition of new metrics means the weighting of some other metrics or metrics must be reduced so the total remains 100%. GEI will look at the current weightings to assess what makes the most sense in today's rapidly changing energy environment, recognizing that these new metrics, while important, are not the only important materials used in renewable technologies.

Since their inception, a goal of the U.S. Index and the International Index has been to identify the best data and analytical techniques to describe energy security risks, and to update these data and techniques whenever improvements are feasible. To this end, and in the spirit of openness, GEI interested in hearing views from Index users on how to best to address these issues. Those interested in providing feedback go the "Contact" section of GEI's website to communicate with us (please use "Energy Security Index" as the subject line).

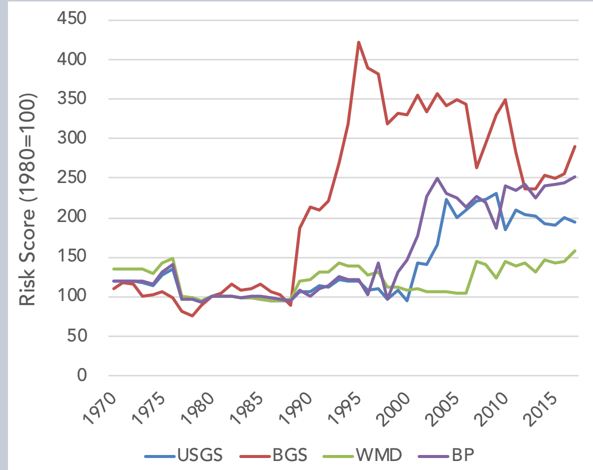
■ Figure 14

Security of World Cobalt Production, 1980 = 100



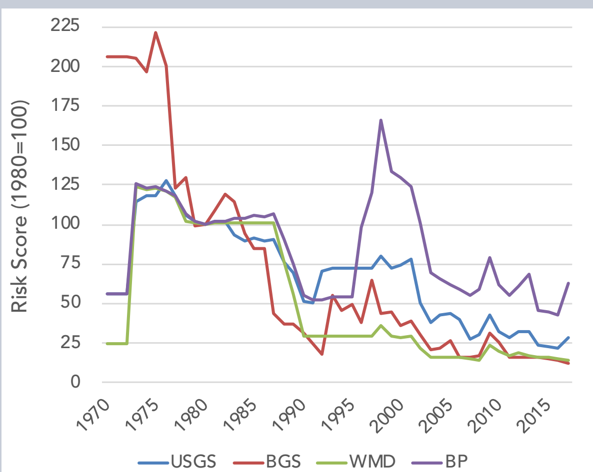
■ Figure 15

Security of World Graphite Production, 1980 = 100



■ Figure 16

Security of World Lithium Production, 1980 = 100



■ Figure 17

Security of World Rare Earths Production, 1980 = 100

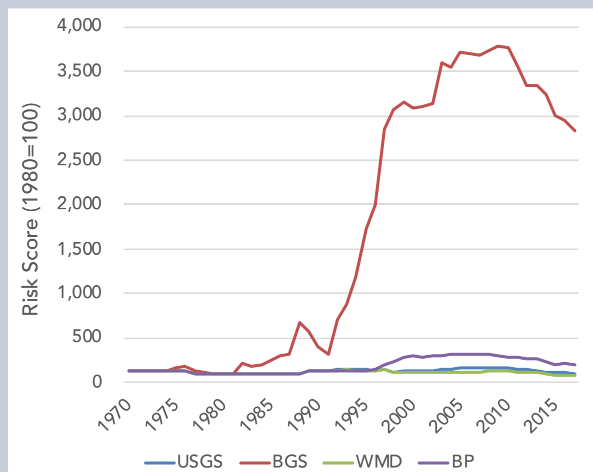


Figure 18

Security of World Cobalt Production, 2010 = 100

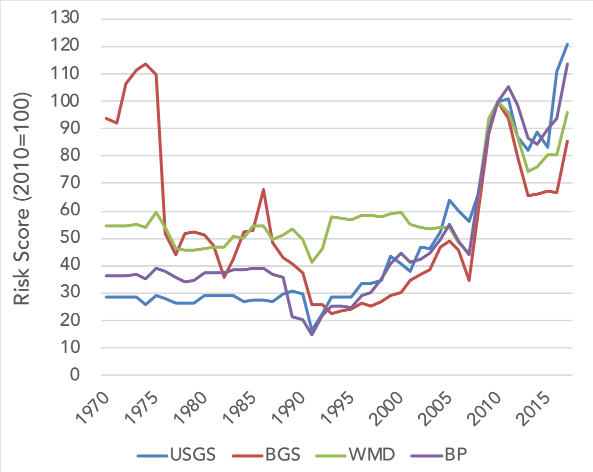


Figure 19

Security of World Graphite Production, 2010 = 100

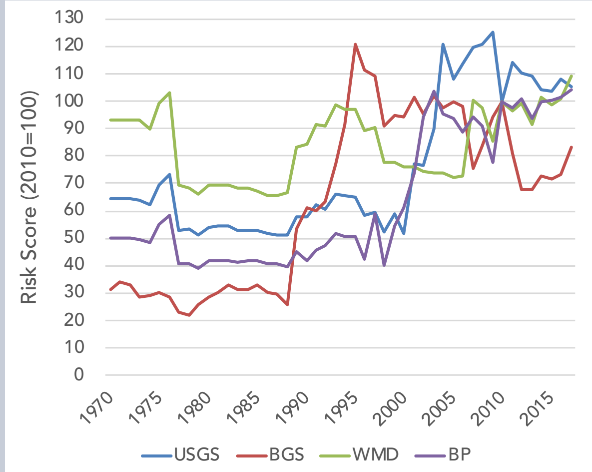


Figure 20

Security of World Lithium Production, 2010 = 100

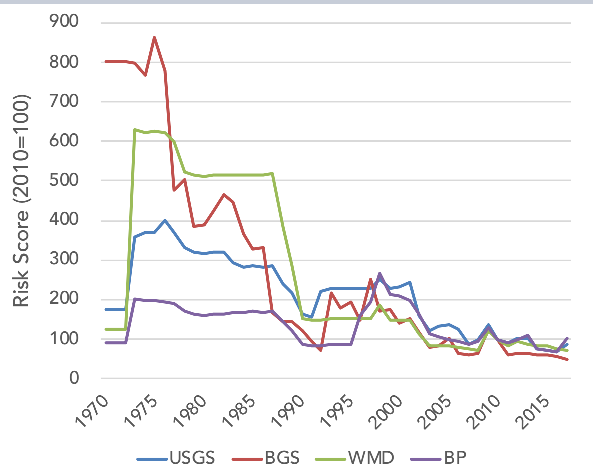
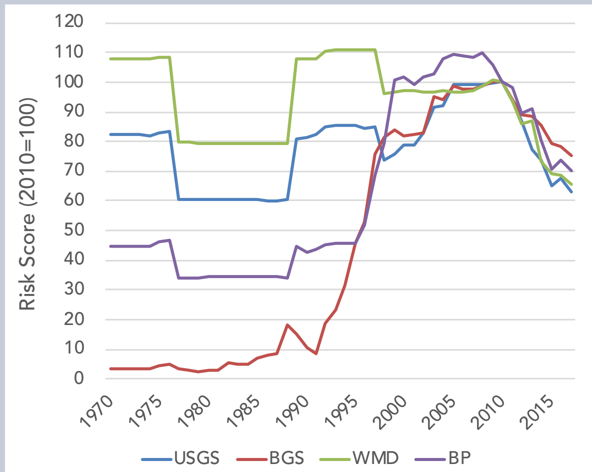


Figure 21

Security of World Rare Earths Production, 2010 = 100



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 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 of 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.

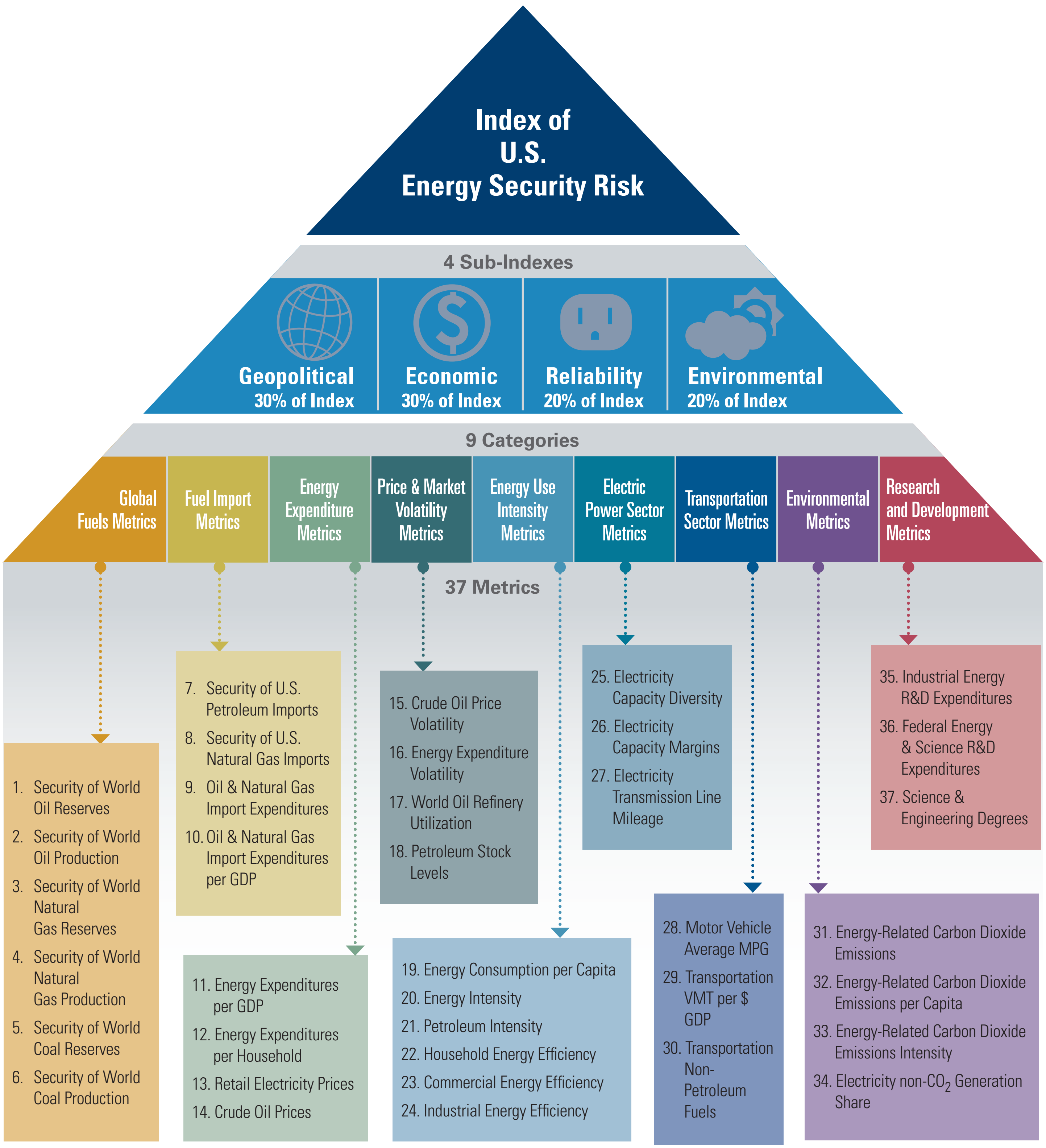
Using these categories as guides, 37 individual metrics were selected and developed covering a wide range of energy supplies, energy end-uses, operations, and environmental emissions. Anywhere from three to six metrics were selected for each metric category.

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



	Metric Category	General Description of the Metrics
Table A1-1. Categories of Energy Security 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 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 spent each year 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.

[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.

- **Environmental:** Fossil fuels—coal, oil, and gas—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 GEI 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. Sub-Indexes, Metrics & Data Tables

Appendix 2 presents and describes the four Sub-Indexes and the individual metrics used to build them and the total U.S. Energy Security Risk Index.

The Sub-Indexes of Energy Security Risk view energy security through four lenses: Geopolitical, Economic, Reliability, and Environmental. There are no clear demarcations 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 oil has economic implications, and its consumption poses environmental risks. As another example, underinvestment in electricity transmission infrastructure 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.

The four Sub-Indexes are provided in chart form. Like the total Index, 1980 is set as the base year with a score of 100.

The Sub-Index charts are followed by information on the 37 individual metrics. 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

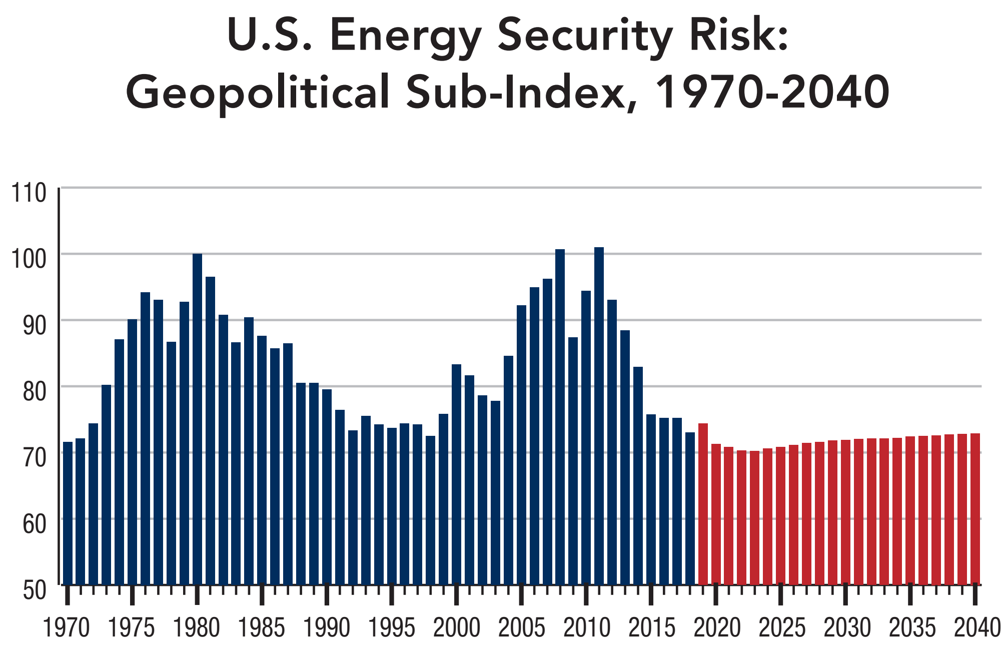
The following information is provided for each metric:

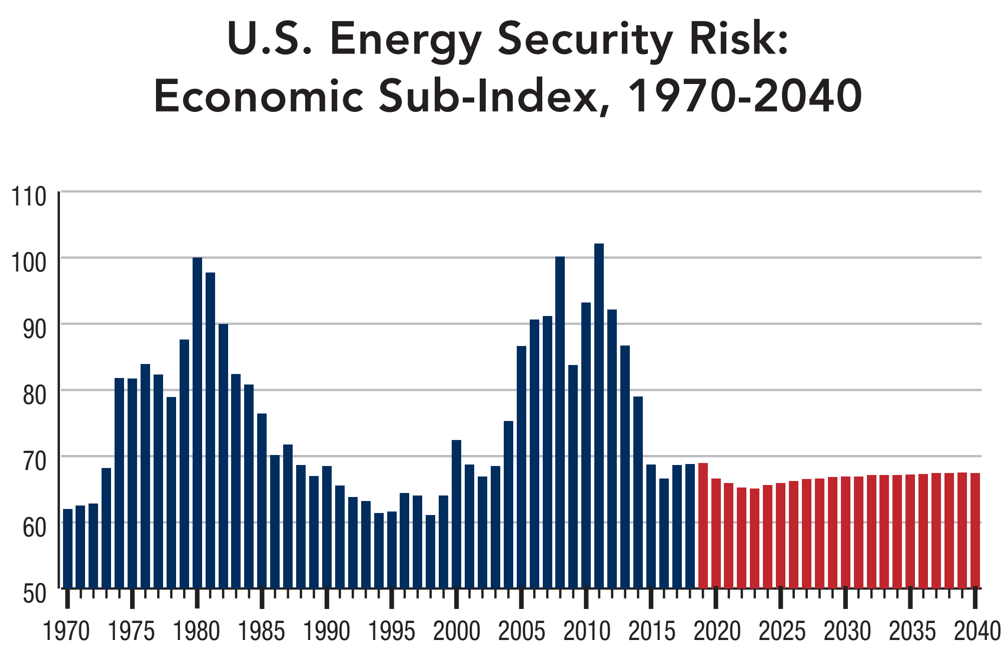
- **Definition:** Describes what is being measured and the units of measurement.
- **Importance:** Describes the potential impact and risks associated with each metric.
- **Category of Metric:** Identifies the metric as one of nine broad types of metrics.
- **Historical and Forecast Values:** Provides 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 Most Recent Contribution of Each Metric to Energy Security Indexes:** Provides a table with: (1) the input 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 contribution of each metric to the resulting Sub-Index value for the most recent year. 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 most recent contribution 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.

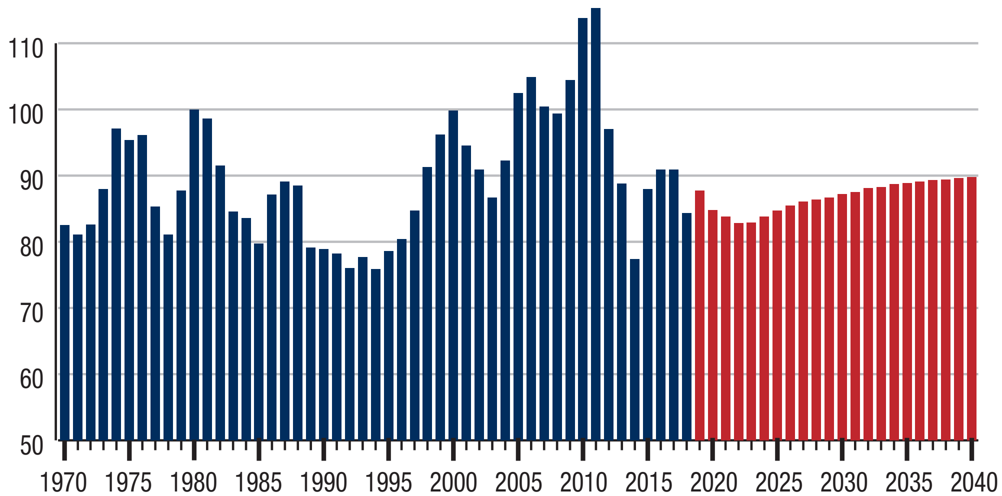
Data references used to develop the metrics are listed at the end of this appendix.

SUB-INDEXES

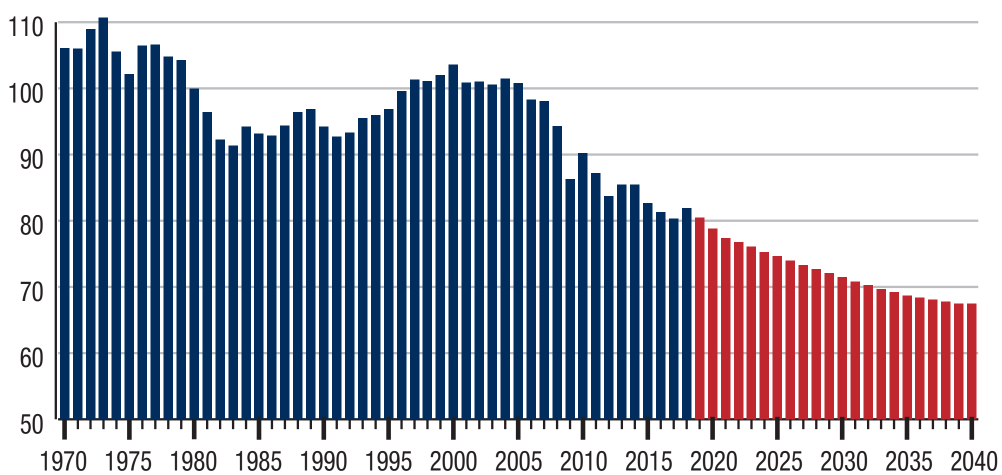




U.S. Energy Security Risk: Reliability Sub-Index, 1970-2040



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



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.

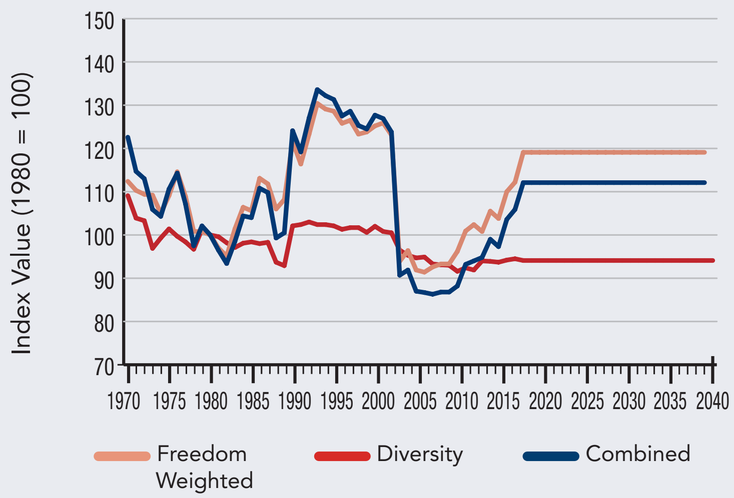
Importance

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
Contribution in 2018	13.8	N/A	N/A	N/A	4.0

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.

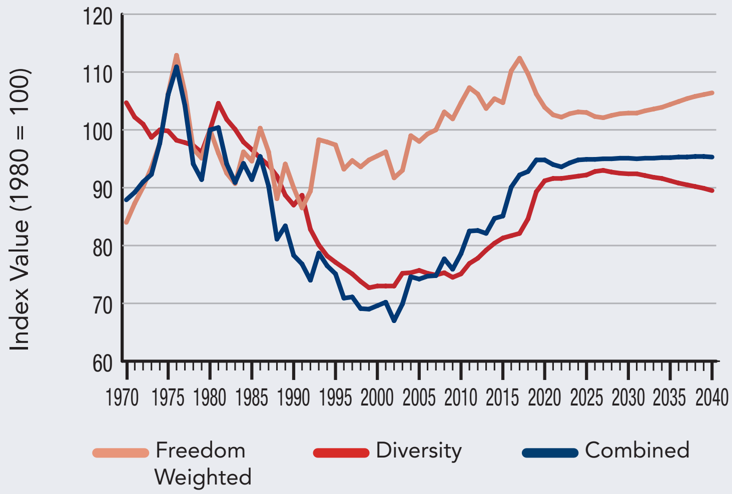
Importance

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

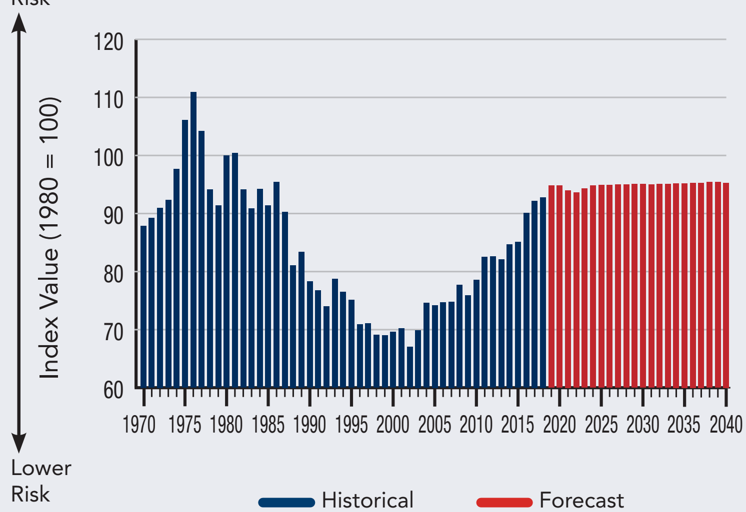
Category of Metric

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
Contribution in 2018	8.9	6.7	6.6	N/A	5.9

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.

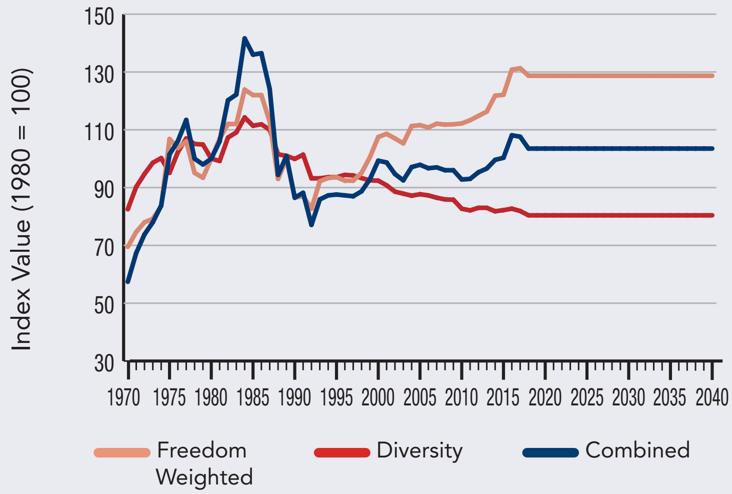
Importance

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.

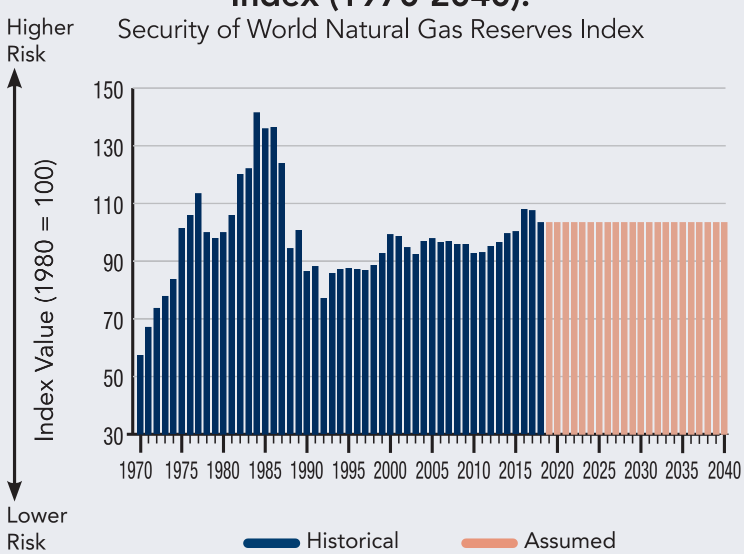
Category of Metric

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
Contribution in 2018	8.5	N/A	N/A	2.5	3.0

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

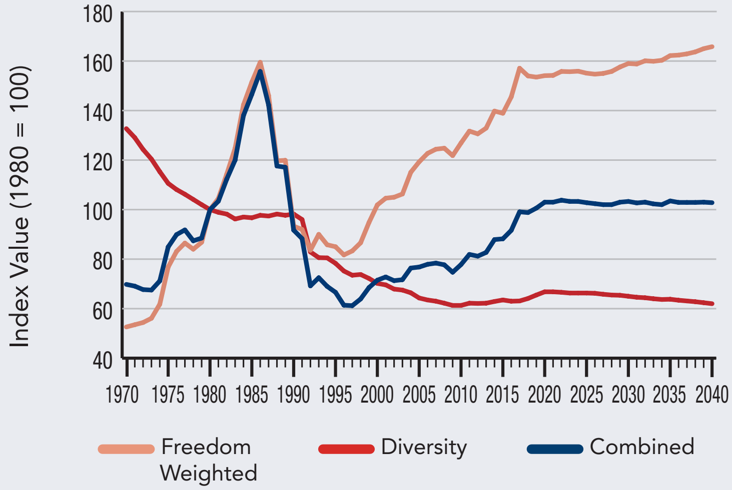
Indicates the level of risk attached to the average cubic foot of natural gas produced globally.

Category of Metric

Global Fuels

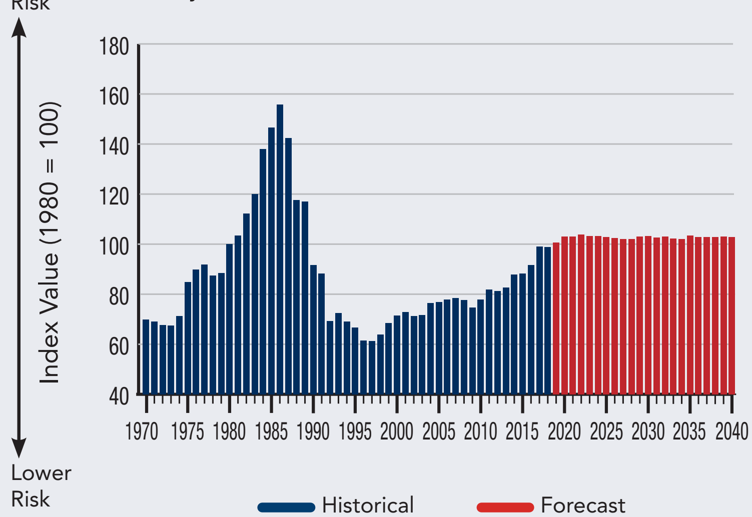
Historical and Forecast Values (1970-2040):

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
Contribution in 2018	6.8	2.9	3.5	2.4	4.0

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

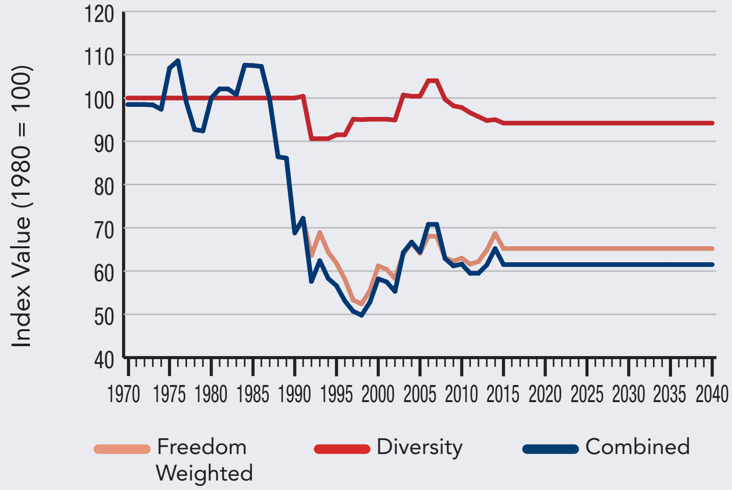
Indicates the risk attached to the average ton of coal reserves globally. As a measure of reserves, it largely reflects longer-term concerns.

Category of Metric

Global Fuels

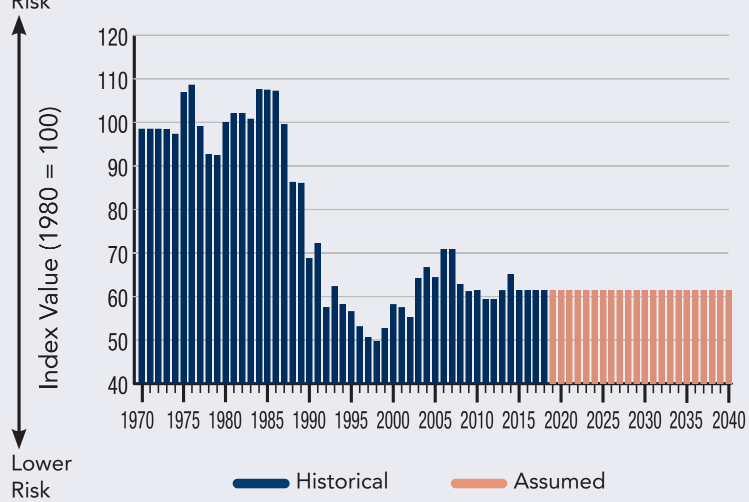
Historical and Forecast Values (1970-2040):

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
Contribution in 2018	3.4	N/A	N/A	N/A	1.0

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

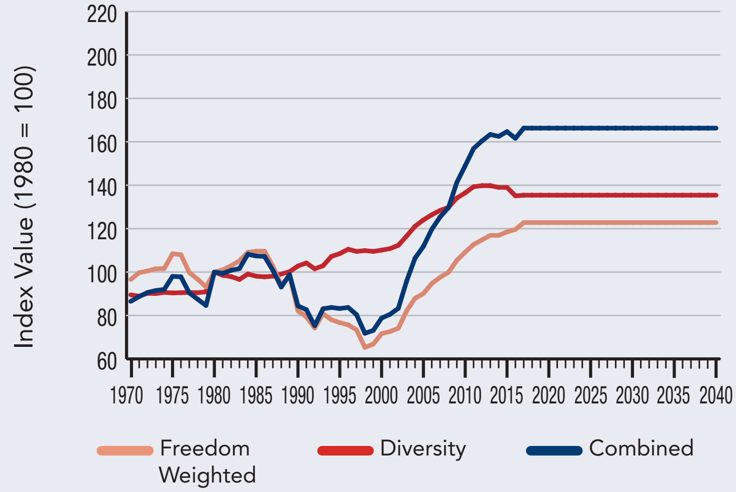
Indicates the level of risk attached to the average ton of coal production globally.

Category of Metric

Global Fuels

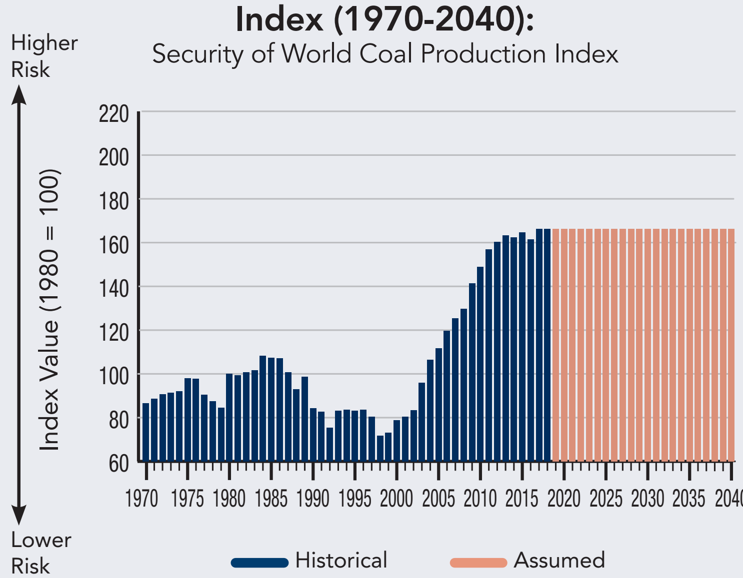
Historical and Forecast Values (1970-2040):

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
Contribution in 2018	4.6	2.4	2.0	N/A	2.4

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.

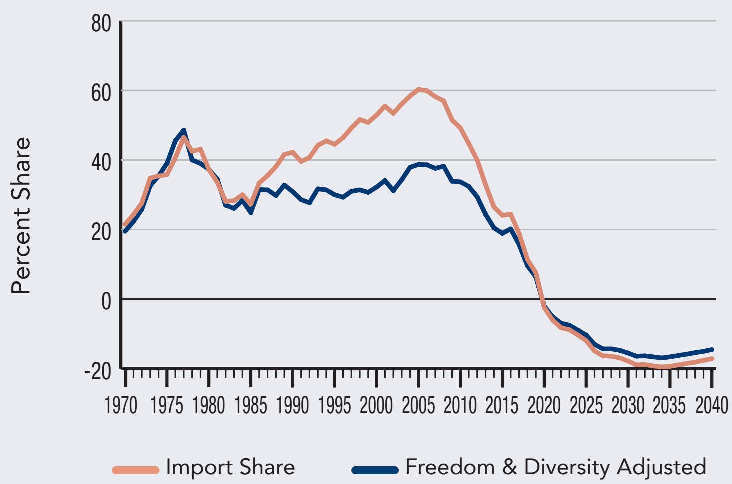
Importance

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.

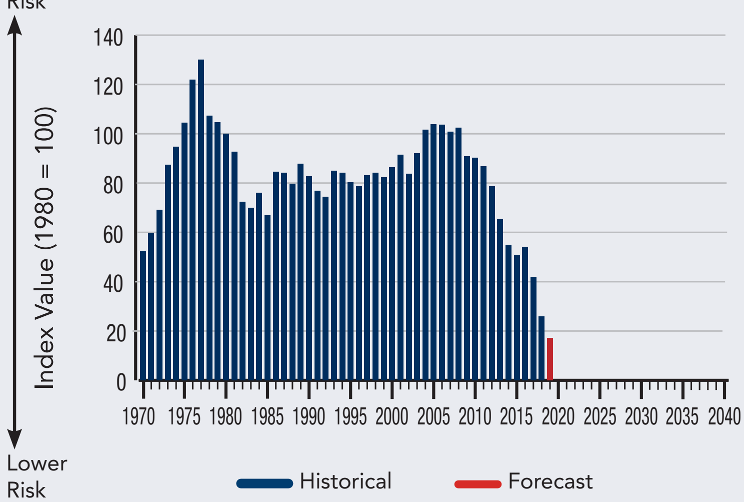
Category of Metric

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
Contribution in 2018	2.8	N/A	2.8	N/A	1.4

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.

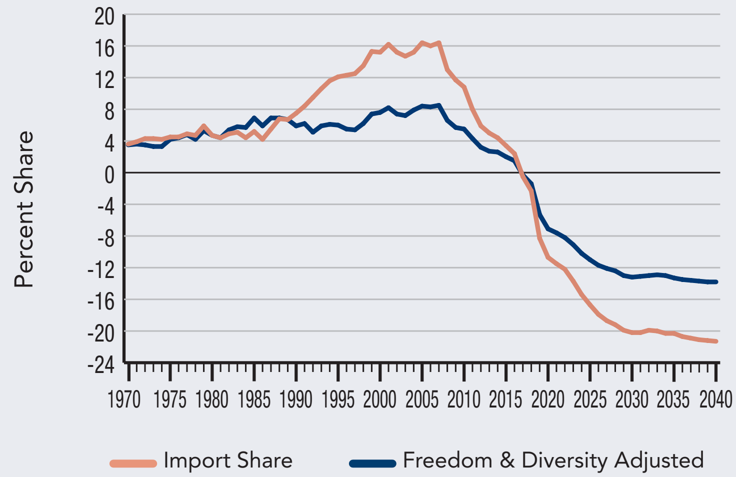
Importance

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

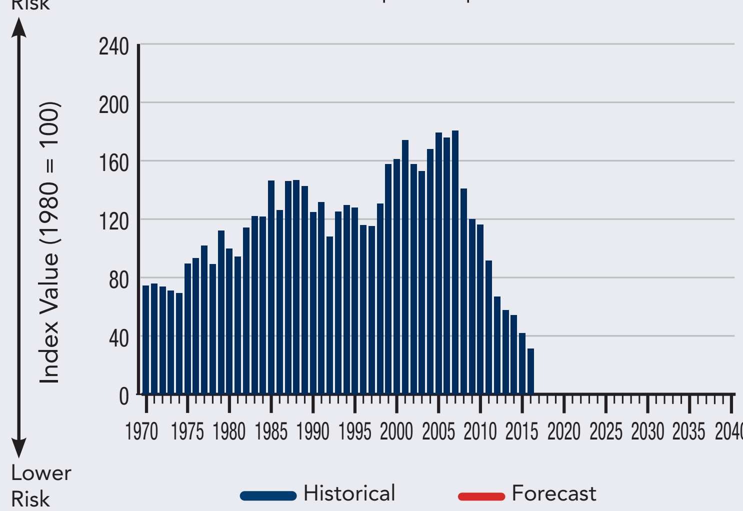
Category of Metric

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



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
Contribution in 2018	0.0	N/A	0.0	N/A	0.0

Oil & Natural Gas Import Expenditures

Definition

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

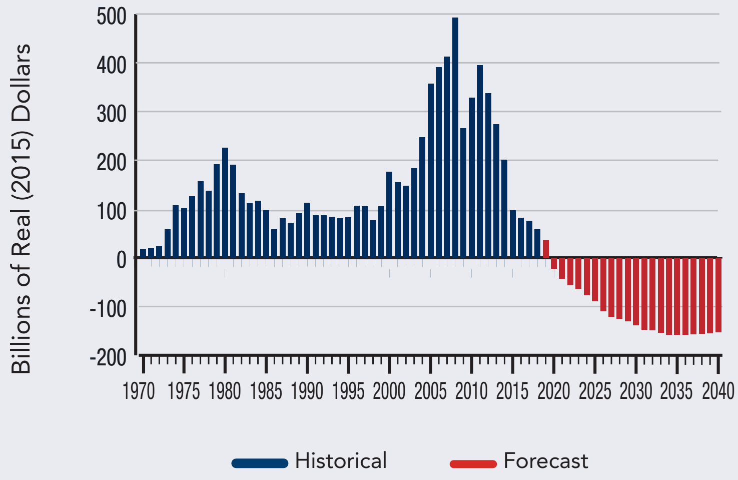
Importance

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

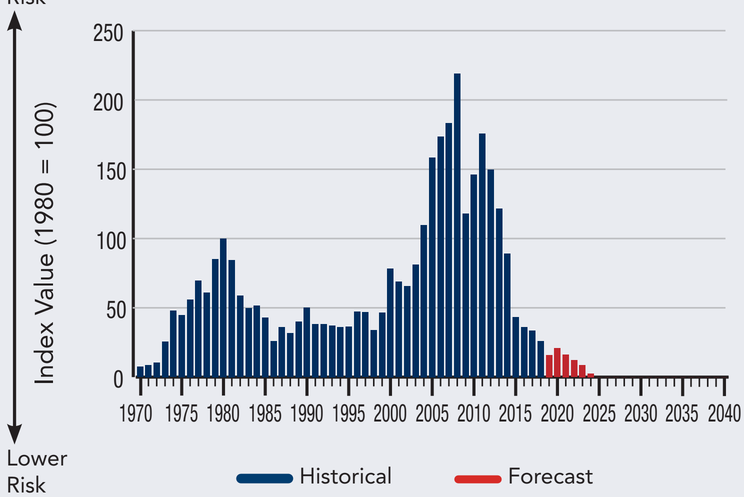
Category of Metric

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
Contribution in 2018	2.1	2.3	N/A	N/A	1.2

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

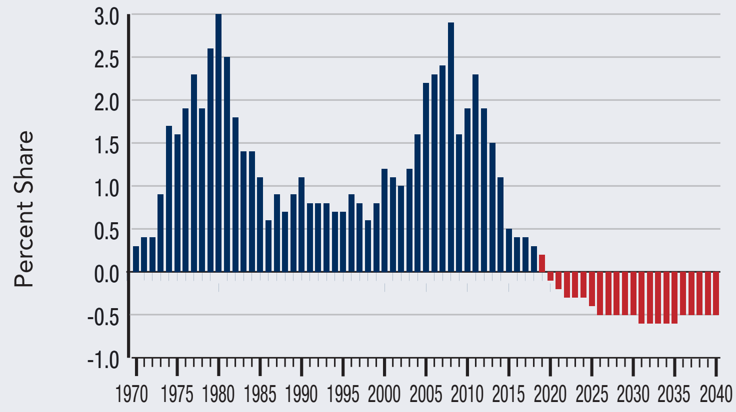
Indicates the susceptibility of the U.S. economy to imported oil and gas price shocks.

Category of Metric

Fuel Imports

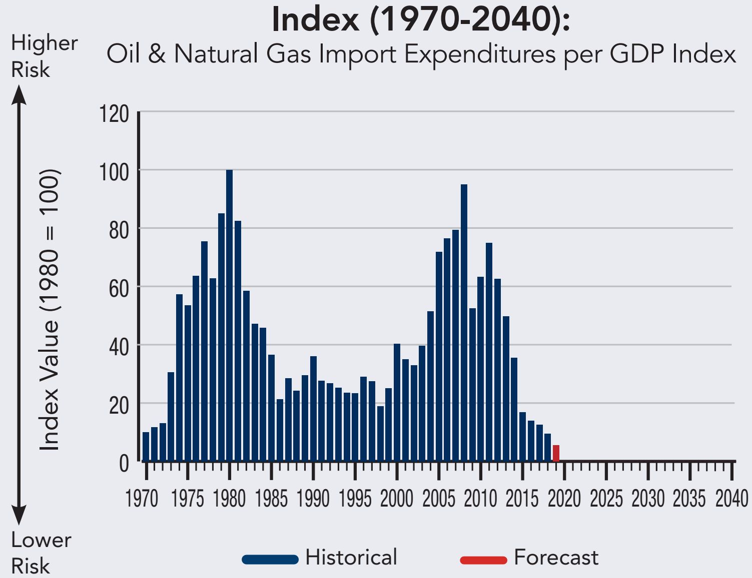
Historical and Forecast Values (1970-2040):

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
Contribution in 2018	N/A	1.2	N/A	N/A	0.3

Energy Expenditures per dollar of GDP

Definition

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

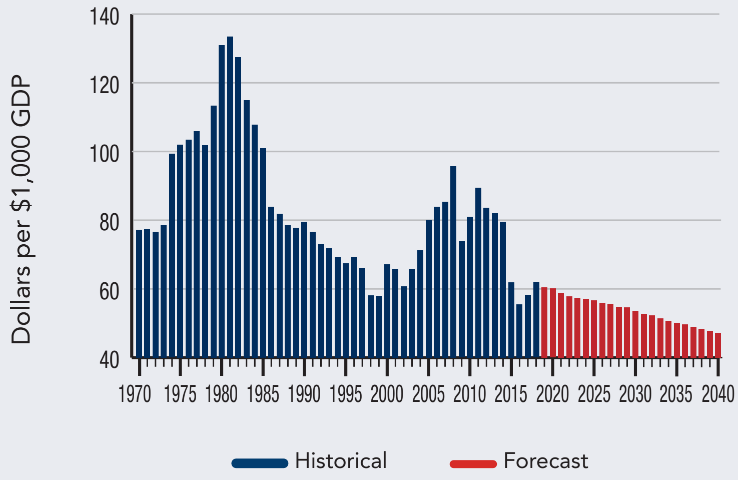
Importance

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

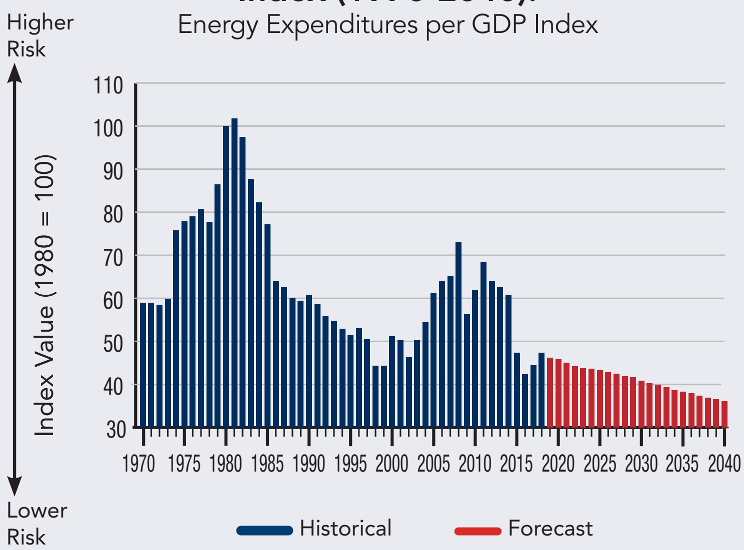
Category of Metric

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
Contribution in 2018	3.2	4.8	N/A	N/A	2.2

Energy Expenditures per Household

Definition

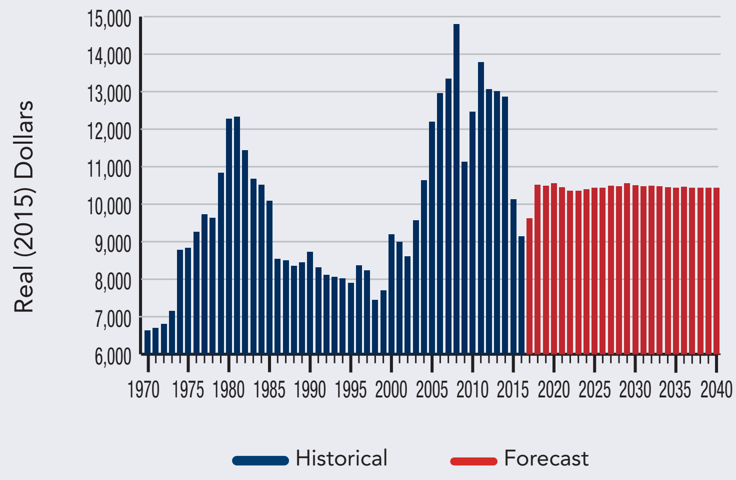
Total real (2015) dollar cost of the energy consumed per household per year.

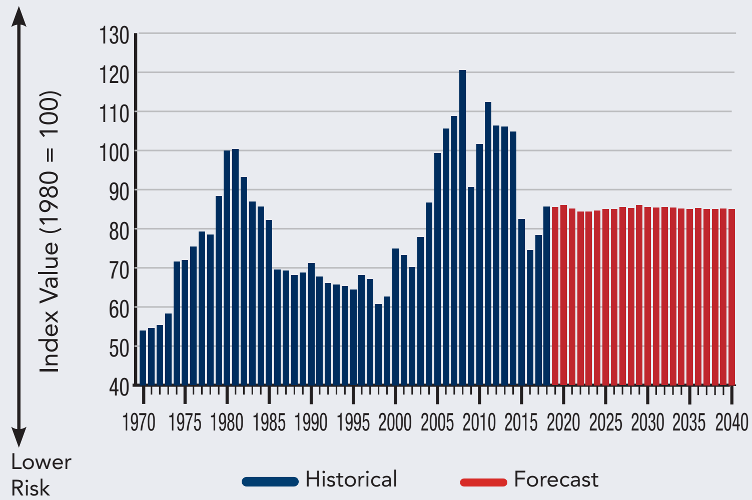
Importance

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

Category of Metric

Energy Expenditures





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
Contribution in 2018	N/A	11.2	N/A	N/A	3.1

Retail Electricity Prices

Definition

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

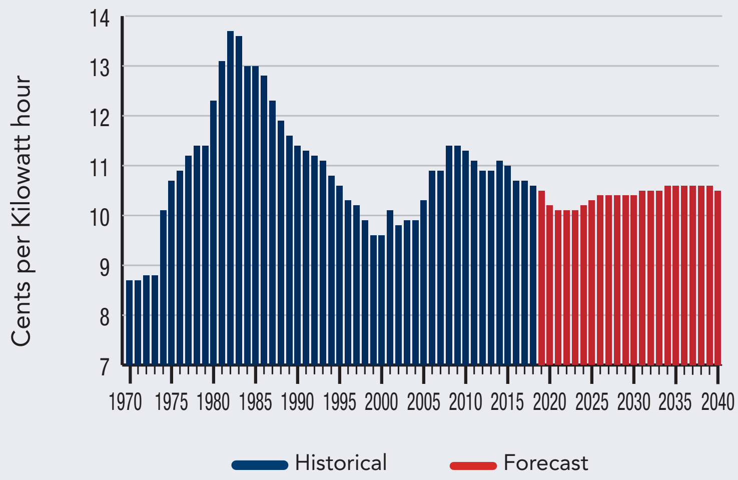
Importance

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

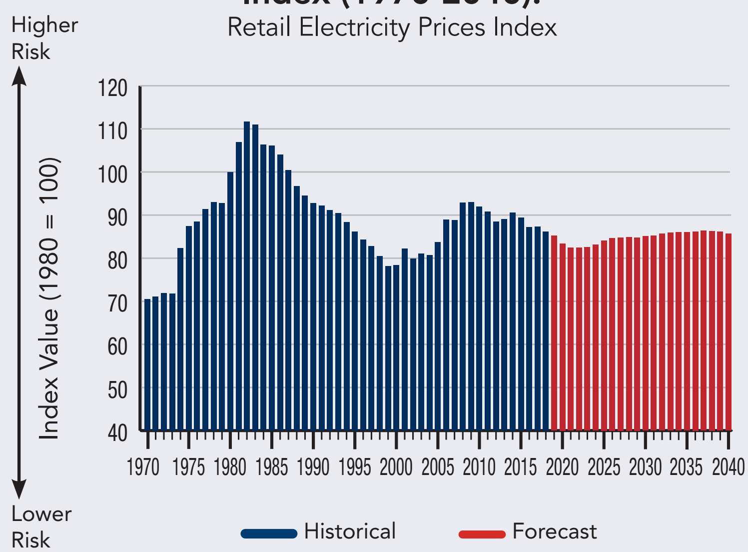
Category of Metric

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
Contribution in 2018	N/A	12.5	N/A	N/A	3.4

Crude Oil Prices

Definition

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

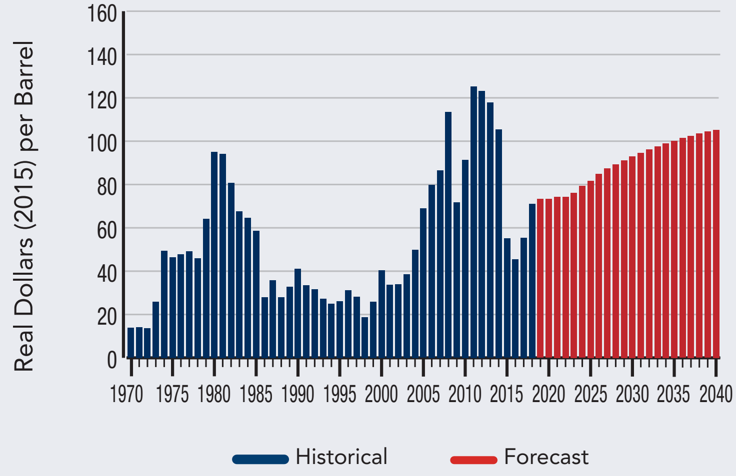
Importance

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

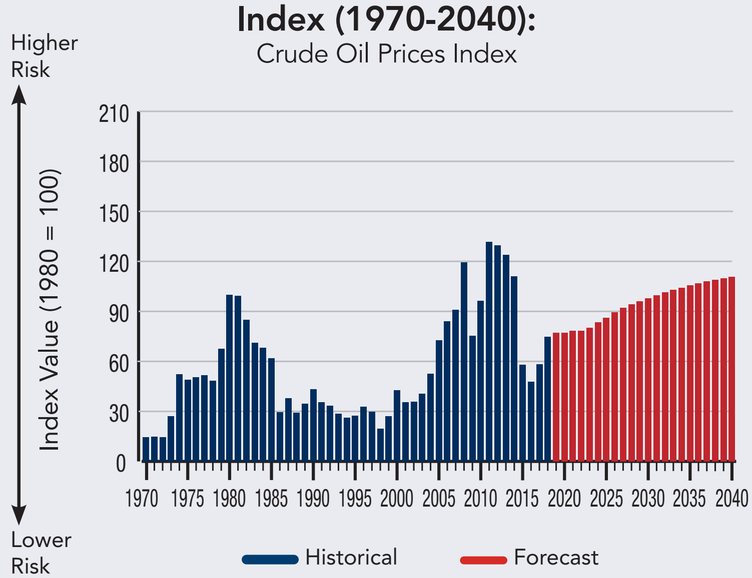
Category of Metric

Energy Expenditures

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



Index (1970-2040):
Crude Oil Prices Index



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
Contribution in 2018	13.3	14.1	5.3	N/A	8.9

Crude Oil Price Volatility

Definition

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

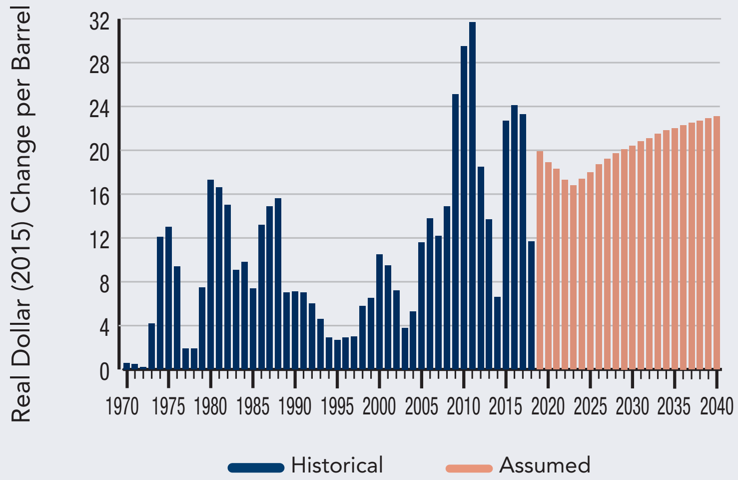
Importance

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.

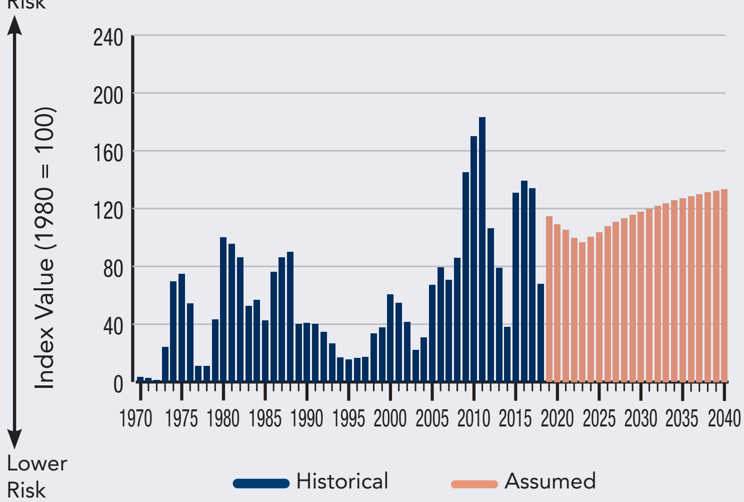
Category of Metric

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
Contribution in 2018	4.6	3.0	8.0	N/A	3.9

Energy Expenditure Volatility

Definition

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

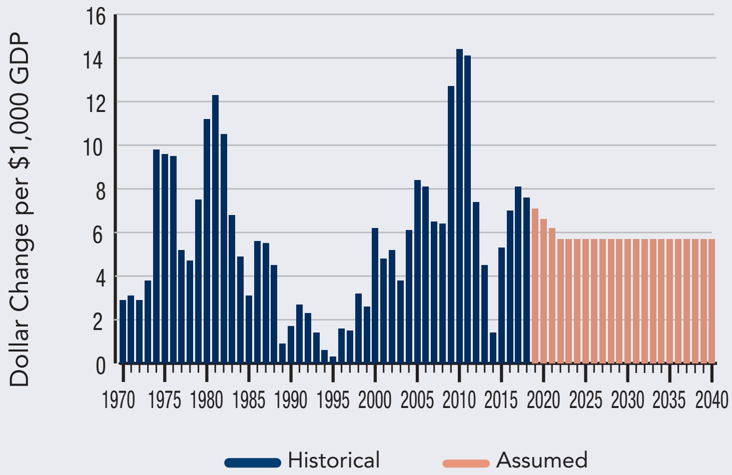
Importance

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

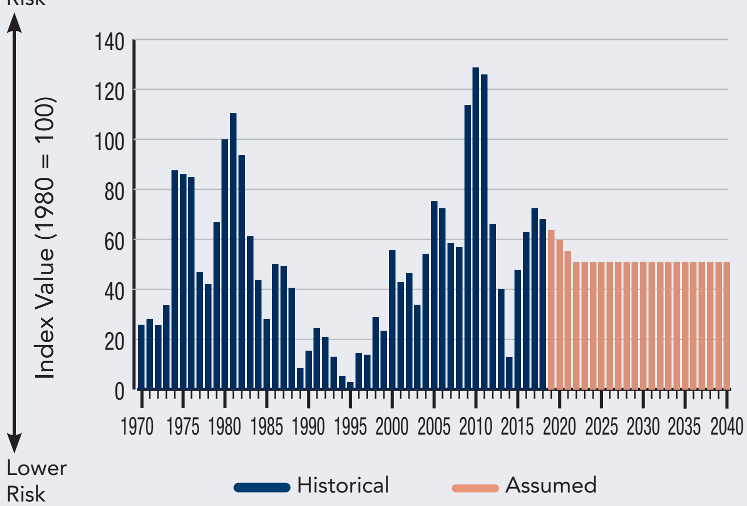
Category of Metric

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
Contribution in 2018	N/A	5.0	11.3	N/A	3.9

World Oil Refinery Utilization

Definition

Average percentage utilization of global petroleum refinery capacity.

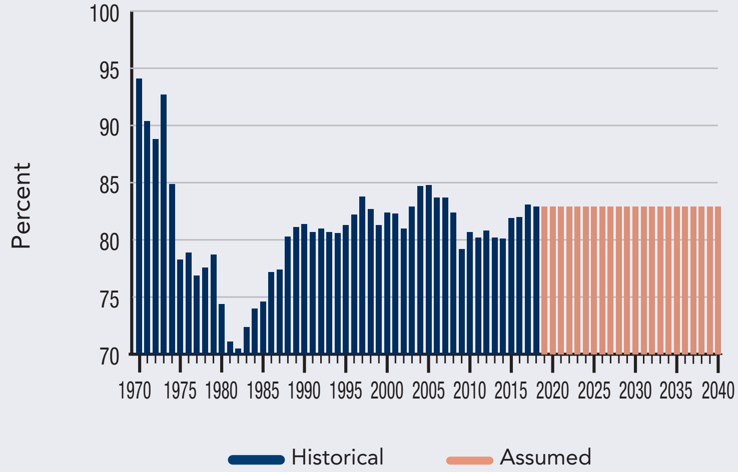
Importance

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

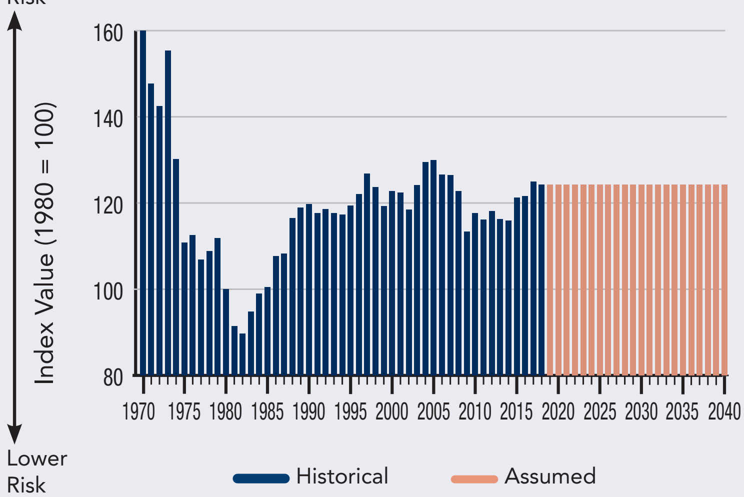
Category of Metric

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
Contribution in 2018	5.1	N/A	8.8	N/A	3.4

Petroleum Stock Levels

Definition

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

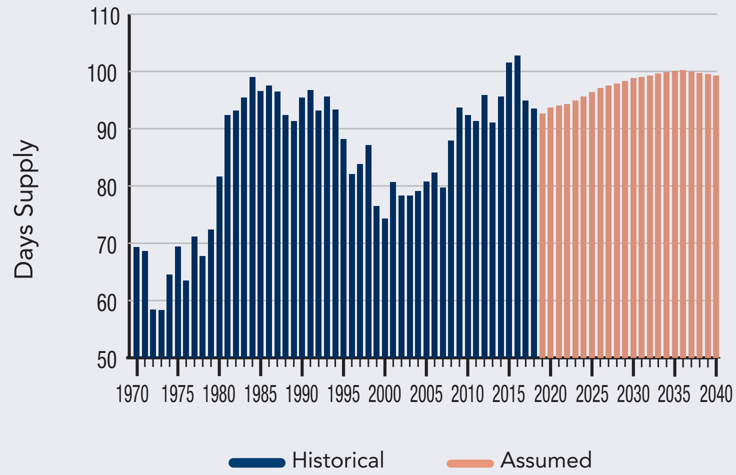
Importance

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.

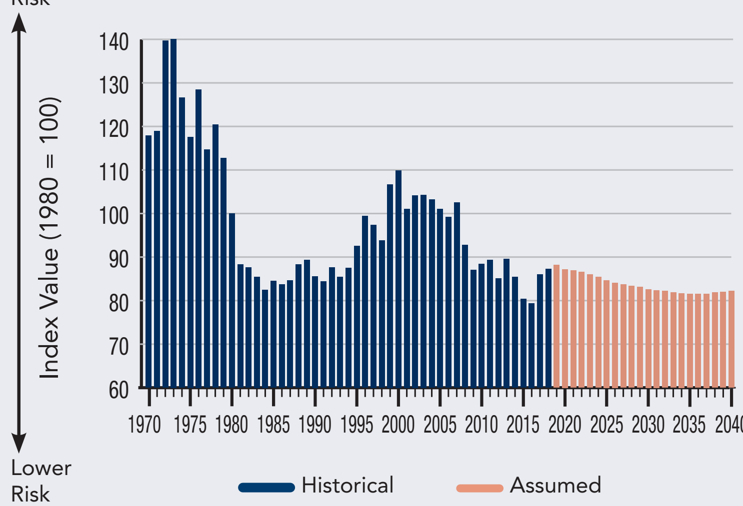
Category of Metric

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
Contribution in 2018	2.4	N/A	6.2	N/A	2.1

Energy Consumption per Capita

Definition

Million Btu consumed per person per year.

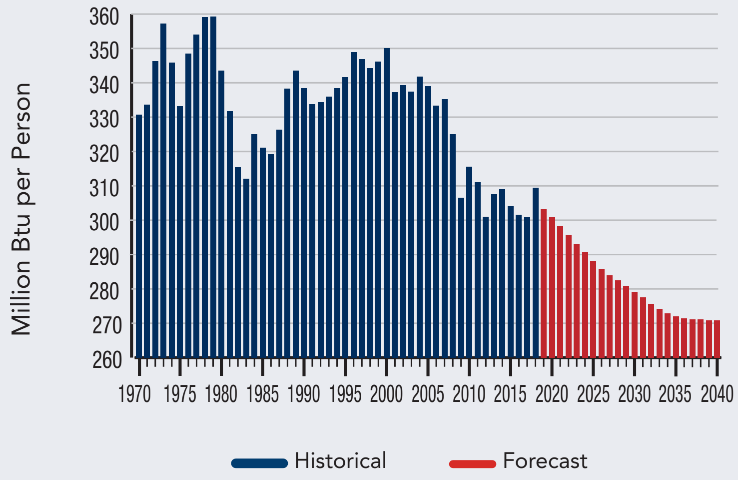
Importance

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

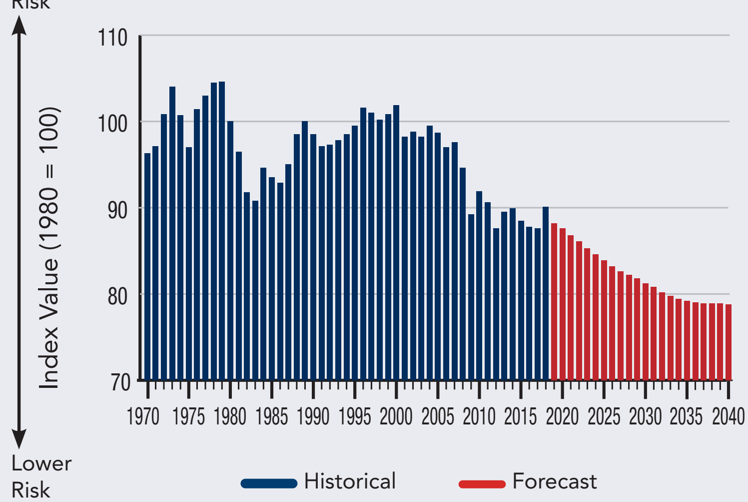
Category of Metric

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
Contribution in 2018	N/A	3.9	N/A	8.8	3.0

Energy Intensity

Definition

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

Importance

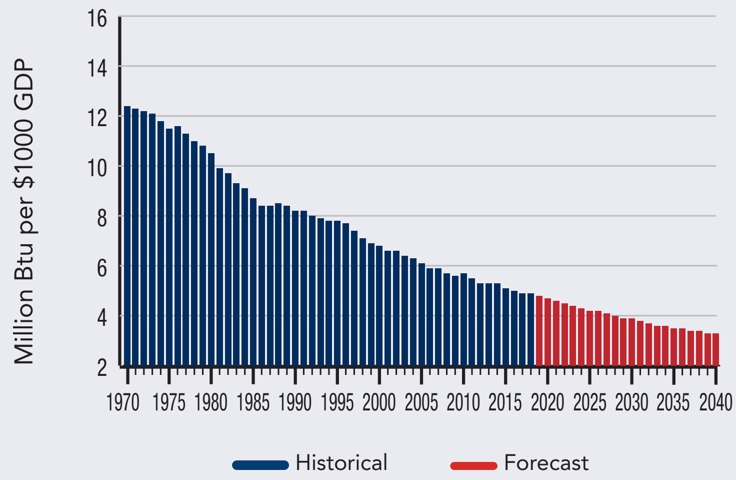
Indicates the importance of energy as a component of economic growth.

Category of Metric

Energy Use Intensity

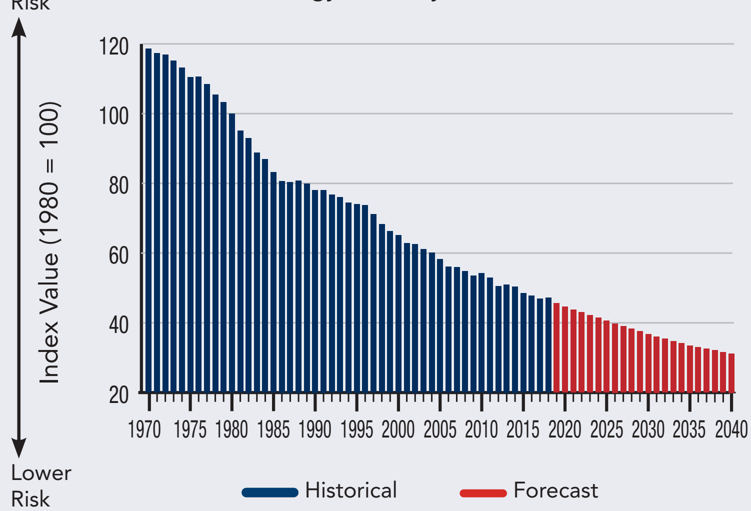
Historical and Forecast Values (1970-2040):

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
Contribution in 2018	N/A	2.7	N/A	5.8	2.0

Petroleum Intensity

Definition

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

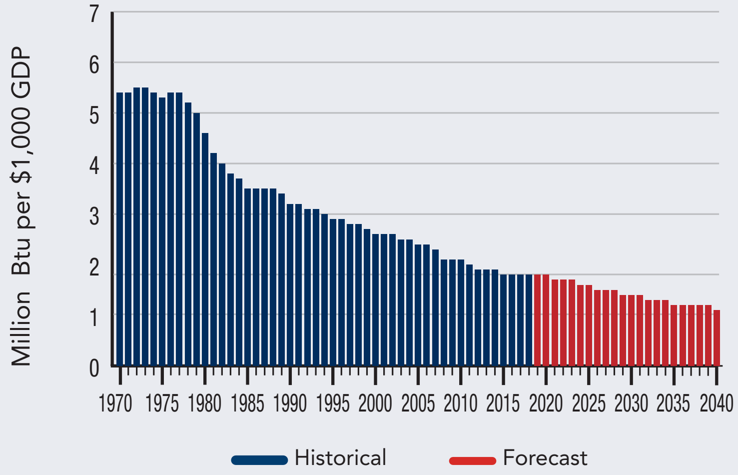
Importance

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

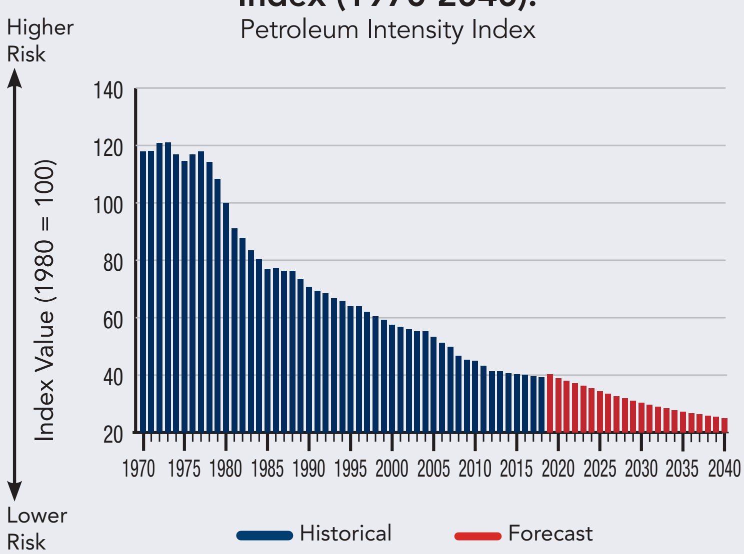
Category of Metric

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
Contribution in 2018	4.3	1.7	N/A	2.9	2.3

Household Energy Efficiency

Definition

Million Btu of total energy consumed per household.

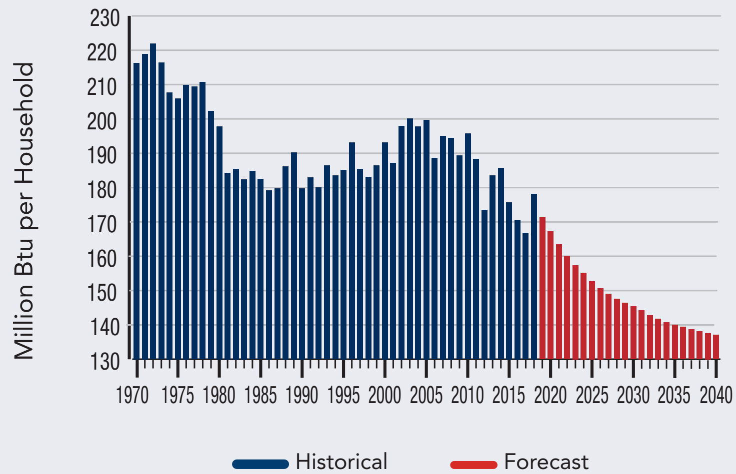
Importance

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

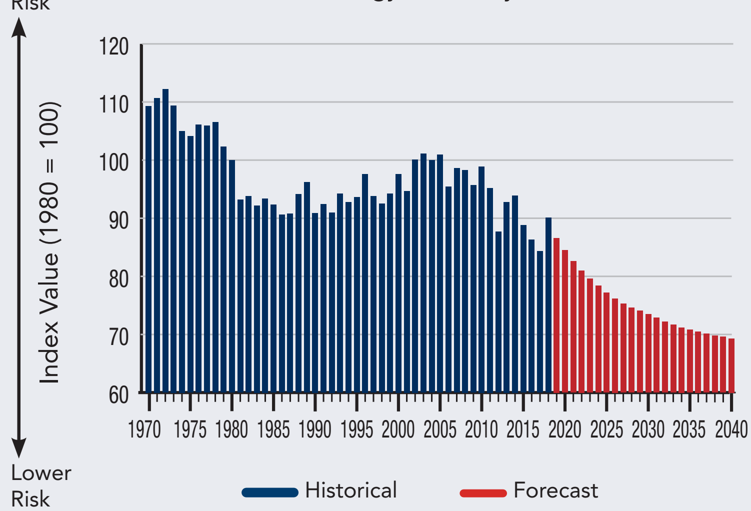
Category of Metric

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
Contribution in 2018	N/A	3.9	N/A	4.4	2.0

Commercial Energy Efficiency

Definition

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

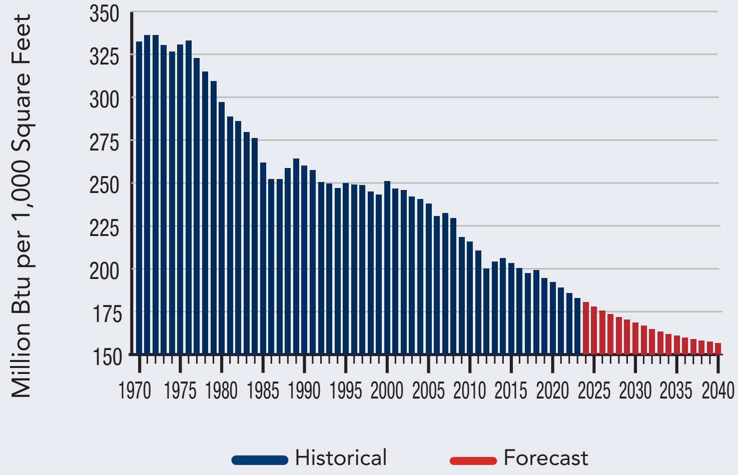
Importance

Indicates the degree to which commercial enterprises use energy efficiently.

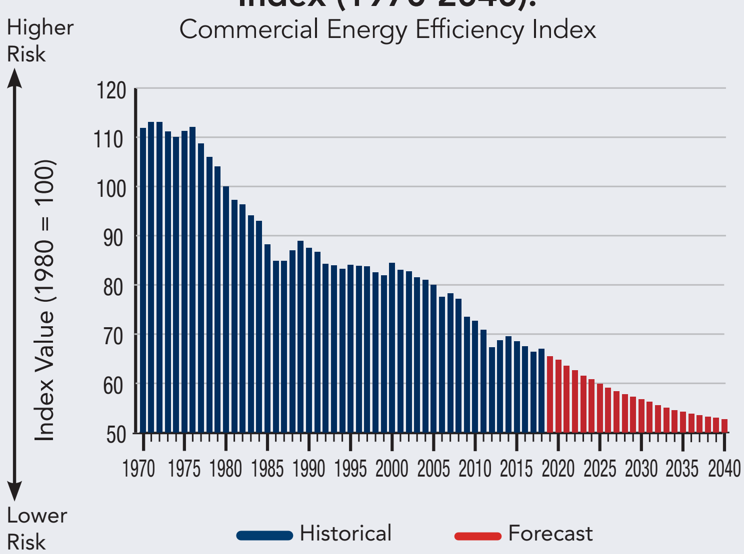
Category of Metric

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
Contribution in 2018	N/A	2.9	N/A	3.3	1.5

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

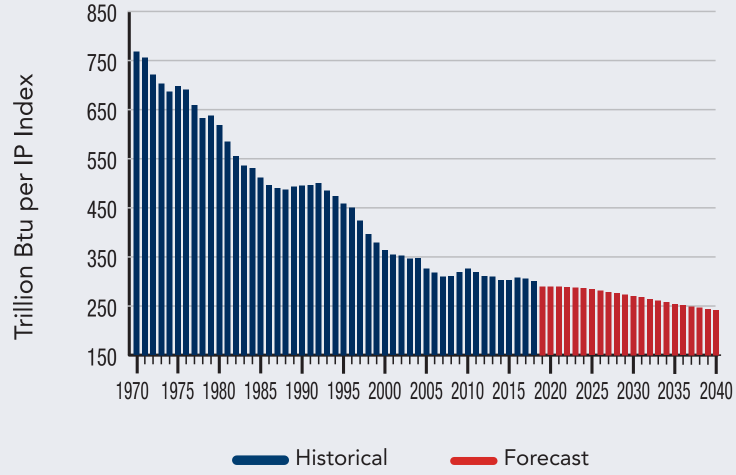
Indicates the degree to which the typical commercial enterprise uses energy efficiently.

Category of Metric

Energy Use Intensity

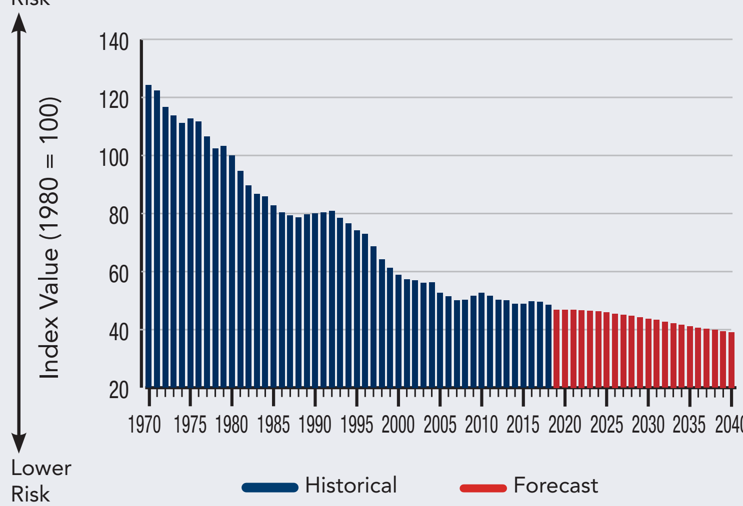
Historical and Forecast Values (1970-2040):

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
Contribution in 2018	N/A	2.1	N/A	2.4	1.1

Electricity Capacity Diversity

Definition

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

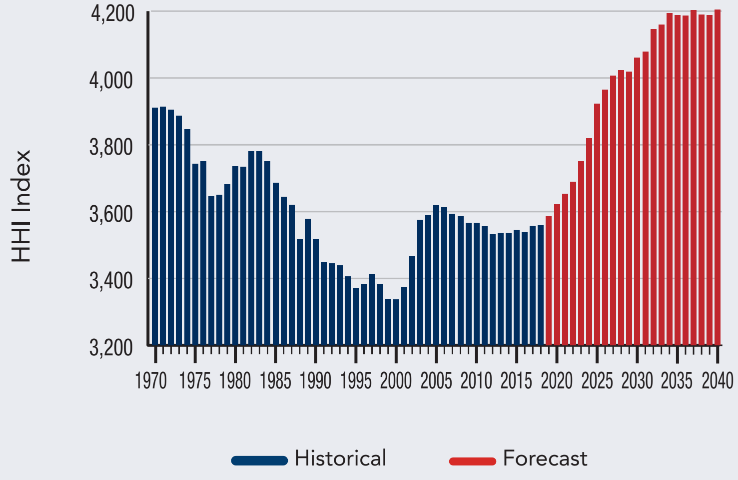
Importance

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

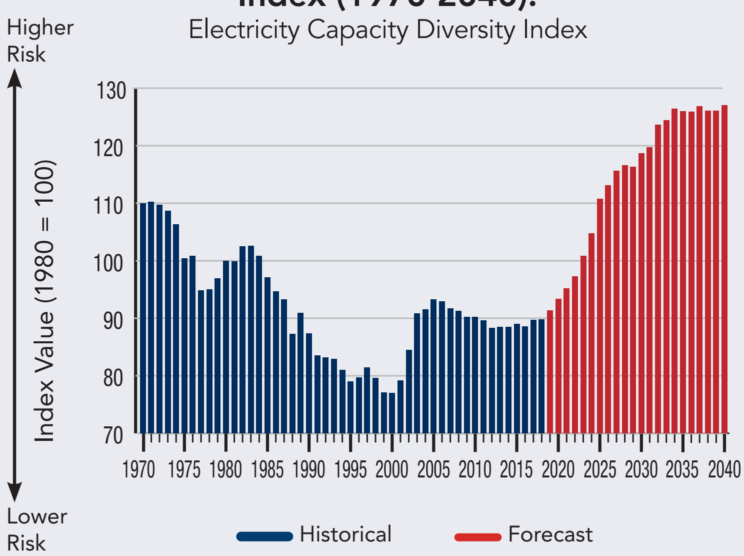
Category of Metric

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
Contribution in 2018	N/A	N/A	7.5	3.3	2.4

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

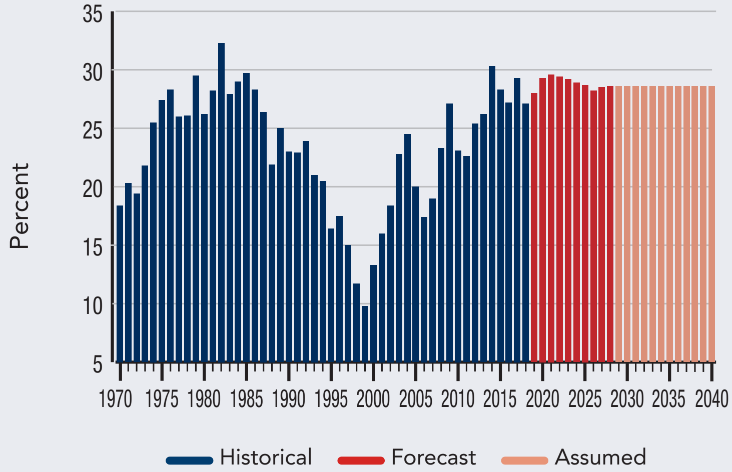
Indicates the ability of the power sector to respond to the disruption or temporary loss of some production capacity without an uneconomic overhang of excess capacity.

Category of Metric

Electric Power Sector

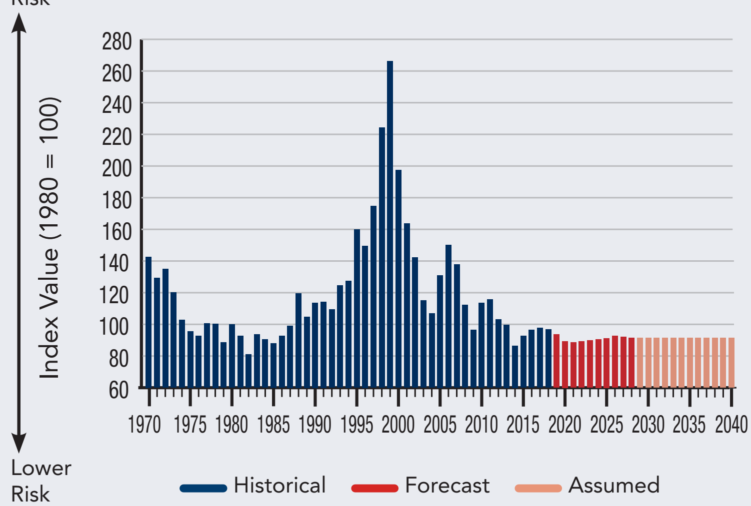
Historical and Forecast Values (1970-2040):

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
Contribution in 2018	N/A	1.4	8.0	N/A	2.2

Electric Power Transmission Line Mileage

Definition

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

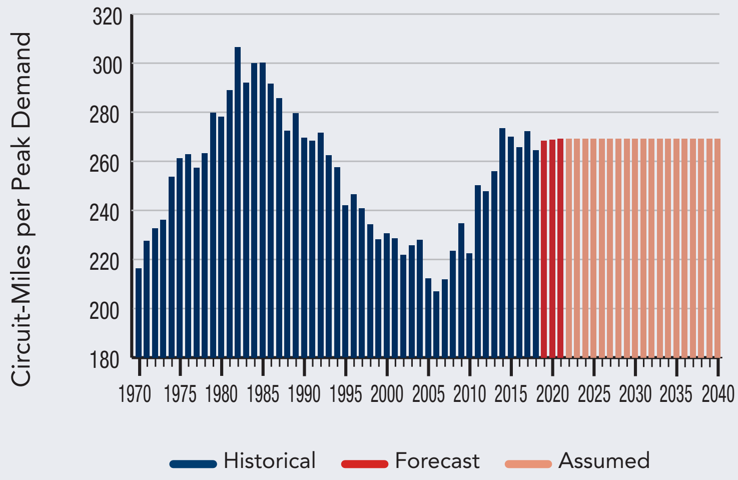
Importance

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

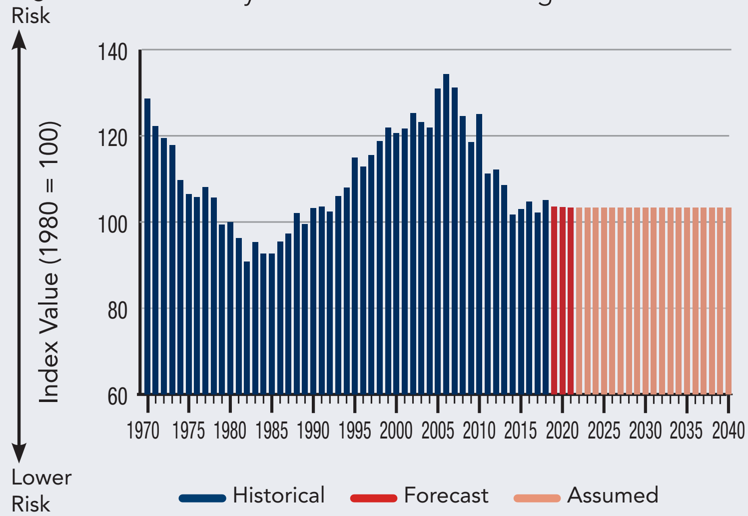
Category of Metric

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
Contribution in 2018	N/A	1.5	10.0	3.9	3.5

Motor Vehicle Average MPG

Definition

Average miles per gallon of passenger car fleet.

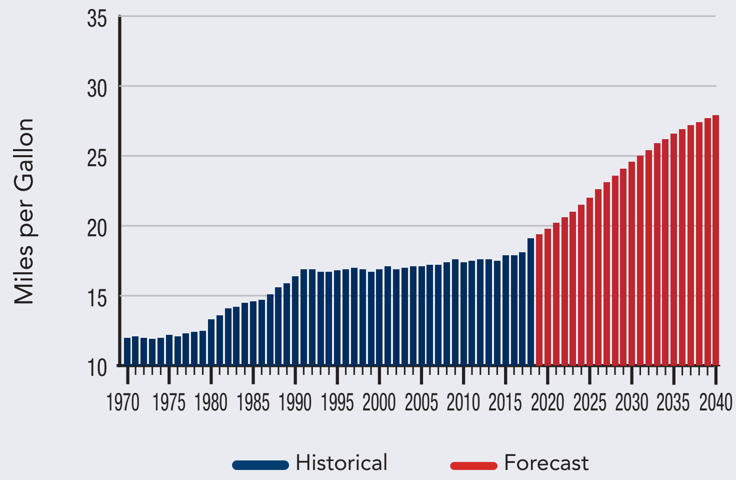
Importance

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

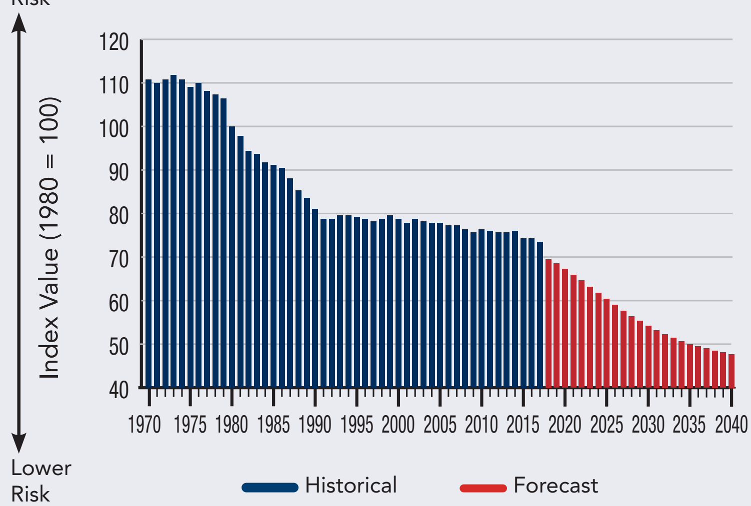
Category of Metric

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
Contribution in 2018	2.9	4.0	N/A	10.2	4.1

Vehicle-Miles Traveled per GDP

Definition

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

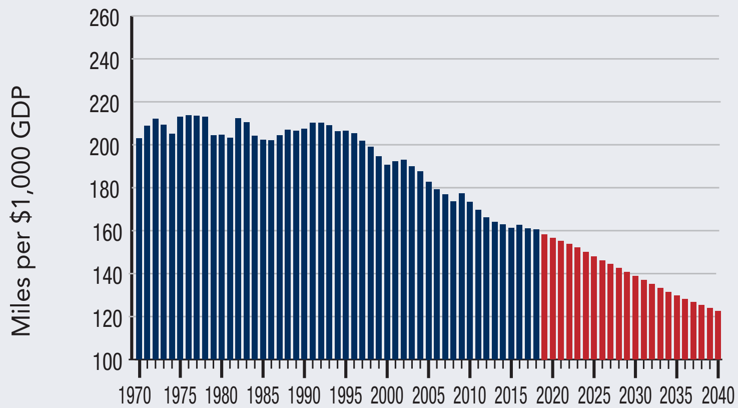
Importance

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

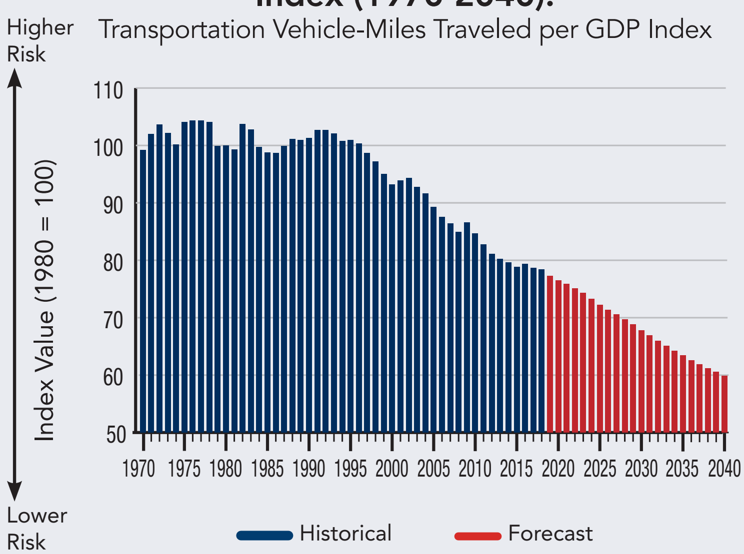
Category of Metric

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
Contribution in 2018	2.1	2.3	N/A	7.7	2.9

Transportation Non-Petroleum Fuel Use

Definition

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

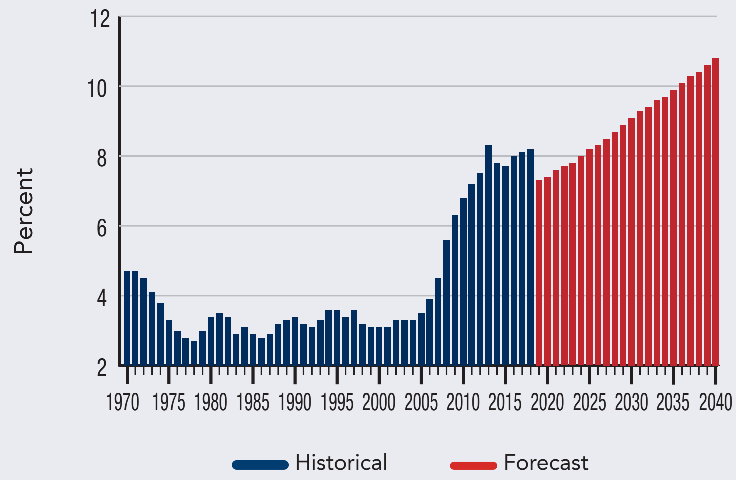
Importance

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

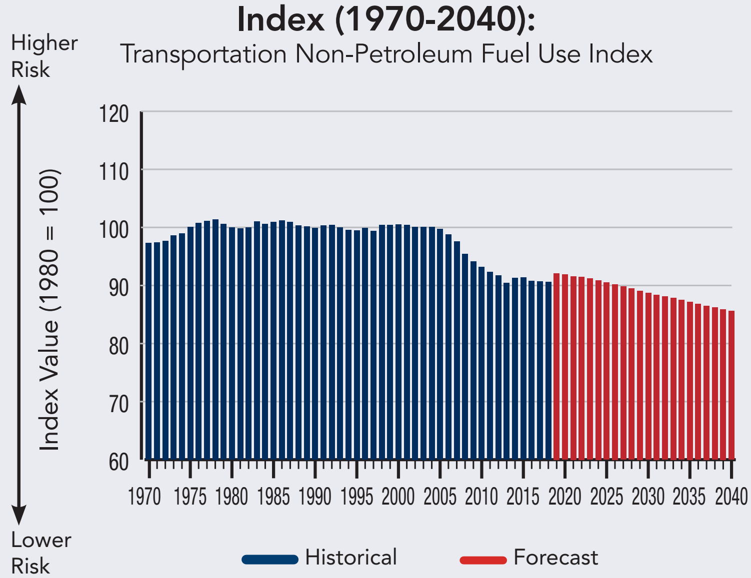
Category of Metric

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
Contribution in 2018	3.7	N/A	4.3	4.4	3.0

Energy-Related Carbon Dioxide Emissions

Definition

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

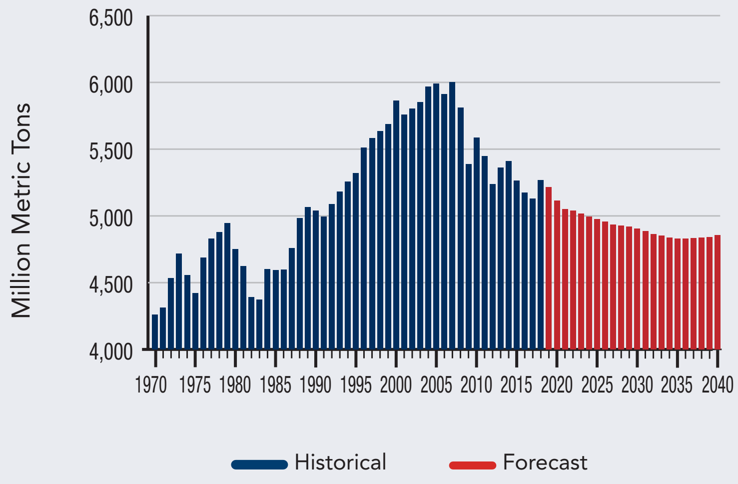
Importance

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

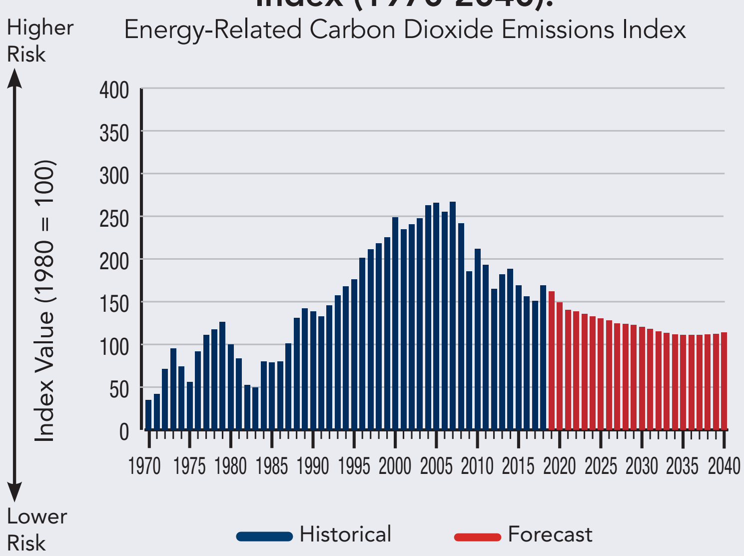
Category of Metric

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
Contribution in 2018	4.6	N/A	N/A	14.5	4.5

Energy-Related Carbon Dioxide Emissions per Capita

Definition

Million metric tons of CO2 emissions from energy per capita.

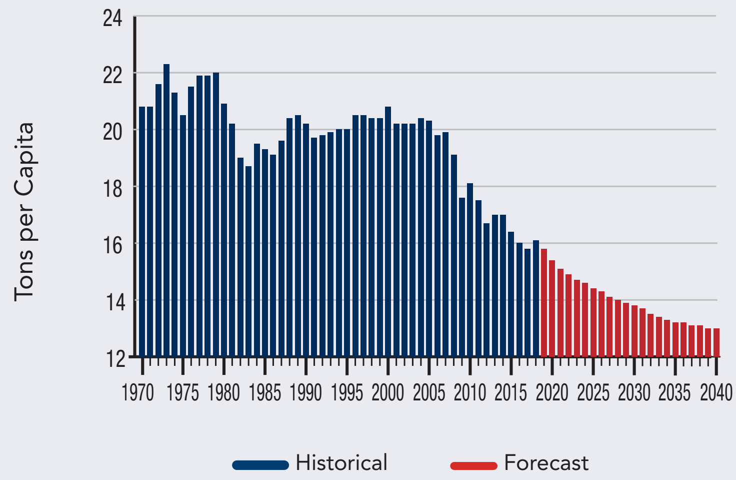
Importance

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

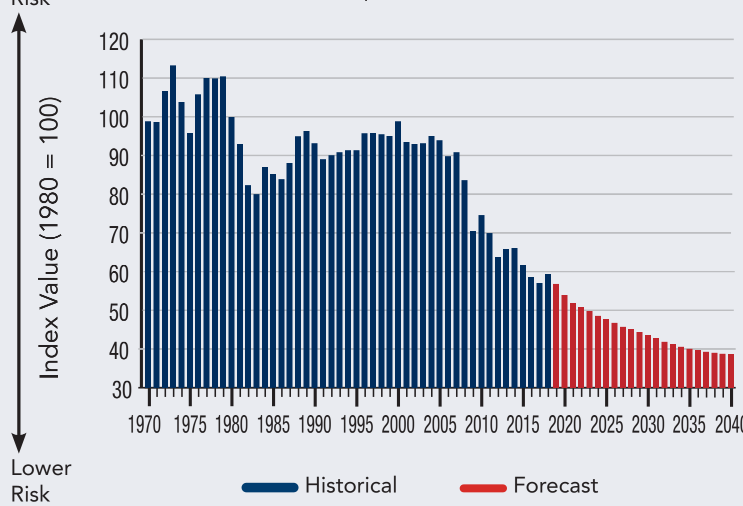
Category of Metric

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
Contribution in 2018	1.6	N/A	N/A	3.6	1.3

Energy-Related Carbon Dioxide Emissions Intensity

Definition

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

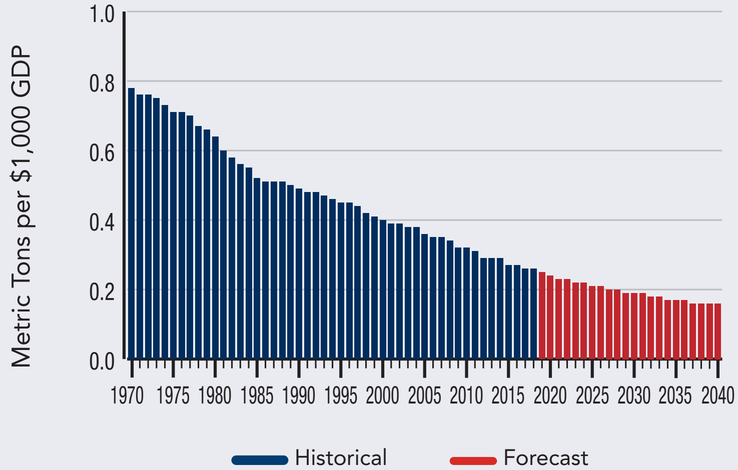
Importance

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

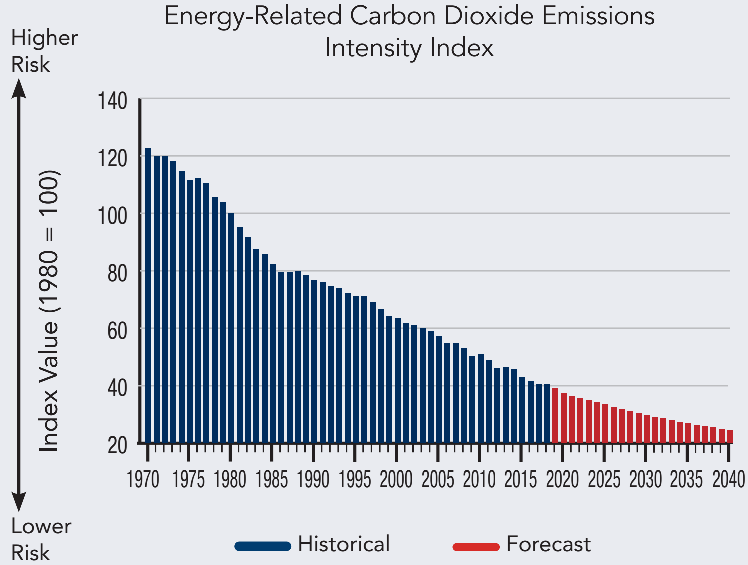
Category of Metric

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
Contribution in 2018	1.1	N/A	N/A	2.5	0.9

Electricity Non-CO2 Generation Share

Definition

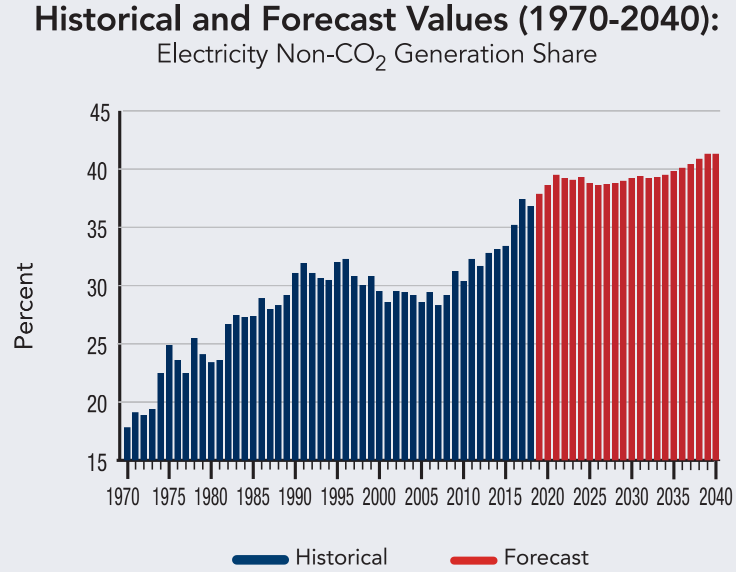
Percentage of total electric power generation contributed by renewables, hydroelectric, nuclear, and fossil-fired plants operating with carbon capture and storage (CCS) technology.

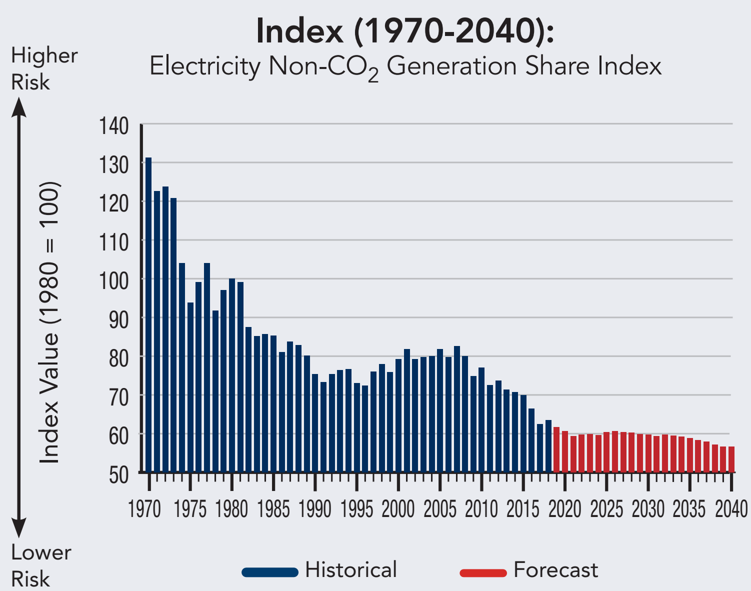
Importance

Indicates the degree to which the power sector is diversifying and employing non-CO2 emitting generation.

Category of Metric

Environmental





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
Contribution in 2018	N/A	N/A	3.8	5.4	2.0

Industrial Energy R&D Expenditures

Definition

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

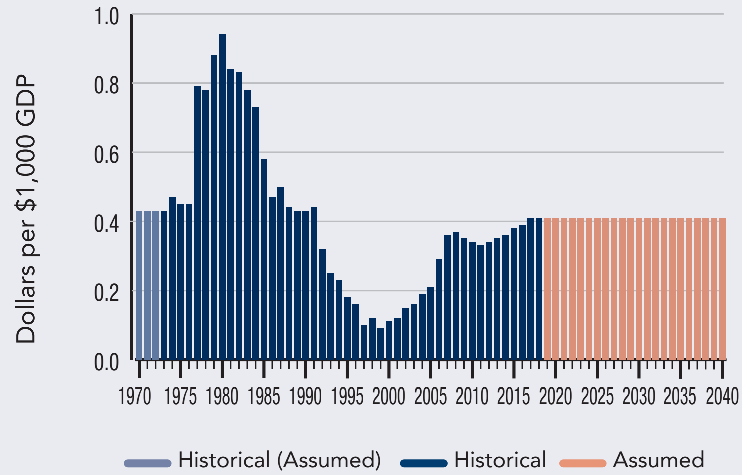
Importance

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

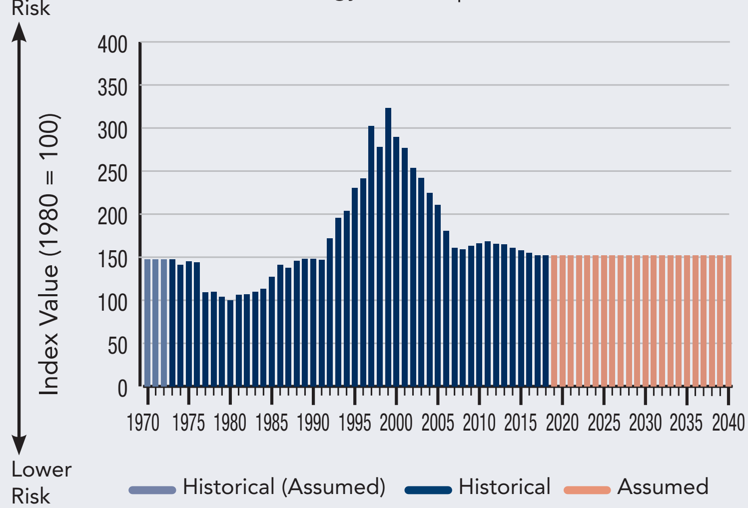
Category of Metric

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
Contribution in 2018	N/A	2.2	3.6	3.7	2.2

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.

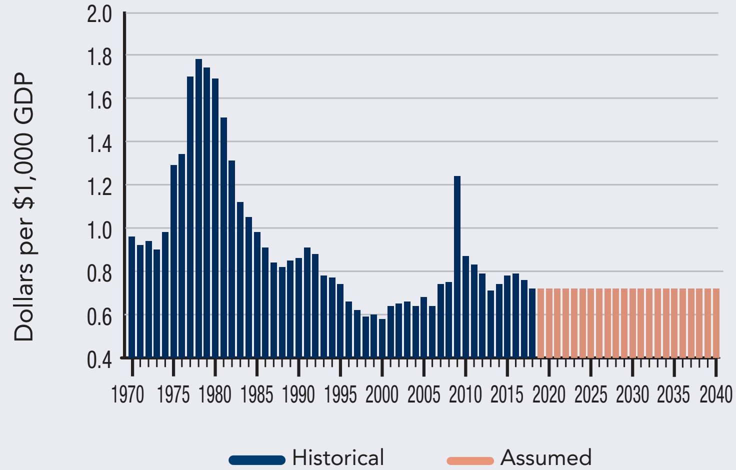
Importance

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

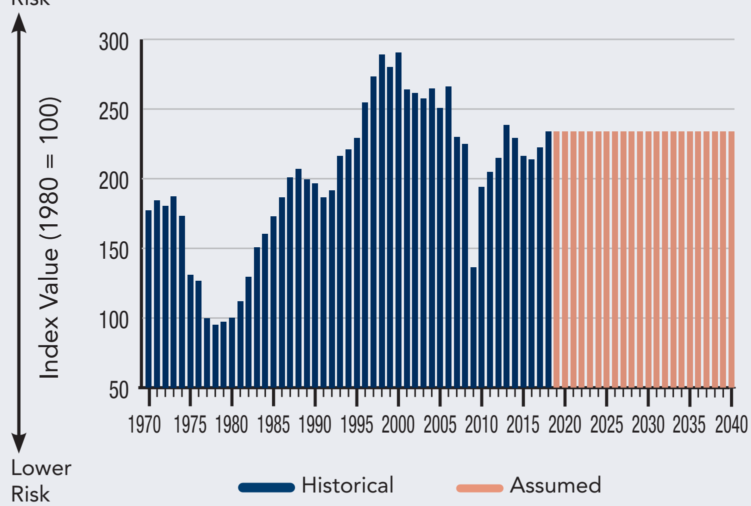
Category of Metric

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
Contribution in 2018	N/A	3.4	5.5	5.7	3.4

Science & Engineering Degrees

Definition

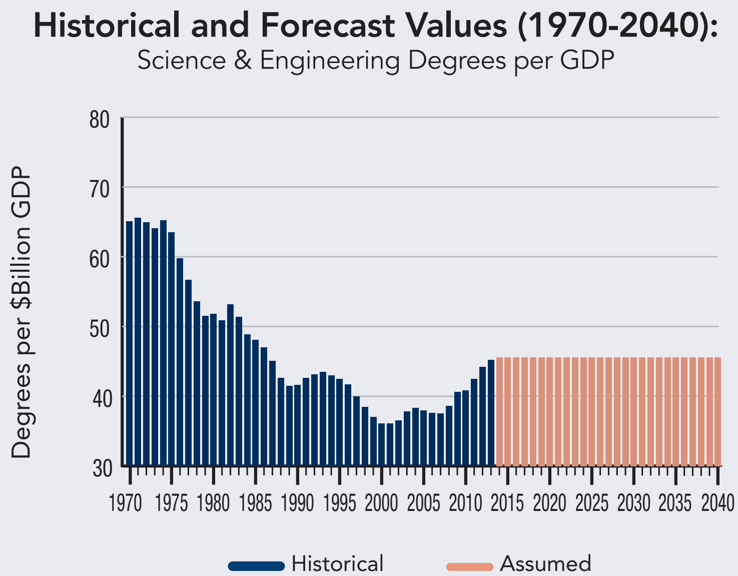
Number of science and engineering degrees, per billion dollars of GDP in real (2015) dollars.

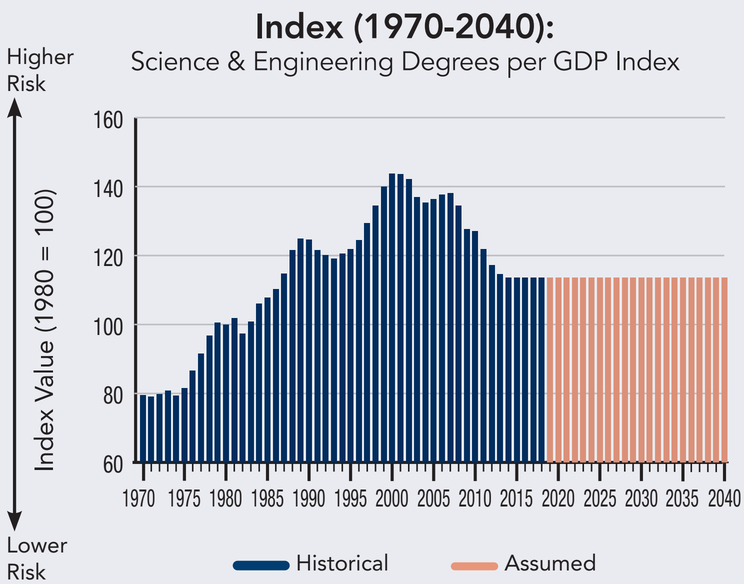
Importance

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





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
Contribution in 2018	N/A	1.7	2.7	2.8	1.6

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	87.9	89.2	91.0	92.3	97.7	106.1	110.9
3	Security of World Natural Gas Reserves	reserves, freedom & diversity-weighted	57.4	67.3	73.8	78.0	83.8	101.5	106.1
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	86.5	88.7	90.6	91.5	92.0	98.0	97.8
Fuel Import Metrics									
7	Security of U.S. Petroleum Imports	oil imports, freedom & diversity-weighted	19.5	22.3	25.8	32.6	35.4	39.0	45.5
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 2018$	$16.7	$19.9	$23.6	$57.7	$107.7	$100.7	$125.8
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 $1,000 GDP (2018$)	$77.22	$77.30	$76.67	$78.50	$99.25	$102.00	$103.51
12	Energy Expenditures per Household	2018$/Household	$6,631	$6,705	$6,805	$7,158	$8,783	$8,836	$9,258
13	Retail Electricity Prices	cents/kWh (2018$)	8.7¢	8.7¢	8.8¢	8.8¢	10.1¢	10.7¢	10.9¢
14	Crude Oil Price	2018$/bbl	$13.83	$14.09	$13.72	$25.78	$49.53	$46.45	$47.85
Price & Market Volatility Metrics									
15	Crude Oil Price Volatility	$ change in year-to-year price	$0.59	$0.51	$0.23	$4.23	$12.06	$12.96	$9.41
16	Energy Expenditure Volatility	average yearly price change/$1,000 GDP (2018$)	$2.90	$3.13	$2.87	$3.76	$9.79	$9.63	$9.49
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/$1,000 GDP (2018$)	12.4	12.3	12.2	12.1	11.8	11.5	11.6
21	Petroleum Intensity	million Btu/real $1,000 GDP (2018$)	5.40	5.41	5.54	5.55	5.36	5.25	5.36
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	768	756	721	703	687	698	690
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/$1,000 GDP (2018$)	203	209	212	209	205	213	214
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	4,715	4,556	4,421	4,689
32	Energy-Related CO_2 Emissions per Capita	metric tons CO_2 /Person	20.8	20.8	21.6	22.3	21.3	20.5	21.5
33	Energy-Related CO_2 Emissions Intensity	metric tons CO_2 /$1,000 GDP (2018$)	0.78	0.76	0.76	0.75	0.73	0.71	0.71
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 $/$1,000 GDP (2018$)	$0.43	$0.43	$0.43	$0.43	$0.47	$0.45	$0.45
36	Federal Energy & Science R&D Expenditures	R&D $/$1,000 GDP (2018$)	$0.96	$0.92	$0.94	$0.90	$0.98	$1.29	$1.34
37	Science & Engineering Degrees	# degrees/$billion GDP (2018$)	65.1	65.6	64.9	64.1	65.2	63.5	59.8

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
104.2	94.1	91.4	100.0	100.4	94.1	90.9	94.2	91.4	95.4	90.3	81.1	83.4	78.3	76.8	74.0	78.7	76.5
113.4	100.0	98.0	100.0	106.0	120.2	122.2	141.6	136.0	136.5	124.1	94.4	100.9	86.5	88.2	77.1	85.9	87.3
91.8	87.4	88.5	100.0	103.4	112.3	120.0	138.0	146.6	155.8	142.3	117.6	117.1	91.7	88.3	69.2	72.5	69.0
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	57.6	62.4	58.3
90.4	87.5	84.6	100.0	99.4	100.8	101.6	108.2	107.4	107.2	100.8	93.1	98.8	84.4	82.7	75.3	83.1	83.7
48.6	40.0	39.0	37.3	34.5	27.0	26.1	28.4	24.9	31.5	31.4	29.8	32.8	30.9	28.6	27.7	31.7	31.4
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	5.9	6.2	5.1	5.9	6.1
$156.2	$137.3	$191.6	$224.9	$190.1	$132.2	$111.7	$116.2	$96.9	$58.3	$80.8	$71.3	$90.5	$112.4	$86.3	$86.3	$83.7	$81.0
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%
$105.92	$101.75	$113.26	$131.01	$133.43	$127.54	$114.92	$107.81	$101.02	$83.87	$81.90	$78.60	$77.82	$79.60	$76.72	$73.13	$71.78	$69.28
$9,730	$9,638	$10,841	$12,274	$12,329	$11,443	$10,677	$10,520	$10,088	$8,543	$8,500	$8,359	$8,446	$8,733	$8,317	$8,111	$8,068	$8,021
11.2¢	11.4¢	11.4¢	12.3¢	13.1¢	13.7¢	13.6¢	13.0¢	13.0¢	12.8¢	12.3¢	11.9¢	11.6¢	11.4¢	11.3¢	11.2¢	11.1¢	10.8¢
$49.09	$46.04	$64.20	$94.97	$94.21	$80.83	$67.56	$64.71	$58.73	$27.89	$35.85	$27.87	$32.79	$41.19	$33.61	$31.68	$27.24	$24.87
$1.91	$1.90	$7.49	$17.33	$16.56	$14.97	$9.14	$9.83	$7.37	$13.22	$14.93	$15.59	$6.96	$7.10	$6.97	$5.97	$4.65	$2.91
$5.24	$4.70	$7.46	$11.16	$12.33	$10.48	$6.83	$4.88	$3.13	$5.59	$5.49	$4.53	$0.93	$1.74	$2.72	$2.32	$1.45	$0.59
76.9%	77.6%	78.7%	74.4%	71.1%	70.5%	72.4%	74.0%	74.6%	77.2%	77.4%	80.3%	81.1%	81.4%	80.7%	81.0%	80.7%	80.6%
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	336.0	338.4
11.3	11.0	10.8	10.5	9.9	9.7	9.3	9.1	8.7	8.4	8.4	8.5	8.4	8.2	8.2	8.0	7.9	7.8
5.40	5.24	4.96	4.58	4.17	4.02	3.83	3.69	3.52	3.55	3.50	3.50	3.37	3.25	3.18	3.14	3.06	3.02
209.4	210.7	202.3	197.8	184.3	185.5	182.4	184.8	182.5	179.2	179.7	186.2	190.3	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	264.1	260.0	257.4	250.4	249.5	247.0
659	633	638	618	585	555	536	531	511	497	490	487	493	495	497	500	485	474
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
214	213	204	205	203	212	210	204	202	202	205	207	207	207	210	210	209	206
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%
4,830	4,879	4,945	4,750	4,625	4,393	4,371	4,600	4,593	4,598	4,757	4,982	5,066	5,038	4,993	5,090	5,181	5,258
21.9	21.9	22.0	20.9	20.2	19.0	18.7	19.5	19.3	19.1	19.6	20.4	20.5	20.2	19.7	19.8	19.9	20.0
0.70	0.67	0.66	0.64	0.60	0.58	0.56	0.55	0.52	0.51	0.51	0.51	0.50	0.49	0.48	0.48	0.47	0.46
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	$0.88	$0.94	$0.84	$0.83	$0.78	$0.73	$0.58	$0.47	$0.50	$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	$0.77
56.7	53.6	51.5	51.8	50.9	53.2	51.4	48.9	48.1	47.0	45.1	42.6	41.5	41.6	42.6	43.1	43.5	43.0

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	75.1	70.9	71.1	69.1	69.0	69.6	70.2
3	Security of World Natural Gas Reserves	reserves, freedom & diversity-weighted	87.6	87.3	87.0	88.7	92.9	99.3	98.7
4	Security of World Natural Gas Production	production, freedom & diversity-weighted	66.6	61.4	61.2	63.9	68.5	71.5	72.8
5	Security of World Coal Reserves	reserves, freedom & diversity-weighted	56.6	53.1	50.7	49.8	52.8	58.2	57.5
6	Security of World Coal Production	production, freedom & diversity-weighted	83.2	83.7	80.4	71.8	73.1	78.8	80.5
Fuel Import Metrics									
7	Security of U.S. Petroleum Imports	oil imports, freedom & diversity-weighted	30.0	29.3	31.0	31.4	30.7	32.2	34.1
8	Security of U.S. Natural Gas Imports	gas imports, freedom & diversity-weighted	6.0	5.5	5.4	6.2	7.4	7.6	8.2
9	Oil & Natural Gas Import Expenditures	billions of 2018$	$82.3	$106.6	$105.5	$76.1	$105.1	$176.2	$154.9
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 $1,000 GDP (2018$)	$67.36	$69.40	$66.22	$58.07	$58.01	$67.08	$65.80
12	Energy Expenditures per Household	2018$/Household	$7,905	$8,369	$8,240	$7,453	$7,695	$9,196	$9,001
13	Retail Electricity Prices	cents/kWh (2018$)	10.6¢	10.3¢	10.2¢	9.9¢	9.6¢	9.6¢	10.1¢
14	Crude Oil Price	2018$/bbl	$26.14	$31.13	$28.34	$18.71	$25.87	$40.52	$33.84
Price & Market Volatility Metrics									
15	Crude Oil Price Volatility	$ change in year-to-year price	$2.69	$2.88	$3.02	$5.80	$6.53	$10.48	$9.50
16	Energy Expenditure Volatility	average yearly price change/$1,000 GDP (2018$)	$0.32	$1.62	$1.54	$3.21	$2.62	$6.23	$4.77
17	World Oil Refinery Utilization	percent utilization	81.3%	82.2%	83.8%	82.7%	81.3%	82.4%	82.3%
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	341.7	348.9	346.9	344.3	346.2	350.1	337.3
20	Energy Intensity	million Btu/$1,000 GDP (2018$)	7.8	7.7	7.4	7.1	6.9	6.8	6.6
21	Petroleum Intensity	million Btu/real $1,000 GDP (2018$)	2.93	2.93	2.84	2.77	2.72	2.64	2.61
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	459	451	424	397	379	364	354
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/$1,000 GDP (2018$)	206	205	202	199	194	191	192
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	$MMTCO_2$	5,321	5,510	5,582	5,635	5,687	5,864	5,759
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/$1,000 GDP (2018$)	0.45	0.45	0.44	0.42	0.41	0.40	0.39
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 $/$1,000 GDP (2018$)	$0.18	$0.16	$0.10	$0.12	$0.09	$0.11	$0.12
36	Federal Energy & Science R&D Expenditures	R&D $/$1,000 GDP (2018$)	$0.74	$0.66	$0.62	$0.59	$0.60	$0.58	$0.64
37	Science & Engineering Degrees	# degrees/$billion GDP (2018$)	42.5	41.7	40.0	38.5	37.0	36.1	36.1

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	94.0	94.8	99.0	97.3	103.6	105.9	112.1	112.1
67.0	69.9	74.6	74.2	74.7	74.8	77.7	75.9	78.6	82.5	82.6	82.1	84.7	85.1	90.1	92.2	92.8	94.8
94.7	92.5	97.1	97.9	96.7	97.0	96.0	96.0	92.8	93.0	95.3	96.6	99.6	100.3	108.1	107.6	103.5	103.5
71.3	71.7	76.4	76.8	77.9	78.4	77.7	74.7	77.8	81.9	81.2	82.7	87.9	88.2	91.6	99.1	98.8	100.6
55.3	64.3	66.7	64.4	70.8	70.8	62.9	61.2	61.6	59.5	59.5	61.4	65.2	61.5	61.5	61.5	61.5	61.5
83.3	95.9	106.4	111.8	119.7	125.4	129.7	141.3	149.0	156.9	160.4	163.4	162.5	164.7	161.6	166.3	166.3	166.3
31.2	34.3	37.9	38.7	38.6	37.6	38.2	33.9	33.7	32.4	29.4	24.4	20.5	18.9	20.2	15.7	9.6	6.4
7.4	7.2	7.9	8.4	8.3	8.5	6.6	5.7	5.5	4.3	3.2	2.7	2.6	2.0	1.5	-0.3	-1.4	-5.3
$147.5	$182.8	$246.7	$356.3	$390.5	$412.2	$492.6	$265.7	$328.4	$395.1	$337.2	$273.6	$200.5	$97.4	$81.4	$75.7	$58.4	$35.7
1.0%	1.2%	1.6%	2.2%	2.3%	2.4%	2.9%	1.6%	1.9%	2.3%	1.9%	1.5%	1.1%	0.5%	0.4%	0.4%	0.3%	0.2%
$60.71	$65.90	$71.33	$80.21	$83.88	$85.38	$95.75	$73.80	$80.98	$89.54	$83.66	$81.99	$79.61	$61.92	$55.49	$58.33	$61.99	$60.52
$8,615	$9,564	$10,642	$12,200	$12,961	$13,350	$14,804	$11,127	$12,465	$13,790	$13,061	$13,018	$12,862	$10,126	$9,146	$9,617	$10,521	$10,493
9.8¢	9.9¢	9.9¢	10.3¢	10.9¢	10.9¢	11.4¢	11.4¢	11.3¢	11.1¢	10.9¢	10.9¢	11.1¢	11.0¢	10.7¢	10.7¢	10.6¢	10.5¢
$34.03	$38.57	$49.81	$68.90	$79.86	$86.46	$113.49	$71.73	$91.43	$125.17	$123.22	$117.76	$105.37	$55.11	$45.47	$55.35	$71.06	$73.26
$7.17	$3.81	$5.33	$11.62	$13.76	$12.21	$14.86	$25.13	$29.50	$31.73	$18.46	$13.71	$6.60	$22.70	$24.10	$23.26	$11.74	$19.85
$5.21	$3.77	$6.06	$8.43	$8.08	$6.54	$6.36	$12.70	$14.37	$14.05	$7.40	$4.47	$1.44	$5.34	$7.03	$8.09	$7.61	$7.13
81.0%	82.9%	84.7%	84.8%	83.7%	83.7%	82.4%	79.2%	80.7%	80.2%	80.8%	80.2%	80.1%	81.9%	82.0%	83.1%	82.9%	82.9%
78	78	79	81	82	80	88	94	92	91	96	91	96	101	103	95	93	93
339.3	337.5	341.8	339.0	333.3	335.2	325.0	306.5	315.6	311.1	301.0	307.6	309.0	304.0	301.6	300.9	309.4	303.2
6.6	6.4	6.3	6.1	5.9	5.9	5.7	5.6	5.7	5.5	5.3	5.3	5.3	5.1	5.0	4.9	4.9	4.8
2.56	2.53	2.53	2.45	2.35	2.29	2.14	2.08	2.06	1.99	1.90	1.89	1.86	1.85	1.84	1.82	1.80	1.84
198.0	200.1	197.8	199.7	188.6	195.1	194.5	189.3	195.7	188.3	173.5	183.6	185.7	175.7	170.6	166.8	178.2	171.4
245.8	242.1	240.6	237.8	230.6	232.5	229.4	218.3	215.8	210.6	200.0	204.2	206.3	203.4	200.4	197.3	199.1	194.4
353	347	348	326	318	310	311	319	326	319	311	310	302	302	308	306	300	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	3,538	3,558	3,558	3,586
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%	27.2%	29.3%	27.1%	28.0%
222	226	228	212	207	212	223	235	223	250	248	256	273	270	266	272	265	268
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	17.9	18.1	19.1	19.4
193	190	188	183	179	177	174	177	173	170	166	164	163	161	163	161	161	158
3.3%	3.3%	3.3%	3.5%	3.9%	4.5%	5.6%	6.3%	6.8%	7.2%	7.5%	8.3%	7.8%	7.7%	8.0%	8.1%	8.2%	7.3%
5,803	5,854	5,969	5,990	5,911	6,002	5,811	5,388	5,586	5,446	5,237	5,363	5,411	5,265	5,172	5,131	5,268	5,217
20.2	20.2	20.4	20.3	19.8	19.9	19.1	17.6	18.1	17.5	16.7	17.0	17.0	16.4	16.0	15.8	16.1	15.8
0.39	0.38	0.38	0.36	0.35	0.35	0.34	0.32	0.32	0.31	0.29	0.29	0.29	0.27	0.27	0.26	0.26	0.25
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%	37.4%	36.8%	37.9%
$0.15	$0.16	$0.19	$0.21	$0.29	$0.36	$0.37	$0.35	$0.34	$0.33	$0.34	$0.35	$0.36	$0.38	$0.39	$0.41	$0.41	$0.41
$0.65	$0.66	$0.64	$0.68	$0.64	$0.74	$0.75	$1.24	$0.87	$0.83	$0.79	$0.71	$0.74	$0.78	$0.79	$0.76	$0.72	$0.72
36.5	37.8	38.3	38.0	37.6	37.5	38.6	40.6	40.8	42.5	44.2	45.2	45.6	45.6	45.6	45.6	45.6	45.6

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	112.1	112.1	112.1	112.1	112.1	112.1	112.1
2	Security of World Oil Production	production, freedom & diversity-weighted	94.8	94.0	93.6	94.3	94.8	94.9	94.9
3	Security of World Natural Gas Reserves	reserves, freedom & diversity-weighted	103.5	103.5	103.5	103.5	103.5	103.5	103.5
4	Security of World Natural Gas Production	production, freedom & diversity-weighted	103.0	103.0	103.8	103.3	103.3	102.8	102.4
5	Security of World Coal Reserves	reserves, freedom & diversity-weighted	61.5	61.5	61.5	61.5	61.5	61.5	61.5
6	Security of World Coal Production	production, freedom & diversity-weighted	166.3	166.3	166.3	166.3	166.3	166.3	166.3
Fuel Import Metrics									
7	Security of U.S. Petroleum Imports	oil imports, freedom & diversity-weighted	-2.0	-5.1	-6.9	-7.5	-8.9	-10.3	-13.0
8	Security of U.S. Natural Gas Imports	gas imports, freedom & diversity-weighted	-7.1	-7.6	-8.2	-9.1	-10.2	-11.0	-11.7
9	Oil & Natural Gas Import Expenditures	billions of 2018$	($22.1)	($42.9)	($55.7)	($63.1)	($76.6)	($88.9)	($108.9)
10	Oil & Natural Gas Import Expenditures per GDP	percent	-0.1%	-0.2%	-0.3%	-0.3%	-0.3%	-0.4%	-0.5%
Energy Expenditure Metrics									
11	Energy Expenditures per GDP	$ per $1,000 GDP (2018$)	$60.06	$58.94	$57.94	$57.43	$57.12	$56.69	$56.04
12	Energy Expenditures per Household	2018$/Household	$10,554	$10,446	$10,359	$10,356	$10,401	$10,437	$10,436
13	Retail Electricity Prices	cents/kWh (2018$)	10.2¢	10.1¢	10.1¢	10.1¢	10.2¢	10.3¢	10.4¢
14	Crude Oil Price	2018$/bbl	$73.27	$74.43	$74.40	$76.21	$79.32	$81.73	$84.87
Price & Market Volatility Metrics									
15	Crude Oil Price Volatility	$ change in year-to-year price	$18.92	$18.27	$17.31	$16.75	$17.44	$17.97	$18.65
16	Energy Expenditure Volatility	average yearly price change/$1,000 GDP (2018$)	$6.65	$6.17	$5.68	$5.68	$5.68	$5.68	$5.68
17	World Oil Refinery Utilization	percent utilization	82.9%	82.9%	82.9%	82.9%	82.9%	82.9%	82.9%
18	Petroleum Stock Levels	average days supply	94	94	94	95	96	96	97
Energy Use Intensity Metrics									
19	Energy Consumption per Capita	million Btu/Person	300.8	298.3	295.8	293.1	290.8	288.2	285.9
20	Energy Intensity	million Btu/$1,000 GDP (2018$)	4.7	4.6	4.5	4.4	4.3	4.2	4.2
21	Petroleum Intensity	million Btu/real $1,000 GDP (2018$)	1.78	1.74	1.71	1.66	1.62	1.58	1.54
22	Household Energy Efficiency	million Btu/household	167.2	163.4	160.1	157.4	155.2	152.7	150.7
23	Commercial Energy Efficiency	million Btu/1,000 sq.ft.	192.3	189.0	185.8	182.8	180.5	177.9	175.5
24	Industrial Energy Efficiency	trillion Btu/IP Index	289	290	289	288	287	284	281
Electric Power Sector Metrics									
25	Electricity Capacity Diversity	HHI Index	3,622	3,653	3,689	3,751	3,820	3,924	3,964
26	Electricity Capacity Margins	percent	29.3%	29.6%	29.4%	29.2%	28.9%	28.7%	28.2%
27	Electricity Transmission Line Mileage	circuit-miles/peak GW	269	269	269	269	269	269	269
Transportation Sector Metrics									
28	Motor Vehicle Average MPG	miles per gallon	19.8	20.2	20.6	21.0	21.5	22.0	22.6
29	Transportation VMT per $ GDP	vehicle miles traveled/$1,000 GDP (2018$)	157	155	154	152	150	148	146
30	Transportation Non-Petroleum Fuels	percent	7.4%	7.6%	7.7%	7.8%	8.0%	8.2%	8.3%
Environmental Metrics									
31	Energy-Related CO_2 Emissions	$MMTCO_2$	5,116	5,050	5,038	5,015	4,994	4,977	4,959
32	Energy-Related CO_2 Emissions per Capita	metric tons CO_2/Person	15.4	15.1	14.9	14.7	14.6	14.4	14.3
33	Energy-Related CO_2 Emissions Intensity	metric tons CO_2/$1,000 GDP (2018$)	0.24	0.23	0.23	0.22	0.22	0.21	0.21
34	Electricity Non-CO_2 Generation Share	percent of total generation	38.6%	39.5%	39.2%	39.1%	39.3%	38.8%	38.6%
Research and Development Metrics									
35	Industrial Energy R&D Expenditures	energy R&D $/$1,000 GDP (2018$)	$0.41	$0.41	$0.41	$0.41	$0.41	$0.41	$0.41
36	Federal Energy & Science R&D Expenditures	R&D $/$1,000 GDP (2018$)	$0.72	$0.72	$0.72	$0.72	$0.72	$0.72	$0.72
37	Science & Engineering Degrees	# degrees/$billion GDP (2018$)	45.6	45.6	45.6	45.6	45.6	45.6	45.6

Summary Table 1: Energy Security Metrics (Values)

2027-2040

2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040
112.1	112.1	112.1	112.1	112.1	112.1	112.1	112.1	112.1	112.1	112.1	112.1	112.1	112.1
95.0	95.0	95.1	95.1	95.0	95.1	95.1	95.2	95.2	95.3	95.3	95.4	95.4	95.3
103.5	103.5	103.5	103.5	103.5	103.5	103.5	103.5	103.5	103.5	103.5	103.5	103.5	103.5
102.0	102.0	103.0	103.3	102.7	103.0	102.3	102.0	103.5	102.9	102.9	102.9	103.0	102.8
61.5	61.5	61.5	61.5	61.5	61.5	61.5	61.5	61.5	61.5	61.5	61.5	61.5	61.5
166.3	166.3	166.3	166.3	166.3	166.3	166.3	166.3	166.3	166.3	166.3	166.3	166.3	166.3
-14.3	-14.3	-14.7	-15.5	-16.4	-16.3	-16.6	-16.9	-16.6	(16.2)	(15.8)	(15.4)	(15.0)	(14.5)
-12.1	-12.4	-13.0	-13.2	-13.1	-13.0	-12.9	-13.0	-13.3	-13.5	-13.6	-13.7	-13.8	-13.8
($121.1)	($124.7)	($130.1)	($137.8)	($147.0)	($148.8)	($153.1)	($157.5)	($157.7)	($157.2)	($156.6)	($155.6)	($154.2)	($152.8)
-0.5%	-0.5%	-0.5%	-0.5%	-0.6%	-0.6%	-0.6%	-0.6%	-0.6%	-0.5%	-0.5%	-0.5%	-0.5%	-0.5%
$55.64	$54.83	$54.59	$53.61	$52.84	$52.29	$51.54	$50.75	$50.13	$49.71	$48.95	$48.40	$47.84	$47.24
$10,491	$10,475	$10,558	$10,503	$10,482	$10,496	$10,478	$10,444	$10,437	$10,468	$10,430	$10,438	$10,442	$10,438
10.4¢	10.4¢	10.4¢	10.4¢	10.5¢	10.5¢	10.5¢	10.6¢	10.6¢	10.6¢	10.6¢	10.6¢	10.6¢	10.5¢
$87.50	$89.42	$91.25	$92.98	$94.62	$96.17	$97.62	$98.98	$100.25	$101.42	$102.50	$103.48	$104.37	$105.16
$19.23	$19.65	$20.06	$20.44	$20.80	$21.14	$21.46	$21.76	$22.03	$22.29	$22.53	$22.74	$22.94	$23.11
$5.68	$5.68	$5.68	$5.68	$5.68	$5.68	$5.68	$5.68	$5.68	$5.68	$5.68	$5.68	$5.68	$5.68
82.9%	82.9%	82.9%	82.9%	82.9%	82.9%	82.9%	82.9%	82.9%	82.9%	82.9%	82.9%	82.9%	82.9%
97	98	98	99	99	99	100	100	100	100	100	100	100	99
283.9	282.5	280.9	279.1	277.6	275.7	274.2	272.9	272.0	271.5	271.1	271.1	270.9	270.8
4.1	4.0	3.9	3.9	3.8	3.7	3.6	3.6	3.5	3.5	3.4	3.4	3.3	3.3
1.50	1.46	1.43	1.39	1.36	1.33	1.30	1.27	1.25	1.22	1.21	1.19	1.17	1.15
149.0	147.6	146.5	145.4	144.3	142.8	141.8	140.8	140.0	139.4	138.7	138.1	137.6	137.1
173.4	171.7	170.3	168.6	166.9	164.9	163.4	162.0	160.9	159.9	158.9	158.1	157.4	156.6
279	276	274	271	268	264	261	257	254	252	249	247	244	242
4,007	4,024	4,019	4,061	4,079	4,146	4,159	4,194	4,187	4,186	4,203	4,190	4,188	4,204
28.5%	28.6%	28.6%	28.6%	28.6%	28.6%	28.6%	28.6%	28.6%	28.6%	28.6%	28.6%	28.6%	28.6%
269	269	269	269	269	269	269	269	269	269	269	269	269	269
23.1	23.6	24.1	24.6	25.0	25.4	25.9	26.2	26.6	26.9	27.2	27.4	27.7	27.9
144	143	141	139	137	135	133	131	130	128	127	125	124	123
8.5%	8.7%	8.9%	9.1%	9.3%	9.4%	9.6%	9.7%	9.9%	10.1%	10.3%	10.4%	10.6%	10.8%
4,935	4,927	4,920	4,903	4,885	4,862	4,851	4,838	4,830	4,830	4,831	4,838	4,841	4,856
14.1	14.0	13.9	13.8	13.7	13.5	13.4	13.3	13.2	13.2	13.1	13.1	13.0	13.0
0.20	0.20	0.19	0.19	0.19	0.18	0.18	0.17	0.17	0.17	0.16	0.16	0.16	0.16
38.7%	38.8%	39.0%	39.2%	39.4%	39.2%	39.3%	39.5%	39.8%	40.1%	40.4%	40.9%	41.3%	41.3%
$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
$0.72	$0.72	$0.72	$0.72	$0.72	$0.72	$0.72	$0.72	$0.72	$0.72	$0.72	$0.72	$0.72	$0.72
45.6	45.6	45.6	45.6	45.6	45.6	45.6	45.6	45.6	45.6	45.6	45.6	45.6	45.6

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	77.8	77.8	79.5	84.3	91.2	91.1	94.0	91.0	86.8	92.5	100.0	97.3
	Sub-Indexes												
	Geopolitical	71.6	72.1	74.4	80.2	87.1	90.1	94.2	93.0	86.7	92.7	100.0	96.5
	Economic	62.0	62.5	62.8	68.2	81.8	81.7	83.9	82.3	78.9	87.6	100.0	97.7
	Reliability	82.5	81.1	82.6	88.0	97.1	95.4	96.1	85.3	81.1	87.7	100.0	98.6
	Environmental	106.1	106.0	109.0	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	87.9	89.2	91.0	92.3	97.7	106.1	110.9	104.2	94.1	91.4	100.0	100.4
3	Security of World Natural Gas Reserves	57.4	67.3	73.8	78.0	83.8	101.5	106.1	113.4	100.0	98.0	100.0	106.0
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	86.5	88.7	90.6	91.5	92.0	98.0	97.8	90.4	87.5	84.6	100.0	99.4
Fuel Import Metrics													
7	Security of U.S. Petroleum Imports	52.4	59.8	69.1	87.4	94.7	104.5	121.9	130.1	107.3	104.6	100.0	92.6
8	Security of U.S. Natural Gas Imports	74.5	75.9	73.9	70.9	69.2	89.5	93.5	101.9	89.3	112.2	100.0	94.4
9	Oil & Natural Gas Import Expenditures	7.4	8.8	10.5	25.7	47.9	44.8	56.0	69.5	61.0	85.2	100.0	84.5
10	Oil & Natural Gas Import Expenditures per GDP	10.1	11.7	13.1	30.5	57.2	53.6	63.6	75.4	62.8	85.0	100.0	82.4
Energy Expenditure Metrics													
11	Energy Expenditures per GDP	58.9	59.0	58.5	59.9	75.8	77.9	79.0	80.8	77.7	86.4	100.0	101.8
12	Energy Expenditures per Household	54.0	54.6	55.4	58.3	71.6	72.0	75.4	79.3	78.5	88.3	100.0	100.4
13	Retail Electricity Prices	70.5	71.1	71.9	71.8	82.3	87.4	88.5	91.4	93.0	92.8	100.0	106.9
14	Crude Oil Price	14.6	14.8	14.5	27.1	52.2	48.9	50.4	51.7	48.5	67.6	100.0	99.2
Price & Market Volatility Metrics													
15	Crude Oil Price Volatility	3.4	2.9	1.3	24.4	69.6	74.8	54.3	11.0	11.0	43.2	100.0	95.6
16	Energy Expenditure Volatility	25.9	28.1	25.7	33.7	87.7	86.2	85.0	46.9	42.1	66.9	100.0	110.5
17	World Oil Refinery Utilization	160.0	147.7	142.5	155.3	130.2	110.8	112.5	106.9	108.8	111.9	100.0	91.4
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	118.6	117.3	116.9	115.2	113.2	110.4	110.6	108.5	105.4	103.3	100.0	95.1
21	Petroleum Intensity	117.8	118.1	120.9	121.0	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	124.2	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	99.2	102.0	103.6	102.2	100.2	104.1	104.3	104.3	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	34.8	41.6	70.9	95.4	74.1	56.2	91.9	110.7	117.3	126.0	100.0	83.4
32	Energy-Related CO_2 Emissions per Capita	98.8	98.7	106.7	113.3	103.9	95.9	105.8	110.1	110.0	110.5	100.0	93.0
33	Energy-Related CO_2 Emissions Intensity	122.5	120.0	119.8	118.0	114.6	111.5	112.2	110.4	105.7	103.8	100.0	95.0
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	147.4	147.4	147.4	147.4	141.3	145.4	144.1	109.2	110.0	103.9	100.0	106.3
36	Federal Energy & Science R&D Expenditures	177.1	184.4	180.6	187.3	173.4	131.1	126.5	99.6	95.1	97.1	100.0	112.1
37	Science & Engineering Degrees	79.5	79.0	79.8	80.8	79.4	81.6	86.6	91.5	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	83.8	82.7	84.2	81.7	79.5	79.0	76.8	75.0	76.3	75.0	75.7	77.6	78.7	78.6	81.6	87.4
90.8	86.6	90.4	87.6	85.7	86.5	80.5	80.5	79.5	76.4	73.3	75.5	74.2	73.7	74.4	74.2	72.5	75.8	83.3
89.9	82.4	80.8	76.4	70.1	71.7	68.6	67.0	68.5	65.5	63.8	63.2	61.4	61.6	64.4	64.0	61.1	64.0	72.4
91.5	84.6	83.6	79.7	87.1	89.1	88.5	79.1	78.9	78.2	76.0	77.7	75.9	78.6	80.4	84.7	91.3	96.2	99.8
92.3	91.4	94.2	93.2	92.9	94.4	96.4	96.9	94.2	92.7	93.3	95.5	96.0	96.9	99.6	101.3	101.1	102.0	103.6
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
94.1	90.9	94.2	91.4	95.4	90.3	81.1	83.4	78.3	76.8	74.0	78.7	76.5	75.1	70.9	71.1	69.1	69.0	69.6
120.2	122.2	141.6	136.0	136.5	124.1	94.4	100.9	86.5	88.2	77.1	85.9	87.3	87.6	87.3	87.0	88.7	92.9	99.3
112.3	120.0	138.0	146.6	155.8	142.3	117.6	117.1	91.7	88.3	69.2	72.5	69.0	66.6	61.4	61.2	63.9	68.5	71.5
102.1	100.8	107.6	107.5	107.3	99.6	86.4	86.1	68.8	72.2	57.6	62.4	58.3	56.6	53.1	50.7	49.8	52.8	58.2
100.8	101.6	108.2	107.4	107.2	100.8	93.1	98.8	84.4	82.7	75.3	83.1	83.7	83.2	83.7	80.4	71.8	73.1	78.8
72.3	69.9	76.1	66.8	84.5	84.1	79.7	87.9	82.7	76.8	74.4	85.0	84.1	80.3	78.6	83.2	84.1	82.3	86.4
114.2	122.2	121.7	146.5	126.3	146.2	146.9	142.7	124.7	131.6	108.0	125.2	129.7	127.8	116.0	115.3	130.7	157.7	161.0
58.8	49.7	51.7	43.1	25.9	35.9	31.7	40.2	50.0	38.4	38.4	37.2	36.0	36.6	47.4	46.9	33.8	46.7	78.3
58.4	47.1	45.8	36.6	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	40.3
97.4	87.7	82.3	77.1	64.0	62.5	60.0	59.4	60.8	58.6	55.8	54.8	52.9	51.4	53.0	50.5	44.3	44.3	51.2
93.2	87.0	85.7	82.2	69.6	69.3	68.1	68.8	71.2	67.8	66.1	65.7	65.4	64.4	68.2	67.1	60.7	62.7	74.9
111.7	111.0	106.3	106.1	104.0	100.4	96.7	94.5	92.8	92.2	91.1	90.4	88.3	86.2	84.3	82.8	80.5	78.2	78.4
85.1	71.1	68.1	61.8	29.4	37.8	29.3	34.5	43.4	35.4	33.4	28.7	26.2	27.5	32.8	29.8	19.7	27.2	42.7
86.4	52.7	56.8	42.5	76.3	86.1	90.0	40.1	41.0	40.2	34.5	26.8	16.8	15.5	16.6	17.4	33.5	37.7	60.5
93.9	61.2	43.7	28.1	50.1	49.2	40.6	8.4	15.5	24.4	20.8	13.0	5.3	2.8	14.5	13.8	28.8	23.4	55.9
89.7	94.8	99.0	100.5	107.7	108.2	116.5	118.9	119.7	117.7	118.6	117.7	117.3	119.4	122.0	126.8	123.7	119.3	122.7
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	100.2	100.8	101.9
93.0	88.8	86.9	83.2	80.7	80.4	80.8	79.9	78.1	78.1	76.7	76.0	74.5	74.1	73.8	71.1	68.3	66.3	65.1
87.8	83.4	80.4	76.9	77.3	76.3	76.3	73.5	70.8	69.4	68.4	66.8	65.9	63.9	63.9	62.0	60.4	59.2	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	87.5	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	76.6	74.2	72.9	68.6	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
103.7	102.8	99.7	98.8	98.7	99.9	101.1	100.9	101.3	102.7	102.7	102.1	100.8	100.9	100.3	98.7	97.2	95.0	93.2
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
52.4	49.5	80.1	79.0	79.8	100.9	130.9	142.2	138.5	132.4	145.3	157.4	167.8	176.2	201.3	210.9	218.0	225.0	248.5
82.3	80.0	87.1	85.3	83.9	88.2	95.0	96.4	93.2	89.1	90.1	90.9	91.4	91.4	95.7	95.9	95.5	95.1	98.8
91.8	87.4	85.8	82.2	79.5	79.5	80.0	78.4	76.6	75.9	74.8	74.1	72.3	71.2	71.1	68.9	66.6	64.2	63.5
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
106.9	109.9	113.4	127.1	141.2	137.9	146.1	148.4	148.3	147.0	171.8	195.5	203.6	230.3	241.6	302.6	278.0	323.1	290.0
129.5	150.7	160.5	172.8	186.4	200.7	206.8	199.3	196.5	186.5	191.7	216.2	220.8	229.3	254.6	273.1	289.0	280.0	290.5
97.3	100.8	106.1	107.8	110.3	114.8	121.6	124.9	124.6	121.6	120.1	119.1	120.6	121.8	124.4	129.4	134.5	139.9	143.7

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	84.2	82.0	81.4	86.7	94.3	96.3	95.9	99.0	89.5	97.1	101.4	91.7
	Sub-Indexes												
	Geopolitical	81.6	78.6	77.8	84.6	92.2	94.9	96.2	100.7	87.4	94.4	101.0	93.0
	Economic	68.7	66.9	68.5	75.3	86.6	90.6	91.1	100.1	83.7	93.2	102.1	92.1
	Reliability	94.5	90.9	86.7	92.3	102.5	104.9	100.4	99.4	104.4	113.8	115.3	97.0
	Environmental	100.9	101.0	100.6	101.5	100.8	98.3	98.1	94.3	86.3	90.2	87.2	83.7
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	94.0
2	Security of World Oil Production	70.2	67.0	69.9	74.6	74.2	74.7	74.8	77.7	75.9	78.6	82.5	82.6
3	Security of World Natural Gas Reserves	98.7	94.7	92.5	97.1	97.9	96.7	97.0	96.0	96.0	92.8	93.0	95.3
4	Security of World Natural Gas Production	72.8	71.3	71.7	76.4	76.8	77.9	78.4	77.7	74.7	77.8	81.9	81.2
5	Security of World Coal Reserves	57.5	55.3	64.3	66.7	64.4	70.8	70.8	62.9	61.2	61.6	59.5	59.5
6	Security of World Coal Production	80.5	83.3	95.9	106.4	111.8	119.7	125.4	129.7	141.3	149.0	156.9	160.4
Fuel Import Metrics													
7	Security of U.S. Petroleum Imports	91.4	83.7	92.0	101.6	103.8	103.6	100.8	102.4	90.9	90.3	86.8	78.7
8	Security of U.S. Natural Gas Imports	174.1	157.8	152.8	168.1	179.3	175.8	180.8	141.0	120.0	116.4	91.7	66.9
9	Oil & Natural Gas Import Expenditures	68.9	65.6	81.3	109.7	158.4	173.6	183.2	219.0	118.1	146.0	175.7	149.9
10	Oil & Natural Gas Import Expenditures per GDP	35.1	32.9	39.6	51.5	71.8	76.5	79.3	94.9	52.5	63.3	75.0	62.6
Energy Expenditure Metrics													
11	Energy Expenditures per GDP	50.2	46.3	50.3	54.4	61.2	64.0	65.2	73.1	56.3	61.8	68.3	63.9
12	Energy Expenditures per Household	73.3	70.2	77.9	86.7	99.4	105.6	108.8	120.6	90.7	101.6	112.4	106.4
13	Retail Electricity Prices	82.2	79.9	81.1	80.7	83.7	88.9	88.8	92.9	93.0	92.0	90.8	88.5
14	Crude Oil Price	35.6	35.8	40.6	52.5	72.6	84.1	91.0	119.5	75.5	96.3	131.8	129.7
Price & Market Volatility Metrics													
15	Crude Oil Price Volatility	54.8	41.4	22.0	30.7	67.1	79.4	70.5	85.8	145.0	170.2	183.1	106.5
16	Energy Expenditure Volatility	42.8	46.7	33.8	54.3	75.5	72.4	58.6	57.0	113.8	128.8	125.9	66.3
17	World Oil Refinery Utilization	122.4	118.5	124.1	129.5	129.9	126.6	126.5	122.8	113.3	117.6	116.1	118.1
18	Petroleum Stock Levels	101.1	104.2	104.3	103.2	101.0	99.2	102.5	92.8	87.1	88.4	89.4	85.1
Energy Use Intensity Metrics													
19	Energy Consumption per Capita	98.2	98.8	98.2	99.5	98.7	97.0	97.6	94.6	89.2	91.9	90.6	87.6
20	Energy Intensity	62.8	62.6	61.1	60.1	58.2	56.1	55.9	54.8	53.5	54.2	53.0	50.5
21	Petroleum Intensity	56.8	55.9	55.2	55.2	53.4	51.3	49.9	46.7	45.3	44.9	43.3	41.4
22	Household Energy Efficiency	94.7	100.1	101.1	100.0	100.9	95.4	98.6	98.3	95.7	98.9	95.2	87.7
23	Commercial Energy Efficiency	83.0	82.7	81.5	81.0	80.0	77.6	78.3	77.2	73.5	72.7	70.9	67.3
24	Industrial Energy Efficiency	57.3	57.0	56.1	56.2	52.7	51.4	50.1	50.3	51.6	52.7	51.6	50.2
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	118.5	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	93.9	94.3	92.8	91.6	89.3	87.5	86.4	84.9	86.6	84.7	82.8	81.1
30	Transportation Non-Petroleum Fuels	100.4	100.1	100.1	100.1	99.7	98.8	97.6	95.4	94.1	93.2	92.3	91.7
Environmental Metrics													
31	Energy-Related CO_2 Emissions	234.6	240.4	247.2	262.6	265.4	254.9	267.0	241.5	185.2	211.5	192.9	165.0
32	Energy-Related CO_2 Emissions per Capita	93.5	93.1	93.2	95.1	94.0	89.8	90.9	83.6	70.6	74.6	69.9	63.7
33	Energy-Related CO_2 Emissions Intensity	61.8	61.2	60.0	59.0	57.2	54.8	54.7	53.0	50.4	51.0	48.9	46.0
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	277.0	253.8	242.0	224.9	211.1	180.5	161.0	159.0	163.3	166.4	168.4	165.7
36	Federal Energy & Science R&D Expenditures	264.1	261.4	257.5	264.7	250.7	266.2	230.0	224.7	136.5	194.0	204.8	214.7
37	Science & Engineering Degrees	143.6	142.1	136.9	135.3	136.3	137.6	138.1	134.4	127.7	127.1	121.8	117.2

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
87.4	81.1	77.5	77.0	77.4	75.8	76.6	74.1	73.3	72.6	72.4	72.7	72.9	73.1	73.2	73.3	73.4	73.4	73.3
88.4	82.9	75.7	75.2	75.2	73.0	74.4	71.3	70.8	70.3	70.2	70.6	70.8	71.1	71.4	71.6	71.8	71.9	72.0
86.7	79.0	68.7	66.6	68.6	68.8	68.9	66.6	65.9	65.2	65.1	65.6	65.9	66.2	66.5	66.6	66.8	66.9	66.9
88.8	77.4	88.0	90.9	90.9	84.3	87.7	84.8	83.8	82.8	82.9	83.8	84.7	85.5	86.1	86.4	86.7	87.2	87.5
85.5	85.5	82.7	81.3	80.3	81.9	80.5	78.8	77.4	76.8	76.1	75.3	74.7	74.0	73.3	72.7	72.1	71.5	70.8
94.8	99.0	97.3	103.6	105.9	112.1	112.1	112.1	112.1	112.1	112.1	112.1	112.1	112.1	112.1	112.1	112.1	112.1	112.1
82.1	84.7	85.1	90.1	92.2	92.8	94.8	94.8	94.0	93.6	94.3	94.8	94.9	94.9	95.0	95.0	95.1	95.1	95.0
96.6	99.6	100.3	108.1	107.6	103.5	103.5	103.5	103.5	103.5	103.5	103.5	103.5	103.5	103.5	103.5	103.5	103.5	103.5
82.7	87.9	88.2	91.6	99.1	98.8	100.6	103.0	103.0	103.8	103.3	103.3	102.8	102.4	102.0	102.0	103.0	103.3	102.7
61.4	65.2	61.5	61.5	61.5	61.5	61.5	61.5	61.5	61.5	61.5	61.5	61.5	61.5	61.5	61.5	61.5	61.5	61.5
163.4	162.5	164.7	161.6	166.3	166.3	166.3	166.3	166.3	166.3	166.3	166.3	166.3	166.3	166.3	166.3	166.3	166.3	166.3
65.3	55.0	50.6	54.1	41.9	25.9	17.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
57.6	54.2	42.1	31.2	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	0.0
121.6	89.1	43.3	36.2	33.7	26.0	15.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
49.8	35.6	16.8	13.9	12.6	9.5	5.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
62.6	60.8	47.3	42.4	44.5	47.3	46.2	45.8	45.0	44.2	43.8	43.6	43.3	42.8	42.5	41.9	41.7	40.9	40.3
106.1	104.8	82.5	74.5	78.4	85.7	85.5	86.0	85.1	84.4	84.4	84.7	85.0	85.0	85.5	85.3	86.0	85.6	85.4
89.0	90.6	89.4	87.2	87.3	86.2	85.2	83.4	82.4	82.4	82.5	83.1	84.1	84.7	84.8	84.9	84.8	85.1	85.2
124.0	110.9	58.0	47.9	58.3	74.8	77.1	77.1	78.4	78.3	80.2	83.5	86.1	89.4	92.1	94.2	96.1	97.9	99.6
79.1	38.1	131.0	139.1	134.2	67.8	114.6	109.2	105.4	99.9	96.7	100.6	103.7	107.7	111.0	113.4	115.7	117.9	120.0
40.1	12.9	47.8	63.0	72.5	68.2	63.9	59.6	55.2	50.9	50.9	50.9	50.9	50.9	50.9	50.9	50.9	50.9	50.9
116.3	115.9	121.2	121.6	124.9	124.2	124.2	124.2	124.2	124.2	124.2	124.2	124.2	124.2	124.2	124.2	124.2	124.2	124.2
89.6	85.4	80.4	79.4	86.0	87.3	88.2	87.2	86.9	86.6	86.0	85.4	84.7	84.1	83.7	83.4	83.1	82.6	82.4
89.5	89.9	88.5	87.8	87.6	90.1	88.2	87.6	86.8	86.1	85.3	84.6	83.9	83.2	82.6	82.2	81.8	81.2	80.8
51.0	50.4	48.5	47.8	46.9	47.2	45.6	44.6	43.8	43.0	42.2	41.5	40.6	39.8	39.0	38.3	37.6	36.8	36.1
41.3	40.6	40.3	40.1	39.6	39.3	40.2	38.9	38.0	37.2	36.3	35.4	34.4	33.5	32.7	31.9	31.1	30.4	29.7
92.8	93.9	88.8	86.3	84.3	90.1	86.6	84.5	82.6	81.0	79.6	78.4	77.2	76.2	75.3	74.6	74.1	73.5	72.9
68.7	69.5	68.5	67.5	66.4	67.0	65.5	64.8	63.6	62.6	61.5	60.8	59.9	59.1	58.4	57.8	57.3	56.8	56.2
50.1	48.9	48.9	49.8	49.5	48.6	46.9	46.8	46.9	46.7	46.5	46.3	45.9	45.5	45.1	44.7	44.3	43.8	43.3
88.5	88.5	89.0	88.6	89.7	89.8	91.4	93.4	95.2	97.3	100.8	104.8	110.8	113.1	115.6	116.6	116.3	118.7	119.7
99.8	86.5	92.7	96.4	89.4	96.7	93.7	89.4	88.6	89.2	89.8	90.6	91.3	92.8	92.0	91.4	91.4	91.4	91.4
108.6	101.7	103.0	104.7	102.2	105.1	103.6	103.5	103.3	103.3	103.3	103.3	103.3	103.3	103.3	103.3	103.3	103.3	103.3
75.6	76.0	74.3	74.3	73.5	69.5	68.5	67.3	65.9	64.6	63.2	61.8	60.4	59.0	57.6	56.4	55.3	54.2	53.2
80.2	79.6	78.8	79.4	78.7	78.4	77.3	76.5	75.9	75.1	74.3	73.3	72.2	71.4	70.6	69.7	68.8	67.8	66.9
90.4	91.3	91.4	90.8	90.7	90.6	92.1	91.9	91.6	91.5	91.2	90.9	90.5	90.2	89.8	89.5	89.1	88.7	88.4
181.8	188.2	168.7	156.3	150.8	169.2	162.2	148.8	140.1	138.4	135.3	132.6	130.3	127.8	124.7	123.7	122.7	120.4	118.0
65.9	66.1	61.7	58.6	57.0	59.3	56.9	54.0	51.9	50.9	49.8	48.7	47.7	46.8	45.8	45.1	44.4	43.6	42.8
46.3	45.6	43.1	41.7	40.4	40.4	39.0	37.4	36.3	35.7	34.9	34.2	33.4	32.7	31.9	31.3	30.6	29.9	29.2
71.4	70.7	70.0	66.5	62.5	63.5	61.7	60.6	59.3	59.7	59.9	59.6	60.4	60.6	60.4	60.3	59.9	59.7	59.4
164.9	161.0	158.0	155.4	152.3	152.3	152.3	152.3	152.3	152.3	152.3	152.3	152.3	152.3	152.3	152.3	152.3	152.3	152.3
238.5	229.3	216.2	213.6	222.3	233.7	233.7	233.7	233.7	233.7	233.7	233.7	233.7	233.7	233.7	233.7	233.7	233.7	233.7
114.6	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	73.4	73.4	73.4	73.4	73.4	73.5	73.5	73.5	73.5
	Sub-Indexes									
	Geopolitical	72.1	72.1	72.2	72.4	72.5	72.6	72.7	72.8	72.9
	Economic	67.1	67.1	67.1	67.2	67.3	67.4	67.4	67.5	67.4
	Reliability	88.1	88.3	88.7	88.9	89.1	89.3	89.4	89.6	89.8
	Environmental	70.3	69.7	69.2	68.7	68.4	68.1	67.8	67.5	67.5
Global Fuels Metrics										
1	Security of World Oil Reserves	112.1	112.1	112.1	112.1	112.1	112.1	112.1	112.1	112.1
2	Security of World Oil Production	95.1	95.1	95.2	95.2	95.3	95.3	95.4	95.4	95.3
3	Security of World Natural Gas Reserves	103.5	103.5	103.5	103.5	103.5	103.5	103.5	103.5	103.5
4	Security of World Natural Gas Production	103.0	102.3	102.0	103.5	102.9	102.9	102.9	103.0	102.8
5	Security of World Coal Reserves	61.5	61.5	61.5	61.5	61.5	61.5	61.5	61.5	61.5
6	Security of World Coal Production	166.3	166.3	166.3	166.3	166.3	166.3	166.3	166.3	166.3
Fuel Import Metrics										
7	Security of U.S. Petroleum Imports	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
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	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10	Oil & Natural Gas Import Expenditures per GDP	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Energy Expenditure Metrics										
11	Energy Expenditures per GDP	39.9	39.3	38.7	38.3	37.9	37.4	36.9	36.5	36.1
12	Energy Expenditures per Household	85.5	85.4	85.1	85.0	85.3	85.0	85.0	85.1	85.0
13	Retail Electricity Prices	85.7	85.9	86.0	86.0	86.2	86.4	86.3	86.1	85.7
14	Crude Oil Price	101.3	102.8	104.2	105.6	106.8	107.9	109.0	109.9	110.7
Price & Market Volatility Metrics										
15	Crude Oil Price Volatility	122.0	123.8	125.6	127.2	128.6	130.0	131.3	132.4	133.4
16	Energy Expenditure Volatility	50.9	50.9	50.9	50.9	50.9	50.9	50.9	50.9	50.9
17	World Oil Refinery Utilization	124.2	124.2	124.2	124.2	124.2	124.2	124.2	124.2	124.2
18	Petroleum Stock Levels	82.2	81.9	81.7	81.5	81.5	81.6	81.9	82.0	82.2
Energy Use Intensity Metrics										
19	Energy Consumption per Capita	80.2	79.8	79.4	79.2	79.0	78.9	78.9	78.9	78.8
20	Energy Intensity	35.4	34.7	34.1	33.5	33.0	32.6	32.1	31.6	31.2
21	Petroleum Intensity	29.0	28.4	27.8	27.2	26.7	26.3	25.9	25.4	25.0
22	Household Energy Efficiency	72.2	71.7	71.2	70.8	70.5	70.1	69.8	69.6	69.3
23	Commercial Energy Efficiency	55.5	55.0	54.5	54.2	53.8	53.5	53.2	53.0	52.7
24	Industrial Energy Efficiency	42.7	42.2	41.6	41.1	40.7	40.3	39.9	39.5	39.1
Electric Power Sector Metrics										
25	Electricity Capacity Diversity	123.6	124.4	126.4	126.0	125.9	126.9	126.1	126.1	127.0
26	Electricity Capacity Margins	91.4	91.4	91.4	91.4	91.4	91.4	91.4	91.4	91.4
27	Electricity Transmission Line Mileage	103.3	103.3	103.3	103.3	103.3	103.3	103.3	103.3	103.3
Transportation Sector Metrics										
28	Motor Vehicle Average MPG	52.3	51.4	50.7	50.0	49.5	49.0	48.5	48.1	47.7
29	Transportation VMT per $ GDP	66.0	65.1	64.2	63.4	62.6	61.9	61.2	60.6	59.9
30	Transportation Non-Petroleum Fuels	88.1	87.9	87.5	87.2	86.8	86.5	86.2	85.9	85.6
Environmental Metrics										
31	Energy-Related CO_2 Emissions	114.9	113.5	111.7	110.7	110.7	110.9	111.7	112.2	114.1
32	Energy-Related CO_2 Emissions per Capita	41.9	41.3	40.6	40.1	39.7	39.3	39.1	38.8	38.7
33	Energy-Related CO_2 Emissions Intensity	28.6	28.0	27.4	26.8	26.3	25.9	25.4	25.0	24.6
34	Electricity non-CO_2 Generation Share	59.7	59.5	59.2	58.8	58.3	57.9	57.2	56.7	56.6
Research and Development Metrics										
35	Industrial Energy R&D Expenditures	152.3	152.3	152.3	152.3	152.3	152.3	152.3	152.3	152.3
36	Federal Energy & Science R&D Expenditures	233.7	233.7	233.7	233.7	233.7	233.7	233.7	233.7	233.7
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

GEI 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 2019 (AEO2019)* 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 GEI's Index of U.S. Energy Security website at https://www.globalenergyinstitute.org/energy-security-risk-index.

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

BP:
BP Statistical Review of World Energy. Available at: https://www.bp.com/en/global/corporate/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: https://www.census.gov/programs-surveys/popest.html. 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 https://www.census.gov/library/publications/time-series/statistical_abstracts.html. For pre-1989 summer peak load aggregates.

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

Energy Information Administration:

- *Annual Energy Outlook 2019*. 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: https://freedomhouse.org/report-types/freedom-world. For 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 and 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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