2020 EDITION

INDEX OF U.S. ENERGY SECURITY RISK®

ASSESSING AMERICA'S VULNERABILITIES IN A GLOBAL ENERGY MARKET

GLOBAL ENERGY INSTITUTE
U.S. CHAMBER OF COMMERCE

Note to Readers

This abbreviated edition of the *U.S. Index of Energy Security Risk* (Index) reflects the energy situation in the United States as it existed from 1970 to 2019 before the COVID-19 pandemic. It is premature to say how the economic slowdown and accompanying plunge in energy demand will affect America's energy security going forward.

Even in a country as energy secure as the United States, a prolonged period of substantially lower demand, coupled with oversupply, has proved too much for some domestic energy producers to stay in business. Price volatility alone is a large source of risk, and the collapsing energy prices we have seen thus far in 2020—and potentially even a sharp spike in prices should production fall and demand rebound next year—will have a big impact on risk scores. So, too, could a consolidation of energy producers, especially if that means U.S. shale production does not recover and a greater share of our energy supply comes from foreign sources. Next year's edition will pick up and report on these and other pandemic-related trends in the United States and other countries as they emerge during the next few years.

From an energy security perspective, the United States was well positioned before the pandemic. In such an uncertain time, Americans can count on a reliable supply of energy. The U.S. energy industry will deliver, as it always does, and with the proper policies in place, it will provide the energy necessary for a robust recovery.

Introduction

The 2020 edition of the Global Energy Institute's (GEI) *Index of U.S. Energy Security Risk* incorporates the most recent historical and forecast data to assess the current and future state of U.S. energy security risk. The Index is made up of 37 different measures of energy security risk in nine categories: global fuels; fuel imports; energy expenditures; price and market volatility; energy use intensity; electric power sector; transportation sector; environmental; and basic science and energy research & development.[1] The Index covers the historical period from 1970 to 2019 and a forecast period out to 2040.

GEI's Index includes four Sub-Indexes that identify the major areas of risk to U.S. energy security: geopolitical, economic, reliability, and environmental. Each of the 37 metrics is mapped to one or more of these four Sub-Indexes. These Sub-Indexes are weighted (30% each for Geopolitical and Economic, 20% each for Reliability and Environmental) and combined to produce a total Index score.[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) 2020.*

The Index is designed to convey the notion of risk: a lower Index score indicates a lower risk to energy security and a higher score indicates a higher risk. When evaluating the results, it is important to recognize that the Index necessarily moves along an open-ended scale. 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.

The average Index score for the 30-year period from 1970 to 1999 is 84.9. This includes years with relatively very high (100 in 1980) and very low (74.9 in 1992) scores. When reviewing this year's results, the 1980 baseline score and the 30-year averages, along with the historical high and low scores also provided, can be used as reference points against which to consider current and future risk scores. Unless otherwise noted, all dollar figures are in real 2019 dollars. "Historic" or "record" high or low risk scores refer to scores since 1970, the beginning year of the GEI Index database.

This report focuses exclusively on the United States and how its energy security risks have shifted over time and where they might be headed in the future. GEI also publishes an *International Index of Energy Security Risk* that analyzes risks to the U.S. in an international context by comparing it with 24 other large energy-producing countries. Readers interested in how U.S. risks compare with those faced by other countries should consult the *International Index.*

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

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

Highlights

In 2019, the U.S. enjoyed its best ever energy security since 1970 (Figure 1). After achieving a record high risk score in 2011 of 100.9, the total U.S. energy security risk score fell in seven of the last eight years, achieving a record low of 70.1 in 2019, a 5.5% decline from 2018.

The total risk score has plunged 30.7 points since the 2011 record-high score (Table 1). In the eight years since the U.S. risk score peaked in 2011, it has tumbled 30%, an unprecedented rate of decline. There has been no comparable increase or decrease in risk in such a short amount of time, not even during the severe geopolitical and energy crises of the 1970s (*e.g.*, the Arab oil embargo, the Iranian hostage crisis, the invasion of Afghanistan by the Soviet Union, *etc.*). The importance of the U.S. shale revolution in driving these remarkable improvements cannot be overstated. The application of hydraulic fracturing, horizontal drilling, and advanced seismic imaging has unlocked a tremendous oil and gas resource, turning energy scarcity into abundance.

The United States became a net exporter of energy in 2019. The United States produced more total energy than it consumed in 2019, making us a net exporter of energy for the first time since 1952. This resulted from a combination of a very large increase in domestic oil and gas production on top of steadily improving energy efficiency and conservation.

Decreasing risks in 2019 were broad based, with 21 metrics showing declines of at least 1%, and nine metrics achieved their lowest score in 2019. Most of the total decline in risk, however, can be attributed to large drops in fuel import-related metrics (Table 2). Metrics measuring oil and natural gas import expenditures as a share of GDP and petroleum imports dropped between 75% and 86% and approached zero in 2019. Natural gas import risks remained at zero. Record-high output of oil and gas from shale formations has turned imports from an energy security weakness to strength. Oil prices continued their decline by 11.4%

FIGURE 1
U.S. Energy Security Risk Index: 1970–2040

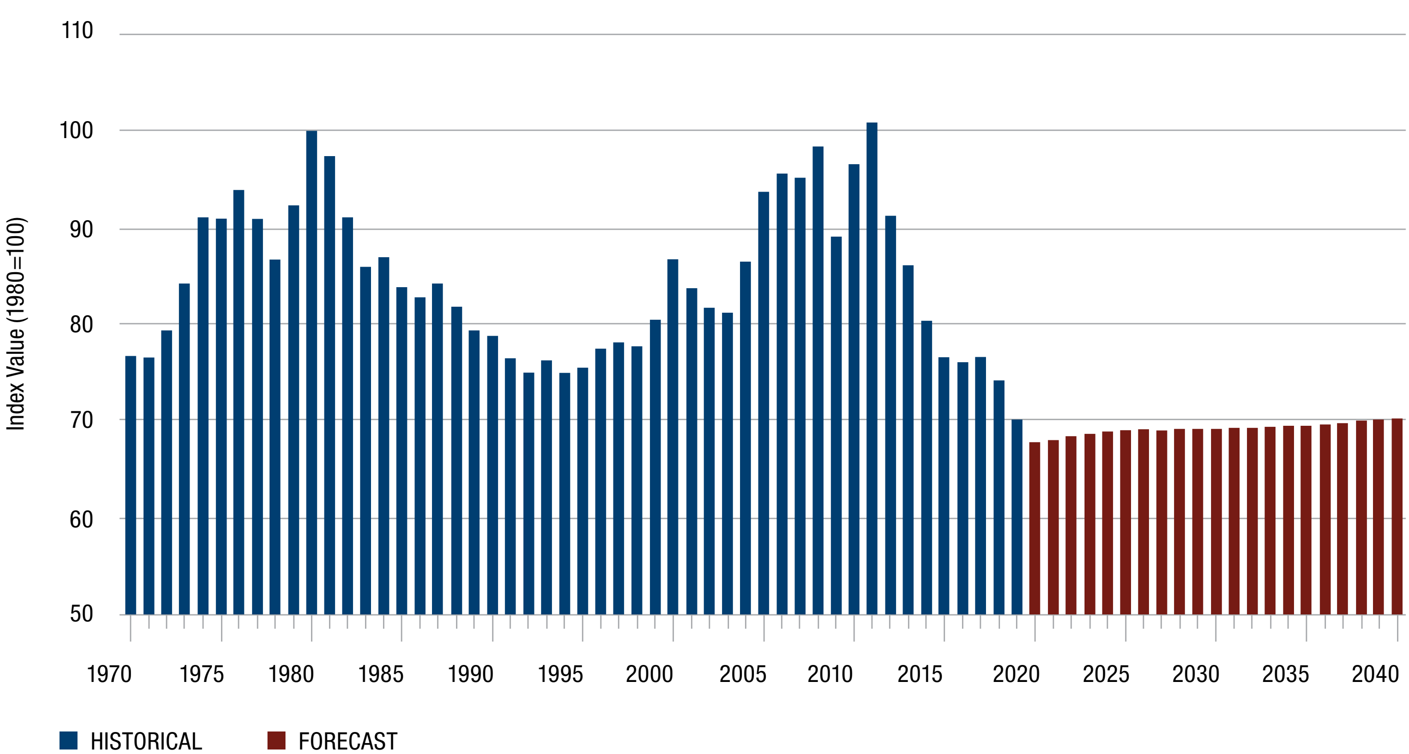


TABLE 1

U.S. Energy Security Risks from 1970 to 2019: 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 INDEX	70.1	100	2011	100.9	2019	70.1	83.8
SUB-INDEXES							
GEOPOLITICAL	68.7	100	2011	100.8	2019	68.7	82.6
ECONOMIC	60.5	100	2011	101.7	1998	60.5	73.2
RELIABILITY	74.7	100	2011	113.9	1994	74.7	85.9
ENVIRONMENTAL	78.6	100	1973	110.8	2019	78.6	99.4

in 2019 from the run-up in 2017. The metric measuring energy-related carbon dioxide emissions also fell significantly (nearly 12%), contributing to the record-low overall risk score (another trend that has also been driven by output from shale formations). Only six metrics displayed increases in risk of at least 1%, but as Table 2 shows, none more than 10%.

Domestic crude oil output rose an extraordinary 11.3%, or nearly 1.3 million barrels per day (bbl/d), to nearly 12.2 million bbl/d in 2019. The volume produced in 2019 was the highest in U.S. history and made the United States the world's largest producer. Texas had by far the largest volumetric increase of any state in 2019 (662,000 bbl/d), followed by New Mexico (221,000 bbl/d), North Dakota (161,000 bbl/d), and the Gulf of Mexico (138,000 bbl/d). Preliminary data indicates that these figures will be lower, perhaps significantly, in 2020.

Natural gas production rose to a record level in 2019, climbing 10.6% to 40.7 trillion cubic feet (tcf). The United States led the world in natural gas production in 2019. Increases in Texas (1.3 tcf) and Pennsylvania (0.8 tcf) accounted for most of the increase. Colorado, Louisiana, New Mexico, North Dakota, Ohio, Oklahoma and West Virginia and also contributed increased output. As with crude oil output, preliminary data show natural gas output will be lower in 2020.

TABLE 2

Movers and Shakers: Energy Security Metrics Changing ±10% or More in 2019

DECLINING RISK		RISING RISK	
METRIC	% CHANGE	METRIC	% CHANGE
OIL AND NATURAL GAS IMPORT EXPENDITURES PER GDP	▼ 85.4%		
OIL AND NATURAL GAS IMPORT EXPENDITURES	▼ 85.1%		
SECURITY OF U.S. PETROLEUM IMPORTS	▼ 75.0%		
ENERGY-RELATED CO2 EMISSIONS	▼ 11.7%		
CRUDE OIL PRICE	▼ 11.4%		

After rising in 2018, crude oil prices dipped 11% in 2019, from $72.58 to $64.30 per barrel. The decline in price was not enough to affect domestic crude oil production appreciably, as output increased to record levels. Despite the 11% change in price, crude oil price volatility, which is measured as the three-year rolling average price change, was much less in 2019 than in 2017 and a little less than in 2018. In 2019, crude oil price volatility was about average. The plunge in price in 2020 suggests that volatility risks will increase considerably for that year.

All metrics measuring energy use efficiency or intensity risks showed improvement in 2019, with five metrics showing their lowest (best) score in the record since 1970. These include the six metrics in the energy use intensity category and the average miles per gallon for the light vehicle fleet, and improvements in all of these metrics have been steady over the decades since 1970. Improvements in 2019 ranged from 1.4% to 5.8%.

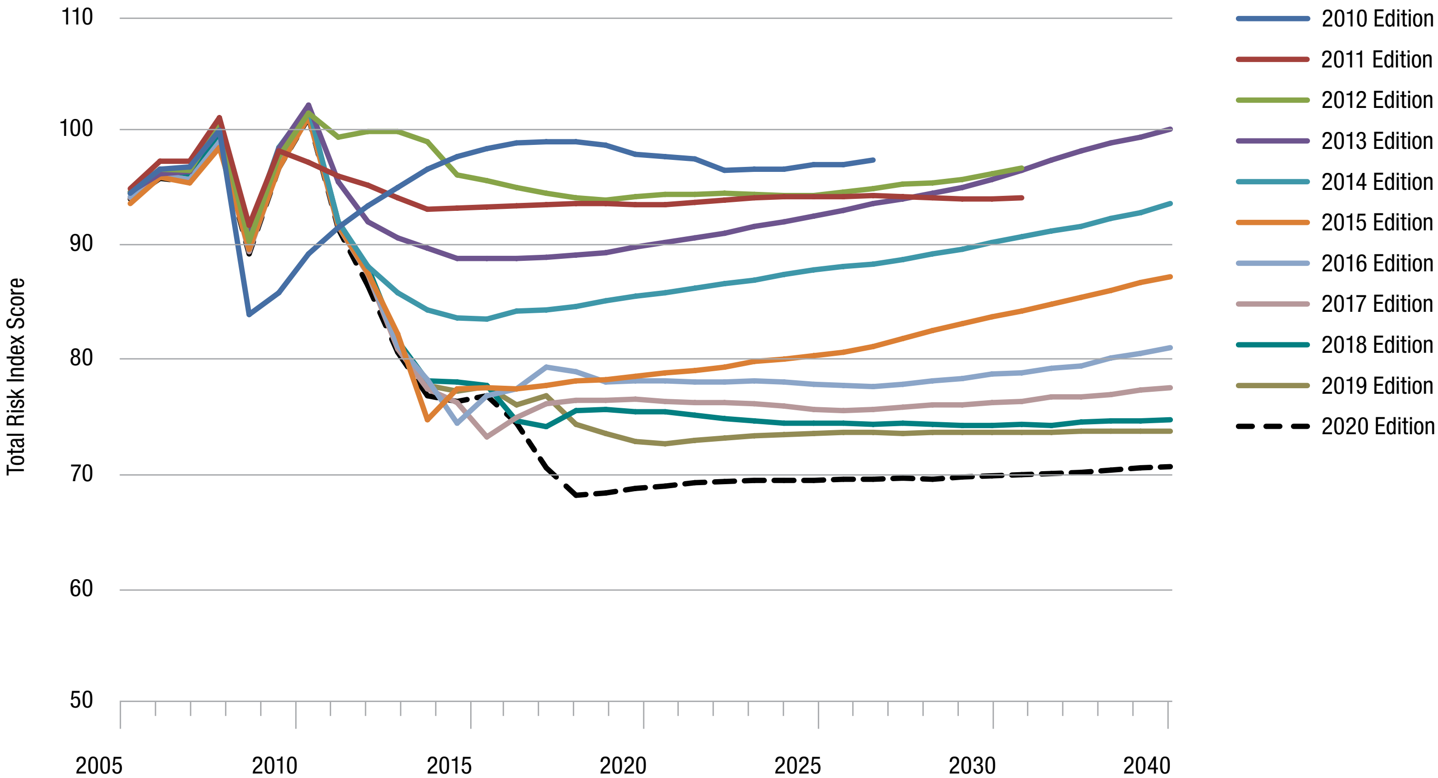
Risks related to all metrics in the Environmental group declined in 2019. Total carbon dioxide emissions from energy have fallen 870 million metric tons since its 2007 peak, and in 2019 emissions stood 14.5% below the 2005 level (a commonly used benchmark). Reductions in power sector emissions have been the main, but by no means only, driver of lower emissions in recent years. Many factors contributed to the reductions in this sector, including switching from coal to natural gas in generation, greater efficiency, and increased generation from renewable sources.

Risks are projected to remain very low out to 2040. Based on EIA's *AEO 2020*, we expect an average U.S. risk score of 69.3 from 2020 to 2040, ranging from 67.9 to 70.4. These are by far the lowest projected figures we have ever calculated using EIA's annual forecast, the first time in 2010 (Figure 2). Continued high domestic energy output coupled with better energy efficiency and environmental performance are some of the factors contributing to this very positive forecast. The impact of the COVID-19 pandemic will certainly affect, and probably increase, risks in the short term, but many of the favorable trends noted here will presumably pick up again and keep future risks low.

The forecast suggests three additional metric risks scores are expected to fall to zero in 2020. In addition to the metric for natural gas import risk, which reached a score of zero in 2017, the risk scores for three other import-related metrics are projected to reach zero in 2020: petroleum import risk; oil and natural gas import expenditures; and oil and natural gas import expenditures per GDP. Again, the coronavirus pandemic may delay achieving these milestones.

FIGURE 2

Changes in Forecast Index Scores Since 2010



Appendix: 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 A-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 A-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.

FIGURE A-1
Building the Index of U.S. Energy Security Risk

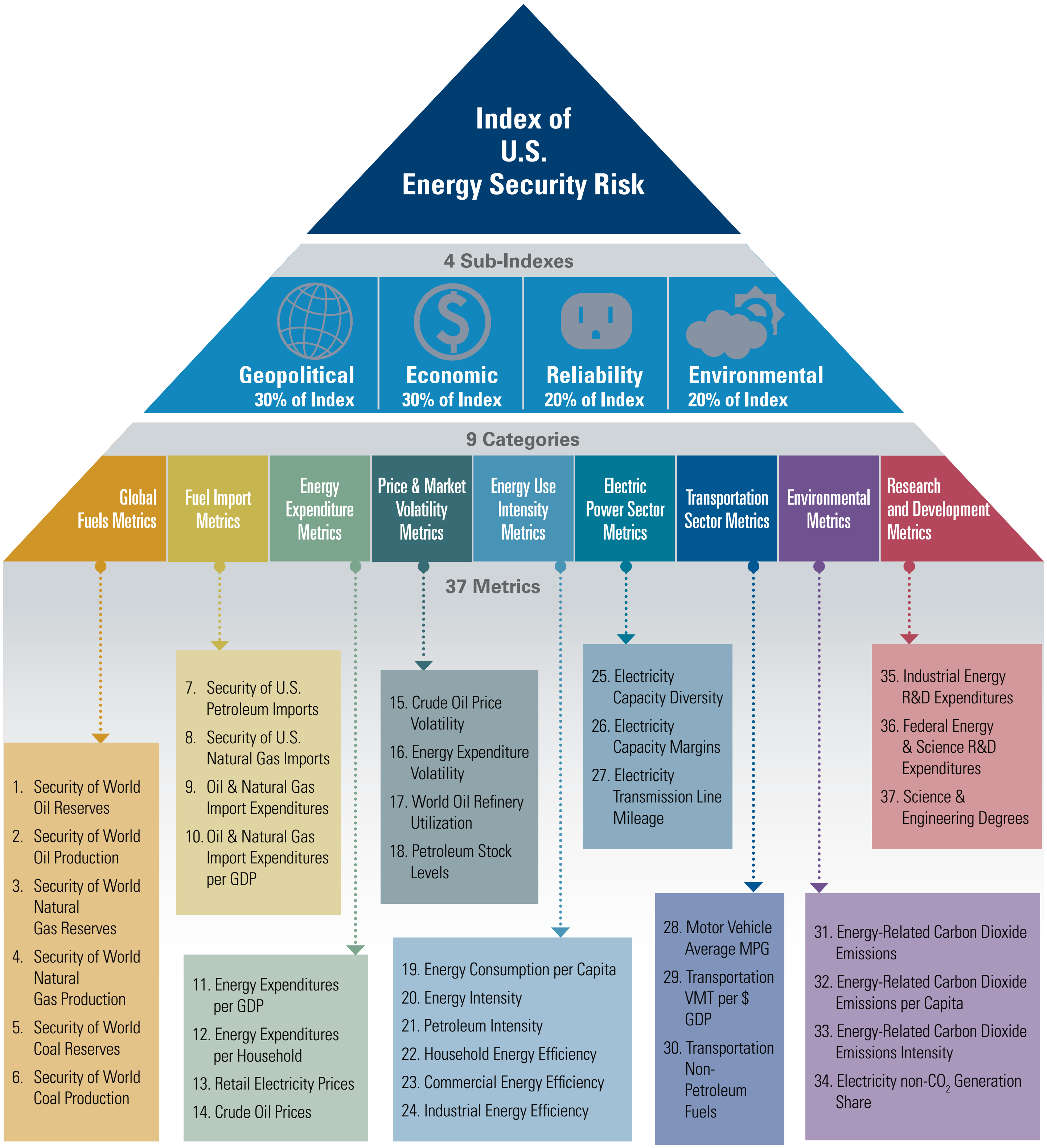


TABLE A-1
Categories of Energy Security Metrics

METRIC CATEGORY	GENERAL DESCRIPTION OF THE METRICS
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.
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.
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.
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.
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.
ELECTRIC POWER SECTOR	Measure the diversity and reliability of electricity generating capacity. Higher diversity and reliability mean a lower risk to energy security.
TRANSPORTATION SECTOR	Measure efficiency of the vehicle fleet and diversity of fuels. Higher efficiency and diversity mean a lower risk to energy security.
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.
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.

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.

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 so 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.

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 website.

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%

[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 States, 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.

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.

- **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 metric 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.

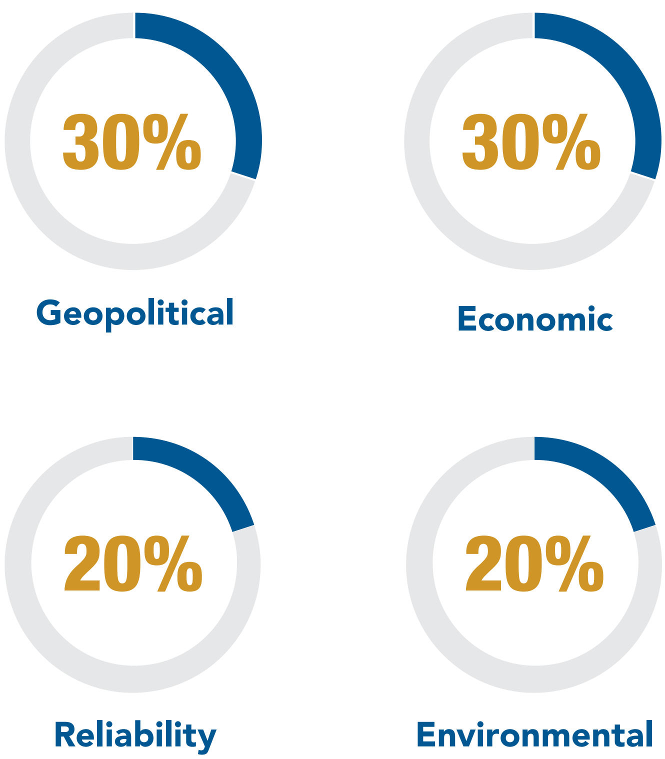
To arrive at the Sub-Indexes, the weightings were applied to each metric within each of the four areas to calculate essentially a weighted average of all the metrics selected for that group. The resulting weighted average is the energy security Sub-Index number.

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

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:



These values were used to arrive at a weighted average of the four Sub-Indexes. 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 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.

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 2020 (AEO2020)* 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.

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- 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 2020*. 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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1615 H Street NW | Washington, DC 20062
globalenergyinstitute.org