INDEX OF
U.S. ENERGY SECURITY RISK

ASSESSING AMERICA'S VULNERABILITIES IN A GLOBAL ENERGY MARKET

2010 Edition

Institute for 21st Century Energy • U.S. Chamber of Commerce

www.energyxxi.org

The mission of the U.S. Chamber of Commerce's Institute for 21st Century Energy is to unify policymakers, regulators, business leaders, and the American public behind a common sense energy strategy to help keep America secure, prosperous, and clean. Through policy development, education, and advocacy, the Institute is building support for meaningful action at the local, state, national, and international levels.

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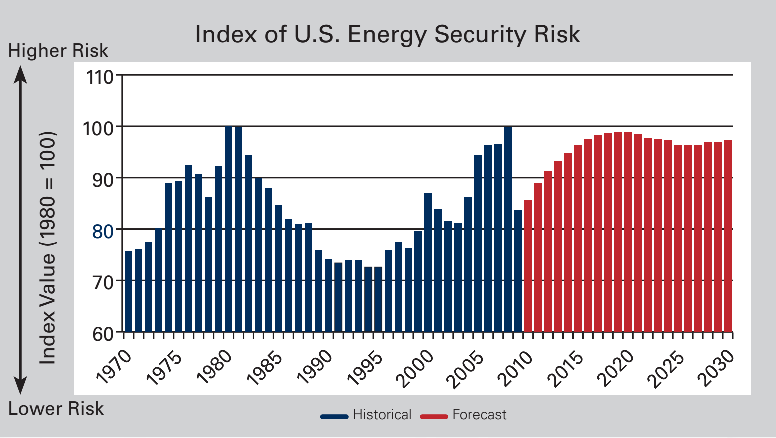

INSTITUTE FOR 21ST CENTURY ENERGY
U.S. CHAMBER OF COMMERCE

Acknowledgements

While the innocent question "How do we know if our energy security is getting better?" is simple in its construction, developing the means to answer it—an Index of U.S. Energy Security Risk—was a very complex and lengthy undertaking that could not have been completed without the extraordinary efforts of a broad array of contributors.

First, the entire staff of the Institute for 21st Century Energy (Energy Institute), especially Stephen Eule, dedicated themselves to design and create a visionary product that would bring more knowledge and facts into our nation's energy debate. The Index most certainly would not have been possible without the herculean effort and determination of Daniel Klein of the firm Twenty-First Strategies of McLean, Virginia. The Institute also wishes to extend special thanks to Guy Caruso of the Center for Strategic and International Studies, Michelle Foss of the Center for Energy Economics, Bureau of Economic Geology at the University of Texas at Austin, Bryan J. Hannegan of the Electric Power Research Institute, Steven F. Hayward of the American Enterprise Institute, and William O'Keefe of the George C. Marshall Institute for lending their time and expertise to review the project and for offering sound advice that made the end product much better than it would have been otherwise. In order to make this Index come to life, we counted on the team of Richard Russell, Dan Garretson and Peter Shoemaker of the firms VIAforward and Pinyon Partners, who miraculously transformed the Index into an exciting interactive web tool available at www.energyxxi.org. A huge debt of gratitude is also due to the entire production team here at the U.S. Chamber of Commerce for getting this publication into shape and making it as pleasing to the eye as we hope it is to the mind. Of course, any errors in this report are the sole responsibility of the Energy Institute.

It is because of the tireless efforts of these and many other people that with the Energy Institute's Index, we now have a tool that can answer that simple question: Is our energy security getting better or worse, and why?

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Preface

The genesis of this project to create an Index of U.S. Energy Security Risk began with a simple question: *How do we know if our energy security is getting better?*

What prompted this question was a series of three energy reports that the Institute for 21st Century Energy (Energy Institute) issued in 2008—*Securing America's Energy Future: An Open Letter to the 44th President of the United States and the 111th Congress, Blueprint for Securing America's Energy Future,* and *Transition Plan for Securing America's Energy Future*. These reports offer a sweeping set of solutions to address the pressing energy security challenges the country faces.

But as comprehensive as these reports are, it became apparent that something was missing: a way to assess the impact of these policy proposals on the Nation's energy security. We cannot assess what we cannot measure.

That was in late 2008. Now, over a year later, the Energy Institute is pleased to present its new Index of U.S. Energy Security Risk at a time when energy is once again front and center in the American consciousness.

It is something of a cliché that every president since Richard Nixon has made energy security and independence a priority, but that does not make it any less true. Indeed, since the early 1970s, energy has occupied the minds of policymakers to a degree rarely seen before the rise of the Organization of Petroleum Exporting Countries in the 1960s.

These concerns have been voiced by a series of administrations, both Democrat and Republican, since about 1970. While aspects of the problem have waxed and waned over the years, energy persists today as a pressing national economic and security priority.

And it is no wonder. Few issues are as essential to our economic well-being and national security as energy. Modern life would not be possible without abundant and reliable energy supplies, and developing countries will need increasing amounts of energy if they are to eradicate poverty and raise the standard of living of their people.

With energy playing such a pivotal role in modern society, the security of energy supplies takes on added importance. Supply interruptions and price volatility, even of short duration, can cause substantial economic dislocation and job losses. U.S. reliance on foreign supplies of energy, particularly petroleum, makes it vulnerable to both short- and long-term supply disruptions.

Tight oil supplies in the face of rapidly growing demand have led to record world oil prices that could over time curb economic growth and adversely affect the United States trade balance. At the same time, new replacements of conventional oil supply are lagging as access to new reserves is becoming more difficult and some traditional longtime suppliers face declining production. In the United States, large areas of the country and Outer Continental Shelf still remain off limits to exploration and production. New investments and regulatory environments are necessary to unlock new supplies of oil and natural gas, to improve or prolong the lifespan of existing sources and to bring new unconventional and renewable sources to market.

Moreover, the Nation's aging energy infrastructure is increasingly inadequate to meet its growing energy demand. Blackouts, brownouts, service interruptions, and rationing could become commonplace without new and upgraded capacity.

Energy prices permeate decisions of all businesses in every sector. Without abundant supplies of clean, reliable, and affordable energy and the infrastructure to distribute and deliver it, our economy and our competitiveness will suffer. If energy prices are erratic or artificially high because of near-sighted policy decisions, America's businesses will produce less output, which in turn will result in fewer jobs, lower wages, higher costs for goods and services, and a smaller tax base. In extreme cases, businesses will relocate overseas to countries with less burdensome regulation.

Other emerging trends reflecting the new global energy landscape could accelerate the impact of the risk to our energy security. Many developing countries have made providing modern energy services to their people a priority because they know the positive impact reliable energy has on economic growth and prosperity.

At the same time that new demand emerges, more and more global energy resources are becoming inaccessible, project costs are climbing rapidly, and qualified engineers and skilled workers are becoming increasingly scarce. These trends promise to place tremendous pressure on energy markets.

For many analysts and policymakers, energy security is inextricably linked to oil imports, a not unreasonable position given the volatility in energy markets that stem from disruptions in international oil supplies. Others view energy security more in terms of the price of gasoline at the pump. Still others view energy security in terms of price stability, vulnerability to disruptions, reliability of the grid, or environmental sustainability.

> *Energy prices permeate decisions of all businesses in every sector. Without abundant supplies of clean, reliable, and affordable energy and the infrastructure to distribute and deliver it, our economy and our competitiveness will suffer.*

Clearly, then, energy security is not a singular concept. It has many dimensions that collectively encompass a range of concerns and time scales—long-term and short-term, domestic and foreign, economic and political, and reliability in the face of natural and man-made risks. From this perspective, energy security is not an "either-or" proposition but rather a "less-more" proposition in which the risks to energy security span a spectrum of possibilities ranging from very good to the very bad. It is this expansive—some might say elusive—view of energy security that the Index is intended to capture and measure.

This report lays out the methodology used to compose the Index from 37 different metrics of energy security, and it provides a detailed look at energy security retrospectively from 1970 to 2009 and prospectively from 2010 to 2030. A companion document, *Index of U.S. Energy Security Risk: Metrics and Data Tables*, provides information on each of the 37 metrics used and is available on the Energy Institute's website.

The methodology used to develop the Index provides a powerful tool to evaluate the effect of alternative policies, quantifying potential energy security impacts such as economic and environmental factors. Indeed, the Index provides a useful tool in identifying and quantifying the sometimes difficult tradeoffs among competing priorities and goals.

Besides providing an historical look at U.S. energy security, the Index can be used to explain whether our energy security is trending better or worse, to assess the potential impact of new policies on U.S. energy security, and to measure the aspects of energy security that have had, or are likely to have, the greatest impact on energy security risks.

Executive Summary

Since the early 1970s, energy has occupied the minds of policymakers to a degree rarely seen before the rise in influence of the Organization of Petroleum Exporting Countries (OPEC) in the 1960s. Indeed, energy is recognized as among the top challenges to our Nation's future prosperity, national security, and quality of life. These concerns have been consistently voiced by a number of administrations, both Democratic and Republican, since the Arab oil embargo in 1973. In the nearly four decades since, the risks of supply disruptions, price spikes, blackouts, shortages, and environmental concerns remain, solidifying energy as pressing national economic and security priority.

While energy security is a significant and continual concern, that concern has not been matched with concrete metrics that allow for a quantifiable and dispassionate assessment of our Nation's energy security, where it has been, where it is now, and where it might be headed.

Today, statistics highlighting the amount of oil we import or the price of gasoline at the pump are a shorthand way to express the vulnerability of U.S. energy supplies. Such statistics, while enlightening, are inadequate for the task of describing the totality of U.S. energy security. They tell us precious little, for instance, about the reliability of the grid, energy efficiency of the economy, availability of human and intellectual capital, supply diversity, price volatility, or energy expenditures, all of which influence our energy security. A more comprehensive measure of energy security that integrates all of these concerns is necessary.

This shortcoming is what the U.S. Chamber of Commerce's Institute for 21st Century Energy (Energy Institute) seeks to address by introducing a first-of-a-kind annual Index of U.S. Energy Security Risk to aid policymakers, government officials, businesses, academics, and the general public in assessing the state of America's energy security.

Given the importance of energy to the U.S. economy, an index that measures our energy security is long overdue. Analysts, policymakers, and the public will find the Index of U.S. Energy Security useful in analyzing and quantifying the impact of economic, political and international events on the energy security of the U.S. Before now, there has been nothing comparable in the energy realm, despite a great wealth of energy data.

The Energy Institute's new annual index has four components that identify the major areas of risk to our energy security: geopolitical, economic, reliability, and environmental. Energy security has many dimensions that collectively encompass a range of concerns—long-term and short-term, domestic and foreign, economic and political. The Index incorporates 37 different measures of energy security risk,[1] covering a wide range of energy supplies, energy end-uses, operations, and environmental emissions, that allow us to answer with precision and regularity the question: **Is our energy security getting better or worse and, importantly, why?**

The methodology used to develop the Index provides a powerful tool to evaluate the effect of alternative policies, quantifying potential energy security impacts such as economic and environmental factors, shedding light on unintended consequences of some policies and the difficult tradeoffs among competing priorities—Figure ES-1 presents this methodology graphically.

The Index is designed to convey the notion of risk, where a lower number corresponds to a lower

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[1] The Appendix to this report discusses in greater detail the methodology used to develop the Index.

level of risk to energy security and a higher number corresponds to a higher level of risk.

Besides providing a historical look at U.S. energy security, the Index can be used in at least three useful ways.

- First, it can use recently collected and published data to help explain whether our energy security is trending better or worse. Our historical data of U.S. energy security over the years shows that, had this Index been available in the past, the warning signs of impending threats to our energy security would have been unmistakable. With the Energy Institute's Index, shifting trends can be spotted.

- Second, the Index can be used to assess the potential impact of new policies on U.S. energy security. Although current projections do not bode well for U.S. energy security, different policies scenarios can lead to measurably different futures.

- Third, various analytical and statistical techniques can measure the aspects of energy security that have had, or are likely to have, the greatest impact on energy security risks (through the 37 metrics) and thus provide insights on where policies should be focused.

The Index begins in 1970, when energy security first began to enter the American public's consciousness, and analyzes every year up to the present before extending years into the future to 2030. The Index relies on widely available US government data and forecasts, and in some instances on accepted industry supplied data.

The year 1980—the worst overall year for U.S. energy security risks—is set with an Index value of 100, and the Index values for all other years are set in relation to 1980 (figure ES-2). The year 1994 represents the year with the lowest energy security risks with a score of 72.6—a virtual tie with 1995.

In this inaugural 2010 edition, the Index of U.S. Energy Security Risk dropped in 2009 to 83.7, an improvement of 16.1 points from the previous year, the largest single-year movement in the Index throughout the entire historical record. This improvement was, however, the by-product of a severe financial crisis that exacted an enormous economic toll with a significant drop-off in energy demand that expected to be temporary.

The Index of U.S. Energy Security Risk for the year 2009 is: 83.7

Note: The Index reached its highest risk level of 100 in 1980 and its lowest risk level of 72.6 in 1994.

Forecasts suggest that as the global economy recovers, the risks to U.S. energy security outlined in the Index will approach the highs seen in 1980–81 and 2008 and remain at over 95 through 2030.

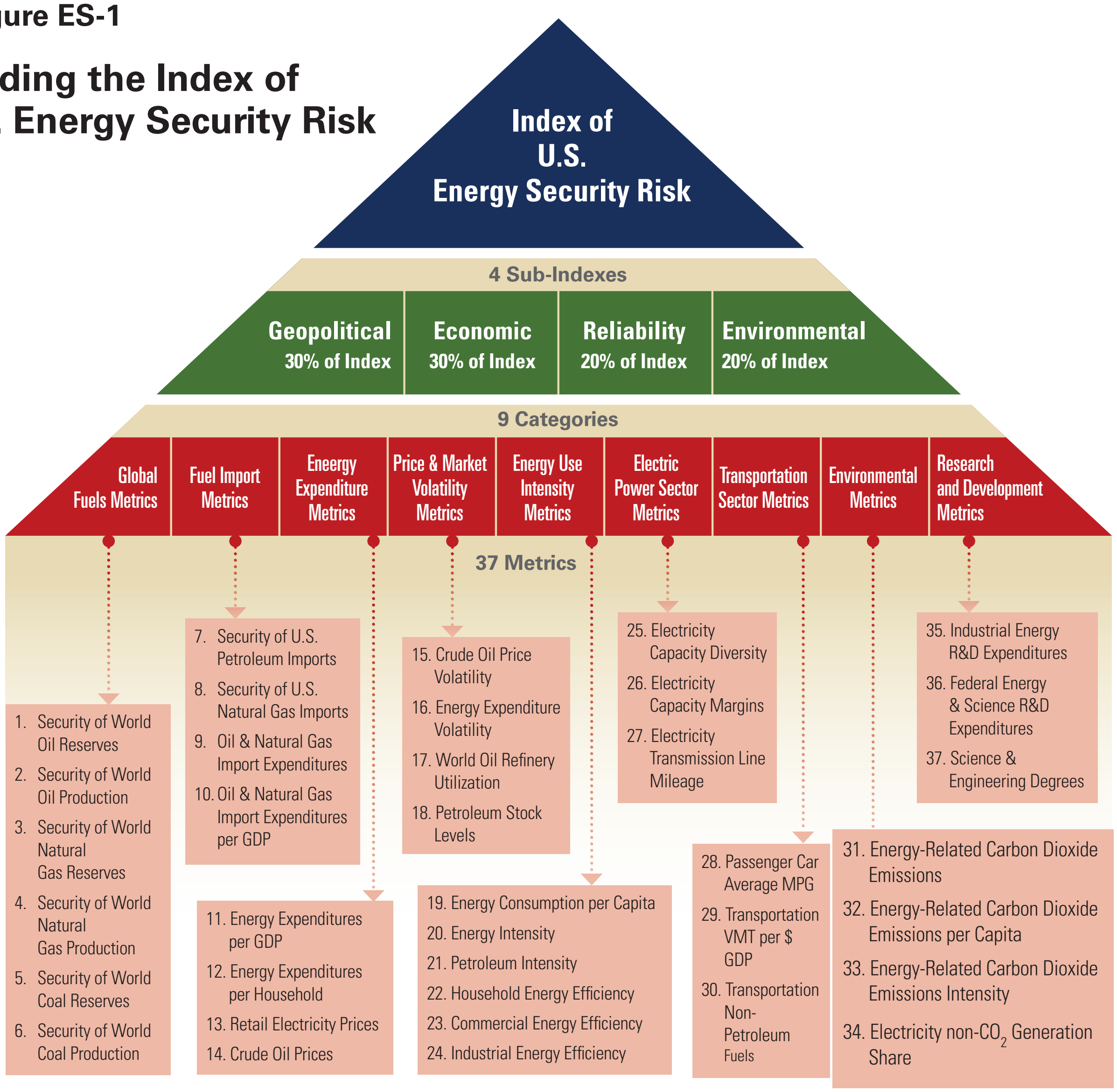
The Index demonstrates that there were two clear spikes in energy security risks over the past four decades: 1980–1981 and 2008, and one large trough connecting them. Highlights of the Index by decade follow.

1970s — Oil Shocks U.S. Complacency: The impacts of the 1973 Arab oil "embargo" and the Iranian revolution are clearly visible in the Index. The Arab oil embargo and its aftermath caused the Index to rise from 79.7 in 1970 to 92.4 in 1976, after which energy security risks began to ease slightly. The economy was soon hit with its second oil shock of the decade in 1979 in the wake of the 1978 Iranian Revolution and the U.S. hostage crisis.

These and other events provoked a panic in world oil markets that spurred sharply higher oil prices. Because oil played a much larger role in our energy economy in the 1970s—especially in the power sector—than it does today, the oil shocks rippled more strongly throughout the economy. After dipping to 86.1 in 1978, the repercussions of the 1979 Iranian revolution propelled the Index to 100 in 1980 and just under 100 in 1981, the highest levels of energy security risk in the historical record.

Figure ES-1

Building the Index of U.S. Energy Security Risk



The oil crises highlighted the need for a national energy policy. In 1973, President Nixon launched "Project Independence," an initiative designed to achieve U.S. self-reliance in energy by 1980. Presidents Ford and Carter also proposed energy plans of their own, with President Carter, likening the battle for greater energy security to the "moral equivalent of war." The decade of the 1970s was, therefore, a busy time for energy policy, with eight major pieces of energy legislation enacted into law.

1980s — Free Markets and the Decline of OPEC: Energy security risks in the United States fell sharply throughout the 1980s. From its peak of 100 in 1980, the Index of U.S. Energy Security Risk to fell to 75.9 in 1989, a 24% reduction in risk over the period. The election of Ronald Reagan signaled a marked shift in U.S. energy policy, with a greater reliance of free markets and a lesser reliance on federal regulation. Also, many positive trends begun in the mid- to late 1970s took hold and continued throughout the 1980s to improve U.S. energy security.

On the supply side, complete oil price decontrol, a more accommodating production posture from OPEC, increasing production outside OPEC (including from Alaska's North Slope and the North Sea), a growing strategic petroleum reserve, and the replacement of oil-fired capacity with coal-fired and nuclear capacity in the power sector combined to increase the amount and diversity of global oil supplies. From a high of over $36 in 1981, crude oil had plunged to a little over $14 per barrel in 1988, its lowest level of the decade.

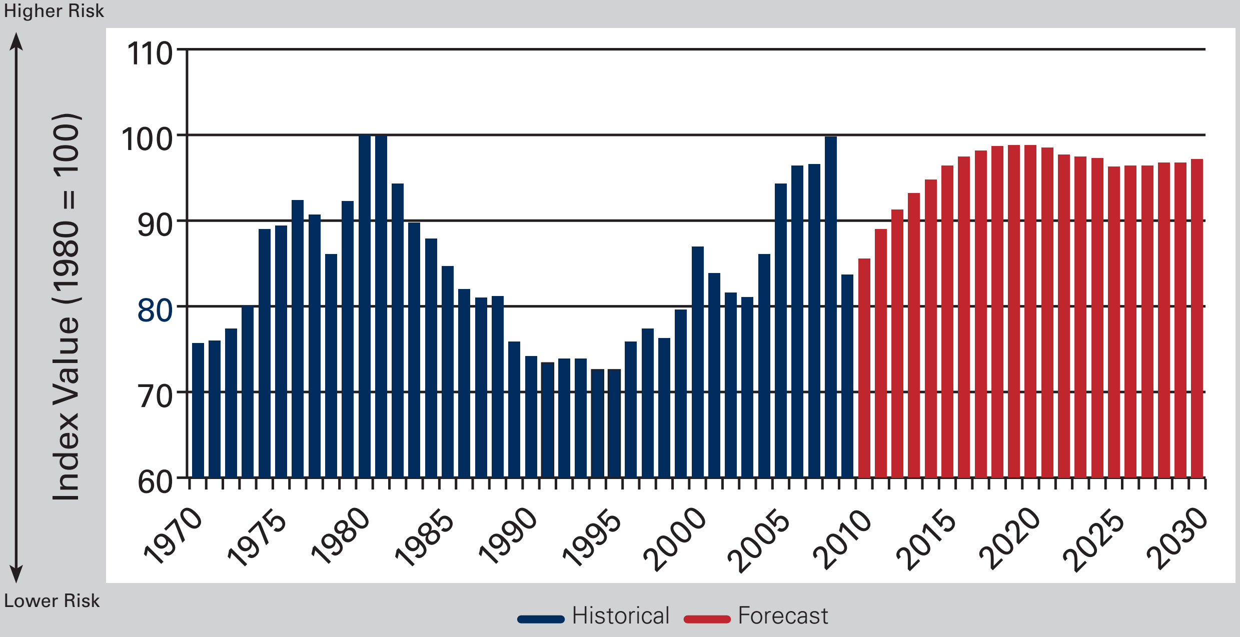
On the demand side, greater energy efficiency across all sectors was spurred on by clear price signals. In the auto sector, implementation of Corporate Average Fuel Economy standards enacted in 1975 increased the efficiency of the U.S. economy at the fastest rate over the historical record.

Policy responses in the 1980s were not nearly as intrusive as those of the previous decade. Many policies focused on repealing earlier provisions that regulated prices and assessed windfall profits on oil. However, Congress also imposed a moratorium on leases for oil and natural gas exploration and production on Outer Continental Shelf (OCS) during the 1980s.

1990s — A Rising Tide of Energy Security Risks: By the end of the 1980s, the risks to U.S. energy security, as measured by our Index, were as low as they were before the Arab Oil Embargo. This was a remarkable turnaround, and the trend towards great energy security continued into the first half of the 1990s, despite the invasion of Kuwait by Iraq in 1990 and Operation Desert Storm. By 1994, the Index achieved its best score—72.6.

However, as the 1990s progressed, a number of factors conspired to reverse the progress made throughout the 1980s. It is difficult to attribute this reversal in energy security risks to any one or even a handful of individual events. Rather, this change was the culmination of many small changes affecting energy security that when combined led to

Figure ES-2



rising energy security risk and thus a higher Index value. Key policy initiatives this decade included the creation of a wholesale market for power that served to encourage construction of natural gas-fired generating capacity. The U.S. also agreed to the UN Framework Convention on Climate Change and signed, but has not ratified, the Kyoto Protocol.

As the decade came to a close, the Index had climbed higher, reaching 79.6 in 1999 and 87.0 in 2000. In due course, energy security risks would approach those seen in 1980 and 1981.

2000s — Energy Security Challenges for a New Century: The worsening energy security situation that began in the mid-1990s carried over into the new century. While the upward trend in energy security risks was interrupted early in the decade by an economic recession caused by the bursting of the high-tech bubble of the late 1990s and exacerbated by the terrorist attacks of September 11, 2001, the economy recovered and the U.S. energy situation worsened.

Increasing reliance on fuel imports, sharply increasing energy demand in China, India, and other emerging economies, and access to global reserves becoming increasingly difficult and capital intensive led to prices that were both volatile and high. After dropping from 87.0 in 2000 to 81.1 in 2003, the Index of U.S. Energy Security reached 99.8 in 2008, just fractionally below the peak index years of 1980-81. It is clear that without continued long-term improvement in energy efficiency, transportation, and environmental measures, our energy security situation in 2008 certainly would have been worse.

However, the economic crisis that began in 2008 caused the Index to fall by 16.1 points to 83.7. Much of the decrease in risk can be traced to lower energy costs and price volatility stemming from a collapse in energy demand.

An increasingly worrisome energy situation led Congress and President George W. Bush to enact two energy bills this decade—the Energy Policy Act of 2005 (EPAct 2005) and the Energy Independence and Security Act of 2007 (EISA). These acts provided a broad range of incentives, loan guarantees, and mandates designed to accelerate the commercial use of clean energy technologies, increase the share of renewables fuels, and achieve greater energy efficiency in appliances, lighting, and transportation. Newly-elected President Obama acted to stem the slide of the economy by enacting a large stimulus package, The American Recovery and Reinvestment Act, which contained about $42 billion in funding for energy programs.

> *While the years 1980-81 and 2008 represent the high water marks for energy insecurity across the entire historical period, there are clear indications that our future energy security risk may approach, and perhaps even exceed, these historic highs.*

2010–2030 — Forecast Energy Security Risks While the years 1980–81 and 2008 represent the high water marks for energy insecurity across the entire historical period, there are clear indications that our future energy security risk may approach, and perhaps even exceed, these historic highs. Index scores of 95 and above are forecast to be the norm in coming decades, well above the historical average of 84.2.

The main drivers to increasing energy security risks appear to be those connected to rising energy costs and expenditures, and these in turn are driven in large part by increasing costs for oil and natural gas affected by geopolitical and economic external factors. Crude oil prices are projected to come under tremendous upward pressure as global demand rises, particularly in large emerging markets. With rising natural gas prices and the expansion of more expensive renewable generating sources on the horizon, electricity prices could be pushed higher.

The main drivers decreasing future risks are for the most part the same ones that helped moderate risks in the 2000s—ample and stable supply of transportation fuels and electricity sources, greater energy efficiency in the residential, commercial, industrial, and transportation sectors and continued diversification.

The Energy Institute's Index of U.S. Energy Security Risk measures what always seemed self-evident—policies matter and have long-term implications. With this new Index, U.S. policymakers have a much better idea of the degree to which they matter. Looking ahead, the outlook for U.S. energy security is full of risks comparable to those of 1980–1981. Uncertainty surrounding legislation, new taxes, mandates, environmental regulations as well as economic growth and trade increase our energy security risk, which can exact a heavy toll in geopolitical, economic, and human terms.

This is not to say, however, that future energy crises are preordained, even if no further policies are implemented. Nor is it to say that implementing smart policies that lower the Nation's energy security risks will guarantee that future crises are avoided. The choice before our nation is whether and how to take the right actions that limit our exposure so that when crises do occur—as they inevitably will—they are less disruptive to our economy, security, and well-being.

The Index shows that energy insecurity anywhere can create energy insecurity everywhere. In a constantly changing world, the nature of the risks to our energy security also is constantly changing, often in unpredictable ways. What is important, therefore, is that our energy systems have the resilience needed to weather the crises of the future.

It is not expected that the Index presented here will be the last word on measuring our energy security. The Energy Institute will continue its efforts to revise and improve its metrics, and we welcome a constructive and active dialogue. By developing a transparent and objective means for measuring the once elusive concept of energy security, the Energy Institute is working to ensure that energy security considerations are more directly incorporated into the policy debates.

Introduction

Measuring, tracking, and evaluating progress should be core elements of a long-term strategy to improve the energy security of the United States. The reality, however, is that while energy security remains a major concern with the public and policymakers, that concern has not been matched with metrics that allow for a dispassionate assessment that quantifies where our energy security has been, where it is, and where it might be headed.

This shortcoming is what the Institute for 21st Century Energy (Energy Institute) seeks to address by introducing a first-of-a-kind Index of U.S. Energy Security Risk to aid policymakers, government officials, businesses, economists, energy professionals, academics, and the general public in assessing the state of our energy security.

The purpose of this report is to introduce the Index to policymakers and the public. The report is organized into three sections.

1. **Quantifying Energy Security:** This section describes some common Indexes used in many different fields and summarizes the methodology used to develop the Index.
2. **Historical Trends and Forecasts in U.S. Energy Security: 1970 to 2030:** This section explores the Index scores and trends since 1970. The discussion is organized by decade and highlights the major international events, legislation, and policy changes that influenced the movement of the Index over the years. It also uses recent forecasts to show where U.S. energy security might be headed in the future.
3. **Conclusions and Policy Implications:** This section suggests how the Index can be used to track shifts in U.S. energy security, assess policy proposals, and identify those areas of energy security that might have the biggest impact on the Index.

An Appendix describes in greater detail the metrics and methodology used to develop the Index.

In addition, a companion report to this one, *Index of U.S. Energy Security Risk: Metrics and Data Tables*, provides specifics of each of the 37 individual metrics used to compile the Sub-Indexes and overall Index and summary tables of the data developed for each metric.

This initial report provides a snapshot of our current energy security and shows how it has changed over the years since 1970 and how it might be expected to change in the future. This 2010 edition is the first of what will be an annual report on the state of U.S. energy security. Subsequent editions of the Energy Security Risk Index will not only update the historical series and projections, but also provide perspective on how national and international events and policy decisions have impacted and may impact energy security in the United States. Special reports also will be produced that both highlight the projected impacts of proposed legislation or regulatory changes on the Index and that explore certain metrics or group of metrics in greater detail.

Quantifying Energy Security

As management guru Peter Drucker once observed, "If you can't measure it, you can't manage it."

Too often, the concept of energy security has been reduced to just one or two statistics that usually revolve around oil, such as the amount of oil the Nation imports or how much consumers pay at the pump for gasoline. As enlightening as they might be, metrics focusing exclusively on oil only tell just a part—not an inconsequential part, but still just a part—of the energy security story. They tell us little, for example, about the reliability of the grid, energy efficiency of the economy, availability of human and intellectual capital, supply diversity, or energy expenditures. Yet, each of these variables and many others influence the reliable supply of affordable energy.

Indexes are a common way to convey information. When discussing the state of the United States economy, it is not long before the conversation turns to the latest Gross Domestic Product (GDP) figure issued by the Department of Commerce, an index that takes into account a broad array of economic data to arrive at a single and widely recognized measure of economic output. The "Misery Index," a combination of the unemployment and inflation rates, provides further insights into the state of the economy.

Investors in the stock market consult the latest VIX Index—known as the "fear index" in some circles—to get a read on the volatility of the S&P 500 and expected moves in the S&P over the next month. The Case–Shiller Home Price Indices measure repeat sales for homes to track home pricing trends in cities throughout the country, and options and futures based on these Indices are traded on the Chicago Mercantile Exchange.

Yale University and Columbia University issue an Environmental Performance Index that ranks 163 countries on 25 indicators covering both environmental public health and ecosystem vitality.

When the conversation turns to political freedom worldwide, many people look to Freedom House's Freedom Index, and for economic freedom, to the Heritage Foundation's Index of Economic Freedom, both issued annually.

Politicians routinely are rated along an ideological spectrum, from liberal to moderate to conservative, by the *National Journal*, American Conservative Union, and Americans for Democratic Action based on key votes on economic, social, and foreign policy issues.

These are just a few examples of widely-respected and commonly-cited indexes that measure interesting and often important trends. Analysts, policymakers, and the public find these measures useful because they take complex issues and reduce them to their essence, usually a single number that everyone understands.

Heretofore, there has been nothing comparable in the energy realm. There is an abundance of widely-available energy data measuring different aspects of the U.S. energy sector, but until now, there has not been a way to integrate that data into a single index measuring energy security. Given the importance of energy to the U.S. economy, an index that measures our energy security is long overdue.

The following is a summary of the way in which the Index was created. Readers seeking greater detail should consult the Appendix to this report.

The Energy Institute's Index of U.S. Energy Security Risk addresses the need for an overarching framework with which to measure energy security in all its facets. Capturing something as complex as the security of the U.S. energy system requires many different metrics. In total, 37 discrete metrics ultimately were used to develop the Index.

The first step was to determine the different types of metrics that would be needed for an index. Nine categories of metrics were selected covering a wide range of energy supplies, energy end-uses, operations, and environmental emissions covering the years 1970 to 2030. These metric categories include:

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

Anywhere from three to six metrics were selected for each metric category.

The data for each individual metric had to meet a number of criteria. They had to be sensible, credible, accessible, transparent, complete, prospective, and updatable. For most metrics, publicly available data from federal agencies—primarily the Energy Information Administration (EIA), Department of Commerce, Department of Transportation, and Federal Reserve Board—were used.

Since the metrics are measured in many different units, it was necessary to convert them into comparable "building blocks." By transforming, or "normalizing" the annual data for each metric into an index in which the value for the year 1980 was set at 100 and the values for all other years were set in proportional relation to 1980 value, a single unit of comparison was established across the 37 metrics. The year 1980 was selected as the reference after an initial analysis of the data suggested that it reflected the worst year overall for U.S. energy security risks in the record since 1970.

Once the metrics were identified, the next step was to use these to create Sub-Indexes that reflect areas of particular concern and that capture different aspects of energy security across different energy sources. Four Sub-Indexes were created around the following issues:

- **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 percent 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 more of an international commodity. For both oil and gas, several of the top reserve-owning countries have uncertain political stability and are at best reluctant business partners with the United States. Dependence upon these fuel sources—for both the United States and the rest of the world—poses political and military risks. Because international disputes can quickly turn into energy problems, and vice versa, energy necessarily occupies a consequential role in U.S. foreign policy.

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

- **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.

Each of the 37 metrics was assigned to one or more of the four Sub-Indexes according to its relevance. The metrics assigned to each of the four Sub-Indexes subsequently were weighted and combined, a process that yielded a Sub-Index value for each. Again, because each metric was given a 1980 value of 100, each of the four Sub-Indexes also has a 1980 value of 100.

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

• Geopolitical	30%
• Economic	30%
• Reliability	20%
• Environmental	20%

This process yielded a weighted average of the four Sub-Indexes, and it is this number that comprises the overall Index of U.S. Energy Security Risk. Figure 1 presents a schematic representation of the process used to create the Sub-Indexes and overall Index.

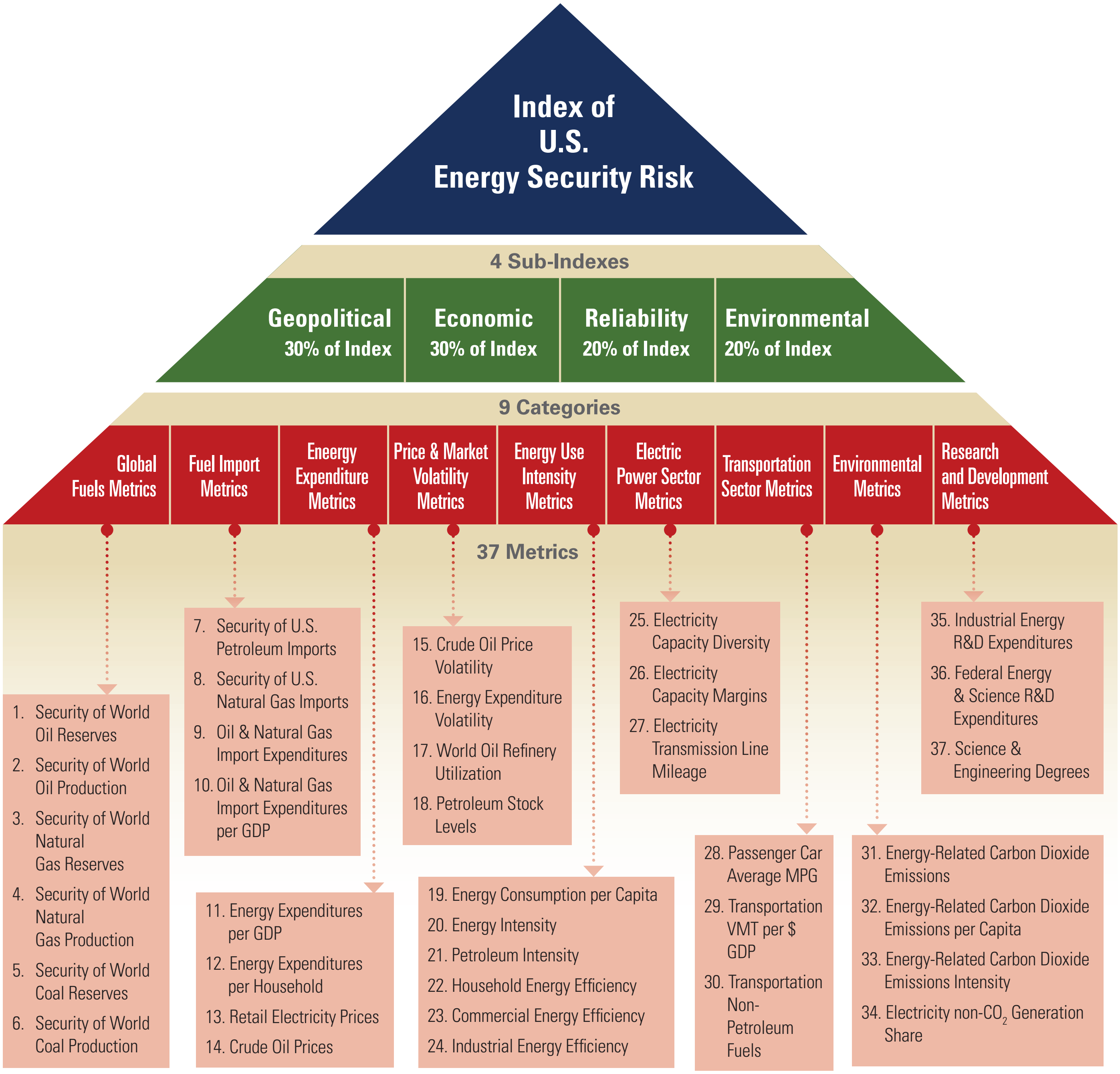
The Energy Institute's Index of U.S. Energy Security Risk is designed to convey the notion of risk. A lower Index number therefore corresponds to a lower level of risk to energy security and a higher number corresponds to a higher level of risk. The results are discussed in the next section.

> *The Energy Institute's Index of U.S. Energy Security Risk is designed to convey the notion of risk. A lower Index number therefore corresponds to a lower level of risk to energy security and a higher number corresponds to a higher level of risk.*

One final note: The Index is not a measure of "energy independence," as that phrase is commonly understood. As enticing as the prospect of complete independence from foreign sources of energy may be, there is no realistic way for the U.S. to achieve this goal, at least in the foreseeable future. In today's globalized economy, complete energy independence may not even be desirable, particularly where it forces reliance on high-cost fuels and strategies that could be better provided by a reliable and diversified global market. This Index, especially in the international context, focuses instead on the perceived reliability and diversity of supplies.

Figure 1

Building the Index of U.S. Energy Security Risk



Historical Trends and Forecasts for U.S. Energy Security: 1970 to 2030

Figure 2 presents the overall Index of U.S. Energy Security Risk for the period 1970 to 2030. Figures 3, 4, 5, and 6 present the Geopolitical, Economic, Reliability, and Environmental Energy Security Sub-Indexes, respectively.

One of the first things to notice is that historical trends visible in the Index generally comport very well with the impression that the public tends to have about U.S. energy security over the years—higher values and spikes generally coincide with times of fuel shortages, high prices, economic turmoil, and international tensions.

Visible in the Index are the effects of major world events over the past four decades, as well as harbingers of risk over the coming two decades. There are four clear spikes in energy security risks and one large trough. To put the Index into some historical perspective, while the year 1980 represents the worst year in the series with a score of 100, 1994 represents the best year with a score of 72.6. As shown in table 1, over the historical period from 1970 to 2009, the Index averaged 84.2, with 18 years displaying above average energy security risks (mostly clustered from the mid-1970s to mid-1980s and since the mid-2000s) and 22 years displaying below average risks (mostly clustered in the very early in the 1970s and the mid-1980s to mid-2000s).

Table 1. U.S. Energy Security Risks from 1970 to 2009: High, Low & Average Index Scores

Indexes of U.S. Energy Security Risk	Highest Risk		Lowest Risk		Historical Average
	Year	Index Score	Year	Index Score	
Total Composite Index	1980	100.0	1994	72.6	84.2
Sub-Indexes:					
Geopolitical	2008	101.1	1995	69.5	82.4
Economic	2008	105.7	1970	62.5	78.5
Reliability	1981	103.9	1995	69.5	84.3
Environmental	1973	104.4	1991	85.0	95.1

In 2009, the Index dropped to 83.7, an improvement of 16 points from the previous year, which represented the largest single-year movement in the Index throughout the entire record. This improvement was, however, the by-product of a severe financial crisis that exacted an enormous economic toll.

Forecasts suggest that the Index will approach the highs seen in 1980 and 1981 and 2008 and remain at over 95 through 2030.

The trends displayed in the composite Index largely mirror the general outlines of in Geopolitical, Economic,

Figure 2 Index of U.S. Energy Security Risk

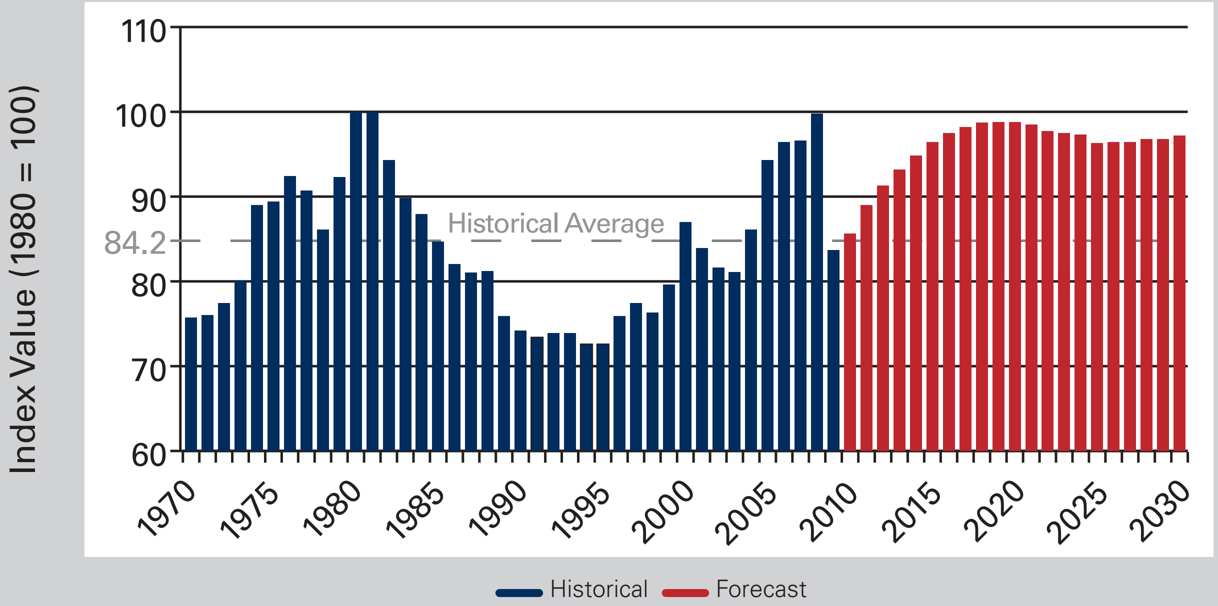


Figure 3 Index of U.S. Energy Security Risk: Geopolitical Sub-Index

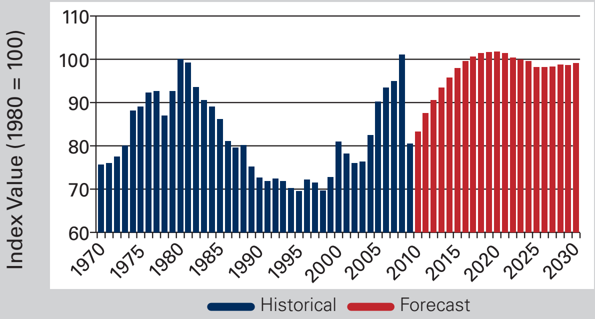


Figure 4 Index of U.S. Energy Security Risk: Economic Sub-Index

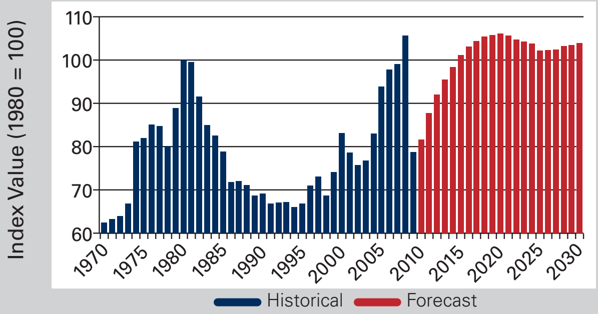


Figure 5 Index of U.S. Energy Security Risk: Reliability Sub-Index

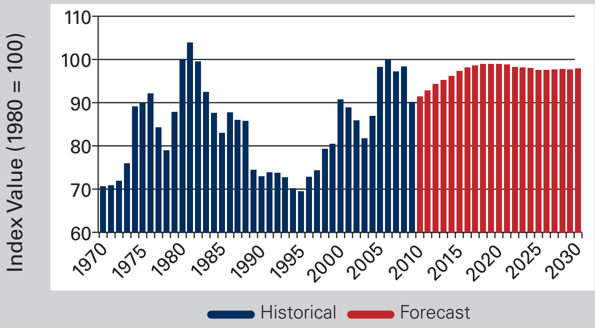
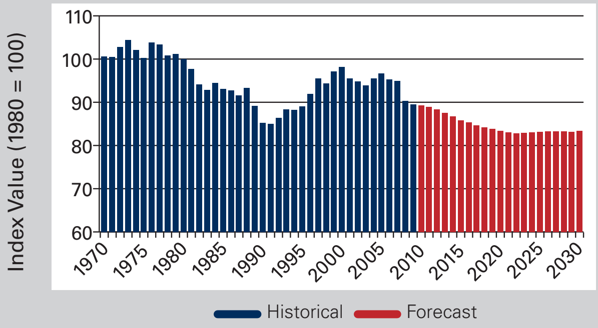


Figure 6 Index of U.S. Energy Security Risk: Environmental Sub-Index



and Reliability Sub-Indexes. The Environmental Sub-Index shows two plateaus at either end of the historical period linked with a u-shaped trough covering the period from about 1980 to 2000.

The following discussion examines by decade movements in the Index and describes the policies that influenced these movements. It also takes a look at where energy security risks might be headed in the future based on EIA's *Annual Energy Outlook*. The discussion at times references individual energy security metrics, and details on these can be found in the companion report to this one, *Index of U.S. Energy Security Risk: Metrics and Data Tables.*

1970s: Oil Shocks U.S. Complacency

The two oil crises of the 1970s were mainly geopolitical crises that culminated in international supply disruptions and soaring fuel prices. The Arab oil embargo and its aftermath caused the U.S. Energy Security Risk Index to rise from 75.7 in 1970 to 92.4 in 1976, after which energy security risks began to ease slightly (figure 7 and table 2).

But because oil played a much larger role in our energy economy decades ago than it does today, oil shocks rippled more strongly throughout the economy. Whereas oil now accounts for about 37% of total U.S. primary energy consumption, it averaged over 45% in the 1970s.

The first crisis was precipitated by the 1973 oil embargo[2] by Arab members of the Organization of Petroleum Exporting Countries (OPEC).[3] OPEC was

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[2] We should note that while this is commonly described as an "embargo," oil is a fungible commodity that cannot be embargoed to any great effect.

[3] Under the rubric of the Organization of Arab Petroleum Exporting Countries, or OAPEC.

Figure 7

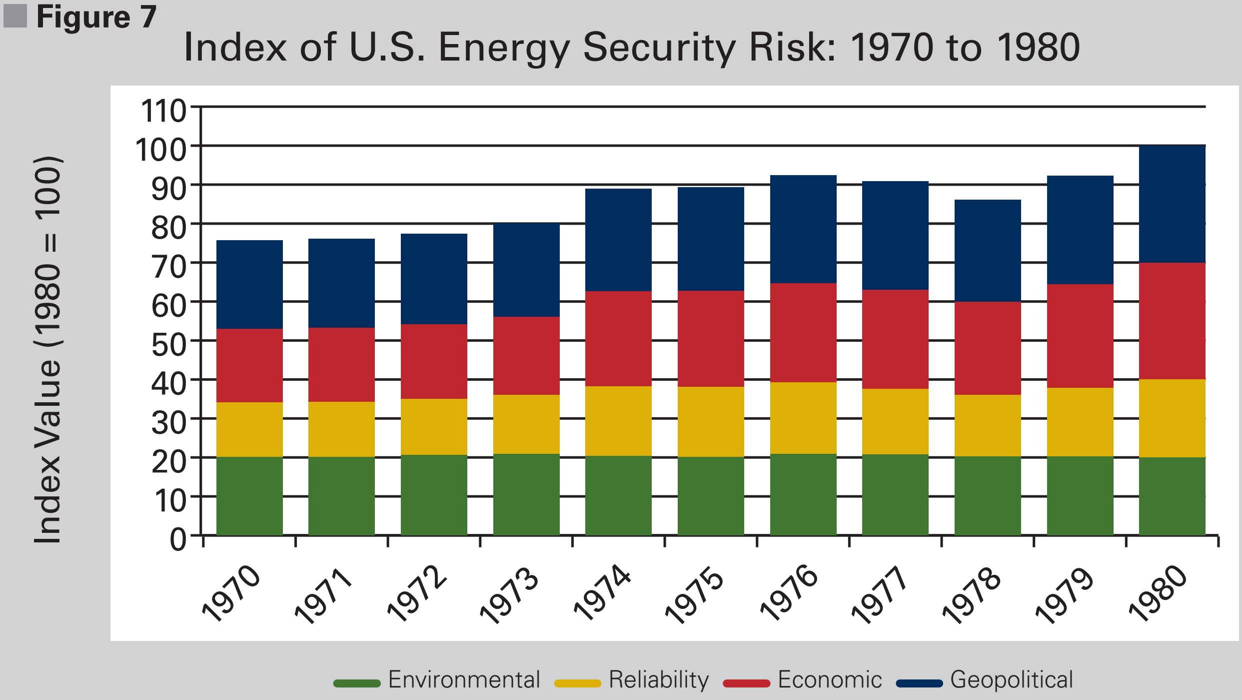

Table 2. U.S. Energy Security Risks: 1970 to 1980

Indexes	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980
U.S. Index	75.7	76.0	77.4	80.1	89.0	89.4	92.4	90.7	86.1	92.3	100.0
Sub-Indexes:											
Geopolitical (30%)	75.7	76.0	77.5	80.1	88.1	89.1	92.3	92.6	87.0	92.6	100.0
Economic (30%)	62.5	63.2	64.0	66.8	81.2	82.0	85.1	84.7	80.1	88.9	100.0
Reliability (20%)	70.7	70.9	71.9	76.0	89.1	90.1	92.1	84.3	79.0	87.9	100.0
Environmental (20%)	100.6	100.5	102.8	104.4	102.1	100.3	103.8	103.4	100.8	101.2	100.0

founded in 1960, and the countries that now make up the organization then produced only 8 million barrels per day (MMbbl/d). By 1970, OPEC output had climbed to over 22 million barrels, and by 1973, its production reached nearly 30 MMbbl/d, over half the world's production. With this astonishing growth in output came increasing economic and political clout, which some of its members were prepared to use.

The embargo was aimed at countries supplying equipment to the Israeli military during the Yom Kippur War, primarily the United States. The embargo—which ended in March 1974—and accompanying production cuts caused steep increases in the price of oil that only began to level off and decline somewhat by 1977–78.

This respite was short-lived. The second oil crisis of the decade followed in 1979 in the wake of the Iranian Revolution that overthrew the Shah in 1978 and the taking of U.S. hostages by Iranian revolutionaries, which provoked panic in world oil markets that spurred sharply higher oil prices. The Soviet Union's invasion of Afghanistan in December of 1979 and Iraq's invasion of Iran in September of the following year compounded the crisis and produced further market turmoil, including a sharp reduction in oil from the Persian Gulf. Oil production from Iran and Iraq, which averaged nearly 8 MMbbl/d in the late 1970s, plunged to just 4.2 MMbbl/d in 1980 and only 2.4 MMbbl/d in 1981.

Crude oil was not the only problem. At the beginning of the 1970s, the utilization of global refining capacity was hovering at around 95%. This lack of spare capacity increased U.S. vulnerability during the crisis.

The repercussions of the 1979 Iranian revolution propelled the Index to 100 in 1980 and just under 100 in 1981, the highest levels of energy security risk in the historical record.

Counter-intuitively, of the 37 individual metrics, only four show the greatest risk in either 1980 or 1981. However, enough show relatively high risks for those two years so that when all the metrics are weighted and combined, 1980 and 1981 become the peak years for U.S. energy security risk.

Given the large role of oil in the U.S. economy in the 1970s, it is not surprising that the indexes for energy expenditures grew much worse as the crises developed. Crude oil prices throughout the decade were extremely volatile. From under $4 per barrel[4] at the beginning at the decade, crude oil prices hit over $12 per barrel during the Arab oil embargo and spiked again to over $30 per barrel[5] during the Iranian crisis. For the first time, U.S. gasoline prices at the pump rose to more than $1 per gallon.

Adding to these woes was a sharp rise in expenditures for electricity. Retail electricity prices, which for most

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[4] About $19 in constant 2000 dollars.
[5] About $61 in constant 2000 dollars.

of the previous 20 years had been falling, began climbing in the late 1970s and by the early 1980s so that the "rate shock" took a much bigger bite out of household incomes.

Policy responses to the two energy crises of the 1970s yielded mixed results. Even prior to the 1970s, energy was beginning to become a greater policy concern. As early as 1967, President Nixon warned of the nation's growing appetite for energy, especially oil. The great Northeast Blackout of 1965, which affected 25 million people in the United States and Canada, and the large brownout in 1971 added to the unease over energy. By the early 1970s, President Nixon observed that the Nation's energy situation was a challenge that eventually could lead to a crisis if not addressed.

The impact of the Arab oil embargo and the Iranian Revolution on oil prices highlighted the need for a national energy policy. In an address to the Nation in November 1973, President Nixon launched "Project Independence," an initiative designed to achieve U.S. self-reliance in energy by 1980. Presidents Ford and Carter also proposed energy plans of their own, with President Carter, in particular, likening the battle for greater energy security to the "moral equivalent of war."

In 1970, the U.S. produced 9.6 million barrels of crude oil per day, over 20% of the world total and far more than any other country, and petroleum imports in 1970 supplied only about a fifth of U.S. supply. However, the U.S. could not maintain this level of domestic production, and declining production coupled with growing demand caused import volumes to soar. With global demand for oil growing strongly, incremental production came mainly from Middle East producers and the Soviet Union. In relatively few years, the U.S. became increasingly reliant on imports production from a handful of global producers whose interests did not always align with U.S. interests.

One of the first responses to the 1973 oil shock was the Trans-Alaska Pipeline Authorization Act (TAP), enacted a mere two weeks after the oil embargo was declared. In January 1968, large reserves of heavy, high-sulfur oil and natural gas were found in Prudhoe Bay, Alaska. With the passage of the TAP Act, a pipeline to carry the oil from Prudhoe to Valdez on the southern coast of Alaska was authorized. Reflecting heightened concerns about oil imports, the TAP Act also effectively prohibited the export of Alaskan oil. As a result, Alaskan North Slope production reversed temporarily the declining trend in U.S. crude oil production and contributed to a modest decrease in risk through the mid-1980s as measured by the metrics for security of World Oil Production and World Oil Reserves.

The 1970s also were a time of growing government involvement in energy markets, especially oil markets. Presidents Nixon and Ford used their authorities under the Economic Stabilization Act of 1970, the Emergency Petroleum Allocation Act of 1973, and the Energy Policy and Conservation Act of 1975 (EPCA) to establish federal control over the price of domestic oil, setting up a complex system of different tiers of oil production (such as "old" versus "new") and allocations to refineries. Several states also implemented a system of odd-even gasoline rationing that matched license plates numbers to certain to days of the week when drivers could purchase gasoline. Combined, these actions had the unintended consequences of raising the level of oil imports and creating long lines at the gasoline pump.

Although President Ford proposed decontrolling oil, the federal government did not begin to wind down oil price controls until after the second oil crisis of the decade hit. In 1980, President Carter signed the Crude Oil Windfall Profit Tax Act, which was designed to capture some of the revenue received by oil producers resulting from the jump in oil prices brought about by crises.[6] As part of the deal with Congress, the Carter Administration began aggressively deregulating many refined products and crude oil categories. In 1981, a newly-sworn in President Reagan finished the job by eliminating all remaining controls.

On the international front, the International Energy Agency (IEA) was launched as an adjunct of the Organization of Economic Co-Operation and Development in 1974. IEA's members largely represented oil consuming countries, and its initial task was to create a counterweight to OPEC. IEA established a crisis management system and response mechanism, and it required its members to maintain a 90-day strategic reserve of oil. It also aided markets by collecting reliable data and promoting greater transparency, sorely lacking in global markets at the time.

In addition to expanding the power of the Federal government to control oil prices and allocations, EPCA of 1975 also authorized establishment of a Strategic Petroleum Reserve (SPR) of up to 1 billion barrels of crude oil, which would allow the United States to meet its IEA obligations to maintain a reserve in case of a severe supply disruption. After acquiring a number of storage sites in Texas and Louisiana, deliveries of crude oil to the reserve began in 1977. From a level of under 8 million barrels (MMbbl) at the end of 1977, SPR stocks stood at well over 500 MMbbl by the middle of the 1980s. This increase is reflected in the metric for Petroleum Stock Levels, which reached its lowest level of risk over the period.

Changes in the power sector—many initiated before the oil crises—also began to take hold during the 1970s and into the 1980s. Oil shocks similar to those experienced in 1973 and 1979 would have much less impact on electricity rates today because very little oil is used as a fuel to produce electricity. This was not the case in the 1970s, when oil was used to generate power to a much greater extent. In fact, prior to the Arab oil embargo, the construction of oil-fired generating capacity was encouraged as a way to improve air quality in many cities, a policy that had unforeseen and certainly unintended consequences for U.S. energy security.

> *Oil shocks similar to those experienced in 1973 and 1979 would have much less impact on electricity rates today because very little oil is used as a fuel to produce electricity.*

Today, the United States uses about 88% less oil to produce electricity than it did in 1978, when oil use in this sector was at its historic high and oil-fired generators accounted for about 15% to 16% of electricity production. The comparable figure today is under 2%. As a result, large moves in oil prices tend to have little direct impact on electricity prices.

The diversity of generating capacity in the power sector generally improved throughout the 1970s. Except for a short-lived diminution in capacity diversity in the first half of the 1980s related to the shutting down of oil-fired plants and building of coal-fired plants, the Electricity Capacity Diversity metric shows for the most part steady declining risks until about 2000. An increasing share of coal and nuclear power and improving availability factors at existing capacity were the primary drivers for this decline.

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[6] The tax was really an excise tax on the difference between the market price of oil and a statutorily-derived price based on production costs plus a reasonable profit and adjusted for inflation.

Nuclear power was another controversial energy issue during the 1970s, with safety, waste, and proliferation concerns dominating the discussion. The Atomic Energy Commission believed that the most appropriate waste management plan was to recycle the used fuel, which would help make nuclear power "too cheap to meter." However, India's atomic weapon test in 1974 increased the public's concerns about proliferation. In 1976, President Ford ceased commercial recycling temporarily, and in 1979, President Carter ended it permanently, ostensibly to set an example for the rest of the world.[7] In opposing the reprocessing of nuclear fuel, the Carter Administration looked to coal as a way to lower the growing U.S. reliance on nuclear power. Furthermore, in 1979 the accident at a nuclear reactor in Three Mile Island, Pennsylvania occurred, which whether justified or not, cast a pall over nuclear energy.

However, these events had surprisingly little impact on nuclear power construction in the United States. While issues like waste, regulatory delays, and public opposition were factors, the economic "stagflation" that produced interest rates in excess of 20% and lowered electricity demand were the primary reasons electric utilities began scaling back planned increases in nuclear generation capacity. Dozens of proposed nuclear plants were cancelled, and by 1979, new orders were nonexistent. Nevertheless, completion of several projects started earlier pushed nuclear capacity higher throughout the 1980s.

Historically, federal and state regulations favored the use of natural gas for home heating and for commercial and industrial uses instead of for use by utilities to generate power. Natural gas had been subject to federal regulation for decades before the 1970s, beginning most notably with the Natural Gas Act of 1938. Over time, controls on well-head prices provided less and less incentive to explore and produce natural gas, and by the late 1960s, reserves of natural gas began to dwindle. Users that could no longer get natural gas switched to oil, exacerbating the economic pain to come from the next decade's oil crises.

With the explosion in oil prices in the 1970s, natural gas became more attractive for home and industry. Greater demand for this fuel, however, came at a time when its base of reserves was shrinking, and regulators were unable to adjust the price to keep it in line with the rapid movement of oil prices. Concerns about the availability of natural gas supplies were very pronounced at this time, and many policymakers, considered natural gas too valuable to use for generate power. The Energy Supply and Environmental Coordination Act of 1974, for example, actually sought to convert power plants from oil and natural gas to coal.

An unusually cold winter in 1976–1977 brought about gas shortages and public clamor for action. The result was the Natural Gas Policy Act (NGPA) of 1978, which created a single regulated market for natural gas in the United States and marked the culmination of natural gas regulation. Among other things, it restricted the end use of natural gas, extended the federal government's reach into intrastate markets while it began partial deregulation of interstate prices, and provided incentives to producers.

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[7] Some 30 years later, it is evident the world did not follow our example: Six other countries operate nuclear fuel recycling facilities, and others are pursuing this path.

The Powerplant and Industrial Fuels Use Act (FUA) of 1978 also affected natural gas markets. It banned all construction of new oil and natural gas-fired electricity generating plants and industrial boilers, which essentially shifted new capacity to coal. Shortly after passage, however, it became apparent well head price regulation largely was responsible for the natural gas shortage the country experienced and that industrial and utility users were necessary to the smooth functioning of natural gas markets that otherwise would be subject to wide seasonal swings. Although Congress revisited the Fuels Use Act in 1981 and removed some of the more troubling provisions of the bill, the law's general thrust remained largely unchanged.

The oil price shock of 1973 also spurred government action to improve energy efficiency, particularly in the transportation sector. The Emergency Highway Energy Conservation Act of 1974 set a national speed limit of 55 miles per hour. The Corporate Average Fuel Economy (CAFE) standards were enacted in 1975 to improve the average fuel economy of cars and light trucks, and the average fuel economy of the U.S. vehicle fleet after 1978 improved rapidly. Higher energy costs also accelerated energy efficiency improvements in the residential, commercial, and industrial sectors.

The energy crises also led to greater recognition of the importance of new energy technologies and a significant jump in energy research and development (R&D) sponsored both by industry and by the federal government. These funding increases, however, were not sustained and continued a steady decline from their peaks of the late 1970s and early 1980s. These indices did not begin to recover (especially in industry) until early 2000s, but in real terms energy R&D expenditures still remain well below their historic highs. Today, most federally-funded energy R&D is supported through the Department of Energy (DOE).

The growing recognition of the strategic importance of energy in the 1970s was reflected in the federal government's reorganization of energy-related agencies. Before the 1970s, energy supplies were seen largely as commodities, so energy data were for the most part collected and reported by the Bureau of Mines and the U.S. Geological Survey, and by regulatory agencies, such as the Federal Power Commission and the Atomic Energy Commission. Following the Arab oil embargo in 1973, many of these activities were coordinated through the Federal Energy Office, which in 1974 became the Federal Energy Administration (FEA). In 1975, the Atomic Energy Commission split into the Energy Research and Development Administration (ERDA) and the Nuclear Regulatory Commission. Then, in 1977 under President Carter, the responsibilities of FEA and ERDA merged, and DOE, a Cabinet-level agency, was formed.

> *Many legislative and policy responses to the two energy crises of the 1970s had direct impacts on future energy security risks in the U.S.*

Many of the legislative and policy responses to the two energy crises of the 1970s described above had direct impacts on future energy security risks in the United States, both as measured by the overall Index and in many of the 37 individual metrics.

1980s: Free Markets and the Decline of OPEC

Energy security risks in the United States fell sharply throughout the 1980s. From its pinnacle of 100 in 1980, the Index of U.S. Energy Security Risk fell to 75.9 in 1989, a 24% decline in risk over the period. The large majority—but not all—of the individual energy security metrics used, and each of the four Sub-Indexes showed improvement, in many cases dramatic, over the period (figure 8 and table 3).

The election of Ronald Reagan signaled a clear shift in U.S. energy policy, with a greater reliance on free markets and a lesser reliance on federal regulation. Foreign policy priorities also shifted markedly, with candidate Reagan taking a tough line on the Soviet Union and the Iran hostage crisis, which had been lingering for over a year (and which ended on the day President Reagan was inaugurated). The policies of the Reagan Administration had far-reaching impacts on U.S. energy security, as did policy changes in the previous decade. Also, many of the positive trends begun in the mid- to late 1970s took hold and continued throughout the 1980s to improve U.S. energy security.

In one of his first acts in office, President Reagan completed the process begun under his predecessor by completely deregulating the price of oil, allowing that commodity once again to achieve a market-clearing level.

On the supply side, a more accommodating production posture from OPEC (and cheating by the "price takers" within OPEC), greater oil exploration and increasing production outside OPEC, including from Alaska's North Slope and the North Sea, a growing SPR, and the backing out of oil from the power sector combined to increase the amount and diversity of global oil supplies.

On the demand side, clear price signals spurred greater energy efficiency across all sectors. Continued implementation of CAFÉ standards

Figure 8

Index of U.S. Energy Security Risk: 1980 to 1990

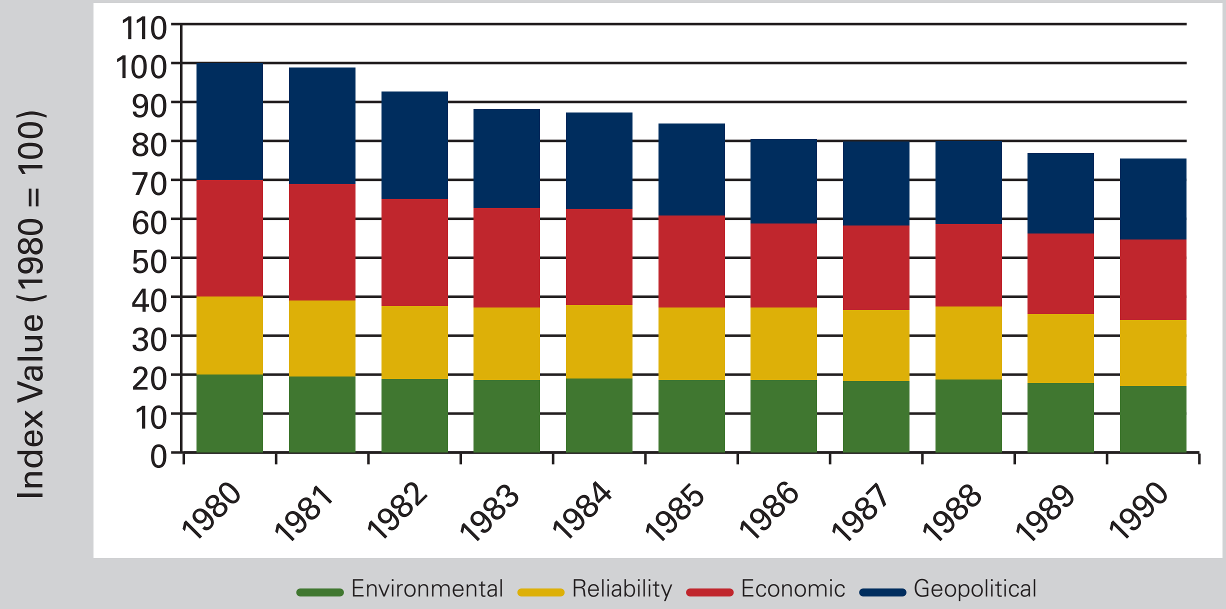

Table 3. U.S. Energy Security Risks: 1980 to 1990

Indexes	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
U.S. Index	100.0	99.9	94.3	89.8	87.9	84.7	82.0	81.0	81.2	75.9	74.2
Sub-Indexes:											
Geopolitical (30%)	100.0	99.2	93.6	90.6	89.0	86.2	81.1	79.6	80.2	75.2	72.7
Economic (30%)	100.0	99.5	91.6	85.0	82.5	78.8	71.8	72.0	71.1	68.7	69.1
Reliability (20%)	100.0	103.9	99.5	92.5	87.6	83.0	87.8	86.0	85.8	74.5	73.0
Environmental (20%)	100.0	97.7	94.1	92.9	94.5	93.1	92.8	91.6	93.3	89.2	85.2

enacted in 1975 increased the efficiency of the U.S. auto sector in particular. The energy intensity of the economy in the 1980s improved at the fastest rate seen over the historical period.

These and many other factors on both the supply and demand side led to price volatility, but in unlike in the 1970s, in this case it was primarily on the down side rather than the up side. Eventually, the dynamics of greater supply and efficiency caused the bottom to fall out of crude oil prices. From a high of over $36 in 1981, the price of a barrel of crude oil plunged to a little over $14 in 1988, its lowest level of the decade. As a result, all of the energy expenditure metrics show dramatic improvement, especially in the first half of the decade.

With no windfalls to tax, by 1988 the revenues from the windfall profits tax on oil were coming in far below official estimates. Moreover, it was recognized that the tax, which did not apply to imported oil, served to encourage reliance on foreign sources. Domestic oil producers found it difficult to pass along the tax to refiners who could simply replace domestically-produced crude with tax-exempt foreign crude, which they did with some regularity. Recognizing this, in 1988 the Congress passed and President Reagan signed into law the Omnibus Trade and Competitiveness Act repealing the tax.

However, along with the deregulation of oil came restrictions on exploration and production. In 1982, Congress began restricting access to the Outer Continental Shelf (OCS), which includes areas more than three miles offshore, by annually denying the Department of the Interior (DOI) the funding necessary to carry out leasing of new offshore areas to oil companies. This moratorium remained in place until 2008. The ban covered about 85% of the U.S. OCS.

In the power generation sector, the Electricity Capacity Diversity metric showed a growing risk in the first half of the decade, continuing a trend begun in 1977. While this might normally be a concern, in this circumstance it actually reflects movement away from a fuel with very large geopolitical and economic risks—oil—towards a fuel with extremely low geopolitical and economic risks—coal. Both coal and nuclear power base load generating capacity grew rapidly through the end of the decade and increased only modestly thereafter. At the same time, regulation of natural gas slowed construction of gas-fired plants. After 1983, this index shows steady improvement.

The demise of America's nuclear fuel recycling program in the 1970s led both the Carter and Reagan administrations and the Congress to begin focusing greater attention on nuclear waste storage, and in 1982, President Reagan signed into law the Nuclear Waste Policy Act. This law committed the United States to a "once through" fuel cycle and direct disposal of spent nuclear fuel. Complicating matters was the law's requirements that the fuel being stored also had to be retrievable. A number of storage sites were examined, and in 1987, Congress designated Yucca Mountain, Nevada as the sole site for the used nuclear fuel repository.

Falling oil prices over the decade were accompanied by falling natural gas prices and, because of restrictions on its use, falling demand. In 1987, the glut of natural gas prompted repeal of those provisions in the 1978 FUA that restricted the use of natural gas by electric utilities and industrial boilers, permitting greater use of natural gas in power plants and for industrial uses.

Efforts at deregulating energy markets continued under President George H.W. Bush. While the NGPA of 1978 began to loosen the reins on natural gas prices, complete decontrol was realized only with the passage of the Natural Gas Wellhead Decontrol Act (NGWDA) in 1989. Under NGWDA, all remaining price regulations on wellhead sales were repealed and by 1993, all other price regulations were scheduled to sunset, leaving market forces to set the price of natural gas at the wellhead.

These two deregulatory actions helped set the stage for enormous growth in the use of natural gas in power generation and industry sectors years later.

Momentous international events also made headlines in the 1980s, especially at the end of the decade. The Iran-Iraq war concluded in August 1988, when Iran accepted a United Nations Security Council Resolution. The breakup of the Soviet Union, which was rich in fossil fuels, was a major historic event that had major ramifications for energy markets. The emergence of the Russian Federation and other countries from the former Soviet Union contributed to an increase in the diversity and reliability of world fossil fuel supplies. This improvement in the security of world fuels production was short lived, however, as output increased rapidly from Iran, Iraq, and other suppliers that, as measured by a Freedom Index, were more unreliable.

The high investments in energy R&D, both publicly and privately funded, fell throughout the first half of the decade and largely stabilized in the second half of the decade at a level a little below that in the early 1970s. Low prices for energy in general, and oil in particular, removed much of the incentive for maintaining high levels of R&D spending.

1990s: A Rising Tide of Energy Security Risks

By the end of the 1980s, the risks to U.S. energy security, as measured by the Index, were as low as they were in 1970. This was a remarkable turnaround, and the trend towards great energy security continued into the first half of the 1990s. By 1994, the energy security Index achieved its best score—72.6.

However, a number of factors in the 1990s conspired to reverse the progress made throughout the 1980s. As the century turned, the Index climbed to 79.6 in 1999, and in the first year of the new millennium climbed further still to 87.0. In due course, energy security risks would approach those seen in 1980 and 1981 (figure 9 and table 4).

While many of the trends in individual energy security indexes continued to improve in the 1990s, they generally did so at a slower rate than previously, particularly in energy efficiency. Moreover, some trends showed a reversal in fortune and by the end of the decade were heading higher.

In his second year in office, President Bush was confronted with his biggest international challenge—the invasion of Kuwait by Iraq in August 1990. The threat that Iraq could invade Saudi Arabia also weighed heavily on international markets and policymakers in Washington and elsewhere. A coalition involving the United States, United Kingdom, Saudi Arabia, Egypt, and others was quickly organized, and troops were dispatched swiftly to Saudi Arabia.

With the sanction of the United Nations (UN), in 1991 Operation Desert Storm was mounted and drove Iraq from Kuwait, but not before the Iraqis set fire to Kuwaiti oil wells. Economic sanctions also were placed on Iraq, and production from that country fell to a fraction of it pre-invasion level. By 1991, Iraqi crude oil output was about one-tenth of what it was in 1989.

Even though significant amounts of oil had been withdrawn from the market, oil prices did not spike because other producers, primarily Saudi Arabia, picked up the slack, and Kuwaiti output recovered quickly. As a result, the crisis made a small impression on the indexes dealing with price volatility and energy expenditures. By 1997, Iraqi oil was allowed back onto the market under the scandal-plagued U.N. Oil for Food Program. From about 300 MMbbl in 1991, Iraqi production reached over 2,000 MMbbl in 1998.

The continued general downward trend in U.S. energy security risks was moderated by an upward trend in the risks associated with world crude oil. Over the 10 years from 1985 to 1994, world oil reserves increased by about 300 billion barrels. Over 95% of this increase was concentrated in a handful of countries—Saudi Arabia, United Arab Emirates, Iraq, Iran, and Venezuela. As a result, while more oil was available, it was also concentrated more in countries with poor Freedom Index rankings, resulting in a sharp rise in the Security of World Oil Reserves index that would reinforce other worsening trends early in 2000.

A steady decline in U.S. oil production added to this risk. Even with Alaskan North Slope production, total domestic production never achieved its pre-1970 peak and after 1985 began a long, steady decline. In 1990, President Bush issued an executive order withdrawing new OCS areas from exploration and drilling, consistent with the restrictions passed by Congress in 1982, and in 1998, President Clinton issued an order extending these restrictions through 2012. Restricted areas amounted to most of the Pacific and Atlantic coasts and the eastern Gulf of Mexico.

Figure 9 Index of U.S. Energy Security Risk: 1990 to 2000

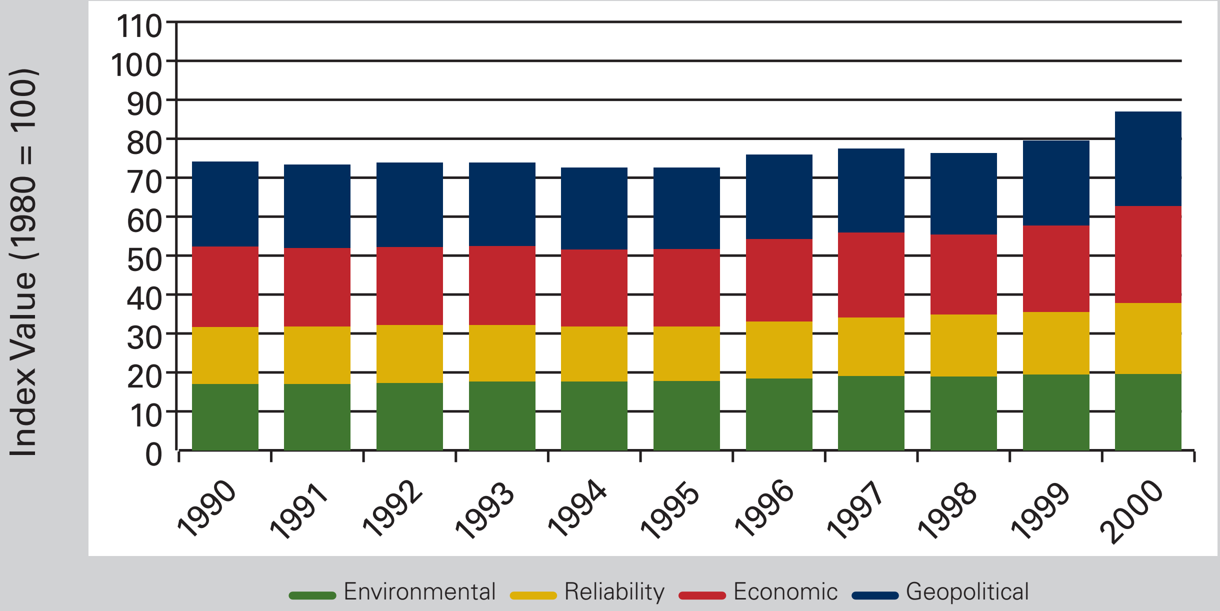

Table 4. U.S. Energy Security Risks: 1990 to 2000

Indexes	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
U.S. Index	74.2	73.4	73.9	73.9	72.6	72.6	75.9	77.4	76.3	79.6	87.0
Sub-Indexes:											
Geopolitical (30%)	72.7	71.8	72.4	71.8	70.2	69.5	72.2	71.5	69.7	72.8	81.0
Economic (30%)	69.1	66.8	67.1	67.2	66.0	66.8	71.0	73.1	68.7	74.1	83.1
Reliability (20%)	73.0	73.9	73.8	72.7	70.2	69.5	72.9	74.4	79.3	80.5	90.8
Environmental (20%)	85.2	85.0	86.4	88.4	88.3	89.1	91.9	95.5	94.4	97.1	98.2

The 1990s also were a time when trade in natural gas became more global following the growth in long-distance pipelines into Europe and the expansion of liquefied natural gas tanker trade. The risks associated with natural gas reserves, natural gas production, and U.S. exposure to natural gas imports all rose during the last few years of the decade. The rise of the Russian Federation, Qatar, and Iran as major natural gas reserve holders and producers was a primarily responsible for this trend.

Though the Persian Gulf War in 1990 to 1991 caused little immediate injury to U.S. energy security, it nonetheless was a potent reminder of the perceived vulnerability of the United States to foreign sources of oil. In response, the Energy Policy Act (EPAct) of 1992 was enacted with the intent of strengthening energy security. One of the Act's goals was to increase the number of alternative-fuel vehicles (AFV) by mandating that Federal and State fleets raise the share of AFV's in their vehicle fleets. By focusing on fleets, the idea was to avoid the need to modify extensively the refueling infrastructure. The bill had little impact on the metric for Transportation Non-Petroleum Fuel Use, which measures the share of alternative fuels in the transport sector.

Perhaps EPAct 1992's biggest impact, however, was in the power market. Throughout most of the 1990s, power-generating capacity became more diverse, primarily because of increases in nuclear and natural gas combined-cycle units. EPAct 1992 created a competitive wholesale market for electricity generation and made it easier to enter this market. Most of the new non-rate-based power plants were expected to be gas-fired, and when combined with natural gas deregulation under the NGPA and NGWDA, EPAct 1992 served to greatly expand the use of natural gas for power generation, a mixed blessing.

The electric power sector also was exposed to increased reliability risks associated, as measured by the metrics for Electricity Capacity Margins and Electricity Transmission Line Mileage.[8] Historically, power generation builds have moved in fits and starts. Long lead times for construction, fluctuations in demand from business cycles, changes in fuel markets, and regulatory uncertainty have caused the power sector to move from periods of relative over capacity to periods of under capacity (as this metric shows).

Also throughout the 1990s, investment in transmission infrastructure declined, leading to a 15% decline in circuit-miles for each gigawatt of peak capacity. This occurred at a time when a growing wholesale power market could have benefitted from growing transmission capacity.

Energy efficiency received greater attention over the period, particularly in the residential and commercial

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[8] The data generally are insufficient to say much about electricity transmission before the 1990s.

sectors. In 1992, the Environmental Protection Agency launched the Energy Star program, a voluntary labeling program designed to promote energy-efficient products to reduce energy use and greenhouse gas emissions (DOE joined in 1996). From humble beginnings, the Energy Star label has expanded to cover 50 kinds of products and has been very successful in penetrating consumer consciousness, with well over 60% of shoppers recognizing the Energy Star brand.

In the vehicle sector, rates of energy efficiency improvements began to slow from their pace in the late 1980s. While average vehicle mpg improved about 50% from the mid-1970s, it began to flatten in the 1990s. A shift from passenger cars to SUVs coupled with increases in the number of vehicle-miles traveled caused the average fuel consumption per vehicle to reverse its downward trend.

There was one trend, however, that began to change discernibly from its historic path. The number of vehicle-miles traveled had historically moved in lock step with GDP—people tended to drive more as the economy grew and less as it shrunk. By the mid-1990s, that dynamic began to change, and economic growth now has less of an impact on driving habits than before. High fuel prices over much of this period may have played a role in this change, but it is likely that other factors were involved. One possible explanation is that personal computers have had an impact on commuting and shopping patterns, as more people elected to work and shop from home. If so, then information technologies could be considered a "mode" by which diversity in the transport sector could be furthered.

Under both the Bush and Clinton administrations, environmental issues, notably climate change, became a bigger overall concern for U.S. energy policy, both domestically and internationally. At the 1992 Earth Summit, the United States under President H.W. Bush signed the UN Framework Convention on Climate Change (UNFCCC), a treaty whose goal is the eventual stabilization of greenhouse gas concentrations in the atmosphere. Negotiations at subsequent UNFCCC meetings produced in 1997 the Kyoto Protocol to the UNFCCC, under which the United States and other developed countries—but no developing countries—would take on binding emissions cuts.

The Kyoto Protocol was signed by the United States, but the political climate was such that ratification by the Senate was unlikely. A few months before the Kyoto meeting, the Senate passed on a vote of 95-0 the Byrd-Hagel Resolution, which among other things stated that it would not support a treaty that only included commitments from developed countries. Recognizing the lack of the support for the treaty, the Clinton Administration chose not to send it to the Senate for ratification.[9]

Despite increased attention to environmental concerns, the individual metrics related to carbon dioxide emissions from energy worsened throughout the period. Strong economic growth coupled with low energy prices acted to slow the rate of energy efficiency improvements in the transportation, industrial, commercial, and residential sectors, and in some cases reversed them for a time. Relatively cheap energy also led per capita consumption to rise

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[9] The George W. Bush Administration did not seek ratification, either.

gradually throughout the decade, part of a long-term trend that started in the mid-1980s.

In the power sector, the continued rise of coal capacity, the slow but steady growth in natural gas capacity, and the slowdown in nuclear plant additions (which essentially ceased after 1990) meant that fossil fuels played a bigger role in power production. These and other factors led to a steep rise in energy-related carbon dioxide emissions unmatched since the 1960s. This drove a turnaround in the trend for the Environmental Sub-Index, which went from 85.2 in 1990—its lowest level up to that point in time—to 97.1 in 1999.

Declining R&D investments and science and engineering degrees—continuing the longer running trends—also contributed to a worsening energy security situation over the second half of the decade.

In many ways, the energy situation in the 1990s benefited from a relative period of peace, low fuel prices, and economic prosperity. But as the Index shows, on the eve of the new millennium, the risks to U.S. energy security clearly were heading in the wrong direction.

2000s: Energy Security Challenges for a New Century

The worsening energy security situation that began in the mid-1990s carried over into the new century, leading to increased risks and higher energy costs. An afterthought throughout much of the 1990s, after 2000 energy once again began to make headlines and draw the attention of policymakers.

Increasing reliance on fuel imports, sharply increasing energy demand in other countries, and global production shifts to less stable regions led to prices that were both volatile and high. After dropping from 87.0 in 2000 to 81.1 in 2003, the Index reached 99.8 in 2008, just fractionally below the peak index years of 1980 and 1981. Of the four Sub-Indexes, those measuring Geopolitical and Economic risks were above the high levels of risk measured in 1980 and 1981, while the Sub-Indexes measuring Reliability and Environmental risks were below the levels of those years (figure 10 and table 5).

The upward trend in energy security risks was interrupted early in the decade by an economic recession. The bursting of the high-tech bubble of the late 1990s, slow growth among major U.S. trading partners, and the terrorist attacks of September 11, 2001, combined to dampen business investment and growth. However, as the economy recovered and grew, so, too, did the risks to U.S. energy security.

The decade was characterized by extreme price volatility in the oil markets. Greater international tensions after the 2001 terrorist attacks caused oil prices to rise, but market fundamentals reasserted themselves and prices soon fell back in line with the slumping economy. It was not long, however, before oil prices began to rise again, and sharply, in response to rising international demand. Economic recovery in the U.S. and explosive growth in China, India, and other large emerging economies put tremendous upward pressure on world oil prices even as production increased. Operation Iraqi Freedom also unsettled oil markets, but it soon became apparent that Iraqi production would not collapse as it had in the six or so years following the first Persian Gulf War. However, the looming threat of a terrorist attack in the Gulf added a "terror" premium to the price of crude oil.

Hurricane Katrina in 2005 caused short-term damage to domestic production and refining facilities in the Gulf of Mexico that also shook global oil markets and led to a decision by President Bush to release onto the market crude oil from the SPR stockpile.

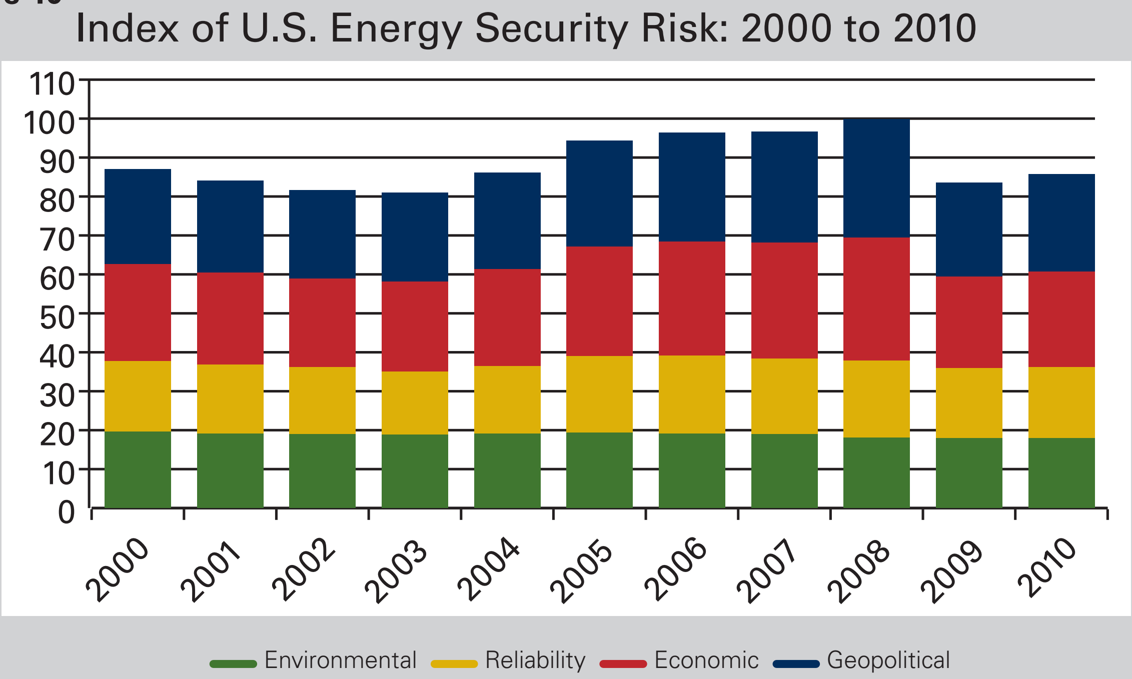
From just over $17 per barrel in 1999,[10] crude oil prices jumped to nearly $95 in 2008,[11] with spot prices at times well over $140 per barrel and gasoline in some areas of the country spiking above $5 per gallon. When inflation is taken into account, the average "real" crude oil price in 2008 exceeded its 1980–81 high.

One favorable development was the large addition of Canadian oil sands to global reserves. In 2003, Canadian reserves shot from under 5 billion barrels to about 180 billion barrels, making it a potentially huge player in international oil markets. Seemingly overnight, the metric for Security of World Oil Reserves plunged from over 120 in 2002 to just above 90 in 2004.

While welcome, the increase in Canadian reserves was not enough to ward off the impacts of increased oil price volatility and the growing insecurity in global natural gas production on the Geopolitical Sub-Index, which began to rise after 2004. As noted earlier, natural gas reserves have become increasingly concentrated in Russia, Qatar, and Iran, which between them hold between 55% and 60% of global reserves. In 2008, these three natural gas giants met to consider creating "big gas troika"—essentially an OPEC for natural gas—to coordinate pricing and supplies.

Natural gas prices also soared during the decade. The evolution of natural gas policy in the United States since 1970—with enactment of NGPA in 1978, NGWDA in 1989, and EPAct in 1992—eventually created the conditions for a huge expansion in

Figure 10



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10 About $18 in constant 2000 dollars.

11 About $77 in constant 2000 dollars.

Table 5. U.S. Energy Security Risks: 2000 to 2010

Indexes	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
U.S. Index	87.0	83.9	81.6	81.1	86.1	94.3	96.4	96.6	99.8	83.7	85.6
Sub-Indexes:											
Geopolitical (30%)	81.0	78.2	76.0	76.3	82.5	90.2	93.4	94.9	101.1	80.5	83.3
Economic (30%)	83.1	78.6	75.7	76.8	83.0	93.9	97.8	99.1	105.7	78.7	81.6
Reliability (20%)	90.8	88.9	85.9	81.7	86.9	98.3	100.1	97.2	98.4	90.2	91.4
Environmental (20%)	98.2	95.5	94.8	93.9	95.5	96.7	95.3	95.0	90.3	89.5	89.3

natural-gas fired power capacity such that most of the new capacity additions after 1999 were natural gas combined-cycle units. From about 10% of electricity generation in the mid- to late 1980s, natural gas plants were providing over 20% of the Nation's power and a much higher percentage of its generating capacity by 2009. Indeed, since about 2005 the diversity of the power sector decreased owing to an over-build of natural gas facilities. This massive new capacity build coupled with bans on domestic exploration and production of natural gas contributed to tight natural gas markets throughout the decade.

The fragility of the Nation's transmission system was revealed in 2003 with a major blackout. Dubbed the Northeast Blackout of 2003, it surpassed its namesake in 1965, leaving an estimated 55 million people without power in a swath extending from Michigan to Rhode Island and northward into Ontario, Canada.

A few favorable trends, however, tended to moderate the impacts of high oil and natural gas prices. Although the metrics for Crude Oil Costs, Oil and Gas Import Costs, and Household Energy Expenditures show risks greater than at any time in the Index's historical record back to 1970, when those same cost and expenditure metrics are put in relation to GDP, 1980 and 1981 once again emerge as the peak risk years.

This illustrates how since 1970, steady improvement in the energy intensity of the U.S. economy—related both to greater energy efficiency and to long-term structural changes away from manufacturing and toward services—has lessened the economic impact of oil price volatility. Moreover, oil now accounts for a negligible amount (less than 2%) of electric generating capacity. High oil prices therefore have much less impact on electricity prices than they did 30 years ago.

Another bit of good news was that after rising steadily throughout the 1990s, the Environmental Sub-Index displayed little movement, and even a slight improvement, in risks since 2000. Though energy-related carbon dioxide emissions continued to rise, their share per person and relative to GDP fell. Moreover, the build-out of natural gas capacity early in the decade and a slow but fairly steady increase in the availability of non-emitting generation capacity, largely from nuclear capacity expansions (not new builds) and to a much lesser extent the relatively large capacity additions in wind power,[12] contributed to the reduced Environmental risk measured by the metric for Electricity Non-CO_2 Generation share.

Looking at each of the 37 metrics for the years 2007 and 2008, five had index scores that were the historical highs for that metric, and these revolved around cost, expenditure, and volatility. Over the same period, six had index scores that were the historical lows in the record, and these revolved around energy efficiency,

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[12] While capacity additions for wind have been quite large as a percentage, wind capacity still only accounts for about 2.5% of overall generating capacity and an even smaller share of generation.

transportation, and environment.[13] But for these positive trends, our energy security situation in 2008 certainly would have been worse.

An increasingly worrisome energy situation led Congress and President George W. Bush to enact two energy bills in rapid succession the Energy Policy Act of 2005 (EPAct 2005) and the Energy Independence and Security Act of 2007 (EISA).

EPAct 2005, which amended the EPAct 1992, was intended to increase the efficiency of the economy and aid commercial adoption of clean energy technologies, primarily renewables. On the supply side, the bill: provided production tax credits for nuclear power and renewable energy resources; set a new Renewable Fuel Standard requiring the annual use of 7.5 billion gallons of ethanol and biodiesel in the Nation's fuel supply by 2012; required mandatory reliability standards for the power grid to prevent blackouts; and authorized a loan guarantee program at DOE to reduce the financial risks of adopting new technologies. On the demand side, the bill set efficiency standards for a wide variety of consumer products and commercial appliances.

EISA built on EPAct 2005 in many ways. Some of its significant provisions include: increasing CAFE standards for light duty vehicles to 35 mpg by 2020 (the first increase in the standard for passenger vehicles since it was established in the 1970s); raising and extending the renewable fuel standard to 36 billion gallons by 2022; setting efficiency standards for more appliances and equipment: and phasing out inefficient light bulbs (essentially traditional incandescent bulbs) beginning in 2012.

The Bush Administration in 2003 and again in 2006 also raised the CAFE standards for light duty trucks through the 2011 model year.

For the most part, the greatest impact of these laws will be reflected in the years beyond 2009. However, EPAct 2005's renewable fuel requirement and along with a ban on the use of the oxygenate methyl tertiary butyl ether (MTBE) by many states[14] increased the share of renewable fuels used in the transportation sector. From less than 4% over most of the period, by the end of the 2000s non-petroleum based fuels accounted for nearly 6% of the transportation fuel used in 2009. EIA forecasts that it could reach about 10% in 2030.

> *From less than 4% over most of the period, by the end of the 2000s non-petroleum based fuels accounted for nearly 6% of the transportation fuel used in 2009. EIA forecasts that it could reach about 10% in 2030.*

Wind power capacity also has risen substantially due to EPAct 2005's tax incentives and renewable or alternative energy portfolio standards that many states have adopted. However, while rapidly growing, wind still makes up only a very small portion of overall capacity (2.5%), so its impact on the metric for Electricity Capacity Diversity has been modest.

There was also growing recognition that American students were not doing as well as their peers in science and math, and that the United States was not graduating enough college students in technical fields. The metric for Science and Engineering Degrees—the number of degrees in these fields per GDP—has been falling inexorably for 40 years, with potentially serious implications for the future competitiveness of the United States and the transformation to more advanced energy systems. In 2007 Congress passed and President Bush signed the America Competes Act, which addressed in particular the insufficient investment in science, technology, engineering, and mathematics education.

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[13] We showed earlier that in 1980–81, when the risks to energy security were at a record high as measured by the U.S. Index, only four individual metrics had record high index scores. It is interesting to note that, unlike in 2007–08, no individual metric had a record low index score over that period (save Transmission Line Mileage, which was set at 100 from 1970 to 1989 because reliable data were not available for these years).

[14] MTBE is an oxygenate that was used in gasoline to meet clean air requirements. Many states banned its use after it was discovered in aquifers used for drinking water.

Responding to skyrocketing oil prices, President Bush also lifted the executive order, first signed by President George H.W. Bush and later extended by President Clinton, prohibiting oil and natural gas drilling on the OCS. Later in the same year, Congress declined to include the prohibition in its appropriations bill, essentially clearing the way for OCS lease sales by DOI. Also in 2008, shipments to SPR were suspended temporarily in an effort to increase oil supplies and reduce their cost. Shipments to SPR resumed once again at the beginning of 2009.

Concerns about energy security and climate change highlighted the need for advanced technologies to reduce emissions of carbon dioxide in a cost-effective manner. This also prompted a turnaround in federal funding for energy R&D in the 2000s, though it remains far below the heights it achieved in the late 1970s and early 1980s. Industrial R&D also stemmed its decline and began to inch upward.

President Obama was sworn into office in 2009 amidst a severe financial crisis and moved quickly on an economic stimulus bill that included significant funding for clean energy projects. The American Reinvestment and Recovery Act (ARRA) of 2009 contains $42 billion in new funding for energy, mainly for energy efficiency, renewable energy programs, and smart grid programs.

In addition, ARRA provides more than $21 billion in energy tax incentives, primarily for energy efficiency and renewable energy. It extends the production tax credit for wind through 2012 and for other renewables through 2013. (In 2008, Congress extended the production tax credit for solar through 2017.)

President Obama also moved forward the date when the more stringent CAFE standards in EISA would have to be met by auto manufacturers (from 2022 to 2016). The Administration estimated that this would result in a projected reduction in oil consumption of approximately 1.8 billion barrels over the life of the program and a projected total reduction in greenhouse gas emissions of approximately 900 MMTCO$_2$.

The risks to energy security neared its record high in 2008. The global financial crisis and the deep recession it spawned then resulted in the largest one-year drop—16.1 points—in the entire 40 year history of the Index. After nearing a record high in 2008, the risks to U.S. energy security plunged to an Index score of 83.7, below the average for the period. Much of the decrease in risk can be traced to lower energy costs and price volatility stemming from a collapse in energy demand.

Nevertheless, bad economic times do not necessarily mean diminishing of energy security risks any more than good economic times mean greater risk. During the stagflation of the 1970s, energy security risks grew, and when the economy was buzzing the 1980s, energy security risks fell appreciably. The Energy Institute's temporarily Index suggests that the economic slowdown has just temporarily masked underlying risks that will reassert themselves as the global economy recovers.

2010 to 2030: Forecast Energy Security Risks

While the years 1980 and 1981 and 2008 represent the high water marks for energy insecurity across the entire historical period, there are clear indications that future U.S. energy security risks will approach, and perhaps even exceed, these historic highs. The forecasts reflected in this analysis are those seen EIA's *Annual Energy Outlook 2009 (AEO 2009)*, where the Reference Case projects an outlook assuming current trends, laws, and regulations. New laws could affect this forecast considerably.

Forecasting is an imperfect science, but forecasts are valuable tools that can provide insights about what might happen. New policies can affect forecasts in major ways.

The relief in energy security risks brought about by the economic recession is projected to be short-lived. EIA's *AEO 2009* forecast indicates that as the economy recovers, our energy outlook will again become increasingly risky, and the risk levels experienced in the 1970s, early 1980s, and late 2000s are forecast to be the norm in coming decades.[15]

Based on this EIA forecast our analysis suggests that by 2015 the U.S. energy security Index will once again top 95 and remain there through to 2030. Three of the four Sub-Indexes—Geopolitical, Economic, and Reliability—show a similar pattern where future risks approach historic highs and retreat only slightly out to 2030. The Environment Sub-Index, however, shows continued improvement in line with historical trends until about 2020 or so, and little improvement, but no real deterioration, thereafter (figure 11 and table 6). Energy

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[15] Forecast data are not as complete as historic data. In most cases where forecast data are not available for a particular metric, a neutral assumption was adopted whereby the value for the most recent year available is extended into the future. This discussion, therefore, is limited to those trends we can identify using *AEO 2009* forecasts.

Figure 11

Index of U.S. Energy Security Risk: 2010 to 2030

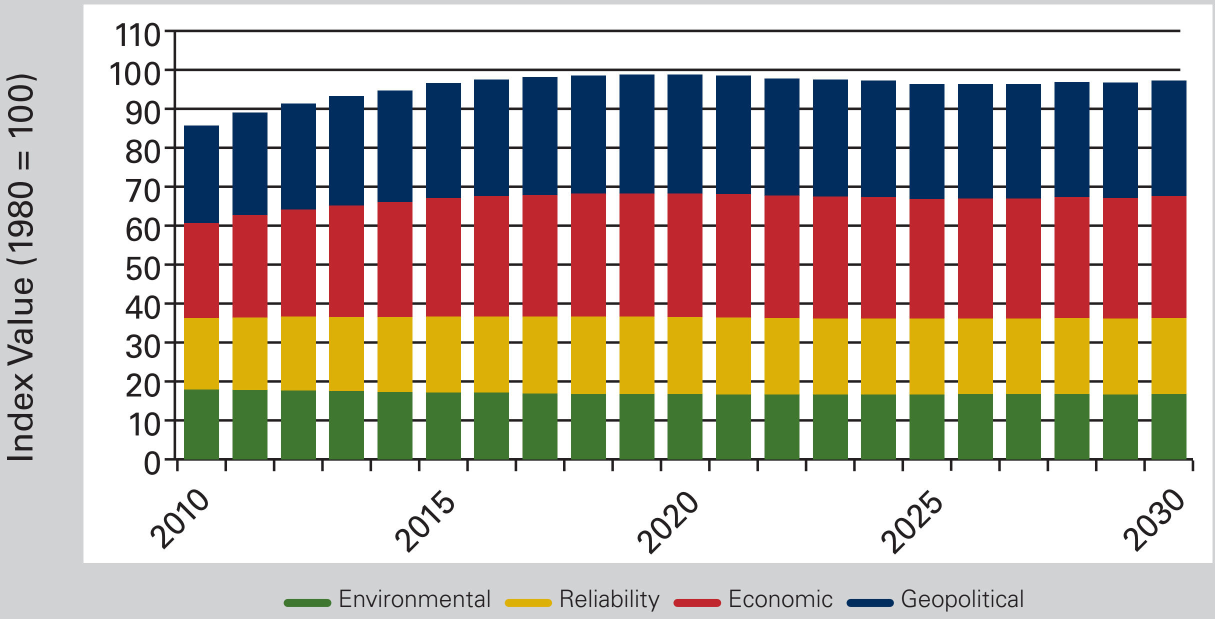

Table 6. U.S. Energy Security Risks: 2010 to 2030

Indexes	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	
U.S. Index	85.6	89.0	91.3	93.2	94.8	96.4	97.5	98.2	98.7	98.8	
Sub-Indexes:											
Geopolitical (30%)	83.3	87.5	90.6	93.4	95.7	98.0	99.6	100.6	101.4	101.7	
Economic (30%)	81.6	87.8	92.0	95.5	98.4	101.2	103.1	104.4	105.4	105.8	
Reliability (20%)	91.4	92.8	94.3	95.2	96.2	97.3	98.1	98.6	98.9	99.0	
Environmental (20%)	89.3	88.9	88.4	87.6	86.7	85.8	85.3	84.7	84.2	83.8	
	2020	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**
U.S. Index	98.5	97.7	97.5	97.3	96.3	96.4	96.4	96.8	96.8	97.2	98.5
Sub-Indexes:											
Geopolitical (30%)	101.4	100.4	99.9	99.6	98.2	98.2	98.3	98.8	98.7	99.1	101.4
Economic (30%)	105.7	104.7	104.3	103.8	102.2	102.3	102.4	103.2	103.4	103.9	105.7
Reliability (20%)	98.8	98.3	98.1	98.0	97.6	97.6	97.7	97.8	97.7	97.9	98.8
Environmental (20%)	83.0	82.8	82.9	83.1	83.2	83.3	83.3	83.3	83.2	83.4	83.0

and climate change legislation now being considered by Congress could affect the future trajectory of carbon dioxide emissions and this Sub-Index.

The main drivers increasing future energy security risks appear to be those connected to rising energy costs and expenditures, and these in turn are driven in large part by increasing costs for oil and natural gas. Crude oil prices are projected to come under tremendous upward pressure as global demand rises, particularly in large emerging markets. By 2015, the inflation-adjusted price for a barrel of crude oil is expected to exceed that reached in 2008. Rising natural gas prices and the expansion of more expensive renewable generating sources also will push electricity prices higher. As a result, energy expenditures as a share of the U.S. economy are expected to grow through about 2020 and decline thereafter.

The main drivers of decreasing future risks are for the most part the same ones that helped curb rising risks in the 2000s—greater energy efficiency in the residential, commercial, industry, and transportation sectors, increasing diversity of energy supplies and suppliers, and ongoing decarbonization of energy supplies. Transportation metrics, in particular, display accelerating trends in vehicle efficiency improvements and the use of renewable fuels mandated by EPAct2005 and EISA. The decoupling of economic growth and vehicle miles traveled—which may signal, as suggested earlier, more telecommuting and on-line shopping—also is forecast to continue unabated.

By affecting the energy market outlook, different approaches to energy policy could improve or worsen our energy security risks. So would international surprises—wars, revolutions, new fuel discoveries, new or re-aligned economic and political alliances—which can occur with little or no warning at the most unexpected times. Nevertheless, if the trends modeled in *AEO 2009* hold, by 2030 the Index will be 97.2, only marginally better than the worst periods recorded from 1970 to 2009.

Conclusion and Policy Implications

The Energy Institute's Index of U.S. Energy Security Risk measures what always seemed self-evident—policies matter. With this new Index, we have a much better idea of the degree to which they matter.

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.

This is not to say that future energy crises are preordained, even if no further policies are implemented. Nor is it to say that implementing smart policies that lower the Nation's energy security risks will guarantee that future crises are avoided. The real choice is hoping for the best or taking action that limits our exposure so that when crises do occur—as they inevitably will—they will be less disruptive to our economy and security.

The Index also shows that energy insecurity anywhere can create energy insecurity everywhere. In a constantly changing world, the types of the risks to our energy security also are constantly changing, often in unpredictable ways. The fall of the Shah of Iran, the collapse of the Soviet Union, the rising economic might of China, India, and other emerging economies have all affected U.S. vulnerability and its ability to make changes unilaterally. What is important, therefore, is that the Nation's energy systems have the resilience needed to weather the crises of the future.

One need only look at EIA's forecast of future crude oil prices for an example. It shows a smooth run-up in prices out to 2030. How does that match up with experience? Not very well. As the Oil Price Volatility metric shows, general trends in oil prices, either up or down, often are punctuated by periods of severe volatility. It is a safe bet that sharp spikes and dips in crude oil prices will occur again, though it is not possible to predict these episodes with any confidence. Nevertheless, sound policies can be designed to limit the impacts of such shocks when they do occur.

And this begs the question: What types of policies will lead to a more secure energy future?

The methodology used to develop the Index provides a powerful tool to evaluate the effect of alternative policies by quantifying energy security impacts. Certain policies may result in outcomes that clearly affect the reliability, affordability, and cleanliness of our energy supplies, and therefore have unambiguous beneficial or detrimental impacts on energy security. Other policies may have a more mixed, nuanced, or even countervailing sets of effects.

Still other policies can have unintended effects that may not make themselves apparent for years or even decades. From the vantage point of the 1960s, who could have foreseen how encouraging oil-fired electricity generation to reduce the health impacts of air pollution would make the U.S. more vulnerable to energy shocks? Could anyone have predicted how the evolution of natural gas policy over the 1970s and 1980s would lead to the overbuild of natural gas generating capacity in the late 1990s and early 2000s?

The methodology developed here provides a useful tool in identifying and quantifying the sometimes difficult tradeoffs among competing priorities and goals. Besides providing a historical look at U.S. energy security, the Index is an analytical tool can be employed in at least three ways.

First, the Index can be used to track energy security over time. Annual updates to the Index using the most up-to-date data can show whether U.S. energy security is trending better or worse. Had this Index been available in the past, the warning signs of impending threats to our energy security would have been unmistakable. For example, the Index shows clearly the shift towards increasing energy security risks that occurred in the mid-1990s, but at the time, the increasing risks to our energy security were not generally recognized. With the Energy Institute's Index—and the luxury of hindsight—this shift is easy to spot, and using the Index, similar shifts either up or down can be better spotted in the future.

Second, the Index can be used to assess the potential effects of new policies on U.S. energy security. Although current projections do not bode well for U.S. energy security, different policies can lead to much different futures. While the Energy Institute's Index is not a model, it can use model output to project future energy security under different policy and regulatory scenarios.

Third, various analytical and statistical techniques can help identify from among the 37 individual energy security metrics used to create the Index those that have had or are likely to have the greatest impact on energy security risks and thus provide insights on where policies should be focused.

The Index presented here is not the last word on measuring our energy security. The Energy Institute will continue its efforts to revise and improve its metrics, and it welcomes a constructive and active dialogue.

In addition to the annual series on energy security in the United States (of which this report is the inaugural edition), the Energy Institute anticipates issuing periodically special reports that explore the energy security impacts of major proposals on energy, economic, and environmental policies. By developing a transparent and objective means for measuring the once elusive concept of energy security, the Energy Institute is working to ensure that energy security considerations are more directly incorporated into the policy debates.

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

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

Boiling down something as multifaceted as U.S. energy security into a single number posed a significant challenge. The Index was built from a foundation of just over three dozen individual metrics measuring energy security in a variety of aspects. The Index uses historical and forecast data covering the period 1970, before the time when energy security first became a large concern with the American public, to 2030 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 extends 20 years into the future, 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 1-A.

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, as shown in table A-2.[16] Anywhere from three to six metrics were selected for each metric category.

The Energy Institute'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

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[16] More detailed information on the metrics we selected, including charts, is found in the companion report, Index of *U.S. Energy Security Metrics and Data Tables*, which is available on our web page.

Table A-1. Categories of Energy Security Metrics

	Metric Category	General Description of the Metrics
1.	**Global Fuels**	Measure the reliability and diversity of global reserves and supplies of oil, natural gas, and coal. Higher reliability and diversity mean a lower risk to energy security.
2.	**Fuel Imports**	Measure the exposure of the U.S. economy to unreliable and concentrated supplies of oil and natural gas and import costs (not necessarily related to the amount of imports). Higher reliability and diversity and lower costs mean a lower risk to energy security.
3.	**Energy Expenditures**	Measure the magnitude of energy costs to the U.S. economy and the exposure of consumers to price shocks. Lower costs and exposure mean a lower risk to energy security.
4.	**Price & Market Volatility**	Measure the susceptibility of the U.S. economy and consumers to large swings in energy prices. Lower volatility means a lower risk to energy security.
5.	**Energy Use Intensity**	Measure energy use in relation to economic output and energy efficiency. Lower energy use by industry to produce goods and services and by commercial and residential consumers mean a lower risk to energy security.
6.	**Electric Power Sector**	Measure the diversity and reliability of electricity generating capacity. Higher diversity and reliability mean a lower risk to energy security.
7.	**Transportation Sector**	Measure efficiency of the auto 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.

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.

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 and/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 2030 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.[17]

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.[18] Additionally, some of the metrics required further transformations to reflect non-linearities in the scale.[19]

EIA's *Annual Energy Outlook 2009 (AEO 2009)* was the primary source for metric forecasts out to 2030. *AEO 2009* 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.[20]

All of these data transformations are discussed in detail in the documentation material available on the Energy Institute's web site.

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

Within the broad framework 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 percent 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

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[17] 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.

[18] 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.

[19] 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.

[20] 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.

become a more international commodity. For both oil and gas, several of the top reserve-owning countries have uncertain political stability and are at best reluctant business partners with the United States. Dependence upon these fuel sources—for both the United States and the rest of the world—poses political and military risks. Because international disputes can quickly turn into energy problems, and vice versa, energy necessarily occupies a consequential role in U.S. foreign policy.

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

- **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.

Each of the 37 metrics listed in table A-2 contributes in different ways and in varying degrees to four Sub-Indexes and the overall Index. It is also clear that some metrics have a comparatively larger influence on geopolitical, economic, reliability, and environmental concerns than do others.

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.[21]

The weightings were applied as fixed values that remain unchanged over the 1970 to 2030 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

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[21] Information on the weighting assigned each metric for each of the Sub-Indexes can be found in the companion report, *Index of U.S. Energy Security Risk: Metrics and Data Tables*, available on the Energy Institute's web site at www.energyxxi.org.

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 2030. 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.[22] 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 60-year period the Index covers. The weightings used to create the Energy Institute's Index are intended to give substantial weight to each of the four Sub-Indexes but to give slightly more weight to the geopolitical and economic risks that, for good reason, tend to dominate much of the public debate on energy security.

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

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

Table A-2. Metrics Used to Create Index of U.S. Energy Security Risk

Metric by Classification		Definition	Importance	Use in Sub-Indexes: Geopolitical	Economic	Reliability	Environmental
Global Fuel Metrics							
1.	**Security of World Oil Reserves**	Global proved oil reserves weighted by each country's relative Freedom Index and by an index of global diversity of oil reserves.	Indicates risk attached to the average barrel of global crude oil reserves. As a measure of reserves, it largely reflects longer-term concerns.	✔	✔	✔	
2.	**Security of World Oil Production**	Global oil production weighted by each country's relative Freedom Index and by an index of global diversity of oil production.	Indicates the level of risk attached to the average barrel of crude oil production globally.	✔	✔	✔	
3.	**Security of World Natural Gas Reserves**	Global proved natural gas reserves weighted by each country's relative Freedom Index and by an index of global diversity of gas reserves.	Indicates the risk attached to the average cubic foot of natural gas reserves globally. As a measure of reserves, it largely reflects longer-term concerns.	✔	✔	✔	✔
4.	**Security of World Natural Gas Production**	Global natural gas production weighted by each country's Freedom Index and by global diversity of gas production.	Indicates the level of risk attached to the average cubic foot of natural gas production globally.	✔	✔	✔	✔
5.	**Security of World Coal Reserves**	Global proved coal reserves weighted by each country's relative Freedom Index and by an index of global diversity of coal reserves.	Indicates the risk attached to the average ton of coal reserves globally. As a measure of reserves, it largely reflects longer-term concerns.	✔			✔
6.	**Security of World Coal Production**	Global coal production weighted by each country's relative Freedom Index and by an index of global diversity of coal production.	Indicates the level of risk attached to the average ton of coal production globally.	✔			✔

Table A-2. Metrics Used to Create Index of U.S. Energy Security Risk

Metric by Classification		Definition	Importance	Use in Sub-Indexes: Geopolitical	Economic	Reliability	Environmental
Fuel Import Metrics							
7.	**Security of World Petroleum Imports**	Net petroleum imports as a percentage of total U.S. petroleum supply, adjusted to reflect the Freedom Index of non-U.S. petroleum producers and the diversity across non-U.S. producing countries.	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.	✔	✔	✔	
8.	**Security of World Natural Gas Imports**	Net natural gas imports as a percentage of total U.S. natural gas supply, risk-adjusted to reflect the Freedom Index of non-U.S. natural gas producers and the diversity across non-U.S. producing countries.	Indicates the degree to which changes in import levels expose the U.S. to potentially unreliable and/or concentrated supplies of natural gas.	✔	✔	✔	
9.	**Oil & Natural Gas Import Expenditures**	Value of net imports of crude oil, petroleum products, and natural gas, in billions of real (2000) dollars.	Indicates lost domestic economic investment and opportunity, and magnitude of revenues received by foreign suppliers.	✔	✔		
10.	**Oil & Natural Gas Import Expenditures per GDP**	Value of net imports of crude oil, petroleum products, and natural gas, as a percentage of GDP.	Indicates the susceptibility of the U.S. economy to imported oil and gas price shocks		✔		

Table A-2. Metrics Used to Create Index of U.S. Energy Security Risk

Metric by Classification	Definition	Importance	Use in Sub-Indexes:			
			Geopolitical	Economic	Reliability	Environmental
Energy Expenditure Metrics						
11. Energy Expenditures per GDP	Total real (2000) dollar cost of energy consumed per $1,000 of GDP per year.	Indicates the magnitude of energy costs in the U.S. economy to energy price shocks, and exposure to price changes.	✔	✔		
12. Energy Expenditures per Household	Total real dollar cost of the energy consumed per household, per year.	Indicates the importance of energy in household budgets and the susceptibility of U.S. households to energy price shocks.		✔		
13. Retail Electricity Prices	Average electricity costs in the U.S. in real (2000) cents per kWh.	Indicates the availability of low-cost, reliable forms of power generation.		✔		
14. Crude Oil Prices	Real cost per barrel (in 2000 dollars) of crude oil, landed in the U.S.	Indicates the susceptibility of the U.S. economy to high prices for petroleum, which supplies a significant portion of U.S. energy demand.	✔	✔	✔	
Price & Market Volatility Metrics						
15. Crude Oil Price Volatility	Annual change in crude oil prices, averaged over a three-year period.	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.	✔	✔	✔	
16. Energy Expenditure Volatility	Average annual change in U.S. energy expenditures per $1,000 of GDP.	Indicates the susceptibility of the U.S. economy to large swings in expenditures for all forms of energy.		✔	✔	✔
17. World Oil Refinery Utilization	Average percent utilization of global petroleum refinery capacity.	Indicates the likelihood of higher prices at high capacity utilization, and higher risk of supply limitations during refinery outages or disruptions.	✔		✔	
18. Petroleum Stock Levels	Average days supply of petroleum stocks, including SPR, non-SPR crude, and petroleum products.	Indicates vulnerability of the U.S. to a supply disruption based on the quantity of oil stocks that are available to be drawn down.	✔		✔	

Table A-2. Metrics Used to Create Index of U.S. Energy Security Risk

Metric by Classification		Definition	Importance	Use in Sub-Indexes:			
				Geopolitical	Economic	Reliability	Environmental
Energy Use Intensity Metrics							
19.	**Energy Consumption per Capita**	Million British thermal units (Btu) consumed per person per year.	Indicates changes in both energy intensity and in per-capita GDP.	✔	✔		✔
20.	**Energy Intensity**	Million Btu of primary energy used in the U.S. economy per $1,000 of GDP.	Indicates the importance of energy as a component of economic growth.	✔	✔		✔
21.	**Petroleum Intensity**	Million Btu of petroleum consumed per real (2000) GDP.	Indicates the importance of petroleum as a component of economic growth.	✔	✔		✔
22.	**Household Energy Efficiency**	Million Btu of total Residential energy consumed per household.	Indicates the degree to which households use energy efficiently.		✔		✔
23.	**Commercial Energy Efficiency**	Million Btu of total Commercial energy consumed per 1,000 square feet of commercial floor space.	Indicates the degree to which the commercial enterprises use energy efficiently.		✔		✔
24.	**Industrial Energy Efficiency**	Trillion Btu of total Industrial energy consumed per unit of Industrial Production (IP) Index.	Indicates the degree to which industrial enterprises use energy efficiently.		✔		✔

Table A-2. Metrics Used to Create Index of U.S. Energy Security Risk

Metric by Classification	Definition	Importance	Use in Sub-Indexes:			
			Geopolitical	Economic	Reliability	Environmental
Electric Power Sector Metrics						
25. Electricity Capacity Diversity	Market share concentration index (HHI) of the primary categories of electric power generating capacity, adjusted for availability.	Indicates the flexibility of the power sector and its ability to dispatch electricity from a diverse range of sources.			✔	✔
26. Electricity Capacity Margins	Unused available capability in the U.S. electric power system at peak load, as a percentage of total peak capability.	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.		✔	✔	
27. Electricity Transmission Line Mileage	Circuit-miles of transmission lines per gigawatt of peak demand.	Indicates the integration of the transmission system and its ability to meet increasing demand.		✔	✔	✔
Transportation Sector Metrics						
28. Passenger Car Average MPG	Average mpg of passenger cars.	Indicates the degree to which the typical light vehicle uses energy efficiently (gasoline consumption accounts for about 17% of total U.S. energy demand).	✔	✔		✔
29. Transportation Vehicle Miles Traveled per GDP	Vehicle-miles traveled (VMT) per $1,000 of GDP.	Indicates the importance of travel as a component of the economy.	✔	✔		✔
30. Transportation Non-Petroleum Fuel Use	Non-petroleum fuels as a percentage of total U.S. transportation energy consumption.	Indicates the diversity and flexibility of the fuel mix for transportation.	✔		✔	✔

Table A-2. Metrics Used to Create Index of U.S. Energy Security Risk

Metric by Classification		Definition	Importance	Use in Sub-Indexes: Geopolitical	Economic	Reliability	Environmental
Environmental Metrics							
31.	**Energy-Related Carbon Dioxide Emissions**	Total U.S. energy-related CO_2 emissions, in million metric tons.	Indicates the exposure of the U.S. economy to domestic and international emissions reduction mandates.	✔	✔		✔
32.	**Energy-Related Carbon Dioxide Emissions per Capita**	Metric tons of CO_2 emissions (energy-related), per capita.	Indicates the joint effect of the amount of energy we use per capita, and the carbon intensity of that energy use.				✔
33.	**Energy-Related Carbon Dioxide Emissions Intensity**	Metric tons of CO_2 per $1,000 of real (2000) GDP.	Indicates the importance of carbon-based fuels as a component of the economy.	✔			✔
34.	**Non-CO_2 Emitting Share of Electricity Generation**	Percentage of total electric power generation contributed by renewables, hydroelectric, nuclear and fossil-fired plants operating with carbon capture and storage technology.	Indicates the degree to which the power sector is employing non-CO_2 emitting generation.			✔	✔
Research & Development Metrics							
35.	**Industrial Energy R&D Expenditures**	Dollars of industrial energy-related R&D (non-Federal) per $1,000 of GDP.	Indicates private industry engagement in improving performance and enabling new technological breakthroughs.		✔		✔
36.	**Federal Energy & Science R&D Expenditures**	Dollars of federal energy and science R&D per $1,000 of GDP.	Indicates prospects for new scientific and technological breakthroughs through federally-supported public-private research.	✔	✔	✔	✔
37.	**Science & Engineering Degrees**	Number of science and engineering degrees per billion dollars of real (2000) GDP.	Indicates the degree to which human capital in high-tech science, technology, engineering, and mathematics fields will be available to the economy.	✔	✔	✔	✔

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Acronyms

AEO	*Annual Energy Outlook*
AFV	alternative-fuel vehicle
ARRA	American Reinvestment and Recovery Act
CAFE	Corporate Average Fuel Economy
DOE	Department of Energy
DOI	Department of the Interior
EIA	Energy Information Administration
EISA	Energy Independence and Security Act
EPCA	Energy Policy and Conservation Act
EPAct	Energy Policy Act
ERDA	Energy Research and Development Administration
FEA	Federal Energy Administration
FUA	Power Plant and Industrial Fuels Use Act
GDP	gross domestic product
IEA	International Energy Agency
MMbbl	million barrels
MMbbl/d	million barrels per day
mpg	miles per gallon
MTBE	methyl tertiary butyl ether
NGPA	Natural Gas Policy Act
NGWDA	Natural Gas Wellhead Decontrol Act
OCS	Outer Continental Shelf
OAPEC	Organization of Arab Petroleum Exporting Countries
OPEC	Organization of Petroleum Exporting Countries
R&D	research and development
SPR	Strategic Petroleum Reserve
TAP	Trans-Alaska Pipeline Authorization Act
UN	United Nations
UNFCCC	United Nations Framework Convention on Climate Change
VMT	vehicle-miles traveled

Institute for 21st Century Energy
U.S. Chamber of Commerce
1615 H Street, NW
Washington, DC 20062
Phone: (202) 463-5558 Fax: (202) 887-3457
energyinstitute@uschamber.com
www.energyxxi.org

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