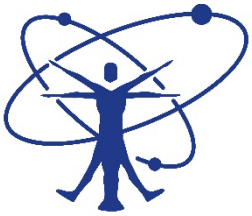
Technical Appendix

to

The Role of Energy in U.S. National Security

Iddo K. Wernick, Senior Fellow, NCEA
Stephen D. Eule, Visiting Fellow, NCEA



NATIONAL CENTER
FOR ENERGY ANALYTICS

The National Center for Energy Analytics' U.S. Energy Security Index (ESI) measures the geopolitical risks to the nation's energy system, both historically and as a leading indicator of future trends based on current forecasts for the coming decade.

The methodology we employed and the indicators we selected for the index account for various aspects of geopolitical energy security. The goal is to create a single, overarching measure to answer a critical question: Is the nation's energy security getting better or worse?

The process used to develop ESI was based on the following five steps:

1. Select a set of indicators that capture the salient geopolitical aspects of energy security.

To capture the energy security of the United States in a single index, we looked at 18 indicators—organized into six indicator groups—that address the key geopolitical vulnerabilities of the U.S. energy system. These groups are representative of the physical flow of fuels and minerals that support the major hydrocarbons; the minerals that are critical to new energy technologies and general energy infrastructure; and the cybersecurity threats to the energy system. In our view, these indicators provide a reasonably comprehensive picture of the foreign-based risks to the U.S. energy system.

We did not consider coal supplies in ESI, as the United States has always produced large volumes of both thermal and metallurgical coal and has long been a net exporter of both. Indeed, the risks surrounding coal are not geopolitical but rather domestically political and regulatory.[1] Similarly, in measuring the risks associated with energy and mineral imports, we treated the highly integrated U.S., Canadian, and Mexican markets as a single domestic market.

2. Organize these indicators into groups representing different aspects of energy security.

ESI combines 18 risk indicators that measure U.S. energy security across a range of fuels,[2] minerals,[3] uranium,[4] and systemic considerations.[5] In general, the indicators we selected measure vulnerabilities associated with imports of traditional fuels, such as U.S. crude oil and natural gas; uranium and foreign enrichment services for nuclear power; aluminum, copper, and steel used in energy infrastructure; and cobalt, graphite, lithium, manganese, nickel, and rare earth elements used extensively in renewable technologies, batteries, and electric vehicles.

These 18 indicators were organized into six indicator groups, as shown in **table A-1**.

Table A-1. ESI Indicators

Table A-1. ESI Indicators		
Indicator Group	**Indicator #**	**Risk to/from**
Crude Oil	1	World Crude Oil and Natural Gas Plant Liquids Production
	2	Net Crude Oil Imports
Natural Gas	3	World Natural Gas Production
	4	Net Natural Gas Imports
Uranium	5	Net Uranium Imports
	6	Uranium Enrichment Services
Energy Technology Minerals	7	Net Cobalt Imports
	8	Net Graphite Imports
	9	Net Lithium Imports
	10	Net Manganese Imports
	11	Net Rare Earths Imports
Energy Infrastructure Minerals	12	Net Aluminum Imports
	13	Net Copper Imports
	14	Net Nickel Imports
	15	Net Steel Imports
Systemic	16	Cybersecurity
	17	Crude Oil Price Volatility
	18	Strategic Petroleum Reserve Stocks

3. Compile historical and forecast data for each indicator.

Nearly all of the data were drawn from government statistical agencies, such as the U.S. Energy Information Administration (EIA), the U.S. Geological Survey, and the British Geological Survey. To provide historical context, we gathered data going back to 1970, a few years before the Arab oil embargo made energy security a perennial political concern for Congress and U.S. presidents. The data used to develop the indicators are updated annually, which allows us to continue to track progress each year.

As a measure of the relative risk and security associated with global energy and mineral supplies, we used two of the primary elements of supply security: reliability and diversity of imports. To measure the reliability of supplies, we used scores of political and civil liberties developed by Freedom House in its annually published Freedom in the World series. To measure the diversity of supply, we employed the Herfindahl-Hirschman Index (HHI), a tool commonly used in antitrust analysis. This diversity component recognizes that greater supply diversity indicates greater competition and less volatility and, consequently, lowers risk.[6]

There also are risks attached to the transport of fuels and materials to markets, traditionally for oil but increasingly for natural gas and energy minerals. Large volumes of crude oil must pass through maritime chokepoints—most notably, the Strait of Hormuz, which handles about 20% of the world's oil supply each day. To account for this vulnerability, we combined the market share of seven Persian Gulf States (Bahrain, Iran,

Iraq, Kuwait, Qatar, Saudi Arabia, and United Arab Emirates) in the HHI calculations for oil and natural gas, as their crude oil exports transit the Strait of Hormuz.

Added to these market- and import-related indicators, ESI includes three systemic indicators designed to capture changing threats to the U.S. energy system that are not attached to the production or import of any particular commodity.

The Combined Crude Oil Price Volatility indicator increases the sensitivity of ESI to risks arising from global hostilities that affect energy production. The Strategic Petroleum Reserve Stocks indicator measures U.S. preparedness to manage disruptions in crude oil supplies. The Cybersecurity indicator measures the risks from cyberattacks on U.S. energy installations, which can originate from both malicious domestic actors and foreign governments hostile to the United States.

EIA's Annual Energy Outlook (AEO) series was the primary source of the forecasts used in ESI. Where AEO projections were not available—such as the freedom weighting of international energy and mineral production—we applied a neutral assumption extended over the forecast period, using the most recent year of available data.

4. Normalize the data to allow adding them together for ESI.

When dealing with metrics expressed in different units, it becomes necessary to convert the data into comparable constituents that can be combined into a single index score. For ESI, each individual metric was normalized so that its maximum historical value—that is, its worst value—from 1970 to 2019 was set to 100. This system of normalization eliminates distortions that arise from using a single base year. It does not mean, however, that indicators' risk scores cannot be greater than 100. For emerging risks in particular, there are instances of post-2019 indicator scores exceeding 100. With this in mind, a total ESI risk score approaching 100 or even 90 indicates very high levels of overall risk across many metrics. Also, it should be noted that there are no negative risk scores; the lowest possible risk score for both individual indicators and total ESI scores is zero.

5. Weigh and combine the data to create an overall score of geopolitical energy vulnerability.

The final step in calculating ESI is to assign weights to the indicators. ESI employs a dynamic weighting scheme, as each indicator's contribution to the final index varies annually. These weighted values reflect indicators' importance to the U.S. energy system; the weights change over time. We assign weights to the various indicators based on their share of U.S. primary energy consumption, their contribution to the economy, or their estimated contribution to total risk. **Table A-2** shows the weighting formulas used in ESI.

Table A-2. ESI Indicator Groups

Table A-2. ESI Indicator Groups			
Indicator Group	**Indicators**	**Share of Weighting**	**Weighting**
Crude Oil	World Crude Oil and Natural Gas Plant Liquids Production	20%	Petroleum consumption as share of total U.S. energy consumption
	Net Crude Oil Imports	80%	
Natural Gas	World Natural Gas Production	10%	Natural gas consumption as share of total U.S. energy consumption
	Net Natural Gas Imports	90%	
Uranium	Net Uranium Imports	50%	Nuclear energy consumption as share of total U.S. energy consumption
	Uranium Enrichment Services	50%	
Energy Technology Minerals	Net Cobalt Imports	20%	Total of electricity generation from wind and solar and electricity going to battery storage and electric vehicles as share of total U.S. energy consumption
	Net Graphite Imports	20%	
	Net Lithium Imports	20%	
	Net Manganese Imports	20%	
	Net Rare Earths Imports	20%	
Energy Infrastructure Minerals	Net Aluminum Imports	25%	Energy industries* as share of U.S. GDP
	Net Copper Imports	25%	
	Net Nickel Imports	25%	
	Net Steel Imports	25%	
Systemic	Cybersecurity	100%	2.5% multiplied by the number of cyber incidents divided by the number of cyber incidents in 2012
	Combined Crude Oil Price Volatility	100%	5%
	Strategic Petroleum Reserve Stocks	100%	5% of Net Crude Oil Imports indicator
Note: ESI weightings were proportionally adjusted to add to 100%.			
*This includes oil and gas extraction; utilities; electrical equipment, appliances, and components; and petroleum and coal products.			

Indicator Summaries

Indicator	**World Crude Oil and Natural Gas Plant Liquids Production**
Indicator Group	Crude Oil
Why It Is Important	This indicates the level of risk tied to each barrel of crude oil and natural gas plant liquids (NGPL) produced globally.
What It Measures	This measures the reliability and diversity of global crude oil and NGPL supplies.
How It Is Calculated	This annual indicator is the product of: (1) the country-weighted average freedom score of each barrel produced (a proxy for geopolitical reliability); and (2) the concentration of production measured by the Herfindahl-Hirschman Index (a measure of market diversity), with Persian Gulf producer countries considered as a single producer, in order to capture the concentration of supplies passing through the Strait of Hormuz. The values for both were normalized (with Freedom House scores squared beforehand) so that the maximum (i.e., worst) historical value from 1970 to 2019 = 100. The product of these normalized values was calculated and normalized using the same procedure.
Data Sources	Freedom House's Freedom in the World series; EIA

Figure A-1. Freedom-Weighted World Crude Oil and Natural Gas Plant Liquids Production Output

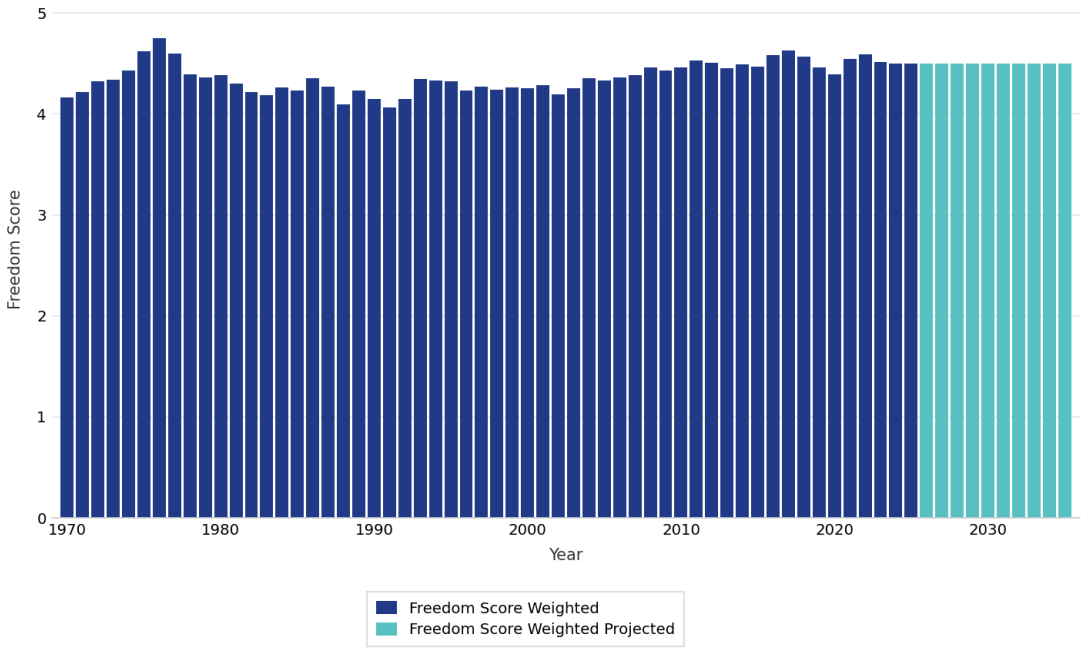


Figure A-2. Diversity of World Crude Oil and Natural Gas Plant Liquids Production Output

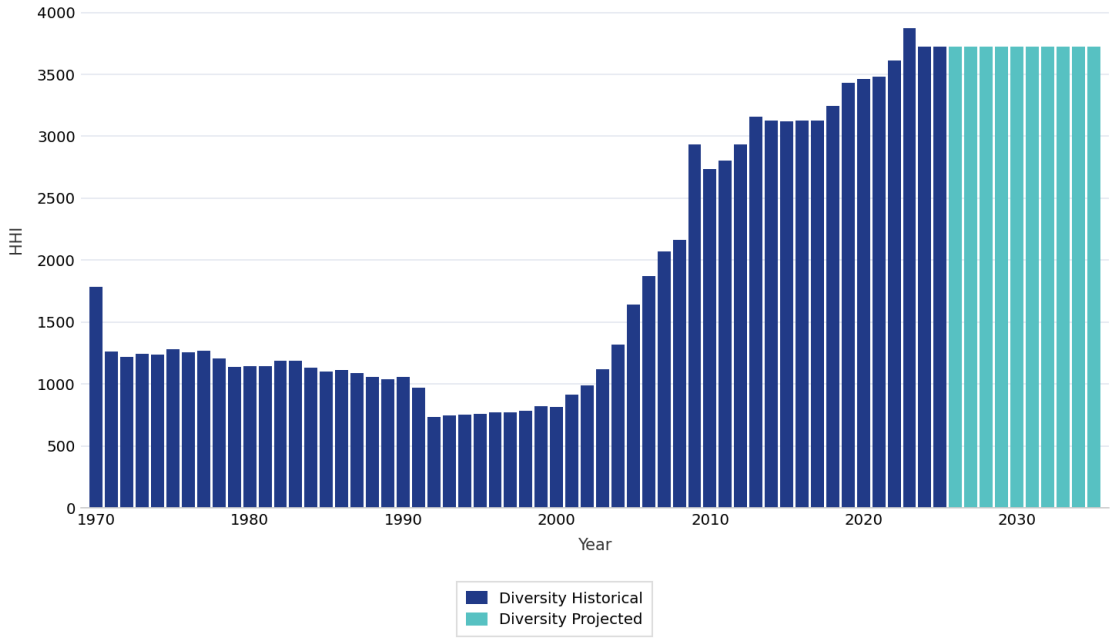
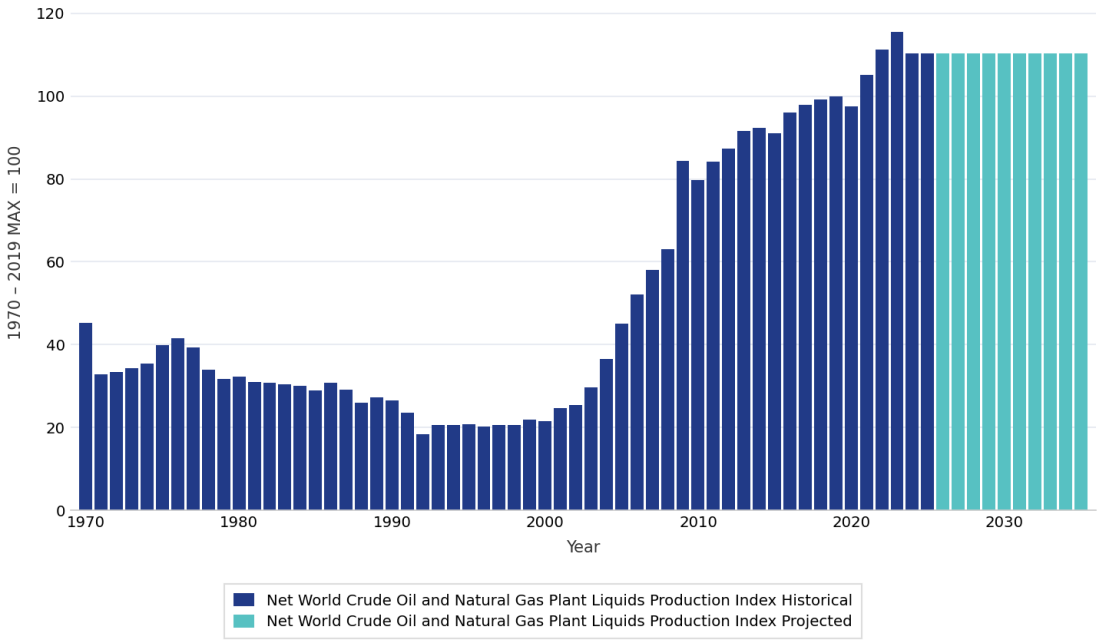


Figure A-3. World Crude Oil and Natural Gas Plant Liquids Production Index



Indicator	**Net Crude Oil Imports**
Indicator Group	Crude Oil
Why It Is Important	This indicates the degree to which changes in import levels expose the United States to unreliable and concentrated supplies of crude oil.
What It Measures	The volume of net crude oil imports is weighted by the reliability and diversity of global crude oil and NGPL supplies. This indicator combines: (1) the quantity of net crude oil imports as a share of refinery inputs, and (2) the level of risk tied to each barrel of crude oil and NGPL produced globally.
How It Is Calculated	This indicator is the product of: (1) net crude oil imports as a share of refinery inputs to distillation units weighted by petroleum consumption as share of total U.S. energy consumption; and (2) the reliability and diversity of global crude oil production, excluding the United States, Canada, and Mexico and combining the Persian Gulf producers. The values were normalized so that the maximum (i.e., worst) historical value from 1970 to 2019 = 100.
Data Sources	Freedom House's Freedom in the World series; EIA's Monthly Energy Review series and International Data

Figure A-4. Risk-Weighted Crude Oil Imports

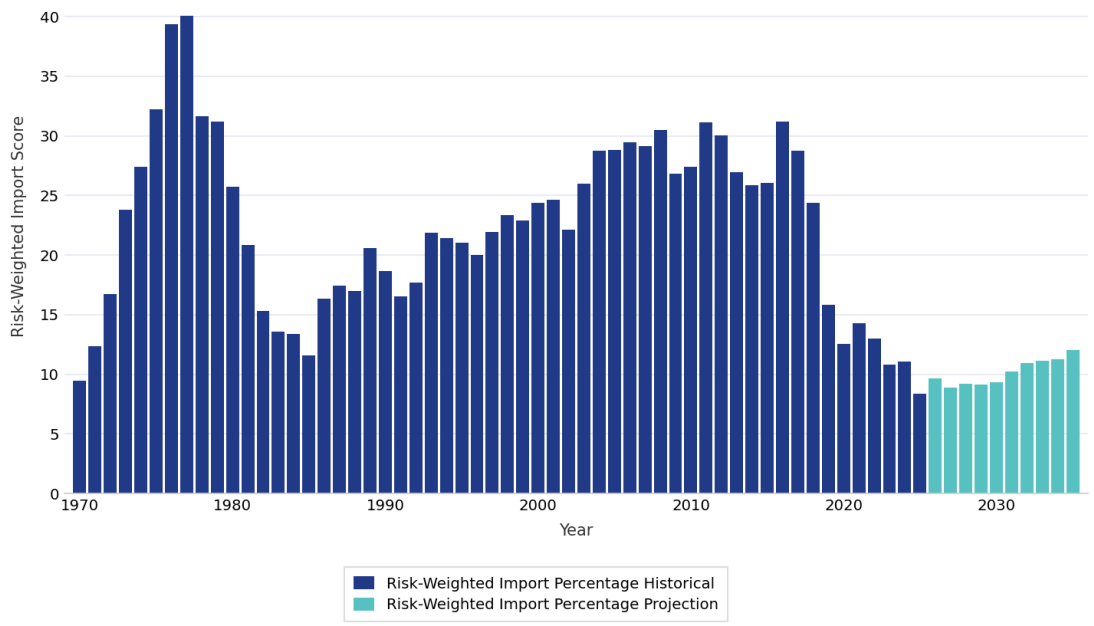
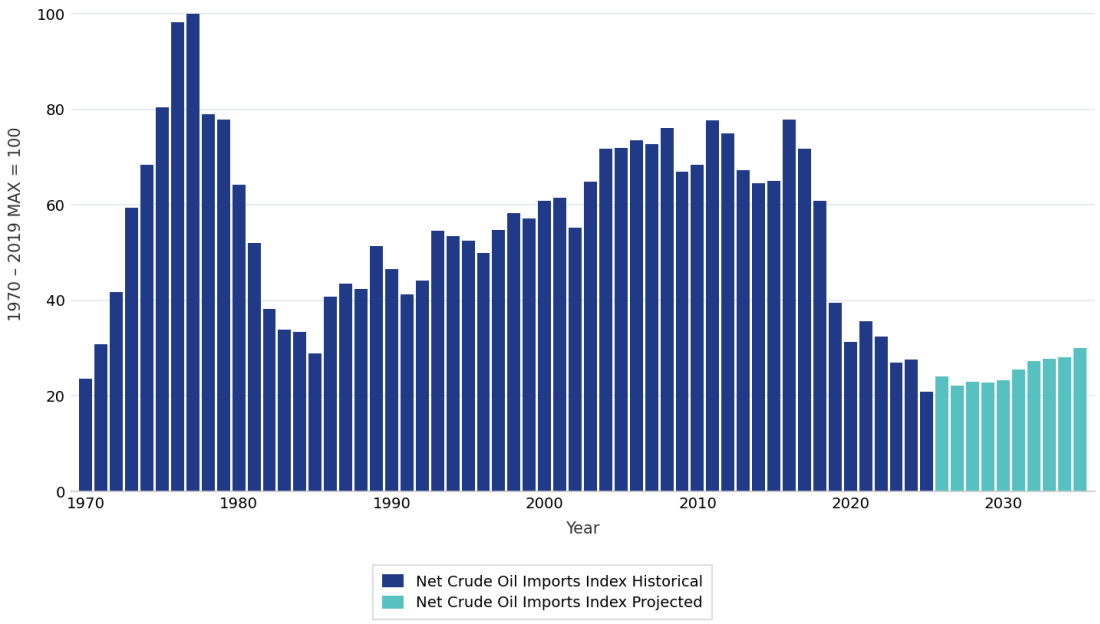


Figure A-5. Crude Oil Imports Index



Indicator	**World Natural Gas Production**
Indicator Group	Natural Gas
Why It Is Important	This indicates the level of risk tied to each cubic foot of natural gas produced globally.
What It Measures	This measures the reliability and diversity of global natural gas production.
How It Is Calculated	This annual indicator is the product of: (1) the country-weighted average freedom score of each barrel produced (a proxy for geopolitical reliability); and (2) the concentration of production measured by the Herfindahl-Hirschman Index (a measure of market diversity), with Persian Gulf producer countries considered a single producer, in order to capture the concentration of supplies passing through the Strait of Hormuz. The values for both were normalized (with Freedom House scores squared beforehand) so that the maximum (i.e., worst) historical value from 1970 to 2019 = 100.
Data Sources	Freedom House's Freedom in the World series; EIA

Figure A-6. Freedom-Weighted World Natural Gas Production

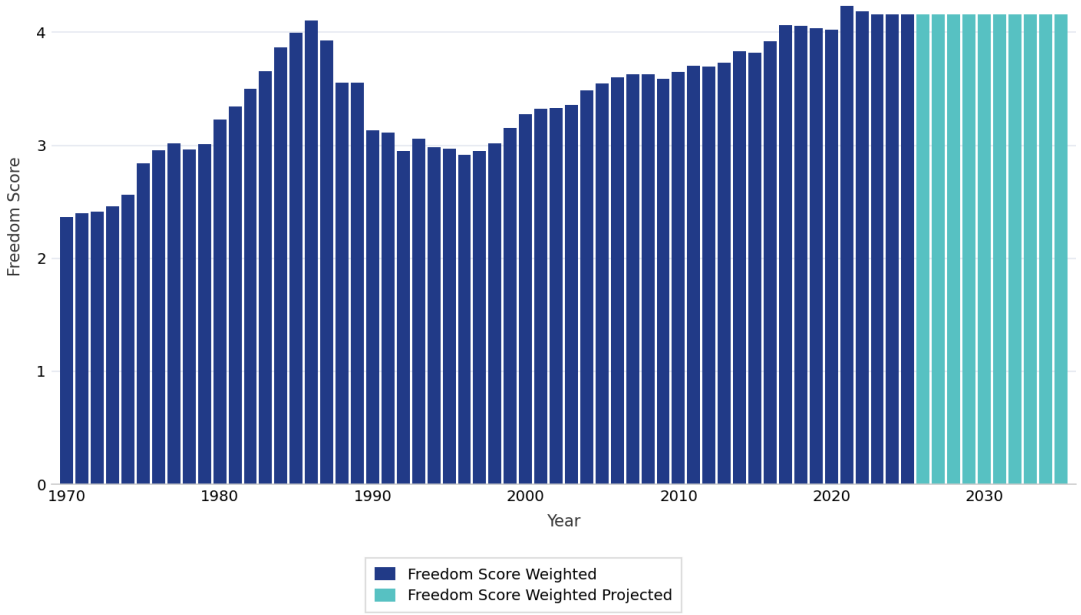


Figure A-7. Concentration of World Natural Gas Production

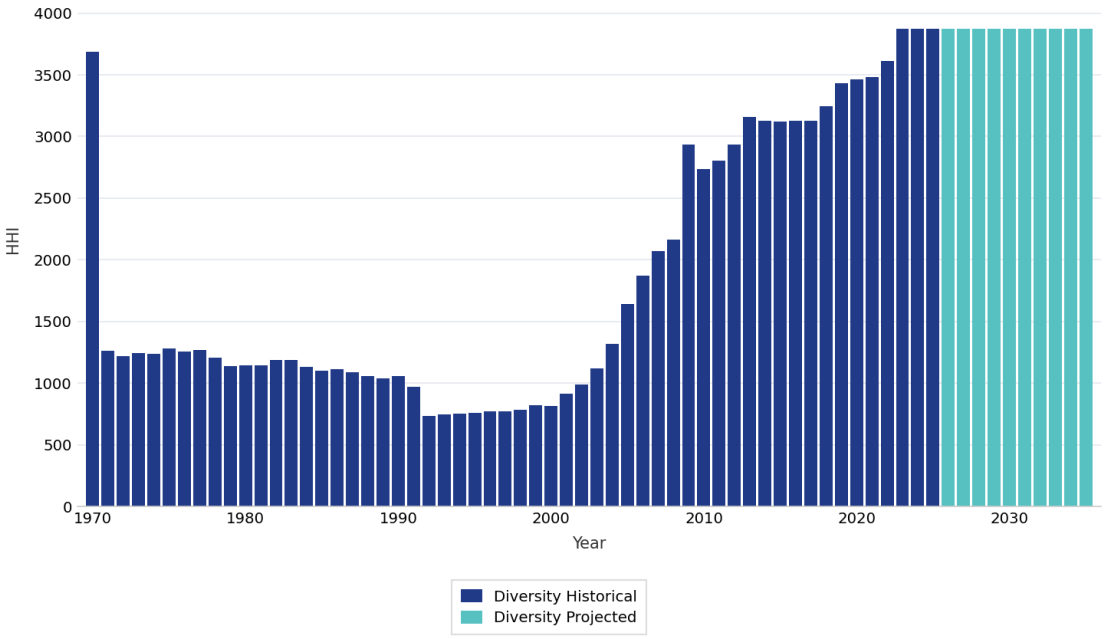
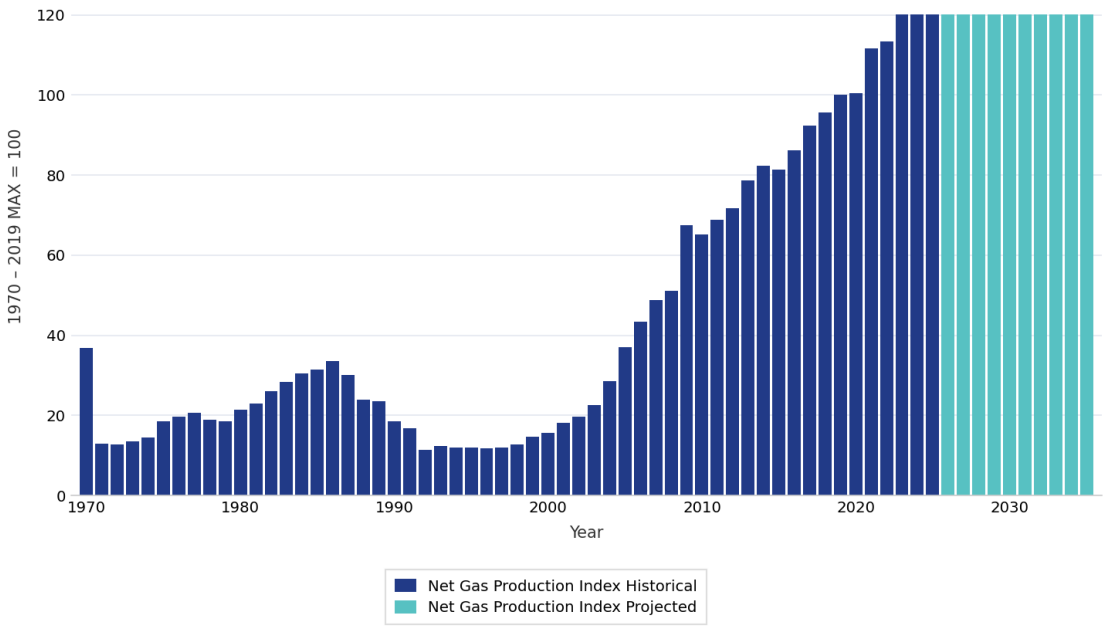


Figure A-8. World Natural Gas Production Index



Indicator	**Net Natural Gas Imports**
Indicator Group	Natural Gas
Why It Is Important	This indicates the degree to which changes in import levels expose the United States to unreliable and concentrated supplies of natural gas.
What It Measures	The volume of net natural gas imports is weighted by the reliability and diversity of global natural gas and NGPL supplies. This indicator combines: (1) the quantity of net natural gas imports as a share of natural gas demand, and (2) the level of risk tied to each cubic foot of natural gas produced globally.
How It Is Calculated	This indicator is the product of: (1) net natural gas imports as a share of demand weighted by natural gas consumption as a share of total U.S. energy consumption; and (2) the reliability and diversity of global natural gas production, excluding the United States, Canada, and Mexico and combining the Persian Gulf producers. The values were normalized so that the maximum (i.e., worst) historical value from 1970 to 2019 = 100.
Data Sources	Freedom House's Freedom in the World series; EIA's Monthly Energy Review series and International Data

Figure A-9. Risk-Weighted Net Natural Gas Imports

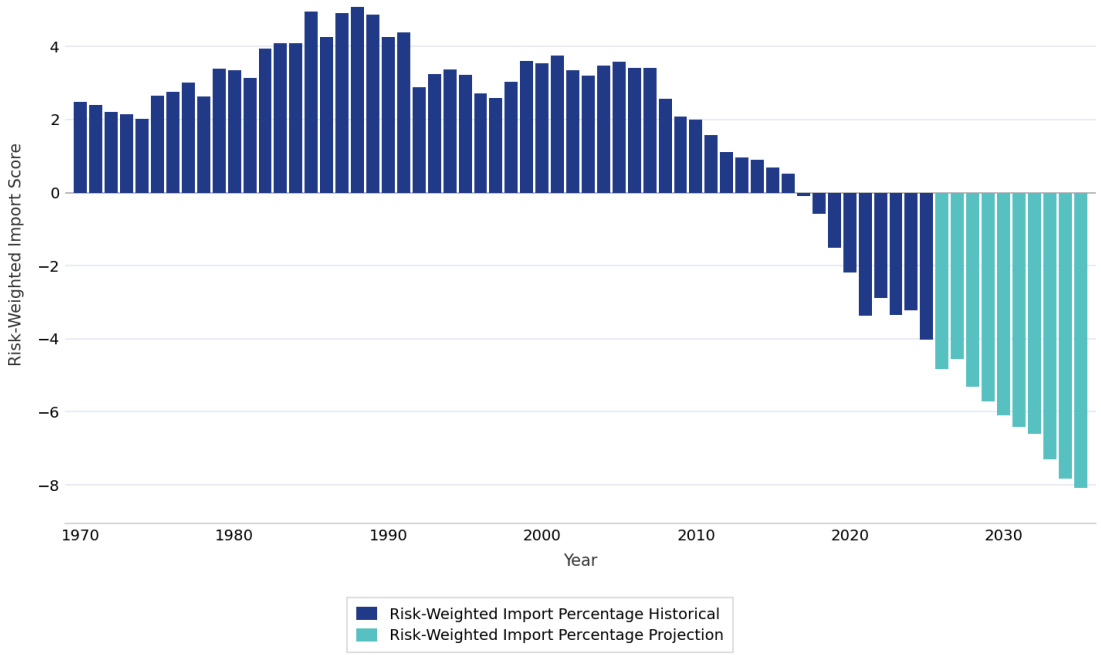
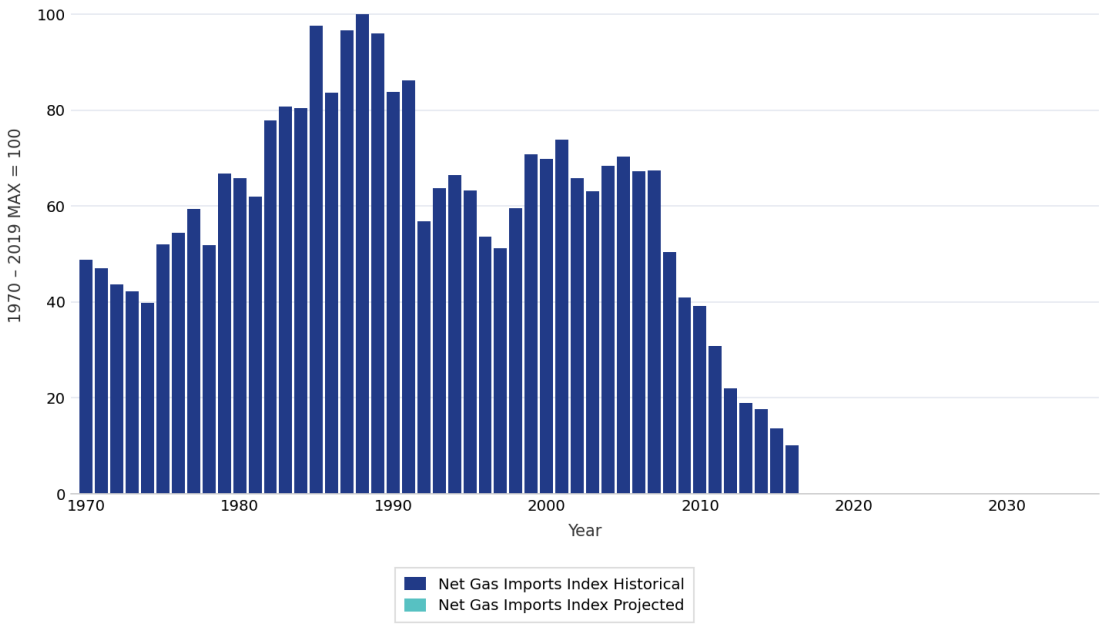


Figure A-10. Net Natural Gas Imports Index



Indicator	**Net Uranium Imports**
Indicator Group	Uranium
Why It Is Important	This indicates the degree to which changes in import levels expose the United States to unreliable and concentrated supplies of uranium.
What It Measures	The volume of net uranium imports is weighted by the reliability and diversity of global uranium supplies. This indicator combines: (1) the quantity of net uranium imports as a share of demand, and (2) the level of risk tied to each unit of uranium produced globally.
How It Is Calculated	This indicator is the product of: (1) net uranium imports as a share of nuclear plant demand weighted by nuclear energy consumption as a share of total U.S. energy consumption; and (2) the reliability and diversity of global uranium production, excluding the United States, Canada, and Mexico. The values were normalized so that the maximum (i.e., worst) historical value from 1970 to 2019 = 100.
Data Sources	Freedom House's Freedom in the World series; British Geological Survey's World Mineral Statistics series; EIA's Uranium Marketing Annual Report series

Figure A-11. Risk-Weighted Net Uranium Imports

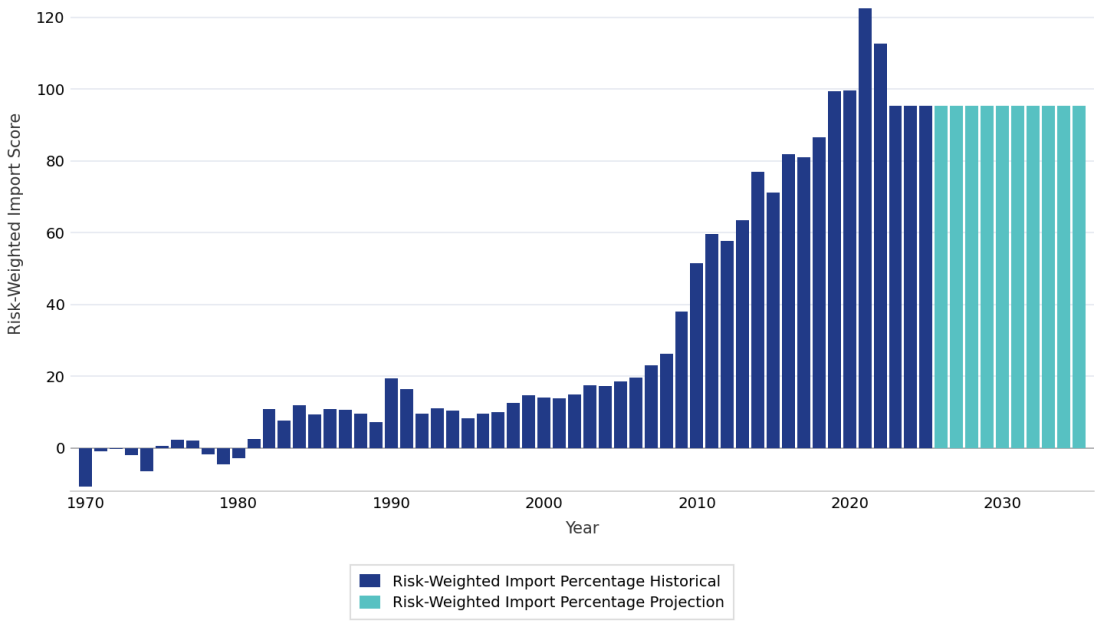
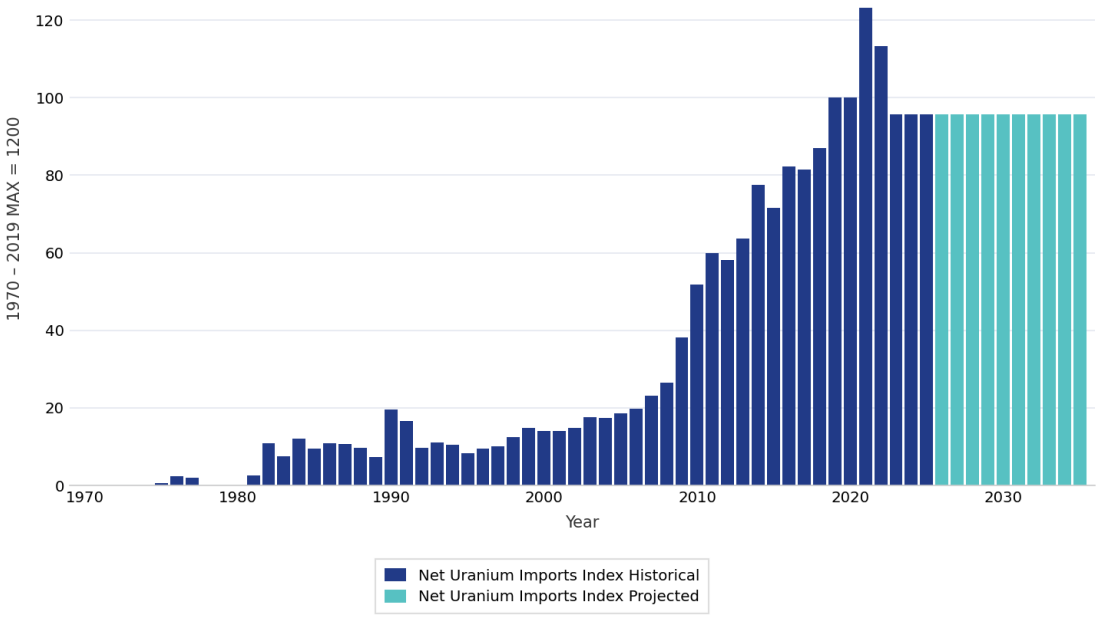


Figure A-12. Net Uranium Imports Index



Indicator	**Uranium Enrichment Services**
Indicator Group	Uranium
Why It Is Important	This indicates the degree to which foreign purchases of separative work units (SWUs) expose the U.S. nuclear industry to unreliable supplies or enriched nuclear fuel.
What It Measures	This measures the share of foreign enrichment services purchased by the total amount of enrichment services purchased.
How It Is Calculated	This indicator is the product of: (1) foreign SWUs purchased, divided by the total number of SWUs purchased; and (2) the total number of SWUs purchased. The values were normalized so that the maximum (i.e., worst) historical value from 1970 to 2019 = 100. These data begin in 1993.
Data Source	EIA's Uranium Marketing Annual Report series

Figure A-13. Uranium Enrichment Services Purchased

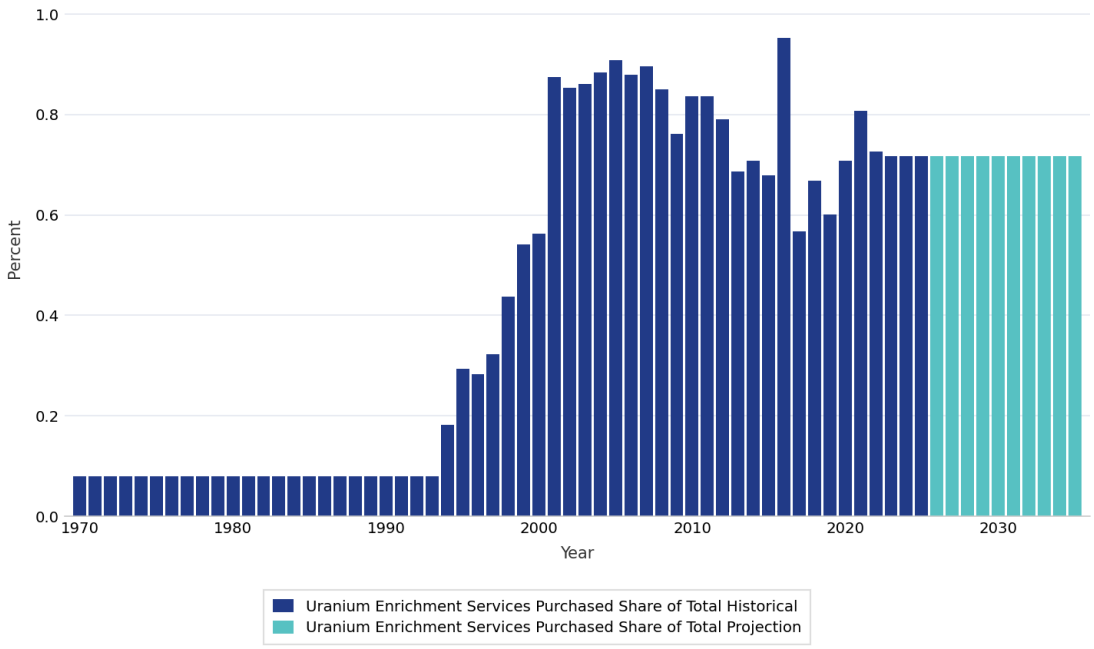
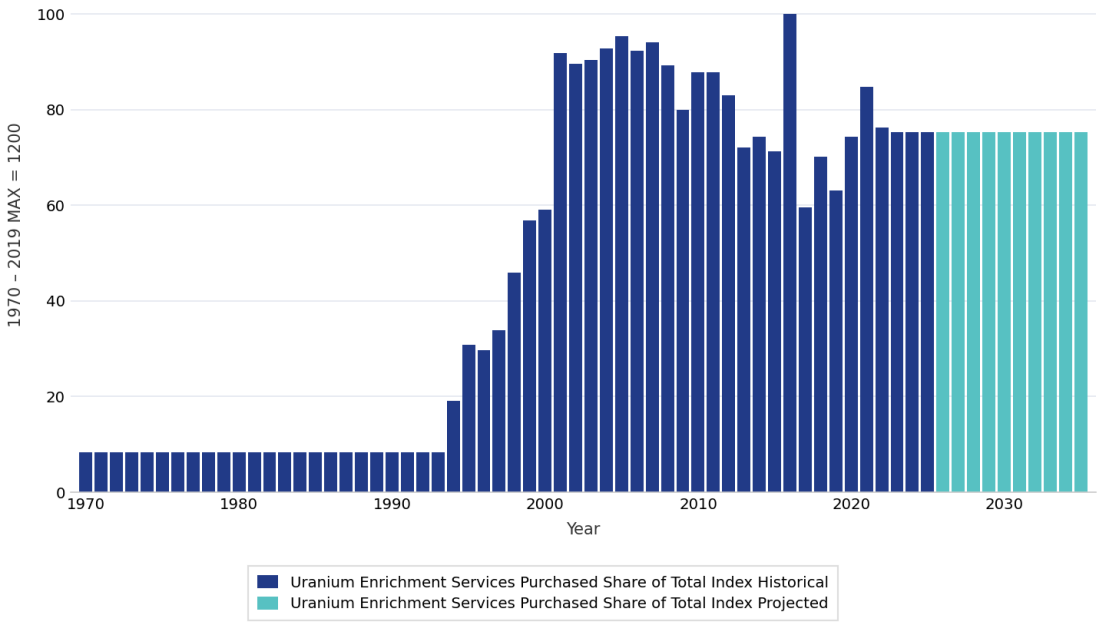


Figure A-14. Uranium Enrichment Services Index



Indicator	**Net Cobalt Imports**
Indicator Group	Energy Technology Minerals
Why It Is Important	This indicates the degree to which changes in import levels expose the United States to unreliable and concentrated supplies of cobalt.
What It Measures	The volume of net cobalt imports is weighted by the reliability and diversity of global mined cobalt supplies. This indicator combines: (1) the quantity of net cobalt imports as a share of apparent consumption, and (2) the level of risk tied to each unit of cobalt produced globally.
How It Is Calculated	This indicator is the product of: (1) net cobalt imports as a share of apparent consumption, weighted by the share of total U.S. energy consumption accounted for by electricity generation from wind and solar plus electricity for battery storage and electric vehicles; and (2) the reliability and diversity of global mined cobalt production, excluding the United States, Canada, and Mexico. The values were normalized so that the maximum (i.e., worst) historical value from 1970 to 2019 = 100.
Data Sources	Freedom House's Freedom in the World series; British Geological Survey's World Mineral Statistics series; U.S. Geological Survey's Mineral Commodity Summaries series

Figure A-15. Risk-Weighted Net Cobalt Imports

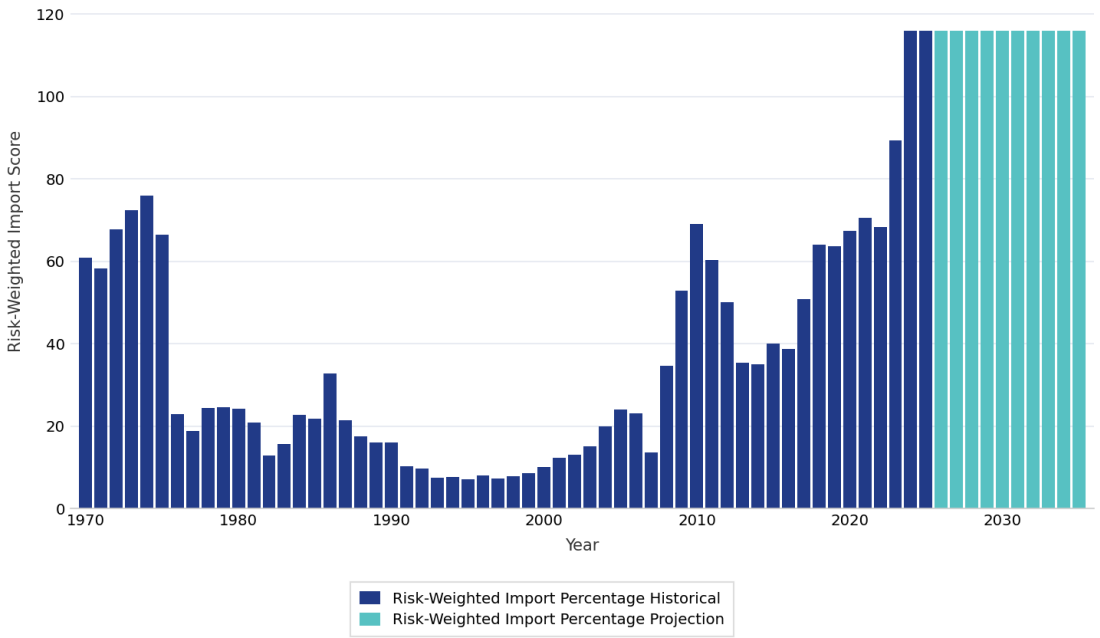
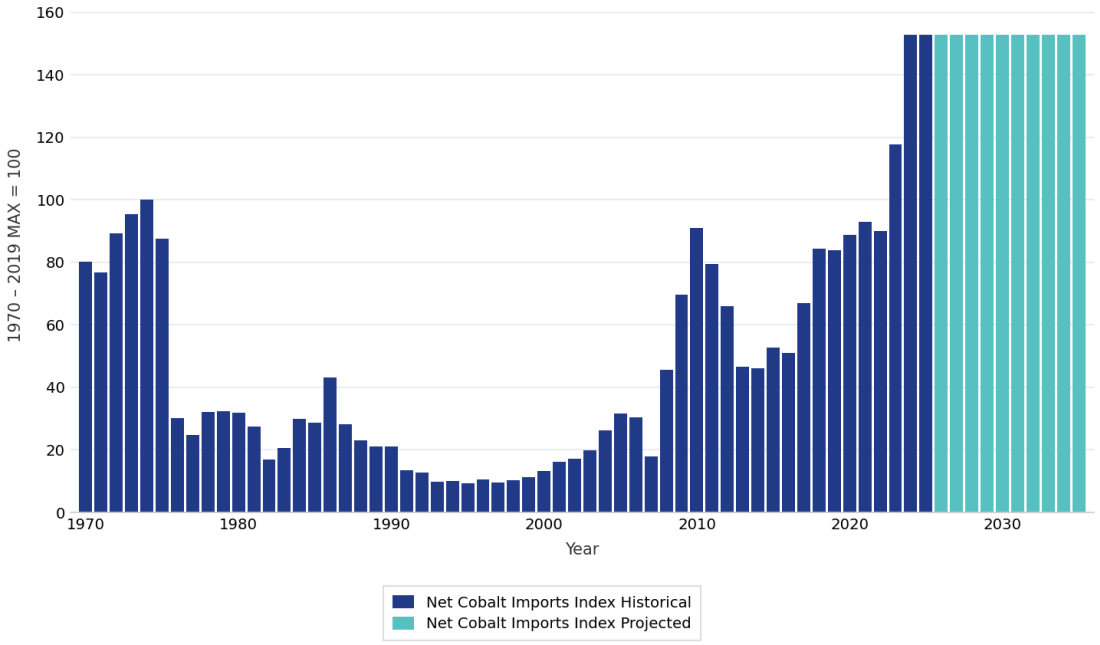


Figure A-16. Net Cobalt Imports Index



Indicator	**Net Graphite Imports**
Indicator Group	Energy Technology Minerals
Why It Is Important	This indicates the degree to which changes in import levels expose the United States to unreliable and concentrated supplies of graphite.
What It Measures	The volume of net graphite imports is weighted by the reliability and diversity of global graphite supplies. This indicator combines: (1) the quantity of net graphite imports as a share of apparent consumption, and (2) the level of risk tied to each unit of graphite produced globally.
How It Is Calculated	This indicator is the product of: (1) net graphite imports as a share of apparent consumption weighted by the share of total U.S. energy consumption accounted for by electricity generation from wind and solar plus electricity for battery storage and electric vehicles; and (2) the reliability and diversity of global graphite production, excluding the United States, Canada, and Mexico. The values were normalized so that the maximum (i.e., worst) historical value from 1970 to 2019 = 100.
Data Sources	Freedom House's Freedom in the World series; British Geological Survey's World Mineral Statistics series; U.S. Geological Survey's Mineral Commodity Summaries series

Figure A-17. Risk-Weighted Net Graphite Imports

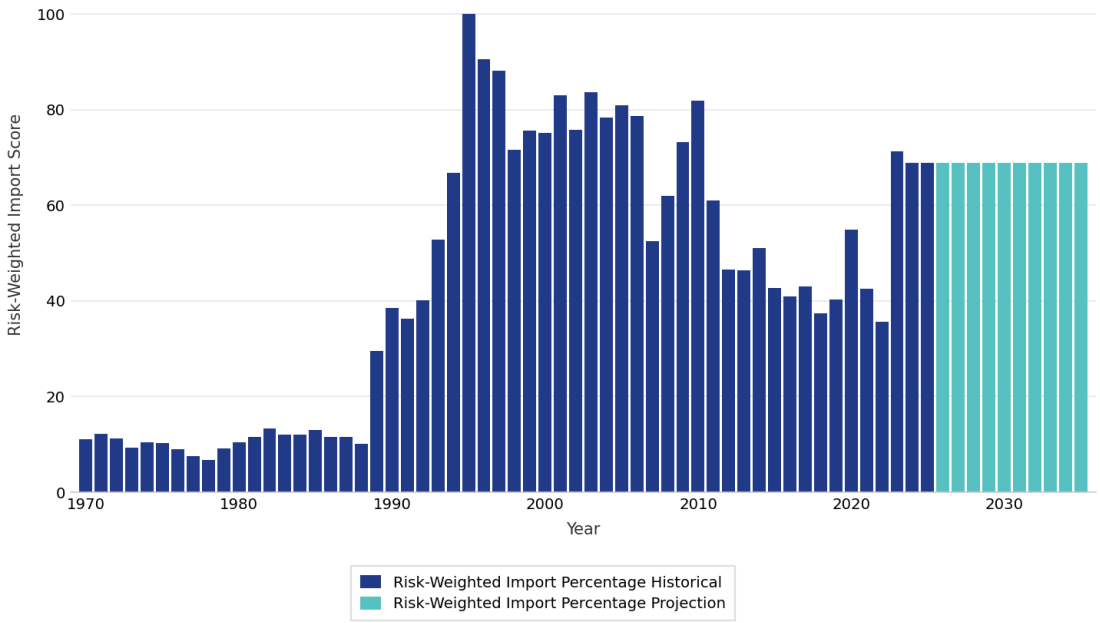
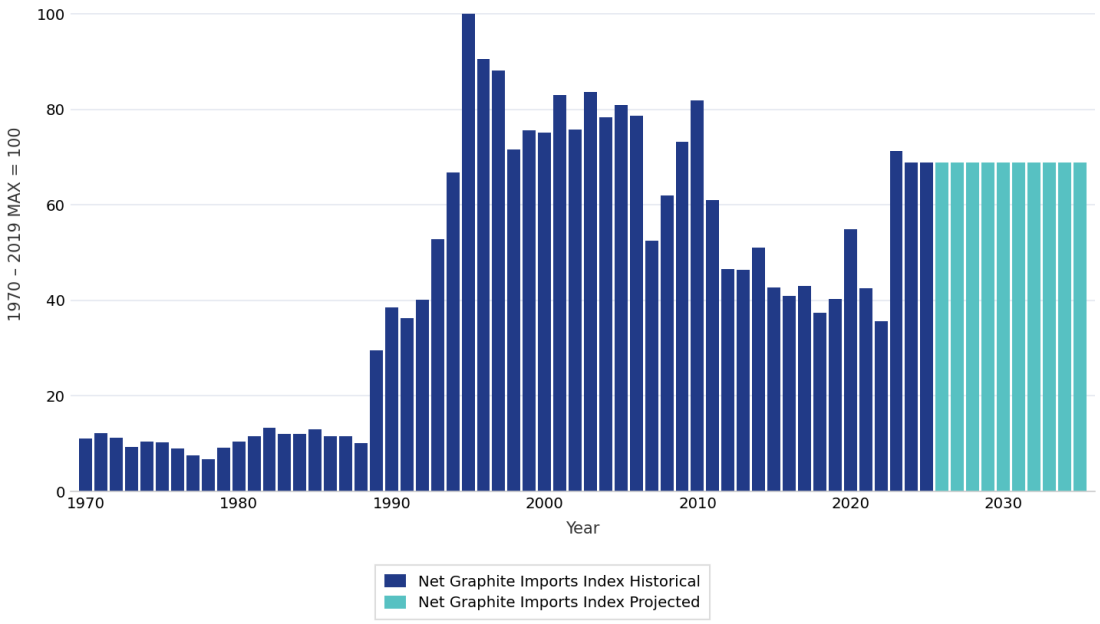


Figure A-18. Net Graphite Imports Index



Indicator	**Net Lithium Imports**
Indicator Group	Energy Technology Minerals
Why It Is Important	This indicates the degree to which changes in import levels expose the United States to unreliable and concentrated supplies of lithium.
What It Measures	The volume of net lithium imports is weighted by the reliability and diversity of global lithium mineral supplies. This indicator combines: (1) the quantity of net lithium imports as a share of apparent consumption, and (2) the level of risk tied to each unit of lithium produced globally.
How It Is Calculated	This indicator is the product of: (1) net lithium imports as a share of apparent consumption weighted by the share of total U.S. energy consumption accounted for by electricity generation from wind and solar plus electricity for battery storage and electric vehicles; and (2) the reliability and diversity of global lithium production, excluding the United States, Canada, and Mexico. The values were normalized so that the maximum (i.e., worst) historical value from 1970 to 2019 = 100.
Data Sources	Freedom House's Freedom in the World series; British Geological Survey's World Mineral Statistics series; U.S. Geological Survey's Mineral Commodity Summaries series

Figure A-19. Risk-Weighted Net Lithium Imports

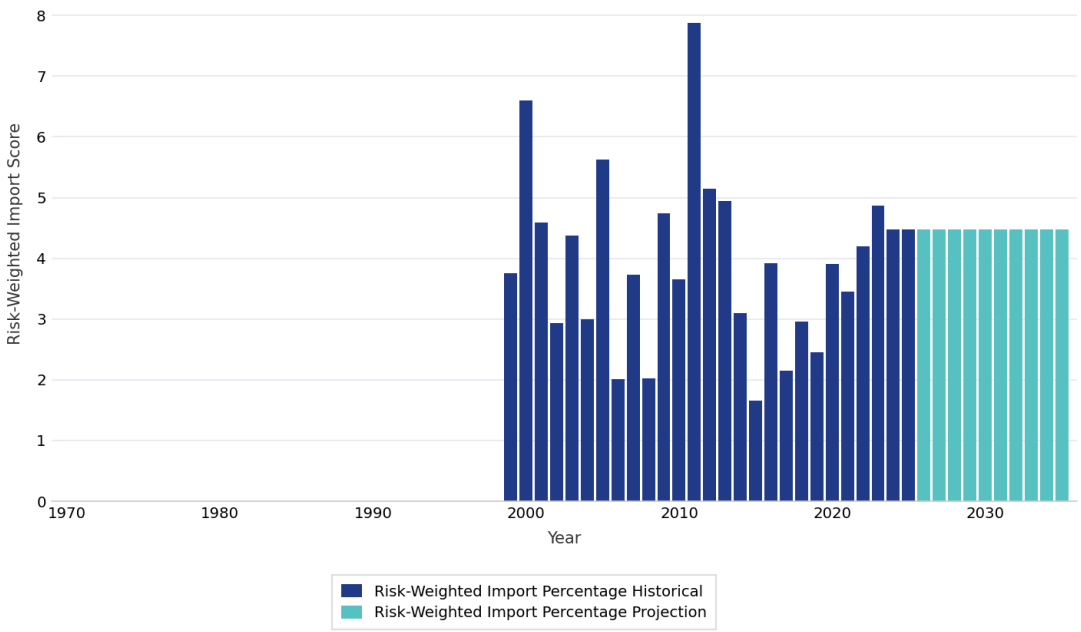
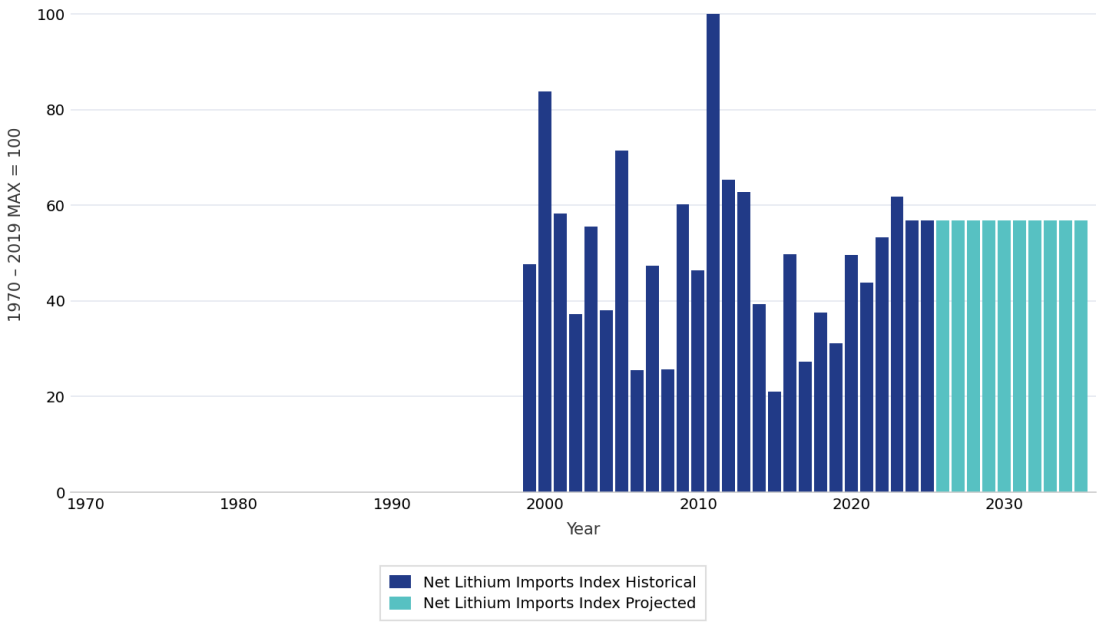


Figure A-20. Net Lithium Imports Index



Indicator	**Net Manganese Imports**
Indicator Group	Energy Technology Minerals
Why It Is Important	This indicates the degree to which changes in import levels expose the United States to unreliable and concentrated supplies of manganese.
What It Measures	The volume of net manganese imports is weighted by the reliability and diversity of global manganese ore supplies. This indicator combines: (1) the quantity of net manganese imports as a share of apparent consumption, and (2) the level of risk tied to each unit of manganese ore produced globally.
How It Is Calculated	This indicator is the product of: (1) net manganese imports as a share of apparent consumption weighted by the share of total U.S. energy consumption accounted for by electricity generation from wind and solar plus electricity for battery storage and electric vehicles; and (2) the reliability and diversity of global manganese ore production, excluding the United States, Canada, and Mexico. The values were normalized so that the maximum (i.e., worst) historical value from 1970 to 2019 = 100.
Data Sources	Freedom House's Freedom in the World series; British Geological Survey's World Mineral Statistics series; U.S. Geological Survey's Mineral Commodity Summaries series

Figure A-21. Risk-Weighted Net Manganese Imports

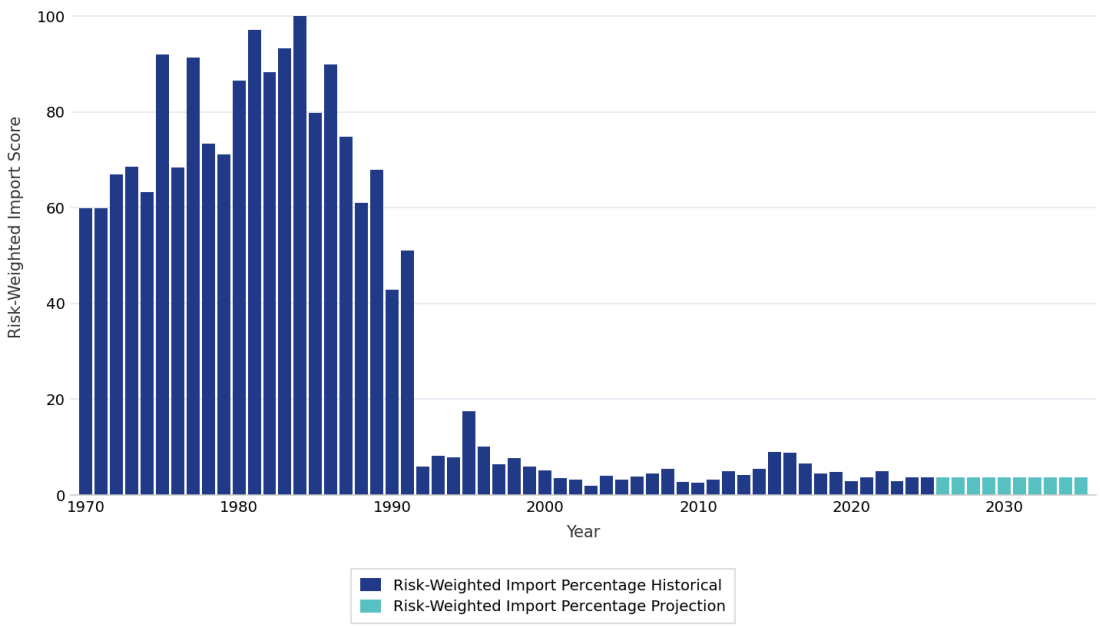
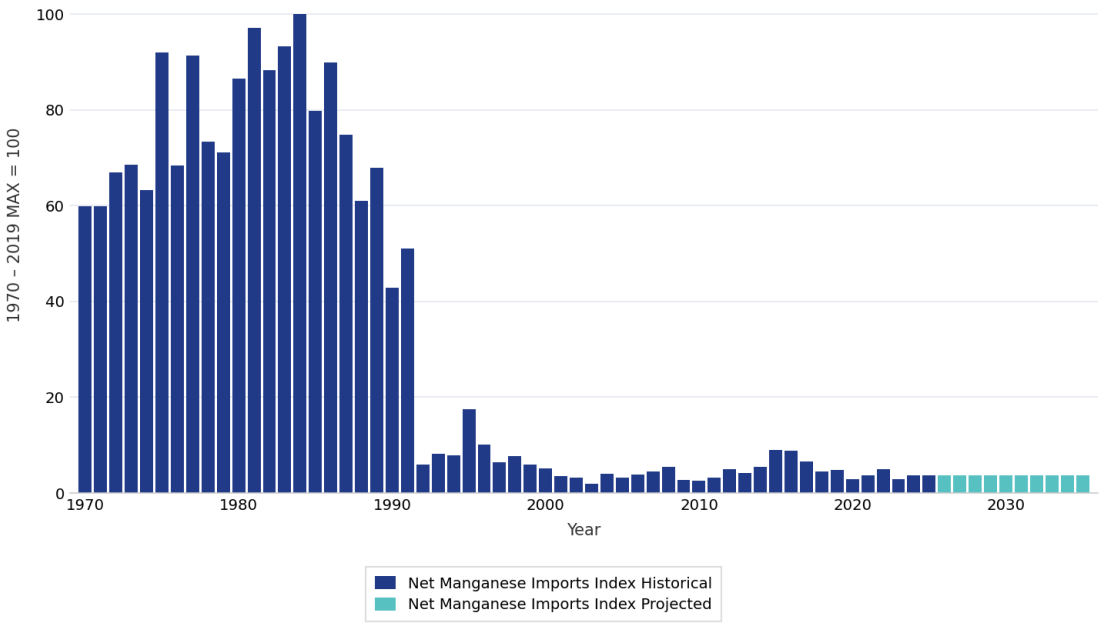


Figure A-22. Net Manganese Imports Index



Indicator	**Net Rare Earths Imports**
Indicator Group	Energy Technology Minerals
Why It Is Important	This indicates the degree to which changes in import levels expose the United States to unreliable and concentrated supplies of rare earths.
What It Measures	The volume of net rare earths imports is weighted by the reliability and diversity of global rare earths mineral supplies. This indicator combines: (1) the quantity of net rare earths imports as a share of apparent consumption, and (2) the level of risk tied to each unit of rare earths minerals produced globally.
How It Is Calculated	This indicator is the product of: (1) net rare earths imports as a share of apparent consumption weighted by the share of total U.S. energy consumption accounted for by electricity generation from wind and solar plus electricity for battery storage and electric vehicles; and (2) the reliability and diversity of global rare earths mineral production, excluding the United States, Canada, and Mexico. The values were normalized so that the maximum (i.e., worst) historical value from 1970 to 2019 = 100.
Data Sources	Freedom House's Freedom in the World series; British Geological Survey's World Mineral Statistics series; U.S. Geological Survey's Mineral Commodity Summaries series

Figure A-23. Risk-Weighted Net Rare Earths Imports

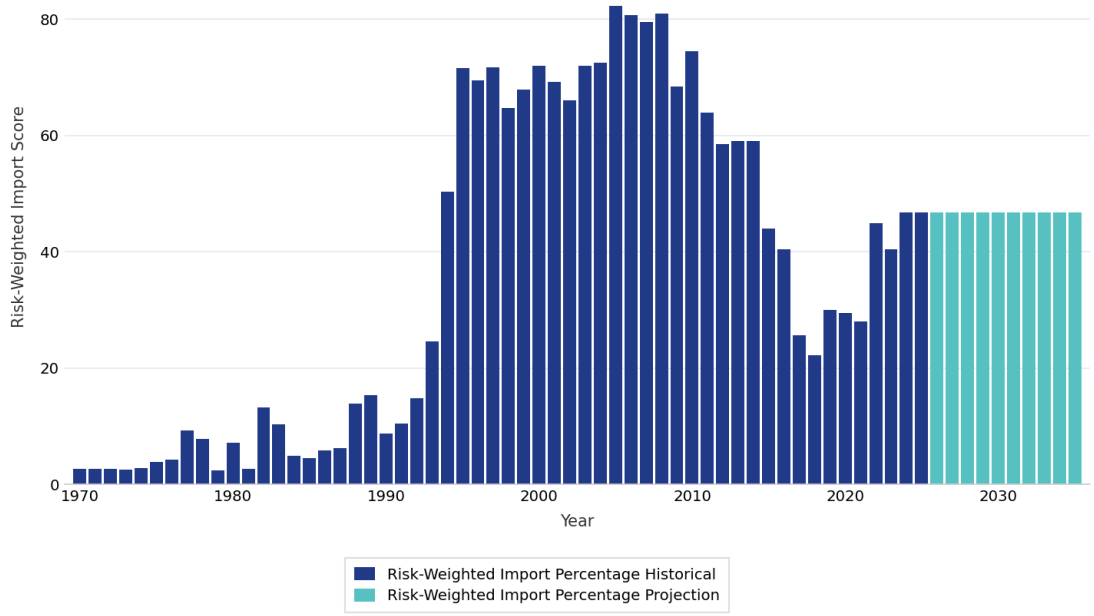
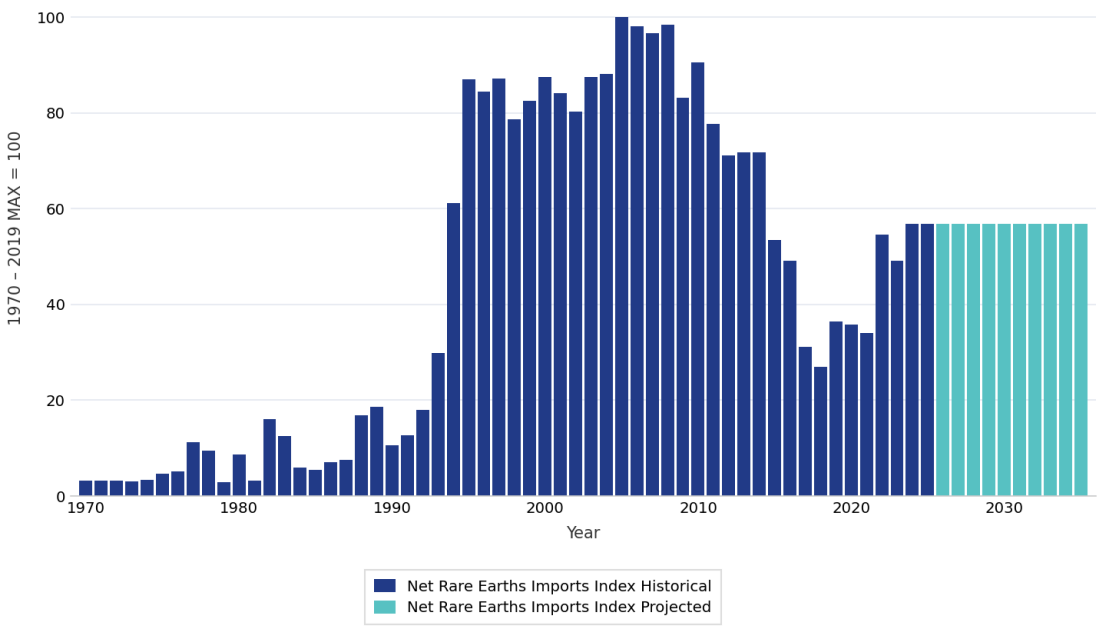


Figure A-24. Net Rare Earths Imports Index



Indicator	**Net Aluminum Imports**
Indicator Group	Energy Infrastructure Minerals
Why It Is Important	This indicates the degree to which changes in import levels expose the United States to unreliable and concentrated supplies of aluminum.
What It Measures	The volume of net aluminum imports is weighted by the reliability and diversity of global primary aluminum supplies. This indicator combines: (1) the quantity of net aluminum imports as a share of apparent consumption, and (2) the level of risk tied to each unit of primary aluminum produced globally.
How It Is Calculated	This indicator is the product of: (1) net aluminum imports as a share of apparent consumption weighted by energy industries (including oil and gas extraction; utilities; electrical equipment, appliances, and components; and petroleum and coal products) as a share of U.S. GDP; and (2) the reliability and diversity of global aluminum mineral production, excluding the United States, Canada, and Mexico. The values were normalized so that the maximum (i.e., worst) historical value from 1970 to 2019 = 100.
Data Sources	Freedom House's Freedom in the World series; British Geological Survey's World Mineral Statistics series; U.S. Geological Survey's Mineral Commodity Summaries series

Figure A-25. Risk-Weighted Net Aluminum Imports

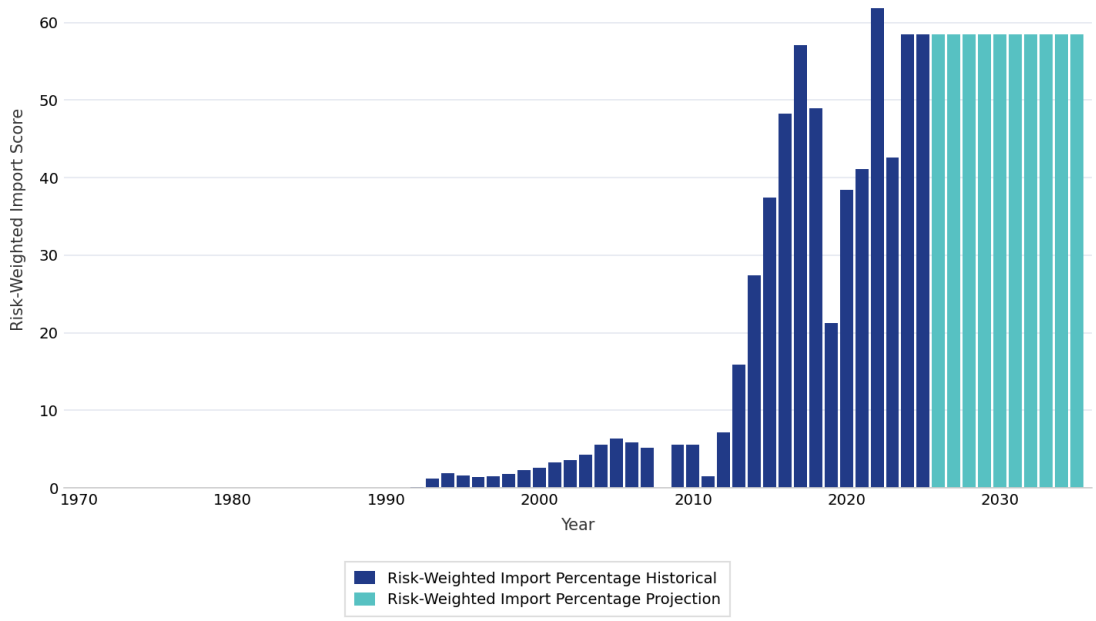
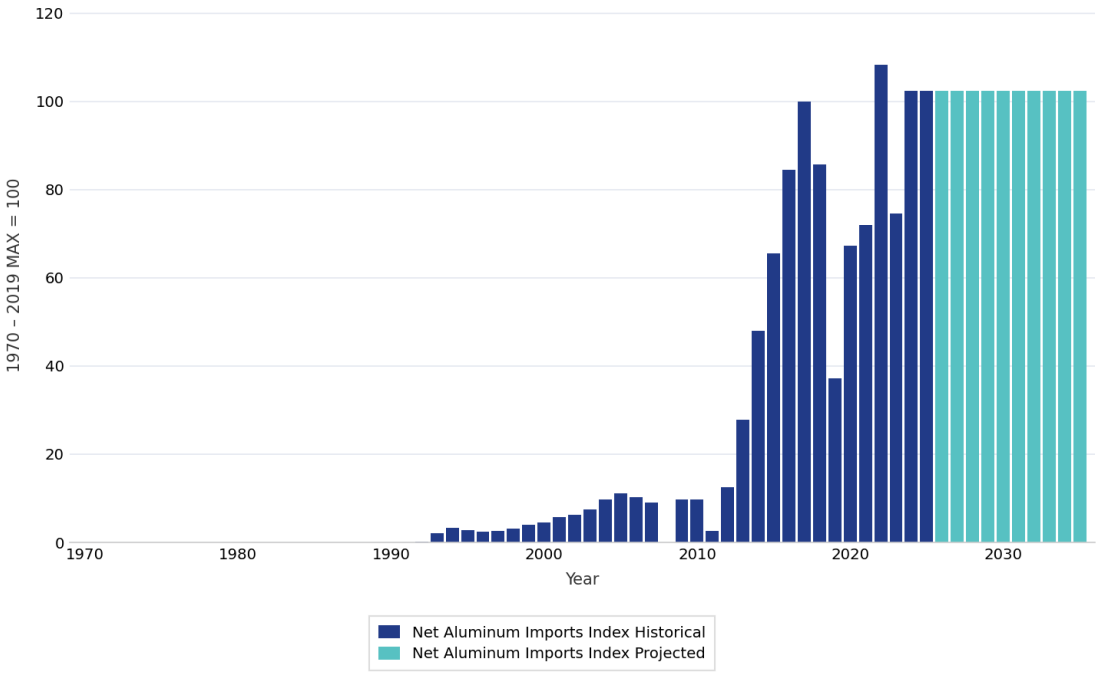


Figure A-26. Net Aluminum Imports Index



Indicator	**Net Copper Imports**
Indicator Group	Energy Infrastructure Minerals
Why It Is Important	This indicates the degree to which changes in import levels expose the United States to unreliable and concentrated supplies of copper.
What It Measures	The volume of net copper imports is weighted by the reliability and diversity of global mined copper supplies. This indicator combines: (1) the quantity of net copper imports as a share of apparent consumption, and (2) the level of risk tied to each unit of mined copper produced globally.
How It Is Calculated	This indicator is the product of: (1) net copper imports as a share of apparent consumption weighted by energy industries (including oil and gas extraction; utilities; electrical equipment, appliances, and components; and petroleum and coal products) as a share of U.S. GDP; and (2) the reliability and diversity of global copper mineral production, excluding the United States, Canada, and Mexico. The values were normalized so that the maximum (i.e., worst) historical value from 1970 to 2019 = 100.
Data Sources	Freedom House's Freedom in the World series; British Geological Survey's World Mineral Statistics series; U.S. Geological Survey's Mineral Commodity Summaries series

Figure A-27. Risk-Weighted Net Copper Imports

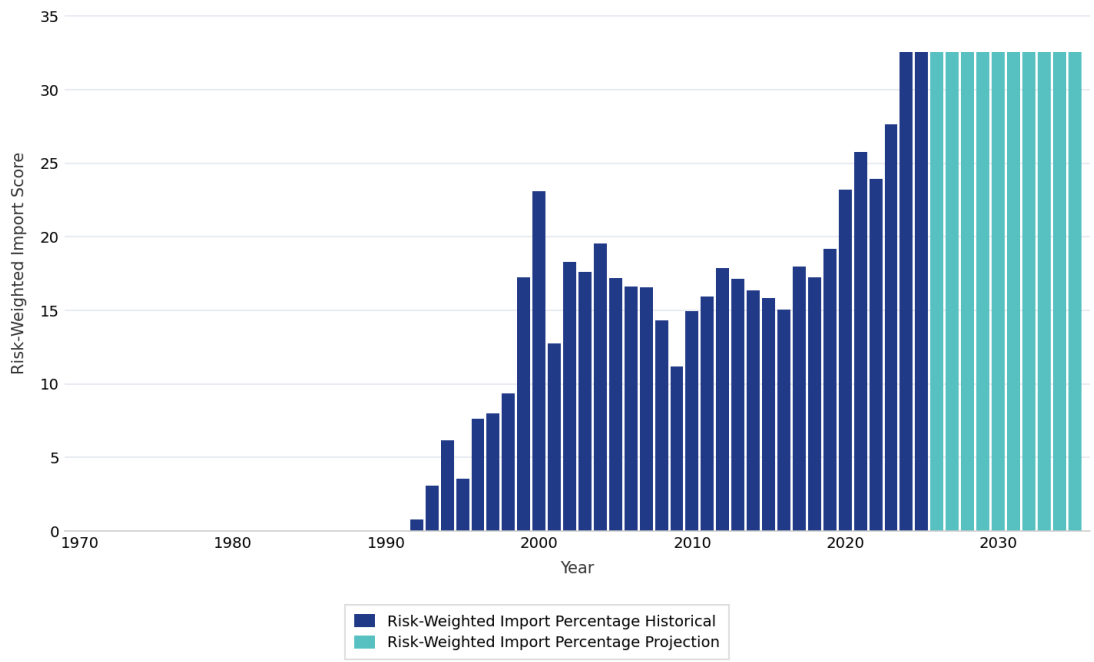
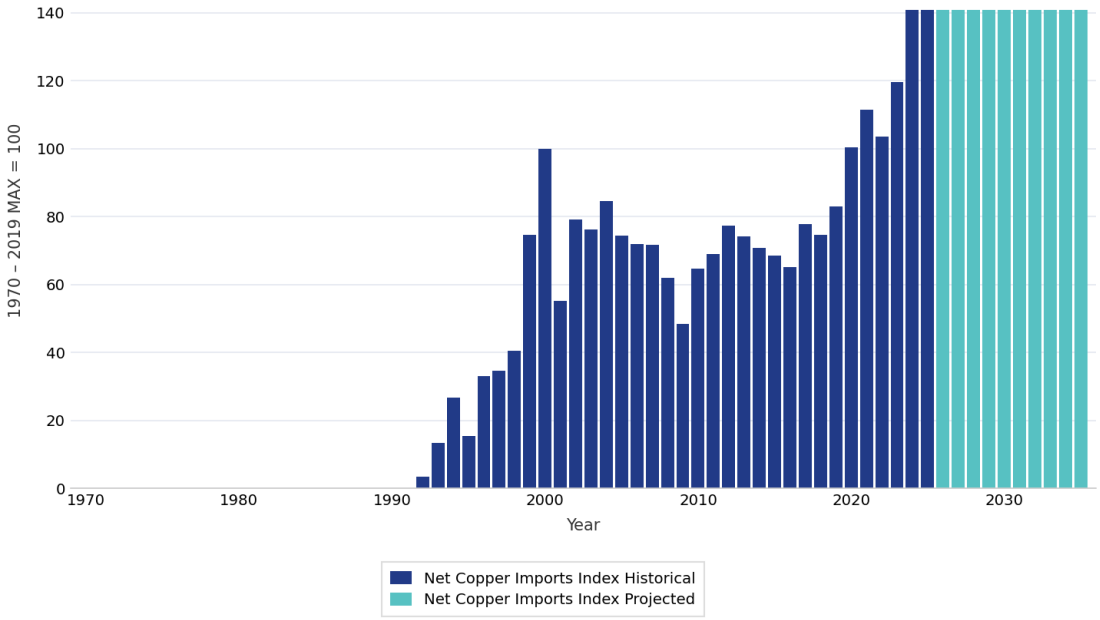


Figure A-28. Net Copper Imports Index



Indicator	**Net Nickel Imports**
Indicator Group	Energy Infrastructure Minerals
Why It Is Important	This indicates the degree to which changes in import levels expose the United States to unreliable and concentrated supplies of nickel.
What It Measures	The volume of net nickel imports is weighted by the reliability and diversity of global mined nickel supplies. This indicator combines: (1) the quantity of net nickel imports as a share of apparent consumption, and (2) the level of risk tied to each unit of mined nickel produced globally.
How It Is Calculated	This indicator is the product of: (1) net nickel imports as a share of apparent consumption weighted by energy industries (including oil and gas extraction; utilities; electrical equipment, appliances, and components; and petroleum and coal products) as a share of U.S. GDP; and (2) the reliability and diversity of global nickel ore production, excluding the United States, Canada, and Mexico. The values were normalized so that the maximum (i.e., worst) historical value from 1970 to 2019 = 100.
Data Sources	Freedom House's Freedom in the World series; British Geological Survey's World Mineral Statistics series; U.S. Geological Survey's Mineral Commodity Summaries series

Figure A-29. Risk-Weighted Net Nickel Imports

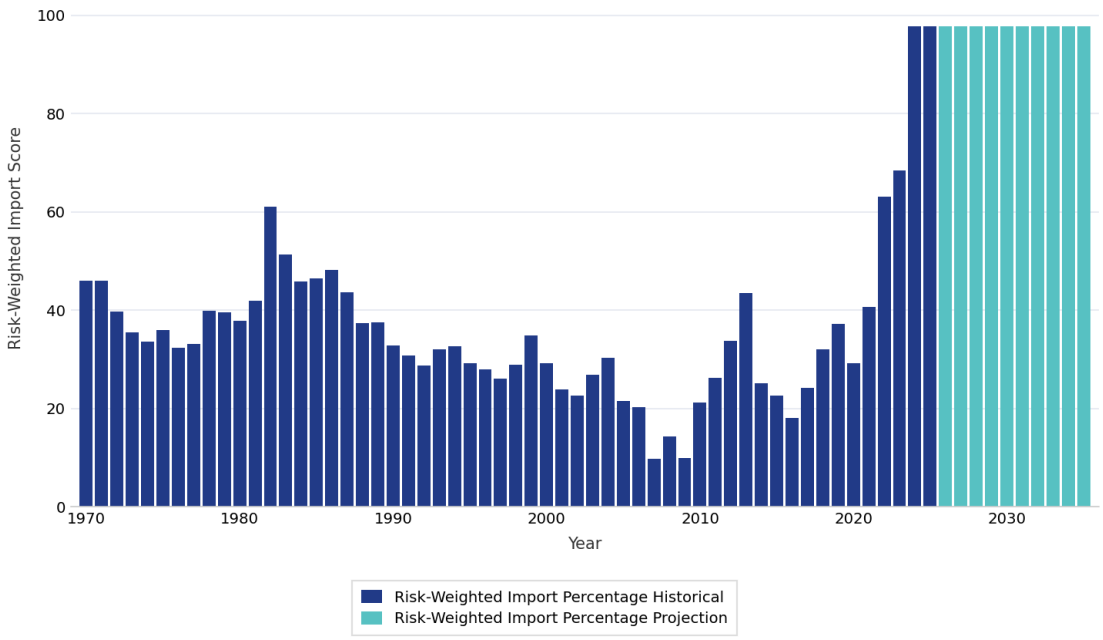
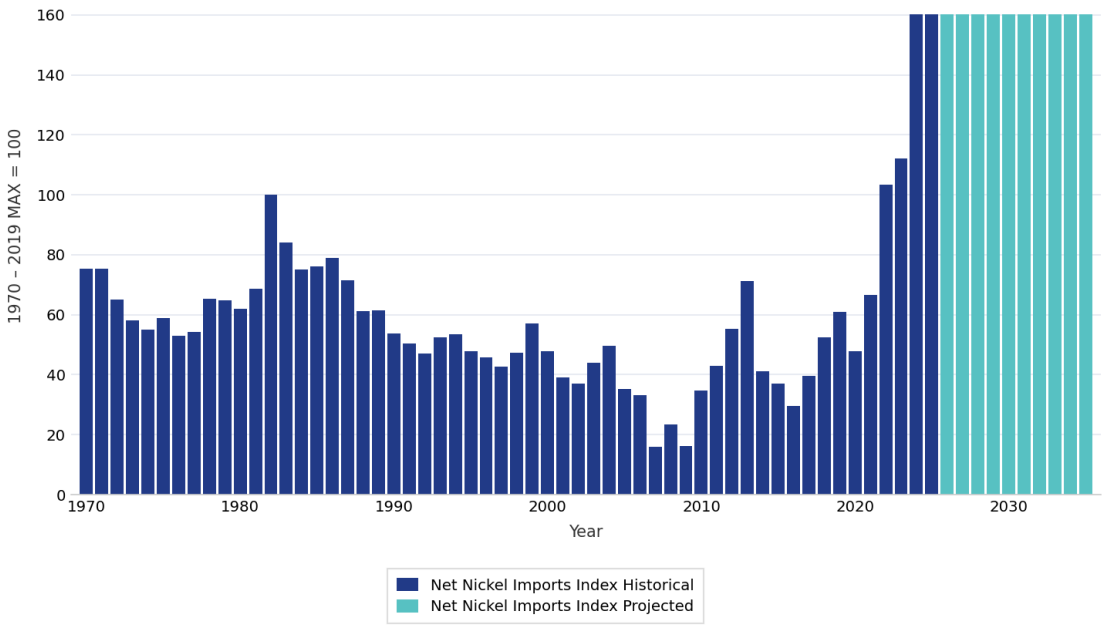


Figure A-30 Net Nickel Imports Index



Indicator	**Net Steel Imports**
Indicator Group	Energy Infrastructure Minerals
Why It Is Important	This indicates the degree to which changes in import levels expose the United States to unreliable and concentrated supplies of steel.
What It Measures	The volume of net steel imports is weighted by the reliability and diversity of global crude steel supplies. This indicator combines: (1) the quantity of net steel imports as a share of apparent consumption, and (2) the level of risk tied to each unit of crude steel produced globally.
How It Is Calculated	This indicator is the product of: (1) net steel imports as a share of apparent consumption weighted by energy industries (including oil and gas extraction; utilities; electrical equipment, appliances, and components; and petroleum and coal products) as a share of U.S. GDP; and (2) the reliability and diversity of global steel mineral production, excluding the United States, Canada, and Mexico. The values were normalized so that the maximum (i.e., worst) historical value from 1970 to 2019 = 100.
Data Sources	Freedom House's Freedom in the World series; British Geological Survey's World Mineral Statistics series; U.S. Geological Survey's Mineral Commodity Summaries series

Figure A-31. Risk-Weighted Steel Imports

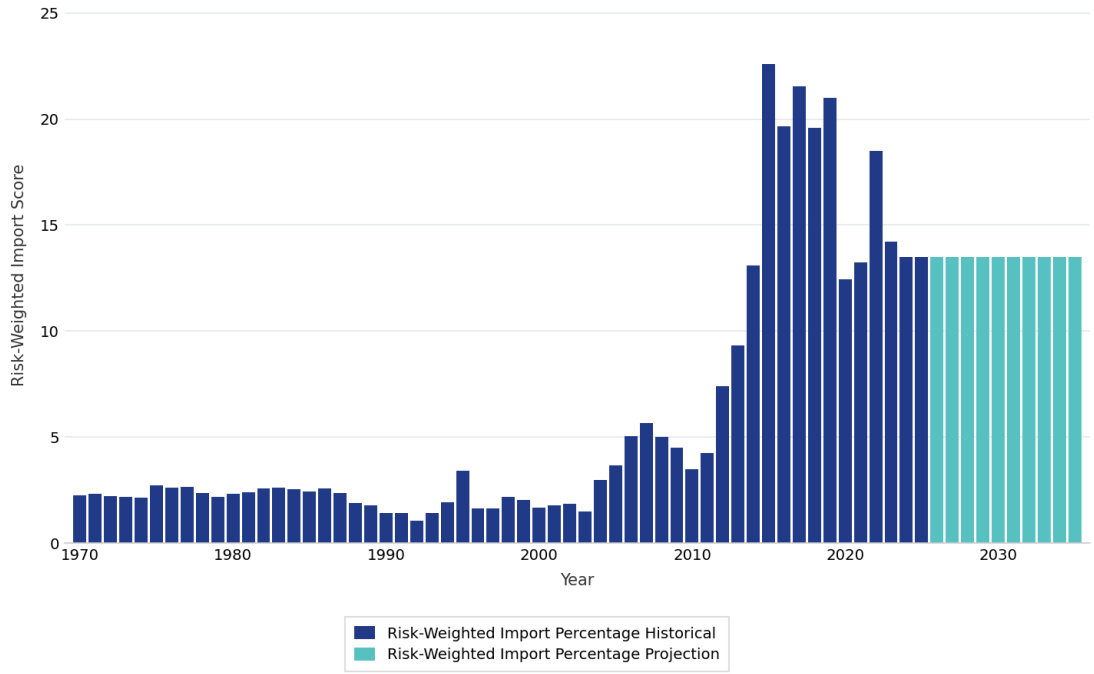
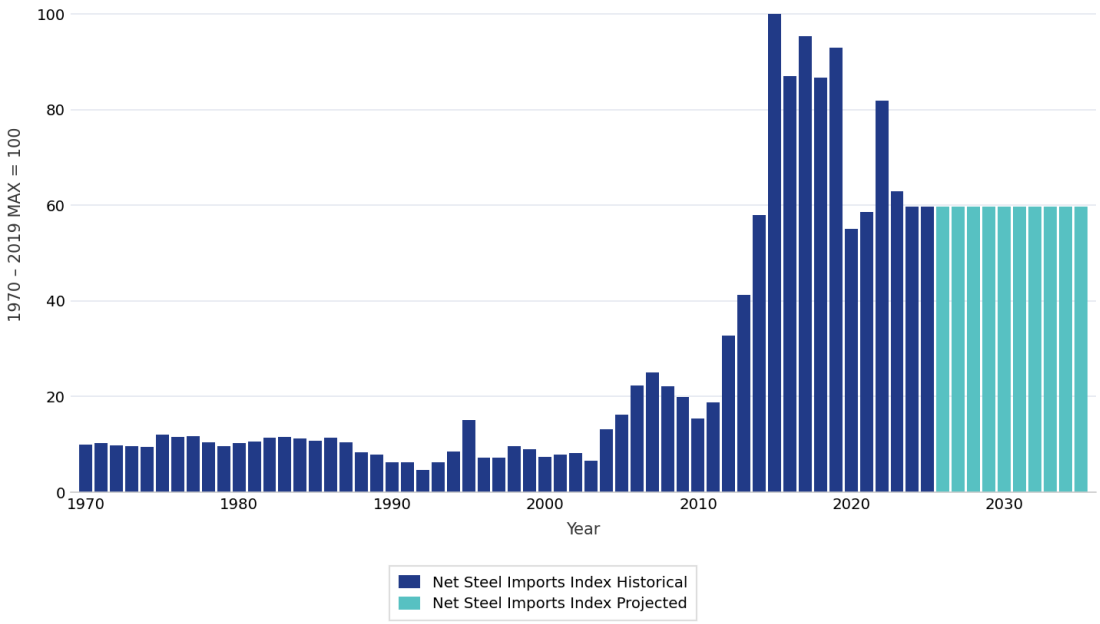


Figure A-32. Net Steel Imports Index



Indicator	**Cybersecurity**
Indicator Group	Systemic
Why It Is Important	This indicates the degree to which U.S. energy infrastructure is vulnerable to cyberattacks.
What It Measures	This measures physical and cyberattacks, or threats against the grid, as reported by utilities to the Department of Energy since 2012.
How It Is Calculated	The values were normalized so that the maximum (i.e., worst) historical value from 1970 to 2019 = 100.
Data Source	U.S. Department of Energy

Figure A-33. Cyberattacks

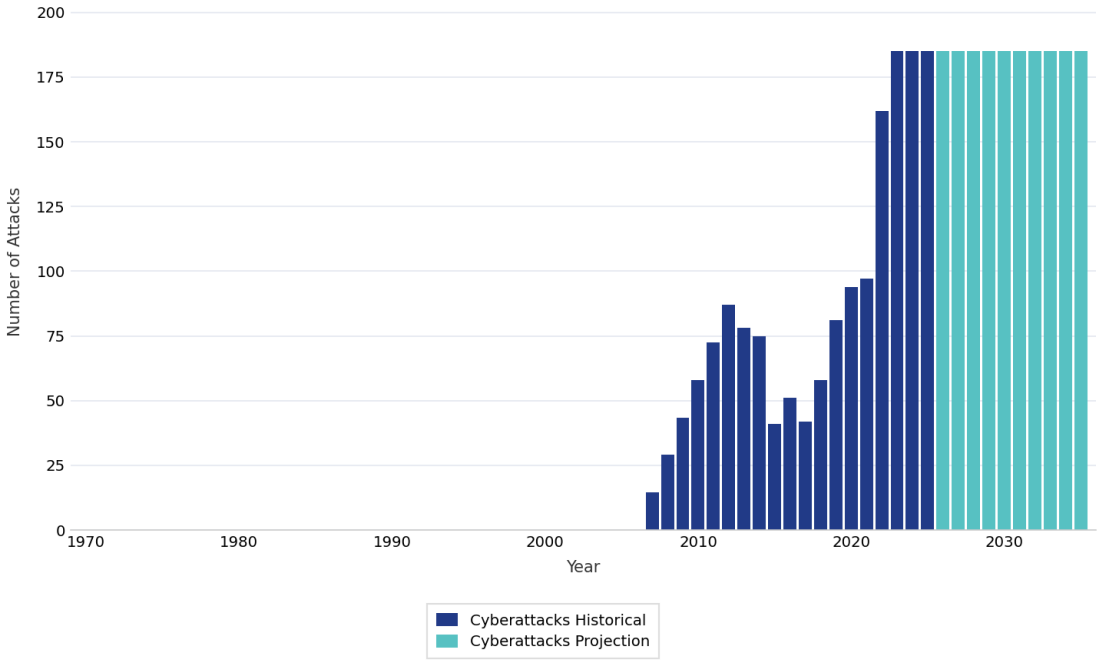
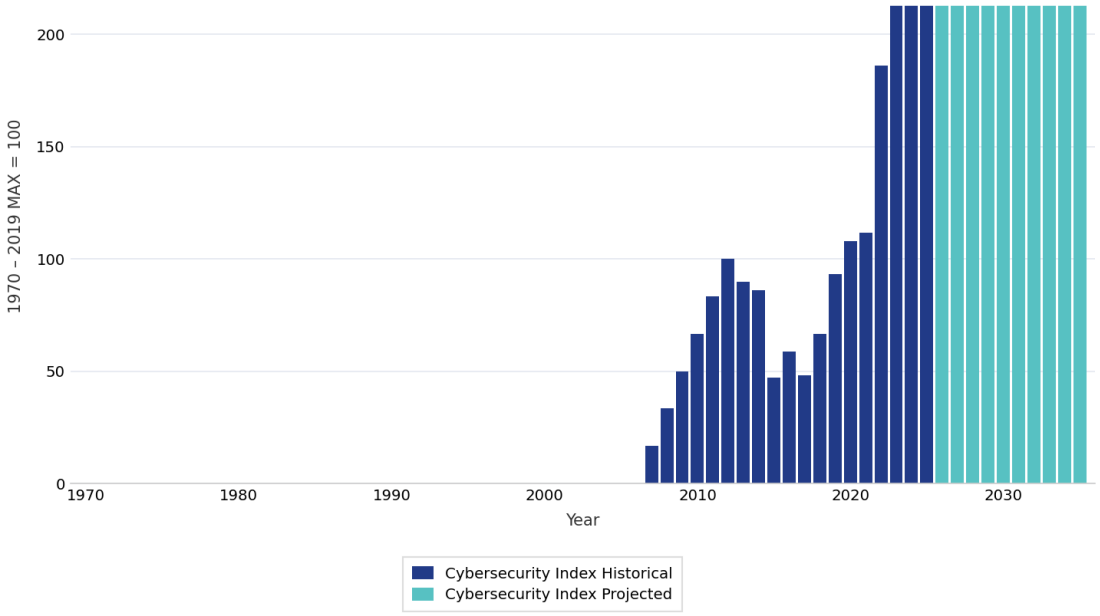


Figure A-34. Cybersecurity Index



Indicator	**Crude Oil Price Volatility**
Indicator Group	Systemic
Why It Is Important	This indicates the vulnerability of the U.S. to large swings in the price of crude oil.
What It Measures	This measures the three-year rolling average of the absolute change in the price of a barrel of crude oil from the previous year: (1) in 2024 dollars, and (2) as a share of the price.
How It Is Calculated	The values and share histories were normalized so that the maximum (i.e., worst) historical value from 1970 to 2019 = 100. The annual average of these was then normalized using the same procedure.
Data Sources	EIA's Petroleum & Other Liquids dataset and Monthly Energy Review series

Figure A-35. Absolute Crude Oil Price Volatility

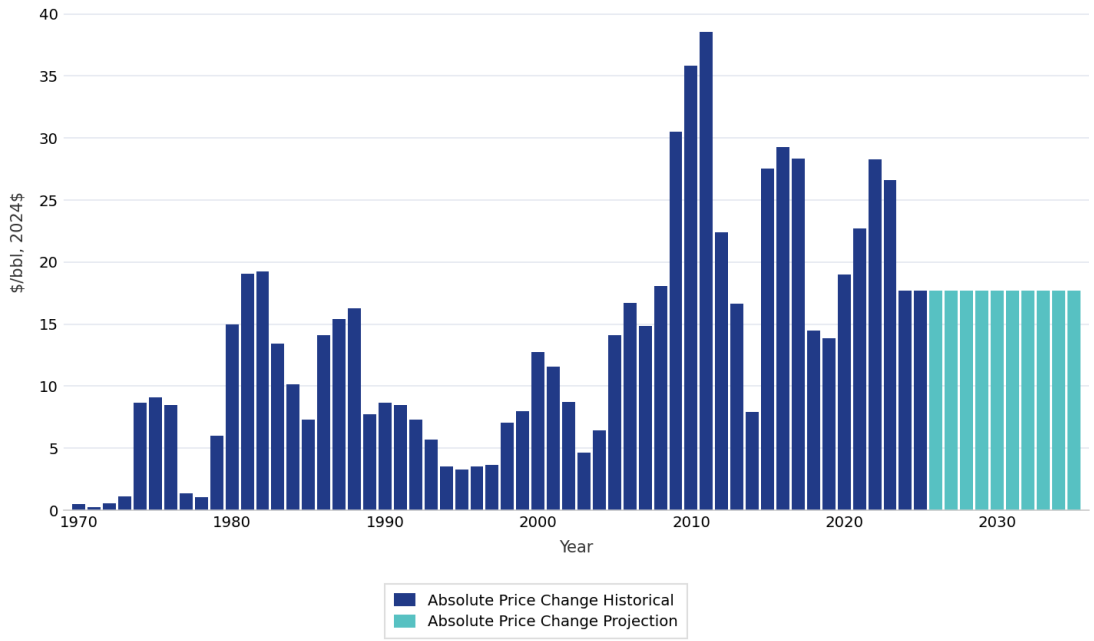


Figure A-36. Crude Oil Price Volatility as Share of Price

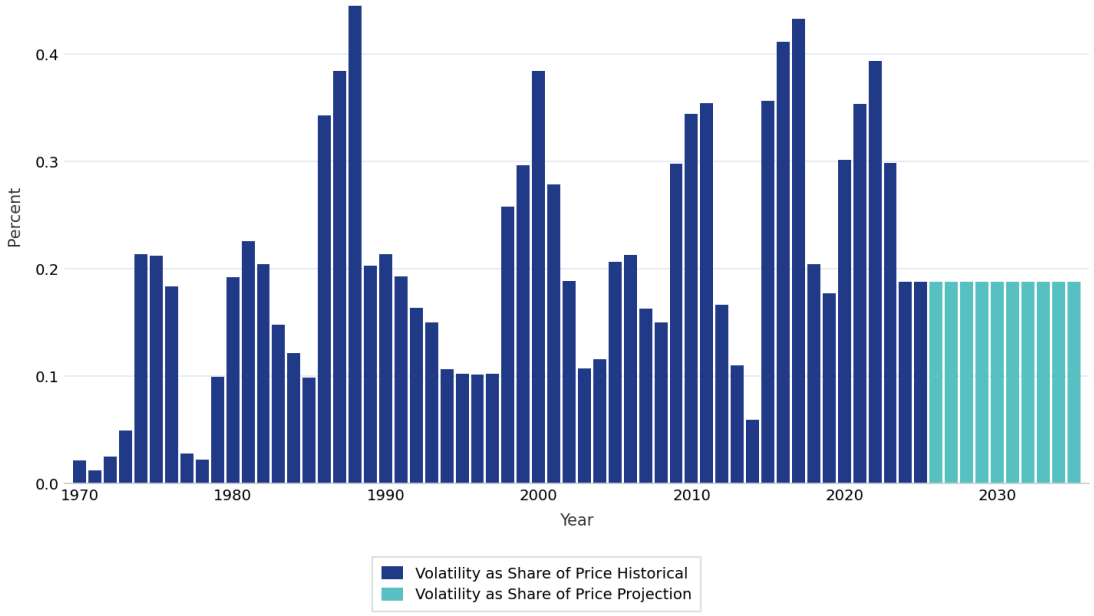
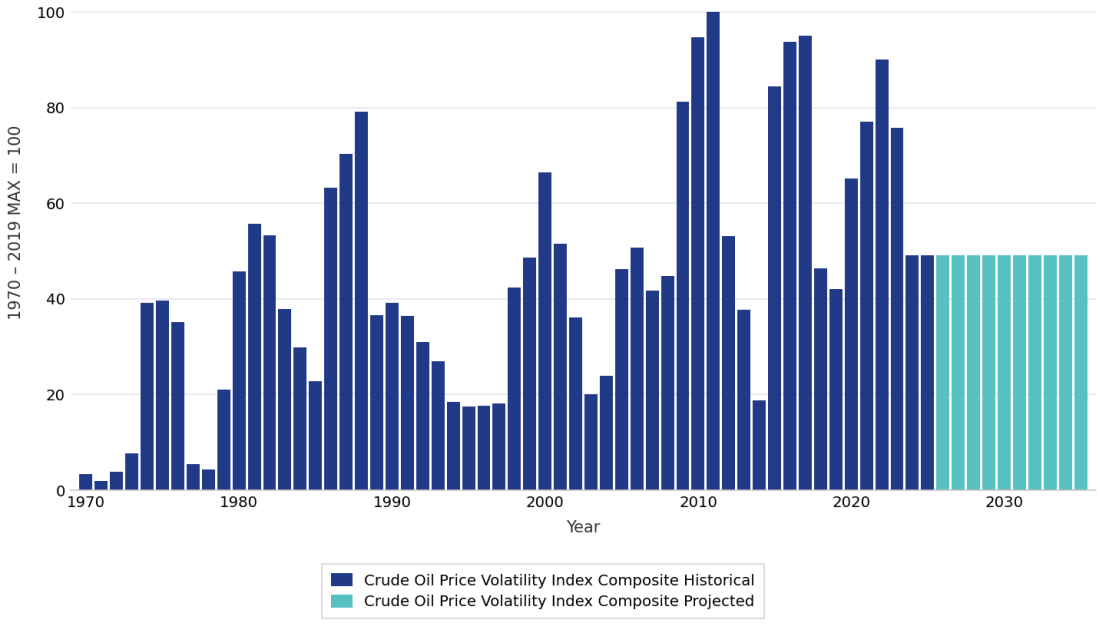


Figure A-37. Crude Oil Price Volatility Index



Indicator	**Strategic Petroleum Reserve Stocks**
Indicator Group	Systemic
What It Measures	This measures the number of days of average refinery crude oil inputs held in the Strategic Petroleum Reserve (SPR).
How It Is Calculated	The risks measured by SPR stock levels move in the opposite direction from the indicator. The indicator was normalized so that SPR supplies for less than seven days were assigned a maximum score of 100. The time series was then inverted.
Why It Is Important	This indicates susceptibility of the U.S. to a crude oil supply disruption, based on the quantity of stockpiled crude oil available to be drawn down during an emergency.
Data Source	EIA's Monthly Energy Review series

Figure A-38. Strategic Petroleum Reserve Stocks

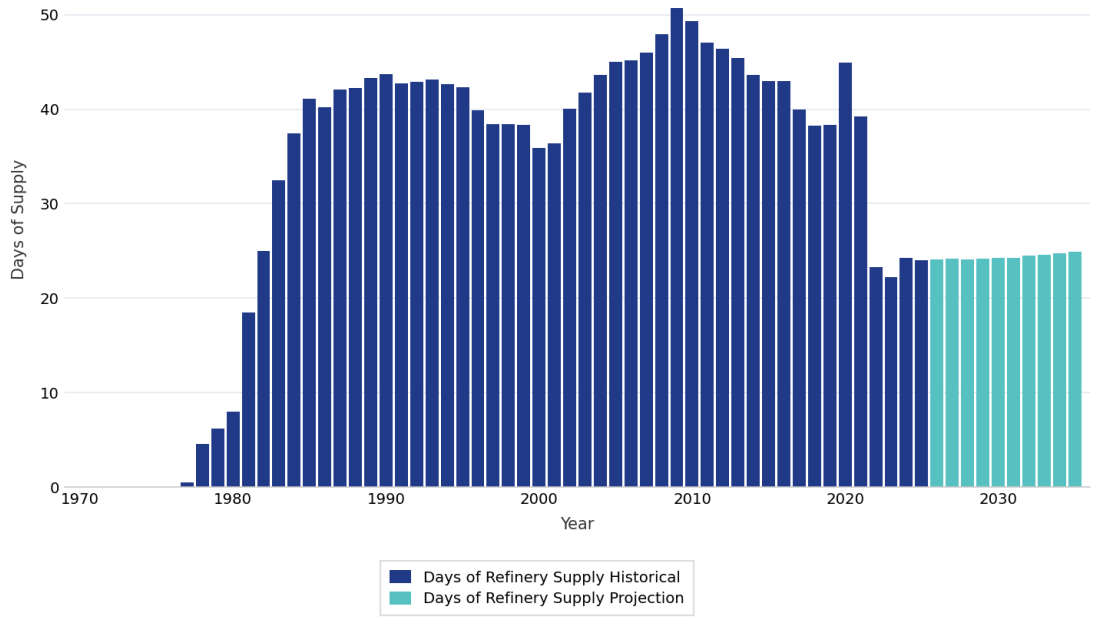
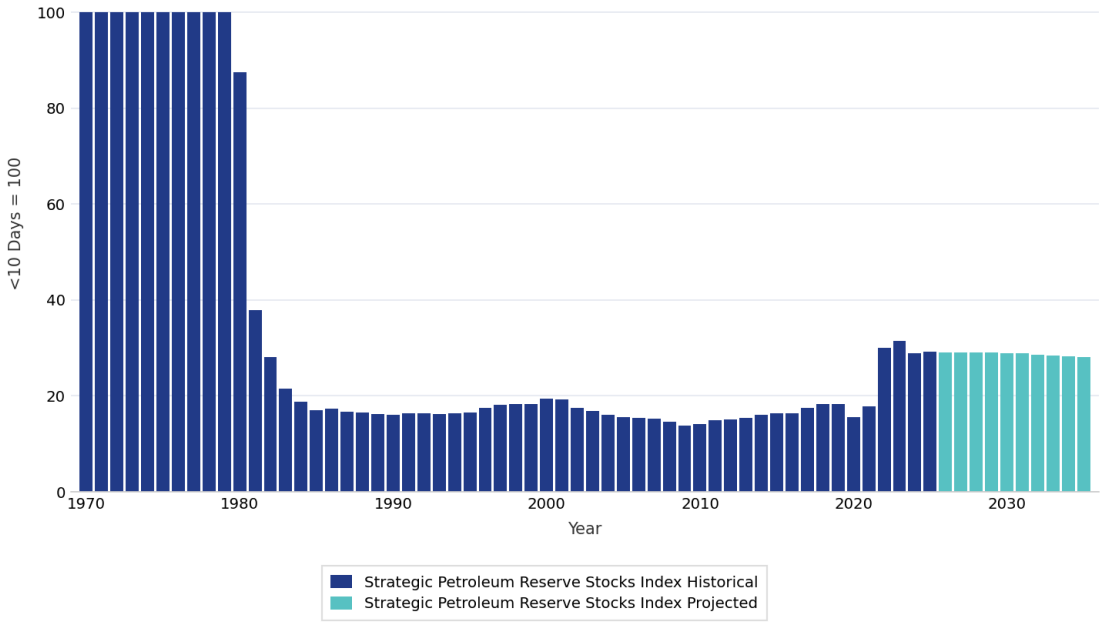


Figure A-39. Strategic Petroleum Reserve Stocks Index



Data Output

Table A-3. Energy Security Index Indicator Values, 1970–2035

Table A-3a. Energy Security Index Indicator Values, 1970-1979											
Indicator	**Value**	**1970**	**1971**	**1972**	**1973**	**1974**	**1975**	**1976**	**1977**	**1978**	**1979**
World Crude Oil and Natural Gas Plant Liquids Production											
Freedom-Weighted Production	average weighted Freedom House Score (1–7)	4.2	4.2	4.3	4.3	4.4	4.6	4.7	4.6	4.4	4.4
Diversity Historical	HHI, 1–10,000	1,774	1,263	1,217	1,245	1,236	1,278	1,255	1,270	1,204	1,139
Net Crude Oil Imports	risk-weighted import score	9.4	12.3	16.7	23.8	27.4	32.2	39.3	40.1	31.7	31.2
World Natural Gas Production											
Freedom-Weighted Production	average weighted Freedom House Score (1–7)	2.4	2.4	2.4	2.5	2.6	2.8	3.0	3.0	3.0	3.0
Diversity Historical	HHI, 1–10,000	3,685	1,263	1,217	1,245	1,236	1,278	1,255	1,270	1,204	1,139
Net Natural Gas Imports	risk-weighted import score	2.5	2.4	2.2	2.1	2.0	2.6	2.8	3.0	2.6	3.4
Net Uranium Imports	risk-weighted import score	(10.7)	(0.9)	(0.4)	(1.9)	(6.4)	0.6	2.4	2.0	(1.8)	(4.4)
Uranium Enrichment Services	percent foreign enrichment services	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Net Cobalt Imports	risk-weighted import score	60.9	58.3	67.7	72.5	75.9	66.5	23.0	18.8	24.4	24.6
Net Graphite Imports	risk-weighted import score	11.0	12.2	11.3	9.3	10.5	10.4	9.1	7.6	6.8	9.2
Net Lithium Imports	risk-weighted import score	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Net Manganese Imports	risk-weighted import score	59.9	59.9	67.0	68.5	63.3	92.0	68.5	91.3	73.3	71.1
Net Rare Earths Imports	risk-weighted import score	2.6	2.6	2.6	2.5	2.8	3.8	4.2	9.2	7.8	2.4
Net Aluminum Imports	risk-weighted import score	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Net Copper Imports	risk-weighted import score	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Net Nickel Imports	risk-weighted import score	46.0	46.0	39.7	35.5	33.5	36.0	32.3	33.1	39.8	39.5
Net Steel Imports	risk-weighted import score	2.2	2.3	2.2	2.2	2.1	2.7	2.6	2.7	2.4	2.2
Cybersecurity	number of physical attacks or cyberattacks	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Crude Oil Price Volatility											
Absolute Price Change	2024$	0.48	0.27	0.53	1.08	8.69	9.08	8.48	1.36	1.07	6.00
Volatility as Share of Price	percent	2.2%	1.2%	2.5%	4.9%	21.3%	21.2%	18.4%	2.8%	2.2%	10.0%
Strategic Petroleum Reserve Stocks	days of refinery supply	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	4.5	6.2

Table A-3b. Energy Security Index Indicator Values, 1980-1989											
Indicator	**Value**	**1980**	**1981**	**1982**	**1983**	**1984**	**1985**	**1986**	**1987**	**1988**	**1989**
World Crude Oil and Natural Gas Plant Liquids Production											
Freedom-Weighted Production	average weighted Freedom House Score (1–7)	4.4	4.3	4.2	4.2	4.3	4.2	4.4	4.3	4.1	4.2
Diversity Historical	HHI, 1–10,000	1,146	1,141	1,186	1,189	1,134	1,099	1,111	1,087	1,057	1,037
Net Crude Oil Imports	risk-weighted import score	25.7	20.9	15.3	13.6	13.4	11.6	16.4	17.4	17.0	20.6
World Natural Gas Production											
Freedom-Weighted Production	average weighted Freedom House Score (1–7)	3.2	3.3	3.5	3.7	3.9	4.0	4.1	3.9	3.6	3.6
Diversity Historical	HHI, 1–10,000	1,146	1,141	1,186	1,189	1,134	1,099	1,111	1,087	1,057	1,037
Net Natural Gas Imports	risk-weighted import score	3.3	3.1	3.9	4.1	4.1	5.0	4.2	4.9	5.1	4.9
Net Uranium Imports	risk-weighted import score	(2.8)	2.5	10.8	7.6	12.0	9.4	10.8	10.6	9.6	7.2
Uranium Enrichment Services	percent foreign enrichment services	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Net Cobalt Imports	risk-weighted import score	24.2	20.8	12.9	15.6	22.6	21.8	32.8	21.4	17.6	16.0
Net Graphite Imports	risk-weighted import score	10.5	11.6	13.4	12.0	12.0	13.0	11.5	11.5	10.2	29.5
Net Lithium Imports	risk-weighted import score	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Net Manganese Imports	risk-weighted import score	86.5	97.1	88.3	93.3	100.0	79.8	89.9	74.8	60.9	68.0
Net Rare Earths Imports	risk-weighted import score	7.1	2.6	13.3	10.3	4.8	4.4	5.8	6.2	13.9	15.3
Net Aluminum Imports	risk-weighted import score	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Net Copper Imports	risk-weighted import score	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Net Nickel Imports	risk-weighted import score	37.8	41.9	61.0	51.3	45.8	46.4	48.1	43.7	37.4	37.5
Net Steel Imports	risk-weighted import score	2.3	2.4	2.6	2.6	2.5	2.4	2.6	2.3	1.9	1.8
Cybersecurity	number of physical attacks or cyberattacks	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Crude Oil Price Volatility											
Absolute Price Change	2024$	14.99	19.04	19.22	13.41	10.15	7.30	14.11	15.41	16.30	7.76
Volatility as Share of Price	percent	19.3%	22.6%	20.5%	14.8%	12.2%	9.9%	34.3%	38.4%	44.5%	20.3%
Strategic Petroleum Reserve Stocks	days of refinery supply	8.0	18.5	25.0	32.4	37.4	41.1	40.2	42.1	42.2	43.3

Table A-3c. Energy Security Index Indicator Values, 1990-1999

Indicator	Value	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
World Crude Oil and Natural Gas Plant Liquids Production											
Freedom-Weighted Production	average weighted Freedom House Score (1–7)	4.2	4.1	4.1	4.3	4.3	4.3	4.2	4.3	4.2	4.3
Diversity Historical	HHI, 1–10,000	1,055	971	732	743	751	758	769	769	781	820
Net Crude Oil Imports	risk-weighted import score	18.7	16.5	17.7	21.9	21.1	20.8	19.7	21.7	23.1	22.6
World Natural Gas Production											
Freedom-Weighted Production	average weighted Freedom House Score (1–7)	3.1	3.1	2.9	3.1	3.0	3.0	2.9	2.9	3.0	3.2
Diversity Historical	HHI, 1–10,000	1,055	971	732	743	751	758	769	769	781	820
Net Natural Gas Imports	risk-weighted import score	4.3	4.4	2.9	3.2	3.4	3.2	2.7	2.6	3.0	3.6
Net Uranium Imports	risk-weighted import score	19.5	16.5	9.7	11.0	10.4	8.3	9.5	10.1	12.5	14.8
Uranium Enrichment Services	percent foreign enrichment services	NA	NA	NA	8.0%	18.2%	29.3%	28.3%	32.3%	43.7%	54.1%
Net Cobalt Imports	risk-weighted import score	16.1	10.2	9.7	7.5	7.7	7.1	8.1	7.2	7.9	8.6
Net Graphite Imports	risk-weighted import score	38.5	36.2	40.1	52.8	66.8	100.0	90.5	88.1	71.7	75.6
Net Lithium Imports	risk-weighted import score	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.7
Net Manganese Imports	risk-weighted import score	42.8	51.1	6.0	8.2	7.9	17.5	10.2	6.4	7.8	6.0
Net Rare Earths Imports	risk-weighted import score	8.8	10.5	14.9	24.6	50.3	71.5	69.4	71.7	64.7	67.9
Net Aluminum Imports	risk-weighted import score	0.0	0.0	0.1	1.2	1.9	1.6	1.4	1.5	1.8	2.3
Net Copper Imports	risk-weighted import score	0.0	0.0	0.8	3.1	6.2	3.5	7.6	8.0	9.3	17.3
Net Nickel Imports	risk-weighted import score	32.8	30.7	28.7	32.0	32.7	29.2	27.9	26.1	28.9	34.8
Net Steel Imports	risk-weighted import score	1.4	1.4	1.0	1.4	1.9	3.4	1.6	1.6	2.2	2.0
Cybersecurity	number of physical attacks or cyberattacks	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Crude Oil Price Volatility											
Absolute Price Change	2024$	8.65	8.49	7.28	5.66	3.55	3.28	3.51	3.68	7.07	7.96
Volatility as Share of Price	percent	21.4%	19.3%	16.4%	15.0%	10.6%	10.2%	10.1%	10.3%	25.8%	29.7%
Strategic Petroleum Reserve Stocks	days of refinery supply	43.7	42.7	42.9	43.1	42.7	42.3	39.9	38.4	38.4	38.3

Table A-3d. Energy Security Index Indicator Values, 2000-2009

Indicator	Value	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
World Crude Oil and Natural Gas Plant Liquids Production											
Freedom-Weighted Production	average weighted Freedom House Score (1–7)	4.3	4.3	4.2	4.3	4.4	4.3	4.4	4.4	4.5	4.4
Diversity Historical	HHI, 1–10,000	812	916	986	1,119	1,318	1,642	1,871	2,067	2,165	2,936
Net Crude Oil Imports	risk-weighted import score	24.1	24.4	21.9	25.7	28.5	28.6	29.2	28.9	30.2	26.6
World Natural Gas Production											
Freedom-Weighted Production	average weighted Freedom House Score (1–7)	3.3	3.3	3.3	3.4	3.5	3.5	3.6	3.6	3.6	3.6
Diversity Historical	HHI, 1–10,000	812	916	986	1,119	1,318	1,642	1,871	2,067	2,165	2,936
Net Natural Gas Imports	risk-weighted import score	3.5	3.7	3.3	3.2	3.5	3.6	3.4	3.4	2.6	2.1
Net Uranium Imports	risk-weighted import score	14.0	13.9	14.8	17.6	17.3	18.5	19.6	23.0	26.3	38.0
Uranium Enrichment Services	percent foreign enrichment services	56.3%	87.6%	85.3%	86.1%	88.3%	90.8%	87.9%	89.6%	85.0%	76.2%
Net Cobalt Imports	risk-weighted import score	10.0	12.2	13.0	15.0	20.0	23.9	23.0	13.7	34.6	52.8
Net Graphite Imports	risk-weighted import score	75.2	83.1	75.8	83.7	78.3	81.0	78.7	52.5	62.0	73.3
Net Lithium Imports	risk-weighted import score	6.6	4.6	2.9	4.4	3.0	5.6	2.0	3.7	2.0	4.7
Net Manganese Imports	risk-weighted import score	5.1	3.6	3.2	2.0	4.0	3.2	3.9	4.5	5.5	2.7
Net Rare Earths Imports	risk-weighted import score	72.0	69.2	66.1	72.0	72.5	82.3	80.7	79.6	81.0	68.4
Net Aluminum Imports	risk-weighted import score	2.6	3.3	3.6	4.3	5.6	6.3	5.8	5.2	0.0	5.6
Net Copper Imports	risk-weighted import score	23.1	12.8	18.3	17.6	19.6	17.2	16.6	16.6	14.3	11.2
Net Nickel Imports	risk-weighted import score	29.2	23.9	22.6	26.9	30.3	21.5	20.2	9.8	14.2	9.9
Net Steel Imports	risk-weighted import score	1.7	1.8	1.8	1.5	3.0	3.7	5.1	5.6	5.0	4.5
Cybersecurity	number of physical attacks or cyberattacks	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Crude Oil Price Volatility											
Absolute Price Change	2024$	12.76	11.58	8.75	4.63	6.47	14.12	16.72	14.82	18.05	30.50
Volatility as Share of Price	percent	38.4%	27.9%	18.8%	10.7%	11.6%	20.6%	21.3%	16.3%	15.0%	29.8%
Strategic Petroleum Reserve Stocks	days of refinery supply	35.9	36.4	40.1	41.7	43.7	45.0	45.2	46.0	47.9	50.7

Table A-3e. Energy Security Index Indicator Values, 2010-2019

Indicator	Value	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
World Crude Oil and Natural Gas Plant Liquids Production											
Freedom-Weighted Production	average weighted Freedom House Score (1–7)	4.5	4.5	4.5	4.5	4.5	4.5	4.6	4.6	4.6	4.5
Diversity Historical	HHI, 1–10,000	2,737	2,803	2,932	3,155	3,127	3,119	3,129	3,125	3,248	3,434
Net Crude Oil Imports	risk-weighted import score	27.1	30.9	29.9	26.7	25.6	25.8	31.0	28.5	24.2	15.7
World Natural Gas Production											
Freedom-Weighted Production	average weighted Freedom House Score (1–7)	3.6	3.7	3.7	3.7	3.8	3.8	3.9	4.1	4.1	4.0
Diversity Historical	HHI, 1–10,000	2,737	2,803	2,932	3,155	3,127	3,119	3,129	3,125	3,248	3,434
Net Natural Gas Imports	risk-weighted import score	2.0	1.6	1.1	1.0	0.9	0.7	0.5	(0.1)	(0.6)	(1.5)
Net Uranium Imports	risk-weighted import score	51.6	59.6	57.8	63.4	77.1	71.2	81.9	81.1	86.5	99.5
Uranium Enrichment Services	percent foreign enrichment services	83.7%	83.6%	79.1%	68.6%	70.8%	67.9%	95.2%	56.7%	66.8%	60.2%
Net Cobalt Imports	risk-weighted import score	69.1	60.3	50.1	35.4	35.0	39.9	38.8	50.9	64.0	63.7
Net Graphite Imports	risk-weighted import score	81.9	61.0	46.5	46.4	51.1	42.7	41.0	43.1	37.4	40.2
Net Lithium Imports	risk-weighted import score	3.7	7.9	5.1	4.9	3.1	1.7	3.9	2.1	3.0	2.5
Net Manganese Imports	risk-weighted import score	2.5	3.2	4.9	4.1	5.4	9.0	8.9	6.6	4.5	4.8
Net Rare Earths Imports	risk-weighted import score	74.5	63.9	58.5	59.0	59.1	44.0	40.4	25.7	22.2	30.0
Net Aluminum Imports	risk-weighted import score	5.6	1.5	7.2	15.9	27.4	37.4	48.3	57.1	49.0	21.3
Net Copper Imports	risk-weighted import score	14.9	16.0	17.9	17.2	16.4	15.8	15.0	18.0	17.3	19.2
Net Nickel Imports	risk-weighted import score	21.2	26.3	33.8	43.4	25.1	22.5	18.1	24.1	32.0	37.2
Net Steel Imports	risk-weighted import score	3.5	4.2	7.4	9.3	13.1	22.6	19.6	21.6	19.6	21.0
Cybersecurity	number of physical attacks or cyberattacks	NA	NA	87.0	78.0	75.0	41.0	51.0	42.0	58.0	81.0
Crude Oil Price Volatility											
Absolute Price Change	2024$	35.81	38.54	22.43	16.64	7.92	27.56	29.27	28.36	14.47	13.87
Volatility as Share of Price	percent	34.4%	35.5%	16.7%	11.0%	5.9%	35.7%	41.2%	43.3%	20.5%	17.7%
Strategic Petroleum Reserve Stocks	days of refinery supply	49.3	47.0	46.4	45.5	43.6	42.9	42.9	40.0	38.3	38.3

Table A-3f. Energy Security Index Indicator Values, 2020-2029

Indicator	Value	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029
World Crude Oil and Natural Gas Plant Liquids Production											
Freedom-Weighted Production	average weighted Freedom House Score (1–7)	4.4	4.5	4.6	4.5	4.5	4.5	4.5	4.5	4.5	4.5
Diversity Historical	HHI, 1–10,000	3,461	3,480	3,610	3,872	3,724	3,724	3,724	3,724	3,724	3,724
Net Crude Oil Imports	risk-weighted import score	12.5	14.2	12.9	10.7	11.0	8.3	9.6	8.8	9.1	9.1
World Natural Gas Production											
Freedom-Weighted Production	average weighted Freedom House Score (1–7)	4.0	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2
Diversity Historical	HHI, 1–10,000	3,461	3,480	3,610	3,872	3,872	3,872	3,872	3,872	3,872	3,872
Net Natural Gas Imports	risk-weighted import score	(2.2)	(3.4)	(2.9)	(3.3)	(3.2)	(4.0)	(4.8)	(4.5)	(5.3)	(5.7)
Net Uranium Imports	risk-weighted import score	99.6	122.5	112.7	95.3	95.3	95.3	95.3	95.3	95.3	95.3
Uranium Enrichment Services	percent foreign enrichment services	70.8%	80.8%	72.7%	71.7%	71.7%	71.7%	71.7%	71.7%	71.7%	71.7%
Net Cobalt Imports	risk-weighted import score	67.4	70.6	68.4	89.4	115.9	115.9	115.9	115.9	115.9	115.9
Net Graphite Imports	risk-weighted import score	55.0	42.5	35.6	71.2	69.0	69.0	69.0	69.0	69.0	69.0
Net Lithium Imports	risk-weighted import score	3.9	3.4	4.2	4.9	4.5	4.5	4.5	4.5	4.5	4.5
Net Manganese Imports	risk-weighted import score	3.0	3.6	5.0	2.9	3.7	3.7	3.7	3.7	3.7	3.7
Net Rare Earths Imports	risk-weighted import score	29.4	28.0	44.9	40.4	46.8	46.8	46.8	46.8	46.8	46.8
Net Aluminum Imports	risk-weighted import score	38.5	41.2	61.8	42.6	58.4	58.4	58.4	58.4	58.4	58.4
Net Copper Imports	risk-weighted import score	23.2	25.7	23.9	27.7	32.6	32.6	32.6	32.6	32.6	32.6
Net Nickel Imports	risk-weighted import score	29.2	40.6	63.0	68.4	97.7	97.7	97.7	97.7	97.7	97.7
Net Steel Imports	risk-weighted import score	12.4	13.3	18.5	14.2	13.5	13.5	13.5	13.5	13.5	13.5
Cybersecurity	number of physical attacks or cyberattacks	94.0	97.0	162.0	185.0	185.0	185.0	185.0	185.0	185.0	185.0
Crude Oil Price Volatility											
Absolute Price Change	2024$	19.01	22.71	28.26	26.61	17.71	17.71	17.71	17.71	17.71	17.71
Volatility as Share of Price	percent	30.1%	35.4%	39.4%	29.9%	18.8%	18.8%	18.8%	18.8%	18.8%	18.8%
Strategic Petroleum Reserve Stocks	days of refinery supply	44.9	39.2	23.3	22.2	24.3	24.0	24.1	24.1	24.1	24.1

Table A-3g. Energy Security Index Indicator Values, 2030-2035							
Indicator	**Value**	**2030**	**2031**	**2032**	**2033**	**2034**	**2035**
World Crude Oil and Natural Gas Plant Liquids Production							
Freedom-Weighted Production	average weighted Freedom House Score (1–7)	4.5	4.5	4.5	4.5	4.5	4.5
Diversity Historical	HHI, 1–10,000	3,724	3,724	3,724	3,724	3,724	3,724
Net Crude Oil Imports	risk-weighted import score	9.2	10.2	10.9	11.0	11.2	12.0
World Natural Gas Production							
Freedom-Weighted Production	average weighted Freedom House Score (1–7)	4.2	4.2	4.2	4.2	4.2	4.2
Diversity Historical	HHI, 1–10,000	3,872	3,872	3,872	3,872	3,872	3,872
Net Natural Gas Imports	risk-weighted import score	(6.1)	(6.4)	(6.6)	(7.3)	(7.8)	(8.1)
Net Uranium Imports	risk-weighted import score	95.3	95.3	95.3	95.3	95.3	95.3
Uranium Enrichment Services	percent foreign enrichment services	71.7%	71.7%	71.7%	71.7%	71.7%	71.7%
Net Cobalt Imports	risk-weighted import score	115.9	115.9	115.9	115.9	115.9	115.9
Net Graphite Imports	risk-weighted import score	69.0	69.0	69.0	69.0	69.0	69.0
Net Lithium Imports	risk-weighted import score	4.5	4.5	4.5	4.5	4.5	4.5
Net Manganese Imports	risk-weighted import score	3.7	3.7	3.7	3.7	3.7	3.7
Net Rare Earths Imports	risk-weighted import score	46.8	46.8	46.8	46.8	46.8	46.8
Net Aluminum Imports	risk-weighted import score	58.4	58.4	58.4	58.4	58.4	58.4
Net Copper Imports	risk-weighted import score	32.6	32.6	32.6	32.6	32.6	32.6
Net Nickel Imports	risk-weighted import score	97.7	97.7	97.7	97.7	97.7	97.7
Net Steel Imports	risk-weighted import score	13.5	13.5	13.5	13.5	13.5	13.5
Cybersecurity	number of physical attacks or cyberattacks	185.0	185.0	185.0	185.0	185.0	185.0
Crude Oil Price Volatility							
Absolute Price Change	2024$	17.71	17.71	17.71	17.71	17.71	17.71
Volatility as Share of Price	percent	18.8%	18.8%	18.8%	18.8%	18.8%	18.8%
Strategic Petroleum Reserve Stocks	days of refinery supply	24.3	24.2	24.5	24.6	24.7	24.9

Table A-4. Energy Security Index Normalized Indicator Risk Scores, 1970—2035

Table A-4a. Energy Security Index Normalized Indicator Risk Scores, 1970–1979

Indicator	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979
World Crude Oil and Natural Gas Plant Liquids Production	44.9	32.9	33.3	34.3	35.5	40.0	41.5	39.4	34.0	31.7
Net Crude Oil Imports	23.5	30.8	41.6	59.4	68.4	80.3	98.2	100.0	79.1	78.0
World Natural Gas Production	36.8	13.0	12.7	13.5	14.5	18.5	19.7	20.7	19.0	18.5
Net Natural Gas Imports	48.8	47.1	43.7	42.2	39.9	52.1	54.4	59.4	51.8	66.8
Net Uranium Imports	0.0	0.0	0.0	0.0	0.0	0.6	2.4	2.0	0.0	0.0
Uranium Enrichment Services	8.4	8.4	8.4	8.4	8.4	8.4	8.4	8.4	8.4	8.4
Net Cobalt Imports	80.3	76.8	89.3	95.5	100.0	87.7	30.3	24.8	32.1	32.5
Net Graphite Imports	11.0	12.2	11.3	9.3	10.5	10.4	9.1	7.6	6.8	9.2
Net Lithium Imports	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Net Manganese Imports	59.9	59.9	67.0	68.5	63.3	92.0	68.5	91.3	73.3	71.1
Net Rare Earths Imports	3.2	3.2	3.2	3.1	3.4	4.6	5.1	11.2	9.5	2.9
Net Aluminum Imports	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Net Copper Imports	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Net Nickel Imports	75.4	75.4	65.1	58.1	55.0	59.0	52.9	54.2	65.2	64.8
Net Steel Imports	9.9	10.3	9.9	9.7	9.5	12.1	11.5	11.8	10.5	9.6
Cybersecurity	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Crude Oil Price Volatility	3.4	1.9	3.9	7.7	39.2	39.6	35.2	5.4	4.3	21.1
Strategic Petroleum Reserve Stocks	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Note: Maximum value is 100.

Table A-4b. Energy Security Index Normalized Indicator Risk Scores, 1980–1989

Indicator	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
World Crude Oil and Natural Gas Plant Liquids Production	32.3	30.9	30.9	30.5	30.1	28.9	30.9	29.0	26.0	27.2
Net Crude Oil Imports	64.2	52.1	38.2	33.9	33.5	28.9	40.9	43.5	42.5	51.5
World Natural Gas Production	21.4	22.8	26.0	28.4	30.4	31.4	33.5	30.0	23.9	23.4
Net Natural Gas Imports	65.8	62.0	77.8	80.7	80.4	97.7	83.7	96.7	100.0	96.0
Net Uranium Imports	0.0	2.5	10.9	7.6	12.1	9.5	10.9	10.7	9.6	7.3
Uranium Enrichment Services	8.4	8.4	8.4	8.4	8.4	8.4	8.4	8.4	8.4	8.4
Net Cobalt Imports	31.9	27.5	17.0	20.5	29.8	28.8	43.2	28.3	23.1	21.1
Net Graphite Imports	10.5	11.6	13.4	12.0	12.0	13.0	11.5	11.5	10.2	29.5
Net Lithium Imports	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Net Manganese Imports	86.5	97.1	88.3	93.3	100.0	79.8	89.9	74.8	60.9	68.0
Net Rare Earths Imports	8.7	3.2	16.1	12.5	5.9	5.4	7.0	7.6	16.8	18.6
Net Aluminum Imports	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Net Copper Imports	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Net Nickel Imports	61.9	68.7	100.0	84.1	75.2	76.0	78.9	71.6	61.3	61.4
Net Steel Imports	10.3	10.6	11.4	11.5	11.2	10.8	11.5	10.4	8.3	7.9
Cybersecurity	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Crude Oil Price Volatility	45.7	55.8	53.3	37.9	29.9	22.9	63.2	70.3	79.2	36.6
Strategic Petroleum Reserve Stocks	87.5	37.9	28.0	21.6	18.7	17.0	17.4	16.6	16.6	16.2

Note: Maximum value is 100.

Table A-4c. Energy Security Index Normalized Indicator Risk Scores, 1990–1999

Indicator	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
World Crude Oil and Natural Gas Plant Liquids Production	26.6	23.5	18.4	20.6	20.6	20.8	20.2	20.6	20.6	21.8
Net Crude Oil Imports	46.6	41.2	44.1	54.6	52.8	51.8	49.3	54.0	57.6	56.4
World Natural Gas Production	18.5	16.8	11.4	12.4	12.0	12.0	11.7	11.9	12.7	14.6
Net Natural Gas Imports	83.8	86.3	56.8	63.8	66.4	63.3	53.7	51.2	59.6	70.8
Net Uranium Imports	19.6	16.6	9.7	11.1	10.4	8.4	9.6	10.1	12.5	14.9
Uranium Enrichment Services	8.4	8.4	8.4	8.4	19.1	30.8	29.7	33.9	45.9	56.8
Net Cobalt Imports	21.2	13.4	12.8	9.9	10.1	9.4	10.6	9.5	10.4	11.4
Net Graphite Imports	38.5	36.2	40.1	52.8	66.8	100.0	90.5	88.1	71.7	75.6
Net Lithium Imports	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	47.6
Net Manganese Imports	42.8	51.1	6.0	8.2	7.9	17.5	10.2	6.4	7.8	6.0
Net Rare Earths Imports	10.6	12.8	18.1	29.9	61.2	87.0	84.4	87.2	78.7	82.5
Net Aluminum Imports	0.0	0.0	0.1	2.1	3.4	2.8	2.4	2.6	3.1	4.0
Net Copper Imports	0.0	0.0	3.3	13.2	26.8	15.3	33.0	34.7	40.4	74.7
Net Nickel Imports	53.8	50.4	47.0	52.5	53.6	47.8	45.7	42.8	47.3	57.1
Net Steel Imports	6.2	6.3	4.6	6.3	8.5	15.1	7.3	7.3	9.7	9.0
Cybersecurity	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Crude Oil Price Volatility	39.2	36.4	30.9	26.9	18.4	17.5	17.7	18.1	42.4	48.6
Strategic Petroleum Reserve Stocks	16.0	16.4	16.3	16.2	16.4	16.5	17.6	18.2	18.2	18.3

Note: Maximum value is 100.

Table A-4d. Energy Security Index Normalized Indicator Risk Scores, 2000–2009

Indicator	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
World Crude Oil and Natural Gas Plant Liquids Production	21.5	24.7	25.4	29.6	36.6	45.0	52.1	58.1	63.1	84.5
Net Crude Oil Imports	60.2	60.8	54.6	64.2	71.2	71.3	72.8	72.1	75.4	66.3
World Natural Gas Production	15.6	18.1	19.6	22.5	28.6	37.0	43.4	48.7	51.1	67.6
Net Natural Gas Imports	69.8	73.9	65.8	63.1	68.5	70.4	67.3	67.4	50.4	41.0
Net Uranium Imports	14.0	14.0	14.9	17.6	17.3	18.6	19.7	23.1	26.4	38.2
Uranium Enrichment Services	59.1	91.9	89.6	90.4	92.8	95.3	92.3	94.1	89.2	80.0
Net Cobalt Imports	13.2	16.1	17.1	19.8	26.3	31.5	30.4	18.0	45.6	69.6
Net Graphite Imports	75.2	83.1	75.8	83.7	78.3	81.0	78.7	52.5	62.0	73.3
Net Lithium Imports	83.9	58.3	37.2	55.5	38.0	71.4	25.5	47.4	25.6	60.2
Net Manganese Imports	5.1	3.6	3.2	2.0	4.0	3.2	3.9	4.5	5.5	2.7
Net Rare Earths Imports	87.5	84.1	80.3	87.6	88.2	100.0	98.1	96.7	98.5	83.1
Net Aluminum Imports	4.6	5.7	6.2	7.5	9.8	11.1	10.2	9.0	0.0	9.7
Net Copper Imports	100.0	55.2	79.2	76.2	84.7	74.4	72.0	71.7	62.1	48.3
Net Nickel Imports	47.9	39.2	37.1	44.1	49.7	35.3	33.1	16.1	23.3	16.2
Net Steel Imports	7.4	7.9	8.1	6.5	13.1	16.2	22.4	25.0	22.2	19.8
Cybersecurity	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Crude Oil Price Volatility	66.5	51.6	36.2	20.0	23.9	46.2	50.8	41.8	44.9	81.3
Strategic Petroleum Reserve Stocks	19.5	19.2	17.5	16.8	16.0	15.6	15.5	15.2	14.6	13.8

Note: Maximum value is 100.

Table A-4e. Energy Security Index Normalized Indicator Risk Scores, 2010–2019

Indicator	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
World Crude Oil and Natural Gas Plant Liquids Production	79.7	84.3	87.3	91.7	92.3	91.1	96.1	98.0	99.1	100.0
Net Crude Oil Imports	67.8	77.1	74.5	66.6	64.0	64.5	77.3	71.2	60.3	39.2
World Natural Gas Production	65.1	68.8	71.8	78.6	82.3	81.3	86.2	92.4	95.6	100.0
Net Natural Gas Imports	39.1	30.8	22.0	18.9	17.7	13.6	10.1	0.0	0.0	0.0
Net Uranium Imports	51.8	59.9	58.1	63.8	77.5	71.6	82.3	81.5	87.0	100.0
Uranium Enrichment Services	87.8	87.8	83.0	72.1	74.4	71.3	100.0	59.6	70.2	63.2
Net Cobalt Imports	91.1	79.5	66.0	46.6	46.1	52.6	51.1	67.1	84.4	84.0
Net Graphite Imports	81.9	61.0	46.5	46.4	51.1	42.7	41.0	43.1	37.4	40.2
Net Lithium Imports	46.4	100.0	65.4	62.8	39.3	21.0	49.8	27.2	37.5	31.1
Net Manganese Imports	2.5	3.2	4.9	4.1	5.4	9.0	8.9	6.6	4.5	4.8
Net Rare Earths Imports	90.5	77.7	71.1	71.7	71.8	53.5	49.1	31.2	26.9	36.5
Net Aluminum Imports	9.8	2.7	12.5	27.9	47.9	65.5	84.5	100.0	85.8	37.3
Net Copper Imports	64.6	69.1	77.4	74.2	70.9	68.5	65.1	77.8	74.7	82.9
Net Nickel Imports	34.7	43.1	55.4	71.2	41.2	37.0	29.7	39.5	52.5	60.9
Net Steel Imports	15.5	18.7	32.7	41.2	57.9	100.0	87.0	95.5	86.7	93.0
Cybersecurity	NA	NA	100.0	89.7	86.2	47.1	58.6	48.3	66.7	93.1
Crude Oil Price Volatility	94.7	100.0	53.2	37.8	18.8	84.4	93.7	95.1	46.5	42.1
Strategic Petroleum Reserve Stock	14.2	14.9	15.1	15.4	16.1	16.3	16.3	17.5	18.3	18.3

Note: Maximum value is 100.

Table A-4g. Energy Security Index Normalized Indicator Risk Scores, 2030–2035

Indicator	2030	2031	2032	2033	2034	2035
World Crude Oil and Natural Gas Plant Liquids Production	110.4	110.4	110.4	110.4	110.4	110.4
Net Crude Oil Imports	23.0	25.4	27.2	27.6	27.9	29.8
World Natural Gas Production	120.1	120.1	120.1	120.1	120.1	120.1
Net Natural Gas Imports	0.0	0.0	0.0	0.0	0.0	0.0
Net Uranium Imports	95.8	95.8	95.8	95.8	95.8	95.8
Uranium Enrichment Services	75.3	75.3	75.3	75.3	75.3	75.3
Net Cobalt Imports	152.8	152.8	152.8	152.8	152.8	152.8
Net Graphite Imports	69.0	69.0	69.0	69.0	69.0	69.0
Net Lithium Imports	56.9	56.9	56.9	56.9	56.9	56.9
Net Manganese Imports	3.7	3.7	3.7	3.7	3.7	3.7
Net Rare Earths Imports	56.8	56.8	56.8	56.8	56.8	56.8
Net Aluminum Imports	102.3	102.3	102.3	102.3	102.3	102.3
Net Copper Imports	140.8	140.8	140.8	140.8	140.8	140.8
Net Nickel Imports	160.2	160.2	160.2	160.2	160.2	160.2
Net Steel Imports	59.7	59.7	59.7	59.7	59.7	59.7
Cybersecurity	212.6	212.6	212.6	212.6	212.6	212.6
Crude Oil Price Volatility	49.1	49.1	49.1	49.1	49.1	49.1
Strategic Petroleum Reserve Stocks	28.8	28.9	28.6	28.5	28.3	28.1

Note: Maximum value is 100.

Table A-5. Energy Security Index Indicator Group Weightings, 1970–2035

Table A-5a. Energy Security Index Indicator Group Weightings, 1970-1979

Indicator Group		1970	1971	1972	1973	1974	1975	1976	1977	1978	1979
Crude Oil		48.7%	48.6%	49.5%	49.9%	48.5%	48.6%	48.9%	49.7%	50.4%	49.1%
Natural Gas		36.0%	35.7%	34.1%	32.3%	31.5%	29.6%	28.3%	26.7%	26.6%	27.4%
Uranium		0.4%	0.7%	0.9%	1.3%	1.8%	2.8%	2.9%	3.6%	4.0%	3.7%
Energy Technology Minerals		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Energy Infrastructure Minerals		5.5%	5.4%	5.3%	5.4%	6.8%	7.0%	7.1%	7.2%	7.1%	7.9%
Systemic	Cybersecurity	2.7%	2.7%	2.7%	2.6%	2.6%	2.6%	2.6%	2.6%	2.6%	2.6%
	Crude Oil Price Volatility	5.5%	5.4%	5.3%	5.3%	5.2%	5.2%	5.1%	5.1%	5.2%	5.2%
	Strategic Petroleum Reserve Stocks	1.3%	1.6%	2.2%	3.1%	3.6%	4.2%	5.0%	5.1%	4.1%	4.1%

Table A-5b. Energy Security Index Indicator Group Weightings, 1980-1989

Indicator Group		1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
Crude Oil		47.4%	46.3%	46.8%	48.0%	47.5%	47.9%	49.8%	48.9%	48.5%	47.3%
Natural Gas		28.1%	28.7%	28.4%	27.6%	28.2%	27.4%	25.7%	26.3%	26.2%	27.1%
Uranium		3.8%	4.4%	4.9%	5.1%	5.4%	6.3%	6.8%	7.1%	7.9%	7.8%
Energy Technology Minerals		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Energy Infrastructure Minerals		9.4%	9.8%	9.6%	8.9%	8.5%	8.1%	6.7%	6.6%	6.2%	6.3%
Systemic	Cybersecurity	2.6%	2.7%	2.7%	2.8%	2.8%	2.9%	2.9%	2.9%	2.9%	2.9%
	Crude Oil Price Volatility	5.3%	5.4%	5.5%	5.6%	5.7%	5.8%	5.8%	5.7%	5.8%	5.7%
	Strategic Petroleum Reserve Stocks	3.4%	2.8%	2.1%	1.9%	1.9%	1.7%	2.4%	2.5%	2.4%	2.9%

Table A-5c. Energy Security Index Indicator Group Weightings, 1990-1999

Indicator Group		1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Crude Oil		46.6%	45.8%	45.8%	45.2%	45.4%	44.5%	44.9%	45.5%	46.0%	46.1%
Natural Gas		27.3%	28.0%	28.3%	28.6%	28.6%	29.4%	29.1%	29.3%	28.6%	28.0%
Uranium		8.5%	9.0%	8.9%	8.6%	8.8%	9.2%	8.9%	8.3%	8.9%	9.3%
Energy Technology Minerals		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Energy Infrastructure Minerals		6.4%	6.2%	5.9%	5.8%	5.5%	5.3%	5.5%	5.1%	4.4%	4.7%
Systemic	Cybersecurity	2.9%	2.9%	2.9%	2.9%	2.9%	2.9%	2.9%	2.9%	2.9%	2.9%
	Crude Oil Price Volatility	5.7%	5.7%	5.7%	5.7%	5.7%	5.8%	5.8%	5.8%	5.8%	5.8%
	Strategic Petroleum Reserve Stocks	2.7%	2.4%	2.5%	3.1%	3.0%	3.0%	2.8%	3.1%	3.3%	3.2%

Table A-5d. Energy Security Index Indicator Group Weightings, 2000-2009

Indicator Group		2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Crude Oil		45.1%	45.6%	45.7%	46.1%	46.3%	46.2%	46.0%	44.6%	42.5%	42.7%
Natural Gas		28.1%	27.3%	28.2%	27.2%	26.5%	25.9%	25.7%	26.8%	27.5%	28.8%
Uranium		9.3%	9.6%	9.8%	9.5%	9.5%	9.4%	9.5%	9.6%	9.7%	10.3%
Energy Technology Minerals		0.0%	0.0%	0.0%	0.0%	0.1%	0.1%	0.1%	0.1%	0.2%	0.3%
Energy Infrastructure Minerals		5.5%	5.6%	4.7%	5.0%	5.2%	6.0%	6.1%	6.4%	7.5%	5.8%
Systemic	Cybersecurity	2.9%	2.8%	2.9%	2.9%	2.8%	2.8%	2.8%	2.8%	2.8%	2.8%
	Crude Oil Price Volatility	5.7%	5.6%	5.7%	5.7%	5.7%	5.6%	5.6%	5.6%	5.6%	5.6%
	Strategic Petroleum Reserve Stocks	3.4%	3.4%	3.1%	3.7%	4.0%	4.0%	4.1%	4.0%	4.2%	3.7%

Table A-5e. Energy Security Index Indicator Group Weightings, 2010-2019

Indicator Group		2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Crude Oil		41.8%	40.7%	40.1%	39.9%	39.8%	40.7%	40.7%	41.0%	39.9%	40.0%
Natural Gas		29.1%	29.3%	30.9%	31.1%	31.5%	32.4%	32.3%	31.9%	33.7%	35.0%
Uranium		10.0%	9.7%	9.5%	9.6%	9.6%	9.6%	9.6%	9.6%	9.1%	9.2%
Energy Technology Minerals		0.4%	0.5%	0.6%	0.7%	0.8%	0.9%	1.1%	1.3%	1.4%	1.5%
Energy Infrastructure Minerals		6.6%	7.2%	6.7%	6.8%	6.6%	4.7%	4.1%	4.5%	4.9%	4.5%
Systemic	Cybersecurity	2.8%	2.8%	2.7%	2.7%	2.7%	2.7%	2.7%	2.7%	2.6%	2.6%
	Crude Oil Price Volatility	5.6%	5.5%	5.4%	5.5%	5.5%	5.4%	5.4%	5.3%	5.3%	5.2%
	Strategic Petroleum Reserve Stocks	3.8%	4.3%	4.0%	3.6%	3.5%	3.5%	4.1%	3.8%	3.2%	2.1%

Table A-5f. Energy Security Index Indicator Group Weightings, 2020-2029

Indicator Group		2020	2021	2022	2023	2024	2025	2026	2027	2028	2029
Crude Oil		38.1%	39.3%	38.1%	38.6%	37.7%	38.4%	38.6%	38.3%	38.1%	37.7%
Natural Gas		37.3%	35.4%	36.0%	36.6%	36.5%	35.9%	35.2%	35.6%	35.6%	35.6%
Uranium		9.7%	9.1%	8.7%	8.8%	8.7%	8.8%	8.9%	8.8%	8.8%	8.8%
Energy Technology Minerals		1.9%	2.1%	2.4%	2.5%	2.9%	3.3%	4.0%	4.4%	4.7%	5.1%
Energy Infrastructure Minerals		3.6%	4.6%	5.5%	4.5%	5.3%	5.1%	4.7%	4.5%	4.4%	4.3%
Systemic	Cybersecurity	2.6%	2.6%	2.6%	2.5%	2.5%	2.5%	2.5%	2.5%	2.5%	2.4%
	Crude Oil Price Volatility	5.2%	5.2%	5.1%	5.1%	5.0%	5.0%	5.0%	4.9%	4.9%	4.9%
	Strategic Petroleum Reserve Stocks	1.6%	1.8%	1.6%	1.4%	1.4%	1.0%	1.2%	1.1%	1.1%	1.1%

Table A-5g. Energy Security Index Indicator Group Weightings, 2030-2035

Indicator Group		2030	2031	2032	2033	2034	2035
Crude Oil		37.3%	36.9%	35.7%	35.3%	35.0%	34.6%
Natural Gas		35.7%	35.4%	36.3%	35.6%	34.9%	34.4%
Uranium		8.7%	8.6%	8.5%	8.6%	8.6%	8.6%
Energy Technology Minerals		5.7%	6.4%	7.1%	8.1%	9.1%	10.1%
Energy Infrastructure Minerals		4.3%	4.2%	4.1%	4.1%	4.0%	4.0%
Systemic	Cybersecurity	2.4%	2.4%	2.3%	2.3%	2.3%	2.3%
	Crude Oil Price Volatility	4.8%	4.8%	4.7%	4.7%	4.7%	4.6%
	Strategic Petroleum Reserve Stocks	1.1%	1.2%	1.3%	1.3%	1.3%	1.4%

Data Sources

The following provides a list of the main sources of the data used to compile ESI indicators.

U.S. Energy Information Administration

International Data is a database with historical international crude oil NGPL and natural gas production data. See https://www.eia.gov/international/data/world

Monthly Energy Review is a series on historical domestic energy production, demand, import, export, refinery inputs, and stocks data, available from https://www.eia.gov/totalenergy/data/monthly.

Petroleum & Other Liquids contains historical crude oil price data. Visit https://www.eia.gov/petroleum/data.php.

Annual Energy Outlook is a report series that forecasts domestic energy production, demand, and refinery inputs data. See https://www.eia.gov/outlooks/aeo.

The Uranium Marketing Annual Report series includes historical data on uranium supplies and imports, available from https://www.eia.gov/uranium/marketing.

U.S. Geological Survey

The Mineral Commodity Summaries series compiles historical international mineral production data and imports data, available from https://www.usgs.gov/centers/national-minerals-information-center/mineral-commodity-summaries.

British Geological Survey

World Mineral Statistics Data includes historical international mineral and uranium production data. See https://www.bgs.ac.uk/mineralsuk/statistics/world-mineral-statistics/world-mineral-statistics-data-download/world-mineral-statistics-data.

Freedom House

Freedom in the World is a series that provides historical data on international political and civil liberties data. Visit https://freedomhouse.org/report/freedom-world.

Contact

For additional information, questions, or comments, use NCEA's contact form or email NCEAInfo@energyanalytics.org.

Notes

[1] Coal's important roles in grid stability, reliability, and affordable electricity will be more apparent in forthcoming components of the Index of Leading Energy Indicators project, which will cover these aspects of the U.S. energy system.
[2] Crude oil, natural gas plant liquids, and natural gas production and imports.
[3] Aluminum, copper, steel, and nickel (key minerals common to all energy machinery), as well as cobalt, graphite, lithium, manganese, and rare earths (some of the key minerals used for alternative energy technologies).
[4] Uranium supplies and enrichment services.
[5] Cybersecurity, crude oil price volatility, and Strategic Petroleum Reserve crude oil stocks.
[6] HHI is calculated by taking the market share percentage of each country's production, squaring that share, and summing those squares across all suppliers. A market with a single supplier would have an HHI score of 10,000. The greater the number of producers, the lower the HHI score.