Tool

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Interactive Pardee RAND Food-Energy-Water Security Index

Updates as of 2023

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About This Tool

More than 2 billion people around the world, especially in developing countries, do not have access to high-quality services related to food, water, and energy. To provide information to development agencies and efforts focused on food, water, and energy resources, the RAND Corporation developed the Pardee RAND Food-Energy-Water Index. The index can be accessed online through an interactive RAND website (www.rand.org/t/TLA2942-1) that allows users to explore the data through maps and charts. The website also contains the technical documentation for the index (*Developing the Pardee RAND Food-Energy-Water Security Index: Toward a Global Standardized, Quantitative, and Transparent Resource Assessment*). This document details the updates made to the index in 2023.

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Pardee RAND Food-Energy-Water Index: Updates as of 2023

In 2016, a group of RAND Corporation researchers first published the Pardee RAND Food-Energy-Water (FEW) Index. This framework was designed to quantify the food, energy, and water security of countries in terms of the availability and accessibility of each resource using a variety of indicators. The purpose of this tool was to identify the predominant sources of insecurity in different nations and to understand how different kinds of security may be interrelated.

The most-recent data incorporated in the first version of the FEW Index were from 2014. This 2023 update extends the work of the previous team by including new data from 2015 through 2019, the last year for which data were available for all indicators. The updated version also incorporates a time-series feature. Whereas, in the original version, the team took the latest data available for every country on each indicator and used those data to calculate and display single values for the subindexes and FEW Index, the 2023 update includes seven data points: five annual values for the indexes from 2015 to 2019, the latest value available from 2015 to 2019, and the value from the original version of the index, which represents the latest value from the pre-2015 era. This update also adds two visualizations that display the predicted trends in the FEW Index and its constituent subindexes over time from 2015 to 2019, by country. We also made some aesthetic changes to improve the accessibility of the visualizations.

Data Sources

Prior to the update, we identified the indicators used to calculate each subindex and sought to verify whether updated data for the same indicator were available. In most cases, updated data were both available for the same indicators and published by the same source. In two cases, however, new data were either unavailable or inaccessible. For these cases, we instead substituted new indicators that measured constructs that were similar to the original. For instance, we were unable to find new data for the food price index, a key component in calculating the food subindex. Therefore, in the updated version, we instead used a similar indicator that measured the proportion of the population able to afford a healthy diet.

Tables 1–3 illustrate the details of the indicators and data sources used to calculate the food, energy, and water subindexes, respectively.

Table 1. Indicators Used to Calculate the Food Subindex

Category	Original Indicator	Measures Needed to Calculate Indicator	Original Data Source	Availability of New Data	New Indicator	New Data Source
Food accessibility	Food Price Level Index	FAO Food Price Index	FAO Food Security Indicators, 2000–2014	Unavailable	Percentage of population able to afford a healthy diet	FAO State of Food Insecurity Report, 2022[a]
	Share of dietary supply from nonstarchy foods	Share of dietary energy supply derived from cereals, roots, and tubers	FAO Food Security Indicators, 1990–2009	Updated data available for 2015–2021[b]	N/A	N/A
Food availability	Supply relative to minimum dietary requirement	Average energy supply	FAO Food Security Indicators, 1990–2014	Updated data available for 2015–2021[b]	N/A	N/A
		Minimum dietary energy requirement	FAO Food Security Indicators, 1990–2014	Updated data available for 2015–2021[b]	N/A	N/A

NOTE: FAO = Food and Agriculture Organization of the United Nations.
[a] FAO, *The State of Food Security and Nutrition in the World 2022*, 2022.
[b] FAO, "Suite of Food Security Indicators," dataset, updated July 2023b.

Table 2. Indicators Used to Calculate the Energy Subindex

Category	Original Indicator	Measures Needed to Calculate Indicator	Original Data Source	Availability of New Data	New Indicator	New Data Source
Energy accessibility	Electrification Rate	Percentage of population with access to electricity	World Bank World Development Indicators 1990, 2000, 2010, 2012	Updated data from 2013–2020 available[a]	N/A	N/A
	Percentage access to modern fuels for cooking and heating	Percentage of population using modern fuels for cooking and heating	UN Statistics Division, MDG Indicators 1990–2010	Unable to access MDG indicator data on the UN statistics website	Percentage of population with access to clean fuels for cooking and heating	SDG Goal 7.1.2 data, WHO[b]
Energy availability	Electricity consumption relative to energy requirement	Total electricity consumption	U.S. Energy Information Administration International Energy Database, 1980–2012	Updated data from 2018–2021 available[c]	N/A	N/A
		Total population	U.S. Energy Information Administration International Energy Database, 1980–2012	Updated data from 2018–2021 available[c]	N/A	N/A

NOTE: MDG = Millennium Development Goal; SDG = Sustainable Development Goal; UN = United Nations; WHO = World Health Organization.
[a] World Bank, "World Development Indicators," dataset, accessed July 2023.
[b] World Health Organization, "Household Air Pollution Data," dataset, accessed July 2023.
[c] U.S. Energy Information Administration, "International Data," dataset, accessed July 2023.

Table 3. Indicators Used to Calculate the Water Subindex

Category	Original Indicator	Measures Needed to Calculate Indicator	Original Data Source	Availability of New Data	New Indicator	New Data Source
Water accessibility	Percentage access to improved drinking water	Percentage of population with access to improved drinking water	WHO/UNICEF Joint Monitoring Programme for Water Supply, Sanitation, and Hygiene 1990–2010	Updated data from 2011–2022 available[a]	N/A	N/A
	Percentage access to improved sanitation	Percentage of population with access to improved sanitation	WHO/UNICEF Joint Monitoring Programme for Water Supply, Sanitation, and Hygiene 1990–2010	Updated data from 2011–2022 available[a]	N/A	N/A
Water availability	Municipal water use over population water requirement	Municipal water withdrawal	FAO AQUASTAT, 1980–2014	Updated data from 2015–2019 available[b]	N/A	N/A
		Total population	FAO AQUASTAT, 1980–2014	Updated data from 2015–2019 available[b]	N/A	N/A
Water adaptive capacity	Per capita water resources	Total internally renewable water resources	FAO AQUASTAT, 1980–2014	Updated data from 2015–2019 available[b]	N/A	N/A

[a] World Health Organization and UNICEF Joint Monitoring Programme for Water Supply, Sanitation, and Hygiene, "Progress on Drinking Water (SDG Target 6.1)," webpage, accessed July 2023.
[b] FAO, "AQUASTAT—FAO's Global Information System on Water and Agriculture," dataset, accessed July 2023a.

Data Processing

The datasets were cleaned and analyzed using Python. For cleaning and calculations, particularly in the absence of certain data, we followed the procedures used by the original team. Specifically, availability, accessibility, or adaptive capacity for any resource could be calculated if at least one of the input indicators was available for that specific year and country, but the food, energy, and water subindexes and the overall FEW Index could only be calculated if all the inputs were available.

We also followed the same procedures as the previous team with regard to top-coding and normalizing certain indicators. Table 4 shows each indicator and its range of values after normalization.

Table 4. Minimum and Maximum Values of Normalized Indicators

Subindex	Category	Original Indicator	Minimum Value	Maximum Value
Food	Food accessibility	Percentage of population able to afford a healthy diet	0	1
		Share of dietary supply from nonstarchy foods	0	1
	Food availability	Supply relative to minimum dietary requirement	0	2
Energy	Energy accessibility	Electrification rate	0	1
		Percentage of population with access to clean fuels for cooking and heating	0	1
	Energy availability	Electricity consumption relative to energy requirement	0	1.3
Water	Water accessibility	Percentage access to improved drinking water	0	1
		Percentage access to improved sanitation	0	1
	Water availability	Municipal water use over population water requirement	0	4
	Water adaptive capacity	Per capita water resources	0	5,000

A small number of data points required hard-coding for appropriate data processing and visualization. There were three main circumstances for which hard-coding was necessary:

1. Some countries with abundant resources scored very highly on certain indicators, to the extent that, even after normalization, the values exceeded the maximum value from Table 4 for that indicator. Because we sought to use the same bounds for normalization as the original version of the index to facilitate comparison between the pre-2015 era and the updated data, values exceeding the maximum were simply set to the maximum in those cases. For instance, certain water-rich countries had annual per capita water resources exceeding the maximum normalized value of 5,000 m^3/person. Those data points were hard-coded to be equal to 5,000 m^3/person.
2. In the raw data for the "percentage access to modern fuels" indicator, very high and very low values were top- and bottom-coded as string values (">95" and "<5," respectively) instead of an exact numeric value. To use those values for calculating the energy index, they needed to be converted to a numeric data type. Hence, we coded them as 95 percent and 5 percent, respectively.
3. Kuwait had very low water resources per capita that were recorded as zero in the raw data, which would carry over in subsequent calculations and yield values of zero for the water subindex and the FEW Index. Therefore, in this case, we instead carried forward the figures used by the previous team for water resources per capita, which represented the latest value available for Kuwait up to 2014.

After data cleaning and processing steps were completed, we merged the individual data into one comprehensive dataset containing the FEW Index, the three subindexes (energy, food, and

water), and the indicators used to calculate them. There were seven periods for which data were collected and indexes calculated:

- five annual readings for the years 2015 through 2019
- one reading covering the whole 2015–2019 period with the latest available data used for each indicator during that time frame
- one reading covering the latest available data from the pre-2015 period. These values are the same as the values provided by the previous team and were taken from their work in order to provide a comparison.

Because of variation in data collection by the publishers of the data sources used for this work, annual data on certain indicators for some countries were unavailable. Table 5 shows the number of countries for which each subindex and parameter could be calculated in each period.

Table 5. Number of Countries for Which Data on Each Parameter Are Available, by Period

Parameter	2015	2016	2017	2018	2019	At Least One Reading from 2015 to 2019	At Least One Reading Prior to 2015
FEW Index	148	148	146	147	145	149	167
Food subindex	159	159	159	160	160	160	177
Food availability	160	160	160	161	161	161	177
Food accessibility	165	165	175	175	175	176	183
Energy subindex	189	190	188	188	189	191	201
Energy availability	192	193	191	195	195	197	210
Energy accessibility	218	218	218	218	219	219	212
Water subindex	179	179	177	173	171	180	178
Water availability	183	183	184	184	184	184	182
Water accessibility	231	231	227	219	217	232	213
Water adaptive capacity	183	183	183	184	183	184	182

In addition to updating the existing data, we plotted the predicted changes in the FEW Index and its subindexes for each country over the 2015–2019 period and measured the practical and statistical significance of these trends. This was done for each index and country by conducting a linear regression using the index value as the outcome and the year as the independent variable. To assess the magnitude of the trend, we used this linear model to predict the index values for each country in the first available year (usually 2015) and the last available year (usually 2019), and we converted the difference between the two values to a predicted percentage change via the following formula:

$$Predicted\ percentage\ change\ in\ index = 100 * \frac{Predicted\ 2019\ index\ value - Predicted\ 2015\ index\ value}{Predicted\ 2015\ index\ value}$$

We also conducted hypothesis tests for each country and index to check the significance of the coefficient on the year term in the associated regression and reported the resultant *p*-values. A nonzero coefficient implies the existence of a temporal trend, whereas a coefficient of zero would imply that the index value neither increases nor decreases over time. This endeavor facilitated a statistically robust insight into the performance of countries and regions on these indexes over the measured period and contextualized the predicted performance on the subindexes by allowing a side-by-side comparison.

Visualization

Once a clean dataset was available, we used Tableau to construct dashboards for the visualization tool. A total of eight dashboards were constructed.

Six of the dashboards were updated versions of the visualizations created for the initial version of the FEW Index tool. These are the following:

- *Map View*. A geographic dashboard overlaying the data on a map of the world, allowing users to select and see data by country.
- *Data View*. A spreadsheet view of the dataset.
- *Plot (FEW)*. A bubble plot that maps the FEW Index and the three subindexes on one set of axes. The energy and water subindexes are the axes of the plot, the FEW Index is represented by the shade of the bubbles, and the food subindex is indicated by the size of the bubbles.
- *Plot (Energy)*. A bubble plot that maps the energy subindex against its components (availability and accessibility)
- *Plot (Food)*. A bubble plot that maps the food subindex against its components (availability and accessibility)
- *Plot (Water)*. A bubble plot that maps the water subindex against its components. Water availability and water accessibility form the axes of the graph, the water subindex is represented by the shade of the bubbles, and water adaptive capacity is indicated by the size of the bubbles.

The remaining two dashboards visualize the predicted changes in each index over time. They are the following:

- *Map Variation*. This visualization is similar to the Map View but displays the predicted percentage change in each index over the 2015–2019 period instead of the index values.
- *Variation Plots*. This is a two-part visualization. First, the predicted percentage change in the FEW Index for each country is plotted on a single axis. Below that plot, the predicted changes in the subindexes are plotted against each other; the predicted percentage changes in the food and energy subindexes form the axes of the graph, while the color of the bubbles indicates the predicted percentage change in the energy subindex.

To improve the accessibility of the FEW Index tool, we changed the color scheme from a diverging red-green scale (red indicating low values and green denoting higher values) to a sequential purple scale in which lighter purples represent lower values and darker purples

indicate higher values. For the latter two dashboards that visualize the predicted change in the indexes over time, we used a diverging light red–light purple scale. In this scheme, no change is represented by gray. From that point, the redder the shade, the larger the decrease in an index value, and the more purple the shade, the larger the increase in the value.

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