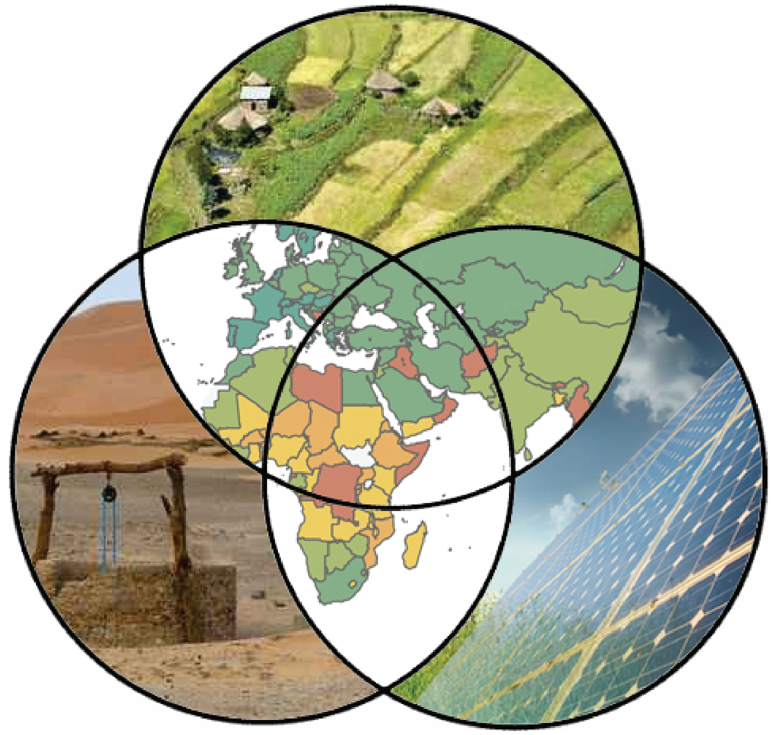

Developing the Pardee RAND Food-Energy-Water Security Index

Toward a Global Standardized, Quantitative, and Transparent Resource Assessment

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Preface

More than 2 billion people around the world, especially in developing countries, do not have access to high-quality services related to food, energy, and water. To provide information to development agencies and efforts focused on food, energy, and water resources, the RAND Corporation developed the Pardee RAND Food-Energy-Water Security Index. The index can be accessed online through an interactive RAND website (www.rand.org/t/TL165) that allows exploration of the data through maps and charts or downloading of the data for offline analysis. This report serves as the technical documentation for the index.

Funding for the development of the Pardee RAND Food-Energy-Water Security Index was provided by philanthropic contributions from RAND supporters and income from operations. Additional funding was made available through the establishment of the Pardee Initiative for Global Human Progress, made possible by the generous support of Frederick S. Pardee.

The index described in this report (available at www.prgs.edu/pardee-initiative/food-energy-water/interactive-index.) provides a standardized, quantitative, and transparent estimation of the nexus between food, energy, and water that can easily be used by policymakers, the development community, scientists, and the public interested in improving human development worldwide.

RAND Infrastructure Resilience and Environmental Policy Program

The research reported here was conducted in the RAND Infrastructure Resilience and Environmental Policy program, which performs analyses on urbanization and other stresses. This includes research on infrastructure development; infrastructure financing; energy policy; urban planning and the role of public–private partnerships; transportation policy; climate response, mitigation, and adaptation; environmental sustainability; and water resource management and coastal protection. Program research is supported by government agencies, foundations, and the private sector.

This program is part of RAND Justice, Infrastructure, and Environment, a division of the RAND Corporation dedicated to improving policy- and decisionmaking in a wide range of policy domains, including civil and criminal justice, infrastructure protection and homeland security, transportation and energy policy, and environmental and natural resource policy.

Questions or comments about this report should be sent to the project leader, Henry Willis (Henry_Willis@rand.org). For more information about RAND Infrastructure Resilience and Environmental Policy, see www.rand.org/jie/irep or contact the director at irep@rand.org.

The Pardee RAND Graduate School

The Pardee RAND Graduate School is unique in American higher education. Founded in 1970 as one of the original eight programs in public policy, Pardee RAND is the only program specializing exclusively in the Ph.D. degree. It is also the only one based at a public policy research organization—the RAND Corporation. With approximately 100 enrolled students, and a faculty-student ratio of 2:1, Pardee RAND offers exceptional training and access to some of the world's leading policy practitioners. The core curriculum focuses on analytic tools and methodologies including economics, statistics, operations research, and the behavioral and social sciences. Students gain practical experience and earn their fellowships through on-the-job training as members of RAND's research teams working on policy projects for a global clientele. As a result, they graduate with an academic and professional portfolio—or, as we say, "Curriculum Plus Vitae." The Pardee Initiative for Global Human Progress supports work by faculty and students that is designed to have a positive impact on the lives of the world's most vulnerable populations.

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Summary

More than 2 billion people around the world, especially in developing countries, do not have access to high-quality services related to food, energy, and water, and that trend is predicted to continue in many areas. The negative consequences of this lack of access are enormous and include environmental degradation, threats to national security, economic hardship, and social strife.

Given the interconnections between food, energy, and water resources, a holistic approach to understanding the state of these resources can improve economic efficiency, resource efficiency, population livelihood, and public health. Further, international development efforts would be more likely to succeed if energy, food, and water resources are understood and managed holistically.

To provide information to development agencies and others studying food, energy, and water resources, the RAND Corporation developed a global Pardee RAND Food-Energy-Water Security Index (FEW Index). The index can be accessed online through an interactive RAND website that allows exploration of the data through maps and charts or downloading of the data for offline analysis. This report serves as the technical documentation for the index.

The integrated FEW Index is comprised of three sub-indices; one each for food, energy, and water. The index combines these sub-indices using an unweighted, geometric mean:

$$\text{FEW Index} = \sqrt[3]{(\text{Food Sub-Index}) \times (\text{Energy Sub-Index}) \times (\text{Water Sub-Index})}$$

Approaches to measuring natural resource security have addressed many dimensions, including scarcity, stress, supply reliability, supply diversity, sustainability, environmental impact, and equity. The resource sub-indices in the FEW Index are each comprised of two or more indicators reflecting dimensions related to:

1. *Availability*: The link between resources and human development is most directly determined by whether the population is provided adequate resources to support needs for dietary requirements, sanitation, and productivity.
2. *Accessibility*: Only measuring the aggregate amount of available resources to support development is an insufficient measure of security. The distribution of those resources across society is also an important consideration.

When resources are not commoditized and traded globally, measures of security ought to incorporate measures of the risk of severe disruptions both in the short and long term. These conditions exist for water. Thus, for water security, the index also reflects how much

slack is available in the natural resource supplies to allow nations to accommodate long-term changes and adapt to short-term disruptions. We refer to a nation's capabilities to provide water resources over time and in response to disruptions as its *adaptive capacity*.

Examining the FEW Index provides a picture of the state of availability and accessibility of these resources worldwide. We calculate and present the index for the 166 countries for which data was publicly available. Examination of the index provides insight into how much variation exists in resource security worldwide, how that variation is distributed, and what factors contribute to resource insecurity for specific countries.

It is our hope that broad use of this index can help improve the effectiveness and efficiency of development efforts worldwide. Toward this goal, we have identified three possible extensions of how the FEW Index can be used: understanding relationships to broader development outcomes, exploring regional relationships among the indicators, and examining how global trends might affect trends in the index.

Acknowledgments

This work was made possible through the generous support of Frederick S. Pardee. The authors also wish to thank Keith Crane, Susan Marquis, Dick Neu, and Rachel Swanger for their guidance and suggestions during development of this work. Finally, this work benefited from the constructive comments and feedback provided by two peer-reviewers, Aaron Strong and Benjamin Sovacool.

CHAPTER ONE

Measuring Food, Energy, and Water Security

Food, energy, and water are considered "the pillars on which global security, prosperity, and equity stand" (Hague, 2010). More than 2 billion people around the world, especially in developing countries, do not have access to high-quality services related to food, energy and water, and this is expected to persist and even worsen in some areas over the coming decades (Bazilian et al., 2011; Rodriquez et al., 2013). The negative consequences of this resource insecurity are enormous and include environmental, security, economic, and social concerns.

Literature on human development also makes clear the importance of food, energy, and water resources to support human development. Over and above the ethical considerations associated with the right to food and water, adequate food and water are important factors in creating an environment conducive to economic growth (Timmer, 2000; Grey and Sadoff, 2007). These resources lead to improved health outcomes (McIntyre, 2003; Gatrell and Elliott, 2009), which in turn improve workforce productivity (Loeppke et al., 2009). Conversely, lack of quality food can lead to physical impairment, which contributes to reduced learning in children and adults as well as a loss of productivity, e.g., in the form of absenteeism at work (Hamelin, Habicht, and Beaudry, 1999). Insufficient clean water can cause death, devastation, and poverty either catastrophically, through drought and epidemic, or progressively, through desertification and endemic disease (Viala, 2008).

Energy supply also underpins human development. Access to modern forms of energy is essential for the provision of clean water, sanitation, and health care and provides great benefits to development through the provision of reliable and efficient lighting, heating, cooking, mechanical power, transport, communications, information technology, and refrigeration (Haines, 2007; International Energy Agency, 2010). Energy production also improves workforce productivity by lengthening productive work hours and mechanization. Enhanced workforce productivity improves economic growth (Sovacool et al., 2012).

Numerous studies have sought to quantify the important links among these three resources. For example, energy is used in conveyance, treatment, and distribution of water. Approximately 7 percent of commercial energy production is used globally for managing the world's freshwater supply (California Energy Commission, 2011). Energy production, in turn, requires substantial quantities of water. Thermal power plants use large amounts of water for cooling (Macknick et al., 2011) and lose a considerable amount of water to evaporation (Torcellini, Long, and Judkoff, 2003). In addition, significant quantities of water are required for other energy processing activities, such as refining oil products or manufacturing synthetic fuels. Hydropower plants also use significant land areas, and thus reduce agricultural potential. The United Nations (UN) estimates that the volume of water evaporated from reservoirs is estimated to exceed the combined freshwater needs of industry and domestic consumption, which represent about 25 percent of global water use. As the UN concluded, hydroelectric dams therefore "greatly contribute to water losses around the world, especially in hot tropical regions" (United Nations Environment Programme, 2008). Finally, production of biofuels affects food markets and requires water.

Food production requires access to both water and energy for irrigation, cooling, processing, and transport. For instance, approximately 60–80 percent of global anthropogenic water is used for irrigation. In arid developing countries, irrigation can account for as much as 90 percent of total water use (Gerbens-Leenes, Hoekstra, and van der Meer, 2009). Among members of the Organisation for Economic Co-operation and Development (OECD), around 3–5 percent of total final energy consumption is used directly in the agriculture sector, and this figure increases to 4–8 percent in developing countries (Food and Agriculture Organization of the United Nations [FAO], 2000).

Many studies have looked at aspects of the food, energy, and water sustainability challenge and nexus. Across this literature, which is described in the next section, we have not identified a body of work that analyzes the state of food, energy, and water in an integrated, transparent, and consistent way at the national level across the globe. Given the interconnections between food, energy, and water resources, a holistic approach to understanding the state of these resources can improve economic efficiency, resource efficiency, population livelihood, and public health. Further, international development efforts would be more likely to succeed if energy, food, and water resources are understood and managed holistically. More precisely, governments, foundations, and non-governmental organizations working on improving human development need an integrated way to measure the state of food, energy, and water security. Moreover, they also need a way to project how development efforts or future trends will affect each of these resources.

To provide information to development agencies and efforts focused on food, energy, and water resources, the RAND Corporation developed a global, integrated Pardee RAND Food-Energy-Water Security Index (FEW Index). The index data can be accessed online through an interactive RAND website that allows exploration of the data through maps and charts or downloading of the data for offline analysis. This report serves as the technical documentation of the index. Subsequent chapters detail the motivation for developing the index (remainder of Chapter One), methods and data used in calculating the index (Chapter Two), observations that can be made using the index (Chapter Three), and a few extensions for the index (Chapter Four).

1.1. Approaches to Measuring the Food, Energy, and Water Nexus

While the vast majority of studies in this area focus on linkages between only two of the three dimensions, i.e., water and energy, water and food, and food and energy, some works analyze the impact of a certain policy on the three domains. For instance, Rajagopal and Priscoli (2008) assesses the implications of India's biofuel policies for food supply, agriculture, and water demand. McCornick, Awulachew, and Abebe (2008) illustrates potential paths for developing renewable energy that maximizes synergies between water, energy, food, and the environment.

Nevertheless, it was not until late 2011 that the international community started to pay special attention to the nexus between water, food, and energy. The international conference on "The Water, Energy, and Food Security Nexus—Solutions for the Green Economy," also known as the Bonn2011 Nexus Conference, sparked global interest in learning about the three dimensions in an integrated manner. As a result of the conference, many policy briefs were published that called for examination of the three sectors together. For example, Bazilian et al. (2011) describes some of the linkages between food, energy, and water and suggests a high-level modeling framework to address the nexus from a developing country perspective. This paper also acknowledges the need to develop tools and analysis to support political dialogue and decisionmaking.

Since then, a few organizations have sought to develop tools to guide policymakers on food, energy, and water. The most comprehensive endeavor is the UN's Integrated Water-Energy-Food Security Framework, a joint effort between the UN's Department of Economic and Social Affairs/Division for Sustainable Development and the Nicholas School of the Environment at Duke University. The project reviewed and analyzed the national reports and proposals submitted following the UN's Sustainable Development Conference (Rio + 20) to extract information on challenges, policies, and strategies related to water, energy, and food security. Eight countries in East Africa, South Asia, and Southeast Asia were shortlisted for additional in-depth research and potential capacity-building work incorporating the integrated framework. The eight countries include Bhutan, Cambodia, Ethiopia, Nepal, Sri Lanka, Tanzania, Timor-Leste, and Vietnam (Cornforth, Becuwe and Sconfienza, 2014).

Other efforts at the nexus level can be roughly divided into two categories: integrated measurements (or indices), and tools that model the linkages between two or three of the domains. This section describes the key approaches in this area, and Table 1.1 lists those and additional tools commonly featured in the literature.

1.1.1. Integrated Indices

A few relatively new indices incorporate the three pillars of food, energy, and water, along with other indicators, to assess different issues. A prominent example is the Notre Dame Global Adaptation Index (ND-GAIN), a project of the Global Adaptation Institute, which was developed and funded by the University of Notre Dame and NGP Energy Capital Partners. The ND-GAIN Index assesses which countries are best prepared to deal with global changes brought about by overcrowding, resource constraints, and climate disruption. It combines 50 indicators into two sub-scores of vulnerability and readiness, which are, in turn, merged to produce a country's overall score.

Vulnerability is defined by ND-GAIN as exposure and sensitivity to climate, population, infrastructure, and resource stress, as well as a country's adaptive capacity to address those stresses. The vulnerability score is calculated from 36 indicators grouped by sectors under the components of exposure and sensitivity to climate risk, and adaptive capacity. In addition to food, energy, and water infrastructure, it considers many other sectors, including health, ecosystems, human habitat, coastal infrastructure, and transportation infrastructure.

For water resources, for example, the exposure variables to climate risk are *projected change in precipitation* and *projected change in temperature*. The sensitivity variables are *internal and external freshwater extracted for all uses* and *mortality among children under five years old due to water-borne diseases*. Adaptive capacity variables for the water sector are *population with access to improved water supply* and *improved sanitation*.

ND-GAIN defines *readiness* as a country's "readiness to leverage investments to enhance adaptive capacity." The readiness score is calculated from 14 measures grouped under eco-

Table 1.1
Indicators and Tools Describing the Food, Energy, and Water Nexus

Index	Organization	Description	Indicators	Countries	Years
ND-GAIN	Climate Change Adaptation program, University of Notre Dame Environmental Change Initiative, and NGP Energy Capital Partners	Shows which countries are best prepared to deal with global changes brought about by overcrowding, resource constraints, and climate disruption. The index incorporates elements of vulnerability (defined as exposure and sensitivity to climate, population, infrastructure, and resource stress) and countries' readiness to respond to those stresses. ND-GAIN focuses on the following elements: water, food, health, ecosystems, human habitat, coastal infrastructure, energy infrastructure, transportation infrastructure, economic/fiscal variables, governance, and social capacity.	50 indicators grouped under vulnerability and readiness scores. The vulnerability score is calculated from 36 indicators and the readiness score is calculated from 14 indicators.	176	1996–2013 (and ongoing)
Environmental Performance Index (EPI)	Yale Center for Environmental Law and Policy and the Center for International Earth Science Information Network at Columbia University, in collaboration with the World Economic Forum	The objective of EPI is to assess environmental health and ecosystem vitality. Environmental health measures the protection of human health from environmental harm, while ecosystem vitality measures ecosystem protection and resource management. These two objectives are divided into nine environmental issue areas, including water and sanitation, water resources, agriculture, climate and energy, and health, among others.	20 indicators calculated that underlie the nine issue categories	178	Back-casts scores starting from 2002–present
Human Insecurity Index (HII)	Institute for Development and Peace	Expands on other work by accounting for security threats caused by nonviolent factors such as undernourishment, infectious diseases, and natural disasters.	30+ indicators that reflect 12 aspects of the economic, environmental, and social fabric of security.	209 (countries and regions)	2008 only

nomic, governance, and social readiness. Some of the indicators include business, trade, fiscal, monetary, and investment freedoms, as well as political stability and accountability.

The index draws on secondary data from international organizations such as the World Bank and the UN. It covers 176 countries for the years 1996–2013 and is ongoing (ND-GAIN, undated).

An additional index that considers aspects of food, energy, and water together with numerous other variables is the Environmental Performance Index (EPI), a joint project between the Yale Center for Environmental Law and Policy and the Center for International Earth Science Information Network at Columbia University, in collaboration with the World Economic Forum. The objective of EPI is to assess environmental health and ecosystem vitality. Environmental health measures the protection of human health from environmental harm, while ecosystem vitality measures ecosystem protection and resource management.

These two objectives are divided into nine environmental issue areas, including water and sanitation, water resources, agriculture, climate and energy, and health, among others. Underlying the nine issue categories are 20 indicators calculated from country-level data and statistics. For example, the indicator for water resources is *wastewater treatment*. For water and sanitation, the indicators are *access to drinking water* and *access to sanitation*. Under agriculture, the indicators are *pesticide regulation* and *agricultural subsidies*. The energy and climate issue area is comprised of three indicators: *trend in carbon dioxide emissions*, *trend in carbon intensity*, and *change of trend in carbon intensity*.

The EPI covers 178 countries for which it back-casts scores (when possible) starting from 2002 (EPI, undated).

A third index in this category is the Human Insecurity Index (HII) developed by the Institute for Development and Peace of the University of Duisburg-Essen in Germany. This index seeks to add to previous attempts to measure human security that adopted a restricted approach to human security and failed to take into account security threats caused by non-violent factors, such as undernourishment, infectious diseases, and natural disasters. The HII considers the following dimensions, each of which is assessed according to different indicators: *economic security*, measured by gross domestic product (GDP) and purchasing power parity; *food security*, focusing on elements of availability and accessibility, and measured by the number of children under five underweighted for age, and by the percentage of population that is undernourished; *health insecurity*, which is closely related to food security and measured by the population affected by diseases and child mortality rate; *environmental security*, which also considers water aspects and is assessed through the percentage of population that is affected by disasters and the percentage of population with access to clean water and improved water sanitation; *personal and community security*, gauged by the number of people assisted by the UN High Commissioner for Refugees and an existing political terror scale; and *political security*, which incorporates the press freedom index and indicators related to personal security.

The HII covers 209 countries and regions (such as Gaza and the West Bank). Because the goal was mainly to operationalize the concept of human security, the index was computed only for the year 2008 (Werthes, Heaven, and Vollnhals, 2011).

1.1.2. Linkages Tools at Nexus Level

No fewer than five tools have been developed to help guide policymakers in decisionmaking processes that concern food, energy, and water holistically. The Foreseer Project of the University of Cambridge, for example, is an online tool for visualizing the influence of future demand scenarios on requirements for energy, water, and land resources. The tool's inputs include forecasts of demand for final services that derive from energy, water, and land resources, as well as editable technology scenarios to predict how technology performance and selection may evolve over time. The tool allows sensitivity studies to predict the value of technology innovations. It visualizes linked energy, water, and land resource futures by outputting a set of Sankey diagrams[1] for energy, water, and land, showing the flow from basic resource (e.g., coal, surface water, forested land) through transformations (e.g., fuel refining, desalination) to final services (e.g., housing, food, transport, goods) (Foreseer, undated).

The World Business Council for Sustainable Development's Pathway WFE Nexus focuses on the food/fiber/feed nexus. In particular, it is interested in answering the following questions: First, which crops and geographies of interest can be considered hotspots today, in 2030, and in 2050? Second, what are the constraints on the availability of water and energy resources as a result of future food/feed/fiber/fuel/biomaterials demand? To address those questions, the Pathway WFE Nexus considers multiple indicators, including crop water use, area, yield, irrigation, total agricultural water, blue water, green water, fuel use, agricultural labor population, fertilizer and pesticide use, pumping, irrigation efficiency, and more (Cramwinckel and Patel, 2013).

Similar tools were tailored to specific local and regional needs. For instance, the Research Institute for Humanity and Nature has embarked on a Water-Energy-Food Nexus project, which develops a method to manage and optimize the human-environmental security of the nexus in Asia-Pacific coastal regions. Similarly, the Qatar Environment and Energy Research Institute developed the Water-Energy-Food Nexus Tool (WEF Nexus Tool 2.0, undated) to allow decisionmakers to create various scenarios and predict their resource demands, focusing on Qatar only. The scenarios are composed of different variations of local food production levels, water sources, energy sources, and food import sources. The output will include a holistic summary of resource needs for a given scenario, including water, energy, land, and financial requirements, as well as identify environmental impacts.

A more focused tool that addresses the linkage between food and energy only is the Global Bioenergy Partnership Indicators for Sustainable Bioenergy, developed by the FAO, the Department for National Planning in Colombia, and three ministries (Energy and Mineral Resources, Environment, and Economic Affairs) in Indonesia. This is a pilot study designed to test 24 indicators for sustainable bioenergy in Colombia and Indonesia. The main objective of the project is to assess data availability and collection capacity, and tailor methodologies for measuring the indicators to country conditions (FAO, 2011).

1.2. A Holistic View of Food, Energy, and Water Resources

The FEW Index described in this paper is different than existing food, energy, or water security indices in several ways. The proposed approach is based on several key concepts:

- **Food, energy, and water are interrelated and each essential for development.** The selected indicators provide a holistic view of the availability and accessibility of food,

[1] Sankey diagrams are a specific type of flow diagram, in which the width of the arrows is shown proportionally to the flow quantity.

energy, and water resources in a country. These data allow those interested in improving development to understand the dominant sources of insecurity for food, energy, and water in a nation and identify cases where many sources of this insecurity are interrelated.

- **Focusing on availability and accessibility of food, energy, and water resources provides clarity when assessing development needs.** The proposed indicators are focused on the two concepts that we conclude are most closely related to human development. Other indices incorporate additional dimensions of security, such as national resource independence, environmental sustainability, resource quality, and social justice.
- **Simple combinations of factors improve transparency.** The proposed index aggregates sub-indices that are simple combinations of observable, measurable indicators. Other sub-indices use subjective, expert judgment for both assessments of component indicators and for weighting factors used to combine indicators into an overall index. Improved transparency will help us to understand insights into how provision of these basic resources influences human development.

Adhering to this approach creates an index that the development community can use to measure the provision of food, energy, and water resources (i.e., security) at a national level for each country in the world. It can be used to answer questions about which resources may be responsible for barriers to human development.

CHAPTER TWO

The Pardee RAND Food-Energy-Water Security Index

The Pardee RAND Food-Energy-Water Security Index is based on the principle that sufficient, widely accessible food, energy, and water are all required for human development, and high security in one or two of these factors cannot completely compensate for low security in others.

The FEW Index is comprised of three sub-indices—one each for food, energy, and water—and combines these sub-indices using an unweighted, geometric mean:

$$\text{FEW Index} = \sqrt[3]{(\text{Food Sub-Index}) \times (\text{Energy Sub-Index}) \times (\text{Water Sub-Index})}$$

Approaches to measuring natural resource security have addressed many dimensions, including scarcity, stress, supply reliability, supply diversity, sustainability, environmental impact, and equity. The resource sub-indices in the FEW Index are each comprised of two or more indicators reflecting dimensions related to two factors:

1. *Availability*: The link between resources and human development is most directly determined by whether the population is provided adequate resources to support needs for dietary requirements, sanitation, and productivity.
2. *Accessibility*: Only measuring the aggregate amount of available resources to support development is an insufficient measure of security. The distribution of those resources across society is also an important consideration.

When resources are commoditized and traded globally, resource security depends on more than infrastructure and markets that support availability and accessibility. Without access to global markets, resource security also depends on domestic supplies. For resources where this condition exists, measures of security ought to incorporate measures of the risk of severe disruptions both in the short and long term. These conditions exist for water. Thus, for water security, the index also reflects how much slack is available in the natural resource supplies to allow nations to accommodate long-term changes and adapt to short-term disruptions. We refer to a nation's capabilities to provide water resources over time and in response to disruptions as its *adaptive capacity*.

The sub-indices were aggregated using similar formulas based on a geometric mean of the appropriate terms for each domain. The specific indicators used in each domain are described in in Sections 2.1 through 2.3.

In developing formulas used to calculate the sub-indices and indices, we were careful that the indices were not influenced by the scale of any single component and that percentage changes in any component had an equivalent effect on the overall index. This required attention to normalization and aggregation of scales. We normalized all indicators to span the range of observed values using the following formula, such that higher values are associated with greater levels of security:

$$\text{Normalized Value} = \frac{(\text{Actual Value} - \text{Logical Minimum})}{(\text{Logical Maximum Value} - \text{Logical Minimum})}$$

The logical minimum and maximum values were selected with consideration both to the concept being measured and the distribution of countries along the scale. For example, in all cases, "0" was the appropriate value to use as a logical minimum. However, in some cases the logical maximum represented the maximum possible value (e.g., a value of "1" for a scale representing a proportion). In other cases, the logical maximum was simply the observed maximum value.

However, in several cases the logical maximum was selected so as to truncate the normalized scale such that it was not overly influenced by outliers (e.g., countries with much more water or fossil fuel resources than others). Truncation of the values emphasizes countries where resource security is below some acceptable level. Using this method, a value of 1 reflects that the conditions for that sub-index, i.e., resource development, are sufficient to meet basic human needs. By truncating sub-indices at the level associated with basic needs, calculation of the index does not allow one element of the combined index, which reflects significantly greater resource security than what is required for basic needs, to compensate for a part of the index that is not. Appendix A lists the values used across all scales described in this report.

The FEW Index uses country-level data from publicly available data sources. (See Appendix A.) Use of publicly available data makes the index more accessible and verifiable than if it were constructed with proprietary data. Data are not available for all countries and all years. To support comparisons across the broadest range of countries, we used the latest year of data available for each variable. Generally, these data are from the past five years, though in some cases data are from the past decade.

This approach maximizes the number of countries for which the index can be calculated. However, the index cannot be used to evaluate how changes have occurred in the recent past because we do not provide values for the index on an annual basis. As more data becomes available, the index could be calculated for five- or ten-year periods by using the most recent data from each period.

2.1. Measuring Food Security

2.1.1. Defining Food Security

Food security is a growing global concern. Over 840 million people worldwide, or one in eight, suffer from undernourishment. Even more alarming, over 100 million children under the age of five are underweight, and childhood malnutrition is a cause of death for more than 2.5 million children every year (FAO, 2012). Future outlook does not look promising either. According to the UN's Intergovernmental Panel on Climate Change (2014), the world's food supply is at considerable risk. This section introduces the basic definition of food security, discusses the different elements that make up this elusive concept, and reviews key efforts to measure it.

A great deal of attention has been paid in the literature to defining food security. An analysis conducted over 20 years ago found more than 200 definitions in published articles (Maxwell and Smith, 1992). Since that time, the definition of food security has evolved and expanded. Early definitions were focused on supply issues, such as the availability of basic foodstuffs and the stability of prices (Clay, 2002). More recent definitions have included aspects related to consumption and access issues, particularly among vulnerable populations. Over time, the definition has converged, with most recent studies using the definition developed at the 1996 World Food Summit (FAO, 1996) and adapted by FAO in *The State of Food Insecurity 2001* (FAO, 2002).

> Food security [is] a situation that exists when all people, at all times, have physical, social, and economic access to sufficient, safe, and nutritious food that meets their dietary needs and food preferences for an active and healthy life.

The key elements in this definition include access, availability, stability, and quality. The *access* concept is quite broad and considers issues related to physical access, economic access, social environment, and others. *Availability* considers the supply of food and whether it is sufficient to meet the needs of the population. *Stability* considers how well the system is able to adapt to shocks and maintain a consistent supply of food so that it is available at all times. The final element, *quality*, considers the safety and diversity of foods available, and is often thought of as part of the broader aspect of *utilization*.

The FAO's aforementioned broad definition has been adopted globally; however, different organizations interpret some pillars—availability, accessibility, and utilization—differently. While availability is a more straight-forward supply element, accessibility attempts to capture a multidimensional demand concept, manifested in uneven food distribution and in sociocultural tastes and values within communities (Barrett, 2010). It includes the infrastructure for distributing food within a country (i.e., physical infrastructure), the price of food relative to income (i.e., economics), safety, and the cultural norms and social environment. *Utilization* refers to the way in which individuals and households use the food to which they have access. As such, it is mostly related to dietary quality but, on a broader scale, is also associated with safety issues, such as access to clean water or to sanitation facilities (FAO, 2012).

2.1.2. Existing Food Security Indices

To help inform food policies, as well as to better direct scarce resources to where they are most needed, multiple organizations have started to measure food security in recent years. The approaches to measurement, however, are as factor-diverse as the institutions themselves, with different organizations focusing on different elements and utilizing different proxy indicators.

In general, the major efforts to measure food security can be broadly divided into three sub-categories: (1) comprehensive across the multiple dimensions (availability, access, and utilization); (2) narrowly focused; and (3) indices that assess capacity/commitment to promote food security. A summary of those and other food security indices is presented in Table 2.1.

Comprehensive Food Security Indices

The FAO offers the most comprehensive set of indicators to measure food security across and within various dimensions. In its annual report, titled *The State of Food Insecurity in the World*, it employs primary and secondary data on food availability, accessibility, utilization, and

Table 2.1
Existing Food Security Indices

Index	Organization	Description	Indicators	Countries	Years
The State of Food Insecurity in the World	FAO	A set of indicators classified along four dimensions: availability, access, utilization, and stability. They are also classified as indicators of determinants and outcomes of food insecurity.	~30 quantitative	228	1990–present
Global Food Security Index	Economist Intelligence Unit (EIU)	Index considers the issues of affordability, availability, and quality. It is a dynamic quantitative and qualitative scoring model. The index is subject to the review of an expert panel.	~27 quantitative and qualitative	107	2012–present
Food Security Risk Index	Maplecroft	Proprietary. Quantitative assessment of the risk from lack of universal access to basic food staples in countries. The index is comprised of four sub-indices: current nutritional and health status of the population, and the three factors determining the intrinsic vulnerability of a country to food insecurity—availability, stability, and access to food stocks.	18 key indicators (including societal, environmental, and macroeconomic risk)	162–197	2010–present
Global Hunger Index (GHI)	International Food Policy Research Institute (IFPRI)	GHI is calculated as the average of three outcome indicators: the proportion of the population that is undernourished, the proportion of underweight children under five years old, and the proportion of children dying before age five. The index ranks countries on a 100-point scale, with 0 being the best and 100 the worst.	3 outcome indicators	129	1990, 1995, 2000, 2005, 2013
Food Security Indicators	IFPRI	In addition to GHI and other vulnerability indices, IFPRI generates several additional food security indictors, including indicators on investment in agricultural research, public spending on economic development in agriculture, global hunger levels, food policy research capacity, and total factor productivity.	Various	Depends on indicator: some only for ~20 developing countries; others for over 100	Depends on indicator; Starting from 1980 to 1990 and ending 2004, 2008, or 2012

Table 2.1—Continued

Index	Organization	Description	Indicators	Countries	Years
Rice Bowl Index	Frontier Strategy Group	Assesses how robust a country's capacity is to address the challenges of food security, and seeks to recognize which areas need to be a focus for intervention. It is comprised of a quantitative component, which examines key barriers and drivers of food security, and a qualitative component. The index is then divided into 4 rubrics: farm-level factors; environmental factors; policy and trade; and demand and price.	28 indicators grouped into 4 rubrics	14: Australia, Bangladesh, China, India, Vietnam, Indonesia, Japan, Malaysia, Myanmar, New Zealand, Pakistan, Philippines, Thailand, South Korea.	2012–present
Nutrition Barometer	World Vision & Save the Children	Assesses the political, legal, and financial commitments of governments to tackling malnutrition. Countries' progress is measured by children's nutritional status—the proportion who are underweight, stunted, or suffering from wasting—and children's chances of survival.	3 child nutrition measures, child mortality, and governments' political and legal food security commitments and financial pledges	36 countries with highest rates of child malnutrition (for example, Guatemala, Afghanistan, Kenya, and India)	2012–present
Hunger and Nutrition Commitment Index (HANCI)	Institute of Development Studies	Ranks governments on their political commitment to tackling hunger and under-nutrition. Index is formed of 2 sub-indices: one for hunger and the other for under-nutrition. Indicators are grouped under three areas of government action: (1) legal frameworks, (2) public expenditures, and (3) policies and programs. HANCI provides a tool for users to explore how the rankings change.	22 indicators of political commitment, split between 2 sub-indices	45 developing countries	2005–present

stability. The indicators are then divided into determinants (structural conditions) and outcomes (results of inadequate food consumption) of food insecurity. Determinants under accessibility include, for instance, physical access indicators—such as the percentage of roads that are paved and rail-lines density—while access outcomes measure prevalence of undernourishment as well as depth of the food deficit of a country. Similarly, utilization determinants include access to improved water sources, while utilization outcomes are percentages of children and adults who are wasted, stunted, and underweight. The FAO covers 228 countries and has data going back to 1990 for most indicators (FAO, 2012).

The EIU Global Food Security Index considers the issues of food availability, affordability, and quality across 107 countries from 2012 onward. The index includes 27 quantitative and qualitative indicators, some of which were developed by the EIU itself. The indicators are combined according to judgments of subject-matter experts.

The EIU's interpretation of the elements of food security is more expansive than the FAO's. For example, it defines *availability* as "the sufficiency of the national food supply, the risk of supply disruption, national capacity to disseminate food, and research efforts to expand agricultural output." This broad definition combines basic elements, such as food supplies and public expenditures on agricultural research and development, with risk indicators, including corruption and political instability. *Affordability* is composed of price indicators as well as GDP and agricultural import tariffs, among others, while *quality* and *safety* are measured by diet diversification combined with nutritional standards and food safety (EIU, 2013).

The third broad index is Maplecroft's proprietary Food Security Risk Index, "which provides a quantitative assessment of the risk from lack of universal access to basic food staples." The index covers 162–197 countries, depending on the year, starting in 2010. According to Maplecroft's website, the index comprises 18 key societal, environmental, and macroeconomic risk indicators, which aggregate to form four sub-indices, the first three of which are considered as determining the intrinsic vulnerability of a country to food insecurity: (1) food availability; (2) food stability; (3) access to food stocks; and (4) current nutritional and health status of the population (Maplecroft, undated b).

Narrow Food Security Indices

One of the most commonly used food security indices is IFPRI's Global Hunger Index (GHI), which covers 129 countries and dates back to 1990. Unlike the broad indices discussed above, GHI focuses only on outcomes of food insecurity. It is calculated as the average of three indicators: the proportion of the population that is undernourished, the proportion of underweight children under five years old, and the proportion of children dying before age five. GHI uses this average as a measure of the sufficiency of supply to meet requirements (Wiesmann, 2006). Throughout the years, annual index reports have focused on different topics. The 2012 issue, for example, investigated how to ensure sustainable food security under conditions of water, land, and energy stress (IFPRI, 2012).

Assessing Government's Capacity and Commitment to Promote Food Security

Some relatively new indices do not measure the actual level of food security but rather assess countries' capacity and/or commitment to address the challenges of food insecurity. Those indices focus on small sets of nations or developing countries more generally.

The Rice Bowl Index, developed by Frontier Strategy Group, assesses how robust a country's capacity is to mitigate food insecurity. It consists of quantitative and qualitative components that are broken down into four rubrics and are weighted as follows: farm-level factors (weight: 30 percent); environmental factors (15 percent); policy and trade (25 percent); and demand and price (30 percent). Metrics employed under farm-level factors include, for example, cereal yield and arable land, literacy rates, mobile phone subscribers, and household credit. Under demand and price, the index incorporates such elements as consumer price index, per-capita food consumption, oil imports, and population figures (Rice Bowl Index, undated). The Rice Bowl Index appeared first in May 2012 and has covered only 14 countries (see Table 2.1).

The Nutrition Barometer, produced by World Vision and Save the Children, assesses the commitments of governments to tackle malnutrition in 36 countries with the highest levels of child undernutrition (e.g., Guatemala, Afghanistan, Kenya, and India). While different in objective, the Nutrition Barometer takes a similar approach to GHI and focuses on health outcomes. Specifically, it incorporates children's nutritional status—the proportion that are underweight or suffering stunted growth—and children's chances of survival. The Nutrition Barometer also considers governments' political and legal commitment to tackling malnutrition; for instance, their financial commitments and whether they have a national nutrition plan (Garde et al., 2012).

The third index in this subgroup is the Hunger and Nutrition Commitment Index (HANCI), which is produced by the Institute of Development Studies in England. HANCI ranks governments on their political commitment to tackling hunger and undernutrition. It utilizes 22 indicators of political commitment, which are further split into two sub-indices—one for hunger and the other for undernutrition. Under each sub-index, indicators are grouped to form three areas of government action. The first group is legal frameworks, which assesses, for example, the level of constitutional protection of the right to food. The second group is public expenditures that consider financial dimensions, such as the percentage of the government budget spent on agriculture. Finally, the third group is policies and programs, such as the extent to which nutrition features in national development policies and strategies (te Lintelo et al., 2013). It assigns the sub-indices equal weights but provides a tool for users to explore how rankings change depending on how they prioritize the three areas of government action. HANCI covers 45 developing countries and goes back to 2005 (HANCI, undated).

2.1.3. Calculating the Pardee RAND Food Security Sub-Index

The Pardee RAND Food Security Sub-Index describes two domains of food security:

- availability of sufficient food—food supplies in the country are sufficient to meet basic nutritional requirements
- access to quality foods—people have access to a diverse diet that meets their nutritional needs.

The food security sub-index is calculated using the following formula:

$$\text{Food Sub-Index} = \sqrt[2]{(\text{Food Availability}) \times (\text{Food Accessibility})}$$

Measuring Food Availability and Accessibility

Availability and accessibility speak to the current situation in a country and reflect the current level of food security. For each domain, we have selected a small number of indicators

(1–2) that provide important information about the domain and for which high-quality data are available for a broad range of countries. Some prior food security indices have focused on outcome measures to represent domains of interest. For example, GHI uses the proportion of the population that is undernourished as a measure of the sufficiency of supply to meet requirements (Wiesmann, 2006). In contrast, the Pardee RAND Food Security Sub-Index uses indicators that represent the determinants of food security. This approach will make the index more useful for policy analysis since it more directly links the index to potential policy levers. While food security would ideally be measured at an individual or household level, the data are not currently available at this level of detail. Instead, the data for the selected indicators come primarily from national balance sheets. These aggregate data provide a national picture but miss potentially important variation within a country.[1] Specific data sources are listed in Appendix A.

Definitions of food *accessibility* call out physical, economic, and social access to a quality diet. While the physical and social aspects of access are important, affordability and related economic issues are the key drivers of a country's access. Moreover, the data for economic indicators tend to be more complete and more directly linked to food security than indicators of the others. For example, existing indicators of physical access focus on general infrastructure within a country, measuring such things as rail-line density and the prevalence of paved roads. While these are related to the ability of a country to distribute food effectively, they are less directly tied to food security than measures of affordability.[2] Therefore, for access, we have chosen an indicator that reflects affordability. The EIU's Global Food Security Index also includes affordability as one of its core dimensions. However, to assess affordability, the EIU combines food-related indicators with a variety of general indicators, such as GDP, the proportion of the population living under the global poverty line, and others. Quality and safety of food are considered by the EIU as a separate dimension. The Pardee RAND Food Security Sub-Index instead focuses on specific food security indicators and introduces the concept of *access to a quality diet* by coupling the affordability indicator with one that reflects access to a diverse diet. The specific indicators are described below.

- **Domestic Food Price Level Index—**This indicator is calculated by dividing the food purchasing power parity by the general purchasing power parity, thus providing an index of the price of food in a country relative to the price of the generic consumption basket. This indicator reflects economic access to food. If the price of food is high relative to the price of the generic consumption basket, it will be more difficult for people, particularly those with low incomes, to purchase and consume an adequate diet. Thus, as the food price index rises, the population is less food secure. So that all indicators move in the same direction, we have inverted (i.e., 1/(food price level index)), the domestic food price level index. Therefore, higher values of the inverted index will reflect greater food security. This indicator is taken from the FAO's Food Security Indicators. We also considered

1 For example, it is possible that the total supply in a country is sufficient to meet minimum dietary requirements, but the distribution of food is highly unequal and some portion of the population does not have sufficient food. In such a case, the national average would make the country seem more secure than it is.

2 Social aspects (e.g., cultural norms), while important, can be difficult to characterize objectively and can vary substantially within a country. In fact, we did not find a single indicator available for a wide range of countries that reflected social access to food.

using an FAO Food Security Indicator that measures the percentage of household income that is spent on food to represent economic access. However, the data for that indicator were missing for many countries.

- **Share of Dietary Supply from Nonstarchy Foods**—This indicator is calculated as the energy supply (in kilocalories per capita per day) provided by all foods except cereals, roots, and tubers divided by total dietary energy supply (also in kilocalories per capita per day). A larger share of nonstarchy foods is associated with a wider array of food groups in the diet; thus, a higher value indicates a higher-quality diet. Therefore, this indicator measures the population's access to a diverse and high-quality diet. As the indicator rises, the population is more food secure. This indicator is derived from an FAO Food Security Indicator that measures the share of dietary supply from starchy foods.

Where both of these data exist for a country, the food accessibility indicator is the geometric mean of both indicators. Where only one of the indicators exists, the available indicator is used.

To focus the sub-index on food-specific indicators, as well as to remain consistent across the areas of food, energy, and water, we interpret *availability* to be whether there is sufficient food to meet dietary needs at the country level. This assessment requires information on the supply of food in a country and a definition of sufficiency.

The supply of food available in a country is a basic concept that is regularly measured and recorded in national food balance sheets. The definition of what amount of food is sufficient to meet dietary needs is a bit more complicated. The FAO has defined a measure of minimum dietary energy requirements based on an FAO, World Health Organization (WHO), and United Nations University expert consultation held in 2001. In this meeting, the group established energy standards for different sex and age groups (FAO, United Nations University, and World Health Organization, 2004). The minimum energy requirement for each group is the amount of food energy needed to balance energy expenditure to maintain body weight, body composition, and a level of necessary and desirable physical activity consistent with long-term good health. Because the standard differs by sex and age, the average requirement for a country will change as the demographics of the population changes. Moreover, the average requirement will vary across countries, reflecting differences in the age and sex distribution across countries.

We have combined these two concepts to create one indicator that speaks directly to the sufficiency of the supply to meet a minimum dietary requirement. We look at the per capita supply of food relative to the minimum dietary requirement within a country. The indicator is described in more detail below.

- **Supply Relative to Minimum Dietary Requirement**—This indicator is calculated as the average energy supply divided by minimum dietary energy requirement (MDER). Dietary energy requirements differ by gender and age. For the population, the minimum energy requirement is the weighted average of the minimum energy requirements of the different gender-age groups in the population. The ratio of supply to MDER indicates whether supply is sufficient to meet basic population needs. The larger the supply of food relative to the MDER, the larger the indicator, reflecting greater food security in the country. Both the average supply and MDER measures come from the FAO Food Security Indicators.

2.2. Measuring Energy Security

2.2.1. Defining Energy Security

Definitions of energy security cover a range of overlapping perspectives, depending on the motivation for studying the issue. A perspective motivated by maintaining energy supply emphasizes existence of primary resources, diversification of sources, and sovereign energy independence. A perspective motivated by geopolitical power emphasizes the geography of primary sources and sovereign energy independence. A perspective motivated by industrial economic growth emphasizes stability and adequacy of energy supplies and economic productivity of energy consumption. A perspective motivated by sustainability emphasizes consumption patterns; efficiency; and environmental impact, including carbon emissions. Finally, a social development perspective emphasizes physical, economic, and societal access to electricity, heating, cooking, and transportation energy (Sovacool, 2011).

These perspectives have been described in terms of aggregations of four dimensions of energy security (Kruyt et al., 2009; Asia Pacific Energy Research Centre, 2007):

- *availability*: most often referring to existence of resources, sometimes referring to adequacy of production and supply
- *accessibility*: sometimes described in terms of access to global markets, other times in terms of individual access to modern distribution and infrastructure
- *affordability*: often treated separately when referring to the cost of energy but, because of economics, not truly separable from availability and accessibility
- *acceptability*: referring to judgments about how the production or use of energy affects other aspects of society, such as the environment, safety, or equality.

2.2.2. Existing Energy Security Indices

Recently, there has been a surge of interest in the development of indicators for energy security. While some focus on only one aspect of the security spectrum, others attempt to measure energy security using an aggregated indicator.

Indices Measuring One Dimension of Energy Security

Access to energy services is crucial to human well-being. Thus, the International Energy Agency developed the Energy Development Index (EDI) to track a society's transition to the use of modern fuels. Mirroring the United Nations Development Programme's Human Development Index (HDI), the EDI includes four indicators that capture the overall economic development of a country, the reliability of electricity services, access to clean cooking facilities, and population access to electricity. The first two indicators can also be viewed as community indicators, while the last two are household indicators. The EDI score is calculated as the arithmetic mean of the four indicators for each country and presents results for 80 countries.

To help policymakers and analysts monitor trends in energy use and greenhouse gas emissions, the World Energy Council created a list of energy efficiency indicators. These indicators also allow assessment of policy impacts on different sectors. The energy efficiency indicators contain global indicators that measure the primary energy intensity, final energy intensity, and greenhouse gas intensity and emissions. A list of efficiency indicators are also developed for specific sectors, including power, industry, transport, households, services, and agriculture. The database has information for 93 countries with data for 1990, 2000, and 2005–2011.

In other cases, indices focus on a single fuel or technology. For example, Gupta (2008), Gnansounou (2011), and Alhajji and Williams (2003) each developed indices that measure a country's dependence on imported oil and vulnerability to shocks in the oil market.

Indicator System That Incorporates Other Energy Security Dimensions

Several different indicator systems attempted to analyze energy security in a systematic manner; many try to use energy-related indicators that reflect the sustainability of the energy sources used by an energy system at the national or subnational level.

The World Energy Council (2013) provides the Energy Sustainability Index, which ranks countries based on their ability to provide sustainable energy policies. The Energy Sustainability Index measures a country's ability to provide sustainable energy policies based on three dimensions: energy security, energy equity, and environmental sustainability. *Energy security* measures the management of a country's primary energy supply, the reliability of energy infrastructure, and the ability of supplier to meet current and future demand. *Energy equity* measures the accessibility and affordability of energy supply. *Environmental sustainability* measures energy efficiency and low-carbon development. Each dimension is measured by a letter score from A (high performance) to D (low performance). The index covers 129 countries for the years 2011–2013.

The International Energy Security Risk Index by the Institute for 21st Century Energy measures 29 global energy security risks for the top 75 energy-consuming countries around the world (Institute for 21st Century Energy, 2013). The purpose of this index is to measure the likelihood of an energy shock and how that might impact a country's economy. The 29 energy security risk indicators fall under seven energy security metrics: *global fuels* measures the reliability and diversity of global energy supply; *fuel imports* measures the exposure of national economies to supply shocks; *energy expenditure* measures the cost of energy to an economy; *price and market volatility* measures the susceptibility of an economy to market shocks; *energy use intensity* measures energy productivity; *electric power sector* measures the reliability of electricity generation capacity; *transportation sector* measures the efficiency of energy use in the transport sector; and *environmental metrics* measures the exposure to international greenhouse gas mandates. The index has global data for the years 2012 and 2013, but OECD countries have data from 1980 to 2010 in increments of five years and for 2011 and 2012.

The UN General Assembly established three global energy objectives to be accomplished by 2030: (1) to ensure universal access to modern energy services, (2) to double the global rate of improvement in energy efficiency, and (3) to double the share of renewable energy in the global energy mix. This Sustainable Energy for All (SE4ALL) initiative was embraced by more than 70 countries, as well as numerous corporations and agencies. To track the global progress in achieving these objectives, SE4ALL developed the Global Tracking Framework (Sustainable Energy for All, 2013), an indicator system that covers 181 countries for clean energy and 212 for modern energy services over the period between 1990 and 2010. The indicator system consists of four indicators measuring the progress of each of the three sustainable-energy objectives. The universal access to modern energy services objective is measured by the percentage of population with electricity access and the percentage of population with primary reliance on nonsolid fuels. Doubling the global rate of improvement of energy efficiency is measured by the rate of improvement in energy efficiency. Doubling the share of renewable energy in the global energy mix is measured by the renewable energy share in total final energy consumption. The analysis also identified "high-impact" and "fast-moving" countries to track their efforts and progress and learn from best practices.

Similar to the examples described in this section, numerous other studies have proposed multidimensional indices that describe energy security for specific energy sectors or sets of countries based on their development status (Frondel, Ritter, and Schmidt, 2009; International Energy Agency, 2007; Kemmler and Spreng, 2007; Neff 1997; Sovacool and Brown, 2010; Sovacool et al., 2011; U.S. Department of Commerce, 2012a and 2012b).

2.2.3. Calculating the Pardee RAND Energy Security Sub-Index

Consistent with our focus on understanding factors that contribute to human development, the energy security sub-index adopts a perspective that describes whether a nation provides its residents with the energy needed to meet basic human needs. To describe the current state of this dimension of energy security, the sub-index is a combination of indicators for two domains:

- *availability of sufficient electricity*—a nation's electricity infrastructure meets the needs of individuals to promote human development
- *accessibility to electricity and modern heating and cooking fuels*—individuals have access to modern forms of energy for residential uses.

The energy security sub-index is calculated using the following formula:

$$\text{Energy Sub-Index} = \sqrt[2]{(\text{Energy Availability}) \times (\text{Energy Accessibility})}$$

For each domain, we selected one or two indicators that are closely related to the concept being assessed and for which high-quality data exist for a large number of countries. Specific data sources are listed in Appendix A.

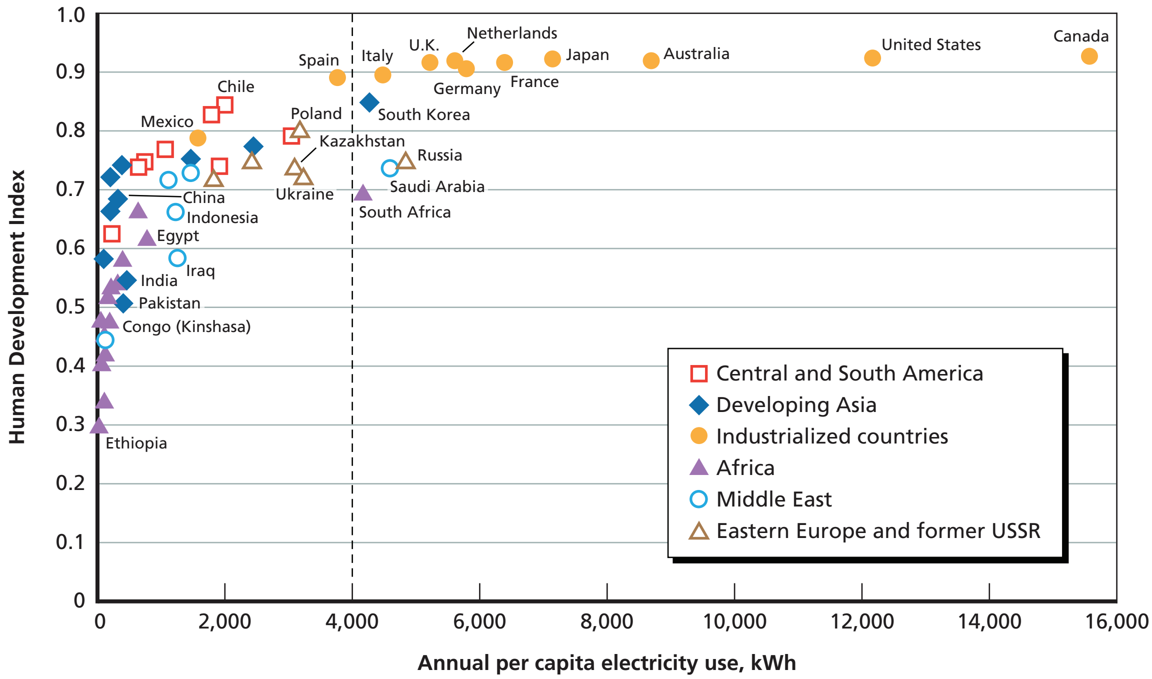
Measuring Electricity Availability

For electricity availability, we selected a ratio of the log of per capita electricity to the log of the per capita electricity consumption required to meet basic needs. This indicator focuses on electricity consumption for three reasons. First, there is a logical link between electricity consumption and human productivity, to a point. For example, electric lighting increases the productive length of a day by allowing activities such as studying and working beyond daylight hours. Second, data on per capita electricity are logarithmically correlated with measures of human development, such as the HDI, supporting the first observation (see Figure 2.1). Third, the U.S. Energy Information Agency provides a summary of electricity consumption for a large number of countries globally. Similarly, comparison of the HDI to per capita electricity consumption suggests that consumption of 4,000 kilowatt-hours (kWh) per capita is the level required to meet basic human needs (Pasternak, 2000; Steinberger and Roberts, 2009).

Measuring Electricity and Domestic Energy Accessibility

For energy accessibility, we calculated the geometric mean of two indicators that represent access to modern sources of fuel: percentage of population with access to electricity and percentage of population using modern fuels for cooking and heating. These indicators were selected because of the observed relationship between use of electricity and development (Pasternak,

Figure 2.1
Comparison of Per Capita Electricity Use to the Human Development Index



RAND *TL165-2.1*

2000; Steinberger and Roberts, 2009) previously described and a similar relationship between use of modern fuels and development (Sovacool, 2011). The latter relationship is believed to be a function of the decreased pollution associated with use of wood and animal waste for food as well as the productivity increases when people (typically women) are freed from the task of collecting fuel.

Data for percentage electrification and percentage using modern fuel are available from the World Bank and United Nations, respectively. Because data are sparser for the indicator on use of modern fuels for heating and cooking, in some cases our measure for accessibility is simply data on percentage electrification (Sovacool, 2011).

2.3. Measuring Water Security

2.3.1. Defining Water Security

Water security is a critical issue in many countries and regions across the world. In the coming years, water insecurity could deepen and spread as the world's freshwater demand is projected to exceed current supply by over 40 percent within the next two decades. The World Economic Forum's *Global Risks 2013* report ranked a water supply crisis as one of the top five risks (World Economic Forum, 2013). Water security may impact food, energy, and human security around the world. For example, countries in Asia will need, on average, 65 percent more freshwater supply by 2030 to meet their economic growth targets (World Economic Forum, 2012).

Water security has been defined as an overarching goal where "every person has access to enough safe water at affordable cost to lead a clean, healthy, and productive life, while ensuring that the environment is protected and enhanced" (Global Water Partnership, 2000). To facilitate the articulation of the post-2015 Sustainable Development Goals, UN-Water proposed the following definition of water security:

> The capacity of a population to safeguard sustainable access to adequate quantities of and acceptable quality water for sustaining livelihoods, human well-being, and socio-economic development, for ensuring protection against water-borne pollution and water-related disasters, and for preserving ecosystems in a climate of peace and political stability. (UN-Water, 2014)

The development of water security indicators and indices has evolved over the past few decades. Below, we provide a brief review of existing water security indices that vary by assessing criteria, their targeted users, and geographical focus.

2.3.2. Existing Water Security Indices

The analysis of water security starts with a focus on identifying the basic human water requirements. Since the 1980s, indices were developed to quantify per capita water use for basic human requirements and to identify thresholds that indicate unmet basic water needs. Among them, the most well known is the Falkenmark Indicator, which calculated water available per person for each country (Falkenmark, 1989). Peter Gleick (1996) later developed a water scarcity index that assessed water requirements for different types of human activities, including drinking water for survival, human hygiene, sanitation, and food preparation. Ohlsson (2000) developed the Social Water Stress Index, which added an adaptive capacity component into the Falkenmark Indicator. The Social Water Stress Index uses the HDI as a measure to account for a country's ability to adapt to water stress.

Measuring the Ratio Between Water Use and Water Resources

With a better understanding of basic human water needs, the study of water security expanded to include renewable water supply and water demands by different sectors and geographical regions. For example, Raskin et al. (1997) created the Water Resources Vulnerability Index, often referred to as the WTA Ratio, to assess the ratio of total annual withdrawal to available water resources. Following the same ratio approach, the Index of Local Relative Water Use and Reuse calculated the ratio of local water use and the river corridor discharge, and the ratio of total water use from all cells divided by the river corridor discharge. The International Water Management Institute also used this ratio approach to assess whether a country is physically water scarce (more than 75 percent of its river flows are withdrawn for agriculture, industrial, and household purposes) or economically water scarce (the country lacks water infrastructure to make renewable water resources available for use) (Brown and Matlock, 2011). Maplecroft, a global risk analysis company, developed the Water Stress Index by calculating the ratio of water consumption and renewable water supplies. This index covers 186 countries and produces a world map with a resolution of 10 square kilometers.

Attempting to evaluate how demand pressure and supply challenges impact the level of water stress, Growing Blue (undated b) conducted scenario analyses that calculated the ratio between water withdrawal and internal renewable water resources in 2030 and 2050. Various growth and water productivity scenarios were assessed to identify which regions may have low water stress scores—i.e., face water scarcity risk in 2030 and 2050.

Incorporating Other Water Security Dimensions

Realizing that assessing water security from a resource-scarcity point of view only may not fully capture a society's capacity for dealing with water risks, newer water security indices take other dimensions into consideration. The Watershed Sustainability Index, developed by Chavez and Alipaz (2007), incorporates hydrologic, environmental, life, and institutional capacity. This index was developed at the watershed or basin level; however, the index could be expanded to a global scale. Lautze and Manthrithilake (2012) proposed a conceptual framework to measure water security focusing on five dimensions: basic needs, agricultural production, the environment, risk management, and independence. Several nongovernmental organizations and consulting companies also created risk assessment tools following a similar multidimensional approach.

The Water Security Risk Index, another water risk analysis index created by Maplecroft (undated a), measures a country's water stress, population rates, reliance on external water supplies, sustainability of water use, intensity of water use in the economy, government effectiveness, and virtual water use. This index covers 165 countries and categorizes countries into four risk levels, from low to extreme risk, according to their index score.

The Growing Blue Tool (Growing Blue, undated a), a similar index-based tool, examines the water stress in terms of water availability and water use. The water availability module considers the sustainability of water withdrawal, precipitation variability, and quality of water. The water use module looks at water withdrawal per capita for municipal, agricultural, and industrial purposes. Statistics for 180 countries are available. However, only individual indicator values are available. No integrated score was assigned for each country.

The Water Risk Filter created by the World Wildlife Fund (undated) is another water risk assessment tool that aims to examine all aspects of water security. The filter considers three types of risks: physical risk that includes measurements of scarcity, pollution, ecosystem threat, and dependence on hydropower; regulatory risk; and reputation risk. Each risk type is measured by a number of indicators. Under each risk type, different indicators were used to assess basin-related risk or company-related risk. Basin-level indicators are provided by the Water Risk Filter, but the risk indicators for individual companies require user-supplied information.

In response to private-sector interest in better understanding the effects that uncertainty in water-related risks pose on business strategies and investments, the World Resources Institute developed the *Aqueduct Water Risk Framework* (Reig, Shiao, and Gasert, 2013). It includes 12 indicators that were grouped in to three types of water risks. First, *physical quantity risk* examines how the exposure to changes in water quantity may impact a company's operations. It includes baseline water stress, inter-annual variability, seasonal variability, flood occurrence, drought severity, upstream storage, and ground water stress. Second, *physical quality risk* evaluates the potential impact on a company's operations from changes in water quality. Third, *regulatory and reputational risk* includes media coverage, access to water, and threatened amphibians. These indicators were chosen based on their relevance to major stakeholders, the availability of publicly available data, and the ability to create sub–basin-level maps. Scores for 180 countries as well as major river basins and sub-basins are available.

UN-Water proposed a broad post-2015 global goal for water to "secure sustainable water for all" (UN-Water, 2014). Attainment of this goal is to be measured with respect to five outcomes: healthy people, increased prosperity, equitable societies, protected ecosystems, and resilient communities. Five related targets were proposed to track the progress of these outcomes: (1) achieve universal access to safe drinking water, sanitation, and hygiene; (2) improve the sustainable use and development of water resources in all countries by a specified percentage; (3) all countries strengthen equitable, participatory, and accountable water governance; (4) reduce untreated wastewater by a specified percentage, reduce nutrient pollution by a specified percentage, and increase wastewater reuse by a specified percentage; and (5) reduce mortality and economic loss from natural and human-induced water-related disasters by a specified percentage. Each target was further separated into different elements. Core and supporting indicators for each element were also identified (UN-Water, 2014).

2.3.3. Calculating the Pardee RAND Water Security Sub-Index

For the FEW Index, we focus on accessibility, availability, and adaptive capacity. In this context, these components reflect the following:

- **Water Accessibility:** access of each countries' population to improved drinking water and sanitation
- **Water Availability:** the amount of water that is used relative to amount needed to support basic domestic activities
- **Adaptive Capacity:** availability of water resources to meet new needs or compensate for declines in existing sources.

The water security sub-index assumes that these three factors are equally important and are non-compensatory. As such, the index is calculated using the following formula:

$$\text{Water Sub-Index} = \sqrt[3]{(\text{Water Availability}) \times (\text{Water Accessibility}) \times (\text{Water Adaptive Capacity})}$$

We elaborate on each of these factors and how they are measured below. Specific data sources are listed in Appendix A.

Measuring Availability of Water Resources

Water availability reflects the level of water resources development and use for domestic needs and compares this to the water requirements to meet basic drinking and sanitation needs. Countries with low relative use are less secure, as low usage hinders economic activity and adversely affects public health and productivity. While increased water use efficiency supports equivalent water use benefits at lower rates, countries that are highly efficient generally use water at a rate that is well above the threshold for basic drinking and sanitation requirements.

We measure the availability of water resources by comparing country-wide total water withdrawals for municipal uses with the country-wide water requirements for basic municipal purposes. Gleick (1996) calculated the per capita minimum level of water used for cooking, eating, and sanitation (i.e., municipal purposes) to be 50 liters per capita per day. More water withdrawals relative to basic requirements indicate greater security and more support for economic activities. This measure does not consider industrial or agricultural water use or requirements, as water use in these sectors is highly variable across countries, depending on the mix of economic activity and level and efficiency of irrigation for agriculture.

Municipal water withdrawals measure the total volume of water delivered by the public distribution network for domestic consumption. It includes renewable freshwater resources as well as potential over-abstraction of renewable groundwater or withdrawal of fossil groundwater and the potential use of desalinated water or treated wastewater.

The water availability sub-index normalizes per capita average municipal water use by 200 liters per day. Thus, any country with a ratio of water use to water requirements greater than four is given a value of 1.0. This level of water use is twice the standard 100 liters per day requirement for basic uses, and four times the bare minimum levels for cooking, eating, and sanitation of 50 liters per capita per day (Gleick, 1996). Normalizing by a level greater than the 100 liters per day standard helps account for the uneven distribution of water across countries and builds in inefficiencies in distribution into the index.

Measuring Water Accessibility

Water accessibility reflects both the state of water infrastructure and the level of distribution of available water resources across a country's population. It is measured by two variables: the proportion of the population that uses an improved source of drinking water and the proportion of the population using improved sanitation facilities. Both these measures are part of the Millennium Development Goals and are viewed as critical to ensure health and environmental sustainability. Countries with large populations without developed water and sanitation services are insecure, and their economic improvement is hindered in these areas.

Drinking water is defined as water used for the purposes of ingestion, food preparation, and basic hygiene. An improved drinking water source is a facility that, by nature of its construction, is protected from outside contamination, in particular, from contamination from fecal matter. Improved drinking water sources include piped water into a dwelling, plot, or yard; public tap/standpipe; borehole/tube well; protected dug well; protected spring; rainwater collection; and bottled water. Improved drinking water sources do not include unprotected wells; unprotected springs; water provided by carts with small tanks/drums; tanker truck–provided water; and bottled water (if the secondary source is not improved) or surface water taken directly from rivers, ponds, streams, lakes, dams, or irrigation channels.

An *improved sanitation facility* is defined as a facility that hygienically separates human excreta from human, animal, and insect contact. Improved sanitation facilities include flush/pour-flush toilets or latrines connected to a sewer, septic tank, or pit; ventilated improved pit latrines; pit latrines with a slab or platform of any material that covers the pit entirely, except for the drop hole; and composting toilets/latrines. Unimproved facilities include public or shared facilities of an otherwise improved type; flush/pour-flush toilets that discharge directly into an open sewer or ditch; pit latrines without a slab; bucket latrines; hanging toilets or latrines; and the practice of open defecation in the bush, field, or bodies of water.

Measuring Adaptive Capacity

Adaptive capacity reflects the potential for developing new sources of water using domestically available sustainable resources. The availability of these resources can help a country accommodate growth or decline in water use as well as increased variability from existing sources. Countries with access to impaired or salty water sources could also develop additional resources through desalination or importation via new facilities or methods (e.g., water bags) from other regions. These options are generally expensive and are not captured by this index.

For adaptive capacity, we evaluated the total per capita internally available renewable water. The internally available water includes the sum of internal renewable water resources and external actual renewable water resources. It corresponds to the maximum theoretical yearly amount of water actually available for a country at a given moment. This excludes any return flow from agriculture or wastewater.

CHAPTER THREE

An Integrated View of Food, Energy, and Water Security Worldwide

Examining the Pardee RAND Food-Energy-Water Security Index provides a picture of the state of availability and accessibility of these resources worldwide. Using the methods described in Chapter Two, we calculated the FEW Index for the 166 countries for which data were publicly available. While the long-term goal is to utilize the integrated index in decisionmaking, the collection of sub-indices provide insight themselves. Examination of the index and its component sub-indices provides insight into how much variation exists among resource insecurity worldwide, how that variation is distributed, and what factors contribute to resource insecurity for specific countries.

3.1. Global Variation and Distribution of Food, Energy, and Water Security

Data from the FEW Index reveal wide variation in resource security among nations (Figure 3.1). While there are some countries with very low FEW Index values, the lowest FEW Index value is considerably higher than the value that would be calculated by combining the minimum value for each of the indices themselves. This indicates that no country scores the lowest for all three indices.

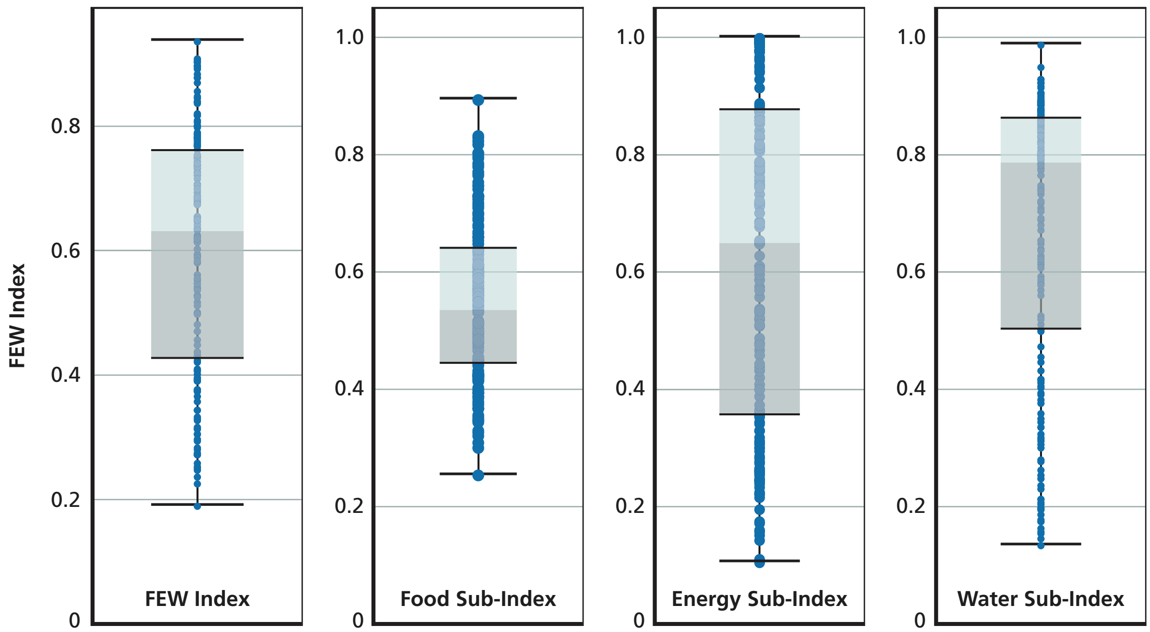
The distribution of food, energy, and water security reveals expected patterns globally. When the index is mapped, as shown in Figure 3.2, results show the expected geographic distribution of resource insecurity. Most countries in Africa receive low or very low scores. Southeast and south Asian countries score a bit better. Some Latin American and European countries also score at medium level.

3.2. Identifying Sources of Resource Insecurity

In addition to revealing geographic patterns of resource insecurity, the FEW Index describes sources of resource strengths and weaknesses within countries. These patterns of resource variation across food, energy, and water sectors are particularly interesting within countries that are judged to have lower performance across human development indicators related to health, economic, and educational outcomes.

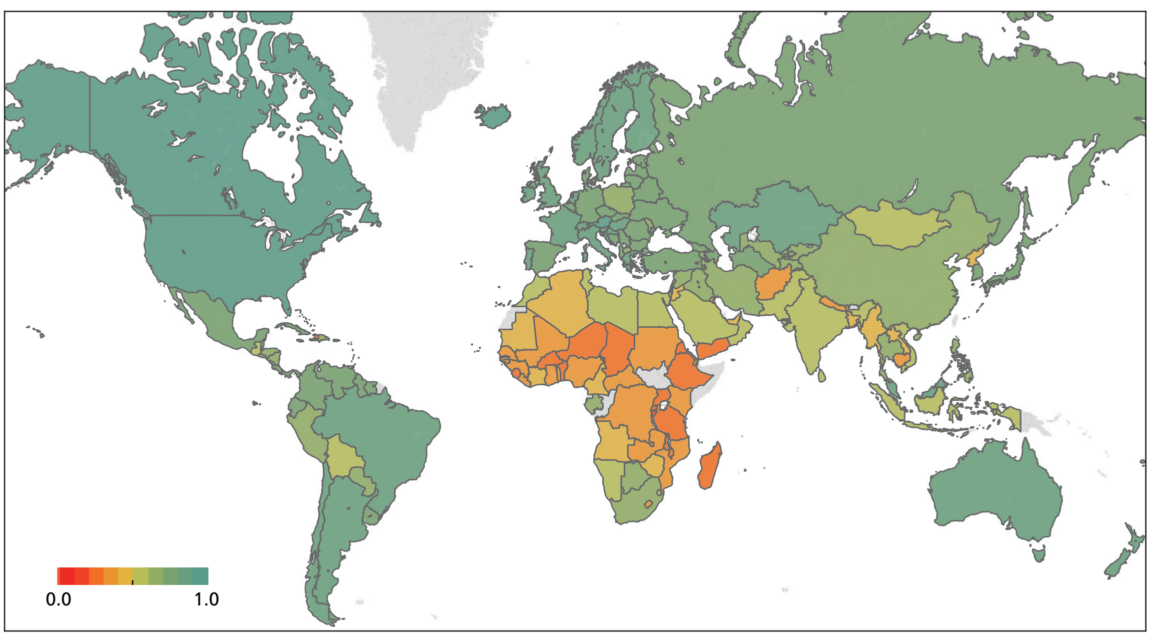
To illustrate these patterns, we examined relationships among the food, energy, and water sub-indices for countries that score low on the HDI. Figure 3.3 illustrates that analysis of these countries allows for additional comparisons between nations on the overall index (color of data point) and food (size of data point), water (horizontal axis), and energy (vertical axis) sub-

Figure 3.1
Distribution of Food, Energy, Water, and FEW Index Scores Across 166 Countries



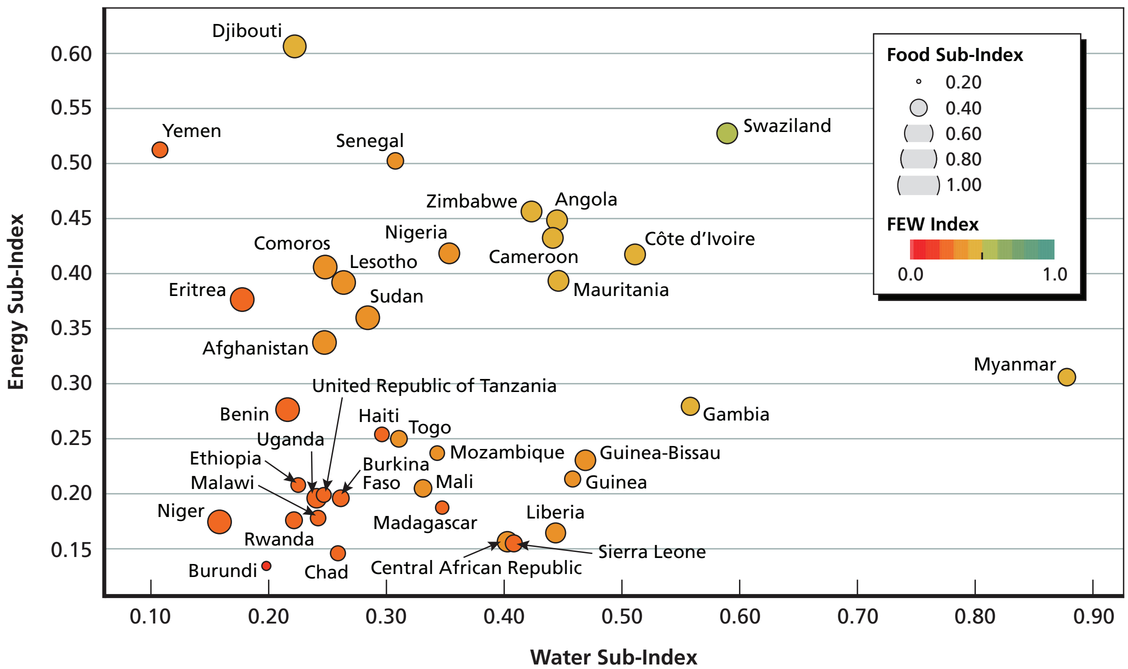
RAND *TL165-3.1*

Figure 3.2
Map of the Pardee RAND Food-Energy-Water Security Index Across the World



NOTE: Green indicates secure states, red indicates insecure states, and light gray indicates missing data.
RAND *TL165-3.2*

Figure 3.3
Comparison of Low HDI Nations Across the Pardee RAND Food-Energy-Water Index and Its Sub-Indices



RAND *TL165-3.3*

indices. Examination of this figure reveals patterns that exist across the countries and leads to questions about what strategies are best suited to improve human development in specific nations.

Some countries with low HDI scores have relatively balanced food, energy, and water scores (e.g., countries at the upper right corner, such as Swaziland. For countries like this, limitations on resources are roughly similar for all three resource sectors. In contrast, for countries at the lower right corner (e.g., Gambia), energy and food appear to be more limited resources than water; however, development strategies that put pressure on water resources could create problems for water security. Countries at the upper left corner, such as Yemen and Djibouti, face more challenges in water security. Countries at the lower left corner face multiple issues at once, and several (such as Rwanda and Chad) scored the lowest values in more than one security pillar.

Examination of the numeric scores for the nexus index and its components provides further insight into the variation in causes of resource security that exists across countries. Data in Table 3.1 reveal different patterns that can emerge across the food, energy, and water nexus. The table presents scores for 11 nations across the overall FEW Index; the sub-indices that constitute the overall index; and the indicators that constitute the sub-indices. These nations were selected because they each score relatively low on the HDI and, as illustrated in Figure 3.3, they demonstrate the variations that exist among nations across the food-energy-water nexus.

By reviewing the index value across each row or column in Table 3.1, one can relatively easily identify which security pillar or country to focus development efforts on. First, significant variation exists on the FEW Index (the first data column in Table 3.1), even among

Table 3.1
Values for the FEW Index and Sub-Indices for Select Nations with Low HDI Scores

Country	FEW INDEX	FOOD SUB-INDEX	Food Access-ibility	Food Availability	ENERGY SUB-INDEX	Energy Access-ibility	Energy Availability	WATER SUB-INDEX	Water Access-ibility	Water Availability	Water Adaptive Capacity
Congo	0.39	0.39	0.25	0.60	0.38	0.31	0.47	0.40	0.34	0.19	1.00
Eritrea	0.27	0.30	0.19	0.48	0.38	0.38	0.37	0.18	0.30	0.08	0.22
Ethiopia	0.25	0.35	0.20	0.62	0.21	0.12	0.37	0.22	0.40	0.11	0.25
Kenya	0.33	0.42	0.27	0.64	0.32	0.21	0.46	0.27	0.44	0.35	0.13
Mauritania	0.42	0.43	0.22	0.83	0.39	0.30	0.51	0.45	0.48	0.32	0.57
Mozambique	0.30	0.35	0.18	0.68	0.24	0.10	0.56	0.34	0.32	0.12	1.00
Pakistan	0.50	0.42	0.26	0.68	0.57	0.58	0.56	0.52	0.76	0.70	0.27
Rwanda	0.25	0.40	0.24	0.66	0.18	0.09	0.32	0.22	0.68	0.07	0.22
Senegal	0.39	0.39	0.22	0.70	0.50	0.52	0.48	0.31	0.61	0.09	0.54
Uganda	0.28	0.47	0.33	0.67	0.20	0.09	0.40	0.24	0.39	0.12	0.31
Yemen	0.27	0.37	0.22	0.64	0.51	0.57	0.46	0.11	0.54	0.14	0.02

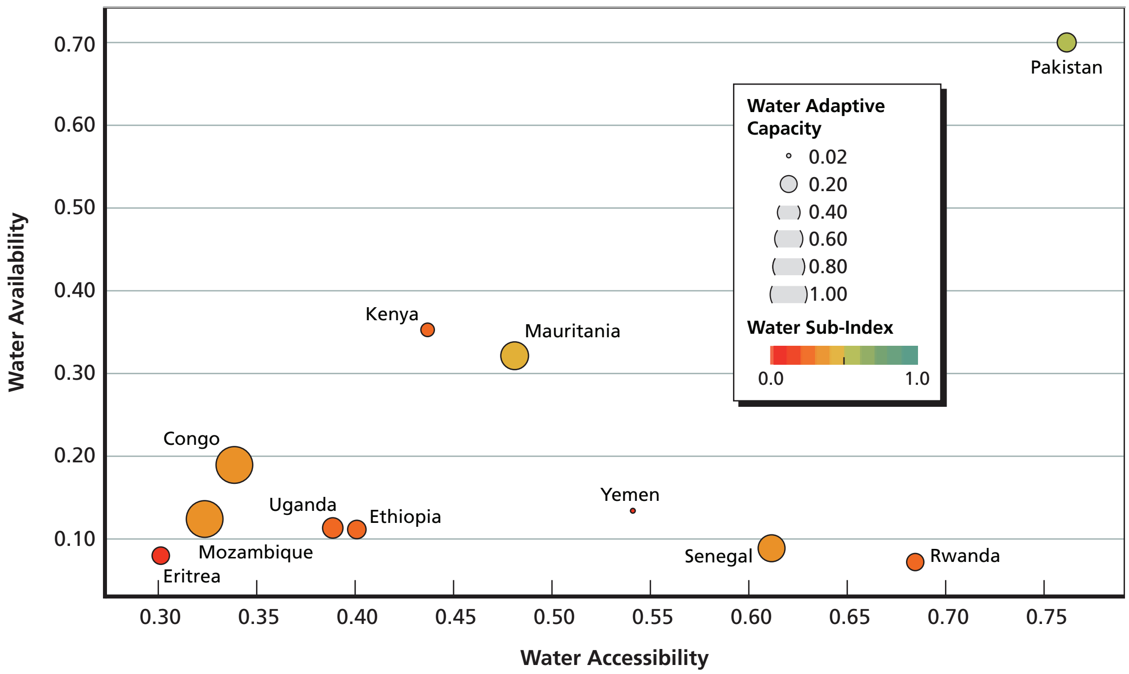
0.0 1.0

nations that do not score high on the HDI. Among the selected nations, Pakistan scored a 0.50 and Ethiopia a 0.25. Also, the variances of water and energy indices values are much larger than that of the food index. Second, variation exists among the reasons that nations score high or low on the overall index. The scores on sub-indices (the second, fifth, and eighth data columns in Table 3.1) reveal reasons for low scores. Mauritania appears to be secure in terms of water and food, but weaker with respect to energy security. Yemen appears to be moderately secure in terms of energy and food, but weaker in terms of water security. In contrast, Eritrea appears weak across all dimensions of the food-energy-water nexus.

The indicators that constitute sub-indices provide further insight into the causes for resource insecurity. For example, on the water sub-index, Mozambique and Senegal both have moderate scores (see Figure 3.4). However, the indicators for water security (water accessibility, water availability, and water adaptive capacity) indicate that, while Mozambique has access to significant water resources, its relatively low score for water accessibility and water availability make it insecure with respect to water. In contrast, Senegal is weak but doing better at providing residents access to drinking water, but has relatively weaker water availability—this means Senegal should improve its capability to meet basic urban water needs.

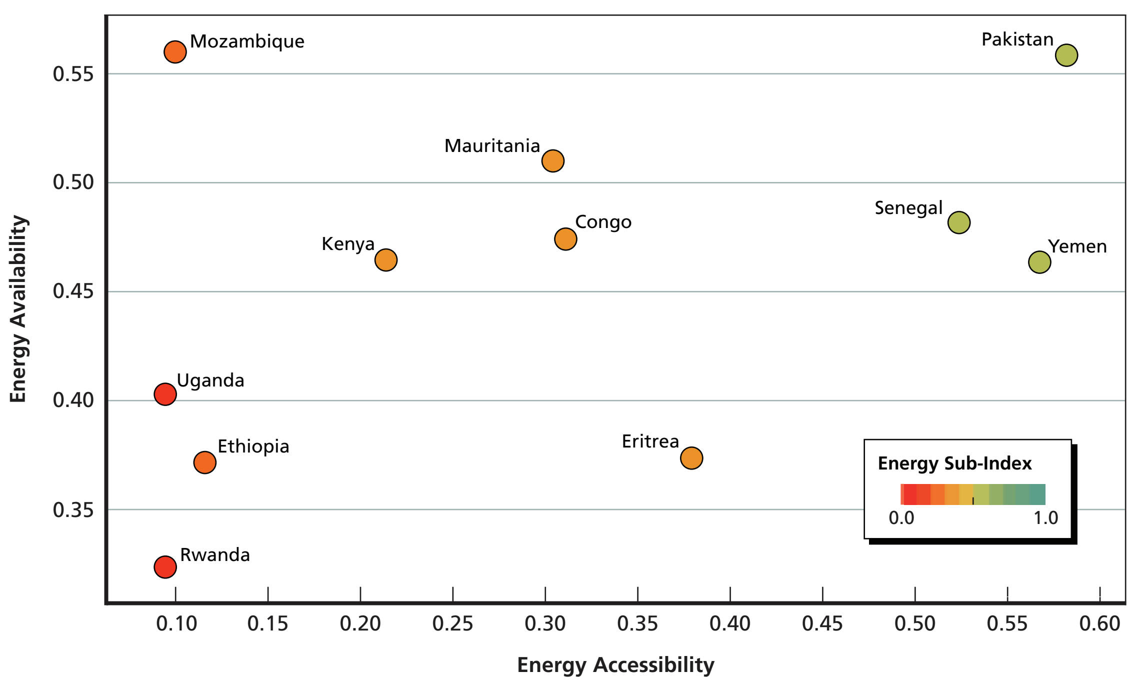
As another example, consider energy security in Mauritania and Eritrea (see Figure 3.5). They have similar energy index values. Values for the sub-indicators suggest energy accessibility and energy availability are low in Eritrea (Energy Accessibility = 0.38, Energy Availability = 0.37). This indicates that both the distribution infrastructure and generation capacity need to be developed to improve Eritrea's human development level. In contrast, the weaker factor for energy security in Mauritania is energy access (0.30), suggesting additional distribution infrastructure is required.

Figure 3.4
Comparison of Select Low and Moderate HDI Nations Across the Water Sub-Index and Its Sub-Indicators



RAND *TL165-3.4*

Figure 3.5
Comparison of Low and Moderate HDI Nations Across the Energy Sub-Index and Its Sub-Indicators



RAND *TL165-3.5*

3.3. Understanding Relationships Between Human Development and Resource Security

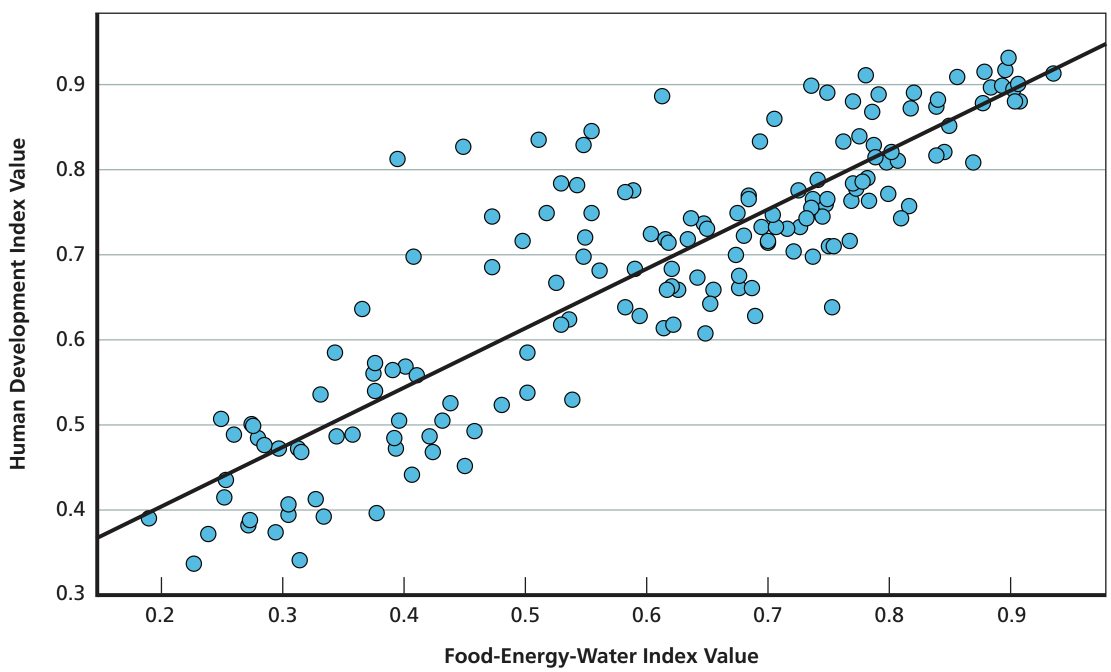
To use the Pardee RAND Food-Energy-Water Security Index to inform development efforts, it is necessary to understand whether and how availability and access to these resources is related to human development. As a measure of this relationship, Figure 3.6 demonstrates the extent to which the FEW Index and the HDI are correlated with each other ($R^2 = 0.77$). In fact, the correlation between the nexus index is stronger with the HDI than it is with the income indicator portion of the HDI ($R^2 = 0.69$), suggesting that the nexus index captures more aspects of development than just income.

This relationship is useful in two ways. First, it supports a hypothesis that improving food, energy, and water security could improve development. Next, it identifies those countries for which the relationship is not strong, which can be examined in greater detail to explore nuances in the relationships among food, energy, and water that are not captured by our relatively simple integrated index. For example, a country with very high human development level, Israel (HDI = 0.89), scored only moderately on the FEW Index (FEW = 0.61) due to a low water security index score.

The relationship between the HDI and the FEW Index and the mathematical structure of the nexus index can be used to inform efforts to improve human development. The simple regression analysis presented in Figure 3.6 suggests that:

$$\text{HDI} \sim \text{FEW Index} = \sqrt[3]{\text{Water}_{\text{Index}} \times \text{Food}_{\text{Index}} \times \text{Energy}_{\text{Index}}}$$

Figure 3.6
Relationship Between FEW Index and HDI



RAND *TL165-3.6*

By decomposing the water, food, and energy indices into their sub-indices and taking the log of both sides, the equation becomes:

$$\log HDI \sim 1/9(\log Water\_avail) + 1/9(\log Water\_access) + 1/9(\log Water\_adapt)$$
$$+\ 1/6(\log Food\_avail) + 1/6(\log Food\_access) + 1/6(\log Energy\_avail)$$
$$+\ 1/6(\log Energy\_access)$$

Taking the derivative of the above relationship with respect to each sub-index yields the percentage change in HDI that results from a percentage change in each sub-index.

For example:

$$\frac{\partial \log HDI}{\partial Water\_avail} \sim \frac{1/9}{Water\_avail}$$

Since each country has a unique value for their food, energy, and water sub-indices, the changes from these sub-indices also provide unique values of potential impacts from them on HDI performance. These values enable us to identify the most-needed improvement for each country regarding their food, energy, and water security performance. Table 3.2 shows the relevant magnitude of change in HDI expected for each percentage-point increase in each of the sub-index values for the 11 countries examined in Table 3.1.

While Table 3.1 helps identify areas of improvement, a logarithm transformation of the relationship between HDI and FEW sub-indices and indicators enables direct comparison of development impacts across countries. A larger derivative value indicates higher priority of

Table 3.2
Elasticity of Food, Energy, and Water Sub-Indices

Country	FEW INDEX	FOOD SUB-INDEX	ENERGY SUB-INDEX	WATER SUB-INDEX	Derivative Food Access-ibility	Derivative Food Avail-ability	Derivative Energy Access-ibility	Derivative Energy Avail-ability	Derivative Water Access-ibility	Derivative Water Avail-ability	Derivative Water Adaptive Capacity
Pakistan	0.50	0.42	0.57	0.52	0.63	0.24	0.29	0.30	0.15	0.16	0.42
Congo	0.39	0.39	0.38	0.40	0.67	0.28	0.54	0.35	0.33	0.59	0.11
Kenya	0.33	0.42	0.32	0.27	0.61	0.26	0.78	0.36	0.25	0.31	0.82
Mauritania	0.42	0.43	0.39	0.45	0.76	0.20	0.55	0.33	0.23	0.35	0.19
Senegal	0.39	0.39	0.50	0.31	0.76	0.24	0.32	0.35	0.18	1.25	0.21
Mozambique	0.30	0.35	0.24	0.34	0.94	0.24	1.67	0.30	0.34	0.89	0.11
Yemen	0.27	0.37	0.51	0.11	0.76	0.26	0.29	0.36	0.21	0.82	6.61
Uganda	0.28	0.47	0.20	0.24	0.51	0.25	1.76	0.41	0.29	0.97	0.36
Eritrea	0.27	0.30	0.38	0.18	0.88	0.35	0.44	0.45	0.37	1.37	0.50
Rwanda	0.25	0.40	0.18	0.22	0.69	0.25	1.76	0.51	0.16	1.53	0.51
Ethiopia	0.25	0.35	0.21	0.22	0.85	0.27	1.43	0.45	0.28	1.00	0.44

0.0 1.0

development effort in that area. For example, a derivative score of 1.76 in energy accessibility for Uganda means that, for each percentage-point increase in energy accessibility, the associated percentage-point increase in human development is much higher than similar improvements done at the other ten countries. Similarly, the comparison between the derivatives for energy accessibility and other security indicators suggests that Mozambique should prioritize improving its electrification rate and modern fuel access.

Overall, by linking human development with food, energy, and water sub-indexes, the FEW Index provides a comprehensive development prescription for each country based on its current state of food, energy, and water resource availability and accessibility.

CHAPTER FOUR

Potential Extensions of the Pardee RAND Food-Energy-Water Security Index

The proceeding chapters of this report described why and how the Pardee RAND Food-Energy-Water Security Index was developed. The index includes an integrated set of indicators providing a holistic view of a nation's availability and access to the resources that are critical to human development. Our goal was to create a standardized, quantitative, and transparent estimation of the food, energy, and water nexus that can easily be used by policymakers, the development community, scientists, and the public. This index can be explored on the RAND website, and the supporting data are available for download.

It is our hope that broad use of this index can help improve the effectiveness and efficiency of development efforts worldwide. Toward this goal, we have identified three possible extensions of how the Pardee RAND Food-Energy-Water Security Index can be used: understanding relationships to broader development outcomes; exploring regional relationships among the indicators; and examining how global trends might affect food, energy, and water resources.

4.1. Relationships Between the Pardee RAND Food-Energy-Water Security Index and Other Development Outcomes

The utility of the FEW Index ultimately stems from how the development community can use it to better understand the state of human development globally. This can be accomplished through further analysis to examine the relationships between the index and its component indicators. Examples of other development outcomes include measures of undernourishment, health status, educational attainment, and income and wealth. This type of analysis can help development organizations better understand barriers to human development and identify strategies to improve human development in countries where it is weak.

At the same time, this analysis could be used to improve the index itself. Currently all indicators and sub-indicators are equally weighted at each aggregation step. However, analysis of development outcomes and the indicators could reveal correlative or causative linkages that would justify alternative sets of weights to use when calculating the overall index and its sub-indices.

4.2. Regional Applications of the Index

The existing index describes the state of food, energy, and water resources at a national level. However, resource insecurity in this domain exists at scales both smaller and larger than a nation.

In some contexts, concerns about resource insecurity surround specific communities or sub-regions of a country. For example, significant development attention is being paid to how inequity in opportunity and resources exist across a rural and urban divide within countries.

In other contexts, resource insecurity can span regions that cross national boundaries. This is most common along river basins that cross several countries and can affect water, food, and energy availability, depending on how uses for water are allocated among the countries in the river basin.

Though constrained by data reliability and availability, regional analysis of the relationship among resource indicators and human development could inform development efforts in ways similar to those presented in Chapter Three of this report.

4.3. Examining How Global Trends Might Affect Food, Energy, and Water Resources

The FEW Index is calculated for each country based on 20 different measures that are combined to create the food, energy, and water sub-indices. As illustrated in Table 4.1, there are common measures used across different security indicators. Such structure provides potential for future nexus analysis. For example, minimum dietary requirements were used to calculate both food availability and water availability. A change in a country's minimum dietary requirement will simultaneously impact both food and water security scores. Population is another common measure between the water and energy indices. Assessing the potential impact from changes in these measures on the FEW Index and potential development needs could be a valuable extension to this study.

Relationships between the index and common measures, like population or consumption rates, could be used to project changes in the index that would result from endogenous trends that could affect the measures. Examples of endogenous trends that would be of interest to the development community include the effects of climate change on water availability or agricultural productivity; the effects of new technologies on energy efficiency or availability; and the effects of shifts in population or changes in population growth rates.

A clear understanding of the relationships among the indicators and endogenous factors affecting them could allow planners to use the FEW Index as a tool to support scenario analyses and long-term development planning.

4.4. Concluding Thoughts

The Pardee RAND Food-Energy-Water Security Index represents an aggregation of existing, publicly available data. As demonstrated in Chapter Three, the integrated index values for a country are correlated with indicators of human development, such as the HDI. However, this relationship is interesting in two ways. First, the FEW Index is more highly correlated with

Table 4.1
List of Measures Used in FEW Index Construction

Sub-Index	Measure
Food security indicators	
Food accessibility	Food price level index
	Share of dietary supply from nonstarchy foods
Food availability	Dietary food supply
	Minimum dietary requirement
Water security indicators	
Water accessibility	Percentage access to improved drinking water
	Percentage access to improved sanitation
Water availability	Municipal water withdrawal
	Population
	Per capita water needs for human consumption
Water adaptive capacity	Total water resources
	Population
Energy security indicators	
Energy accessibility	Electrification rate
	Percentage access to modern fuel for cooking and heating
Energy availability	Electricity consumption
	Per capita electricity requirement
	Population

the HDI than with the income portion of the index, which suggests that access to resources is more closely related to development status than to aggregated measures of individual income. Second, the FEW Index is not perfectly related to the HDI, meaning that variation exists among countries as to which resources may be limiting human development across the globe from place to place. Further exploration of the FEW Index and its relationship to human development, in the ways discussed in this section, may provide insights into where and how to improve the effectiveness of development funding.

APPENDIX A

Data Used in Analysis

Table A.1
Logical Minimum and Maximum Values Used to Normalize Indicators

Indicator	Minimum Value	Maximum Value
Food Security Indicators		
Food Accessibility Sub-Index		
Food Price Level Index	0	1
Share of Dietary Supply from Nonstarchy Foods	0	1
Food Availability Sub-Index		
Supply Relative to Minimum Dietary Requirement	0	2
Energy Security Indicators		
Energy Accessibility Sub-Index		
Electrification Rate	0	1
Percentage Access to Modern Fuel for Cooking and Heating	0	1
Energy Availability Sub-Index		
Electricity Consumption over Energy Requirement	0	1.3
Water Security Indicators		
Water Accessibility Sub-Index		
Percentage Access to Improved Drinking Water	0	1
Percentage Access to Improved Sanitation	0	1
Water Availability Sub-Index		
Municipal Water Use over Population Water Requirement	0	4
Water Adaptive Capacity Sub-Index		
Per Capita Water Resources	0	5,000

Table A.2
Data Sources Used in Indicator

Indicator	Data Availability	Country Coverage	Source
Food Security Indicators			
Food Accessibility Sub-Index			
Food Price Level Index	2000–2014	148	FAO, Food Security Indicators
Share of Dietary Supply from Nonstarchy Foods	1990–2009, data reported in 3-year average	172 (5 from 2013)	FAO, Food Security Indicators
Food Availability Sub-index			
Supply Relative to Minimum Dietary Requirement	1990–2014, data reported in 3-year average	176 (72 from 2013)	FAO, Food Security Indicators
Energy Security Indicators			
Energy Accessibility Sub-Index			
Electrification Rate	1990, 2000, 2010, 2012	212	World Bank, World Development Indicators
Percentage Access to Modern Fuel for Cooking and Heating	1990–2010	201	Millennium Development Goals Indicators, United Nations Statistics Division
Energy Availability Sub-Index			
Electricity Consumption over Energy Requirement	1980–2012	219	U.S. Energy Information Administration International Energy Database
Water Security Indicators			
Water Accessibility Sub-Index			
Percentage Access to Improved Drinking Water	1990–2010	189	WHO/UNICEF Joint Monitoring Programme for Water Supply and Sanitation
Percentage Access to Improved Sanitation	1990–2010	186	WHO/UNICEF Joint Monitoring Programme for Water Supply and Sanitation
Water Availability Sub-Index			
Municipal Water Use over Population Water Requirement	1980–2014	181	FAO AQUASTAT
Water Adaptive Capacity Sub-Index			
Per Capita Water Resources	1980–2014	181	FAO AQUASTAT

NOTE: During an early iteration of creating the FEW Index, the FAO Food Security Indicators were downloaded in March 2013. For the most recent version, the Indicators were downloaded in October 2015. The authors found that some historical data that existed in the 2013 download were no longer present in the 2015 download. In these instances, we used the data from the 2013 download to fill in the gaps. For instance, historical data for the share of dietary supply from nonstarchy foods were no longer included in five countries (Comoros, Eritrea, Libya, State of Palestine, and Syrian Arab Republic). In addition, historical data for the MDER and dietary energy supply indicators were missing for 72 countries in 2015. This included all of the “developed countries,” as delineated by the FAO, as well as Antigua and Barbuda, Bahamas, Burundi, Comoros, Dominica, Eritrea, Grenada, Israel, Libya, State of Palestine, Saint Kitts and Nevis, Saint Lucia, Serbia, Seychelles, and Syrian Arab Republic.

APPENDIX B

Country Values for FEW Indices and the Human Development Index

This appendix contains four tables that list countries with low, medium, high, and very high HDI scores. Each table provides FEW index, sub-index, and domain scores for the countries listed.

Table B.1
Low HDI Countries

Country	FEW Index	HDI Value	Food Sub-Index	Energy Sub-Index	Water Sub-Index	Food Accessibility	Food Availability	Energy Accessibility	Energy Availability	Water Accessibility	Water Availability	Water Adaptive Capacity
Swaziland	0.54	0.53	0.50	0.53	0.59	0.41	0.62	0.43	0.64	0.65	0.44	0.71
Myanmar	0.48	0.52	0.41	0.31	0.88	0.24	0.72	0.20	0.46	0.80	0.84	1.00
Zimbabwe	0.46	0.49	0.50	0.46	0.42	0.40	0.62	0.37	0.57	0.53	0.52	0.27
Côte d'Ivoire	0.45	0.45	0.43	0.42	0.51	0.22	0.82	0.35	0.50	0.43	0.38	0.81
Angola	0.44	0.53	0.42	0.45	0.44	0.24	0.76	0.41	0.49	0.50	0.17	1.00
Cameroon	0.43	0.50	0.42	0.43	0.44	0.24	0.74	0.37	0.51	0.59	0.14	1.00
Djibouti	0.42	0.47	0.57	0.61	0.22	0.44	0.73	0.68	0.54	0.65	0.25	0.07
Mauritania	0.42	0.49	0.43	0.39	0.45	0.22	0.83	0.30	0.51	0.48	0.32	0.57
Gambia	0.41	0.44	0.43	0.28	0.56	0.23	0.82	0.18	0.44	0.73	0.28	0.84
Nigeria	0.40	0.50	0.42	0.42	0.35	0.23	0.77	0.38	0.46	0.45	0.31	0.32
Sudan	0.39	0.47	0.60	0.36	0.28	0.53	0.67	0.26	0.49	0.36	0.32	0.20
Senegal	0.39	0.49	0.39	0.50	0.31	0.22	0.70	0.52	0.48	0.61	0.09	0.54
Guinea-Bissau	0.38	0.40	0.50	0.23	0.47	0.36	0.69	0.17	0.30	0.41	0.25	1.00
Comoros	0.36	0.49	0.46	0.41	0.25	0.44	0.47	0.45	0.37	0.57	0.08	0.32
Lesotho	0.34	0.49	0.40	0.39	0.26	0.21	0.74	0.29	0.54	0.50	0.13	0.29
Guinea	0.33	0.39	0.38	0.21	0.46	0.20	0.74	0.11	0.40	0.39	0.24	1.00
Liberia	0.33	0.41	0.48	0.17	0.44	0.34	0.68	0.07	0.39	0.36	0.24	1.00
Afghanistan	0.32	0.47	0.38	0.34	0.25	0.23	0.62	0.25	0.45	0.42	0.09	0.42
Togo	0.31	0.47	0.39	0.25	0.31	0.20	0.77	0.14	0.46	0.27	0.26	0.42
Central African Republic	0.31	0.34	0.49	0.16	0.40	0.44	0.55	0.07	0.33	0.39	0.17	1.00

Table B.1—Continued

Country	FEW Index	HDI Value	Food Sub-Index	Energy Sub-Index	Water Sub-Index	Food Accessibility	Food Availability	Energy Accessibility	Energy Availability	Water Accessibility	Water Availability	Water Adaptive Capacity
Mozambique	0.30	0.39	0.35	0.24	0.34	0.18	0.68	0.10	0.56	0.32	0.12	1.00
Haiti	0.30	0.47	0.35	0.25	0.30	0.22	0.55	0.18	0.35	0.40	0.24	0.27
Mali	0.30	0.41	0.42	0.20	0.33	0.20	0.85	0.11	0.37	0.44	0.08	1.00
Sierra Leone	0.29	0.37	0.40	0.15	0.41	0.23	0.69	0.08	0.29	0.29	0.24	1.00
Uganda	0.28	0.48	0.47	0.20	0.24	0.33	0.67	0.09	0.40	0.39	0.12	0.31
Benin	0.28	0.48	0.39	0.28	0.22	0.19	0.80	0.18	0.41	0.39	0.05	0.50
Madagascar	0.28	0.50	0.32	0.19	0.35	0.17	0.61	0.09	0.41	0.25	0.17	1.00
Eritrea	0.27	0.38	0.30	0.38	0.18	0.19	0.48	0.38	0.37	0.30	0.08	0.22
Burkina Faso	0.27	0.39	0.40	0.20	0.26	0.20	0.77	0.10	0.38	0.40	0.28	0.16
Yemen	0.27	0.50	0.37	0.51	0.11	0.22	0.64	0.57	0.46	0.54	0.14	0.02
United Republic of Tanzania	0.26	0.49	0.35	0.20	0.25	0.19	0.65	0.09	0.42	0.29	0.14	0.38
Ethiopia	0.25	0.44	0.35	0.21	0.22	0.20	0.62	0.12	0.37	0.40	0.11	0.25
Rwanda	0.25	0.51	0.40	0.18	0.22	0.24	0.66	0.09	0.32	0.68	0.07	0.22
Malawi	0.25	0.41	0.37	0.18	0.24	0.19	0.69	0.07	0.45	0.61	0.11	0.21
Chad	0.24	0.37	0.36	0.15	0.26	0.20	0.64	0.08	0.25	0.25	0.10	0.69
Niger	0.23	0.34	0.42	0.17	0.16	0.23	0.77	0.08	0.36	0.25	0.04	0.37
Burundi	0.19	0.39	0.26	0.13	0.20	0.14	0.46	0.06	0.31	0.60	0.05	0.24
South Sudan		0.46			0.33	0.53		0.05		0.20	0.21	0.84
Dem. Rep. of the Congo		0.34		0.21	0.32			0.11	0.43	0.39	0.08	1.00

Table B.1—Continued

Country	FEW Index	HDI Value	Food Sub-Index	Energy Sub-Index	Water Sub-Index	Food Accessibility	Food Availability	Energy Accessibility	Energy Availability	Water Accessibility	Water Availability	Water Adaptive Capacity
Papua New Guinea		0.49		0.35	0.48			0.22	0.56	0.27	0.40	1.00
Solomon Islands		0.49	0.49	0.26		0.33	0.71	0.15	0.46	0.49		1.00

NOTE: Missing values indicate that data were not available for the specific country.

Table B.2
Medium HDI Countries

Country	FEW Index	HDI Value	Food Sub-Index	Energy Sub-Index	Water Sub-Index	Food Accessibility	Food Availability	Energy Accessibility	Energy Availability	Water Accessibility	Water Availability	Water Adaptive Capacity
Guyana	0.75	0.64	0.61	0.72	0.97	0.50	0.75	0.86	0.61	0.91	1.00	1.00
Turkmenistan	0.74	0.70	0.58	0.83	0.83	0.41	0.82	0.97	0.71	0.62	1.00	0.93
Suriname	0.72	0.71	0.47	0.83	0.95	0.30	0.74	0.94	0.74	0.87	1.00	1.00
Kyrgyzstan	0.69	0.63	0.60	0.75	0.74	0.46	0.77	0.81	0.69	0.92	0.52	0.84
El Salvador	0.69	0.66	0.50	0.73	0.88	0.35	0.72	0.86	0.63	0.84	1.00	0.82
Uzbekistan	0.68	0.66	0.57	0.80	0.68	0.42	0.78	0.94	0.68	0.93	1.00	0.33
Paraguay	0.68	0.68	0.51	0.68	0.89	0.36	0.73	0.71	0.66	0.93	0.75	1.00
Dominican Republic	0.67	0.70	0.54	0.79	0.72	0.41	0.71	0.95	0.65	0.84	1.00	0.45
Syrian Arab Republic	0.66	0.66	0.68	0.79	0.52	0.53	0.88	0.95	0.66	0.93	1.00	0.15
Iraq	0.65	0.64	0.45	0.80	0.76	0.27	0.74	0.97	0.66	0.86	1.00	0.52
Tajikistan	0.65	0.61	0.48	0.75	0.76	0.38	0.61	0.81	0.69	0.84	1.00	0.52
Gabon	0.64	0.67	0.49	0.72	0.75	0.31	0.79	0.81	0.64	0.62	0.67	1.00
South Africa	0.63	0.66	0.57	0.81	0.53	0.39	0.83	0.85	0.76	0.79	1.00	0.19
Honduras	0.62	0.62	0.51	0.61	0.77	0.33	0.77	0.63	0.60	0.87	0.53	1.00
Botswana	0.62	0.68	0.51	0.62	0.75	0.42	0.63	0.58	0.67	0.78	0.53	1.00
Republic of Moldova	0.62	0.66	0.47	0.79	0.65	0.33	0.66	0.94	0.66	0.82	0.49	0.67
Philippines	0.62	0.66	0.43	0.63	0.87	0.24	0.75	0.66	0.59	0.82	0.85	0.96
Nicaragua	0.61	0.61	0.49	0.59	0.79	0.33	0.74	0.60	0.59	0.77	0.64	1.00
Guatemala	0.59	0.63	0.45	0.58	0.81	0.27	0.73	0.58	0.58	0.77	0.70	1.00

Table B.2—Continued

Country	FEW Index	HDI Value	Food Sub-Index	Energy Sub-Index	Water Sub-Index	Food Accessibility	Food Availability	Energy Accessibility	Energy Availability	Water Accessibility	Water Availability	Water Adaptive Capacity
Indonesia	0.59	0.68	0.40	0.63	0.82	0.21	0.77	0.66	0.60	0.73	0.74	1.00
Viet Nam	0.58	0.64	0.56	0.66	0.54	0.40	0.78	0.66	0.65	0.87	0.18	1.00
Egypt	0.56	0.68	0.46	0.81	0.48	0.22	0.97	0.97	0.68	0.97	0.79	0.14
Mongolia	0.55	0.70	0.48	0.58	0.59	0.33	0.69	0.50	0.67	0.62	0.33	1.00
Namibia	0.54	0.62	0.45	0.56	0.61	0.36	0.56	0.46	0.68	0.56	0.41	1.00
Morocco	0.53	0.62	0.49	0.78	0.39	0.26	0.91	0.97	0.62	0.81	0.42	0.17
Bolivia	0.53	0.67	0.43	0.69	0.49	0.29	0.65	0.80	0.59	0.67	0.17	1.00
India	0.50	0.59	0.45	0.59	0.48	0.30	0.69	0.58	0.60	0.61	0.59	0.30
Pakistan	0.50	0.54	0.42	0.57	0.52	0.26	0.68	0.58	0.56	0.76	0.70	0.27
State of Palestine	0.47	0.69	0.52	0.80	0.25	0.45	0.60	0.98	0.66	0.73	0.59	0.04
Bangladesh	0.41	0.56	0.33	0.35	0.61	0.16	0.69	0.23	0.51	0.73	0.31	1.00
Maldives	0.41	0.70	0.58	0.77	0.15	0.41	0.83	0.96	0.61	0.98	0.21	0.02
Lao People's Dem. Rep.	0.40	0.57	0.34	0.32	0.58	0.18	0.66	0.19	0.56	0.73	0.26	1.00
Congo	0.39	0.56	0.39	0.38	0.40	0.25	0.60	0.31	0.47	0.34	0.19	1.00
Nepal	0.38	0.54	0.37	0.40	0.36	0.18	0.77	0.37	0.44	0.65	0.07	1.00
Ghana	0.38	0.57	0.49	0.41	0.26	0.25	0.95	0.32	0.53	0.36	0.12	0.43
Zambia	0.38	0.56	0.31	0.34	0.51	0.17	0.58	0.19	0.58	0.54	0.25	1.00
Cape Verde	0.37	0.64	0.48	0.64	0.16	0.31	0.76	0.69	0.58	0.81	0.04	0.12
Cambodia	0.34	0.58	0.37	0.30	0.37	0.19	0.71	0.18	0.49	0.57	0.09	1.00
Kenya	0.33	0.54	0.42	0.32	0.27	0.27	0.64	0.21	0.46	0.44	0.35	0.13

Table B.2—Continued

Country	FEW Index	HDI Value	Food Sub-Index	Energy Sub-Index	Water Sub-Index	Food Accessibility	Food Availability	Energy Accessibility	Energy Availability	Water Accessibility	Water Availability	Water Adaptive Capacity
Sao Tome and Principe		0.56	0.42	0.47		0.24	0.75	0.42	0.54	0.58		1.00
Vanuatu		0.62	0.66	0.32		0.53	0.82	0.21	0.49	0.74		
Tonga		0.71		0.64				0.74	0.56	0.95		
Timor-Leste		0.62	0.45		0.81	0.30	0.66	0.18		0.54	1.00	1.00
Samoa		0.69	0.76	0.62		0.71	0.80	0.69	0.57	0.95		
Micronesia		0.63						0.59		0.71		
Kiribati		0.61	0.72	0.41		0.59	0.87	0.34	0.50	0.52		
Equatorial Guinea		0.56		0.50	0.53			0.57	0.44	0.60	0.26	1.00
Bhutan		0.58		0.69	0.60	0.20		0.68	0.71	0.71	0.30	1.00

NOTE: Missing values indicate that data were not available for the specific country.

Table B.3
High HDI Countries

Country	FEW Index	HDI Value	Food Sub-Index	Energy Sub-Index	Water Sub-Index	Food Accessibility	Food Availability	Energy Accessibility	Energy Availability	Water Accessibility	Water Availability	Water Adaptive Capacity
Kazakhstan	0.82	0.76	0.73	0.86	0.87	0.61	0.87	0.95	0.78	0.95	0.68	1.00
Brazil	0.81	0.74	0.66	0.83	0.97	0.50	0.87	0.97	0.72	0.90	1.00	1.00
Malaysia	0.80	0.77	0.60	0.86	0.99	0.43	0.83	0.97	0.77	0.97	1.00	1.00
Costa Rica	0.78	0.76	0.59	0.82	0.99	0.45	0.78	0.97	0.70	0.96	1.00	1.00
Uruguay	0.78	0.79	0.57	0.84	0.99	0.42	0.78	0.97	0.73	0.98	1.00	1.00
Belarus	0.78	0.79	0.56	0.86	0.99	0.34	0.91	0.97	0.75	0.97	1.00	1.00
Russian Federation	0.77	0.78	0.55	0.89	0.94	0.37	0.83	0.97	0.80	0.84	1.00	1.00
Romania	0.77	0.79	0.59	0.81	0.96	0.39	0.91	0.91	0.71	0.89	1.00	1.00
Venezuela	0.77	0.76	0.54	0.85	0.98	0.36	0.82	0.97	0.74	0.94	1.00	1.00
Dominica	0.77	0.72	0.73	0.79	0.79	0.63	0.85	0.94	0.66	0.87	1.00	0.56
Colombia	0.75	0.71	0.61	0.76	0.92	0.49	0.77	0.91	0.64	0.86	0.89	1.00
Ecuador	0.75	0.71	0.56	0.79	0.95	0.44	0.71	0.96	0.66	0.86	1.00	1.00
Panama	0.75	0.77	0.58	0.77	0.94	0.43	0.77	0.86	0.70	0.84	1.00	1.00
Turkey	0.75	0.76	0.61	0.84	0.82	0.37	1.00	0.97	0.72	0.97	1.00	0.56
Serbia	0.74	0.75	0.53	0.78	0.99	0.39	0.73	0.82	0.74	0.98	1.00	1.00
Bahamas	0.74	0.79	0.67	0.87	0.70	0.62	0.72	0.97	0.78	0.95	1.00	0.37
Trinidad and Tobago	0.74	0.77	0.56	0.89	0.81	0.39	0.79	0.97	0.80	0.93	1.00	0.57
Mexico	0.74	0.76	0.57	0.80	0.88	0.39	0.83	0.92	0.70	0.90	1.00	0.75
Georgia	0.73	0.74	0.56	0.72	0.98	0.42	0.75	0.73	0.70	0.93	1.00	1.00
Ukraine	0.73	0.73	0.53	0.86	0.84	0.33	0.85	0.97	0.75	0.96	1.00	0.62

Table B.3—Continued

Country	FEW Index	HDI Value	Food Sub-Index	Energy Sub-Index	Water Sub-Index	Food Accessibility	Food Availability	Energy Accessibility	Energy Availability	Water Accessibility	Water Availability	Water Adaptive Capacity
Bulgaria	0.73	0.78	0.55	0.84	0.82	0.42	0.72	0.93	0.77	0.92	1.00	0.59
Bosnia and Herzegovina	0.72	0.73	0.50	0.74	0.99	0.32	0.77	0.74	0.74	0.97	1.00	1.00
Belize	0.71	0.73	0.59	0.80	0.74	0.44	0.78	0.94	0.69	0.95	0.43	1.00
Azerbaijan	0.70	0.75	0.55	0.82	0.78	0.37	0.81	0.96	0.69	0.88	0.73	0.73
Albania	0.70	0.72	0.49	0.72	0.98	0.30	0.78	0.78	0.67	0.94	1.00	1.00
Jamaica	0.70	0.72	0.51	0.77	0.88	0.35	0.75	0.91	0.64	0.88	1.00	0.77
Macedonia	0.70	0.73	0.51	0.79	0.83	0.35	0.75	0.82	0.75	0.95	1.00	0.61
Lebanon	0.68	0.77	0.73	0.84	0.52	0.61	0.87	0.97	0.72	0.89	0.89	0.18
Mauritius	0.68	0.77	0.52	0.82	0.75	0.32	0.83	0.97	0.70	0.96	1.00	0.44
Thailand	0.68	0.72	0.50	0.78	0.81	0.33	0.75	0.86	0.71	0.95	0.55	1.00
Iran	0.68	0.75	0.53	0.84	0.69	0.32	0.88	0.97	0.72	0.93	1.00	0.35
Armenia	0.65	0.73	0.44	0.78	0.79	0.25	0.77	0.90	0.68	0.95	1.00	0.52
Peru	0.65	0.74	0.51	0.70	0.76	0.33	0.77	0.76	0.65	0.81	0.55	1.00
Grenada	0.64	0.74	0.45	0.80	0.72	0.30	0.69	0.93	0.68	0.97	1.00	0.38
China	0.63	0.72	0.56	0.74	0.61	0.38	0.83	0.73	0.75	0.85	0.67	0.40
Saint Lucia	0.62	0.71	0.45	0.80	0.66	0.29	0.70	0.93	0.69	0.93	0.93	0.33
Saint Vincent/ Grenadines	0.62	0.72	0.58	0.74	0.54	0.44	0.78	0.85	0.65	0.85	1.00	0.18
Fiji	0.60	0.72	0.50	0.62	0.71	0.32	0.79	0.61	0.63	0.93	0.39	1.00
Barbados	0.59	0.78	0.66	0.83	0.38	0.53	0.80	0.93	0.75	0.98	0.96	0.06
Antigua and Barbuda	0.58	0.77	0.50	0.83	0.48	0.38	0.66	0.93	0.75	0.95	1.00	0.11

Table B.3—Continued

Country	FEW Index	HDI Value	Food Sub-Index	Energy Sub-Index	Water Sub-Index	Food Accessibility	Food Availability	Energy Accessibility	Energy Availability	Water Accessibility	Water Availability	Water Adaptive Capacity
Saint Kitts and Nevis	0.55	0.75	0.59	0.67	0.43	0.49	0.69	0.63	0.72	0.93	1.00	0.09
Tunisia	0.55	0.72	0.57	0.80	0.36	0.35	0.94	0.97	0.65	0.95	0.60	0.08
Oman	0.54	0.78	0.60	0.88	0.30	0.43	0.83	0.96	0.80	0.95	0.41	0.07
Libya	0.53	0.78	0.65	0.87	0.26	0.49	0.86	0.97	0.77	0.83	1.00	0.02
Sri Lanka	0.52	0.75	0.43	0.52	0.63	0.25	0.73	0.47	0.57	0.95	0.53	0.49
Algeria	0.50	0.72	0.52	0.79	0.30	0.29	0.92	0.97	0.65	0.86	0.55	0.06
Jordan	0.47	0.75	0.54	0.83	0.23	0.34	0.87	0.97	0.70	0.98	0.53	0.02
Montenegro		0.79	0.51	0.82		0.34	0.78	0.85	0.79	0.98	1.00	
Palau		0.78						0.75		0.98		
Seychelles		0.76	0.33	0.85		0.15	0.71	0.97	0.74	0.97	1.00	

NOTE: Missing values indicate that data were not available for the specific country.

Table B.4
Very High HDI Countries

Country	FEW Index	HDI Value	Food Sub-Index	Energy Sub-Index	Water Sub-Index	Food Accessibility	Food Availability	Energy Accessibility	Energy Availability	Water Accessibility	Water Availability	Water Adaptive Capacity
United States of America	0.94	0.91	0.89	0.92	1.00	0.87	0.92	0.97	0.87	1.00	1.00	1.00
Luxembourg	0.91	0.88	0.83	0.92	0.99	0.74	0.92	0.97	0.86	0.99	0.99	1.00
Canada	0.91	0.90	0.80	0.93	1.00	0.76	0.85	0.97	0.89	1.00	1.00	1.00
Austria	0.90	0.88	0.83	0.90	0.99	0.72	0.97	0.97	0.82	1.00	0.97	1.00
Iceland	0.90	0.90	0.75	0.99	1.00	0.66	0.85	0.97	1.00	0.99	1.00	1.00
Norway	0.90	0.94	0.77	0.95	1.00	0.68	0.87	0.97	0.92	0.99	1.00	1.00
Australia	0.90	0.93	0.80	0.91	1.00	0.74	0.86	0.97	0.85	1.00	1.00	1.00
Switzerland	0.90	0.92	0.81	0.89	1.00	0.75	0.87	0.97	0.82	1.00	1.00	1.00
Ireland	0.89	0.90	0.83	0.88	0.98	0.73	0.94	0.97	0.79	0.94	1.00	1.00
Sweden	0.88	0.90	0.75	0.92	1.00	0.70	0.80	0.97	0.88	1.00	1.00	1.00
Netherlands	0.88	0.92	0.77	0.89	0.99	0.73	0.82	0.97	0.81	0.99	0.99	1.00
Finland	0.88	0.88	0.73	0.93	0.99	0.65	0.82	0.97	0.89	0.99	1.00	1.00
Argentina	0.87	0.81	0.79	0.84	0.99	0.64	0.97	0.97	0.73	0.98	1.00	1.00
New Zealand	0.86	0.91	0.69	0.90	1.00	0.61	0.80	0.97	0.84	1.00	1.00	1.00
Greece	0.85	0.85	0.70	0.88	1.00	0.52	0.94	0.97	0.79	0.99	1.00	1.00
Portugal	0.85	0.82	0.70	0.87	1.00	0.52	0.93	0.97	0.77	1.00	1.00	1.00
France	0.84	0.88	0.77	0.89	0.87	0.65	0.91	0.97	0.82	0.99	1.00	0.65
Slovenia	0.84	0.87	0.67	0.89	1.00	0.53	0.84	0.97	0.81	0.99	1.00	1.00
Hungary	0.84	0.82	0.69	0.86	1.00	0.54	0.89	0.97	0.76	0.99	1.00	1.00
United Kingdom	0.82	0.89	0.82	0.87	0.77	0.76	0.89	0.97	0.78	1.00	1.00	0.46

Table B.4—Continued

Country	FEW Index	HDI Value	Food Sub-Index	Energy Sub-Index	Water Sub-Index	Food Accessibility	Food Availability	Energy Accessibility	Energy Availability	Water Accessibility	Water Availability	Water Adaptive Capacity
Italy	0.82	0.87	0.73	0.87	0.85	0.57	0.93	0.97	0.79	1.00	1.00	0.63
Croatia	0.81	0.81	0.62	0.86	0.99	0.46	0.82	0.96	0.78	0.98	1.00	1.00
Chile	0.80	0.82	0.61	0.86	0.99	0.46	0.81	0.97	0.75	0.99	0.97	1.00
Latvia	0.80	0.81	0.61	0.86	0.98	0.48	0.76	0.97	0.75	0.93	1.00	1.00
Japan	0.79	0.89	0.63	0.89	0.88	0.56	0.72	0.97	0.82	1.00	1.00	0.68
Cuba	0.79	0.82	0.72	0.79	0.86	0.56	0.93	0.95	0.66	0.94	1.00	0.68
Slovakia	0.79	0.83	0.60	0.87	0.93	0.50	0.73	0.97	0.78	0.99	0.81	1.00
Spain	0.79	0.87	0.71	0.88	0.78	0.61	0.83	0.97	0.79	1.00	1.00	0.47
Germany	0.78	0.91	0.78	0.89	0.68	0.68	0.90	0.97	0.81	1.00	0.86	0.37
Estonia	0.78	0.84	0.62	0.87	0.86	0.48	0.81	0.94	0.80	0.98	0.65	1.00
Belgium	0.77	0.88	0.78	0.89	0.65	0.65	0.95	0.97	0.82	1.00	0.86	0.33
Lithuania	0.76	0.83	0.62	0.81	0.89	0.42	0.91	0.89	0.74	0.94	0.74	1.00
Republic of Korea	0.75	0.89	0.71	0.91	0.65	0.55	0.91	0.97	0.85	0.99	1.00	0.28
Denmark	0.74	0.90	0.80	0.88	0.57	0.74	0.86	0.97	0.80	1.00	0.87	0.21
Czech Republic	0.71	0.86	0.68	0.88	0.59	0.55	0.84	0.97	0.80	1.00	0.83	0.24
Poland	0.69	0.83	0.64	0.86	0.61	0.47	0.87	0.97	0.75	0.98	0.72	0.32
Israel	0.61	0.89	0.73	0.89	0.36	0.54	0.97	0.97	0.81	1.00	1.00	0.05
Cyprus	0.56	0.85	0.64	0.86	0.31	0.60	0.68	0.97	0.76	1.00	0.22	0.14
Malta	0.55	0.83	0.66	0.87	0.29	0.50	0.88	0.97	0.77	1.00	1.00	0.02
Saudi Arabia	0.51	0.84	0.61	0.89	0.25	0.42	0.87	0.96	0.83	0.98	0.93	0.02

Table B.4—Continued

Country	FEW Index	HDI Value	Food Sub-Index	Energy Sub-Index	Water Sub-Index	Food Accessibility	Food Availability	Energy Accessibility	Energy Availability	Water Accessibility	Water Availability	Water Adaptive Capacity
United Arab Emirates	0.45	0.83	0.70	0.91	0.14	0.58	0.85	0.96	0.85	0.99	0.92	0.00
Kuwait	0.39	0.81	0.64	0.92	0.10	0.47	0.87	0.96	0.88	0.99	1.00	0.00
Singapore		0.90		0.90	0.28	0.98		0.97	0.83	1.00	1.00	0.02
Qatar		0.85		0.92	0.17	0.57		0.96	0.89	0.99	1.00	0.01
Liechtenstein		0.89						0.97				
Brunei Darussalam		0.85	0.60	0.84		0.43	0.83	0.85	0.83		1.00	1.00
Bahrain		0.82		0.90	0.26	0.45		0.96	0.84	1.00	1.00	0.02
Andorra		0.83						0.97		1.00		0.79
Hong Kong		0.89		0.89				1.00	0.80			

NOTE: Missing values indicate that data were not available for the specific country.

Abbreviations

EDI	Energy Development Index
EIU	Economist Intelligence Unit
EPI	Environmental Performance Index
FAO	Food and Agriculture Organization of the United Nations
FEW Index	Pardee RAND Food-Energy-Water Security Index
GDP	gross domestic product
GHI	Global Hunger Index
HANCI	Hunger and Nutrition Commitment Index
HDI	Human Development Index
HII	Human Insecurity Index
IFPRI	International Food Policy Research Institute
kWh	kilowatt-hour
MDER	minimum dietary energy requirement
ND-GAIN	Notre Dame Global Adaptation Index
OECD	Organisation for Economic Co-operation and Development
SE4ALL	Sustainable Energy for All
UN	United Nations
WHO	World Health Organization

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