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# Addressing the Food, Water, and Energy Nexus

## Transatlantic Perspectives and Africa's Great Chance

Peter Engelke

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by Peter Engelke

Atlantic Council



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# Executive Summary

This report explores how the relationships between food, water, and energy resources shape our world and its future, with emphasis on Africa and the transatlantic region. Called the food-water-energy "nexus," the interdependencies between these resources are fundamental to all human endeavor on Earth. Understanding this nexus and managing it effectively is a critical challenge for policymakers and thought leaders in the transatlantic arena. Solving the challenges found on the African continent might present both the greatest task and the greatest reward. The potential pitfalls of failing to tackle Africa's food-water-energy challenges are enormous, for Africans themselves and for all countries sharing the Atlantic Ocean space. But the potential downside is more than matched by the potential upside, and the gains to be had from solving nexus problems in Africa might prove as profound as any set of goals in the world.

Food, water, and energy security are three nontraditional security challenges that have taken on much greater visibility in recent years. High-level political leadership has helped reframe food as a global security priority, and food security has risen to the top of many countries' concerns around the world, including in the Middle East and North Africa. While not yet a source of interstate conflict, many observers fear that fresh water scarcity, driven by increasing population, overconsumption, and climate-induced scarcity, will likewise reshape the global security landscape in the years ahead. This will occur as water shortages impact food and energy production systems, sources of drinking water, and critical ecosystems. And, of course, energy security has been a major preoccupation of the security community for decades. As with food and fresh water, energy producers and consumers alike have an interest in a secure, stable, and unimpeded energy market.

In the transatlantic arena, there is a growing awareness about the need to treat natural resource stresses as security challenges in addition to economic and social ones. Building the political and technical capacity to understand, monitor, and address potential nexus-related problems before they begin to decay national and/or transnational stability is needed. Unfortunately, the institutional structures that will be required to accomplish these tasks are largely absent, often at national levels and almost always on regional and global scales. Solving nexus-related challenges necessitates creative and sustained partnerships among and between government, industry, and civil society.

Rising demand for food, water, and energy around the world and in Africa means that African production of all three goods will have to rise. Africa has a rapidly growing population and the highest rate of urbanization on Earth, both of which are driving demand within Africa itself. Significant hurdles must be cleared, however, before such demand can be translated into best-case prosperity. The continent's resource endowment is highly uneven, a reality that limits prosperity in many places while exposing much of the continent to especially severe climate change-induced stresses. In the area of food security, too, Africa's low agricultural productivity suffers from limited water (irrigation) and energy (fertilizer, mechanization) inputs, both of which must be overcome if Africa is to fulfill its promise as a global breadbasket.

This report identifies five core principles to guide the planning, production, regulation, and use of the food, water, and energy nexus in Africa, and for the ecosystems that sustain the nexus. Policymakers should follow these core principles:

- **Stress integration**: Failing to engage in integrated food-water-energy planning and management increases the odds of negative consequences including economic inefficiencies, greater exposure to external resource shocks, and the possibility that scarcities of one of the nexus elements will negatively impact the others. Governments should create mechanisms built upon a solid understanding of the food-water-energy nexus. Multi-stakeholder coalitions from the public and private sectors and from civil society should be involved in policy formulation from the beginning.

- **Maximize efficiency**: Moving to a more sustainable economy will depend on dramatic improvements in resource productivity. Strategies for doing so include pricing resources to encourage efficiency gains, removing waste along supply chains (in Africa, most food waste is upstream), viewing waste as an asset, and managing demand through influencing consumer behavior. Hurdles to greater efficiency in Africa and elsewhere include economic, technological, and financial barriers, inefficient legacy infrastructure, policy roadblocks, vested interests, and cultural inertia.

- **Enable access**: Increased resource production is not always the same thing as increased consumption and broad distribution. Access issues involve complex social, political, and economic policy questions. While poverty is increasingly an urban phenomenon in Africa, the poorest people are rural smallholders. Subsistence farmers in Africa are most vulnerable because their production levels are low, they lack technology and access to markets, and have low resiliency to climate variability, particularly rainfall variability.

- **Strengthen resiliency**: The complexity of the nexus—of intersecting and overlapping ecological and human systems—suggests that we should strengthen system resiliency to absorb short-term external shocks and adapt to long-term changes. Intact watersheds, forests, soils, wetlands, and coastal environments provide the ecosystem services without which human systems cannot function. Governments will need to incorporate ecosystem perspectives into nexus management.

- **Embrace innovation**: Solving nexus challenges will require the utilization of innovative tools. The scaling of existing best-practice technologies, methods, and systems can go a long way toward increasing output while conserving nexus resources. Expanding existing best practices such as drip irrigation, subsurface drip irrigation, and "fertigation" would make African agriculture far more resource-efficient than it is now. But toolkits also must embrace breakthrough, "emerging," and "disruptive" forms of innovation. Creating systems that identify and scale novel advances is the key to translating innovative technologies, methods, and practices into successful on-the-ground application. While scientific and technological advances are key, success depends on the interactive participation of researchers, practitioners, and consumers to bring innovations into usable and practical form.

Unfortunately, the nexus' complexity means that from a technical perspective we likely will never be able to fully and accurately model it. While the world's best scientists constantly improve their modeling capabilities, they admit that they are unable to quantify the extraordinarily complex relationships across the full spectrum of physical and human systems.

Absent such capability, the easiest solution is to continue to treat resources separately through narrow sectoral lenses. Yet doing so reduces the odds that we can build a more stable, prosperous, and sustainable world. Strengthening Africa's interlinked food, water, and energy systems provides Africa and the transatlantic community with a great chance and opportunity to build a brighter future.

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# Foreword

The smart and productive use of the most precious of natural resources—food, water, and energy—has become one of the great challenges of our times. For too long, we have taken for granted their availability. Outside of the occasional shock to the smooth global flow of oil, it appeared that food, water, and energy would be available all the time, in the right quantity, and indefinitely into the future. Events have undermined this confidence, as when severe drought in one part of the world has caused food prices in another to spike dramatically. Just as critically, we have become increasingly conscious of the fundamental linkages between these resources, as brought together through the concept of the food-water-energy "nexus."

As this report argues, the Atlantic community has an enduring interest in building more resilient food-water-energy production and distribution systems. Strengthening the nexus is imperative if we are to both avoid disruptive resource shocks and share a more prosperous future. As members of the broader Atlantic community, African countries possess a significant and, in many ways, underutilized natural endowment. If harnessed in a fashion that serves the interests of all the nations and peoples of the continent while protecting the natural environment, those resources can become a source of broadly shared prosperity in Africa—and, indeed, beyond. Unleashing Africa's potential in this area is a must, and not just for African development itself. If Africa's trade in food and energy products (and indirectly in water as well) can be boosted, the continent's future and its fortunes will be bound more tightly with those of the Atlantic community.

It is in this context that we undertook an effort to engage questions about the nexus of food, water, and energy with the aim of both closely examining the interrelationships between the three as well as laying the groundwork for a possible broader initiative aimed at mobilizing the transatlantic community around the concrete challenges posed by the nexus as well as the opportunities therein. In this effort, we were very fortunate to be able to partner with the OCP Group, and not only because of its unique commercial and scientific experience on these questions. Beyond that, its home, Morocco, is uniquely positioned on the Mediterranean and the Atlantic to take leadership as the hub for an effort on Africa involving the whole Atlantic community.

We are deeply grateful for the vision and the support of Mostafa Terrab, chairman, and his gifted team at the OCP Group, for not only making this pilot project possible, but also providing a wealth of experience and insight to the project and the resulting report. At the Atlantic Council, we hope to deepen and build upon this effective partnership to mobilize regional transatlantic and global action around this set of issues.

We are also fortunate to have benefited from the contributions of a number of leading experts from around the world who participated in the conference hosted at the Atlantic Council's headquarters earlier this year, who subsequently provided feedback on the draft report.

Within the Atlantic Council, I want to recognize Peter Engelke, senior fellow in the Strategic Foresight Initiative of the Brent Scowcroft Center on International Security, for his impressive work and creativity as author of this study, as well as the team at the Council's Energy and Environment Program, which also contributed to the report. I am very proud that—in keeping with our unique ethos of cutting-edge, cross-program work—this initiative on food, water, and energy has been a collaborative effort across different centers and programs at the Atlantic Council.

Thanks in particular to J. Peter Pham, director of the Africa Center, who has shepherded this project along since its inception two years ago, as well as the support that Barry Pavel, director of the Brent Scowcroft Center, has given to it. Under Peter Pham's remarkable leadership, the Africa Center has established itself as a go-to place for these sorts of rich discussions and significant projects. His deputy director Bronwyn Bruton contributed to the day-to-day management of the project.

The Atlantic Council believes that the Atlantic community must be at the forefront in guiding an uncertain world toward a more secure, peaceful, and prosperous future. This project and the work that will follow it are grounded in this belief. The broader Atlantic community, including Africa, has a strong interest in ensuring a brighter future for the continent and its citizens, and thereby for the entire world. Through this work, the Council continues to show its commitment to vibrant and effective transatlantic leadership on issues of the greatest importance.

**Frederick Kempe**
President and CEO
Atlantic Council

## The Nexus Challenge as an Opportunity for Africa

by **J. Peter Pham,** *Director, Africa Center,* Atlantic Council

One of the unfortunate consequences of all the "bad news" out of Africa—concerning a handful of very real conflicts of global consequence and a number of other ongoing political, economic, social, and humanitarian challenges—is that most of the continent's "good news" tends to get eclipsed. As a result, it is often forgotten that what the *Economist* described just over a decade ago in an infamous cover as "the hopeless continent" was later heralded by the same magazine as "Africa rising."

Today, Africa is home to seven of the decade's ten fastest growing economies in the world. While, admittedly, the starting points for some African countries are relatively low and growth for some has been driven by fickle demand for their commodities, a significant proportion of the growth is nonetheless due to deeper, long-term trends, including demographics and technology. For example, one in four workers in the world will be an African by 2050, and the world's fastest-growing urbanization rates will lead to lower basic infrastructure costs and concentrated consumer markets. Meanwhile, the rapid expansion of mobile telephony and Internet usage growth rates at five times global averages over the last decade ensure that businesses across the continent have access to new markets and can compete in the globalized economy.

Whereas African countries used to be written off as "risky" bets or thought of only as sources for raw natural resources, robust GDP growth rates coupled with improved regulatory and commercial environments have made the continent an increasingly attractive place to do business. Consequently, it was no surprise that the US-Africa Business forum was a central component of the August 2014 US-Africa Leaders Summit in Washington, the largest gathering of African heads of state and government ever convened by an American president. During the forum, a number of American firms announced multimillion and even multibillion dollar deals with African partners, and President Barack Obama used the occasion to announce that the annual Global Entrepreneurship Summit would be held in Marrakech in November, marking the first time that signature event has ever been held in Africa.

Although the story of Africa is increasingly one of economic dynamism—driven, in part, by political reform and improvements in governance—there remain nevertheless some very real developmental challenges that, if not addressed, have the potential to seriously impair the momentum of progress. And many of these challenges are closely connected to the nexus of food, water, and energy, the very basis of life. If Africa's buoyant economic prospects are based in part on countries' expanding (and youthful) populations and their tendency to be increasingly urbanized, then there will be a need for a surge in both absolute agricultural production and relative productivity to feed them. It is no accident that the African Union proclaimed 2014 to be the "Year of Agriculture and Food Security" with the theme of "transforming Africa's agriculture: harnessing opportunities for inclusive growth and sustainable development." To achieve that last objective—sustainability of development—will require integrating considerations of water, energy, and other resource inputs into agricultural planning as well as tackling issues of climate resilience.

Although the story of Africa is increasingly one of economic dynamism—driven, in part, by political reform and improvements in governance—there remain some very real developmental challenges that, if not addressed, have the potential to seriously impair the momentum of progress.

Meeting these challenges must be a process owned and led by Africans, but there is an opportunity for other members of the international community as well. There are lessons to be learned from global best practices for investing in research, boosting productivity, and expanding access to markets, among other priorities. Foreign governments and the private sector also have a role to play as active participants in African development, and may even find that they may do so most effectively working with key African partners already active in the sector. Moreover, African agriculture's importance is growing at a time when demand for food by the developing world's rising and increasingly affluent populations surges even as local resources diminish in many other parts of the globe—and thus Africa's potential bounty is a question of great importance to the world as a whole.

Questions abound: Will these dynamics result in the introduction of new capital, skills, and technology into an underdeveloped sector that could unlock its extraordinary potential to both feed Africa's burgeoning population and meet wider food security needs, or will it simply lead to the exploitation of the continent's potential croplands for the benefit of others? Is there a way to transform resource development from a linear progression from primary-commodity exporters to ultimate consumers into a win-win scenario for both Africans and their international partners? In short, can there be a transition from *exploiting* Africa's resources to *developing* them?

This report opens the door to examining how Africa can best leverage its food, water, and energy resources for sustainable development, and also what the wider international community, especially the broader Atlantic community, can do to assist in the process—not only because it is the right thing to do, but because it is in the Atlantic community's interest to do so. If the current opportunity is seized, Africa can truly be transformed into a place where international engagement is driven primarily by neither aid and humanitarian sentiments nor commercial exploitation, but rather where economic opportunities and the potential therein for mutual benefit form the basis not only for a new social contract between African governments, businesses, and civil society, but for true partnerships between Africa and its international partners on both sides of the Atlantic, north as well as south.

## The Nexus Challenge from an Atlantic Perspective

by **Barry Pavel**, *Vice President and Director, Brent Scowcroft Center on International Security,* Atlantic Council

This report outlines the natural resource opportunities and challenges facing both Africa and the broader Atlantic community. It is a truism that societies must have access to a stable supply of natural resources for their security, stability, and prosperity. This equation is most true for food, water, and energy, without which nothing can survive for long.

Every serious assessment of the coming decades predicts strong and rising global demand for core natural resources. This demand is being driven not just by China, India, and emerging middleweight economic powers (e.g., Turkey), but increasingly by vibrant economies located in Africa. Africa has a large and rapidly growing population and, just as importantly, a growing middle class. Africa is set to become an important driver of global resource demand, in a fashion similar to East Asia.

These observations have serious ramifications for the Atlantic community. Going forward, Atlantic basin economies will be as dependent on natural resources as they are now and—as forecasts for Africa show—in some cases will use them even more intensively. Increased competition for resources is a likely outcome, a disconcerting scenario made more probable when considering the effects of climate change. As a "threat multiplier," climate change might make the expected resource crunch worse, aggravating international tensions and raising the unpleasant specter of conflict over resources.

For the Atlantic community, a necessary first step is to invest resources in better understanding how ecosystems, natural resources, and social and political systems intersect. Effective intergovernmental nexus management is another critical step, one that will require building consensus regarding how best to tackle a range of difficult and complex questions. Similarly, the construction of strong, resilient, and cooperative partnerships among public, private, and nonprofit stakeholders is a necessary but also challenging task. Finally, the Atlantic community would be well served if it were to give the field of "environmental security" greater strategic priority.

> The larger Atlantic community is no longer just about North-North exchange; it is defined as much by North-South and South-South exchange.

As global power becomes more diffuse, the countries within the Atlantic basin will have a more difficult time shaping trends and outcomes around the world. The larger Atlantic community is no longer just about North-North exchange; it is defined as much by North-South and South-South exchange. As such, it is imperative to enlist Africans as partners in efforts to address nexus issues.

We believe that this report strikes the right balance between an optimistic view of Africa's future and a well-placed concern about the pitfalls that could derail the continent's prospects. Most fundamentally, success or failure should not be viewed as just an African question. Whether Africa becomes one of the world's greatest breadbaskets, for instance, is a question with obvious and enormous significance for Africans themselves and for everyone else in the Atlantic basin. Securing a resilient and prosperous future for Africa is in the best interests of the entire Atlantic community.

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# I. The Food-Water-Energy Nexus

This report explores how the relationships between food, water, and energy resources shape our world and its future. Called the food-water-energy "nexus," these resources and their interdependencies represent the most fundamentally important systems that support human endeavors on Earth. Understanding this nexus and managing it effectively is a critical challenge for policymakers and thought leaders in the transatlantic arena. The stakes cannot be higher. Continuing to treat food, water, and energy systems as separate phenomena is an approach almost certain to make our world a less prosperous, less resilient, and less secure place than it otherwise might become. Conversely, successfully managing the interdependencies across these systems will contribute to a much better future. For foreign and security policymakers in the transatlantic arena, it is likely that this century's looming food-water-energy nexus challenges will become central concerns. Within this set of nexus challenges, solving those found on the African continent might present both the greatest task and the greatest reward. The potential pitfalls of failing to tackle Africa's food-water-energy challenges are enormous for Africans themselves and for all countries sharing the Atlantic Ocean space. But the potential downside is more than matched by the potential upside, and the gains to be had from solving nexus problems in Africa might prove as profound as any set of goals in the world.

Continuing to treat food, water, and energy systems as separate phenomena is an approach almost certain to make our world a less prosperous, less resilient, and less secure place than it otherwise might become.

Natural resource strains already affect large numbers of people around the world and are likely to feature even more prominently during this century. Global demand for natural resources—food, water, energy, minerals, timber, and other commodities—has never been higher, while demand for these goods is forecasted to rise continuously over the coming decades. A growing global population, combined with increased per capita consumption due to rising wealth and ongoing urbanization, drive this process. All analyses forecast substantial increases for the core resources of food, water, and energy. One recent estimate predicts global demand to rise as much as 35 percent for food, 40 percent for water, and 50 percent for energy by 2030.[1] These figures may turn out to be underestimates; the global consumption of food might rise by as much as 70 percent or even more by 2050.[2] Most of the increase in demand for natural resources will come from emerging economies. Going forward, non-OECD countries will continue to be the primary drivers of global energy consumption. Although per capita energy consumption will remain much higher in OECD countries, the massive scale of economic growth in Asia, Africa, and elsewhere will account for nearly all of the projected growth in energy consumption over the coming two decades.[3]

At the same time, it is not clear how humankind will meet this demand. A resource-constrained future, resulting from increased human interference in finite ecosystems and from climate change's predicted impact on these ecosystems, is foreseeable. Such constraints threaten to limit our ability to meet rising consumption through the usual strategy of increasing global supply.

Over the past decades, research and policymaking have focused more on natural resource sectors than on the intersections among them. This focus has overlooked interdependencies, leading to narrow investment and policy decisions. Recently, however, the nexus idea—the notion that the core natural resources of food, water, and energy are interlinked—has gained considerable traction. For instance, food and energy production is impossible without water, the "indispensable ingredient for life"

1 National Intelligence Council, *Global Trends 2030: Alternative Worlds* (Washington: Office of the Director of National Intelligence, 2012), p. iv.

2 Bernice Lee al., *Resources Futures. A Chatham House Report* (London: Royal Institute of International Affairs, 2012), p. xiii; T. Searchinger et al., *The Great Balancing Act. Working Paper*, installment 1 of *Creating a Sustainable Food Future* (Washington, DC: World Resources Institute, 2013), p. 1.

3 See, e.g., British Petroleum, *BP Energy Outlook 2035* (January, 2014), http://www.bp.com/content/dam/bp/pdf/Energy-economics/Energy-Outlook/Energy_Outlook_2035_booklet.pdf.

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that has "no substitute and no alternative."[4] Yet rising consumption and climate-induced ecological changes threaten the world's water supplies. Similarly, drawing water from underground sources, or moving it from place to place, requires a great deal of energy inputs. Energy, in turn, is linked to food through numerous pathways, most often as an input to food production and transport but occasionally as an output of agricultural production (via biofuels).

The nexus approach to food, water, and energy resources emphasizes the gains to be had from recognizing interdependencies and the losses to be suffered from ignoring them. The potential losses from ignoring interdependencies might be catastrophic, ranging from greater volatility in food and energy markets to absolute scarcities of water and food. The indirect consequences include greater social and political unrest from commodity price spikes and resource shortages.

Conversely, the potential gains are just as significant. Focusing on nexus interdependencies encourages policymakers, business and community leaders, and producers to think systematically about ecosystems, build coherent policies using multi-stakeholder structures, focus on improving resource productivity, treat waste as a resource, and internalize externalities.[5]

Growing awareness of the need to treat food, water, and energy through an integrated framework has created an intense global dialogue surrounding the nexus. In a very short period of time, nexus thinking has become a well-established and global storyline. In 2011, the World Economic Forum announced that the food-water-energy nexus had become "part of the modern development canon."[6]

4 Dominic Waughray, *Water Security: The Water-Food-Energy-Climate Nexus. The World Economic Forum Water Initiative* (Washington: Island Press, 2011), p. 2.

5 H. Hoff, *Understanding the Nexus. Background Paper for the Bonn 2011 Conference: The Water, Energy and Food Security Nexus* (Stockholm: Stockholm Environment Institute, 2011), pp. 5-6.

6 Quoted in Livia Bizikova, *The Water-Energy-Food Security Nexus: Towards a Practical Planning and Decision-Support Framework for Landscape Investment and Risk Management* (Winnipeg: International Institute for Sustainable Development, 2013), p. 1.

## II. The Transatlantic Arena and Nexus Geopolitics

The food, water, and energy nexus is an increasingly important concern for the regions surrounding the Atlantic Ocean. While the great challenges of the last century were largely confined to ideological and geopolitical competition, today's policymakers must grapple with nontraditional security challenges that necessitate multilateral solutions. Food, water, and energy security are three nontraditional security challenges that have taken on much greater importance in recent years. Of these, food is the most visible, especially since the 2008 global food price spike that shook markets and drove political unrest around the world. High-level political leadership has helped reframe food as a global security priority, and food security has risen to the top of many countries' concerns around the world, including in the Middle East and North Africa. While not yet a source of interstate conflict, many observers fear that fresh water scarcity, driven by an increasing population, overconsumption, and climate-induced scarcity, will likewise reshape the global security landscape in the years ahead. This will occur as water shortages impact food and energy production systems, sources of drinking water, and critical ecosystems.[7] And, of course, energy security has been a major preoccupation of the security community for decades. As with food and fresh water, energy producers and consumers alike have an interest in a secure, stable, and unimpeded energy market.

Aware of the rising demand for natural resources and the potential for supply disruptions through climate-related shocks, foreign and security policymakers have placed greater emphasis on natural resource issues.

Aware of the rising demand for natural resources and the potential for supply disruptions through climate-related shocks, foreign and security policymakers have placed greater emphasis on natural resource issues. As recently as January 2014, for example, James Clapper, the US Director of National Intelligence (ODNI), testified before Congress that "competition for and secure access to natural resources (e.g. food, water, and energy) are growing security threats. . . . Many countries important to the United States are vulnerable to natural-resource shocks that degrade economic development, frustrate attempts to democratize, raise the risk of regime-threatening instability, and aggravate regional tensions. Demographic trends, especially increasing global population and urbanization, will also aggravate the outlook for resources, putting intense pressure on food, water, and energy."[8]

Within the American national security context, these remarks reflect growing concern that natural resource scarcities, in particular food, water, and energy scarcities, might become sources of conflict and instability. A 2012 report on water security, issued by ODNI, made the blunt assertion that water scarcity will become a destabilizing factor in those countries that do not have the financial or technical capacity to respond effectively. Moreover, it claimed that water scarcities could be expected to cause turmoil when other conditions such as widespread poverty, poor political leadership, or weak institutions are present.[9] Likewise, in 2013, ODNI issued a broader report on natural resources and came to similarly grim conclusions. It forecast that global food imbalances will become more problematic in the coming decades, as global demand growth begins to outstrip productivity gains.[10] For billions of poor people around the world,

7 See, e.g., Moises Naim's essay, "More Dangerous than Oil?," *Oil Magazine*, September 2013, pp. 29-31.

8 James R. Clapper, "Statement for the Record. Worldwide Threat Assessment of the US Intelligence Community" (Washington: Senate Select Committee on Intelligence, January 29, 2014), p. 9. http://www.dni.gov/index.php/newsroom/testimonies/203-congressional-testimonies-2014/1005-statement-for-the-record-worldwide-threat-assessment-of-the-us-intelligence-community.

9 Office of the Director of National Intelligence, *Global Water Security. Intelligence Community Assessment* (Washington: Office of the Director of National Intelligence, 2012), p. iii.

10 Office of the Director of National Intelligence, *Natural Resources in 2020, 2030, and 2040: Implications for the United States* (Washington: Office of the Director of National Intelligence, 2013), p. vi.

the consequences—significant food price hikes amidst chronic price volatility—are hardly comforting. From a state's perspective, the security implications of such a scenario are both clear and worrisome.

In the transatlantic arena, there is a growing awareness of the need to treat natural resource stresses as core security considerations. In Europe, the Americas, and Africa alike, there is an emerging consensus that food, water, and energy security are not only functionally linked but together represent emerging security concerns that require greater monitoring and attention in the coming decades.

Aside from conflicts over management of global commons resources (e.g., ocean fisheries, the Arctic), analysts generally worry about three major forms of natural resource-driven insecurity.[11] Interstate conflict, driven by natural resource scarcities, is the first and most obvious. Here, the thesis is that states facing severe resource shortages will begin acquiring resources through force, or threat of force, from their neighbors. Disputes over the control of shared water sources, in particular river systems, that erupt into violent interstate conflict is one classic scenario. While there is scant evidence in the post-1945 era that natural resource scarcities have moved states to war with one another, it is logical to be concerned that future scarcities may cause the world's chronic disputes to become violent, in particular in resource-constrained regions such as the Middle East, South Asia, and parts of Africa.[12] For instance, some believe that disputes over control of the Nile River have such potential for escalation into direct and violent interstate conflict, and the development of the Grand Ethiopian Renaissance Dam may indeed test that belief. All the riparian states in the Nile's largely arid basin claim rights to the river's limited water for growing food and energy production as well as direct water consumption needs. These disputes threaten regional stability, as upstream countries' plans for use of the river water clash with those of downstream countries.

A second security worry involves the transnational effects that are likely to follow from disruptions to the food, water, and energy nexus. As suggested in ODNI's brief, price spikes in essential commodities (such as food) and declines in ecosystem productivity for subsistence farmers (through soil loss, worsened droughts, disease, and other climate change impacts) are likely to induce greater transnational migration. Even in the face of large-scale relief efforts, the economic and social dislocations arising from food and water shortages might force people to flee difficult conditions at home in search of better circumstances abroad. While mass migration has an indirect, complex, and often diffuse impact on international security, observers tend to agree that migration under these circumstances is not ideal, often leading to heightened tensions along international borders and between countries, as well as conflict between new migrants and indigenous populations.

Finally, a closely related third security worry involves the linkages between state fragility and natural resource volatility—meaning the *resilience* of the state to resource fluctuation. In security terms, the concern has to do with how governments that already struggle to provide basic services, employment opportunities, and other necessities for their citizens can cope with episodic food, water, and energy shocks. Under normal conditions, when systems are resilient, shortfalls in local commodity supplies can be easily made up through trade in global markets. But as developments in global food markets have shown in recent years, disruptions in the global supply system can overwhelm the smooth operation of normal trade processes. If there are enough bad harvests in a few major producing countries, as in 2010-2011 with the global wheat harvest, food prices can spike dramatically around the world. Under the right conditions, these commodity shocks, wherein prices skyrocket out of reach of poor citizens, can set off major social turmoil resulting in political upheaval.[13]

Yet despite the justified concerns about threats arising from scarcities, multilateral cooperation can help avoid resource-driven conflict. While some analysts worry that access to food and water resources will become as conflict-ridden as access to the world's oil reserves has been in the past, others counter that natural resource constraints will lead to greater cooperation between states instead of more conflict. Historically, these analysts assert, transboundary resource disputes have not only often been settled through bargaining, but have also been used to set precedents for greater cooperation between hostile states. Israel and Jordan, for example, began a long-term series of "picnic table talks" in the 1950s to cooperate in Jordan River water management, despite the fact that the two countries were legally at war with one another until 1994.[14]

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11 This section from Philip Andrews-Speed et al., *The Global Resource Nexus: The Struggles for Land, Energy, Food, Water, and Minerals* (Washington: Transatlantic Academy, 2012), pp. 43-64; ODNI 2012, pp. iii-iv.

12 Oregon State University's Transboundary Freshwater Dispute Database is an outstanding source for examination of international water disputes and agreements: http://www.transboundarywaters.orst.edu/database/DatabaseIntro.html.

13 For an example of how this occurred in the Middle East in 2010-2011, see Troy Sternberg, "Chinese Drought, Wheat, and the Egyptian Uprising: How a Localized Hazard Became Globalized," in Caitlin E. Werrell and Francesco Femia, eds., *The Arab Spring and Climate Change: A Climate and Security Correlations Series* (Washington: Center for American Progress and Stimson Center, 2013), pp. 7-14.

14 A good summary of this water-for-peace argument is provided by Aaron Wolf, Annika Kramer, Alexander Carius, and Geoffrey Dabelko, "Viewpoint: Peace in the Pipeline," BBC News, February 13, 2009, http://news.bbc.co.uk/2/hi/science/nature/7886646.stm.

*Source*: African Development Bank.

For countries in Europe, the Americas, and Africa, therefore, the key challenge is to construct systems that build the political and technical capacity to understand, monitor, and address potential nexus-related problems before they begin to decay national and/or transnational stability. Unfortunately, while awareness of and interest in nexus linkages is growing, the institutional structures that will be required to accomplish these tasks are largely absent, often at national levels and almost always on regional and global scales.[15]

The transatlantic arena, firmly centered in the North Atlantic during the twentieth century, is rapidly becoming an ever more dynamic and crowded neighborhood. Historically, the United States and Europe dominated the region, but the twenty-first century is bringing a rebalancing of relations across the Atlantic and a transformation of the basin into a key arena of global cooperation. Closer examination of the nexus can help lay the groundwork for mobilizing the transatlantic community around a common vision. Grounds already exist for broad cooperation on natural resource issues, as the countries surrounding the Atlantic have extensive trading links in food, energy, and fresh water (indirectly, through trade in "virtual water," as discussed below). The International Energy Agency once argued that meeting the natural resource challenge given a changing climate would require "unprecedented cooperation between the developed and developing nations, and between industry and government."[16] Indeed, solving nexus-related challenges necessitates sustained, deep, and creative partnerships among and between government, industry, and civil society.

Morocco is especially well-positioned to serve as a hub for such an examination. As the preamble of the country's Constitution reads, Morocco is "forged by the convergence of its Arab-Islamic, Amazigh, and Saharan-Hassani roots and nourished by its African, Andalusian, Hebrew, and Mediterranean components." Indeed, Morocco's diverse heritage, its commercial and scientific strengths, and rich natural endowment—especially when combined with the country's political stability and reformist national agenda,[17] and its unique geographic position on the shores of the Mediterranean and the Atlantic—make the country a natural partner for such an endeavor.

15 Marianne Beisheim, "The Water, Energy & Food Security Nexus. How to Govern Complex Risks to Sustainable Supply?" *SWP Comments* 32 (Berlin: German Institute for International and Security Affairs, September 2013), pp. 1-8.

16 Quotation in Richard L. Lawson, John R. Lyman, and Erica R. McCarthy, *A 21st Century Marshall Plan for Energy, Water and Agriculture in Developing Countries* (Washington, DC: Atlantic Council, September 2008), p. 1.

17 J. Peter Pham, "Morocco's Momentum," *Journal of International Security Affairs* 22 (Spring 2012), pp. 13-20.

## III. Africa and the Nexus

While the nexus affects all the world's regions, Africa's situation is unique. On the one hand, the continent has enormous natural bounty—including generous land, water, and energy endowments. Yet on the other hand, many Africans suffer from food, water, and energy insecurity, meaning they do not have reliable access to these goods in sufficient quantities to meet their needs.

Both conditions are ripe for change. Rising demand for food, water, and energy will almost certainly mean that African production of all three goods will rise. This rising demand is an African story as well as a global one. Africa has a rapidly growing population (more than 1.5 billion people by 2035) and the highest rate of urbanization on Earth (box 1), both of which are driving demand. Additionally, a number of African countries have vibrant economies that have been diversifying rapidly and are poised for rapid growth. African countries thus have an opportunity to translate demand for food, water, and energy into economic and social development.[18]

Significant hurdles must be cleared, however, before rising resource demand can be translated into best-case prosperity for Africa. Some of these hurdles are explored in the following sections. The largest hurdles may very well be the ways in which climate change will impact the food-water-energy nexus. As shown in figure 3, Africa has numerous agro-ecological zones. Climate change is likely to impact Africa more than other regions because it will make Africa's many semi-arid and arid regions drier, reduce surface water availability, make already-inconsistent rainfall even more so, make an already-warm continent warmer (crops and other plants are already at the higher end of their temperature tolerances in many places), and make it harder to squeeze productivity out of Africa's generally poor soils.[19]

Water is indispensable for primary production (food and energy production, mining), secondary production (manufacturing), and direct human use (drinking water and sanitation). As the large green and blue swathes in figure 1 suggest, Africa has significant water resources, enough to meet food and energy production needs in many places. Unfortunately, these water resources

18 An optimistic take on Africa's prospects is provided in Jasper Grosskurth, *Futures of Technology in Africa* (The Hague: STT Netherlands, Study Center for Technology Trends, 2010), chapter 1.

19 Ramasamy Selvaraju and Michele Bernardi, "Climate Change Impacts on Agriculture in Africa: Current Assessments and the Way Forward," *Nature & Faune* 25, p. 1 (2010), pp. 29-30; Jakkie Cilliers, Barry Hughes, and Jonathan Moyer, *African Futures 2050: The Next Forty Years* (Pretoria: Institute for Security Studies and Pardee Center for International Futures, 2011), pp. 40-42.

### Box 1. Nexus Case Study: Africa's Cities

It is commonplace to think of Africa as a continent dominated by rural and village life, but the reality is quite different. Africa has an extensive network of large, intermediate, and small cities, with concentrations along the Nile River, the Mediterranean basin, in southern and western Africa, and elsewhere (figure 1). While Africa's population remains mostly rural, Africa is the fastest urbanizing region on earth. Today, only 40 percent of Africa's population lives in cities, but by mid-century around 60 percent will do so. The number of urbanites in Africa will triple from around 400 million today to 1.25 billion by 2050 (figure 2). As elsewhere in the world, Africa's rural populations are either "pulled" into cities by opportunities to be found there (education, services, employment) or "pushed" into them by poor conditions in rural areas.

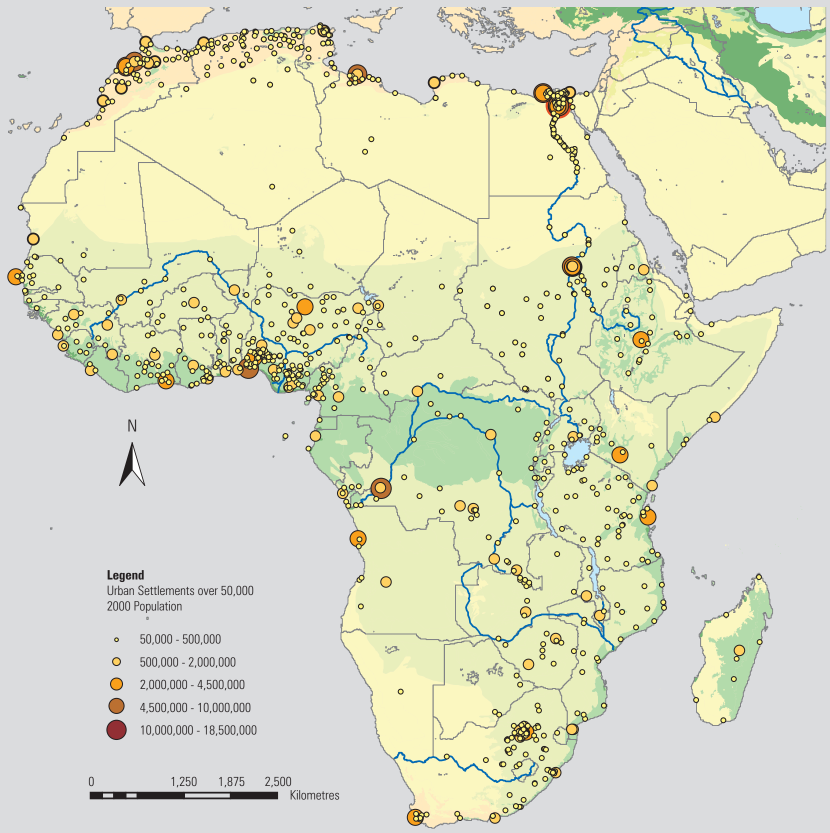
Africa's urban-demographic shift has significant consequences with both positive and negative implications. Enormous quantities of food, water, energy, and other resources will be required to adequately feed, power, provide sanitation to, house, and otherwise service Africa's 1.25 billion urbanites in 2050. Generally speaking, Africa's cities are nowhere close to doing so now. They face problems ranging from large-scale slum formation (perhaps two-thirds of Africa's urban dwellers live in informal settlements) and spatial and economic segregation to poor infrastructure and services. Most Africans who live in cities do not have adequate access to potable water or sewage, nor do they have enough electricity. Moreover, they have to buy food at the market and most often cannot resort to subsistence farming when times are tough, as people can in rural areas. Concentrated poverty in cities means that spikes in the prices of basic commodities—especially food—cause swift social and political reactions.

Yet despite these problems, African cities are and can become powerful assets. Compared with rural areas, cities provide more economic and social opportunities at a fraction of the investment cost in infrastructure and services, owing to the scaling benefits of higher density levels. In the African case, even though many cities function poorly, human development indexes suggest that more urbanized countries fare better than less urbanized ones. If Africa's cities were to function better, the prospects for the continent's future would be even brighter. Greater urban wealth, to name just one example pertinent to the food-water-energy nexus, would induce higher demand for foodstuffs from adjacent peri-urban and rural areas. Urban development would thereby contribute to the maturation of Africa's agricultural sector, in turn making a positive contribution to both rural development and bolstering food production. Doing so will require improved infrastructure to better link African cities more closely to one other and to the rural communities that will provide critical resources.

*(Box continued on p. 7)*

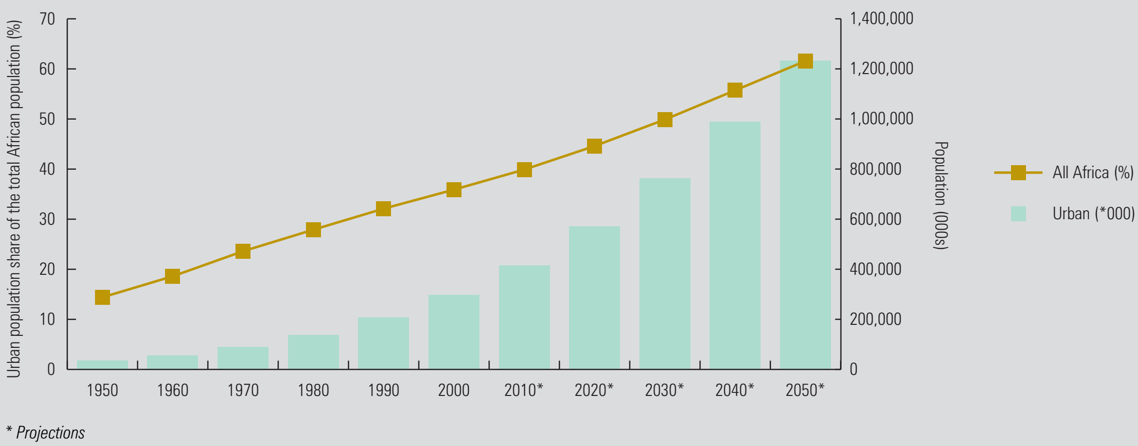
## Box 1 (continued). Nexus Case Study: Africa's Cities

### Figure 1. Cities over 50,000 Population In Africa, 2000




*Source*: UN-HABITAT 2010, p. 62.

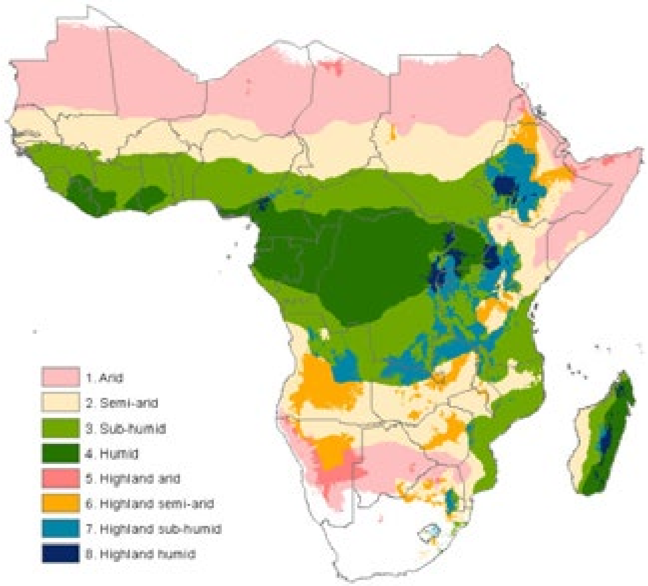
### Figure 2. Urban Population Trend in Africa, 1950-2050




*Source*: UN-HABITAT 2010, p. 1.

*Source*: United Nations Human Settlements Program, *The State of African Cities 2010: Governance, Inequality and Urban Land Markets* (Nairobi: United Nations Human Settlements Program, 2010), pp. 1-3, pp. 19-20, p. 56; United Nations Human Settlements Program, *The Challenge of Slums: Global Report on Human Settlements 2003* (Nairobi: United Nations Human Settlements Program, 2003), pp. 25-28; Caspar van Vark, "Food Security: An Urban Issue," *Guardian*, (December 17, 2013), http://www.theguardian.com/global-development-professionals-network/2013/dec/17/africa-peri-urban-food-security; The World Bank, *Harnessing Urbanization to End Poverty and Boost Prosperity in Africa: An Action Agenda for Transformation* (Washington: The World Bank, 2013), pp. 1-6, pp. 19-24.

Figure 3. Agro-Ecological Zones In Sub-Saharan Africa




*Source*: International Potash Institute.

are unevenly distributed, both across space and over seasonal cycles. The northern and southern regions of Africa are particularly dry, although groundwater resources also exist across these regions.

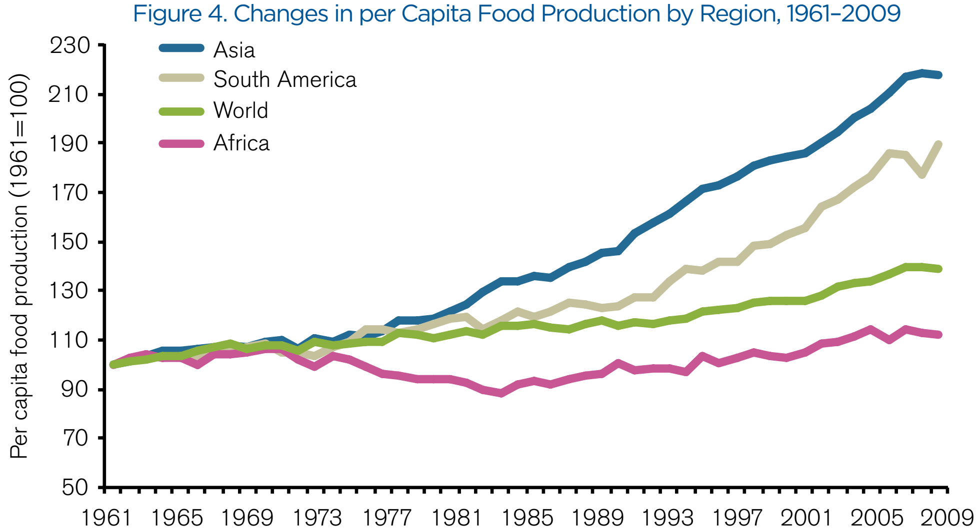
African food production is dominated by the continent's low yields, with some exceptions. Although yields can vary significantly by crop and country, African yields have fallen well behind other regions. At the beginning of this century, African grain yields were between one-third and one-half the world average.[20] A combination of low agricultural commercialization levels, low use of inputs such as fertilizer and machinery, an overreliance on rainfall, poor storage, high transportation costs, generally poor soils, and smallholder farmers' lack of access to finance all contribute to this outcome. On a per capita basis, African food production has been in stasis for a half century (figure 4).

Low yields have dampened Africa's full development until now, but at the same time this "yield gap" between Africa and the rest of the world is also reason for optimism about the continent's future. Raising African yields to global production standards might double or triple African grain output, and would go a long way toward feeding the continent and the world. Moreover, it would provide a tremendous economic boost for African countries. Many believe that an "African Green Revolution" is a global development imperative; the idea is to improve upon the Green Revolution through the modernization of Africa's agricultural sector. Starting in the 1960s, international effort focused on raising crop yields in the developing world through new high-yield seed varieties, increased fertilizer and irrigation, and greater mechanization. This effort—the Green Revolution—did increase yields, sometimes dramatically, in Asia and Latin America. African yields, however, did not rise much, partly because Africa was land-rich (giving farmers little incentive to intensify production), and partly because the narrow set of Green Revolution seeds were not appropriate for Africa's heterogeneous agroecology and crop mix. An African Green Revolution would build upon lessons from elsewhere, emphasizing the same mix of increased inputs and high technology while paying closer attention to the needs of smallholder farmers, Africa's varied agroecology, and myriad linkages to water and energy.[21]

20 Alliance for a Green Revolution in Africa (AGRA), *Africa Agriculture Status Report: Focus on Staple Crops* (Nairobi: Alliance for a Green Revolution in Africa, 2013), p. 21.

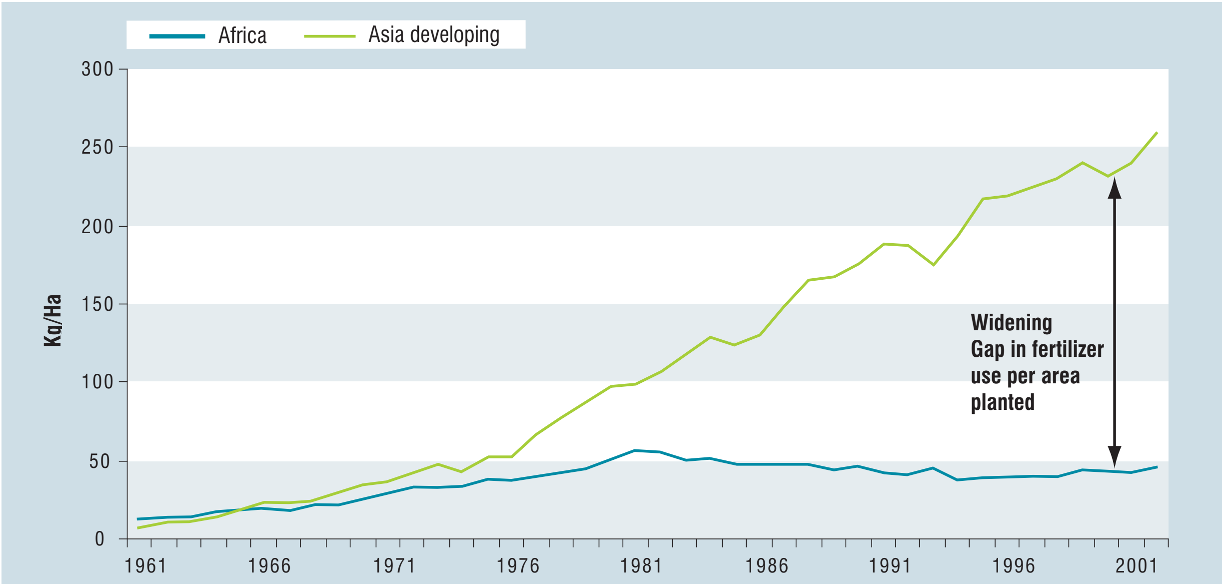
21 Salif Diop, "Water Resources Management and Sectoral Analysis in Africa: Challenges, Constraints and Opportunities for Sustainable Development," *Whyddah: Information and Policy Magazine of the African Academy of Sciences 17, 3* (September 2013), pp. 3-4; Acha Leke, Jens Riese, and Sunil Sanghvi, "Sizing Africa's Agricultural Opportunity," *McKinsey Quarterly* (April 2011), pp. 3-4; Prabhu L. Pingali, "Green Revolution: Impacts, Limits, and the Path Ahead," *PNAS: Proceedings of the National Academies of Science* 109, 31 (July 31, 2012), pp. 12302-12308.

Figure 4. Changes in per Capita Food Production by Region, 1961–2009



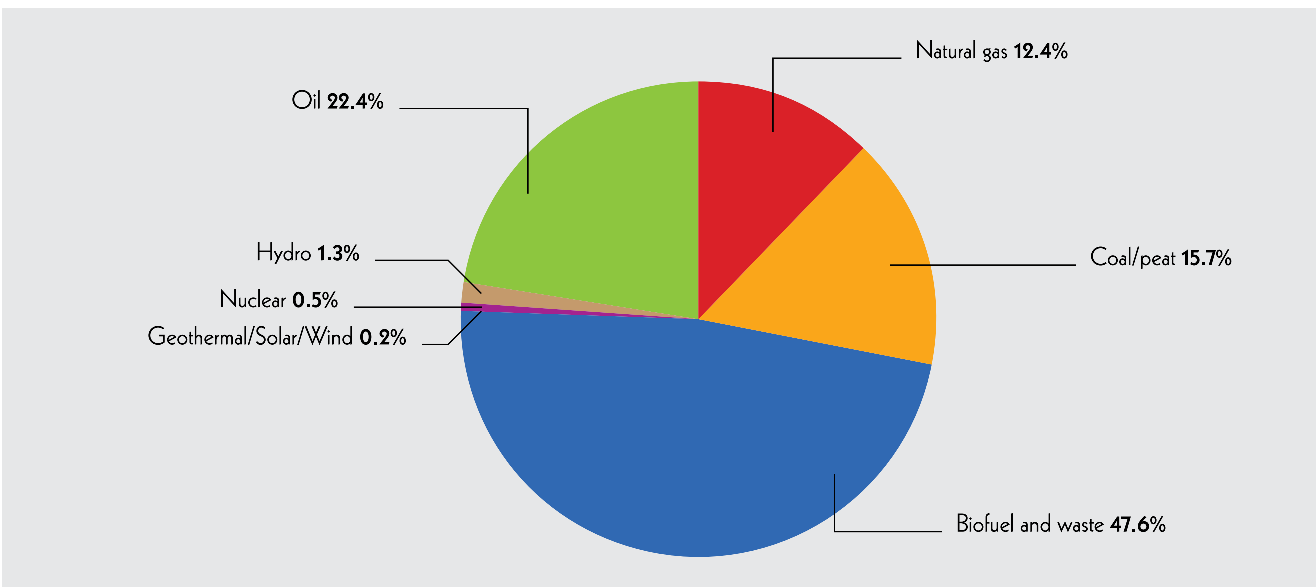

*Source:* Lee et al. 2012, figure 3.6, p. 47.

Figure 5. Fertilizer Consumption in Africa And Asia (Kg/Ha of Cereals)




*Source:* UNCTAD 2010, Figure 18, p. 79.

Figure 6. Share of Total Primary Energy Supply in Africa, 2009




*Source:* African Development Bank Group, *African Development Report 2012: Towards Green Growth in Africa* (2012), p. 71.

Successful modernization of Africa's agricultural sector, if accomplished in twain with social and ecological goals, would provide a tremendous boost to food production, allowing Africa to become a breadbasket for itself and the broader Atlantic community. Fertilizer use provides a narrow but important illustration. Farmers in sub-Saharan Africa apply about a tenth of the amount of inorganic fertilizer as do farmers in the rich world, about a fifth of that of South Asian farmers, and less than a third of that of Latin American farmers. Since the onset of the Green Revolution in the 1960s, Africa has been losing productive ground to Asia in great part because of low fertilizer usage (figure 5). There are several important reasons why African farmers use so little fertilizer, including low smallholding farmer incomes, inadequate rural infrastructure, high fertilizer prices in Africa relative to the rest of the world, and governments' abandonment of fertilizer subsidies over the past decades.[22] While these obstacles are significant, they should not be viewed as impossible to overcome, especially given the rich returns (higher crop yields) that would result from increasing fertilizer application above such a low baseline.

22 United Nations Conference on Trade and Development (UNCTAD), *Technology and Innovation Report 2010: Enhancing Food Security Through Science, Technology and Innovation* (New York and Geneva: United Nations, 2010), p. 79.

On the energy side, Africa has extensive and diverse energy resources, including significant fossil fuel reserves (oil, gas, and coal) and renewable resources (hydropower, geothermal, biofuels/biomass, and solar). As shown in figure 6, in 2009 fossil fuels were around 54 percent of Africa's total primary energy supply, but biofuels and biomass accounted for about 48 percent.[23] In Africa as elsewhere, hydropower and coal historically have delivered the cheapest electrical power, although shale gas is now changing that equation in some parts of the world.[24]

As assessed in a 2013 US Energy Information Administration (EIA) report, Africa has diverse energy production and consumption patterns. South Africa and Egypt alone account for almost two-thirds of Africa's total electricity generation. As a major industrial power, South Africa accounts for roughly 40 percent of the continent's total and is one of the most coal-reliant countries on Earth (coal accounted for some 93 percent of its electricity generation in 2010). Likewise, Egypt (22 percent of the continent's total electricity generation) is as dependent on fossil fuels (about 90 percent of its generation), with the rest mostly from hydropower. Both countries plan to diversify their energy mix to nuclear power and renewables.[25]

Fossil fuels likely will remain central to Africa's energy mix going forward. As shown in figure 7, EIA projects that in 2040 coal's share will decline from about 40 percent of total electricity generation in 2010 to roughly a quarter. But electricity generation from natural gas will jump by 40 percent over that timeframe, and African gas consumption in general is forecasted to more than double. Northern, western, and eastern Africa have large gas deposits.[26] Forecasts for Africa's fossil fuel use are consistent with global projections and have important implications for energy, the environment, and climate change.

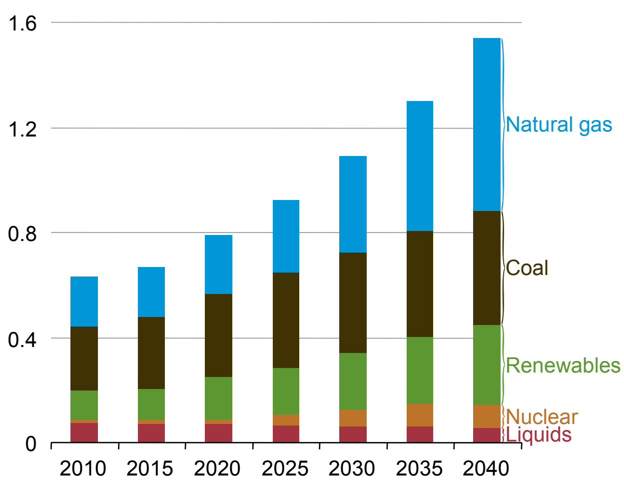
Africa has an extraordinary renewable energy potential, but to date that potential largely has been undeveloped. Hydroelectricity is the most developed renewable resource, generating 16 percent of Africa's electricity. However, that figure represents a small portion of Africa's potential, with some estimating that untapped resources in just three countries (Cameroon, the Republic of Congo, and Ethiopia) could produce about seventeen times as much power (other studies project lower but still multifold increases).[27] Similarly, although Africa has vast solar and wind resources, both sources are underdeveloped nearly everywhere, but with proper investment, both could be dramatically scaled. The International Energy Agency believes that African wind power capacity could increase sixteenfold by 2035, to 16 gigawatts.[28] For its part, the EIA projects solar electricity generation to increase nearly threefold, to 21.1 billion kWh in 2040. Large solar projects have been planned in Morocco ($1 billion of investment planned, with 2,000 megawatts by 2020), South Africa (762 megawatts), and Ghana (155 megawatts).[29]

However, despite Africa's energy riches, the reality is that most Africans face energy poverty. The very large share (48 percent) of African energy supply from biofuels/biomass demonstrates this (biomass refers to organic material, usually collected from the local environment). More than two-thirds of all people living in sub-Saharan Africa have no electricity, constituting a central focal point of the Obama administration's Power Africa initiative.[30] Yet even with such initiatives and the projected long-term growth in energy production, African per capita energy consumption is likely to remain very low relative to the world's wealthiest regions.

Climate change adds a further layer of complexity. Extreme weather (prolonged and more frequent droughts and major floods) as well as increased temperatures will affect the Earth's many ecosystems.[31]

23 African Development Bank, *African Development Report 2012: Towards Green Growth in Africa* (Tunis-Belvedere: African Development Bank Group, 2013), p. 71.
24 On shale, see Robert A. Manning, *The Shale Revolution and the New Geopolitics of Energy* (Washington: Atlantic Council, 2014).
25 US Energy Information Administration, *International Energy Outlook 2013* (Washington: Energy Information Administration, July 2013), pp. 73, 77, 105.

Figure 7. Africa Net Electricity Generation by Fuel 2010-2040 (Tn Kwh)




*Source:* US Energy Information Administration, *International Energy Outlook 2013*, p. 105.

26 Ibid., pp. 48, 53-54, 105.
27 International Energy Agency, *World Energy Outlook 2012* (Paris: OECD/IEA, 2012), p. 226
28 International Energy Agency 2012, p. 227; African Development Bank 2013, p. 84.
29 US Energy Information Administration 2013, p. 105.
30 White House, Office of the Press Secretary, "Fact Sheet: Power Africa" (Washington: June 30, 2013), http://www.whitehouse.gov/the-press-office/2013/06/30/fact-sheet-power-africa.
31 See Atlantic Council and Mihaela Carstei, "Climate Change and Extreme Weather: Vulnerability Assessment of the US Energy Sector," event summary, July 24-25, 2012, http://www.atlanticcouncil.org/events/past-events/climate-change-and-extreme-weather-vulnerability-assessment-of-the-us-energy-sector.

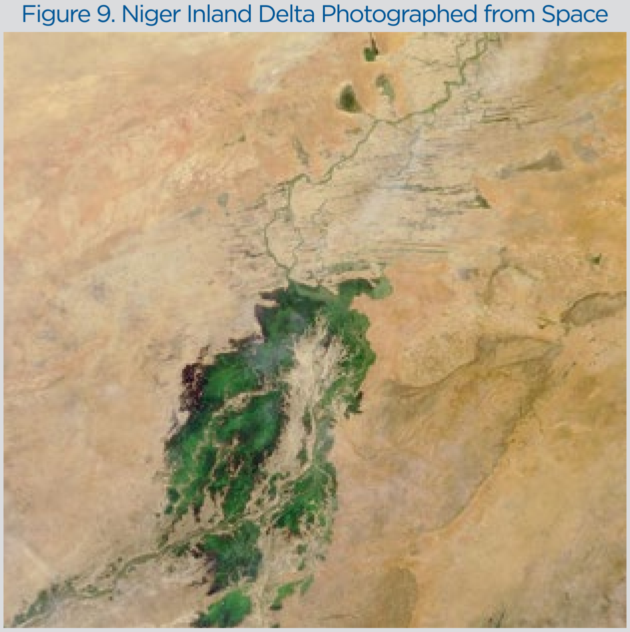
## Box 2. Nexus Case Study: Niger River Basin

The Niger River Basin provides an illustration of the interdependence between food, water, and energy security in Africa. The Niger River is western Africa's primary river and, at 4,200 kilometers, is the third longest in Africa after the Nile and Congo. It passes through five countries (Guinea, Mali, Niger, Benin, Nigeria), and several more share its drainage basin (figure 8).

Figure 8. Niger River Basin


*Source:* "Niger River Basin Map," Mappery, http://www.mappery.com/map-of/Niger-river-basin-Map.

Figure 9. Niger Inland Delta Photographed from Space



*Source:* NASA Jet Propulsion Laboratory, http://www.jpl.nasa.gov/spaceimages/images/wallpaper/PIA03429-1024x768.jpg.

Intermittency in water supply is the basin's dominant characteristic. Heavy rainfall at the river's source in the Guinea Highlands and southwestern Mali, and at the river's mouth in Nigeria, contrast with extreme aridity along the interior stretches. Rainfall intermittency creates a boom-and-bust water cycle along the entire river. Seasonal flooding, for instance, creates the Niger Inland Delta, located in Mali, a region of marshlands surrounded by a massive arid landscape (figure 9). Millions of people in Mali depend on this delta for their livelihoods, primarily in agriculture and fishing. The delta is also a critical habitat for migratory birds. Additionally, the entire basin has a history of decadal-long periods of wetter or drier conditions. In the past, long dry periods have created regional food crises. Although global climate models do not agree on whether the region will become more or less arid in the coming decades, scientists do agree that climate change is likely to increase this variability.

Management of the river basin's water is difficult owing to its transboundary nature and ecological complexity. Three major management challenges exist. The first is a demand-side problem. Today, some one hundred million people in the basin depend on its water for sustenance. As population growth is high (around 3 percent per year), regional demand for food, energy, and drinking water will grow rapidly in coming years. The basin is the primary water source for food and energy production, so competition for water between upstream and downstream users and between sectors is already intense (e.g., hydroelectric production versus irrigation versus fisheries). These demand-side pressures will only increase in the future. The second challenge is a supply-side problem. The basin's water supply is constrained under the best circumstances. Greater climate-driven rainfall variation plus higher temperatures will further stress supplies, especially along the large middle stretches of the basin already under severe pressure. The third challenge consists of the difficult management issues involved in producing enough food in a context so constrained by critical inputs. Management structures are in place regarding water: a regional water body (the Niger Basin Authority); national water management plans; and local communities' long experience with intermittent supply management. Strengthening these structures plus harmonizing water management policies at regional, national, and local levels will be essential strategies for securing the basin's future. Regarding other inputs, Morocco recently announced that it would finance a production unit in Mali for phosphate fertilizer that will generate more than a million tons a year exclusively for the African market, with much of that amount targeted for Mali and other countries in the Niger River region.

*Source*: Marisa Goulden and Roger Few, *Climate Change, Water and Conflict in the Niger River Basin* (London: International Alert and University of East Anglia, 2011); International Union for Conservation of Nature and the International Water Association, Nexus Dialogue on Water Infrastructure Solutions, *Africa Nexus Dialogue Workshop: Workshop Report* (Nairobi: International Union for Conservation of Nature and the International Water Association, 2013), pp. 10-11; Eddy Wymenga, Leo Zwarts, and Bakary Kone, *Water Sharing in the Upper Niger Basin. A&W-report 1739* (Bamako/Sévaré, Mali: Wetlands International; Feanwâlden, Netherlands: Altenburg & Wymenga, 2012); "Entire Output of New Moroccan Fertilizer Plant to Be Destined to Africa," *North Africa Post* (February 20, 2014).

Africa's soils, forests, rivers, and lakes are not immune and all will be impacted. Altered precipitation patterns are forecasted to change local and regional conditions, for instance reduced rainfall is expected to make the southern part of Africa even drier.[32] Increased competition for resources, with water as a linchpin, is a predictable outcome (box 2).

## A. Food and Water Linkages

A major part of the explanation for Africa's low yields is the agricultural sector's heavy reliance on irregular rainfall patterns and low reliance on irrigation. Africa is troubled by greater seasonal rainfall variability than other continents, which means wide annual swings in agricultural output. Climate change will add to this variability, affecting river flows and soil moisture levels.[33] Irrigation can hedge against such variability, but only about 7 percent of agricultural land in Africa is irrigated (in sub-Saharan Africa, about 6 percent). More than 90 percent of agricultural lands in Africa depend on rainfall for production.[34] As water is an indispensable input for food production, irrigated land tends to be much more productive than non-irrigated land, particularly in semi-arid and arid regions and in regions with unreliable rainfall.

Two major difficulties are involved in increasing African irrigation. First, expanding irrigation to millions of smallholder farmers is a complex and expensive proposition. Not only is irrigation infrastructure costly to build and maintain, but productivity gains are moot even after such infrastructure is provided—unless smallholder farmers can translate surplus production into distant market sales. Second, expanding irrigation demands access to stable sources of fresh water supply. As desalination prices are still too high for agricultural application in most places (in Africa and elsewhere), irrigation by definition draws upon limited surface and groundwater resources. Irrigation places a heavy demand on surface water supplies, a problem that becomes acute in arid and semi-arid regions. Lake Chad, for example, was once the sixth largest lake on Earth. Over the past decades, however, it has shrunk by 90 percent, due largely to irrigation withdrawals plus persistent drought.[35] Groundwater is an alternative source, and is particularly important in North Africa. Large groundwater resources that have yet to be discovered and tapped likely exist throughout Africa, but no one is certain how large they are, nor how fast they can be drawn down.

The large-scale acquisition of land by foreign investors is becoming an important dimension of the food-water linkage in Africa. Often referred to by critics as "land grabbing," this trade is a way for major food consumers in one country (say, a national government or a large firm) to insulate themselves from production shortfalls in their home markets. Through the acquisition of large tracts of arable land, consumers in distant markets gain access to the land's production. This bounty is not just in the form of food but also in the water used to grow or raise the exported crops and farm animals, as well as the water contained in the exported plants' or animals' tissues. Through this "virtual water" trading, consumers in one country gain access to water resources in distant regions. Freshwater in the home country, whether from rainwater, surface water, or groundwater, is removed but not restored through this mechanism.[36]

While there is much disagreement as to the exact size of large-scale land acquisition, nearly every observer agrees that the global scale of the phenomenon is massive. Africa possesses a disproportionate amount of the land acquired through such large transactions. One study, for instance, estimated that between 2000 and 2010, some 203 million hectares of land deals were negotiated globally (an area about eight times the size of Great Britain), with 134 million of these in sub-Saharan Africa alone. Another estimated that in 2008-2009, 46 million hectares of land were acquired, with two-thirds in sub-Saharan Africa. Food crops, cash crops, and biofuels all drove these deals.[37]

## B. Energy and Food Linkages

As is true of water-food linkage, energy and food are linked through bi-directional pathways. Energy inputs are indispensable at every aspect of the food chain, and thus greater energy inputs usually translate into more food output, processing, shipment, and consumption. Energy inputs are necessary for on-farm mechanization (tractors, etc.), water pumping (for irrigation), off-farm transport and processing, storage (refrigeration), and cooking. A significant share of energy inputs to food production and distribution is indirect, as when rural roads are built to facilitate farm-to-market exchange.

The energy-food linkage in Africa is dominated by the gap between Africa's energy endowment and the amount of the energy used for food production. Like the irrigation issue, this gap between energy availability and application is a major reason why African food yields lag behind other world regions. The continent possesses an enormous energy endowment consisting

32 Hugh Turral, Jacob Burke, and Jean-Marc Faurès, *FAO Water Reports 36. Climate Change, Water and Food Security* (Rome: FAO, 2008), pp. 26, 47, 59.
33 Richard G. Taylor, Antonis D. Koussis, and Callist Tindimugaya, "Groundwater and Climate in Africa—a Review," *Hydrological Sciences Journal* 54, 4 (August 2009), p. 659.
34 AGRA 2013, 76; Claudia Ringler, Zhenya Karelina, and Rajul Pandya-Lorch, *Emerging Country Strategies for Improving Food Security: Linkages and Trade-Offs for Water and Energy Security* (Bonn: International Food Policy Research Institute, 2011), unpaginated.
35 H. Gao et al. (2011), "On the Causes of the Shrinking of Lake Chad," *Environmental Research Letters* 6, 1 (2011), pp. 1-4.

36 Bizikova 2013, p. 1; Rulli, Saviori, and D'Odorico 2013, p. 892.
37 Studies summarized in Lee et al. 2012, p. 106.

*Source*: Arne Hoel/World Bank.

of every type of fossil fuel and renewable energy source. Only a small share of this energy endowment is used for food production, however, with some important exceptions. Most rural Africans in sub-Saharan Africa rely on biomass to meet their energy needs, reflecting both their own energy poverty and the underdeveloped energy status of the African agricultural sector. There are multiple explanations for this state of affairs, including the fact that rural areas tend to be relegated to secondary status in national energy assessment and planning. Rural areas have a small energy footprint compared with other sectors (manufacturing, etc.) and thus receive lower priority.[38] But basic economics provides the simplest explanation. Energy is expensive, and Africa's smallholder farmers often cannot afford high energy inputs. Inorganic fertilizer production, for instance, is energy intensive and thus expensive, and is a reason why African farmers' fertilizer usage is low.[39]

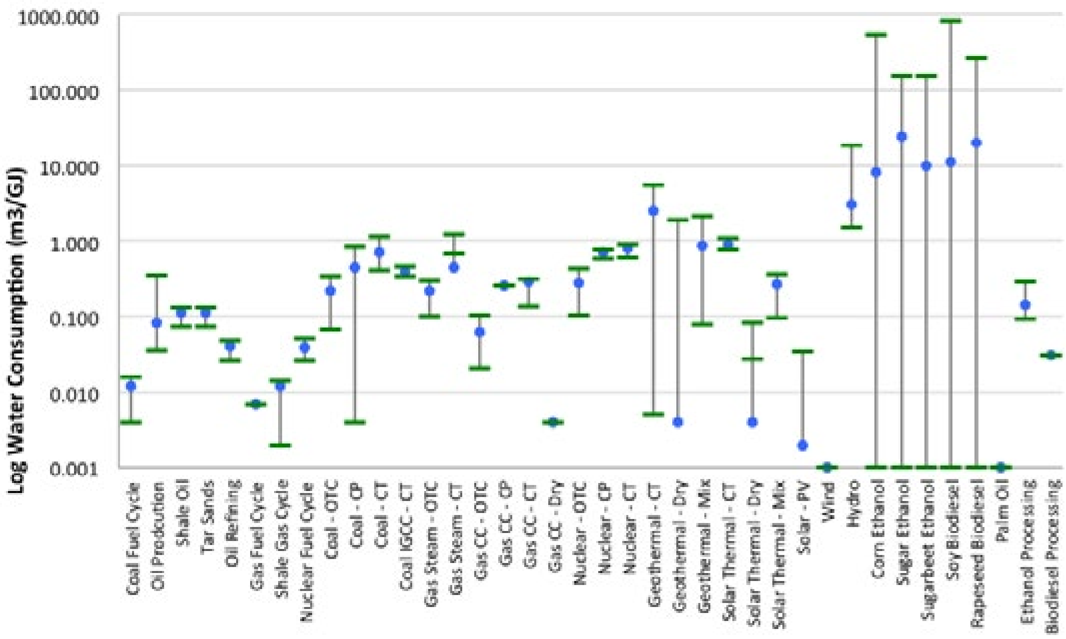
Lack of energy access is a major reason why African agricultural production and commercialization lag behind the rest of the world. Energy poverty is a reality for many African farmers, smallholders in particular, providing an obstacle to closing Africa's yield gap. Energy poverty prevents movement from a traditional biomass-based agricultural sector to one based on diversified sources. Greater energy inputs are needed at every stage of the food chain process, from on-farm production through off-farm processing through transport and end use.

Conversely, food can also be an input for energy through the production of biofuels such as ethanol. The energy-to-food pathway is not the only way in which the two goods are linked. An important food-to-energy pathway also exists. As with the virtual water story, the food-to-energy pathway includes the use of arable land for agricultural production. Food becomes energy when land that might be used to produce foodstuffs is instead used for biofuel production. The energy derived from these biofuels is then used for non-food purposes (powering vehicles, etc.). In essence, the land that otherwise might be used for food production or for other purposes (e.g., forest) is instead diverted into energy production.

This food-to-energy conversion process forms an important part of large-scale global land acquisition. Corn, sugarcane, jatropha, and palm oil are now used to produce ethanol and biodiesel on large scales in different parts of the world, including Africa. As is true with virtual water trading, investors are attracted to places with the right mix of land, water, and agroecological assets for biofuel production. Foreign

38 Environment and Natural Resources Service (SDRN), "Energy and Food Security in Africa" (FAO Research, Extension and Training Division, December 18, 2013), http://www.fao.org/sd/fsdirect/fbdirect/FSE002.htm.
39 UNCTAD 2010, p. 79.

Figure 10. Water Consumption Coefficients for Energy Technologies




*Source:* Edward Spang, *A Thirst for Power: A Global Analysis of Water Consumption for Energy Production* (Davis, CA: Center for Water-Energy Efficiency, University of California, Davis), http://www.globalwaterforum.org/wp-content/uploads/2012/10/Spang-Figure-1.png.

investors have taken great interest in the potential for the development of African biofuels, with agroecological conditions in parts of Africa similar to those found in Brazilian and Southeast Asian biofuel-production areas. Both the Brazilian government and Brazilian firms such as the Petrobras energy company, for example, have been investing in and otherwise supporting African biofuel development. To illustrate the genuinely global nature of large land deals, much of Brazil's business interest in African biofuels is based on the desire to produce biofuel energy in Africa and then export it to third parties abroad, in particular to markets in Europe and Japan.[40]

## C. Water and Energy Linkages

Water and energy systems are joined in numerous ways. Reliable access to both resources is fundamental: energy is needed to treat water (for drinking and other uses), transport it, and dispose of it, while water is indispensable for energy production.[41] As shown in figure 10, all energy generation requires water, whether for the cooling of thermal power plants or hydropower generation. Energy resource extraction processes, for example coal mining, also need water inputs. Although the water-energy linkage is highly complex, managing it properly is absolutely necessary for social and economic development. Energy-water linkages recently have gotten more attention from researchers and (to a more limited extent) policymakers, driven by increased demand for both resources.[42]

Africa's linked energy and water resources will be strained by the combined effects of population and economic growth, rapid urbanization, and climate variability. As is true of food, Africa will need to increase its output of energy and water resources to meet global sources of demand as well as African. As discussed in the previous section, Africa has roughly half of the world's 1.3 billion people without access to electricity and perhaps a quarter of the 2.6 billion people worldwide who use traditional biomass as a cooking fuel.[43] On the water side, Africa likewise has many of the eight hundred million people globally without clean drinking water and the 2.5 billion people without proper sanitation.[44]

As discussed in the last section, fossil fuels will account for most of the expected global and African increase in energy use over the coming decades. Greater energy production, whether through fossil fuels or other means, will increase demands on fresh water resources. Already, 2.8 billion people around the world live in areas defined as having high water stress, and 1.2 billion live in regions defined as having physical water scarcity. Put bluntly,

40 Paul Isbell, *Energy and the Atlantic: The Shifting Energy Landscape of the Atlantic Basin* (Washington: German Marshall Fund of the United States, 2012), pp. 70-72.
41 Edward Spang, *A Thirst for Power: A Global Analysis of Water Consumption for Energy Production* (Davis: UC Davis Center for Water-Energy Efficiency, 2013), http://128.120.151.3/cwee/wp-content/uploads/2013/10/10-25-2013-ThirstforPower_Final.pdf.
42 Diego J. Rodriguez, Anna Delgado, Pat DeLaquil, and Antonia Sohns, *Water Papers: Thirsty Energy* (Washington: World Bank, June 2013), p. v.
43 International Energy Agency 2012, p. 51
44 Natural Resources Defense Council, *Water Facts: Global Safe Water* (Washington: NRDC, March 2012), http://www.nrdc.org/international/files/safewater.pdf.

*Source*: Lotus Head (licensed under Creative Commons).

the world is likely to face more water scarcity going forward.[45]

Climate change will have a number of unpleasant impacts on the water-energy linkage around the world, including in Africa. Climate change is likely to make dry regions drier, which will mean greater dependency on expensive water delivery systems. Conversely, some areas should have more storms and get wetter, which will mean more flooding. Elevated water temperatures from increased heat will restrict electricity generation (thermal power plants require water below a certain temperature for cooling). There are myriad indirect effects as well. Drought can impede energy transport, such as moving coal by barge along rivers. More frequent heat waves will stress power grids, while increased heat reduces transmission efficiencies. Sea-level rise and storm surges will damage offshore oil and gas platforms.[46]

The upshot is that climate change adds a stressor to an already problematic water-for-energy picture. Climate change's many effects, including higher air and water temperatures, will require more water for energy production at the same time as residential and industrial energy demands are projected to increase. The water pathway is yet another reminder of the need to transition to low-carbon energy sources, but even here the equation is complicated. Hydropower is a low-carbon energy source, but water is the main ingredient in its production. Moreover, the dams' reservoirs evaporate massive amounts of water, especially in arid climates. Of all energy sources, only wind energy and solar photovoltaic energy (solar PV) have low water requirements.[47]

Finally, it should be recalled that water is needed for the extraction of energy sources and, of course, for food production. Neither observation is trivial. Water use is at the center of the debate over the merits and drawbacks of fracking, for example. Both energy and water are central to all crop production, and some crops are used to make energy (biofuels).[48]

The energy sector's enormous use of water has significant consequences for ecosystems. For example, in 2000, water withdrawals in the United States just for thermal power plant cooling was about equal to

45 World Bank, *Rio+20, A Framework for Action for Sustainable Development: Water* (Washington: World Bank Group, May 2012), http://siteresources.worldbank.org/EXTSDNET/Resources/RIO-BRIEF-Water.pdf.
46 US Department of Energy, *US Energy Sector Vulnerabilities to Climate Change and Extreme Weather* (Washington: US Department of Energy, July 2013), pp. i-iii, 1-7.

47 Rodriguez et al. 2013, p. 3; US Department of Energy 2013, pp. i-iii, 1-7. The solar and wind argument does not take into account the water required for production of wind turbines or silicon-based solar PV panels. See Spang 2013.
48 Rodriguez et al. 2013, p. 3.

*Source*: African Development Bank.

agricultural withdrawals.[49] While the energy sector in the US and elsewhere returns most of the water it withdraws (in water parlance, this means that the sector does not "consume" most of the water it "withdraws"), the withdrawal nonetheless impacts regional ecosystems because thermal power plants return water that is warmer than the water they withdrew.[50] However, it is important to point out that the effects on ecosystems depend greatly on the type of energy generation process and the levels of technology employed. Going back to the hydropower example, electricity generation from hydropower does require large quantities of water, but much of that water is released downstream for use by other sectors. In the biofuels case, in contrast, irrigation consumes much of the water (plants absorb a large amount of the water) and only a reduced amount is returned to the local water source. At the local scale, mining and drilling for energy production (for instance, coal mining or shale gas fracking) requires considerable amounts of water and can pollute water sources.[51] In sum, these differences across the energy sector complicate the already complex linkage between energy and water.

The energy-to-water pathway is significant as well, as energy is required for water treatment, transport, and pumping. Water is a heavy substance, hence transporting it over long distances or vertically over mountain ranges requires significant amounts of energy. Speaking generally, water is undervalued around the world and policies rarely reflect the true cost of water provision.[52] For instance, treating water in cities requires much energy, yet city leaders and managers most often do not incorporate energy costs into water pricing schemes.[53]

49 US Department of Energy, *Energy Demands on Water Resources. Report to Congress on the Interdependency of Energy and Water* (Washington: USDOE, December 2006), p. 9.

50 E. D. Williams and J.E. Simmons, *Water in the Energy Industry. An Introduction* (2013), pp. 11-14, 72-73, http://www.bp.com/content/dam/bp/pdf/sustainability/group-reports/BP-ESC-water-handbook.pdf.

51 United Nations Energy Program, Oko-Institute e.V., and International Energy Agency, *The Bioenergy and Water Nexus* (2011), http://www.unep.org/ pdf/Water_Nexus.pdf; Diana Glassman, Michele Wucker, Tanushree Isaacman, and Corinne Champilou, *The Water-Energy Nexus: Adding Water to the Energy Agenda. A World Policy Paper* (March 2011), pp. 11-12, http://www.worldpolicy.org/sites/default/files/policy_papers/THE%20WATER-ENERGY%20NEXUS_0.pdf.

52 UNESCO, "United Nations Report Warns Rising Energy Demand Will Stress Fresh Water Resources" (Paris: UNESCO Press, March 21, 2014), http://www.unesco.org/new/en/natural-sciences/environment/water/wwap/display-single-news/news/united_nations_report_warns_rising_energy_demand_will_stress_fresh_water_resources/#.VIslVDHF8nV.

53 Asian Development Bank, *Thinking about Water Differently: Managing the Water–Food–Energy Nexus* (Mandaluyong City, Philippines: Asian Development Bank, 2013), p. 15. On municipal water and energy in the United States, see Blythe Lyons, *Impact of Municipal, Industrial, and Commercial Water Needs on the Energy Water Nexus: Challenges, Solutions, and Recommendations* (Atlantic Council, 2012), http://www.atlanticcouncil.org/images/files/publication_pdfs/403/ee121101waterneeds.pdf.

# IV. Core Nexus Principles

We identify five core principles to guide the planning, production, regulation, and use of the food, water, and energy nexus, and for the ecosystems that sustain the nexus.

## A. Stress Integration

An underlying ecological principle is that every resource—including the core resources of food, water, and energy—requires other resources in order to be produced, processed, shipped, consumed, and disposed. Failing to engage in integrated food-water-energy planning and management therefore increases the odds that a country and its citizens will suffer negative consequences from ignoring these linkages. Consequences include economic inefficiencies, greater exposure to external resource shocks, and the possibility that scarcities of one of the nexus elements will negatively impact the others.[54] While this idea is simple in concept, integration is much more difficult in practice. Yet despite the complexities involved, researchers are building models that integrate resource assessment into climate scenarios. Policymakers can use these models to understand the impacts of different pathways.[55] On-the-ground policy integration is also underway, with novel approaches to integrating nexus thinking into programs at the core (box 3).

The nexus literature emphasizes that integrated, cross-sectoral, and multi-stakeholder planning and management is the best way to enable more sustainable and prosperous outcomes. Governments should create mechanisms built upon a solid understanding of the food-water-energy nexus. Multi-stakeholder coalitions from the public and private sectors and from civil society should be involved from the beginning. Such coalitions are key to breaking down administrative boundaries within bureaucracies and for creating buy-in for plans and policies. High-level public commissions and task forces, established by the head of state, are one means of doing so (see Malawi case study, box 4).

54 This section is based on Office of the Director of National Intelligence 2012, pp. 6-7; Bonn 2011 Conference, *Bonn 2011 Conference: The Water, Energy and Food Security Nexus—Solutions for a Green Economy. Policy Recommendations*, pp. 7-8; World Economic Forum, *Global Risks 2011, Sixth Edition* (Geneva: World Economic Forum, 2011), p. 30.

55 See, for instance, the CLEWS modeling approach (climate, land-use, energy and water strategies): Mark Howells et al., "Integrated Analysis of Climate Change, Land-Use, Energy and Water Strategies," *Nature Climate Change* 3 (July 2013), pp. 621-6, doi:10.1038/nclimate1789.

### Box 3. Policy Integration

Policy integration is required to adequately address challenges within the food-water-energy nexus. Unfortunately, natural resource management often suffers from stovepiped approaches that fail to take nexus interconnections into consideration. Despite the very real complexities involved in understanding the nexus, it is imperative that imaginative, cross-cutting policy approaches be designed and implemented. Failing to do so will result in sub-optimal outcomes, and will increase the risk of catastrophic events.

Examples of innovative nexus policymaking do exist. One is a public-private partnership (PPP) between the US government (USAID and the Overseas Private Investment Corporation), the Swedish and German governments, and Duke Energy. Titled *Powering Agriculture*, this initiative is the third in the USAID "Grand Challenges" series that uses PPPs to explore innovative solutions to the world's biggest development issues. As the title suggests, *Powering Agriculture* is built upon the premise that raising farm incomes requires smallholders to have access to affordable energy resources. The initiative awarded grants for on-the-ground projects that brought affordable energy solutions, especially renewable energy solutions, to small-scale agricultural production in Benin, Senegal, Mozambique, Uganda, Kenya, and other countries in Africa and elsewhere. Several grant recipients focused their efforts on finding affordable energy solutions for powering irrigation systems for smallholder farmers—providing a fine example of how agricultural production, water systems, and energy availability are intertwined.

*Powering Agriculture* is a proverbial drop in the bucket. In December 2013, USAID announced that twelve winners would share project funding of $13 million, a paltry sum given the scale of nexus-related challenges in Africa and around the world. Nonetheless, the project's importance lies in two policy-related demonstration effects. First, the project's design explicitly favors the tearing down of sectoral boundaries (water versus energy versus food) in favor of integrative policy solutions (water and energy and food). Second, the project assumes that building effective, transnational PPPs is an indispensable strategy for solving nexus problems. Indeed, the vast scale of nexus challenges in Africa and around the world virtually requires the adoption of innovative PPPs by the US government and other national governments in the transatlantic arena. Through intelligently constructed partnerships, the US government can service its policy goals through leveraging the extensive resources, skills, technologies, and know-how of private, nonprofit, philanthropic, and community actors.

*Source*: *Powering Agriculture* website, http://www.poweringag.org; Issie Lapowsky, "USAID Grants $13 Million to Innovative Agriculture Startups," Inc.com (December 11, 2013), http://www.inc.com/issie-lapowsky/usaid-powering-agriculture-challenge.html and "USAID Offers $25 Million for Solutions to Global Food Crisis," (November 4, 2013), http://www.inc.com/issie-lapowsky/usaid-asks-entrepreneurs-to-solve-food-crisis.html; Paul Stephens, "Trendy vs. Mundane, Imagination vs. Impact—the Innovation Dilemma," Devex (December 12, 2013), https://www.devex.com/en/news/trendy-vs-mundane-imagination-vs-impact-the/82492.

### Box 4. Nexus Case Study: Malawi

Malawi is a landlocked country in southeastern Africa, with an economy and the majority of its thirteen million citizens heavily dependent on rain-fed agriculture. Maize is the main crop and is grown by 97 percent of farmers. Malawi's rainy season is highly variable, with frequent drought and dry spells. Malawi's smallholder farmers historically have had low access to fertilizer, irrigation systems, hybrid seeds, and other inputs, leading to low yields (in the 1990s and 2000s, maize production averaged around 1.3 metric tons per hectare, in contrast to American rain-fed corn yields of around 10 tons per hectare). Agricultural production has also suffered from nutrient-deficient soils, low commercialization, and high on-farm and post-harvest food losses.

In 2005, these factors combined with an extended dry period to depress agricultural production. Facing a food crisis, the Malawian government created an ambitious, multi-stakeholder, and cross-sectoral growth and development strategy with sustainable agricultural production at its core. This strategy focused on improving yields through subsidizing inputs, in particular improved maize seed and fertilizer, for smallholding farmers. Benefiting in part from improved weather, the fertilizer subsidy program enabled maize production to double in 2006 and nearly triple in 2007. Malawi went from a 43 percent food deficit in 2005 to a 53 percent surplus by 2007. Malawi's experiment became a famous case study and an example of how it might be possible to begin closing Africa's yield gap. Observers later claimed that the southern African country's government had "implemented one of the most ambitious and successful assaults on hunger in the history of the African continent."

While the government's development strategy was a step in the right direction, Malawi's larger challenge is sustaining this improvement. Variable energy and fertilizer prices will likely continue to expose Malawi to external commodity shocks, while climate change will cause more weather variability and higher temperatures. Malawi's challenge is therefore significant, and one faced by numerous other African countries. Malawi will need to further develop and perfect water conservation strategies, increase yields while protecting ecosystems, and find ways to buffer maize production against higher temperatures and greater rainfall variability.

*Source*: G. Denning et al., "Input Subsidies to Improve Smallholder Maize Productivity in Malawi: Toward an African Green Revolution," *PLoS Biology* 7, 1, 0002-0010 (January 2009), quotation, p. 0002; Government of Malawi, *Malawi Growth and Development Strategy 2006-2011* (October 2006); Juma, 2011, pp. 1-4; Jonathan D. Moyer and Eric Firnhaber, *Cultivating the Future: Exploring the Potential and Impact of a Green Revolution in Africa* (Pretoria: Institute for Security Studies and Pardee Center for International Futures, 2012), p. 3; Ringler, Karelina, and Pandya-Lorch, 2011.

Stakeholders should be directed to assess current nexus conditions, build mechanisms to enable policymakers and other actors to react to changing conditions in real time, and anticipate future conditions. It is imperative to incorporate both spatial and temporal perspectives into this work. Building coalitions around entire ecosystems, in particular transboundary ecosystems, can act as a framing device for nexus thinking. Ecosystem-based framing also enables stakeholders to create mechanisms for sharing resources and avoiding conflict over them. Similarly, long-term thinking and planning acts as a way to engage stakeholders in the consequences of climate change on nexus resources.

## B. Maximize Efficiency

A recent Chatham House report on global resource use made the bold claim that the "seminal economic and environmental challenge" facing humankind in the coming decades is the improvement of resource productivity.[56] As this statement makes clear, maximizing resource efficiency must become a central strategy if the clash between rising demand for natural resources and restricted supply is to be managed. Moving to a more sustainable economy depends on dramatic improvements in resource productivity, defined as output per unit input (e.g., calories of food produced per liter of water). Huge economic, social, and environmental opportunities are involved in shifting Africa's and the world's economies to greater resource efficiency. More resource-efficient economies are less exposed to global commodity shocks, for instance, because they are less dependent on imported resources for economic output. Over the past several decades, both Japan and Germany, for example, have crafted policies sufficient to make them roughly a third more energy efficient than the United States.[57]

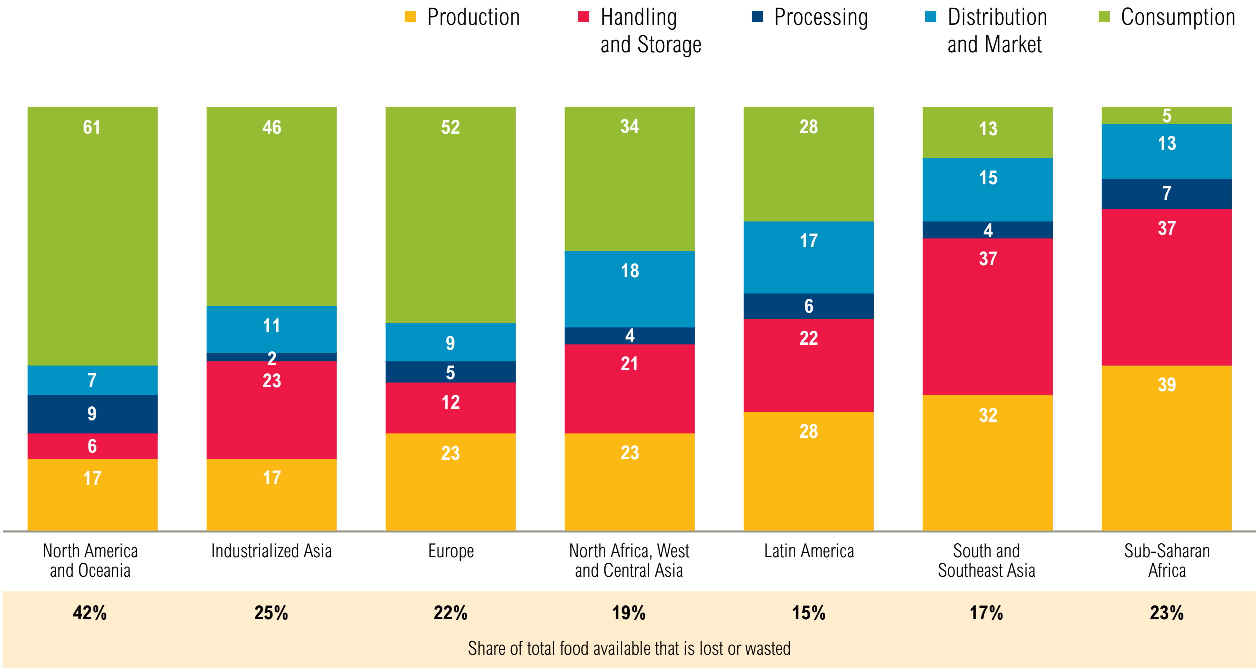
A resource efficiency emphasis finds waste in everything and roots it out to the maximum extent possible, and there are numerous strategies for doing so. Pricing resources to encourage efficiency gains is one. While important social goals can be involved in keeping some resource prices artificially low, one downside to artificially low prices is that they discourage the efficient use of resources. Economists regard the price of water, for instance, as being too low nearly everywhere.[58] Removing waste along supply chains is a second strategy. Here, governments, firms, and other stakeholders collaborate to identify, understand, and remove waste along these chains. In the African food context, understanding where food is lost and wasted, from

56 Lee et al. 2012, p. 2.

57 Hoff 2011, 14; Lee et al. 2012, 113.

58 A caveat is that, without proper oversight and governance, the privatization of water resources as a market-based pricing strategy can threaten established local water usage norms. See *Office of the Director of National Intelligence 2012*, p. 10. On resource pricing generally, see *World Economic Forum 2011*, p. 31.

Figure 11. Food Lost or Wasted by Region and Stage in Value Chain, 2009 (Percent Kcal Lost / Wasted)




*Source:* Lipinski et al. 2013, figure 6, p. 9.

the producer through the processor to the consumer, is beneficial to productive and useful policymaking. A third strategy is to view waste as an asset. Best-practice firms attempt to find secondary markets for their waste that they otherwise would have sent to landfills.[59] This idea is consistent with nexus thinking, wherein one sector's outputs are another's inputs. A final strategy is to manage demand by altering consumer behavior. Increasing wealth within the global South, including in Africa, is creating billions of newly affluent consumers. While altering behavioral patterns is among the most difficult of tasks, awareness-raising campaigns designed to stress food, water, and energy consumption might make some headway. Small dietary shifts that reduce per capita meat consumption, especially beef, would shift crop production away from livestock feed.[60]

Food production and distribution provide an important illustration of the efficiency imperative. Aware of looming water shortages, agriculturalists are emphasizing the need to squeeze as much food production from each unit of water input—"more crop per drop," in their parlance. Integrated approaches to agricultural production are required in order to maximize water savings, including tailoring solutions to local conditions that allow farmers to save water and other inputs through effective land stewardship. Excess on-farm fertilizer and manure application is a major problem, leading to nutrient pollution and degradation in many parts of the world. Savings from technological gains will also be critical. Genetic seed modifications, for instance, that will create water-saving plants are being developed (though the continued political resistance to genetic modification in much of Africa could prove problematic).[61]

Food loss and waste is an important component of the inefficiency equation. Each kilogram or calorie of food that is produced but unused is a waste of valuable food, water, and energy resources. Globally, the world wastes about a quarter of the food it produces, whether by accident or intent. While reducing this number down to zero would not itself be sufficient to close the global food demand and supply gap, cutting this number would go a long way in that direction. As shown in figure 11, wealthier countries in North America, Europe, and industrializing Asia tend to waste most of their food toward the consumption-end of the food chain. This is because the food supply chain works very well at the production, post-harvesting, transport, and processing stages. Efficient production and storage systems, adequate refrigeration, and high-quality transport infrastructure all lead to this outcome. In poorer countries, the exact opposite is true. Very little food that reaches the consumer is wasted, but the problem lies in the earlier stages. About three-quarters (76 percent) of food wasted in sub-Saharan African systems is at the production and post-harvest stages, the result of poor harvesting techniques, low market access,

59 Eric Orts and Joanne Spigonardo, *Special Report: The Nexus of Food, Energy and Water* (Philadelphia: University of Pennsylvania Wharton School, Institute for Global Environmental Leadership, 2013), p. 5.
60 Jonathan A. Foley et al., "Solutions for a Cultivated Planet," *Nature* 478 (October 20, 2011), p. 340; T. Searchinger et al. 2013, table 1, pp. 10-12.

61 Waughray 2011, p. 18, p. 26; Foley et al. 2011, p. 340.

and inadequate transport infrastructure and storage/refrigeration systems. Simple investments in low-cost technologies would do much to improve this situation. Metal grain silos, for instance, limit losses to rotting and pests over long timeframes.[62]

While pointing out the need to increase resource efficiency is obvious, it is difficult to scale efficiency gains in practice. Hurdles include economic, technological, and financial barriers, inefficient legacy infrastructure, policy roadblocks, vested interests, and cultural inertia. Drip irrigation systems, for instance, hold great promise for addressing water shortages in Africa and elsewhere. This irrigation method delivers water and fertilizer directly to plant roots as opposed to spraying water over wide areas as in conventional irrigation systems. Compared with conventional irrigation, drip irrigation systems can double yields while saving water, fertilizer, pesticides, and farm labor. While this method is now an expanding form of irrigation in sub-Saharan Africa, scaling drip irrigation systems to meet the continent's needs is a significant challenge. The technology is proven, but smallholders may not have access to water sources, reliable and inexpensive energy sources for water pumping, or institutional support for financing and maintaining such systems.[63]

## C. Enable Access

Investing in agricultural commercialization, better infrastructure, and rural development will improve the fortunes of Africa's poor. But proper investment strategies must also address important access issues. Increased resource production is not always the same thing as increased consumption, in particular consumption by poor people. Africa exports a significant portion of its fossil fuel production, for instance, at the same time that hundreds of millions in Africa exist in energy poverty.[64] "The poor [in Africa] suffer most from inefficiencies involving food, water, and energy," observe several researchers. "They have the lowest levels of calorie availability, lowest access to safe drinking water and irrigation, and little or no access to electricity."[65] Roughly three hundred million Africans subsist on less than a dollar a day (in sub-Saharan Africa, about 40 percent of the population).[66]

While poverty is increasingly an urban phenomenon, in Africa and elsewhere the poorest of the poor are disproportionately rural smallholders. Subsistence farmers in Africa are among the most vulnerable to food, water, and energy insecurity because their production levels are low, they lack technology and access to markets, and have low resiliency to weather variability, particularly rainfall variability.[67] Boosting smallholding farmer productivity is a development imperative because doing so would raise incomes of the poorest Africans. One of the great fears of an African Green Revolution is that it might benefit larger farmers over smaller ones, in turn pushing smallholders to the economic brink. Such outcomes did occur during the twentieth century's Green Revolution. Yet there also were cases of successful smallholder-based green revolutions. Through well-designed land policies and other mechanisms, for example, Thailand's policymakers managed to retain smallholding farms in its northeast while dramatically increasing cassava, maize, and rice production.[68]

Large-scale land transactions between countries, as described in the above sections, provide additional examples of complex resource access issues, and clear benefits for both countries are involved in these transactions. In an ideal global trading system, it makes sense to have resource-rich countries export a portion of their food and "virtual water" to resource-deficient countries so that everyone benefits and no one loses. Indeed, international trade along these lines will likely become an increasingly important hedging strategy against climate-related shocks. For countries in Africa and elsewhere that sell rights to their land, such deals can have numerous benefits ranging from increased foreign direct investment, higher employment, improved infrastructure, and the upgrading of workforce skills. Moreover, as investors tend to focus investment in countries with low agricultural productivity, yields can be raised through infrastructural and technological investments.[69]

There are also dangers. Critics point especially to the adverse social and environmental effects of large land transactions. In their view, such transactions are often conducted through opaque decision processes with little input from local communities, resulting in the "transfer of the right to own or use the land from local communities to foreign investors through large-scale

62 B. Lipinski et. al., "Reducing Food Loss and Waste," Working Paper, Installment 2 of *Creating a Sustainable Food Future* (Washington, DC: World Resources Institute, 2013), pp. 2-10.

63 Jennifer Burney et al. (2010), "Solar-Powered Drip Irrigation Enhances Food Security in the Sudano–Sahel," *PNAS: Proceedings of the National Academy of Sciences* 107, 5 (February 2, 2010), pp. 1848–1853; ODNI 2012, p. 8.

64 Cilliers, Hughes, and Moyer 2011, p. 43.

65 Ringler, Karelina, and Pandya-Lorch 2011.

66 Food and Agricultural Organization of the United Nations, *Water for Agriculture in Africa: Resources and Challenges in the Context of Climate Change* (Sirte: FAO, 2008), p. 9; Cheryl A. Palm et al. (2010), "Identifying Potential Synergies and Trade-Offs for Meeting Food Security and Climate Change Objectives in Sub-Saharan Africa." *PNAS: Proceedings of the National Academies of Science* 107, 46 (November 16, 2010), p. 19661.

67 Christopher Gordon et al. (2010), "Food Security and Natural Resources Management: Overview on Climate Change Implications for Africa," *Nature & Faune* 25, 1 (2010), p. 12.

68 Morris and Larson 2009 compare Thailand with Brazil and sub-Saharan Africa.

69 Office of the Director of National Intelligence 2012, p. 8; Lee et al. 2012, p. 106.

land acquisition."[70] Investors, they insist, target countries with weak governance structures so as to best avoid complex multi-stakeholder bargaining. Critics argue that these processes lead to the displacement of local people, reduction of local employment, and damage to local ecosystems through poor resource management.[71] Assuming appropriate safeguards are built and followed, however, international trade of this sort can be made to benefit all populations.

### D. Strengthen Resiliency

Nexus thinking asserts that societies should incorporate the intersections between food, water, and energy into decision-making and policymaking. In this view, the linkages between food, water, and energy are as important as the individual components themselves. The complexity of the nexus equation, however, and of the human systems that depend on these resources, means that we will likely never be able to fully grasp, much less be able to fully model, all the implications. This complexity also means that we are not going to be able to precisely predict how a changing climate will shape nexus outcomes in specific places and times. Observing that the nexus is extraordinarily complex does not justify abandoning the idea. Rather, this complexity is simply a reality that we cannot avoid. It suggests that one of our wisest strategies is to strengthen the resiliency of the various environmental and human systems that either produce or depend upon nexus resources. In general, systems are more resilient when they can absorb short-term external shocks or adapt to long-term changes to the external environment and still remain productive and vibrant.[72]

> Between 1980 and 2000, intact forests accounted for nearly 60 percent of land converted to agriculture in Africa. Tropical forests were most often cleared, causing harm to biodiversity, watershed integrity, and other forest-based livelihoods.

Intact watersheds, forests, soils, wetlands, and coastal environments (fisheries, mangroves, etc.) provide the ecosystem services without which human systems cannot function. Ecosystem services need to be sustained so that food, water, and energy production can be safeguarded over the long run. Stresses caused by climate change (increased rainfall variability, coastal degradation, and higher temperatures) also call for successful climate resiliency strategies. To avoid resource shocks, governments will need to incorporate ecosystem perspectives into their nexus management plans, including land, watershed, and forest management.[73]

The African food production debate has important ecological components. Many fear that Africa's forests will fall victim to agricultural expansion, as has occurred in parts of Brazil's Amazon. This has historically been true across Africa. Cropland expansion—extensification—has driven much of Africa's growth in agricultural production, with the continent's forests having borne the brunt. Between 1980 and 2000, intact forests accounted for nearly 60 percent of land converted to agriculture in Africa.[74] Tropical forests were most often cleared, thereby causing great harm to biodiversity, watershed integrity, and forest-based livelihoods from small-scale timber harvesting and other activities. Moreover, yields on the newly cleared land were often low.

African agricultural production can be increased through a combination of appropriate extensification and ecologically sensitive intensification (increasing crop productivity on already farmed land). Both food production strategies have advantages and disadvantages. Regarding extensification, expanding cultivation can have serious consequences, in particular

70 Maria Cristina Rulli, Antonio Saviori, and Paolo D'Odorico, "Global Land and Water Grabbing," *PNAS: Proceedings of the National Academies of Science* 110, 3 (January 15, 2013), p. 892.
71 Lee et al. 2012, p. 106; Bizikova 2013, p. 1; Rulli, Saviori, and D'Odorico 2013, pp. 893-895.
72 For a valuable definition and discussion of resiliency in an agricultural context, see The World Bank, *Policy Brief: Opportunities and Challenges for Climate-Smart Agriculture in Africa* (Washington: World Bank, June 27, 2011), pp. 19-24.

73 Gordon et al. 2010, p. 14.
74 There was, however, significant variation across the continent. See H.K. Gibbs et al., "Tropical Forests Were the Primary Sources of New Agricultural Land in the 1980s and 1990s," *PNAS: Proceedings of the National Academies of Science* 107, 38 (September 21, 2010), p. 16734; Taylor, Koussis, and Tindimugaya 2009, p. 655.

## Box 5. Nexus Case Study: Gabon

### His Majesty King Mohammed VI of Morocco and Gabonese President H.E. Ali Bongo Ondimba

*Source:* Facebook, Ali Bongo Ondimba.

### US Marines Train Gabonese National Park Rangers (ANPN), June 2013

*Source:* US Embassy in Gabon.

The central nexus challenge for the West African country of Gabon is at the heart of sustainable development: how to have prosperity while preserving ecosystems for future generations. Gabon has a tremendous natural endowment, possessing significant energy and water resources and astonishing biodiversity. With this endowment plus good governance and a small population, Gabon is a wealthy country (per capita GDP in 2010 was $8,643) that is poised to join the world's dynamic emerging economies.

Oil exports have formed the backbone of Gabon's economy for decades, giving it much wealth. But dependence on energy production has atrophied other sectors. Agriculture constitutes less than 5 percent of national GDP, and the sector generates few jobs. Gabon also imports most of its food. Government policy now aims to boost agriculture's share of national GDP. Intensification is the core strategy, with priority given to input investment, rural infrastructure, and cash crops. Gabon's climate is favorable for palm oil production (increasingly used for biofuel), which has attracted significant foreign direct investment. Additionally, Gabon is exploring how its fossil fuel endowment can enhance agricultural production. In March 2014, Gabon signed a $2.3 billion joint-venture deal with Morocco in which fertilizer production plants in each country will be fed by Moroccan phosphoric acid and Gabonese ammonia. The fertilizer will be applied to undernourished soils across the region. The project's production capacity is expected to reach two million tons a year by 2018 and create more than five thousand jobs in both countries. The project includes building the region's first factory to produce ammonia from natural gas in Gabon, as well as a facility at the oil hub of Port Gentil to turn this into fertilizer.

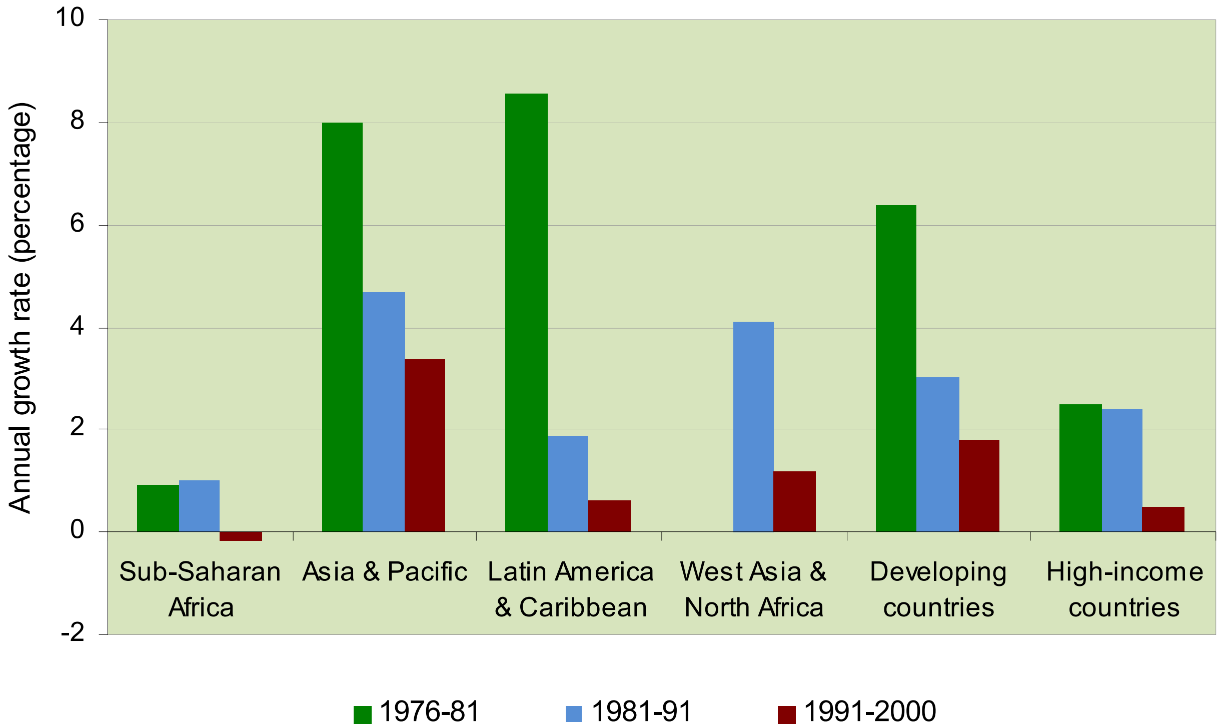
Gabon's forests are a significant part of the country's natural endowment. About 85 percent of Gabon is forested, much of it pristine rainforest. The government has embraced sustainable forestry as a development strategy, and wildlife conservation as a means of reinforcing national pride. Gabon's biggest conservation gem consists of its thirteen national parks, created in 2002 to preserve the country's most ecologically important landscapes.

Unfortunately, poaching in Gabon's forests has created a crisis with significant implications for West Africa. Elephant poaching, driven by global demand for ivory, is the primary dilemma. Gabon's forest elephants, Africa's last big concentration, have been slaughtered by the thousands in recent years. Poachers from abroad pillage Gabonese wildlife, the proceeds of which then finance regional terror networks. Such poaching could not only permanently disfigure Gabon's natural endowment and harm ecotourism development, it might also undermine regional stability.

Gabon's president, Ali Bongo Ondimba, has undertaken aggressive action to halt wildlife poaching. Since assuming power in 2009, Bongo has increased Gabon's national parks budget and staff, including the creation of an armed, 250-strong anti-poaching patrol that is being equipped with helicopters and other sophisticated accoutrements. Bongo has become one of the world's foremost advocates of coordinated multilateral action to stop poaching and to prioritize it as an international security problem. He has also entered into anti-poaching security arrangements with the US government and other partners.

*Source*: International Bank for Reconstruction and Development and International Finance Corporation, *Country Partnership Strategy (FY2012-FY2016) for the Gabonese Republic* (Washington: World Bank and IFC, 2012); Food and Agriculture Organization of the United Nations, *Gabon: Forests and the Forestry Sector* (Rome: FAO, 2004); FAOSTAT, *Gabon Country Profile* (Rome: FAO); "HM the King, Gabonese President Sign Strategic Partnership in Field of Fertilizer," MAP: Agence Marocaine de Presse (March 6, 2014); "Africa 'Under Attack'" and "Tactical Intelligence," *Gabon Magazine* (Autumn 2013), p. 9; Martin Fletcher, "Fighting with Fire," *The Daily Telegraph* (February 1, 2014), pp. 26-33; Eleanor Whitehead, "Gabon Agriculture—15 Percent of GDP by 2020," *This is Africa* (December 19, 2012).

Figure 12. Annual Growth Rates in Agricultural R&D, by Geographic Area




*Source:* FAO 2009, figure 2.

for forests. Deforestation for agriculture has been a major problem in Africa, but at the same time the continent still has large amounts of non-forested land that are also suitable for agricultural production. The FAO estimates that sub-Saharan Africa could more than double the amount of land under production, from 183 million hectares to 451 million, without significant deforestation.[75] Whether such expansion would occur without large-scale deforestation is an open question. Intensifying agricultural production, on the other hand, avoids deforestation altogether. Intensification has been a major farming strategy for millennia, but it was only after the invention of modern inputs (chemical fertilizers and pesticides and mechanical irrigation, primarily) and machines (tractors) that the dream of perpetually high yields at relatively low cost could be realized. The challenges related to intensification are managerial, between using modern inputs for high and sustained yields while preserving ecosystems and controlling costs. One applied strand of research, called agroecology, aims to treat inputs, technologies, soils, plants, climate, nutrients, bacteria, pests, and farming methods as linked components in an integrated system. While agroecology does not reject high technology, its goal is to raise productivity through an appropriate mix of inputs, technologies, and farming techniques while utilizing natural processes to both boost yields and preserve local ecosystem services. Among other things, advocates believe that this approach helps smallholding farmers remain competitive with larger farms.[76]

## E. Embrace Innovation

Solving food, water, and energy security challenges will require the utilization of every tool available to humankind. The scaling of existing best-practice technologies, methods, and systems can go a long way toward increasing output while conserving nexus resources. Expanding existing best practices such as drip irrigation, subsurface drip irrigation, and "fertigation" (all discussed in box 6) would make agriculture—in Africa and elsewhere—far more productive and resource-efficient than it is now. Our toolkit must also include embracing breakthrough, "emerging," and "disruptive" forms of innovation. If we are to meet this century's massive resource needs, then leapfrog advances in productive technologies, supply chain management, and on-the-ground practices will be required.

Creating systems that identify and scale novel advances is the key to translating innovative technologies, methods, and practices into successful on-the-ground application, whether in Africa or elsewhere. Although science and technology are central drivers of innovation, successful innovation ecosystems depend on the participation of diverse networks of actors. Ideally, researchers,

75 Nikos Alexandratos and Jelle Bruinsma, *World Agriculture Towards 2030/2050: The 2012 Revision, Food and Agricultural Organization Working Paper* (Rome: Food and Agricultural Organization of the United Nations, June 2012), pp. 10-12.

76 Orts and Spigonardo 2013, p. 14.

practitioners, and consumers would work interactively to bring innovations into usable and practical form.

In the agroecological context, the scholar Calestous Juma writes about placing the “farmer-innovator” at the center of African agricultural innovation systems. Juma argues that innovation will be most effective at transforming African agriculture if smallholding farmers become key participants in an ongoing, iterative dialogue with researchers.[77] Other observers make similar arguments, stressing how scientific and technological innovation depends on multi-stakeholder processes, based on the notion that innovation is not just a question of developing new forms of technology but also of technology’s diffusion and impact on the ground.[78] Particularly in the agroecological arena, success occurs when innovation fits into local economic conditions and the constraints imposed by local ecosystems. The empowered local smallholding farmers that result from this process can then be linked to regional and global networks and supply chains for access to inputs, financing, and technology. In this model, the policymaker’s task is to create the conditions in which these networks and processes can flourish, which includes the creation of knowledge networks between and among themselves, across departmental and jurisdictional boundaries.[79] In the African case, this task also includes finding ways to upgrade investment in research and development for agroecological systems. Although investment has been declining everywhere, it has always been much lower in the sub-Saharan African context than in other regions (figure 14).

Government policy and regulatory action are as important as technological innovation in other contexts as well. Bringing stakeholders together to help solve resource challenges, seeking efficiency gains, and finding innovative technological approaches also are core ideas for solving water-energy challenges. One example of a promising technology is the Fresno Clean Energy Park concept, which seeks to maximize water efficiency in the production of energy and a host of other purposes. The idea is to colocate multiple uses around a water source. In this idea, a concentrated solar plant would be placed next to a water source and would provide electricity for a nearby water treatment plant, a manufacturing facility, and enough for agriculture as well. In the future, this vision might be enlarged and extended. One such vision is to colocate low-carbon power plants and desalination plants to produce cheap fresh water with minimal climate impact.[80]

The private sector will respond to shifting demand signals in the water-energy context to develop innovative practices and technologies. For example, General Electric’s Ecomagination initiative is investing billions into greentech development in the expectation that energy- and water-efficient engines, devices, machines, storage systems, and consumer goods will be in huge global demand going forward.[81]

Demand pressures in the energy and water sectors are motivating researchers and industry to develop innovative practices and technologies. For example, GE will invest ten billion dollars over the next five years into new technologies to help reduce the impacts of primary energy and transportation fuels extraction and production on water supplies and quality. Another example comes from the US national labs, which are proposing innovative wastewater treatment options.[82] Advanced membrane technology will enable wastewater from shale gas operations to be moved to nearby coal-fired plants for treatment. Coal plant waste heat could be used to treat this brackish water, which could then be recycled back into fracking wells, further reducing water use. All of these technologies could have applications in the African resource context.

Finally, it is important to acknowledge the important role that scientists will play in innovation, in particular in nexus modeling. This report has repeated the basic observation that despite the great complexity of the nexus, we must attempt to understand it better so we can build more capable and resilient tools and systems to manage it. Sandia National Laboratories in New Mexico, for example, is one scientific organization that is at the forefront of global efforts to build integrated models focusing on elements of the nexus. While Sandia’s researchers admit that they do not yet possess the tools or data necessary to model the full range of social and ecological variables involved in the nexus, they also suggest that vastly improved computing power and much cheaper data and data storage are creating the conditions in which scientists have the ability to tease out the most important relationships. Their models integrate data about food, water, and energy production and bring in political and social factors as well. These tools are not just for the American geospatial context; Sandia’s researchers are building tools that can be applied in other countries and regions, including in Africa.[83]

77 Calestous Juma, *The New Harvest: Agricultural Innovation in Africa* (New York: Oxford University Press, 2011), chapter 3.
78 See, for example, United Nations Energy Program, *Green Economy Briefing Paper: Innovation* (Geneva: United Nations Environment Program, 2012), pp. 1-2.
79 See, e.g., UNCTAD 2010, pp. 2-4, pp. 87-92.
80 Blythe Lyons, *Energy for Water and Water for Energy* (Atlantic Council, October 11, 2011), p. 15, http://www.atlanticcouncil.org/images/files/publication_ pdfs/403/111011_ACUS_EnergyWater.PDF.

81 See GE’s Ecomagination site, http://www.ge.com/about-us/ecomagination.
82 Sandia National Laboratories, US Department of Energy, 2014, www.sandia.gov/mission/energy/arra/energy-water.html.
83 See for example the short summary of Sandia’s Energy Water Decision Support System in Lyons 2011, p. 16.

## Box 6. Smarter Agriculture

Expanding the amount of land under cultivation—extensification—has played an important role in keeping global food supply ahead of demand. Over the past two centuries, agriculture greatly expanded its reach into the world's grasslands and forested lands. But intensification—increasing crop yields—has also played a fundamental role. Innovative agricultural practices and emerging technologies have helped much to prevent Malthusian food scarcity scenarios. Critical breakthroughs have ranged from synthetic fertilizers to hybrid seed varieties. Going forward, extensification is a less viable option compared with preceding centuries: while there is untapped arable land in Africa, at a global level, there is far less non-forested and untapped land for expansion now compared with previously. Climate-induced stressors are also forecasted to harm agricultural systems in Africa and around the world.

Producing more food under more difficult conditions is our century's greatest agricultural challenge, so making agriculture smarter is an imperative. Smarter agriculture means improved resource efficiency, reduced wastage and spoilage, greater resistance to higher temperatures and increased aridity, lower ecosystem impacts, and better informed practices.

In Africa, much of the challenge is about finding ways to scale existing best practices. Technologies and methods already exist to dramatically improve African agriculture's efficiency, resiliency, and output, but the major task that remains is how these can be adopted by millions of smallholding farmers. Reducing the costs and operational complexity of these best practices is absolutely essential.

Water and fertilizer inputs for food production provide good examples. Large-scale irrigation is expensive, often requiring massive infrastructure projects, and is inefficient to boot. Flood irrigation wastes half or more of the water applied, much of it through evaporation. But there are fixes. Drip irrigation (DI), which applies piped water in concentrated fashion directly to a plant's roots, and the more advanced subsurface drip irrigation (SDI), which uses the same system but is entirely underground, have been shown to improve crop yields while dramatically lowering water use. "Fertigation," a best-practice fertilizing method, uses drip and SDI systems to deliver fertilizer directly to a plant's roots. Fertigation and DI/SDI improve efficiency and reliability by delivering inputs in small doses directly to crop roots, improving input accuracy and uniformity. Their side benefits can include reduced time and labor costs, reduced need for heavy machinery, and greater seasonal flexibility.

While these systems have origins extending back several decades, their use in many parts of the world has been limited, owing to either low input costs that discourage innovation (for example, subsidized water prices) and/or their relatively high initial investment and ongoing maintenance costs. While drip irrigation has been spreading throughout the world, including in Africa, the key obstacles preventing faster adoption of DI and the other advanced systems remain investment cost and operational complexity.

Scaling of existing best practices is only one strategy for smarter agriculture. Ongoing innovation in the form of new 'disruptive' technologies and practices, developed to meet African conditions, will be needed as well. A technological imperative is to develop and scale biotechnologies that are adapted specifically for African growing conditions and that can thrive within Africa's social systems. Hybrid seeds that enhance output while protecting against pests and diseases for Africa's most important crop varieties are biotech examples that can transform agriculture on the continent. A recent example is a hybrid strain of rice called NERICA ("New Rice for Africa"). Funded by the African Development Bank, the United Nations, and the Japanese government, NERICA married the high yields of an Asian rice strain with the hardiness and drought resistance of an African strain. Under the right conditions, NERICA has produced higher yields (with fertilizer use, greater than 200 percent), earlier maturity, and greater resistance to environmental stressors. Some twenty varieties of NERICA have been developed.

NERICA is a biotech innovation but it is not, strictly speaking, a genetically modified organism (GMO), which is a plant or organism whose genetic characteristics have been altered through the insertion of other organisms' genes. While GMOs remain controversial, genetic engineering advances hold great promise for Africa, through higher yields, improved nutritional quality, and greater plant resilience to pests, diseases, weeds, and environmental stress. To date, soybean, maize, cotton, and other GMO crops have been developed containing such qualities, and several are in widespread use globally.

Finally, it is important to remember that not all innovation happens in the laboratory, and not all comes from expected sources or directions. Innovation also happens organically, through unexpectedly swift technological adoption or methodological innovation by users on the ground. The exceptionally rapid spread of mobile phones in Africa, for instance, has had many benefits. One of these is how smallholding farmers have taken mobile technology and used it for better and timelier access to weather and market data, thus enabling smarter planting, delivery, and marketing strategies.

*Source*: United Nations Conference on Trade and Development (UNCTAD), *Technology and Innovation Report 2010: Enhancing Food Security Through Science, Technology and Innovation* (New York and Geneva: United Nations, 2010), pp. 74-84; Juma 2011, pp. 29-47; World Bank, *Policy Brief: Opportunities and Challenges for Climate-Smart Agriculture in Africa* (Washington: World Bank, June 27, 2011); D. Reich, R. Godin, J.L. Chavez, I. Broner, *Subsurface Drip Irrigation*, Colorado State University Extension Fact Sheet No. 4716 (Fort Collins: Colorado State University Extension, 2009); Sandra Postel, "Drip Irrigation Expanding Worldwide," *National Geographic's Water Currents* (June 25, 2012), http://newswatch.nationalgeographic.com/2012/06/25/drip-irrigation-expanding-worldwide/; William D. Jones, "Proportional to Flow Fertigation Protects Groundwater, Saves Money," Western Farm Press (December 17, 2012); Luke Frank, "Fertigation and Landscape Health," *Landscape & Irrigation* 30, 4 (April 1, 2006), p. 37; David Elstein, Jan Suszkiw, and Marcia Wood, "The Best of Both Worlds? Fertigation is an Efficient Way for Many Farmers to Grow Crops," *Agricultural Research* 52, 11 (November 2004), pp. 18-19.

## V. Conclusion: Risk, Resilience, Reward

In 2011, as part of the sixth edition of its *Global Risks* report series, the World Economic Forum asserted that food, water, and energy insecurity had become "chronic impediments to economic growth and social stability," and an emerging form of global risk.[84] The report defined negative impacts that might arise from this risk, ranging from stalled economic development to political unrest, loss of livelihoods, damaged ecosystems, increased disaster relief, more hunger and poverty, rising commodity prices, and more volatility on global markets. Indeed, food, water, and energy insecurity raises the odds that these negative conditions will arise, therefore the risk to global security is a very real one.

While Africa's future will be determined by a confluence of factors, nexus management will also play a central role in shaping that future. Poor nexus management amplifies the risk of an African future characterized more by volatility, poverty, insecurity, and conflict, while smart nexus management increases the odds of a stable, prosperous, secure, and peaceful future. It goes without saying that the bleaker future is one that Africans themselves want to avoid, but the Atlantic community as a whole also has an enormous stake in finding ways to reduce the risks of such a future.

The biggest risk involves what is likely to occur if poor nexus management amplifies food, water, and/or energy insecurity across Africa. Food insecurity, to give only one example, has been a proximate cause of social upheaval and political revolution in world history, not to mention the cause of frequent humanitarian disasters. An African future consisting of hundreds of millions of people facing chronic hunger or sudden food shortages is not a happy one for the individuals involved, the countries in which they live, or for the Atlantic community writ large. The social dislocation and political turbulence that often accompanies hunger and food price volatility are rarely containable. Hunger ripples outward, from empty stomachs to street protests to regime instability and collapse. In the worst-case scenario, these crises can upset the international system, through upending geopolitical structures, generating need for humanitarian intervention, and on rare occasions requiring peacekeeping or even military operations. In a transnational context, such upheavals stifle trade and investment flows, spur illegal (occasionally mass) emigration, and stimulate the formation of crime, illegal trafficking, and terror networks.

Unfortunately, the nexus' complexity means that from a technical perspective we will likely never be able to fully and accurately model it. While the world's best scientists constantly improve their modeling capabilities, they admit that they are unable to quantify the extraordinarily complex relationships across the full spectrum of physical and human systems involved in the nexus.

> While Africa's future will be determined by a confluence of factors, nexus management will also play a central role in shaping that future.

Absent such capability, the Atlantic community's best strategy for reducing nexus risk might be to adopt a resiliency strategy. Through anticipating potential shocks to the physical systems that source the nexus and to the human systems that benefit from the nexus, we can make all such systems better withstand shocks when they do occur. Ecologists, for example, have long claimed that intact ecosystems are more resilient than fragmented, disrupted, and simplified ones. When stressed by higher temperatures or reduced rainfall, fully functional and intact ecosystems will serve human ends far better than damaged ones. Using a similar logic, crafting policies that examine the linkages between food, water, and energy is a way to overcome sectoral silos and build increased resiliency into physical and human systems. A greater focus on the linkages between food, water, and energy will enable smarter policies through drawing attention to cross-sectoral interdependence. Policy regimes that emphasize interdependence should yield far greater resource efficiencies.

It is important to recall that reward is the flip side of risk. If one were to turn the World Economic Forum's *Global Risks* report on its head and ask about nexus opportunities instead of risks, one might get a very different set of answers to the question of what the future might hold. Table 1, adapted from that report, is the outcome of our thought experiment, showing

84 World Economic Forum 2011, p. 28.

Table 1. Food-Water-Energy Nexus: Positive Impacts from Successful Management (Non-Exhaustive)

| Impacts | Direct Impacts | Indirect Impacts |
|---|---|---|
| On Government | • Ongoing economic development<br>• Reduced potential for political unrest<br>• Decreased cost of emergency food relief<br>• Increased agricultural yields<br>• Greater energy security | • Decreased social welfare expenditures from food insecurity and unemployment<br>• Reduced potential for conflict over natural resources |
| On Society | • Reduced hunger and poverty<br>• Decreased environmental degradation<br>• Food and water sufficiency/stable prices<br>• Social calm | • Low migratory pressures<br>• Protected water sources<br>• Preservation of economic livelihoods |
| On Business | • Export opportunities<br>• Stable resource and commodity prices<br>• Energy and water sufficiency | • Greater investment opportunities in the food, water, and energy sectors |

*Source:* Adapted from World Economic Forum 2011, table 4, p. 28.

what might occur if the nexus were managed for long-term sustainability. The *Global Risks* report envisions a world wherein failure to manage the nexus drives down economic development, worsens political unrest and conflict, increases price volatility and hunger, and degrades the environment. Table 1, on the other hand, flips the script and asks what might result if nexus challenges were to be addressed successfully. While there certainly are no guarantees, that world might be more prosperous, successful, peaceful, and resilient than it is now.

The food-water-energy nexus is an enormously complex phenomenon. Coming to grips with the complexity of the nexus is a difficult intellectual task; managing that complexity is even harder. It should come as no surprise, therefore, that solving nexus challenges is not a straightforward proposition, whether in Africa or anywhere else. The simplest and easiest solution is to continue on as before, treating resources separately through narrow sectoral lenses. Yet without paying close attention to how food, water, and energy intersect, we are guaranteeing a dimmer future. Assuredly, the positive social, political, economic, and ecological outcomes shown in table 1 would not arise from healthy nexus conditions alone. But these outcomes provide a glimpse into what a more stable, prosperous, and sustainable world might look like. Building resiliency into Africa's interlinked food, water, and energy systems greatly increases the odds of realizing a very bright future. This is Africa's chance—and the transatlantic community's great opportunity.

Without paying close attention to how food, water, and energy intersect, we are guaranteeing a dimmer future.

# About the Author


Peter Engelke is a resident senior fellow with the Atlantic Council's Strategic Foresight Initiative, which aims to enhance analysis and policymaking through understanding future challenges and opportunities at global scale. His work involves identifying and assessing long-range trends, connecting them to current challenges, and designing innovative strategic responses for policymakers and thought leaders in Washington and beyond. Engelke's project work at the Council examines how trends in demography, technology, economy, and geopolitics are shaping US national security and the transatlantic alliance, how rapid global urbanization is shifting the global governance challenge for foreign and security policymakers, how technological changes are altering labor markets in Europe and the United States, and how global trends are affecting food, water, and energy security in Africa and the Atlantic basin.

Engelke previously was a visiting fellow at the Stimson Center, where his work linked environmental change with global security challenges. Formerly, he was on the research faculty at the Georgia Tech Research Institute, where he authored his first book, a study of public health and urban form. He is also a former Bosch Fellow with the Robert Bosch Stiftung in Stuttgart, Germany.

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