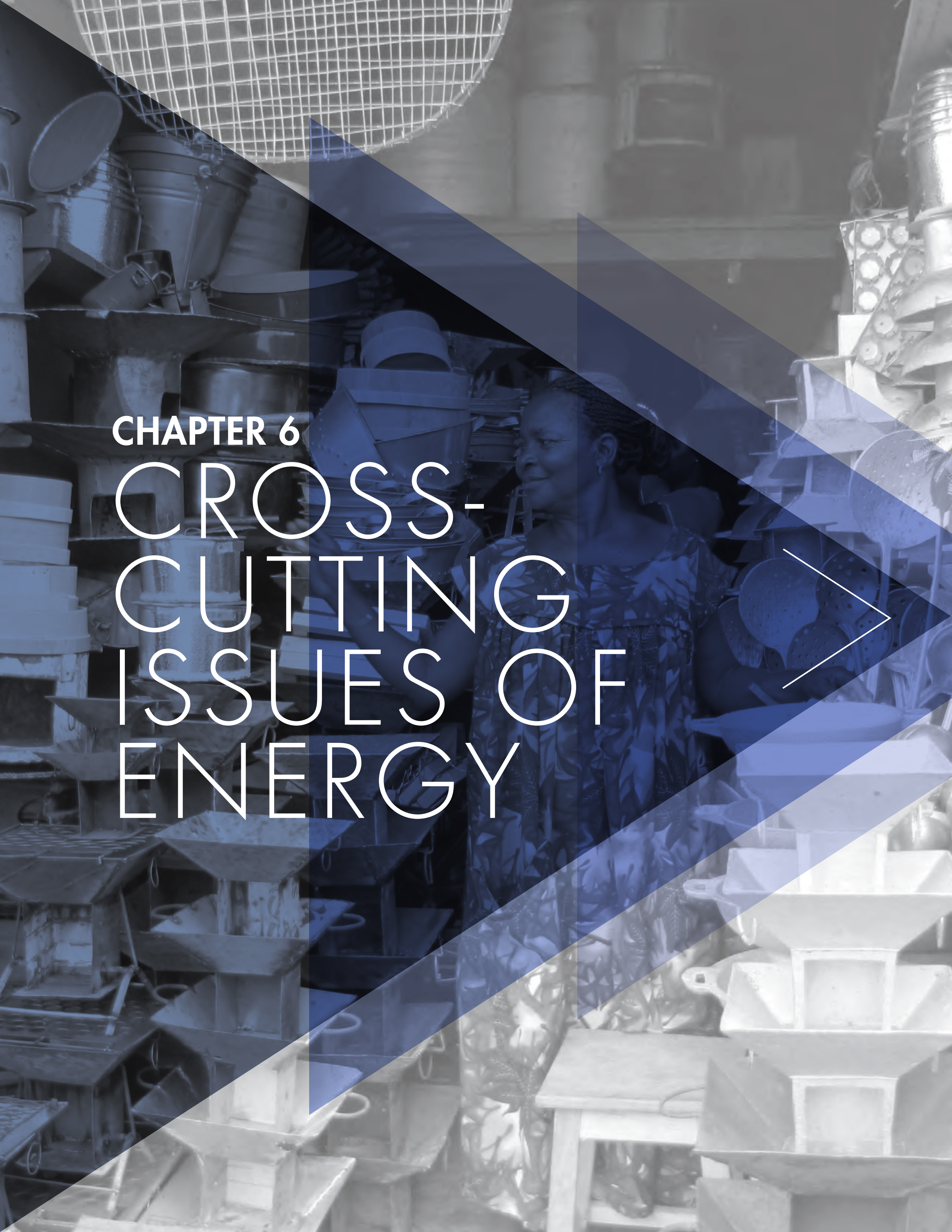


CHAPTER 6
CROSS-CUTTING ISSUES OF ENERGY

Cross-cutting issues of energy: Exploring the nexus of water, food, health, and gender

Highlights

- The energy sector is intertwined with water, food, public health, and gender matters. Hence a nexus perspective increases understanding of these interdependencies, enhancing efficiency, balancing trade-offs, building synergies, and improving governance. Energy helps to achieve secure and equal access to productive resources and inputs, helps to sustain food production systems, and helps to boost investment in rural infrastructure and technology. It also facilitates access to safe drinking water and sanitation, improvement of water quality, and expansion of wastewater treatment. Energy can help reduce death and illness from air, water, and soil pollution and contamination. It can also support women's equal rights to economic and natural resources, enhance use of enabling technology, and help prevent violence against women and girls in public and private places.

- The three objectives of Sustainable Energy for All (SE4All) are closely interwoven into the four nexus areas—water, food, health, and gender. Providing universal access to modern energy services, increasing the share of renewable energy (RE), and improving energy efficiency will greatly influence them.

- The SE4All objectives generate multiple nexus opportunities and challenges. Water security may be increased if water-related risks are managed well and contamination risks minimized. Similarly, food security may improve, and RE sources may help decouple food prices from energy prices, while managing production of energy crops. Global health may improve further as efforts focus on reducing air pollution and strengthening health services delivery. Finally, gender equality can be enhanced as time poverty decreases through better energy services and as women participate more actively in the energy value chain.

- Although existing data capture part of the nexus approach, improvements are needed in all four sectors to accurately monitor intersectoral impacts, supporting policymakers in developing integrated policies.

Introduction

The energy sector's interactions with water, food, public health, and gender are tightly linked to energy services and energy systems. They are also fundamental to meeting the objectives of Sustainable Energy for All (SE4All). Numerous opportunities will arise from more holistic decision making in energy if a wider set of cross-sectoral perspectives can be generated.

This chapter, part of the SE4All *Global Tracking Framework (GTF)* for the first time (in this 2015 edition), is different from the other three main, quantitative chapters (2, 3, and 4) that track the direct objectives of SE4All. Rather, this chapter is conceptual and introduces nexus concepts addressing four areas and their links to energy: water, food, health, and gender. While energy has links to and influences many other areas (such as education), these four form the initial foray for the GTF. The chapter also considers existing data and indicators, and gaps in them.

What is a nexus?

The interlinked nature of the development challenge is often known by the term "nexus." It simply means that two or more elements, or sectors, are inextricably intermeshed and that actions in one area have impacts on one or more of the others. The literature has highlighted multiple links between environmental, social, and economic development factors: development objectives such as poverty reduction, shared prosperity, and environmental sustainability cannot be addressed in isolation: they require an integrated approach.

The Sustainable Development Goals (SDGs) for energy seem to be interleaved with other goals such as water and sanitation, food security and nutrition, health, and gender. Energy facilitates, for example, access to safe drinking water and sanitation, improvement of water quality, and expansion of wastewater treatment. It also helps achieve secure and equal access to productive resources and inputs, sustainable food production, and increased investment in rural infrastructure and technology development. Energy can contribute to reducing death and illness from air, water, and soil pollution and contamination. It can also support women's equal rights to economic and natural resources, enhance use of enabling technology, and help curtail violence against women and girls in public and private places.

The term *nexus* has in particular been used to describe interdependencies in managing resources. The *energy-water-food nexus* refers to the synergies and trade-offs between the use of energy and water and the production of food. Attaining the SDGs hinges on availability of these resources, and on responsible and efficient resource use that limits humanity's impact on the climate and on ecosystems. Hence the need to analyze how all these systems interact and overlap.

The *energy-health* nexus encapsulates the positive and negative effects of energy on global health. Reduced energy poverty offers huge benefits for human health, but energy systems can also have negative impacts due to air pollution from incomplete combustion of fossil fuels and solid biofuels. As energy demand is expected to grow, particularly in emerging economies, the impact of energy systems on the global burden of disease may rise unless health-sensitive energy policy interventions are introduced.

Finally, the *energy-gender* nexus focuses on the role of energy in gender equality and in women's empowerment. Links between energy and gender have garnered greater attention, as evidence shows that improving gender equality and social inclusion is critical to maximizing the development impacts of energy programs. As emphasized by the *World Development Report 2012: Gender Equality and Development* (World Bank 2012a), greater gender equality can enhance productivity, make institutions more representative, and improve development outcomes for the next generation.

Why the nexus approach?

Despite growing awareness of the interconnectedness of the SDGs, the global community has so far addressed nexus challenges in isolation. It has neglected intersectoral links, often leading to incoherent and inconsistent strategies that fail to leverage synergies and balance trade-offs. Per the *World Water Development Report 2014*, "at the country level, fragmented sectoral responsibilities, lack of coordination, and inconsistencies between laws and regulatory frameworks may lead to misaligned incentives" (WWAP 2014, p. 61). There is, however, an emerging consensus that systemic problems should be addressed in a holistic manner focusing on inherently interlinked aspects to obtain sustainable outcomes. The World Economic Forum argues in its 2011 report that "any strategy that focuses on one part of the water-food-energy nexus without considering its interconnections risks serious unintended consequences" (van der Elst 2011). Any responsible development pathway therefore needs to account for these interdependencies in order to be coherent. Decision makers—even those responsible for only one sector—need to consider cross-sectoral impacts if energy, water, and food security are to be simultaneously achieved, global health improved, and gender equality promoted.

A nexus perspective increases the understanding of the interdependencies across sectors, enhancing efficiency, balancing trade-offs, building synergies, and improving governance across sectors. It builds the informed and transparent frameworks necessary to meet the world's increasing energy, water, and food demand, without compromising sustainability, and ensuring optimum health impacts and gender equality. Conventional policy and decision making in silos should therefore give way to an integrated approach.

Decision makers should develop strategies and investments to explore and exploit synergies, and to identify and optimize trade-offs among the intersecting objectives. The recognition has been growing that a more integrated approach to policy and practice of sustainable development is needed in the post-2015 world to break down the silo approach and to focus instead on the coherence of the SDGs and their targets. The preamble to the Open Working Group's final document of late 2014 states that the proposed SDGs constitute "an integrated, indivisible set of global priorities for sustainable development."

Although the theory of coordinated strategies and actions sounds wonderful, the reality is a different matter. Governance is first and foremost sectoral and emanates from discrete, institutional entities. Coordination between, for example, ministries—as well as between levels of government (national and local)—has often failed to reach expectations. Such failures may be driven by power rivalries among ministries, whether political or personal, further exacerbated by unclear or overlapping responsibilities and jurisdictions. Frequently the capacity (human, skills, funding, and infrastructure) may not be enough: short of resources, institutions' priorities will often be core duties, leaving cross-cutting efforts to suffer.

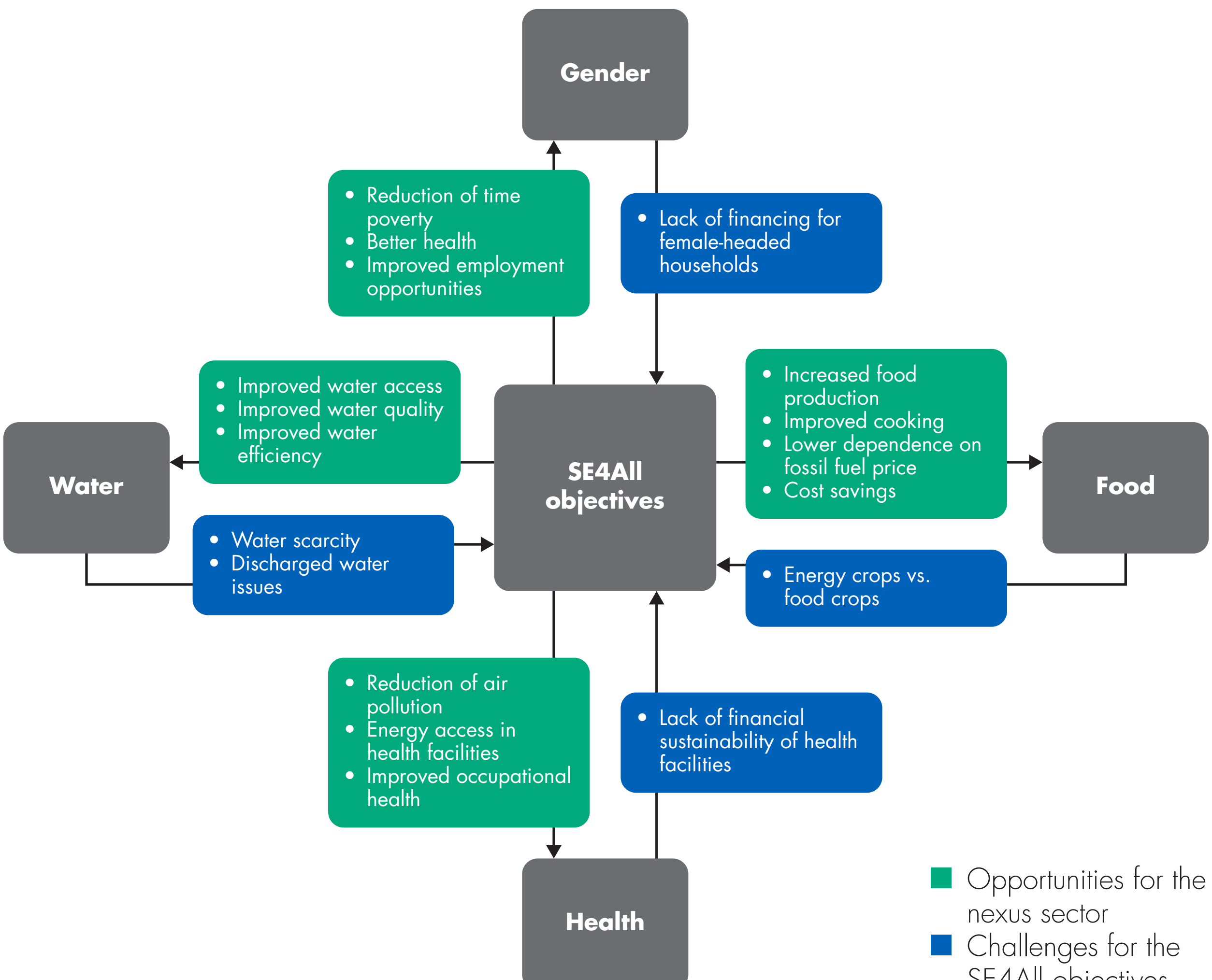
Adopting and realizing a nexus approach require robust incentives and frameworks that stimulate stakeholders to take part. This is because—despite a broad consensus on the potential of the nexus perspective—implementation faces many hurdles. Policies, incentives, and empowering frameworks to avoid unintended consequences are all necessary, bringing in government agencies, the private sector, and civil society. An evaluation system completes the loop.

Indicators that track the contribution of one sector to others inform decision makers, encourage coordination, and guide progress, offsetting data gaps and asymmetric access to information that can block cohesive governance. If information is missing or not available to all departments or levels, this can hamper productive dialogue and action. Thus arises the need for information and measurement systems on nexus indicators that enhance coordination and provide guidance on achieving tangible outcomes.

The nexus and SE4All

Achieving the SE4All objectives has implications for water and food security, global health, and gender equality. The three SE4All objectives are closely interwoven into the four nexus areas analyzed in this chapter, and so providing universal access to modern energy services, increasing the share of RE, and improving energy efficiency will affect them all. These implications may entail opportunities or challenges (figure 6.1). Thus identifying the intersectoral

Figure 6.1. **Implications of SE4All objectives for the four nexus sectors**



Source: Authors.

relationships early on is of great importance in targeting synergies and forestalling potential tensions. The means by which the SE4All objectives are pursued (policies, regulations, technology, and institutions) will determine the positive and negative impacts on nexus areas.

Water requirements will depend on the amount of energy produced and on the technology mix. Improved energy access will raise the energy available for extracting and treating water, but will add pressure on water resources. A higher share of RE in the energy mix may help reduce water intensity in energy, as photovoltaic (PV) panels and wind energy gain share, but global energy supply from water-intensive thermal plants is also expected to grow. Water efficiency should increase as old, inefficient power plants are replaced.

Food security will benefit. Access to modern energy services in agriculture helps raise food production, often improving farm income, while the uptake of RE in agrifood systems helps in decoupling agricultural production from the fossil fuels market. Energy efficiency in agriculture and agrifood systems usually has a positive effect on economic returns of food production in the long run through savings on energy costs.

Access to modern energy services cuts air pollution, particularly electric lighting and clean cooking and heating solutions, while reliable access to energy in often-remote health facilities should also improve access to health services. Such facilities could become anchor customers, committing to off-take electricity, and incentivizing energy providers to enter remote markets, although their financial ability to do this should be scrutinized. RE, too, can reduce outdoor air pollution and improve occupational health in that it replaces polluters of air, water, and soil. Energy efficiency may improve indoor and outdoor air pollution, and modern appliances should enable off-grid health facilities to provide a wider range of health services.

Women and men will be affected differently as the world moves toward the SE4All objectives. Improved access reduces time poverty and drudgery, particularly for women, and improves indoor air pollution (which disproportionately affects women and children). Dissemination of RE off-grid solutions to the base of the economic pyramid may be boosted by women entrepreneurs, if empowered.

The next four sections explore the links between energy, on the one hand; and water security, food security, global health, and gender equality, on the other. Each section first analyzes the indicators needed for monitoring progress toward the SE4All objectives and second proposes tentative nexus indicators—summarized in tables 6.1, 6.2, 6.3, and 6.4—to enable better monitoring.

Energy and water

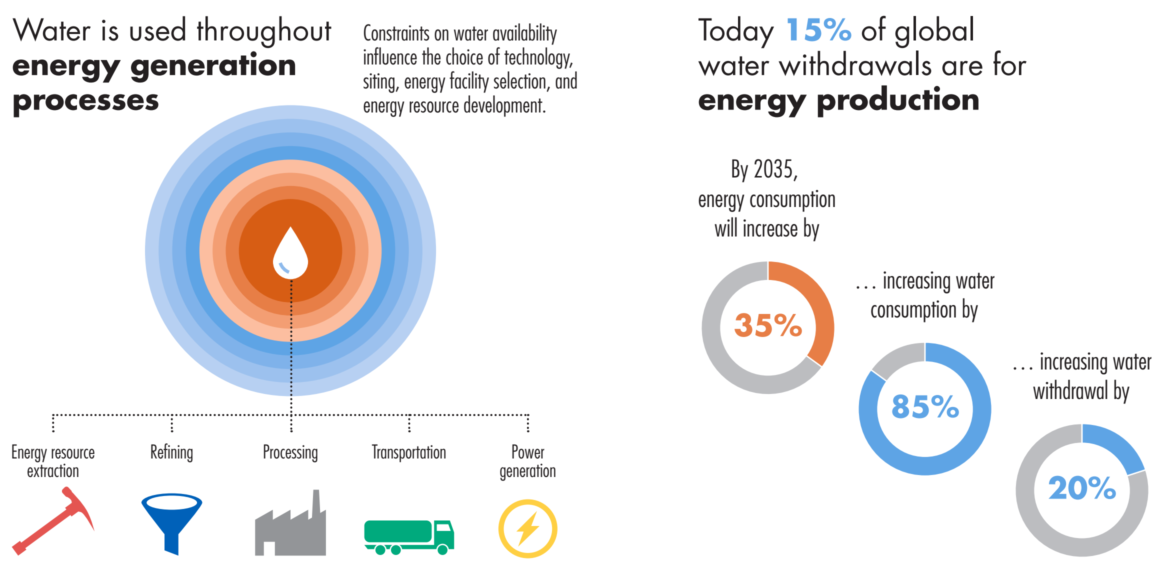
Introduction

The trade-offs between energy and water have been gaining international attention in recent years as demand for resources mount and as governments continue their struggles to ensure reliable supply to meet sectoral needs. About 748 million people still lack access to improved sources of drinking water. Nearly half of those people are in Sub-Saharan Africa. And more than one-third of the global population—around 2.5 billion people—remains without access to improved sanitation (WHO-UNICEF 2014). Water scarcity already affects every continent. Some 1.2 billion people live in areas of physical scarcity,[1] and 500 million are approaching this situation, while another 1.6 billion people face economic water shortage,[2] as countries lack the infrastructure to take water from rivers and aquifers (FAO 2007).

Energy and water resources are inextricably tied together. Huge amounts of water are needed, in almost all energy generation, including fossil fuel extraction and processing (figure 6.2). Conversely, the water sector needs energy to extract, treat, and transport water. Energy and water are used in producing crops, including those generating energy through biofuels. This relationship is what is known as the energy-water nexus (sometimes the energy-water-food nexus) (U.S. DOE 2014; WWAP 2014; Bazilian et al. 2011; Stillwell et al. 2014). These interdependencies could complicate solutions and make a compelling case to improve integrated water and energy planning to forestall unintended outcomes.

While the energy-water challenge is increasingly recognized, energy planners and governments often plan without considering existing and future water constraints. Planners in both sectors are frequently ill-informed about the drivers of these challenges, how to address them, and the merits of technical, political, management, and governance options, which themselves are poorly tracked. Hence it is vital to develop indicators (integrated where possible) and tools that tackle energy and water challenges on a country basis. Integrated planning will become crucial to ensure a sustainable strategy for many

Figure 6.2. **Water needs in the energy sector**



Source: Rodriguez, Delgado, and Sohns 2014.

Note: For example, in 2012, the *World Energy Outlook* of the International Energy Agency (IEA) concluded that water constraints could challenge the reliability of existing energy operations, require costly adaptive measures, and threaten the viability of proposed projects. Expansion plans for coal power plants in China and India, for instance, could become unfeasible due to water scarcity (Adelman 2012). In water-scarce regions like the Middle East and North Africa, desalination of water, which is very energy intensive, is increasing energy demand substantially, pushing water utilities to explore ways to reduce their energy demand, produce energy on site, or both (World Bank 2012b; Siddiqi and Anadon 2011). In the United Arab Emirates in 2010, for example, desalination absorbed an estimated 24 percent of total energy needs (World Bank 2012b).

countries, especially where climate change, urbanization, and population and economic growth are going to exacerbate water scarcity (Rodriguez et al. 2013; Hadian and Madani 2013).

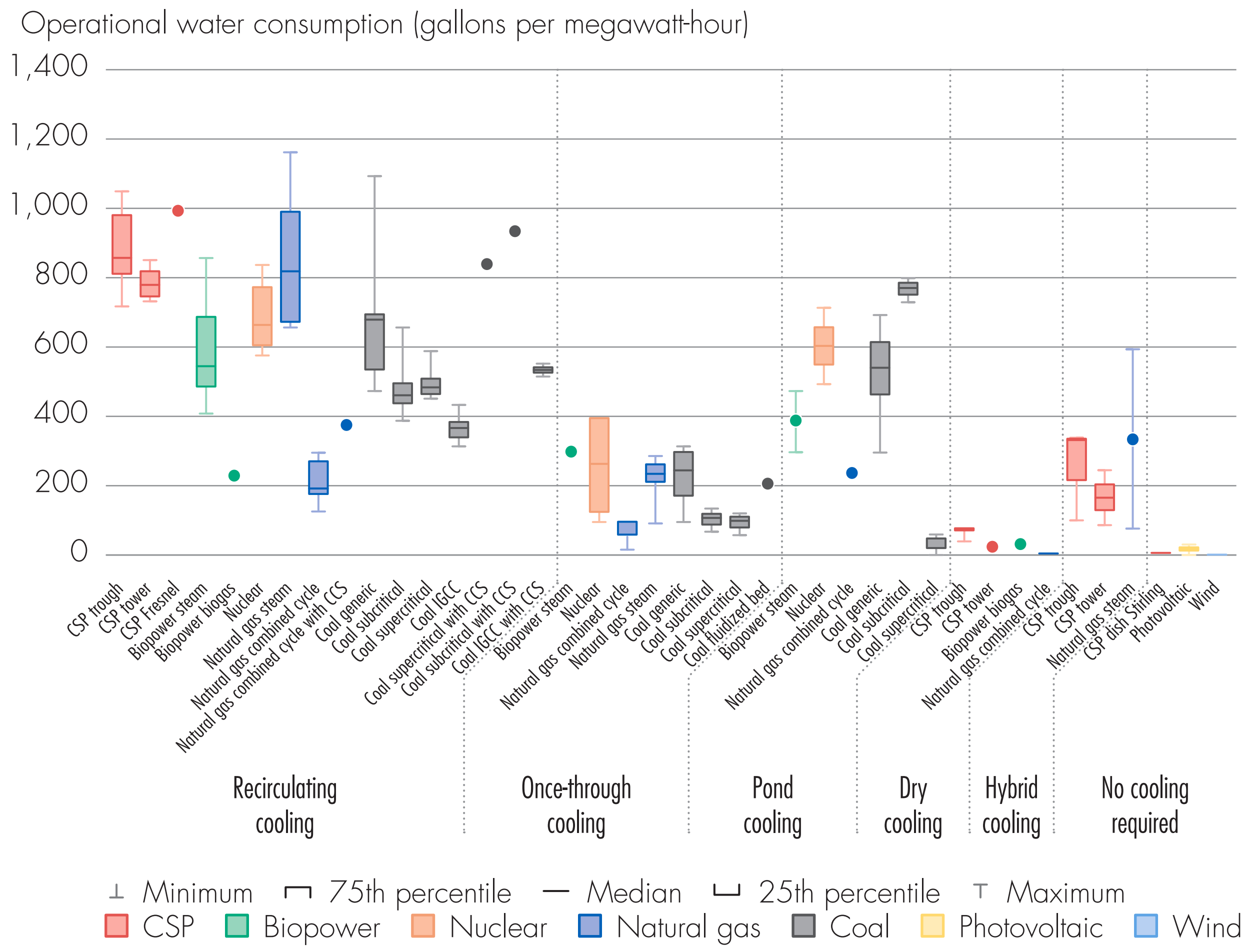
Energy-water nexus and the SE4All objectives

Energy can affect water security[3] elements such as access, safety, and affordability. Access to water can be jeopardized by insufficient or intermittent supply of electricity (or liquid fuel) for pumping, treating, and distributing water. Reliable and affordable access to energy can ensure continuous supply of the required quantities of safe water as well as wastewater treatment services. Improved energy access can also support the use of energy-intensive technologies, such as desalination or more powerful groundwater pumps, which are expected to expand rapidly as easily accessible freshwater resources are depleted (IRENA 2015).

In 2030, almost half of the world population will be living in areas of high water stress if no new policies are introduced (WWAP 2012) and the increased demand for energy could put additional pressure on already constrained water resources. With extraction of energy resources, such as oil, gas and coal, and unconventional sources such as shale and tar sands, water is required for acquiring, transporting, processing, and refining (Mauter et al. 2014; IEA 2012; Fry et al. 2012). Thermal power plants,[4] such as fossil fuel, nuclear, and concentrated solar power plants, require large amounts of water, mainly for cooling, depending on the type of cooling system (Rodriguez et al. 2013; NETL 2009; figure 6.3)[5]. So they are often placed near a water source (river, lake, or ocean). Solar power also requires water for washing collectors and panels. Hydropower can be generated only if water is available in reservoirs or rivers. Finally, feedstock production for biofuels may depend on irrigation (Stone et al 2010).

The energy sector not only withdraws and consumes water (box 6.1), altering water flow patterns and water quantities, but also generates substantial wastewater. Energy operations can greatly undermine water resources through post-production water discharge and possible contamination of aquifers during drilling (IRENA 2015). Water used during

Figure 6.3. **Operational water consumption factors for electricity-generating technologies**



Source: Macknick et al. 2011.

Note: CSP is concentrating solar power. CCS is carbon capture and sequestration; IGCC is integrated gasification combined cycle.

extraction and wastewater generated from energy production must be managed carefully to protect the environment and water resources in the long term. But under stringent regulations, wastewater treatment may add heavy costs.

Changing water supply patterns—due to unanticipated weather activity, reallocation of water resources into other sectors or new regulations—may constrain opportunities for power generation or energy extraction (IRENA 2015). Climate change is intensifying energy insecurity through changing rainfall and surface runoff averages, increased water temperatures, and greater probability of extreme weather conditions (US DOE 2013, van Vliet 2012). Water scarcity, variability, and quality can constrain or raise the cost of thermal power generation and energy extraction (although in most cases the cost of accessing water is small compared with the revenue generated). In the United States, several power plants have been affected by low water flows or high water temperatures (U.S. DOE 2013). In India, a thermal power plant had to shut down due to a severe water shortage (Rajput 2013). France has been forced to reduce or halt energy production in nuclear power plants during heat waves, due to high water temperatures threatening cooling processes (van der Elst 2011). Recurring and prolonged droughts are threatening hydropower capacity in many countries, such as Brazil (Barrucho 2013), China (Stanway 2011), Sri Lanka (Sirilal 2012). The likely consequences are alarming enough to require more accurate integrated planning tools urgently.

Box 6.1. **The difference between water withdrawn and water consumed**

To ensure that water-energy indicators are useful, it is important to understand the difference between water withdrawn and water consumed, as the amounts vary greatly.

Withdrawal is typically defined as the amount of water taken from a water source (such as lake, river, ocean, or aquifer). Consumption is the water not returned to the water body after use. Discharge is the amount of water returned to the water source, and its quality matters for environmental reasons. These requirements for and impacts on water resources can differ sharply depending on the type of process or technology employed.

Hydropower, for example, requires large quantities of water, but the water is only diverted and can be used downstream by other sectors, such as agriculture. However, depending on certain climate conditions, some water evaporates from the reservoirs. In biofuels, most of the water is consumed through irrigation, and a small amount is returned to the water body. In thermal power plants, large quantities of water are withdrawn for cooling, but most of the water is returned to the freshwater source. For example in the United States, the thermal power sector accounts for about 40 percent of total freshwater withdrawals, but only 4 percent of consumption (Maupin et al. 2014).

However, even if water use does not involve consumption, the timing of water releases and other water quality issues can have material impacts on other sectors or hinder other simultaneous use. This can raise trade-offs and potential conflicts with other water uses, particularly in water scarce regions and basins.

There are no simple solutions, as seen in the fact that raising the share of water-intensive RE sources, such as irrigated biofuels and thermal power sources,[6] can increase demand for water, exacerbating competition with other sectors and creating social tensions among users. However, greater use of RE sources that require small volumes of water, such as PV panels and wind energy,[7] could reduce energy's water needs (IRENA 2015; Liu et al. 2015). The state of Texas, for example, to cope with drought and the state's arid climate, has seen over 12 GW of wind energy plants installed (U.S. DOE 2014).

Similarly, increasing the share of hydropower may facilitate water access to other sectors if the multipurpose benefits of dams are developed. Hydropower planners are of course fully conversant with the energy-water nexus, and hydropower normally sees only small water consumption caused by evaporation from the reservoir. However, reservoir water can also be used for irrigation, water supply, flood control, and recreation. And while hydropower projects are sparse consumers of water, they may materially affect the quality of downstream flows (timing, route, and duration), stressing fish and other aquatic life (IRENA 2015). Run-of-river hydropower plants, which store no water, have water-evaporative losses near zero but are less likely to be used for generation of peak loads or during dry seasons. They can also have potential cumulative ecological impacts downstream.

Despite the potential losses from reservoirs, hydropower dams may increase water availability for downstream users when needed most, as during a drought. They may also be used to mitigate impacts from other extreme events such as floods—all of which underlines the benefits of joint planning for equitable, sustainable power and water infrastructure in river basins.

The impact of biofuels and biodiesel on water use varies substantially, depending on where the biofuel crop is planted, and whether it implies land conversion or land use changes, requires irrigation, or replaces a more (or less) water-intensive crop (Gerbens-Leenes and Hoekstra 2011; Stone et al. 2010). Ambitious plans in China and India to boost domestic production of biofuels could therefore place extra pressure on already scarce water supplies, if traditionally irrigated food crops are used to meet bioenergy targets. If biofuels are grown in rain-fed regions, however, they may have only a slight impact on water allocations. For example, in Brazil, where most sugarcane is rain-fed, a liter of ethanol requires only 90 liters of irrigation water to produce. But in India a liter of ethanol can take up to 3,500 liters of irrigation water (IWMI 2008). Again, plans and forward-looking assessments are needed.

Solar-based solutions can offer an alternative to grid- or diesel-based electricity for water pumping, water heating, and desalination, mitigating environmental impacts and in some places reducing energy subsidies. That is why, despite high capital costs and lack of established solar pump markets, India plans to replace 26 million groundwater pumps for irrigation with solar pumps. The drawback is that solar pumps can stimulate excessive (and unsustainable) water withdrawal given that operational costs are negligible (IRENA 2015). Solar water heaters are generally competitive with electricity- and gas-based heating and are making their way into emerging markets such as China (IRENA 2015). And although desalination based on solar energy is still expensive, moves like Saudi Arabia's Solar Water Desalination initiative will drive down costs and advance the technology, no doubt turning solar desalination into a competitive solution in the long term (IRENA 2015).

But beyond RE production increases, increased efficiency on the supply and demand sides must be maximized. On the supply side, one approach to enhancing efficiency is to shift from old, inefficient power plants to new and more efficient ones, both to save energy and water and to decrease greenhouse gas emissions. The amount of cooling water withdrawn and consumed by thermal power plants (with the same cooling system) is determined mainly by the power plants' efficiency (Delgado 2012). For example, old coal power plants with an efficiency of 25 percent may well require almost twice the amount of water of new coal power plants with an efficiency of 36 percent (with the same type of cooling system). Combined-cycle gas turbines (CCGTs) waste less heat per unit of electricity produced due to higher thermal efficiency, and so they require less cooling (IEA 2012). Water-use efficiency may also be improved by fostering water-efficient cooling systems in thermal power plants such as dry-cooling systems.[8]

All options carry a series of trade-offs, however: power plants with dry-cooling systems consume up to 90 percent less water than power plants with cooling towers (U.S. DOE 2014), but dry-cooled systems can cost 2–16 percent more than closed-loop cooled systems (Maulbetsch and DiFilippo 2006). Dry cooling also decreases the energy efficiency of the power plant, particularly in hot and dry climates. These trade-offs must be evaluated case by case, considering factors such as regional conditions, ambient conditions, and regulations.

On the demand side, energy efficiency gains—those, for example, from energy-efficient appliances and equipment and improved insulation—would decrease demand for energy, saving water (given that most energy generation requires water).

Increased energy efficiency in the water sector may cut the cost of delivering water and save water. Electricity costs usually stand at 5–30 percent of total operating costs for water and wastewater utilities. The share is usually higher in developing countries, where it might hit 40 percent or more. Such energy costs often contribute to high and unsustainable operating costs that directly affect utilities' financial health (ESMAP 2012). Finally, because treating and distributing water requires heavy energy consumption, leakage reduction is a cost-effective way to save not only water but also energy. And it is a solution often adopted alongside more efficient pumps (Barry 2007).

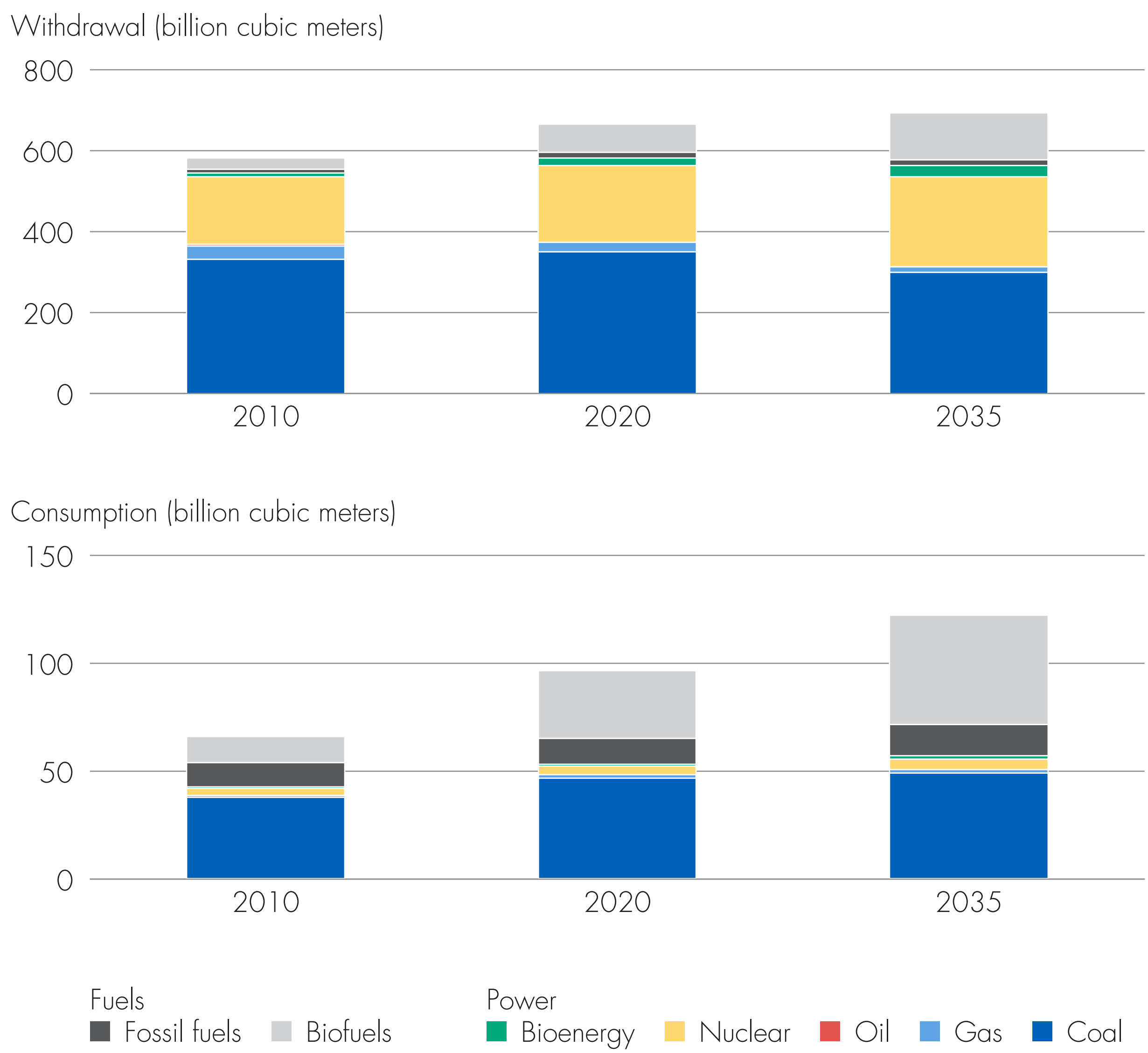
Existing indicators and challenges

Data open to the public on water use are usually statistics on water withdrawal and the volumes of wastewater. The Aquastat database of the UN Food and Agriculture Organization (FAO) is one of the most frequently used water data sets. Water withdrawals are tracked in the residential, industry, and agriculture sectors at country level. But for some countries, data sets may be limited, out of date, or nonexistent. In addition, the energy sector is lumped with the industry sector, making it impossible to estimate water withdrawals tied to power generation or to energy extraction. Water consumption data are not available, nor are estimates on water supply variability, which are critical for operations and planning across sectors (see box 6.1). Produced, collected, treated, and non-treated municipal wastewater is tracked at country level.

Most existing global estimates on the water needs of the energy sector are derived from assumptions. Some researchers use an average number of cubic meters per gigajoule (m^3/GJ) for each energy source, multiplied by projected future energy demand. Such average calculation is misleading, however, because water requirements vary greatly even within the same energy process or source. As seen, water requirements vary at all stages of energy operations and depend on several factors (including technology employed in energy generation and production, regional variable conditions such as climate, and efficiency of the process), and so there is no single "water factor" (water requirement per unit of energy produced) for a given energy process (Madani and Khatami 2015).

In 2012, the IEA published a set of macro-level indicators measuring global trends of global water use for energy production. Such measurements help capture upcoming changes globally, but are less useful for the operational and planning needs of, for example, developing countries alone (figure 6.4).

Figure 6.4. **Global water use for energy production in the New Policies Scenario by fuel and power generation type**



Source: IEA 2012.

Note: The New Policies Scenario refers to IEA's baseline scenario. For the difference between water withdrawal and consumption, see box 6.1.

To fully understand water requirements by energy source, lifecycle analysis should be adopted. IRENA (2015) argues that RE usually requires less water than fossil fuels based on a lifecycle assessment of water used in energy production. For example, a solar thermal power plant might require more water than a coal power plant to generate electricity (using the same type of cooling system). But because of the water needed for coal mining, the solar thermal process requires a lot less water. These vast differences have to be considered in analyzing and quantifying constraints.

The *World Water Development Report 2014* of the United Nations (UN) is a first attempt to gather indicators on the energy-water nexus. It argues that indicators are indispensable tools for establishing common ground for examining status, measuring progress, and planning targets (WWAP 2014). Its "Data and Indicators Annex" has 41 indicators, analyzing demographic statistics, global water demand statistics, and data on global energy supply by source and energy consumption, among other indicators. It has specific indicators on water and energy interactions, including "global water use for energy production by scenario," "indicative energy use of municipal water and wastewater services," and "energy requirements and cost implications of desalination by technology." These UN indicators are relatively complete, but still make it hard to identify energy-water hot spots. Moreover, most of the energy-water data are from other sources using global estimations with modeled averages. As said, this is not enough to begin to appreciate the challenge facing developing countries.

At a more micro level, indicators measuring companies' water risk due to variable supply and quality expose how business strategies have adapted to changes and uncertainties. Water risk indicators aim to highlight regional differences and complement data on water uses. Since 2010, the Carbon Disclosure Program (CDP) *Global Water Report* provides investors with information on how companies identify, manage, and mitigate risks and opportunities related to water. The CDP water questionnaire generates data for indicators on water risk, governance, accounting, and strategy (CDP 2014a). In 2014, 86 percent of utility companies and 82 percent of energy companies indicated that water was a "substantive risk" to business operations. Physical water risks such as water stress and floods presented the most prevalent water-related threat for utilities. Other water risks included a decline in incoming water quality, reputational damage, and regulatory uncertainty. In addition, 50 percent of utility companies and 41 percent of energy companies had experienced water-related business impacts in the reporting year (CDP 2014b).

Data gaps and required indicators

Reliable and comprehensive data on the energy-water nexus are scarce, inhibiting informed decisions on operations and investments and on monitoring them over the long term. Data on energy consumption and production by country are usually more abundant and accurate than data on water, as energy data often convey the importance of the sector to economic development, while conversely the central role of water is under-acknowledged. Even when energy data are collected in detail, those on water requirements or risks are patchy. Monitoring availability and use of water is a continuing challenge, especially given variable distribution of water over time and space, and given country differences in data availability of surface versus ground water. Water resource management and wider decision making are thus difficult, making it extremely hard to implement water-sensitive policies to improve energy access and efficiency.

One reason why it is hard in most countries to obtain water-related data from the energy sector (such as power plant operators, mining and oil extraction facilities) is that companies may not be legally required to report information on their water use and discharge. Critical topics suffer from data paucity, such as water withdrawn and discharged (thus consumed) by the energy sector, use of alternative water sources in energy (such as saline water and wastewater), and type of cooling system in power plants. Therefore making credible assumptions on the energy sector's water needs is problematic (Madani and Khatami 2015).

Hence it is recommended that governments request all energy production facilities to start reporting water-related information, in the same way that energy operators report on, for example, greenhouse gas emissions. Before that request, however, the number of energy companies disclosing their water use (withdrawal, consumption, and discharge) should be assessed, and context-specific information on the efficiency of power plants and water use (and its competing uses in, for example agriculture, industry, urban, and other sectors) should be gathered and analyzed.

As energy's environmental impact on water resources is rarely well documented, indicators on water use in energy processes should also consider that area—whether through companies withdrawing or discharging water at critical times, polluting water resources, or making other impacts. Indicators that focus solely on the amount of water used could incentivize unsustainable practices: for example, reducing the water withdrawn from a water source per unit of energy produced is not always better for the environment if the quality of discharged water prevents its future use, due to changes to temperature and chemical or sedimentary load of the water.

Indicators measuring sustainable water use are critical for the energy sector and should reflect region-specific challenges. Energy infrastructure is designed to last for decades. So decisions should consider future water availability, including climate change impacts, exposure to extreme weather events, and future competing water demands. Electricité de France is leading the Water for Energy Framework (W4EF), an official Action Group of the European Innovation Partnership on Water (EIP Water). W4EF is developing a common terminology and methodology to help energy actors assess and report on the relations between energy production activities and the local water environment, which requires going further than simple volume estimates. This framework will consider quantity and quality issues of water use and systematically relate use to the local conditions (EIP Water 2015). Such assessments are necessary for balancing trade-offs between water sustainability and energy production costs.

Definitions, metering, and measurements of energy by the water sector are rarely fully aligned. It is important, for instance, to rectify the mismatch of flow data for water and wastewater, as current end-use metering is not universal, and as not all wastewater is treated. Energy use per unit of water produced is used as an indicator, instead of water delivered, overlooking physical network losses (World Bank 2012b). Additionally, indicators capturing regional differences of water's demand on energy must be developed. In the United States, national water-related energy use is expected to increase as water-stressed states—like California, Florida, and Texas—shift to more energy-intensive technologies (Sanders and Webber 2012). In short, the economic value of water should be recorded in assessment tools.

Energy needs for water differ vastly, as energy use for water extraction, treatment, and transport depends on location, technology, and amount of water treatment necessary. At present, indicators aim to quantify both energy required to treat water—whether groundwater or surface water—and energy needed for water and wastewater service—whether pumping, distribution, or wastewater collection, treatment, or sludge disposal (World Bank 2012b). Yet operating conditions and processing technologies are often incomparable, due to differences including daily flow, length of water mains, and mix of water sources (World Bank 2012b). More energy-intensive water treatment processes, such as desalination, have energy use indicators for the different technologies involved (IRENA 2012).

Integrated policy and planning indicators are needed to inform country policies and help ensure sustainable and efficient use of water and energy resources. Such indicators could measure how governments plan and invest, whether they do so in an integrated manner that considers water requirements of different scenarios and alternative uses, whether water is a factor in decision making and in how the energy mix is selected, and whether water is considered at the planning stage or during project development. The Thirsty Energy Initiative by the World Bank, for example, aims to help countries to ensure a sustainable development of their water and energy resources breaking disciplinary silos and fostering cross-sectoral planning.

A first attempt to compile possible indicators for tracking the energy-water nexus across countries is shown in table 6.1 and are intended to stimulate discussions on a future nexus-tracking framework. It appears that most of these indicators have only limited data that would eventually enable consistent tracking over time. Data may be limited to only some countries, or not open to the public, or available mainly through self-reporting, driven by initiatives that encourage energy and water companies to respond to survey questionnaires.

Conclusion

If achieved, the SE4All objectives can improve water security. But they cannot be met unless water aspects are properly addressed and incorporated into the planning and implementation of energy investments. The water sector can benefit from moving toward the SE4All objectives by improving access to reliable, affordable, and safe water supplies. Yet meeting rising energy demand may have a

Table 6.1. **Possible indicators for tracking the energy-water nexus at country level worldwide**

Component	Indicator	Data availability	Current or potential source
Impacts of energy on water access	Water (m^3) pumped/treated/distributed/desalinated by energy source/technology (if off grid)	Limited data at utility level	
	Shutdown time (hours) and operational losses ($) due to energy-related issues (at the water utility level)	No public data	
Energy requirements of the water sector	Energy intensity (GJ/m^3) and unit cost ($/m^3$) by energy source/technology (if off grid) of drinkable water/treated wastewater/desalinated water	Limited data at utility level	*World Water Development Report* 2014
	Energy intensity (GJ/m^3) and unit cost ($/m^3$) of water heating by energy source/technology (if off grid)	No data	

(continued)

Table 6.1. **Possible indicators for tracking the energy-water nexus at country level worldwide** *(continued)*

Component	Indicator	Data availability	Current or potential source
Water requirements of the energy sector	Water (m^3) withdrawn/consumed/discharged by energy source (and cooling technology) at the energy production facility level	Limited data	IEA 2012/ Carbon Disclosure Program (CDP)
	Number of operating power plants by energy source and cooling technology	Limited data	IEA 2012/CDP
	Intensity of water withdrawn/consumed/discharged (gallons per megawatt-hour) by energy source at the energy production facility level—disclosing type of cooling system (for thermal power plants), type of water used (freshwater, saline, wastewater, other) and regional climate	Limited or no public data	CDP/Water for Energy Framework (W4EF)
	Yields (kilograms or hectares) and water requirements (m^3) for major biofuel crops (at the country level)	Limited data	FAO
	Cost of water withdrawn ($/liter) for the energy sector (by energy facility)	Limited or no public data	
	Number of energy companies disclosing their water use (withdrawal, consumption, discharge) and water risks	Limited data	CDP
Impacts of the energy sector on water resources	Percentage of water treated prior to discharge at the energy production facility level	Limited data	CDP
	Number of aquifers contaminated during drilling related to energy extraction	Limited data	
	Number of energy extraction facilities that recycle water	Limited data	
	Percentage of available water (in the water body) used by energy activities	Limited data	W4EF
	Water stress levels prior and after the establishment of energy activities	Limited data	W4EF
Water risks for energy companies	Percentage of energy companies considering water-related issues as a major risk to business operations	Limited data	CDP
	Percentage of energy companies that have water risk assessment	Limited data	CDP
Integrated policy and planning	Perceived change over the past 20 years in the importance of water for energy by country governments (percentage scale, from significant decrease to significant increase)	Limited data	UNEP 2012
	National energy policy/strategy/plan with water resources management component (percentage scale; water resources management ranked from not relevant to fully implemented)	Limited data	UNEP 2012
	Water requirements and water sustainability considered at planning stage or during project development (yes/no)	No data	
	Percentage of energy companies with water integrated into their business strategy	Limited data	CDP

negative impact on water resources as water supply is necessary for most energy production processes. Thus water-related risks could well affect the energy sector and hinder progress to the objectives.

Nexus indicators measuring inter-sectoral links are necessary for optimizing management of water and energy resources, as the international community lacks a common language and methodology to assess water use by the energy sector. Data on water-related risks (actual or perceived) facing energy companies should be accompanied by indicators tracking integrated policies and planning processes. Indicators should be used together to reveal the full effect of an energy development decision—avoiding unintended outcomes and degraded water resources—and to feed into policies that are contextualized to enhance their utility and relevance. Improved information could also drive technological innovation, which would also help improve efficient and integrated management of water and energy resources.

Energy and food security

Introduction

Any assessment of the links between energy and food security requires an understanding of what food security means. The internationally agreed definition states that "Food security exists when all people, at all times, have physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life" (World Food Summit 1996). Based on this definition, food security has four dimensions, which need to be fulfilled simultaneously:

- *Availability:* Availability of sufficient quantities of food of appropriate quality.
- *Access:* Whether households or individuals have enough resources to acquire enough, quality food. It encompasses income, expenditure, and buying capacity of households or individuals.
- *Utilization:* Concerns the nutritional outcome of the food eaten by an individual. It is appropriate and optimum only when food is prepared and cooked properly, diversity of diet is adequate, and proper feeding and care are practiced. Thus having enough energy to cook food for a long-enough time matters.
- *Stability:* Stability of the other three dimensions over time. People cannot be considered food secure until they feel so. Major factors affecting stability are swings in market prices of staples, inadequate capacity to bear adverse conditions (such as natural disasters or bad weather), political instability, and unemployment.

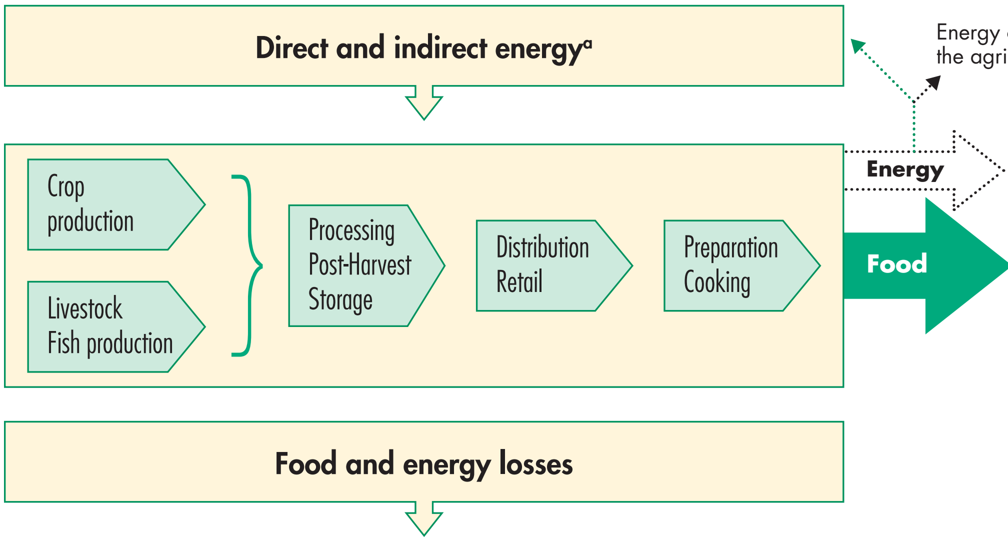
Energy—direct and indirect—is essential to all steps of the agrifood chain: in both the agricultural stages, for crops, fish, livestock, and forest products; and the postharvest stages, including food storage and processing, transport and distribution, and preparation (figure 6.5). Direct energy includes electricity; mechanical power; and solid, liquid, and gaseous fuels. Indirect energy is that required to manufacture inputs such as machinery, farm equipment, fertilizers, and pesticides. Agrifood systems not only are energy consumers, but can also produce energy, helping improve energy access.

Relying on cheap fossil fuels, modernized agrifood systems have increased food security over the last several decades. Energy from fossil fuels has further mechanized farm activities, food processing, and transport, helped expand irrigated land areas, and expanded use of inorganic fertilizers (FAO 2011, 2012). Yet the global food sector's dependence on fossil fuels is a concern, amid projections that food production will rise by 70 percent by 2050 compared with 2005–07 levels (FAO 2012).

Food prices are often influenced by energy prices given energy's large share in production costs in most farming (figure 6.6). After world oil prices surged in 2007 and 2008, higher food prices hit food access, leading millions of people into food insecurity, and worsening conditions for the many who were already food insecure (FAO 2012).

Agrifood systems consume 30 percent of the world's energy; 70 percent is consumed beyond the farm gate. Energy use per capita for food and agriculture amount to 35 GJ per year (nearly half in processing and distribution) in developed countries, but only 8 GJ (nearly half for cooking) in developing countries (FAO 2012, figure 6.7). Agrifood systems produce about 20 percent of the world's greenhouse gas emissions,[10] with the largest share attributed to livestock. Yet over one-third of the food produced is lost or wasted, and with it about 38 percent of the energy consumed in the agrifood sector. In low-income countries, food losses occur mainly during harvest and storage, while in high-income countries, food waste

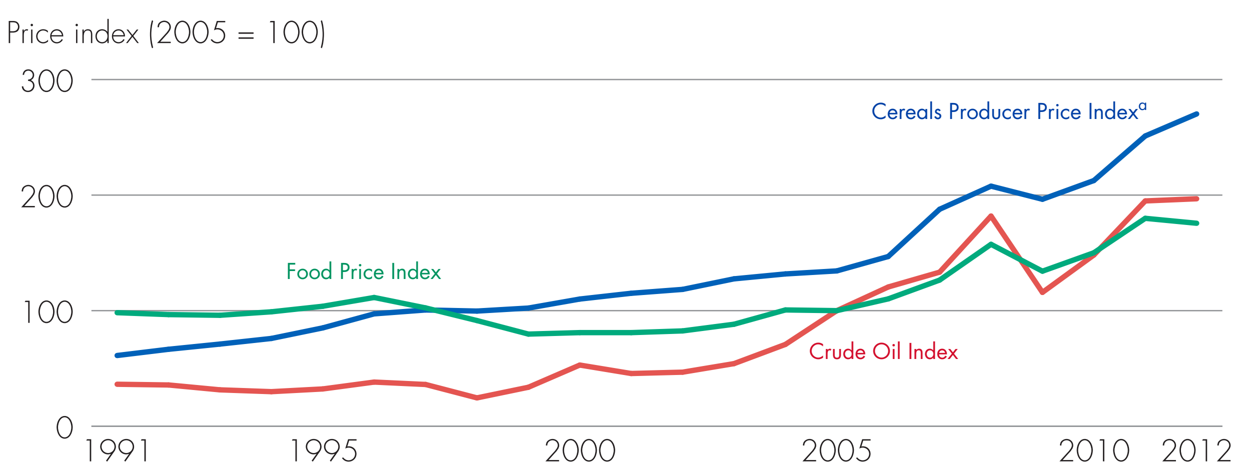
Figure 6.5. **Energy to and from the agrifood chain**



Source: FAO 2012.

a. *Direct energy* includes electricity, mechanical power, and solid, liquid, and gaseous fuels, among other sources. *Indirect energy* refers to the energy required to manufacture inputs such as machinery, equipment, fertilizers, and pesticides.

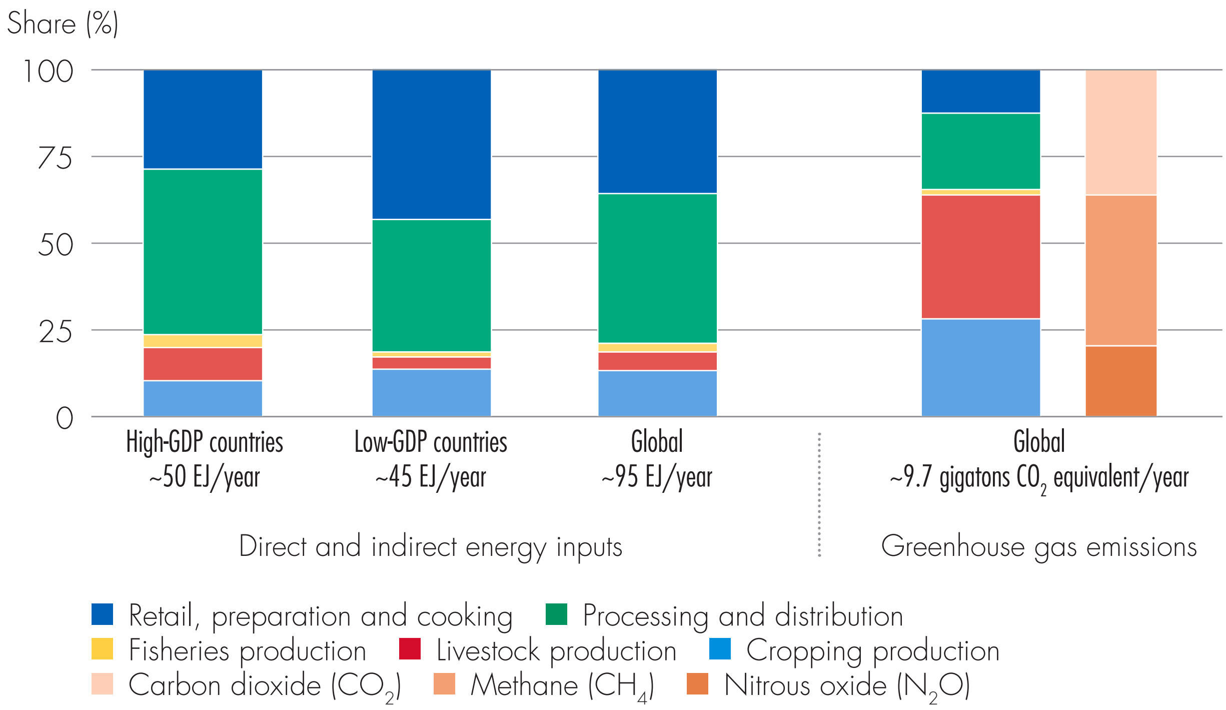
Figure 6.6. **Comparative trends of food, crude oil, and cereals price indices, 1991–2012[9]**



Source: The Commodity Food Price Index and the Crude Oil (petroleum) Price Index are from IMF 2014. The Total Cereals Producer Price Index is from FAO 2015. For details, see endnote 9.

a. Based on a value of 100 for 2004–06.

Figure 6.7. **Energy consumption and greenhouse gas emissions in the agrifood chain**



Source: FAO 2011.

occurs mainly during the retail, preparation, cooking, and consumption stages (FAO 2012).

Energy-food nexus and the SE4All objectives

Universal access to modern energy services in agriculture can help increase food supply through higher productivity via, for example, greater use of water pumps in irrigation, mechanization, and fertilizers. (Mechanized production also often reduces food losses.) It may also improve the livelihood of subsistence farmers and fishers, and lift small farmers' incomes, again via greater productivity. New opportunities for income generation may emerge from increased irrigation capacity and improved crop processing and storage (FAO 2012). Universal access to modern cooking solutions and refrigeration can vastly raise food quality and nutrition, at household level through longer cooking time and frequency, and food conservation.

Greater access to energy may, however, put more pressure on natural resources. Access to electric water pumps raises the chances of depleting underground aquifers, and causing water runoffs and erosion, which could reduce yields and put food stability at risk in the long run. Yields can in fact be sustainably increased in other ways, including good soil management, organic fertilizers, and minimum tillage. Similarly, the link between the embedded energy used in the manufacture of inputs and production or even yields is not obvious, while more mechanized agriculture and greater use of fertilizers and pesticides may deteriorate soil condition.

RE in agrifood systems can replace fossil fuels and help decouple food prices from fossil fuel prices, replacing fossil fuels and leading to energy cost savings in the long run. On-site power generation (solar, wind, or biogas) can cut electricity costs, facilitating post-harvesting operation. Greater liquid biofuel production can reduce dependence of fossil fuels for land management and transportation. Increased production of biofuels can also increase and diversify farm income. Excess energy can be sold outside the farm. For example, recent findings show that bioelectricity could provide almost 40 percent of Cameroon's electricity consumption (including agrifood industries) without compromising national food security (Ackom et al. 2013; IEA 2014). Biogas coproducts can also help raise yields.

The production and use of biofuels is increasing around the world as countries seek to diversify their energy sources, while promoting economic development, energy security, and environmental sustainability. Modern biofuels can provide multiple benefits, including promoting rural economic development, increasing household income, mitigating climate change, and providing access to modern energy services.

One disadvantage of biofuels is that any quality change or price fluctuation is likely to affect the sustainability of such a system (IRENA 2015). A reliable and affordable feedstock supply is thus a key factor. Another drawback is that a sharp increase in biofuel production may have a negative effect on food availability due to increased competition, because the production and use of energy crops may cause biodiversity loss, deforestation, additional pressure on water resources, and increased demand for agricultural inputs, land, and commodities.

Unless they are harvested sustainably, reliance on solid biofuels such as wood fuel or charcoal can degrade forests and destroy water catchments used for other activities, affecting local livelihoods. Time spent in gathering cooking and heating fuels may also rise when the local population needs to walk further.

Energy efficiency in the agrifood chain usually has a positive effect on economic returns of food production in the long run through savings on energy costs. New technologies and practices, such as energy-efficient engines for farm machinery and minimum tillage can reduce the use of fossil fuels while maintaining a stable food production. Biogas production, using animal waste and manure, increases the overall energy efficiency of meat production, while providing low-cost fertilizers that help increase yields sustainably.

Energy-efficient cookstoves may allow for longer cooking times and improve nutrition outcomes, as they have high heat transfer and thus need less fuel, directly translating into lower household outlays on fuel or time spent collecting it.

Conversely, energy efficiency in the food chain may be undermined by increasing long-distance food transport. Although international food trade can help mitigate domestic food price volatility, it also raises "food miles"—the distance that food travels from where it is grown to where it is ultimately consumed—and associated pollution.

Existing indicators and challenges

A pragmatic approach in two steps is proposed for national targets and indicators for the energy-food security nexus. Both require heavy efforts in developing methodologies, gathering data, and building capacity.

1. Start with targets and indicators that, while capturing all types of energy inputs and outputs from agrifood chains, are currently measurable. These concern primarily fossil fuels inputs to "behind the farm gate" operations; traditional wood fuel use; and changes caused by bioenergy development on the supply and prices of national food basket elements.

2. Complement these indicators with important information on energy currently not measured by national statistics. These include energy used to manufacture agrifood chain inputs; energy used beyond the farm gate (such as in the food cold chain); and RE produced along agrifood chains.

Partial measurement of the energy-food security links can be measured through indicators related to fossil fuel use in agriculture, using current data. Data on energy use can be combined with data on arable land area, the value of agricultural output, and the calorie equivalent of output. All three can be developed with data from FAOSTAT[11] and FAO Food Balance Sheets, generating three energy intensity indicators on fossil fuel used on farms:

- Direct use of fossil fuel energy in agriculture per hectare of arable land (possibly differentiated by agricultural product) (in J/ha).

- Direct use of fossil fuel energy in agriculture per unit of value of output (J/$).

- Direct use of fossil fuel energy in agriculture per unit of calorie of food produced (J/cal).

The value of capital stock of machinery per unit of arable land, available from FAOSTAT, can be used as a proxy indicator of agricultural mechanization. Indicators on fossil fuel use in agriculture should be normalized by mechanization levels, that is, levels of capital stock of machinery per unit of arable land. A combination of such normalized indicators should capture the efficiency of energy use in agriculture.

Access to cooking fuel can be measured using cooking fuel distribution across households. The role of energy in the food utilization and quality dimensions (see the start of chapter) could be approximate with an indicator measuring access to different cooking fuels. Access to fuel-efficient cooking solutions may be reflected through an indicator measuring cooking time to ensure food quality.

Measurement of the effects of bioenergy on food price and supply can reflect the links between RE and food security. The only internationally agreed indicator on these links is on the effects of bioenergy use and domestic production on the price and supply of a national food basket. This indicator is part of the Global Bioenergy Partnership sustainability indicators (GBEP 2011), whose practical applicability is still being tested.

Meeting the SE4All objectives, given their multifaceted links to food security, can make a critical contribution to achieving the Zero Hunger Challenge program of the UN Secretary General. This program aims to achieve 100 percent access to adequate food all year round; zero stunted children under two years of age; sustainability of food systems; 100 percent increase in smallholder productivity and income; and zero loss or waste of food.

Data gaps and required indicators

Any attempt to comprehensively measure energy-food links requires national data on use of energy to manufacture agricultural inputs, on energy use beyond the farm gate, and RE for and from agrifood chains, including the cold chain. Further needed indicators include energy used in agrifood systems (including postharvest stages) and energy intensity per economic value of production; amount of RE produced by agrifood systems; changes in food prices; and farming or land income/revenue impacts of access to modern energy services.

A nexus-assessment methodology has been developed under the SE4All High Impact Opportunities in Sustainable Bioenergy and the Water-Energy-Food Nexus.[12] The nexus assessment methodology aims to help governments and investors address water, energy, and food/land demand in an integrated way. It starts by raising awareness on possible trade-offs and synergies between these sectors. It then uses index matrices to assess the pressure on the nexus factors, including energy, water, food, income, and labor. Finally, it proposes a simple way to assess the performance of specific interventions from a nexus perspective and how they should be assessed against the context status.

A first attempt to compile possible indicators for tracking the energy-food nexus across countries is shown in table 6.2. These are intended to stimulate discussions on a future "nexus-tracking" framework.

Conclusion

There is increasing consensus that agrifood systems have to become "energy smart" (see just below) to meet future energy and food challenges. A shift to energy-smart agrifood systems would involve greater use of RE sources and energy efficiency technologies, while integrating food and energy production, to reduce dependency on fossil fuels and build resilience against energy price fluctuations. This shift should also improve productivity in the food sector, reduce energy poverty in rural areas, and help achieve goals for national food security, climate change, and sustainable development (FAO 2012).

FAO has launched the Energy-Smart Food for People and Climate Program, a multi-partner initiative to assist member countries make the shift. The Program focuses on improving: energy efficiency in agrifood systems, use of RE in these systems, and access to modern energy services through integrated food and energy production. The Program follows an interdisciplinary "nexus" approach.

A substantial effort in methodological development, data gathering, and capacity building will be required to measure the energy and food nexus indicators. Beyond measurement of direct fossil fuel use in agriculture, additional indicators are required for monitoring RE production and use by the agrifood sector, including biofuels, as well as indirect energy inputs. Energy intensity should also be tracked. All indicators need to capture national circumstances and capacities.

Energy and health

Introduction

Energy is a prerequisite of good health and a source of many serious health risks, notably air pollution. It offers multiple health benefits by ensuring clean water, improving food quality and nutrition through cooking and refrigeration, and enabling health facilities to improve delivery of health services. However, dirty fuels and inefficient technologies generate air pollution. Poor planning of, for example, housing and urban transport can also increase air pollution. Optimizing the health benefits of energy access,

Table 6.2. **Possible indicators for tracking the energy-food nexus at country level worldwide**

Component	Indicator	Data availability	Current/ potential source
Energy use for food production	Direct use of fossil fuel energy in agriculture per hectare of arable land (by agricultural product) (J/ha) per unit of value of output (joule/$) per unit of calorie of food produced (joule/calorie)	Yes	FAO
	Energy inputs in agrifood chains (beyond farm gate), by type of energy source	Limited public data	UNSD, IEA
	Energy intensity in agrifood systems per economic value of production	Limited public data	UNSD, IEA, FAO
Energy use for cooking	Percentage of people using modern cooking solutions as primary cooking solution	Yes[a]	USAID, WHO
Energy produced by the agrifood sector	Energy output across the agrifood sector by type of energy source	No data	FAO
	Correlation rate of changes in price and supply of a national food basket and changes in domestic biofuel production and use	No data	FAO

a. The available data track solid versus non-solid fuels.

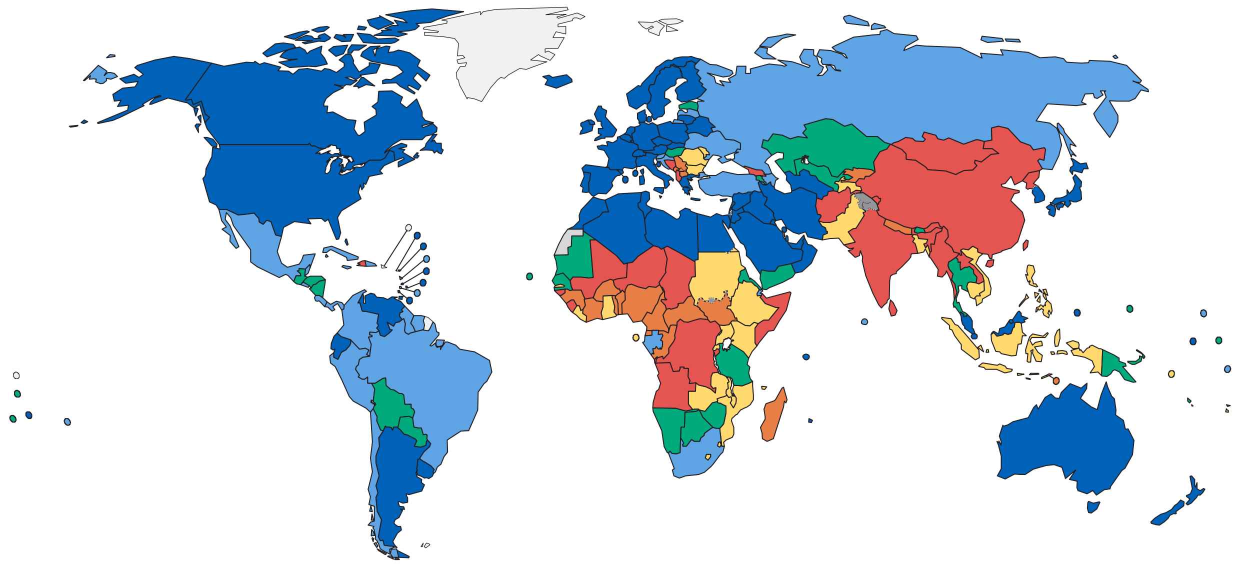
efficiencies, and use of renewables, while minimizing energy-related risks, is thus critical to achieving the SDGs of the SE4All initiative.

The greatest single health risk along the energy nexus is air pollution. Outdoor (ambient) and indoor (household) air pollution are responsible for about 7 million premature deaths annually, making air pollution one of the largest single causes of premature mortality and morbidity worldwide (figures 6.8 and 6.9). Inefficient production, use, and distribution of energy services compound polluting emissions. Energy risks to health are thus closely associated with the built environment, and in the way we produce and use energy at household, community, and urban levels.

Besides air pollution are many other health risks associated with a lack of modern energy access or inefficient energy use. Reliance upon rudimentary solid fuel cookstoves or kerosene lamps, for instance, can be a factor in domestic injuries such as burns or poisonings. Energy-inefficient buildings and homes not only require more heat and power, but also leave occupants more exposed to extreme weather, placing vulnerable groups, such as the elderly, at increased risk of heat stress and heat-related stroke or, conversely, hypothermia (WHO 2011). Increased incidences of asthma, allergy, and respiratory illness are also associated with chronic damp and cold housing conditions that are more common in energy-inefficient dwellings and affect more the poor, elderly, and children. In urban areas, physical inactivity and pedestrian traffic injury rates tend to be higher when public transport systems are weak and inefficient, leaving people reliant on private motor vehicles, which burn more energy and produce more air pollution per unit of travel than efficient rapid transit modes (Hosking, Mudu, and Dora 2011).

Modern energy provision is a critical enabler of universal access to health care and universal health coverage. Although the world's attention on the need for expanded access to life-saving interventions has focused on skilled care, essential medicines, and medical technologies for priority diseases and health conditions, less attention has been given to energy's vital role as an enabler of health care delivery. Without energy, many life-saving interventions cannot be undertaken, and essential medical devices and appliances for prevention, diagnosis, and treatment cannot be powered. Yet data and anecdotal examples indicate that even the most basic modern energy services are often unavailable in thousands of facilities across the developing world. One study covering 11 countries in Sub-Saharan Africa found that on average one in four health facilities had no access to electricity and that 34 percent of hospitals had unreliable access to electricity[13] (Adair-Rohani et al. 2013).

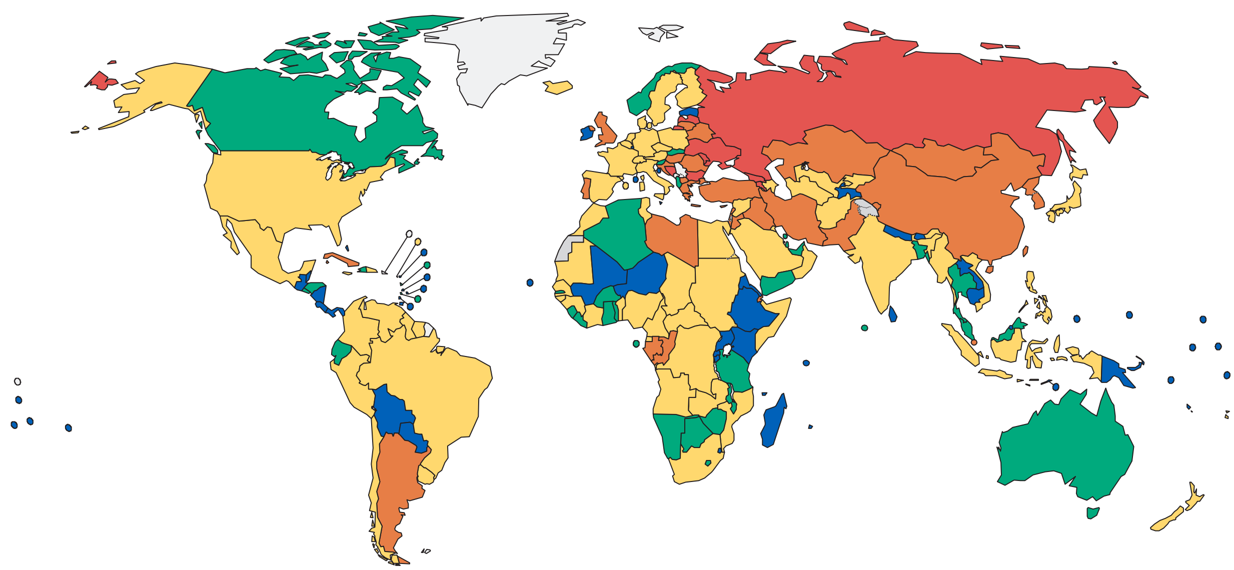
Figure 6.8. **Deaths attributable to indoor air pollution from solid fuels, 2012**



Deaths per 100,000 population
- 0–5
- 6–29
- 30–49
- 50–69
- 70–89
- 90 or more
- Data not available
- Not applicable

Source: WHO.

Figure 6.9. **Deaths attributable to outdoor air pollution, 2008**



Deaths per 100,000 population
- 0–5
- 6–10
- 11–20
- 21–40
- More than 40
- Data not available
- Not applicable

Source: WHO.

Health sector energy needs of low- and middle-income countries are expected to grow steeply: needs for vaccine cold storage space are slated to grow eightfold or more in coming decades (PATH-WHO 2008). The growing need to fight non-communicable diseases, which requires complex interventions, will drive additional energy requirements (such as those of imaging equipment for cancer detection) (WHO and World Bank 2014).

Energy-health nexus and the SE4All objectives

Universal access to reliable and affordable modern energy solutions can greatly reduce the burden of diseases associated with indoor air pollution, burns, and poisonings. Increasing access to and sustained adoption of clean cooking solutions—such as liquefied petroleum gas (LPG), natural gas, electric induction stoves, and biogas[14]—would reduce the long-term exposure to health-damaging pollutants[15] created by inefficient open fires and to traditional solid biofuel and coal cookstoves. These exposure reductions would decrease the burden from cardiovascular disease (ischaemic heart disease) and respiratory disease (such as childhood pneumonia, chronic obstructive pulmonary disease, or lung cancer) as well as stroke. Use of clean and safe cooking solutions will also reduce the risk for burns, scalds, and poisonings. By replacing polluting and dangerous kerosene lamps with electric lighting, health risks related to exposure to indoor air pollution, burns, and poisonings can be reduced.[16] Similarly, increasing access to modern energy heating services will reduce health risks linked to indoor air pollution and safety risks from inefficient space heating —common in low- and middle-income households— and such risks tied to inadequate and unsafe indoor temperatures.[17]

More reliable energy access in health facilities can significantly enhance health care provision. It can provide lighting, power medical devices, and enable refrigeration for blood and vaccines. Electricity access seems to have a notable impact on some key health service indicators, such as prolonging nighttime service provision, attracting and retaining skilled health workers (especially in rural areas), and providing faster emergency response, including for childbirth. Electricity access also enables mobile-health and telehealth applications and facilitates public health education and information. Thermal energy is also critical for space and water heating, sterilizing medical equipment, and incinerating medical waste safely.

RE can reduce indoor air pollution. PV power can significantly reduce indoor air pollution as it provides a nonpolluting alternative to kerosene-based lighting in households and health facilities. Fuels such as ethanol and biogas have a high supply potential, low carbon and pollution emissions, and broad social acceptability. Millions of households in countries such as China and Nepal already use biogas produced from livestock manure, agriculture waste, and other raw materials as a cooking fuel, replacing coal and wood. In rural homes, the domestic biogas digester systems also use fecal sludge from household latrines, in an onsite waste management system.

Passive solar design and active solar thermal or solar PV systems can support space heating, space cooling, and hot water for homes and health facilities (WHO 2011). For space and water heating, rooftop-based thermal solar water heating systems and advanced biomass heating stoves of the kind common in northern latitudes' developed countries (such as sealed pellet stoves) also support sustainable energy and health goals (WHO 2011).

RE sources powering medical devices may improve delivery of health services, particularly in the most remote settings. New portable, low-energy direct current medical devices are being introduced for simple procedures such as ultrasound or blood oxygen measurement, and they can also operate from PV solar power panels. LED-illuminated microscopes and direct current vaccine refrigerators can store solar energy in freezer packs, rather than a battery, thus avoiding the costs of battery maintenance and replacement. Increased access to such portable devices is creating new opportunities to improve health care delivery even in the most remote settings, where PV solar power systems are increasingly available. Small and medium PV power arrays can usually cover lighting, communications, and a few basic medical devices or one water pump. For facilities with higher energy requirements, hybrid systems combining PV solar and fuel-based generators can provide a generator boost during peak power demand, saving fuel when solar power is available (USAID 2013; Anayochukwu and Nnene 2013).

A transition to RE sources should gradually reduce occupational respiratory diseases, injuries, and cancers related to fossil fuel extraction (such as coal mining or oil refining). More immediately, it will reduce indoor air pollution in small shops, workshops, and off-grid cottage industries that now rely on kerosene lamps or portable diesel generators. Solar-powered electricity may also raise workers' productivity in these places. Even so, production and use of RE also create new hazards and risks, such as those from dust particles generated in production of silicon PV solar panels and the risk of falling from wind power installations.

Health can be improved by increased urban energy efficiency. This entails compact cities with efficient rapid transit systems with dedicated roads or tracks, walkable mixed-use neighborhoods with services close to homes, and more energy-efficient housing and buildings. Cities are a critical nexus point in the built environment where public health benefits from greater energy efficiency, as over two-thirds of global energy consumption is in urban areas (IPCC 2007). Energy efficiency in housing and transport can be optimized through more compact, "smart" urban design that yields a range of health benefits including, for a start, lower air pollution. In this approach neighborhoods are closer to services, making it easier to walk and cycle, and employment centers or other city center destinations are clustered, enabling better public transport. Partly due to such features, mid-rise European cities are among the most energy-efficient cities. Conversely, low-density North American cities are among the heaviest users of energy, particularly in transport (Hosking, Mudu, and Dora 2011).

Infrastructure investments in energy-efficient rapid transit, including pedestrian and bike systems, encourage healthy active transport and support mobility of vulnerable socioeconomic groups that lack access to cars, protecting them far more from traffic injury. The benefits of safe access to energy-efficient urban transit and pedestrian/bike lanes can be enjoyed very broadly. This is because a high proportion of trips in low-income countries are on foot or by public transport. And many groups—including women, children, the elderly, and people with disabilities—make many local trips, often by foot or bicycle. High rates of urban walking and cycling not only drive reductions in energy use for transport and consequent urban pollution, but also help decrease obesity risks through more physical activity.

Energy efficiency gains through housing structures and design features improve inhabitants' health. Housing thermal envelopes better protect occupants from cold- and damp-related illnesses and allergies. "Daylighting" can improve mental health. Good landscaping and natural ventilation for cooling reduces the need for air conditioning, which is energy intensive, produces noise harmful to health, and can exacerbate transmission of infectious bacteria and allergens. Housing energy efficiency measures and green building certification labels need to consider health parameters as, for instance, weather-proofed buildings that restrict ventilation too greatly can be unhealthy insofar as they may allow the buildup of indoor air pollutants. Ensuring use of non-toxic insulation and building materials is also critical for health, along with consideration of energy efficiency ratings.

Energy efficiency gains and health benefits can be maximized through multiunit housing, a feature of more compact cities that is typically more energy efficient than low-density housing of the same building style and standard. Compact housing forms—including mid-rise, multiunit buildings with shared walls—are more energy efficient than stand-alone structures of similar size and quality. Compact urban housing forms also lend themselves more readily to district heating systems or combined heat and power (CHP) cogeneration[18] (WHO 2011) and to efficient provision of sewage and sanitation, power, and waste management.

With very high-rise structures, some energy efficiency gains from greater housing densities may be offset by increased power requirements of large elevator systems and heating, ventilation, and air conditioning. This is because natural ventilation is more complex in such environments. Young children can also face barriers against moving safely and independently, as they are dependent on elevators, restricting physical activity.[19] In very low-rise buildings in sprawling neighborhoods, adolescents often lack access to public transport and depend on their parents for personal mobility (WHO 2011).

CHP cogeneration can provide a reliable and more energy-efficient form of electricity and thermal energy to institutional and commercial buildings than the grid (IPCC 2007). Nowhere is this reliability more important than in the hospital sector, one of the largest building energy consumers in high-income countries. Many hospitals across North America and Europe—as well as some in emerging economies (such as Brazil and India)—have adopted CHP technologies to reduce energy expenses, protect vital health care services from extreme weather and chronic grid failure, and reduce environmental emissions (WHO and World Bank 2014; Carbon Trust 2013). Such technology may play a key role in the fast-growing global health sector of low- and middle-income countries.

Existing indicators and challenges

WHO's Global Household Energy Database has data from over 800 household surveys in 157 countries and has been updated annually for over a decade from national household surveys and censuses.[20] These health and energy statistics are used for monitoring health impacts of energy access policies and programs at national, regional, and global scales.

The share of the population relying primarily on solid fuels for cooking, whose value comes from this database, serves as a useful proxy to measure exposure to household air pollution. This indicator fails, however, to consider the full range of health impacts resulting from lack of modern heating or lighting and from use of non-solid fuels like kerosene. Nor does it reflect practices of fuel and technology "stacking"—the parallel use of modern cooking fuels, such as LPG, with, for example, less efficient solid fuels.

The burden of disease from indoor air pollution exposure is estimated from data on primary household cooking fuel use by country (from the Global Household Energy database) in association with multi-country studies of average air pollution concentrations in homes where such fuels are used (WHO 2014a). Based on those exposure estimates, estimates of premature mortality and morbidity from cardiovascular disease, stroke, and cataract and respiratory diseases are made, using risk estimates based on epidemiological meta-analysis or dose-response curves integrating exposures to fine particulate matter (particles less than 2.5 micrometers in diameter) ($PM_{2.5}$) across combustion sources (for example, second-hand smoke) and location (for example, an outdoor environment).

Data on outdoor air pollution for some 1,600 cities are collected in WHO's Ambient Air Pollution in Cities database[21] and are regularly updated with new air quality measurements. But gaps remain: fewer than a dozen cities in Africa have air quality monitoring systems, and many major cities in Latin America and Asia also lack them. There are problems with data quality due to frequent breakdowns in monitoring equipment as well as problems with transparency (such as conflicting data reporting from civil society and official sources) and locations of data collection. Only 12 percent of the world's urban population lives in cities that meet WHO guideline levels for air pollution, and most developing cities of the world have $PM_{2.5}$ annual average concentrations several times higher than the WHO guideline level of 10 micrograms per cubic meter ($\mu g/m^3$).

WHO regularly estimates the burden of disease from exposure to outdoor air pollution of $PM_{2.5}$ exceeding its air quality guidelines. WHO's global estimates are calculated using information from satellites combined with data from chemical transport models, which are calibrated using ground-level measurement data. WHO then examines exposure estimates to air pollution worldwide and by region, combined with excess risks estimated by an integrated dose-response curve, to estimate disease incidence at the corresponding ambient $PM_{2.5}$ concentrations. WHO is improving the model to increase the depth and breadth of ground-monitoring data worldwide and the resolution of satellite imagery.

An important indicator of energy access is being developed by the World Bank and WHO: electricity access in health facilities. Data on electricity for about 20 developing countries are available in a WHO Health Facility Energy Access database. Data held in that database come primarily from the two most common and comprehensive health care facility surveys administered at country level: the U.S. Agency for International Development's (USAID's) Service Provision Assessment and WHO's Service Availability and Readiness Assessment (SARA). Those surveys have traditionally referred to a small set of questions on whether electricity is available; whether it is from a grid, a backup generator, or another source; and whether the generator has fuel and is functioning. Recently the SARA survey questions were expanded to include more detailed questions. These now include all the types of primary and backup electricity sources used; the reliability of electricity supply; and a rough indicator of the quantity of power available (whether power is enough for lighting only, enough for lighting and one or two medical devices, or enough for all facility needs).

Data gaps and required indicators

Indicators measuring household air pollution caused by lack of access to lighting and heating are required to accurately assess the total burden of disease related to energy access in homes. It is essential to track all fuels and technologies used in the household for all cooking, heating, and lighting activities. To advance data collection for these indicators, WHO has started expanding its Global Household Energy database to include survey data on fuels and technologies used for lighting and space heating. It is also harmonizing questions in national surveys to better account for the health impacts of home energy use for cooking, heating, and lighting. WHO recently published new indoor air quality guidelines for household fuel combustion, which establish performance standards for household fuels and stove technologies (WHO 2014a). These health-based guidelines provide emission rate targets for the sum of energy technologies, with and without a chimney, used in the home, and recommendations to avoid use of unprocessed coal and kerosene.

Performance and safety standards for cooking solutions were proposed by the Partnership for Clean Indoor Air (PCIA) and the International Organization for Standardization (ISO) in 2012 (PCIA 2012). Under an International Workshop Agreement overseen by ISO, experts have developed a set of voluntary standards for cookstoves in low- and middle-income countries. Based on emerging consensus that not all reductions in emissions are of equal value to human health, the Agreement provides the basis for measuring cookstove performance on four technical attributes: efficiency, indoor pollution, overall pollution, and safety. This is the first step toward full ISO standards, which are being developed.

WHO's database of urban air pollution exposure, while very broad, does not include many major cities in low- and middle-income countries, and suffers from shortcomings in data collection. Improved monitoring efforts in urban areas are needed to generate more data of higher quality, for a broader range of cities. The new WHO global platform on air quality monitoring aims to address current data shortcomings created by a dearth of ground-monitoring stations in rural areas, by integrating satellite-monitoring and emissions (chemical transport) data.[22]

Outdoor air pollution concentrations and exposure should be measured for each economic sector. While the most-polluting sources are transport, power generation, building emissions, industry, and waste incineration, their proportionate contributions vary by region and city around the world. Knowing what the heaviest local sources of pollution are can help policymakers assess and prioritize the most effective interventions.

A combined indicator, or index, reflecting the proportion of cyclists and pedestrians who can travel safely is required to measure sustainable transport systems in cities. Such an index would potentially measure the proportion of urban trips via walking or cycling (typical range being 1–40 percent) in association with either the proportion of pedestrian or cyclist fatalities in total traffic fatalities (typical range being 10–40 percent) or the proportion of total kilometers travelled annually by pedestrians and cyclists.

A multitier approach measuring energy access in health care facilities, proposed by WHO-World Bank (2014), requires new data from health facility surveys. Most current survey tools and indicators are based on a simple binary indicator: availability or not of electricity. Richer surveys capturing more indicators of the different attributes of energy—such as reliability, quality, peak and average daily power capacity, and operational and environmental sustainability—are being developed, within the multitier tracking framework.

A first attempt to compile possible indicators for tracking the energy-health nexus across countries is summarized in table 6.3. These are intended to stimulate discussions on a future "nexus-tracking" framework.

Conclusion

Universal access to modern energy sources can contribute to improving health, by reducing the burden of disease related to air pollution and by improving the delivery of health services. Improved energy efficiencies and increased use of renewables can significantly reduce a range of energy-related health risks, such as air pollution, but can also increase energy access in remote areas by small-scale RE solutions for homes and health facilities.

Existing indicators capture most of the energy and health links, and data improvements are being developed. WHO's databases on household fuel, indoor and outdoor air pollution, and access to energy in health care facilities provide essential indicators for monitoring the health and social benefits from the energy transition. Additional work to map emission rates by type of cooking and heating technology is under way, aiming to accurately monitor health benefits of improved biomass stoves. A multitier framework for accurately measuring electricity access in health facilities aims to better understand the role that energy access has on health service delivery. Indicators for energy efficiency in the urban environment are being developed based on a scientific understanding of the links from transport, buildings, and land use to human health.

Table 6.3. **Possible indicators for tracking the energy-health nexus at country level worldwide**

Component	Indicator	Data availability	Current/ potential source
Household air pollution	Estimated burden of disease related to indoor air pollution: Type of primary cooking fuel used in households. Household air pollution indicators. Estimated indoor air pollution exposure.	Yes	WHO
	Type of primary cookstove used in households.	Limited	
	Type of secondary (and beyond) cooking fuel and cookstoves used in households.	Limited	
	Type of lighting and heating fuels and stoves/devices used in households.	Limited	
	Mortality and morbidity attributed to household air pollution from all cooking, heating, and lighting activities.	No	WHO
Outdoor air pollution	Air quality measures in urban areas.	Yes	WHO
	Estimated burden of disease related to outdoor air pollution.	Yes	WHO
Built environment	Outdoor air pollution concentrations by sector (for example, transport- or housing-related emissions).	No	WHO
	Percentage of safe active urban transport.	No	
	Percentage of urban trips via walking/cycling.	Yes	OECD/UNECE
	Percentage of pedestrian and cyclist fatalities in total traffic fatalities.	No	OECD/UNECE
	Pedestrian and cyclist fatalities per kilometers of annual pedestrian/ cyclist travel.	Limited	
Energy access in health facilities	Percentage of health care facilities with access to a reliable, affordable, and sustainable source of electricity (using the multitier frameworks).	Limited	WHO/USAID

Energy and gender

Introduction

Gender and energy have emerged as a point of discourse in development since the Beijing Conference in 1995 (Clancy et al. 2011). As highlighted in *World Development Report (WDR) 2012* (World Bank 2012a) and *World Survey on the Role of Women in Development 2014* (UN Women 2014a), gender equality is critical for development across all sectors. Access to sustainable energy often liberates men and women from drudgery and frees time for leisure, rest, and investing in human capital. However, women in most developing countries suffer more severely than men from energy deficits and energy poverty (UNIDO-UN Women 2013).[23]

Energy interventions are likely to affect women and men differently, as they have different roles and voices in the household and wider community (World Bank 2005). For example, electric light after dark may improve the quality of life for some, by allowing reading, entertainment, or education via radio and television, whereas for other it may simply extend the working day. Reaching equitable outcomes is challenging as women often have less influence over decisions and exercise less control over their own lives and resources.

Energy projects, including those focusing on cookstoves, do not always take a gendered perspective. Instead projects resort to using the term "people," "community," or "consumers."[24] The terms "women" and "gender" are often used interchangeably, but are distinctly different concepts: this section uses "gender"—defining the socially constructed relations between women and men—rather than "women," as the second includes the first, while the first does not necessarily include the second.

Gender issues are interspersed all along the nexus chain.[25] It includes energy demands based on women and men's roles, which are met through energy supply chains of different degrees of formality (from self-collection to commercial provision). At household level, men generally make the final decision on energy access (Clancy et al. 2011). At macro level, decisions on policy instruments (including incentives to encourage a transition to cleaner energy) require gender analysis and gender budgeting to avoid inadvertent gender blindness or bias in energy policies (Clancy 2009). All along the chain are entry points where women can be a target group and can benefit in three specific areas: time poverty and drudgery reduction, economic empowerment, and health and safety improvement.

Women are particularly time poor, and the associated drudgery of their tasks (particularly collecting firewood, fetching water, and processing food) is mainly fulfilled through their own physical labor, which has implications for their health and the well-being of their children and families. Time poverty can be conceptualized as the condition in which an individual does not have enough time for rest and leisure after the time spent on productive and reproductive work.[26] Time poverty has been increasingly recognized as a dimension of poverty (World Bank 2005; Blackden and Wodon 2006). Studies have shown that women, as well as girls, can have longer working days than men, particularly in rural areas, and carry (usually on their heads) more weight than men (Bardasi and Wodon 2006; Charmes 2006). Women are often the main fuelwood collectors, although men tend to take over responsibility when the fuelwood supply close to the household decreases (Cooke, Köhlin, and Hyde 2008), when greater amounts of physical capital and machinery are required to harvest fuelwood, or in urban areas (Blackden and Wodon 2006). Time spent on reproductive activities varies by gender depending on environmental conditions, social setup, and distance to forest, wasteland, and water resources.

Energy is often a key input to the production process, driving higher efficiency and greater returns for most activities. However, external factors such as access to finance, to natural and human resources, and to technology are often required for establishing productive activities. Barriers related to low levels of ownership and control over resources, illiteracy, lack of exposure, and poor information and training may affect women more than men, as women are often excluded from decision making. Dutta and Clancy (2005) indicate that the informal nature of many women's enterprises is linked to problems of access to credit, equipment, and other support services. UN statistics show that the informal sector (which includes micro and small enterprises) is a larger source of employment for women than for men (ILO 2002), particularly outside agriculture (Chen 2014).

Encouraging women to become involved in the energy sector, for example as energy entrepreneurs, offers multiple development benefits, like expanding economic activities for women, diversifying productive options, and creating new sources of wealth and income to support family investments in education and health.[27] Women's economic empowerment in energy (as in other sectors) contributes to broader aspects of empowerment, such as political participation and consultation in interventions where women are the identified beneficiaries.

Women and children bear the heaviest burden of indoor air pollution, which causes 4.3 million premature deaths worldwide (WHO 2014b), due to their high exposure. It leads to more deaths than HIV/AIDS, malaria, tuberculosis, and malnutrition combined (Lim et al. 2012). There is emerging evidence that men's health can also be affected by exposure to indoor air pollution when they spend time in the kitchen, increasing their mortality risk when combined with other health issues (World Bank 2012c). Depending on culture, boys or girls spend more time in the kitchen, and hence siblings have different exposure levels.[28] Before preparing the food, women and men may suffer skeletal damage from carrying heavy loads, such as fuelwood and water. At that time, women may also be exposed to sexual and other forms of violence.[29, 30]

Energy-gender nexus and the SE4All objectives

Access to affordable modern energy services can reduce both time and effort spent in reproductive and productive labor. By increasing efficiency and productivity, better access improves well-being and frees up time for leisure and rest. Time spent on fetching water can be sharply reduced through piped water supply, often made possible through fuel-based water pumps. The use of non-solid (liquid or gaseous) cooking fuel can decrease time spent in collecting fuelwood, while reducing indoor air pollution. Access to electric labor-saving appliances, such as food processors or washing machines, further improves women's quality of life, and may create income-generating opportunities. Micro hydro plants powering grain mills in Nepal were instrumental in bringing down women's workload considerably, from at least two hours of grain processing by hand to around half an hour with mechanization (Mahat 2004). But the time saved by improved energy access is often used differently by men and women. Men are more likely to use it for recreation and leisure, while women tend to use the time for housework and child care, as well as for resting, socializing, and watching TV, and not necessarily for income-generating activities (Matly 2003).

Although machines now perform much of the hard labor formerly done by people, there are some drawbacks. Evidence from Bangladesh and Indonesia suggests that women lost jobs as agriculture mechanized (Cecelski 2004). And in China electrical technologies increased women's workloads as they took over many agricultural tasks from men (Ramani and Heijndermans 2003).

Although social norms and values can take time to adjust after new technologies are brought in,[31] empirical evidence suggests that street lighting may increase women's and girls' mobility after dark and in the early morning (Cecelski et al. 2005). Street lighting may also reduce the risk of gender-based violence (Doleac and Sanders 2012).

Access to energy in health care facilities is a critical enabler for vital health care services and can improve maternal care and facilitate childbirth deliveries. Every day, some 800 women die worldwide from preventable causes related to pregnancy and childbirth (SE4All 2013). Access to electricity in health facilities can increase the number of successful childbirth deliveries, especially at night. Electricity is also needed for sterilization and obstetric equipment.

Besides being energy consumers, women can with men be important energy providers, expanding energy access to poor and hard-to-reach customers, individually and through their networks. A growing number of energy enterprises have begun to employ women as sales representatives to reach low-income consumers at the base of the pyramid with lighting and cooking solutions. Women help ensure that energy products reflect the priorities of women users, increasing the likelihood of adoption and continued use. One example is dissemination of improved cookstoves through women artisans in Nepal by the Centre for Rural Technology (CRT/N 2014). A second example is sales of clean energy and water products by Kopernik Solutions in Indonesia through largely women-run Tech Kiosks and Tech Agents (Hamakawa, Nakamura, and Wojkowska 2014). And a third example is sales of solar lights, mobile phone chargers, and other products in Africa by Solar Sister (Lucey 2014).

High up-front costs of access to modern energy services may more severely affect female-headed households, often overrepresented in poorer quintiles. Low-income groups, particularly women, rarely have access to finance from formal institutions (Alstone et al. 2011). This circumstance prompted the introduction of a range of financing schemes beyond microcredit (which offers only very small amounts). A key design feature aiming to match women's capacity to pay has been used in two of the best-known programs: Grameen Shakti, promoting solar home systems in Bangladesh (Schalatek 2009); and the ENSIGN project of the Asia/Pacific Development Centre and UNDP, working with the Self-Employed Women's Association Bank in India, promoting process-heat technologies (Ramani 2002).

As with time saved and interventions tied to electricity, women and men respond differently to energy efficiency incentives and energy use alternatives. Women are usually the primary energy users in the household as they perform most household chores that require energy (such as cooking, washing, or cleaning) and are therefore in good position to manage electricity use. However, women are not always involved in making decisions on use of energy sources or appliances, particularly in traditional contexts, and often lack access to finance for investing in energy-efficient appliances in their homes or businesses (ENERGIA 2006). A recent study in the Europe and Central Asia region finds that men are better informed and active in applying energy efficiency measures because insulation repairs are commonly perceived as a "man's job." Conversely, women are interested in the economic aspect of energy efficiency, such as cost and potential savings, but such information is not always easily accessible (World Bank 2014).

Finally, women's empowerment can support the energy efficiency goal. Evidence has shown that where there is a monetary opportunity cost of women's time, people are more open to adopting energy saving devices and to making adjustments within the family to share the burden of, for instance, fuelwood collection, facilitating women's participation in economic activities (Kelkar and Nathan 2005).

Existing indicators and challenges

Statistics on the energy-gender nexus come from global surveys such as the Living Standards Measurement Study (LSMS), the Demographic and Health Survey (DHS), and the Multiple Indicator Cluster Survey (MICS). Other studies can also be important sources.

Rates of access to modern energy services are often obtained with the gender of the head of the household. Access to electricity is tracked in household surveys through questions related to presence of a grid connection or electric lighting in the household. The use of solid versus non-solid fuels as a primary cooking fuel is also monitored (Chapter 2). Most surveys report whether the head of the household is male or female and usually have a roster of household members by gender and age among other socioeconomic characteristics. Thus the share of male- or female-headed households with access to electricity and to non-solid fuels for cooking[32] can be reported. Data have been compiled for high-impact countries, represented in figures 6.10, 6.11, and 6.12.[33]

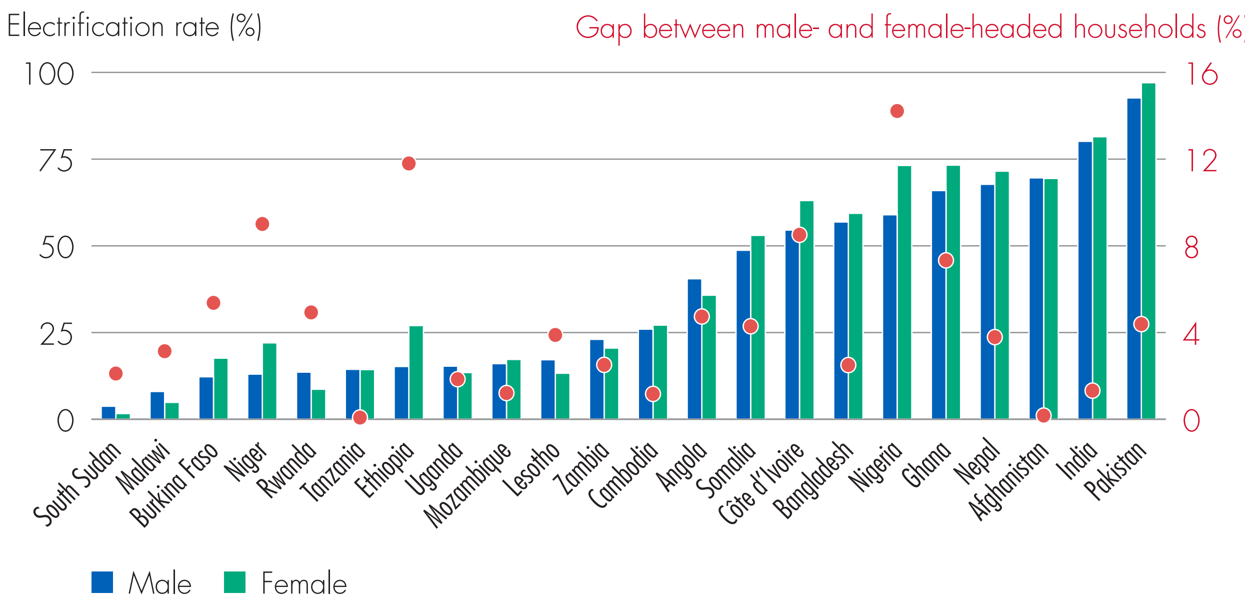
Electrification rates for 22 high-impact countries range from 2 percent to 97 percent (see figure 6.10). In 14 countries, female-headed households have higher access rates than male-headed households. In countries with nationwide electrification rates under 20 percent, male-headed households show higher access rates in six out of 10 countries. In countries with nationwide electrification rates over 60 percent, female-headed households show higher access rates in five out of six countries. The access gap between female- and male-headed households does not seem to be strongly correlated with the level of access. And it ranges from close to zero in Tanzania and Afghanistan to over 10 percent in Ethiopia and Nigeria.

In 12 out of 20 countries, female-headed households have higher access rates to non-solid cooking fuel than male-headed households (see figure 6.11). Among the 10 countries with the highest access rates, female-headed households show better rates in eight countries. By contrast, among the 10 countries with the lowest access rates, male-headed households show better rates in six countries. The access gap for non-solid cooking fuel between female- and male-headed households is generally smaller than that for electrification, at less than one percent in 12 countries, and only one country (Nigeria) has a gap of more than 10 percent.

The share of electrification expenditure as a share of total expenditure is higher for female-headed households across 20 countries (except Tanzania). The gap is generally very small (< 1 percent in 17 countries) and does not exceed 2 percent (see figure 6.12).

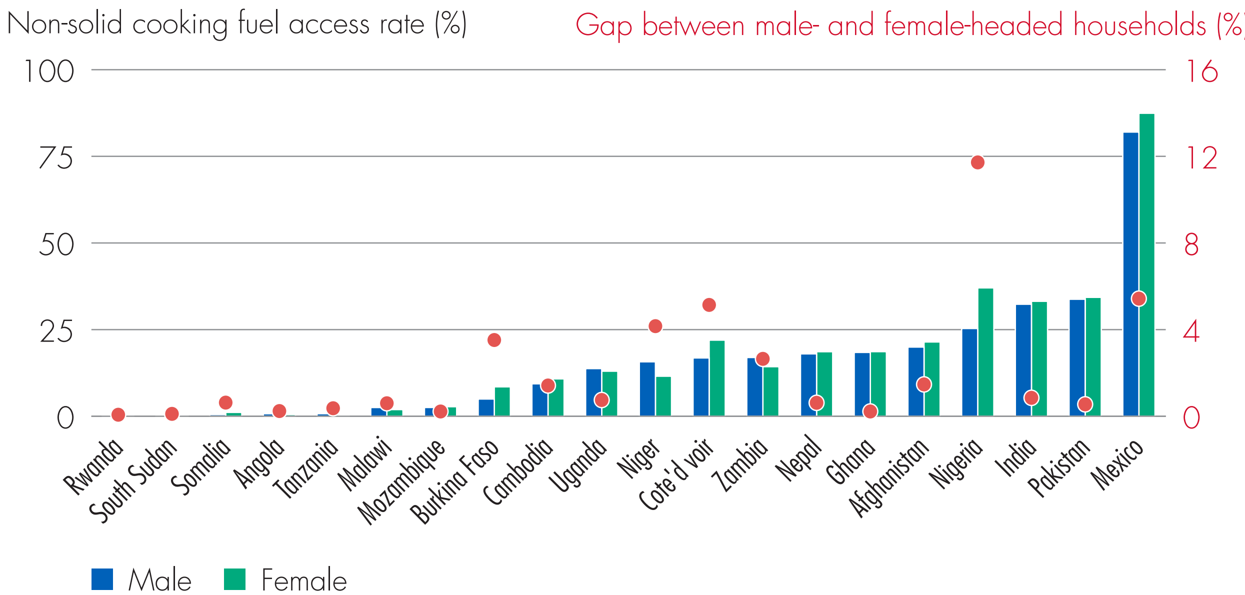
Depending on data availability, further disaggregation between urban and rural households, as well as by income quintile, can be made, as raw data are available for most

Figure 6.10. **Electrification rate by gender of head of household, 2012, and gap**



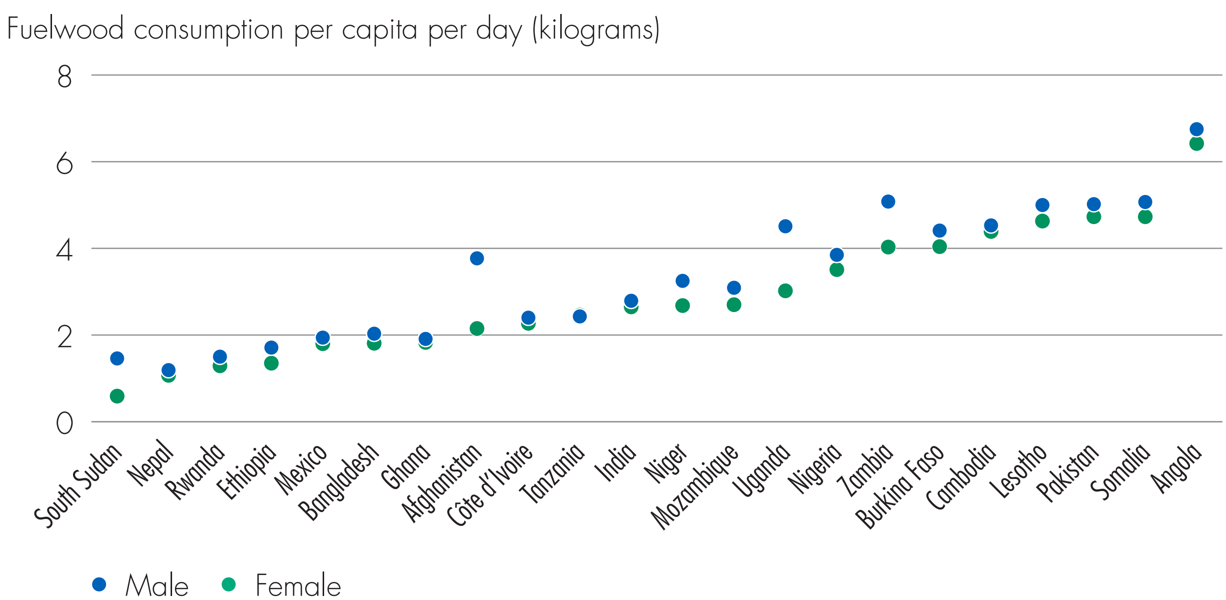
Source: Household surveys.

Figure 6.11. **Non-solid cooking fuel access rate by gender of head of household, 2012, and gap**



Source: Household surveys.

Figure 6.12. **Share of electricity expenditure by gender of head of household, 2012**



Source: Household surveys.

countries. But such indicators have not been systematically tracked globally.

Time allocation by men and women on productive tasks such as engaging in farms, shops, and small businesses, as well as nonmarket tasks such as fetching water, collecting firewood, cooking, and carrying out other household chores are tracked by several household surveys, including LSMS. However, indicators are challenging to track due to multiple methodological issues related to data consistency (questions vary across countries).[34]

Other standardization challenges in time-use surveys relate to the inventory and definition of tasks. For example, people have different notions of how to measure time, not everyone uses a clock or a watch, and some people may use "fluctuations of nature such as day time or the season" (Blackden and Wodon, 2006). This variation requires special data-gathering tools to translate local perceptions of time. Also, women in particular often multitask but may report only one task, thus causing miscounting as all activities are not fully captured. Further, some surveys may not consider household chores as productive.[35] Data on average time spent on fuel collection in male- and female-headed households can usually be compiled. Some surveys may also report which member of the household performs the task, enabling further analysis.

Women's economic empowerment can be tracked through labor statistics. The International Labour Organization (ILO) database covers over 100 sex-disaggregated indicators and 230 countries, with labor force participation rates, self-employment rates, distribution of employed population by sector (agriculture, industry, and services), unemployment rates, and so on (ILO 2014). Along with formal employment, the ILO also reports informal employment (for some countries only). But tracking employment in the informal sector (a large part of women's employment) can be methodologically difficult, given the sector's diffuse nature, which renders sampling difficult, and given the reluctance of informants to reveal sensitive data. Variations in survey techniques, particularly sample size and source of information, such as individual versus enterprise data add to the complexity (Margolis 2014).

Data on mortality and morbidity due to indoor air pollution come from WHO. With other researchers, WHO has built since the mid-1980s a large body of evidence and data on the links between women's health and such pollution (Rehfuess 2006). However, fewer data sets on men's exposure to indoor air pollution are comprehensive, and data on children's exposure are seldom disaggregated by sex (World Bank 2012c).

Data gaps and required indicators

Gender analysis asks questions in relation to women and men about who is doing what, who owns what, who makes decisions about what and how, and who gains and who loses by a planned intervention. Gender as a concept explains the differentiated responses of household members to energy interventions (such as improved cookstoves and electrification) and identifies how the benefits accrue within the household (Clancy et al. 2011).[36]

Quantitative assessments of differential impacts of energy on the lives of women, men, girls, and boys are scarce. Sex-disaggregated data on energy use are lacking, with most of the data qualitative and limited to rural areas. When available, evidence focuses on women rather than on women and men. There are only a few insights into men's activities and on changes in gender roles. The scarcity of impact data partly stems from methodological difficulties such as relying on respondent recall and allocation of time to tasks carried out simultaneously. These obstacles are, however, beginning to ease slightly as several multi- and bilateral development agencies have started to mainstream gender into their policies and operations, including energy. Organizations such as the Norwegian Agency for Development Cooperation (Norad), World Bank, and Global Environment Facility (GEF) Small Grants Programme are now tracking gender within energy projects and energy sector operations (Norad 2011; ESMAP 2013; GEF 2014).

Yet there's a long way to go. The impact of energy access on household income and how that income is used from a gender perspective is not well documented. Also evidence is limited about the way energy interventions influence accumulation of assets, including the types of assets women and men own. Nor is the evidence on the impact of modern energy on small enterprises extensive from a gender perspective, with the two most comprehensive studies more than 10 years old (Meadows et al. 2003; Ramani and Heijndermans 2003). Most studies focus on electricity with little attention to process heat (used by many women in their enterprises) and mechanical energy in small and informal sector enterprises. Finally, it is not well understood from a gender perspective how the cost of energy or the promotion of energy efficiency affects enterprise profitability.

The impacts of energy access on health conditions related to drudgery and nutrition are not monitored with gender-disaggregated data. There is little robust epidemiological data on the drudgery and physical injuries resulting from fuel and water collection, and evidence is largely anecdotal. The health links between improved nutrition, access to enough clean water, and energy access also receive little attention. No empirical studies look at the impacts of modern energy—or the lack of it—on HIV/AIDS infected populations, and none specifically on the connections among gender, energy, and major diseases such as malaria. These illnesses can reduce the capacity to undertake physical labor, such as wood collection, while healthy household members also suffer additional stress when having to care for the sick, who may require more warmth, more nutritious meals, and more boiled water (ENERGIA 2006).

Qualitative indicators measuring viewpoints, judgments and perceptions of women and men can show important perspectives on the adoption of an energy source or solution. Focus group discussions or in-depth interviews can gather data about opinions, beliefs, perceptions, benefits, and impacts related to energy interventions (IOB 2013). Such indicators may offer insight into social systems and explain the effectiveness of energy interventions. The ultimate goal of many rural electrification projects for example is to 'improve people's quality of life'. However, notions of what constitutes a good quality of life are multifarious and perceptions will vary from person to person. A more holistic understanding of the level of access to energy and the impact of interventions may be obtained when qualitative indicators are used in combination with quantitative data.[37]

Gender sensitive surveys should interview both male and female household members, not focus on the head of household. This is because—although the "household" is typically considered as a unified entity that pools resources whose preferences can be expressed in terms of a single utility function—it is inaccurate to assume, for example, that when household income increases the well-being of all household members improves equally. The household is the center of both cooperation and conflict between women and men, who have different interests and priorities (World Bank, 2005). Tracking progress toward meeting women's and men's interests and priorities is necessary for ensuring equalities of outcomes. Although this approach increases the complexity and hence the time and cost of data gathering and analysis, it also contributes to better-informed policies and interventions. A comparison may be drawn with the health sector, where surveys such as USAID's DHS collecting information at the individual level led to robust data on diseases and health issues across the world.

Based on a series of indicators recently proposed by UN initiatives aiming to monitor gender across several areas, a list of existing and new indicators focusing on the energy and gender nexus has been compiled to track access to modern energy services, time poverty, women's empowerment, and health. In February 2013, the UN Statistical Commission (UNSC) identified a minimum set of gender indicators comprising 52 quantitative and 11 qualitative indicators covering norms and laws on gender equality, as a guide for the national production and international compilation of gender statistics (UN 2014).[38] In June 2013, UN Women suggested a series of indicators to monitor gender equality, women's rights, and women's empowerment in the post-2015 development framework and the SDGs (UN Women 2013, 2014b). Platforms such as the World Bank Gender Data Portal[39] and the Evidence and Data for Gender Equality (EDGE) initiative[40] may be used for hosting and promoting new gender data and indicators.

A first attempt to compile possible indicators for tracking the energy-gender nexus across countries is summarized in table 6.4. These are intended to stimulate discussions on a future "nexus-tracking" framework.

Conclusion

Improved access to sustainable energy services has the potential to reduce drudgery and the time burden, as well as increase income-generating opportunities for women and men. Gender-informed investments in sustainable energy can increase income and well-being for women and men, improve food security and nutrition, and reduce time poverty. Supporting women to become energy entrepreneurs can help increase energy access and improve energy efficiency.

Data disaggregated by sex can ensure that SE4All objectives are met in a gender equitable way, and contribute to better understanding the effectiveness of energy interventions and adoption of sustainable energy solutions. The collection and use of such data should become the standard practice, and gender-neutral terms such as "consumer," "children," and "community" should be avoided. Marketing campaigns promoting RE solutions or energy-efficient devices should be targeted to women and men to maximize impact and improve adoption rates.

Table 6.4. **Possible indicators for tracking the energy-gender nexus at country level worldwide**

Component	Indicator	Data availability	Current/ potential source
Access to modern energy services	Percentage of households with access to electricity, by sex of household head	Yes[a]	UN Women
	Use of electrical appliances available in the household, by sex of household member	No	
	Percentage of households using modern cooking solutions as primary cooking solution, by sex of household head	Yes[a,b]	UN Women
	Percentage of micro and small businesses with access to electricity/modern cooking and heating solutions, by sex of owner	No	
Time poverty	Average weekly time spent on fuelwood collection, by sex and age of household member	Limited[c]	UN Women
	Average weekly time spent in water collection (including waiting time at public supply points), by sex and age of household member	Limited[c]	UN Women
	Average weekly hours spent on reproductive work, by sex and age of household member	Limited[c]	UNSC, UN Women
	Average weekly time spent in hand processing grain/tubers, by sex and age of household member	No	
Women's empowerment	Percentage of enterprises owned by women	Yes	ILO
	Female share of employment in the energy sector	Yes	ILO
	Number of energy entrepreneurs, by sex	No	
Health	Percentage of births supported by electricity	No	WHO
	Mortality and morbidity rates due to indoor/outdoor air pollution, by sex	Yes	WHO

a. Raw data generally available, but not treated.

b. Available data track solid versus non-solid fuels.

c. Depending on type of survey.

Notes

1. Physical water scarcity occurs when the demand outstrips the land's ability to provide the needed water.
2. Economic water scarcity exists when a population does not have the necessary monetary means to utilize an adequate source of water.
3. Water security refers to the capacity of a population to safeguard sustainable access to adequate quantities of and acceptable quality water for sustaining livelihoods, human well-being, and socioeconomic development, for ensuring protection against waterborne pollution and water-related disasters, and for preserving ecosystems in a climate of peace and political stability (UNU 2013).
4. Thermal power plants generate around 80 percent of the world's electricity (IEA 2013).
5. Once-through cooling requires large amounts of water, but consumes a very small fraction of it. Closed-loop cooling systems withdraw much less water but consume most of it as water evaporates. Dry-cooling systems use air instead of water to cool the steam, hence there is no water used or consumed in the process. The cooling system employed by the power plant affects power plant efficiency, capital and operating costs, water consumption, water withdrawal, and the environment.

6. Water intensity of thermal power sources (such as geo-, solar, and biomass thermal), depends on the type of cooling system. Dry-cooling systems can lower water needs by 90 percent.
7. Solar PV systems require small quantities of water for mirror washing (which can nonetheless be challenging in arid locations), while wind turbines do not require any water for operations.
8. Other ways to increase water efficiency in power plants are using non-freshwater for cooling (such as seawater or wastewater) and recycling and reusing water in energy-extraction facilities.
9. The Commodity Food Price Index has price indices for cereals, vegetable oils, meat, seafood, sugar, bananas, and oranges, from IMF data (index, 2005 = 100). The Crude Oil (petroleum) Price Index is the simple average of three spot prices: dated Brent, West Texas Intermediate, and the Dubai Fateh, retrieved from IMF data (index, 2005 = 100); the Total Cereals Producer Price Index is retrieved from FAOSTAT (index, 2004–06 = 100, divided by 100).
10. This includes both direct and indirect energy inputs along the whole agrifood chain and agricultural emissions. It excludes forestry and land use emissions.
11. The FAO Corporate Statistical Database (FAOSTAT) website disseminates statistical data collected and maintained by the FAO. FAOSTAT data are provided as a time-series from 1961 in most agricultural domains for 245 countries in English, Spanish, and French. http://faostat3.fao.org/home/E.
12. High Impact Opportunities are categories of action that have been identified as having significant potential to advance the three objectives of SE4All, providing a platform for stakeholders from the private sector, public sector, and civil society to work together.
13. Fuel-based power generators meant to serve as a facility's "back-up" solution may be the only source of electricity, but often they are broken or lack fuel. The above review found that in six countries with data, only one in three generators were operational.
14. Although advanced combustion biomass cookstoves have undergone technological development, many still emit pollutants into the air at rates above WHO guidelines. Such technologies must be measured against health-relevant standards (WHO 2014a).
15. Health-harmful household emissions include fine particulate matter ($PM_{2.5}$) as well as carbon monoxide, oxides of nitrogen (NOx), carcinogens such as benzene, and in the case of unprocessed coal or liquid fuels such as kerosene and diesel, a range of other toxins and heavy metals (WHO 2006).
16. WHO discourages the use of kerosene as a household fuel in the new indoor air quality guidelines for household fuel combustion (WHO 2014a).
17. Exposure to persistent cold or damp can cause morbidity (including asthma, allergies, and respiratory illnesses) and death.
18. CHP is far more efficient than conventional centralized grid power plants.
19. Many countries forbid children under the age of 14 to use an elevator unaccompanied.
20. The main nationally representative household surveys collecting data on primary cooking fuel use are USAID's Demographic Health Surveys (DHS) and World Bank's Living Standard and Measurement Surveys (LSMS), along with national censuses.
21. Ambient (outdoor) air pollution in cities database 2014. http://www.who.int/phe/health_topics/outdoorair/databases/cities/en.
22. Ambient (outdoor) air pollution in cities database 2014. http://www.who.int/phe/health_topics/outdoorair/databases/cities/en/.
23. Energy poverty can be defined as an absence of sufficient choice in accessing adequate, affordable, reliable, clean, high-quality, safe and benign energy services to support economic and human development (Clancy, Skutsch, and Bachelor 2003).
24. The benchmark paper by Barnes (1994) on stoves is a good example.
25. Detailed reviews of the energy-gender nexus may be found in Clancy et al. (2011), Köhlin et al. (2011), and World Bank (2005).
26. Reproductive work refers to the unpaid work performed in the home, usually by women, and encompasses tasks related to caring for, nurturing, and sustaining human beings, including bearing and rearing children, cooking and feeding, caring for the sick, cleaning and washing, and so on.
27. Resources controlled by women tend to be invested more heavily in children (at the margin) than resources controlled by men (World Bank 2001).
28. For instance, incidence of acute respiratory infections among boys is higher than among girls in India (World Bank 2012c).
29. Women living in war-torn areas and camps for displaced persons seem particularly vulnerable to sexual violence while they search for fuelwood in surrounding areas (Kasirye, Clancy, and Matinga 2009).
30. See Matinga (2010) for a review of the literature.
31. In hill tribes in northern India, perceptions that existed before the advent of street lighting about women who leave the home after dark continued to act as

a barrier to women's mobility (Kelkar and Nathan 2007).

32. To increase data accuracy on access to primary cooking fuels, it is preferable to interview the cook of the household, not the head of the household.
33. These include (subject to data availability) the 40 countries with the highest access deficits (number of people without access) and the 40 countries with the lowest electrification/access rate to non-solid cooking fuels.
34. Some surveys ask how many times per day or week household members collect fuel, but do not specify duration. Other surveys focus on the time required for reaching the location where fuel is collected but do not ask for overall time commitment.
35. Nonmarket tasks are not always covered in national surveys as they are not considered to contribute to the productive economy (Charmes 2006).
36. For a review of gender and urban energy issues see Clancy, Maduka, and Lumampao (2007).
37. The evaluation of rural electrification on the quality of life in Bhutan collected both quantitative and qualitative data. Qualitative data gathered through focus group interviews provided additional insights that would have been difficult to capture through standard questionnaires; for example, feelings about social inclusion and discussions about personal matters such as family size.
38. The list of indicators is also available at: http://genderstats.org.
39. http://datatopics.worldbank.org/gender.
40. http://unstats.un.org/unsd/gender/default.html.

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