Climate-proofing Energy Systems

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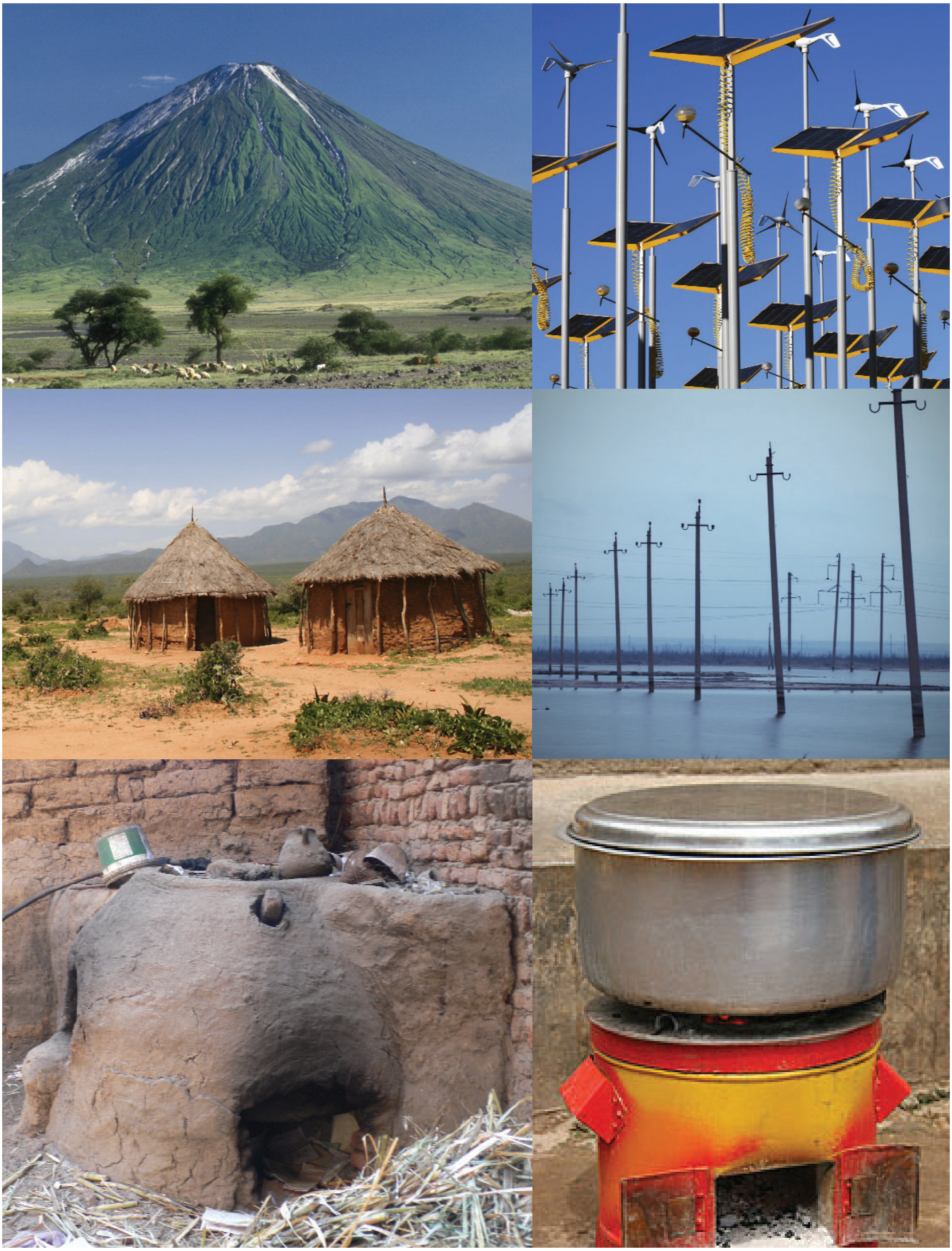

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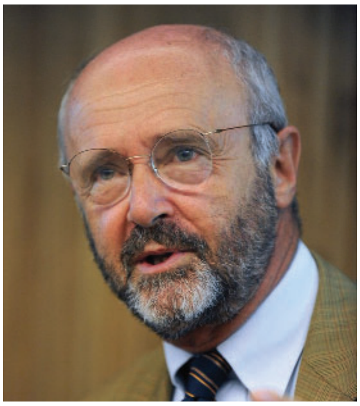
Table of Contents



Forewords

Measuring Vulnerabilities to Define Adaptation Policies and Measures

This is a most welcome and timely study that will open the way for many others.

Climate change is happening and will happen regardless of the efforts countries make in the future to reduce their emissions. We are going to have to adapt to change, especially altered rainfall patterns and extreme weather events. The consequences will be particularly serious for the poorer countries and above all for those in the intertropical zone, where the effects will be more violent and where resources for adaptation are scarce. Sub-Saharan Africa could be the region to suffer most.

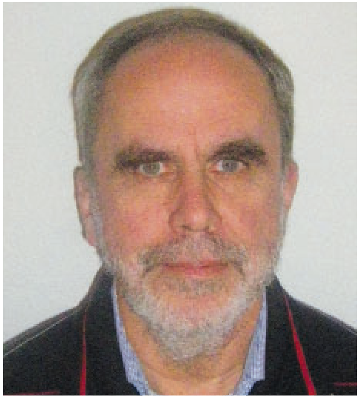
Within just a few years adaptation to climate change has become as great a concern as the need to reduce greenhouse gas emissions. Adaptation means taking account of the changes predicted by the scientific community for the different parts of the world, of countries' differing degrees of vulnerability, of efforts to prevent degradation or destruction, of measures to speed up repair, and of financial solidarity and technical assistance, etc. Basically, adaptation is another word for development, made more difficult by the climate. This is a clear signal that development policies must include adaptation to climate change. It is also the reason that initiatives like HELIO International's Vulnerability, Adaptation, Resilience (VAR) reports raise the hope that rational approaches and reproducible methods can and will be developed.

Amongst the pillars of development included in the Millennium Development Goals, such as health, education and security, one important area that seemed to have been neglected is now central to policies on the climate and environment: that is access to modern forms of energy, something of which the majority of Africans are deprived. There can be no development without a minimum of energy for lighting, motive power, refrigeration, cooking of food, telecommunications, computers, etc. France considers that access to modern, and clean, forms of energy should be at the core of the solidarity between the developed countries and Africa, since it enables both development and adaptation. Cooperation to provide such access is one of our proposals for successful climate negotiations.

It is precisely the often nascent and fragile systems of access to energy in Sub-Saharan Africa that are most threatened by climate change. Any policy on energy services in Africa must therefore be accompanied by a policy for adaptation. But what form should this adaptation take? HELIO's VAR study provides us with a set of indicators to assess the vulnerability of the energy systems of ten Sub-Saharan African countries. It will prove useful in international negotiations on adaptation and in improving future policies in support of development.

Brice Lalonde
Ambassador for Climate – France

A Tool to Identify Innovative Approaches



More than half of the world's greenhouse gas emissions are produced by the combustion of fossil fuels, with the global energy sector being a major producer of emissions. However, the energy sector is not only contributing to climate change, it is also vulnerable to climate impacts. Natural disasters that interrupt supply chains and disrupt service are on the rise. In developing countries, which are often heavily dependent on biomass for energy, resource scarcity exposes vulnerable populations even further. Given the inextricable link between socio-economic development and access to energy, it is clear that any approach to securing development in the context of a changing climate must consider the adaptation needs of the energy sector.

The GTZ works on behalf of the German Ministry for Economic Development (BMZ) to provide technical assistance to developing country partners. Our support of HELIO International in the preparation of this report arose from a shared interest in identifying risks and needs within the region's energy sector, as we seek new and innovative approaches to supporting our partners in their efforts to adapt to climate change.

Dr. Lorenz Petersen, Head of the Climate Protection Program for Developing Countries
Holger Liptow, Deputy Head Energy and Transport
GTZ

"We must treat climate as a security issue, the most important threat to global security we will ever face. Energy is at the heart of this transition. Climate security and energy security are two sides of the same coin: one cannot be achieved without the other."

– Maurice Strong, former Secretary General of the UN Conferences – Stockholm (1972) and Rio (1992)

List of Acronyms

ADB	African Development Bank
°C	Degree centigrade
CO_2	Carbon dioxide
D. R. Congo	Democratic Republic of Congo
G8	Group of Eight
GDP	Gross Domestic Product
GNI	Gross National Income
GNP	Gross National Product
GW	Gigawatt
gWh	Gigawatt-hour
HELIO	Hydro, Eolien, Light, Insulation, Organomass
HPI	Human Poverty Index
IMF	International Monetary Fund
IPCC	Intergovernmental Panel on Climate Change
km	Kilometre
kW	Kilowatt
kWh	Kilowatt-hour
kV	Kilovolt
MDG	Millennium Development Goal
MW	Megawatt
NAMA	National Appropriate Mitigation Action
NAPA	National Adaptation Plan of Action on Climate Change
PAM	Policy and Measure
PV	Photovoltaic
SSA	Sub-Saharan Africa
TOE	Tonne of Oil Equivalent
TPE	Tonne of Petroleum Equivalent
UNDP	United Nations Development Programme
VAR	Vulnerability, Adaptation, Resilience

Executive Summary

Current energy policies in industrialised countries are driven predominantly by the need to reduce greenhouse gas emissions. However, measures under the Kyoto Protocol to mitigate the climatic impacts of energy production have failed to take into account the full impact of increased climatic variability: e.g., flooding, seasonal droughts, storm surges, landslides, extreme winds, freezing conditions, heat waves. Adaptation efforts are therefore urgently needed—not only in geographically-vulnerable countries such as Bangladesh, Central Africa or Tuvalu—but everywhere, as climate change is a global phenomenon.

Compared to mitigation—where a common metric in terms of "tons of CO_2 equivalent reduced" has traditionally been used—identification of adaptation measures is still in its infancy. There are as yet no commonly accepted parameters and indicators to compare adaptation needs and the effectiveness of adaptation measures. *Given the importance of energy in any economy and in any development efforts, it is vital that vulnerabilities within the energy sector itself be reduced substantially*. Proposed adaptation measures must also support ecodevelopment goals if these and the Millennium Development Goals (MDGs) are to be reached. Thus, *parameters and indicators (a metric) for energy systems need to be developed and tested* to assess whether proposed measures are appropriate.

This report explains why a metric for the vulnerability and resilience of energy systems is needed and proposes a methodology. It summarises anticipated climate-induced impacts on key energy systems and outlines possible adaptation measures. Observations and analyses from studies of ten Sub-Saharan countries currently applying the developed metric are presented. The report concludes with a series of recommendations to help reinforce the resilience of energy systems.

Recommendations

1. **Systematically assess and monitor energy systems to ensure that they are robust enough to adapt to anticipated climate-related impacts**

   Decision makers and relevant funders have to focus on how to "climate-proof" current and future energy systems. Basic information is still lacking in most countries, thereby hindering robust evaluation and discouraging vital investment.

2. **Expand the current assessment process for new energy systems**

   Decisions about energy systems—regarding what kind (fossil, renewable) and where (location)—can no longer be made using standard environmental and economic assessment tools: climate and poverty issues must be assessed simultaneously.

3. **Develop a medium- to long-term strategy to move toward a safer, decentralised, low-carbon energy supply system**

   The ability to manage energy services and secure access to clean, efficient and renewable energy is the first step in developing a resilient, thriving community. Based on the vulnerabilities assessed, the development strategy should ensure the diversification, decentralisation and modernisation of identified energy systems.

4. **Implement energy demand management as an adaptation measure**

   The magnitude of climate-induced impacts is not proportional to a particular country's emission levels. Improving energy efficiency should be a cornerstone of any energy policy, regardless of consumption levels. Moving from a business-as-usual scenario to one where energy efficiency is the objective reduces the need for new energy sources. Using energy more efficiently through the deployment of low energy technologies will help decrease the sector's vulnerability.

5. **Cultivate in-country capacity to evaluate and respond to energy needs from a climate perspective**

   Energy security cannot be guaranteed until such broader issues as how energy supply, production and distribution will be affected by climate change are addressed. Therefore, in-country expertise must be developed further and supported through on-going educational efforts.

6. **Invest in ecosystem services that support existing and planned energy production**

   Ecosystem assets such as water and biomass undergird energy services. Depletion of these resources will undermine electricity production of hydro and thermal power plants, impact mining operations, and deprive millions of households of their main fuel source.

7. **Establish transparent technology transfer and financing procedures**

   Almost every country surveyed is increasingly dependent on foreign oil imports. Simultaneously, the financial crisis has withdrawn aid from many Sub-Saharan African countries, thus delaying further progress on most of the Millennium Development Goals (MDGs). To reinforce the ability of these countries to cope, resilience has to be integrated into the energy sector by developing diversified energy systems that utilise national resources. However, for this to occur there must be an infusion of strategically-directed capital. Furthermore, scepticism about technology transfer has to be overcome: systematic and fair regulation of the process is one way of establishing trust and confidence.

8. **Develop participatory energy governance to cultivate first-hand knowledge of energy needs and to mobilise vital support from beneficiaries**

   Many projects fail because anticipated energy needs are improperly assessed. Often popular support is also lacking, particularly if the energy development involves displacing people. Nevertheless, energy system diversification is key if a satisfactory level of national energy system resilience is to be achieved. Consultation with, and participation of end users are therefore crucial in helping ensure that the final system meets energy and broader community needs.

Setting the Context: An introduction

Climate change isn't happening as a single phenomenon, or in isolation; there are numerous factors that converge and interact in various ways, creating a new challenge of unprecedented complexity and gravity.

According to the UN International Strategy for Disaster Reduction, weather and climate-related hazards accounted for 71 percent of large-scale natural disasters from 1995 to 2005. Moreover, reported disaster occurrences almost doubled over the same period (UNISDR 2008). While this increase may be partially a result of better reporting, the observed increase in storms, droughts and intense rainfall as reported by the IPCC Fourth Assessment suggests that we should not be surprised to see increasing changes in the amplitude and impact of such hazards (IPCC 2007).

Under these conditions the concept of "climate proofing" must shift from *insulating human activities* from severe weather conditions *to decreasing exposure* to climate change impacts.[1] Therefore, what we can and must do is systematically identify and reduce vulnerabilities to the identified risks. Given energy's role—particularly that of clean, efficient energy—in economic development, it is crucial that energy system vulnerability is reduced and the variety of ways for increasing system resilience are identified and implemented.

Rationale

New insights have been gained over the last ten years about the essential role of energy system resilience in the prosperous development of societies.[2] A growing number of case studies has revealed the tight connection between resilience, diversity and sustainability of social and ecological systems (IUCN 2008, MEA 2005). Furthermore, climate change, superimposed on poverty, invariably exacerbates existing social and environmental problems. *Whatever threatens the viability of ecosystems also ultimately threatens human societies, starting with the people who most directly rely on natural resources for their livelihoods*.

Climate change also directly impacts both the demand- and supply-side of energy services. Energy systems and equipment are already subject to substantial temperature and other climatic changes. Climate change can also indirectly impact any part of the energy sector. For example, a change in electricity supply can affect energy distribution and consequently services to energy users.

However, energy policies in industrialised countries are increasingly driven by the need to mitigate greenhouse gases. In addition, measures under the Kyoto Protocol to mitigate the climatic impacts of energy production have failed to take into account the expected consequences of increased climatic variability.[3] Thus, adaptation is now the order of the day, not only in geographically-vulnerable countries, but also increasingly in northern and moderate latitudes.

1 By aiming to decrease exposure, the definition of climate proofing now defines a process not an end state and that, while the objective may be unattainable, effective, operational steps toward achieving increasing protected (adapted) society is an attainable goal (Glantz 2006).

2 While standards of energy use in industrialised countries should not be the norm and, therefore, need not be adopted in developing countries, access to some level of affordable energy is appropriate and necessary.

3 http://data.ukcip.org.uk/resources/publications/documents/4.pdf

> The resilience of a country's energy system is underpinned by at least two key elements: its adaptive capacity and the country's level of ecodevelopment.

Given the importance of energy in the economy and in the promotion of ecodevelopment,[4] it is vital that vulnerabilities within the energy sector be reduced. Energy systems must be adapted to withstand anticipated climate change and its impacts. This can be achieved by increasing the resilience of the energy system, e.g., by reinforcing its technical equipment, diversifying energy supply sources, siting power equipment more appropriately, expanding linkages with other regions, disaster preparedness planning, managing demand and investing in technological change—renewables, efficiency, management, etc.—to further expand the portfolio of options. Given the slow rate of capital stock turnover in the energy sector and the long lifetime of equipment, it is important that energy suppliers, policy makers and citizens be well-informed as to the possible impacts of climate change on the energy sector so that necessary mitigation and adaptation measures can be taken.

Unfortunately, when energy vulnerability is discussed at the national level, it is traditionally focused around issues of energy supply security and how to improve it. There is little policy formulation around the broader context of reducing energy system vulnerability through integrated ecodevelopment strategies, e.g., addressing simultaneously environmental, social, economic, technical and governance issues.

Approach

In order to better understand how to trigger and sustain positive synergies, HELIO has developed a straightforward methodology and a set of indicators to assess the vulnerability and resilience of national-level energy systems to climate change. By applying the indicators to energy systems, HELIO aims to help identify policies and measures (PAMs) that can best facilitate and support adaptation activities.

As Africa is one of the continents most vulnerable to climate change and climate variability (IPCC Working Group II), this region was chosen as the first "testing ground." An upsurge in assistance at the national, regional and international levels (including the development of various initiatives by the G8 nations and others to improve energy access) provides additional incentive: in order to ensure that proposed energy systems are able to withstand climate change impacts, system-level vulnerabilities also need to be established and tools for increasing resilience identified.

This global report presents the rationale for analysing energy systems in a climate change context and details two sets of proposed indicators. Results from applying the indicator sets to ten Sub-Saharan countries[5] and their energy systems are summarised.[6]

4 Ecodevelopment became "sustainable development" (SD) with the release of the 1987 Brundtland Report. The abstract notion of SD can be broken down into three distinct sets of activities aimed at: (1) satisfying basic human needs; (2) creating communities that establish norms, rights, and collaborative behaviour as a prerequisite for participating in social and economic development; and (3) translating the more abstract needs of future generations into action today. A compact definition is offered by the Organisation for Economic Cooperation and Development (OCED):

> "Eco-development refers to development at regional and local levels, consistent with the potentials of the area involved, with attention given to the adequate and rational use of natural resources, technological styles and organizational forms that respect the natural ecosystems and local social and cultural patterns. The term is also used to describe an integrated approach to environment and development." See http://stats.oecd.org/glossary/detail.asp?ID=710

5 This work builds on the initial findings presented in *A preliminary assessment of energy and ecosystem resilience in ten African countries* (HELIO 2007). Seven of the ten countries participating in the VAR work were part of the 2007 assessment. Benin, Cameroon and Kenya were added to this latest project to round out the regional balance.

6 Individual Country Reports can be found at: www.helio-international.org

Process

The work was carried out by in-country energy analysts from academia, government and non-governmental sectors.[7] A methodological workshop was held at the start of the project to outline the approach and ensure that each analyst understood how to apply the indicators and interpret the results. A detailed outline of how the report was to be prepared was also distributed. Each report was prepared individually and reviewed by a regional coordinator and HELIO staff. As data availability and quality varied substantially across countries, analysts had to make individual judgements regarding the best data sets to use and where and how to use them, and specifically, what information could be used to calculate a proxy indicator.

Of Special Note

Given the preliminary nature of this work there are variations across the reports in terms of data collection, data quality and analysis and, in some cases, differing understandings about the precise definition of an indicator. Of particular challenge has been the standardisation of data across the ten countries. Differences in the data available for each country, the form in which it is reported and the complexity of the conventions used for quantification, made it impossible to completely harmonise the data with the resources at hand. Despite these challenges, the reports provide a good preliminary view of the key vulnerabilities that these countries face and each report presents options for how resilience can be increased.

Ten Sub-Saharan countries participated in the testing of the VAR indicators:

Benin
Burkina Faso
Cameroon
D. R. Congo
Kenya
Mali
Nigeria
Senegal
Tanzania
Uganda

Wind Farm – Zafarana, Egypt – *Hélène Connor*

7 See Annex Two for a listing of analysts and their contact information.

Why a Metric for Vulnerability and Resilience is needed

Since the development of global climate policy in the early 1990s, the process has been dominated by emissions reductions policies and measures, i.e., mitigation. It was only with the start of negotiations on the post-2012 climate policy regime, that adaptation to climate change was given as equal importance as mitigation activities.[8]

Evaluating vulnerability includes:

- identifying the elements that make a system work on a daily basis
- assessing the inherent vulnerability of the identified elements
- assessing how the interaction of these elements affects the system's vulnerability
- finding ways to enhance the system's ability to cope with crisis situations, e.g., adaptation

(Dalziell *et al.* 2009)

Compared to mitigation, where a common metric in terms of "ton of CO_2 equivalent reduced" has been used for many years, evaluation of adaptation measures is still in its infancy (Stratus Consulting and UNFCCC 2005). There are also no commonly accepted parameters and indicators (Tyndall Centre 2004; USAID 2007) to compare adaptation needs and the effectiveness of adaptation measures.[9]

HELIO International, therefore, developed a methodology and a series of indicators to measure the resilience of energy systems. This work builds on HELIO's preliminary assessment of energy and ecosystem resilience in Sub-Saharan Africa (HELIO 2007).

The Vulnerability-Adaptation-Resilience (VAR) indicators measure the:

1. vulnerability of energy systems; and,
2. effectiveness of adaptation efforts in the energy sector.

These indicators were developed in line with HELIO's guiding principle that the underlying metric—the actual measurement or statistic used—must be generally available for most, if not all, countries. If calculation is required to derive an indicator, it must be simple to do.

Additionally, the indicators themselves must:

- be clearly definable, simple to understand, and easily communicated to citizens and decision-makers alike;
- be relevant to actual or anticipated policies;
- reflect an important aspect of the social, economic, environmental, technological or governance elements of the energy system;
- measure something of obvious value to observers and decision-makers; and,
- exhibit robustness, durability and long-term relevance.

Climate-induced Impacts on Energy Systems and Related Vulnerabilities

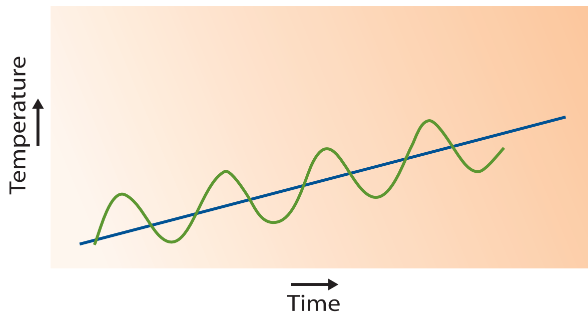
Climate change can cause different impacts. For example, the mean of climatic parameters as well as the intensity of meteorological extreme events can change. Moreover, these impacts can be translated to other climatic parameters such as precipitation, windspeed and sunshine. Based on climate change research to date, temperature and windspeed are likely to increase in most regions; precipitation and sunshine will either increase or decrease.

8 The Adaptation Fund, financed by the adaptation tax on Clean Development Mechanism (CDM) projects, was implemented in early 2008.

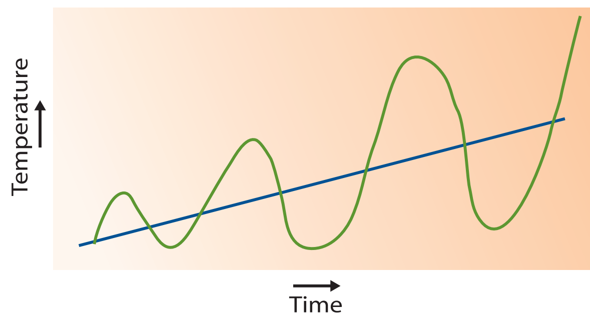
9 Possible adaptation metrics could be the number of disability-adjusted life-years saved and the value of property protected. However, determining the baseline impacts without adaptation efforts would be extremely challenging.

Figure 1: Changes of meteorological parameters due to climate change

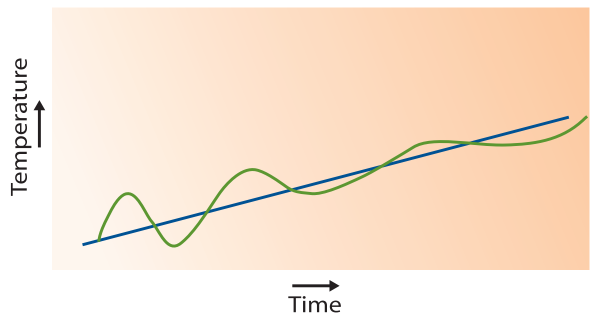
1. Increase of average temperature without change in temperature variability



2. Increase of average temperature with increase in temperature variability



3. Increase of average temperature with decrease in temperature variability



As variability increases the impacts will be larger. However, even when variability decreases, impacts will occur if the meteorological parameter passes the design threshold of a given infrastructure.

Impacts can also be direct or indirect with indirect impacts frequently being much stronger. For example, an increase in temperature alone is unlikely to destroy any energy infrastructure. However, the melting of glaciers, induced by temperature increases, can negatively impact hydropower system in terms of infrastructure damage—from flooding and siltation—as well as affecting generation capacity.

Table 1 gives an overview of direct and indirect impacts of change in meteorological variables. It also outlines various cross-effects, i.e., interactions between different impacts.

Table 1: Examples of direct and indirect impacts of changes in meteorological variables

Direct change	Direct impact	Indirect impact	Cross effects
Increase in temperature	Heat-wave	Increase in electricity demand	
	Glacier melting	Short term: Increase in water flow Long-term: Decrease in water flow	Droughts/floods
		Formation of moraine lakes with subsequent overflow or bursting of containment	Floods
		Sea-level rise	Floods
	Increase in evaporation[10]	Decrease of stream flow	Droughts
	Stronger cyclones/storms		Floods
Increase in precipitation	Floods		
Decrease in precipitation	Droughts		
Decrease in cloud cover	Increase in evaporation	Decrease of stream flow	Droughts
Increase in cloud cover	Decrease in evaporation	Increase of stream flow	Floods

Changes in meteorological variables will have an impact on energy transmission and use regardless of how the energy is produced. Extreme events may increase the risk of collapsing transmission lines and consequently reduce electricity demand due to physical elimination of electricity-consuming entities, e.g., business, industry, households.

Table 2: Examples of direct and indirect impacts of climate on electricity systems

Change in meteorological variable	Impact on electricity transmission	Impact on electricity use
Increase in temperature	Some	Increase in higher cooling needs Decrease if sea-level rise displaces population and industrial production
Decrease in cloud cover	None	Decrease in lighting needs
Increase in cloud cover	None	Increase in lighting needs
Increase in frequency and/or strength of storms/cyclones	Failure/damage of transmission lines	Decrease in demand due to the destruction of houses and factories
Floods	Failure of transmission equipment from flooded power plants	Sharp decrease in demand due to interruption of production in flooded factories/cessation of electricity consumption in flooded houses
Droughts	Risk of destruction of transmission lines due to forest fires	Slight decrease in demand due to interruption of production in factories whose supply of raw materials have been depleted/cessation of electricity consumption in houses of people abandoning the drought area

10 While the rate of evaporation depends on wind speed, humidity and temperature, temperature is the dominant effect.

Meteorological Parameters

In order to begin the process of identifying how to increase energy system resilience it is important to understand how changes in meteorological parameters affect different energy production systems.

Fuel from Mined Resources

Current energy systems are mainly based on fossil fuels such as solid fuels like coal or liquid fuels such as oil and gaseous fuels or uranium. Extraction of fossil fuels as well as their utilisation can be impacted by climate change.

Table 3: Climate change impacts on fossil-fuel/uranium based energy

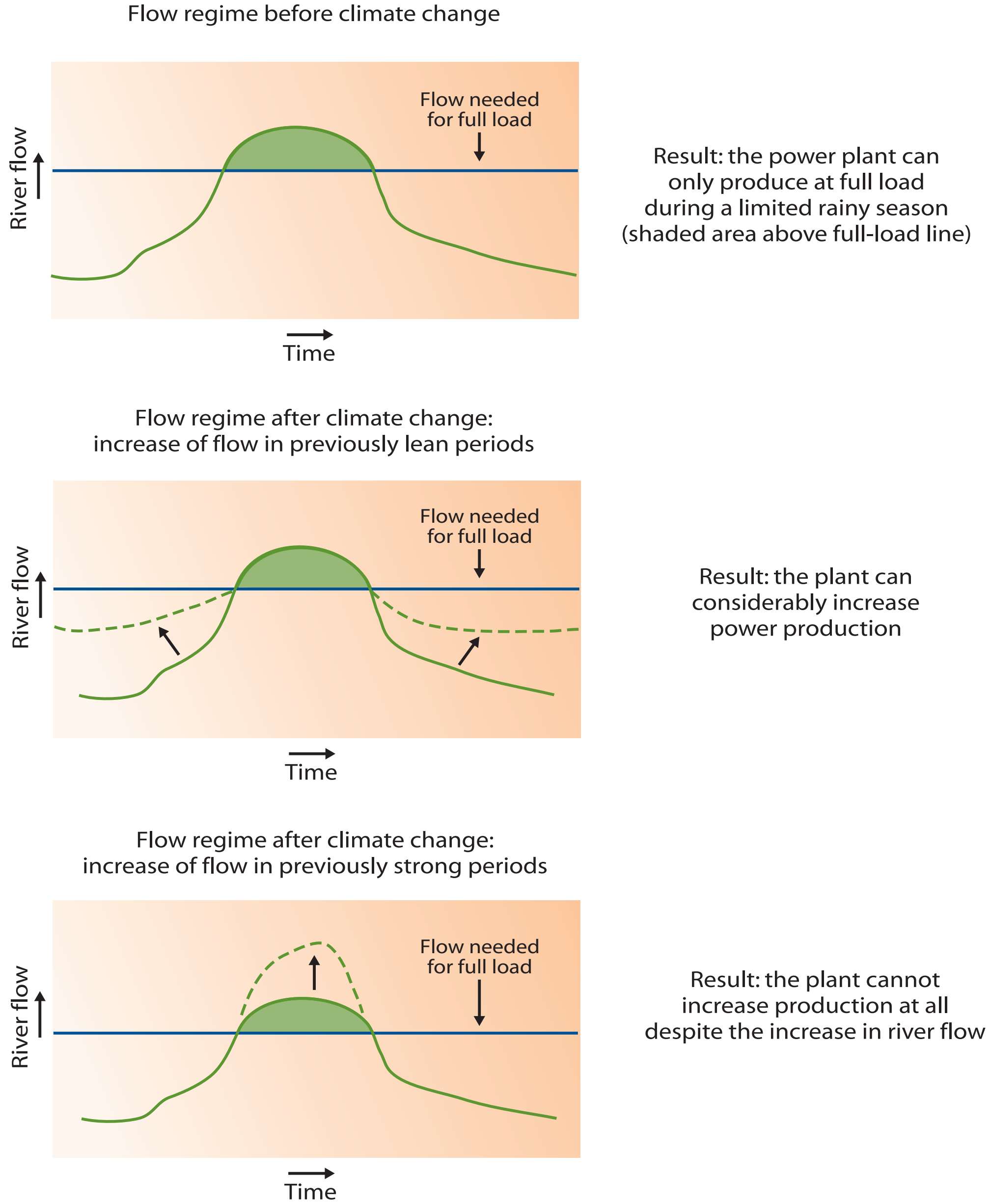
Change in meteorological variable	Impact on fuel availability	Impact on energy generation
Increase in temperature	None unless pipelines are interrupted by melting pergelisol	Decrease of power plant efficiency due to higher temperature of cooling water
Increase in average precipitation	Decrease in coal quality due to higher moisture content of coal from opencast coal mines Increase in coal availability if coal seam fires are extinguished	None
Decrease in average precipitation	Decrease due to higher probability of coal seam fires	None
Droughts	Decrease due to lack of water necessary for mining air conditioning and operations	Decrease due to reduced availability of cooling water
Glacier melting	None	Increase in the medium term (for power plants located close to the glaciers) due to lower cooling water temperature and increased availability of cooling water Decrease over the long-term once glaciers have disappeared
Floods	Decrease if floods affect mines	Decrease if power plant is flooded or fuel cannot reach the plant
Increase in frequency and/or strength of storms/cyclones	Decrease if storms affect vulnerable mining equipment such as offshore oil platforms or opencast coal mine excavation equipment	Decrease if equipment is destroyed or fuel availability is reduced

Hydropower Energy

Electricity via hydropower can be generated via a wide range of plant sizes ranging from kW to GW capacity. The siting of hydropower plants is usually based on multi-decadal river flow measurements.

Changes in average precipitation will change river flow. However, the impact on hydropower production will depend on plant-specific characteristics. While plants with large reservoirs can buffer river flow variability, run-of-the river plants are directly dependent on the actual river flow. The actual change in power production is therefore strongly dependent on the flow regime and utilisation rate of river flow as illustrated in Figure 2.

Figure 2: Scenarios for hydropower river flow utilisation and consequent changes in the flow regime (assuming the glaciers and reservoirs remain stable)



Normally, hydropower plants are able to withstand flooding events by opening floodgates and shutting down turbine operation. Only in rare cases are hydropower plants and/or dams destroyed by flood events. Thus they are less prone to flooding impacts than other power plant types if well-designed and situated in areas not prone to landslides (although reservoirs can fill up with debris and silt thus reducing their long-term power generation capacity).

Given that hydropower plants are normally robust structures, an increase in the strength/frequency of storms and cyclones elevates only slightly the risk of hydropower plant destruction.

Biomass Energy

Biomass energy comes in many different forms. It can be used for heat generation in small, decentralised devices such as household stoves or for power generation in plants, several MWs in size. Biomass can be sourced from forests or agricultural residues.[11]

Climate change impacts the availability of biomass as well as energy generation facilities, as illustrated in Table 4.

Table 4: Climate change impacts on biomass energy

Change in meteorological variable	Impact on biomass availability	Impact on energy generation
Increase in temperature	Increase provided that no lack of other resources constrains plant growth BUT Decrease if plants reach threshold of biological heat tolerance or sea level rise reduces area where plants grow	Decrease if power plant is impacted by sea level rise – otherwise impact depends on availability of biomass
Increase in average precipitation	Increase if increase occurs during the growing season	Increase
Decrease in average precipitation	Decrease unless decrease occurs outside the growing season	Decrease
Droughts	Decrease	Decrease
Glacier melting	Depends on situation of glaciers with regards to the current and future snow lines. If biomass is under irrigation: Increase short- to medium-term Decrease over long-term If not, none	Depends on availability
Floods	Decrease if floods affect area where biomass is sourced	Decrease if power plant is flooded or biomass availability is reduced
Increase in frequency and/or strength of storms/cyclones	Decrease if storms affect area where biomass is sourced	Decrease if equipment is destroyed or biomass availability is reduced

Wind Energy

Wind energy is generally harnessed in a decentralised manner and in locations chosen for their high average windspeed.[12] However, climate change can affect average windspeeds and thus electricity production.

- Increase in average windspeed results in an increase in electricity generation (unless the increase only occurs in the highest windspeed categories)

11 Dedicated biomass plantations are also possible but rare due to high financial and political costs.

12 Typically, windspeeds are measured for several years before investors install a wind turbine.

- Decrease in windspeeds results in a decrease in electricity generation
- Increase in high windspeeds results in an increase in the amount of time when wind turbines are stopped and therefore a decrease in electricity generation, as well as an increase in the likelihood of turbine destruction

Wind turbines start producing electricity at a certain windspeed which increases with a power of three as windspeeds rise. At a certain maximum windspeed, the turbine automatically shuts off to prevent damage: modern turbines can withstand windspeeds of 70 m/s before being destroyed.

Solar Energy

Similar to wind, solar energy is generally harnessed in a decentralised manner and in locations chosen for their high average sunshine. Changes in cloud cover have an impact on electricity production. While photovoltaic cells and solar water heaters can produce electricity even with a certain degree of cloud cover, mirror-based solar thermal applications need full sunlight. Furthermore, the efficiency of solar power production decreases as ambient temperatures rises.[13]

- Increase in temperature results in a decrease in electricity production
- Increase in the strength and/or frequency of storms and cyclones results in an increase in the risk of destruction of solar energy generation equipment

Adaptation Measures for Energy Systems

Adaptation measures can be categorised into infrastructural/technical and behavioural/social responses.

- Technical adaptation tries to make infrastructures invulnerable against long-term changes in meteorological variables and extreme events.
- Behavioural adaptation adjusts the operation of the infrastructure (both existing and new) and the siting of new infrastructures to minimise damages.

Table 5: Technical and behavioural adaptation

Energy System	Technical Adaptation	Behavioural Adaptation
Fuel from mined resources	Improve the robustness of mining installations – particularly important for: – offshore installations that are vulnerable to storms – opencast and underground mines that are vulnerable to both flooding and shortage of water[14]	Site of future mines in areas that have a limited exposure to flooding or drought risk
		Site power plants in places with an ample supply of cooling water available at a low water temperature
		Replace water cooling systems with air cooling

13 The ideal value for optimal output of a PV panel is calculated as 25°C-1000 w/m² with output decreasing once temperatures surpass 25°C. The level of decrease is dependent on a number of factors including the ambient temperature, solar radiation and other parameters related to climate and solar panel manufacturing.

14 Water is necessary to sustain mining operations.

Energy System	Technical Adaptation	Behavioural Adaptation
Hydropower	Build desilting gates to "flush" silted reservoirs	Implement changes in plant operation to account for changes in river flow patterns
	Increase dam height and enlarge floodgates to accommodate increased river flow extremes and variability	
	Upstream land management to reduce possible erosion and dam siltation	
	Expand installed capacity to accommodate increase in flow regime[15]	
Biomass	Use of crops that have higher biological heat tolerance and tolerate higher water stresses than current crops	Implement early warning systems to alert for rainfall and temperature anomalies
	Expand irrigation systems or improve efficiency of existing irrigation to counteract drought impacts[16]	Support for emergency harvesting of biomass in the case of an imminent extreme event
	Protect against floods by building dykes and improving drainage	Provision of crop insurance schemes
	For biomass power plants: increase the robustness of the construction if they are located in storm-prone areas	Site biomass power plants in less flood and storm-prone areas
Wind	Construct turbines that can operate at and physically withstand higher wind speeds	Siting procedure to take into account expected changes in windspeeds during the lifetime of the turbines
		Siting procedure to account for anticipated sea-level rise and changes in river flooding
		Develop insurance schemes for long-term wind power yields and damage from storms[17]
		Availability of rapid emergency repair teams to quickly repair damaged turbines
Solar	*Technical adaptation is limited as solar panels cannot be more robust than the building on which they are located*	Site panels based on expected changes in cloud cover
		Ensure that the design of large concentrating solar power (CSP) plants are robust enough to withstand most storms
		For distributed solar systems: availability of mobile repair teams to ensure functioning of systems after damage from extreme events

15 This is for areas experiencing increased flows from glacier melting *and* if increased levels are likely to persist over the technical lifetime of the system's extra capacity.

16 Provided that sufficient water is available from sources outside the drought-hit area or unconventional sources such as desalinated seawater or fossil water resources are used.

17 This would require good statistics of windspeed changes and extreme storm events from climate information (including forecasts).

Occasionally adaptation measures of different energy forms can impact each other. For example, an improved operation schedule of a hydropower plant may conflict with an improved irrigation schedule of a downstream irrigation system. Likewise, desilting reservoirs may negatively impact the water supply used for downstream irrigation. The rush of power plant developers to claim sites with limited flood risk may result in a decrease in the number of suitable sites in the future.

Top: Nubie Transport - Assouan, Egypt – *Hélène Connor*; bottom: Local Transportation – Deir El Bahari, Egypt – *Hélène Connor*

Country-level Analysis

Sub-Saharan Africa's Poverty Challenge

Countries making up Sub-Saharan Africa (SSA) have an estimated population of 782 million and occupy a land area of 23.6 million km^2. Aggregate GDP for region is USD712.7 billion. The region has a GNI per capita of USD829 and an urban population of about 35.8 percent. Urban population growth from 1990 to 2006 was 4.1 percent while overall population growth over the same period was 2.6 percent.

An estimated 44 percent of total land area is available for agriculture although only 3.5 percent of total cropland is under irrigation. Fertiliser use per hectare of arable land is the lowest in the world. Total forested area is 26.5 percent of total land area. The average rate of deforestation is about 0.7 percent annually (based on figures from 1990 to 2005); only 11.3 percent of the total land area is preserved as protected space.

Internal freshwater resources per capita are 5,093 cubic metres while total freshwater withdrawal as percentage of internal resources is 3.1 percent. Agriculture represents 87 percent of total freshwater withdrawal in the region. Only 56 percent of the total population has access to improved water sources. In rural areas only 40 percent of the population has access to improved water sources; while the figure for urban areas is almost double (80 percent). Only 37 percent of the region's population has access to improved sanitation. This, combined with the impact of accompanying poverty, results in 157 out of 1,000 children dying before their fifth birthday.[18]

Between 1981 and 2005 SSA was the only region in the world that did not see a decline in poverty levels.[19] The overall poverty rate stood at 50 percent in 1981. In absolute terms, the number of poor people has nearly doubled from 200 million in 1981 to 380 million in 2005. If this trend continues, by 2015 one in two of the world's poorest people will live in SSA compared with one in ten in 1980.

Before the fuel and food shocks of 2008, SSA witnessed remarkable positive economic development. From 2003 to 2008, annual growth averaged six percent and inflation fell to single-digits. Many countries, especially commodity exporting countries, built up significant external reserves. These positive developments came about from stronger economic reforms, rise in commodity prices, favourable external environment, debt relief and increased aid (IMF 2009).

Despite this growth, gains of the past years may be at risk as a result of the current global economic slowdown (IMF 2009). Demands for African commodities have fallen; commodity prices have collapsed; and, remittances to the region have shrunk. Foreign direct investment has slowed and portfolio investor flows are being reversed—shaking Africa's once vibrant capital markets. In many ways, the meltdown may be reversing the gains of the past decade of reforms—gains that provided a flicker of hope that equitable growth would begin to reduce the number and proportion of poor people in the region.

Poverty and Vulnerability of Energy Systems

Energy Resources

Poverty and the weakness of SSA's energy systems are inextricably linked. The region has significant energy resources, fossil and renewable alike, although unevenly distributed. Oil and gas are mostly found in Western Africa while coal is the predominant energy resource in the southern region. Hydropower and geothermal resources are mostly found in Eastern Africa. Central Africa has huge hydropower resources as well as biomass.

18 Regional description, resource, environmental and social assessment statistics are drawn from The Little Green Data Book, World Bank 2008.

19 Global poverty has fallen sharply on the strength of China's growing prosperity over the past two decades. The proportion of the world's population living in poverty fell by half—from 52 percent in 1980 to 26 percent in 2005. In the past 20 years, poverty has been declining at the rate of one percent annually (Collier 2007). As a whole, the developing world appears on track to meet the MDG of reducing by half in 2015 the number of people living in poverty from 1990 levels (World Bank 2008).

According to the IEA, in 2007 12.7 percent of total world crude oil production occurred in Africa—much of it in Nigeria and Angola. The region also produces 6.8 percent of total world gas output.

Over 70 percent of Africa's crude oil production is exported. However the region's refining capacity is only 3.3 percent of the world's total. *Even in major oil producing countries like Nigeria, no new refineries have been built over the last decade*. This inertia deprives the region of the value-added benefits of hydrocarbon products and hinders the region's ability to meet regional demands for refined petroleum products.

Nearly five percent of the world's total coal production occurs in Africa, essentially South Africa. While the region has nine percent of total world uranium deposits, South Africa is the only country that has the relevant infrastructure to support nuclear power installations.

Barely seven percent of the region's hydropower potential is being utilised (Davidson 2009). This offers a huge potential to close the energy gap in the region through a clean and cost-effective renewable energy source.

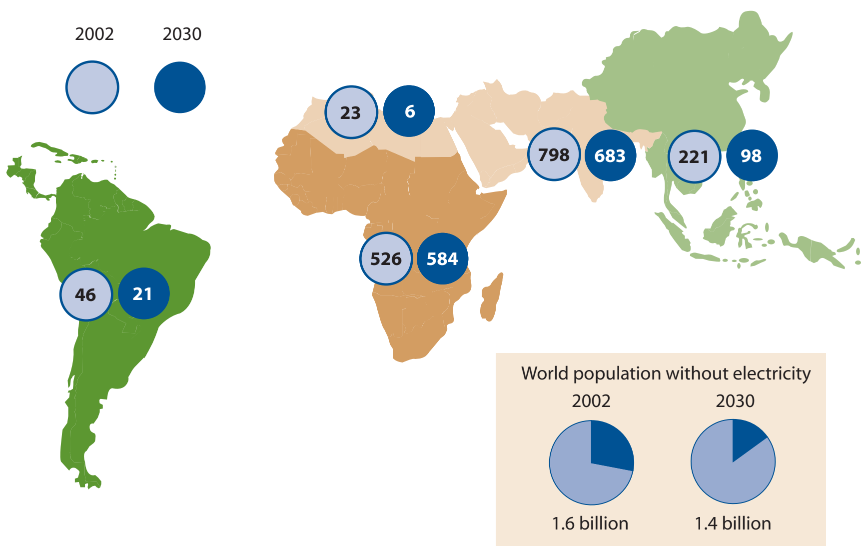
SSA has about 12 percent of the world's population but accounts for approximately only three percent of world's energy use. Disparities within the region are significant, with South Africa representing a huge proportion of total energy production and use.

Electricity

About 80 percent of SSA's electricity is produced from fossil fuels, mainly coal in South Africa as well as oil and gas in North and West Africa. Approximately 17 percent of power production comes from hydropower while nuclear power from South Africa accounts for 2.5 percent of the continent's power production. The remaining 0.5 percent is produced from non-hydro renewable energy sources including geothermal, wind and solar energy (Davidson 2009).

Less than 20 percent of SSA's population has access to electricity services. There are also important regional variations; in certain countries less than ten percent of the population has access to electricity. Annual per capita consumption of power in the region is 542 kWh (World Bank 2008). In several countries in SSA, electricity use per capita is in rapid decline. From 1990 to 2004 electricity use per capita in Sierra Leone, D. R. Congo, Chad, Ghana, Sao Tome and Principe and Zimbabwe declined by 54.7 percent, 42.1 percent, 31.3 percent, 22.3 percent, 23.8 percent, and 10.1 percent, respectively (UNDP 2007).

Figure 3: Quantity of the world's population without electricity in 2002 and 2030 (estimated)



Source: Liaison Énergie-Francophonie 2008

Result

Weak energy systems constrain efforts to meet the MDGs. For instance, energy is essential in reducing disease levels and decreasing child and maternal mortality. It is a key component of functioning health systems, e.g., lighting operating theatres, refrigeration of vaccines, and other medicines, sterilisation of equipment and transport to health clinics. Clean, household energy improves household health by reducing or eliminating smoke from cooking fires. According to WHO (2007), Africa loses nearly half a million lives (mainly women and children) as a result of respiratory diseases attributable to traditional burning of wood.

Table 6: Number of people using traditional biomass (in millions)

Region	2000	2030
China	706	645
India	585	632
Other Asia	420	456
Latin America	96	72
Sub-Saharan Africa	583	996

Source: Karakezi *et al*. 2008

Beyond 2015, the outlook for access to modern energy services remains bleak. While electricity services are in decline, nearly one billion people in SSA will still rely on traditional biomass energy by 2030. This scenario portends great danger for human survival and health in the face of climate change.

Efficient cookstove - Darfur, Sudan – *Stovesonline*

Country Summaries

Africa remains at the epicentre of the evolving climate crisis, despite contributing the least to greenhouse gas emissions. Inherent vulnerabilities of SSA energy systems will be magnified by climatic changes, further weakening the ability of the energy sector to contribute to economic growth, poverty reduction and ecodevelopment.

Below are short descriptions of the ten SSA countries studied with key vulnerabilities of each country's energy systems briefly summarised.

1 – BENIN

In Benin, biomass (firewood and charcoal) remains the dominant source of energy, followed by petroleum products and, to a lesser degree, electricity.

The country is 100% dependent on petroleum imports, making it vulnerable to dollar exchange rates and fluctuations in oil prices. Fluctuations in fossil fuel prices also compromise Benin's domestic capacity to develop its energy services. In 2007 national electrification was 25% overall although electrification in rural access was estimated to be less than 2%.

While Benin has a large hydroelectricity potential only one major hydroelectric site currently functions. Development of over 80 pre-identified sites using micro-hydro applications would help Benin increase its energy resilience.

Despite having a huge and untapped renewable energy potential, low levels of domestic capital formation and little internal capacity (engineers, technicians, etc.) hinder development. The absence of hazard or siting maps for equipment installations means that Benin's existing energy infrastructure remains extremely vulnerable to anticipated climate change impacts. While Benin's National Adaptation Plan of Action notes the necessity of an emergency response plan to deal with the impacts of meteorological extreme events, this plan has yet to be developed.

2 – BURKINA FASO

As throughout much of SSA, biomass is the country's main energy source, providing 84% of all energy consumed. The country is 100% dependent on fossil fuel imports and has seen a 125% increase in energy dependence over the past ten years. Energy imports, representing 10-20% of all of the country's gross imports are increasing rapidly in the face of growing demand.

Hydroelectricity, generated locally or supplied over inter-connected grids, provides for 6% of total energy consumption. However changing weather patterns threaten hydroelectricity output. The average rainfall in Burkina Faso is decreasing and moving southward. Current predictions anticipate a loss of 100 mm by 2025-2050, as well as temperature increases of 2°C to 4°C over the same period. While there is a national plan for the optimised operation of hydropower plants under projected flow regimes, it is not clear how severely this sector will be impacted by climate change.

New plant installations in Burkina Faso have to meet a national Environment Code that requires an environmental impact assessment as well as environmental and social management plans. Unfortunately, there is no inclusion of climate change issues. Moreover, no emergency plans for anticipated environmental disasters are in place nor are flooding or drought hazard maps available.

Given the growing pressure on Burkina Faso's biomass reserves (both from consumption and changing weather patterns), investment in research, development and dissemination budget for heat and drought resistant crops are crucial. Greater substitution of household biomass use is needed as is an increase in the installed capacity of renewables (especially solar) from its currently low level of 1,000 kWs.

3 – CAMEROON

Cameroon's energy mix consists of biomass, petroleum and hydro. Currently 97% of all electricity consumed is produced by one, 40 year-old hydropower dam. However a rehabilitation and operational optimisation programme has been put in place that takes into account water flow variations. This should help to offset the impacts associated with the 2% decrease in rainfall that the country is experiencing annually.

The aging distribution and transmission equipment means that there are frequent electricity outages. An inability to withstand high winds further contributes to overall network vulnerability.

Despite being a modest, oil-producing country (84,000 barrels/day in 2007), Cameroon must import light crude to operate its thermal plant. This import dependence makes Cameroon vulnerable to fluctuations in oil prices. With all of Cameroon's oil installations, refineries and oil fields located on the coast or offshore the likelihood that one or more of these installations will be hit by a storm of more than 70 m/s gusts within the next 20 years is estimated to be about 80%.

Overall, Cameroon's internal capacity to adapt to climate-induced impacts on its energy systems is weak. Only 300 engineers graduate annually and there are no power plants siting construction guidelines that take into account the likelihood of extreme climatic events. Following on the 1986 Lake Nyos disaster, a national disaster response plan was introduced. The plan outlines disaster management and describes the response levels of the different teams, however, there is no reference of how to respond to climate induced impacts.

The continued high dependence on rain-fed biomass only serves to exacerbate the country's energy vulnerability.

4 – DEMOCRATIC REPUBLIC OF CONGO (D. R. Congo)

Since 1997, D.R.Congo has been in political and social turmoil. Inadequate governance, chaotic economic management and the freezing of international cooperation had resulted in D.R.Congo having one of Africa's lowest GDPs and a poverty rate of 71%.

The D. R. Congo remains one of the few countries in the world with large hydroelectric resources. It has an estimated 66% of central Africa's potential and 35% of the continent's potential. Despite this "energy wealth" electricity only makes up 6% of all energy consumed nationally.

Potential for exploiting D. R. Congo's "energy wealth" is limited, particularly when viewed through a climate change scenario. Variations in annual rainfall are predicted to increase 7-11% however there are no optimisation plans for projected flow regimes. An aging and under-maintained transmission infrastructure limits distribution. With half of the hydroelectric power concentrated at a single facility this lack of infrastructure presents a key vulnerability. Moreover, with only 550 engineers graduating annually, D. R. Congo's technical capacity to maintain a robust network is severely constrained. Emergency repair teams, skilled in responding to storm related damage, are non-existent.

5 – KENYA

Kenya's economy has been hit hard by the current global financial crisis and recent election violence. This has scaled back near-term projections for economic growth. Gross domestic product per capita is very low and as poverty deepens; the ability to invest in new energy systems is reduced.

While the Government of Kenya is trying to reform the energy sector by encouraging private sector ownership and by implementing policies that support diversification of energy sources, several specific steps to offset current vulnerabilities have yet to be taken.

Kenya produces only 700 engineers annually. This amount is inadequate to meet the challenges of expanding and diversifying the country's energy systems. Several key instruments that support increased resilience in the energy system such as the availability of flood maps, existence and enforcement of power plant siting and construction guidelines and emergency plans to react to extreme weather events are not available. Even though the country depends heavily on hydropower systems for electricity supply, there are no national plans for optimising hydropower plants operation under alternative future flow regimes. Moreover dams are not equipped with desilting gates nor are upstream land use management systems in place.

Despite the fact that traditional biomass dominates the energy landscape, little or no budget is provided for research, development and dissemination for heat and drought resistant crops, biofuels or modern biomass energy use. While some progress has been made in disseminating efficient wood and charcoal stoves, more needs to be done. New initiatives to promote feed-in tariffs for renewable energy would build more diversity and strengthening energy system resilience.

6 – MALI

Mali's energy situation is characterised by the predominance of biomass (87%) in meeting the needs of households for cooking, and by a very low level of electrification (16%). Extreme poverty denies access to modern energy services to much of the population. Mali is a net importer of petroleum products.

Despite changing temperatures and migrating rainfall patterns, Mali appears well placed to increase the resilience of its hydropower and renewable energy systems. Plans for optimised operation of hydro plants under projected flow regimes are in place and siting maps that detail projected changes in windspeed, floodplains, and areas impacted by sea level rise exist.

Projects for building of solar thermal plants with a capacity of more than 100 MW are being prepared although climate proofing these installations is not yet considered. Given biomass's central role in Mali's energy mix, more work needs to be done on researching and developing drought resistant crops. The development of alternative fuels from biomass residues would help to off-set household energy vulnerability, particularly in rural areas. Local production and use of jatropha has already been proven to be a successful energy source.

7 – NIGERIA

The economic fortunes of Nigeria have fluctuated with the vagaries of the international oil market. Although endowed with significant natural and human resources, corruption has robbed Nigeria of its potential to become an emerging economy. The current global financial meltdown has further compounded the country's abysmal governance record. Paradoxically, despite being the world's seventh largest oil exporter, Nigeria has SSA's most energy-starved economy with an annual electricity use per capita standing of 157 kWh (compared to a SSA average of 550 kWh).

The absence of a diversified energy policy portfolio is further compounded by the lack of basic tools to assess energy resilience: siting maps that anticipate for future environmental hazards for power plants are not available; only 2,500 engineering students graduate annually; and, there is little resource data to encourage investment in potential renewable energy sources.

Moreover, while the traditional use of biomass dominates the energy scene, there are no government-led investments in new research and development or initiatives to promote the dissemination and use of biomass energy technologies. The little research that does exist is within the academic structure and is often disconnected from the energy market and potential investors.

8 – SENEGAL

Senegal's energy balance is predominately biomass (58%) and petroleum products (38%). The lack of diversification is compounded by the absence of efficient technologies, a low density of distribution grid, as well as a lack of regulatory framework and weak financial structures. Senegal's hydroelectric potential remains untapped. However with rainfalls predicted to decline by 17% over the next 20-50 years, attention will need to be paid to hydropower's role in the country's energy mix. The development of flow regime optimisation plans will help in this regard.

Senegal already has some key adaptation elements in place. The country has a national contingency plan that includes studies of natural disasters such as flooding, and of the areas where disasters might occur. Maps showing projected cloud cover and

wind speeds are available. Biomass consumption is also being tackled with substantial research on biomass issues and promotion of improved woodstoves.

Flooding of thermal plants is a real vulnerability that will need to be addressed. Already one plant has suffered damage due to heavy rains.

9 – TANZANIA

Tanzania remains one of the poorest countries in SSA. Its economy is dependent on rain-fed agriculture, tourism and tea and coffee exports—all of which are climate sensitive. Two-thirds of the country's electricity comes from hydropower while the remainder is produced from natural gas, which is piped over considerable distances.

Building a resilient energy infrastructure requires the services of engineers. Currently there are only 500 who graduate annually. There are no hazard maps for floods or droughts or any clear guidelines nor enforcement of power plant siting regulations that take into consideration the possibilities of extreme weather events. Despite its coastal location, Tanzania has no emergency plans for responding to extreme meteorological events that could threaten its energy infrastructure.

Tanzania however does have a national plan to optimise operation of hydropower plants under various projected flow conditions. Such contingency planning is necessary in order to anticipate and respond to climate change induced events.

Although biomass accounts for 90% of Tanzania's energy supply, minimal attention is given by government to this energy source. Very few households use efficient wood stoves.

10 – UGANDA

The country's economy is dominated by climate sensitive agriculture. Its economic resilience is further eroded by its total dependence on imported petroleum and on international donors.

Although Uganda has hazard maps for events such as floods and droughts, emergency preparedness is weak. There are no existing power plant siting construction guidelines that take into account the likelihood of extreme climatic events.

Two dams in Uganda are equipped with desilting gates and have proper plans for the management of upstream water and land use issues. However, there are no national plans for optimised operation of power plants under variable flow regimes.

The share of biomass in total energy supply in Uganda (94%) is one of Africa's highest. Only 8.7% of all households use efficient wood stoves. As in most African countries, research, development and dissemination of efficient and modern biomass technologies are inadequate.

Country-level Vulnerabilities

When vulnerability is discussed at the national level it is traditionally around issues of energy supply security and how to improve it. There is little policy formation around the broader context of reducing energy system vulnerability and improving resilience through ecodevelopment strategies, e.g., addressing environmental, social, economic, technical, and governance issues.

In order for proposed policies and measures to be effective, it is necessary to quantify the country's state of overall vulnerability. HELIO's first set of indicators therefore measure the overall vulnerability of a country.

Many national emergency plans, National Adaptation Programmes of Actions (carried out under the UNFCCC), and research publications detail various vulnerability aspects. Thus analysts are encouraged to use the existing documentation to collect the necessary information and to analyse the data from an ecodevelopment perspective.

Following on HELIO's principle—that the actual measurement or statistic used must be generally available and that collection and vector calculation must be do-able—analysts were asked to calculate the indicators listed in Table 7. In keeping with Kyoto Protocol guidelines, the reference year is 1990 or the nearest year for which data are available. For each group of indicators, analysts were also asked to provide a short, qualitative summary, highlighting any key issues that may have not been captured by the indicators or that affected the indicator calculations.

Table 7: Country-level vulnerabilities

Sector	Indicator	Calculation
Environmental	1. Change in rainfall patterns	% change between 1990 and current year – describe the change in rainfall patterns Additional information that can be included: • Volume and frequency of rainfall • Number of rain days per year • Number of days with heavy precipitation (> 50mm) • Length of seasons • Maxima/minima rainfall
	2. Variation in temperature	Temperature evolution (in °C) between 1990 and current year • Average • Minimum/maximum per season
Economic	1. Proportion of households acquiring access to electricity in the last two decades	% of households who have gained access to electricity between 1990 and current year
	2. Level of increased energy autonomy	For a country that is a net importer of oil and gas (non-renewables) • Ratio between imports of non-renewable energy and the consumption of non-renewable energy (in Joules) in comparison to 1990 Importing countries can improve resilience by reducing either imports or consumption of non-renewables, or by increasing imports or consumption of renewable energy, and increasing overall energy efficiency For a country that is a net exporter of oil and gas (non-renewables) • Ratio between the export of non-renewable energy and the value of all exports (in monetary value) in comparison to 1990

Sector	Indicator	Calculation
Technical	1. Change in the amount of energy supplied by renewables	1a. Aggregate heat and electric power production from renewables (MWh) 1b. % change between 1990 and current year of % of power from renewable sources in total power production 1c. Volume of renewable fuel consumption (in TOE) 1d. % change between 1990 and current year of % fuel from renewable sources in total fuel consumption
	2. Level of diversity of renewable energy sources and technologies	% contribution of the following to total renewable energy use, describing what the renewable energy source is used for • Electricity • Heating • Transport
Social	1. Change in prevalence of diseases	% change in rate of waterborne diseases between 1990 and current year • Comment on unreported incidences if possible
	2. Change in employment	% change in unemployment rates reported between 1990 and current year • Comment on unreported incidences if possible
Civic (Governance)	1. Land reform improvement	1a. % change of farmers owning or having permanent access to their own land between 1990 and current year 1b. % of women owners Proxy: Presence of land ownership policies and enforcement of legislation
	2. Change in public participation in planning process	2a. % participation in national elections or in Agenda 21 planning and implementation processes 2b. % change between 1990 and current year

The following section summarises the calculated indicators for all ten countries. With the exception of temperature, the absolute change (as opposed to relative change) has been used to facilitate cross-country comparison.

Of Special Note

As with any new tool there are difficulties in collecting data and finding them in consistent forms. While much effort has been devoted to presenting indicator values that are consistently defined across the various countries, this was not always possible. Differences in the data available for each country, the form in which they are reported, and the complexity of the conventions used for quantification, made it impossible to completely harmonise the data with the resources at hand. Even for some basic indicators, e.g., the reliability of electricity supply, there is currently no standard set of reporting conventions suitable for cross-country comparison. Similarly—despite its high usage—data on biomass use and biomass systems' vulnerability and resilience are especially difficult to collect, primarily because of biomass's decentralised nature.

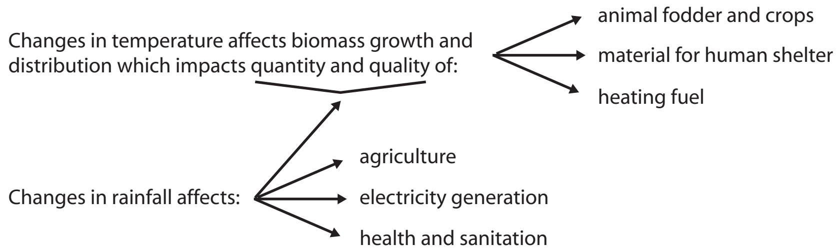
Given the problem of data harmonisation, preparing policy-relevant comparisons across countries was challenging. Rather than suppress useful data, the summary tables provide as much defensible data as possible, noting major differences in reporting. As a result, the data reported in the tables below are not always identical to the data reported in the country reports; instead, original indicator values have sometimes been reformulated to better fit with conventions used by other countries. Major differences in reporting are noted whenever possible.

Drawing from the present experience, indicator definitions could be further refined and harmonised to increase consistency of reporting in future work.

Environmental Indicators

1. Change in rainfall patterns	2. Variation in temperature

Most countries in SSA are directly impacted by changes in rainfall and temperature levels. Rain-fed agriculture and husbandry are the norm; biomass is the primary energy source as well as the main fodder for animals. Significant changes in rainfall and temperature patterns have wide-reaching implications for many, as is illustrated in the simple diagram below. Thus it is important to understand how these patterns are evolving in order to reduce the vulnerability.



Rather than define a complicated indicator, for which data support would rarely be available, the indicator values reported in the table below are intended as simple point-to-point comparisons.[20, 21] HELIO opted to use this form of comparison to mark the importance of weather patterns in energy systems and as a means of assessing data availability. The point-to-point comparisons are not necessarily indicative of a trend. For temperature, HELIO was able to obtain additional data that underscores an upward trend (Figure 4) as suggested by the indicator values.

Table 8: Precipitation and temperature indicators

	Precipitation (mm)	% change	Temperature (average, unless otherwise noted)[22]	% change
Benin	1990: 239 2007: 254	+ 6%	1990: 21-25°C 2007: 20-25°C	—
Burkina Faso	1990: 850 (650-1055) 2007: 800 (600-1000)	-6%	1990: 34°C 2007: 35°C Average daily max	+1°C
Cameroon	~4% decrease 1990-2007[23]	-4%[24]	0.7°C increase between 1960 and 2007	+0.7°C

20 Depicting moderate-term trends and patterns in a country as a whole is notoriously difficult due to the complexity of weather, its natural variability across time and geographically, as well as data limitations (Easterling *et al.* 2000; Molua 2006). Results depend on the statistical methods and definitions used.

21 The Country Reports include more detailed assessments of weather trends and patterns as pertains to climate change and energy system vulnerability. See www.helio-international.org

22 In some cases, average daily maximum temperature is reported, and in some cases, data for a single city or region rather than an average across multiple sites in the country. All data are taken directly from individual Country Reports, unless otherwise noted.

23 Derived from reported 2.2% decrease in rainfall per decade since 1960 (Cameroon Country Report).

24 Approximate; derived from trend data reported.

	Precipitation (mm)	% change	Temperature (average, unless otherwise noted)	% change
D. R. Congo	1990: 1298 2006: 1200	+4%	1990: 24.8°C 2006: 26.5°C	+1.7°C
Kenya	1990: 806 2008: 763	-5%	1990: 23.7°C 2009: 24.1°C[25]	+0.4°C
Mali	1999: 1400 2004: 1300[26]	-7%	1990: 28.3°C 2005: 28.4°C[27]	+0.1°C
Nigeria	2000: 733 2008: 494[28]	-32%	1990: 35.2°C 2008: 36.1°C[29] City average max	+0.9°C
Senegal	1990: 750 2008: 840	+12%	1990: 28.1°C 2008: 28.7°C	+0.6°C
Tanzania	1990: 502 2007: 864[30]	+72%	1990: 22.7°C 2008: 23.1°C	+0.4°C
Uganda	1990: 1159 2005: 932[31]	-20%	1990: 22.0°C 2005: 22.7°C[32]	+0.7°C

❑ *Snapshot Assessment*

Change in Rainfall Patterns

In some cases the reported precipitation is for a major city, while in other cases it is an average of data over more than one locale. While observed rainfall sometimes increased, and sometimes decreased, *no definitive change in precipitation patterns can be deduced from the data at hand* for the SSA region studied.

Variation in Temperature

With the exception of Benin (for which averages temperatures were not reported) all point-to-point comparisons of temperature shown above *indicate an increase in average (or average daily maximum) temperature* for the region.

For seven of the ten countries, Figure 4 shows trends in annual average temperature from 1960 to 2006.[33] Despite the consistent large drop in temperature in the final year depicted (2006), this 47-year view shows a past trend of increasing average temperature for all countries, amounting to approximately 0.5°C-1.0°C across the 15-year period. The pattern is remarkably consistent across all countries.

25 Projection based on recent trends, as per Kenya Country Report.

26 Data for Sikasso, city with the most rainfall. In contrast, the driest city, Tessalit, gets only about 15 mm of rainfall per year (Mali Country Report).

27 Data are from UNDP Climate Change Country Profile data base (http://country-profiles.geog.ox.ac.uk/, file Mali.ts.obs.temp.ts.ensemblemean.txt).

28 Data are from Sokoto, rather than over multiple cities.

29 Average maximum daily temperature for Sokoto.

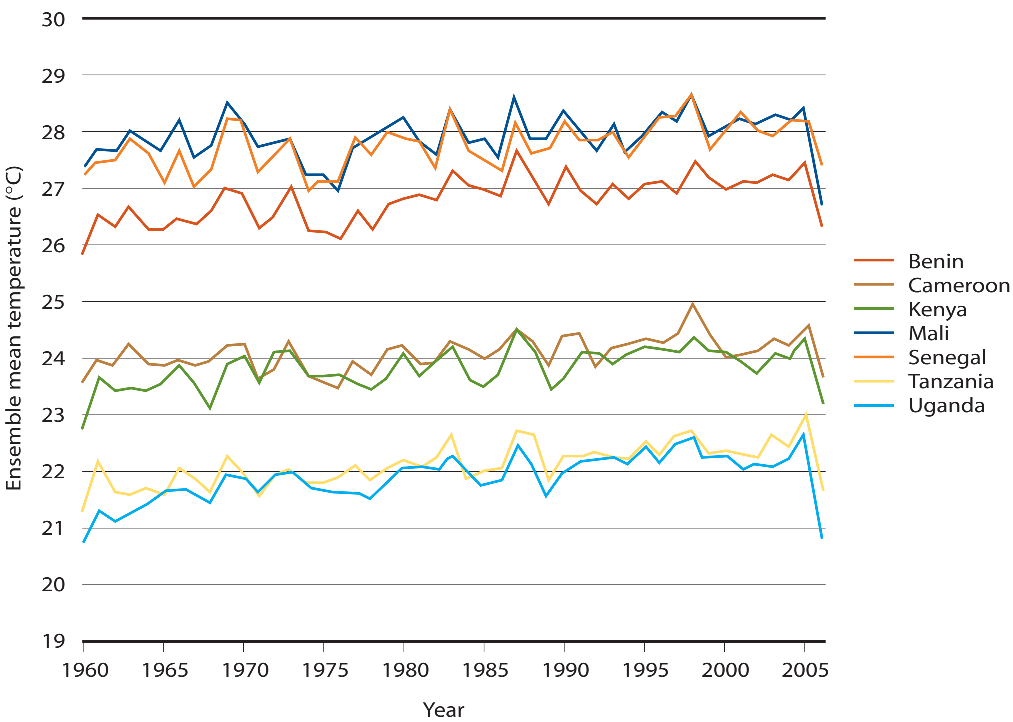
30 Data are from the Dodoma region.

31 Data reported in table are from UNDP Climate Change Country Profile data base (http://country-profiles.geog.ox.ac.uk/, file Uganda.ts.obs.temp.ts.ensemblemean.txt). See also Uganda Country Report.

32 Data from UNDP Climate Change Country Profile, *op. cit*.

33 Data source is the UNDP Climate Change Country Profile data base (http://country-profiles.geog.ox.ac.uk/, accessed September 2009). The figure shows ensemble average over a geographically-defined grid. No data were available for Burkina Faso, Nigeria or the D. R. Congo. Additional data on precipitation, temperature and precipitation extremes, and anomalies are also available in the UNDP data base.

Figure 4: Trends in ensemble average temperature 1960-2006



Note: The ensemble average/mean is the annual temperature averaged over a geographic grid overlaid on the country

Source: UNDP Country Profile Reports – climate data

Economic Indicators

1. Proportion of households acquiring access to electricity in the last two decades	2. Level of increased energy autonomy

Access to electricity is considered a social good; it helps spread literacy and education, it contributes to improved health through the refrigeration of food and medicines, and to increased communication and awareness. While western standards of electric use need not be adopted, access to some level of affordable power is appropriate.

Many countries in SSA are highly dependent on imported fuels for transportation, heating, cooling and lighting of buildings and electric power generation. The threat of supply interruption is real, due to unforeseeable political reasons, pipeline accidents, system vulnerabilities, embargoes, terrorism, civil strife, etc. A universal threat is price fluctuations that can destabilise both importing and exporting nations, thereby increasing overall vulnerability.

Table 9: Access to electricity and energy dependence

	Access to Electricity (% of households)[34]	Absolute Change in %	Energy Dependence: Imports as % of total or non-renewable energy	Net Exports[35] (1,000 bbl/day)	Absolute Change in %
Benin	1990: 8.6% 2005: 23.2%	+15%	1990: 24% 2005: 51% Total energy	-4 (I)	+27%
Burkina Faso	2002: 8.5% 2008: 12%*	+4%*	2002: 79% 2008: 82%* Non-renewables	-9 (I)	+3%*
Cameroon	1996: 37.0% 2007: 48.2%	+11%	1990: 4.5% 2003: 46.2% Non-renewables	55 (E) 46% of exports	+42%
D. R. Congo	1990: 5% 2007: 6%	+1%	1990: 8% 2006: 69% Total energy	9 (E)[36]	+61%
Kenya	2000: 8.7% 2008: 10.5%	—	—	-75 (I)	—
Mali	2001: 9% (32% urb.) 2007: 17% (51% urb.)	+8%*	2007: 14% Total energy	-5 (I)	—
Nigeria	2008: 40% (est.)[37] (18% rural)[38]	—	1996: 98%[39] Export importance	1883 (E)	
Senegal	2000: 30% (58% urb.) 2006: 44% (77% urb.)	+14%*	2000: 77% 2007: 77% Total energy	-38 (I)	0%
Tanzania	2004: 11%[40]	—	—	-32 (I)	—
Uganda	1991: 5.6% 2006: 9.0%	+3.4%	1990: 100% 2008: 100% Non-renewables	-13 (I)	—

*Short time span used for comparison.

34 Changes are expressed in terms of absolute percentage of household population, i.e., percentage of households electrified in final year less percentage of households electrified in base year.

35 "E" denotes net exporter; "I" denotes net importer. Statistics on energy imports and exports are from the Energy Information Administration (http://www.eia.doe.gov/emeu/cabs/). For net exporters, percentage of the value of petroleum product exports relative to total exports is provided where available. Data are drawn from country reports unless otherwise noted.

36 While D. R. Congo imports oil, this does not mean that the country is a *net* importer. D. R. Congo imports oil mainly in the form of crude oil and petroleum products. Exports are made up of fuel oil and Congolese oil which cannot be processed in any local refinery.

37 Per capita consumption has decreased sharply from 209 kWh/person to 157 kWh/person between 2000 and 2008.

38 Nigeria's Electricity Sector for the Sub-Committee of the Presidential Advisory Committee on 25 Years Electric Power Supply Plan, page 26.

39 Frynas 2000.

40 Tanzania Country Report indicates that electrification rate was 45% in 1990. Because that estimate seems extraordinarily high relative to the 2004 value (meaning a 34% drop) only the data for the latter year are shown.

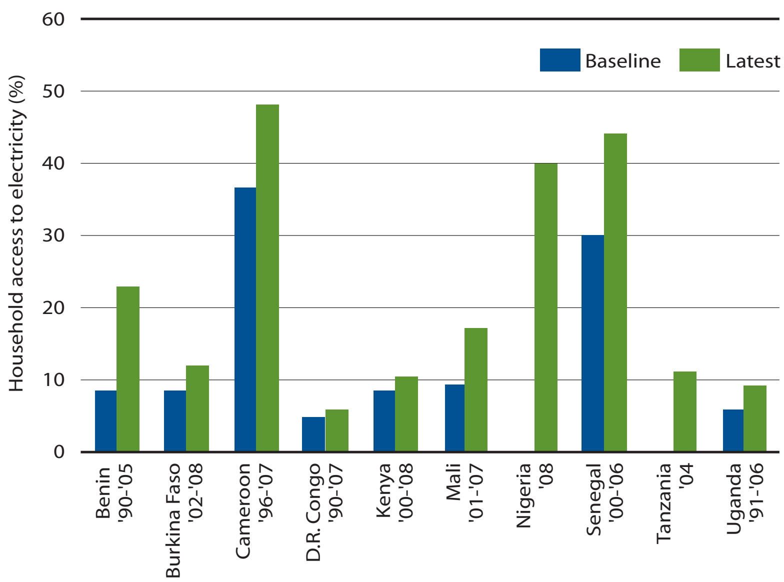
❑ *Snapshot Assessment*

Household Access to Electricity

Of the six countries with fairly reliable data, all show an increase in the percentage of households with access to electricity.

Cameroon and Senegal show the highest levels of electricity access, at 48 percent and 44 percent, respectively. Access in Benin, at almost 25 percent, has more than doubled in a 15-year period. In the D. R. Congo, in contrast, access has increased by only one percent (from five percent to six percent) between 1990 and 2007. Access in rural areas is often very low, as is illustrated by Mali and Uganda (one percent access). Figure 5 reports the patterns graphically (note varying baseline years).

Figure 5: Percentage of households with access to electricity for base year and latest year available



Energy Autonomy

In four of the six countries for which both historical and current data on energy imports are reported—Benin, Burkina Faso, Cameroon, and D. R. Congo—dependence on non-renewable imports has increased over the reporting period, sometimes tremendously. Imports of non-renewable energy supplied 100 percent of Uganda's non-renewable energy in both 1990 and 2008. Imports remained stable at 77 percent of non-renewable energy in Senegal between 2000 and 2007.

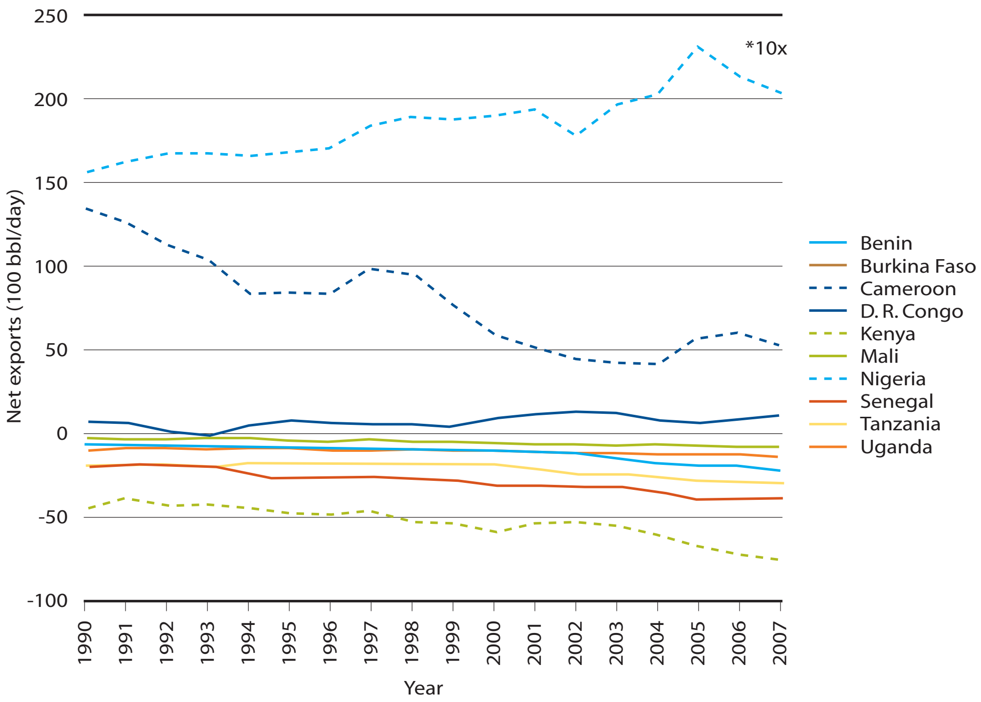
Three of the ten countries are net exporters of petroleum: Cameroon, D. R. Congo, and Nigeria. Nigeria ranks seventh highest in the world for volume of petroleum exports (EIA 2009).

Figure 6 illustrates trends in net petroleum exports (total production less consumption) for each of the ten countries between 1990 and 2007. Values for Nigeria have been divided by 10 to fit the scale of the graph. A *decreasing* trend indicates an *increase* in net imports.

Nigeria is by far the biggest exporter; its exports increased 33 percent between 1990 and 2007, with 2007 exports topping 210,000 barrels/day.[41] Cameroon shows a sharp drop (54 percent) in net exports between 1990 and 2007, but still exports over 5,000 barrels per day. The D. R. Congo is also a net exporter with current levels remaining at 1990 export levels.

41 Despite being the world's seventh largest oil exporter, the country remains a net importer of petroleum products and cooking kerosene fuel, primarily because of a lack of refining capacity. This vulnerability is further compounded by the fact that the Nigerian economy is heavily dependent on its oil export earnings (EIA 2009).

Figure 6: Trend in net petroleum exports 1990-2007



*Nigeria values have been divided by 10 to fit scale.
Source: U.S. Department of Energy Country Energy Profiles

The remaining seven countries are net importers. For all seven, net imports have been steadily *increasing* between 1990 and 2007. Graphically, the trends appear minor because of the scale of the graph, but the increase in imports has been dramatic. *For all seven net importers, net imports in 2007 are at least 60 percent higher than they were in 1990.*

Analysis of the indicator results illustrates that *the dependence on oil exports increases a country's level of vulnerability, just as being dependent on oil imports does.* A heavy dependence on oil export earnings makes the country economically vulnerable, as is illustrated by Nigeria's case: the oil sector accounts for over 95 percent of export earnings and approximately 85 percent of government revenues (EIA 2009; Frynas 2000).

Technical Indicators

1. Change in the amount of energy supplied by renewables	2. Level of diversity of renewable energy sources and technologies

Hydropower (augmented by thermal plants) generates most of SSA's electricity. However, biomass is the predominant energy form, accounting for over 70 percent of all energy consumed in nine of the ten countries reporting.[42] This widespread traditional use of biomass is both a cause and a consequence of poverty.

A diversified energy mix is one way to increase a country's resilience. Use of renewable energy can help offset the vulnerability generated through high import/export levels of fossil fuels. Micro- and pico-hydro systems reduce the need for extensive transmission and distribution lines, which present new vulnerabilities. Wind, solar and local biofuel applications allow for energy generation according to the best resource available.

42 Biomass contributes only 58% of Senegal's total energy mix.

Table 10: Energy supplied by renewables and levels of diversification

	Renewables as % of electricity*	Renewables as % of energy mix*	Change (% absolute)	Diversification of renewable energy sources: as % of electricity*	Diversification of renewable energy sources: as % of energy mix*
Benin	1996: 0.2% 2005: 0.7%[43]	—	+0.5%	—	2004: 59.5% Wood/charcoal
Burkina Faso	—	2002: 86% 2008: 84%[44]	-2%	2002: 14.5% 2008: 16%[45]	—
Cameroon	—	1990: 81.3% 2002: 84.5%	+3.2%	1990: 98% Hydro 2003: 96% Hydro	—
D. R. Congo	—	—	—	1990: 100% Hydro 2006: 100% Hydro	—
Kenya	1990: 87% 2008: 73%	—	-14%	1990: 100% Hydro 2008: 78% Hydro + 22% Geothermal[46]	—
Mali	2003: 94% 2004: 75%[47]	—	—	Mali has four dams, several thousand photovoltaic, solar water heating, and solar dryers, but barely any wind energy systems	—
Nigeria	1990: 24.8% 2004: 33.4%	—	—	—	—
Senegal	—	2000: 100% 2006: 98%	+5%	—	2006: 98% biomass
Tanzania	2001: 61% 2009: 86% Electricity (non-oil)[48]	—	—	—	—
Uganda	1990: 100% 2008: 64.5%[49]		—	—	2009: 99% biomass

* Because the majority of analysts reported renewables as a percent of the *electricity* mix as opposed to a percent of the *total energy* mix, a second column has been added to both indicators to allow the information to be presented.

43 Percentages represent proportion of hydroelectricity to all electricity. Contribution varies from year to year based on water availability and is as high as 2% in some years (2.1% in 2003).

44 Includes hydroelectricity, solar energy and biomass. The percentage contribution of hydroelectricity and solar alone (excluding biomass) ranged from 5.4% (2002) to 5.8% (2008).

45 Hydroelectricity and solar as a percentage of total electricity.

46 Since 1990, there is also a small amount of cogeneration and wind, though in the 2008 the contribution of each of these sources was less than 1%.

47 The figures refer to contribution of hydroelectricity versus thermal electricity.

48 Natural gas is used for electricity generation.

49 Hydroelectricity as a proportion of total electricity.

❑ *Snapshot Assessment*

Despite the uneven reporting on energy supplied by renewables, it is clear that the predominant renewable electricity source is hydropower. However, the majority of these hydro systems (as described in the country reports) are greater than 10-15 MWs, which is often considered the upper limit of "small" hydro.[50]

Table 10 also illustrates little diversification within each country's "basket" of possible renewable energy sources. The high percentages of hydro in the energy mix for Cameroon, D. R. Congo and Kenya is cause for concern, as is the predominance of biomass throughout SSA. With Africa's high vulnerability to climate change and the rapid deterioration of these energy-providing ecosystem services—water and biomass—there is a high likelihood that these energy services will be severely compromised.

While Benin, Burkina Faso, D. R. Congo, Kenya, Mali, Senegal and Tanzania all have some level of solar application, the combined installed capacity is under 15 MW. Senegal is the only country that has a wind project planned for 15 MW.

In all the countries reviewed, investments in renewable energy are very low. Considering that only seven percent of the total hydropower potential of SSA is currently used, the scope for growth in investment (particularly in small hydropower systems) is significant. Beyond hydropower, enhanced efficiency standards in biomass use, investments in modern biomass, including biogas, biofuels and biomass cogeneration technologies represent opportunities that have not been fully utilised.

Greater diversity and increased investments in energy supply and demand-side management will be crucial in stimulating growth and hedging energy systems against current and future climatic challenges.

Social Indicators

1. Change in prevalence of diseases	2. Change in employment

People in SSA suffer from a vast range of preventable and curable infectious diseases. HIV/AIDS, tuberculosis and malaria are estimated to kill about three million people every year in the region (WHO 2006). Children bear the burden of poor health caused by measles, water-borne infections and parasitic diseases. The result is hardship, impoverishment, countless lives lost and reduced productivity. The diversion of scarce resources to tackle these diseases traps countries in a seemingly endless cycle of poverty and illness. Containing the spread and managing treatment of disease, and doing both effectively, is central to the overall health and productivity of a community. A healthy society is productive and resilient.

Employment is another basic indicator of a nation's health. The lack of employment results not only in household poverty but in losses to the economy as a whole, in terms of potential output, tax revenues and human capital. Inadequate employment also lessens opportunities for human development and restricts social and political participation. Employment is noted as one of the key requirements for achieving the MDGs.

❑ *Snapshot Assessment*[51]

Prevalence of Disease

For all ten countries studied water-borne diseases (whether cholera, dysentery, malaria or a combination thereof) were selected by the HELIO analysts as being the most prevalent disease(s).

50 Large hydro has significant impacts on the surrounding biodiversity. Catchment areas increase the level of water-borne diseases and the amount of rotting vegetation, which releases greenhouse gases contributing to global warming. Water quality is also degraded. The dam structure itself hampers fish migration, disrupting water and sediment flows. Aging structures also pose particular safety hazards. Reduced water flows have downstream impacts, including disrupted water and sediment flows, reducing biodiversity. Communities suffer from poor water quality, lower crop production and decreased fish populations (International Rivers).

51 The range of diseases selected and variations of measurements made it impossible to create a comparative chart. A qualitative assessment with information drawn from the Country Reports is presented instead.

All numbers provided by the analysts point to water-borne disease rates as being epidemic. While the rate of infant diarrhoea has been reduced in Burkina Faso and Cameroon, malaria has increased significantly in Uganda (although it is not clear whether this is because of an increase in the disease or because of improved reporting).

Overall the epidemic nature of some water-borne diseases makes it difficult to deduce trends from limited data. It is not clear whether changes from year to year are due to systematic changes in health infrastructure or to more or less "random" variations in the disease itself. However, what is clear is that *changing climatic conditions will only exacerbate this situation*.

As pointed out earlier in the report, climate change will not only alter rainfall patterns and quantity, it will increase the frequency of extreme events such as excessive rainfall, storm surges, floods and droughts. These extreme weather-related events affect water availability, quality, or access, in turn posing a threat to human populations. Water-borne pathogens (that cause diarrhoea, malaria, dysentery, etc.) are spread to drinking water and recreational water use. Aging water treatment and distribution systems are also susceptible to weather extremes, increasing significantly the vulnerability of the drinking water supply. Excess rainfall can over-extend the capacity of water treatment facilities. Droughts or extended dry spells can reduce the volume of river flow leading to an increased concentration of effluents and pathogens.[52]

Change in Employment

Information in the ten country reports illustrated that not enough has been done to explicitly incorporate employment objectives in national poverty reduction strategies and development programmes. Much of this information, however, is anecdotal, as there is little *official* information on employment figures. Where such information does exist the unemployment numbers are surprising low. Based on analysts' observations, it is likely that official unemployment rates understate the true magnitude of the number of people without work or who are underemployed.[53]

Despite appreciable improvement in the level of economic growth in SSA in recent years, aggregate employment growth has been slow relative to population growth. Consequently, the ratio of employed to the adult population in SSA declined from 69 percent to 67 percent in 2005 (ILO 2006).

The number of the working poor is also increasing as a result of the declining number of well-paid jobs and the continuing exclusion of a sizeable proportion of the labour force from the benefits of economic growth. Based on the USD1 per day poverty line, there were over 148 million working poor in SAA, representing 56.3 per cent of total employment (ILO 2006). Many of the working poor are employed in the informal sector.[54]

Simply put, the level of underemployment in rural and agricultural economies remains high because of the continuing neglect of the rural and agricultural sectors. Most people are employed in low-productivity activities due to low investments, limited and poor access to urban markets, dependence on the weather and limited availability of appropriate technology (ILO and ECA 2006).

Informal sector workers' dependence on the land and the sheer size of the informal sector represent huge vulnerabilities. Changing and unpredicted weather patterns affect how crops are grown, harvested, transported and sold. Jobs in the informal sector shift, causing instability within families and communities. A secondary impact of un- and under-employment is the increase in conflict as people fight for limited resources.

52 European Center for Disease Prevention and Control (ECDC) http://www.ecdc.europa.eu

53 This evidence is corroborated by a 2006 International Labour Organisation study, as well as by a statement issued by the Economic Commission for Africa at its 2006 regional conference, which noted that: "[the] dearth of employment statistics imposes severe constraint to policy making. Africa is the most under-reported region in the world with regard to employment records…Many national statistical offices lack the human and financial capacity to collect and disseminate employment data. This is compounded by the growing "informalisation" of the economy, necessitating more innovative fiscal and technical approaches to the production of employment statistics."

54 The informal sector is economic activity that is neither taxed nor monitored by a government and therefore is not included in that government's Gross National Product (GNP).

Civic (Governance) Indicators

1. Land reform improvement	2. Change in public participation in planning process

Land tenure is an integral part of a healthy social, political and economic framework (ODI 1999). For those who rely largely on local rural resources (as much of SSA's population does) a secure place to live, free from the threat of eviction, with access to land and natural resources is the cornerstone of a productive life. Access to capital assets, such as land, determines how and how far livelihoods can be enhanced and protects poor and vulnerable members of the community.

Social capital in form of public participation is also important. The essential fabric of any true democracy is the presence and inclusion of "civil society" in the decision-making process. This participation can be in the form of independent groups and bodies, ranging from professions and churches to non-governmental organisations. These groups represent the voice of those that may be not heard elsewhere. Where democratic governance fails civil society, non-governmental organisations can help to fill the void.

Table 11: Land ownership and participation

	Land Ownership/Use	Change (%)	Level of Participation in Planning Process
Benin	A rural land act has been introduced but there is no law covering urban land ownership	—	Trend toward decentralised governance, but capacity- and institution-building are needed
Burkina Faso	All land is state-owned[55]	—	Relatively strong; supported by laws of 1992-2004; thousands of NGOs and associations
Cameroon	1996: 48% 2001: 59% Households with land	+11%	Laws passed in 1992 gave new foundation for civil society; participation however is weak on energy issues relevant to climate change
D. R. Congo	1990: 67.4% 2000: 59.7% Agricultural population	-7.7%	—
Kenya	Land policy is under review to create a more equitable distribution of land resources. A land policy was developed between 2004 and 2008, but has not yet been implemented	—	1990: 35% 2007: 39% Registered voters
Mali	Land rights issues are linked to the national decentralised process that has been ongoing for several years. Eight laws cover the creation of municipalities one of which is the development of local government regulations and codes. In principle, rural populations will be able to (and will have to) manage their assets and ensure open land access	—	—
Nigeria	Government owns all land and issues Certificates of Occupancy to applicants	—	—

55 Thirteen percent of the total area of Burkina Faso is cultivated and 25 percent is forested.

	Land Ownership/Use	Change (%)	Level of Participation in Planning Process
Senegal	1994: 33.4% 2002: 32.7% Agricultural population[56]	-0.7%	Limited, but since 2001 environmental impact studies are required
Tanzania	2000: 16% urban, 19% rural 2006: 15% urban, 22% rural	-1% urban +3% rural	Limited, but some improvement; stakeholders now consulted for tariff changes
Uganda	1990: 0% 2006: 28% Households owning land	+28%	—

❑ *Snapshot Assessment*

Although land ownership is still low, it is good to note that overall the numbers are increasing, albeit slowly. *Attention will need to be paid to urban tenure issues particularly if the effects of climate change push people off the land in search of employment and/or resources*. None of the ten countries studied have initiated urban land reform policies.

Civic participation is starting to take hold with a particularly vibrant civil society sector in Burkina Faso. It remains to be seen whether this has a positive impact on overall welfare and poverty reduction.

Hornitos (volcanic structures created by the slow upwelling of magma) - Ol Doinyo Lengai, Tanzania – *iStockphoto: guenterguni*

56 Percentage of total population that owns agricultural land or has access to it.

Energy Systems: Vulnerability and resilience

As detailed earlier in this report, climate change will directly impact both the demand- and supply-side of energy production. How it will affect the latter, however, is less obvious.

Given energy's central role in economic and social development, and the fact that climate change will impact energy-providing ecosystem services, assessing key vulnerabilities of each energy system is crucial. Once vulnerabilities have been identified, appropriate adaptation measures can be designed and implemented. This process should be applied to both existing energy infrastructure and anticipated developments.

The vulnerability indicators are listed in the following table. The indicators cover all major energy systems. They aim to measure the level of vulnerability to those key climatic elements that HELIO has identified.

HELIO analysts applied the vulnerability indicators to the national energy systems. Their findings are summarised in the following pages.

Vulnerability Indicators: The vulnerability of each energy system is calculated according to the relevant indicators noted below

Coal

- VC1: Number of coal mines plants located at less than one metre above sea level and within the area that could be flooded by a flood with a current recurrence period of 100 years

Oil and Gas

- VOG1: Share of offshore oil and gas installations likely to be hit by a storm of more than 70 m/s gusts within the next 20 years (%)
- VOG2: Share/number of refineries likely to be hit by a storm of more than 70 m/s gusts within the next 20 years (%)

All Fossil Fuels

- VF1: Number of thermal (coal, oil and gas) power plants located at less than one metre above sea level and within the area that would be flooded by a flood with a current recurrence period of 100 years

Additional information: Expected number of droughts that lead to a capacity decrease of thermal power plants by more than 10% within the next 30 years.

Nuclear

- VN1: Number of nuclear power plants located at less than one metre above sea or river level and within the area that would be flooded by a flood with a current recurrence period of 100 years
- VN2: Number of incidents/accidents since the plant was built
- VN2b: Describe the most significant incidents

Hydro

- VH1: Expected precipitation change over next 20-50 years (%) *and/or* probability of floods in each watershed
- VH2: Number of multiple-use dams in the country today: volume of water (m^3) of each dam
- VH2b: Describe what % of the water is used for: agriculture; power; drinking

Additional information: Expected additional run-off from glacier melting (million m^3)

Transmission Systems

- VT1: Length of in-country, above-ground transmission and distribution lines (km)
- VT1b: Distinguish between: high (transmission); middle + low voltage lines (distribution)
- VT1c: Describe any transnational lines

- VT2: Number and length of power cuts (differentiate between failures due to weather or equipment failure and those cuts due to rationing)
- VT2b: Average hours of interruption per year
- VT3: Percentage of energy supply requiring regional transport over 50 km
- VT3b: % that is transportation of fossil fuel
- VT3c: % that is transportation of biomass

If possible, comment on the informal sector

Biomass

- VB1: Proportion of biomass used for energy purposes (%) in total biomass production
- VB1b: If possible distinguish between different sources and different applications – agricultural biomass harvest; electricity; heat
- VB1c: Forest (as defined by FAO) biomass harvest: electricity; heat
- VB2: Expected precipitation change over next 20-50 years (%)

Additional information: Probability of temperature increase beyond biological heat tolerance of key biomass crops within the next 20 years (%)

Wind

- VW1: Number of wind turbines at less than one metre above sea level
- VW2: Projected change of average windspeed over the next 20 years, based on regional climate models (%)

Solar

- VS1: Capacity of solar installations already in place (m^2)
- VS1b: Distinguish between PV (MW) and thermal (m^2)
- VS1c: Describe sites (quality of the insulation and of the building on which systems are installed) and type of ownership (private, government, public/private partnership, etc.)
- VS2: Expected temperature (°C) increase in the next 20 years relevant for PV capacity

Additional information: Projected change in rainfall and cloud cover over next 20 years (%)

Vulnerability Indicators

The major energy systems for each country have been evaluated against the vulnerability indicators listed. As there are currently no nuclear power installations in any of the ten countries surveyed, this indicator was not calculated. Transmission indicators have been reported separately.

VC1: Number of coal mines less than one metre above sea level	**VOG1: Number of oil and gas installations likely to be hit by severe storms**
VOG2: Number of refineries likely to be hit by severe storms	**VF1: Number of thermal power plants located less then one metre above sea level**
VH1: Expected change in rainfall over next 20-50 years (hydro)	**VH2: Number of multi-functional dams**
VB1: Proportion of biomass used for energy purposes	**VB2: Expected change in rainfall over next 20-50 years (biomass)**
VW1: Number of wind turbines less than one metre above sea level	**VW2: Project change in average windspeed**
VS1: Capacity of existing solar systems	**VS2: Expected temperature increase over next 20-50 years**

Table 12: Summary of energy system vulnerabilities by country

	Coal, oil, gas + all fossil fuels	Hydro	Hydro + biomass	Biomass	Wind	Solar
	Installations vulnerable to extreme weather (Indicators VC1, VOG1, VOG2, VFI)	Dams (Indicator VH2)	Change in precipitation (Indicators VH1, VB2)	% used for energy purposes (Indicator VB1)	Wind installations vulnerable to flooding and wind speeds (Indicators VW1, VW2)	Current solar capacity and temperature increases (Indicators VS1, VS2)
Benin	1 power plant	No multifunctional dams	No data available	No data available	None	0.6MW
Burkina Faso	None	2,500 dams	Increase of 15 to 30%, moving southward	No data available	None	1000kWp Increase in temperatures 2°C to 4°C by 2025
Cameroon	80% of oil/gas units; also 1 refinery	3 multifunctional dams, total capacity 7.6m^3	Decrease of 2.2% per decade since 1960	No data available	None	No data available
D. R. Congo	None; the 4 coal mines are located in the in-land province of Katanga	No multifunctional dams	Increase of 7-11%	No data available	None	836 PV installations, capacity 760 kWp Lat -2.5°: increase of 2.5-3.2°C Lat -7.5°: increase of 2.8-3.0°C Lat -12.5°: increase of 3.3°C
Kenya	None	No data available	Decrease of 2.6% per decade between 1960 and 2006 Anticipated decrease of 15.6% by 2050	45% of biomass is used for thermal purposes (cooking, heating)	None	4.3MW of home PV Expected temperature increase 0.42°C
Mali	None	5 dams	Increase 10-40% by 2050 at high latitudes and in some wet areas Decrease 10-30% mid-latitude and dry tropical areas	78% of biomass is used for energy[57]	None	>3MW (solar water heaters, dryers, PV) No temperature data available
Nigeria	4 oil/gas units; refineries also somewhat vulnerable (10-15% likelihood of damage)	4 dams total power capacity 55 MW; not yet used for generating electricity	Increase of 10%	34% of biomass is used for energy	None; study of wind trends recently completed found a decrease of 5% in wind speeds between 1990 and 1999	2375 m^2 of thermal; less than 0.25MW of PV Minimum of 7°C increase
Senegal	3 power plants	2 multifunctional dams	Decrease of 17%	45% of biomass is used for heat production	None Site for first wind farm is being investigated	2315 kWp Temperature increase of 11.7%
Tanzania	1 refinery	6 multifunctional dams; approximately 4200 MW combined capacity	Bimodal[58] rainfall will increase 5%-45% Unimodal[59] will decrease 5%-15%	Biomass contributes 90% to TPE; some used in factories	None	1.7MW PV Temperature increase of 0.8%

57 This includes biomass for household purposes (cooking). Use for biomass energy systems, e.g., electricity generation is much lower.

58 Two distinct seasons.

59 One distinct season.

	Coal, oil, gas + all fossil fuels	Hydro	Hydro + biomass	Biomass	Wind	Solar
Uganda	None	60 micro-hydro with 210 MW capacity; hundreds of valley dams	The vast majority of hydro is generated from the outflow of Lake Victoria: outflow reduction of 3-4% by 2035 against 1945 baseline; outflow increase of 6-10% by 2085 against 1945 baseline.	95% of wood is used for energy; 50% of crop residues are used	None	No data available for either
❏ Snapshot Assessment	The majority of the thermal power plants in the countries surveyed are not vulnerable to coastal storms and erosion. The exceptions are Cameroon and Nigeria. Cameroon is particularly vulnerable, given that most of its thermal plants and refineries are situated on the coast.	With few multi-functional dams in any of the countries, it can be assumed that the majority of water will be used for hydroelectric purposes. Thus, during water-constrained periods, the need to divert water for other applications, e.g., agriculture, human consumption, etc., is lower reducing the amount of load shedding and associated power outages.	As detailed in the section on country level vulnerabilities, there are changing rainfall patterns, however there is currently no definitive patterns of increasing or decreasing levels. Trends that have been observed are the southward migration of rains in Burkina Faso and Mali and a northward migration in Senegal and Tanzania. While an increase or decrease in rainfall could be beneficial or detrimental to a region, the unpredictability underlines the difficulty in anticipating appropriate responses, thereby increasing vulnerability.	Biomass is not widely used for electricity generation but is used extensively for household energy purposes. A few countries are exploring the use of biomass in industrial applications (Benin, D. R. Congo, Senegal, and Tanzania)	Aside from a planned 10MW wind farm in northern Senegal, there are no wind installations in the countries surveyed.	Overall PV installations are small in scale. Main uses are for communications, heating water, powering refrigeration units and electrifying homes, schools and clinics. The main vulnerability of these systems is the structure on which they are built. Most are on roof tops with some larger installations on independent structures. Predicted temperature increases are currently not significant enough to effect power output.

The purpose of the following indicators is to determine the level of vulnerability in the energy transportation infrastructure.

VT1: Length of national transmission and distribution lines

General wisdom has been that, in order to increase electrification rates, transmission and distribution systems have to be extended. However, from a climate change perspective transmission and distribution systems are seen as vulnerabilities.

Changes in weather patterns will impact energy transmission and use regardless of how the energy is produced. Intense heat can affect the conductivity of lines and decrease their efficiency. Extreme events may increase the risk of collapse of transmission lines, denying electricity to users. Severe weather can also reduce electricity demand due to physical destruction of electricity-consuming entities, e.g., business, industry and households, which in turn has implications for the transmission system.

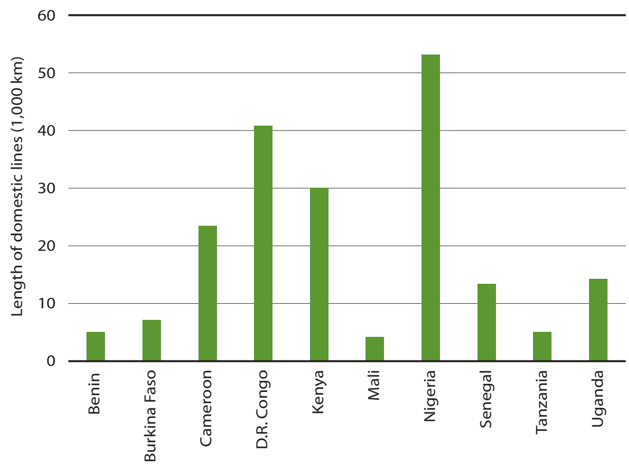
This indicator measures the length of domestic transmission and distribution lines and any transnational lines.

Table 13: Indicator VT1

Country	Length of Domestic Transmission and Distribution Lines (km)	Transnational Lines (km)
Benin	5,620	618
Burkina Faso	7,521	600
Cameroon	23,783	—
D. R. Congo	40,917	—
Kenya	30,404	249
Mali	4,436	600
Nigeria	53,979	—
Senegal	13,477	945
Tanzania	5,451	—
Uganda	14,312	—

Note: A blank cell indicates that data was either not available or transnational lines do not exist.

Figure 7: Total length of domestic transmission and distribution lines



Note: Some countries have substantial transnational lines, e.g., Mali has 3,289 km of transnational distribution line and over 600 km of interconnection with Ivory Coast.

❑ *Snapshot Assessment*

The vulnerability of transmission/distribution lines to extreme weather events depends on the extent of these lines as well as on the structure of the grid and operational characteristics. In general, the longer the length of the transmission/distribution systems, the higher the vulnerability of these systems to possible damage. This is particularly challenging for geographically large countries such as D. R. Congo, Mali and Nigeria. Nigeria, with the highest rate of household electricity access (roughly 40 percent), has the longest expanse of domestic transmission and distribution lines among all the countries—ten times the length found in Mali.

The vulnerability of transmission/distribution systems can be reduced, and reliability increased, by focusing on the installation of decentralised or local energy systems (as in micro grids), designed to allow isolation and containment of disturbances. Increasing internal capacity, through the training and hiring of engineers, to maintain and repair the systems is another adaptation option.

VT2: Number and length of power cuts

Robustness of the transmission/distribution system is measured by the number and length of scheduled and unscheduled power cuts. Failures due to weather, equipment failure or rationing are also detailed.

Table 14: Indicator VT2

Country	Number and Length of Power Cuts
Benin	Approximately 2,800 hours of electricity cuts due to rationing and just over 620 hours of unscheduled cuts. Not clear how many of these unscheduled cuts were due to weather-induced equipment failure or simply equipment failure due to the age of the system, vandalism, etc.
Burkina Faso	In 2007, there were 1,513 electricity power cuts in cities of Ouagadougou and Bobo Dioulasso. 5.1% of these cuts were due to rationing.
Cameroon	2,985 MW of generating capacity were not used between January and October 2005 as a result of technical incidents on the transmission and distribution grids.
D. R. Congo	788 cuts in 2006 and 846 cuts in 2007. The western sector of the country was particularly affected in 2007 with 302 cuts. 70% of incidents are attributable to equipment failures, 20% to weather conditions and 10% per cent to rationing. Kinshasa is the most affected, as it consumes 70% of all electricity generated.
Kenya	11,000 power outages per month. 32 million hours of interruption per year, 60% of which are due to tampering of power lines.
Mali	HV grid: • Number of cuts: 2006 = 56; 2007 = 49 • Duration of cuts: 2006 = 35 hours; 2007 = 19 hours • Number of cuts scheduled for works 2006 = 15; 2007 = 19 MV grid: • Number of cuts 2006 = 1,251; 2007 = 1134 • Duration of cuts: 2006 = 1,071 hours; 2007 = 583 hours • Number of cuts scheduled for works 2006 = 349; 2007 = 486
Nigeria	Approximately 600 per year. Interruptions are due to many reasons, including low water levels in dams due to drought. The number of drought induced interruptions is not known.
Senegal	From 2005 to 2008, the quality of service was characterised by an increasing number of incidents and non-distributed energy. • Severe rationing due to lack of generation and several major cable faults led to a rise in cuts from 587 to 1792 • Over the same three-year period interruptions due to technical incidents on the 30 kV grid almost doubled from 1,257 to 2,219 • The number of high-voltage grid interruptions due to technical failures fell 16% from 150 to 126
Tanzania	From 2006 to 2007 there were, on average, 12 cuts per day.
Uganda	No data available.

❑ *Snapshot Assessment*

Despite the range of data provided, it is clear that each of the ten countries has limited ability to provide a stable electricity supply. Not surprisingly, there is no information currently being collected as to which outages are caused by weather-related incidences. The vulnerability of the transmission/distribution systems can be reduced by the installation of decentralised or local energy systems. Increasing internal capacity, through the training and hiring of engineers is also needed.

In order to reduce the frequency of outages, information needs to be disaggregated into technical/human induced failures and weather-induced failures as illustrated below.

Table 15: Disaggregation of system failures

Power Generation		Transmission/Distribution	
Technical	**Weather-induced**	**Technical**	**Weather-induced**
• System malfunction • Obsolescence	• Delayed shipment of fuel due to storms	• Vandalism • Mis-use	• Downed lines as a result of heavy winds, icing, rain and/or landslides

Disaggregating information in this way would allow decision makers to better identify the appropriate response. Technical issues can be addressed by improving physical and human capacities. Identification of climate-induced failures can be offset by suitable adaptation measures.

VT3: Energy Supply requiring regional transportation

The quantity of the energy supply requiring transport and the distances covered is measured here. The original indicator asks for the percentage of the two fuel types (fossil and biomass) as a percentage of *all* fuels transported over 50 km. However, because of difficulty in finding data, most analysts reported each fuel as an absolute percentage.

Table 16: Indicator VT3

Country	% of fossil fuel transported > 50km	% of biomass transported > 50km
Benin	No disaggregated data available	No disaggregated data available
Burkina Faso	68.05	< 1.0[60]
Cameroon	100	90
D. R. Congo	—	—
Kenya	> 90 Most of the fuel is pumped through the Kenya Pipeline from Mombasa, located on the Kenyan coast	No data available All charcoal used in urban centres is transported regionally. Figures of the actual volumes of biomass are not available
Mali	100	86% for Bamako 70% for Ségou
Nigeria	75	50
Senegal	90.8	No data available
Tanzania	3.5 (diesel) 100 (natural gas)[61]	—
Uganda	100	80

60 This number does not include firewood.

61 Natural gas makes up 25.1% of the energy supply.

❑ *Snapshot Assessment*

The high dependence of all ten countries on road, rail or pipeline infrastructure presents a real vulnerability. Transportation infrastructure is weak in all ten countries. Poorly maintained roads and bridges are vulnerable to landslides and flooding. Shifting ground from water saturation and landslides can crack and break pipelines. Rail is somewhat more robust but its resilience is dependent on the land or infrastructure, e.g., bridges, on which the rails sit.

While data on biomass transportation is limited, all analysts reported high usage of biomass in urban centres, most of which comes from rural areas. This rate can only be expected to increase as urbanisation rates rise, pushing access to nearby biomass resources further out. Concentrated commercial demand for biomass also "pulls" the resource away from rural areas, thereby reducing local availability. The use of efficient wood stoves and alternative cooking fuels would serve to relieve some of this pressure.

Adaptive Capacity Indicators: Measuring successful interventions that increase resilience

The level of resilience is based on a system's adaptive capacity. In the context of developing countries, this capacity needs external support, for example through financial mechanisms under the international climate policy regime. To avoid the inefficient spending of scarce funds, a set of criteria has been developed to gauge the efficiency of adaptation efforts. The indicators listed were applied to each of the ten countries.

The results are summarised on the following pages.

Solar power - Isla Contoy, Mexico – *iStockphoto: zhuzhu*

Adaptive Capacity Indicators: The adaptive capacity of each energy system is calculated according to the relevant indicators noted below

Implementation

- AI1: Domestic capital formation (million USD per year) – Proxy: Domestic savings (million USD per year)
- AI2: Domestic investment in renewable energy (million USD per year)
- AI3: Number of technical engineers graduating annually as a percentage of the total population
- AI4: Availability of hazard maps for floods/droughts
- AI5: Existence and enforcement of power plants siting and construction guidelines taking climate change into consideration (If there is no information available, discuss qualitatively how climate change could effect siting and construction guidelines)
- AI6: Existence of emergency plans to react to extreme meteorological events and availability of local emergency repair teams
- AI6b: Comment if possible on the level of implementation
- AI7: Domestic availability of insurance schemes
- AI8: Existence of citizens' users groups in the energy governance structure (enforcement of participatory decision-making)

Coal, Oil, Gas, Nuclear Fuel Sources

- ACOG1: Existence and use of a siting map for mines and power plants taking into account projected storms, floods and drought areas
- ACOG2: Implementation of national regulations for thermal power plant siting at sites with sufficient cooling water availability over the next 50 years

Hydro

- AH1: Existence of a national plan for optimised operation of hydropower plants under projected flow regimes for systems
- AH1b: Is such a plan currently in place?
- AH1c: If not, has the government decided to have one at a future date?
- AH2: Number of dams equipped with desilting gates and/or number of up-stream land use management and water catchment plans for each hydro installation

Biomass

- AB1: Research, development and dissemination budget for heat and drought resistant crops, biofuels, agricultural* waste for energy and vulnerability of forest (million USD/year)

  *does not include municipal waste as this is usually considered in mitigation plans
- AB1b: If possible, comment on consistency of funding
- AB2: In-country utilisation of biomass fuels not traditionally used by private enterprises and cooperatives (percentage of total fuels)
- AB3: Percentage of households using improved woodstoves out of total number of households using woodstoves

Wind

- AW1: Existence and enforcement of national regulations requiring storm proofing of wind power plants to withstand highest anticipated windspeed
- AW2: Existence of siting maps that detail projected changes in: windspeed; floodplains; and, areas impacted by sea level rise

Solar

- AS1: Existence of siting maps that detail projected changes in cloud cover
- AS2: Existence and enforcement of national regulation requiring storm proof concentrating solar power plants (CSP) to withstand the highest anticipated windspeed

AI1: Domestic capital formation	AI2: Annual investment in renewables

Domestic capital formation is a measure of total investment in a country, covering fixed assets of the economy and net changes in inventory, without adjusting for consumption. Unfortunately, data on domestic capital formation was difficult to find; gross capital formation was therefore used as a proxy indicator.[62] The accompanying chart illustrates gross capital formation per capita (million of USD per 1000 persons).

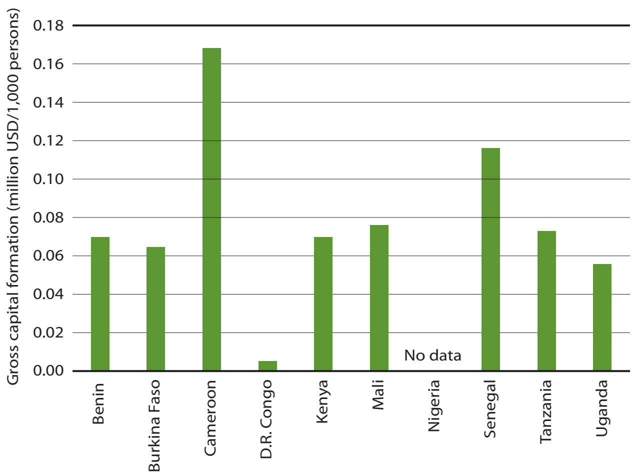
Domestic investment in renewable energy was also measured.

Table 17: Indicators AI1 (proxy), AI2

Country	Gross Fixed Capital Formation (million USD/year)*	Annual Investment in Renewable Energy (million USD/year)
Benin	552	—
Burkina Faso	895	4.6[63]
Cameroon	2,780	—
D. R. Congo	137	1.19
Kenya	2,626	12.6
Mali	930	6.62
Nigeria	—	—
Senegal	1,378	—
Tanzania	2,493	—
Uganda	1,722	—

*Gross Fixed Capital Formation for most recent year available as reported by Nation Master in millions of 2000 USD.[64] These data are a proxy for indicator AI1 (see footnote 62).

Figure 8: Gross fixed capital formation per population



62 To avoid possible inconsistencies in reporting, the data for capital formation in the table and figure were retrieved from an external source, rather than referring to the County Reports. Data were retrieved from Nation Master (www.nationmaster.com) and are reported for the latest year available (usually 2004 or 2005) in USD.

63 Estimated number based on 15-year timeline under EU MEPRED project (2010-2025). Total project amount is FCFA34.640 billion (approx. USD 69 million) and consists of 33% of pre-electrification spending and 17.8% of all future investment.

64 http://www.nationmaster.com/graph/eco_gro_cap_for_con_2000_us-capital-formation-constant-2000-us. Source for the Nation Master data is the World Development Indicator Database maintained by the World Bank.

❑ Snapshot Assessment

Setting aside Nigeria, for which no additional data were available, two extremes are evident: the per capita gross capital formation for Cameroon is more than twice that for most other countries, while for D. R. Congo, gross capital formation is miniscule. Across the remaining countries, per capita investment varies by a factor of about two.

Annual investment in renewable energy is more difficult to find. It is only available for half of the countries and is more variable. D. R. Congo's almost non-existent investment in renewables (one million USD per year) illustrates the complete lack of capacity that the country has to develop and diversify its energy options.

Qualitative assessments from the other HELIO analysts point to similar low investment levels in their respective countries. Investments in small hydro[65] and geothermal (particularly for Kenya, Tanzania and Uganda) are logical, immediate renewable energy developments. Keeping these systems as decentralised as possible would help to offset the vulnerabilities identified by indicators VT1 and VT2.

AI3: Number of engineers graduating annually

Adaptive capacity can be either technical or behavioural. Here the institutional capacity of the energy sector is measured. The number of engineers graduating annually is used to assess the level of behavioural capacity.

Table 18: Indicator AI3

Country	Number of engineers graduating per year	As % of total population
Benin	No data available	—
Burkina Faso	1,420	0.01 (population: 14,017,262)
Cameroon	300	0.002 (Population: 12,300,000)
D. R. Congo	550	0.0009 (Population: 60,000,000)
Kenya	700	0.0018 (Population: 37,953,840)
Mali	Approx. 30-40	0.0003 (Population:12,300,000)
Nigeria	2,500	0.0018 (Population: 141,356,000)
Senegal	342	0.003 (Population:11,894,343)
Tanzania	500	0.0014 (Population: 34,443,603)
Uganda	No data available	—

❑ Snapshot Assessment

For all of the countries surveyed, technical capacity in the form of engineers is severely limited. Burkina Faso has the highest percentage at 0.01 percent; Nigeria and Kenya follow with almost 0.002 percent a piece. In addition to these meagre numbers it is not clear whether once these engineers graduate, they remain in-country and are able to find work.

With the on-going push for increased electrification, an ever-aging infrastructure and anticipated increases in the amplitude of weather impacts, *all ten of these countries will be severely constrained in their ability to maintain existing infrastructure let alone respond to emergencies*. Improving national engineering and technical capacity through educational and financial incentives is one way to increase capacity.

65 See footnote 50 regarding the negative impacts of large hydro.

AI4: Hazard maps for floods and drought	**AI5: Siting and construction guidelines**
AI6: Emergency plans for meteorological events	**AI7: Availability of domestic insurance schemes**
AI8: Citizens' users groups	**ACOG1: Siting maps for mines/power plants usable for climate events**
ACOG2: National regulations for thermal plants siting with sufficient cooling water availability	**AH1: National plans for hydro optimisation**
AH2: Presence of desiltation gates	**AW1: Storm proofing of wind installations**
AW2: Siting maps – wind installations	**AS1: Siting maps – cloud cover**
AS2: National regulations requiring storm proofing of concentrating solar plants	

The table below provides a summary of non-quantitative energy system adaptation indicators, organised by energy source. As indicated in the table key, a tick means "yes, present" while a cross means "not present." Alternatively, the table indicates where data are not available, work is in progress or the indicator is relatively inapplicable, e.g., siting maps for wind turbines when no wind turbines are installed or planned.

Of Special Note

The information presented is a snapshot of a country's current situation. Due to data gaps, analysts had to complement data with qualitative assessments. Therefore, because some of the information is, to a certain extent, subjective, it is not possible to create any harmonious expression of degree or quality. Overall the table presents the most positive interpretation, e.g., if some, but not all, multifunctional dams have desiltation gates, then the table shows a checkmark. In most cases, the County Report gives more detail.[66]

Table 19: Non-quantitative energy system adaptation indicators

Key: ✔ = Yes ✗ = No ○ = Not applicable **?** = Unknown **…** = In process

Adaptation Indicators	Benin	Burkina Faso	Cameroon	D.R. Congo	Kenya	Mali	Nigeria	Senegal	Tanzania	Uganda
Implementation										
Hazard maps for floods and drought (Indicator AI4)	✗	?	✔	✔	…	✔	?	✔	✗	✔
Siting and construction guidelines enforced (Indicator AI5)	✗	✗	✗	✗	✗	✗**	?	✔	✗	✗
Emergency plans for meteorological events (Indicator AI6)	✗	?	✗	…	✗	✔	✔	✔	✔	✗
Domestic insurance schemes available (Indicator AI7)	✔	✗	✗	✗	✗	✔	✔	✗	✔	✔
Citizens' users groups (Indicator AI8)	✗	✔	✔	✗	✔	✔	✔	✔	✗	✔

66 See www.helio-international.org for individual Country Reports.

Adaptation Indicators	Benin	Burkina Faso	Cameroon	D. R. Congo	Kenya	Mali	Nigeria	Senegal	Tanzania	Uganda
Planning and Regulation										
Fossil fuels: Siting maps for mines/ power plants usable for climate events (Indicator ACOG1)	✗	✔	✗	✔	✗	✔	?	✔	✗	○
Fossil fuels: Implementation of national regulations for thermal plants siting with sufficient cooling water availability (Indicator ACOG2)	✗	✗	✗	✗	✗	✔	✔	✗	✗	✗
Hydro: National plan for hydro optimisation (Indicator AH1)	✔	✔	✔	✗	✗	✔	?	✔	✔	?
Hydro: Desiltation gates* (Indicator AH2)	○	○	✗	✔	✔	✔	✔	✔	✔	✔
Wind: Storm-proofing for wind installations (Indicator AW1)	✗	○	✗	…	✗	✔	○	✗	✗	○
Wind: Siting maps taking into account wind (Indicator AW2)	✗	○	✗	✗	✗	✔	○	✗	✗	○
Solar: Siting maps taking into account cloud cover (Indicator AS1)	✗	?	✗	✗	✗	✗	✗	✗	✗	✗
Solar: National regulations on solar plant storm-proofing (Indicator AS2)	✗	?	✗	✗	✗	…	○	✗	✗	○

*A ✔does not necessarily mean that all dams are equipped with desiltation gates.

** Regulations are in place and enforced, however it is not clear whether anticipated climate change impacts are considered.

❑ *Snapshot Assessment*

From the table above, Mali appears to have many of the adaptation criteria needed to increase energy system resilience, as does Senegal and, to a lesser degree, as do Nigeria, Tanzania and Uganda. The remaining countries—Benin, Burkina Faso, Cameroon, D. R. Congo and Kenya—lack many of the recommended adaptation elements that would allow them to increase the resilience of their energy systems.

The development and availability of hazard maps for flooding, optimisation plans for hydro installations as well as the presence of desiltation gates are encouraging, as is the growing presence of citizen groups. The lack of power plant siting guidelines that take into account changing meteorological events is worrying as it illustrates a disconnect between observed weather pattern changes and plant operation (outputs).

The absence of any planning measures for wind and solar applications—in the form of siting maps and design regulations—demonstrates lost potential for energy diversification.

AB1: Biomass research and development for heat and drought resistant crops, alternative biofuels, etc.	AB2: In-country use of biomass fuels not traditionally used
AB3: Percentage of households using improved woodstoves	

Forms of biomass used as a fuel source and the level of use efficiency are measured here. Measurements include funding levels for research, diversification of biomass fuel stocks and use of efficient cookstoves.

Table 20: Indicators ABI, AB2, AB3

Country	Biomass research and development	In-country use of non-traditional biomass fuels	% of households using improved cookstoves
Benin	—	Three agri-food facilities use process wastes. In the public sector, energy recovery from agricultural waste is at the pilot stage.	—
Burkina Faso	—	—	—
Cameroon	There is no specific research in this area. Any research is carried out in training laboratories with occasional financing. ENSP's Energy, Water and Environment laboratory received about USD 80,000 between 2006 and 2007.	Households recover wood chips and off-cuts from wood processing facilities on the outskirts of towns for cooking purposes. No statistics on quantities used are available.	—
D. R. Congo	Research is ongoing but it is far from being cutting edge.	None	Use of improved cookstoves is not very common in Congolese households.
Kenya	—	—	70% in urban areas
Mali	Research programmes on biomass varieties suited to the Sahelian conditions are under way at national and sub-regional levels.	The alternative fuels (biomass) supplied by private enterprises are, essentially, briquettes made from cotton stalks, typha autralis or wood charcoal dust. The quantities produced are very marginal.	Approx. 50%; penetration rates are higher in urban areas.
Nigeria	—	—	—
Senegal	The Institut Senegalais de Recherche Agricole (ISRA - Senegal agricultural research institute) is responsible for research on crop varieties. It has a budget of USD 14 million.	Senegal does not yet have any biomass plants. A 20 MW plant is being constructed for gasification of typha, an aquatic plant invading the Senegal river.	27% of households use improved stoves. The Government of Senegal has overseen dissemination of 19,000 improved stoves.

Country	Biomass research and development	In-country use of non-traditional biomass fuels	% of households using improved cookstoves
Tanzania	Figures not available but the government (through the Ministry of Energy and Minerals together with other stakeholders) has conducted a baseline survey to review the current state of biomass energy activities as well as setting regulations on how bio-fuel activities will be carried out.	—	—
Uganda	—	Sugar manufacturing is the only business that utilises residues in energy production to any extent. A small amount of coffee and rice husks are also utilised in heat production in cement and tiles manufacturing. Annual tonnages of coffee and rice husks are 60,000 and 10,350 respectively.	8.7%

❑ *Snapshot Assessment*

With the exception of Senegal, overall research and development of heat and drought resistant biomass crops, are not occurring at any significant level. This low level of investment does not bode well for a continent that is overwhelmingly dependent on biomass as an energy source. More research needs to occur in this area.

Use of non-traditional biomass fuels by enterprises is still limited although Benin and Uganda have some penetration in agri-food facilities. Senegal's pilot biomass gasification plant could stimulate alternative biomass use in the area.

Use of improved woodstoves is also uneven. Kenya and Mali have good penetration, while Senegal and Uganda follow with a combine use of just over 35 percent. The non-existent use of these stoves in D. R. Congo, presents a good opportunity for developing this sector. A lack of user information in Benin, Burkina Faso, Cameroon, Nigeria and Tanzania make an assessment of these countries' progress impossible.

Recommendations

This report has outlined the need and the means to analyse energy systems in a climate change context and has provided two sets of indicators—collectively called the Vulnerability-Adaptation-Resilience (VAR) indicators—as guidance. The rationale for two sets of indicators is the following: if countries are to successfully adapt to anticipated climatic impacts, their energy system must also be assessed—not merely for their efficiency—but also for their adaptive capacity. Additionally, designed responses must fit within an ecodevelopment framework if such responses are to support larger development objectives such as the MDGs.

Ten Sub-Saharan African (SSA) countries were chosen to test the VAR indicators. The region itself was chosen because of its vulnerability to climate change and its high level of energy poverty. The intensification of energy-related development activities in the region, and the urgency that these projects support, improved access to clean and efficient energy sources was also an important factor. It is only by measuring and assessing current and proposed energy systems under a climate change scenario that we can collectively hope to bring much needed energy services to the people of the region.

While this first application of the VAR indicators has been far from perfect, the process has yielded some important insights. The following section results from this assessment process and includes specific recommendations.

1. **Systematically assess and monitor energy systems to ensure that they are robust enough to adapt to anticipated climate-related impacts**

   Decision makers and relevant funders have to focus on how to "climate-proof" current and future energy systems. Basic information is still lacking in most countries, thereby hindering robust evaluation and discouraging vital investment. In order for SSA countries to be able to use planning, assessment and decision-making tools effectively they must first:

   - improve, standardise and systematise data collection relevant to climate change and projected adaptation and mitigation activities;
   - establish maps showing the renewable energy potential and areas vulnerable to weather induced impacts; and,
   - design simple methodologies and monitoring protocols. The VAR indicators[67] provide a solid methodological approach that can be used for this purpose.

2. **Expand the current assessment process for new energy systems**

   Decisions about energy systems—regarding what kind (fossil, renewable) and where (location)—can no longer be made using standard environmental and economic assessment tools: climate and poverty issues must be assessed simultaneously. Such assessments must be underpinned by:

   - national and local Agenda 21 as required by the Rio commitments;
   - the need to achieve the Millennium Development Goals as soon as feasible;
   - other Multilateral Environmental Agreements; and,
   - a socially, equitable framework.

3. **Develop a medium- to long-term strategy to move toward a safer, decentralised, low-carbon energy supply system**

   The ability to manage energy services and secure access to clean, efficient and renewable energy is the first step in developing a resilient, thriving community. Based on the vulnerabilities assessed any strategy should:

67 The indicators are detailed in the body of this report. A full set of the indicators can also be found at: www.helio-international.org

- couple energy system diversification with decentralisation to increase resilience to climate change, while decreasing the pressure on the environment;
- ensure that regional needs are included in the energy policy and planning process (different parts of a country have different energy needs);
- modernise electrical infrastructure and improve maintenance capacity to insure the security of the electrical supply and reduce wastage (utilities from industrialised country can play a key role here by selling technical services and know-how rather than hardware); and,
- require concerted dissemination and use of improved cookstoves to reduce emissions, protect biomass sources and improve respiratory health.

4. Implement energy demand management as an adaptation measure

The magnitude of climate-induced impacts is not proportional to a particular country's emission levels. Improving energy efficiency should be a cornerstone of any energy policy, regardless of consumption levels. Moving from a business-as-usual scenario to one where energy efficiency is the objective reduces the need for new energy sources. Using energy more efficiently through the deployment of low energy technologies will help decrease the sector's vulnerability. The approach should:

- improve (as much as possible) the energy-efficiency of the economy;
- maximise the use of renewable energy;
- set a more sustainable supply/demand balance by applying a standardised process to accurately match energy needs (light, heating/cooling, transport, mechanical) with available energy resources as a precursor to determining energy imports; and,
- use National Appropriate Mitigation Actions (NAMAs) to drive the political agenda. (NAMAs are gaining visibility within climate negotiations. They encompass all sectors and aspects of energy production and use. NAMAs are required to: evaluate actual energy needs, including suppressed demand; and, outline clean, efficient energy saving mechanisms.)

5. Cultivate in-country capacity to evaluate and respond to energy needs from a climate perspective

Energy security cannot be guaranteed until such broader issues as how energy supply, production and distribution will be affected by climate change are addressed. Therefore, in-country expertise must be developed further and supported through on-going educational efforts that should include:

- the design of research and energy development programmes based on local needs and energy resources;
- building up national engineering and technical capacity through educational and financial incentives;
- the inclusion of climate and ecosystem issues in engineering curricula; and,
- training of local businesses in modern energy techniques by experts familiar with internationally developed technologies.

6. Invest in ecosystem services that support existing and planned energy production

Ecosystem assets such as water and biomass undergird energy services. Depletion of these resources will undermine electricity production of hydro and thermal power plants, impact mining operations, and deprive millions of households of their main fuel source. Efforts should be made to:

- establish integrated watershed management places to protect and expand catchment areas;

- develop and implement community-based forestry management approaches; and,
- increase research funding on alternative biomass energy sources.

7. **Establish transparent technology transfer and financing procedures**

   Almost every country surveyed is increasingly dependent on foreign oil imports. Simultaneously, the financial crisis has withdrawn aid from many SSA countries, thus delaying further progress on most of the MDGs. To reinforce the ability of these countries to cope, resilience has to be integrated into the energy sector by developing diversified energy systems that utilise national resources. However, for this to occur there must be an infusion of strategically-directed capital. Furthermore, scepticism about technology transfer has to be overcome: systematic and fair regulation of the process is one way of establishing trust and confidence. To build this new relationship:

   - beneficiaries should take an active part in the needs evaluation process to ensure that the identified technologies will contribute to the improvement of society's capacity to cope with climate change;
   - only the cleanest and most efficient technologies should be proposed, allowing for technological "leapfrogging," e.g., LEDs, solar rechargeable phones, etc.; and,
   - strict monitoring and enforcement of technology transfer regulations carried out by an independent, third party.

8. **Develop participatory energy governance to cultivate first-hand knowledge of energy needs and to mobilise vital support from beneficiaries**

   Many projects fail because anticipated energy needs are improperly assessed. Often popular support is also lacking, particularly if the energy development involves displacing people. Nevertheless, energy system diversification is key if a satisfactory level of national energy system resilience is to be achieved. Consultation with, and participation of end users are therefore crucial in helping ensure that the final system meets energy and broader community needs. Creating this civic synergy is difficult and requires:

   - learning about the local culture so as to integrate energy needs, environmental constraints and anticipated climate change impacts;
   - investing in social capital by stimulating citizens' participation and providing ways and means for the involvement of independent users' groups; and,
   - developing legal tools to codify citizen participation.

Tree in desert - Namibia – *iStockphoto: Mlenny*

Conclusion

The good news is that awareness on improving resilience in the face of climate change is growing (Dalziell *et al*. 2009; Tyndall 2004). The bad news is that little of that awareness applies to improving the robustness of energy systems, and where it does occur, the process concentrates primarily on increasing reliability of supply (DTI 2006; Wildavsky 1998). This focus is misguided. As Amory Lovins points out in his book *Brittle Power*, an emphasis on reliability undermines the very concept of resilience, which is to accept the inevitability of failure and to seek how best to limit the damage that failure can do.

The level of a system's resilience depends on the robustness of the system in which it is located. Thus it is not enough to simply assess an installation's impact on the environment; the impact of a changing environment on the installation must also be determined (Paskal 2009). Additionally, a resilient energy sector is central to achieving greater community resilience. Energy supports the delivery of essential services such as food, healthcare and education, and through its application in business and manufacturing it helps to provide employment and improves living standards. Hence in order to properly assess how to increase the resilience of an energy system, the system must be examined from a broader ecodevelopment context.

As defined at the start of this report, ecodevelopment considers simultaneously all five development pillars: environmental, economic, technical, social and civic (governance). A truly resilient energy system, therefore, involves more than selecting an efficient and clean system to deliver the required energy services. It also involves ensuring that the system meets broader social and environmental objectives. Therefore, the following aspects must also be assessed:

- the capability of the energy system to resist damage and loss of function (technical);
- the organisational capacity, planning, training, leadership, experience and information management to improve emergency-related, organisational performance (civic/organisational);
- the capacity of the managing enterprise to make timely adaptation for post-disaster remediation, improvisation, innovation and resources substitution (economic);
- the ability of decision-makers to anticipate the effect/impact of the energy system on local ecosystems and ecosystem services (environment); and,
- the characteristics of the affected population and community that render social groups either more vulnerable or adaptable to energy system-related disasters (social and cultural).

A resilient energy supply system consists of numerous, relatively small components with a low individual cost of failure. A key feature which helps to make these energy sources resilient is that "they are *renewable*: they harness the energy of sun, wind, water, or farm and forestry wastes, rather than that of depletable fuels."

(Lovins *et al*. 1982)

Although climate change threatens all countries, it also offers a genuine opportunity for socio-economic progress and ecodevelopment. Across Africa, innovative strategies are being developed that show that real improvement is possible. This energy needs to be harnessed and applied to the growing energy infrastructure so that it is resilient to the impacts of climate change and supportive of broader ecodevelopment objectives.

Top left: African family in a village near Kalahari desert – *iStockphoto: poco_bw*; top right: Hut with PV panel - Peru – *iStockphoto: YangYin*; centre left: Lagoon village, Calavi, Benin – *iStockphoto: peeterv*; centre right: Electricity line in desert – *iStockphoto: Mlenny*; bottom left: Lightning strike – *iStockphoto: dasilvafa*; bottom right: Maasai lighting fire - Kenya – *Hélène Connor*

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Annex One: Glossary of terms[68]

Adaptation

In natural or human systems adaptation is a response to actual or expected stimuli, e.g., climate change or their effects, which moderates harm or exploits beneficial opportunities. In natural systems adaptation is reactive. In human systems adaptation can be both anticipatory and reactive and can be implemented by public, i.e., government bodies at all levels and private actors, i.e., individuals, households, communities, commercial companies and NGOs.

Adaptive capacity

It is the ability of people and systems to adjust to environmental change, e.g., by individual or collective coping strategies for the reduction and mitigation of risks or by changes in practices, processes or structures of systems. It is related to general levels of sustainable development such as political stability, material and economic well-being, and human, institutional and social capital.

Resilience

Amount of change the exposed people, places and ecosystems can undergo without permanently changing states. That is, their ability to recover from the stress and to *buffer* themselves against and *adapt* to future stresses and perturbations.

Sensitivity

The degree to which people, places and ecosystems are affected by the stress, including their capacity to anticipate and cope with the stress. The effect may be direct or indirect.

Vulnerability

Vulnerability is the degree to which a system or unit (such as a human group or a place) is likely to experience harm due to exposure to risk, hazards, shocks or stresses. In relation to the concept of poverty, vulnerability is more dynamic since it captures the sense that people move in and out of poverty.

68 Simonsson 2003

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Supporting energy and climate policies conducive to ecodevelopment

HELIO International

Who We Are

Founded in 1997, HELIO International is an independent, international network of leading energy analysts whose objective is to identify, assess, measure and publicise the contribution of energy systems and policies to sustainable and equitable development. These analysts carry out independent evaluations of national energy policies and inform decision- and policy-makers about their value and effectiveness. They constitute the Sustainable Energy Watch (SEW). They also analyse and advise on ecodevelopment and climate stabilisation and cooperate with major energy organisations and networks.

HELIO International is a non-profit organisation based in Paris, France. It is an accredited observer to the United Nations Economic and Social Council (ECOSOC), the United Nations Framework Climate Convention (UNFCCC) and the United Nations Environment Programme (UNEP).

Our Activities

SEW is the core activity of HELIO International. SEW's objective is to measure progress toward sustainable energy and development practices nationally, regionally and globally. National reporters and regional coordinators collect and analyse energy data against a series of indicators selected for their relevance, clarity, balance and timeliness. Using the SEW indicators as benchmarks, the in-country reporters provide an independent view of the national energy scene. Their reports can then be used by governments, industry, NGOs and other stakeholders to promote ecodevelopment through policy development, projects and local activities.

This work has recently expanded to address the interface of the vulnerability and resilience of energy systems within the context of climate change.

HELIO's other activities include:

- providing independent input to the design and implementation of ecodevelopment, energy and climate projects (CDM indicators);
- designing analytical tools and organising training workshops on energy policy assessment and monitoring;
- promoting the creation and integration of citizen users' councils in the energy decision-making process;
- supporting the work of other international energy and development networks by providing strategic expertise and disseminating information via the HELIO network; and,
- maintaining a website that includes SEW reports on national and regional energy developments, information on HELIO projects and relevant energy developments occurring elsewhere.

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