

Vulnerability – Adaption – Resilience (VAR): Climate-proofing Energy Systems

Climate change 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.¹ Thus, adaptation is now the order of the day, not only in geographically-vulnerable countries, but also increasingly in northern and moderate latitudes.

Given the importance of energy in the economy and in the promotion of ecocodevelopment² 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.

¹ <http://data.ukcip.org.uk/resources/publications/documents/4.pdf>

² 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>

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.

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.

General Indicators: Measuring 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 are asked to calculate the indicators listed below. In keeping with Kyoto Protocol guidelines, the reference year is 1990 or the nearest year for which data is available. For each group of indicators, analysts are 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.

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: <ul style="list-style-type: none"> • 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 <ul style="list-style-type: none"> • 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	<i>For a country that is a net importer of oil and gas (non-renewables)</i> <ul style="list-style-type: none"> • Ratio between imports of non-renewable energy and the consumption of non-renewable energy (in Joules) in comparison to 1990 <p>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</p> <p><i>For a country that is a net exporter of oil and gas (non-renewables)</i></p> <ul style="list-style-type: none"> • Ratio between the export of non-renewable energy and the value of all exports (in monetary value) in comparison to 1990
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

Sector	Indicator	Calculation
	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 <ul style="list-style-type: none"> • Electricity • Heating • Transport
Social		
	1. Change in prevalence of diseases	% change in rate of waterborne diseases between 1990 and current year <ul style="list-style-type: none"> • Comment on unreported incidences if possible
	2. Change in employment	% change in unemployment rates reported between 1990 and current year <ul style="list-style-type: none"> • 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	a. % participation in national elections or in Agenda 21 planning and implementation processes b. % change between 1990 and current year

Energy System Indicators: Measuring vulnerability

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 apply the vulnerability indicators to the national energy systems and report their findings.

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 1 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 1 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 1 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 (m³) 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 m³)

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 1 m 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 (m²)

VS1b: Distinguish between PV (MW) and thermal (m²)

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 (%)

Energy System Indicators: Measuring adaptive capacity to 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 below help in that assessment process

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 fuels)

AB2: In-country utilisation of biomass fuels not traditionally used by private enterprises and cooperatives (% of total fuels)

AB3: % 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