56, rue de Passy – 75016 Paris – France
Tel: (33) 1.42.24.51.48 – Fax: (33) 1.42.24.86.33
Email: helio@helio-international.org
www.helio-international.org

Indicators as a way of improving communication on energy systems vulnerability, resilience and adaptation to climate change

Hélène Connor[1], Axel Michaelowa[2] and Laura Williamson[3]

NATO Advanced Research Workshop:
Weather/Climate Risk Management for the Energy Sector
S. Maria di Leuca (Lecce, Italy), 6 - 10 October 20008

HELIO INTERNATIONAL

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 experts 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. 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
- 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

Contacting Us
helio@helio-international.org
www.helio-international.org

[1] Sustainable Energy Watch, HELIO International, 56, rue de Passy, 75016 Paris
[2] Obere Geerenstr. 66a, 8044 Gockhausen, Switzerland, michaelowa@perspectives.cc
[3] HELIO-USA

Section I. Introduction

New insights have been gained over the last ten years about the essential role of energy resilience in the prosperous development of society. A growing number of case studies have revealed the tight connection between resilience, diversity and sustainability of social and ecological systems. Currently energy policies are primarily driven by the need to reduce or otherwise manage anticipated climate risks. However measures under the Kyoto Protocol to mitigate climatic impacts have failed to the expected consequences of climatic variability: cold years, flood events, seasonal droughts, storm surges, extreme wind speeds, freezing conditions, heat waves.[4] Adaptation is fast becoming the order of the day, not only in geographically-vulnerable countries such Bangladesh or Tuvalu, but also in northern and moderate latitudes.

Global warming directly impacts both the demand- and supply-side of energy production. Energy systems and equipment are already being submitted to substantial temperature and 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 the energy users.

Given energy's importance in the economy and in the promotion of ecodevelopment,[5] it is vital that vulnerabilities within the energy sector are reduced. Energy systems must be adapted to withstand anticipated climate change and impacts by increasing the resiliency of the energy system e.g., by reinforcing present devices, diversifying energy supply sources, siting power equipment differently, expanding its linkages with other regions, and investing in technological change—renewables, efficiency, etc.—to further expand the portfolio of options. Moreover, given the slow rate of capital stock turnover in the energy sector and the long lifetime of equipment, it is important that energy providers, 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. Ultimately, the resiliency of a country's energy system is underpinned by at least two key elements: its adaptive capacity and the country's level of ecodevelopment.

In order to better understand how to trigger and sustain positive synergies, HELIO is developing straightforward methodology and indicators to assess the vulnerability and resilience of energy systems to climate change. The entry point for this work is at the national level. The final objective is to help identify policies and measures (PAMs) that can best facilitate and support adaptation activities. This process must involve—simultaneously and on an equal footing—government officials, business, environmental non-governmental organisations (ENGOs) and relevant agencies that collectively assess whether the implemented PAMs are effective in supporting/promoting adaptation of energy systems thereby contributing to increased resiliency and ecodevelopment.

---

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

[5] Ecodevelopment became "sustainable development" with the 1987 Brundtland Report. The abstract notion of SD has been variously operationalised. it can be deconstructed 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 (examples of BRAC, Bangladesh, Sekem and a social enterprise called WasteConcern, Spain)

Section II. Project Summary

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 gained an equal importance. And it was only in early 2008, the Adaptation Fund, financed by the adaptation tax on CDM projects, was implemented.

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 (see Stratus Consulting and UNFCCC 2005). There are no commonly accepted parameters and indicators (see Tyndall Centre 2004, USAID 2007) to compare adaptation need and the effectiveness of adaptation measures.

This paper aims to contribute to the development of such parameters and indicators for energy systems. It builds on HELIO's earlier work that did a preliminary assessment of energy and ecosystem resilience in sub-Saharan African countries affected by climate change.[6] Based on feedback and HELIO's ten years of experience in applying indicators, HELIO is now developing a set of indicators to measure the vulnerability of energy systems and develop indicators to measure the effectiveness of adaptation efforts in the energy sector.

HELIO's philosophy is that the underlying metric—the actual measurement or statistic used—must be generally available for most, if not all, countries. This combines measurability, data availability, and achievability; data collection and vector calculation must be *do-able*. Therefore, if calculation is required to derive an indicator, it must be simple to do.

Overall 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,
- have robustness, durability and long-term relevance.

---

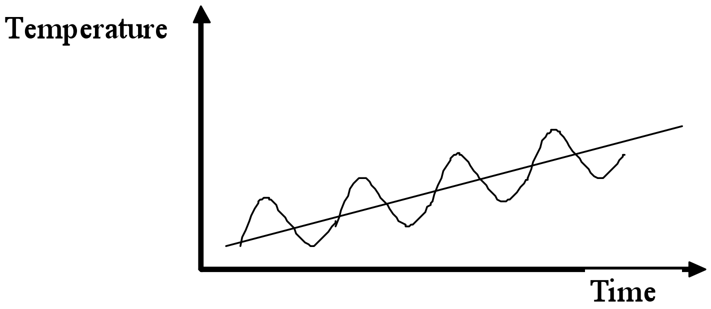
[6] A preliminary assessment of energy and ecosystem resilience in ten African countries, 2007 see: http://www.helio-international.org/energywatch/2007.cfm

Section III. Climate Induced Impacts on Energy Systems and Related Vulnerabilities

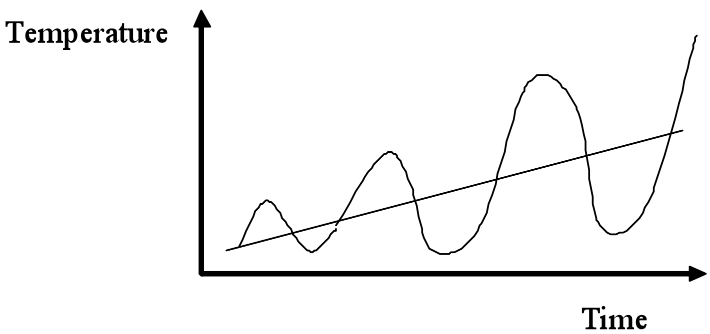
Climate change can cause different impacts. For example, the mean of climatic parameters as well as the intensity of meteorological extreme events can change. The possible changes for temperature are shown in Figure 1. They can be translated to other climatic parameters such as precipitation, windspeed and sunshine. With climate change, temperature and windspeed are likely to increase in most regions whereas trends in precipitation and sunshine can go in either direction.

Figure 1: Changes of Meteorological Parameters Due to Climate Change

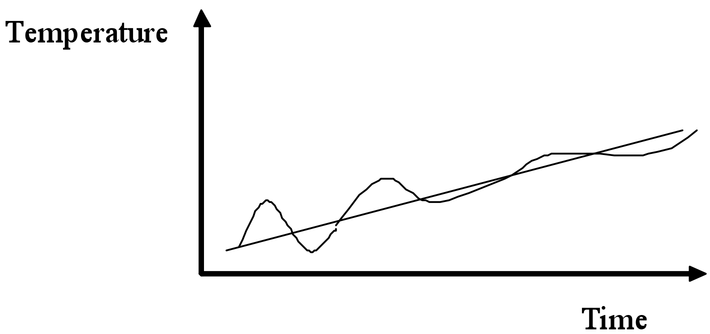
a) Increase of average temperature without change in temperature variability



b) Increase of average temperature with increase in temperature variability



c) Increase of average temperature with decrease in temperature variability



It is obvious that impacts will be larger if variability increases. But even in a situation with decreasing variability, impacts will occur if the meteorological parameter passes the design threshold of an infrastructure.

Of course, impacts can be direct or indirect. Frequently, indirect impacts are much stronger. For example, an increase in temperature alone is extremely unlikely to destroy any energy infrastructure. However, the melting of glaciers induced by temperature increase will have a strong impact on hydropower resources.

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

Table 1: Direct and Indirect Impacts of Changes in Meteorological Variables

Direct change	Direct impact	Indirect impact	Cross effects
Temperature increase	Heat-wave	Increased electricity demand	
	Glacier melting	Short term increase of water flow, long term reduction	Droughts/floods
		Formation of moraine lakes with outbursts	Floods
		Sea-level rise	Floods
	Increased evaporation	Reduction of stream flow	Droughts
	Stronger cyclones		Floods
Precipitation increase	Floods		
Precipitation decrease	Droughts		
Decrease in cloud cover	Increased evaporation	Reduction of stream flow	Droughts
Increase in cloud cover	Decreased evaporation	Increase of stream flow	Floods
Windspeed increase	More/stronger storms/cyclones		Floods
Windspeed decrease	Less/weaker storms		

Changes in meteorological variables will have an impact on energy transmission and use regardless of how the energy is produced. Extreme events increase the risk of destruction of transmission lines and reduction of electricity demand due to destruction of electricity-consuming entities.

Table 2: Direct and Indirect Impacts of Climate on Electricity Systems

Change in meteorological variable	Impact on electricity transmission	Impact on electricity use
Temperature increase	None	- Increase due to higher cooling needs - Decrease if sea-level rise displaces population and industrial production
Decrease in cloud cover	None	Decrease due to less lighting need
Increase in cloud cover	None	Increase due to more lighting need
Increased frequency and/or strength of storms/cyclones	Destruction of transmission lines	Reduced electricity demand due to destruction of houses and factories
Floods	Destruction of transmission equipment from flooded power plants	Sharply reduced electricity demand due to interruption of production in flooded factories/stop of electricity consumption in flooded houses
Droughts	Risk of destruction of transmission lines due to forest fires.	Slightly reduced electricity demand due to interruption of production in factories that do not get raw materials any more/stop of electricity consumption in houses of people fleeing the drought area

In the following sections, impacts of change of meteorological parameters are assessed for different energy production systems. They are grouped according to generation of energy and transport of the energy to the user.

a. Wind

Wind energy is generally harnessed in a decentralised manner and in locations chosen for their high average windspeed in the recent past. Usually, windspeeds are measured for several years before investors decide to set up a wind turbine. Wind turbines start production of electricity at a certain windspeed and increase electricity generation with a power of three as windspeeds increase. At a certain maximum windspeed, the turbine is automatically shut off to prevent damage. Modern turbines withstand windspeeds of 70 m/s before being destroyed.

Climate change can change average windspeeds. An increase in average windspeed would generally increase electricity generation unless the increase is only happening in the highest windspeed categories. A decrease in windspeeds leads to a reduction in electricity generation. An increase in the highest windspeeds increases the periods where wind turbines are stopped and the risk of destruction. Table 3 summarizes the effects.

Table 3: Climate Change Impacts on Wind Energy

Change in meteorological variable	Impact on electricity generation
Temperature increase	Decrease due to flooding of wind turbines on exposed coastal sites
Average windspeed increase	Increase
Average windspeed decrease	Decrease
Increased frequency and/or strength of storms/cyclones	Decrease due to stopping / destruction of wind turbines
Floods	None

b. Solar

As in the case of wind, solar energy is generally harnessed in a decentralised manner and in locations chosen for their high average sunshine duration in the recent past. While photovoltaic cells and solar water heaters can produce electricity even during a certain degree of cloud cover, mirror-based solar thermal applications need full sunlight.

The efficiency of solar power production decreases with the ambient temperature. So an increase in temperature will reduce electricity production.

An increase in the strength / frequency of storms and cyclones increases the risk of destruction of solar energy generation equipment. Table 4 summarizes the effects for grid-connected photovoltaics and concentrating solar power (CSP), Table 5 for stand-alone solar thermal systems.

Table 4: Climate change Impacts on Grid-connected Photovoltaics and Concentrating Solar Power

Change in meteorological variable	Impact on electricity generation
Temperature increase	Decrease due to lower efficiency
Decrease in cloud cover	Increase
Increase in cloud cover	Decrease
Increased frequency and/or strength of storms/cyclones	Destruction of electricity generation equipment

Table 5: Climate Change Impacts on Stand-alone Solar Thermal Systems

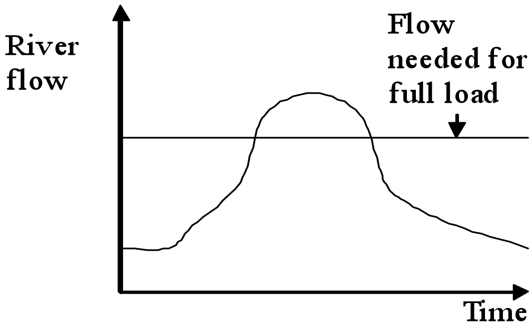
Change in meteorological variable	Impact on hot water generation	Impact on hot water use
Temperature increase	Increase	Decrease
Decrease in cloud cover	Increase	None
Increase in cloud cover	Decrease	None
Increased frequency and/or strength of storms/cyclones	Destruction of panels	Destruction of houses

c. Hydro

Hydro power can be generated in a wide range of power plant sizes from GW to kW scale. Siting of hydropower plants is usually based on multi-decadal river flow measurements. Changes in average precipitation will change river flow and have an impact on hydro power production, each system which depends 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 strongly depends on the flow regime and utilisation rate of river flow which is shown in Figure 2.

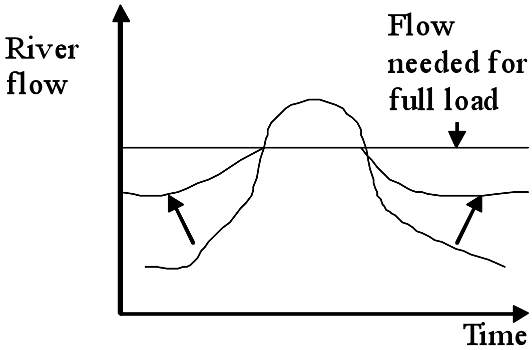
Figure 2: Hydro Power River Flow Utilization and Impact of Changes in the Flow Regime (assuming the glaciers and reservoirs remain stable)

a) Flow regime before climate change



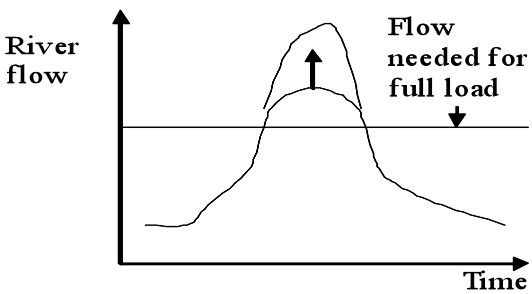
The power plant can only produce at full load during a limited rainy season.

b) Flow regime after climate change: increase of flow in previously lean periods



Now the plant can considerably increase power production

c) Flow regime after climate change: increase of flow in previously strong periods



In this case the plant cannot increase production at all despite the increase in river flow
Normally, hydro power plants are able to withstand flooding events by opening floodgates and shutting down turbine operation. Only in rare cases, hydro power plants and/or dams are destroyed by flood events; they are less prone to flooding impacts than other power plant types if well-designed and situated in areas not prone to landslides. However, reservoirs can be filled up by debris and silt and thus long-term power generation capacity be reduced.

Given that hydro plants are normally built in sturdy structures, an increase in the strength/frequency of storms and cyclones only marginally increases the risk of destruction of hydro power plants. Table 6 summarizes the effects.

Table 6: Climate Change Impacts on Hydro Power

Change in meteorological variable	Impact on electricity generation
Average precipitation increase	Increase. Temporal spacing of increase decisive for degree of increase – the better distributed over time, the stronger the increase.
Average precipitation decrease	Decrease
Droughts	Decrease due to reduced river flow
Glacier melting	Short-to medium term increase, long-term decrease (depends on situation of glaciers with regards to the current and future snow line)
Floods	Decrease if reservoir is filled with debris / silted. In rare cases destruction of power plant / dam.
Increased frequency and/or strength of storms/cyclones	Marginal increase of risk of destruction of electricity generation equipment

d. Biomass

Biomass energy comes in many different forms. Biomass can be used for heat generation in small, decentralised devices such as household stoves. It can also be used for power generation in plants of several MW size. Biomass can be sourced from forests or agricultural residues. Dedicated biomass plantations are also possible but rare due to the high costs involved.

Climate change impacts the availability of biomass as well as energy generation facilities, as shown in Table 7.

Table 7: Climate Change Impacts on Biomass Energy

Change in meteorological variable	Impact on biomass availability	Impact on energy generation
Temperature increase	Decrease if plants reach threshold of biological heat tolerance or sea level rise reduces area where plants grow, otherwise increase (provided that no lack of other resources constrains plant growth)	Decrease if power plant is impacted by sea level rise. Otherwise depending on biomass

Change in meteorological variable	Impact on biomass availability	Impact on energy generation
		availability.
Average precipitation increase	Increase if increase occurs during the growth season	Increase.
Average precipitation decrease	Decrease unless decrease occurs outside the growing season	Decrease
Droughts	Decrease	Decrease
Glacier melting	If under irrigation: short-to medium term increase, long-term decrease (depends on situation of glaciers with regards to the current and future snow line) Otherwise: none	As per availability
Floods	Decrease if floods affect area where biomass is sourced.	Decrease if power plant is flooded or biomass availability is reduced.
Increased 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

e. Fuel from Mined Resources

Current energy systems are mainly based on fossil fuels, be it solid fuels like coal, liquid fuel such as oil and gaseous fuels. Extraction of fossil fuels as well as their utilization will be impacted by climate change, as shown in Table 8.

Table 8: Climate Change Impacts on Fossil-fuel Based Energy

Change in meteorological variable	Impact on fuel availability	Impact on energy generation
Temperature increase	None, unless pipelines get interrupted by melting pergelisol or discontent	Decrease of power plant efficiency due to higher temperature of cooling water.
Average precipitation increase	Reduced coal quality due to moisture content of opencast coal mining. Increased coal availability if coal seam fires are extinguished	None.
Average precipitation decrease	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 non-availability of cooling water

Change in meteorological variable	**Impact on fuel availability**	**Impact on energy generation**
Glacier melting	None	Increase in the medium term (for power plants located close to the glaciers) due to lower cooling water temperature and higher availability of cooling water. Decrease in the long term once glaciers have vanished.
Floods	Decrease if floods affect mines.	Decrease if power plant is flooded or fuel cannot reach the plant.
Increased 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

Section IV. Possible Adaptation Measures for Energy Systems

Adaptation measures can be categorised into infrastructural/technical and behavioural ones. Technical adaptation tries to make infrastructures invulnerable against long-term changes in meteorological variables and extreme events. Behavioural adaptation tries to adjust operation of existing and location of new infrastructures in a way to minimize damages.

a. Wind

Technical adaptation for wind power would mean that turbines are built in a more robust way to operate at and to physically withstand higher windspeeds.

Regarding behavioural adaptation, siting could take into account expected changes in windspeeds during the lifetime of the turbines, as well as sea-level rise and changes in river flooding. Insurance schemes for long-term wind power yields and damages from storms should be developed. This would require a good forecasting skill regarding changes in windspeed and extreme storm events. Moreover, rapid emergency repair teams could be set up to get damaged turbines repaired as quickly as possible.

b. Solar

For all solar technologies, technical adaptation is limited as they cannot be more robust than the building on which they are located. Behavioural adaptation would include siting according to expected changes in cloud cover. Large CSP plants should be designed in a way to make them robust with regards to storms. For distributed systems, mobile repair teams would be key to get them operational again after damage from extreme events.

c. Hydro

Technical adaptation for hydro projects can consist in building desilting gates to “flush” silted reservoirs. Moreover, dams can be increased in height and floodgates enlarged to cater for increased river flow extremes and variability. Upstream land management can also reduce possible erosion and resultant siltation of dam.

The change in flow regime might allow to expand the installed capacity. Increased flows from glacier melting should be taken into account if they are likely to persist for the technical lifetime of the extra capacity. Behavioural adaptation would include change of the plant operation regime to take into account changes in river flow patterns.

d. Biomass

Biomass availability can only be increased if crops are bred that have a higher biological heat tolerance and tolerate higher water stresses. Moreover, expansion of irrigation systems or improvement of efficiency of existing irrigation can counteract drought impacts provided sufficient water is available from sources outside the drought-hit area. This might imply tapping unconventional sources such as desalinated seawater or fossil water resources. Protection against floods can be provided by building dikes and improving drainage. Regarding biomass power plants, the robustness of the construction should be increased if located in storm-prone areas.

Behavioural adaptation would include early warning systems for rainfall and temperature anomalies, support of emergency harvesting in case of an imminent extreme event and the provision of crop insurance systems. Biomass power plants should be sited in less flood and storm-prone areas.

e. Fuel from mined resources

Technical adaptation for fossil fuel mining means improving the robustness of mining installations. This is especially important for offshore installations that are vulnerable to storms but also opencast as well as underground mines vulnerable to both flooding and shortage of water to sustain mining operation.

Behavioural adaptation would include siting of future mines in areas that have a limited exposure to flooding or drought risk. Power plants should preferably be sited at places with ample cooling water availability, especially with water of low temperature. They could also replace water with air cooling.

f. Interaction of adaptation measures between different energy forms

In several cases, adaptation measures of different energy forms influence each other. For example, behavioural adaptation of hydro power plants due to an improved operation schedule may conflict with an improved irrigation schedule of a downstream irrigation system. Likewise, desilting of reservoirs may have negative impacts on water supply for downstream irrigation. All power plant developers will rush for sites that have limited flooding risk and might compete for the limited number of good sites.

Section V. Indicators for Energy Systems' Vulnerabilities to Climate Change

The following section develops a set of indicators for the vulnerability of each energy system.

a. Transmission systems

The vulnerability of transmission systems would be shown by the following indicator:

VT1: Length of above-ground transmission lines (km)

Decentralised systems are much less vulnerable to failures in the transmission systems than centralised ones (see WADE 2007).

b. Wind

The vulnerability of the wind energy system would be shown by the following indicators:

VW1: Number of wind turbines at less than 1 m above sea level
VW2: Projected change of average windspeed in the next 20 years based on regional climate models (%)
VW3: Projected share of windspeeds over 25 m/s in average annual windspeed 20 years from now based on regional climate models
VW4: Projected likelihood of a storm with gusts over 70 m/s reaching areas where wind turbines are located (% over 20 years)

VW4 should be based on past experiences coupled with regional climate models.

c. Solar

The vulnerability of the solar energy system would be shown by the following indicators:

VS1: Expected temperature increase in the next 20 years (°C)
VS2: Projected change in cloudiness in the next 20 years based on regional climate models (%)
VS3: Projected likelihood of a storm with gusts over 70 m/s reaching areas where solar power plants are located (% over 20 years)

VS3 should be based on past experiences coupled with regional climate models.

d. Hydro

The vulnerability of the hydro energy system would be shown by the following indicators:

VH1: Expected precipitation change in the next 50 years, differentiated by watersheds (%) VH2: Projected additional runoff due to glacier melting in the next 50 years based on regional climate models, differentiated by watersheds (million m^3) VH3: Projected flood frequency in the next 50 years (number of floods that would be more intense than a flood currently having a 100 year recurrence time)

If runoff forecasts are available, VH1 should use runoff instead of precipitation.

e. Biomass

The vulnerability of the biomass energy systems would be shown by the following indicators:

VB1: Probability of temperature increase beyond biological heat tolerance of relevant crop within the next 20 years (%) VB2: Expected precipitation change during the growth season in the next 20 years, differentiated by crop regions (%) VB3: Projected drought frequency in the next 20 years (number of droughts that would lead to a reduction of crop yield by more than 20%) VB4: Projected flood frequency in the next 20 years (number of floods that would lead to a reduction of crop yield by more than 20%) VB5: Number of biomass power plants located at less than 1 m above sea level and within the area that would be flooded by a flood with a current recurrence period of 100 years

Indicators should be calculated for each crop that generates residues used for energetic purposes.

f. Fuel from mined resources

The vulnerability of the fossil fuel energy systems would be shown by the following indicators:

VF1: Expected temperature increase of cooling water for thermal power plants within the next 30 years (°C) VF2: Expected number of droughts that lead to a capacity decrease of thermal power plants by more than 10% within the next 30 years VF3: Number of thermal power plants located at a river fed by glacial melt where the glaciers are unlikely to vanish in the next 30 years VF4: 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 (%) VF5: Number of coal mines plants located at less than 1 m above sea level and within the area that would be flooded by a flood with a current recurrence period of 100 years VF6: Number of thermal power plants located at less than 1 m above sea level and within the area that would be flooded by a flood with a current recurrence period of 100 years

Section VI. Indicators for Countries' Capacity for Implementation of Energy Adaptation Projects

Countries differ considerably in their capacity to implement adaptation measures in the energy sector. Capacity can be differentiated into monetary, technological, human and administrative components. The following chapter develops indicators for such capacity.

a. Monetary capacity

CM 1: Domestic capital formation (million €/year)
CM 2: Domestic investment into the energy sector (million €/year)
CM 3: Domestic investment into renewable energy (million €/year)
CM 4: Capital of domestic insurance companies (million €)

b. Technological capacity

CT 1: Domestic graduation of engineers (100/year)
CT 2: Domestic engineers specialised in renewable energy technology (100)
CT 3: Number of domestic companies able to construct renewable energy plants
CT 4: Availability of hazard maps for droughts
CT 5: Availability of hazard maps for floods
CT 6: Availability of coastal maps with a 1 metre altitude contour

c. Human and administrative capacity

CH 1: Number of domestic mechanics trained in repairing of renewable energy systems
CH 2: Number of domestic companies specialised in servicing renewable energy systems
CH 3: Availability of early warning systems for meteorological extreme events
CH 4: Existence of plans to react on meteorological extreme events and of mobile teams
CH 5: Existence of siting guidelines for new power plants taking into account climate change impacts
CH 6: Existence of guidelines for power plant robustness with regards to storms

Section VII. Indicators for Successful Interventions that Increase Resilience

A necessary condition for adaptation is the existence of capacity to embark on adaptation activities. In the context of developing countries, this capacity needs external support, for example through the financial mechanisms of the international climate policy regime. To avoid that the scarce funds for such support are spent inefficiently, a set of criteria is developed to gauge efficiency of adaptation action.

a. Wind

Indicators for effective adaptation support in the context of wind power could be as follows:

EW 1: Domestic regulation for storm proof wind power plants is enacted and enforced. The regulation ensures that during the technical lifetime of the wind turbines, they withstand the highest windspeed that is likely to occur in the area during that period
EW 2: A siting map for wind power plants has been developed taking into account projected changes in windspeeds, floodplains and area impacted by sea level rise
EW3: An insurer offers an insurance against wind turbine storm damage

b. Solar

ES1: A siting map for solar power plants has been developed taking into account projected changes in cloud cover
ES2: Domestic regulation for storm proof concentrating solar power plants has been enacted, which ensures that during the technical lifetime of the CSP plant it withstands the highest windspeed that is likely to occur in the area during that period

c. Hydro

EH1: All new dams are equipped with desilting gates
EH2: It has been mapped which hydro plants should expand their capacity due to projected improvements in river flow regime
EH3: A siting map for new hydro power plants has been developed taking into account projected changes in river flow
EH4: A plan for optimized operation of hydro plants under projected flow regimes has been developed, with upstream land management to reduce possible erosion and resultant siltation of dam

d. Biomass

EB1: An irrigation masterplan has been developed taking into account projected changes in drought occurrence
EB2: A research budget for heat and drought resistant crops has been allocated and a realistic plan for this research has been drafted (for small countries: participation in the Consultative Group on International Agricultural Research - CGIAR - activities for crop improvement research has been organised)

EB3: A siting map for biomass power plants has been developed to prevent siting in floodplains and areas impacted by sea-level rise EB4: Domestic regulation for storm proof biomass power plants has been enacted, which ensures that during the technical lifetime of the biomass plant it withstands the highest windspeed that is likely to occur in the area during that period

e. Fuel from mined resources

EM1: A siting map for mines has been developed taking into account projected flooding and drought-prone areas EM2: Domestic regulation for siting of thermal power plants at sites with sufficient cooling water availability in the next 50 years has been enacted

Section VIII. Conclusions

It is possible to assess adaptation needs for the energy sector and to determine indicators for vulnerability, adaptation potential and effectiveness of adaptation support. Human resources for rapid reaction in case of meteorological extreme events are necessary, but not sufficient condition for successful adaptation. Energy systems are strategic goods and can only be as resilient as the environment and human milieu in which they are located.

Using planning tools such as indicators to assess resiliency and adaptation options are key to avoid siting future power plants in areas prone to impacts from extreme meteorological events. Moreover, understanding the vulnerabilities of particular energy systems allows for improved robustness of plant design to take into account projected changes in windspeeds and how to design plants to adjust to changing energy resources.

The future is not what it used to be and energy planners need both the tools and the knowledge of scientists, energy analysts, economists and all stakeholders. Users who legitimately represent the needs of present and future generations and know their own needs must also be included if we are to ensure the resiliency of our energy systems in the face of climate change impacts.

Section IX. References

ActionAid USA, **Compensating for Climate Change: Principles and Lessons for Equitable Adaptation Funding,** 2007, www.actionaidusa.org

HELIO International: **A preliminary assessment of energy and ecosystems resilience in ten African countries**, 2007, http://www.helio-international.org/energywatch/2007.cfm

IPCC, **Summary for Policy Makers of the Synthesis Report of the IPCC Fourth Assessment Report,** November 2007, http://www.ipcc.ch/press/index.htm

OECD, **Stocktaking of Progress on Integrating Adaptation to Climate Change into Development Co-operation Activities,** 2007
http://www.oecd.org/document/34/0,3343,en_2649_37425_39313186_1_1_1_37425,00.html

SSN**, SouthSouthNorth New Methodology for Community Based Adaptation – SSNAPP,** 2005
http://www.southsouthnorth.org/library.asp

Stratus Consulting Inc. /- UNFCCC Secretariat (2005): **Compendium on Methods and Tools to Evaluate Impacts of, and Vulnerability and Adaptation to, Climate Change**
http://unfccc.int/files/adaptation/methodologies_for/vulnerability_and_adaptation/application/pdf/consolidated_version_updated_021204.pdf

Tearfund, Christain Aid, Practical Action, Oxfam,**Two degrees, One Chance – the urgent need to curb global warming,** 2007,
http://tilz.tearfund.org/Research/Climate+change+reports/Two+degrees+One+chance.htm

Tyndall Centre for Climate Change Research (2004): **New Indicators of Vulnerability and Adaptive Capacity**, Tyndall Centre for Climate Change Research Technical Report 7
http://www.tyndall.ac.uk/theme3/final_reports/it1_11.pdf

UKCIP, **Climate adaptation: Risk, uncertainty and decision-making**
Technical Report, May 2003, http://www.ukcip.org.uk/resources/publications/pub_dets.asp?ID=4

UNFCCC, **National Adaptation Programmes of Action,**
http://unfccc.int/national_reports/napa/items/2719.php

UNFCCC, **National communications from Non-Annex 1 Countries**
http://unfccc.int/national_reports/non-annex_i_natcom/submitted_natcom/items/653.php

UNFCCC, **Impacts, Vulnerabilities and Adaptation in Developing Countries,** 2007
http://unfccc.int/files/essential_background/background_publications_htmlpdf/application/txt/pub_07_impacts.pdf

UN Secretary General, **Millennium Development Goals**, 2000, http://www.un.org/millenniumgoals/

USAID, **Adapting to Climate Variability and Change: A guidance manual for development planning**, 2007, Washington, www.usaid.gov

WADE: **Security via Decentralised Energy**, 2007, http://www.localpower.org/getreport.php?id=1020

WRI, **Growing in the Greenhouse: Protecting the Climate by Putting Development First**, 2005
http://archive.wri.org/item_detail.cfm?id=3744&section=climate&page=pubs_content_text&z=?