Energy and Climate Change Adaptation in Developing Countries

euei pdf
Strategic Energy Advisory and Dialogue Services

giz Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

Published by
European Union Energy Initiative
Partnership Dialogue Facility (EUEI PDF)

c/o Deutsche Gesellschaft für
Internationale Zusammenarbeit (GIZ)
P.O. Box 5180, 65726 Eschborn, Germany

info@euei-pdf.org
www.euei-pdf.org

Place and date of publication
Eschborn, September 2017

Author
Christina Stuart (EUEI PDF)

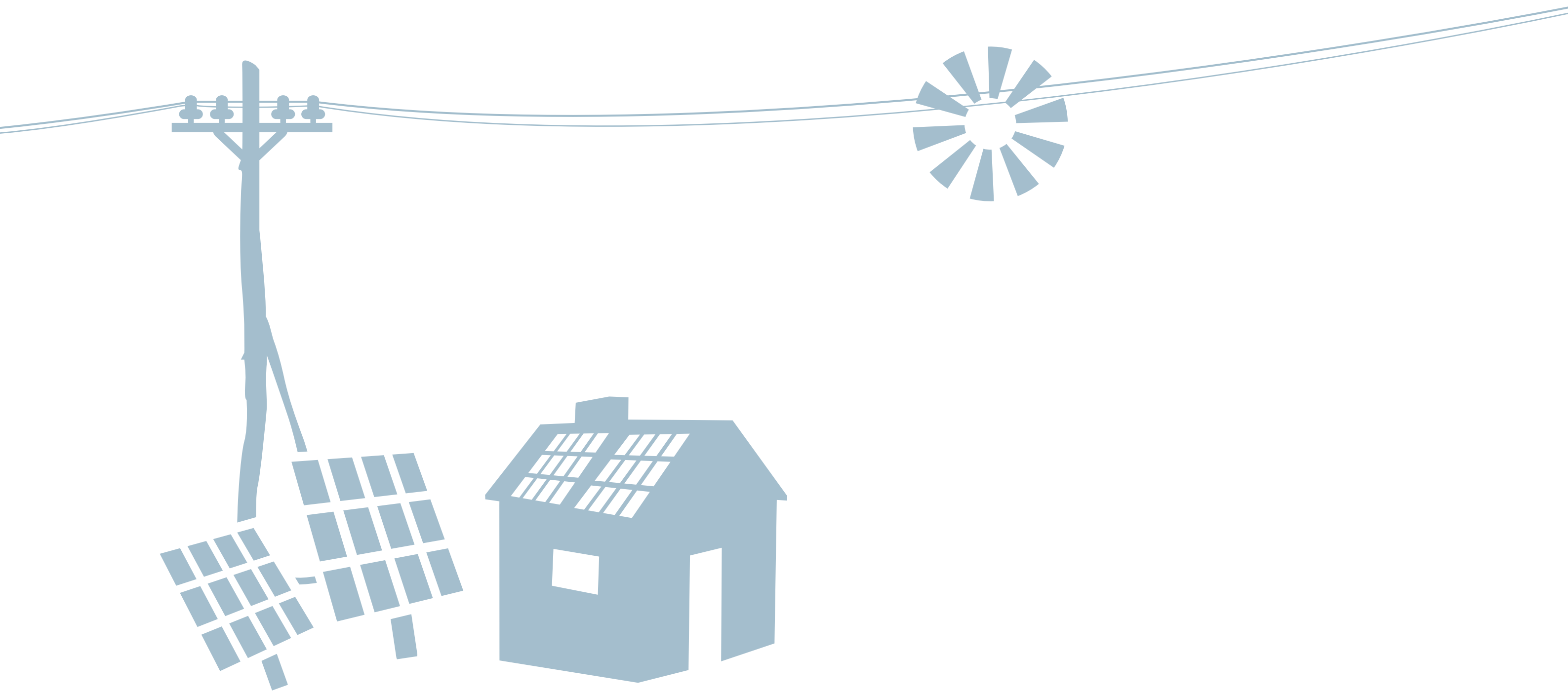
Editor
Silvia Escudero (EUEI PDF)

With comments and contributions by
Silvia Escudero (EUEI PDF); Silvia Cabriolu Puddu (EUEI PDF); Mario Merchan (EUEI PDF); Sandra Schuster (GIZ); Susanne Schwan (GIZ); Hadley Taylor (EUEI PDF); Daniel Werner (EUEI PDF)

Design and layout
SCHUMACHER — Brand + Interaction Design
www.schumacher-visuell.de

Photos
© GIZ, cover, pp. 7, 13, 17, 18, 21, 25, 28, 34, 38, 42, 44, 45 left, 56
© GIZ/Ines Adingni, p. 45 right
© GIZ/Albrecht, p. 15
© GIZ/Samuel Goda, p. 32
© GIZ/Kirchgessner, p. 39
© GIZ/Meyer, p. 31
© GIZ/Ostermeier, pp. 22, 27, 35, 37
© GIZ/Vogel, p. 40
© GIZ/Alan Walsch, p. 50
© NASA, p. 9
© Carolin Weinkopf, p. 10
© Wikicommons, Sea Level Rise, p. 4
© Wikicommons, Greenland Glaciers outside of Ammassalik, 5562580093, p. 49

The **Partnership Dialogue Facility (EUEI PDF)** is an instrument of the EU Energy Initiative (EUEI).
It currently receives contributions from the European Commission, Austria, Finland, Germany, Italy, the Netherlands and Sweden.

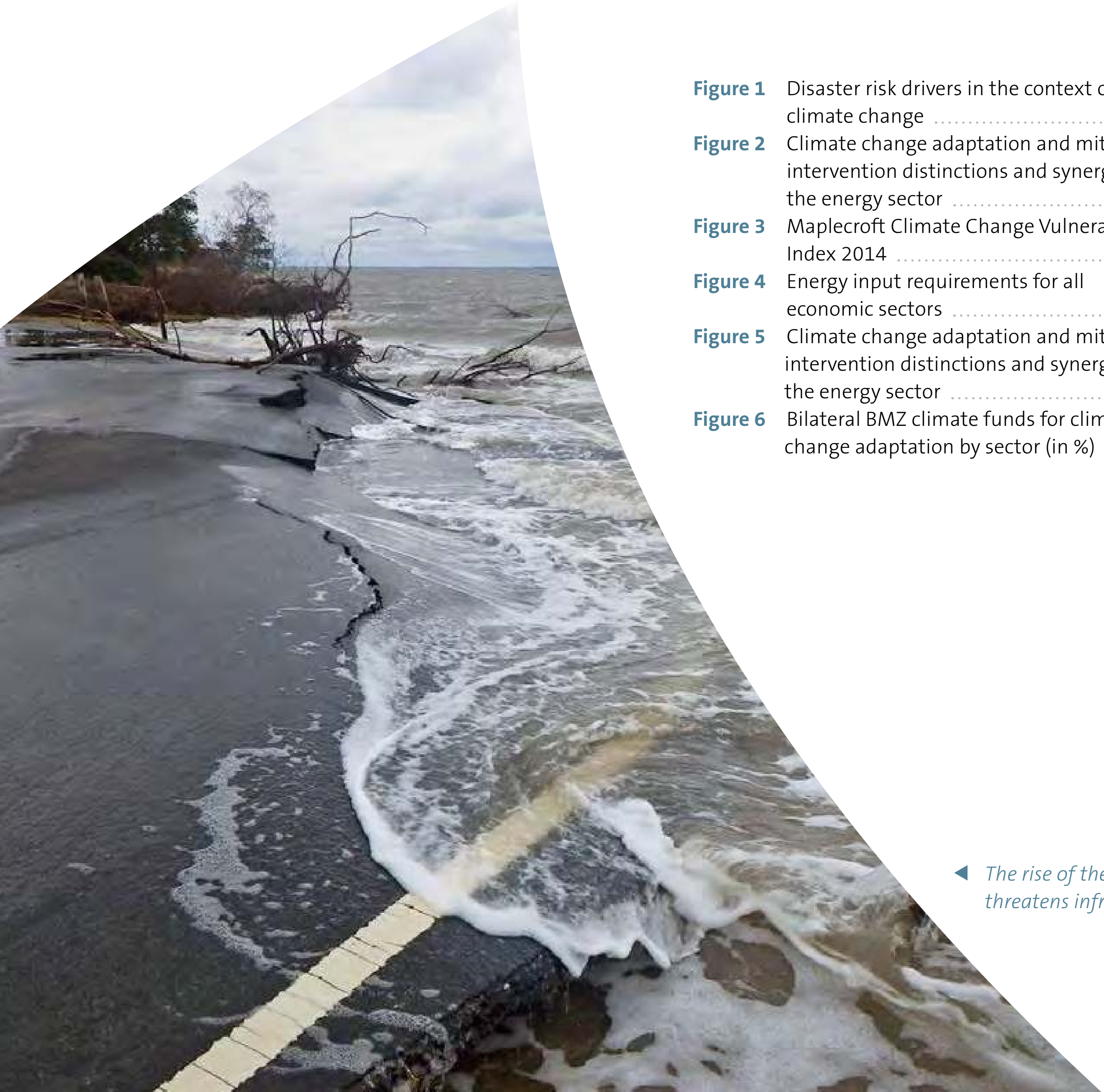


Energy and Climate Change Adaptation in Developing Countries

euei pdf
Strategic Energy Advisory and Dialogue Services

Contents

List of Figures



The rise of the sea level threatens infrastructure.

List of Tables

Acronyms and Abbreviations

CARICOM	Caribbean Community and Common Market
CCVI	Climate Change Vulnerability Index
CIF	Climate Investment Funds
CSP	Concentrated Solar Power
EUEI PDF	European Union Energy Initiative Partnership Dialogue Facility
GCF	Green Climate Fund
GDP	Gross Domestic Product
GIZ	Gesellschaft für Internationale Zusammenarbeit GmbH
IPCC	Intergovernmental Panel on Climate Change
LDCF	Least Developed Countries Fund
NAP	National Adaptation Plans
NDC	Nationally Determined Contributions
ODA	Official Development Assistance
ODI	Overseas Development Institute
OECD	Organisation for Economic Cooperation and Development
PPCR	Pilot Program for Climate Resilience
SDG	Sustainable Development Goal
SIDS	Small Island Developing States
UNFCCC	United National Framework Climate Change Convention
WMO	World Meteorological Organisation

Executive summary

The energy sector does not only drive climate change due to greenhouse gas emissions, but is also being severely affected by its impacts. Particularly, the energy sector in developing economies will witness strong climate change impacts, whilst having the lowest capacity to increase their resilience. As energy demand is set to increase by 71% in these countries by 2040, there is an opportunity for this sector to undergo a resilient energy sector transformation in order to avoid the risk of locking into unsustainable energy growth patterns.

The whole value chain of the energy system – generation, transmission, distribution, as well as consumption – is being increasingly impacted by climate events. Droughts and floods will significantly affect hydropower generation output. Transmission and distribution lines are at risk of storm and cyclone induced catastrophic damage, which could cause expensive power outages. Energy demand is also set to increase as the warmer climate will call for additional cooling needs.

Adaptation measures imply reducing both exposure and vulnerability of the energy system to climate change hazards. Adaptation solutions, whether structural or policy-driven, exist for each energy stakeholder and market segment. Fortifying power plants close to coastlines prone to flooding can safeguard resilience. Diversifying energy generation sources can increase energy security and therefore the resilience of the whole energy system.

However, it is estimated that adaptation to a global average temperature increase of 2.0 degrees Celsius could cost between $70 billion to $100 billion a year. This price tag is equivalent to almost 70% of total Official Development Assistance (ODA) disbursement in 2015. Currently, not even 10% of the required funds are being transferred. Moreover, there is an imbalance in climate funding: in 2015, only 24% of approved climate financing since 2003 went to support adaptation, the remainder going to mitigation. Other barriers to adaptation in the energy sector include a lack of climate change readiness via ex ante climate risk assessments, as well as no standardised monitoring and evaluation of adaptation practices.

This study aims to provide a rarely discussed analysis of the interlinkages between the energy sector and climate change adaptation in order to support the donor community with recommendations on how to effectively introduce a climate change adaptation approach for energy sector projects. Indeed, the conclusions from this report reflect that increased funding for climate change adaptation in the energy sector, as well as targeted specific interventions for climate-adapted energy systems can fill the resilience gap and spur sustainable energy development.

Desertification in Boutilimit, Mauritania. ▶

Introduction

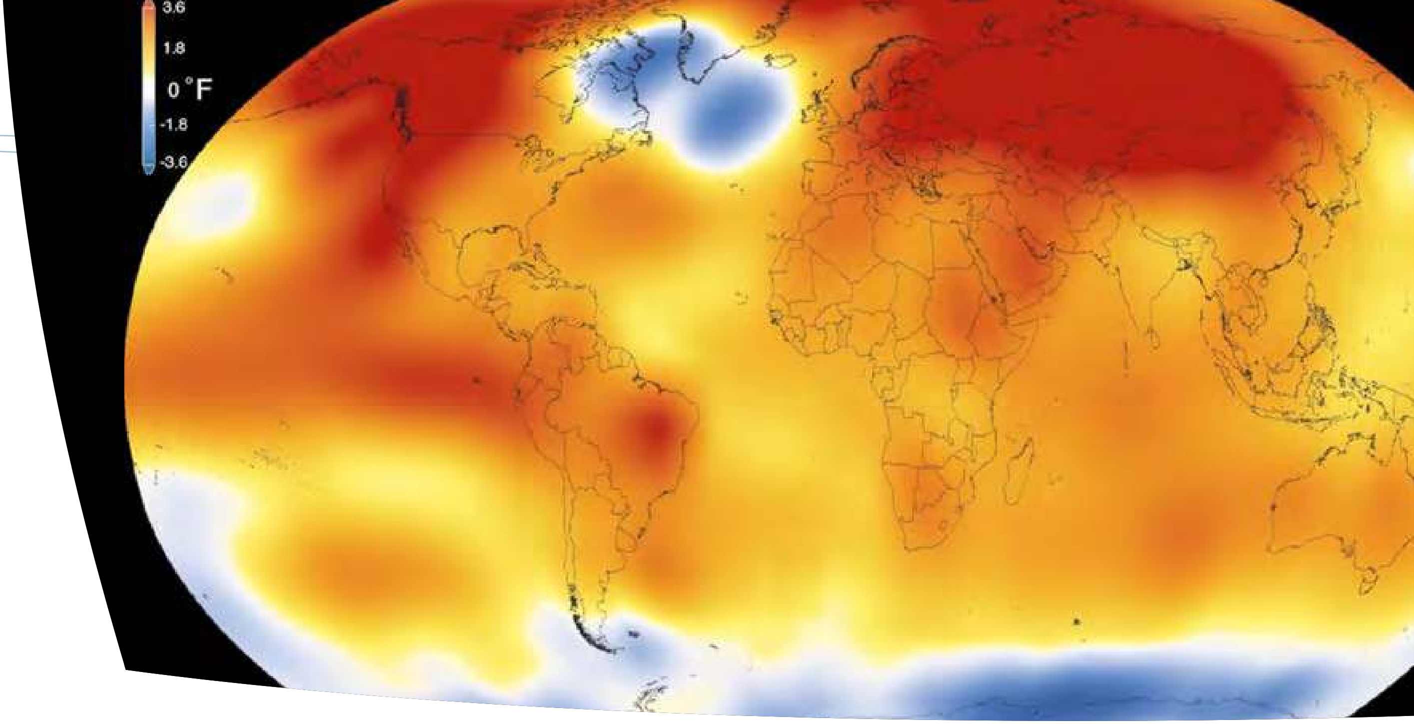
Study context

The energy sector is not only a driver of climate change due to greenhouse gas emissions, but is also seriously affected by its impacts. “In Kenya, drought between 1999 and 2002 drastically affected hydroelectric generation, and in 2000 capacity fell by 25%. The resultant cumulative loss in generation was variously estimated at between 1.0 and 1.5% of total GDP:”[1] Such negative climate impacts on the sector have costly consequences on almost all goods and services, in particularly fresh water distribution and food production. The energy sector therefore plays an important role in creating and maintaining a climate resilient society.

The Intergovernmental Panel on Climate Change (IPCC) projects a 2.6 to 4.8-degree Celsius increase in global average temperature by the end of the century, as well as precipitation fluctuations, frequent extreme weather events and sea-level rise of between 0.26 and 0.55m above the 2005 level in 2100, for a +2-degree Celsius scenario[2]. Due to past emissions, even if greenhouse gas emissions are halted today, the world is already locked into “substantial irreversible commitments to future changes in the geography of the Earth”[3]. Mitigation remains a priority. However, as climate change is already happening and is irreversible, we have no choice but to adapt to the climate-related challenges that are causing economic disruption today.

The Paris Agreement stresses the importance of adaptation, stating that developing countries will receive “enhanced and continuous” support for actions that contribute to climate resilience. Climate change vulnerability is of greatest concern to developing countries, as they already face challenges due to droughts, floods and slow-onset changes such as temperature rise and changing rainfall patterns. According to Maplecroft’s Climate Change Vulnerability Index (CCVI)[4], the top ten countries at ‘extreme risk’ are developing economies with high population growth rates, such as Bangladesh, Haiti, Zimbabwe, Madagascar and the Philippines. As energy growth is also set to increase by 71% between 2012 and 2040 in developing countries[5], the risk of embarking into unsustainable patterns of growth in the energy sector is high. This rapid development is also an opportunity, as there is significant potential for sustainable and resilient energy sector transformation in these regions.

1) Centre for International Governance Innovation, 2009
2) IPCC, 2014
3) Solomon et al., 2009
4) Maplecroft, 2014
5) EIA, 2016



2015 was one of the warmest years on record (NASA image).

Purpose of this study

This study aims to:

- present an analysis of the interlinkages between the energy sector and climate change adaptation;
- highlight key areas of action in order to build a resilient energy sector;
- outline stakeholders' responsibilities for energy sector adaptation.

Target audiences

This report targets energy and climate stakeholders, in particular the donor community. It highlights the need for action in this cross-sectoral field and present corresponding recommendations for solutions that cover a holistic approach to climate change adaptation for the energy sector.

Study approach

The first section will focus on defining adaptation to climate change as key for economic development and inseparable from the energy sector. The second section will present the vulnerability of the energy sector to climate change stressors. The third section will formulate key measures and actions needed to create a climate resilient energy system in developing countries. The final section will address how different stakeholders can share the responsibility for adaptation, focussing on how the donor community in particular can build a resilient energy system.

1. Climate change adaptation: a concept for energy sector resilience

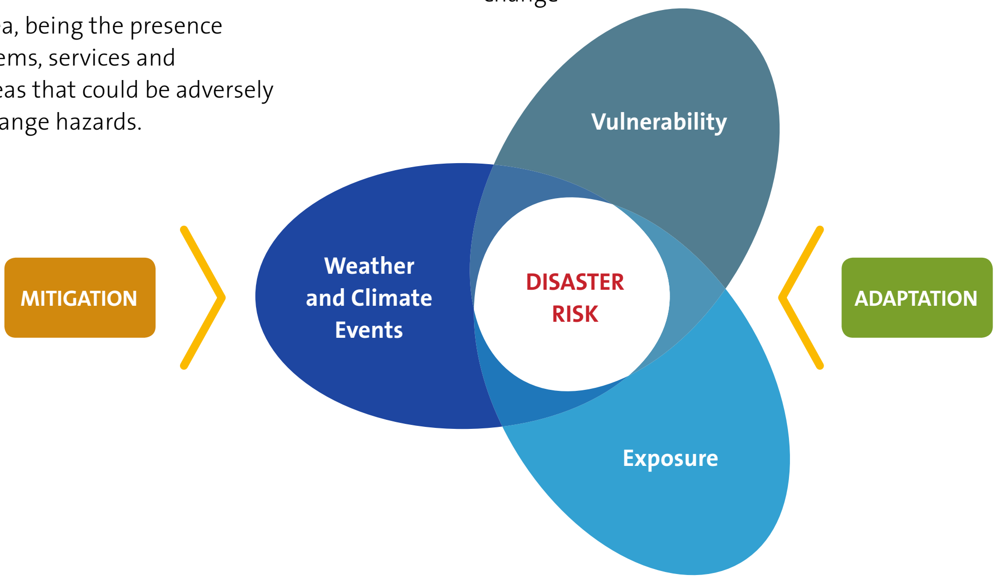
What is climate change adaptation?

Adaptation is defined as “an adjustment in natural and human systems in response to actual or expected climatic stimuli or their effects”[6]. Whilst climate change mitigation reduces the severity and frequency of climate change hazards, climate adaptive actions counteract a changing environment, in order to reduce:

- the vulnerability of a system, being the propensity or predisposition of a system to be adversely affected; and
- the exposure of an area, being the presence of livelihoods, ecosystems, services and economic assets in areas that could be adversely affected by climate change hazards.

Illustrated in *Figure 1*[7], a disaster risk exists once a socio-ecological system is simultaneously vulnerable and exposed to climate hazards. The benefits of mitigation are to globally reduce climate hazards and cover many non-specific climate aspects. On the other hand, adaptation efforts are required to reduce both vulnerability and exposure to existing and projected climate change. The benefits of adaptation are to reduce disaster risk at a local and specific level for a sustainable society in the long-term.

Figure 1 Disaster risk drivers in the context of climate change



◀ *Wind turbines in Morocco.*

6) IPCC, 2012

7) IPCC, 2012

Understanding the difference between adaptation and mitigation is primordial to understanding what adaptation means for the energy sector. As the energy sector is most often associated with mitigation efforts, the energy adaptation opportunities are regularly not taken into account.

Figure 2[8] details how climate and energy interventions can both reduce emissions and build resilience or do both simultaneously, incurring both mitigation and adaptation benefits.

8) Adapted from S. Winkelman, 2016

Energy efficiency programmes, for example, are a mitigation intervention and will lower carbon emissions. These programmes will however also decrease the vulnerability of an energy system to climate hazards that could affect security of energy supply. If less energy is required for an identical service, power outages will cause less damage and thus encourage climate resilience. Other examples include micro grids, which are both low-carbon and create more resilient power systems. Water efficiency measures also have the dual benefit of requiring less pumping energy, lowering its carbon footprint and preparing for a possible decrease in future water supplies. In fact, mitigation finances can contribute indirectly to adaptation efforts.

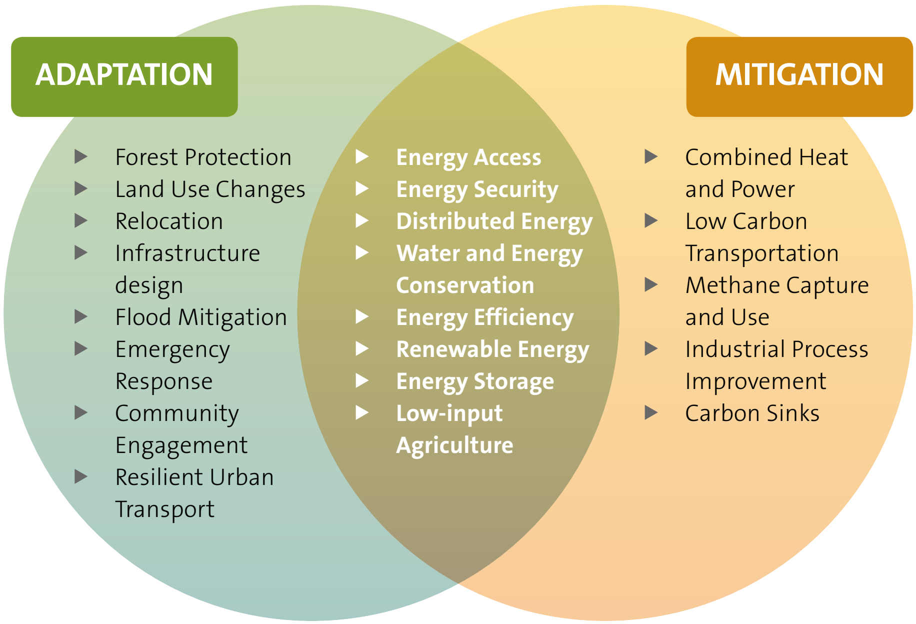


Figure 2 Climate change adaptation and mitigation intervention distinctions and synergies in the energy sector

Drought conditions in Bou Hanifia, Algeria.

Indeed, it is important to understand from the onset both the distinctions and synergies between mitigation and adaptation. Recognising the differences and overlaps will help appreciate in the following sections why the energy sector is not prepared for severe climate change and variability and what makes an energy system resilient.

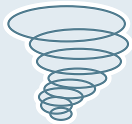
Where is climate change adaptation needed?

In 2016, according to the World Meteorological Organisation (WMO), global warming had already reached +0.83 degrees Celsius compared to the pre-industrial reference period. The IPCC projections state a warming trend of 2.6 to 4.8 degrees Celsius by 2100, a likely sea-level rise of 0.26 to 0.55 metres and a very likely increase in propensity and frequency of extreme weather events, such as tropical cyclones[9].

In order to visualise geographically where vulnerability and exposure need to be addressed, Maplecroft has designed a Climate Change Vulnerability Index.

Figure 3[10] illustrates that the regions most vulnerable to climate change constitute developing countries. For this reason, this report will solely focus on developing countries when addressing the issue of climate change adaptation and the energy sector. This index takes into account exposure to climate-related events such as sea-level rise, a country's dependency on certain sectors such as agriculture as well as a government's financial capacity to adapt. Data for 170 countries are covered by this Climate Change Vulnerability Index.

For example:



In Bangladesh, damage costs from single cyclone events are expected to rise fivefold to nearly $9 billion by 2050, accounting for 0.6% of GDP with the burden falling disproportionally on poor households in coastal areas. Coastal embankments and cyclone shelters are effective in limiting the damages and the number of fatalities due to cyclones[11].

The countries at extreme risk have many similar climate vulnerable characteristics, including:

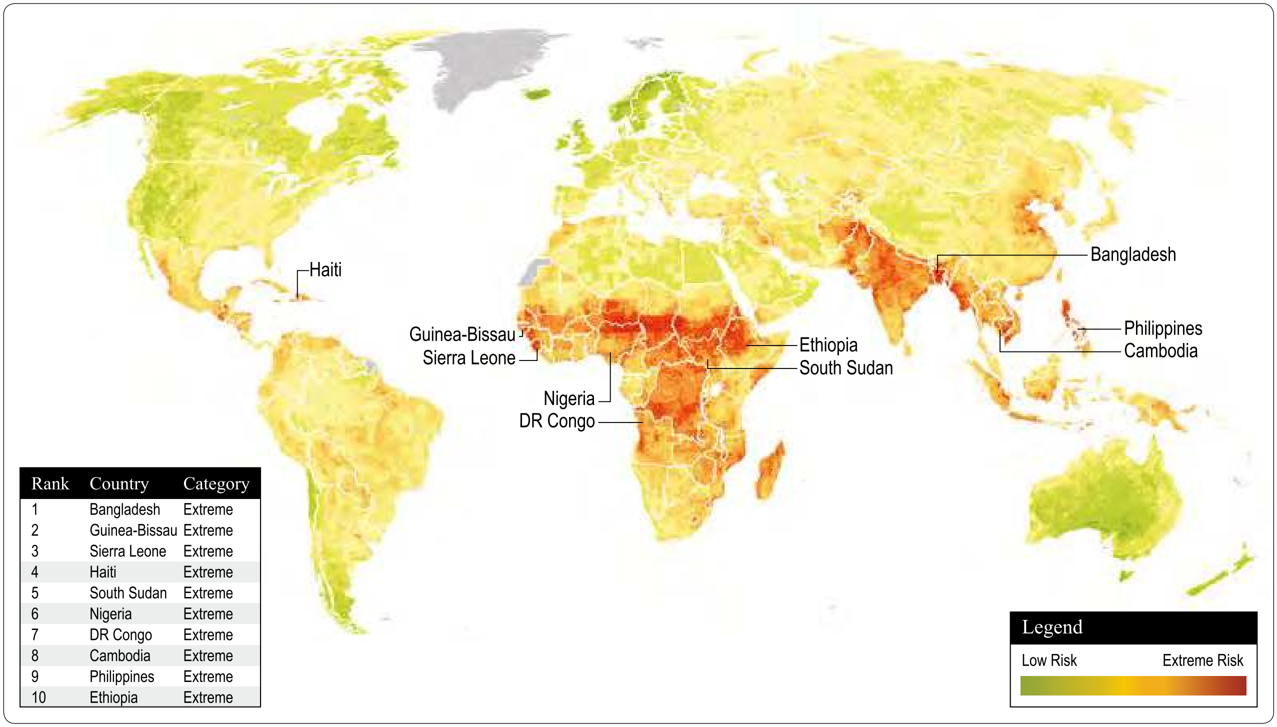
- high levels of poverty;
- dense populations;
- high exposure to climate-events;
- high reliance on agricultural land in flood and drought risk zones; and
- poor access to reliable energy.

9) IPCC, 2014

10) Maplecroft, 2014

11) World Bank, 2010

Figure 3 Maplecroft Climate Change Vulnerability Index 2014



Rank	Country	Category
1	Bangladesh	Extreme
2	Guinea-Bissau	Extreme
3	Sierra Leone	Extreme
4	Haiti	Extreme
5	South Sudan	Extreme
6	Nigeria	Extreme
7	DR Congo	Extreme
8	Cambodia	Extreme
9	Philippines	Extreme
10	Ethiopia	Extreme

Small Island States are not covered in this chapter, as even with different levels of economic development, the risk of submergence linked to sea-level rise is unavoidable.

Using the ranking from this index, it is clear that the countries with a lower level of economic development are in most need of climate change adaptation. This is mainly because they have little financial capacity to adapt their economies to projected climate hazards. There is a direct correlation between vulnerability to climate change and the level of economic development, which is why this study focusses on developing regions.

Food market in Yemen illuminated at night. ▶

How does the energy sector contribute to climate change adaptation?

Before detailing how to build a more resilient energy system (*Section 3*), one must recognise the role of the energy sector for adaption in general. In other words, this section explains how energy and access to energy can support adaptation in all sectors.

As energy provides input into almost all goods and services of an economy, a sustainable energy system contributes to adaptation. In particular, food production as well as water treatment and distribution sectors require energy as a primary input. A robust energy sector can provide input to GDP, jobs, trade opportunities and welfare benefits that strengthen an economy's resilience. *Figure 4* illustrates how energy is an input into all primary and secondary sectors, as well as most tertiary sector services. The words in grey define weak energy input links, whereas the words in black define strong energy input links.

With increased economic growth, an economy as a whole is more resilient to climate change impacts. In China, India and South Korea investment in non-traditional energy sources such as renewables is being used to lever economic growth[12]. As energy demand growth will increase by 71% in non-OECD countries by mid-century[13], there is a large potential for this sector to play an important role for economic growth and resilience.

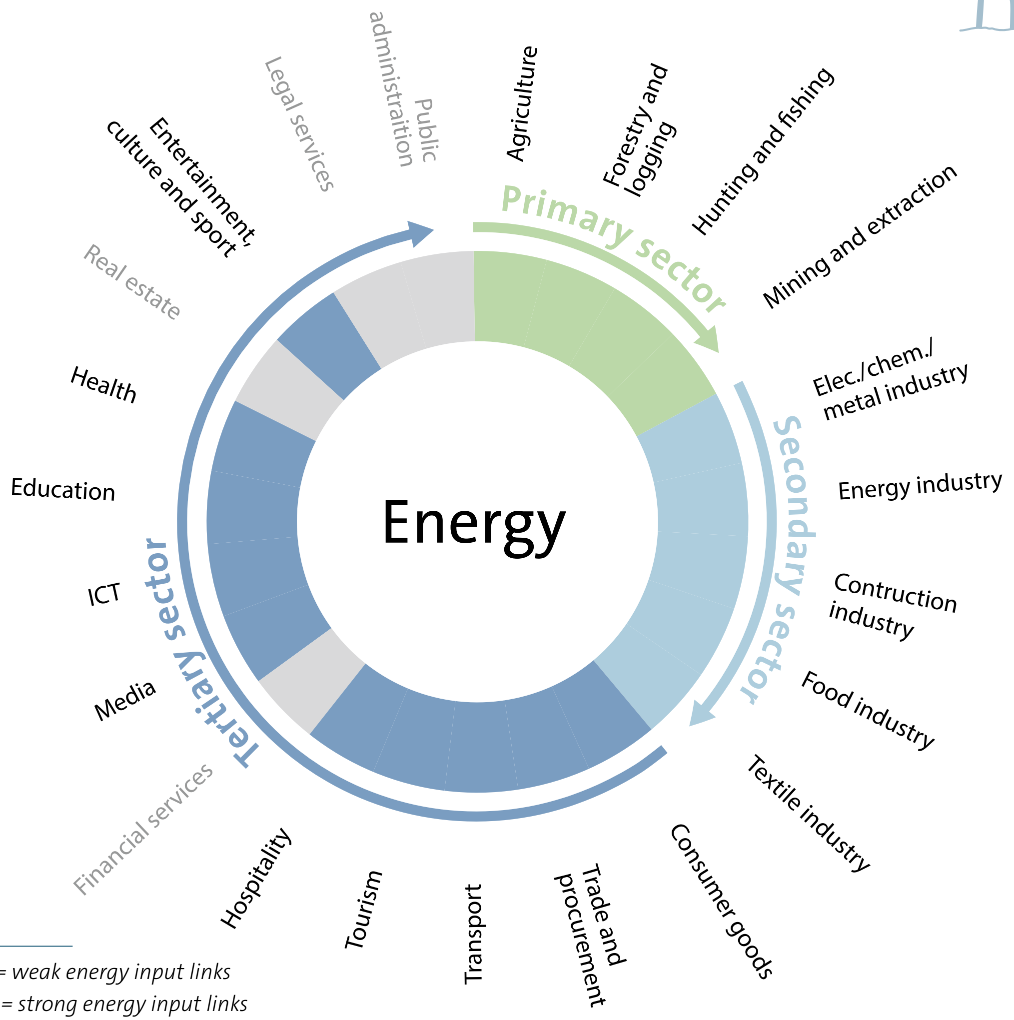
As well as diversifying the energy mix, the energy sector can ensure more productive agriculture activities, through enhanced irrigation systems. Moreover, providing energy access for education allows higher quality tools to be used by more people for more hours during the day. Enhanced capacity building in turn increases climate change awareness and informs adaptation strategies.

Another example of how the energy sector contributes to adaptation is related to all the additional energy demand that will be required during heat waves. Adaptation measures include air conditioning installations in public buildings in order to prepare for the warmer climate. A reliable energy supply is the backbone for such a measure to be effective.

12) World Economic Forum/ HIS CERA, 2012

13) IEA/OECD, 2016

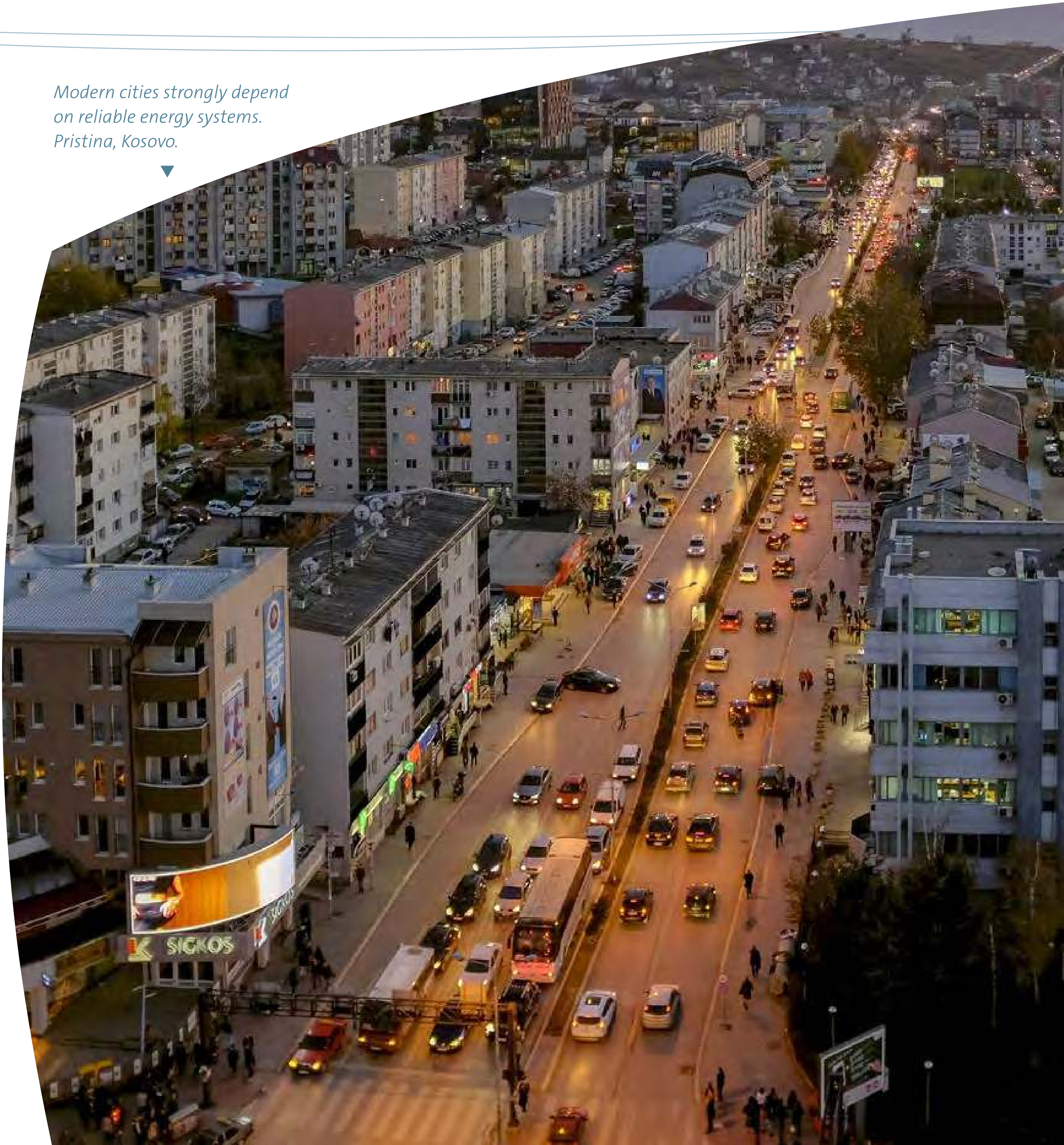
Figure 4 Energy input requirements for all economic sectors



Grey words = weak energy input links
***Black words** = strong energy input links*

As of yet however, the Nationally Determined Contributions (NDCs) and National Adaptation Plans (NAPs) often omit the energy sector as a contributor for adaptation and are focussed on using the energy system purely for mitigation. The energy sector is not yet a structural component of adaptation planning, even though energy can be an essential tool for resilience.

Modern cities strongly depend on reliable energy systems. Pristina, Kosovo.



2. Climate change impacts on the energy sector

What makes the energy sector vulnerable to climate change?

The energy sector is a main contributor to climate change, as 70% of global greenhouse gas emissions originate from energy activities[14]. However, the energy sector itself is affected by climate change and the modalities of these effects can have dire consequences on the economy depending on the area and intensity of the impact. To date, insufficient attention has been paid to energy sector vulnerability in relation to projected climate change[15].

Several characteristics of the energy sector make it vulnerable to climate change and in need of sustainable transformation.

The energy sector consists of a large network of physical infrastructure which is vulnerable to damage caused by extreme climate events.

The energy sector requires long-lifetime infrastructure, which could increase the risk of locking into unsustainable energy growth. In fact, power plant infrastructure lifetimes are between 15 to 40 years (even higher for nuclear plants) and transmission line lifetimes are between 40 and 75 years. This means that it is important to plan strategically in accordance with climate projections and be aware of the long-term climate change impacts.

Additionally to energy being an input to many sectors, the energy sector also depends on other sectors in order to function. The water and agricultural sectors are examples of indispensable inputs for energy production and use, which are themselves at risk of climate change impacts.

Most importantly, the energy sector generation sources, such as thermal power and hydropower, all depend on climatic conditions.

This section focusses on how four climate stressors impact the energy system: temperature increase, precipitation fluctuation, extreme weather events (storms, cyclones) and sea-level rise[16].

◀ *Powerplant in Ulaanbaatar, Mongolia.*

14) IEA, 2015

15) ADB, 2012

16) The IPCC has identified other climate stressors, such as ocean acidity increases, which have not been analysed in this study as their impact on the energy sector is less direct.

How does climate change impact energy generation?

Table 1 The main impacts of climate change on energy generation sources by climate stressor

Climate stressor	Warming trend	Precipitation	Cyclone	Sea level
Hydro power	High temperatures may induce glacier melting, increasing water quantities in hydro basins. Extreme temperatures may affect energy generation due to increased reservoir evaporation.	Changes in precipitation may increase run-off variability. Droughts may affect run-off and energy output.	Equipment damage may decrease output.	*No significant impact*
Wind power	Increased temperatures may decrease air density decreasing energy output.	*No significant impact*	Alteration in wind speed may increase output variability. Damage from cyclones may decrease plant lifetime and output.	Sea-level rise may damage off-shore infrastructure.
Biomass	Increased temperatures may impact crop yield and irrigation needs. Extreme temperatures may induce fires and threaten crops.	Precipitation fluctuations may cause variable irrigation needs. Droughts may impact crop yield.	Storms may threaten crop yield.	Erosion and salinisation may threaten crop productivity.

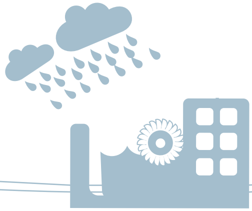
Men working with fire in Laos.

Solar power[17]	High temperatures may reduce solar PV cell efficiency. High temperatures may alter Concentrated Solar Power (CSP) efficiency (see Thermal power).	Increased cloud cover may decrease solar PV generation output. Droughts may affect Concentrated Solar Power (CSP) generation (see Thermal power).	Extreme events may damage structures and decrease plant lifetime.	*No significant impact*
Thermal power[18, 19]	Higher temperature of cooling water may decrease plant efficiency.	Increased water content may affect fossil fuel quality. Droughts may affect water availability for cooling.	Cyclones may damage plant infrastructure.	Sea-level rise may increase risk of damage to off-shore infrastructure and coastal stations.

17) Solar power includes: photovoltaic (PV) and Concentrated Solar Power (CSP).

18) Thermal power includes: fossil fuel powered plant and nuclear plants.

19) Ocean energy is not being considered as it is still at the research phase. Geothermal is not being considered as it will not be significantly impacted by climate change.



For example:
Power output for gas turbines decreases proportionally to temperature increase. A 5.5-degree Celsius increase in ambient air temperature results in a 3 to 4% reduction in energy output[20].

In Kenya, for a high climate change scenario the economic losses up to 2100 of decreased hydropower potential, as a result of precipitation scarcity, could be equivalent to $4 to $19 million[21].

During the 2003 and 2007 heat waves in Europe, 17 thermal power plants had to be shut down or cut production in Germany, France, Spain, Romania, the Czech Republic and Slovakia, as there was insufficient cooling water and the plants' waste water exceeded temperature limits[22].

The hydropower sector will be particularly affected by changes in water run-off due to snow and glacier melt, rainfall variability, heat waves, droughts, floods as well as extreme storms. In *Figure 5*[23], the projected changes in hydropower generation in 2050 are presented based on the IPCC A1B emissions scenario from 12 General Circulation Models (GCM) and on hydropower production in 2006[24].

It is important to recognise that many countries with strong dependence on hydropower, such as in South America and Africa will face large fluctuations in water run-off and have little adaptive capacity to deal with these changes.

◀ *Climate variability threatens the energy production of hydropower plants. Small hydropower plant, Nepal.*

20) Neumann et al., 2009
21) Droogers, 2009
22) Linnerud, 2010

Figure 5 Climate change adaptation and mitigation intervention distinctions and synergies in the energy sector

23) Hamududu et al., 2010

24) It must be noted that the scenario A1B used for this *Figure 5* is no longer used by the IPCC reports. The *Figure 5* nevertheless presents well the projected changes in hydropower generation.

Construction work of a hydropower plant in Nepal. ▶

How does climate change impact energy transmission and distribution?

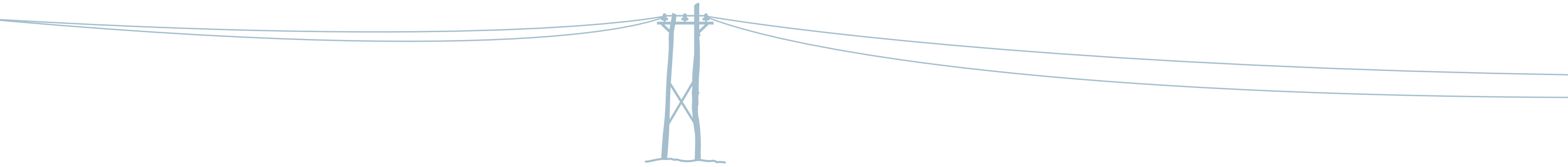
Impacts of climate variability and change on energy generation are most obvious, however energy transport, transmission and distribution infrastructure will also be indirectly and directly affected.

For example:
In the electricity sector, resistance of copper lines increases by **0.4%** and transformer capacity decreases by **1% for each degree** temperature increase in Celsius[25].

Table 2 The main impacts of climate change on energy transmission and distribution by climate stressor

Climate stressor	Warming trend	Precipitation	Cyclone	Sea level
Transmission and distribution	Higher temperatures may increase electrical resistance for transmission lines, decreasing transmission efficiency. Higher temperatures may increase fire risk, damaging infrastructure including electricity lines.	Precipitation variations may block or delay road transport, affecting transport of oil or gas.	Storms and strong winds may damage infrastructure and electricity lines, reducing system reliability.	Sea-level rise may damage infrastructure through salt-water corrosion.

25) Aivalioti, 2015



How does climate change impact energy consumption?

Additionally to energy demand considerably increasing due to development and population growth, the usage of energy will change. Global warming will induce increased energy needs for cooling in summer seasons and decreased heating needs in winter seasons. Overall, additional energy reserves and emergency energy capacity will be needed for extreme events, such as heat waves.

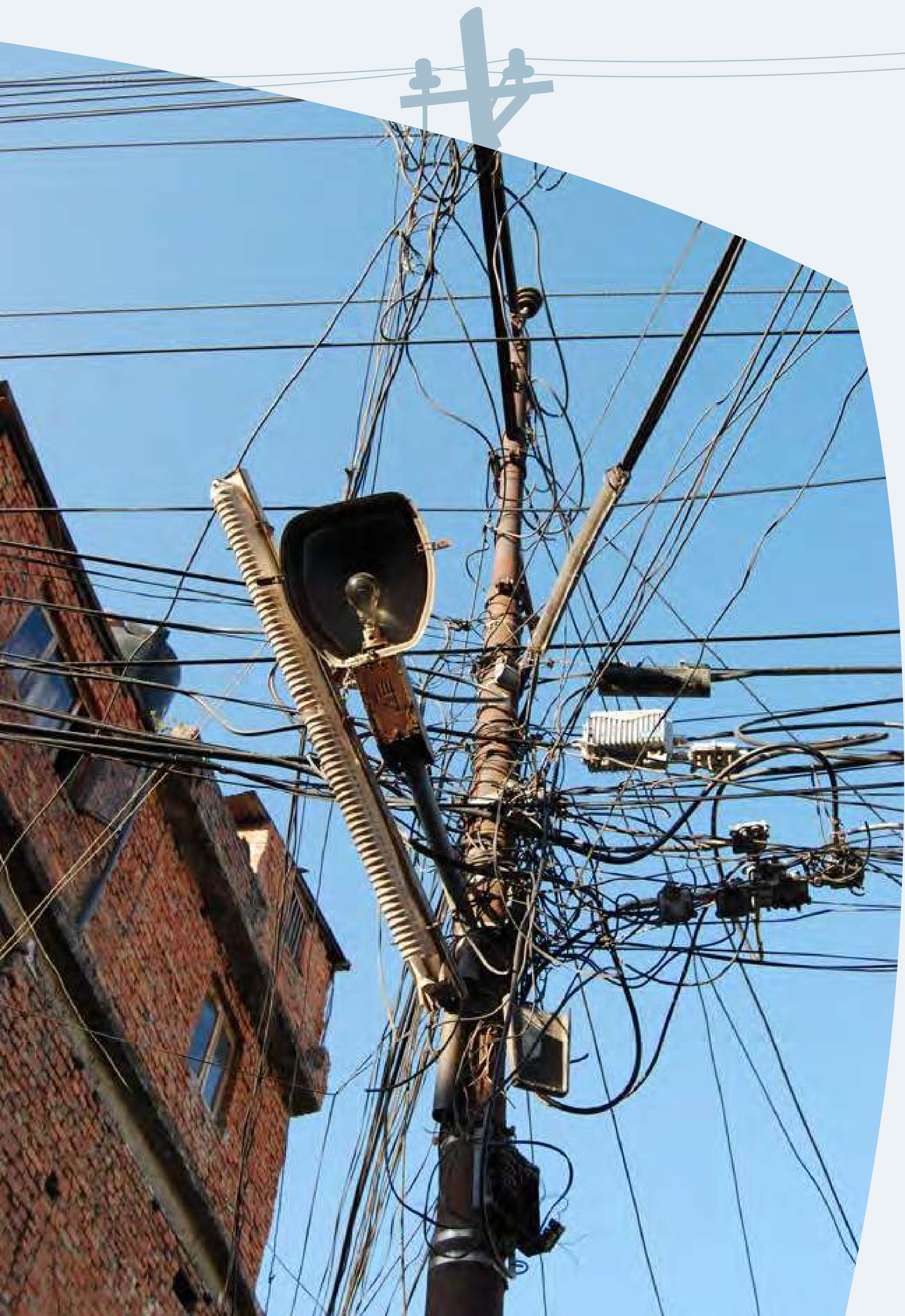
For example:
In Thailand, a global temperature rise of 1.7 to 3.4 degrees Celsius could induce an increase in peak electricity demand by 6.6 to 15.3% by 2080. As temperatures increase, peak electricity demand on days of extreme heat waves will increase requiring significant extra power capacity[26].

Table 3 The main impacts of climate change on energy consumption by climate stressor

Climate stressor	Warming trend	Precipitation	Cyclone	Sea level
End-User	Higher temperatures may increase energy demand for cooling, and reduce energy demand for heating.	Variable precipitation may increase power outages and cause disruptions. Floods and droughts may require additional emergency energy capacity.	Extreme weather events may damage end-user infrastructure and cause power outages.	Sea-level rise may increase the need for energy for desalinisation plants (as fresh water sources are threatened) and for water efficient irrigation techniques (as crops are threatened).

Energy transmission network in Nepal.

26) ADB, 2010



Energy generation will be particularly vulnerable to temperature increases and precipitation fluctuations. Transmission and distribution networks will suffer from extreme storms and tropical cyclones. Energy consumption will be highly sensitive to heat waves for cooling energy demand.

The energy sector therefore will be increasingly affected by climate change impacts. Moreover, the climate-vulnerability of the developing countries adds to the severity and urgency of these consequences. As mitigation is currently a priority for climate action in the energy sector, the following section will detail the key areas of action for a more resilient energy system.

3. Key areas of action in order to build a resilient energy sector

What adaptation measures exist in order to adapt the energy sector to climate change?

Climate proofing refers to the "consideration and internalisation of the risks and opportunities that climate change scenarios are likely to imply for the design, operation, and maintenance of infrastructure"[27].

Climate proofing also includes prevention of maladaptation, which is "adaptation that does not succeed in reducing vulnerability but increases it instead"[28]. For example, simply providing a community with access to energy can lead to over-extraction of natural resources. Often water is the targeted resource, as solar or diesel pumps make water extraction much easier in comparison to manual labour. In general, energy generation also requires immense quantities of water, making the challenge of balancing water availability with energy demand and supply an issue with increasing urgency and importance. Whilst energy will predominantly contribute positively to climate change adaptation, awareness of maladaptation must exist during energy project planning and implementation. Projects must be implemented using a holistic approach considering all the natural, human, social and financial resources specific to the socio-ecological system where the project is based.

◄ *The indigenous people of Mongolia benefit from solar power.*

As there will always be uncertainties concerning the nature and intensity of future climate change as well as the vulnerability of systems, climate adaptation will remain an ongoing process.

There are many types of adaptation measures for the energy sector. First, adaptation measures can be proactive, and reduce exposure to future risks, such as by planning the location of future power systems in less exposed areas. Second, adaptation measures can be reactive, and reduce the impacts on already installed systems, such as by fortifying a dam on an installed hydropower plant.

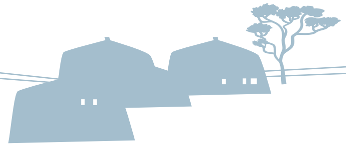
Below are certain general adaptation solutions that protect market segments of the energy sector:

- **In order to address climate change uncertainty, a critical adaptation measure is to ensure enough adaptive capacity**[29]. Adaptive capacity refers to the "ability or potential of a system to respond successfully to climate variability and change". This can be facilitated through the control and access to social, human, natural and financial resources. For example, in developing countries women are often more vulnerable to climate change as they lack access to information; and where there is little access to financing for infrastructure, buildings and transport systems are vulnerable to climate events.

27) UNDP, 2011

28) IPCC, 2007

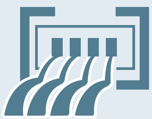
29) Adger et al., 2006



- **Access to energy in particular in rural areas in developing countries reduces climate vulnerability.** Populations without access to energy are more vulnerable to extreme weather events, as without water pumps rainfall variations can have severe consequences on water availability for a community. Access to energy can also increase livelihood diversification. As rural families diversify their portfolio of activities and social capabilities, they can improve their standard of living. However, as extending an electricity network to rural regions is often costly, an effective means to increase energy access in rural areas is through off-grid renewable energy systems. With this renewable and decentralised approach, populations are less vulnerable to climate variations.

- **Energy diversification eliminates reliance on one single generation source to enhance security of supply.** By diversifying the energy sector, energy supply is less vulnerable to climate variability and change, in particular to fluctuations in water availability.

For example:



East Africa is particularly vulnerable to climate change as 80% of the electricity production is derived from hydropower sources, yet precipitation fluctuations in this area will create a risk[30]. Energy diversification could reduce a large part of East Africa's energy sector vulnerability.

- **Energy efficiency, water efficiency and demand—side management can also alleviate supply constraints.** Developing countries suffer not only from vulnerable infrastructure and poorly maintained power generation sources, but also from inefficient usage of electricity. Moreover, projected higher temperatures lower generation efficiency and increase energy demand during the warmer seasons. These effects can be compensated for by designing more efficient energy infrastructure. Especially in the building sector, there is vast potential for efficient resource use. This potential is particularly important for urban areas, as cities are major consumers of energy.

- **Reducing and shifting energy demand away from peak hours and thus smoothing the demand curve for energy over the day and the year, will lower overall required energy capacity.** By smoothing peak energy demand, the risk of power outages and load shedding will be reduced resulting in increased security of energy supply and a more resilient energy system. Technologies such as energy storage (e.g. batteries), smart grids for the electricity network as well as other flexibility and demand-side management measures can enable this energy load shifting.

Installation of a tool to measure wind power in northern Chile.

30) Karekezi et al., 2005

- **Distributed as opposed to centralised energy systems can increase resilience.** In general, centralised energy systems that are interconnected with many different energy producers and consumers are more vulnerable to climate change, as one disruption at one point of the system can affect the entire network. Decentralised systems, with shorter transmission and distribution lines are not dependent on each other and therefore can reduce climate-related risks that occur in one specific area.

The following *Table 4* lists further key adaptation measures by energy source and climate stressor that will be needed in order to build resilient energy systems.

A person using a water pump in Bolivia.

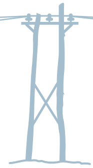
Table 4 The main impacts of climate change on energy transmission and distribution by climate stressor

Climate stressor	Warming trend	Precipitation	Cyclone	Sea level
Hydro power	Glacier melt may increase the water capacity requirements of a hydro plant, thus inducing the requirement for enlarged and strengthened dams and hydropower station fortification.	Precipitation increases may increase mountain erosion and the quantity of silt and grit in the water being transported to the hydro plants. This effect would require improved de-siltation[31] gates and improved hydrological forecasting. Floods may require enlarged hydro flood gates and increased dam height. Based on flow regime (e.g. in case of precipitation decrease), relocation of upstream river tributaries or dams can be considered.	Increased storm and cyclone intensity and/or frequency may require resilient hydropower infrastructure.	*No significant adaptation measure*

31) De-siltation gates are used to remove grit and silt from water, which, if left in the hydropower water stream, damages the turbines. Erosion and increased precipitation are the main causes for increased siltation.

Wind power	*No significant adaptation measure*	Flood risks may require plant relocation.	Increased storms and cyclones may require turbine designs to withstand high wind speeds. Increased wind speeds will be maximal at higher altitudes and in order to capture the strongest winds higher towers could be used. Variation in wind speed may require the consideration of vertical axis turbines as the latter are less sensitive to rapid changes in wind direction.	Sea-level rise may require plant relocation.
Biomass	Higher temperatures may require crop species that can tolerate these high temperatures.	Precipitation uncertainties may require enhanced irrigation systems. Increased precipitation may require crop selections for biomass that can tolerate higher water stresses. Floods may require building of dykes and drainage.	Storms may require early warning systems for emergency harvesting.	Sea-level and risk of salinisation may require building of dykes and drainage systems.

Harvesters gather firewood in Uganda.



Solar power	Increased temperatures may require increased airflow beneath mounting structure to cool.	Decreased precipitation risks for CSP plants may require air cooling systems instead of water cooling systems. Water re-use can also be considered.	Increased storms and cyclones may require panels designed to withstand strong winds.	Sea-level rise may require plant relocation.
Thermal power	Increased temperatures may require more efficient cooling systems (wastewater usage, water reuse, water recovery from heat exchangers, reduction of evaporative losses) and decentralised generation.	Droughts and floods may require improvements in robustness of plant stations. Flood risks may require relocation of storage reservoirs. Decreased precipitation may require air cooling systems instead of water cooling systems. Water re-use can also be considered.	Storm risks may require improvements in robustness of plant stations. Extreme events may require additional storage capacity. Extreme events may require emergency planning procedures. Increased storms may require wind proof standards.	Sea-level rise may require plant relocation, flood control systems (embankments, dykes, ponds, barriers).

Long lines form at a water pump in Nepal.

Transmission and distribution	Increased temperatures may require additional powerline protection. Underground transport and transfer structures could be used. Cooling for substations and transformers & ICT components that are resistant to high temperatures could be considered.	*No significant adaptation measure*	Extreme events may require enhanced powerline robustness. Extreme events may require emergency planning procedures and regular infrastructure assessments and monitoring. Extreme events may require concrete-sided buildings instead of metal (structure is more resistant to wind and corrosion).	Sea-level rise may require relocation and robustness increases to avoid salt-water corrosion.
End-User	Increased temperatures may require energy efficient appliances/fuel substitutes for heating/cooling and transport.	Variable precipitation may require water efficient appliances.	Extreme storms may increase power outages and require investment in decentralised power at the household level for energy supply stability.	Sea-level rise may require relocation.

The adaptation measures presented in *Table 4* can only be utilised after a site-specific climate risk assessment has been made. Large infrastructure projects already require environmental impact assessments in order to reduce the actual impact on the ecosystem; this includes for example an analysis of a dam construction in a particular environment. However, climate risk assessments are not conducted systematically.

A climate risk assessment will evaluate the risks of climate variability on infrastructure, unlike the environmental impact assessment, which assesses the risk on the ecosystem. It is crucial that all infrastructure projects, especially those with long lifetimes, conduct both an environmental impact assessment and a climate risk assessment, or combine the two assessments in order to identify where extra fortification and adaptation needs lie in the present and future. More on the topic of climate risk assessments will be discussed in *Section 4*.

A region also has to take into account its current energy system and identify the sector upon which energy supply relies most. For example, in a region highly dependent on hydropower, local governments and private sector should initially focus on diversifying the energy mix and secondly on fortifying dams, creating dykes and diverting upstream river tributaries to prepare for water run-off fluctuations. Adaptation measures cannot be generalised, as specific geographic and socio-economic conditions require a differentiated local approach.

For example:
In order to protect the Dong Nai River Basin hydropower plants in Ho Chi Minh City, technological adaptation mechanisms include

- diversion of upstream river tributaries;
- placement of new storage reservoirs; and
- replacement of old turbines with adapted new turbine designs.

Non-technological adaptation will also be necessary, meaning adapting the operations of the facilities through

- enhanced hydrological forecasting; and
- retrofitting high-risk infrastructure against extreme weather events. Transmission and distribution lines for example are set to be relocated to avoid strong winds, flooding and corrosion.

Finally, decentralised energy solutions improve energy security and stability. Renewable energy is the key to creating this decentralisation, with both mitigation and adaptation benefits[32].

32) ADB, 2010

Checking the turbine of a hydropower plant in Nepal.

Adaptation to a global average increase of 2 °C would amount to almost 70% of ODA.

What is the financial implication of implementing adaptation strategies?

It is estimated that adaptation to a global average temperature increase of 2.0 degrees Celsius could cost between $70 billion to $100 billion a year[33]. This price tag is equivalent to almost 70% of total Official Development Assistance (ODA) disbursement in 2015[34]. Infrastructure-upgrading, as well as new infrastructure is set to incur the majority of adaptation costs. Geographically, the adaptation costs will be unequally distributed. Sub-Saharan Africa will incur the greatest costs of up to $20 to $30 billion a year until mid-century[35]. Resilience building in coastal zones will be the most expensive component of adaptation, as they are exposed not only to extreme weather events, but also to slow-onset changes such as erosion, salt water intrusion and sea-level rise. For the energy sector alone, studies show that even the European Union's adaptation costs could be between €636 and €654 million a year by 2025[36].

33) World Bank, 2010

34) World Bank, 2017

35) AfDB, 2011

36) Altvater et al., 2012

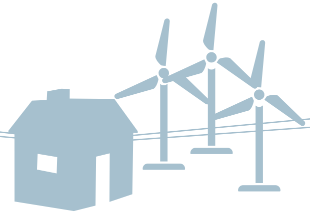
Unfortunately, there is currently not enough investment in adaptation to address this challenge. In 2015, adaptation investment amounted to $8 to $10 billion; not even 10% of the required amount. The main contributors to these funds in 2015 were from the World Bank's Climate Investment Funds (CIF) and the Global Environmental Facility's Least Developed Countries Fund (LDCF)[37].

As well as too little investment in adaptation, there is an investment imbalance between mitigation and adaptation. The 2015 Climate Funds Update report from the ODI indicates that only 24% of approved climate financing since 2003 went to support adaptation, the remainder going to mitigation[38].

Currently, finances to adapt the energy system are sourced mostly from climate adaptation funds and not from energy sector funds, which instead are focussing on mitigation. At the German Federal Ministry for Economic Cooperation and Development (BMZ), an analysis of climate change adaptation funds over the year of 2016 illustrates how little attention is paid to the energy sector for adaptation measures. In the *Figure 6*, in 2016 only 2% of all BMZ climate change adaptation funds were attributed to the energy sector.

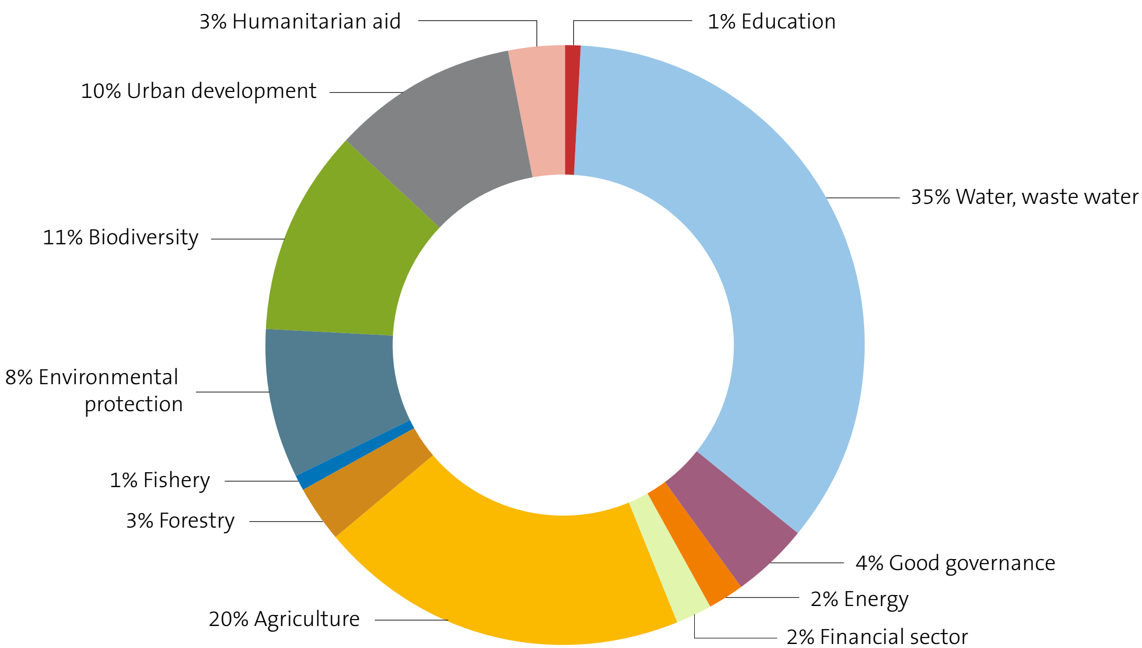
37) ODI, 2014a

38) ODI, 2014a



◀ *Discussing adaptation strategies.*

Figure 6 Bilateral BMZ climate funds for climate change adaptation by sector (in %); 2016[39]



Although adaptation is costly, many low-cost solutions exist; such as introducing early warning systems and "no-regret" adaptation solutions, such as power source diversification that have many co-benefits (e.g. security of energy supply and greenhouse gas emission reductions).

In summary, in the energy sector, climate adaptation funds are insufficient and unbalanced even though climate change impacts are already and will have costly consequences in the future.

39) GIZ, 2017a


Post P.S.K.
PUTTING AN END TO NUCLEAR TEST EXPLOSIONS
FOR A HEALTHY EARTH
FOR A SECURE WORLD
FOR A SAFER PLANET
CTBTO
WWW.CTBTO.ORG
YOUR RESOURCE ON STOPPING NUCLEAR TESTING

4. Stakeholders' responsibilities for energy sector adaptation

How can stakeholders contribute to climate change adaptation in the energy sector?

Efficient implementation of adaptation measures requires the mobilisation of all stakeholders. The donor community can implement local or regional projects as well as providing financial support to existing funds. The public sector can contribute to adaptation by creating an enabling policy framework and by supporting research and development in academic institutions. Energy regulators also have an important role to play in order to ensure long-term investment security. Energy utilities and industries should ask themselves the following questions:

i) How vulnerable are we to climate change?

ii) What climate resilience building options exist?

iii) How can we anticipate future vulnerabilities to better target investment?

The *Table 5* describes how certain stakeholders can contribute to climate change adaptation in the energy sector.

Table 5 Categories of climate change adaptation interventions in the energy sector by stakeholder

Stakeholders	Academia	Regulator	Government	Industry	Donors[40]
1. Climate change impacts awareness raising	x		x		x
2. Climate change risk assessments	x	x	x	x	x
3. Diversify & increase energy supply/storage capacity/access	x		x	x	x
4. Site location planning		x		x	
5. Early warning and disaster recovery management systems		x	x	x	x
6. Fortify infrastructure		x		x	x
7. Energy/water efficiency	x		x	x	x
8. Energy security standards		x	x	x	x
9. Monitoring and evaluation	x	x	x		x

40) Donors include both technical assistance as well as finance assistance for energy-adaptation projects.

◀ *Discussing adaptation strategies.*

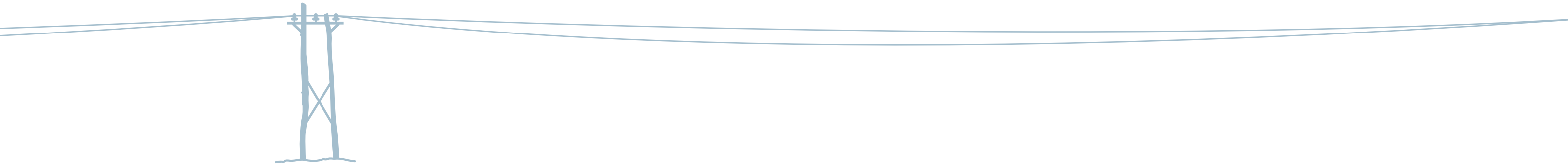
As shown in the industry column in *Table 5*, energy utilities and industries have a very important role to play in adaptation. In the long-term, utilities and companies have a self-interest to protect their assets from climate change impacts.

For example:

In South Africa, Eskom Holdings is a power sector utility with a generation portfolio of 85% coal fired plants. The utility adopted a Climate Change Policy in 2004. In 2007, the company set one of the priorities of its Six Point Plan to climate change adaptation. Part of the adaptation strategy includes assessing climate variables and their impacts on company assets, as well as defining plans to adapt to these impacts. Concretely, the company invested heavily in dry-cooling technologies to replace water cooling technologies as droughts have been identified as a severe risk to Eskom's thermal plants[41].

Man assessing forest degradation.

41) Braun et al., 2016



How can the donor community contribute to adapting the energy sector?

The technical donor community is prepared to address many of the aforementioned adaptation actions. The Gesellschaft für Internationale Zusammenarbeit (GIZ) has begun addressing this issue directly by integrating an adaptation approach into a renewable energy development project (see *box below*).

In most cases, however, energy adaptation benefits are only unintended co-benefits of energy mitigation programmes or general climate resilience projects. Positive adaptation effects in the energy sector could be increased by specifically considering adaptation in the project or programme design.

Table 6 highlights examples of climate and energy projects from GIZ, the EUEI PDF, the UNFCCC and the World Bank that include adaptation benefits.

For example:
An exceptional illustration of how the energy sector is contributing directly to climate change resilience is the "Advancing Climate Risk Insurance for Renewable Energy in Barbados" project, funded by the Advancing Climate Risk Insurance Plus (ACRI+) programme hosted by GIZ.

This particular project aims to develop a roadmap, which adopts the Integrated Climate Risk Management (ICRM) approach, to ensure that existing and future energy generation, transmission and distribution infrastructure is climate and disaster resilient. Examples of specific measures that will be undertaken in order to achieve this include:

- understanding of climate projections;
- integration of risk transfer mechanisms, through insurance for infrastructure damage;
- access to finance for post-disaster management;
- improved location planning based on risk mapping;
- resilient building design standards; and
- early warning systems for energy suppliers.

◀ *Solar power in Kaolack, Senegal.*

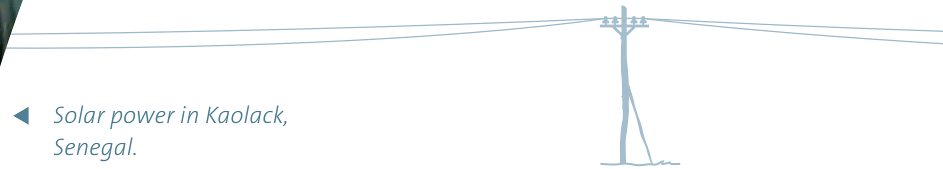


Table 6 Climate and energy development funding projects with climate change adaptation benefits

Examples of CLIMATE projects with energy sector adaptation	Examples of ENERGY projects with energy sector adaptation
Energy/Water efficiency: GIZ, with the Caribbean Community and Common Market (CARICOM) supports eight small islands and coastal states in the Caribbean in climate change adaptation efforts to conserve natural resources, such as water and forests[42]. **Disaster recovery management systems:** GIZ supports the Western Balkans in climate change adaptation, focusing especially on flooding and drought risk management in the Drin River Basin. The Basin provides resources for electricity generation, irrigation, fishing and recreational activities[43]. **Disaster recovery management systems:** In Nepal, adaptation projects received funding from the UNFCCC Least Developed Country Fund (LDCF) of $6.37 million to conduct vulnerability assessments and provide early warning systems. Thanks to this project, 35 Community Disaster Management Committees and eight Village Disaster Risk Management Committees were formed in Terai[44].	**Energy Efficiency:** The EUEI PDF provided support to the Energy Ministries of Cameroon and Cambodia in the development of National Energy Efficiency Policies, strategies and Action Plans.[45] Developing countries suffer from inefficient usage of electricity; this consumption challenge can be compensated by designing more efficient energy infrastructure. **Diversify and increase energy supply/access:** In West Africa, the EUEI PDF provided the policy and regulatory framework support for clean energy mini-grids[46]. By increasing energy access, vulnerable rural communities are made more resilient with regards to climate hazards. For example, aid from cities and disaster management systems can be put in place and executed quickly. **Diversify and increase energy supply/access:** The World Bank's Scaling Up Renewable Energy in Low Income Countries Program (SREP) has committed $11.78 million to achieve electricity access for 30,500 households in Nepal[47], with adaptation benefits. **Energy security standards:** The EUEI PDF provided support to Member Countries of the Secretariat of the Pacific Commission in developing energy security indicators[48]. Energy infrastructure must be designed to resist fluctuating temperatures as well as extreme climate events such as floods and storms.

42) GIZ, 2017b
43) GIZ, 2017c
44) ODI, 2014b
45) EUEI PDF, 2017a
46) EUEI PDF, 2017b
47) ODI, 2014
48) EUEI PDF, 2017c

Scouting project land in Benin.

Workers preparing a construction site in Mongolia.

Currently, many of the aforementioned adaptation categories lack technical and financial support, especially for projects in developing countries. This section will describe in detail two specific adaptation categories that are crucial to properly address energy sector adaptation: "Climate change risk assessments" and "Monitoring and evaluation".

Climate change risk assessments

Indeed, the lack of climate risk assessments is a barrier to resilience building. As the development of energy access and infrastructure in developing countries can be urgent, climate risk assessments are not made systematically. This assessment practice however can help energy projects remain sustainable in the long-term. Climate risk assessments and vulnerability assessments belong to preventive actions, to reduce the risk of climate change. The assessment should be made preferably prior to the commencement of the energy project and carefully consider long-term climate risks.

Examples of methodologies for climate risk assessments by developed countries include the European Union's Climate Change Vulnerability and Risk Assessment. For more details on the methodology, refer to Annex 1. The Vulnerability Sourcebook developed by GIZ can also be used as a tool to evaluate the risk of a project to climate change[49].

Climate change adaptation monitoring and evaluation

An additional barrier to adaptation development is monitoring and evaluation of adaptation projects after their implementation. The latter is essential in order to attract funds, as without impact assessments funding agencies cannot legitimise spending. Also, best practices remain unidentified if there are no means of recording the success rate of adaptation projects. There is a lack of standardised monitoring and evaluation tools. According to the ODI, "In contrast to monitoring and reporting against mitigation targets, adaptation and resilience building activities have been more difficult to distinguish from activities that contribute to 'good' development. This can make it more difficult to measure and report on the impact of adaptation finance[50]".

GIZ has compiled a set of example indicators from various international examples relating to adaptation by sector. In *Table 7*[51], these example indicators are presented in the dark grey boxes. In light of knowledge regarding co-benefits, additional indicators can be added to this list, which take into account the increased resilience from renewable energy generation; for example. These potential additional indicators have been added to the table in light grey.

49) GIZ, 2017d

50) ODI, 2014

51) GIZ/IISD, 2014

Table 7 Climate change adaptation example indicators in the energy sector and additional potential indicators

	Indicator type	Indicators
Pre-adaptation project implementation	**Climate parameters**	▶ **Change in annual temperature** ▶ **Mean monthly temperature** ▶ **Number of hot days** ▶ **Change in annual precipitation**
	Climate change readiness	▶ Number of climate change hazard communication dissemination outlets ▶ Number of climate change vulnerability assessments at national and local levels ▶ Percentage of government investment in adaptation targeted programmes ▶ Percentage of policies using results from climate change vulnerability assessments ▶ Number of natural disaster early warning systems
	Climate impacts	▶ **Weather-related disruption of electricity supply** ▶ **Losses of GDP in percentage per year due to extreme rainfall**
Adaptation action and long-term impacts	**Adaptation action**	▶ **Percentage of new hydroelectric projects that consider future climate risks** ▶ **Number of water efficiency measures used in energy generation/extraction** ▶ **Percentage increase of energy storage capacity** ▶ **Number of new major infrastructure projects located in areas at risk**
	Adaptation action	▶ Percentage increase in additional energy capacity and access to energy ▶ Percentage increase in retrofitted energy capacity by level of vulnerability to climate change ▶ Percentage increase in renewable energy generation capacity ▶ Level of diversification of energy supply **Examples by technology:** ▶ Thermal energy: Siting map accounting for projected flood and drought prone areas ▶ Hydro power: Number of dams equipped with desilting gates; mapping of hydro plants that require capacity expansion due to changes in river flow regime ▶ Biomass: Irrigation planning accounting for projected floods and droughts; budget for research into heat resistance crops; domestic regulation for storm proof biomass power plants ▶ Wind: Siting map taking into account projected wind speed changes and sea-level rise
	Long-term adaptation impact	▶ Percentage decrease in monetary damages to energy facilities due to climate change impacts ▶ Percentage decrease in energy users losing access to energy due to climate change induced power outages

Recommendations

The donor community has the ability to contribute to overcoming barriers to adaptation and thus enhance their current portfolios. It is necessary that the donor community engage in projects that fully account for climate change impacts in order to manage climate risks.

Recommendations for the donor community to increase effectiveness of climate change adaptation in the energy sector include the following:

- The donor community should enhance communication and offer a reliable information source on the benefits of adaptation in the energy sector and the benefits of a resilient energy system for climate adaptation. Proper understanding and dissemination of information concerning adaptation in the energy sector is necessary to tackling climate change. Academia and national government actors are also importance stakeholders to facilitating information communication.

- Through dialogue services, the donor community can contribute to coordination between stakeholders relevant for climate change adaptation. Especially at the policy level, cross-ministerial and cross-sectoral coordination is essential. Energy planning departments, the agricultural, water and other natural resource sectors need to cooperate. This will also increase project implementation efficiency.

- Recognising that projects in the energy sector often have a cross-cutting win-win focus to both mitigate climate change and adapt to its impacts is necessary. By recognising the mitigation-adaptation synergies for the energy sector, funds will be able to be more appropriately allocated and more sustainable and efficient measures will be put in place.

- In order to prevent, respond to and prepare for climate risks the donor community should introduce climate proofing measures into sustainable energy projects. Developing projects with a climate risk-based approach, such as the project in Barbados cited in *Section 1*, the donor community can enable and ensure that energy will be accessed, produced and used sustainably. This climate risk management approach can play an important role in ensuring climate resilient development of energy systems.

- Incorporating climate vulnerability assessments and standards before implementation of infrastructure projects can also successfully reduce costs of climate change. The *Annex 1* provides an example of a climate change risk assessment methodology.

- Developing indicators in order to track adaptation benefits before and after project implementation will allow for correct monitoring and evaluation of adaptation. Using a base-line, adaptation indicators will contribute to identifying best practices. Reference to the previous section provides examples of indicators that the donor community can track and follow for its projects.

Conclusion

In conclusion, all components of the energy system are increasingly affected by climate change. As the energy sector is the backbone of the economy, adaptation to climate change is a necessity. Only a resilient energy sector will be able to provide sustainable patterns of growth for developing countries threatened by climate change. Precipitation fluctuations affect hydropower output, extreme events disrupt electricity transmission and warming temperatures increase end-user energy demand. All market segments of the energy sector are vulnerable.

To combat these impacts, adaptation solutions exist both structural or policy-driven, for each energy stakeholder and market segment. Fortifying existing infrastructure ensures resilience. Diversifying the energy sector increases energy security. Finally, energy efficiency can provide energy sector flexibility.

The cost of adaptation however is not to be overlooked, as it is estimated that $70 to $100 billion a year will be required until mid-century to build societal resilience. At present, only 10% is available. Energy sector stakeholders must focus dually on mitigation and adaptation efforts in order to sustainably combat climate change. Cross-cutting projects with both mitigation and adaptation benefits would lead to the most efficient and effective measures.

In order to effectively combat the impacts of climate change, the donor community has the capacity to overcome structural barriers to increase resilience. In the energy sector, energy adaptation projects lack consistent strategies and best practices. Ex ante climate change readiness including climate risk assessments, as well as post-implementation monitoring and evaluation of adaptation projects are necessary to ensure resilience.

The energy sector and climate change adaptation are unequivocally interlinked. With increased funds and targeted action for an adapted energy sector, we can fill the resilience gap and spur sustainable development.

Glaciers of Ammassalik, Greenland. ▶

Annex

Annex: Extract from the European Union's Climate Change Vulnerability and Risk Assessment example

A climate risk assessment methodology outlines "the process of managing climate adaptation issues for a project in order to improve the project's resilience to climate change. It involves identifying which climate hazards the project is vulnerable to, assessing the level of risk, and considering adaptation measures to reduce that risk to an acceptable level."[52]

For the following methodology, the IPCC 2-degree scenario out to the year 2100 has been used. By combining a sensitivity analysis and exposure analysis, the vulnerability of a project is assessed. Once risk levels have been attributed to impacts, adaptation options can be informatively applied to account for potential climate change damages. Below is an example of how part of the assessment matrix can be used to classify local risks to climate phenomena[53].

52, 53) European Commission, 2016

Villagers pushing a car out of a flooded area.

Table 8 Example of a methodology for the vulnerability and risk assessment of major projects

This table illustrates the vulnerability and risk assessment method presented in the Guidance for project managers on making Infrastructure climate resilient[5]. It is one among several methods. Proper planning often includes an expert analysis and choice of the appropriate methodology.

SENSITIVITY ANALYSIS

Sensitivity table: *(example)*		Climate variables and hazards: Flood	Heat	…	Drought
Themes	On-site assets, …	High	Low	…	Low
	Inputs (water, …)	Medium	High	…	Medium
	Outputs (produts, …)	High	Medium	…	Low
	Transport links	Medium	Low	…	Low
	Highest score 4 themes	High	High	…	Medium

The output of the sensitivity analysis may be summarised in a table with the sensitivity ranking of the relevant climate variables and hazards for a given project type, irrespective of the location, including critical parameters, and divided in e.g. the four themes.

EXPOSURE ANALYSIS

Exposure table: *(example)*	Climate variables and hazards: Flood	Heat	…	Drought
Current climate	Medium	Low	…	Low
Future climate	High	Low	…	Medium
Highest score, current + future	High	Low	…	Medium

The output of the exposure analysis may be summarised in a table with the exposure ranking of the relevant climate variables and hazards for the selected location, irrespective of the project type, and divided in current and future climate. For both the sensitivity and exposure analysis, the scoring system should be carefully defined and explained, and the given scores should be justified.

VULNERABILITY ANALYSIS

Vulnerability table: *(example)*		Exposure (current + future climate): Low	Medium	High
Sensitivity	Low			
(highest,	Medium		Drought	
4 themes)	High	Heat		Flood

Legend:

Vulnerability level
Low
Medium
High

The vulnerability analysis may be summarised in a table for the given specific project type at the selected location. It combines the sensitivity and the exposure analysis. The most relevant climate variables and hazards are those with a high or medium vulnerability level, which are then taken forward to the risk assessment. The vulnerability levels should be carefully defined and explained, and the given scores justified.

LIKELIHOOD ANALYSIS

Scale for assessing the likelihood of a climate hazard (example):

Term	Qualitative	Quantitative (*)
Rare	Highly unlikely to occur	5%
Unlikely	Unlikely to occur	20%
Moderate	As likely to occur as not	50%
Likely	Likely to occur	80%
Almost certain	Very likely to occur	95%

The output of the likelihood analysis may be summarised in a qualitative or quantitative estimation of the likelihood for each of the essential climate variables and hazards.
(*) Defining the scales requires careful analysis for various reasons including e.g. that the likelihood and impacts of the essential climate hazards may change significantly during the lifespan of the major project (due e.g. to global warming and climate change). Various scales are referred to in the literature

IMPACT ANALYSIS

Scale for assessing the potential impact of a climate hazard (example):

Risk areas: / Impacts:	Insignificant	Minor	Moderate	Major	Catastrophic
Asset damage, engineering, operational					
Safety and health					
Environment					
Social					
Financial					
Reputation					
Overall for the above-listed risk areas					

The impact analysis provides an expert assessment of the potential impact for each of the essential climate variables and hazards.

RISK ASSESSMENT

Risk table: Overall impact of the essential climate variables and hazards (example)

Likelihood	Insignificant	Minor	Moderate	Major	Catastrophic
Rare				Flood	
Unlikely			Drought		
Moderate			Heat		
Likely					
Almost certain					

Legend:

Risk level
Low
Medium
High
Extreme

The output of the risk analysis may be summarised in a table combining likelihood and impact of the essential climate variables and hazards. Detailed explanations are required to qualify and substantiate the assessment conclusions. The risk levels should be explained and justified.

IDENTIFYING ADAPTATION OPTIONS

Option identification process:
- Identify options responding to the risks (expert workshops, meeting, evaluation, ...)

Adaptation may involve a mix of responses:
- training, capacity building, monitoring, ...
- use of best practices, standards, ...
- engineering solutions, technical design, ...
- risk management, insurance, ...

APPRAISING ADAPTATION OPTIONS

The appraisal of adaptation options should give due regard to the specific circumstances and availability of data. In some cases a quick expert judgement may suffice whereas other cases may warrant a detailed cost-benefit analysis. It may be relevant to consider the robustness of various adaptation options vis-à-vis climate change uncertainties.

ADAPTATION PLANNING

Integrate relevant climate resilience measures into the technical project design and management options. Develop implementation plan, finance plan, plan for monitoring and response, and so on. The vulnerability and risk assessment and adaptation planning is aiming to reduce the remaining climate risks to an acceptable level.

References

Adger, W. N. 2006. "Vulnerability." Global Environmental Change 16 (3): 268–281.

African Development Bank (AfDB). 2011. The Cost of Adaptation to Climate Change in Africa.

Aivalioti, S. 2015. Electricity sector: adaptation to heat heaves. Columbia Law School.

Altvater, S. et al. 2012. Adaptation Measures in the EU: Policies, Costs, and Economic Assessment. Report for the European Commission.

Asian Development Bank (ADB). 2012. Climate risk and adaptation in the electric power sector. Mandaluyong City, Philippines.

Asian Development Bank (ADB). 2010. Ho Chi Minh City: Adapting to Climate Change. Summary report. Manila.

Braun, M. and Fournier, E. 2016. Adaptation Case Studies in the Energy Sector – Overcoming Barriers to Adaptation, Report presented to Climate Change Impacts and Adaptation Division, Natural Resources Canada, p. 114.

Centre for International Governance Innovation (CIGI). 2009. CIGI Special Report: Climate Change in Africa: Adaptation, mitigation and governance challenges, Waterloo, Canada.

Droogers, P. 2009. Climate Change and Hydropower, Impact and Adaptation Costs: Case Study Kenya, The Netherlands: Future Water.

World Bank (WB). 2011. Ebinger and Vergara, Climate Impacts on Energy Systems Key Issues for Energy Sector Adaptation, World Bank, Washington.

Energy Information Administration (EIA). 2016. International Energy Outlook 2016.

EUEI PDF. 2017a. Cameroon: National Energy Efficiency Policy, Strategy and Action Plan in the electricity sector (*http://www.euei-pdf.org/sites/default/files/field_publication_file/140605_euei_factfile_cameroon_rz_01_web.pdf*)

EUEI PDF. 2017b. Development of Energy Security Indicators and Support to the Regional Implementation Plan (I) (*www.euei-pdf.org/en/seads/capacity-building/development-of-energy-security-indicators-and-support-to-the-regional*)

EUEI PDF. 2017c. Improvement of the Policy and Regulatory Framework for Clean Energy Mini-grids (*www.euei-pdf.org/en/seads/policy-strategy-and-regulation/improvement-of-the-policy-and-regulatory-framework-for-clean*)

European Commission (EC). 2016. Climate Change and Major Projects, Brussels.

Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH. 2017a. Kommunikationsprodukt zur politischen Inwertsetzung des BMZ-Anpassungsportfolios. SV Klima/313Gliederungsvorschlag zur Darstellung des BMZ Anpassungsportfolios. Eschborn.

Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH. 2017b. Adapting to climate change in the Caribbean to conserve natural resources and diversify farming and forest management (*www.giz.de/en/worldwide/24160.html*)

Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH. 2017c. Climate change adaptation in the Western Balkans (*www.giz.de/en/worldwide/29000.html*)

Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH. 2017d. Vulnerability Sourcebook (*www.adaptationcommunity.net/vulnerability-assessment/vulnerability-sourcebook/*)

Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH/International Institution for Sustainable Development (IISD). 2014. Repository of Adaptation Indicators: Real case examples from national Monitoring and Evaluation Systems, Eschborn, Germany.

Hamududu and Killingtveit. 2010. Estimating effects of climate change on global hydropower production. Norwegian University of Science and Technology. Hydropower 10 — 6th International Conference on Hydropower; Hydropower supporting other renewable Tromsø, Norway, 1–3 February 2010.

International Energy Agency (IEA)/Organisation for Economic Cooperation and Development (OECD). 2015. World Energy Outlook: Special Report, Energy and Climate Change, Paris, France.

International Energy Agency (IEA)/Organisation for Economic Cooperation and Development (OECD). 2016. International Energy Outlook 2016 (IEO), Paris, France.

Intergovernmental Panel on Climate Change (IPCC). 2007. Mimura, N., L. Nurse, R.F. McLean, J. Agard, L. Briguglio, P. Lefale, R. Payet and G. Sem, 2007: Small islands. Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson, Eds., Cambridge University Press, Cambridge, UK, 687–716.

Intergovernmental Panel on Climate Change (IPCC). 2012. Cardona, O.D., M.K. van Aalst, J. Birkmann, M. Fordham, G. McGregor, R. Perez, R.S. Pulwarty, E.L.F. Schipper, and B.T. Sinh, 2012. Determinants of risk: exposure and vulnerability. In: Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation [Field, C.B., V. Barros, T.F. Stocker, D. Qin, D.J. Dokken, K.L. Ebi, M.D. Mastrandrea, K.J. Mach, G.-K. Plattner, S.K. Allen, M. Tignor, and P.M. Midgley (eds.)]. A Special Report of Working Groups I and II of the Intergovernmental Panel on Climate Change (IPCC). Cambridge University Press, Cambridge, UK, and New York, NY, USA, pp. 65–108.

Intergovernmental Panel on Climate Change (IPCC). 2014. Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, R.K. Pachauri and L.A. Meyer (eds.)]. IPCC, Geneva, Switzerland, pp. 151.

Karekezi, S. et al. 2005. The potential contribution of non-electrical renewable energy technologies to poverty reduction in East Africa. AFREPEN/FWD, Nairobi.

Linnerud, Kristin, Ruebbelke, Dirk, and Voegele, Stefan. 2010. Heat waves can close nuclear power plants. Klima (Oslo 2007), (2), 14.

Maplecroft. 2012. Climate Change Vulnerability Index 2011 (*https://maplecroft.com/about/news/ccvi.html*)

Neumann, J. and J. Price. 2009. Adapting to Climate Change: The Public Policy Response: Public Infrastructure. Resources for the Future Climate Policy Program. June.

Overseas Development Institute (ODI). 2014a. Climate Funds Update. Climate Finance Thematic Briefing: Adaptation Finance, London, December 2014.

ODI (Overseas Development Institute). 2014b. Climate finance: is it making a difference? A review of the effectiveness of Multilateral Climate Funds, London, England.

Winkelman, S. 2016. Green Resilience: Adaptation + Mitigation synergies. Centre for Clean Air Policy.

Solomon et al. 2009. 'Irreversible climate change due to carbon dioxide emissions', The National Academy of Sciences of the USA, vol. 106 no. 6.

United Nations Development Programme (UNDP). 2011. Paving the Way for Climate-Resilient Infrastructure: Guidance for Practitioners and Planners. New York, New York: United Nations Development Programme.

World Bank (WB). 2008. Eberhard, A., V. Foster, C. Briceno-Garmendia, F. Ouedraogo, D. Camos, and M. Shkaratan. Underpowered: The State of the Power Sector in Sub-Saharan Africa. Africa Infrastructure Country Diagnostic Background Paper. World Bank, Washington DC, May 2008.

World Bank (WB). 2009. World development report 2009: Reshaping economic geography, Washington, D.C.

World Bank (WB). 2010. Economics of Adaptation to Climate Change, Synthesis Report, Washington D.C.

World Bank (WB). 2015. World Development Indicators Database, Washington D.C.

World Bank (WB). 2017. Net official development assistance and official aid received (current US$) (*http://data.worldbank.org/indicator/DT.ODA.ALLD.CD?end=2010&start=2010&view=bar*)

World Economic Forum (WEF)/ HIS CERA. 2012. Energy for Economic Growth, Energy Vision Update 2012.

▲
Man and child observing the Mekong river.

For more information,
please contact:

EU Energy Initiative
Partnership Dialogue Facility (EUEI PDF)

c/o Deutsche Gesellschaft für
Internationale Zusammenarbeit (GIZ) GmbH
P.O. Box 5180
65726 Eschborn, Germany

E info@euei-pdf.org
I www.euei-pdf.org

EUEI PDF is an instrument of the