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Making the energy sector more resilient to climate change

INTERNATIONAL ENERGY AGENCY

The International Energy Agency (IEA), an autonomous agency, was established in November 1974. Its primary mandate was – and is – two-fold: to promote energy security amongst its member countries through collective response to physical disruptions in oil supply, and provide authoritative research and analysis on ways to ensure reliable, affordable and clean energy for its 29 member countries and beyond. The IEA carries out a comprehensive programme of energy co-operation among its member countries, each of which is obliged to hold oil stocks equivalent to 90 days of its net imports. The Agency's aims include the following objectives:

- Secure member countries' access to reliable and ample supplies of all forms of energy; in particular, through maintaining effective emergency response capabilities in case of oil supply disruptions.
- Promote sustainable energy policies that spur economic growth and environmental protection in a global context – particularly in terms of reducing greenhouse-gas emissions that contribute to climate change.
- Improve transparency of international markets through collection and analysis of energy data.
- Support global collaboration on energy technology to secure future energy supplies and mitigate their environmental impact, including through improved energy efficiency and development and deployment of low-carbon technologies.
- Find solutions to global energy challenges through engagement and dialogue with non-member countries, industry, international organisations and other stakeholders.

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The European Commission also participates in the work of the IEA.

Introduction

The energy sector faces multiple threats from climate change, in particular from extreme weather events and increasing stress on water resources. Greater resilience to climate change impacts will be essential to the technical viability of the energy sector and its ability to cost-effectively meet the rising energy demands driven by global economic and population growth.

Energy sector stakeholders, including governments, regulators, utilities/energy companies and financial institutions (banks, insurers, investors), will need to:

- define climate change resilience and adaptation challenges (Sections 1 and 2).
- identify actions needed to address these challenges (Sections 3 and 4).

Key Messages

- ***The energy sector must identify and evaluate how climate change impacts can disrupt supply, alter demand patterns and damage infrastructure.***
- ***Electricity and fuel supply systems must become more resilient to extreme weather and increasing stress on water resources.***
- ***Businesses are the key actors in designing and implementing resilience-building measures and adaptive practices.***
- ***Governments should encourage resilience-building actions, and also have a role to play in implementation, both in emergency response support and in managing their own energy assets.***
- ***The International Energy Agency (IEA) is working with governments and businesses to help them address the challenge of resilience in the face of climate change.***

What is resilience?

Resilience of the energy sector refers to the capacity of the energy system or its components to cope with a hazardous event or trend, responding in ways that maintain their essential function, identity and structure while also maintaining the capacity for adaptation, learning and transformation.

Because **climate change** can create conditions that will negatively impact the energy sector, resilience becomes increasingly important.

The resilience "value chain" integrates robustness, resourcefulness and recovery.

- *Robustness*: the ability of an energy system to withstand extreme weather events as well as gradual changes (e.g. sea level rise) and continue operating.
- *Resourcefulness*: the ability to effectively manage operations during extreme weather events.
- *Recovery*: the ability to restore operations to desired performance levels following a disruption.

Adaptation of an energy system to climate change refers to the process of adjustment of all components of the energy system to actual or expected climate and its effects.

Source: Adapted from the IPCC Fifth Assessment Report (AR5) and NARUC.

1. Should the energy sector be worried about climate change impacts?

The energy sector must identify and evaluate how climate change impacts can disrupt supply, alter demand patterns and damage infrastructure.

Hurricane Sandy hit New York City and the surrounding East Coast in 2012, causing power outages for eight million residents. The same year, a delayed monsoon and heat waves in India caused major blackouts (affecting almost half the country's population) due to surged electricity demand and reduced hydropower output. These events are a forewarning of the kind of impacts that can be expected from a changing climate. To deal with these challenges the energy sector must be more resilient and make efforts to adapt to climate change.[1]

> ***Hurricane Sandy caused USD 30 to USD 50 billion in losses from power outages, liquid fuel shortages and the shutdown of the region's transportation system.***
>
> Source: Hurricane Sandy Rebuilding Task Force, US Government

Risks to the energy sector from climate-change impacts

Changes in climate and weather extremes will affect all regions of the globe, albeit unevenly, according to Intergovernmental Panel on Climate Change (IPCC) projections. Climate change affects the energy sector in various ways:

- **Extreme weather events** such as storms, forest fires, landslides, floods and extreme temperatures affect energy production and delivery facilities, cause supply disruptions and affect infrastructure that depends on the energy supply. The risk to energy infrastructure will grow as the frequency and intensity of certain types of extreme weather events increase.
- **Changes in water availability** will exacerbate existing challenges to energy production. Reduced water availability and a rising demand for water from a growing population will constrain hydropower, bioenergy (particularly biofuel production) and some solar power systems as well as the operation of thermal power plants (fossil fuel and nuclear), which require water for cooling. Too much water – in the form of increased flooding, extreme precipitation and storms – poses other challenges to energy infrastructure.
- **Unusual seasonal temperatures** can change energy demand patterns. For example, **higher summer temperatures** increase electricity demands for cooling, and the corresponding higher peak loads may require additional generation capacity, while warmer winters will reduce heating energy demand.
- **Rising sea levels** will affect coastal and off-shore energy infrastructure. The greatest concern is storm surge as more water is transported by winds, tides and waves. Greater storm surges and coastal erosion pose risks to existing and future infrastructure.
- Northern energy infrastructure is exposed to an additional risk of **permafrost thaw**, which can lead to surface subsiding and result in damage to pipeline and other energy infrastructure.

1. In addition to climate change, the energy sector is exposed to risks such as cyber-attacks, electromagnetic interferences, and political and social instability and conflicts.

2. What climate impacts present the greatest concerns for electricity and fuel supply?

Electricity and fuel supply systems must become more resilient to extreme weather and increasing stress on water resources.

Climate change impacts pose a new challenge to energy security, namely to the uninterrupted availability of energy sources at an affordable price. Short-term interruptions due to extreme weather events have already caused multi-billion-dollar losses for the countries affected. The increasing scarcity of water due to global warming and the rising demand are serious concerns for the energy sector in many countries around the world.

Extreme weather events

Extreme weather events pose significant risks to electricity production and fuel supply. In the United States, for example, weather-related disturbances to the power sector are responsible for a far greater number of customer interruption hours than component failures, physical attacks and cyber incidents combined, with the cost to the economy estimated between USD 25 to USD 70 billion annually. Sequential or compounded extreme weather events can result in significant economic and safety hazards. Continued increases in the magnitude and frequency of extreme weather can intensify the stress on energy systems in several ways:

- Transmission, storage and distribution (TS&D) networks are very vulnerable to extreme weather events. Climate-related threats to TS&D systems include high winds, falling trees, snow and ice accumulation, temperature-related equipment failures, lightning strikes, storm surges and floods, efficiency losses and sagging of lines.
- High ambient temperatures may reduce power plant efficiency and increase demand for cooling water.
- Increased flooding, extreme precipitation and storms threaten energy infrastructure located in flood-prone areas.
- Extreme weather events have long been a cause of oil and gas production disruptions. For example, in May 2015 wildfires near oil sands production areas in Alberta, Canada reduced total oil output by around 10%, its lowest level in almost two years. Hurricanes Katrina and Rita damaged more than 100 oil drilling platforms in the Gulf of Mexico in 2005.
- Flooding, wildfires and icy conditions affect roads and other fuel transportation networks. Railways and marine transportation that move oil, coal and liquefied gas are also vulnerable to other extreme weather events. In addition to physical damage to infrastructure, oil and gas pipeline disruptions are often caused by power outages during extreme weather.

Emergency preparedness and response strategies are needed to keep critical infrastructure functioning and protect lives and livelihoods.

"Electricity systems are indispensable to the performance of the essential functions of society."

Water constraints

Anticipated changes in water quantity and distribution as a result of climate change will affect the energy supply in various ways.

- Hydropower production in some regions may be impeded by prolonged and repeated droughts or seasonal changes in water availability. For example, droughts in Brazil and Zambia in 2015 severely restricted hydropower production. Zambia experienced a 560megawatt power deficit — equal to about one-quarter of its total generating capacity. Brazil had to switch to back-up fossil-fuelled generation. For countries that rely heavily on hydropower (e.g. Paraguay, at 100%), water stresses exacerbated by climate change may pose serious energy security concerns. When two or more countries depend on the same river water for hydropower and for other important uses, water constraints may lead to regional energy security issues and conflicts.
- Rapid thawing of the snowpack can overload reservoirs and result in lost energy in the spring and inadequate water reserves in the summer.
- Cooling thermal-electric power plants (including nuclear, natural gas, coal, concentrated solar and geothermal) rely on water availability. Higher water temperatures reduce their cooling efficiency and result in a proportional increase in the demand for cooling water. This also creates challenges for meeting river temperature regulations. For example, in 2009, France lost 1/3 of nuclear capacity, to stay within thermal discharge limits.
- Many upstream and midstream activities (extracting, processing, upgrading, transporting, and storing) associated with oil, gas, coal and biofuel production are water-intensive. Areas that are already water-stressed are especially at risk. 93% of onshore oil reserves in the Middle East are located in medium- to extremely high-risk areas for overall freshwater quantity.[2] Around 38% of the areas where shale resources are located are arid or under high levels of water stress, while production of shale resources (oil sands and shale gas) are water-intensive processes. Compliance with water quality requirements is also an issue for many fuel extraction and processing operations.
- Biofuel crops require water for irrigation and can be affected by droughts. Water scarcity may restrict bioethanol and biodiesel production.[3]

Integrated water resource management will be an increasingly important tool for optimising the use of water in the energy sector and for other users.

2. SBC Energy Institute (2014), Introduction to the Water and Energy Challenge.
3. IEA (2012), World Energy Outlook 2012, OECD/IEA, Paris.

“Global water withdrawal for energy production is projected to increase 20% by 2035.[3]”

Energy sector resilience is a national and local challenge in all countries

As the droughts in Brazil and Zambia and hurricanes in the United States have shown, countries at all stages of economic development are vulnerable to extreme weather and face the challenge of making their energy sectors more resilient. While the challenge is common, responses need to be location-specific and they will depend on impacts and the nature of the energy system. Various approaches will be required, including risk assessment, technological solutions and adapted flexible management practices, as well as emergency preparedness measures. Policy, institutional and fiscal responses will be necessary to facilitate these processes. National, regional and sectoral strategies and action plans need to be developed to guide the necessary adaptation and resilience-building actions in an informed and coordinated manner. Some countries will require technical assistance and help with capacity-building from the international community in order to engage in these activities effectively. The UNFCCC National Adaptation Plans provide a useful mechanism for identifying priorities.

How we decarbonise will affect the climate-resiliency challenge

To mitigate climate change, the energy supply of the future will need to rely more on low-carbon energy technologies that limit the use of fossil fuels and emit much less carbon dioxide (CO_2). In this context, it is important to explore the climate mitigation-adaptation nexus. Below are examples of possible benefits and challenges to energy sector resilience that can be expected of a decarbonising energy system characterised by increased electrification, more variable renewable energy, other low-carbon energy technologies and improved energy efficiency and demand-side management.

- **Increased low-carbon electrification** and the subsequent displacement of oil by electricity may reduce exposure to global fuel supply disruptions (caused by extreme weather events and water stresses), while the expanded generation and TS&D infrastructure can create new exposures that need to be evaluated.
- **More renewable energy** can generally reduce water demand compared with thermal power, but new water challenges related to water-intensive concentrating solar power and bioenergy production may emerge. Variable renewable energy production is subject to risks of source supply intermittency (e.g. wind and solar) that may be exacerbated by climate change. On the other hand, these sources are often associated with a more distributed generation, creating a profusion of electricity sources and a greater ability to localise and buffer disruptions. Expanded regional renewable grid interconnections may present resilience benefits as well as challenges which need to be evaluated on a case-by-case basis. Infrastructure is also subject to risks from high winds, flooding and heavy precipitation. Hydropower can increase pressure on water resources, which may lead to regional water-related conflicts.
- **Improved demand-side management and energy efficiency** can lead to greater responsiveness to changes in both demand and supply (including those caused by climate change), and to reduced water demand. More efficient power plants use less water for cooling, while demand-side energy efficiency offsets the need for electricity capacity additions and, in turn, additional water for cooling. However, new smart grid infrastructure may be exposed to new risks.
- **Low-carbon energy technologies** such as nuclear and fossil-fuelled plants with carbon capture and storage (CCS) can provide reliable base-load power and reduce the vulnerability of a variable renewables-only grid. However, growth in nuclear energy can result in increased cooling water demand, as well as increased public safety concerns with rising extreme-weather risks. Water demand of power plants with CCS can almost double compared to non-CCS plants.

All changes in energy infrastructure related to decarbonisation efforts need to be evaluated in terms of potential exposure of new and refurbished infrastructure to climate change. Decarbonised energy systems should be made climate-resilient.

3. Who is at the front line building energy resilience?

Businesses are the key actors in designing and implementing resilience-building measures and adaptive practices.

In the area of climate change and extreme weather events, businesses (private and government-owned) are developing adaptive practices and tools. These practices and tools are designed to help manage physical hazards, adjust planning based on forecasts of future climate-related events and facilitate recovery actions. Businesses have a wealth of experience in identifying risks, managing their practices in a manner that minimises their exposure to risks and insuring against likely damages.

Climate risk assessment, prevention and management

Businesses as well as governments use risk assessment and management tools to identify physical and financial risks and to determine relevant strategies and investment plans. Risk management is integral to business decision-making. However, to make assets and operations resilient to climate-change impacts and to adapt them to future changes, businesses and government agencies need to assess the risks of future climate-change impacts. Emerging responses include:

- **Risk assessment, auditing and reporting**

  The self-evaluation and reporting of future climate risks and their management is a useful exercise for government agencies and companies. Investors need to conduct climate change impact risk assessments to anticipate future risks posed by a changing climate. Governments could catalyse such assessments by requiring them as part of permitting processes for new infrastructure projects and major retrofits. For example, the United Kingdom requests strategic companies to conduct self-reporting of climate risks every five years. The Carbon Disclosure Project encourages public companies and their suppliers to disclose climate change risks and opportunities, including physical risks of climate change, to institutional investors. Climate risk auditing could also be introduced to encourage regular evaluations and to recommend state-of-the-art resilience improvement measures.

- **Risk prevention**

  While not all risks can be avoided, preventive measures minimise residual risks. According to Swiss RE, up to 65% of future climate-related losses can be averted using cost-effective adaptation measures/ adaptive practices. Some of these measures are described below.

- **Emergency preparedness and response**

  Once risks are identified, measures need to be developed to manage the anticipated risks. Emergency preparedness and response measures enable organised and co-ordinated reactions to disasters. Governments and companies need to work together to ensure the functioning of strategic assets and a quick recovery from the emergency. The IEA conducts peer reviews of member countries' preparedness for emergency situations affecting energy supply.

- **Insurance**

  Insurance is a critical tool for risk-sharing, maintaining economic stability, and motivating resilience-building and risk-preventive behaviour. The insurance industry has a shared interest in limiting the damage caused by a changing climate. Weather coverage is an emerging insurance product, with pay-outs based on measurable weather events and not on individual loss assessments. Complementarities between government-guaranteed and private insurance products could be helpful.

Adaptive practices

Actions by business to respond to various threats posed by the changing climate could be categorised as management and technical measures to prevent risks; technological and structural measures to prevent risks; training; and recovery actions. It is important to document experiences from around the world and to share best practices. Below are examples of emerging adaptive practices by businesses:

- **Management and technical measures**

  Examples include programmes for pruning and managing trees near transmission and distribution (T&D) lines; placing T&D networks underground; installing pumping back-up systems to allow for water pumping when water levels are low; manufacturing non-wooden or reinforced poles; modifying the siting of infrastructure during renovations or while planning new developments; undertaking load forecasting using climate information; modelling climate impacts on existing and planned assets in collaboration with meteorological services; and assessing hydrological data and simulating situations for hydropower planning.

  Demand-side management may be critical for handling disruptions of electricity from hydropower.

  To address water scarcity, upstream energy companies are recycling water when possible: some companies use municipal waste water, brackish water or sea water instead of scarce fresh water. There are also attempts to conduct waterless hydraulic fracturing (e.g. with propane or CO_2).

- **Technological and structural measures**

  Examples include fortifying coastal, off-shore and flood-prone infrastructure against flooding and sea level rises; designing wind turbines to better manage high wind speeds; and modifying pipeline materials to withstand extreme weather events and temperature fluctuations. The use of improved technologies that enhance the energy and water-use efficiency of energy processes is another adaptive measure, beneficial for both the water and energy sectors.

  New technologies to reduce water consumption and enhance water re-use also play an important role. Thermal power plants are introducing improved cooling systems. Recirculating cooling systems are less vulnerable to modifications in water availability than once-through cooling systems. Air-cooled (or "dry cooling") systems help to reduce evaporative losses and do not use water in the process, but they require extra energy (in the order of 5%-7%) and may not be suitable for retrofitting existing plants.

  Microgrids and distributed generation provide options for improved resilience. Interregional connections can help countries draw power from unaffected areas (e.g. outside affected hydrological water basins).

  Underground water storages have also been tested to ensure water availability for critical uses during emergency situations caused by extremely low water levels (e.g. the aquifer storage and recovery (ASR) technique which has been used in the United Arab Emirates).

- **Training and education**

  Training emergency response teams is imperative for a fast and proper response in the case of a disaster, and also for quick repair and restoration actions. Training for data management, modelling and forecasting is necessary to start integrating climate forecasts into energy system planning. These activities can be organised in co-operation with government-led capacity-building programmes.

- **Recovery and resourcefulness in addition to robustness**

  While robustness (the ability to withstand the event) is an important element of resilience, supply-side disruptions may be unavoidable in certain cases. Thus, resourcefulness (the ability to manage operations during an extreme weather event) and efficient recovery actions are important and need to be thought through in advance. An important strategy for businesses is to develop logistical and back-up plans to provide for a rapid recovery from supply interruptions. These include pre-deploying emergency response vehicles, training teams for specific recovery actions and developing recovery strategies. Activities in this area focus on shortening the period needed to recover from an extreme weather event. New management practices using smart meters and automated switching devices that allow for much quicker recovery times from disruptions have also been used.

4. Why should governments get involved?

Governments should encourage resilience-building actions, and also have a role to play in implementation, both in emergency response support and in managing their own energy assets.

Uncertainties regarding the timing, magnitude and location of anticipated impacts complicate the development of cost-effective response strategies by businesses. Governments should play an active role by creating an enabling environment that facilitates business resilience-building actions; by developing stimulating and supportive policies; and also by setting an example by integrating future climate concerns into current planning for publicly controlled assets and enterprises. In addition, governments themselves are important in protecting and supporting recovery of assets.

Governments need to create enabling frameworks to facilitate resilience-building

Enabling frameworks imply favourable and facilitative conditions for businesses to act. Government and business activities that enhance resilience to climate change can be facilitated through access to information (e.g. climate data, research results and climate services), stakeholder engagement and collaboration, clear institutional links among different levels and domains of governments, and public-private partnerships. Examples include:

- **Climate information**

  This includes the collection and tracking of statistical data on weather and climate, the development of regional vulnerability assessments, the development of scenarios of future regional and local weather patterns, and the communication of data and information to all stakeholders. Governments should support the development and dissemination of climate information.

- **Adaptation strategies and plans**

  Governments could provide overall guidance to the energy sector on how to enhance its resilience to climate change impacts, increase energy security and create synergies between mitigation and adaptation. Governments are also the key players in fostering regional co-operation (e.g. the European Commission provides subsidies for regional programmes) and inter-sectoral management plans (e.g. the UK infrastructure plan).

- **Institutional co-ordination and partnerships**

  Integrating adaptation considerations across policies and management approaches requires coordination across policy domains (e.g. water, transportation, energy) and levels of government (e.g. between central and local governments), engagement of non-governmental organisations and the private sector, and mobilisation of scientific knowledge. New institutional and informational links should be incorporated into established processes of decision-making and management. For example, Canada launched an adaptation platform in 2012 to promote collaboration and produce information and tools that could be used by all sectors and regions to understand and adapt to the effects of a changing climate. The platform includes an energy sector working group. Local institutions play a critical role in dealing with location-specific impacts.

- **Capacity building**

  Capacity building includes the exchange of information and best practices, training for risk auditing and resilience enhancing measures, training for fast emergency response and recovery, and training for data management and forecasting. Special attention is needed for capacity building in developing countries.

- **Action across the resilience "value chain": robustness, resourcefulness and recovery**

  The enabling environment should support actions across the three main elements of resilience promoting increased robustness, facilitating the ability to manage operations during extreme events and enhancing the ability to recover quickly.

Regulatory and fiscal measures are needed to drive timely actions by businesses

Designing and implementing policies that encourage investments in resilience building and adaptive practices is necessary to motivate companies to act, despite uncertainties regarding the magnitude and timing of climate change impacts. Below are examples of emerging and recommended policies that governments should consider:

- **Design and safety standards**

  New design and safety standards are needed for equipment and infrastructure to withstand the extreme weather events of the future. For example, the United States is raising its flood standards to reduce the vulnerability of federally funded infrastructure. Only those facilities that meet resilience standards can be insured by the federal government. The Province of Quebec in Canada changed design standards for transmission lines after a 1998 ice storm, to improve the resilience of transmission lines.

- **Permitting, siting and zoning**

  The location of energy sector assets may determine the scale of their vulnerability to current and future climate-change impacts. Governments could use zoning with assigned vulnerability criteria based on climate forecasts when developing infrastructure plans and delivering construction permits. Governments could also use individual permitting processes for new energy infrastructure projects to request an assessment of climate vulnerabilities and require necessary adjustments to make planned infrastructure resilient to the anticipated climate-change impacts.

- **Efficiency standards**

  Enhanced water and energy efficiency standards would reduce exposure to climate-change impacts, including disruptions in water and energy availability as well as changes in water temperature. Demand-side management measures such as technology performance standards, smart meters, information campaigns can be applied to energy and water users.

- **Economic incentives**

  As an incentive, regulators could allow companies to receive a return on investments in resilience by passing the costs on to consumers, at least partially (e.g. the UK regulator Ofgem lets energy companies incorporate a return on resilience-building investments into electricity tariffs). Investments in efficiency and distributed generation are viable strategies for improving energy system resilience, again highlighting the resilience co-benefits of emissions mitigation measures. There are several examples of US regulators allowing resilience-building costs to be incorporated into electricity rates. New York State approved resilience-building projects as part of a broader rate case. In 2013, New Jersey Natural Gas was granted more than USD 100 million to "harden" its distribution infrastructure following Hurricane Sandy; the costs would be recuperated through a rise in customer base rates. Public Service Electric & Gas (PSE&G) was approved for a USD 1.2 billion infrastructure enhancement programme which included upgrading and moving substations, modernising low-pressure cast iron gas mains in flood risk areas, creating system redundancies and deploying smart grid technologies. These costs will also be passed along to customers.

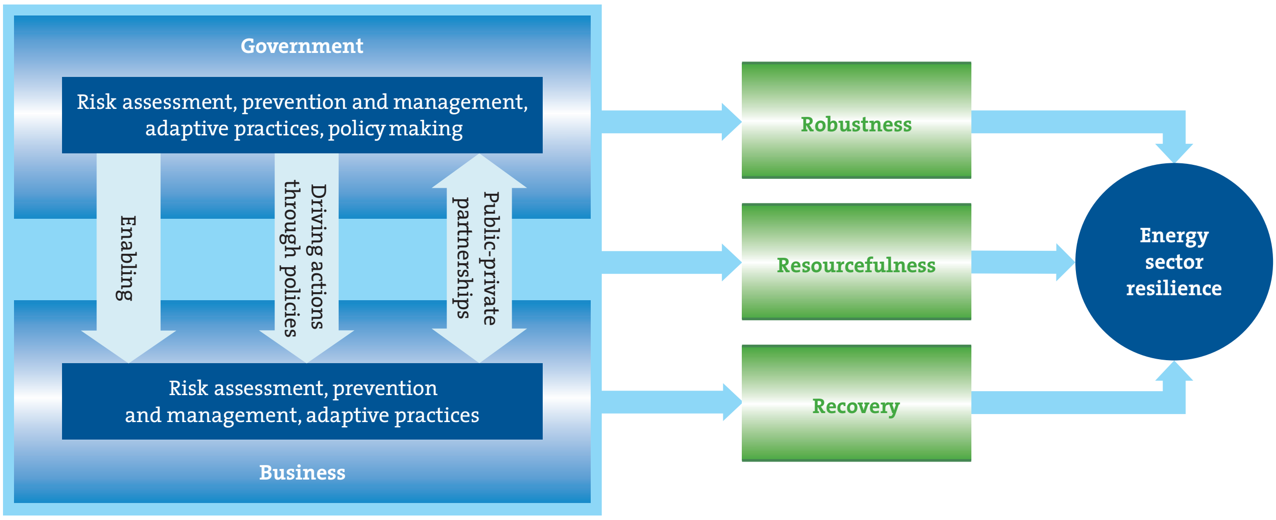
- **Innovation/research and development (R&D)**

  Government support is necessary for accelerated innovation in resilient energy systems. For example, the US Department of Energy is calling for a Response Framework to enhance RD&D of Climate-Resilient Energy Technologies. Technological innovation in the deployment of energy efficiency, smart grids and distributed renewables can help achieve both mitigation and adaptation objectives.

Governments themselves should be active players in resilience-building actions

Governments are key players in emergency preparedness and response measures. They develop early warning systems and participate in recovery actions. Government-led work to promote resilience to climate change should be incorporated with work on resilience to other risks to avoid duplication.

Governments are also responsible for managing a wide array of their own energy assets, from electrical power plants and transmission and distribution systems, to fuel delivery systems. As asset owners and managers, governments (and their specialised agencies and companies such as utilities) should adopt practices similar to those being developed by private businesses. Such practices should cover the whole spectrum of resilience-building, including robustness (withstanding change), resourcefulness (managing assets during an extreme weather event) and the capacity for rapid recovery from supply-side interruptions.



"Governments and business each have important and complementary roles to play in building energy sector resilience."

5. The IEA has the expertise to help

The International Energy Agency (IEA) is working with governments and businesses to help them address the challenge of resilience in the face of climate change.

The threat that climate change poses to the energy sector is an issue that touches the IEA's core mission of enhancing energy security. To help address this new challenge, the IEA analyses various aspects of climate-change resilience in its flagship publications such as the *World Energy Outlook* and in-depth energy policy reviews of countries. The IEA also launched the Climate-Energy Security Nexus Forum in 2012 as a platform to enhance awareness of the impacts of a changing climate on the energy sector and to share emerging experiences and expertise in building energy sector resilience.

The IEA is currently working to enhance its emphasis on climate change resilience in several of its core activities:

- **Dialogue facilitation**

  The IEA promotes dialogue on climate-change impacts and resilience topics of relevance to businesses and policy makers through the Nexus Forum workshops on the climate change-energy security nexus. Key topics covered so far are: Implications for Business; Cities and Insurance; Electricity Sector Resilience; Water and Energy; and Policies and Practices. Such dialogues will continue on an annual basis.

- **Data and modelling**

  The IEA investigates how modelling of climate-change impacts on the energy system can be improved. The IEA had already begun to deepen its analysis of resilience issues in the 2013 *World Energy Outlook* (*WEO*) Special Report on climate, and has continued to do so through case studies on water restrictions and coal power production in China and India in the *WEO 2015*.

- **Research stocktaking on impacts, vulnerability and resilience policy**

  Since 2012, the IEA has collected and reviewed information on climate-change impacts on the energy sector, the sector's vulnerability to these impacts, and developments on the ground in resilience and adaptation-building. Some of the stocktaking and analysis can be found in *WEO* regular reports and Special Reports on climate. The IEA Policies and Measures Database (PAMS) is being expanded to include relevant resilience policies. IEA in-depth energy policy reviews of countries have started integrating information on climate impacts and resilience in the climate change chapter if such information is provided by reviewed countries. Reviews of emergency policies include policies for dealing with extreme weather events and will gradually address the issue of climate resilience of oil, gas and electricity supplies in the overall resilience assessment.

- **Policy analysis**

  The IEA plans to include recommendations on the development of resilience and emergency preparedness policies in its guidance to member countries and beyond. Building on the experience of the Nexus Forum to date, the IEA is exploring how it could play a more proactive role in relevant policy and practice development by working more closely with governments and businesses.

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