The 3rd Meeting of

The Forum on the Climate-Energy Security Nexus [The Nexus Forum]

Electricity Sector Resilience

25 OCTOBER 2013

SUMMARY REPORT

BACKGROUND

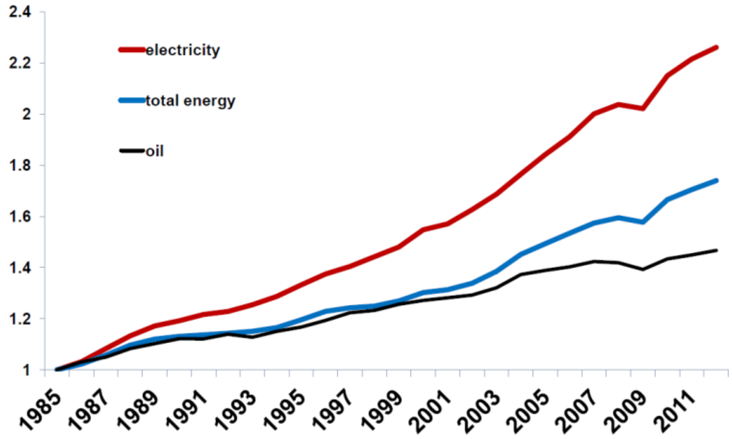
On 8 November, 2012, the IEA and FCO launched the Forum on the Climate-Energy Security Nexus (Nexus Forum). The first meeting at the IEA headquarters served as an agenda-setting session on energy resilience to a changing climate both on the energy supply- and demand-side. The second Nexus Forum, held in London on 26 June 2013, focused on two specific issues which emerged from the first Forum - cities and insurance - exploring opportunities for city-level responses and the role of insurance in building energy resilience to the impact of a changing climate.

The third Forum in the Nexus series was held on 25 October 2013 and, one year after the launch of this enquiry, the fullness of the agenda underlined the increasing attention directed at the issue of energy sector resilience over the past year. This Report provides a brief overview of the context for this discussion, then outlines some of the key messages, issues and ideas that were identified during the expert presentations and discussion at the 3rd IEA Forum on the Climate-Energy Security Nexus.

THE CLIMATE-ENERGY NEXUS

The third forum focused on resilience in the electricity sector specifically – an increasingly important subject as global electricity generation has tripled and electricity demand nearly doubled between 1990 and 2011, and continues to grow rapidly. A changing climate can impact availability of feed stocks for electricity generation, and the integrity and efficiency of transmission and distribution systems. Typical of the energy sector, electric power investment decisions have long lead times and long-lasting effects so medium- and long-term impacts need to be considered early.

Figure 1. Final energy consumption trends by fuel source



Source: IEA Data, 2012

Final electricity demand is expected to grow faster than any other form of final energy out to 2035. Participants at the Nexus Forum heard that global energy demand for space cooling currently represents 3% of final global electricity needs and is projected to be the fastest growing electricity end use sector (at a rate of 3.4% pa) in the coming years.

Increasing global average temperatures will exacerbate this, putting pressure on peak-load demand in some countries. The IPCC's AR5 report[1] projects higher temperatures and changes in weather patterns as "virtually certain" by the end of the 21st century. This will have an impact on energy generation using both renewable and fossil fuel technologies as well as on demand patterns, especially in fast-growing urban areas. According to IEA estimates, 1°C of warming can be expected to reduce available electric capacity by up to 19% in summer in Europe in the 2040s[2].

Changes in weather extremes, specifically an increase in the frequency, intensity, spatial extent, duration and timing of extreme weather events such as heat waves, droughts, flooding and storms has been assessed by the IPCC as "very likely". Combinations of these changes will intensify their effect and will have significant impacts on business as usual in the energy sector. Reduced water availability, and competition for limited water resources needed for thermal power plant cooling and for hydropower generation stood out as a major threat to the energy sector in coming years.

Figure 2. Climate impacts on energy resources

Energy (re)source	Gradual climate change	Extreme weather events	Combinations
Coal		P∧ flooding open pit sites	T∧ + P∨ + W∧ dust blown from stockpiles
Oil and gas	T↑ melting permafrost: destabilizing equipment SL↑ inundating coastal / off-shore sites	W∧ damaging onshore wells, cyclones damaging offshore platforms	SL↑ + W∧ severe damage to onshore wells SL↑ + S or cyclones severe damage to offshore platforms
Uranium		P∧ flooding open pit sites	
Hydro	T↑ higher evaporation losses P↑/↓ more/less water availability		
Wind	W↑/↓ more/less wind resource		
Solar	I↑/↓ more/less solar energy		

Notes: ↑ increasing, ↓ decreasing, ∧ extreme high, ∨ extreme low, T temperature, P precipitation, W windiness, I insolation, SL sea level, S storm

Figure 3. Climate impacts on energy generation technologies

Conversion technology	Gradual climate change	Extreme weather events	Combinations
Thermal power plant	T↑ decreasing thermal efficiency T↑ decreasing cooling efficiency P↓ less and warmer cooling water	T∧ larger efficiency loss T∧ larger cooling challenge P∨ even less and warmer cooling water W∧ damage cooling towers	T∧ + P∨ acute cooling problem T∧ + P∨ + W∧ dust blow from stockpiles and waste (fly ash, bottom ash)
Oil refinery Gas treatment	SL↑ inundating coastal / off-shore sites	P∧ flooding conversion sites	SL↑ + W∧ flooding conversion sites
Nuclear power plant	Same as thermal and oil/gas.	Same as thermal and: P∧ flooding emergency equipment and spent fuel storage	T∧ + P∨ + W∧ smoke from forest fire damaging instrumentation, inhibiting access
Hydropower		P∧ flood causing structural damage to dam wall, debris damaging dam / turbines T∨ ice blocking turbine inlet	P∧ + W∧ waves causing dam overflow
Wind power	T↑ less frequent icing P↓ more dust deposition SL↑ inundating coastal / offshore sites	W∧ structural damage T∧ & T∨ materials/fluids failing L damaging blades	T∨ + P ice on blades reducing efficiency, causing structural damage
Solar energy	T↑ higher SH performance T↑ lower PV and CSP	P∧ material damage to PV W∧ material damage SH,	T∧ + P∨ + W∧ dust or sand depositing on collectors reducing

[1] IPCC, (2013), *Climate Change 2013: The Physical Science Basis,* Working Group I Contribution to the IPCC 5th Assessment Report - Changes to the Underlying Scientific/Technical Assessment" (IPCC-XXVI/Doc.4).

[2] IEA, 2013, *Redrawing the Energy-Climate* Map: WEO Special Report, OECD/IEA, Paris

	efficiency	CSP H material damage PV	efficiency PV, CSP

Notes:↑ increasing, ↓ decreasing, ^ extreme high, ˅ extreme low, T temperature, P precipitation, W windiness, I insolation, SL sea level, S storm, L lightning, H hail, SH solar heating, PV photovoltaic, CSP concentrated solar power
Source: Ferenc L. Toth,(2013) *Impacts of climate change on energy systems*. Submitted

The IEA projects that power generation revenues will be USD 3 trillion higher in 2035 under a 2 °C path, than under the IEA's current New Policies scenario[3]. However, most of this rise will occur in the renewable generation sector, and in nuclear, while revenues in the fossil fuel generation are expected to decline.

There will be particular challenges, but also new opportunities, for power generators in thermal power generation and in renewables. It is expected that, in Europe, nearly 20% of coal-fired power generation will need additional cooling capacity in the future due to increasing temperatures[4]. This could mean major costs for generators and potential losses if the additional capacity is not installed in time. Several companies present at the Forum outlined efforts that are already underway to understand and respond to climatic changes both in terms of generation and in electricity transmission and distribution. The leaders in this area are generally companies which have already felt the impact of climate extremes and therefore have a concrete example of the impact on their business case and data upon which to calculate possible future impacts. The experience being developed in these areas can be shared to support pre-emptive resilience efforts in areas that have not yet suffered local climatic extremes. In light of the sustained global climate change predicted by the IPCC, ad hoc efforts need to be scaled up to the level of standard practise in order to guard against adverse affects to national and global energy security, as well as economic impacts of energy shortages.

There is an important role for government in incentivising resilience building action in the electricity sector through information provision and policy. Industry participants called for a strong lead from government on the kinds of action that should be taken and suggested that, without this policy signal, business would be slow to act, even on the strong messages that are coming through from the climate scientists about the impacts they need to be preparing for. A shift in mindset is yet to occur in the electricity sector that would reposition very likely future events, instead of actual past events, as the driver for business and asset planning. Key questions that arise for policymakers to consider are:

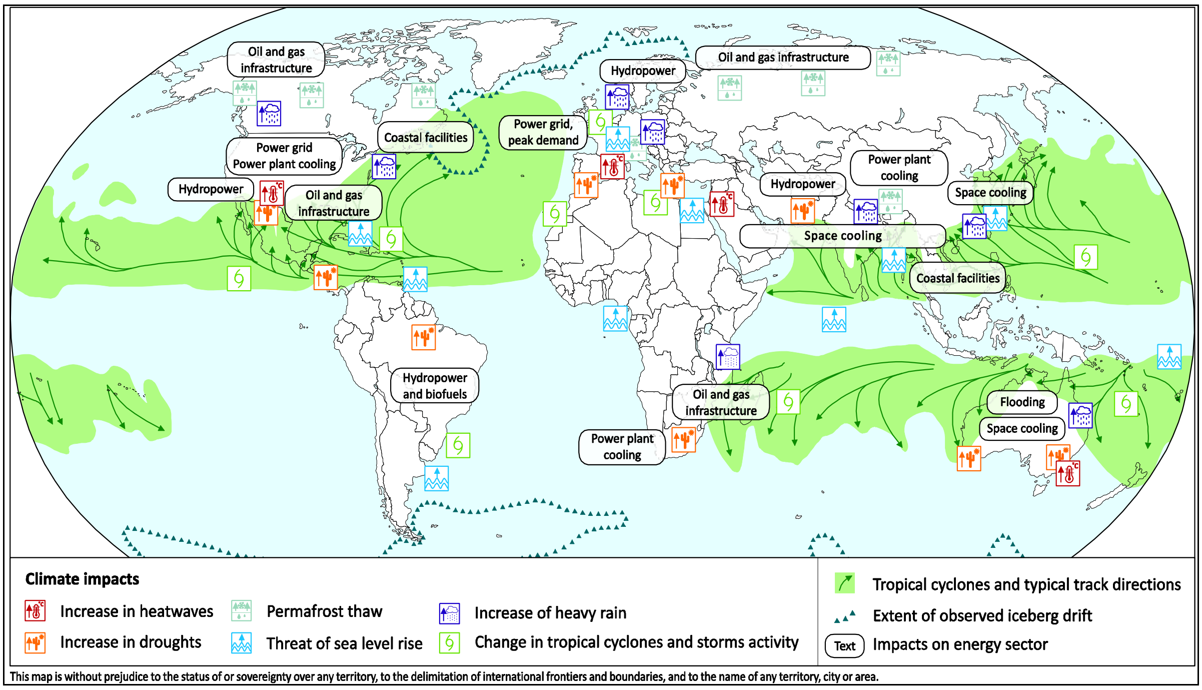
- What are the best policies to incentivise action in resilience building?
- How to prioritise resilience-building action?
- Who should be taking resilience actions?
- What are the barriers to action? Is it simply funding, do we still need more information, or is it something deeper?

Forum participants suggested that the various threats faced in the electricity sector (*e.g.* geo-political risks, market functioning, network balance, technological and management issues) are currently well managed. The increasing integration of renewable energy still poses something of a challenge for grid and system operation and good market management will remain important. Nevertheless, it was argued that the impact of climate change on the energy sector - generation, transmission, distribution and demand - likely presents the greatest risk to electricity security of our time.

[3] IEA, 2013, *Redrawing the Energy-Climate* Map: WEO Special Report, OECD/IEA, Paris
[4] Ibid.

Existing energy security measures will be useful for building the resilience of the electricity sector to some of the impacts of climate change, in particular the incidence of extreme weather events of which there is some experience. Nevertheless, there is an urgent need to better understand what the impacts of the future will be and what they will cost, and to build these new parameters into the traditional decision-making and risk assessment processes that inform planning in the electricity sector. The data is there and the technical solutions are often already available. The next step is to communicate the urgency of resilience-building action and the cost/benefit case for investments in resilient technologies needs more clearly to the electricity sector, as well as to the energy sector more broadly.

Figure 4. Selected climate change impacts on the energy sector



Source: IEA 2013, *Redrawing the Energy-Climate Map*, OECD/IEA, Paris. Based on ©Munich RE (2011), with information from Acclimatise (2009), Foster and Brayshaw (2013), Schaeffer, *et al.* (2012) and IEA analysis.

KEY LESSONS ARISING FROM THE 3[RD] NEXUS FORUM

The third forum focused on resilience in the electricity sector specifically and discussions brought to light many interesting new and emerging ideas on this subject. The following material summarises the key messages, issues and ideas that were identified during the expert presentations and discussion in the following areas:

A. Overarching Issues
B. Energy Sector Perspective
C. Utilities Perspective
D. Policy Perspective
E. Procedural Perspective (Risk Assessment / Data & Modelling)

A. OVERARCHING ISSUES

Participants discussed some key cross-sectoral issues relating to the need to develop a stronger analytical base for resilience planning, and improving communication of this information the various sectors impacted in order to overcome uncertainty issues. It was observed that adaptation and mitigation can go hand in hand and that synergies between existing energy security measures could likely be expanded to address climate resilience.

- The IPCC Fifth Assessment Report provides a **strong analytical basis** for resilience planning, and work on extrapolating this data to support local planning efforts should be scaled up.

- Work is needed to identify the barriers to **good communication of climate data** to the energy sector players, and to over come the, for example by "translating" messages for communication to different disciplines/ sectors/ contexts

- More analysis is needed to **quantify the impact of climatic changes** in order to support decision-making. For example, assessment of:
  - the impact of changing long-term demand patterns on energy capacity needs
  - the financial impact of climatic events on individual utilities - combine cost figures gathered from past events with projected scale and frequency of future events
  - the cost of adequate resilience building vs. the cost of projected climate impacts without resilience measures

- **Uncertainty** of climate impacts should not be a barrier to resilience-building action – it is inherent in all risk assessment processes and can be overcome by repeating model runs and generating as many scenarios as possible to support proactive decision-making.

- Increased supply/demand imbalance from climate change directly impacts energy security and the **synergies between existing energy security measures and climate resilience** measures could be enhanced. For example:
  - latest regional climate change data should be factored into risk assessment
  - gradual long-term impacts on supply and demand should be factored in

- Adaptation is not just a developing country issue - **adaptation and mitigation approaches** should go hand in hand. A synergistic approach could maximise co-benefits and availability of funding sources.

- There are distinct but equally important **issues for both developed and developing countries,** however, special attention could be devoted to building resilience in developing countries because of the particular demographic and climatic pressures in these countries.

B. ENERGY SECTOR PERSPECTIVE

Discussions centred on the various impacts that could and have been felt on the energy sector, in particular in electricity, including the impacts already felt in transmission and distribution of electricity. Forum participants shared their own experience with adaptive technologies, processes and measures that could be used to harden and smarten generation and transmission and distribution systems.

- **Climate change impacts will hit the energy sector directly**: in exploration; production; refining; fuel transport; generation; delivery/transmission; end-use and indirectly: through impacts on energy demand, health; agriculture; water; transport and socio-economic development that will exacerbate these pressures.

- It is becoming necessary to **harden (build resistance)** and **smarten (build in additional flexibility)** the energy system and individual assets in response to latest climate projections

- An initial focus should be on resilience-building on **operational and structural measures**, in particular new-build plants

- RD&D should expand in currently available **adaptive technologies and measures**, such as:
    - unconventional cooling technologies (e.g. dry cooling; waste-water cooling)
    - flood walls and water tightness measures
    - installation and equipment siting options
    - improved weather alert systems

- Resilience building of **transmission and distribution systems** will need to consider all components: towers, lines, substations, disconnecters, breakers needs to be assessed

- Climate threats to T&D systems include high winds, falling trees, loading of snow and ice; temperature related equipment failures; lightening strikes; reacting to relocation of coastal assets; increased efficiency losses and sagging of lines

- **Solutions already tested** include:
    - design changes (e.g. anti- cascading towers)
    - logistics software improvements
    - logical infrastructure redundancy
    - R&D on new monitoring tools
    - measures for managing physical hazards (e.g. tree management programmes)
    - planning based on forecasting of future events
    - load forecasting using climate information
    - training teams for fast response

- RTE suggest **four keys** to building transmission resilience:
    - Consider the future energy mix (supply)
    - Set conditions for a more flexible electricity demand (demand)
    - Develop and reinforce grid infrastructures (hardware)
    - Develop new mechanisms for a more intelligent power system (software)

C. INDUSTRY PERSPECTIVE

Some industry-level participants voiced their hesitation as to the economic viability of resilience action in what are perceived as high uncertainty conditions, but many pointed to experience which has show that there may in fact be considerable strategic advantage in taking earlier action and harnessing opportunities and avoid negative impacts that a changing climate could present. It was agreed that better quantification, communication, and incentives would likely be needed to mobilise business, but some recommendations for company-level adaptive action were also provided.

- Many businesses in the energy/ electricity sector are yet to **internalise the economic implications** of currently available climate information and still view resilience measures as high cost but low probability, and therefore un-economic.

- Key message from recent study by WBSCD is: **Anticipation is cheaper!**

- **Communication is key** – more cross-sectoral discussion and agreement is needed

- Some businesses, alert to climate risk, have developed adaptation strategies tailored to the particular regional impacts and business case impacts they could face. These examples illustrate some of the **strategic options available** (e.g. Eskom; EDF; Hydro-Quebec).

- Studies to date indicated that the costs of climate-related events on energy infrastructure and for business are high and rising, but **costs still need to be better quantified**.

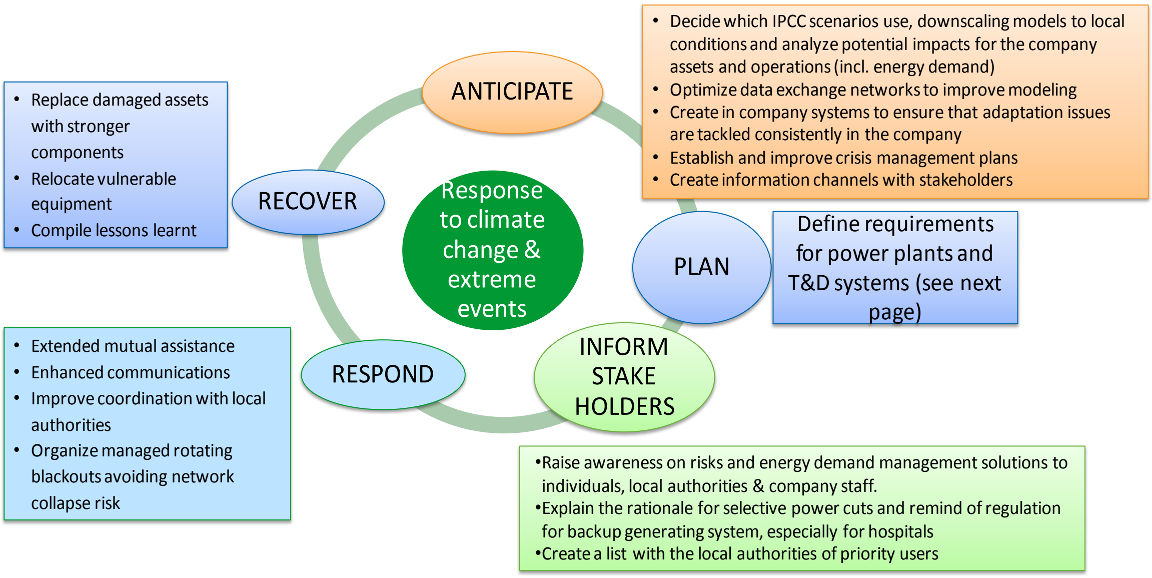
- Business should grasp the opportunity to take resilience measures, both to limit any adverse effects, but also to **harness potentially positive impacts**.

- **Drivers** of industry action:
    - Business risk (supply and demand)
    - Resource scarcity
    - Changing cost profiles
    - Compliance (incl. legislation and standards)
    - Stakeholder engagement

- **Incentives** from external sources may necessary to drive action in industry. For example:
    - Governments requiring resilience measures in tenders for power supply contracts and writing such requirements into supply contracts at the outset
    - Company shareholders exerting their power to pressure companies to take steps to protect shareholders investment
    - Insurance contracts building-in requirements for resilience measures

- A **business adaptation** approach: Anticipate - Plan - Inform stakeholders - Respond – Recover

Figure 5. Integrating resilience-building thinking into company strategy



Source: WBCSD (2014), *Building a Resilient Power Sector*, Geneva.

D. POLICY PERSPECTIVE:

Forum participants went on to discuss the possible role for government in designing policy and regulation that enables and encourages effective and cost-efficient resilience-building measures. Opportunities were identified for increased cooperation between public and private sectors, as well as between central and local government and local utilities to address the regionally specific potential impacts of a changing climate.

- To date, governments have limited experience in **designing enabling policy frameworks** to support resilience measures and development of climate-resilient technologies. Experience sharing needs to start urgently.

- Better **climate impact information, with regional specificity**, should be channelled to decision-makers, at various levels of government and in business.

- There is an important role for policymakers to provide guidance in several areas – most impact will likely be achieved by feeding into **regulation and operating rules**, i.e.:
    - GUIDELINES: e.g. siting, safety standards
    - DESIGN: e.g. requiring climate change information to be integrated into parameters
    - TECHNOLOGY DEVLOPMENT: e.g. cooling technologies
    - PLANNING AND PLANT MANAGEMENT e.g. demand forecasting, outage planning

- **Public/Private partnerships** can play a significant role in this field by:
    - pooling of expertise & supporting R&D for development of resilient technologies
    - accessing technical information needed for cost benefit assessments and key to developing new business models which price and manage risk
    - fostering policy support for resilience-building action in mitigation and adaptation
    - convening and partnering with business and other stakeholders at the local level to plan effective resilience strategies adapted to local circumstances.

- **Local Governments and utilities** should work together to raise awareness of climate impacts and solutions for local impacts and circumstances.

- Policy should be designed to encourage **coordination of energy sector RD&D projects** to support and prioritise a coordinated effort to respond to the requirements of the changing climate.

E. PLANNING PERSPECTIVE

Representatives of the insurance industry explained how climate information is already being integrated into risk assessment processes with a potentially major effect on longer-term investment planning, indicating a need to develop risk/cost/benefit approaches for the energy sector. Participants shared their experience with climate/energy data gathering, analysis and modelling and discussed the need for better quantification of impacts as well as development of ways to integrate climate models with energy models and derive results at the regional level.

E.1 RISK ASSESMENT:

- The "1 in a 100 years" event is **increasing in frequency, intensity, spatial extent and duration**.

- The changing climate is **already having an impact on risk assessment** in the energy sector:
  - Single and accumulation risks: changing loss probabilities for single risks; new risks that affect whole regions and distributed energy installations
  - Performance related risks: performance risks of renewable energy technologies; impacts on performance of power plants.

- **Changing probabilities** for climate-related events are already appearing in insurance cost calculations.

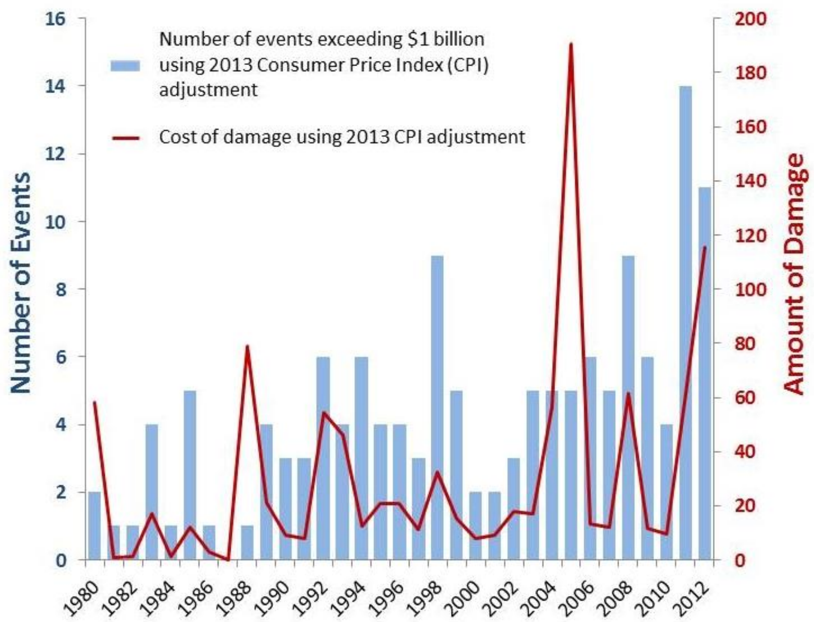
- Broad consensus on **methodology for assessing climate risks** against each other is needed.

- It is necessary to **compare costs/benefits** of taking adaptive action vs. costs/benefits of continuing business as usual.

- A **risk/cost/benefit analysis approach** involves several evaluation and implementation criteria:
  - Evaluation criteria: risk assessment; cost/benefit analysis; timing
  - Implementation criteria: budget constraints; regulatory frameworks; technical skills required; political ambition; institutional capability.

- New climate risks to geographically dispersed power generation and/or grid portfolios should have an **impact on long-term investment decision-making** in energy (Munich RE).

Figure 6. Observed cost of weather and climate disasters, US, 1980–2012



Source: U.S. Department of Energy (DOE), 2013. *U.S. Energy Sector Vulnerabilities to Climate Change and Extreme Weather.* http://energy.gov/downloads/us-energy-sector-vulnerabilities-climate-change-and-extreme-weather. Data: U.S. National Oceanic and Atmospheric Administration, 2013. "Billion-Dollar Weather/Climate Disasters." http://www.ncdc.noaa.gov/billions/events.

E.2 DATA & MODELLING:

- Better **quantitative data** on climate impacts in the energy sector is essential to supporting resilience action. (see: overarching issues section above).

- Without **mandatory reporting** on climate-related drivers of outages/interruptions, data on these events is often unavailable: regulation could address this issue.

- **Successful attempts at quantification** of impacts have been made. Two examples presented at the Nexus Forum were:
  - NEA is measuring costs on basis of loss of output (GWh) as a result of observed weather events.
  - Entergy has quantified impacts on the basis of loss averted

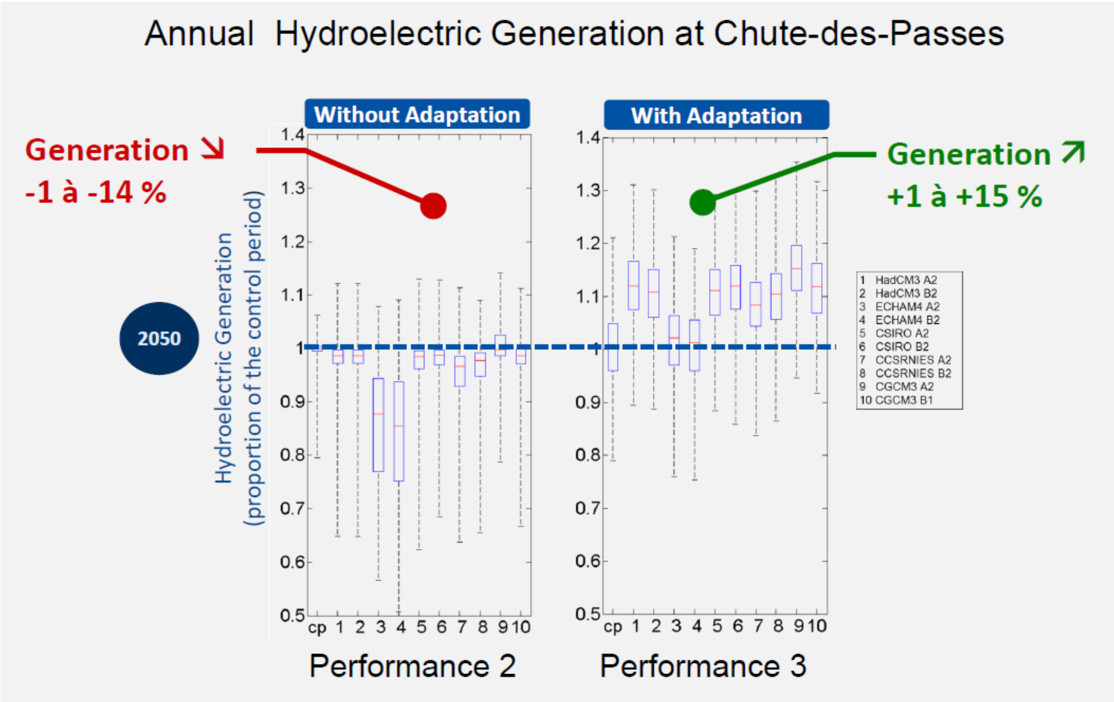
- **Climate models and energy models do not speak the same language**, making it challenging to integrate these models to support resilience planning. Efforts are needed to bridge the gap between the approaches and language used by engineers and by climate scientists.

- Climate models are done at the global level – it is essential for this data to be systematically translated into **local-level models** to inform decision-making.

- Successful attempts at **bridging the modelling gap** have been made. Two examples presented at the Nexus Forum are:
  - Hydro-Quebec have developed a modelling chain approach to drill down from global climate impacts to impacts on their individual business
  - South Africa's Long Term Adaptation Scenario Research Flagship Programme (LTAS)

- Hydro-Quebec has proposed **a four-step approach** to quantifying climate risks to their business:
  1. Identify the main resilience challenges
  2. Participate in the development of climate scenarios at the right level of extraction
  3. Analyze the impacts of climate change on targeted activities
  4. Develop and implement appropriate adaptation strategies

Figure 7. Benefits of Adaptation in an individual Hydropower plant



Source: Minville, M., Brissette, F., & Leconte, R. (2010). Impacts and uncertainty of climate change on water resource management of the Peribonka river system (Canada). *Journal of Water Resources Planning and Management*, *136*(3), 376–385. doi:10.1061/(ASCE)WR.1943-5452.0000041/ Minville, M., Krau, S., Brissette, F., & Leconte, R. (2009). Behaviour and Performance of a Water Resource System in Québec (Canada) Under Adapted Operating Policies in a Climate Change Context. *Water Resources Management*, *24*(7), 1333–1352. doi:10.1007/s11269-009-9500-8

CONCLUSION

The Third Nexus Forum brought together a broad range of actors within the energy and electricity sectors, as well as experts in climate data collection, analysis and risk assessment. This provided a rich context for discussion of the implications of the latest report from the IPCC, and the impacts and costs that have been felt by some, and could be expected more broadly and frequently in the energy sector in the medium- and long-term. It was clear that there are particular challenges in electricity generation, transmission and distribution as the share of electricity in global energy demand continues to grow. This Forum presented the current state of the art in terms of assessing impacts as well as emerging approaches and ideas for responding to them, both in practical terms and through regulation, policy and planning.

Since the first IEA Forum on the Climate - Energy Security Nexus the issue of resilience has gradually grown in visibility to the point where, in late 2013, participants were able to discuss a range of possible ways forward. Many of the ideas captured in this report could provide a starting point for active next steps, not only in understanding, but also in addressing the challenge of building the resilience of the energy sector to a changing climate.