National Topic Summary
State of the Sector

- Changes in the **frequency and intensity of climate extremes** relative to the 20th century and **deteriorating water infrastructure** are contributing to declining community and ecosystem resilience.

- **Climate change is a major driver of changes** in the frequency, duration, and geographic distribution of severe storms, floods, and droughts. **Population and land use changes increased disaster risk exposure.**

- Gains in water-use efficiency over the last 30 years have resulted in total U.S. water consumption staying relatively constant. **Increases in water stress due to persistent climate changes** may be **harder to mitigate through additional conservation.**

- **Aging and deteriorating dams and levees** also represent an increasing hazard when exposed to extreme or, in some cases, even moderate rainfall. The national exposure to this risk has not yet been fully assessed.
Fig. 3.1: Billion-Dollar Weather and Climate Disaster Events in the United States

The figure shows (a) the total number of water-related billion-dollar disaster events (tropical cyclones, flooding, and droughts combined) each year in the United States and (b) the associated costs (in 2017 dollars, adjusted for inflation). Source: adapted from NOAA NCEI 2018.19
Key Message #1

Changes in Water Quantity and Quality

Significant changes in water quantity and quality are evident across the country. These changes, which are expected to persist, present an ongoing risk to coupled human and natural systems and related ecosystem services. Variable precipitation and rising temperature are intensifying droughts, increasing heavy downpours, and reducing snowpack. Reduced snow-to-rain ratios are leading to significant differences between the timing of water supply and demand. Groundwater depletion is exacerbating drought risk. Surface water quality is declining as water temperature increases and more frequent high-intensity rainfall events mobilize pollutants such as sediments and nutrients.
Fig. 3.2: Depletion of Groundwater in Major U.S. Regional Aquifers

(1900–2000) Groundwater supplies have been decreasing in the major regional aquifers of the United States over the last century (1900–2000). (Right) This decline has accelerated recently (2001–2008) due to persistent droughts in many regions and the lack of adequate surface water storage to meet demands. This decline in groundwater compromises the ability to meet water needs during future droughts and impacts the functioning of groundwater dependent ecosystems (e.g., Kløve et al. 2014). The values shown are net volumetric rates of groundwater depletion (km³ per year) averaged over each aquifer. Subareas of an aquifer may deplete at faster rates or may be actually recovering. Hatching in the figure represents where the High Plains Aquifer overlies the deep, confined Dakota Aquifer. Source: adapted from Konikow 2015. Reprinted from Groundwater with permission of the National Groundwater Association. ©2015.
Deteriorating Water Infrastructure at Risk

Deteriorating water infrastructure compounds the climate risk faced by society. Extreme precipitation events are projected to increase in a warming climate and may lead to more severe floods and greater risk of infrastructure failure in some regions. Infrastructure design, operation, financing principles, and regulatory standards typically do not account for a changing climate. Current risk management does not typically consider the impact of compound extremes (co-occurrence of multiple events) and the risk of cascading infrastructure failure.
Key Message #3

Water Management in a Changing Future

Water management strategies designed in view of an evolving future we can only partially anticipate will help prepare the Nation for water- and climate-related risks of the future. **Current water management and planning principles typically do not address risk that changes over time, leaving society exposed to more risk than anticipated.** While there are examples of promising approaches to manage climate risk, the gap between research and implementation, especially in view of regulatory and institutional constraints, remains a challenge.
Fig. 3.3: Colorado River Basin Supply and Use

The figure shows the Colorado River Basin historical water supply and use, along with projected water supply and demand. The figure illustrates a challenge faced by water managers in many U.S. locations—a potential imbalance between future supply and demand but with considerable long-term variability that is not well understood for the future. For the projections, the dark lines are the median values and the shading represents the 10th to 90th percentile range. Source: adapted from U.S. Bureau of Reclamation 2012.114
Regional Chapter Examples
**Alaska**
- Erosion and flooding due to sea level rise
- Threatened salmon populations

**Northwest**
- Salmon populations threatened by drought, diminished streamflow, increased water temperatures, decreased snowpack, flooding

**Hawai‘i & U.S.-Affiliated Pacific Islands**
- Extreme weather
- Threatened water supply due to drought, flood, saltwater intrusion

**Northeast**
- Extreme weather
- Deteriorating infrastructure
- Compounding stressors threaten communities and infrastructure

**Midwest**
- Changing precipitation, flooding impact infrastructure
- Harmful algal blooms decreased water quality

**Southern Great Plains**
- Drought disrupts agriculture and river navigation
- Water supply threatened by drought, downpours, and reduced snowpack

**Southeast**
- Extreme weather
- Flooding
- Deteriorating infrastructure

**Northern Great Plains**
- Flooding
- Precipitation changes

**Southwest**
- Water supply decreases during drought
- Compounding stressors: human water use, groundwater depletion

**U.S. Caribbean**
- Extreme weather damaged energy and water supplies
- Threatened freshwater supply due to drought, flood, saltwater intrusion
Dependable and safe water supplies for the communities and ecosystems of Hawai‘i and the U.S.-Affiliated Pacific Islands are threatened by rising temperatures, sea level rise, saltwater intrusion, and increased risk of extreme drought and flooding.

In water emergencies, some islands rely on temporary water desalination systems or have water sent by ship, both of which are costly but life-saving measures.
Summer surface water temperature increased in most areas between 1994 and 2013. Increased water temperatures contribute to algal blooms, including harmful cyanobacterial algae that are toxic to people, pets, and many native species.
Regional Examples: Northwest

Pacific salmon populations in the Northwest are being affected by climate stressors, including low snowpack, decreasing summer streamflow, habitat loss through increasing storm intensity and flooding, physiological and behavioral sensitivity, and increasing mortality due to warmer stream and ocean temperatures.
During 2010–2015, the **multiyear regional drought severely affected agricultural systems**. In one year, planted acres of rice in Matagorda County, Texas, dropped from 22,000 acres to 2,100 acres.

- **Ripple effect on local economy**: 70% decline in sales of farm implements and machinery

- **Irrigation strategies shifted** away from river-based; dozens of new wells were drilled, resulting in declining groundwater levels and **increased water stress**

- Impacts lessened by implementation of **drought contingency plans** and **water-use cutbacks** in the City of Austin
Regional Examples: Southeast

Rainfall totals from the October 2015 South Carolina flood event. Extreme precipitation events will likely increase in frequency in the Southeast.

As of 2016, the City of Charleston has spent or set aside $235 million to complete ongoing drainage improvement projects to prevent current and future flooding.
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Key Messages of Energy Chapter

- Key Message 1: Impacts on Energy Sector Extend Across the Nation

- Key Message 2: Transformations in the Energy System Are Changing Vulnerabilities to Climate and Weather Impacts

- Key Message 3: Actions are Underway to Improve Energy System Resilience
Potential Impacts from Extreme Weather and Climate Change

Extreme weather impacts all components of the Nation’s energy system, from fuel production and distribution to electricity generation, transmission, and demand.

Climate change will likely result in more frequent and longer-lasting impacts, damaging infrastructure, and creating fuel availability and demand imbalances.


Projected Changes in Energy Expenditures

This figure shows county-level median projected increases in energy expenditures for average 2080–2099 impacts under the higher scenario (RCP8.5). Impacts are changes relative to no additional change in climate. Color indicates the magnitude of increases in energy expenditures in median projection; outline color indicates level of agreement across model projections (thin white outline, inner 66% of projections disagree in sign; no outline, more than 83% of projections agree in sign; black outline, more than 95% agree in sign; thick gray outline, state borders). Data were unavailable for Alaska, Hawai‘i and the U.S.-Affiliated Pacific Islands, and the U.S. Caribbean regions. Source: Hsiang et al. 2017.14
Transformations in the Energy System Are Changing Vulnerabilities to Climate and Weather Impacts

- Changes in energy technologies, markets, and policies are affecting the energy system’s vulnerabilities to climate change and extreme weather.

- Some of these changes may increase reliability and resilience, while others create additional vulnerabilities.

- Changes include:
  - Natural gas is increasingly used for power
  - Renewables expanding market share
  - Energy efficiency efforts increase
  - Electrification of other sectors and more interconnected
Key Message 3

Actions are Underway to Improve Energy System Resilience

- Actions are being taken to enhance energy security, reliability, and resilience with respect to the effects of climate change and extreme weather.

- This progress occurs through:
  - Improved data collection, modeling, and analysis to support resilience planning;
  - Private and public-private partnerships supporting coordinated action;
  - Development and deployment of new, innovative energy technologies for adapting energy assets to extreme weather hazards.

- Although barriers exist, opportunities remain to accelerate the pace, scale and scope of investments in energy systems resilience.

- Flood Protection
  - Building/strengthening berms, levees, and floodwalls
  - Elevating substations, control rooms, and pump stations
  - Expanding wetlands restoration
  - Installing flood monitors

- Wind Protection
  - Inspecting and upgrading poles and structures
  - Burying power lines underground
  - Improving vegetation management efforts

- Drought Protection
  - Adopting water efficient thermoelectric cooling
  - Utilizing non-freshwater sources
  - Expanding low water-use generation

- Modernization
  - Deploying sensors and control technology
  - Installing asset databases/tools, including supervisory control and data acquisition (SCADA) system redundancies
  - Deploying energy storage and microgrid infrastructure (distributed energy resources, demand response programs, islanding capabilities)

- Advanced Planning and Preparedness
  - Conducting extreme weather risk assessment planning, preparedness, and training
  - Participating in mutual assistance groups and public-private partnerships
  - Purchasing or leasing mobile transformers and substations
  - Utilizing geographic information systems (GIS) analysis to help identify vulnerabilities and plan for new builds and relocations

- Storm-Specific Readiness
  - Coordinating priority restoration and waivers
  - Securing emergency fuel contracts
  - Improving communication during outages to assist customers
Key Takeaways

- Extreme weather events are already impacting the energy sector and resulting in annual costs in the billions. The current pace, scale, and scope of efforts to improve energy system resilience are likely to be insufficient given the nature of the challenge.

- The need for adaptation will only increase without substantial mitigation efforts to reduce global greenhouse gas emissions and avoid more severe consequences in the long-term.

- Several key barriers:
  - Lack of reliable projections of extreme weather and climate change at a local level
  - Lack of established cost-benefit methodologies to fully account for benefits of resilience investments
  - Lack of resilience-based codes and standards
  - Lack of enabling policy framework to incentivize resilience investments

- Resilience Opportunities include:
  - Improved awareness of energy asset vulnerability
  - Cost-effective resilience-enhancing energy technologies
  - Standardized methodologies and metrics
  - Expanded public–private partnerships to address vulnerabilities collaboratively
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➢ Reports

- Climate Change and the Electricity Sector: Guide for Climate Change Resilience Planning:

- Climate Change and the Electricity Sector: Guide for Assessing Vulnerabilities and Developing Resilience Solutions to Sea Level Rise

- Climate Change and the U.S. Energy Sector: Regional Vulnerabilities and Resilience Solutions;
