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Climate Change

trends, projections and impacts

- a focus on the energy sector

U.S. Geological Survey,
U.S. Department of the Interior

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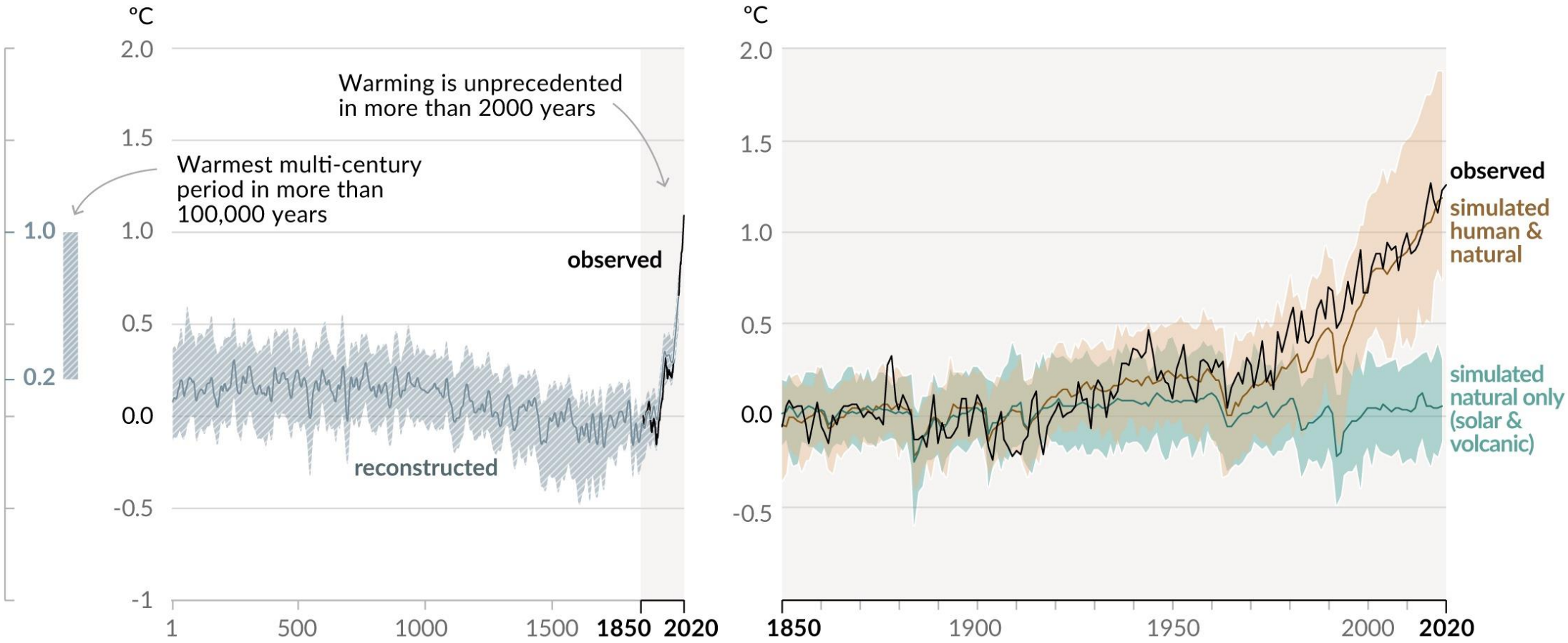
Chief Scientist for Climate and Land Use Change

Human influence has warmed the climate at a rate that is unprecedented in at least the last 2000 years

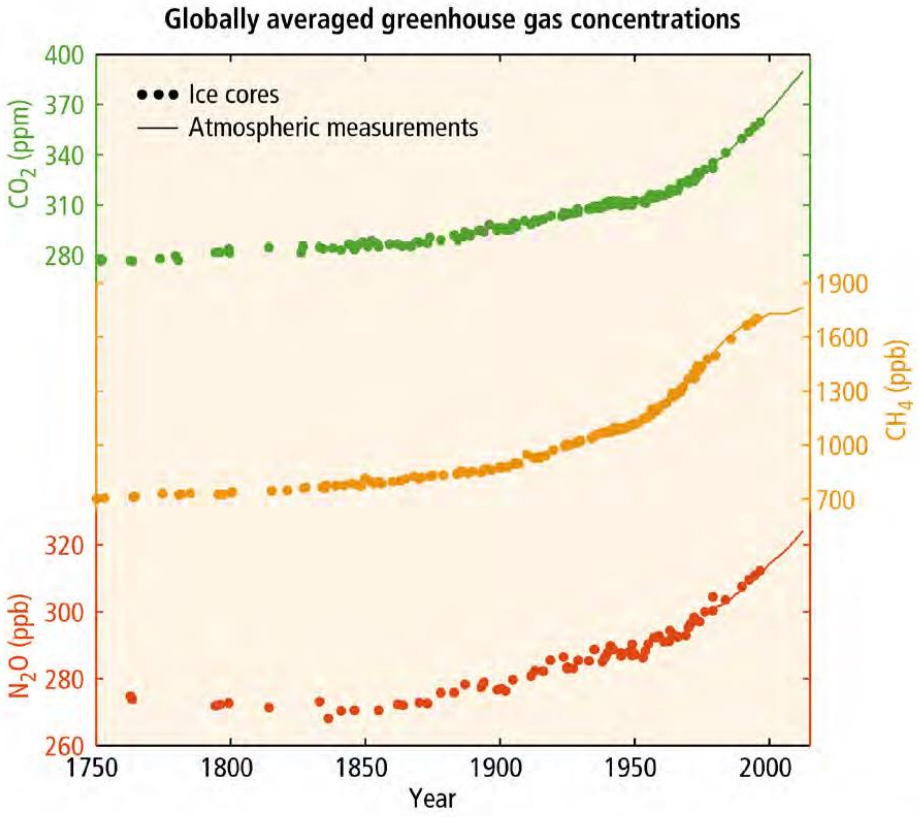
Changes in global surface temperature relative to 1850-1900

a) Change in global surface temperature (decadal average) as reconstructed (1-2000) and **observed** (1850-2020)

b) Change in global surface temperature (annual average) as **observed** and simulated using **human & natural** and **only natural** factors (both 1850-2020)



(Figure source: IPCC WGI, Summary for Policy Makers, 2021)

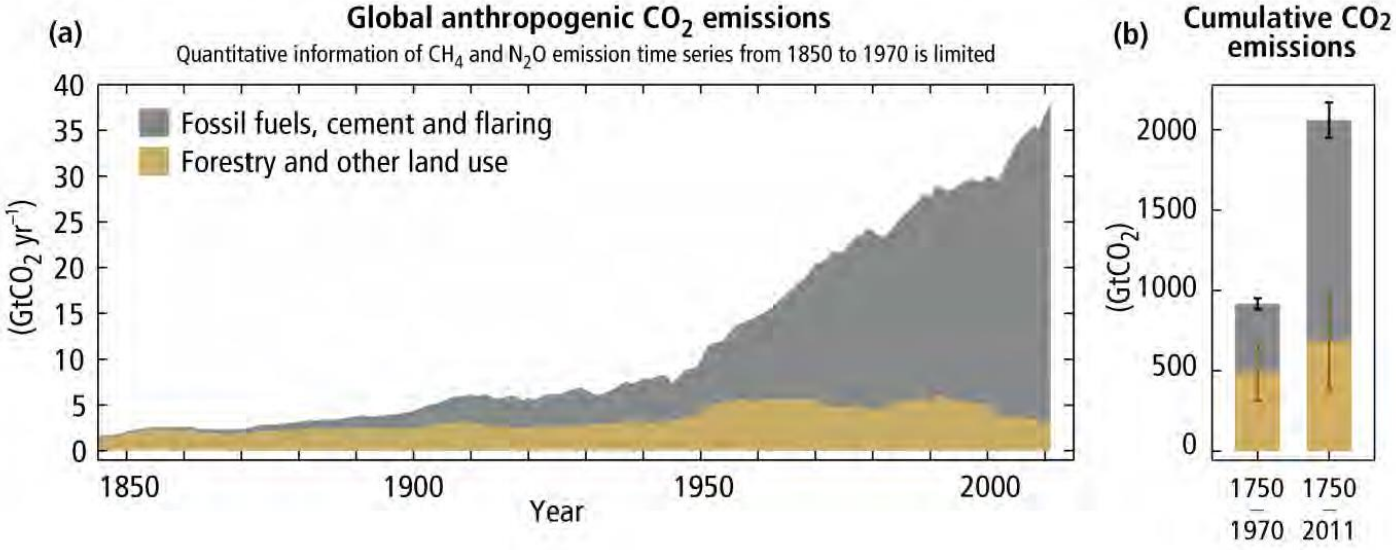


Atmospheric carbon dioxide level now is highest in at least 2 million years.

(IPCC AR6 WGI SPM, 2022)

Since 1970 cumulative CO2 emissions from fossil fuel combustion, cement production (2.4% of total emissions) and flaring have tripled.

(IPCC AR5, 2014)



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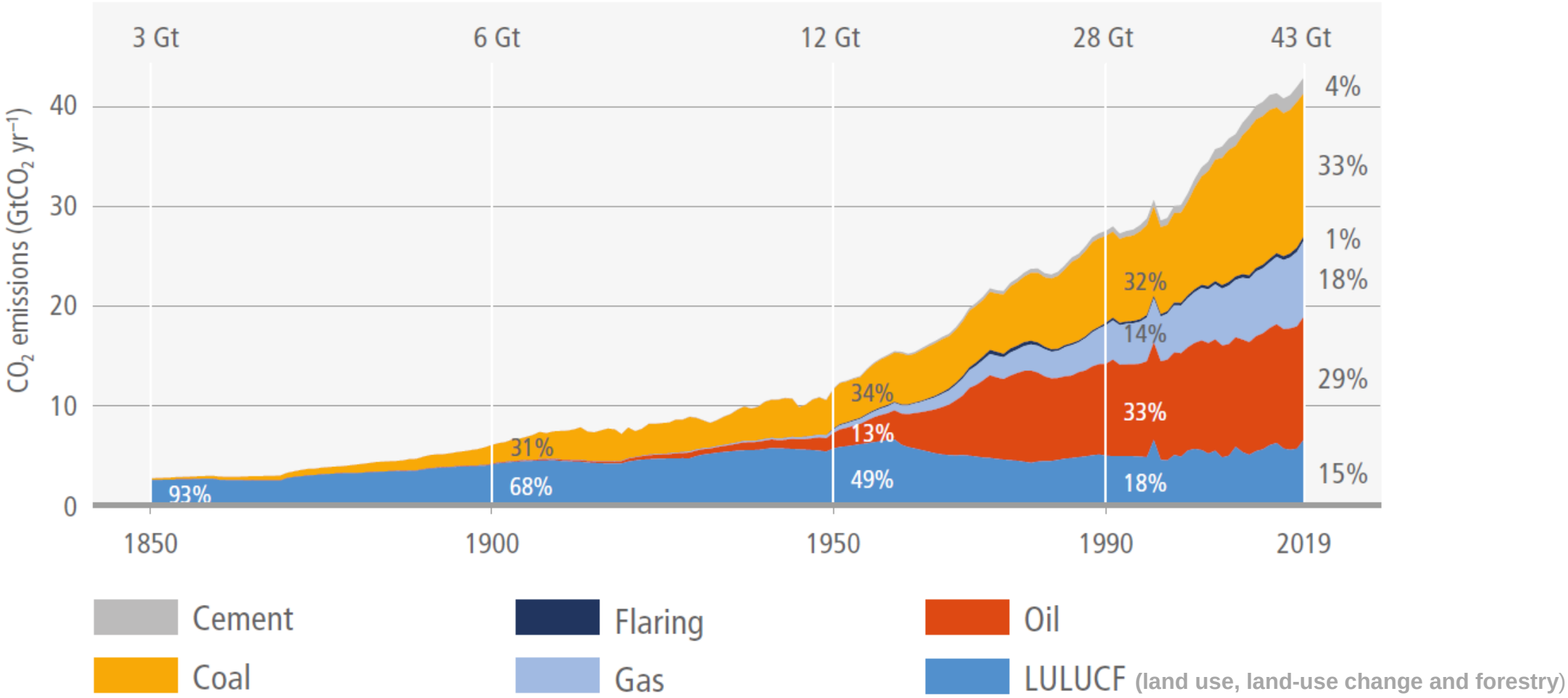
Long term global trend of anthropogenic CO2 emissions sources



(IPCC AR6 WGIII, 2022)

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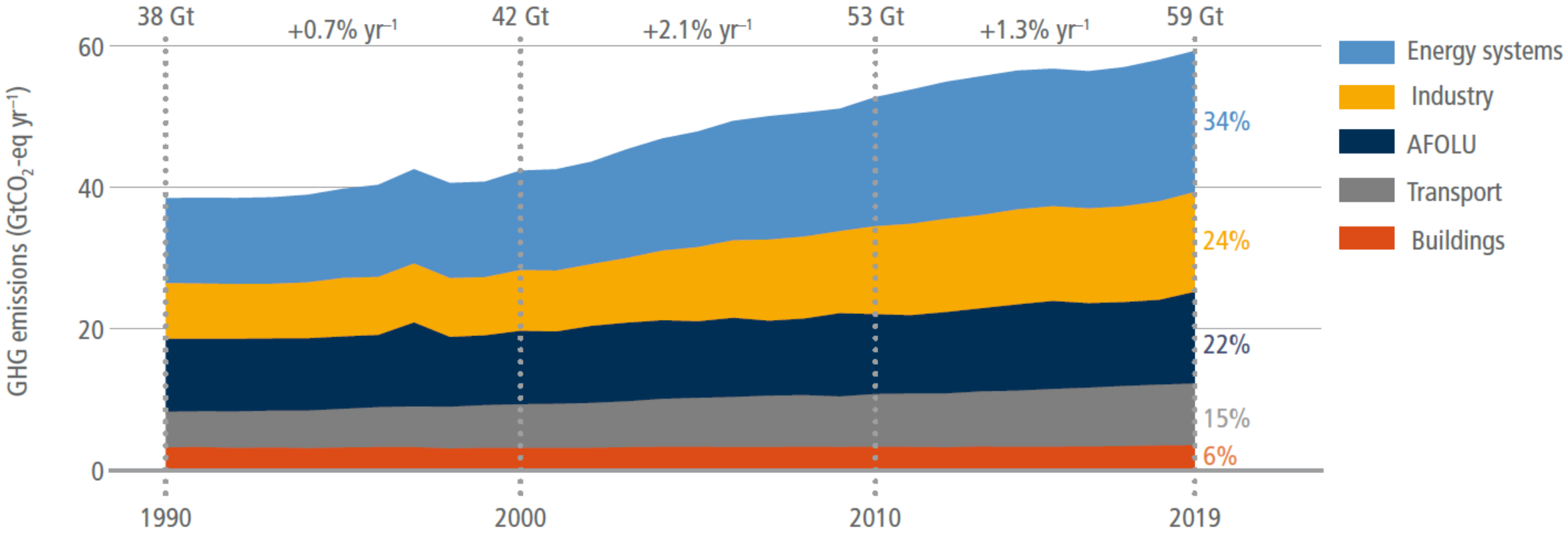
Trends and drivers of global GHG emissions, by sectors 1990–2019



Most of the 14 GtCO2-eq from electricity and heat generation (23% of global GHG emissions in 2019) were due to energy use in industry and in buildings. (IPCC WGIII, 2022)

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Percentage of CO_2 Emissions per Sector, 2018

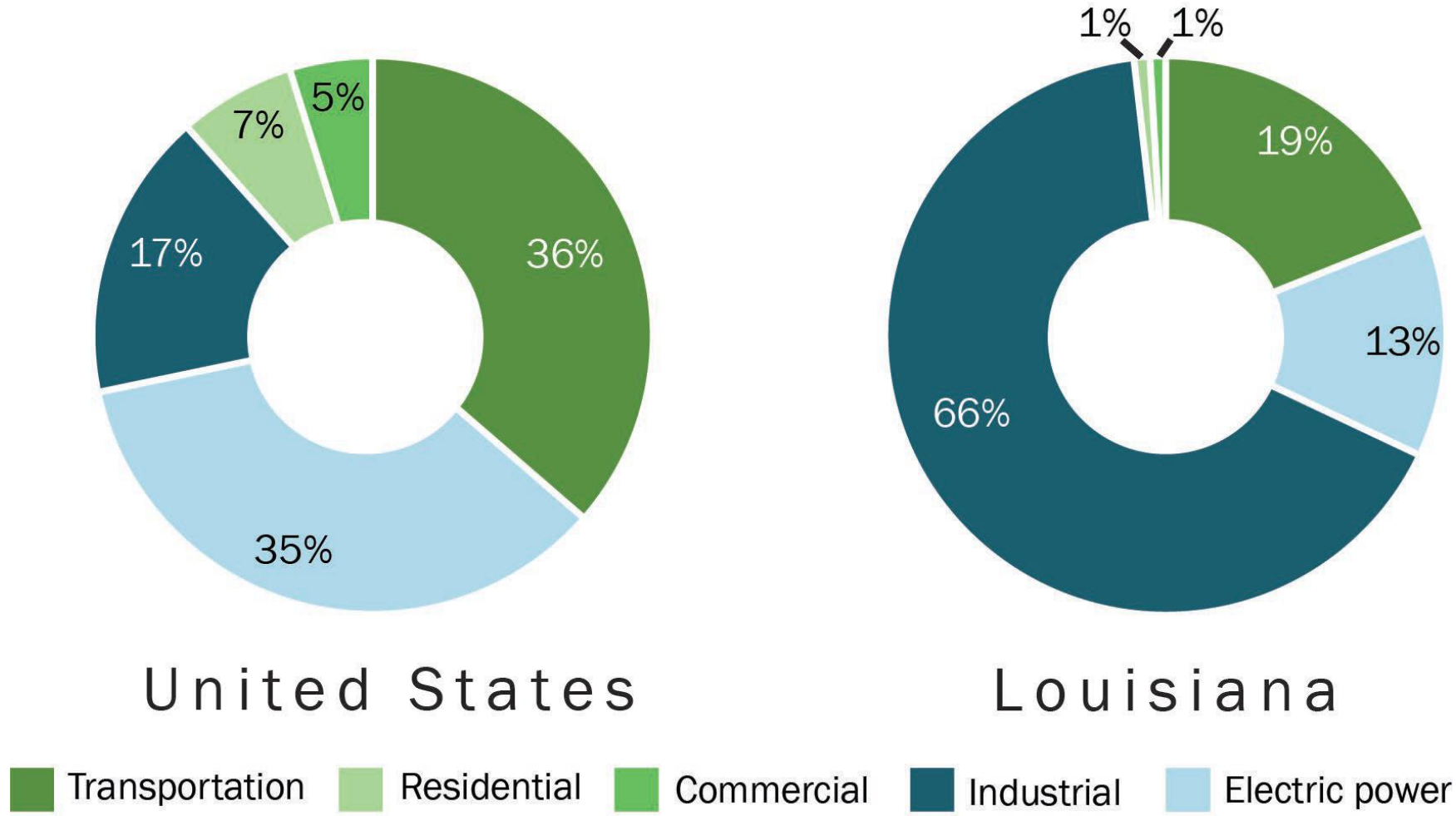

Figure 4. Summary of United States and Louisiana emissions per sector, 2018. (Source: Louisiana Climate Action Plan, 2022)

Power Generation Fuel Mix, 2019

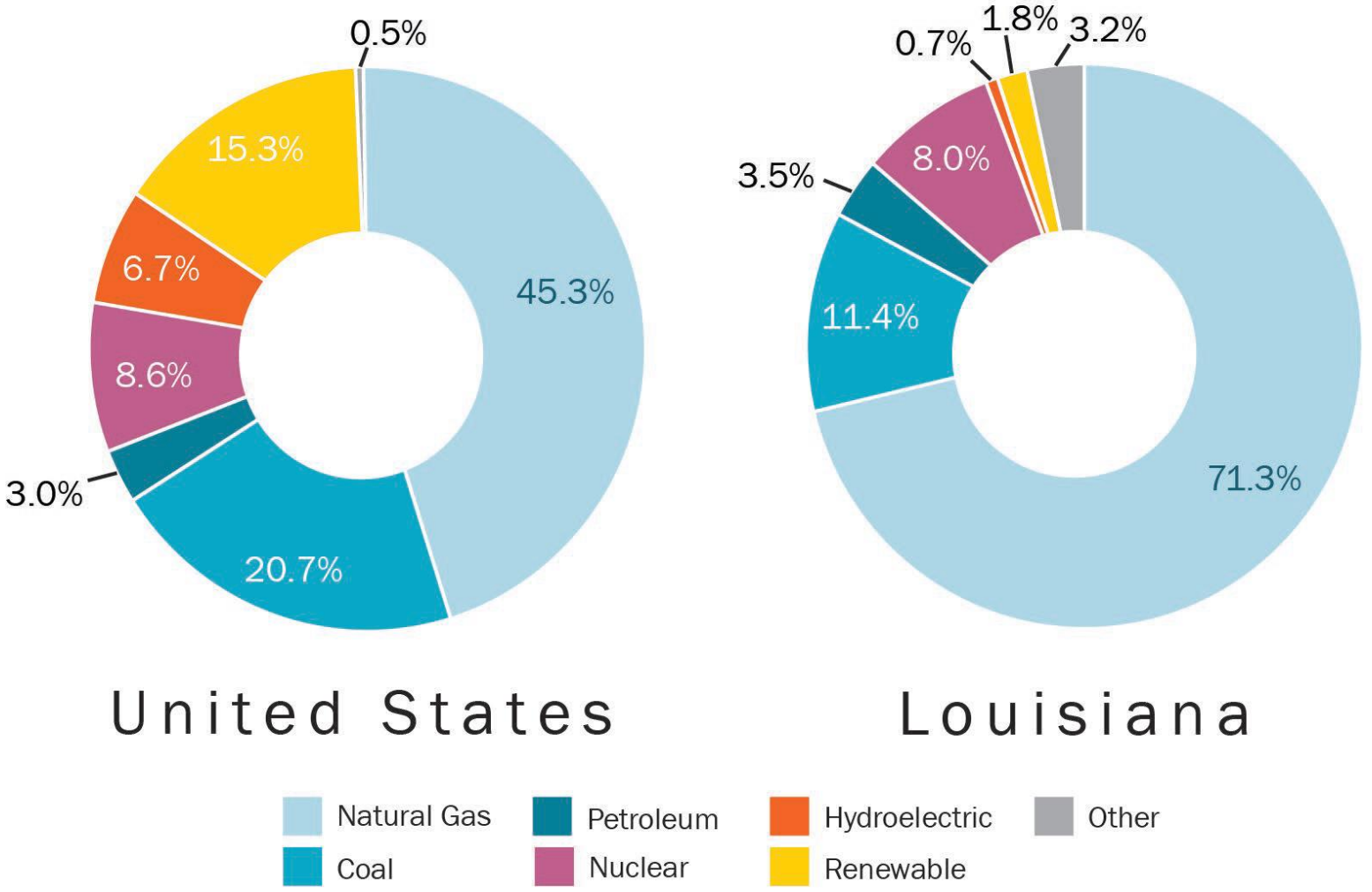

Figure 5. Comparison of power generation fuel mix in the United States and Louisiana in 2019. (Source: Louisiana Climate Action Plan, 2022)

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Louisiana Observed and Projected Temperature Change

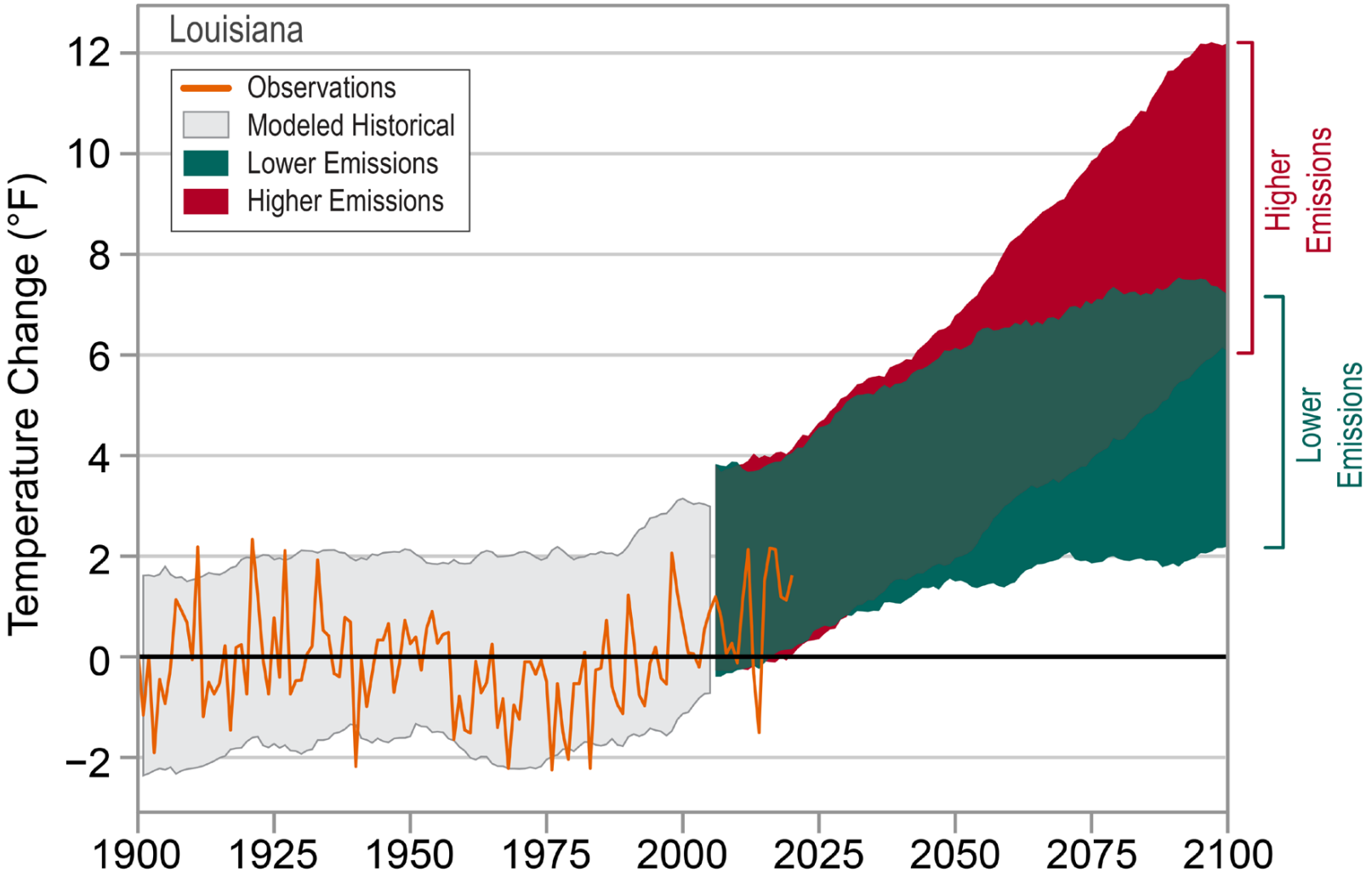

Figure 10. Observed and projected changes (compared to the 1901–1960 average) in near surface air temperature for Louisiana (from NOAA NCEI, Louisiana State Climate Summary, 2022).

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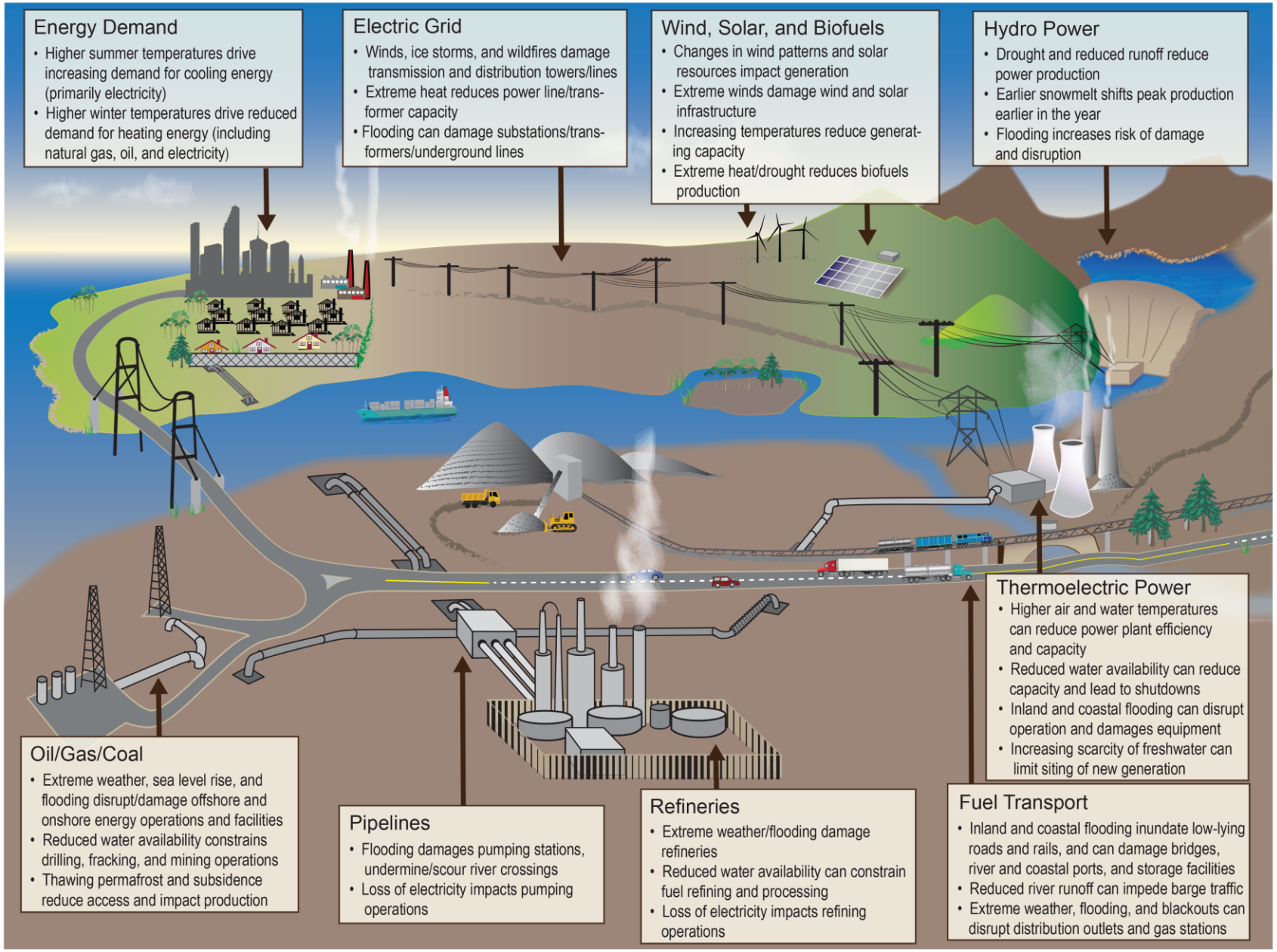
Potential Impacts from Extreme Weather and Climate Change

Extreme weather and climate change can potentially impact all components of the Nation's energy system, from fuel (petroleum, coal, and natural gas) production and distribution to electricity generation, transmission, and demand.

(NCA4, Chapter 4, 2018)



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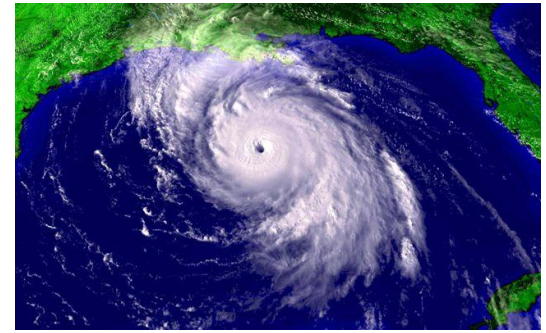
Post Hurricane Ivan, ENSCO platform off the Louisiana Coast



Post Hurricane Lilli, BP platform off the Louisiana Coast

Wildfire in Sabine Parish This week

Toledo Bend Dam, Hydropower, TX and LA

Projected change in hours worked in 2090 (%)

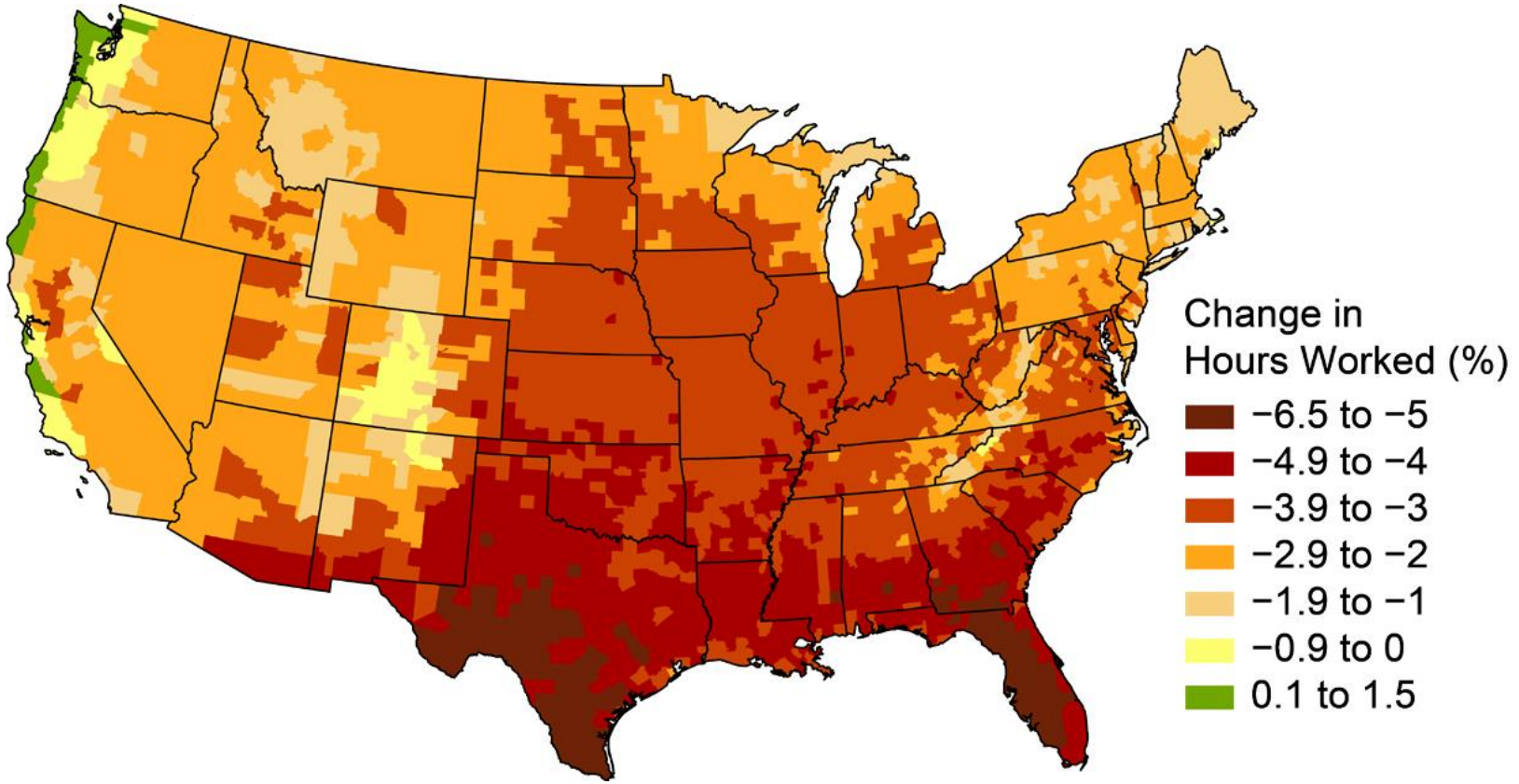


Figure 11. This map shows the estimated percent change in hours worked in 2090 under a higher scenario (RCP 8.5, from NCA4, 2018).

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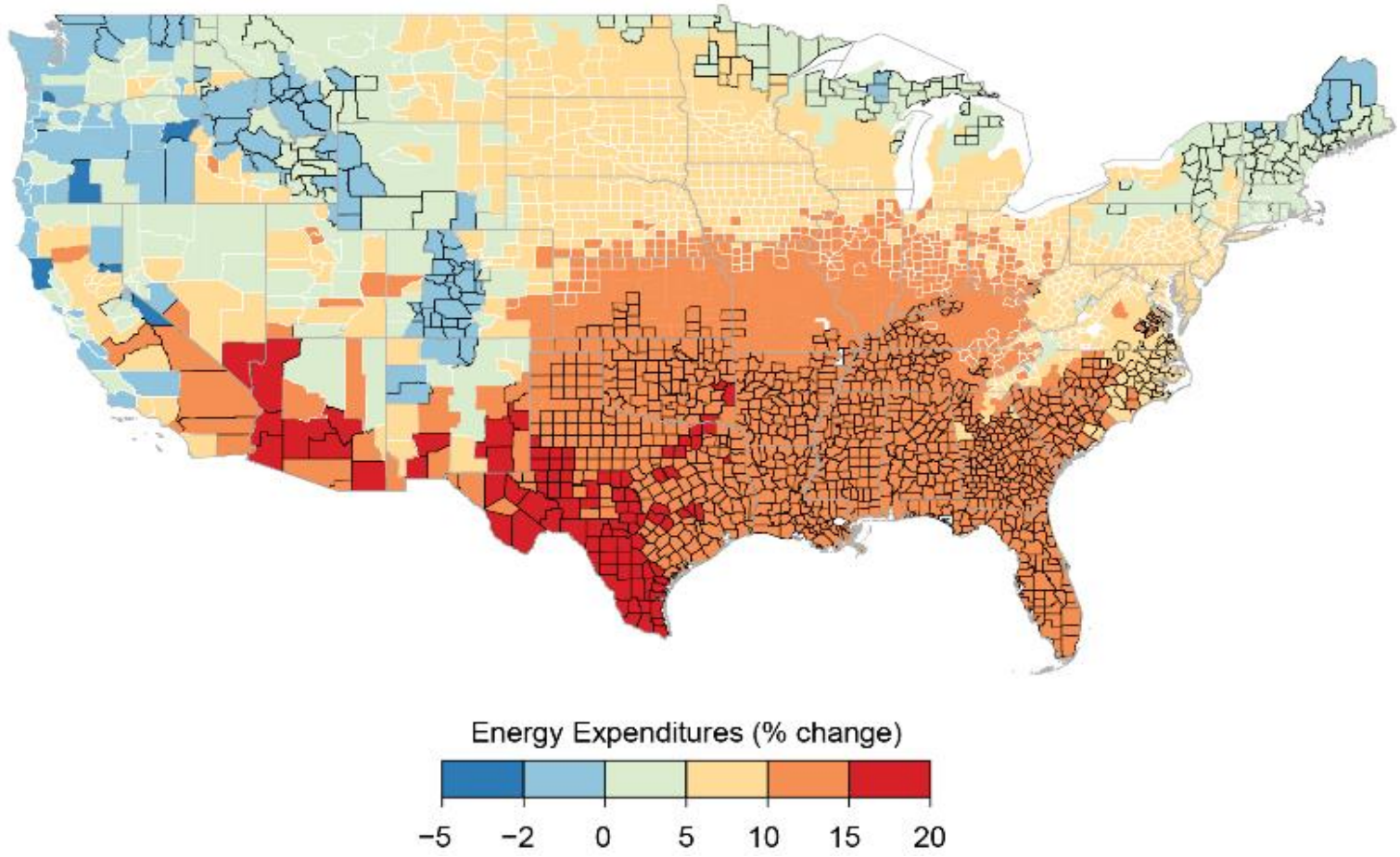
Key messages - Energy Supply, Delivery and Demand
(NCA4, Chapter 4, 2018)

1. **The Nation's energy system is already affected** by extreme weather events and, due to climate change, it is projected to be increasingly threatened by more frequent and longer-lasting power outages affecting critical energy infrastructure and creating fuel availability and demand imbalances.
2. **Changes in energy technologies, markets, and policies are affecting the energy system's vulnerabilities** to climate change and extreme weather. Some of these changes increase reliability and resilience, while others create additional vulnerabilities.
3. **Actions are being taken to enhance energy security, reliability, and resilience** with respect to the effects of climate change and extreme weather.



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: NCA4, Chapter 4, credit: Hsiang et al. 2017.*

Energy Sector Resilience Solutions

Solutions are being deployed in the energy sector to enhance resilience to extreme weather and climate impacts across a spectrum of energy generation technologies, infrastructure, and fuel types.

The figure illustrates resilience investment opportunities addressing specific extreme weather threats, as well as broader resilience actions that include grid modernization and advanced planning and preparedness.

Photo credits (from top): Todd Plain, U.S. Army Corps of Engineers; Program Executive Office, Assembled Chemical Weapons Alternative; Lance Cheung, USDA; Idaho National Laboratory (CC BY 2.0); Darin Leach, USDA; Master Sgt. Roy Santana, U.S. Air Force.

Source: NCA4, Ch. 4, 2018, Energy Supply, Delivery, and Demand

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

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