Climate Change Impact on Engineering Design Parameters for Utility-Scale Renewable Projects

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Intro

Utility-scale **wind**, **solar**, and **storage** projects are designed to operate for 30+ years. However, climate change, particularly extreme temperatures, may impact their long-term resilience and efficiency.

Wind Impact: Extreme temperatures may compromise wind turbine suitability, performance, and reactive power design.

Solar Impact: Temperature changes can affect solar string sizing, inverter selection, and thermal losses, which are critical for maintaining reliability and performance.

Storage Impact: Temperature extremes can reduce BESS capacity and efficiency, affecting energy storage reliability.

Methods

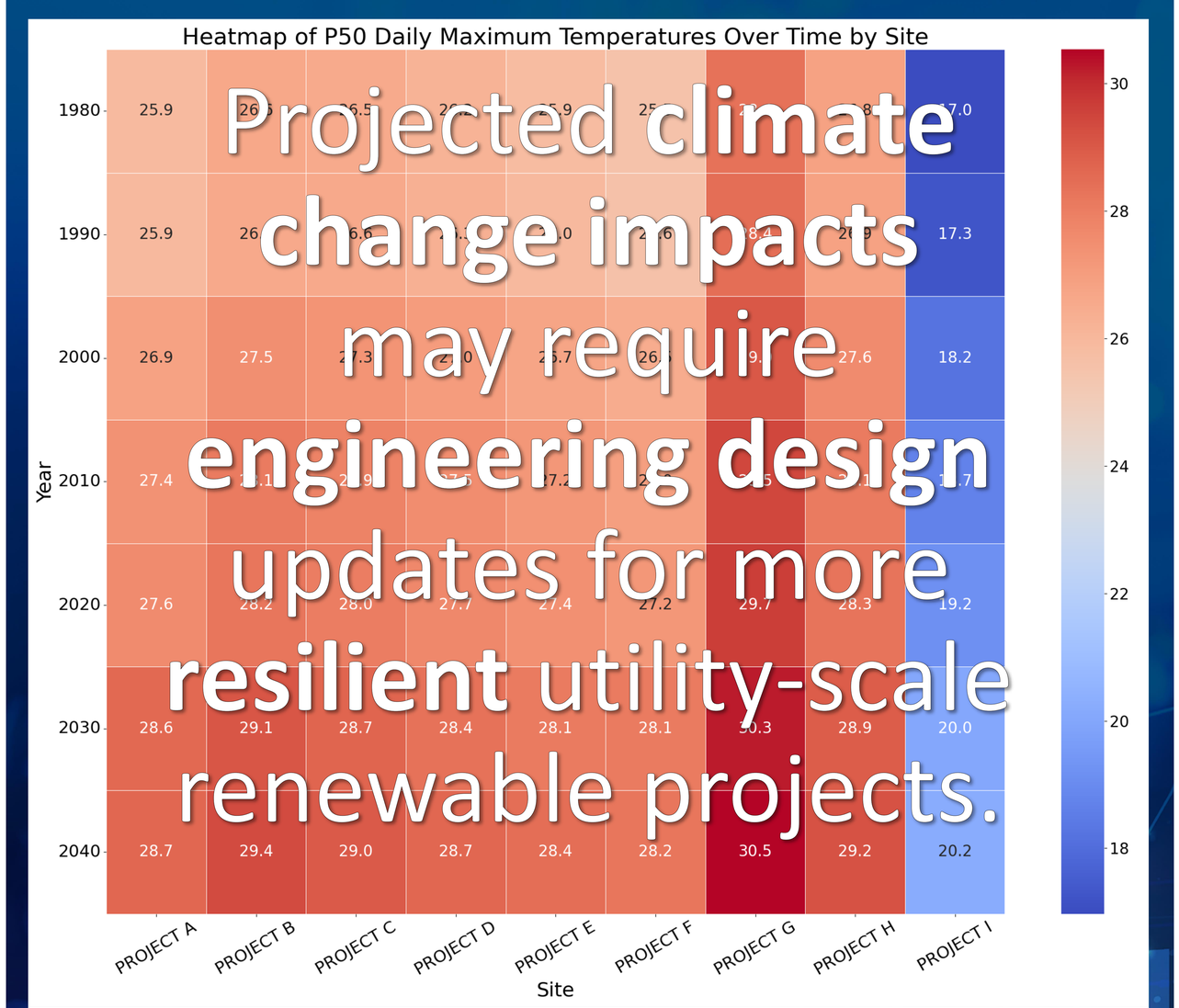
1. Analysis based on **12-member simulation ensemble** of six General Climate Models from the CMIP6 framework[1], focusing on the SSP585 high-emission scenario.
2. DBCCA Downscaled to **1/24° or 4 km spatial resolution** using Daymet and Livneh reference training datasets.
3. **Daily minimum and maximum temperatures** were extracted for nine ENGIE sites from gridded netCDF datasets spanning a **temporal range of 1980 – 2049**.
4. Baseline (1980–2019) temperature statistics were compared with projections for 2020–2039 and 2020–2049, visualizing changes over time.

Results

- P50 daily minimum and maximum temperatures are expected to **rise by 1.1 – 2.0 °C** across all sites over the next 20-30 years.
- Frequency of days above 40 °C per decade expected to **increase to 167 by 2050**; In contrast, frequency of days below 0 °C per decade expected to **decrease by 50%**.
- Largest observed change compared to baseline:
  - Minimum temperature: +4.8 °C, PROJECT E
  - Maximum temperature: +2.7 °C, PROJECT F

Discussion

- **Median temperatures are expected to rise**, with site-specific variations in extreme temperatures.
- Extreme **high temperatures** will become **more** frequent.
- Extreme **low temperatures** will become **less** frequent.
- Projected temperature increase will prompt changes in design parameters for renewable projects.



Projected **climate change impacts** may require **engineering design** updates for more **resilient** utility-scale renewable projects.

Table 1. Description of ENGIE sites used in analysis.

PROJECT NAME	LOCATION	TECHNOLOGY
PROJECT A	Jones County, TX	Solar
PROJECT B	Crockett County, TX	Wind
PROJECT C	Bell County, TX	Solar
PROJECT D	Limestone County, TX	Solar
PROJECT E	Navarro County, TX	Solar
PROJECT F	Callahan County, TX	Storage
PROJECT G	Goliad County, TX	Solar
PROJECT H	Milam County, TX	Solar
PROJECT I	White County, IN	Solar

Table 2. Description of General Climate Models (GCMs) used in analysis.

MODEL	INSTITUTE, COUNTRY OF ORIGIN	RESOLUTION (LAT X LON, VERT.)
ACCESS-CM2	CSIRO and Bureau of Meteorology, Australia	1.25°×1.875°, 85 levels
BCC-CSM2-MR	Beijing Climate Center, China	1.125°x1.125°, 46 levels
CNRM-ESM2-1	CNRM-CERFACS, France	0.9375°x0.9375°, 91 levels
MPI-ESM1-2-HR	Max Planck Institute for Meteorology, Germany	0.9375°x0.9375°, 95 levels
MRI-ESM2-0	Meteorological Research Institute, Japan	1.125°x1.125°, 80 levels
NORESM2-MM	Norwegian Climate Centre, Norway	0.9375°x1.25°, 32 levels

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Tables, Figures & Graphs

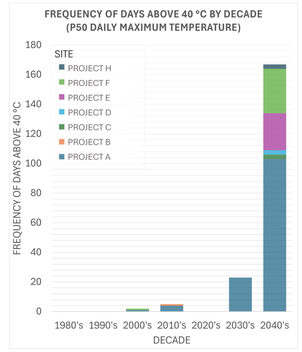

Figure 1. Frequency of days above 40 °C by decade.

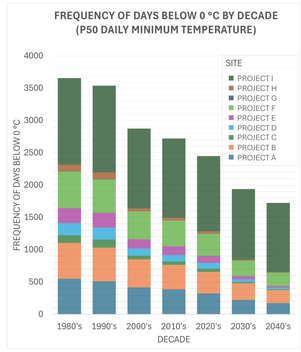

Figure 2. Frequency of days below 0 °C by decade.

Table 3. Temperature extremes by site during each period.

Project Name	Temperature Extremes	Temperature (°C) 1980-2019 (Baseline)	2020 to 2039	2020 to 2049
PROJECT A	Minimum	-21.9	-18.3	-19.0
	Maximum	45.9	48.3	48.3
PROJECT B	Minimum	-21.1	-18.7	-18.7
	Maximum	44.1	46.4	46.4
PROJECT C	Minimum	-17.9	-14.0	-16.3
	Maximum	43.2	44.0	45.2
PROJECT D	Minimum	-19.2	-14.6	-14.7
	Maximum	43.1	43.9	45.4
PROJECT E	Minimum	-20.3	-14.9	-15.5
	Maximum	43.8	44.0	46.3
PROJECT F	Minimum	-23.4	-16.6	-21.8
	Maximum	42.5	44.7	45.2
PROJECT G	Minimum	-13.1	-9.9	-15.5
	Maximum	43.5	43.9	45.2
PROJECT H	Minimum	-17.3	-13.1	-15.5
	Maximum	43.3	44.3	45.2
PROJECT I	Minimum	-38.2	-34.5	-34.5
	Maximum	39.2	40.7	41.1

References

[1] Kao, S.-C., Ashfaq, M., Rastogi, D., & Gangrade, S. (2022). The Third SECURE Water Act Section 9505 Assessment. U.S. DOE. https://doi.org/10.21951/swa9505v3/1887469

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