Sandia National Laboratories

Building Energy and Resilience Modeling

Sandia National Laboratories conducts combined energy efficiency and resilience studies for communities, cities, and institutions using building energy and resilience modeling (BERM), building system data, and climate data. Combined with analyses of the electric grid and other networks, Sandia's studies provide a holistic view of buildings' energy use and supplies to improve efficiency and resilience.

IMPORTANCE OF BUILDINGS

The buildings sector presents a significant opportunity to improve both resilience and efficiency. In 2023, residential and commercial buildings accounted for 36.9% of total U.S. energy consumption, highlighting the significant impact of the sector on energy use.[1] Efficient buildings reduce strain on the grid, reduce costs, and enable growth in new locations. Additionally, buildings designed with increased resilience can offer dual advantages. More resilient buildings can offer increased comfort and productivity for occupants, provide shelter that better withstands disruptions and the effects of natural disasters, and allow for quicker restoration to operation following emergencies.

Achieving Resilient and Efficient Buildings

Increasing buildings' resilience and efficiency requires a multi-disciplinary, systems-wide approach. Emerging challenges include assuring buildings are:

1) Ready for the worst of floods, storms, wildfires, and extreme heat or cold;
2) Can provide clean air and a comfortable environment to occupants;
3) Prepared to directly integrate and exchange data with future smart electric grid and gas networks
4) Able to provide uninterruptable power for critical functions; and
5) Able to give owners a competitive edge through direct participation in energy markets.

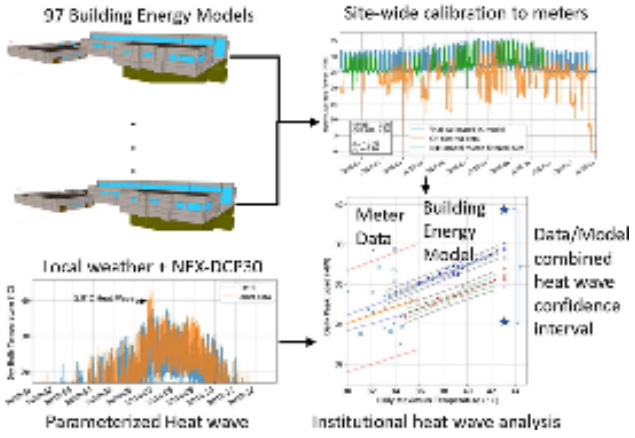
Essential solutions to reduce buildings' energy use include energy efficient technologies, such as light emitting diodes and high efficiency motors, fans, and heat pumps. Combined with smart control systems, these technologies can greatly reduce energy use. New technologies such as smart windows, ambient temperature thermal loops, and new kinds of insulation can also greatly enhance building performance. Onsite electricity generation and storage is becoming more cost-effective as well, making continuous electric service increasingly common.

Optimal solutions for combined energy consumption and production will require integrated efforts to generate, use, and store energy efficiently. When incorporated into infrastructure analysis, BERM enables stakeholders to consider realistic tradeoffs between efficiency, resilience, and other competing priorities.

ENHANCING RESILIENCE AND EFFICIENCY

Sandia is working on new applications of BERM, including detailed analysis of existing buildings, multi-sector infrastructure analysis, and extreme weather effects on energy consumption and thermal safety.

Sandia has invested in 120 building energy models (BEMs) of its own site that have been used for studies such as the site-wide heat wave sensitivity study shown below.

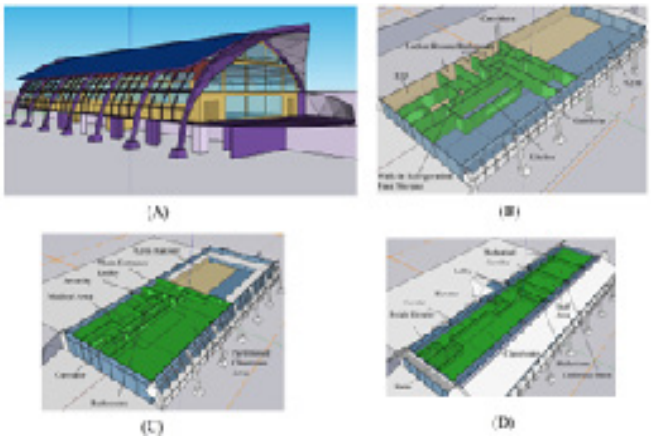


Fusing BERM, historic data, and climate projections helps planners identify opportunities to increase resilience and efficiency, such as this analysis which examines sensitivity to heat waves for buildings at Sandia (Villa, 2021).

Sandia's BEMs have established new ways to evaluate energy efficiency for Sandia's New Mexico and California (CA) sites. For Sandia's CA site, it is planned to use the BEMs to help establish a smart campus with added energy efficient and resilient features.

[1] https://www.eia.gov/tools/faqs/faq.php?id=86&t=1

Sandia also provides BERM analysis of resilience hubs being created for communities that are hard to reach after storms and provide 30 days of support to surrounding areas. Sandia's work in Hau'ula, Hawai'i, showed that highly efficient thermal systems are likely to pay for themselves due to the reduced need for fuel, batteries, and renewable power sources in the resilience hub microgrid. For thermal resilience, it was verified that air conditioning was not needed even for worst case heat, except in three key thermal shelters which included staff areas and the medical clinic (Villa et al., 2023).



Resilience hub BERM in Hau'ula, HI showing three levels (A) isometric view with covered parking (B) lower floor, (C) main entrance floor, and (D) upper floor. Model created by Sandia and design is by +Lab Architect, PLLC.[2]

Research at Sandia includes coordinated BERM and electric grid studies, thermal systems studies for connected communities, software development to enable extreme weather analyses, and tiered circuits effects evaluations for combined building-microgrid analyses, including off-grid cases.

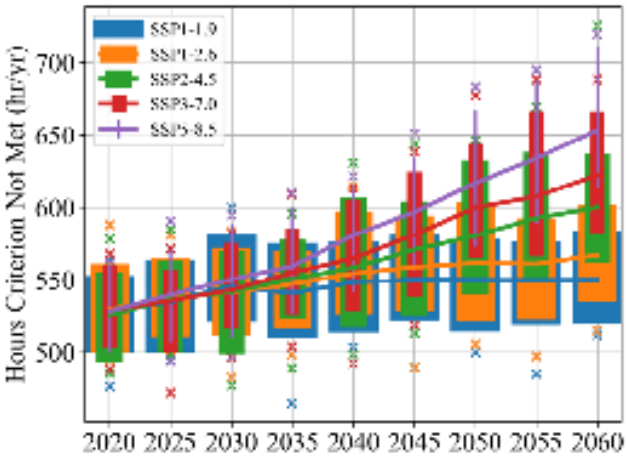
FEATURED STUDIES

- Villa, Daniel et al., 2024. "Futures for electrochromic windows on high performance houses in arid, cold climates." Energy and Buildings 315:114293. 10.1016/j.enbuild.2024.114293
- Villa, Daniel et al., 2023. "Multi-scenario Extreme Weather Simulator application to heat waves: Ko'olauloa community resilience hub." Science and Technology for the Built Environment 30(4): 375-393. 10.1080/23744731.2023.2279467
- Villa, Daniel, 2021. "Institutional heat wave analysis by building energy modeling fleet and meter data." Energy and Buildings 10.1016/j.enbuild.2021.110774

FEATURED TOOLS

Multi-Scenario Extreme Weather Simulator (MEWS)

The multi-scenario extreme weather simulator (MEWS) has been developed for extreme weather boundary conditions BERM analyses. MEWS uses historical weather and climate projections to output weather files that include intensification of heat for future conditions.
www.github.com/sandialabs/MEWS



An analysis produced by MEWS projects thermal resilience in an office building experiencing extreme heat waves.

Tiered Energy in Buildings (TEB)

A tool called Tiered Energy in Buildings (TEB) has been created, in collaboration with the micro-grid design analysis for the El Caño community in San Juan, Puerto Rico. As part of the analysis, the TEB tool helped illustrate how tiered configurations of residential and community center loads could reduce the cost of microgrids while increasing microgrids' ability to reliably supply critical loads.
www.github.com/sandialabs/TEB

WORK WITH US

We partner with other national laboratories, universities, manufacturers, communities, and industry to pursue transformative energy efficiency and advanced manufacturing solutions.

[2] Azaroff, I. 2023. https://www.pluslabglobal.com

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U.S. DEPARTMENT of ENERGY NNSA National Nuclear Security Administration

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