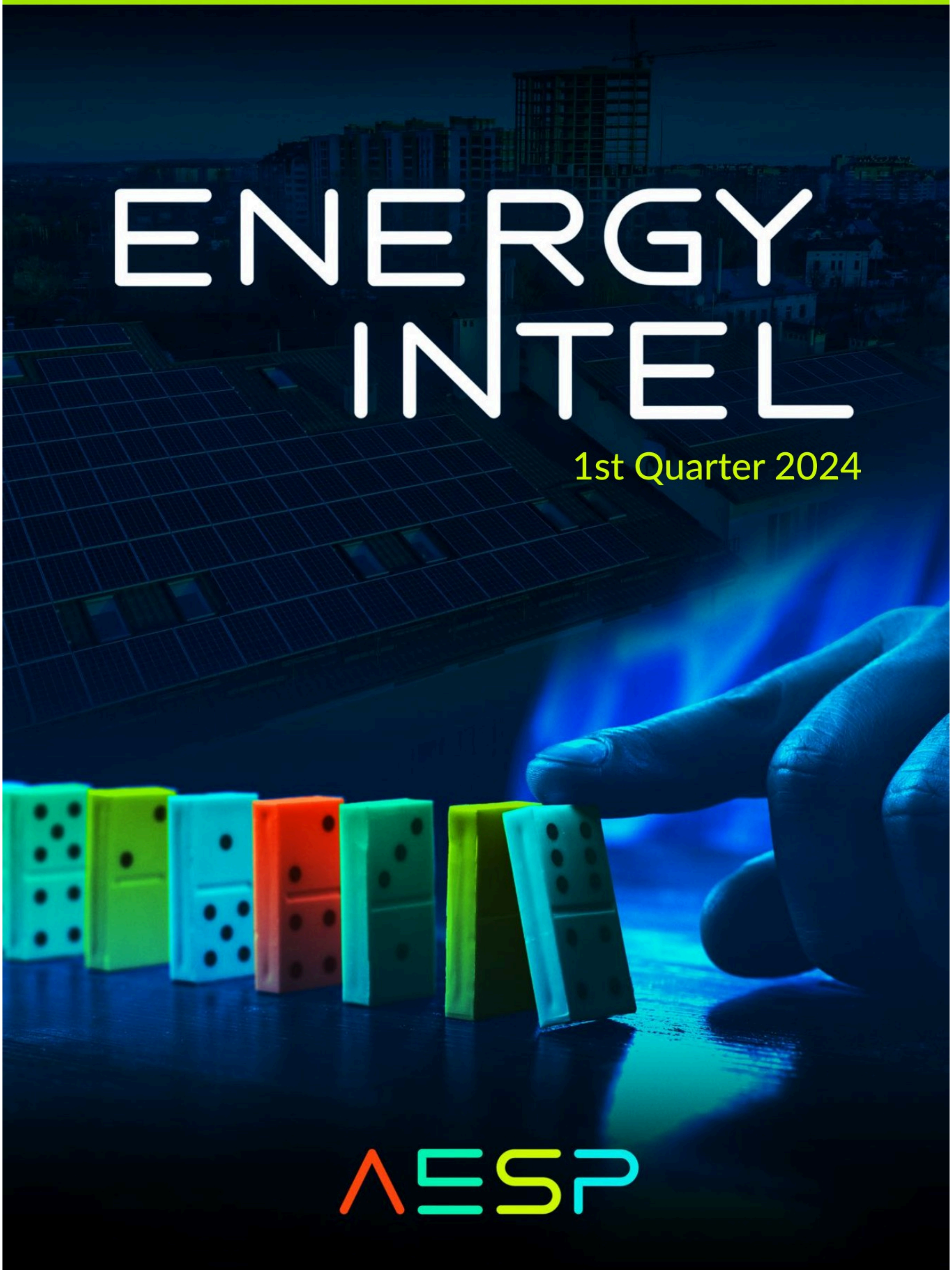
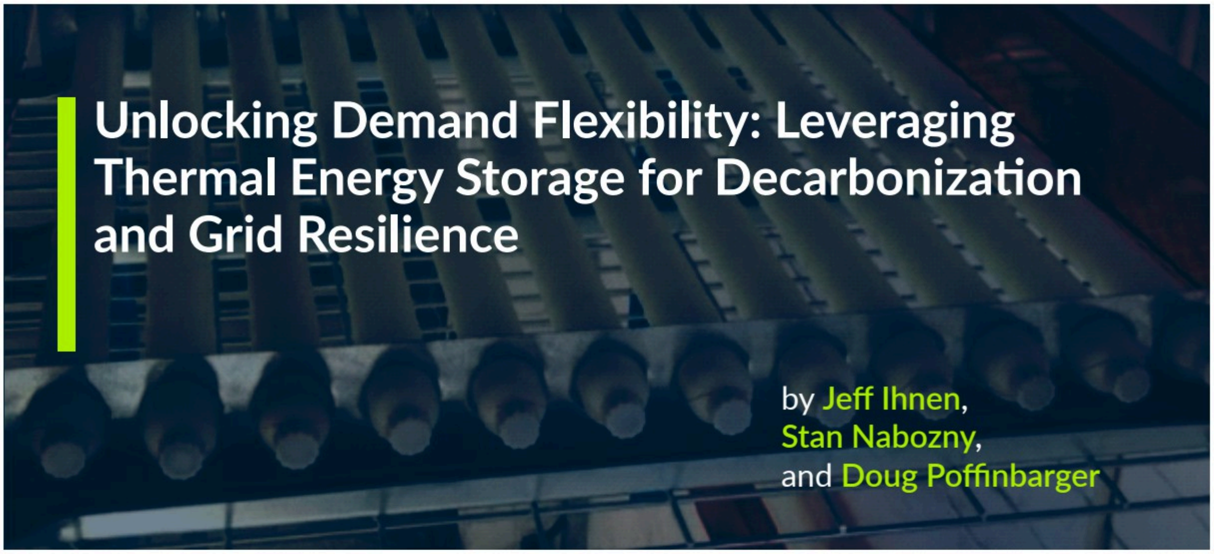
Demand Flexibility | EE and DER for Multifamily and Small and Midsize Businesses (SMB)
Community Engagement and Empowerment | Innovative Rate Design

ENERGY INTEL

1st Quarter 2024



AESP



Unlocking Demand Flexibility: Leveraging Thermal Energy Storage for Decarbonization and Grid Resilience

by Jeff Ihnen,
Stan Nabozny,
and Doug Poffinbarger

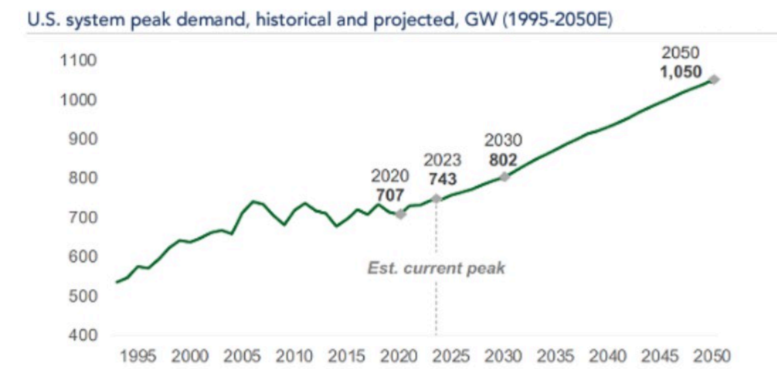
In today's rapidly evolving energy landscape, building owners and utilities face challenges such as demand for energy, coupled with the imperative to reduce carbon emissions and maintain operational flexibility. Thermal Energy Storage (TES) emerges as a promising technology, offering a versatile approach to address these challenges across various sectors, including refrigeration, chilled water, and rooftop unit HVAC. Given that cooling loads constitute roughly 25 percent of the total U.S. grid load, equivalent to approximately 185 gigawatts, leveraging TES presents a significant opportunity to effectively balance the grid.

Utilities across the United States have a challenge as electric loads surge due to electrification trends in both transportation and buildings with the proliferation of data center for AI, and crypto mining. This surge in demand, compounded by the intermittent nature of renewables, leads to rising prices, shrinking reserve margins, and a general shortfall in capacity. Utilities or merchant generators find themselves grappling with this insufficient reserve margins, resorting to costly methods like permanent or portable gas peaker plants. The transition away from baseload and load-following thermal power plants exacerbates these challenges, heightening the risk of rolling outages.

The duck curve, once emblematic of California and Arizona, is now spreading across the continental United States and Hawaii. It shows the non- renewable electricity (fossil-based, mostly) supplied by the grid in each 24-hour period. As can be seen in this California example, every day during the afternoon and evening, the grid needs to add 18 GW to replace the solar, and power up dozens of power plants to do so. This phenomenon amplifies the risk of outages. As the demand for electricity peaks, the strain on the grid intensifies, necessitating proactive measures to enhance grid resilience and stability.

Thermal Energy Storage as a DER and VPP

Virtual Power Plants (VPPs) stand out as a crucial component in the energy transition. VPPs aggregate various distributed energy resources, including solar photovoltaic (PV) systems, wind turbines, energy storage systems, and demand response technologies, to function as a unified power generating entity. By harnessing the capabilities of diverse DERs, VPPs offer a flexible, scalable, and dynamic approach to energy management.



Note: National coincident peak demand is based on sum of peaks across FERC regions.
Source: Historical energy demand sourced from AEO. Coincident peak demand (point-in-time peak, not total energy consumption) estimated by The Brattle Group (2023) based on forecasted total energy consumption sourced from OP-NEMS mid-case scenario. This mid-case scenario includes increasing consumption from industrial electrification and electrification of HVAC; however, the EVs contribute the most demand to coincident peak according to estimated hourly consumption patterns that will vary by region.

As the United States advances towards its renewable energy goals set by the Department of Energy (DOE) for 2030, there is a need to bolster the nation's energy infrastructure to accommodate the increasing demand on the grid to over 800 GW. According to DOE projections, the country will require an additional 80-160 GW of new DER capacity by 2030 and even more by 2050 when it projects the nation’s peak load to be over 1000 GW.

Thermal Energy Storage (TES) emerges as a strategic solution that aligns with the objectives of the DOE's VPP programs. TES systems enable the efficient capture and storage of thermal energy during periods of low demand or excess renewable generation. This stored energy can then be deployed during peak demand periods or when renewable resources are unavailable, or can be dispatched, to effectively mitigat grid imbalances and enhanc overall system reliability.

The integration of TES into VPP frameworks unlocks a myriad of benefits for utilities, grid operators, and energy consumers alike. By leveraging TES capabilities within VPPs, utilities can optimize energy usage patterns, reduce reliance on fossil fuel-based generation, and relieve grid congestion. Additionally, TES-equipped VPPs enhance grid resilience by providing rapid-response capabilities and supporting load balancing during periods of peak demand or renewable intermittency.

Thermal Energy Storage for Refrigeration

Cold storage warehouses, which rank highest in consumption per square foot among occupied buildings, offer a prime starting point for TES implementation which comprised roughly 44GW of load across the United States. The potential applications extend beyond cold storage warehouses to various refrigeration settings such as grocery stores, distribution centers, and restaurants.

One of the primary advantages of TES for refrigeration lies in its ability to enhance food preservation. Through phase change energy transfer, TES ensures a stable and safe temperature environment for food storage, thereby bolstering food safety standards and reducing the risk of spoilage.

TES for refrigeration offers significant environmental sustainability benefits. With a useful lifespan of 20 years and no disposal issues, TES systems contrast favorably with the shorter lifespan of around five years for lithium-ion batteries. Additionally, TES systems pose minimal fire risks and utilize non-toxic materials like salt, water, and stabilizers, aligning with sustainability goals.

In terms of energy efficiency, TES for refrigeration provide gains ranging from 10 to 20 percent in refrigeration applications, offering opportunities for reducing energy consumption and enhancing operational efficiency. The increase in equipment efficiency occurs when "charging" the thermal energy storage during early morning and night hours by achieving the refrigeration set point with cooler ambient conditions. By strategically shifting refrigeration loads to hours with improved system efficiency, we can operate refrigeration systems at full capacity during optimal periods, reducing energy consumption and enhancing overall performance.

TES solutions qualify for a 40 percent tax credit through the Inflation Reduction Act, enhancing their financial attractiveness and supporting widespread adoption in commercial sectors with less than a three-year payback period.

From a cost perspective, TES for refrigeration systems exhibit a significantly lower Levelized Cost of Energy (LCOE) of $.02/kWh compared to lithium-ion batteries, which average around $.20/kWh. This cost-effectiveness makes TES a more appealing long-term investment for refrigeration applications.

Refrigerated Warehouse Case Example
In a small cold storage warehouse, TES successfully shifted 80 percent of the load during the peak period. Operating at 0F in a 50,000 sq. ft. facility, TES displaced 350 kW of electric load for five hours. **Try that with a battery!**

This application also reduced energy consumption by 14 percent by allowing the TES system to charge at night when its cooler outside, allowing the refrigeration system to operate at its full-load maximum efficiency. Conversely, electric batteries waste energy with round-trip losses and standby parasitic losses to condition their storage containers.

The distribution of PCM in the freezer room not only leads to substantial energy savings but also enhances temperature stability, safeguarding food integrity. When refrigeration equipment is turned off, cold air falls, maintaining consistent temperatures, offering peace of mind during refrigeration or grid failures. With a 10-hour storage capacity, these benefits can be extended as needed, providing additional backup protection for food in unforeseen circumstances.

Installing PCM facilitates a reduction in defrosting energy by removing at least one defrost cycle during a peak period, resulting in energy savings and decreased compressor workload. All installations are validated through revenue-grade metering and measurement and verification processes, ensuring accurate assessment and verification of achieved savings.

Thermal Energy Storage for HVAC

Across the United States, chilled water air-conditioned office buildings command approximately 21 percent of the office building market. This sizable market share translates to a substantial energy demand, with a total load of approximately 24 gigawatts (GW) on the grid nationwide. Notably, HVAC systems typically account for a significant portion of a building's energy consumption, with around 35 percent of the total load attributed to cooling needs. This highlights the immense potential for TES to optimize energy usage and alleviate strain on the grid during peak demand periods.

By reducing HVAC energy costs for commercial buildings, behind-the-meter storage also improves building profitability. Instead of pulling electricity from the grid during periods of high demand, behind-the-meter technologies let commercial buildings make use of their own previously stored energy. Building owners can now decide when to purchase energy from the grid, this positively supports a building’s bottom line.

The recent passage of the Inflation Reduction Act — which offers 30 to 50 percent tax credits for standalone energy storage technology — means commercial buildings have an even greater incentive to invest in behind-the-meter energy storage technology, and are now directly supported by government funding. Also, those who may have previously been wary of battery energy storage due to concerns about toxic materials and fire hazards now have access to groundbreaking technologies that store energy without the use of lithium batteries. For example, **new ice-based energy storage technologies** use clean energy during the day to freeze water, and utilize this ice to support HVAC cooling systems during peak demand hours.

Behind-the-meter energy storage presents a massive opportunity for building owners and operators to profitably address the need to improve sustainability. As commercial buildings account for more than a third of electricity consumption in the United States, energy storage also has a clear role to play in fighting climate change as well. With effective, affordable, and safe technologies now available, the commercial building sector is poised to execute a much-needed reduction in carbon emissions.

Take Back Control of your Energy: Implementing TES

So, if buildings have little say in what energy it uses, what real and meaningful choices do business and building managers have in reducing their carbon emissions?

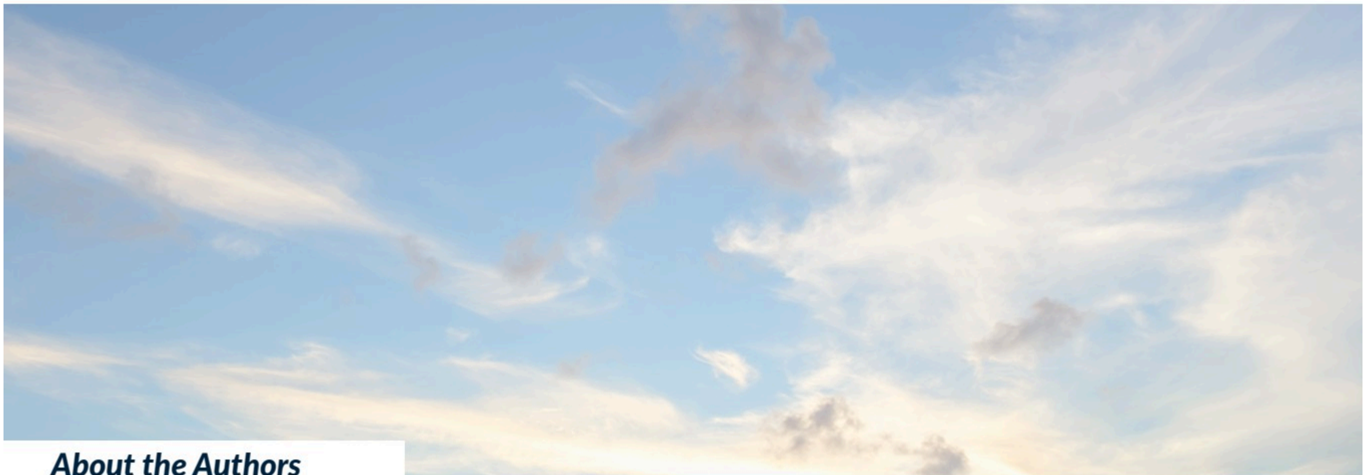
The answer is by implementing technology. Through installing TES, we can transform the way our buildings and air conditioning systems are powered. With TES, there is no need to change the way air conditioning systems are used but rather, the way we power them and our buildings through onsite renewable energy sources.

TES can use renewable energy to charge at times when it is available and discharge when the grid uses fossil fuels, ensuring a building is predominantly using sustainable energy. This would reduce a building’s carbon footprint as well as lead to long-term cost savings as it would avoid using energy during peak hours when electricity is most expensive.
The technology is there, but we need to invest in it to ensure the results are seen as quickly as possible.

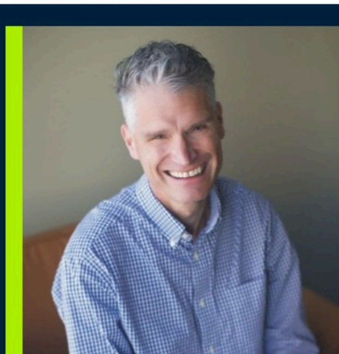
Now is the time to take a giant leap towards a sustainable and responsible approach to cooling and heating, setting a positive example for generations to come.

Conclusion

In summary, Thermal Energy Storage serves as a pivotal strategy for load shifting, enabling facilities to harness operational benefits during off-peak hours and subsequently leveraging stored energy during peak demand periods. TES offers a promising solution to address energy and decarbonization challenges. As the United States progresses towards a greener energy future, harnessing the capabilities of TES technology holds the promise of unlocking substantial benefits, strengthening energy resilience, and fostering a sustainable tomorrow.



About the Authors



Jeff Ihnen CEO, Michaels Energy

Jeff Ihnen, CEO of Michaels Energy, is a thermal energy storage and distributed energy resource visionary. He presented a paper, "Thermal Energy Storage with Phase Change Materials – Shifts Load, Saves Energy, Costs Less." for the Association of Energy Engineers' 2020 World Energy Conference. He teaches residential, commercial, industrial and transportation electrification for the Wisconsin Public Utilities Institute and The Three-Leggest Stool (reliability, affordable, clean) of Decarbonization for AESP.

Stan Nabozny Director of Thermal Energy Consulting, Michaels Energy

Stan Nabozny, Director of Thermal Energy Consulting, Michaels Energy, manages market development, engineering, cost estimating, and commissioning for Michaels' thermal energy storage (TES) programs. He holds patents in TES using phase change materials and has ten years of experience in designing, sourcing, and deploying TES in multiple countries. Stan's focus to date has been TES for industrial refrigeration, shifting load off-peak, and saving energy. He leads Michaels' load management portfolio for TES in refrigeration and HVAC, as well as monitoring-based commissioning.

Doug Poffinbarger Director of Commercial Operations, Nostromo Energy

Doug Poffinbarger, Director of Commercial Operations, manages business development and deployments for Nostromo Energy Inc. Doug leads Nostromo's development of $300MM in deployments for the US DOE program and other public and private portfolio customers. Doug is an AEE Fellow, AEE Legend in Energy and past President of AEE SoCal. He is a mechanical engineer, licensed general contractor with certifications in Energy Management, Lighting Design and Auditing. Doug is also a Six Sigma Green Belt and USGBC LEED AP. Doug has managed utility demand response and power generation programs with a construction value over $500MM.