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# ENERGY INTEL

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# Thermal Energy Storage – 65 GW of DERs Ready for Deployment

Jeff Ihnen and Stan Nabozny

Federal, state, and local policies are driving a clean energy transition. But clashing forces of physics, engineering, and economics are converging to trigger grid reliability and price volatility the United States has not experienced in 120 years. Utility Dive summarizes the issues well in their 2023 outlook[1]:

- The energy transition continues in the U.S. with increasing momentum but with some \ significant bumps in the road.
- Supply chain and economic challenges persist while grid reliability and security concerns grow.
- Ambitious government and corporate decarbonization goals are also helping to drive renewable and energy storage deployments.
- Inflation, rising interest rates, and high commodity prices [particularly with rare-earth materials needed to manufacture batteries] are pressuring investments.
- Distributed energy resource supply chains are stunting expansion.
- Slow FERC action on proposed natural gas pipelines and liquefied natural gas projects is squeezing fuel supply for dispatchable generation.
- Regional transmission planning and construction takes 10-plus years to develop.
- The rise of distributed energy resources creates a larger [cyber] attack surface.
- Extreme weather conditions beyond what has been planned for in the past, especially heat waves, can lead to high electric loads, as well as wildfires and storms that can damage generators and transmission lines.

**The following headlines from recent Wall Street Journal articles paint the picture:**

**"Electric Shortage Warnings Grow Across U.S."**

**"America's Power Grid Is Increasingly Unreliable"**

**"Prep Your Tech for Power Outages and Energy Blackouts"**

**"Get Ready for Blackouts"**

**"Coming to a Town Near You: Power Blackouts"**

**"Wary of Being Left in the Dark, Americans Produce Their Own Power"**

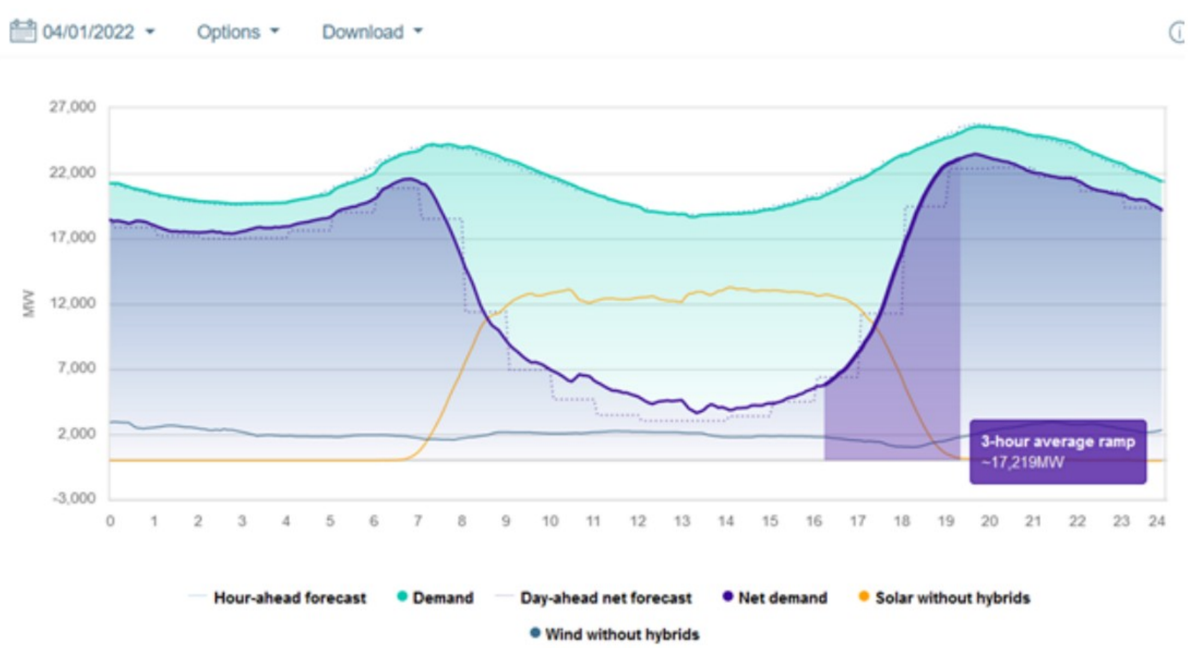
**"S.O.S for the U.S. Electric Grid"**

In our AESP training course, The Three-Legged Stool of Decarbonization (register today), the three legs represent affordable, reliable, and clean energy. It's a play on the old engineering axiom: cheap, fast, or good; pick two. Delivering all three is hard. The same applies to the energy transition. The clean attribute is leaving affordable and reliable in the dust.

Challenges with reliability and affordability are rooted in several things.

According to North American Clean Energy[2], wind generation "often varies more than 40% from one minute to the next," and a "solar photovoltaic (PV) system can transition from full power to 30 percent output in a matter of seconds." Where solar doesn't vary that fast, we have duck curves developing from California to Arizona and soon to the Eastern Interconnection, where solar photovoltaic is the leading source of new generating capacity. California sees over 5 GW per hour of net load ramp, as shown in Figure 1[3] —to be met by something—a lot of hot spinning reserves, imports, or expensive batteries.

Figure 1 CAISO Net Load




Load curves, net of renewable resources, will not get smoother. The following two charts show total renewable generation and a breakdown by type.

1 Utility Dive's 2023 Outlook for the US Power Sector Trends to Watch | 2 NA Clean Energy | 3 CAISO

Figure 2 U.S. Electric Generating Build by Fuel Type

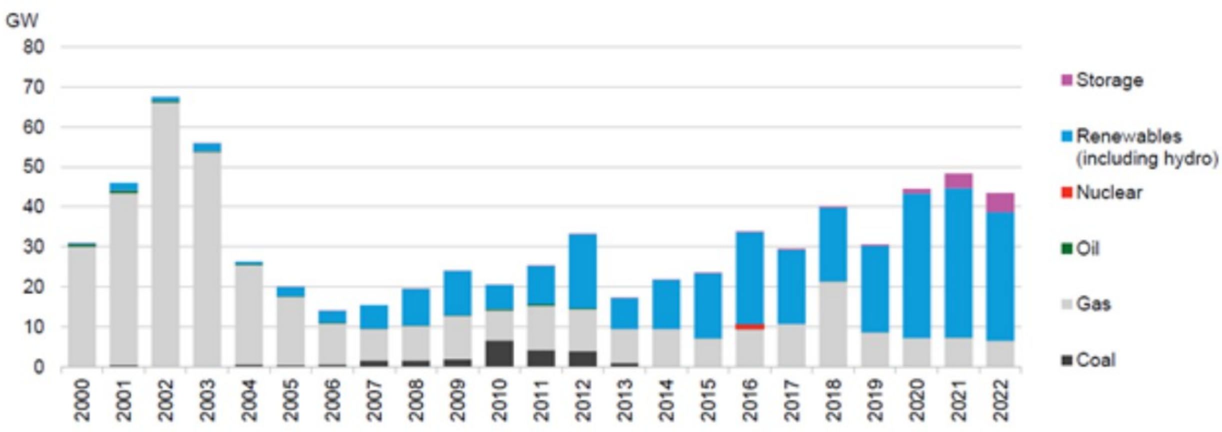
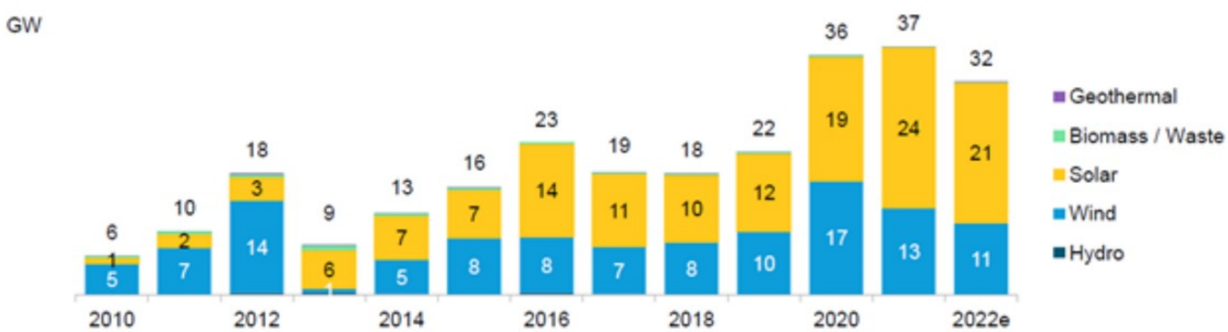



Figure 3 Renewable Capacity Build by Technology




Battery storage has grown rapidly, but only to 11 GW at the end of 2022. Using the nation's annual energy consumption, 11 GW of battery storage is good for about five and a half minutes nationwide. Pumped hydro represents two-thirds of electricity storage, and our total peak demand in the lower 48 is about 700 GW. We need additional storage and load flexibility—FAST!

## The Global Energy Transition and Thermal Energy Storage

What are other countries doing in their energy transitions? We should observe what to mimic and what to avoid.

Japan is demonstrating the proactive leadership required to navigate the energy transition with aggressive decarbonization and the buildout of microgrids across the country. They face the same problems we have with the duck curve and solar penetration as they move toward energy independence (Japan produces only 8% of their primary energy through solar). The government has hired Kyocera and other companies to implement this strategy. They are inventing a sophisticated microgrid system with city and building-level controls integrated with energy efficiency, generation, and storage technologies, including thermal energy storage (TES), to help manage their demand profile.

In a microgrid design, managing the largest loads on the grid is complex. Managing these loads with the complexities of co-incidental peaks, multiple generation sources, and multiple forms of storage is a challenge. Stan Nabozny, coauthor of this article, was fortunate to work with Kyocera a year ago to design and implement their first TES project in a cold storage facility to span the 4:00 P.M. to 9:00 P.M. peak window; the steep ramp period on their duck curve. They plan to roll out this technology to hundreds of other cold chain warehouses to manage the demand profile of their microgrids. In a few years, we will see Japan emerge as one of the leaders in microgrid technology and decarbonization.

South Africa (RSA) is another example of a country using TES. The grid in RSA is unreliable. Currently, customers do not have electricity 41% of the time. Businesses are closing, they have massive problems with grid reliability, and everyone is crying for generators and diesel fuel. Corruption, mis-management, and sabotage are the primary causes of this crisis. This is an example of poor leadership from the government with no proactive plan for the energy transition. It will take RSA years to recover from this national emergency. Thermal energy storage is used in RSA to protect the food; it serves as a thermal battery keeping temperatures stable during power outages.

This dichotomy between Japan and South Africa leads to a question about the United States. **What are we doing to lead the energy transition while fending off challenges noted in the introduction to this article?** If we're leading the energy transition, we need to explore innovations the way Japan is and integrate various technologies to proactively head off problems before they worsen. Thermal energy storage is one solution to the duck curve and sudden fluctuations in wind-generated electricity that we should all consider to shift load and create energy efficiency in refrigeration-based businesses and chilled water systems serving buildings, campuses, and cities.

## Where to Begin with Thermal Energy Storage for Grid Resilience

Thermal energy storage is a fantastic, distributed energy resource for microgrids and macrogrids. Air conditioning and refrigeration are two of the largest loads on the grid. Cold storage warehouses have the highest consumption per square foot of any occupied building. It makes sense to start with the largest loads on the grid, as they have in Japan. Advantages of TES technology include:

- Green Technology: There are no disposal issues, and the useful life for TES technology is 20 years. A Li-ion battery, for example, has a useful life of about five years.
- TES technologies will not catch fire and release toxic gases like hydrofluoric acid.[4] They are non-toxic solutions of salt, water, and stabilizers.
- Cost-Effective: Six to eight times more cost-effective than a typical Li-ion battery for the same load over 20 years.
- Protection of Food: Energy transfer during phase change ensures stable, safe temperature for food.
- Food Safe: The materials used for TES include salt, water, and other non-flammable and food-safe additives.
- Grid Resilience: Utility peak load management through demand response, load shifting, and peak shaving applications.
- Energy Efficiency: Along with the load-shifting benefits, there is an energy efficiency benefit that can range from a 15% to 30% reduction in consumption in both air conditioning and refrigeration applications. Round trip losses and parasitic loads for space conditioning of battery units can easily waste 40% of delivered power from Li-ion batteries.
- Inflation Reduction Act Tax Credit of 30%: With the Inflation Reduction Act, installing a TES system now comes with a 30% tax credit. This incentive can be taken in one tax year or spread over three years. It can also be sold on the open market. With this tax incentive, a TES system is inside of a three-year payback period in most markets across the United States and has a ten-year IRR of over 20%. This will support the adoption of TES in commercial businesses.
- Levelized Cost of Energy (LCOE): LCOE measures lifetime costs and energy production for a present value of the total cost of a system. This measure allows for comparing technologies with an unequal life span. The LCOE for a TES system is \$.02/kWh compared to Lithium-Ion batteries, which is ~\$.20/kWh.

Every utility across the United States has more than ample opportunities to use this technology to support grid resiliency and decarbonization. Energy is the second largest expense in the U.S. Cold Chain at over \$40B per year and growing. U.S. refrigeration-based businesses consume over 200B kWh per year. With more than 4,200 Cold Storage Warehouses, 40,000+ supermarkets, and over 620,000 restaurants in the U.S., reducing consumption and shifting load at a large scale is now possible.

## *What Does Thermal Energy Storage Look Like?*

Figure 4 Thermal Energy Storage Module

Figure 4 and Figure 5 show TES up close and deployed in a frozen food warehouse.

The load-carrying capacity for TES is demonstrated in Figure 6, representing a small 30,000 sq ft cold storage warehouse operating at 0F. The TES is displacing 200 kW of electric load for six hours. Try that with a battery!

Figure 5 Thermal Energy Storage Deployment

This application also reduces energy consumption by 14% by allowing the TES system to charge at night when it's cooler outside and 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.

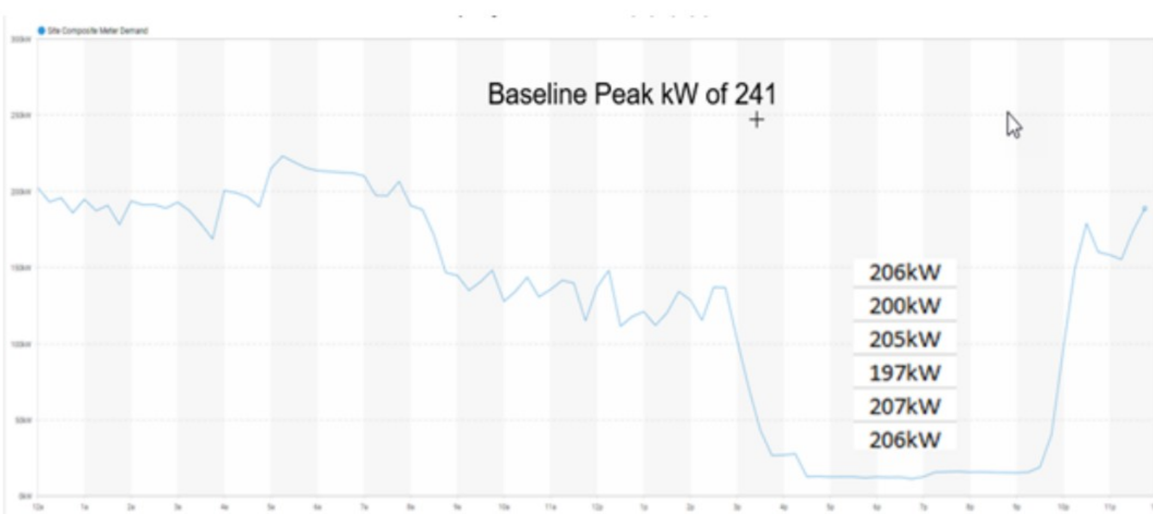



Figure 6 TES Load Shifting Capacity

## Perspective

At the end of 2022, there was 11 GW of grid-connected electric batteries in the U.S. The peak load is about 700 GW. About 10% of that peak load, or 65 GW, is commercial and industrial refrigeration and chilled water systems. This is a huge slice of untapped distributed energy resources for grid resilience and efficiency!

## Call to Action

The energy transition is upon all of us, and how we respond will be judged by future generations. Grid innovation we see in Japan provides food for thought as we respond to decarbonization and grid resiliency challenges. Thermal energy storage opportunities are immense, with over 21 billion cubic feet of industrial refrigeration globally. Pile on frozen storage in groceries, C-stores, and restaurants, plus chilled water air conditioning, and the opportunities are endless.

We can conquer much of our energy-transition challenge without massive upgrades to generation, transmission, storage, and distribution upgrades, while leveling the three-legged stool with greater reliability and lower-cost alternatives like TES.

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4 ScienceDirect

# About the Authors

### Jeff Ihnen

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 Loads, 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-Legged Stool (reliable, affordable, clean) of Decarbonization for AESP.

### Stan Nabozny

Stan Nabozny, Director of Thermal Energy Consulting, Michaels Energy, manages strategic account design, engineering, estimates, utility incentive programs, and the ongoing performance of our installations. He is a patent holder for Thermal Energy Storage using Phase Change Materials. His experience is broad in this field in that he has set up sourcing and production in multiple countries, implemented Thermal Energy Storage in industrial refrigeration, developed algorithms for energy efficiency and ongoing continuous commissioning and is now developing comprehensive utility load-shifting programs for aggregating islanded loads for peak demand load shifting.