FRANKLINWH

Powering Through the Winter

How FranklinWH Ensures Unmatched Home Energy Reliability

Executive Summary

The FranklinWH system provides comprehensive home energy management designed to seamlessly integrate multiple power sources, including PV, battery energy storage systems (BESS), electric vehicle, grid, and generator. The aPower X unit delivers robust performance with a 5 kW discharge and charge rate and a 13.6 kWh capacity, enabling homes to achieve energy independence. This advanced system empowers households to take control of their energy needs, supporting resilience and reducing reliance on the grid.

Cold temperatures are often considered a challenge for lithium-ion-based batteries due to their impact on device performance. Low temperatures can negatively affect lithium batteries, leading to reduced overall capacity, slower charge rates, increased internal resistance, and other issues. One of the primary causes of this degraded performance is the slowing of intercalation, the process by which lithium ions move into the graphite layers of the anode at these colder temperatures.

To provide thermal reliability in cold weather, FranklinWH has opted for a reliable silicone rubber pad heater for the Battery Energy Storage System (BESS) pack heating often called the heating blanket, bypassing alternative approaches such as cell self-heating. This in addition the thermal mass of the system ensures system and thermal reliability. Each aPower battery comes with an optimized heating blanket built into the battery that ensures the system operates effectively within a broad temperature range from –4° F (-20° C) to 122° F (50° C), supporting outdoor installations in harsh environments without sacrificing efficiency. With an IP67 weatherproofing rating, it's fully sealed against dust and protected from water immersion ensuring reliability to power through the harsh climates.

The aPower 2 is the latest FranklinWH BESS. It has not been through a full winter, so analysis is not yet available. However, given the construction of the unit, including case, cell packs, firmware and heating units, the expectation is that the results will be similar or better to the following analysis of the aPower X. Both aPower X and aPower 2 units can be installed indoors or outdoors. Please consult the installation guide for more information on installation locations and practices.

High reliability at low temperatures

In certain regions of the United States and Canada, winter temperatures consistently fall below 32° F (0° C) for extended periods, which can negatively impact the performance of lithium-based batteries. The FranklinWH system continuously monitors temperature data through its sensors and adjusts the charging rate to ensure safe and efficient charging. Each aPower X unit has battery cell packs embedded with sensors for temperature and voltage. There are 16 sensors for the 16 cells on the aPower X. The Battery Management System (BMS) constantly detects every cell’s temperature and voltage in real time to ensure both are within the acceptable optimal limits.

Lithium batteries will have slightly derated charging performance once the temperatures fall below 50° F. More importantly, the aPower X equipped with the heating pad minimizes the need for these adjustments by reducing instances of derated charging behavior. The onset of the heating blanket ensures that the cell temperatures remain high and maintain favorable charging behavior. The battery charge/discharge performance will be normal even if the ambient temperature is down to -4° F (-20° C) provided cell temperature is high enough. At FranklinWH, we are focused on reliable residential BESS installation and energy freedom.

Environmental Specifications		
Operation Ambient Range		-4° F ~ 122° F (-20° C ~ 50° C)
Derated Ambient Range		113° F ~ 122° F (45° C ~ 50° C)
Recommended Ambient Range		32° F ~ 86° F (0° C ~ 30° C)
Storage Duration		
Allowable Ambient Range	-22° F ~ 14° F (-30° C ~ -10° C) 113° F ~ 122° F (45° C ~ 60° C)	≤ 24 hours
	14° F ~ 113° F (-10° C ~ 45° C)	≤ 9 months
Installation Environment		
Indoor or Outdoor Shielded		
Altitude (maximum)		
9843 feet (3000 m)		
Physical parameters		
Size		29.5 in. X 45.3 in. X 11.4 in. (750 mm x 1150 mm x 290 mm)
Weight		395 lbs. (179 kg)

Table 1. aPower X environmental specifications

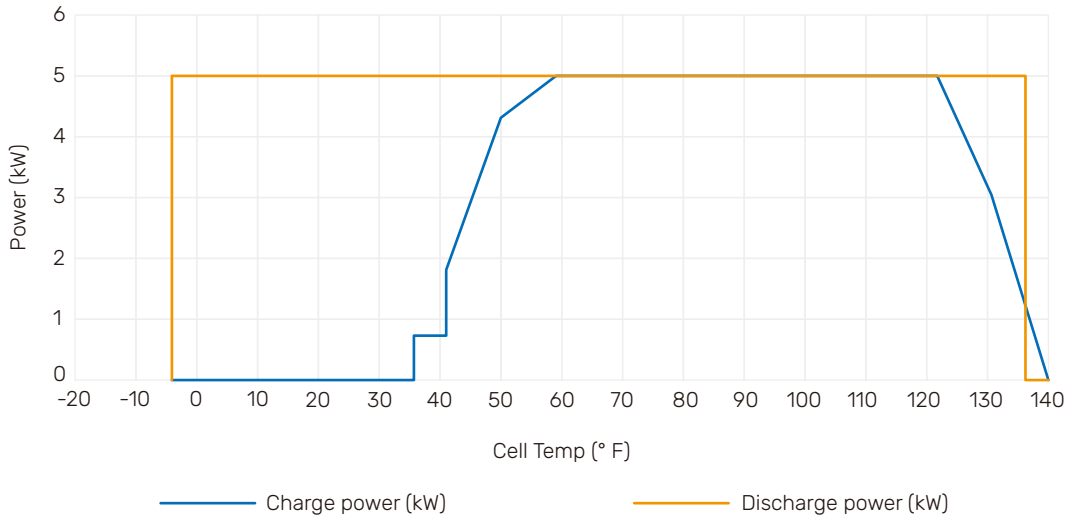

Figure 1 . aPower X battery cell deration

The low charging current is protected between 35.6° F (2° C) to 41° F (5° C) and down to 0 kW charge under 35.6° F (2° C). This curve shows the cells' performance without the heat blanket operation. All aPower X systems come with a heat blanket to extend the charge power window down to −4° F ambient.

Cell temperature	Charge behavior	Discharge behavior
> 50° F (10° C)	Normal	Normal
Between 32° F (0° C) and 50° F (10° C)	Derated	Normal
Between −4° F (−20° C) and 32° F (0° C)	Derated	Normal
< -4° F (-20° C)	None	None

Table 2 . aPower charge and discharge behavior vs temperature

The FranklinWH aPower has an embedded heating blanket on the cell packs to heat cells so the batteries can be charged and power dispatched to home loads even when the ambient temperature is down to −4° F (−20° C).

Ambient temperature	Charge behavior	Discharge behavior
> −4° F (-20° C)	Normal	Normal
Between −4° F (-20° C) and −22° F (-30° C) temporarily	Temporarily derated	Normal

Table 3 . aPower behavior performance with thermal blanket heating on

Case studies

There are thousands of aPower batteries deployed across North America, including many in colder regions such as New England, the Midwest, and Canada. Based on our fleet performance we had negligible battery downtime due to low temperature during the winter of 2023, indicating excellent thermal performance and reliability. The heating blanket not only improved the cell temperature, thereby reducing charging deration, but also consumed minimal electricity. The heating blanket typically prioritizes the availability of solar PV before drawing from the grid or the aPower batteries. During on grid if solar PV is unavailable, the blanket will draw power from the grid. From our analysis of several outdoor systems installed in Vermont, we found that the heating blanket's power draw was less than 0.5 kWh/day even on the coldest nights. It's important to note that the heating blanket's functionality is optimized for system performance and reliability.

Based on the installations in cold weather regions such as Vermont, Michigan, Connecticut, South Dakota, and Minnesota in the winter of 2023 (November 2023-April 2024) that our team analyzed, here's some of the key takeaways:

- In only 2.6% of the instances, the average cell temperature was between 23° F and 32° F (–5° C and 0° C).
- In 11.6% instances, the average cell temperature was between 32° F and 42.8° F (0° C and 6° C).
- In 86% of the instances, the average cell temperatures measured was over 42.8° F (6° C).
- In 31.8% instances, the average cell temperature was between 42.8° F and 50° F (6° C and 10° C).
- In 53.5% instances, the average cell temperature was over 50° F (10° C).

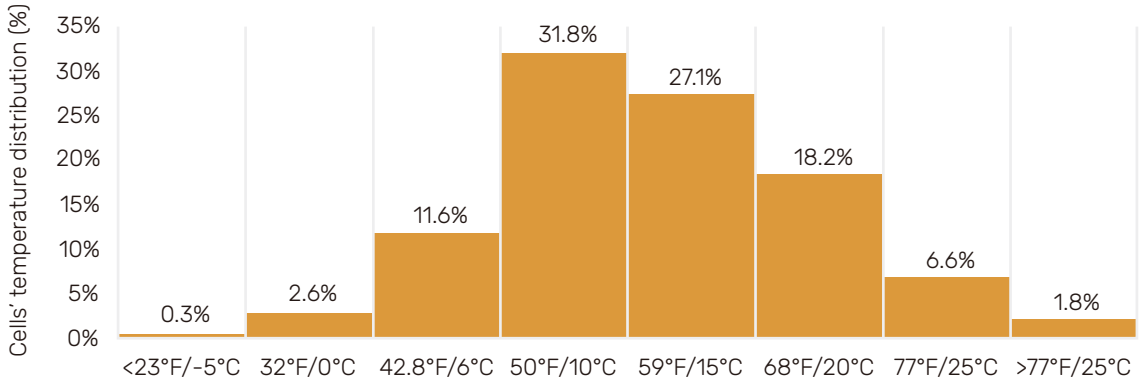

Figure 2 . Cell temperature in Winter

Note that in some of these instances analyzed, the aPower batteries were installed indoors or in a conditioned space and not necessarily outdoors. From all the systems analyzed in the study, we will be focusing on a few installations based in South Dakota, Michigan and Massachusetts specifically. January was reported to be the coldest month in our analysis and the section below introduces the aPower experience with cell temperature, PV generation, and battery charge, discharge in January for installations in Michigan, Massachusetts and South Dakota.

aPower X in January 2024, Michigan

The system analyzed at this site in Michigan suffered from reduced PV production due to seasonal overcast weather conditions. The heating blankets ensured the cell temperatures remained warmer than ambient conditions thereby contributing to system resiliency. The cell temperature was between 32° F and 50° F (0° C and 10° C) with the heating blanket working as programmed. Having aPower X batteries ensured continuous power during winter storms and outages, providing peace of mind. They offered a reliable backup source, keeping essential appliances running and reducing reliance on potentially variable solar or the grid.

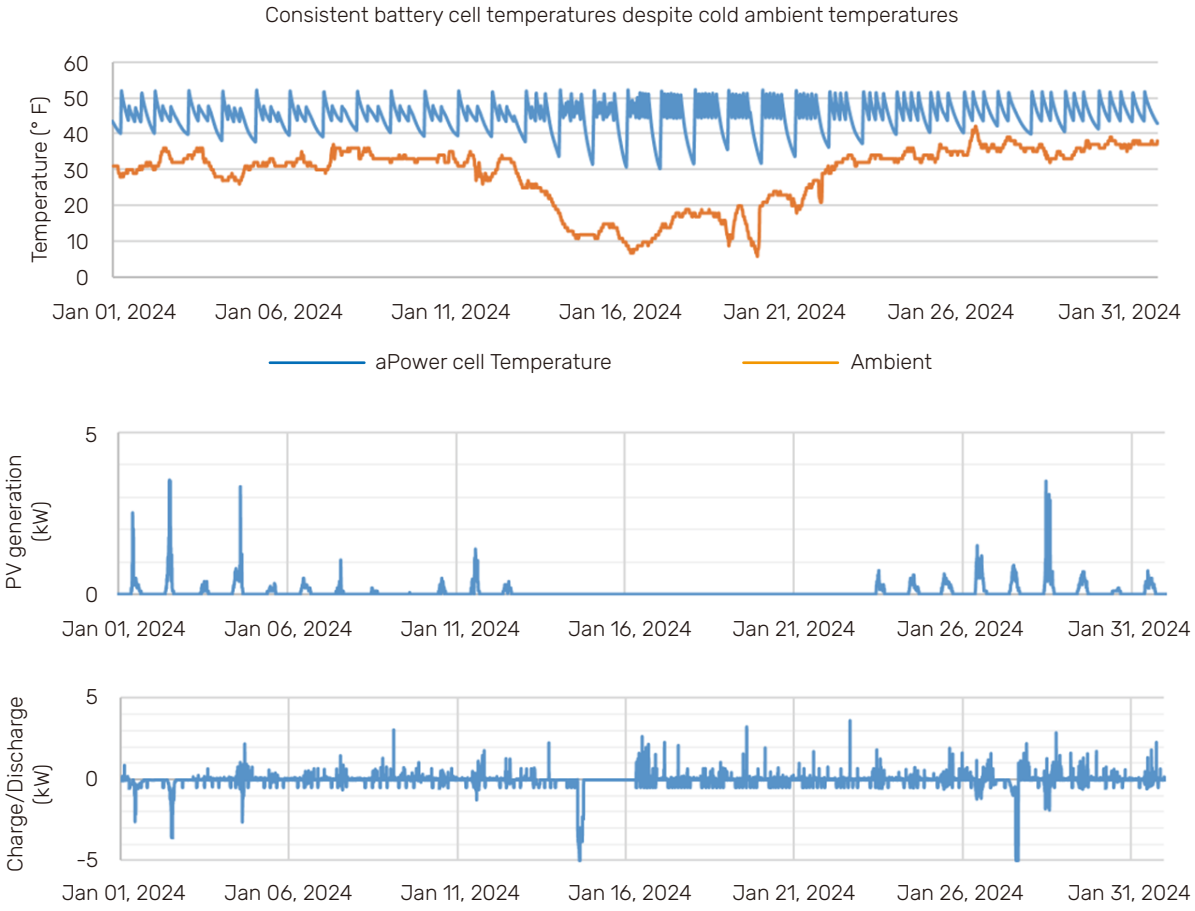

Figure 3 . aPower X in January 2024, Michigan

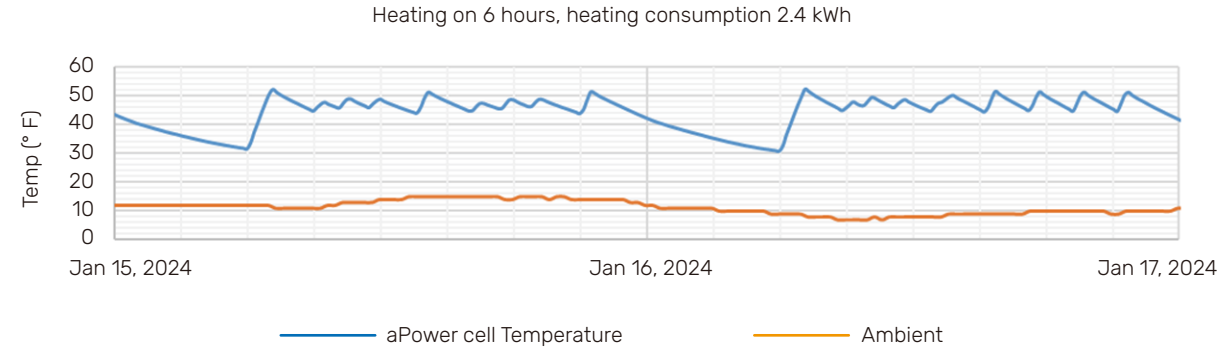

Figure 4. aPower heating experience, January 15-17, 2024, Michigan, ambient down to 5° F (–15° C)

aPower X in January 2024, South Dakota

This site in South Dakota encountered a situation similar to the one in Michigan, with the key difference being that the heating blankets ensured the batteries remained warm enough to charge from the PV system, even as ambient temperatures plummeted to -22° F (-30° C). This allowed for reliable energy storage, despite the extremely cold conditions.

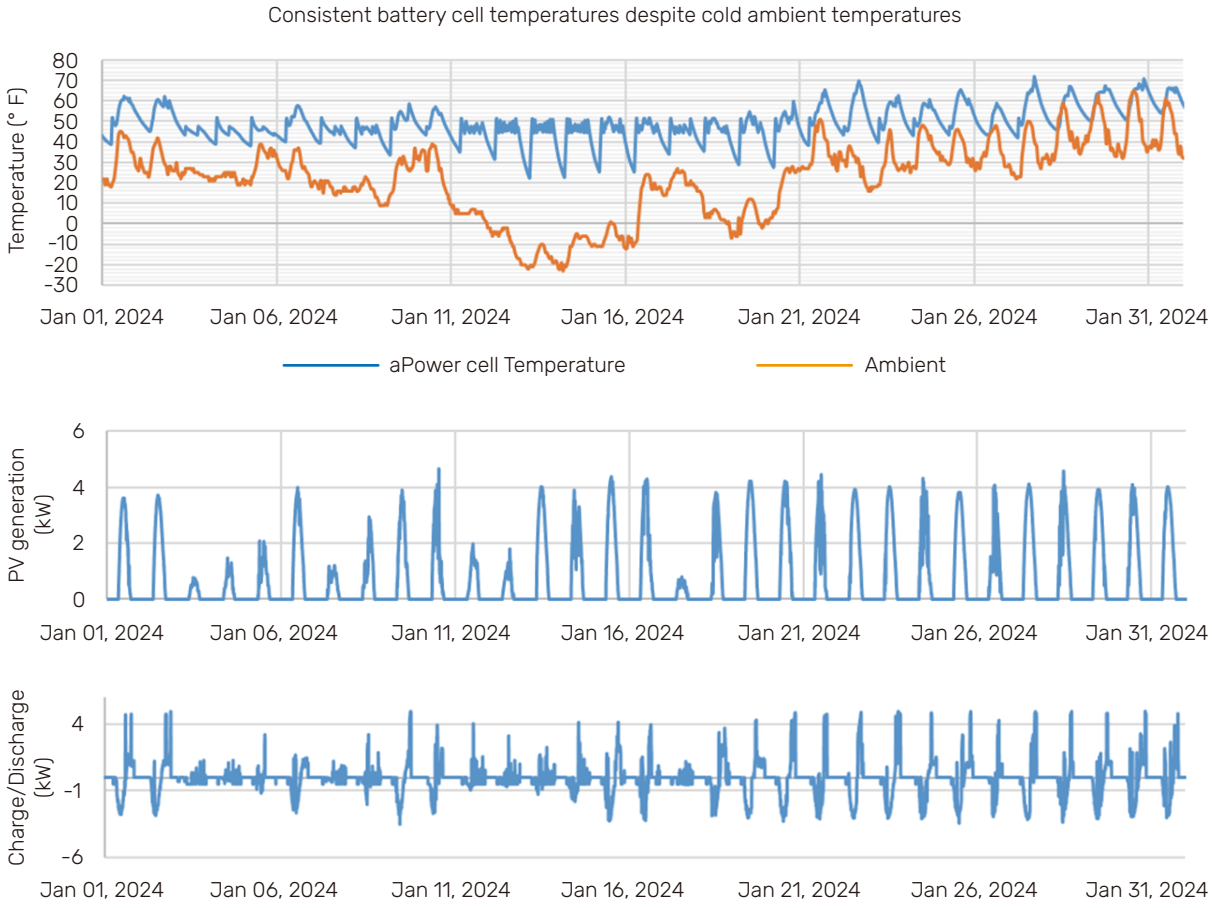

Figure 5. aPower X experience, January 2024, South Dakota

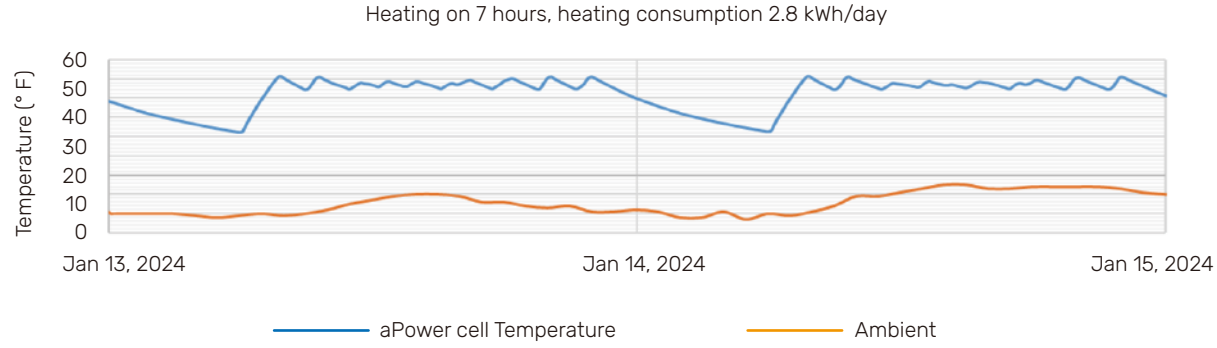

Figure 6. aPower heating experience, Jan 13-15, 2024, South Dakota

aPower X in January 2024, Massachusetts

When installing batteries indoors, certain parts of Massachusetts require additional safety equipment such as smoke and heat detection systems, ventilation or other safety measures which increase both the complexity and cost of the overall installation. Often installers place batteries outdoors to avoid additional equipment and cost. The following data illustrates the battery discharge and charge patterns for January 2024, with normal grid operation. This real-world data shows outdoor installation of aPowers is a viable option in Massachusetts.

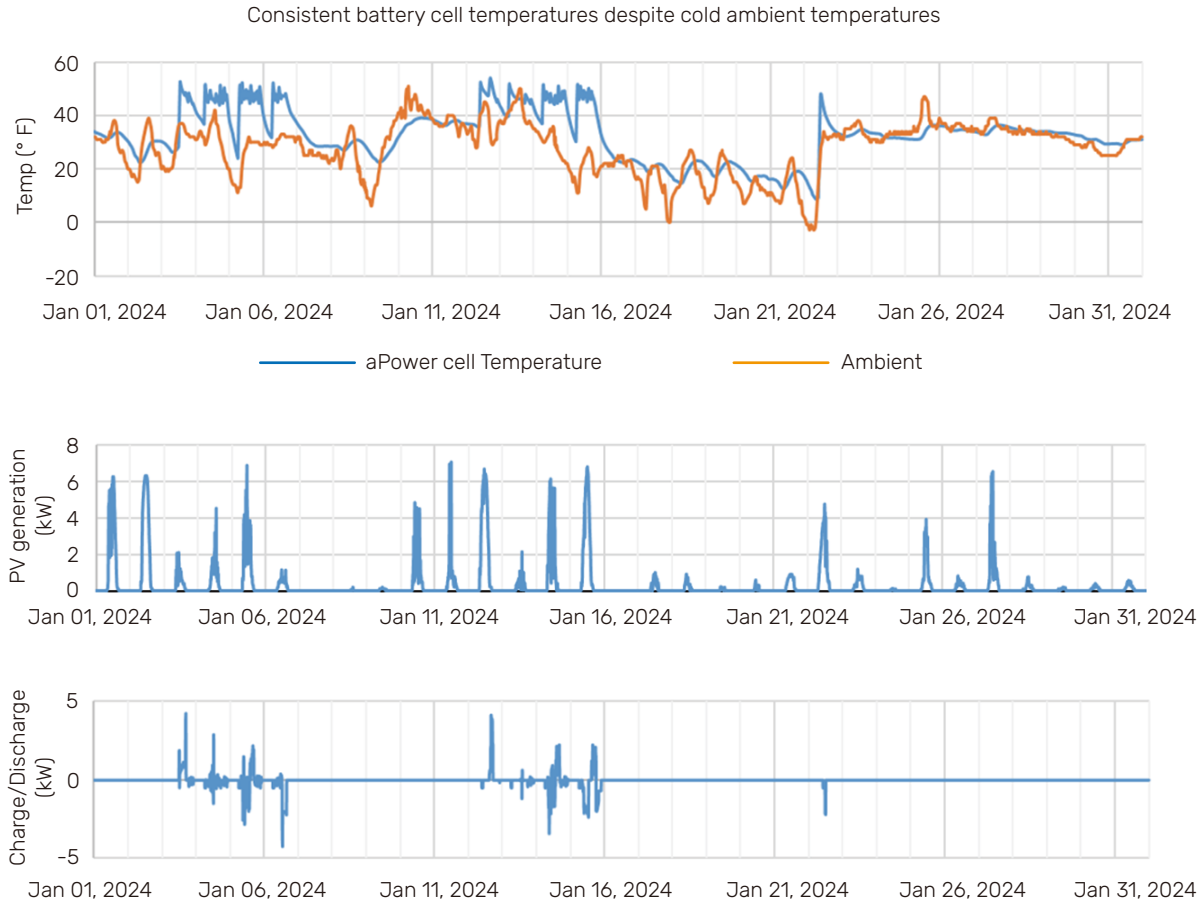

Figure 7. aPower heating experience Jan 5-6, 2024, Massachusetts

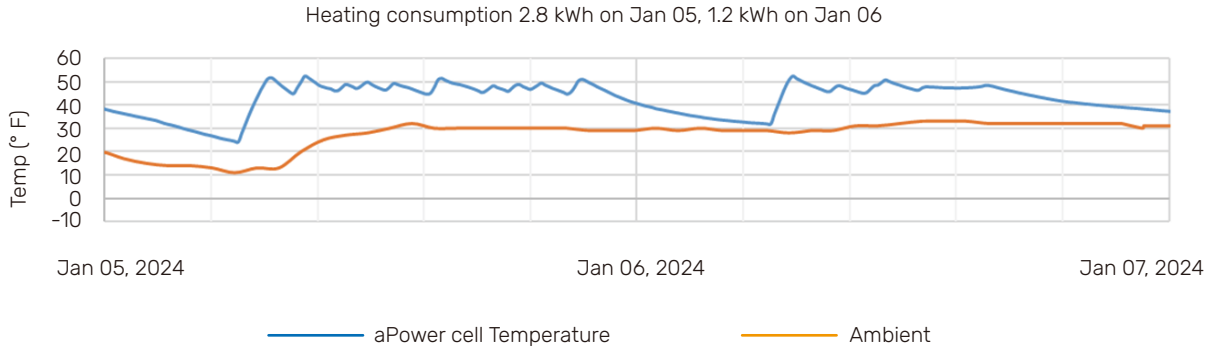

Figure 8 . aPower heating experience Jan 06-07, 2024, South Dakot

FAQs

1. **What will happen if the ambient temperature around the aPower drops below –4° F (-20° C)?**
   During winter, if the aPower X has been operating rather than in standby/emergency backup mode, the average aPower X cell temperature is usually higher than the ambient temperature. If the ambient temperature is lower than –4° F and the cell temperature is higher than that, the aPower X will continue to discharge normally and charge at derated rate depending on the cell temperature. However, if cell temperature falls below –4° F, the entire system will shut down and come back online when cell temperature rises above –4° F.

2. **How much energy does heating consume?**
   There are four heating pads, each rated for 100 W, with 400 W total power drawn on the aPower X. Depending on how long the heating pad runs, the total energy consumption can be calculated. The heating pad operation is automatically optimized for system performance and reliability. Depending on the mode of operation, the heating blanket will prioritize solar PV first before relying on the grid or battery. During an outage, if solar PV is unavailable, the heating blanket shall draw power from the batteries, based on battery parameters and condition.

3. **Can I view the heating blanket functionality with the FranklinWH App?**
   Currently, the FranklinWH App does not indicate the heating blanket. The energy consumed by the heating blanket will be displayed as a load in the app power flow window.

4. **What are some tips for optimizing cold weather performance?**
   The FranklinWH System is designed for energy freedom and thermal reliability. While the heating blanket is optimized for superior reliability, a few additional cold weather tips include:

   - A quick discharge cycle can generate enough heat to raise the battery temperature by a few degrees, improving system reliability.

   - Pre-conditioning the battery helps ensure more efficient charging behavior. For instance, setting a short artificial time-of-use schedule during cold nights ensures the battery is pre-conditioned and ready to charge without any deration.

   - If the installation site experiences prolonged cold temperatures during winter, it is advisable to install the batteries indoors in a controlled environment to protect their performance.

5. **Does discharge behavior get affected at cold temperatures?**
   The aPower X will continue to discharge at 5 kW for most of the temperature range. The charging rate is affected more severely than discharge rate depending on the cell temperature.

6. **Can I install the batteries outdoors?**

   Yes, both the aPower X and aPower 2 can be installed indoors or outdoors. With the IP67 rating and thermal reliability, they are designed for outdoor use. However, if the installation site experiences prolonged cold weather, we recommend installing the batteries indoors in a regulated environment. Please consult your FranklinWH certified installer.

NOTE: We've enhanced the thermal reliability on our second-generation battery, aPower 2, through design improvements and operational changes. The aPower 2 features two 220 W heating blankets with enhanced firmware for improved performance. In the future, we'll be releasing an additional white paper with reliability metrics for aPower 2. If you have any further questions on thermal reliability of the FranklinWH solution, please contact **engineering@franklinwh.com**.

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