Powerwall 3 Heat Mode White Paper

2024

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Executive Summary

In pursuit of Tesla's mission to accelerate the world's transition to sustainable energy and support the projected 5X increase in home and EV electricity demand, it is critical that distributed home energy storage reaches immense global scale. To realize that goal, Tesla has designed and engineered Powerwall 3 to remove installation barriers, making the product flexible across a variety of different installation scenarios, regulatory restrictions, and geographic climates.

With the spread of costly interior installation requirements coupled with the increase in extreme weather events across the globe, Tesla has developed Heat Mode for Powerwall 3, driven by an entirely new heating architecture that uses dedicated cell-level heating in conjunction with intelligent controls software to efficiently manage Powerwall cell performance in cold outside temperatures as low as -20°C. With Heat Mode, customers no longer have to trade off installation savings with Powerwall charge/discharge performance, yielding an improved customer experience which maximizes overall installation affordability and energy bill savings.

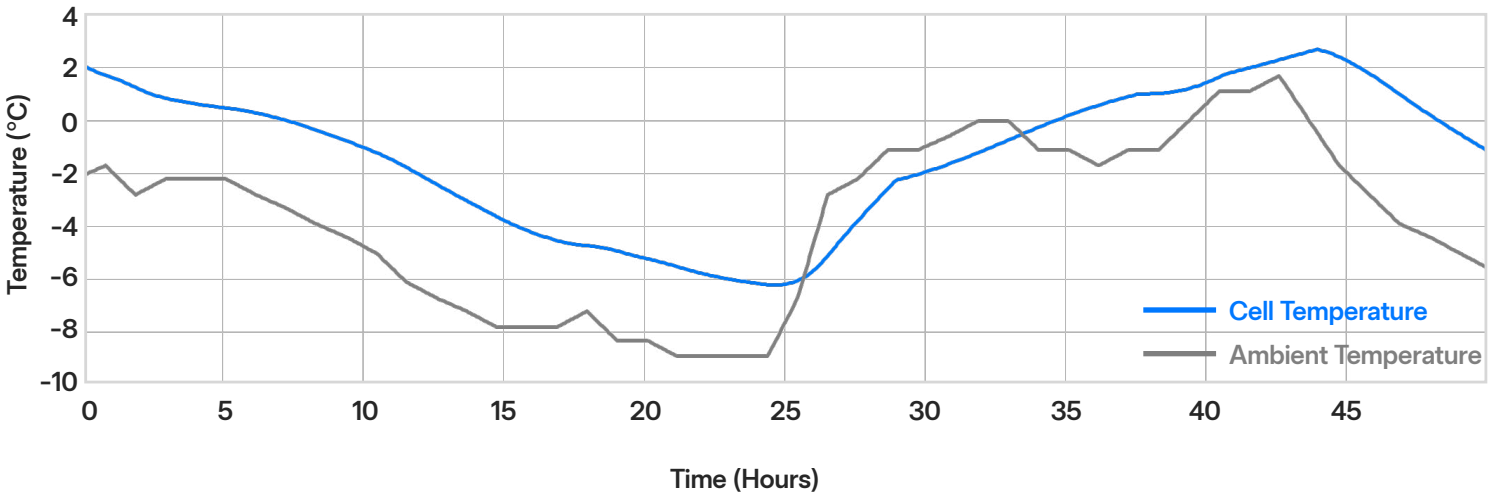
How Does Heat Mode Work

Given lithium-ion battery cell operational parameters such as voltage and charge current vary based on cell temperature, it is important that each Powerwall 3 cell is within an optimal temperature range to effectively charge and discharge energy. To maintain cell temperature throughout Powerwall's ambient temperature operating range, -20°C to 50°C, each Powerwall 3 cell has dedicated resistive heating elements which conduct heat directly at the cell level when activated.

With Heat Mode, Powerwall will heat itself intelligently and efficiently to maintain optimal cell temperature for charge and discharge performance, using solar and battery usage history from the past 7 days to determine when and how much power is needed. Like a Tesla vehicle preparing to Supercharge, Powerwall conditions itself and optimizes for things like sunrise so it can charge the battery as soon as solar begins producing.

Cell vs. Ambient Temperature

To preface, it is important to note that Powerwall's internal cell temperature does not always equal daily outside ambient low temperatures. Cell temperature is insulated from fluctuations in ambient temperature due to a cell's thermal mass in addition to self-heating as a byproduct of Powerwall normal daily operations. The below demonstrates the differences in both measurements at a Powerwall site **without** Heat Mode:



Expected Behavior

Based on the optimal charge and discharge power that a customer needs, as the outside temperature drops towards freezing, Heat Mode activates Powerwall's resistive heaters to maintain internal cell temperature at minimum above 0°C. The following table shows the internal cell temperature range that Heat Mode targets, yielding the associated charge/discharge behaviors:

Cell Temperature	Charging Behavior	Discharging Behavior
Cell Temperature > 10°C	Normal	Normal
Cell Temperature between 0°C and 10°C	Limited	Normal
Cell Temperature between -20°C and 0°C	None	Limited
Cell Temperature < -20°C	None	None

Expected Behavior, cont.

When Outside Temperature is 0 - 10°C

Depending on when charge power is needed, for example to consume excess solar or grid charge to maximize energy savings, Heat Mode will intelligently heat to raise cell temperature above 0°C at the optimal time. If peak charge power is needed, Heat Mode will maintain cell temperature above 10°C. For discharge power availability, Heat Mode will also keep internal cell temperature above 0°C.

When Outside Temperature is < 0°C

As the surrounding ambient temperature drops below 0°C, Heat Mode will maintain internal cell temperature at 0°C for optimal discharge behavior, and will heat up to prepare available charge power when excess solar is expected to be available. If Powerwall is initially installed in cold below 0°C, once commissioned Heat Mode will heat at an average rate of 6.7°C per hour, bringing cell temperature within the optimal range to enable charging.

When Powerwall is Off Grid

While Powerwall is off grid and state of energy is > 10%, Heat Mode will maintain optimal cell temperature for charge and discharge availability. If Powerwall's state of energy is < 10%, Heat Mode will mitigate brick risk by deactivating until either solar DC power can bring state of energy > 10%, or AC grid power returns.

Power Supply

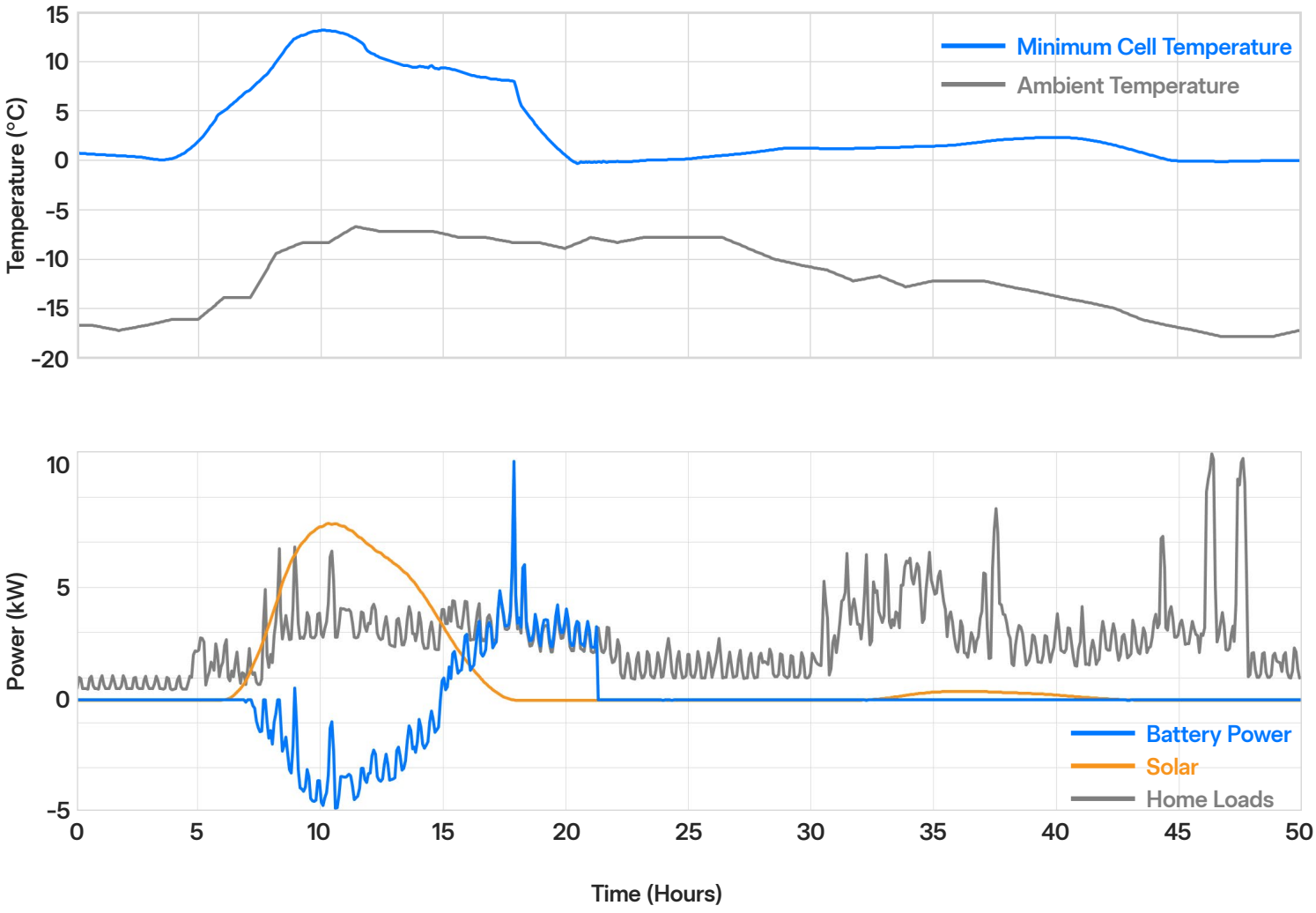
To supply power for Heat Mode operation, Powerwall uses the following hierarchy based on power source availability, its state of energy (SOE), and the customer's desired Backup Reserve:

	On Grid		Off Grid	
Power Source Preference	SOE > Backup Reserve	SOE < Backup Reserve	SOE > Backup Reserve	SOE < Backup Reserve
1	Solar	Solar	Solar	Solar
2	Battery	Grid	Battery	Battery
3	Grid	Battery		

Case Studies

Site Level

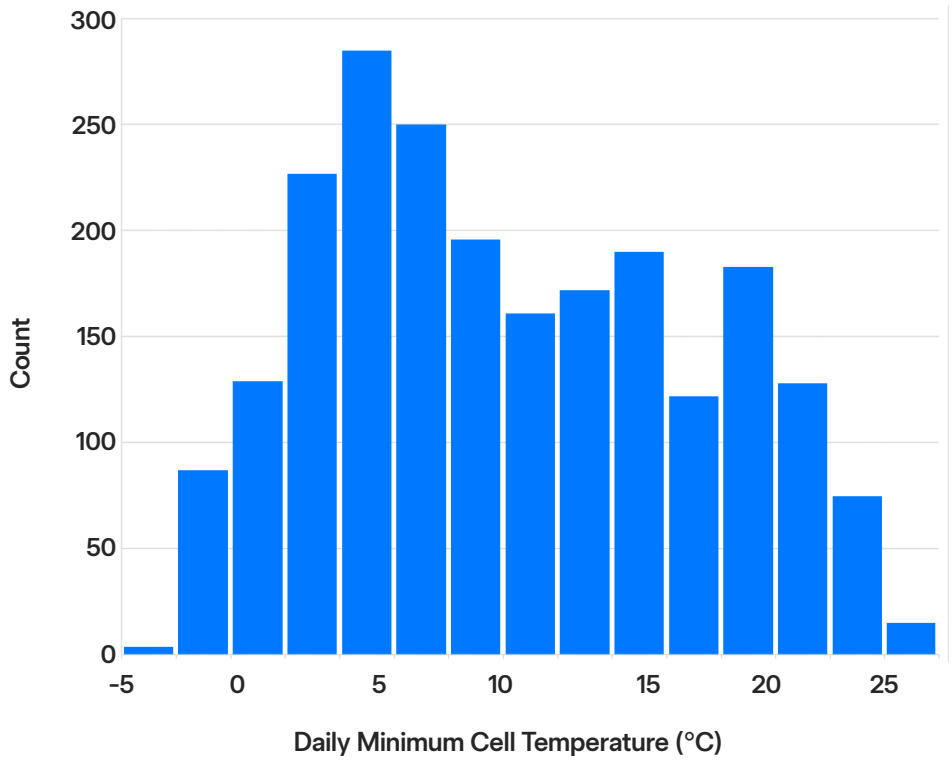
The below shows Powerwall 3 operating with Heat Mode over two days, one with solar production and one without, at a site in Toronto, Canada. In cold ambient temperature, Heat Mode heats up Powerwall internal cell temperature to prepare for daily solar charging and maintains temperature above 0°C to enable discharge to the home at night. When no solar production is forecasted, Powerwall will conserve energy and maintain internal cell temperature above 0°C.



Case Studies, cont.

Fleet Level

The following histogram plots daily minimum cell temperature throughout the month of February 2024 for a fleet of 100 Powerwall 3 sites across Colorado, Utah, New York, New Jersey, Connecticut, and Massachusetts. Across the fleet, we see Heat Mode maintain Powerwall 3 at minimum above 0°C. Due to full state of energy, a small group of Powerwall sites drop below 0°C, which is expected operation – Powerwall does not heat in this condition as it cannot charge any further.



How is This Different from Powerwall 2/+?

While Powerwall 2 and Powerwall+ also have a Heat Mode, their internal architecture is different from Powerwall 3, leading to different heating efficiency and overall operation. In Powerwall 2/+, the heat generated from the internal power electronics is absorbed via heat sink and then circulated throughout the Powerwall cell array by liquid coolant. In contrast, Powerwall 3, which is air cooled, uses designated cell-level heaters to directly transfer heat, improving the capability of Powerwall 3 to control and heat the cells as compared to the previous architecture.

Frequently Asked Questions

When is Heat Mode supported?

Heat Mode is standard on Powerwall 3 with firmware version 23.40 or later, which rolled out to the existing fleet in November 2023.

What happens if the ambient temperature surrounding Powerwall 3 drops below -20°C?

Heat Mode will maintain a minimum internal cell temperature of 0°C in ambient temperature as low as -20°C. Below -20°C ambient, Heat Mode will still activate, although depending on the depth and duration of the extreme cold may not be able to heat the cells as quickly as heat is dissipating from the Powerwall. In the rare case Powerwall can't heat and prolonged outside temperature below -20°C causes cell temperatures to also drop below that level, Powerwall will enter a deep sleep mode for up to 30 days to prevent bricking. Prolonged exposure to temperatures below -20°C do not pose a safety hazard but may negatively affect product performance and longevity. Powerwall should not be installed outside in areas where it is common to have daily high temperatures of < -20°C.

How much energy does Heat Mode consume?

In -20°C ambient temperature, Heat Mode typically will only consume 200 Wh to prepare the cells to accept daily charge from solar. For comparison, less energy is needed to heat the Powerwall than to power a single computer monitor for 3 hours.

Can I see if Heat Mode is working in my Mobile App?

When Powerwall is On Grid, Heat Mode will appear in the Power Flow diagram as a home load. When Powerwall is Off Grid, Heat Mode will either be powered by solar or battery and will not show up in the Power Flow diagram.