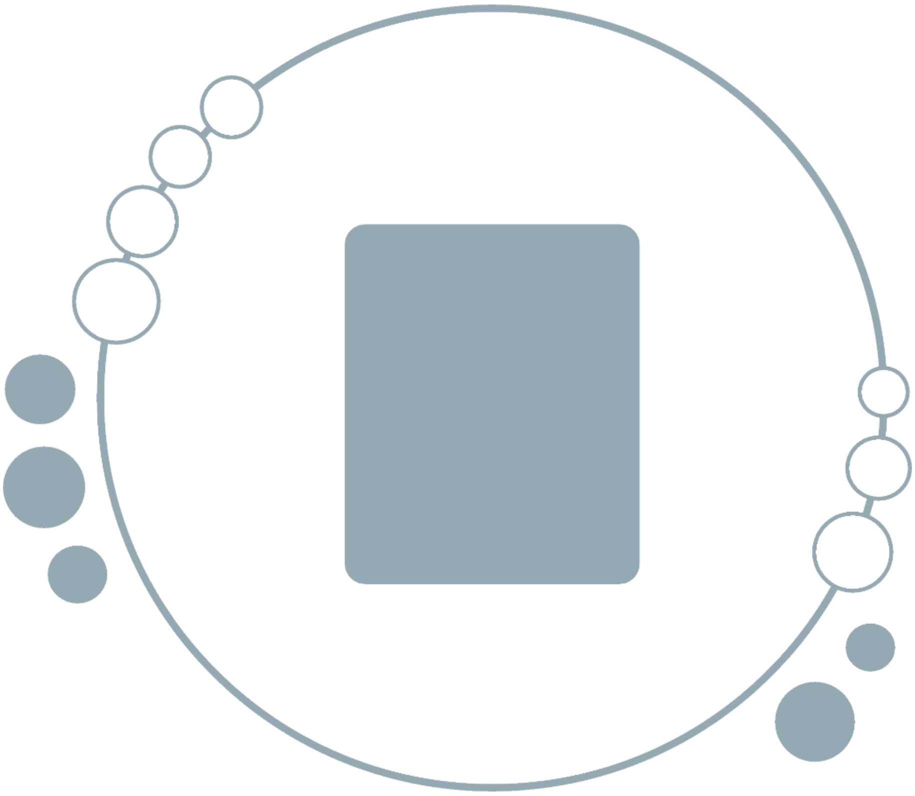


Modelling Phase Change Material Heat Batteries within the Home Energy Model

A technical explanation of the methodology

February 2026

Acknowledgements

This methodology has been developed for the Department for Energy Security & Net Zero by a number of organisations and individuals, including Sustenic, Quidos, Scene Connect, City Science, Hoare Lea, Oxford Brookes University, University of Bath, 10-x, Building Research Establishment (BRE), AECOM, Kiwa Ltd., Loughborough University Enterprises Limited, Chris Martin and John Tebbit.

Quality assurance has been undertaken by a consortium led by Etude, including Levitt Bernstein, People Powered Retrofit, University of Strathclyde's Energy Systems Research Unit, Julie Godefroy Sustainability, and UCL.

Document reference: HEM-TP-15

Document version: v1.0

Issue date: February 2026

Home Energy Model version: HEM v1.0

Any enquiries regarding this publication should be sent to us at: homeenergymodel@energysecurity.gov.uk

Contents

Background to the Home Energy Model

What is the Home Energy Model?

The Home Energy Model (HEM) is a calculation methodology designed to assess the energy performance of homes, which will replace the government's Standard Assessment Procedure (SAP).

Where can I find more information?

This document is part of a wider package of material relating to the Home Energy Model.

Home Energy Model technical documentation (e.g. this document)

What: This document is one of a suite of technical documents, which explain the calculation methodology in detail. New documents will be added, and the content amended, when necessary to ensure documentation is sufficiently comprehensive. This will usually, but not always, occur alongside the release of a new version of HEM.

Audience: The technical documentation will be of interest to those who want to understand the detail of how the Home Energy Model works and how different technologies are treated.

The Home Energy Model consultation and government response

What: The Home Energy Model consultation introduces the overhaul to the SAP methodology and sought views on the approach taken by the new Home Energy Model. The Home Energy Model consultation summarises the feedback to the consultation and the actions taken subsequently in development, ahead of the initial release of HEM.

Audience: The Home Energy Model consultation will be of interest to those seeking a general introduction to HEM and its role in government policy on domestic energy performance.

The Home Energy Model reference code

What: The full Python source code for the Home Energy Model core engine has been published as a Git repository. Note the reference code for official HEM wrappers is published separately.

Audience: The reference code will be of interest to those who want to understand how the model has been implemented in code, and those wishing to fully clarify their understanding of the new methodology. It will also be of interest to any potential contributors to the Home Energy Model or those wishing to use it within their own projects.

Related content

To understand how this methodology has been implemented in computer code, please see:

src/core/heating_systems/heat_battery_pcm.py

Overview

Heat batteries are thermal storage systems that efficiently store and release heat. Their ability to store surplus energy for later use can support grid flexibility and facilitate the integration of renewable energy sources into home heating.

This document introduces the methodology for modelling phase change material (PCM) heat batteries. PCM heat batteries use a phase change material as the storage medium, which changes state from solid to liquid as it stores thermal energy. They also contain an integrated heat exchange mechanism for transferring that energy to a separate working fluid. Dry core heat batteries are also modelled in HEM, but representing their solid “dry core” storage medium requires a different methodology, documented in HEM-TP-13.

Methodology

A bespoke methodology[1] for PCM heat batteries has been developed to ensure the flexibility and accuracy of the model. However, testing and validation align with existing standards such as the indirect charging method described in EN 15502-1:2021+A1:2023 or an equivalent method described in IEC 60379:2023. This alignment ensures consistency with recognised best practices while allowing for innovations tailored to the unique requirements of PCM heat battery modelling in HEM.

1. Details of the approach

1.1 Purpose

The purpose of this methodology is to simulate the energy storage and delivery of a PCM heat battery system. It is designed to account for all the main factors that govern the behaviour of such systems, including their inherent physical and operational characteristics, external conditions, and energy demand patterns.

1.2 Basic Principles

The methodology simulates PCM heat battery operations at a granular level, accounting for thermal energy flows, PCM dynamics, and the interactions between internal and external factors. Internal factors include the thermal properties of the battery’s materials, such as heat capacity, phase transition behaviour, and thermal conductivity, as well as the distribution of temperature within its layers. External factors encompass influences such as the temperature of the incoming water, the flow rate of heat transfer fluids, ambient environmental conditions,

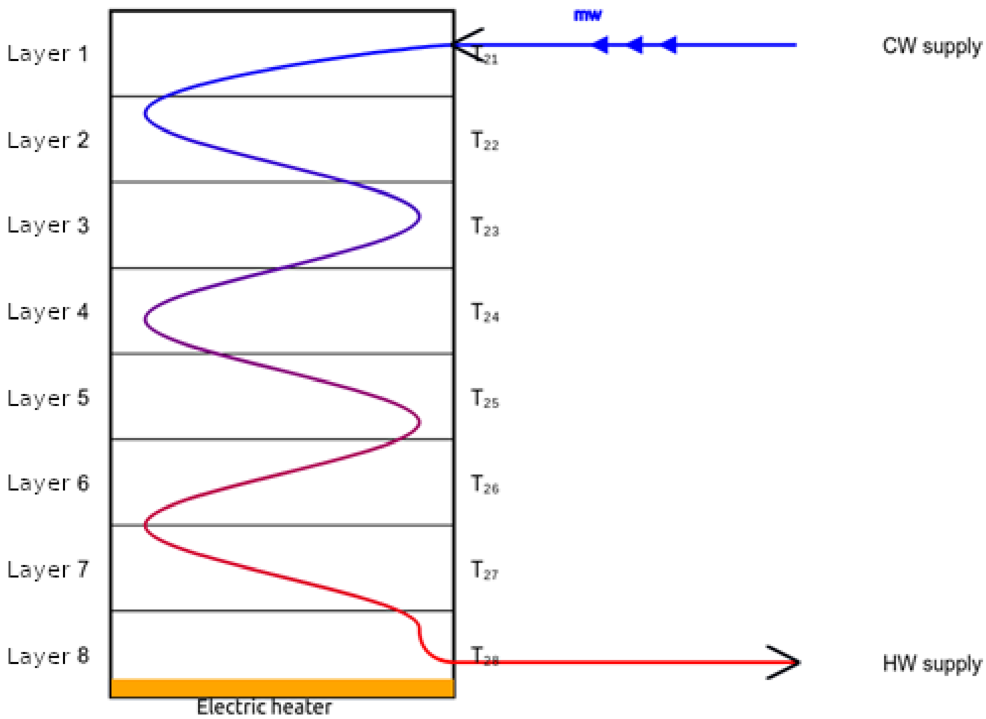
[1] During the development of the methodology for modelling PCM heat batteries in the Home Energy Model (HEM), EN 15316-5:2017 was evaluated as a potential basis. This standard includes a framework for dividing PCM heat batteries into eight layers and incorporates PCM modelling using thermal capacity data. While it provided a reasonable foundation, significant limitations emerged. The model struggled to maintain stability at higher flow rates, often "crashing" under such conditions. Additionally, it relied on a manually set parameter, which proved challenging to determine accurately through testing. While the outputs were acceptable under specific conditions, the model lacked robustness when adapting to varying flow rates, a critical requirement for the diverse operational scenarios in HEM.

and external energy inputs or demands, such as those governed by user schedules or grid constraints. The key principles underpinning this approach are outlined below.

Layer Representation

PCM heat batteries are modelled as a series of interconnected temperature layers, each representing a specific segment of the thermal storage medium. The implementation allows for a variable number of layers to be considered in the calculation, currently defaulted to 8, depending on the balance between accuracy and computational requirements. This layer-based approach allows the model to capture detailed thermal interactions during charging, discharging, and standby modes, as well as the dynamic behaviour of phase change materials (PCM).

Figure 1: PCM Heat Battery model – Simplified diagram



The model simulates the thermal dynamics of the PCM heat battery by iteratively calculating heat transfer and temperature updates for each layer within the system during every timestep. The process includes the capability for simultaneous charging and discharging.

Phase State Representation

The methodology does not explicitly track the phase state (solid, liquid, or transitioning) of each layer. Instead, phase change behaviour is represented implicitly through temperature-dependent heat capacities. Three distinct heat capacity values are provided as input parameters:

- Heat capacity below the phase transition temperature range (PCM in solid state)

- Heat capacity during the phase transition temperature range (PCM undergoing phase change)
- Heat capacity above the phase transition temperature range (PCM in liquid state)

The phase transition temperature range is defined by upper and lower temperature thresholds. When calculating temperature changes for a layer, the model determines which heat capacity to apply based on the layer's current temperature and the direction of energy flow. If a temperature change spans multiple regions (e.g., from above the transition range to below it), the calculation accounts for the different heat capacities in each region proportionally.

This approach simplifies the calculation while capturing the key characteristic of PCM behaviour: the significantly higher effective heat capacity during phase transition, which represents the latent heat absorbed or released as the material changes state.

Incorporation of Empirical Data

The modelling process makes use of performance parameters derived from empirical testing to accurately characterise the behaviour of PCM heat batteries. These include heat transfer coefficients that define energy exchange rates with incoming water, thermal properties of the PCM across solid, liquid, and transitional states, and phase transition temperatures. Additionally, standby heat loss rates and other operational characteristics are based on laboratory data. These parameters are taken as inputs to the calculation and enable realistic calculations of thermal losses, energy outputs, and overall system efficiency, ensuring alignment with observed performance metrics.

1.3 Calculation Overview

The calculation uses the core layer-by-layer heat transfer algorithm (described in section 1.4) multiple times per timestep, applied with different parameters depending on context (demand processing, maximum output estimation, charging, or standing losses). The following steps summarise the overall flow of the calculations used:

1. Initialisation: Retrieve the current temperature distribution across all layers, inlet water temperature, mass flow rate, and operational mode. Prepare heat transfer coefficients and PCM thermal properties.

2. Maximum output assessment: Determine the theoretical maximum energy deliverable given the current thermal state, to assess whether demand can be met.

3. Demand processing: Calculate actual energy delivered to each service (space heating, hot water), limited to the maximum output, updating layer temperatures after each service is processed.

4. Electric charging: If permitted by the charge control, distribute charging power across layers to raise temperatures toward the target charge level.

5. Standing loss calculation: Apply thermal losses based on the temperature difference between each layer and the environment.

6. Finalisation: Store updated layer temperatures and record energy delivered, losses, and auxiliary energy consumption for the timestep.

1.4 Core heat transfer calculation steps

The core calculation described in this section is used in several time within each timestep, as described in the steps above. The same fundamental layer-by-layer heat transfer calculations apply in each case, with variations in the input parameters (such as flow rate, inlet temperature, and whether electric charging power is applied). Sections 1.5 Calculating Maximum Output and
2.1 Electric Charging of the PCM Heat Battery describe in more detail how these specific use cases invoke the core calculation with their respective parameters.

The following steps describe the details of the calculations used for this process:

1. Initialisation of Parameters:
   At the beginning of each timestep, the model retrieves the current temperature distribution across all PCM heat battery layers, the inlet temperature to the PCM heat battery, and the mass flow rate of water (the amount of water flowing through the PCM heat battery), which directly influences the rate of heat transfer.

   It also determines the operational mode (e.g., charging, discharging, or standby) and prepares relevant parameters, such as the heat transfer coefficients and phase change material (PCM) properties.

   Electric charging is activated when a charge control mechanism determines that the battery's charge level is below the target state. Parameters such as rated charging power and energy transfer coefficients are prepared for subsequent calculations.

2. Electric Charging Energy Input:
   When the system is in charging mode, the model calculates the power supplied to the battery by its electric source, P_{in}:

$$P_{in} = Rated\ Charging\ Power$$

   The input power is distributed across the layers of the battery to raise their temperatures. The power is applied in a manner that respects physical constraints, ensuring it does not exceed the system's thermal capacity or the layer's maximum allowable temperature.

3. Heat Transfer from PCM Heat Battery Layer to Flowing Water:
   For each layer, the model calculates the outlet water temperature iteratively using the energy balance equation:

$$Q_{layer} = m_w c_w (T_{out} - T_{in}) = UA\left(T_{layer} - \frac{T_{in}+T_{out}}{2}\right)$$

Rearranging to make T_{out} the subject:

$$T_{out} = \frac{2UAT_{layer} - UAT_{in} + 2m_w c_w T_{in}}{2m_w c_w + UA}$$

where:

Q_{layer}: Heat transferred to water.
m_w: Mass flow rate of water.
c_w: Specific heat capacity of water.
T_{in}, T_{out}: Inlet and outlet water temperatures for the layer.
UA: The overall heat transfer coefficient of the heat exchanger (W/K)

The overall heat transfer coefficient is calculated using an empirically derived correlation:

$$UA = A \cdot \ln\left(Re_1 \cdot \dot{V}\right) + B$$

where:

A and B are empirically derived coefficients from laboratory testing
Re_1 is the Reynolds number calculated at a reference flow rate of 1 litre per minute
$\dot{V}$ is the volumetric flow rate through the heat battery (litres per minute)
The Reynolds number at the reference flow rate is calculated as:

$$Re_1 = \frac{(v_1 \cdot d)}{\nu}$$

where:
v_1 is the fluid velocity in the heat exchanger at 1 litre per minute flow rate (m/s), provided as an input parameter
d is the heat exchanger inlet diameter (m)
ν is the kinematic viscosity of water at the average circuit temperature (m²/s)

The kinematic viscosity of water varies with temperature and is calculated using a quadratic correlation based on the average of the inlet and outlet water temperatures:

$$\nu = a \cdot {T_{avg}}^2 + b \cdot T_{avg} + c$$

where:
T_{avg} is the average of inlet and outlet temperatures (°C)
a = 1.45238×10^{-10}
b = -2.48238×10^{-8}
c = 1.432×10^{-6}

This correlation is valid for the operating temperature range typical of heat battery circuits.

This step is repeated for each layer, using the outlet temperature of the current layer as the inlet temperature for the next.

4. Update PCM Heat Battery Layer Temperatures:
   Layer temperatures are updated based on the energy exchanged with the water and adjacent layers, as well as the energy supplied by the electric charging process. The update accounts for:

   a. Heat loss to the environment: Standing heat losses are calculated separately at the end of each timestep using the methodology described in Section 1.6. During the main demand calculation, layer temperatures are updated based only on the energy exchanged with the flowing water and any simultaneous electric charging. The standing loss calculation is then applied after all service demands have been processed.

   b. Heat transfer within the PCM based on its phase state:

$$T_{layer}^{new} = T_{layer}^{current} - \Delta T_1 - \Delta T_2 - \Delta T_3$$

where ΔT_i values represent temperature changes in solid, liquid, and phase transition states based on energy flows.

$$\Delta T_1 = \frac{Q_{exchange_{solid}}}{Heat\ Capacity\ PCM\ as\ solid\ [kJ/K]}$$

$$\Delta T_2 = \frac{Q_{exchange_{transition}}}{Heat\ Capacity\ PCM\ during\ transition\ [kJ/K]}$$

$$\Delta T_3 = \frac{Q_{exchange_{liquid}}}{Heat\ Capacity\ PCM\ as\ liquid [kJ/K]}$$

Where:
$Q_{layer} = Q_{exchange_{solid}} + Q_{exchange_{transition}} + Q_{exchange_{liquid}}$

$Heat\ Capacity\ PCM\ (at\ different\ states)$ are input parameters.

The electric charging energy is integrated into the PCM’s energy balance, modifying ΔT_i values as required.

In simultaneous charging mode, electric charging influences T_{layer}^{new} by increasing it according to the energy input distributed evenly across the layers.

5. Iterative Solution Across Layers:
   The calculations for each layer are performed iteratively within a timestep, updating all

layer temperatures and outlet water temperatures in sequence. The iterative process ensures energy conservation across the system while accounting for interactions between layers and the flowing water. The calculation process continues until one of the following termination conditions is met:

a. The required energy demand has been satisfied (within a tolerance of 1×10^{-10} kWh)
b. The available time within the HEM timestep has been exhausted
c. The heat battery outlet temperature falls below the inlet temperature, indicating the battery can no longer deliver useful energy to the flow.

The model uses an adaptive sub-timestep approach. The sub-timestep duration is calculated based on the current rate of energy delivery and the remaining energy demand but is capped at a maximum of 20 seconds. This adaptive approach ensures accurate matching of energy supply to demand without over-delivery, while maintaining computational efficiency.

6. Finalisation:
   At the end of the timestep, the model stores the updated layer temperatures, charge levels, and any residual energy for subsequent timesteps. It also calculates and records energy losses due to standby heat dissipation, auxiliary energy consumption for system components such as circulation pumps, and the total energy delivered to meet demand. These results are aggregated alongside operational metrics, providing a detailed representation of the PCM heat battery's performance for the timestep. The outputs include layer-specific temperatures, water outlet temperatures, energy delivered, energy losses, and auxiliary energy usage, ensuring a comprehensive accounting of the system's thermal and energy dynamics.

1.5 Calculating Maximum Output

Accurate calculation of the PCM heat battery's maximum output and standing loss is critical to assessing its performance. This section outlines the methodology for determining these values, incorporating layer-specific modelling and empirical performance data.

Maximum Output Calculation

The maximum output calculation determines the theoretical maximum energy the battery could deliver within a timestep, given its current thermal state. This is used by the HEM core to assess whether the battery can meet demand. The calculation uses the core layer processing algorithm described in Section 1.4 Core heat transfer calculation steps, with the following specific parameters:

- The inlet temperature is set to the required output temperature (e.g., the emitter flow temperature for space heating)
- The operational mode is set to discharging

- No electric charging power is applied during this calculation
- A longer sub-timestep (up to 100 seconds, compared to 20 seconds for demand calculations) is used for computational efficiency, as this is an estimation rather than an actual state update
- The calculation runs until either all layer temperatures reach the inlet temperature, or the outlet temperature falls below the required temperature

The layer temperature distribution used for this calculation is a copy of the current state; the actual battery state is not modified.

The resulting value represents the maximum amount of energy deliverable within the timestep, which may vary depending on the charge state, flow rates, and demand conditions.

1.6 Calculating Standing Loss

Standing loss represents the thermal energy dissipated by the PCM heat battery passively, due to the temperature difference between the battery and the environment. These losses are based on experimental data and decrease as each layer's temperature approaches that of the ambient environment.

Standing losses are calculated based on a maximum rated loss parameter provided from laboratory test data (i.e. at the maximum temperature from the test). The model applies the rated loss power proportionally across all layers, with energy only extracted from layers where the temperature exceeds a reference temperature. The current implementation uses a fixed reference temperature of 22°C. This is a simplification; future versions may link this to the actual dwelling zone temperature where the heat battery is located.

The calculation proceeds as follows:

1. The maximum heat loss energy for the timestep is calculated from the rated loss power:

$$Q_{loss,max} = P_{rated\_loss} \times \Delta t$$

where $P_{rated_loss}$is the maximum rated heat loss (kW) from test data, and $\Delta t$is the timestep duration.

2. This energy is distributed equally across all layers:

$$Q_{loss,layer} = \frac{Q_{loss,max}}{n_{layers}}$$

3. For each layer, the loss is only applied if the layer temperature exceeds the reference temperature (currently fixed at 22°C). If the layer temperature is at or below the reference temperature, no loss is applied to that layer.

4. Layer temperatures are then updated using the same temperature change calculations described in Section 1.4, based on the energy removed.

This approach ensures that cooler layers do not contribute unrealistically to standing losses and that losses decrease naturally as the battery discharges and layer temperatures approach ambient conditions.

Standing losses from PCM heat batteries are counted as thermal energy input to the dwelling zone where the heat battery is located and are accounted for when calculating thermal energy demand in subsequent timesteps.

Layer temperatures are updated at the end of each HEM timestep to account for cumulative losses, ensuring the battery's thermal state is accurately captured for subsequent calculations. The model also monitors the total operational time within the timestep, which influences both the maximum output and the evolution of thermal losses.

1.7 Operational Logic

The operational logic governs how the PCM heat battery dispenses, charges, and manages energy under various demand conditions during each simulation timestep. It ensures that energy demands are met efficiently while maintaining accurate charge levels and accounting for system constraints.

Energy Dispensing and Demand Management

If the demand for the time step can be met by the battery, the model dispenses the energy required from the battery and updates its charge level accordingly. If the energy demand exceeds the maximum output:

- The battery dispenses as much energy as it can within its performance limits.
- Any unmet demand is recorded by HEM’s core modules. This unmet demand affects the energy requirements in the subsequent timestep, ensuring continuity and consistency in demand handling.

The model then returns the energy output provided and updates the total time running for the current timestep. It separately calculates the results for each service (space heating, hot water), including the service name, the time spent running, and the current power output of the PCM heat battery. These results are needed later in the core model, for example at the end of the timestep, where some general calculations and integrations of services are handled.

1.8 Service Types

The PCM heat battery module supports three distinct service types, each with specific operational characteristics and energy accounting methods.

Direct Hot Water Service

This service type provides instantaneous hot water on demand, operating similarly to a combination boiler or heat interface unit. Cold mains water flows directly through the heat battery's heat exchanger and is heated to the required setpoint temperature. Key characteristics include:

- No separate storage cylinder is required
- The flow rate through the heat battery is determined by the design flow rate parameter
- Achievable outlet temperature depends on the current thermal state of the heat battery layers, the volume of water being drawn, and the cold water inlet temperature
- No circulation pump energy is consumed as mains water pressure drives the flow
- For large draw-off volumes, the outlet temperature may decline as the battery depletes during the draw-off event

The model calculates the achievable hot water temperature for a given draw-off volume by simulating the flow through all heat battery layers over the duration required to deliver the requested volume. The outlet temperature from each layer becomes the inlet temperature for the next, and the final outlet temperature (capped at the setpoint) represents the delivered hot water temperature.

Space Heating Service

This service type provides thermal energy to space heating distribution systems such as radiators or underfloor heating circuits. Key characteristics include:

- Operates based on temperature setpoint controls that determine when heating is required
- Flow and return temperatures are determined by the emitter system design
- Uses a circulation pump for water circulation through the heating circuit
- Energy delivery is calculated based on the heating demand and the heat battery's ability to meet the required flow temperature

Regular Hot Water Service

As with any other wet heat source within HEM, heat batteries can be linked to a separate hot water storage cylinder. This service type, which may be less common in typical installations, represents configurations where the heat battery charges a cylinder through a heat exchanger circuit. Water circulates between the heat battery and the cylinder, transferring thermal energy to heat the stored water. Key characteristics include:

- Requires specification of minimum and maximum temperature controls for the circulation loop
- Uses a circulation pump for water circulation, with pump energy consumption accounted for
- Flow temperature and return temperature are determined by the cylinder and system design
- Energy delivery is calculated based on the temperature differential and flow rate through the heat battery

Service Priority and Sequencing

When multiple services demand energy within the same HEM timestep, they are processed sequentially. The time spent serving each demand is tracked, and subsequent services have access to the remaining time within the timestep. The thermal state of the heat battery (layer temperature distribution) is updated after each service demand is processed, ensuring that later services account for any depletion caused by earlier demands.

2. Electric Charging and Auxiliary Energy Calculation

2.1 Electric Charging of the PCM Heat Battery

Electric charging adds thermal energy to the heat battery's storage medium when permitted by the charge control. The charging calculation uses the same core layer processing algorithm described in Section 1.4, but with mode set to charging-only (no water flow) and with the electric charging power distributed across layers.

Charging occurs in two contexts:

1. **Simultaneous charging during demand:** If the heat battery supports simultaneous charging and discharging, electric charging power is applied during the demand calculation itself. This is handled within the core calculation when processing energy demand.
2. **End-of-timestep charging:** After all service demands have been processed, if charging is permitted by the charge control, the remaining time in the timestep is used for charging. This updates the layer temperatures before the next timestep begins.

Charge Control Interface

The heat battery's charging behaviour is governed by a charge control object that provides two key functions:

1. **Charging permission** - determines whether charging is currently permitted based on time schedules, tariff periods, or other control logic

2. **Target charge level** - specifies the desired charge level as a fraction (0 to 1) of the maximum operating temperature

The charging process continues until all the layers reach or exceed the target temperature, or until the charging permission period ends. The specific control logic (such as time-based schedules aligned with off-peak tariffs) is implemented within the charge control object, which is configured separately from the heat battery specification. The heat battery module responds to the control signals without knowledge of the underlying control strategy.

Charging Logic and Methodology

The charging process determines the energy added to the PCM heat battery during each timestep, reflecting the current charge level, the target charge level, and the operational constraints. For electric charging, the process dynamically adjusts based on the battery's capacity, temperature distribution, and available charging time. When simultaneous charging and discharging occur, iterative calculations, as described in section 1.4, are used to maintain accuracy. The following steps outline the charging process:

1. Charge Level Assessment:

   The charge control object determines whether charging is permitted and the target charge level. If charging is permitted and the current charge level is below the target, the energy that can be added is:

   $$\Delta E_{charge} = P_{rated} \times t_{available}$$

   Where:

   P_{rated}: Rated charging power (retrieved from test data).

   $t_{available}$: Time available for charging within the timestep.

2. Layer-Specific Charging:

   The energy increment is distributed across the PCM heat battery's layers based on their current temperatures and thermal properties. Layers with lower temperatures or in phase change states (e.g., PCM transitioning from solid to liquid) receive proportionally more energy to reflect real-world thermal behaviour.

   If simultaneous discharging occurs, the charging process becomes iterative:

   a. The model dynamically adjusts the energy input to account for simultaneous heat losses and energy extraction by the discharging process.
   b. Iterative calculations, as described in section 1.4 with suitable sub-timesteps adjusted up to 20 seconds, ensure energy conservation and accurate temperature updates for all layers.

3. Temperature Update for Layers:

   For each layer, the added energy is used to update the temperature, considering the phase state and specific heat properties of the material:

   $$T_{layer}^{new} = T_{layer}^{current} + \Delta T_{charge}$$

   Where:

   ΔT_{charge}: Temperature increase based on the net energy added and the specific heat capacity of the layer's material.

   Layer-specific constraints ensure that temperatures do not exceed maximum allowable thresholds.

4. Capacity Constraints:

   If the calculated charge increment exceeds the energy required to reach the target charge level, the model limits the increment to prevent overcharging.

5. Finalisation:
   At the end of the timestep, the model records the updated charge level and temperature distribution across layers. If the battery is not fully charged, the residual capacity remains available for subsequent timesteps. When simultaneous discharging occurs, the model ensures that any net energy changes are accounted for in the updated charge level and energy balance.

2.2 Auxiliary Energy Consumption Calculation

In almost any energy system, not all energy consumed is directly used for the primary service (in this case, the delivery of heat). Some energy is used to keep the system running and to ensure that everything is working as it should. In the case of a PCM heat battery, this includes the operation of the internal circulation pump (for services other than direct hot water provisions) and maintaining the system's standby mode and powering the controls.

The circulation pump plays a crucial role in the system as it transfers heat from within the PCM heat battery to the heat distribution system. The energy used by this pump is assumed to be proportional to the total time the system is running in a given period.

Similarly, even when the PCM heat battery is not actively being charged or discharged (i.e. standby mode), it may still consume energy to maintain system functions. The amount of energy used during standby mode depends on the length of time the system is in this mode and the standby power consumption.

The energy used in standby and active modes (beyond that used for charging) is an input to the calculation.

Future development

PCM heat batteries represent a relatively novel technology in the UK, with their adoption and deployment still in the early stages. HEM aims to remain adaptive, incorporating advancements in PCM heat battery design, control options, and integration capabilities as the technology evolves. Future enhancements to the PCM heat battery methodology may include:

Incorporation of Emerging Heat Battery Types and Configurations:

As new heat battery types and configurations emerge, these may be incorporated into the HEM framework. This could include systems with enhanced phase change materials (PCMs), improved energy density, advanced thermal management features, or the ability to be charged through alternative means, such as heat pumps, solar thermal systems, or other renewable energy sources.

Advancement of Control Options:

Future iterations of the model may introduce improved control logic for PCM heat batteries, enabling smarter operation.

Support for External Charging Sources:

Current implementations focus primarily on electric charging; however, future updates may enable heat batteries to be charged by external sources such as:

- Heat pumps or solar thermal systems, enhancing the flexibility and sustainability of the technology.
- Waste heat recovery systems, which could further reduce energy costs and improve overall system efficiency.

These developments would require modifications to the charging logic and additional empirical data to characterise the performance of external charging methods.

Removal of Reynolds number input:

Recent manufacturer feedback suggests that the Reynolds number dependency may not provide significant computational benefit compared to simpler flow-rate-based approaches. Independent verification through comparative analysis would be able to validate whether simplified approaches provide equivalent accuracy. Future versions may support direct specification of the UA heat transfer coefficient as determined through standardised testing protocols, which would simplify data specification and protect commercially sensitive heat exchanger design details.

Improved Modelling of Standby Mode Dynamics:

Future versions of the model may include a more detailed representation of heat transfer between thermal layers during standby mode. This would capture complex thermal interactions that occur when the battery is not actively charging or discharging, improving the fidelity of loss calculations.

This publication is available from: https://www.gov.uk/government/publications/home-energy-model-technical-documentation