Modelling heat batteries within the Home Energy Model

A technical explanation of the methodology

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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).

The Home Energy Model is still under development and its first version will be implemented alongside the Future Homes Standard (FHS) in 2025. We are publishing information about the model while it is still at a formative stage to enable industry to participate in the ongoing development process.

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 go into further detail on the methodology and the validation exercises that have been carried out. We intend to update and produce further technical documentation throughout the model development process.

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

What: The Home Energy Model consultation, which explains the overhaul to the SAP methodology and seeks views on the approach taken by the new Home Energy Model.

Audience: The Home Energy Model consultation will be of interest to those who want to understand the proposed changes to the SAP methodology and wider SAP landscape.

The Home Energy Model reference code

What: The full Python source code for the Home Energy Model and the Home Energy Model: FHS assessment has been published as a Git repository. This code is identical to that sitting behind the consultation tool. We are currently considering whether the open-source code could serve as the approved methodology for regulatory uses of the Home Energy Model.

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.

Related content

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

heat_battery.py

Overview

Heat batteries are units designed to store significant amounts of heat for later use, for example storing heat generated at night for use during the following day to provide space and water heating. The main factors affecting their performance are the amount of heat they can store and how well they can retain this heat. The rate at which they can charge up with and release their heat is also important.

Depending on their design, heat batteries can be charged with heat from different sources/fuels, but generally the benefits of demand shifting are greatest where they are charged with electricity at times when it is cheap or free (e.g. on-site renewables).

Despite some similarities, heat batteries are treated as a separate class of products from electric storage heaters in the Home Energy Model on the basis that a heat battery's heat output would generally feed a separate distribution/emitter system and may also be used for water heating. (See paper HEM-TP-13 Storage heaters for more information on the treatment of storage heaters.)

This paper sets out the methodology for modelling the behaviour of electrically charged heat batteries within the Home Energy Model core engine. Other configurations may be added in future.

Methodology

The modelling approach taken avoids directly modelling the components of heat batteries. Instead, it is empirically driven, using the results of lab tests yielding measured heat output over the unit's full range of charge level. The key advantage of this approach is that it avoids the need to model potentially complex/non-linear behaviour, for example the rate of heat release from phase change materials as a function of temperature, and allows accurate predictions from a simple model.

In outline, the modelling approach is as follows:

- System Initialisation: Set the initial state of the system and the control logic.
- Electric Charging: Determine the amount of energy input to the heat battery during the time step, based on the current charge level and control logic.
- Energy Output Calculation: Calculate the maximum possible energy output by the system in the next time step, taking into account the charge level and the energy demand.

- Auxiliary Energy Consumption Calculation: Account for the energy used for the operation of internal systems like the circulation pump and the energy consumed when in standby mode.
- Update and Repeat: Update the system's state based on the energy input, output, and losses, and repeat the process for the next time step.

1. Details of the approach

1.1 Purpose

The purpose of the model is to simulate the energy storage and delivery performance of a heat battery system. It is designed to take into account all the factors that govern the behaviour of such systems, including their inherent physical and operational characteristics, external conditions, and energy demand patterns. The model provides an understanding of the system's ability to meet varying energy demands, its efficiency, and operational performance.

1.2 Basic Principles

The heat battery model is underpinned by a combination of fundamental physical principles and empirically-derived performance data. The heat battery stores thermal energy by heating a storage medium and releases it by cooling the medium. The capacity of the heat battery is one of the critical factors that influence its operation.

The model captures this through a charge level, which represents the current amount of stored heat relative to the heat storage capacity of the battery. The charge level is affected by energy inputs (charging), outputs (discharging), and standing losses[1].

1.3 Incorporating Empirical Data

Empirical data from laboratory tests play a crucial role in this method, serving as the foundation for determining the energy output and losses associated with different charge levels. These data allow the model to accurately capture the performance characteristics of the system. The model interprets these data through interpolation functions, ensuring a realistic representation of the system's behaviour across a range of operating conditions.

Model users need only select the correct model from the product characteristics database (PCDB) (or future equivalent), which will allow the correct performance data to be imported[2].

[1] If the unit is inside the dwelling standing losses will contribute to heat gains.
[2] Performance data for a hypothetical product is currently included in the demonstration software for illustrative purposes.

There is no existing standard test for this at the time or writing, so a specification will need to be formalised in due course, but we envisage a relatively simple full charge and discharge test, to determine the power output and standing loss rate across the performance range.

1.4 Interacting with Energy Demand

The first step to reflect the interaction between the building's heat demand and the heat battery is to initialise the necessary variables, such as the current timestep and the charge level of the battery. The model also references the target charge level set by the control system. This target charge level dictates the desired state of charge for the battery. At present only a single basic control system has been defined in which the unit attempts to achieve a full state of charge during the 7 off-peak hours of an 'Economy 7' style tariff. It is envisaged that more advanced control options will be added, from which the user can choose.

For the first call in each timestep, the model will calculate the amount of charge to be added to the system, based on the duration of the timestep, and update the charge level accordingly, ensuring it doesn't exceed the target charge level. The model estimates the maximum possible output for the next timestep (see below), then refers to the test data to determine the power output the unit is capable of at that level of charge.

Next, the model calculates the total energy demand from the heat battery, distributing this between units if there is more than one heat battery present. The model then recalculates the charge level considering the energy in, energy out and energy losses during the timestep.

1.5 Calculating Maximum Output and Standing Loss

The maximum output in any given time step is derived from laboratory test results, by mapping the charge level to the output rating at that charge level achieved during the test. The model estimates the output rating at the average charge level for the timestep, ensuring the system operates at the correct level.

The model also calculates standing losses based on the lab results at this average charge level, reflecting the unit's energy storage efficiency.

The model keeps track of the total time spent running in the current timestep, which influences how the maximum output and losses evolve.

1.6 Operational Logic

If the demand for the time step can be met by the battery, the model will dispense the energy required and update the charge level accordingly.

If the energy demand exceeds the maximum output, the battery dispenses as much energy as it can. The Home Energy Model’s core modules record the remaining unmet demand (as well as this affecting the demand in the subsequent timestep). In these situations, the model ensures that the charge level doesn't exceed the target charge level and adjusts the energy input if necessary. The model keeps track of the energy provided and the time spent running the service.

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 heat battery. These results are needed later in the core model, for example in the timestep_end function, which is used to handle the integration when a heat source provides energy for more than one service.

2. Other elements of the method

2.1 Electric Charging of the Heat Battery

Charging the heat battery refers to the process of adding thermal energy to the storage medium. The amount of energy supplied to the heat battery is determined by a charging function, which calculates the electric charge input to the system.

The process of electric charging is an exercise of balancing. The goal is to reach the target charge level without exceeding the heat storage capacity. For each timestep in the simulation, the model estimates the amount of charge to be added to the system based on the target charge level, the current charge level, and the available time for charging.

The charging process follows a logic whereby if the current charge level is less than the target charge, the model calculates the possible increment of charge level that could be achieved in the next timestep by multiplying the electric charge input (calculated by the electric charge function) by the timestep duration and dividing by the heat storage capacity. This potential increment is then added to the current charge level. The maximum rate of charge is taken from the PCDB (or future equivalent) entry, rather than being input by the user.

However, if the calculated charge amount exceeds the target charge, the model restrains the charge level to the target charge level, ensuring maximum capacity is not exceeded. This method ensures that the heat battery is charged in a controlled manner that mirrors the actual behaviour of such systems, taking into account the battery's capacity, the target charge level, and the time available for charging.

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 heat battery, this includes the operation of the internal circulation pump 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 heat battery to the heat distribution system. The energy used by this pump is proportional to the total time the system is running in a given period.

Similarly, even when the heat battery is not actively being charged or discharged (i.e. standby mode), it still consumes 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 taken from the PCDB (or future equivalent) entry.

In essence, the total auxiliary energy consumption during a given period is determined by the energy used for the operation of the circulation pump and the energy consumed during the system's standby mode. This energy usage is an essential aspect of the system's overall performance and efficiency, contributing to the total energy demand of the heat battery.

Future development

Heat batteries are a relatively novel, or at least not widely used, technology in the UK. Types/configurations of heat battery not yet recognised may be added to the Home Energy Model in future on the basis of consultation responses received or technological/market developments.

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