CASE STUDY

DYNAMIC ENERGY MODELLING OF AN INNOVATIVE AND EFFICIENT HOT WATER SOLUTION

SUMMARY

The UK's Net Zero target commits the country to all but eliminate greenhouse gas emissions by 2050. To achieve this, it will be necessary to drastically reduce emissions arising from domestic heating and hot water, which make up 25% of total energy use[1] and 15% of emissions in the UK[2].

Mixergy has designed an innovative, smart hot water storage tank that allows consumers to heat only the water they need, rather than conventional hot water tanks which heat all or nothing. This saves on energy, cost and carbon emissions.

Energy Systems Catapult works with Government, business and industry, innovators and consumers to help decarbonise the UK energy system - with a key focus on home heating. Their Home Energy Dynamics (HED) toolkit helped Mixergy simulate how their hot water tank interacts with different building and occupancy profiles without needing to deploy the innovation in the real world.

THE INNOVATIONS - HOME ENERGY DYNAMICS

Energy Systems Catapult has developed the Home Energy Dynamics[3] (HED) tool-kit - which can dynamically simulate different aspects of home heating, including building fabric, hydraulic systems and energy-related household behaviour. This provides detailed analysis of the interactions between different aspects of home energy use.

The HED tool-kit was developed to provide data and evidence to innovators, the building sector, and the wider housing and energy markets to help target the most efficiency and cost effective low carbon technologies for retrofitting the wide range of UK housing types and consumer profiles.

HED has been tested on a number of homes to date, and demonstrated a very strong correlation between predicted and measured energy performance (Figure 1), which supports the validation work undertaken with Salford University.

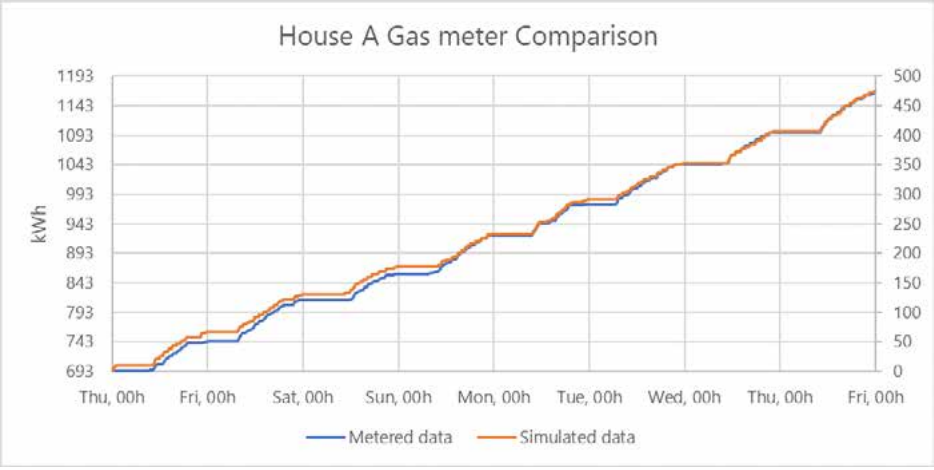

Figure 1 depicts gas metered data compared to simulated data from a previous study. It demonstrates a significant reduction in the 'performance gap' typically found when comparing modelled with actual energy performance, which allows the model to be used to evaluate upgrade options and their impact on comfort and energy usage.

[1] BEIS (2018) Energy Consumption in the UK, Table 1.04: Overall energy consumption for heat and other end uses by fuel 2010 to 2017.
[2] CCC (2018) Reducing UK emissions – 2018 Progress Report to Parliament. This includes emissions from electricity demand for heating and hot water in homes, which accounts for 1% of UK GHGs.
[3] HED is developed in Dymola® (a graphical interface to the Modelica® Language) and has been validated against Salford University's Energy House. See Pathways to Low Carbon Heating: Dynamic Modelling of Five UK Homes with modelling details in the appendices of the full report.

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THE INNOVATIONS - MIXERGY HOT WATER TANK

Mixergy[4] has designed an innovative, smart hot water storage tank that heats water by volume according to what is required, thereby conserving energy and reducing carbon emissions. Unlike conventional hot water tanks which heat all or nothing, the Mixergy cylinder exploits the thermocline[5] principles - where warmer water rises above cooler water - to start heating water from the top of the tank, rather than trying to heat the entire volume at once. The heating element (immersion heater and/or coil) at the top of the tank works together with a variable speed pump which operates when the hot water demand is above a certain level of the tanks total volume (e.g. 15%). This top-up technology enables selective heating of water which improves the efficiency, reduces heat losses and moreover, it could allow for a smaller size tank thereby conserving space.

Mixergy tanks can provide hot water through direct electric heating (immersion heaters) or indirectly through an internal coil which is designed for use with electric, gas or oil-fired boiler. Additionally, they can be fitted with external heat exchanger for use with heat pump systems.

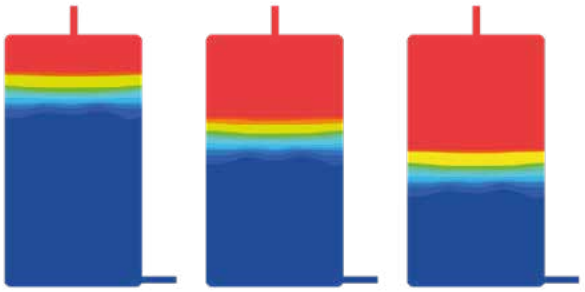

Figure 2 Volumetric heating and stratification in Mixergy tank (adopted from Mixergy website).

OUR APPROACH

Home Energy Dynamics (HED) ran a simulation comparing the performance of a Mixergy hot water storage tank with a conventional storage tank to establish the difference in energy consumption between both systems.

To match a home being used by Mixergy in a real-world trial, we selected for a semi-detached three-bedroom 2-storey house (steel framed modular-build) to run the simulation from a library of housing types compiled using the HED tool-kit. The house has three bedrooms on the first floor with a bathroom and landing. The ground floor is open plan including a dining room, kitchen and a living room. It is assumed that the hot water storage tank is in the utility room on the ground floor.

[4] See Mixergy Tank and Mixergy tank technical specification brochure
[5] Thermocline is a thin layer of water where the temperature drops noticeably across a small change in water depth.

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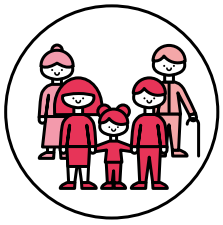
OCCUPANCY PROFILE

The HED tool-kit is novel in its inclusion of occupancy data from a range of different householder, rather than relying on standardised occupancy patterns. This is continually refined by insights from our Living Lab[6] - ESC's unique real-world trial facility of 100 connected homes, where innovative businesses can rapidly design, market-test and launch smart energy products and services.

Hot water consumption pattern can vary significantly for different homes according to the size and behaviour of the household. In order to address different hot water usage patterns, we selected two consumption profiles from a range of possible options:



Family of five: It is assumed the family living in this home comprises a couple with two teenagers and a pre-school child, one of the parents working part time and the other working full time.

Family of two: It is assumed the house is home to a retired couple.

The household profile contains data about the desired temperature and heating schedule for each for each room, the thermal efficiency of doors and window such single and double glazing and the hot water consumption details for occupants.

HEATING SYSTEMS

Similar to conventional storage cylinders, Mixergy tanks can provide hot water through direct electric heating or indirectly through an internal coil from a boiler (e.g. gas boiler, electric boiler, etc). The house model is assumed to have a fully electric heating system, so the direct electric hot water option was chosen to evaluate:

- Fully electric heating: The homes heating system comprises electric panels for space heating (SH) demand and direct electric heating hot water storage tank for hot water provision. Both storage tank models use an immersion heater (max 3 kW) to heat the water
- The target temperature for the two hot water storage tanks being compared in the simulation is set to 55°C and to reduce the risk of legionella's disease/infection, heating to 65°C is included once a week for both Mixergy and conventional storage tanks.

[6] See Energy Systems Catapult's Living Lab.

RESULTS

Table 1 and Table 2 present the summary of results over a two-week period in winter for a family of five and a family of two, respectively. HW Energy In: is the total energy input into each hot water tank in kWh and the HW Energy Out: is the actual energy extracted from the tank in the form of hot water. Cumulative electricity consumption and CO_2 emissions also includes the energy from space heating for the two week period.

Table 1 Energy consumption for a family of five.

	Storage capacity	HW Energy In	HW Energy Out	Efficiency (HW Energy Out / HW Energy In)	Cumulative electricity consumption for heating*	Cumulative CO_2 emissions for heating
	[litre]	[kWh]	[kWh]	%	[kWh]	[kg]
House model with Mixergy storage tank	215	116.1	114.3	98.4	301.1	80.9
House model with conventional storage tank	215	129.2	114.3	88.5	310.2	85.9

*It comprises electricity consumption for both space heating and hot water supply.

Table 2 Energy consumption for a family of two.

	Storage capacity	HW Energy In	HW Energy Out	Efficiency (HW Energy Out / HW Energy In)	Cumulative electricity consumption for heating	Cumulative CO_2 emissions for heating
	[litre]	[kWh]	[kWh]	%	[kWh]	[kg]
House model with Mixergy storage tank	215	56	52	92.9	239	62.1
House model with conventional storage tank	215	65.1	52	79.9	246	66.1

[9] House of Commons Committee for Public Accounts (2018) Renewable Heat Incentive in Great Britain.
[10] NAO (2018) Low carbon heating of homes and businesses and the Renewable Heat Incentive.

In both cases, the results illustrate that the Mixergy tank operates more efficiently compared to the conventional storage tank and it is possible to reduce hot water energy consumption by 11% and 14% for a family of five and retired couple, respectively. The results indicate the input energy and output energy in the Mixergy tank are very close which implies the Mixergy tank loses less energy in comparison to conventional tank.

It is worth noting that for the smaller household with a lower hot water demand, although the storage tank seems oversized for the household demand, the Mixergy solution still loses less heat compared to the conventional one.

This can be explained by examining how water is heated in both tanks over the two-week period. Figure 3 illustrates the comparison of heated volume of water in both the Mixergy and the conventional tank. The volume of heated water in Mixergy tank is closer to the actual demand in comparison to conventional solution which heats up a larger portion of the tank.

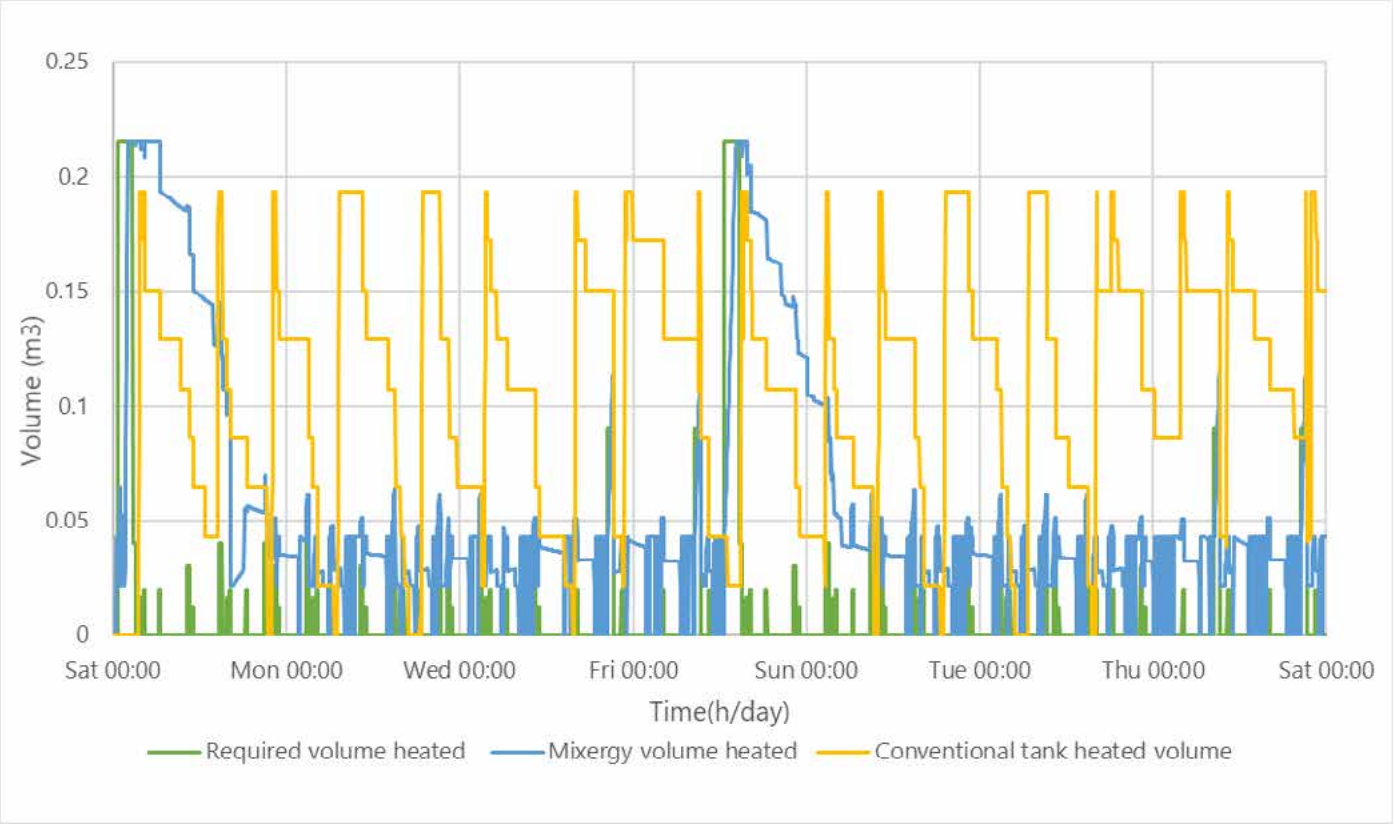


Figure 3 Comparison of volume of heated water in Mixergy and conventional storage tank

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IMPACT

The Home Energy Dynamics (HED) modelling toolkit illustrates that the Mixergy tank operates more efficiently compared to the conventional storage tank. The input and output energy in the Mixergy tank are very close which implies the Mixergy tank loses less energy in comparison to a conventional tank. These initial results could be validated with measurements from a real installation and used to inform product offerings.

It is worth highlighting that the simulation performed in this study did not take into account Mixergy's Machine Learning schedule optimisation function that could potentially lower energy and carbon even further by factoring in off-peak vs. peak tariffs and also end-user behaviour.

HED is a powerful toolkit which can be used to simulate the energy and carbon savings provided by low carbon heating solutions, either as standalone measures, or in combination with other energy efficiency measures. It can provide innovators, with detailed performance data and analysis of new heating technologies, in combination with building fabric upgrade options and different occupancy behaviours which can provide evidence for product and service offerings for both developers of new housing and the growing home retrofit market.

TESTIMONIALS

"Working with Energy Systems Catapult and their Home Energy Dynamics modelling tool-kit has been a really insightful process. It allows us to test Mixergy's product when deployed in a varied ecosystem of products and applications, which is often challenging to model. These insights are extremely valuable when articulating to prospective clients and stakeholders the full impact of deploying smart home technologies."

David White – Head of Commercial Operations, Mixergy

"We are delighted to apply our dynamic modelling toolkit to help Mixergy on their exciting journey, and to continue enhancing our library of innovative low carbon heating solutions which builds on our experience on the Smart Systems and Heat programme, Electrification of Heat project, our 100-home Living Lab and our Innovator Support Platform"

Bunmi Adefajo – Business Lead, Modelling, Energy Systems Catapult

For more information on Mixergy, visit: mixergy.co.uk/mixergy-tank.

For information on Home Energy Dynamics, see: Pathways to Low Carbon Heating.