PEAK PERFORMER

Transitioning the UK to renewable energy means being smarter about managing peaks and troughs. "Active buildings" are the next frontier of demand-side technology, and thermal mass can play a vitally important role. By Tom De Saulles

The UK's energy supply is undergoing a visible transformation as more and more wind and solar farms are connected to the grid. Less apparent is what's happening further downstream: a quiet revolution is just beginning in the way buildings regulate their energy use to cut carbon and save money. This centres on the introduction of active buildings, capable of electrical and/or thermal storage, a technological development that will be included in the next major SAP update (SAP11). Active buildings represent an important step towards meeting our carbon targets, and materials with high thermal mass such as concrete can play a part in maximising their effectiveness.

How do active buildings work?

An active building supports the energy network by intelligently controlling the way power is used. Central to this is the use of smart controls and some form of energy storage system, whether electrical, thermal or both. For example, dwellings can provide thermal storage using their domestic hot water cylinder and/or the thermal mass of the building fabric, while electric cars can provide power storage via the home charging system. Smart control of these and other technologies enables the electrical load for heating, hot water and power to be shifted, creating a much flatter demand profile that helps support the UK's already stretched supply network. The net result is less reliance on fossil fuel power generation to cope with peak demand, and greater use of renewable energy at times when it might otherwise be wasted. Carbon savings are a key driver for active buildings, along with reduced operating costs resulting from the ability to capitalise on time-of-use (TOU) tariffs. These have now been extended to the domestic sector, allowing a much broader market for the purchase of energy when it's cheap, avoiding high-demand periods. For example, one currently available tariff allows users to coordinate energy consumption with half-hourly prices, updated daily based on wholesale costs.

Thermal storage using the building fabric is becoming a practical option, made possible by modern domestic heating controls that can adjust the temperature in individual rooms using remotely controlled valves. These respond to timing and temperature commands from a central controller, a system recognised in the current version of SAP. This technology is now being developed to include load shifting and TOU tariffs, with the potential for additional enhancements such as the ability to take account of weather forecasts and occupancy patterns based on self-learning. In response to new technologies such as these, a SAP industry forum was established to consider priorities for inclusion in SAP 11, and to provide a route for industry and government to discuss views and policy. In April 2020, the forum published a report detailing the likely mainstream technologies that SAP 11 may need to cover when launched in the mid-2020s, of which active buildings and their systems are a major part.

THERMAL STORAGE USING THE BUILDING FABRIC IS MADE POSSIBLE BY MODERN DOMESTIC HEATING CONTROLS

LEFT Agar Grove in north London by Hawkins\Brown and Mæ Architects. Set to become the largest Passivhaus development in the UK, it aims to reduce heating bills by around 90% compared with conventional homes. The highly insulated concrete structure is designed to retain heat in summer and coolth in summer. This retention capacity will play an even more important role in the next generation of "active buildings"

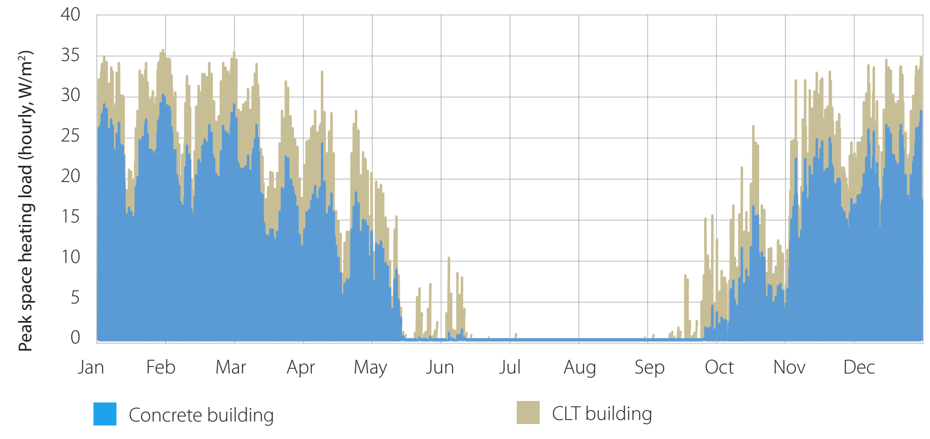
Photo: Jim Stephenson

STRUCTURAL COMPARISON

Heat pumps, thermal mass and flattening the load

With the shift away from gas heating towards heat-pump technology, loads on the national grid may be more affected by weather conditions during the heating season. However, medium and heavyweight buildings can reduce stress on the supply network at times of high demand by using their thermal mass to help flatten the space-heating load profile. This can be seen in the graph below, produced as part of a recent study of the comparative life-cycle performance of two six-storey apartment blocks, one with a concrete structure and one made from cross-laminated timber (CLT). The modelling shows that the average daily peak space-heating load of the heavier-weight concrete building is 25% lower than that of the equivalent CLT building, both of which used a heat-pump system. The study was carried out by environmental engineering consultancy Max Fordham, commissioned by The Concrete Centre.

Predicted peak space heating demand (hourly, 2020- 2040 time period, intermittent occupancy)



How do active buildings use thermal mass?

Active buildings provide a new perspective on the role of thermal mass, which is arguably more relevant today than ever. This ancient and widely understood technology continues to provide an effective means of reducing the problem of overheating, and its use is now growing to address the challenge of low-carbon design. Active buildings will harness the ability of heavyweight materials such as concrete and masonry to store and release significant amounts of heat. For example, a heat pump supplying underfloor heating to a concrete floor can be operated with a smart controller monitoring air/fabric temperature and half-hourly electricity prices from a smart meter. When power is cheap, the controller is able to charge the slab with heat, while ensuring both the floor and living space remain within comfort limits. Heat is then slowly released over several hours, limiting the need to operate the heat pump at times of high grid demand and prices.

WHEN POWER IS CHEAP, THE CONTROLLER CAN CHARGE THE SLAB WITH HEAT, WHILE ENSURING THE LIVING SPACE REMAINS WITHIN COMFORT LIMITS

As this form of thermal storage uses the building fabric, it is a simple, low-cost option. The control technique also works with traditional space-heating systems, where heat from radiators is indirectly absorbed and released from heavyweight walls and floors in the usual way, albeit with slightly less control and efficiency.

Even a modest change to the temperature of heavyweight floors and walls requires a relatively large amount of heat to be absorbed. The effect on occupant comfort remains small since the surface temperature is changed neither significantly nor quickly, a useful property of thermal mass.

This method of controlling space heating does, however, incur a small rise in energy use, because the slightly higher average temperature results in increased storage losses from the building fabric. The increase in energy use has been shown to be around 3.5% for dwellings with underfloor heating supplied by a heat pump.

However, this loss only occurs at the building level; at grid level, much larger savings are realised as renewable energy from the supply network can be used for longer periods. For example, when underfloor heating is controlled in response to grid demand, curtailment – or reduction of output – of renewable energy sources has been shown to lessen by around 30-45%. This type of saving is expected to be included in the SAP 11 results, which won't be limited to evaluating carbon emissions at the building level, as is currently the case.

Curtailment can be significant at times of low demand – in China around 7% of wind power was wasted in 2018, and Ontario, Canada lost about 25% of all renewable generation in 2017. The UK is not immune to this problem, particularly as the renewable capacity grows, making periods of excess more of an issue than shortfalls. So, alongside battery storage to help balance supply and demand, thermal storage has an important role to play, especially during winter when heat demand is what peaks most.

ABOVE AND RIGHT Powerhouse Telemark, an "energy positive" office in Norway, features a heating and cooling system that supplies pipes embedded in the concrete slab. Here the source is geothermal, but when combined with smart controls, such embedded systems will be a particularly effective way for heavyweight buildings that are reliant on grid energy to maximise renewable sources, by storing heat and coolth and therefore spreading out demand

ABOVE LEFT As seen on Grand Designs, Concrete House by Raw Architecture is constructed entirely from exposed, in-situ concrete. Its thermal mass, coupled with a high level of insulation, retains heat so well that owner Adrian Corrigall has only had to switch on the underfloor heating once in two years

Cooling in active buildings

The application of thermal mass is equally relevant to active buildings with mechanical cooling and air conditioning, which can be controlled to pre-cool heavyweight floors and walls when grid demand and TOU tariffs are favourable. The fabric can then slowly absorb internal heat gains while providing passive radiant cooling to the occupants. This works particularly well with water-cooled concrete floors supplied by a heat pump, which also delivers warm water in the heating season for year-round smart control of the floor slabs.

The benefits to the grid of active cooling control depend on many variables, but research into the use of thermal mass in a nearly zero-energy office building found that peak power demand can be decreased by around 55% during the occupied period. It is estimated that every 1°C of pre-cooling gives two hours of storage. So if the comfort limit is set to 4°C below the maximum temperature of, say, 22-24°C, the pre-cooling duration is limited to a maximum of eight hours. The subsequent period of heat absorption varies with the characteristics of the building, but to maintain comfort, the indoor temperature should not rise by more than 2.1°C per hour, according to US building services organisation ASHRAE.

With institutional investors already focusing on low-energy design as a way to future-proof property assets, it seems highly likely that this will broaden to include active buildings. A good example of the cost saving this technology can provide is at the Bullring shopping centre in Birmingham, a leader in the use of this technology. Owner Hammerson worked with Aston University spin-out Grid Edge to optimise energy demand for heating and cooling on a day-ahead basis while allowing for changes in footfall and weather. Grid Edge's control technology uses AI learning to predict the energy profile. This enables the heat flow to and from the building's thermal mass to be managed so that HVAC loads are shifted in response to the cost and carbon volatility of the grid, while internal conditions always remain within desired comfort limits. Over a six-week test period, the system delivered £23,000 in energy savings.

The use of energy storage and smart controls in active buildings shifts them from being passive, standalone energy consumers to become active participants in a much wider system that optimises energy use and carbon emissions – potentially a new energy asset class for investors. High thermal mass construction now has smart thermal storage to add to its other future-proofing attributes.

Tom De Saulles is building physics advisor at MPA The Concrete Centre

Photos: Ivar Kvaal; Tarry + Perry