Guide to Thermal Storage

Energy Managers' Guide to Thermal Storage

Produced by the **Energy Managers Association**

Summary

This EMA Energy Managers' guide has been designed with Ecopilot (UK) Ltd to offer some basic information and guidance on understanding thermal storage, how it works within buildings and what the common misperceptions are when accessing buildings' thermal inertia.

An Overview

The vast majority of buildings are thermally inert by nature. This means that the buildings' framework has a self-regulating ability to maintain the correct temperature – but is this being utilised by the buildings' managers? Most control and regulating systems currently in use are set to instantly compensate for each temperature variation that occurs in a building. As a result, the installed systems are forced to work against the natural self-regulation, which leads to the waste of both cooling and heating capacity.

An example of this would be early in the day, following a night set back or system shutdown when the internal air temperature and external temperature are cooler. With a standard control strategy, the temperature measured by the return or extract air temperature sensor would increase the duty requirement of the supply air, modulating the heating valve to the heating coil open to reach the required space temperature set point. During the course of the day, the outdoor temperature rises and therefore the external temperature influence on the building increases. The effect of this is that the temperature internally increases therefore the duty requirement of the heating to the supply air is reduced, eventually reaching equilibrium and the heating valve is closed. Should the external and internal temperature influences surpass the equilibrium point, the valve to the cooling coil would be modulated open to reach the set point of the space temperature. The result of this would be that the building would have been heated and cooled within the space of one day, requiring energy input to both systems. With a more intelligent and long term control strategy taking in to account the internal and external influences this could certainly be avoided.

Varieties of systems that optimise buildings with regard to the buildings' natural thermal inertia are available on the market today. Measured reductions in energy consumption of 20-40%* for heating and cooling of buildings are common after installation. Pay-off times for the systems normally appear to be approx. 2-5 years. The interesting thing is that these results are achieved by letting the buildings' technical installations work with the laws of nature to store the free heat and cold that would otherwise have been "discarded". If you manage properties with modern computerized BMS systems (no older than approx. 10 years), a

**Figure has been taken from the 500+ installations already carried out.*

system that works with the building's inertia could be one of the most viable measures to install in the property that you manage.

Research in the field and barriers for take up in the past

As early as the 1970s, research results from the Royal Institute of Technology (KTH) in Stockholm showed the importance of adopting a holistic view and taking advantage of the building framework's thermodynamic properties.

The basic idea involves utilising the heat, for example from machines and people, which is stored in the framework of the building. Actually, controls and regulating technology only need to observe the temperature curves and intervene when necessary. The secret was said to be the ability to do this in a controlled manner without negatively affecting the indoor climate. One problem which existed during the 1970s was collecting and processing enough data to be able to regulate buildings in accordance with the principles of thermal inertia. Good measurement of the indoor environment is required to put theory into practice.

High costs, lack of sensor technology and lack of computing power put a stop to a practical rollout of the research findings which were produced. These problems no longer exist today as stable wireless technology is available in cases where there is no measurement of the indoor climate, and a standard phone has more computing power than that available to a whole research team in the 1970s. Costs have come down and installation technology is more sophisticated. Today, it is largely traditions within the real estate and control and regulating industries that hold back the development of technology for utilising thermal inertia in buildings.

Way forward - Control strategy that takes account of the buildings' thermal inertia

This text provides examples of how modern dynamic systems can be designed so that the building's thermodynamics are best utilised, which results in reduced energy consumption and lower power peaks.

The building's thermodynamic function – How does it work?

A thermally inert building can store surplus heat at high temperatures and then emit this heat when the temperature drops. Figure [1] illustrates the most common heat flows in a building. We have heat loss through the building fabric, through ventilation and leaks and through flushed hot water. In order to

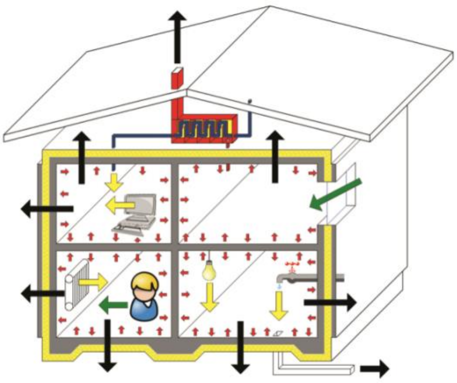


Figure 1

maintain a comfortable indoor temperature, the building needs to be heated during the winter months with a heating system and the building may also need to be cooled in the summer. Even hot water and electrical appliances add heat to the building. We define all these sources as purchased energy and they are highlighted in yellow in the figure. In addition to the purchased energy, heat from the sun or atmosphere is also supplied to the building when the weather is warm and users also contribute with their own body heat. These sources are highlighted in green in the figure and defined as free heat. Free heat and some of the purchased energy, in particular the energy required to power electrical equipment, is often difficult to control, and causes undesired high temperatures during sunny times of the year. In order to make best use of the free heat, the building's thermal inertia can be used so that the building stores energy when there is an excess of free heat, which can later be used when there is a deficit. However, for this to be successful, it must be acceptable for the indoor temperature to vary slightly. Heat storage/reuse is illustrated by the red arrows in the figure [1].

Time constant and load variations – variables to consider

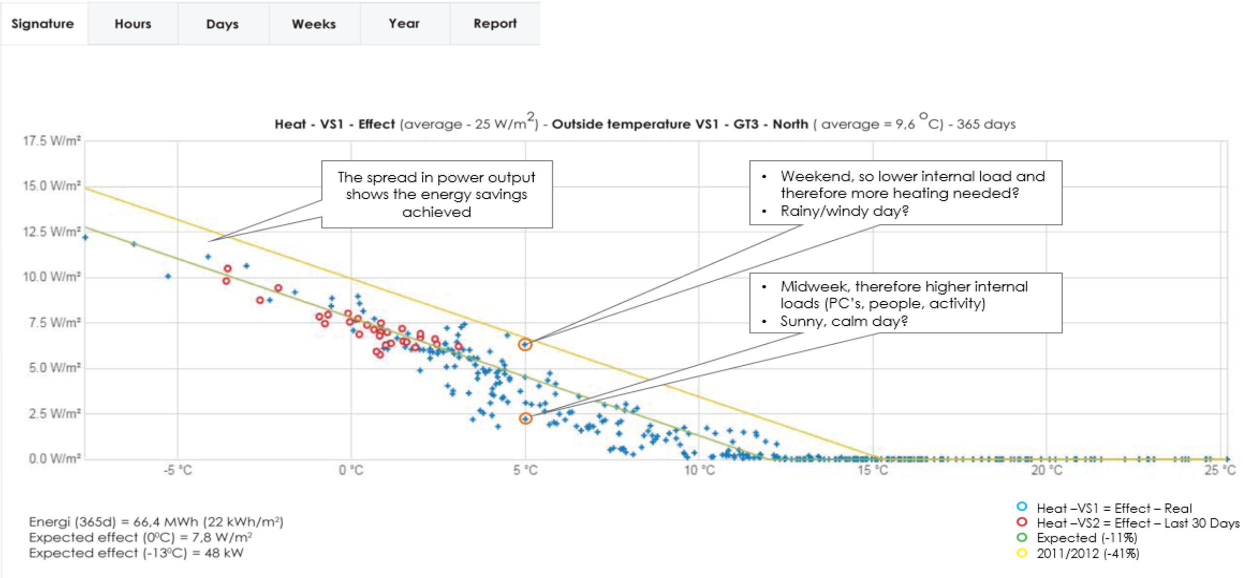
A measure of a building's thermal inertia is the time constant, which is the quotient of the building's heat capacity divided by the ventilation and transmission losses.**
Heat recovery takes into account the ventilation losses when the time constant is calculated. The time constant can also be calculated as the time taken before 63% of the final temperature is reached when a temperature change has occurred. A change of temperature can either be due to a change in the outdoor temperature or one of the internal loads. In an existing building with a heavy framework, time constants are often close to 200-300 hours.

But even with a time constant of 100 hours, you can save large amounts of energy by utilising technology that regulates using a principle based on thermal storage. This means that short-term changes, such as daily variations of the outdoor temperature and internal loads, hardly affect the indoor temperature. This, in turn, means that the power requirement of the cooling and heating system is not particularly affected by these short-term temperature changes either. These systems work best in climates which experience short-term changes and seasonal changes. The proof of working in this way is illustrated in the energy signature below;

*** Equations such as the below can be used;*

$$\tau = \frac{\sum c \cdot m}{\sum U \cdot A + \sum \psi \cdot l + \sum \chi + \rho \cdot c \cdot q_{Vent} \cdot d \cdot (1-\eta) + \rho \cdot c \cdot q_{leakage}}$$

An Example



Key:

- The BMS set points which will dictate the amount of energy that will be consumed based on the outdoor temperature. The line is taken from the data gained from a previous year's consumption (or, when considering a new building, the independently supplied consumption estimates)

- Assessment of the energy that will be utilised at a given outdoor temperature, once a system has been implemented that has the ability to offset systems based on the thermal mass and balance temperature of a building.

- The power consumed on a specific day given the average temperature for that day.

- Blue dots from last 30 days.

- Two days that have the same outdoor temperature, however different amounts of power needed to maintain ambience inside the building.

Common misperceptions

1. Traditional control and regulating systems

Traditional systems aim for a constant indoor temperature based on fixed reference values, time channels or outside temperature. However, the building's thermal inertia means that installation systems often have to work reactively, which means that the control system is often out of phase with the building's natural behaviour.

Adjustment according to the building's dynamic behaviour only takes place using heat regulation curves or with constant temperatures, but this often occurs empirically and rarely optimally. For example, many buildings have outdoor temperature-compensated flow curves for their radiators and underfloor heating systems. This often means that the radiators and underfloor heating get out of phase because internal loads, the effect of the sun and wind, and the building's inertia often have a greater influence on the indoor climate in a modern building than the outdoor temperature.

Ventilation units and post-processing batteries often have a constant flow temperature for cooling and heating. The batteries in the unit or at room level then control the inflow air temperature by opening and closing their heating and cooling valves. This is based on having to achieve a set temperature in the room/area. In many cases, this common type of system structure means that boilers/cooling machinery have to work unnecessarily hard when they are set to maintain a constant flow temperature. This could be adapted to the amount of energy that is available in the building and the framework and could thus often be reduced. There is also a major risk that cooling of "free heat" occurs when ventilation systems regulate to a constant temperature and an unnecessary amount of heat is purchased instead of using the heat that is stored in the building's framework.

Many existing control and regulating systems are also unnecessarily complex, which can result in them counteracting the thermodynamic process. In the worst case, the property is heated and cooled at the same time.

2. Temperature variations under controlled conditions

A common misconception also is that systems must be designed to maintain a constant indoor temperature to ensure a good indoor climate and therefore satisfy users. Since a standard system is primarily controlled by the space temperature sensor and the heating system has built-in inertia, this is impossible to achieve in practice. It is much better to let the indoor climate follow the laws of nature and control it using current indoor temperatures within an acceptable band of comfort. In this way, we can automatically include the building's thermodynamics in the regulation. Allowing a greater temperature variation creates greater savings. The important thing is therefore that regulation occurs under controlled conditions. Many property owners experience an improved indoor climate when switching from a traditional system to a dynamically controlled system.

3. Do not regulate against the laws of nature

The industry likes to talk about intelligent control and regulating systems but forgets about the "intelligence" that is already built into the building fabric. It is high time that we started to simplify our thinking and take the laws of nature into account. If we take into account and make use of the opportunities provided by thermally inert frameworks, the installations can be simplified. Consequently, it will be possible to reduce installation costs and the systems will also provide better functionality and safety while in operation. Savings of 20-40% and pay-off times of 2-5 years are not uncommon when a building's thermal inertia can be fully exploited.

Available technology

Software products which allow BMS systems to take the thermal inertia of buildings into account are currently available on the market. The theory behind these software products is simple and is based on buildings being partitioned into different thermal zones. In addition to the zone's thermal inertia, partitioning also depends on sunlight, the effect of the wind and other known heat loads. Each zone has its own local time constant and one or more temperature sensors are located in each zone.

Heating, ventilation and cooling are then controlled mainly through internal temperatures in accordance with a given comfort requirement. An installation consists of a main unit with software connected to the existing control system as well as a room sensor.

Requirements for these solutions to work

A fairly modern control and regulating system must be installed in the building and the building must have functioning technical installations. It is favourable if the control system is not older than approx. 10 years and can communicate, directly or through a gateway, using one of the BMS industry's standard protocols, Modbus or BacNet. The building must also have internal loads and a relatively thermally inert design or interior fittings so that software can produce good results. If a building has the right thermal conditions, a modern BMS system or undergoes a replacement/upgrade of the BMS, there is no reason not to consider the software solution. This type of technology has great potential to reduce gas and electricity consumption in the UK.

Choose your technology supplier

Ecopilot (UK) Ltd is a company currently working to offer an innovation that utilises your building's thermodynamic functions to reduce consumption and deliver savings, whilst improving indoor comfort. The company was founded in Sweden, but has been exploring UK building characteristics for suitability since summer 2016, establishing the UK Ltd company in January of 2017. Their software product, also called Ecopilot, delivers an automatic reduction of energy consumption and its associated costs. It is proven to function with all modern BMS and HVAC systems.

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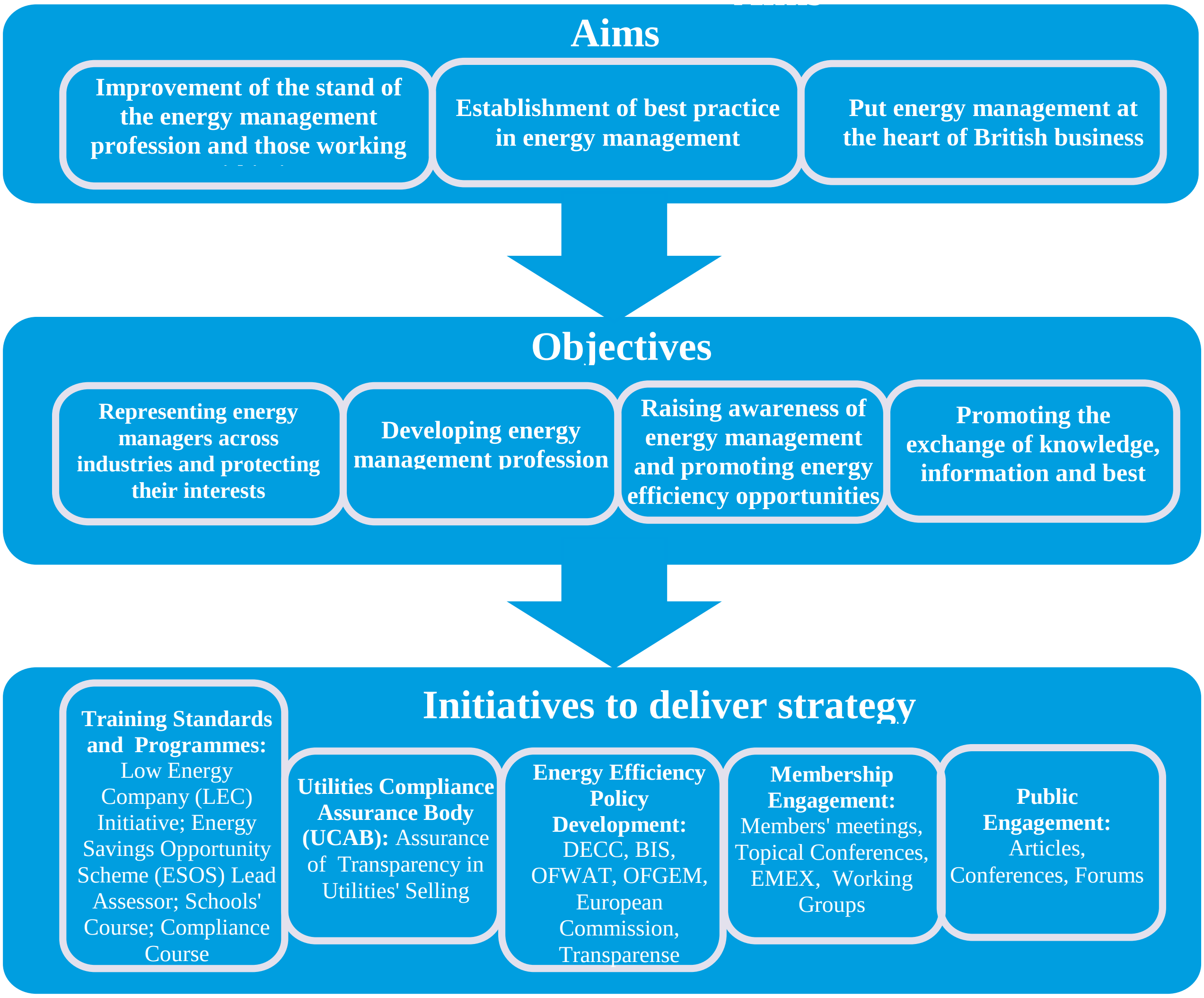

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