

# E L E M E N T A L S O L U T I O N S

E n e r g y & W a t e r

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## IWM Duxford

Energy Strategy for proposed paper store '104b'

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## Introduction

These proposals are informed by our experience designing and monitoring the Hereford Archive and Records Centre (HARC). The approach at HARC was heavily inspired by the work of Tim Padfield and his colleagues at the Technical University Denmark combined with our experience designing very airtight, well insulated buildings to the Passivhaus Standard. Whilst HARC is a fully certified Passivhaus building it owes more to the genuinely passive approach of Padfield and his colleagues.

This passive approach forms the basis of recommendation in PD 5454 and the current draft BS EN 16893. However the energy strategy for HARC was conceived to meet the then current British Standard which was based around a higher fixed temperature without seasonal variation. This resulted in a number of design decisions that would have been made differently in light of PD 5454.

An initial energy balance for the proposed store 104b has been carried out using the Passivhaus design software PHPP 9.6.

The proposed design will allow an environment in the range 13°C to 18°C and 40-60% RH to be met with minimal energy use and a high level of stability. Based on our experience with HARC we propose a hybrid approach with a combination of modified conservation heating for winter and supply air dehumidification in summer. This provides considerable flexibility and resilience.

The availability of supply air dehumidification means that summer temperatures can be kept low without the risk of high RH. This allows the coupling of the building to the ground with an un-insulated slab. (HARC incorporates ground floor insulation as the final decision to allow winter temperatures to drop to around 13°C was only agreed after construction had started.) Feedback from HARC is that low temperatures are fine, but high temperatures are not, so a “passive” way to keep the store cool is advantageous.

We have also found that supply air dehumidification is effective in suppressing higher than desirable RH caused by residual construction moisture<sup>1</sup>.

This approach also allows the building to be run cooler in winter than the 13°C minimum temperature recommended in PD 5454 should this be required, now or in the future. However if higher winter temperatures than 13°C are required for some reason then there will be an increase in energy consumption for heating.

## Building Fabric

The proposed building is a single storey simple rectangular box. This emerges from building height restrictions, the need for efficient racking, a cost-effective structure (given high loading) and a form that can easily be made very airtight.

The form factor of a building this size is inherently favourable but any deviation from a rectangle in plan or section will have significant cost implications, some unforeseen.

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<sup>1</sup> However this is not a substitute for drying the building out as much as is practical before occupancy, typically using large portable dehumidifiers.

Super-airtight construction is key to the proposed strategy. The more airtight the building, the less air flow is needed to create a slight positive pressure to prevent infiltration of outside air with associated moisture load and pollutants. This considerably reduces the size of plant and results in very stable conditions with minimal variation despite very simple controls.

Our assumed air permeability for the proposed store is 0.15 m<sup>3</sup>/(m<sup>2</sup>.hour). This is over sixty times less air leakage than current building regulations but only slightly better than is regularly achieved for Passivhaus homes with complex fenestration and intermediate floors.

This level of airtightness would be very difficult to retrofit in many existing buildings and is something that must be designed in. For a rectangular plan, single storey building is very easy to achieve with masonry construction.

The proposed levels of insulation are modest for a low energy building due to the acceptable low winter operating temperature and the excellent volumetric form factor (volume divided by heat loss area).

**Provisional insulation proposal:**

<b>Element</b>	<b>Insulation mm</b>	<b>λ</b>	<b>U value</b>
Walls	150mm	0.04 W/mK	0.23 W/m <sup>2</sup> .K
Floor	None	n/a	n/a
Roof	250mm	0.035 W/mK	0.134 W/m <sup>2</sup> .K

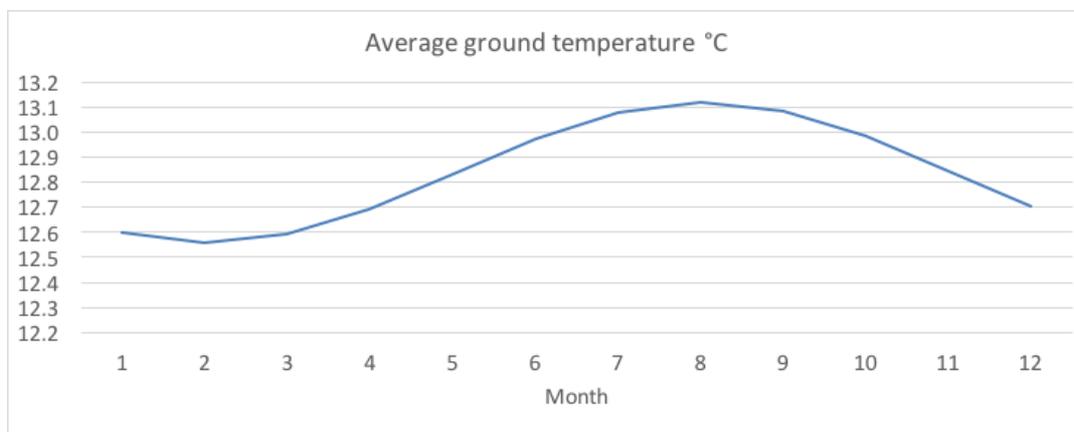


Figure 1. Ground temperature calculated in PHPP based on 13°C minimum winter temperature in the archive.

Note the graph above does not represent the ground temperature generally, just that below the building, so the ground temperature is being raised by heat loss from the store as this is heated to 13°C.

Whilst an uninsulated ground floor is proposed, care must be taken to avoid mould risk at the floor wall junction. The usual test is to determine the  $f_{rsi}$  which should be greater than 0.7 for UK Building Regulations or > 0.8 for Passivhaus Certification. Because we can predict the internal temperature and humidity at the coldest time of year we can determine the minimum acceptable surface temperature to avoid risk of mould growth. This is above the dew point temperature and corresponds to the temperature that will result in a localised rise in RH to 80%. See figure 3.

Figure 2 shows the sort of detail that can be used to reduce the wall/floor thermal bridge though use of perimeter below ground insulation and so eliminate mould risk. The exact detail will depend on the construction method chosen and structural details of the foundations but projecting pile caps should be avoided.

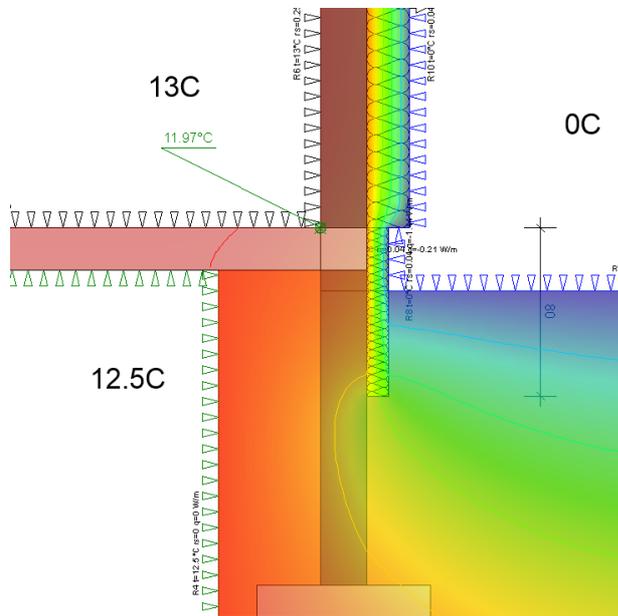


Figure 2. Improved edge detail 13°C air temperature and 12.5°C winter ground. This example is for rain screen cladding.

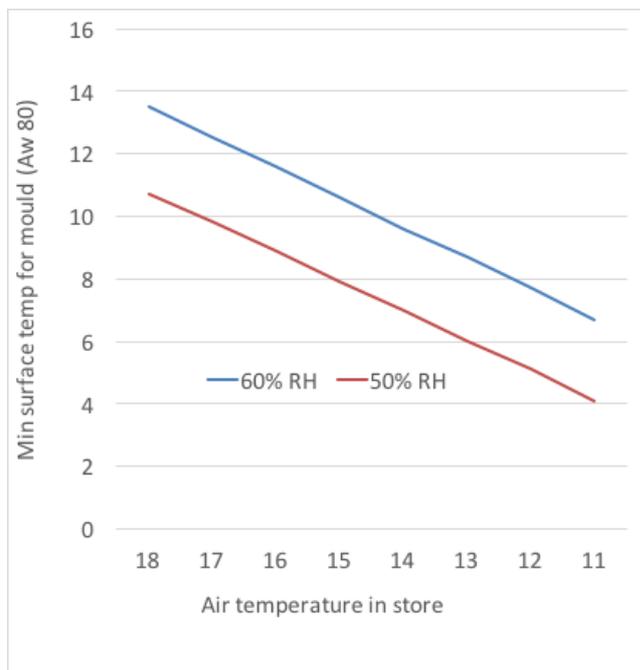


Figure 3. Mould safe surface temperature with varying repository air temperature at 50% and 60% RH.

The plant room should be located within the thermal envelope of the strong room but with suitable fire separation (4 hour assumed). This simplifies structural and airtightness details and allows the gains from plant to usefully contribute to the building's energy balance.

## Energy and Power

The proposed building has been modelled in PHPP to inform, among other things, design U values. As there are no windows the small but significant amount of solar gain in the graph is directly through walls and, more significantly, the roof.

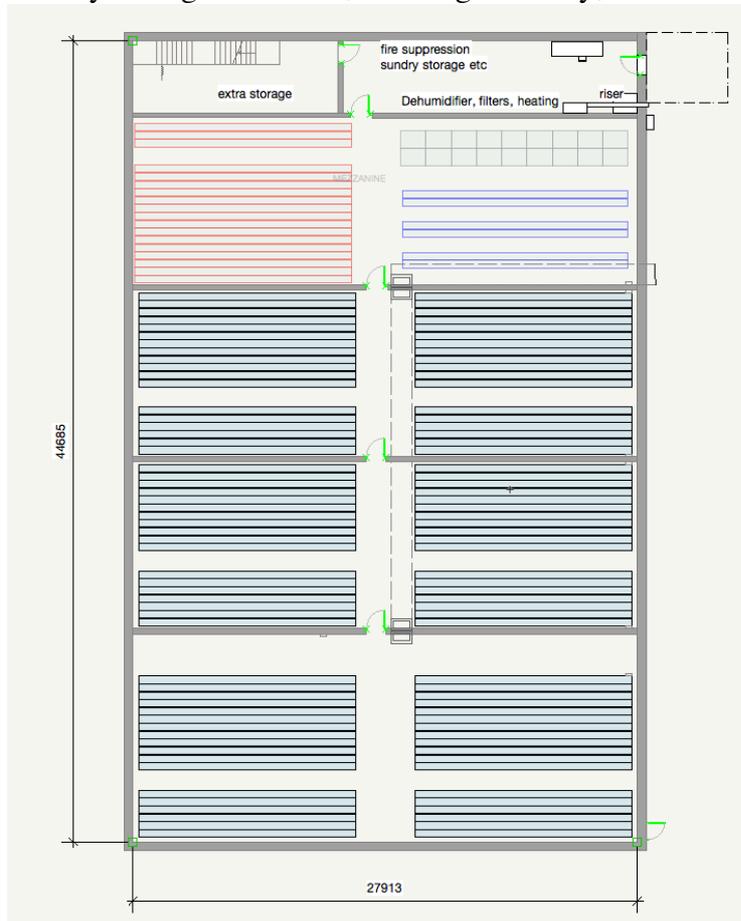


Figure 4. Simple building as modelled pending design freeze.

Whilst the current model shows the building meeting the Passivhaus  $15\text{kWh}/(\text{m}^2.\text{a})$  target, the target relates to dwellings with domestic ceiling heights heated to  $20^\circ\text{C}$  and has no real basis in terms of a building such as this. However we would be confident in arguing for Passivhaus certification on the basis of the proposed approach.

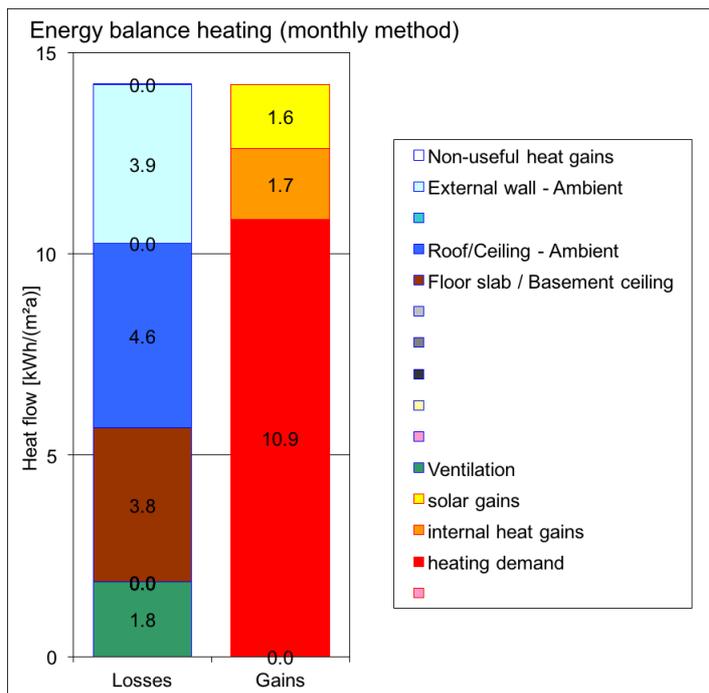


Figure 5. Provisional heating energy balance assuming 13°C winter temperature.

The results are very sensitive to internal heat gains (IHG) assumptions which will be largely due to lighting. The collection at HARC is regularly accessed and the lighting and people plus other minor IHGs are providing all the heating. Building 104a is assumed to have less regular access and so lower gains.

We do not see this uncertainty as a risk. If gains are even lower than modelled, we can see from the graph that this will have little impact on the annual energy requirement and overall energy costs will be slightly less. Conversely initial modelling suggests that even regular occupancy by staff (with all lights on for 8 hours per day) will have minimal impact on summer temperatures. This is not surprising as our reference building HARC remains under 20°C despite very high usage, twice the insulation and a 3-storey compact form with one wall adjacent to permanently heated offices.

## Conditioning the Space

### Heating

With no floor insulation, our model suggests that the strong room temperature will stay low in summer. This means that additional heating would be needed to raise the temperature to allow modified conservation heating to regulate RH. As the temperatures rise, losses to the un-insulated ground slab become significant.

The details for heating will be developed post planning but several simple options are possible and can be compared for capital and running costs once the building design is finalised.

Assuming a delivered heat cost of around 5p/kWh the heating bill should be under £1000/year for a 1,260m<sup>2</sup> building. Dehumidification electricity use will be in addition to this. Our initial model suggests a total annual energy cost less than £2,000.

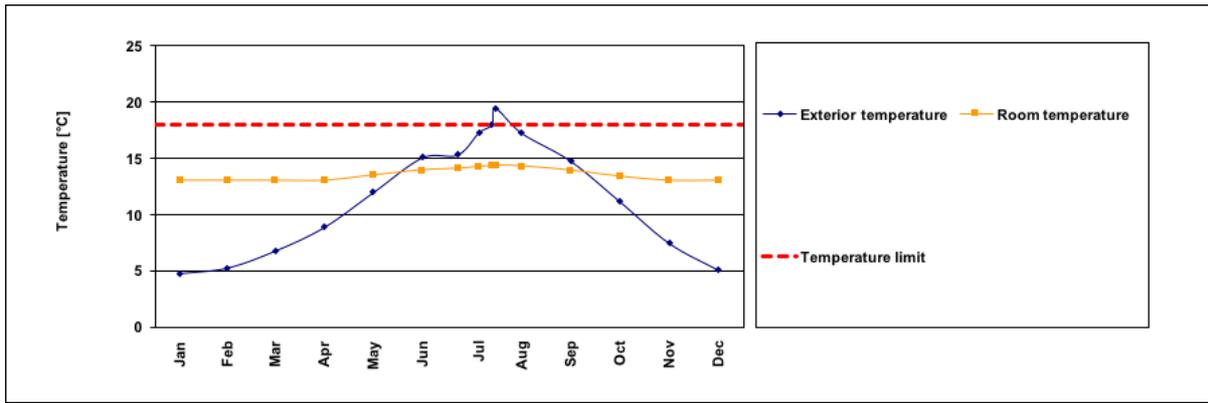


Figure 6. The yellow line shows predicted internal temperature assuming a 13°C winter heating set-point.

### Dehumidification

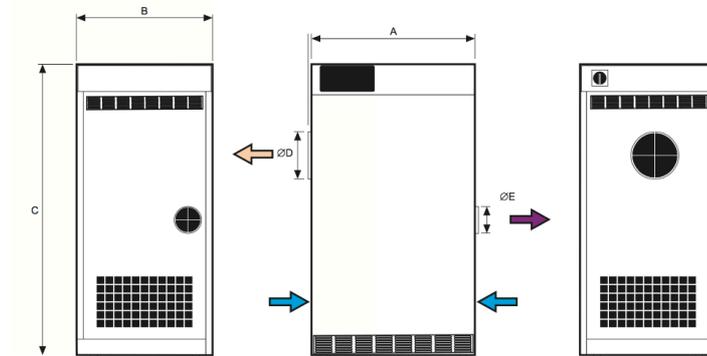
The low internal gains and proposal to avoid under-slab insulation (to reduce cost and simplify the structure) guides us towards running the store at a lower temperature but with supply air dehumidification. For HARC, heat gains from the desiccant dehumidifier had to be removed by a cooling coil but for this building the gains are beneficial.

The provisional proposal is to use either a Munters ML270 dehumidifier supply outdoor air at a flow rate of about 250m<sup>3</sup>/h or the smaller ML180 at a supply air flow of 180m<sup>3</sup>/hour.

#### Model ML270

Diagram measurements are for reference only.

Scaled and dimensioned AutoCad drawings are available in Munters DryCap program.

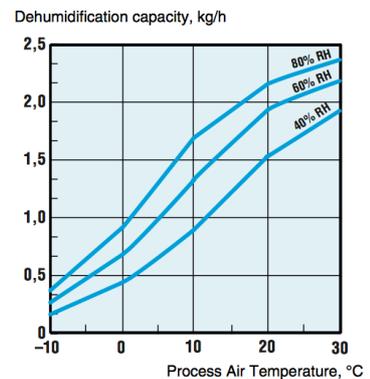


Width (A)	Depth (B)	Height (C)	Diam. (D)	Diam. (E)	Weight
513 mm	410 mm	1010 mm	160 mm	100 mm	58 kg

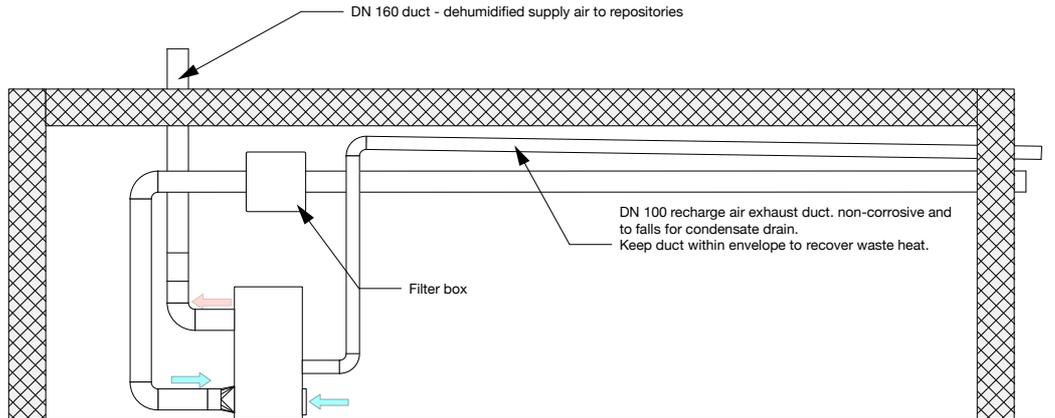
#### Technical Specification

#### Dehumidification Capacity

Approximate capacity in kg/h at different inlet process air relative humidity, % RH.



The ML270 requires a 3 phase supply with total power about 3kW but the smaller ML180 is single phase with a total power of 2kW.



1 Dehumidifier - indicative layout

Figure 7. Indicative Dehumidifier schematic.

### Control

There are a few options for controlling dehumidification – the more sophisticated approach modulates the level of dehumidification in response to the humidity in the supply air, however this is normally only used on larger units with 3 phase power supplies. The alternative is simple on/off control, which was used at HARC for both photo-store and fresh air supply.

The photo-store is a small room with little moisture absorption from contents, but monitoring showed control over a 2%RH band, thanks to good control and frequent cycling of the dehumidifier on and off. The larger repositories are much more representative of the system proposed for 104a, with dehumidification of supply air only, and demonstrate significant humidity buffering and stability.

Figure 8 shows the result of turning off the supply air dehumidification at HARC. The result is very slow and subtle despite a step change in the supply air condition.

This stability is the result of relying on the building and contents to maintain stable conditions through airtightness, insulation, thermal mass and moisture capacity. This limits the influence of the very variable outside conditions.

The excellent airtightness allows a controlled supply air volume of about one air change per day. This is more than enough to provide fresh air for people working in the repositories but low enough to limit the impact of changes in outdoor conditions.

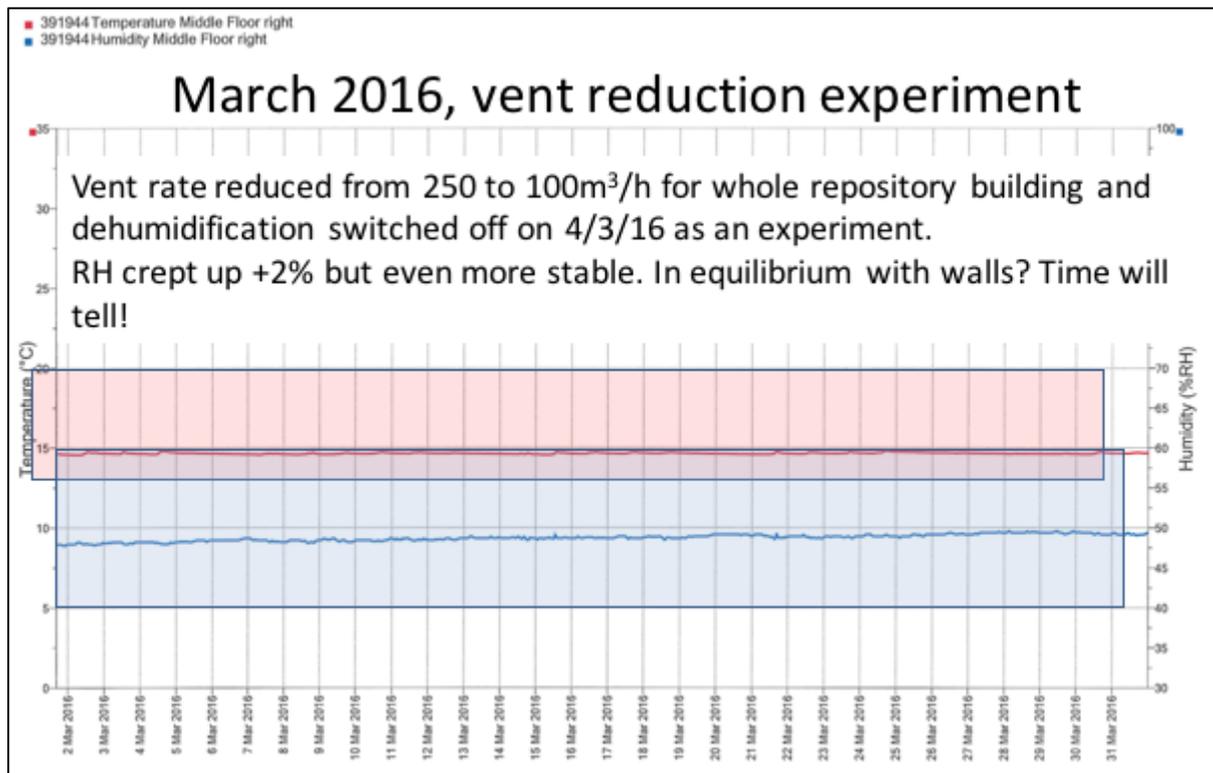


Figure 8. The slow and subtle impact of turning off the supply air dehumidification at HARC. Dehumidification was turned back on again.

The very slow response of the building combined with very limited capacity for heating and dehumidification result in a very stable environment with only the simplest of controls. No attempt is made to control the RH in the space directly using sensors as this will not work because of the buffering. Instead the trend can be observed and dehumidification can be turned on or off on a seasonal basis. Unlike recirculating conditioning, the system cannot accidentally over – dry the air, for example if a sensor fails.

Similarly with a limited heating capacity there is almost no risk of the building accidentally overheating.

This extreme damping of RH and temperature should allow a simplified control strategy without resorting to a BMS. The larger 3 phase dehumidifiers include a modulating control and dew point sensor. The smaller dehumidifiers are supplied with simple RH control but this could be located at the far end of the supply air duct rather than in the room. This would allow the air to reach a stable temperature so that the measured RH would reflect the resultant room RH without buffering.

Alternatively, given the annual average temperature in the store we will know the desired moisture content of the supply air needed, and can switch the dehumidifier on when that moisture content is exceeded.

Using a dehumidifier undersized relative to the peak load is a sensible strategy since occasional peaks in supply humidity will be absorbed by the building, and in general the dehumidifier will be the right size for running continuously.

Simple control strategies can be evaluated at the detail design stage in consultation with the manufacturer and appointed building services engineers. The benefit of pursuing an innovative approach is the potential to eliminate the usual Building Management System, (BMS).

### Electrical Load Limit

It is understood that the available electrical supply is limited but we are awaiting information on the supply limit.

Heating load, assuming 13°C winter set point, is estimated at about 8kW peak or 4kW continuous for January. This could be provided by gas or air source heat pump which could be set to operate when the outside air temperature was above a chosen set point thus ensuring a better COP. The very slow thermal response of the building would allow this. Thus using an air source heat pump the average electrical load for heat could be around 2-3kW

### Summary of main electrical loads:

Dehumidifier	3kW
Lighting	3.8kW*
Heat (heat pump)	3kW
Fire suppression, e.g. pump for mist system	TBC.

Heating and dehumidification need not be concurrent. Dehumidification is expected to run in summer and heating in winter.

\*Lighting peak load will depend on required Lux levels but assuming say 3W/m<sup>2</sup> we get a peak of about 3.8kW with all lights on and no sophisticated control.

These loads are very low but if the electrical supply really is very limited, the peak could be controlled by turning off heat and dehumidification when the building is occupied but it is difficult to imagine why a standard supply could not be provided to meet these loads with some margin.

We advise against using an autonomous electricity supply using PV and battery storage.

### Fire suppression

This is outside our brief and expertise but all aspects of the design should be considered by all disciplines because of the potential synergies or unintended consequences of decisions. Our main concern would be to avoid any electrical frost heating of water pipes and storage should a mist system be used. Also any standby electrical consumption would be of interest to us.

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