Tradical® Hemcrete®
Thermal performance

Thermal performance

- Hemcrete® – the science
  1. Thermal conductivity (U values)
  2. Thermal mass
  3. Thermal inertia (diffusivity)
  4. Amplitude suppression and phase displacement
  5. Air-tightness
  6. Thermal bridging and Y values
  7. SAP & CSH
  8. Summary
- Hemcrete® – in practice
  - Lime Technology offices
  - Adnams brewery warehouse
  - Wine Society warehouse
  - Private houses

Thermal Properties

Materials have 3 key thermal properties:-

1. Thermal conductivity – the energy transfered through a material in steady state
2. Thermal mass – or thermal capacity, the amount of energy required to raise the temperature of a material
3. Thermal inertia – or diffusivity resistance to changes of temperature of a material

It is a combination of these three properties which dictate how a material performs in real buildings with changing temperatures

1. Thermal conductivity

- Is the rate of energy transfer under a constant temperature difference in a steady state, where temperatures inside and outside the building remain constant
- It is a simple but crude measure of thermal efficiency as temperatures are always changing
- To measure how buildings perform in real life under changing temperatures other measures such as thermal capacity and inertia are needed

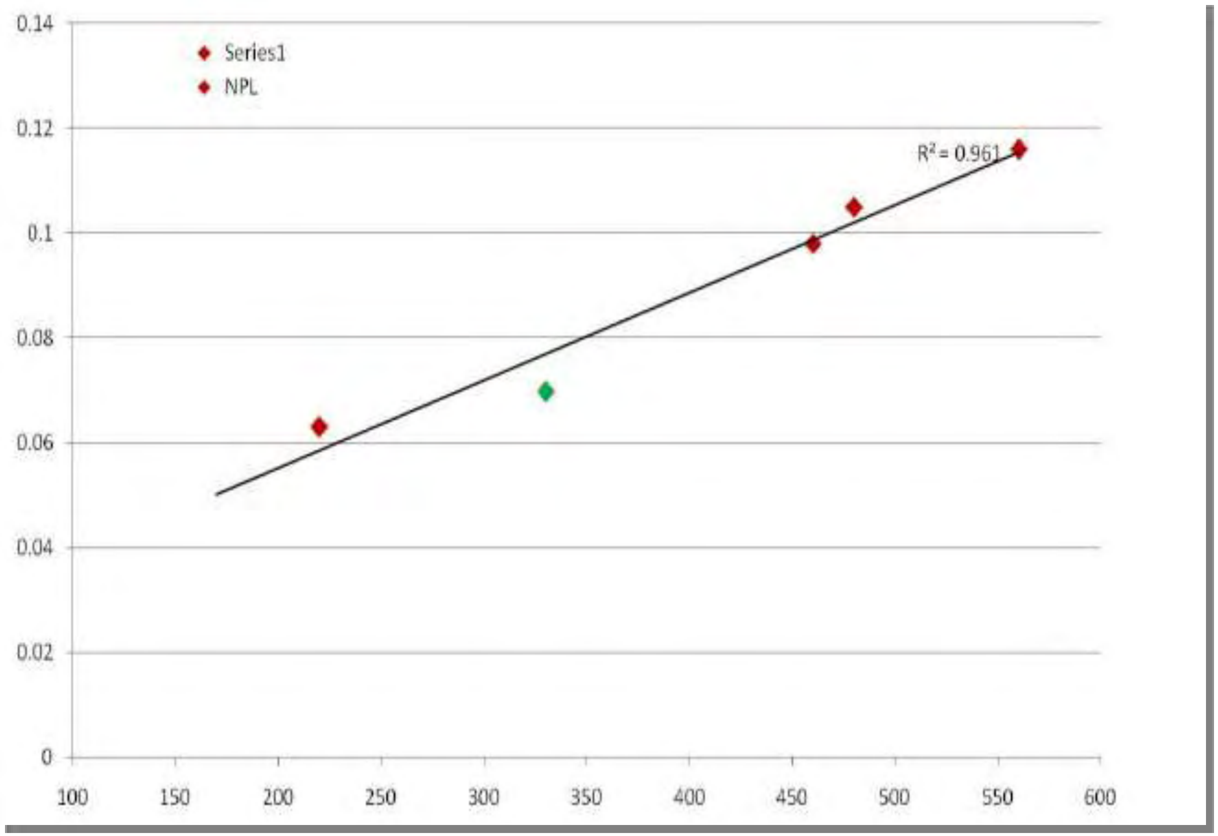
1. Thermal conductivity

- Thermal conductivity (k or λ) defines the energy transferred in steady state situations
- For a wall the individual material k values are combined into a single U value for the wall
- Hemcrete® buildings are designed to the same U values as other buildings and so will perform just as well in constant internal and external temperature situations
- The performance of Hemcrete® as a steady state insulator is defined by its density as shown in the following slide....

1. Thermal conductivity

Graph of Hemcrete® thermal conductivity (k) versus density

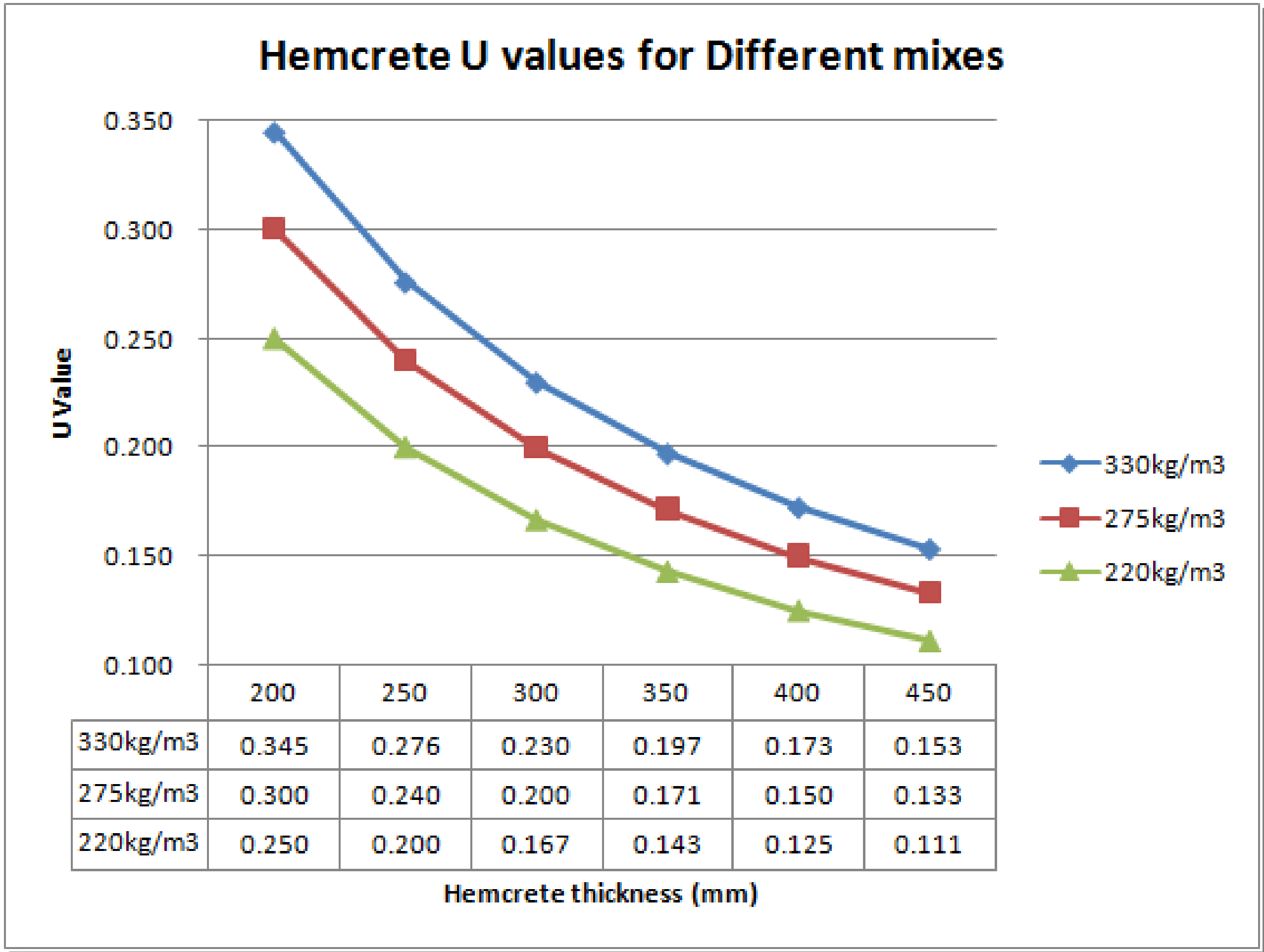
Thermal conductivity W/m.k



Density kg/m3

Thermal conductivity increases with density

1. U values for different density Hemcrete® mixes



	200	250	300	350	400	450
330kg/m3	0.345	0.276	0.230	0.197	0.173	0.153
275kg/m3	0.300	0.240	0.200	0.171	0.150	0.133
220kg/m3	0.250	0.200	0.167	0.143	0.125	0.111

Lower density mixes create thinner walls for the same U value

2. Thermal inertia (diffusivity)

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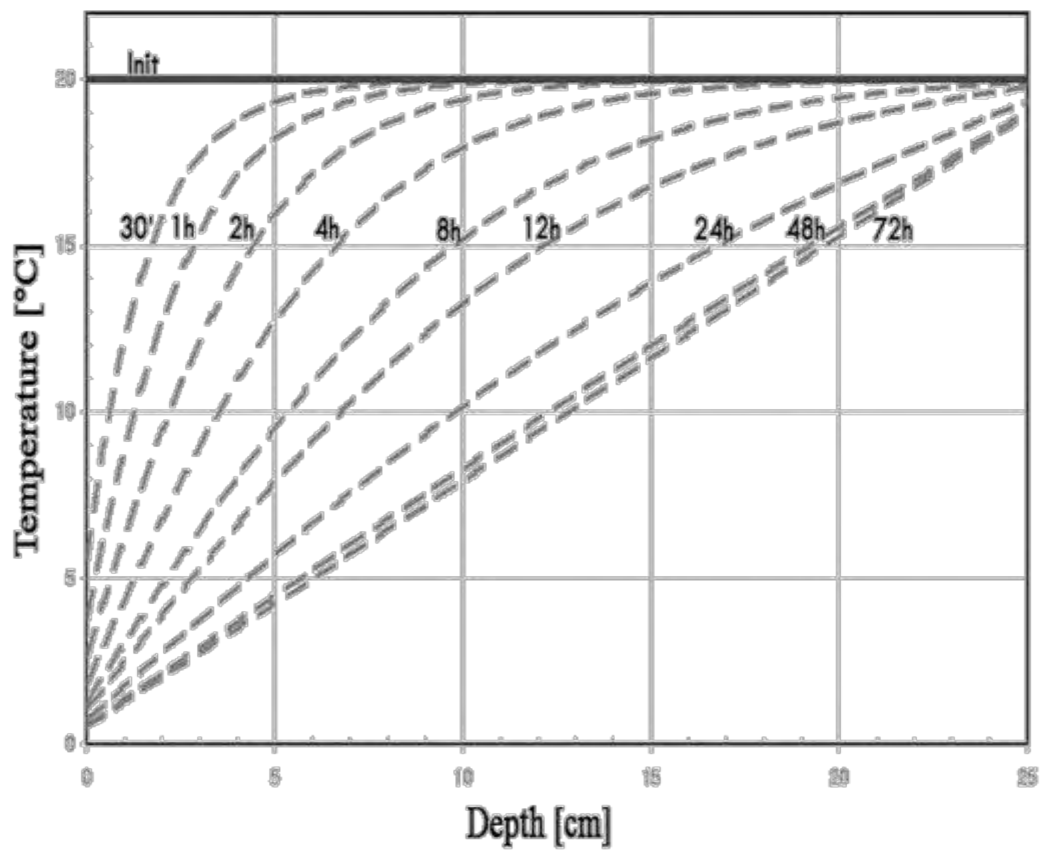
- Hemcrete® has a low thermal diffusivity compared to other building materials
- This gives it a high thermal inertia and means it is slow to change temperature and slow to reach steady state
- This slows heat transfer down whilst the material is in the process of reaching steady state (most of the time)

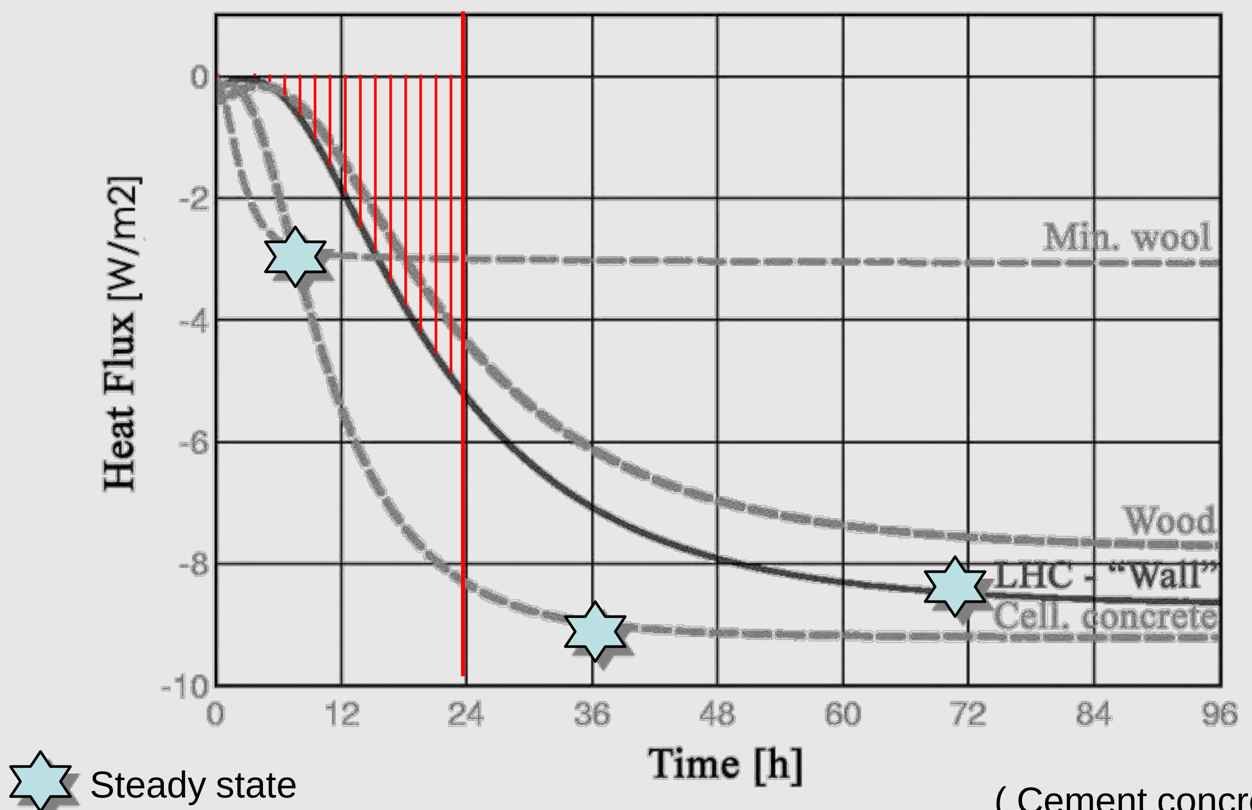
Material	Diffusivity (m2/s x 10-7)
Hemcrete®	1.4
Wood	1.6
AAC	2.3
Clay brick	4.1
Polyuerethane insulation	7.9
Concrete	8.5
Mineral fibre	14.4
Expanded polystyrene	18.4

2. The importance of thermal inertia

- Graph shows the temperature profile through a 250mm Hemcrete® wall after a 20 ° C change
- Hemcrete® takes 2-3 days to reach a steady state of energy transfer (constant temperature profile)
- This compares with around 6-8 hours for mineral wool



2. Heat flux over 24 hours for a 250mm wall



Q_{24h} [kJ/m^2]

→ 229

→ 146

→ **187**

→ 410

(Cement concrete → 3163)

Under a dynamic load Hemcrete heat flux is lower than mineral wool despite mineral wool having a much better insulation value

2. Effective U-value of Hemcrete®

- 187,000 J/m² lost in 24 hours
- 1W = 1J/s
- There are 86,400 seconds in 24 hours
- The temperature difference was 20ºC
- **So the real heat loss was only 0.11W/m²k**
- Theoretical U-value is 0.29W/m²k

In this case Hemcrete® has transferred almost 3 times **less** heat than the steady state model would have estimated

3. Thermal Capacity (mass)

- Hemcrete ® has an average volumetric thermal capacity
- Its ability to store and then re-emit heat (or cool) is less than block or concrete
- But much higher than pure insulation materials

Material	Thermal Capacity (KJ/m3.K)
Mineral wool	12
Expanded Polystyrene	22
Polyuerethane insulation	41
Hemcrete®	512
Aircrete (AAC)	560
Brick	1360
Dense block	1800
Concrete	2000

4. Combined effects

- The combined effects of thermal inertia and thermal mass slow the temperature change down inside the building
- They also delay the peak internal temperature by a number of hours
- The optimum delay is 12-15 hours so that peak internal temperature occurs at night
- Shorter delays cause summer overheating in the afternoons/early evening – a characteristic of lightweight buildings.

4. Amplitude suppression and phase displacement

- A 250mm Hemcrete® wall reduces external temperature changes by 98%
- A day/night change from 0 to 20°C over 24hrs is almost completely dampened to less than +/- 1°C
- Examples such as the Wine Society and Adnams have proved this in operation
- Any temperature change that does occur is delayed so that heating occurs at night and cooling during the day

4. Amplitude suppression with a 20˚ C external temperature change

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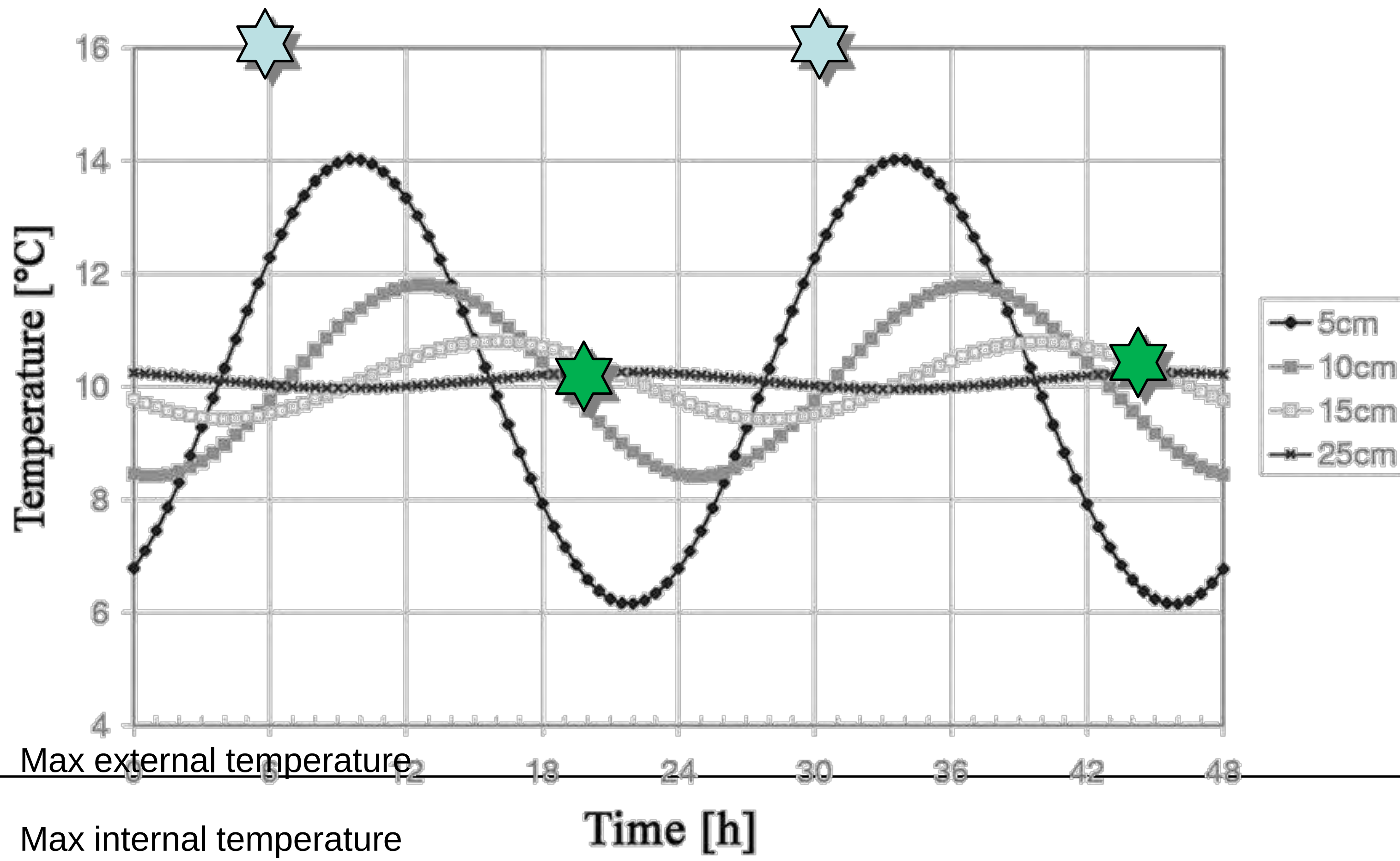
External temperature represents the normal day/night 24 hour cycle



Max external temperature

Max internal temperature

4. Dampening and time shift

	Dampening factor at 25 cm $\upsilon_{25cm} = 1-(\theta_{25cm} / \theta_{init})$ [%]	Time shift at 25 cm $\eta_{25cm} = t_{max,25cm} - t_{max,init}$ [h]
Hemcrete®	98%	15
Solid Wood	98%	16
Cellular concrete (AAC)	95%	10
CEM concrete	89%	7
Mineral wool	77%	6

4. Dampening and time shift

- AAC, Hemcrete® and solid wood each have a beneficial mix of thermal capacity and thermal inertia to provide excellent dampening
- Concrete has high thermal mass, but no thermal inertia so does not perform as well
- Mineral wool and other insulators perform the worst as they have low thermal mass and thermal inertia

5. Air Permeability tests

- Hemcrete® is a single homogeneous materials will no layers, membranes, gaps, joints or cavities
- This monolithic nature of Hemcrete® makes it inherently air tight
- Figures below $2m^3/m^2/hr$ at 50 pascals are achievable

Project	Approximate area	Air permeability test achieved
Wine Society Warehouse 4	2500m2	3.5
Adnams brewery warehouse	4500m2	3.1
Lime Technology's office	250m2	2.3
Crawford private house	150m2	1.5
Renewable House - BRE	94m2	2.5

6. Thermal bridging

- Hemcrete has very few elements that can provide a thermal bridge, no ties, lintels, bridging structure etc
- Psi (Ψ) value calculations confirm this
- Typical Y values of 0.03 can we used in SAP
- Looking to improve the wall/slab junctions to reduce this further to 0.02

Renewable House

BRE Innovation park
DECC funded
Affordable code level 4 house
Upgrades to code level 5&6

7. Renewable House SAP assessment – code level 4

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- U values for walls 0.19 (roof 0.13, floor 0.15)
- Requiring a 300mm Hemcrete® wall
- U values for windows 1.3
- Y value 0.03
- Air permeability 2.5 (post construction test)
- Ventaxia mvhr
- Air source heat pump
- No other renewable technologies required
- Resulting in DER/TER 45%
- HLP 0.98

7. Code level 5 house

- U values for walls 0.19 (roof 0.11, floor 0.11)
- Requiring a 300mm Hemcrete wall
- U values for windows 0.7
- Y value 0.02
- Renewable options:
  - GSHP/ASHP
  - Pellet boiler
  - CHP
- Resulting in DER/TER 76%
- HLP 0.57-0.81 (depending on renewables chosen)
- PV required ranges from 1.3-2.0 kW peak depending on renewables chosen

8. Summary

	Insulator	Thermal capacity	Thermal inertia	Scoring
Mineral wool	High	Low	Low	5
EPS	High	Low	Low	5
PIR	High	Low	Low	5
AAC	Med	Med	Med	6
Hemcrete®	High	Med	High	8
Brick	Low	High	Med	6
Block	Low	High	Low	5
Concrete	Low	High	Low	5

No single material can achieve the thermal performance of Hemcrete®, this combination of properties and its inherent air tightness make it a highly thermally efficient walling material

Hemcrete® Thermal performance

Practical examples

Lime Technology Office

Before

Brick and block in steel frame

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Sumatec® clay blocks provide internal wall thermal mass

The finished office

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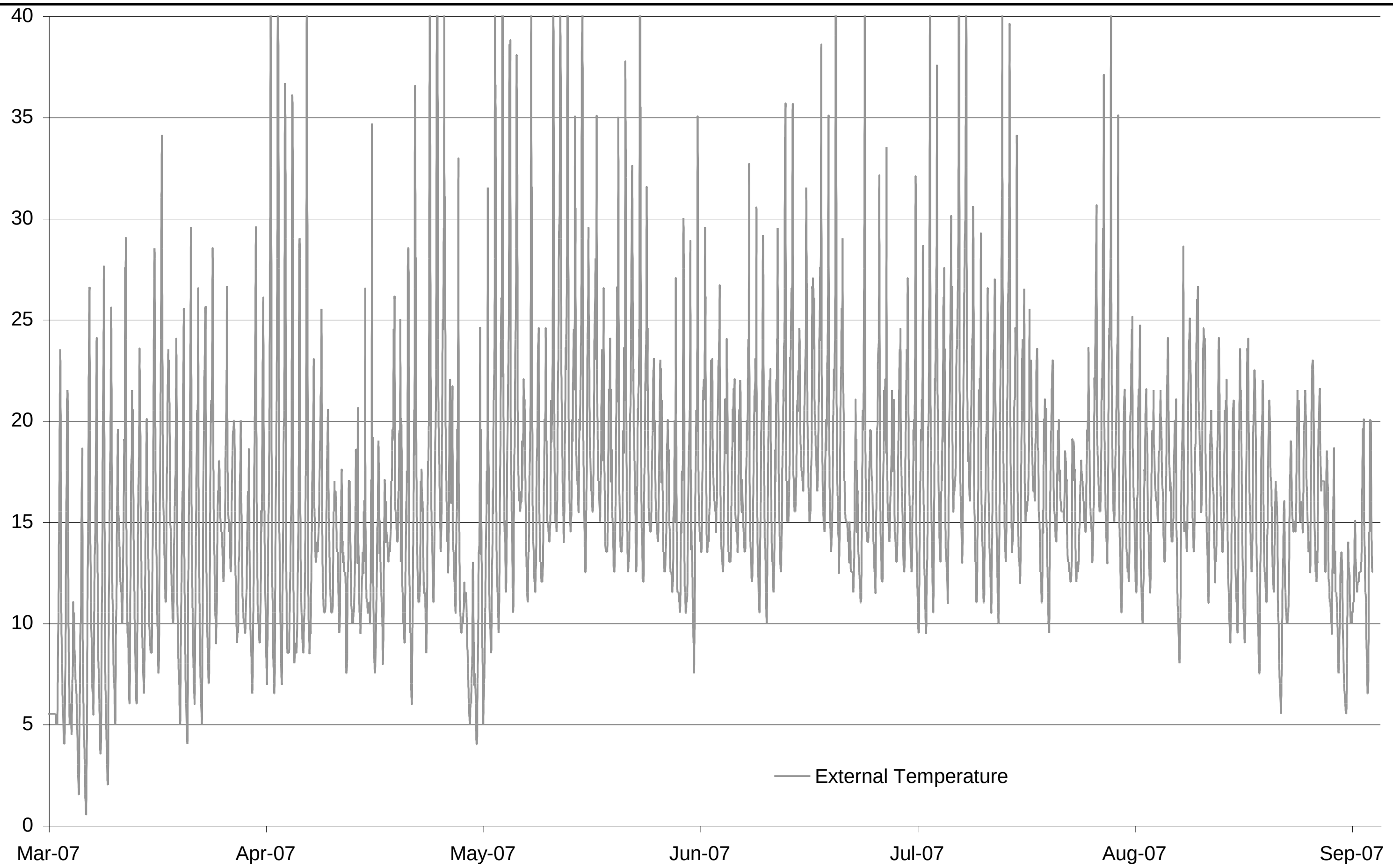
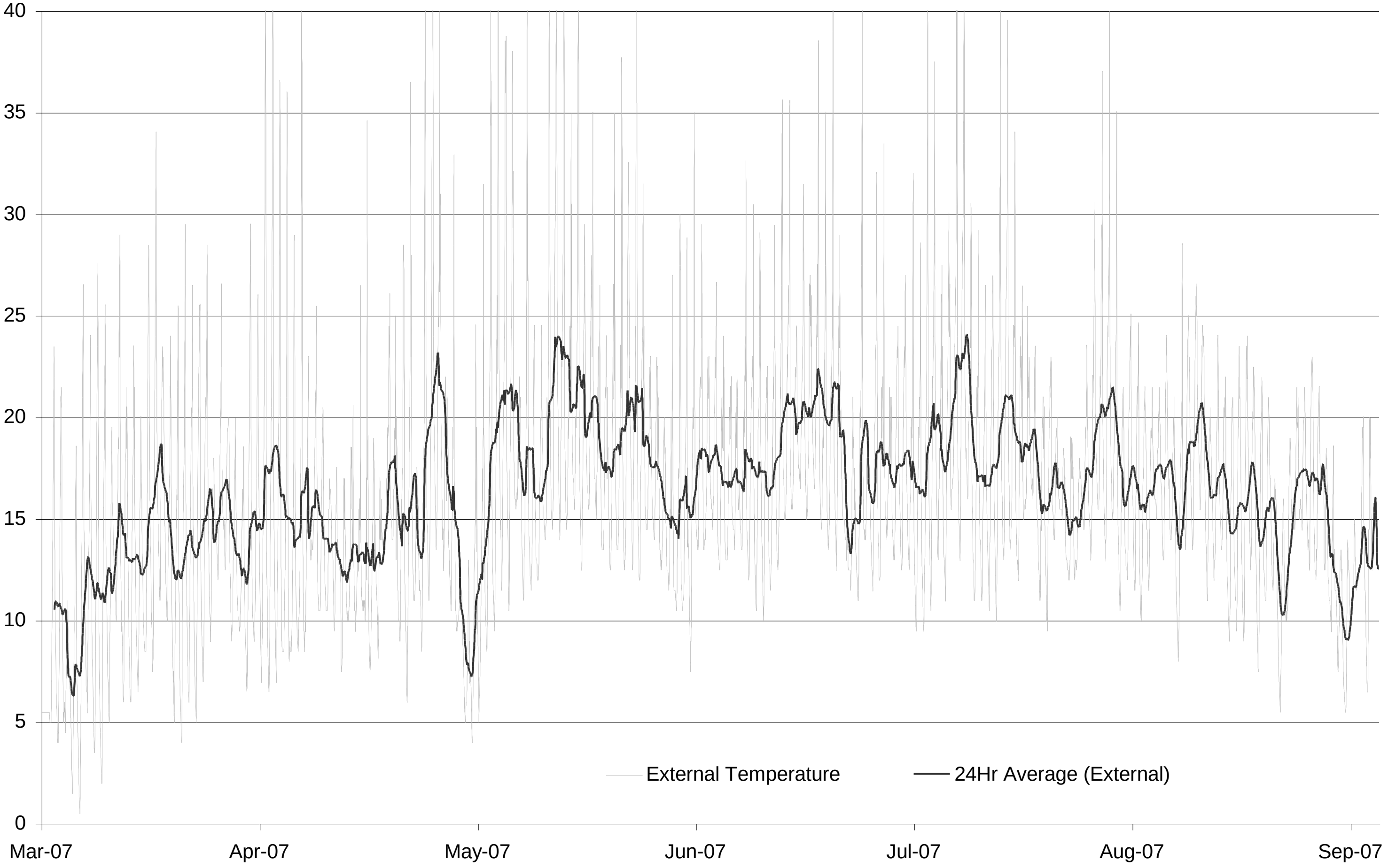
External temperature



External recorded temperature – April to September 2007

24h average external temperature



Addition of 24hourly average external temperature trend line

Existing offices internal temperature

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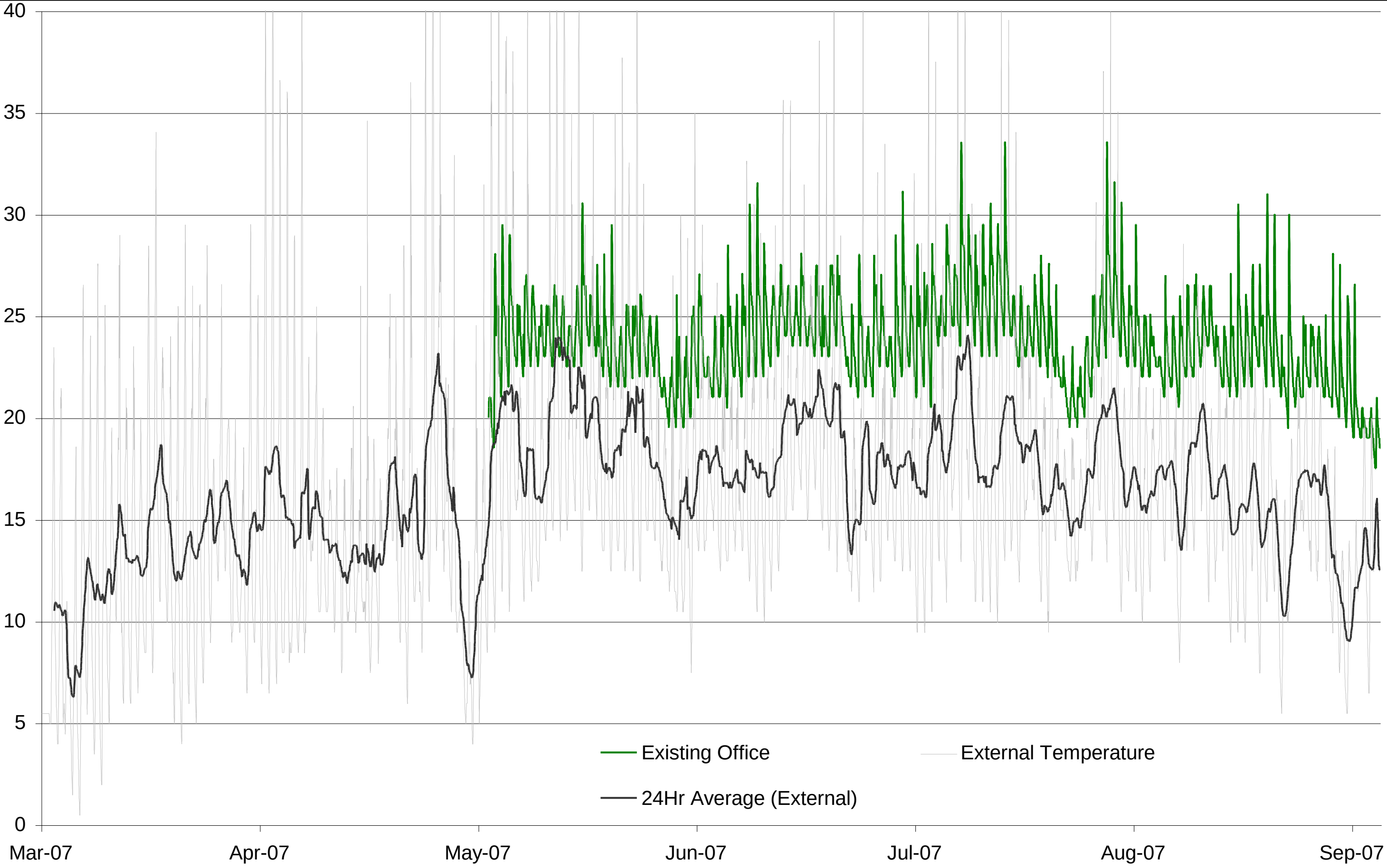
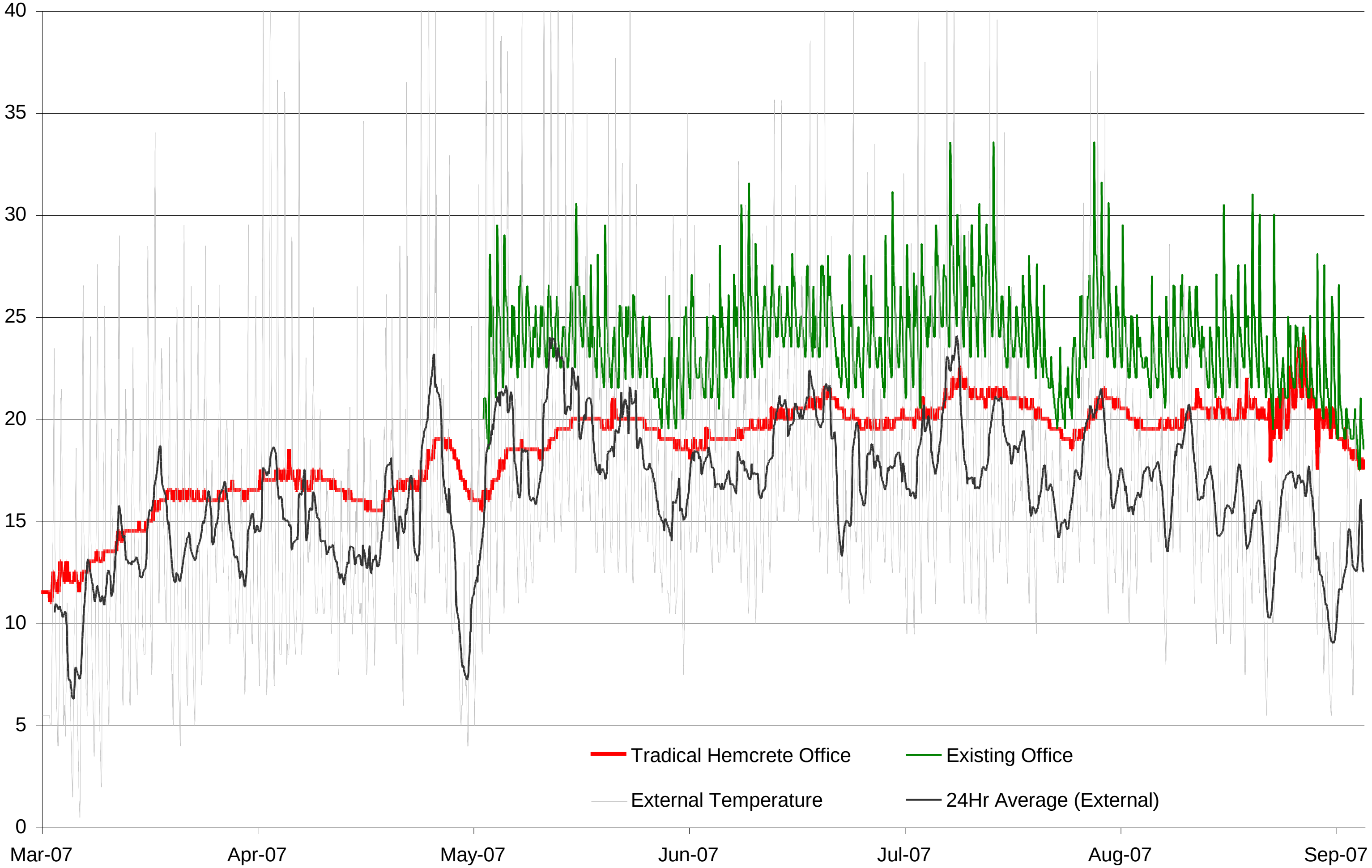


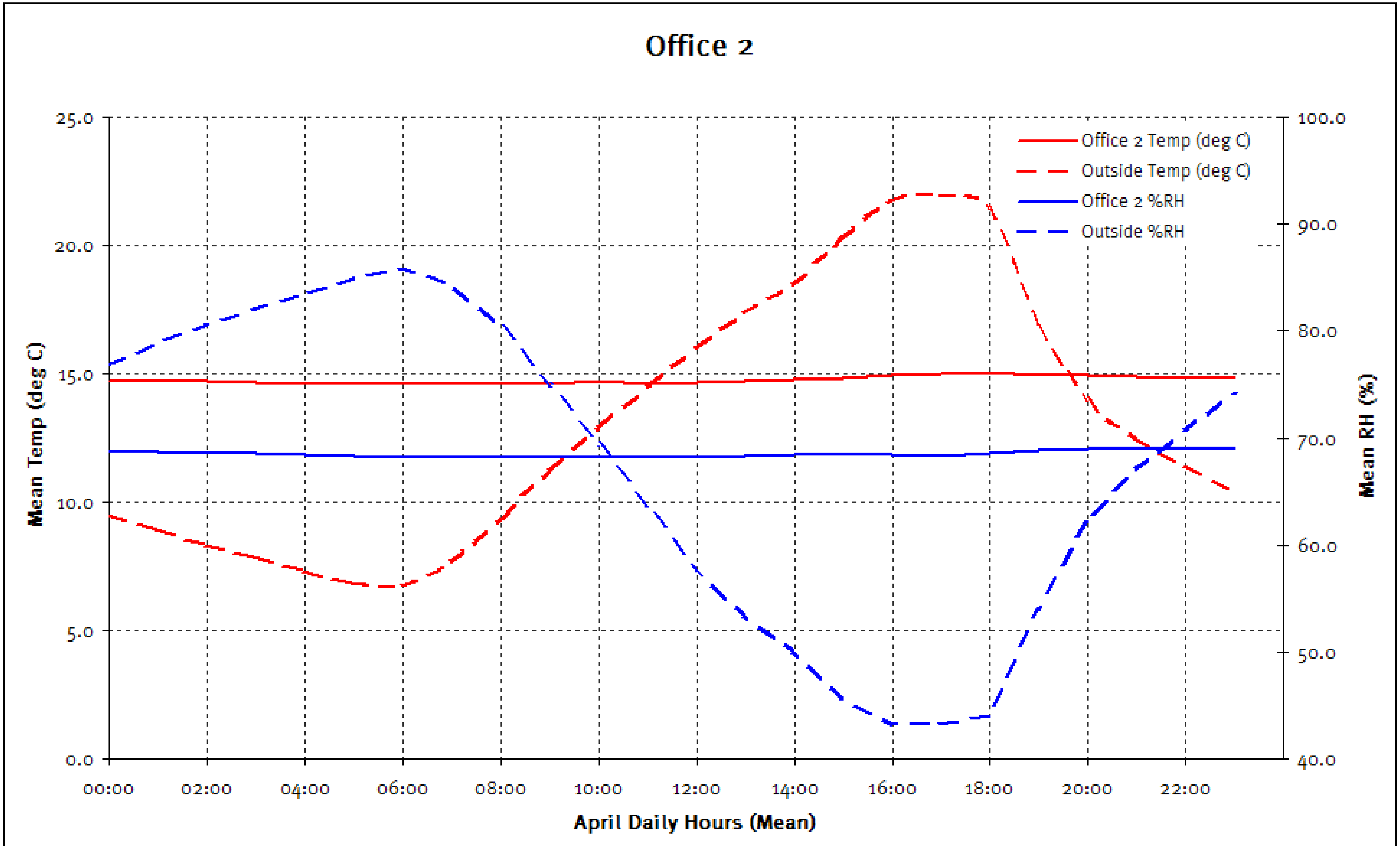
Existing offices (monitored June onward) showing high internal temperature swing

Hemcrete® offices internal



By comparison, the Hemcrete offices show a low internal temperature swing, which is characteristic of heavyweight structures.

Hemcrete® offices daily averages (unoccupied)

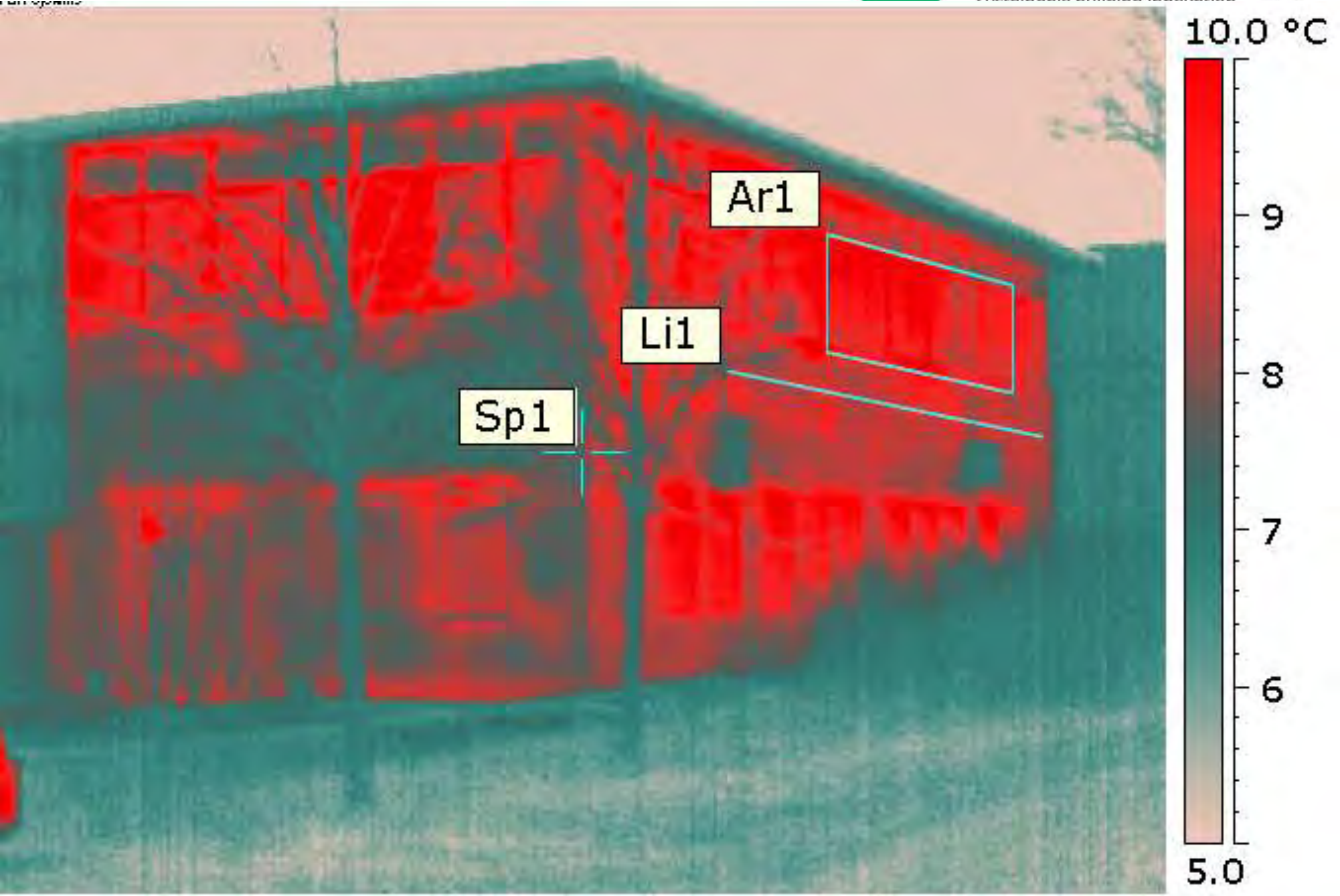


Daily averages - occupied

The finished office

Hemcrete® offices imaging

Old offices imaging



Summary

- Minimal use of heating throughout the year in the Hemcrete® offices
- Upstairs offices have required no heating for over a year (except after Xmas break)
- Cool in the summer due to thermal mass
- Exceptionally low office running costs
- Air tightness of 2.3

Adnams Brewery

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Adnams Brewery

- Constant temperature of 13 +/- 1 ° C throughout the year
- £400,000 air conditioning unit in original design was not installed due to the exceptional thermal performance in use
- Around £50,000 per annum of electrical running costs saved through the avoidance of heating and air conditioning
- A passive temperature controlled warehouse
- Air tightness of 3.1

Wine Society – warehouse 4

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Wine Society in construction

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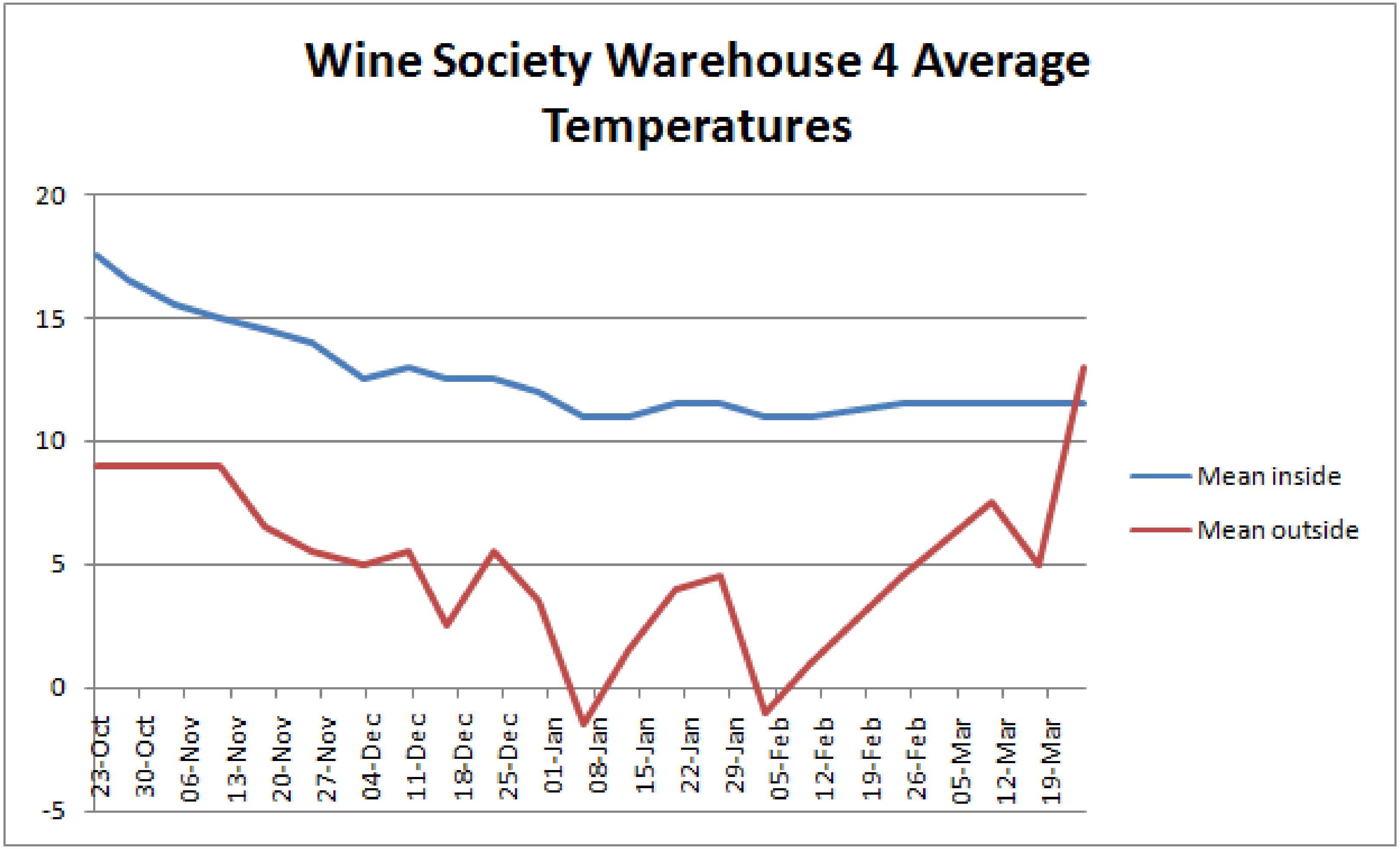
Average Temperatures
(without heating)



Temperature ranges
(without heating or cooling)

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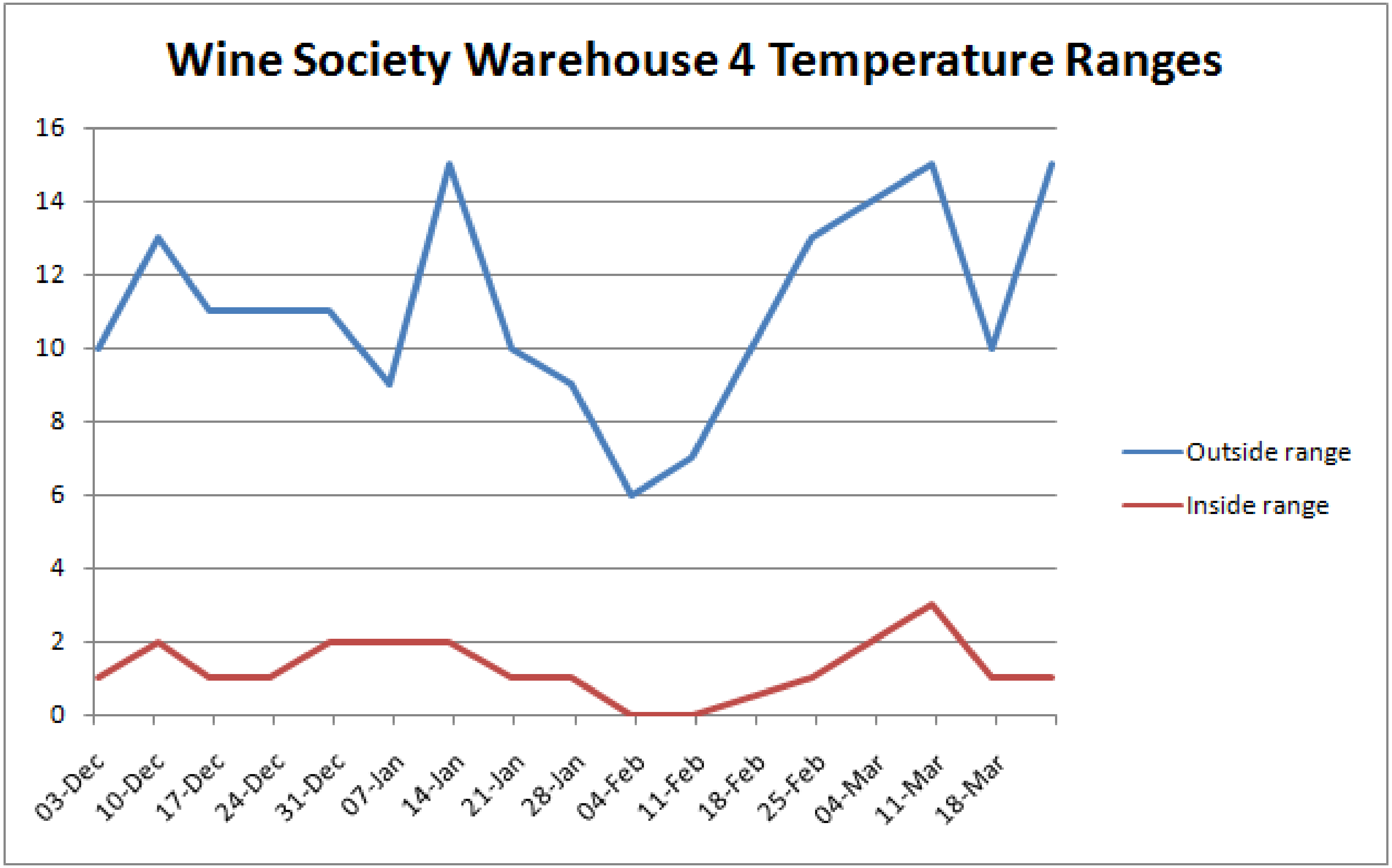

Wine society - summary

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- Heating and cooling systems yet to be commissioned
- Average internal temperatures remain around 10 ° C higher than external winter time temperatures
- Internal temperature range of less than 3 ° C despite external 10 ° C range
- Expected savings in excess of £50,000 per annum compared to foam insulated panels
- Air tightness of 3.5

Private Housing

This stone faced Hemcrete® house required no heating through the 2008/9 winter

Case Studies - summary

- In all cases heating and cooling systems were either not required or used only very rarely
- Internal temperature variations were reduced to almost zero
- High levels of air tightness required mechanical ventilation systems to be installed

The best way to predict the future, is to create it !