# Proceedings of the UK Controlled Environment Users' Group

## 2005 SCIENTIFIC MEETING

## "THE EDEN PROJECT – THE CHALLENGES OF CONTROLLING A LARGE SCALE CE"

**Volume 16**

Contents



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# UK CONTROLLED ENVIRONMENT USERS' GROUP

## 2005 SCIENTIFIC MEETING

## "THE EDEN PROJECT – THE CHALLENGES OF CONTROLLING A LARGE SCALE CE

The scientific part of the annual meeting consisted of three invited contributions. Summaries of these, supplied by the speakers, follow.

SUMMARIES OF PAPERS

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**Tony Kendle** (Foundation Director, Eden Project, Boldeva, Par, Cornwall PL24 0SG. E-mail: tkendle@edenproject.com) **Brief introduction to the Eden Project**

The Eden Project was established as one of the landmark Millennium projects in the UK to mark the year 2000. The overall cost of the project was £100 million, nearly half of which was provided by Millennium funds.

**Figure 1.** The three biomes looking down from the visitor centre with the Outdoor biome in front of the Humid Tropics biome on the left and the Warm Temperate Biome on the right.

The project carries a remit to help stimulate the Cornish region, an area that has seen the collapse of traditional industries and land uses and now has one of the highest levels of deprivation within Europe. The particular aim was to help encourage tourism to the area.

Eden is structured as a charitable trust, and receives no recurrent government income. It relies on visitor income to survive, and also to fulfil the aims of its funders. Eden is in a very rural location, in a county of the UK that has a relatively low population (approx 400 000 people). The visitor base is made up of tourists, primarily from urban locations. Since opening, starting

from March 2001, Eden has attracted over 6 million visitors many of whom chose to visit Cornwall because Eden was there. Through this activity the project generated income into the local region of more than £150 million.

Eden belongs to the tradition of botanic gardens, but there were many issues that were taken into account when developing the nature of the living collection that have led to a very different style of presentation from that normally seen.

**Figure 2.** A closer view of the Warm Temperate biome (foreground) and the Humid Tropics biome behind. The inflated pillows with ETFE windows in the curved space frame can be seen with the air input louvres bottom left and some air vents open at the top of the domes.

Eden's collections were established not with a conservation focus, but with an education focus. Our contribution to plant conservation, we hope, comes through the development of a greater constituency of public support for the need for conservation more than from maintenance of *ex-situ* specimens. By education we also mean something more fundamental than passive information delivery - we hope to foster in our visitors a stronger emotional understanding of how important plants are in their lives, an understanding that will stay with them longer than facts and figures do.

The site is a worked-out china clay quarry, a legacy of some of the last remaining mining in Cornwall. The garden, about 15 hectares in size, is therefore set within a dramatic sunken bowl, dominated visually by two major conservatories. One contains tropical plants and is just under two hectares in size and 50 m tall. The other includes the Mediterranean regions and is approximately one hectare in size and 30 m tall.

**Figure 3.** Inside the Humid Tropics biome with the Indonesian house in the background.

The scale of the development was crucial in meeting the economic regeneration aims - we wanted something so spectacular that it did not take visitors away from other gardens, but rather opened up entirely new markets of people who would traditionally not visit gardens at all. The success of this ambition has also given us a rather different target audience from those that more traditional gardens would expect to have.

Our approach to developing the education garden has of necessity been experimental. As much as anything we did not have the money to commission expensive interpretation houses or rely on touch screen multi-media.

Our strategy was first to build a spectacle, to attract an audience. This was particularly where Tim Smit's determination and refusal to compromise was crucial. Money was tight and compromises were inevitably made, but the crucial point is that there is no such thing as a 'small spectacle'; every available pound went on the visitor experience.

We try to approach our interpretation in an innovative way, and we develop our exhibits with a combination of plant scientists, artists and educationalists working together in teams. Our displays fall into two types - there are representations of geographic areas that illustrate the land uses and ecological patterns where plants are found, and displays that focus on specific

and individual crops or useful plants. We try to give a sense of context, and an insight into how these plants grow, and if they are cultivated, how they are grown. Therefore rather than one cocoa plant, for example, we have a mini-plantation to emphasise to our visitors that there are entire land uses and livelihoods behind every chocolate bar that they buy.

**Figure 4.** Part of the spectacle

We see ourselves as an educational project, but we are not naïve – many of the visitors do not come to be 'educated', they come to be amazed and delighted. We don't try to download large amounts of factual information; we hope to send people home with a few big ideas and insights that they did not have before. Our favourite visitors are arguably those who come to see the spectacle and think they are not interested in the plants – we see it as a challenge to get them to understand that they already *are* interested. They are interested because it's all about them. Our displays are not just about plants, they are about our food, our clothes, our cultures, our history and societies and almost everything that makes up the fabric of our lives.

**Further Reading**

Smit, T. (2001) *Eden.* Eden Project Books, London. 286 pp.

Anon (2005) *Out of Eden: The Eden Project Companion.* Eden Project Books, London. 239 pp.

**Sue Minter** (Director of Horticulture, Eden Project, Boldeva, Par, Cornwall PL24 0SG. E-mail: sminter@edenproject.com) **Providing, maintaining and displaying the living collections**

The Eden Project is a multi-million pound regeneration project in the far south-west of the UK, built for the new Millennium as a celebration of the interaction of plants and people. The largest glasshouses in the world now exist in a derelict china clay pit which has been transformed into a global garden involving the manufacture of 83,000 tonnes of soil from china clay waste, green waste and composted bark.

Crucial to its success has been the interdisciplinary nature of the staff working to create the 80 or so principal exhibits, most of which are based on 'economic botany'. These include the famous 'Plant takeaway' where everything based on a plant is stripped away from a breakfast scene, leaving the puppets naked! The Project is the brainchild of Tim Smit who first created 'The Lost Gardens of Heligan' and crucial to its success has been the stress on sustainable futures. In this the geodesic dome shapes of the ETFE-covered conservatories have helped since they look futuristic and put people in the right frame of mind.

Visitors are more diverse than the usual A, B social groups who visit botanic gardens - just anyone on holiday in Cornwall. The Project takes a broad, global focus and uses humour, music, art and performance art to engage visitors with the plant and crop exhibits. There is an emphasis on human use of habitats within the biomes and agroforestry systems as well as trade, because Cornwall is linked to the tropics via the importation of agricultural goods.

The Warm Temperate Biome has been harder to interpret to the public which is strange as most people are surely more familiar with the Mediterranean than the rainforest through holidays. We have had to 'set dress' some exhibits, for example, California, to get people to understand better. This biome is obviously seasonal and we vent hard in winter to get the leaves off the orchard crops and relieve fungal disease. This sometimes means manual override of the normal computer controlled environment systems. We also use displays of cropped produce (on market stalls for example) to prolong displays. Recently we have staged temporary displays of the dried flower industry, of minor grain crops and the citrus industry.

Pest and disease is managed by integrated pest control with introduced predators-some of which have been specially licensed for us. We have had to install a robust plant isolation (quarantine) facility at our nursery to prevent introductions of pests, particularly those like tobacco whitefly and palm thrip for which the UK has pest-free status. Defra's Plant Health and Seeds Inspectorate have forced us to eliminate one outbreak of TWF in our Humid Tropics Biome which cost us a quarter of a million pounds (uncompensated) in order to maintain this UK status, so this is a huge business risk. Subsequently we have stopped TWF in quarantine five times and we have robust protocols based on risk assessment. This approach is now spreading in more of the UK's botanic gardens.

The majority of Eden's planting is actually outside the conservatories and represents the Cool Temperate 'biome' of Cornwall. We celebrate this environment with a major bulb festival called Bulb Mania which lasts from March until June and follow it up with huge displays of wildflowers - all this superimposed on the crop exhibits where space allows. Crop exhibits which are particularly popular are 'Plants for Taste' (outside our main restaurant) and hemp

(licensed *Cannabis sativa*), as well as lavender and the Crops for Tomorrow's Industry exhibit which covers industrial crops such as Crambe, sunflowers and borage (for oils) and maize and potatoes(for starch for bioplastics). They are displayed with the crop and product next to each other. Several exhibits owe their biodiversity to material provided by the international crop gene banks (CGIAR network).

In the summer and autumn we also celebrate Jungle Season with our 'largest rainforest in captivity' incorporating balloons and zipwires as used by rainforest scientists (on loan to us when not on expedition use).We also engage children with school activities and also as part of family groups. In order to provide a permanent home for schools work, as well as public exhibitions of how plants drive the planet, we have built an education resource centre called 'The Core'. This is an exhibit in itself with its design based on nature's double spiral (the Fibonnaci sequence) which has been incorporated into the roof design. This building functions like a tree with a 'canopy' roof embedded with PV cells which power the building and vented with air warmed though underground ducting. Light wells and reflectors deflect light down into the inner space. The roof is clad with copper to demonstrate traceability in metal sourcing and the wood (*Picea rubens*) is Forest Stewardship Council certificated and formed into glulam beams.

As to the future we hope to be able to apply for funding for a Dry Tropics Biome based on issues to do with water management to sustain plant and human life. The building design here will have to maximise light and therefore needs to address the minimum number of ETFE layers required, how to reduce the steelwork to a minimum (currently a cablenet structure is proposed) and height of the structure within the pit. With this, capital build within the pit itself would be complete.

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**Steve Williamson** (Buro Happold. E-mail: steve.williamson@BuroHappold.com) **The Eden Biomes – technical aspects**

**Introduction**

The Eden Project Biomes were designed by:

1. Grimshaw (for architecture)
2. Anthony Hunt Associates (for structure)
3. Arup (for environmental and building services)

Buro Happold is responsible for the design of the latest major building at the Eden Project, its just opened Educational Resource Centre.

**The Designs of the Biomes**

The properties of the two biomes are:

**Table 1.** Properties of the humid tropics and warm temperate biomes

| The Biomes | Humid Tropics Biome | Warm Temperate Biome | Total |
|---|---|---|---|
| Area | 15,590m$^2$ | 6,540m$^2$ | 22,130m$^2$ |
| Maximum Internal height | 47m | 35m | |
| Maximum External Height | 55m | 35m | |
| Steelwork (including nodes) | 465 tonnes | 202 tonnes | 667 tonnes |
| Area of ETFE Foil | 20,000m$^2$ | 9,200m$^2$ | 29,200m$^2$ |
| Volume | 330,110m$^3$ | 85,620m$^3$ | 415,730m$^3$ |
| Concrete in Foundations | 1,500m$^3$ | 980m$^3$ | 2,480m$^3$ |
| Reinforcements in Foundations | 178 tonnes | 106 tonnes | 284 tonnes |
| Frame Weight (surface area) | 24 kg/m$^2$ | 22 kg/m$^2$ | |

The Humid Tropics Biome is the largest conservatory in the world at 240 m long, 110 m wide and 50 m high.

**Light**

The successful growth of plants in the biomes depends on the maximum interception and transmission of solar radiation to their leaves by:

*1. Optimising orientation of the biome soil surface*

- Choose a south facing slope
- Avoid over-shadowing from the adjacent landscape and structure
- Angle the slope to allow for the different summer and winter paths of the sun i.e. mid-way at approx. 61° - 17.5° = 43.5° (see Figure 1)

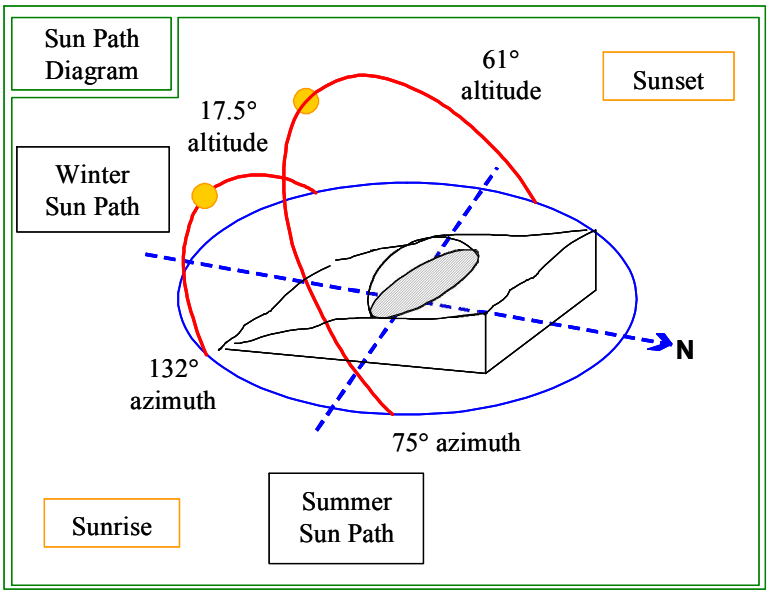


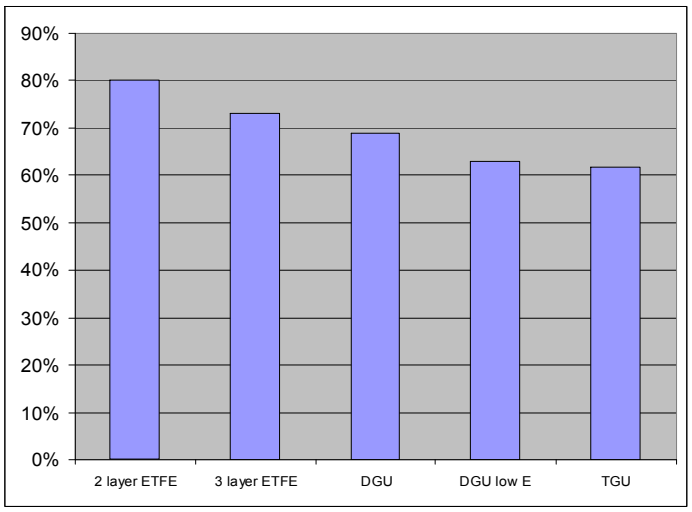

**Figure 1.** The sun's path for winter and summer in relation to a sloping surface

*2. Minimising solid structure*

*3. Maximising transmittance of materials*

**Table 2.** Properties of ETFE cushions

| | | 80µm clear | 100µm clear | 150µm clear | 200µm clear | 100µm white | 200µm white |
|---|---|---|---|---|---|---|---|
| Light | Transmittance | 0.93 | 0.93 | 0.91 | 0.90 | 0.45 | 0.37 |
| | Reflectance | 0.07 | 0.07 | 0.08 | 0.09 | 0.50 | 0.59 |
| Solar | Direct transmittance | 0.94 | 0.93 | 0.92 | 0.91 | 0.55 | 0.47 |
| | Reflectance | 0.06 | 0.07 | 0.07 | 0.08 | 0.39 | 0.47 |
| | Absorbtance | 0.00 | 0.00 | 0.01 | 0.01 | 0.06 | 0.06 |
| | Total transmittance | 0.94 | 0.93 | 0.92 | 0.91 | 0.57 | 0.49 |
| Shading coefficent | Short wave | 1.08 | 1.07 | 1.06 | 1.05 | 0.63 | 0.54 |
| | Long Wave | 0.00 | 0.00 | 0.00 | 0.00 | 0.03 | 0.02 |
| | Total | 1.08 | 1.07 | 1.06 | 1.05 | 0.66 | 0.56 |
| UV | Transmittance to 380 nm | 0.88 | 0.86 | 0.83 | 0.76 | 0.06 | 0.01 |
| | Transmittance to 400nm | 0.89 | 0.87 | 0.83 | 0.79 | 0.13 | 0.06 |
| U Value | $W/m^2$ K | 5.70 | 5.70 | 5.70 | 5.70 | 5.70 | 5.70 |
| Descriptive code | | 94/94 | 93/93 | 91/92 | 90/91 | 45/57 | 37/49 |
| Solar gain factors (environmental) | Mean | 0.86 | 0.86 | 0.85 | 0.84 | 0.52 | 0.45 |
| | Alt. Light | 0.70 | 0.69 | 0.69 | 0.68 | 0.43 | 0.37 |
| | Alt. Heavy | 0.52 | 0.51 | 0.51 | 0.51 | 0.32 | 0.28 |
| Sample thickness | mm | 0.082 | 0.105 | 0.155 | 0.206 | 0.097 | 0.205 |




**Key:**

DGU = double glazed unit

DGU low E = double glazed unit

TGU = triple glazed unit

**Figure 2.** Comparison of transmission (%) of EFTU cushions with glass sandwiches

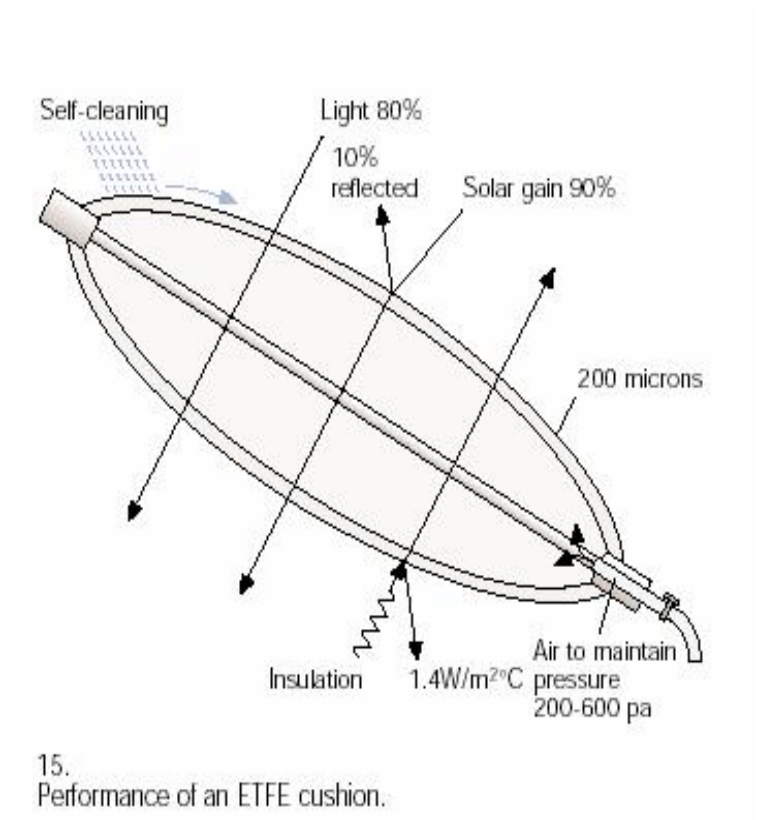



**Figure 3.** Performance of inflated three-layer ETFE cushions showing radiation fluxes

**Temperature**

In a typical large-scale glasshouse temperature control is achieved through heat transfer from hot water pipes in service trenches along and under walkways e.g. in the Princess of Wales Conservatory at Kew Gardens.

**Temperature Control of Hot Tropics Biome**

Heat is provided by the gas fired, low temperature hot-water heating (LTHW) system, supplying hot water to the heat exchanger within each air heating unit (AHU). Warm air is injected into the space via a number of AHUs located externally around the perimeter of the biomes (Figure 4a). Natural ventilation is provided by vents in the apex and louvres at ground level around the perimeter (Figure 4b).

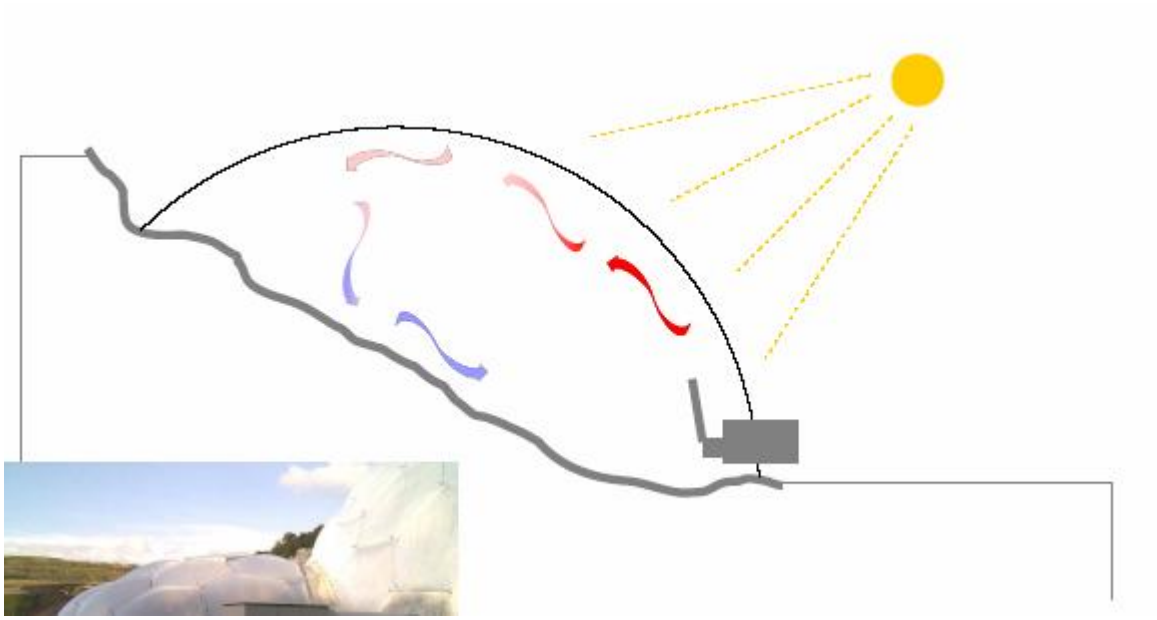


**Figure 4a.** Mechanical ventilation mode with apical and basal vents closed

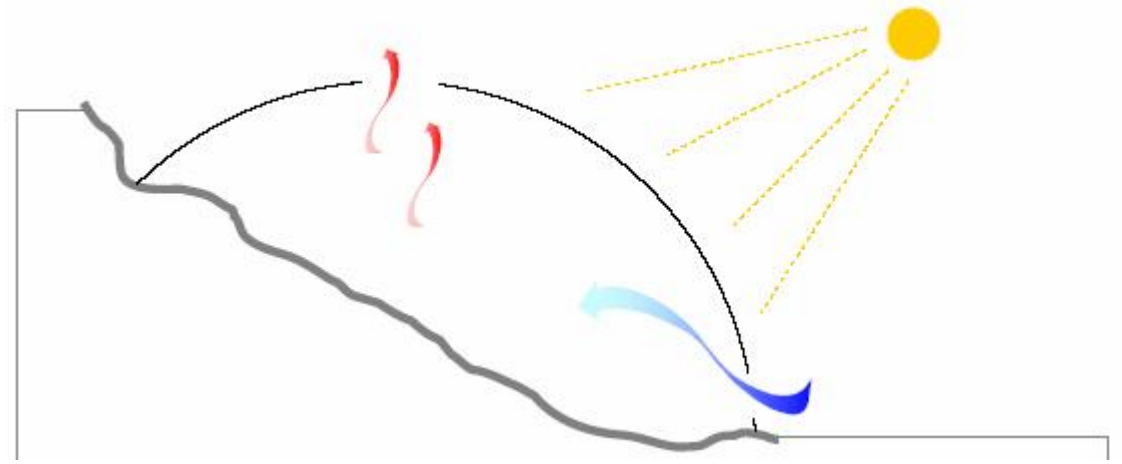


**Figure 4b.** Natural ventilation mode with apical and basal vents open

*Control strategy*

If internal air temperature < 20°C then AHUs are on to maintain incoming air at 24°C.
If internal air temperature > 20°C then AHUs are off.
If internal air temperature > 25°C then vents are opened.
If outside wind velocity > 5 m/s then vents are closed, AHUs are on but no heat is supplied.
This set up will allow cold external air (say at 5°C) to enter directly, across plants, into the space.

An example of one day's control is shown in Fig. 5.

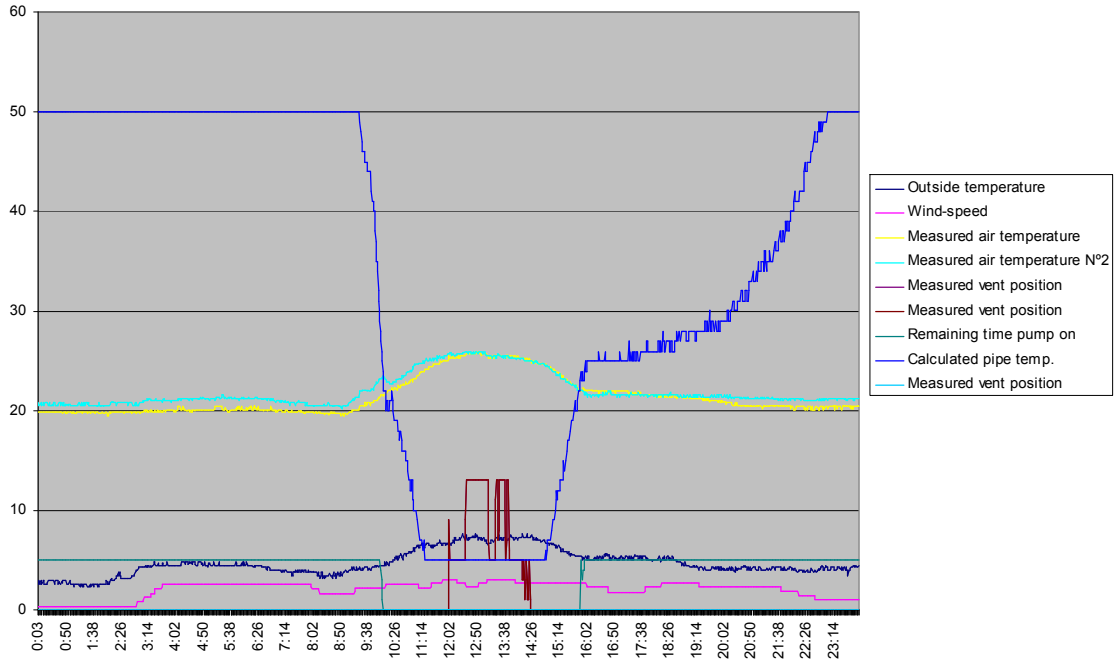



**Figure 5.** Biome performance during a sunny winter's day showing heating during night and opening of vents during day to keep temperature between limits required by biome manager

**Testing for air leakage**

Tests were undertaken on a calm day with a wind speed = 1.5 m/s, showed that biome structure is highly airtight with air permeability = 2.22 $m^3$ $s^{-1}$ $m^{-2}$ = 0.41 air changes/h. This is well within Chartered Institution of Building Services Engineers good practice recommendations. Main areas where air leakage is occurring are loading bay doors, visitor access doors, fire exit doors, and low level louvres but high level vents appear to be well sealed.

**User feedback on performance of biomes**

- Humidity control is difficult
- Has poor air movement at centre
- Has excessive air movement at low level perimeter
- Need new biome link doors!
- Want lower peak loads
- Want self-cleaning internal surface of biome!

**Suggestions for next generation biomes**

- Have more smaller ventilation openings
- Have summer mechanical mode using heat recovery AHUs to temper air
- Create air locks at entrances, perhaps buffer zones
- Use ground ducts or large seasonal thermal store to allow tempering of ventilation air
- Reduce temperature in winter to stop plant growth!!