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ATRIA AND CONSERVATORIES

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ABSTRACT

The paper examines the factors which influence the energy saving performance of atria and conservatories. Technical factors such as shape, insulation and ventilation are discussed. Factors relating to occupant behavior and indoor planting are also considered.

INTRODUCTION

We now have a decade of experience of atria and conservatories, and from a glance through the Architectural journals, or around the Energy World exhibition site, we see that enthusiasm for these forms shows little sign of waning.

Both atria and conservatories have strong associations with energy conservation - it is often tacitly assumed that the inclusion of either of these features will ensure energy saving. This paper sets out to examine this assumption, and shows that in many cases both of these features can lead to considerable energy wastage. Sometimes this is due to gross design errors - other times it may be due to a misunderstanding of how the occupants use the atrium or conservatory.

THE ATRIUM ENVIRONMENT

First let us briefly recap on the mechanism by which these features should be able to reduce energy consumption of the parent building. In the case of the atrium it is helpful to consider it to have developed from an outdoor court or lightwell.

The original function of the court would have been to provide daylight and ventilation to the surrounding rooms - i.e. it is the court that distinguishes the building from a deep plan design which would necessitate mechanical ventilation and permenant artificial lighting. Firstly then, the covering over of the court should preserve these functions. If it does not - if the surrounding rooms have to be mechanically ventilated and permenantly artificially lit, then we just have a deep plan building with a rather extravagent multi-storey high top-lit space in the centre. It is not difficult to find atrium buildings of this type.

But worse is to come. The atrium has become a prestigous feature, and out of concern for its maximum use as an amenity, clients often insist that it is heated. Furthermore, heavy planting is almost de rigueur for atria, and conventionally these are relatively tender indoor plants. Thus heating, and in some cases cooling, may have to be provided even during periods outside human occupation. Added to this there is the problem of humidity control, a problem brought about by the high transpiration rates of the plants, conflicting with the need to eliminate condensation on the external glazing surfáces. Finally, in the interests of reducing summer solar gains to a minimum, the light transmittance or the area of the atrium glazing is often reduced. This compromises the winter performance, when the low light levels actually require permenant artificial lighting in the atrium, in order for the plants to survive.

We can see that these factors all conspire to produce a gas-guzzler rather than a low energy building. Let us now explore an alternative avenue.

THE ENERGY SAVING ATRIUM

Going back to the concept of covering over an otherwise open court, how can the requirements for the daylighting and natural ventilation be met. Firstly the atrium glazing must respond to the problem of too little light in winter and too much in summer by adopting moveable shading devices. Fixed shading, or tinted or reflective glass is no answer to the problem. Indeed, reducing the glazing area with opaque panels is a much more intelligent solution than the use of low transmittance glass, since the opaque sections can have good thermal resistance. The other important requirement is that the interior of the atrium is as light-reflective as possible.

Secondly, the atrium should if possible provide a ventilation source to the surrounding rooms. In winter, temperature differentials between the rooms and the atrium will provide enough thermal buoyancy to give single-sided ventilation for fresh air only. In summer, where the atrium itself is now ventilated at a high rate, it may be used to generate cross-ventilation to the rooms, driven by stack effect, even on windless days. To attain this large openings in the atrium roof will be required, probably electrically operated under thermostatic control, and linked with the automatic shading devices. Automatic opening vents are often a requirement for smoke venting - if they are there anyhow, why not use them for normal ventilation? Single-sided ventilation may present problems in summer, due to the lack of significant air movement in the atrium. This is an appropriate situation for the use of a low powered window-mounted fan to create a rapid exchange of air and perceptable air movement.

Assuming then, that these two basic requirements are met, and that we have rejected the idea of artificial heating and cooling in the atrium, we are now at least back to where we started - i.e. the atrium is not actually costing us energy in comparison to the building with the open court. Let us now explore the benefits.

The most important physical effect is that in winter the temperature of the atrium will be much higher than that of the ambient air. Heat enters the atrium from the walls separating the atrium from the heated building, and also, in the form of solar gains. At the same time, heat is lost through the atrium glazing, and it is not surprising that the thermal balance (and hence the

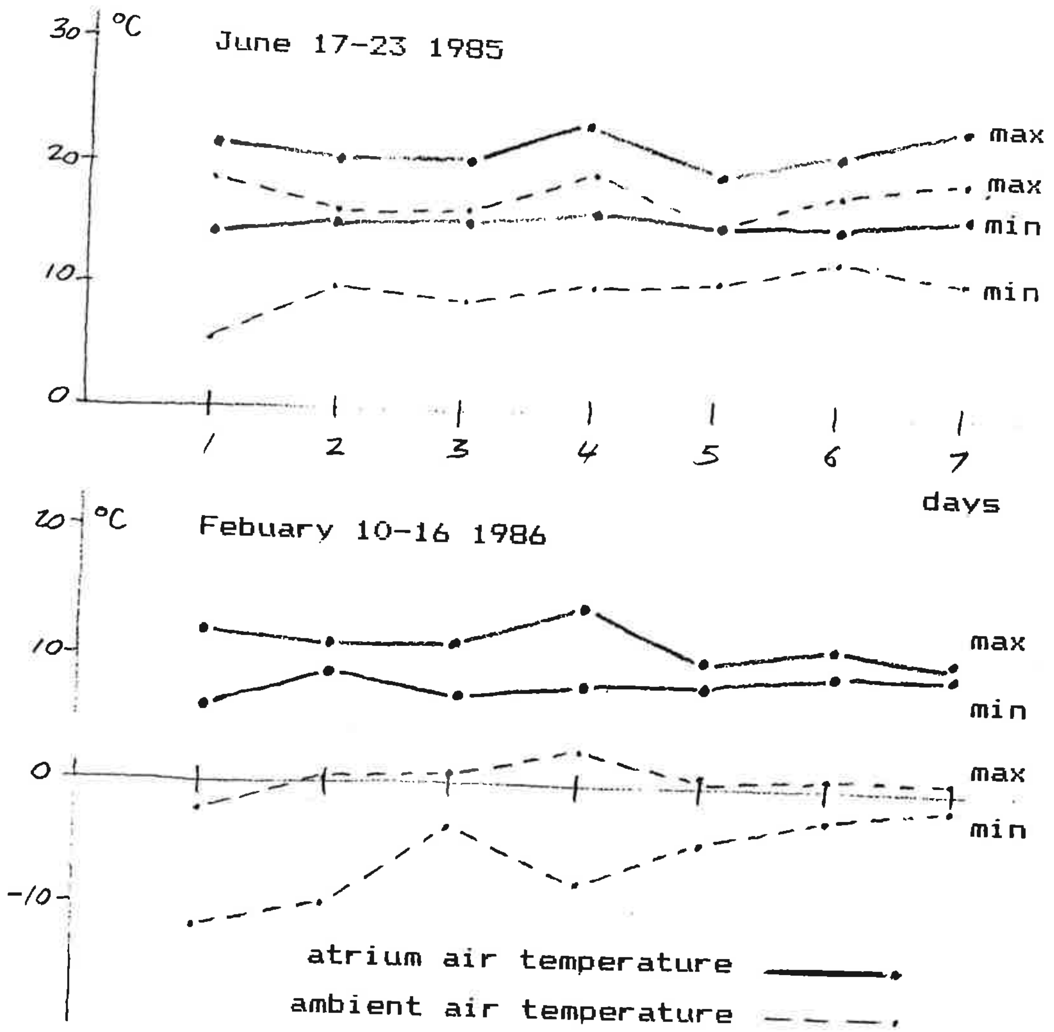


Fig (1) Air temperatures recorded in atrium at CCL, Cambridge.

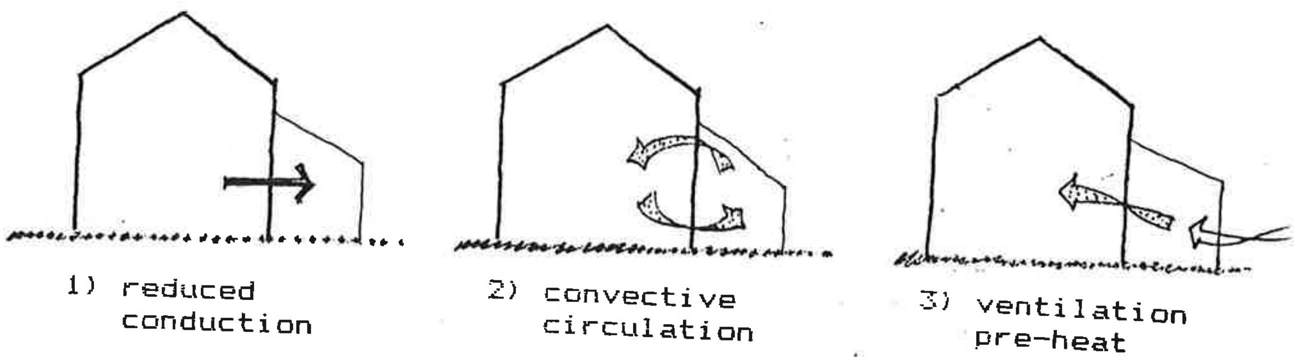


Fig (2) Modes of heating energy saving by a conservatory.

atrium temeparture), is sensitive to the relative area of atrium glazing to that of the surrounding walls and their thermal transmittance, the thermal transmittance of the glazing, and the geometry.

The results of this elevation of temperature in energy terms, are twofold. Firstly the conductive losses from the surrounding building are reduced, since the temperature differential is reduced. (Another way of looking at this is that a further thermal resistance has been added in series.) This reduction may be very significant in cases where the surrounding wall is of high thermal transmittance, i.e. has a large proportion of glazing. Secondly the atrium offers the posssiblity of providing pre-heated air for ventilation purposes, therby reducing the ventilation heat loss of the heated spaces.

Thirdly the amenity value of the court is greatly increased. Not only is it protected from rain and wind, but it is of course, in winter, much warmer than the outside.

Finally, even in summer we can improve conditions compared with outside. Because we have a structure upon which to hang shading devices, the whole court can be shaded. It is not difficult to provide sufficient ventilation to keep the atrium temperatures less than about 3 degC above ambient temperatures, about 10% of the roof glazing being openable will be sufficient. This leads to a lower environmental temperature than one would experience outside, where direct sun would elevate the effective temperature about 6 degC above the air temperature.

Furthermore, if the wall and floor surfaces of the atrium are massive, night ventilation set up by the stack effect, will cool down the structure and lower the mean radiant temperature in the atrium, therby lowering the environmental temperature further.

We have recently studied a small atrium in the new building of Cambridge Consultants Ltd on the Cambridge Science Park. This unheated atrium has all the basic ingredients listed above, unobstructed roof glazing with automatic shading devices, automatic opening vents in the roof and at low level, high reflectance surfaces and openable windows into the atrium. Sample temperature data for seven day periods in winter and summer are shown in fig (1) Note that with ambient temperatures in Cambridge as low as -12 degC, the minimum in the atrium was 6 degC, and as the plots show for most of the time it was well above this. In the summer however, the atrium air temperature was on average only about 4 degC above ambient, and due to the low surface temperature, the environmental temperature was significantly less than this.

Another welcome observation is that the planting, far from suffering from the rather losely controlled environment, has thrived, far better than the same species are seen to fare in closely controlled atria. This has attracted the attentions of Landscape Research Cambridge, who in collaboration with the Martin Centre and the University Botany Department, are carrying out a research programme on the aspect of "low energy atrium planting".

THE CONSERVATORY

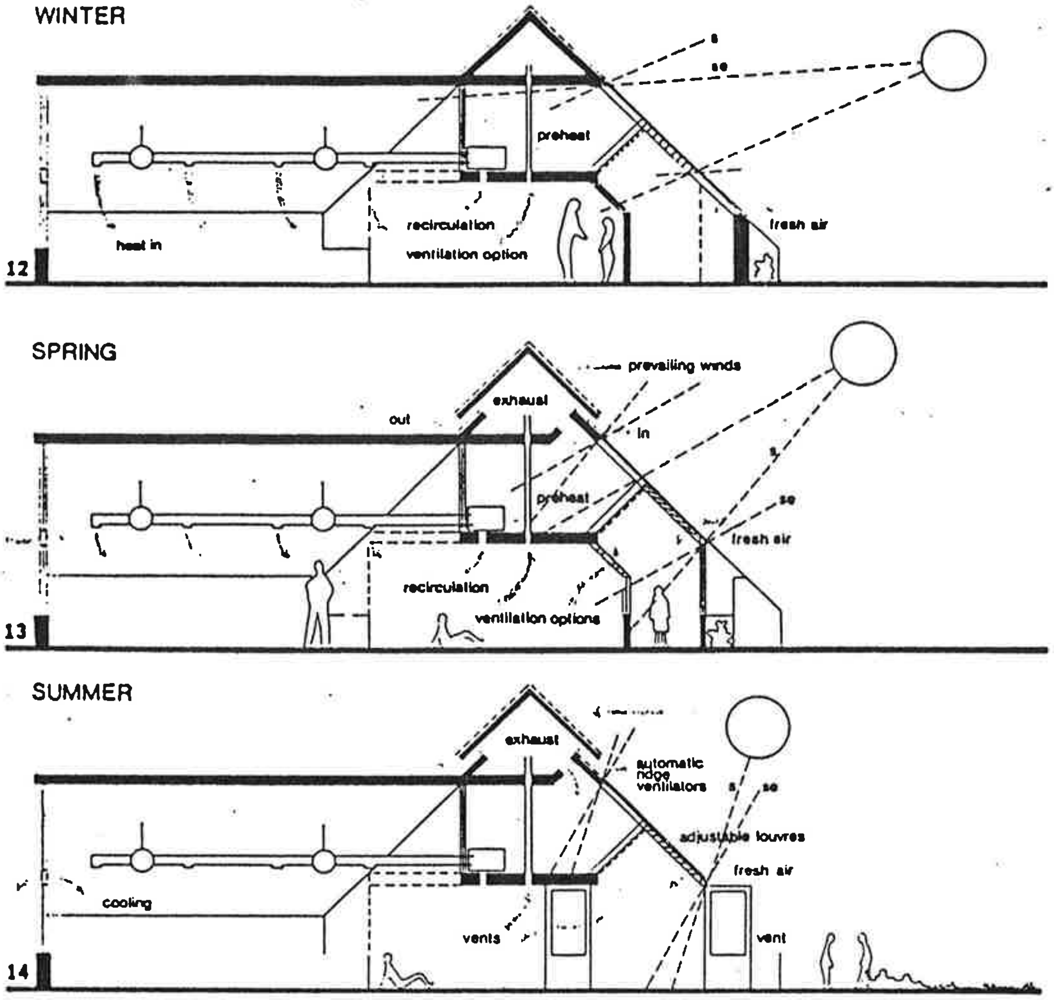
Now let us direct a critical eye towards conservatories, but first we will recapp on the mechanisms by which a conservatory could, in ideal situations, save energy. There are three distinct modes and they do not differ in principle from those applying to the atrium. They are (i) the reduction of conductive losses through the separating wall, due to the elevated temperatures prevailling in the conservatory, (ii) the possibility of a positive heat flux via convective (or mechanical) air circulation operating when the temperature in the conservatory is greater than the temperature in the house, and (iii) the use of the conservatory to provide pre-heated ventilation air. The three modes are illustated in fig (2).

The first mode, whilst it is probably the most significant in the case of the atrium, is less important in the case of the conservatory on the side of a domestic building. This difference stems mainly from the relative areas of protected wall (and window) in relation to the conservatory glazing area. Insulation standards of opaque wall are now high, and studies (1) have shown that there is no advantage in deliberately making the separating wall between the house and the conservatory of lower than normal insulation standard with double or single glazed conservatories.

The second mode represents the classic view of the conservatory function, as imported from the States, where high levels of solar radiation combined with low air temperatures may have resulted in good performance in this mode. It is the "Trombe Wall mode". However in the UK climate the periods for which conservatories are significantly above room temperatures during the heating season, are relatively few. Both field studies (2) and simulations (1) have confirmed this.

The third mode looks more hopeful. With high insulation standards becoming the norm, the proportion of heat loss due to ventilation has increased. Efforts to lower ventilation rates in low energy buildings have often been met with problems of condensation and poor indoor air quality. Thus it seems appropriate that we should link solar gains with ventilation, in the conservatory, in order to reduce ventilation heat loss. The great advantage of this mode, is that unlike the second mechanism, there is no "threshold effect", i.e. any increment of temperature, however small is usable. This has significance for both the comfort of people and plants (and hence the amenity value of the conservatory) for in the circulatory mode described above, temperatures have to get dangerously high before any significant convective input to the house can be made.

Indeed, a study carried out by the author for the Department of Energy (1), involving a thermal simulation model incorporating a naturally induced ventilation model, suggests that for the UK climate, solar ventilatin pre-heating (SVP) is the only way that conservatories can make significant savings in heating energy. The study points out that in optimising this mode, natural ventilation must be designed and not just left to chance, and that this will carry the extra benefit of improving indoor air quality, as well as reducing heating costs. It is clear. however,



12 Winter operation. Air is preheated in the atrium and fed to heaters (sun angle: s = south; se = south-east).
13 Spring operation. Options for shading and ventilation or preheating air for heaters.
14 Summer operation. Using through-ventilation and the stack effect.
15 View along the atrium. Apart from coat and bag storage in recesses, right, and sand trays outside one classroom, the atrium is a pleasant corridor.
16 End of the atrium: a sense of enclosure and no through-traffic encourages its active use.

Fig (3) Netley Infants School, Hampshire.
(source - Architects Journal)

Fig (4) The Hughes House, Energy World.
Architects ECD Partnership (source - Building Design)

that the air entering the house from the conservatory should not be extra over and above sufficient infiltration already entering the building from elsewhere. This calls for a tight building envelope with a controlable purpose-provided ventilation route via the conservatory.

There are a number of buildings which adopt the SVP principle. The Hampshire School at Netley fig (3) uses a long conservatory as a source of pre-heated air, as well as the main circulation route to the classrooms. In this case however the flow of air is handled mechanically, integrated with the circulating warm air heating system for each classroom.

A number of houses in the recently completed Energy World Exhibition also explicitly adopt the SVP mode of operation. The Hughes house fig (4) uses a two storey hight conservatory to provide air directly to almost all the rooms of the house, with passive and fan assisted extracts terminating in a ridge vent. This ridge vent ensures that the airflow direction is always the optimal south to north, irrespective of wind direction. In summer the vent area is greatly increased and is linked to the conservatory directly.

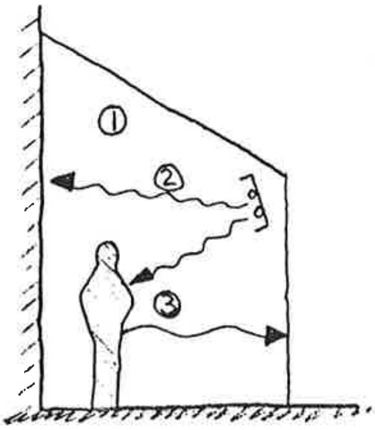
It must be pointed out here that many conservatory designs probably perform largely in the SVP mode, although this may not have been the explicit intention of the designer. This is because conservatories are usually on the south, and often cover parts of the envelope where there are most openings. With prevailing winds from the south-west, it is likely then that a fairly high proportion of infiltration will enter via the conservatory.

The majority of conservatries attached to houses, are there not for reasons of energy conservation at all, but simply for their amenity value. Clearly if this is the case then their cost effectiveness as energy savers only has to support the marginal costs incurred in optimising the conservatory for SVP performance. These costs, covering grilles, ducting, auto-vents etc, are relatively small and thus the use of the conservatory as an energy conserving feature should show good cost effectiveness.

THE HEATED CONSERVATORY OR ATRIUM

But are the pitfalls, resulting in poor performance, or even negative performance where a conservatory will increase energy consumption? The pleasantness of the conservatory frequently persuades owners to heat them in order to extend their occupiable period. Does this mean automatically that the conservatory becomes a net energy looser?

The answer is - probably yes, but not necessarily. Once a conservatory is heated, we now have in effect, a direct gain system. The same rules will apply - i.e. that the gains made during sunlit hours must balance the losses, occuring during times of poor or zero radiation. This balance will depend upon the heating regime, and the total conductance of the glazing. The latter is dependent upon the area (and hence shape) of the conservatory, and

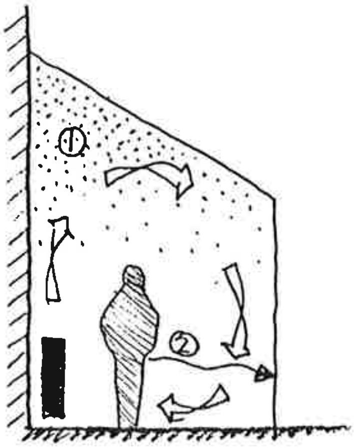


RADIANT SOURCE

1 air temperatures remain low

2 radiation directed inner wall

3 radiation compensates for radiant loss to cold glass



CONVECTIVE SOURCE

1 high air temperatures exacerbate conductive loss through glass - temperature gradiant reduces comfort at low level

2 no compensation for radiant loss

Fig (5) Convective and radiant heating in a conservatory.

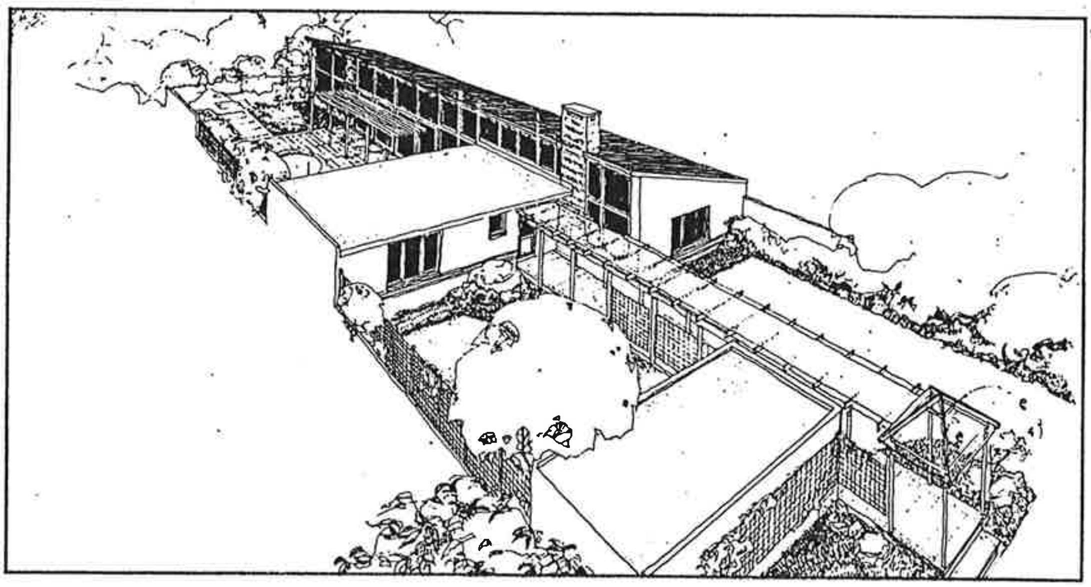


Fig (6) Haslam Homes, Energy World. Architect - Fielden & Clegg, (source - Building Design) upon the nature of the glazing and use of moveable insulation etc. The actual energy balance at the glazing is also influenced by the nature of the heat input. Fig (5) illustrates that certain arrangements of radiant heating would lead to far lower losses than convective inputs required to give the same comfort conditions.

An example of where the heat balance has been favorable, mainly as a result of shape factors, is where a lightwell in a SCOLA System school building was covered over. The original intention was that this space should be left unheated, in the true spirit of the atrium as outlined previously. However, the decision to use the space for a libraray demanded that this space be heated. Surprisingly, subsequent calculation showed that even when heated the covering of the lightwell would still save energy.

This was due to a number of factors - firstly the ratio of area protected to the area of external glazing was about 2 : 1. Secondly the external glazing was double whereas the original lightwell wall was 65% single glazed and the remainder poorly insulated. Finally, the occupancy period coincided with maximum availability of sunlight and useful daylighting.

It is easy to envisage a very different energy balance resulting from the heating of a single glazed attached domestic conservatory for periods including evening use.

On the other hand, new developments in glazing materials may make even heated domestic conservatories viable. For example the Haslam Homes fig (6), at the Energy World exhibition use triple heat-mirror glazing. Simulations carried out by the Research in Building Group using SERI-RES, have shown that this glazing, together with night curtaining, will result in an improvement in performance up to 100% glazing of the south wall. This has promted the designers to adopted very large areas of glazing for all south facing habitable rooms - i.e. the house has virtually become a heated conservatory, with automatic shading devices to reduce the risk of overheating. Considerable care has been applied to the planning of the houses to maintain privacy, but whether the occupants will thrive in such an environment remains to be seen.

CONCLUSION

To summarise, the energy performance of glazed spaces, wether they be heated or unheated, of atrium or conservatory form, depends upon a number factors. These include area and shape, relative insulation values of external glazing and internal walls, occupancy patterns and heat emmiters. It is not possible to make definitive predictions on form alone. However a few generalizations can be made.

Firstly, it is difficult to envisage an unheated space ever increasing the heating energy demand of the adjacent heated building, although it could result in an increase in lighting and mechanical ventlation costs.

Secondly, the atrium form is likely to perform mainly by reducing conductive losses from the surrounding walls, whereas the conservatory form has the potential for major energy saving by the SVP mechanism.

We feel that the amenity value of an unheated space may even be enhanced by their possessing a "climate" as distinct from an "environmental standard". Planting must be compatible with this internal climate and not demand heating or other conditioning for its survival.

Where heating is used, this should be a local and radiant source, simulating the warming effect of sunlight, rather than the environment of the cosy living room.

We believe that the recognition of these broad principles will not only ensure that atria and conservatories are indeed energy saving features, but also that they will continue to possess distinctive architectural and environmental qualities.

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