VENTILATION AND AIR POLLUTION
BRE/CIBSE SEMINAR Watford 27 February 1997

Low Energy Strategies in Urban Areas

Chris Twinn Associate Director Ove Arup & Partners
13 Fitzroy Street, London W1P 6BQ, UK
Tel +44 (0)171 465 3411 Fax +44 (0)171 465 3673 E-mail chris.twinn@arup.com

DEFINING THE PATH

So what is likely to influence the HVAC form of the urban office of the future? There seems little doubt that where external noise levels are not too intrusive, natural ventilation with its cost and user perception advantages will predominate. Indeed as the techniques of acoustic shielding, buffer zones and passive cooling develop its application is likely to expand. However, what about the parts of our urban environment from which there has been an abdication in favour of the internal combustion engine? Until such time as the true cost of this so called individual freedom is established we will be obliged to provide an alternative internal environment behind a sealed facade.

The path we tread must have as its ultimate objective a truly sustainable built form. Following this path involves addressing issues of pollution levels, conserving the dwindling earth resources and the increasing frailty of our natural world. It also concerns maximising the use of our urban centres to reduce transport needs and to preserve the countryside. A significant part of this overall equation is reducing our dependance on fossil fuels. Fortunately, as far as the built form is concerned, there is a clearly defined path opening up for us to pursue. This can be summarized as the following steps:

1. Identifying and then eliminating the most energy intensive components of a building.
2. Designing the building fabric as the primary internal climate modifier.
3. Introducing building engineering systems to assist the building fabric to recycle ambient energy.
4. Ultimately, designing these systems so their motive force is ambient energy.

Step 2 is represented by the new generation of naturally ventilated buildings. Typically they tend to use the building fabric in association with advanced digital controls to take advantage of night cooling to maintain suitable daytime room temperatures. However, they need significant heating energy to cope with winter ventilation and fabric heat loss. Step 3 seeks to address this by identifying, recovering and reusing a wide range of ambient energy sources to reduce the need for high grade delivered energy. The New Parliamentary Building being constructed in Westminster, London addresses this Step 3. The path to Step 4 takes many features used on this project to allow a future where the building becomes a zero net user of imported high grade energy .

AN URBAN MODEL

The New Parliamentary Building is located on a central urban site dominated in pollution terms by the automobile. The brief demanded the highest quality internal room conditions in terms of air quality, temperature and acoustics. Starting with the pre-requisite of a sealed facade, the design fully uses the passive abilities of the building's materials and form to maintain the indoor climate. Only then were building services systems chosen to enhance these abilities and introduce energy harvesting and recovery.

At the conceptual stage the project started with an analysis of the major ambient energy flows entering the building, how they could circulate through it and finally, how they would leave. The architecture together with the engineering services systems were developed to complement these flows. Added to this process was a brief requirement for a building with a minimum fabric design life of 120 years, so cost in use, material durability, replacement strategy, and effective use of space, all became significant design factors. It is interesting to find that the long life of the building fabric and systems means the embodied energy pales into insignificance compared with the building lifetime energy consumption. The resulting design has an energy consumption target of 90 kWh/m² per annum (based on a 50 hour week including ventilation, heating, cooling, lighting, office small power allowance and miscellaneous electrical power use).

The Building Facade

The cladding system provides an integrated solution to the provision of outdoor view, room daylight control, passive and active solar energy collection, excess solar heat protection, the minimising of room heat loss, ventilation supply and extract, and heat recovery.

The fenestration super glazing consisting of triple glazing with mid pane ventilated blinds. The outer double glazed unit is argon filled with a low emissivity (low E) coating to retain winter heat. The inner cavity contains retractable dark louvre blinds designed to maximise the absorbed solar heat. This cavity is ventilated with a proportion of room extract air and acts as a solar collector. The blind material and finish are specifically chosen to maximise short wave solar absorption and minimise long wave heat loss, in association with low E coatings on the glazed surfaces either side of the ventilated cavity. This arrangement results in less than 25 W/m² summer solar heat gain across the floor area of a 4m deep perimeter room. In shading performance terms the glazing system is comparable with external shading, but in energy efficiency terms far exceeds it because of its solar heat recovery ability.

The window arrangement uses a lightshelf to preserves room daylighting when solar shading is in use, so avoiding the 'blinds down, lights on' scenario, with its additional luminaire heat gain and energy use. The lightshelf form has a corrugated reflective surface designed to maximise high altitude skylight reflections but to reject the lower altitude direct shortwave sun radiation.

In many senses the facade is a highly active system. It has many elements serving a wide variety of functions at differing levels and for differing orientations. Yet it is predominantly a passive system, with the only moving component being the blinds operated by the room occupants across which the air is drawn.

Cooling

To satisfy the brief requirement of an occupied room temperature range of 22±2°C using passive cooling needed a detailed in-depth understanding of the heat flowing into and out of the room. With a facade with an overall high level of thermal resistance most of the room daytime heat gain is retained, so for the majority of the year there is a heat excess to be managed. This heat is stored, first to deal with the night heat loss and to avoid boost heating prior to morning occupancy, and then to allow night ventilation to remove any surplus from the building. High thermal capacity room surfaces with a density range between 50 and 200kg per m² are provided at the rate of 2.5m² per m² of room floor area. This is used as the heat storage medium with its ability to function with small temperature difference changes and to take full advantage of both radiated and convective heat transfer.

The room thermal capacity handles the internal room heat gains, but for ventilation when the outside air is above 19°C, groundwater at about 14°C is drawn from two on site boreholes to cool the outside supply air down to room temperature. A displacement ventilation system is used to allow this cooling to be achieved without any mechanical refrigeration.

Ventilation System.

The mechanical ventilation system serves a network of linked floor plena throughout the building via ductwork in the facade to provide 100% outside air ventilation to each room. High efficiency heat recovery is the key benefit mechanical ventilation has over conventional natural ventilation. Not only does it allow generous year round ventilation with outside air, together with the higher supply temperatures needed of displacement ventilation, but it also permits the recovery of solar heat from the window system, the occupants, their electrical equipment and the room radiators. Rotary heat exchangers operating at efficiencies of more than 85% provide this function. They are of the hygroscopic type to simultaneously recover winter moisture from the exhaust air and so reduce supply air humidification requirement.

The selection of very low pressure loss air handling and duct system components mean the ventilation energy use target is 1 Watt per litre of air supplied. The fan total pressure generated by supply and extract fans together is 640Pa with fan efficiencies (fan, drive, motor and inverter combined) of 65%. Typically the air handling plant component face velocities are 1.2m/s, with the filters at 0.8m/s. Fans are inverter driven so that when commissioned the sizing margin does not becoming a lifelong energy penalty, and fan efficiency can be retained for half speed night operation.

The same full fresh air system is able to serve all different room types, so allowing future changes of room function without dictating a services refit. Not only does this make the services more compatible with the long life of the building fabric, but it considerably reduces the embodied energy content of the engineering services across the building lifetime.

Heating

For most of the year a significant proportion of the building will have internal heat gains, from occupants, machines, lights and beneficial solar gain, that more than satisfy the fabric heat loss. Heating of the outside supply air then becomes the dominant heating demand. Consequently the ventilation system design centres on developing its ability to recover heat from all the internal heat sources and the window solar collectors so allowing heat recovery to do most of this ventilation heating.

The heating system is a variable water volume system with thermostatic valves on the room heat emitters, allowing the system to throttle in response to beneficial internal and solar heat gain, and occupant temperature trim control. The water has a 70°C flow and a 50°C return design temperatures to promote flue gas condensation efficiency in the condensing natural gas boilers. Compared with standard UK practice the mass of water to be circulated round the building is almost halved and using pipe sizing at 50Pa /m results in significant pump power reductions. Thus for this 23000m^2 building the duty pair of perimeter heating pumps generate a head of only 40kPa with a peak energy consumption of 450W each. The low pressure head also allows thermostatic radiator valves to operate with a 1°C proportional band without the proliferation of pressure reducing valves on each branch and their accompanying pressure head requirements.

THE NEXT STEP

The development of the urban building model has been the subject of a series of Joule II research programmes. This research has had many strands to it including, full scale component and assembly mock-ups, PASSYS cell testing, wind tunnel research, daylight modelling, thermal and energy computer analysis and software development, and computational fluid dynamics (CFD) modelling. The research aims to fill the technical knowledge gaps to allow the implementation of the model within the overriding consideration of an integrated and stimulating architecture.

Many of the initial research results have been applied to the New Parliamentary Building but its most exciting prospects relate to the ultimate potential of a building fabric requiring no refined energy consumption. In essence one starts with a strategy which is purely based on the use of ambient energy inputs from:

- solar gain
- daylight
- occupant activity
- cool outside air
- wind
- photovoltaic (PV)

With an urban building facade closed due to external pollution, the internal ventilation is driven by buoyancy stack affect through low pressure routes from roof level down to the rooms and then back up to the roof . These routes can be in a variety of forms, for example, staircases, atria, within the facade or dedicated air ducts. Direct wind pressure is used to drive the incoming outside air supply through roof top air to air heat recovery, with negative wind pressure drawing the exhaust air out through the heat recovery. Not only does a rooftop location give the best access to wind but it provides the freshest source of supply air. The rooftop cowls are arranged as wind scoops with the ability to rotate to face the incoming wind direction. A highly insulated building facade allows almost all the internal heat gains to provide extract air buoyancy and to satisfy the fresh air intake heating via the exhaust air and the heat recovery. There is a critical balance between the level of heat recovery and maintaining adequate stack affect.

The glazing system develops the principles of allowing high levels of natural daylight while providing practically total protection from the summer sun direct solar heat component. The window solar collection allows the recovery of the incident solar radiation via the exhaust ventilation so it is also available for heat recovery.

Large areas of high thermal capacity surfaces are arranged to temper the ventilation air supply on its route to the rooms, as well as in the room to smooth out heat gain excesses and deficiencies. The ability to do this will considerably increase as phase-change heat storage materials are integrated into the building fabric.

To reduce winter ventilation air dryness and summer excess humidity, room finishes are chosen to allow the building fabric to function at a hygroscopic level, absorbing moisture at times of room excess and emitting it at time of deficiency. This supplements the moisture recover function done by the ventilation system.

Photovoltaics generate the high grade electrical power needed for the building occupant's office machines. This electrical power in turn provides waste room heat recoverable via the exhaust ventilation. In addition when used in hybrid configuration the photovaltaic cells heat provides buoyancy assistance to the ventilation extract air and further enhances fresh air pre-heat.

Mid-sized wind turbines replace the conventional collection of rooftop plant to provide additional high grade electrical power with an availability profile which compliments photovaltaics. The National Grid infrastructure then becomes the manager of the individual building harvested energy using pumping systems and fuel cell type technology to store and then redistribute electrical energy.

THE CHALLENGE

The more one fundamentally re-examines the conventional methods available for achieving an appropriate internal climate, the more opportunities it opens up for addressing the serious environmental and resources issues currently facing our society and our urban concerns.

To date the assumption has been that a facade sealed to cope with external pollution, means air conditioning with an energy consumption a factor of two times or more greater than that for natural ventilation. What is becoming clear is that buildings which integrate the building environmental approach with simplified engineering system support have the potential to use considerably less energy than their naturally ventilated counterparts. In essence the challenge is to develop fabric and systems with the ability to capture and repeatedly recycle ambient energy and to use those same energy sources for the system's motive force . Used in unison with the principle of low embodied energy achieved by long life building and systems, we will be well on our way to the zero energy building and a sustainable future.

Chris Twinn CEng, BSc, MCIBSE, MinstE. Associate Director, Ove Arup & Partners

Ove Arup & Partners	Environmental, building services & structural engineers
Michael Hopkins & Partners	Architects
Conphoebus, Sicily	Test laboratory & PV research
Bartenbach Licht Labor, Austria	Lighting consultant
CSTB, France	Aerodynamic engineers
MBM, Germany	Prototype development

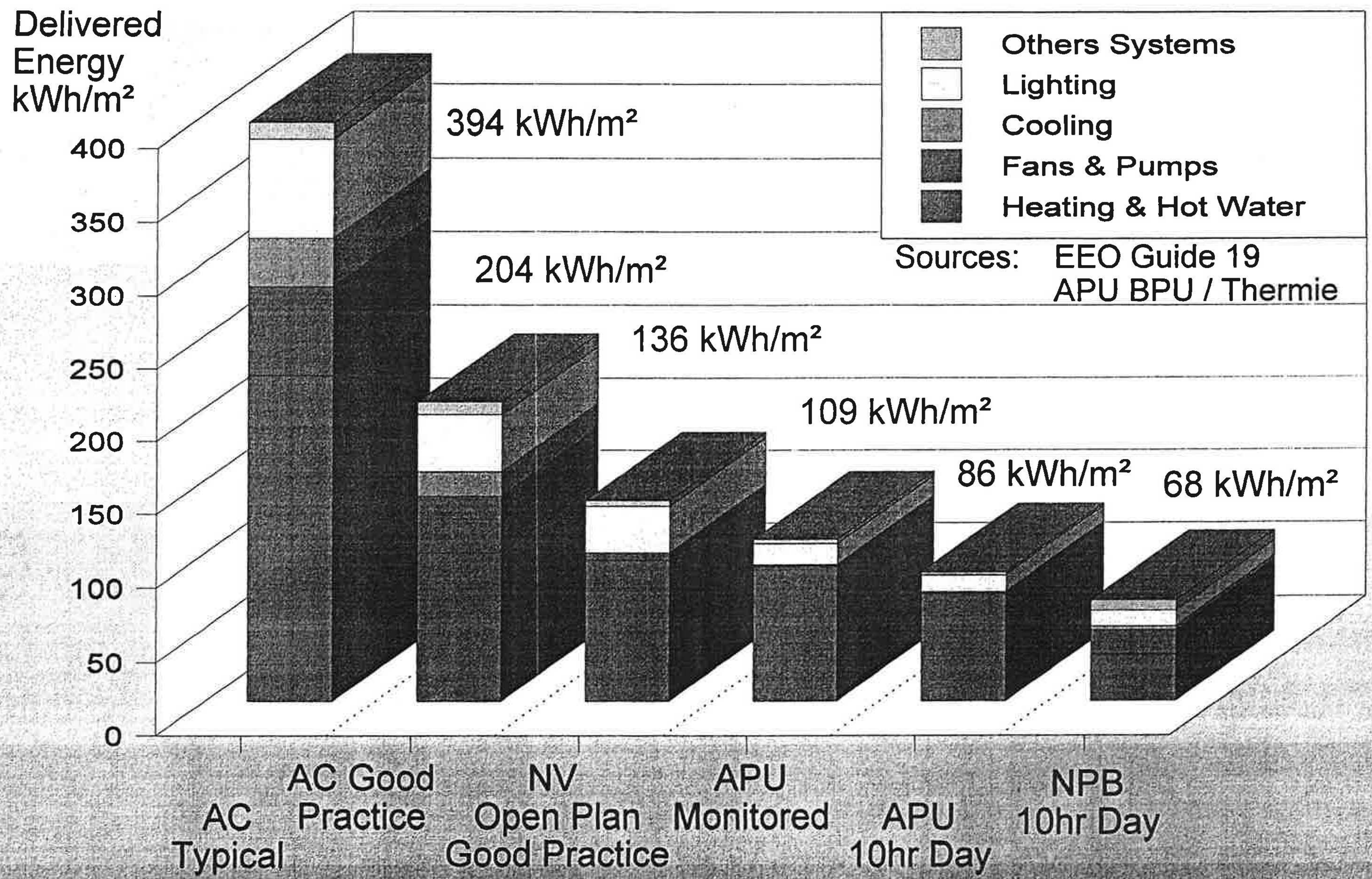
Ventilation and Air Pollution

BRE / CIBSE NVG Seminar 27 February 1997

Low Energy Strategies in Urban Area

Chris Twinn BSc(Hons) CEng MInstE MCIBSE

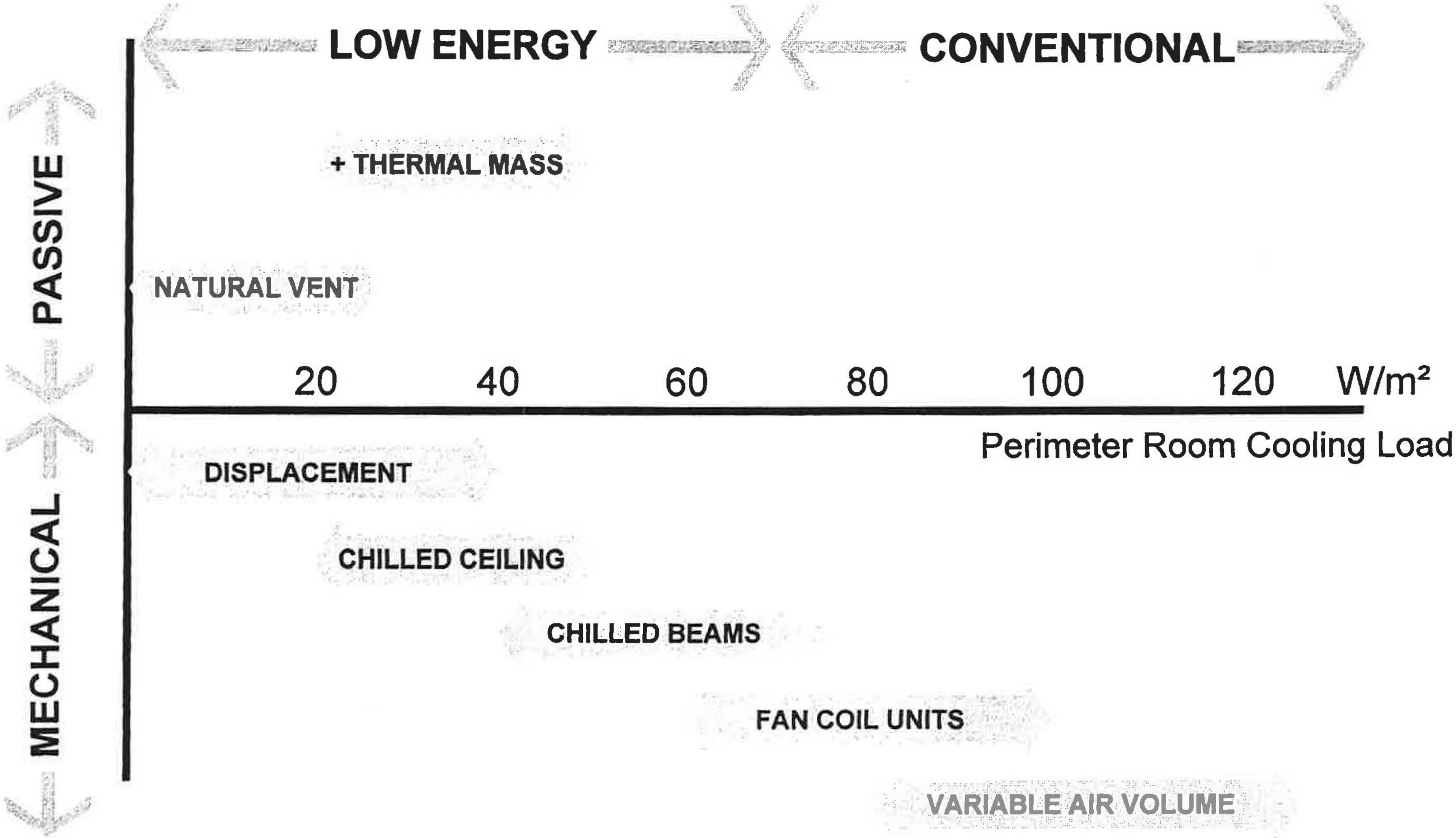
Associate Director Ove Arup & Partners



Energy Consumption

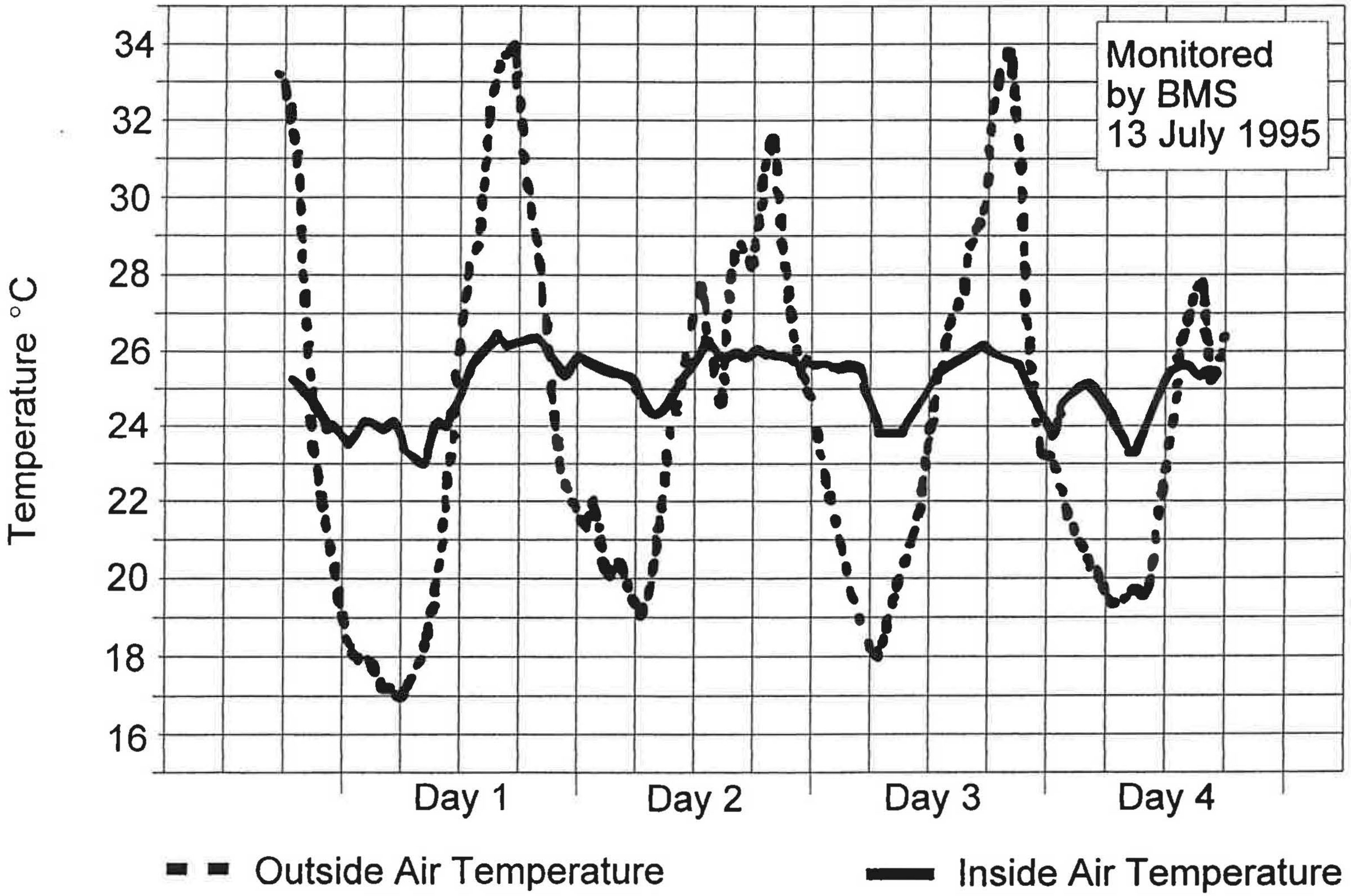
ARUP

CHRIS TWINN ENERGY3.SHW



Room Cooling Methods

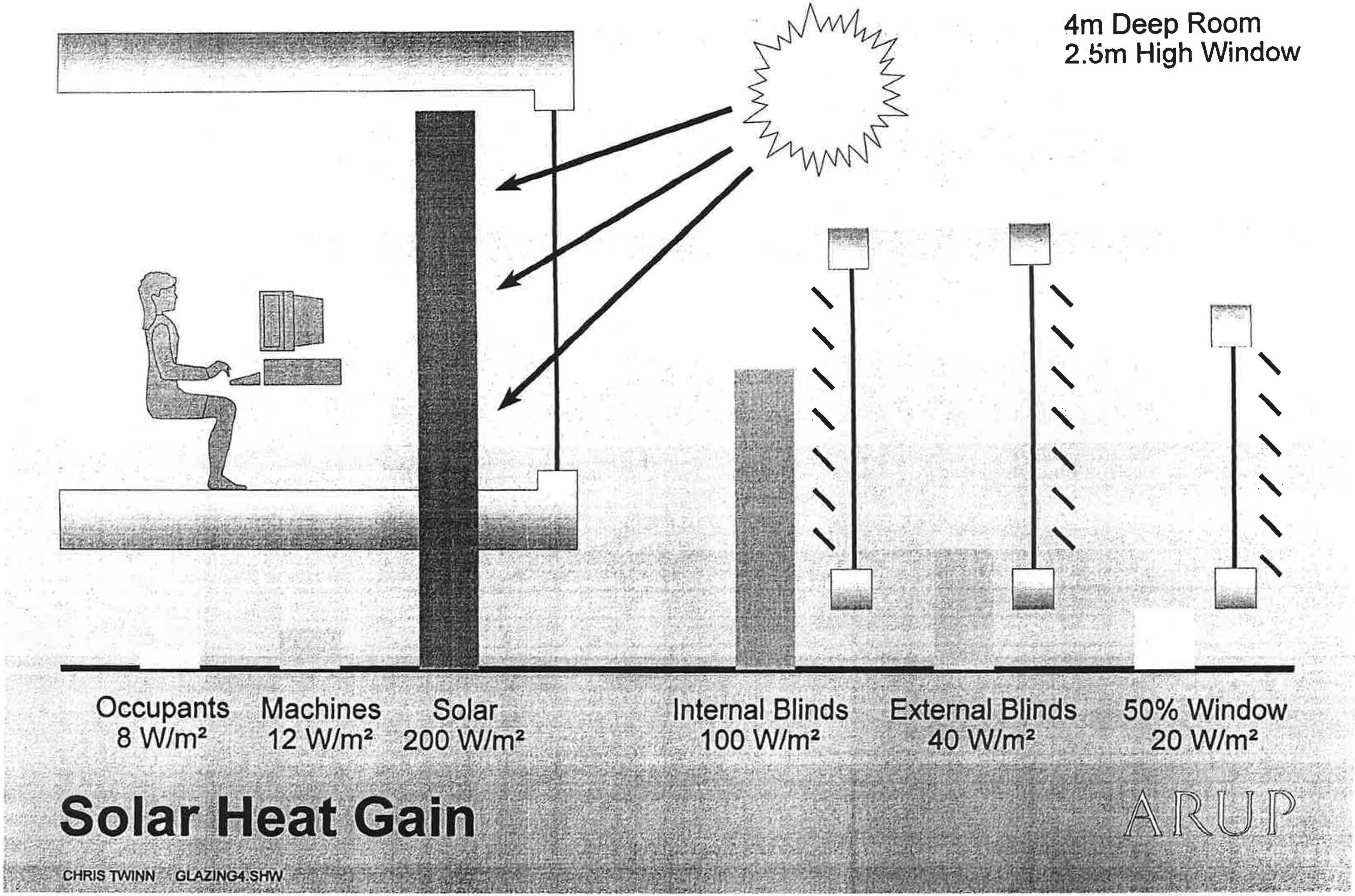
CHRIS TWINN SYSTEM1.SHW

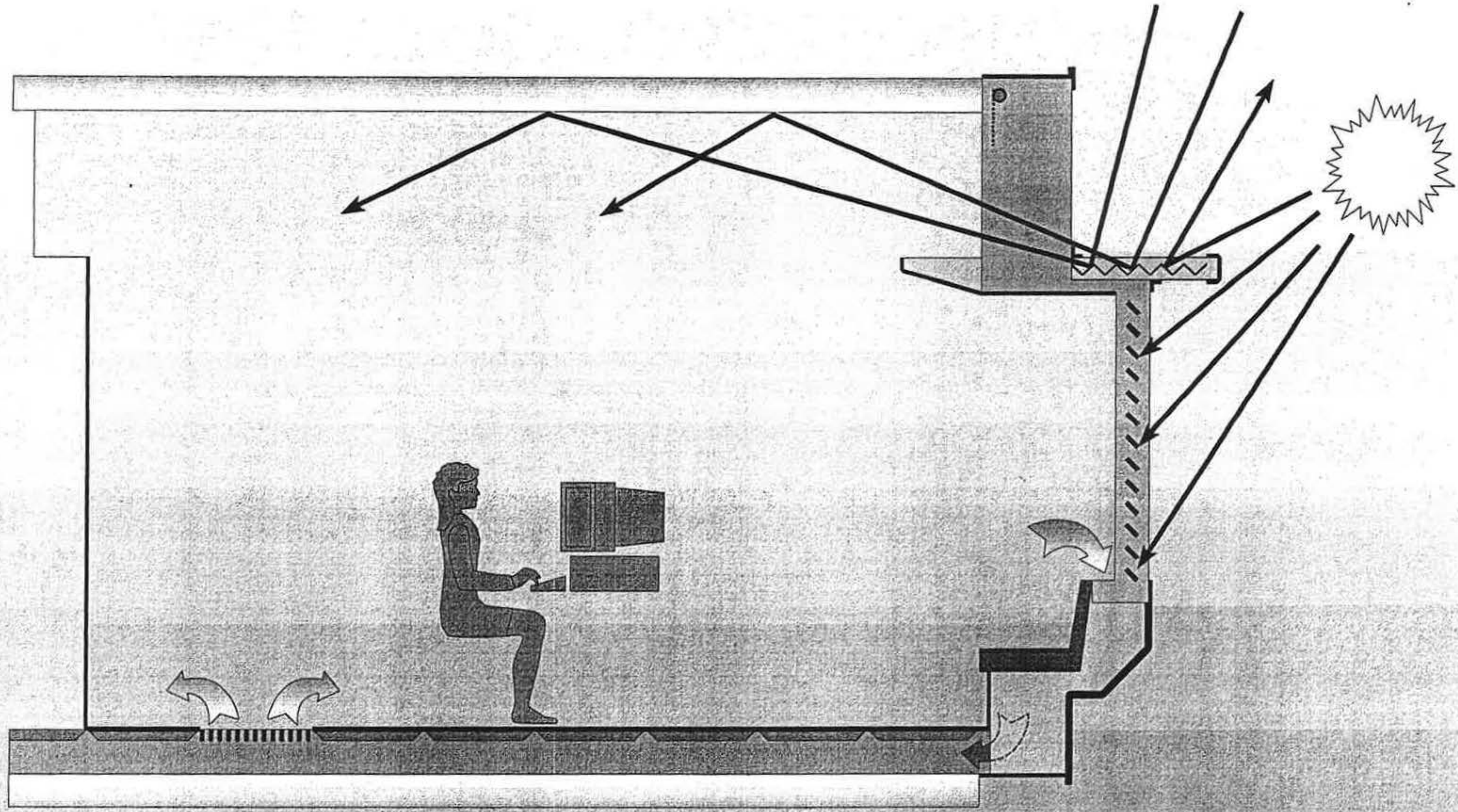


Recorded Peak Temperatures

ARUP

CHRIS TWINN APUTEMP1.SHW

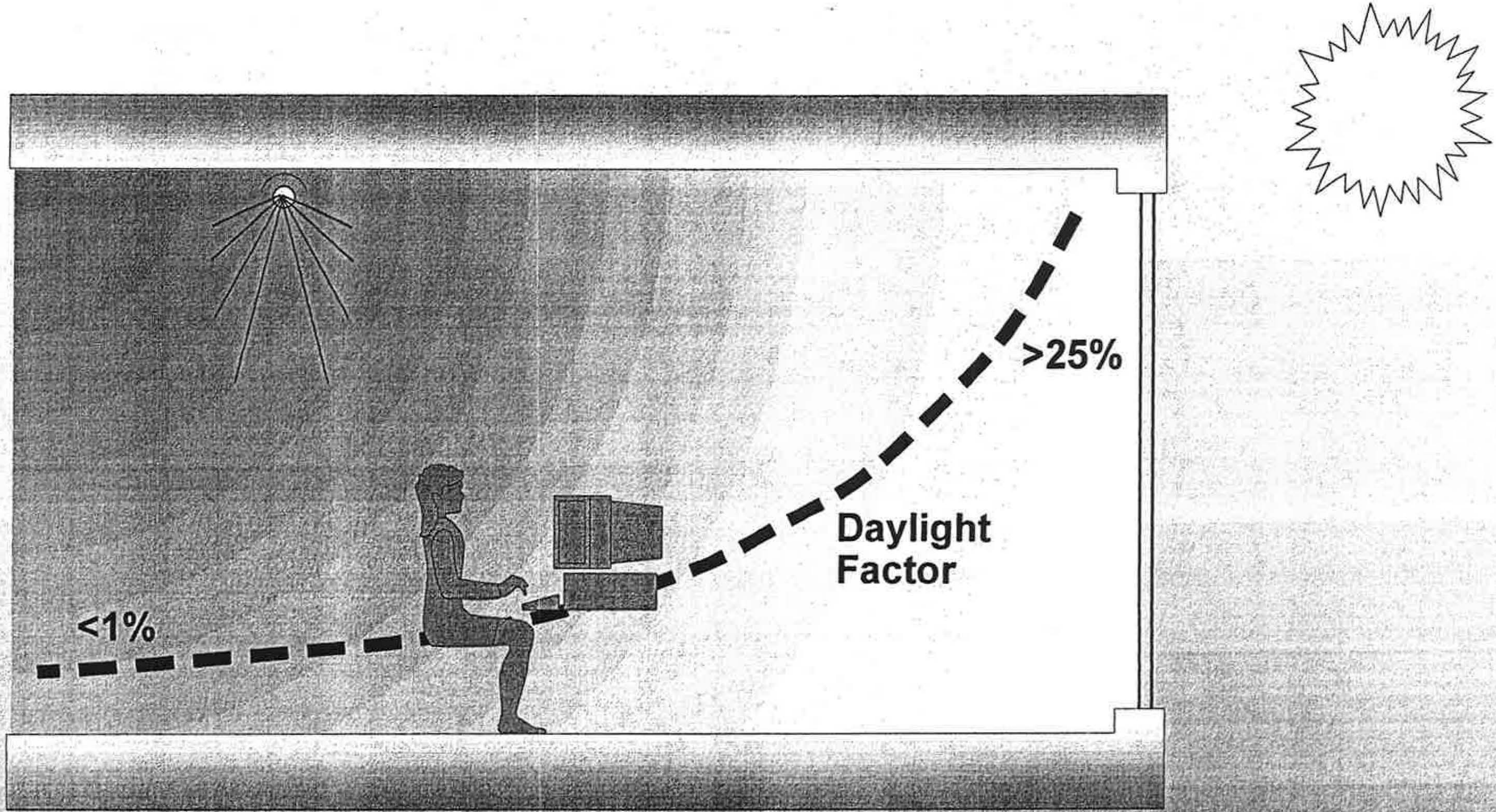

4m Deep Room
2.5m High Window
Occupants
8 W/m²
Machines
12 W/m²
Solar
200 W/m²
Internal Blinds
100 W/m²
External Blinds
40 W/m²
50% Window
20 W/m²
Solar Heat Gain
ARUP
CHRIS TWINN GLAZING4.SHW



Daylight & Solar Control

ARUP

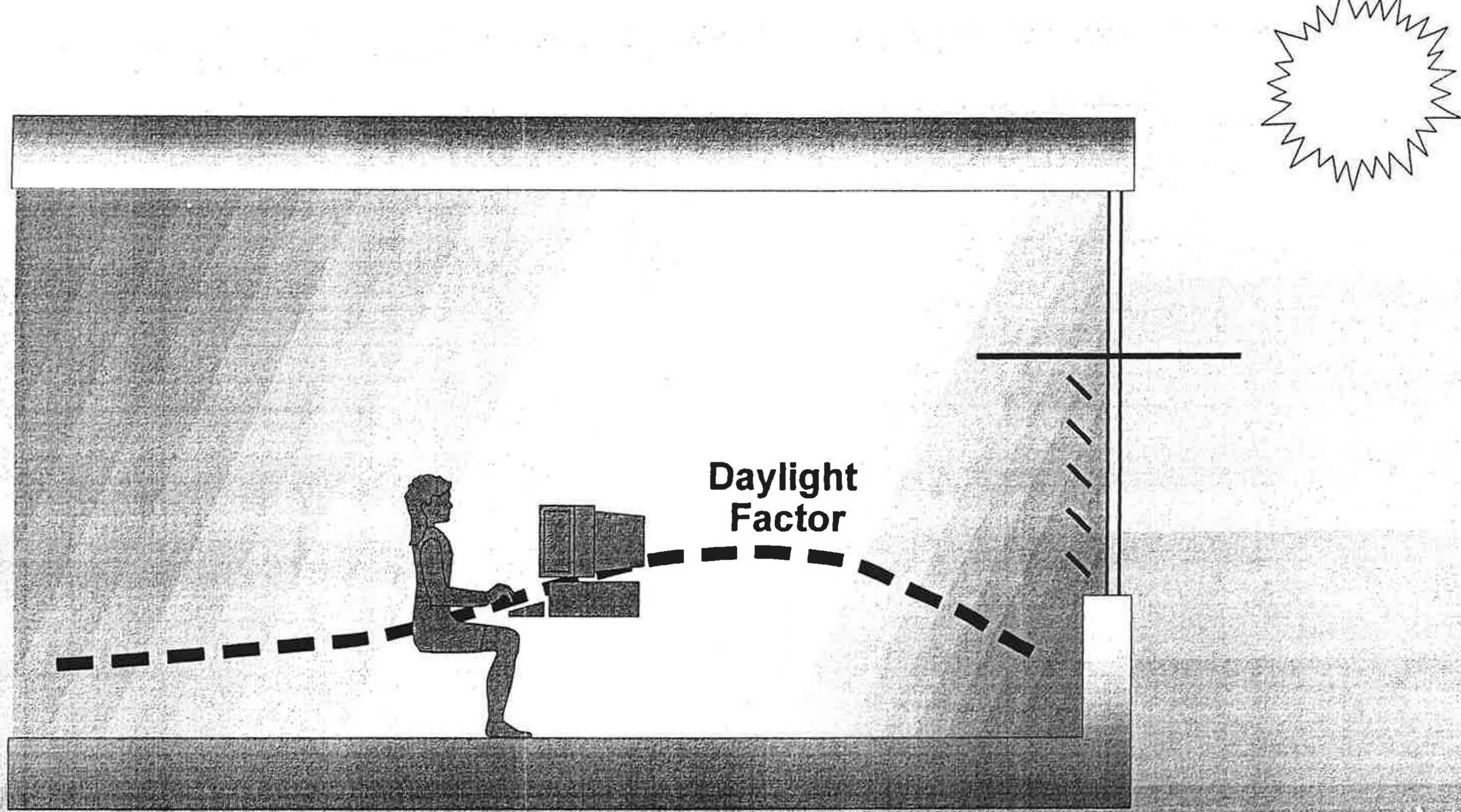
CHRIS TWINN NPB4RM.SHW



Daylight Contrast

ARUP

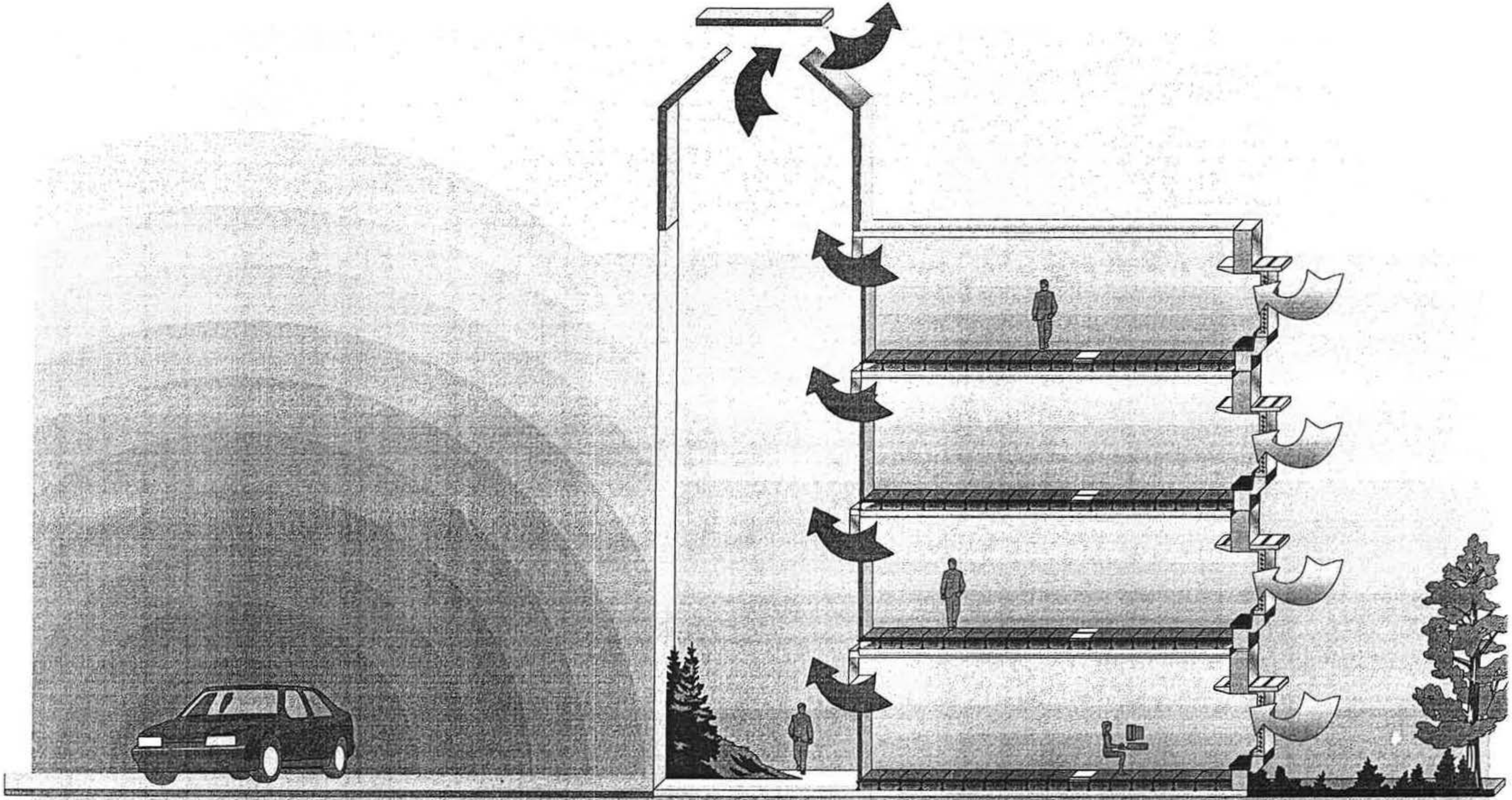
CHRIS TWINN GLARE1.SHW



Daylight Control

CHRIS TWINN GLARE2.SHW

ARUP

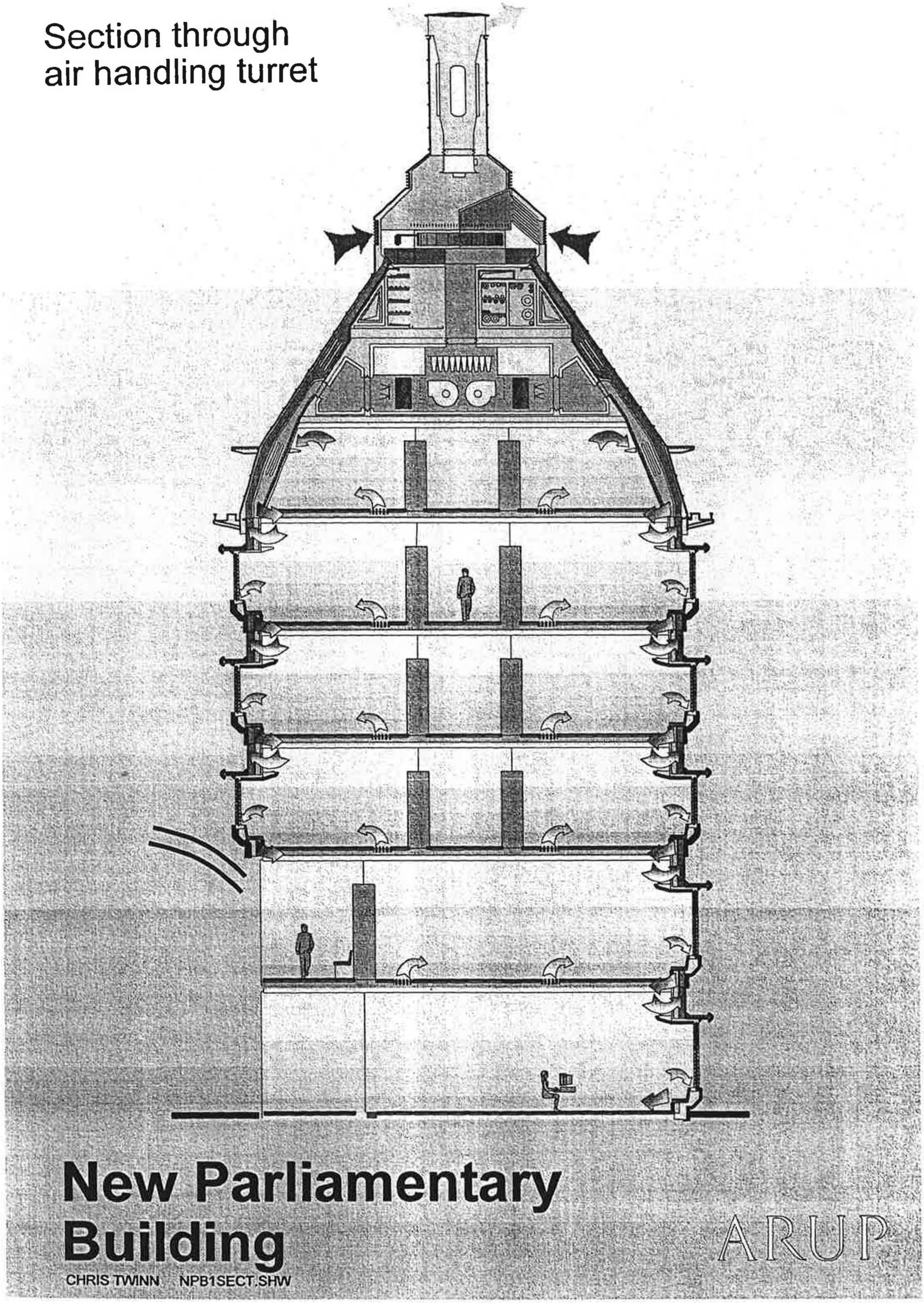


Barrier zoning

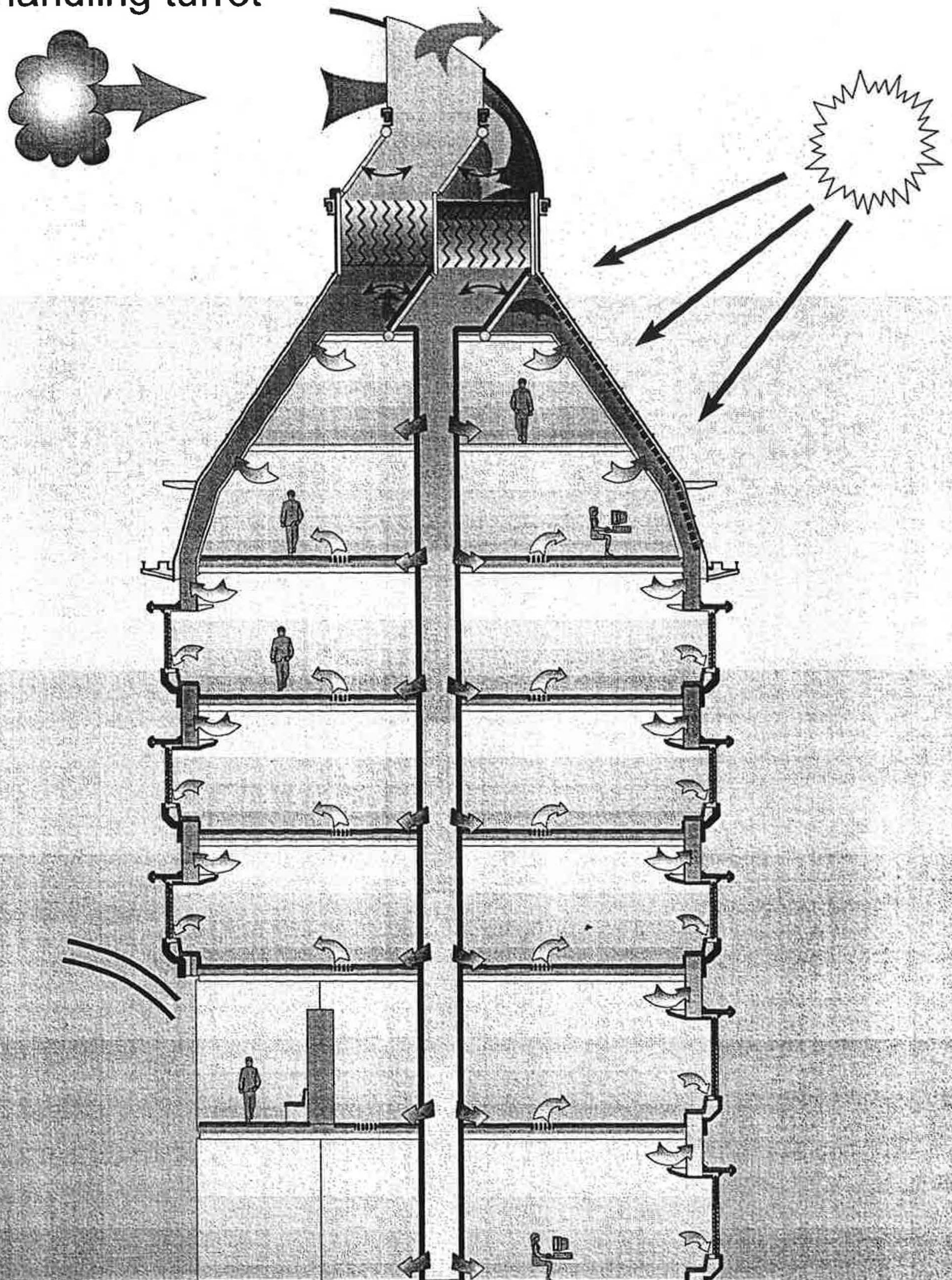
CHRIS TWINN NV1BAR.SHW

ARUP

Section through air handling turret



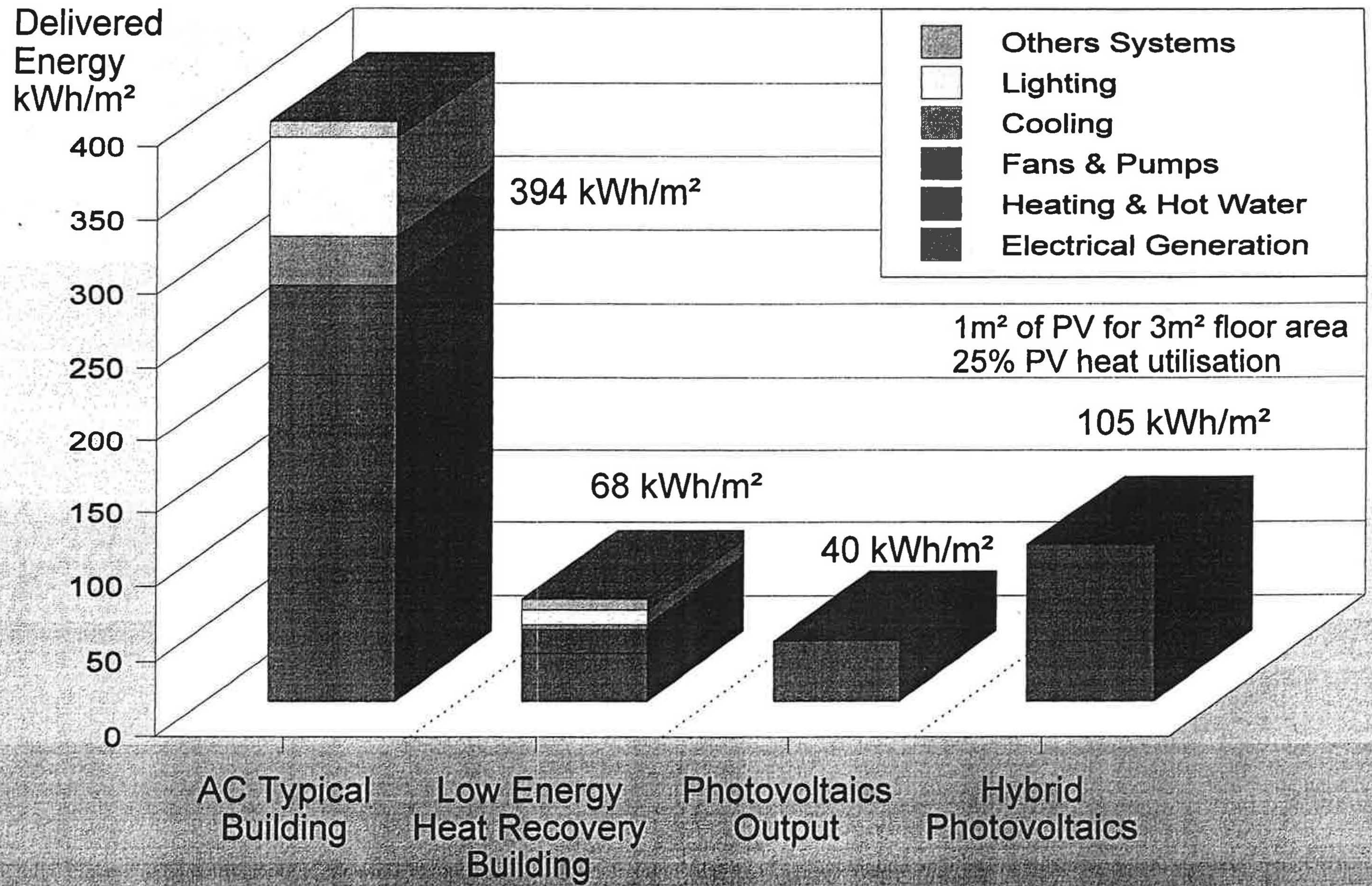
Section through air handling turret



Wind & Buoyancy Driven Ventilation

CHRIS TWINN URBAN4.SHW

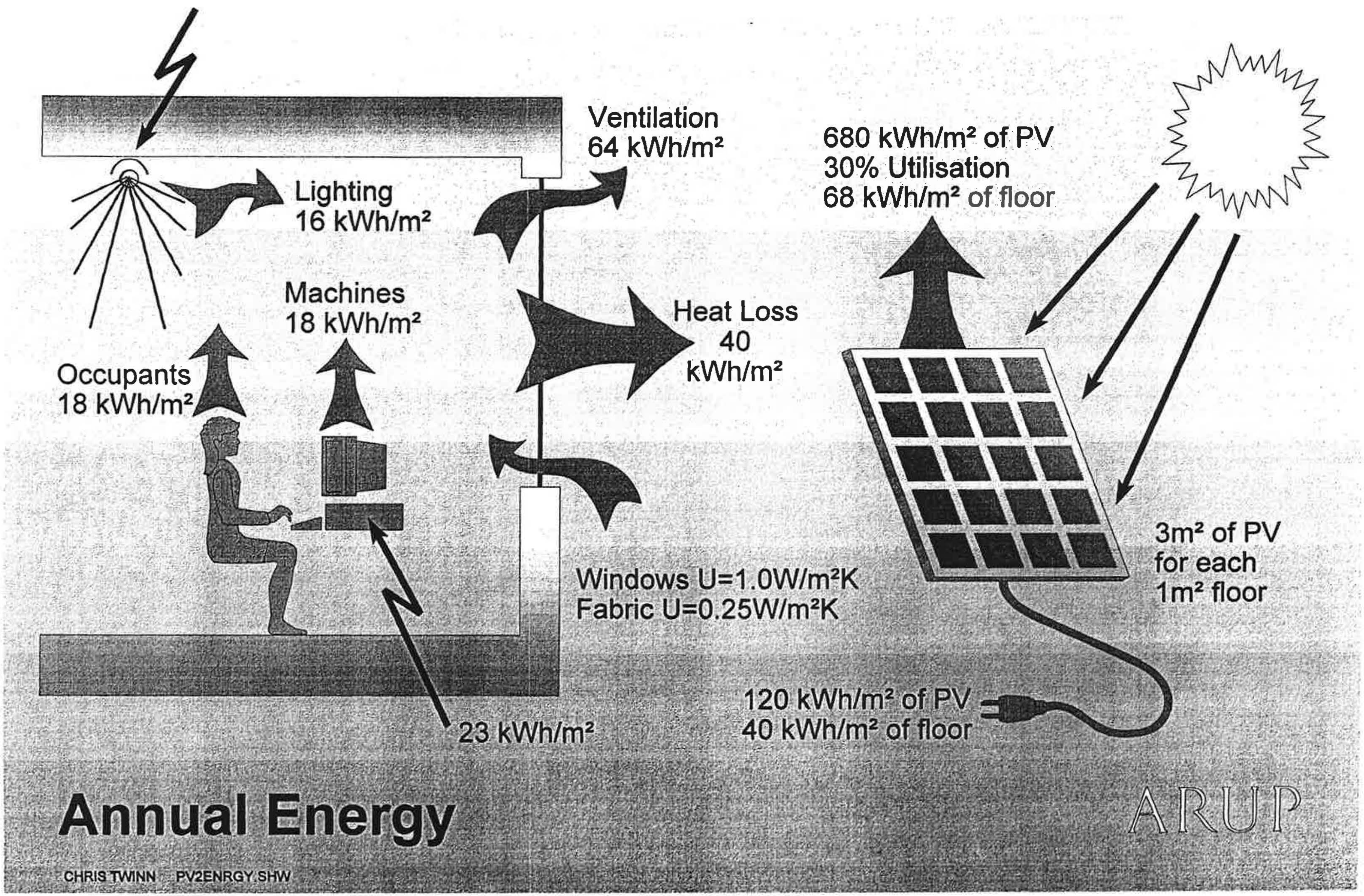
ARUP

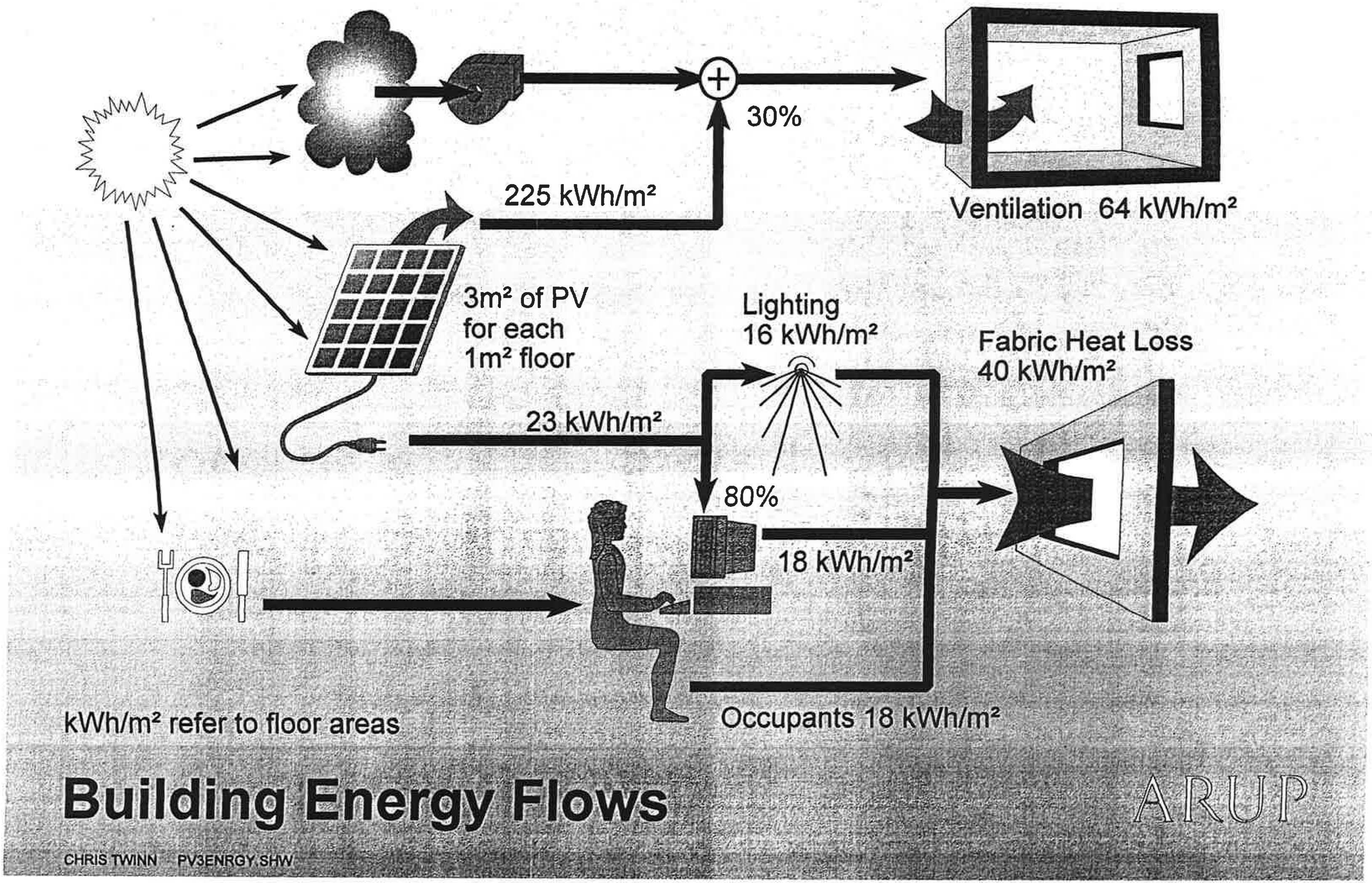


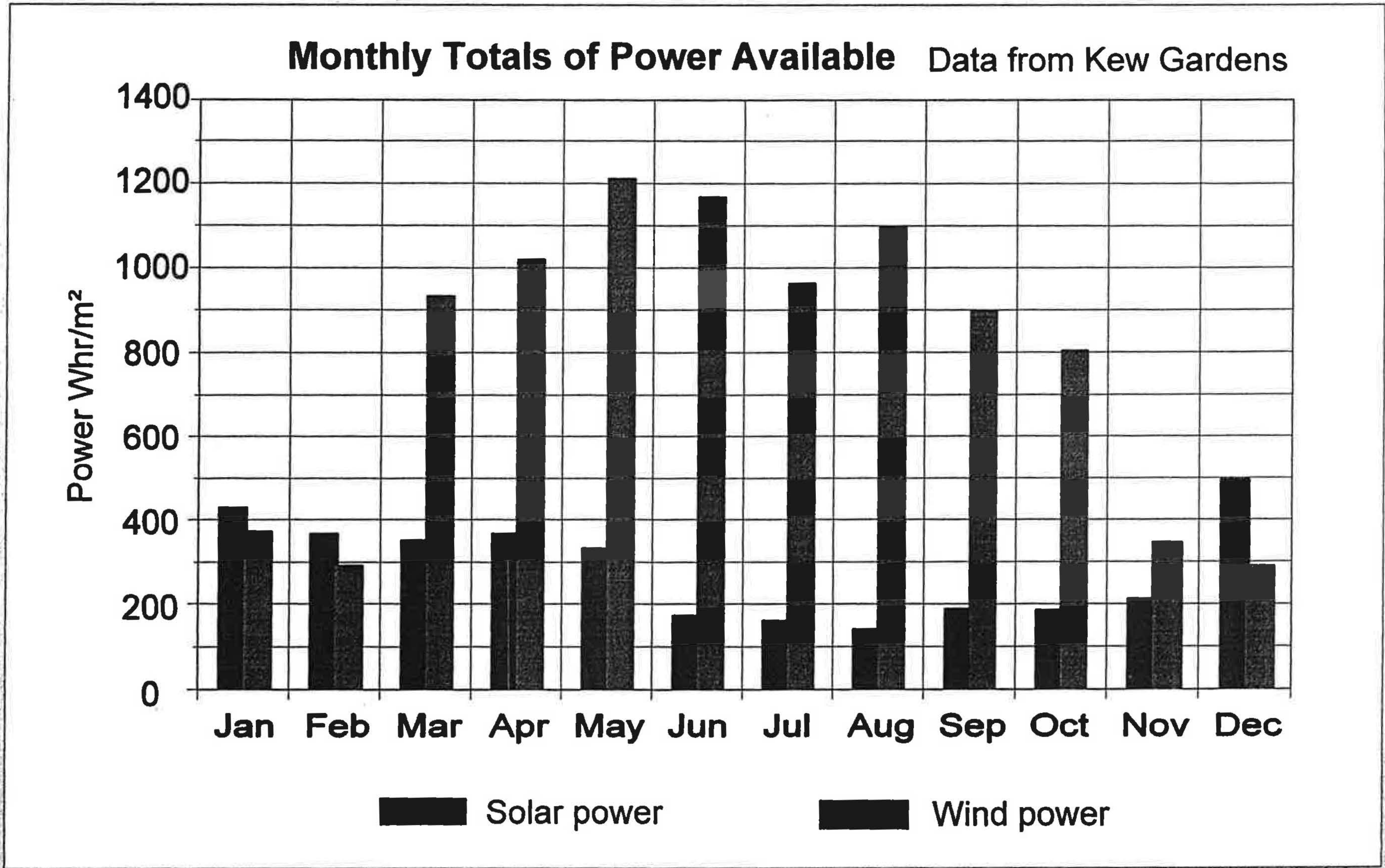
Energy Consumption

ARUP

CHRIS TWINN PV4ENRGY.SHW


Ventilation
64 kWh/m²
Lighting
16 kWh/m²
Machines
18 kWh/m²
Occupants
18 kWh/m²
Heat Loss
40
kWh/m²
23 kWh/m²
Windows U=1.0W/m²K
Fabric U=0.25W/m²K
680 kWh/m² of PV
30% Utilisation
68 kWh/m² of floor
3m² of PV
for each
1m² floor
120 kWh/m² of PV
40 kWh/m² of floor
Annual Energy
ARUP
CHRIS TWINN PV2ENRGY.SHW


30%
225 kWh/m²
Ventilation 64 kWh/m²
3m² of PV
for each
1m² floor
Lighting
16 kWh/m²
Fabric Heat Loss
40 kWh/m²
23 kWh/m²
80%
18 kWh/m²
Occupants 18 kWh/m²
kWh/m² refer to floor areas
Building Energy Flows
ARUP
CHRIS TWINN PV3ENRGY.SHW



Hybrid Photovoltaics

ARUP