Leaflet 12

Energy Efficiency in Offices

- Mechanically ventilated office block – purpose-built in the late 1980s
- Air-conditioning avoided by a well-designed mechanical ventilation system
- Well-insulated, heavyweight construction which retains night-time heating or cooling
- Simple controls maintain a comfortable, well-lit environment

The windows are argon-filled, double-glazed units in timber frames. They are lightly tinted and roller blinds are used to reduce solar gain and glare. Only 27% of walls are glazed, providing reasonable daylight whilst minimising heat gain and loss. The second floor is protected from excessive solar gain by a roof overhang.

Posford House Peterborough

The Project

Posford House in Peterborough was built in the late 1980s adjacent to, and to extend, the head office of engineering consultants Posford Duvivier.

The three-storey open plan office of 1400 m^2 gross area was designed with particular attention to energy efficiency and user control. Electric heating was chosen because the capital cost of installation was cheaper than other alternatives, and control was easier. The need for air-conditioning was avoided by a combination of thermal mass and a well-designed, fresh air mechanical ventilation system, which uses passive cooling in summer.

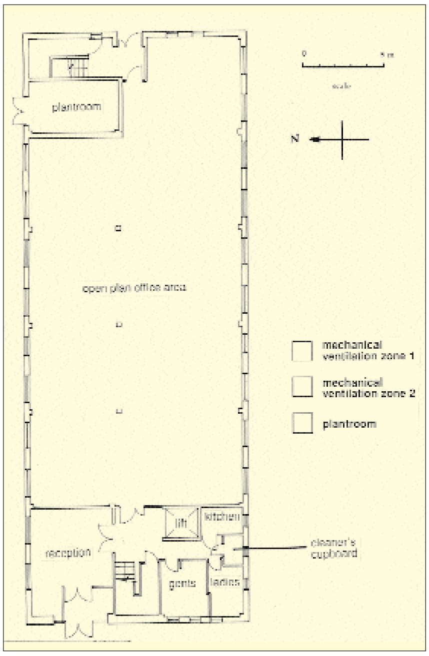
The building has a reinforced-concrete frame, cavity brick and block walls and a pitched roof. Most of the windows face north or south.

Office type 1. Naturally-ventilated, cellular
A fairly small, simple building with largely individual offices, and perhaps a few group spaces. Daylight is good while artificial lighting is usually less intense than in the other three office types[1], and is easily controlled by individual switches by the doors. There are few common facilities.

Office type 2. Naturally-ventilated, open-plan
Largely open-plan but with some cellular offices and special areas such as conference rooms. Light levels and lighting power tend to be higher, and with deeper plans daylight is less available. Lights also tend to be switched in large groups.

Office type 3. Air-conditioned
Similar in occupancy and planning to type 2, but usually larger and with a deeper floor plan and tinted or shaded windows which reduce the availability and use of daylight still further. The air-conditioning system may be either all-air or air/water.

Reference: ECON 19 [1]



Floor plan

> *"A well-insulated office designed to minimise day-time heating and avoid air-conditioning by means of mechanical ventilation with passive cooling."*

BEST PRACTICE PROGRAMME
ENERGY EFFICIENCY

Posford Duvivier used the Electricity Association specification for Energy Efficient Design (EED) for heating.

The Result

The building is used predominantly for engineering design; high lighting levels are needed for the considerable drawing board work. The occupancy density is 11 m^2 per person, and there is approximately one desk-top computer per five members of staff.

It is well-insulated with wall and roof U-values, at 0.3 W/m^2, noticeably better than the Building Regulations. The resulting low rate of heat loss allows a large amount of heating to occur during the electric, off-peak, tariff period. During the hours of occupation, any additional heating needs are met mainly by internal heat gains and ventilation heat recovery.

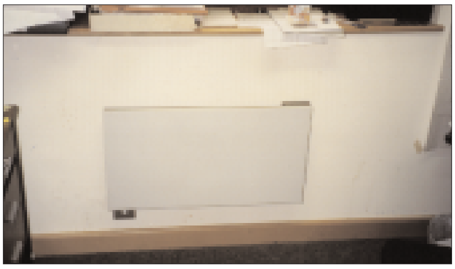
High comfort levels have been achieved throughout the year by a combination of natural and mechanical ventilation, and passive cooling using night-time low ambient air to sub-cool the building floor slab and fabric.

In 1991, the building was awarded national and regional Beta Awards by the Electricity Association and Eastern Electricity respectively for the efficient use of electricity in buildings over 1000 m^2 floor area.

The thermal mass, mechanical ventilation system and tinted windows together allow the building to achieve standards resembling those of an air-conditioned building without the additional installation and running costs. Energy costs in 'good practice' offices are usually 30-50% below average levels. The energy consumption (131 kWh/m^2/yr) and costs (£7.9/m^2/yr) are low compared to 'good practice' levels for air-conditioned buildings of 232 kWh/m^2/yr and £8.5/m^2/yr respectively, but the electrical heating energy cost is three times that of a comparable gas-fired system. This higher cost is offset by the saving in initial installation costs, which are substantially lower than for a gas-fired wet system, and by lower-than-normal use of energy in other areas.

Despite the mechanical ventilation and the additional lighting due to tinted glazing, the 70 kWh/m^2/yr of electricity used for non-heating purposes is only slightly more than the figure of 61 kWh/m^2/yr for a 'good practice' naturally-ventilated office.

Floor diffuser



Perimeter electric heaters

Although its carbon dioxide emission level of 94 kg/m^2/yr is better than that for a 'good practice' air-conditioned building, both its annual energy cost and its carbon dioxide emission levels are substantially above those associated with a 'good practice' naturally ventilated building. Thus, although the building does not meet the overall 'good practice' criteria and cannot be considered as a 'good practice' Case Study, valuable lessons can be learnt from the way the low energy consumption has been achieved.

Designers will benefit from the many pointers in this General Information Leaflet to 'good practice' in buildings generally, and not just those which are electrically-heated. Energy Consumption Guide 19[1] gives figures for the energy consumption and costs of typical and 'good practice' office buildings of various types.

Heating System

Each floor is heated by two zone electric wall-mounted panel heaters. One zone covers the open-plan office areas whilst a smaller one covers the reception area, conference rooms, stairs and toilets of each floor. The heaters are controlled by a programmable process controller which responds to input from external weather compensators, zone temperature sensors, and individual unit thermostats. Off-peak electricity is used to preheat the building. Heating is time controlled for the occupancy periods of 8am to 6pm, 5 days per week. Fabric protection at 12°C is also incorporated. The heating control panel in the plantroom includes an override facility for longer hours of heating, but this option is rarely needed because of the thermal stability of the building.

Adoption of the electric heating system has substantially reduced both the initial installation costs and maintenance costs in comparison with an equivalent gas-fired low-pressure hot water system. Also, it has increased lettable floor area by minimising the plant room space requirement. Such a system is both easier to maintain and easier to alter than wet systems. However the main drawbacks of electric heating are the high cost of fuel and the increased CO_2 emissions, even for better-insulated buildings.

Mechanical Ventilation

During occupancy periods, the building is ventilated with 100% fresh air through diffusers in the office floor. The incoming air is preheated by heat recovered from the exhaust air stream and is topped up when necessary to 18°C by a duct mounted electric heater coil. The air is ducted through the floor void to six points on each floor. Extract is through the light fittings and ceiling.

The compact plantroom, in a small area at the rear of the building, includes a run-around heat-recovery coil system which operates with an efficiency of 60%. In such systems, increased power is required for the fans to overcome the additional resistance of the heat exchanger. Care should be taken to ensure that the overall energy gains are not exceeded by the losses when planning such an installation.

One multi-functional electronic control unit in the plantroom operates both the heating and ventilation systems, normally from 8am-6pm, Monday to Friday.

By using a rolling average of sampled outside temperatures, the control unit can automatically select either summer or winter mode. In summer mode, the heating is turned off and fans are run at high speed to provide six air changes per hour. In winter mode the heating is turned on to give a pre-occupancy heating and day-time boost, together with the air heater battery and the fans which are set at low speed to give a sufficient two air changes per hour.

Windows, blinds and solar shielding

Ceiling and task lighting

The controls determine both the pre-occupancy and the day-time heating periods for each of the six heating zones, and are able to run the ventilation plant for off-peak night-time cooling when required. To increase individual choice, the windows can be opened by occupants at any time, but usually most are shut.

Domestic Hot Water

On each floor, hot water is provided in the toilets, kitchens and cleaners' cupboards by means of six 1.5 kW, 8 litre electric water heaters.

Lighting

Lighting from recessed, twin-tube high-frequency fluorescent units with low brightness mirror optic diffusers provides between 500 and 600 lux of illumination, a level selected for the drawing office work. There is some additional task lighting above drawing boards and the installed lighting in the office area is 15.5 W/m^2.

The lighting is locally switched using hand-held infra-red remote controls.To ensure the lights do not stay on unnecessarily, the lighting is controlled overall by a control system which 'pulses' the lights off at lunchtime, 6.00 pm and every 2 hours throughout the evening. Solar cells on each side of the building both inhibit the off signal during periods of poor daylight levels and turn the perimeter lights off during bright periods. Compact fluorescent U-tubes light the reception area, toilets and stairs.

Despite the relatively high illuminance levels, the running costs are better than 'good practice' levels for a type 3 building and close to those normally associated with a simpler type 2 naturally ventilated building.

Building Team

Architect:
Ruddle Wilkinson Partnership, Peterborough

Project Managers & Building Services, Structural and Civil Engineers:
Posford Duvivier

Electrical Contractor:
Hedley Electrical

Building Details

This is a purpose built 3-storey, open plan office, completed in 1989.

Gross floor area	1433 m²
Treated floor area	1349 m²
Nett lettable floor	1152 m²
Typical number of occupants	120
Typical hours of use	8am-6pm – weekdays Occasional Saturday use

Fabric

	U-value (W/m²K)
Walls	0.3
Double glazing	1.6
Roof	0.3

Heating

Eighty-five 1 kW electric wall-mounted panel heaters are used with off-peak electricity under optimum start control to preheat the building, and subsequently maintain the temperature during occupancy. The building is divided into six heating zones: two per floor.

Hot Water

Hot water is provided to toilets, kitchens and cleaners' cupboards from six 1.5 kW 8 litre electric storage heaters.

Ventilation

100% fresh air is delivered at floor level through diffusers, and extracted through light fittings. Heat is recovered from exhaust air to preheat incoming air.

Summer	6 air changes per hour
Winter	2 air changes per hour

The supply and extract fans, nominally 9 kW each, consume 7.7 kW at high speed and 0.9 kW at low speed. Supply air pre-heated to 18°C by exhaust ventilation, is supplemented when necessary by an electric heater battery.

Lighting

High frequency recessed fluorescent lighting with both local control and an automatic central control system.

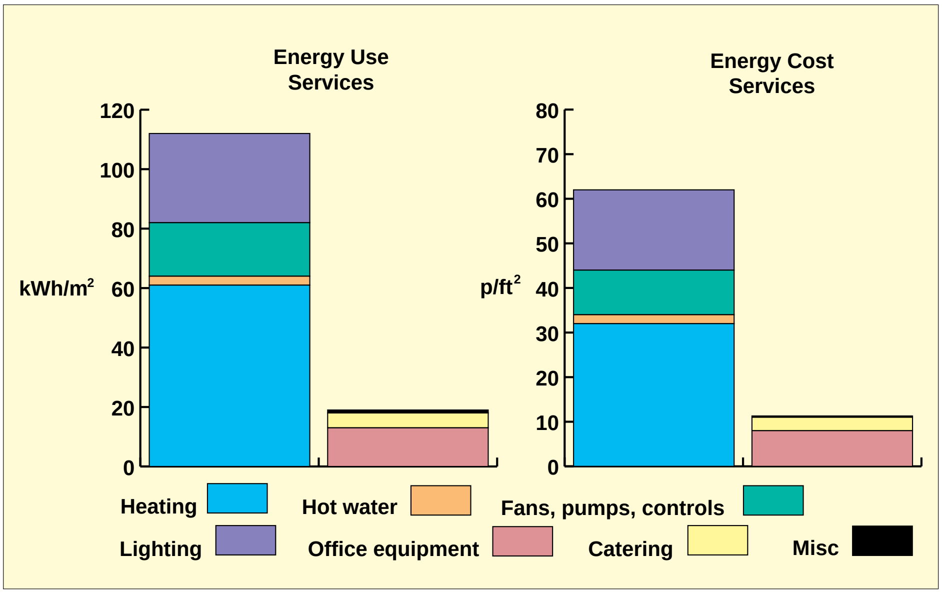
Installed load	15.5 W/m²
Typical illumination	500-600 lux

Energy Consumption

Initially, joint readings were taken for both Posford House and the adjacent head office building, and these were later checked by a separate period of readings for Posford House alone. For the 12 months from September 1990 to August 1991 (2392 degree-days), it was assessed that Posford House consumed 168 000 kWh of electricity. For the 12 months from January 1992 (2282 degree-days), direct readings showed a consumption of 173 020 kWh, equivalent to 177 000 kWh for a year with 2392 degree-days. Around one-third was used during the off-peak night period.

The total delivered energy was only 131 kWh/m²/year, a figure substantially lower than the 232 kWh/m²/year for a 'good practice' air-conditioned building, as defined by Energy Consumption Guide 19, and better than the 156 kWh/m²/year of a 'good practice' naturally ventilated building. Energy costs at £7.9/m²/year were lower than 'good practice' levels for an air-conditioned building but were 15% more than 'good practice' levels for a naturally ventilated building with added fans and pumps.

The higher overall energy costs were due to the selection of electricity as the source of energy for heating. The higher 1992 consumption levels, compared to those for 1991, can be partly attributed to a warmer temperature setting of 22°C for the building in 1992.



Annual energy use and cost for Posford House

Heating — **61 kWh/m²**, **32 p/ft²**

The heating energy consumption is little more than half that of a 'good practice' air-conditioned building. This is due to good insulation and control, and the lack of the distribution losses associated with on-site boilers and systems of other forms of heating. However, the energy cost of the electrical heating system is far more than that of a similar building with other heating systems and, as a result, the overall heating energy cost is more than 'typical' buildings of its type and nearly three times that of a 'good practice' building.

Hot Water — **3 kWh/m²**, **2 p/ft²**

The hot water supplies are from six local heaters to toilets, cleaners' cupboards and three small kitchens with a resulting low distribution loss.

Fans, Pumps, Controls — **18 kWh/m²**, **10 p/ft²**

The consumption is half that of the comparative 'good practice' air-conditioned buildings. Of the energy used by fans and pumps, most is consumed by the fans (providing 6 air changes per hour in summer and 2 in winter) to achieve a fresh environment, to remove stale air and to limit peak temperatures.

Lighting — **30 kWh/m²**, **18 p/ft²**

This is less than both the 'good practice' figures of 39 kWh/m²/year for air-conditioned offices and 32 kWh/m²/year for naturally ventilated offices, and reflects the effective manner in which the individual controls and master controls work together to provide illumination levels of 500 to 600 lux.

Office Equipment — **13 kWh/m²**, **8 p/ft²**

The energy used is lower than the 'good practice' figure of 16-22 kWh/m² found in a type 2 office and reflects the lower than average level of equipment. It is consumed mainly by 4 photocopiers, 26 PCs and 8 computer terminals.

Catering — **5 kWh/m²**, **3 p/ft²**

This consumption is similar to 'good practice' levels. Demand is from one hot drink machine per floor, available for use 10 hours/day.

Miscellaneous — **1 kWh/m²**, **0.3 p/ft²**

This category includes lifts and telecommunications equipment.

User Reactions

Staff are very satisfied with the fresh working environment and the summertime conditions which are more comfortable than those in their adjacent 1970s office. The local switching of lights and the ability to open windows help staff to feel in control, although they rarely find the need to open the latter.

The fresh air supply system through the floor is largely successful. Low level draught problems were eliminated by adjusting the damper baskets in the floor diffusers, as necessary, to fine-tune the air delivery rate. Staff feel that it gives an excellent indoor air quality.

General Appraisal

In determining their requirements for this building, Posford Duvivier chose a mechanical ventilation system with passive cooling to give a better internal environment than that of typical naturally-ventilated offices without all the extra costs and space requirements of air-conditioning systems. For simple, low-cost, low-maintenance heating, it chose the Electricity Association's EED concept of a well-insulated building with thermal capacity and well-controlled electric panel heaters.

Off-peak electricity preheats the building's mass and this is then topped-up as necessary during the day.

The building is ventilated using full fresh-air mechanical ventilation throughout the year. Heat is recovered from a slower system in winter whilst a high-speed system is operated in hot summer weather or when overnight cooling is needed. The openable windows are retained to give individual choice and to provide extra ventilation if required.

The thermal capacity of the building helps to stabilise temperatures and reduce overheating in summer. Solar heat gains are reduced further by the siting of the building with its main walls facing north and south and by the incorporation of moderate window sizes and lightly-tinted glass.

Energy consumption and heat gains are also reduced by using high-efficiency, well-controlled lighting. The installed electrical load of the office lighting (including its electronic control gear) is 2.5 W/m^2 of floor area per 100 lux compared to more than 3 W/m^2 per 100 lux in many recent installations.

The lighting control systems are effective in stopping the lights being switched-on, regardless of need, from morning to night or being left on for long periods after staff have finished work. However, during the day itself drawing-board work often requires the lights to be on, partly because of the window sizing, tinting and roller blinds.

Main Conclusions

Traditionally, mechanical ventilation has been seen as having only a limited range of applications in offices, and combinations of natural and mechanical systems have not been used widely. Posford House demonstrates that such systems in relatively simple and straightforward buildings can improve upon the performance of naturally ventilated offices without excessive cost or complexity.

	Energy use in kWh/m^2 per year			Carbon dioxide emissions in kg/m^2 per year		
Fuel type	Typical building type 2	'Good practice' building type 2	Posford House	Typical building type 2	'Good practice' building type 2	Posford House
Fossil fuels	200	95	–	46	22	–
Electricity	85	61	131	61	44	94
Cost in £/m^2	7.9	5.0	7.9			

The figures above compare Posford House with 'good practice' type 2 open-plan, naturally-ventilated office buildings. Nearly half of the excess carbon dioxide emissions and power costs compared to 'good practice' levels are attributable to the extra fans and pumps used for mechanical ventilation and heat recovery – not normally found in a type 2 building. Coupled with tinted glass to limit solar gain, the mechanical ventilation avoids the need for air-conditioning and achieves energy consumption and costs and carbon dioxide emissions substantially below the 'good practice' levels for buildings in an air-conditioned category type 3 office.

Energy use and costs and carbon dioxide emissions

The following sections refer to the various elements of the building.

Thermal insulation, thermal mass, siting and glazing: The building fabric measures adopted have been effective in reducing heating requirements and helping to avoid summer overheating.

Heating: By controlling the electric heaters effectively and including ventilation heat recovery, the annual electricity consumption for heating, including heating the ventilation air, is low at 61 kWh/m^2/year compared with 'good practice' levels of around 100 kWh/m^2/year for naturally-ventilated and normal air-conditioned buildings. The cost of this electrical heating energy is, however, nearly three times the 'good practice' levels for such buildings. Heating costs could be reduced a little by operating the building at the slightly lower temperature.

Mechanical ventilation: The building has demonstrated the effectiveness of mechanical ventilation with underfloor supply in a building which also has openable windows.

Fan energy consumption: The controls and pumps account for little energy consumption, unlike the fans which consume around 17 kWh/m^2/year. About 70% of this is consumed in summer, when the fans run at high speed. Future low-energy designs should consider how this figure could be reduced further, such as by by-passing the run-around coils during the high speed summer operation to reduce flow resistance.

Lighting: The design illuminance level of 500-600 lux is on the high side for a modern office although justified for drawing-board work. A level of 500 lux is more typical for offices with levels of 300-400 lux considered more appropriate for VDU operators. Nevertheless, owing to the high-efficiency luminaires and the controls provided, annual energy consumption by the lighting is less than the 'good practice' level for type 3 offices and equal to that for type 2. The consumption is likely to decrease with the increasing transfer of work from drawing boards to CAD systems.

The building has performed very much to expectations. However, although the overall annual energy cost is below that of a 'good practice' air-conditioned building and no worse than 'typical' costs for a naturally-ventilated building (despite the additional mechanical ventilation), the annual cost of energy for heating is high at £3.5/m^2.

The environmental impact of the CO_2 emissions in kilograms per kilowatt-hour of energy is of particular concern for buildings using electrical heating. However, in this case the low amount of energy used elsewhere and the avoidance of cooling means that conditions resembling an air-conditioned building have been achieved whilst producing emissions of only 94 kg/m^2 of CO_2 compared to the 116 kg/m^2 of CO_2 for 'good practice' air-conditioned buildings.

This analysis and all Case Study analyses in this series are based on at least one year's measured fuel consumption and costs. Further breakdown into sub-headings is by a combination of sub-meter readings, on-site measurements and professional judgment. The technique of apportionment is the same for this and each Case Study, and all quoted building areas have been remeasured for the project.

This study has been carried out by ECD Architects and Energy Consultants. The co-operation of the owners, designers, managers and the occupants of this building is gratefully acknowledged.

[1] Energy Consumption Guide 19. Energy Efficiency in Offices. A technical Guide for owners and single tenants. EEO, October 1991. For copies of Best Practice programme publications in this series contact BRECSU Enquiries Bureau (see below).

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