DESIGN PRIMER PART 1: PASSIVE DESIGN

In this regular series **Professor Doug King** of Bath University will explain the principles of environmental design. First, the fundamentals of passive design.

Abundant cheap energy liberated the development of our cities and our architecture in the second half of the 20th century, allowing forms of building that could not have existed before. Now buildings must evolve again.

The need to mitigate future climate change by reducing our carbon dioxide emissions has become well understood. However, the impact of inescapable climate change, warmer summers and an increasing demand for air-conditioning will coincide with reduced availability of cheap energy as fossil fuels pass their peak of production and go into decline.

Highly volatile energy prices are likely to become a fact of life over the next decade as our increasing demand for energy outstrips static or dwindling production capacity. To conserve energy for the really necessary things, we will have to cut its use for things that are not. This means making real advances in buildings' energy efficiency, not just bolting "green bling" on to conventional, energy hungry, designs.

Originally buildings just sheltered us from the elements, then developed to allow us to control the internal environment to improve our comfort. As we became more sophisticated so did our demands. These days the practice of designing buildings is mostly about providing the facilities necessary for an organisation to function, be it a business, a school or a museum.

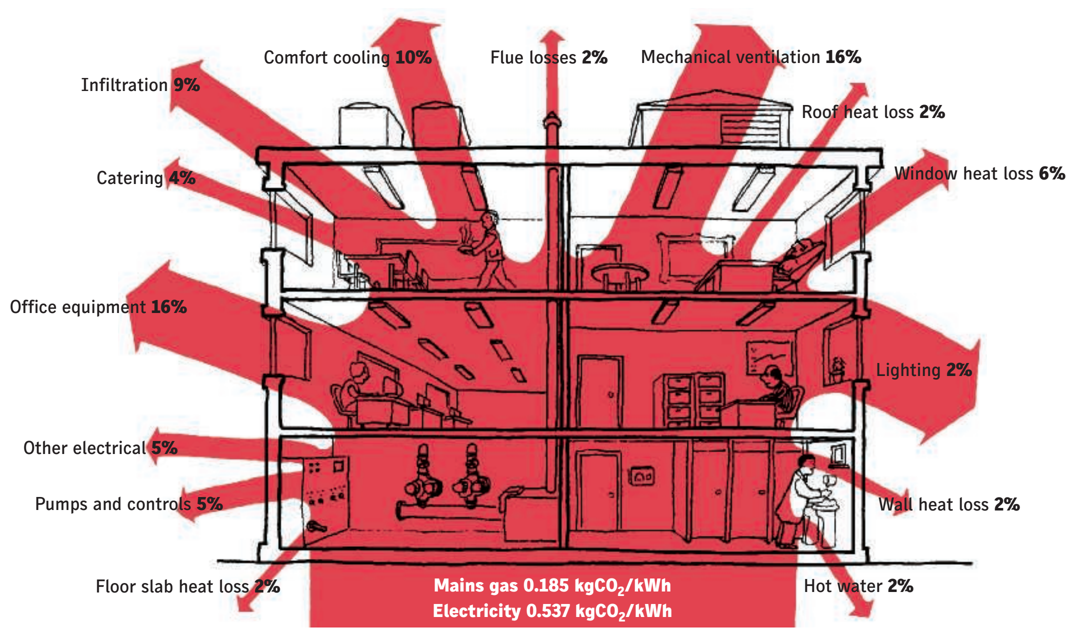
Buildings can be incredibly durable; our cities are replete with examples of historic structures still in daily use. If the ones we design now are to be sustainable, they will still be in use in 30, 50 or even 100 years. Within the lifespan of our buildings a time will come when we will need all the generation potential of on-site renewables to meet the energy needs of business functions; so using them simply to compensate for poor building design will no longer be an option.

To effectively conserve energy in buildings it is first necessary to understand where it is used. **Figure 1** (below) indicates the carbon dioxide emissions from a typical new-build office under the 2006 Building Regulations Part L. About 75% of the total CO_2 emissions are regulated: that is they are associated with the fixed building services and measured under the Building Regulations, BREEAM and other assessments. This is the part of the building performance that we can influence in the design. The remaining 25% of emissions relate to the occupancy and business functions of the building and arise mainly from the use of IT and office equipment.

Mechanical ventilation and comfort cooling represents about 35% of the regulated CO_2 emissions and artificial lighting about another 25%. It is obvious that avoiding or minimising the need for these artificial forms of conditioning is paramount in developing energy efficient designs. Electric light fittings are fantastically inefficient, converting about 90% of the electrical energy into heat and only 10% into light. Reliance on electric lighting often leads to additional need for comfort cooling, compounding the dependence on artificial conditioning.

The building envelope is the primary means of controlling the internal environment, keeping out the weather and providing insulation against heat losses and gains, but also admitting daylight and beneficial solar gains. To deliver genuine sustainability we need to make these durable parts of the building, the →

Figure 1
Building services account for about 75% of the CO2 emissions from a typical modern office building, while the rest relate to the business functions of the occupants. Incremental improvements to any of the systems or in the building insulation will have little overall impact. However, by designing to minimise the use of air-conditioning and electric lighting, substantial savings can be made. Expressing energy as kgCO2 equivalent allows direct comparison not only of the environmental impact, but also the fossil fuel depletion, of various energy sources.



→ structure and envelope, work as hard as possible in controlling the internal climate so as to avoid reliance on mechanical systems that consume energy, wear out and have to be replaced.

During the early stages of a new commission the building form is fluid as various options for massing and layout are tested through sketch design. This is also the stage at which most of the factors that influence the final energy performance are also fixed, albeit sometimes unwittingly. The aim for the designers at this stage should be to maximise the ratio of area that can be passively conditioned to that requiring active systems.

The perimeter of each floor plate, and typically the whole of the top floor beneath the roof, can be lit with daylight using simple windows and roof lights and, circumstances permitting, be naturally ventilated by the same means. This is known as the “passive zone” as indicated in **Figure 2**, while the interior of the building is known as the “active zone” as this will typically require artificial lighting and mechanical ventilation.

Without calculating even a single kWh of energy use, we can clearly see that the higher the ratio of passive to active areas, the better the ultimate building energy performance will be. This performance will depend largely on the initial form and massing of the building.

There are a number of options for increasing the passive ratio by manipulating the building form, some of which are shown in **Figure 3**. These may include increasing the perimeter or enhancing natural ventilation with devices such as stack effect chimneys. However, some of these forms may only produce a partial passive zone such as the atrium, which admits daylight but has limited opportunities for natural ventilation.

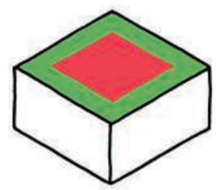
The passive zone can also be effectively extended, by careful planning of the interior design, to cover a much higher proportion of the building’s occupants than the simple area ratio would suggest. Many support functions, such as storage, copy rooms and circulation, do not require high levels of lighting and are infrequently occupied. Thus the active zone does not necessarily need to be quite as active as it first appears. Other areas such as toilets and kitchenettes, which would require active systems in any case, can also be migrated into the active zone, leaving more of the passive zone for general occupancy.

Finally, I’d like to introduce the idea of “passive survivability”. This is a concept that will become far more important as we start to feel the pinch of declining fossil fuel resources and over-stretched utility infrastructure. One of the first effects of energy demand exceeding supply will be rolling power cuts, as happened in London’s West End during July 2006. While some businesses may be able to operate with emergency generators, for many the impact could be catastrophic as deep plan buildings will be uninhabitable without artificial lighting and ventilation. Some buildings may have to shut down during the power cuts and for a business, having sent staff home, a whole day’s production may be lost. Passive buildings, on the other hand, should continue to be habitable, albeit with reduced comfort levels, and the backup power supply will only be required to maintain the office equipment.

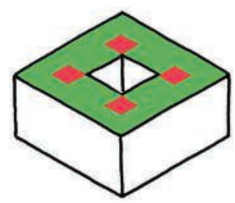
By planning for passive environmental conditioning from the early design stages we can achieve the single biggest step towards a functionally robust and energy efficient building. If we were to morph the typical building indicated in Figure 1 into the passive/active building in Figure 2, leaving just the active zone with air-onditioning and artificial lighting, this alone could represent a reduction of about 33% of the regulated carbon dioxide emissions. As the energy efficiency measures are built in they will never go wrong or need replacing. The result is a genuinely sustainable design.

FIGURE 3

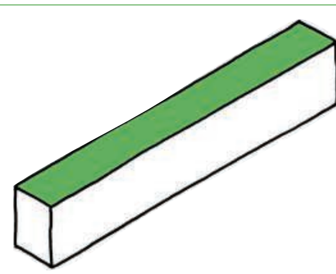
The building form affects the passive ratio, and therefore the energy consumption, as well as how it fits on a site.



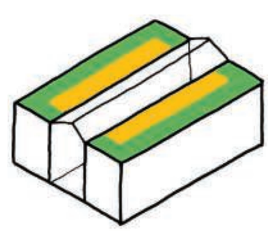
Deep plan buildings have the lowest surface area for heat loss, but typically have the highest energy consumption due to the reliance on artificial lighting and air conditioning.



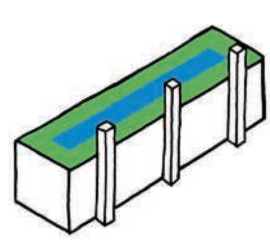
Courtyard buildings increase the passive ratio by introducing daylight and the possibility of natural ventilation to the centre of the plan with little increase in the site ratio.



Shallow plan buildings typically have the lowest energy consumption as they can be entirely passively conditioned, but can be awkward to fit on the site and have the highest facade costs.



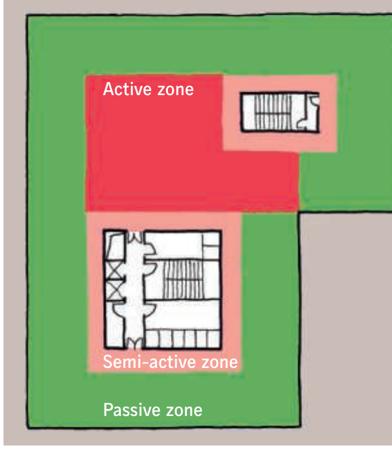
Atrium buildings are a compromise between deep and shallow plan. The covered atrium admits daylight to the whole plan, but natural ventilation can be difficult on the atrium face.



Stack ventilation Enhanced ventilation by stack chimneys allows natural ventilation to be achieved through a deeper plan building, but the centre of the building will not get any daylight.

FIGURE 2

The passive zone extends 6-8m from the perimeter of a building, depending on the floor to ceiling height. The interior, or active zone, requires artificial lighting and ventilation. The area of active zone around the cores is ideal for circulation and storage, requiring lower levels of conditioning than normal office occupancy; thus in this example the office occupancy within the active zone, requiring full artificial lighting and ventilation, is less than 25% of the total occupancy.



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