Energy, Environment and Buildings

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It would be appropriate to consider the subject of energy conservation in buildings in the overall perspective of protecting the environment. Essentially, there are three kinds of environments that refer directly to building activity:

1. The immediate environment in building, which is related to the problem of heating, cooling, ventilation and lighting within it.
2. The environment outside the building owing to air quality, pollution, noise and public hygiene.
3. The overall environment which is affected by the very act of building (deforestation, soil erosion, pollution of rivers, etc.)

Energy Types in Building Activity

Buildings use up energy in three ways:

1. *Embodied Energy:* This is used for production and transportation of building materials and for their assembly on site. Few people realize that there could be great variations in the quantum of embodied energy used in buildings and that a great deal of environmental degradation could be stopped by proper selection of building materials. The Central Building Research Institute (CBRI), Roorkee, has compiled data on the energy consumed in the production of various building materials (Table I), which can serve as a guideline for materials selection.
2. *Maintenance Energy:* This is used for the maintenance of comfortable and functional environmental conditions such as lighting, ventilation and air-conditioning, and for running any equipment installed in the building. In a house this could be a cooking stove, while in an office it could be typewriters and computers and other such equipment. Very often the only energy that architects concern themselves with is the building maintenance energy because this is what is visible and this is what the building user directly pays for. It is also the kind of energy use over which the architect can have some control.
3. *External Services Energy:* This energy is used for supplying water, removing solid and liquid wastes, transporting goods and people, and for communication of several other kinds.

Compared with energy uses in the first two ways outlined above, the architect has little control over the energy consumed in external services. Any conservation in this area has to be attempted by town planners and urban designers.

Energy Conservation in Buildings

The type of building, the income level of users, the climate and location all influence the amount of energy a particular building utilizes. It would nevertheless be convenient to have a reference index of the quantum of energy consumed in a building (e.g.,in kwh/sq m/year), so as to rate buildings either as energy wasters or as energy savers.

Table I ENERGY CONSUMPTION IN PRODUCTION OF BUILDING MATERIALS IN INDIA*

Materials	Basis	Energy (K/cal)
Cement	1Kg	1.93×10^3
Burnt Clay Bricks	1000 Nos	1020.60×10^3
Surkhi	1Kg	0.33×10^3
Quick Lime	1Kg	1.51×10^3
Mild Steel	1Kg	6.30×10^3
PVC	1Kg	27.75×10^3
Sheet Glass	1Sq M	63.80×10^3
LD Polyethylene	1Kg	5.20×10^3
Burnt Clay Roofing Tiles	1060.00 Nos	1060×10^3
Sand-Lime Bricks	1000 Nos	665.00×10^3
Wood Particle Board	1Kg	0.74×10^3
Linoleum	1Sq M	39.80×10^3
Sanitaryware	1Kg	7.80×10^3
Stoneware Pipes	1Kg	5.07×10^3
Aluminium	1Kg	34.30×10^3
Clay Fly-Ash Bricks	1000 Nos	553.00×10^3
Bloated Clay Aggregate	1Kg	1.27×10^3
Gypsum (Calcined)	1Kg	0.36×10^3
Crushed Aggregate	1Kg	0.05×10^3

* Not including human energy

(Compiled by C B R I Roorkee)

Hotels, which use energy for ventilation, lighting, cooling or air-conditioning, water heating and for running various machines are the most energy intensive buildings (Fig II). Compared to this, educational buildings consume energy only for lighting and ventilation. Domestic buildings, use energy mainly for cooking and, in some cases, for lighting, ventilation and water heating. Specifically, in this category, high-income households do consume more energy for space heating and cooling and for running equipment, such as refrigerators, washing machines and television sets,etc. (Fig III). There is no great difference in the energy consumed by low-income urban households and that used by rural households because consumption here depends not only upon felt needs but also upon affordability and availability.

It is obvious from Figure III that in domestic buildings, the group in which the highest percentage of savings can be effected is the high-income group. But given the small number of households that belong to this group, the overall national picture will not change much by savings in this group. Since the largest numbers belong to the low-income group it is here that the thrust of our conservation programmes must be aimed. This group consumes very little energy (because it cannot afford any more). Conservation efforts here must therefore be coupled with efforts to improve energy availability. The traditionally used energy conversion devices, that is, the *chulha* for burning fuelwood or cowdung and kerosene oil lamps are inefficient devices, and any improvement in their thermodynamic performance will increase fuel savings and its availability. Several well publicized and successful programmes for production and sale of an improved *chulha* and also for installation of bio-gas plants are already under way in our country. Such devices have the added advantage of improving the environment within the kitchen.

Various other available energy saving devices, such as solar water heaters and cook-

ENERGY USE / BUILDING TYPE	HOTELS	ENTERTAINMENT BUILDINGS	HIGH RISE OFFICES	INDUSTRY	HOSTELS	HOMES	INSTITUTIONAL BUILDINGS	EDUCATIONAL BUILDINGS
VENTILATION	■	■	■	■	■	◩	■	■
LIGHTING	■	■	■	■	■	◩	■	■
WATER HEATING	■	□	□	□	■	◩	□	□
MACHINE AND EQUIPMENT	■	■	■	■	□	□	◩	□
COOKING	■	□	□	□	■	■	□	□
SPACE HEATING AND COOLING	■	■	■	□	□	□	□	□

FIG II ENERGY USE PATTERN OF BUILDINGS ACCORDING TO FUNCTION

■ MOST BUILDINGS
◩ SOME BUILDINGS
□ FEW BUILDINGS

ENERGY USE / BUILDING TYPE	HOTELS	ENTERTAINMENT BUILDINGS	HIGH RISE OFFICES	INDUSTRY	HOSTELS	HOMES	INSTITUTIONAL BUILDINGS	EDUCATIONAL BUILDINGS
VENTILATION	◪	■	■	■	◪	□	■	◪
LIGHTING	◪	■	◪	◪	■	□	◪	■
WATER HEATING	▨	□	□	□	▨	◪	□	□
MACHINE AND EQUIPMENT	■	■	■	■	□	□	□	□
COOKING	■	□	□	□	◪	◪	□	□
SPACE HEATING AND COOLING	◪	■	◪	□	□	□	□	□

FIG IV POTENTIAL REPLACEMENT OF ENERGY CONSUMPTION BY ALTERNATIVE SOURCES

▨ FULL POTENTIAL REPLACEMENT
◪ PARTIAL REPLACEMENT
□ REPLACEMENT NOT NEEDED
■ REPLACEMENT NOT POSSIBLE

ers concern the architect directly, as they depend upon sunlight being available in the house for a major part of the day. This can be achieved only if housing layouts and building designs are suitably planned by town planners and architects. The cost of present day solar cookers and water heaters is high while their performance is low and therefore they cannot be expected to find widespread use. Nevertheless, houses ought to be designed with such devices in mind so that these could be easily installed in the future when better models are sure to be available.

Alternative Sources of Energy

Given the low levels of environmental comfort that Indians are willing to live with and the subsequent low level of energy consumption in our buildings, the potential for replacement with alternative energy sources is rather limited. Figure IV shows the energy uses in buildings that can be potentially replaced by alternative sources. Much of the energy for artificial lighting in homes, for instance, is consumed at night, leaving no scope for any savings by daylighting. Passive solar architecture can increase the comfort level in buildings in colder regions, such as Ladakh, and save on fuelwood or kerosene. In the plains, however, where the problem is of cooling rather than of heating, passive solar architecture can also improve comfort levels (sometimes with small additional energy inputs), but it will rarely lower energy consumption to any appreciable extent.

For energy conservation in buildings we must rely on other methods which include the use of more efficient mechanical heating and cooling systems, more efficient devices, such as electric bulbs, cookers, waste heat recovery systems, better fenestration, more efficient fuels and fuel conversion methods, more efficient transportation, etc. Efficiency here becomes a matter of plugging energy leaks and of better utilization of available natural or artificial energy sources. This could be effected by bringing in more solar energy (using mirrors, perhaps) and by better control of the heating system, that is, by switching it off when it is not essential. In the West, this is done by micro-processor control so that it is no longer left to the individual's judgement to decide when the optimum time for switching off the heating or even for drawing curtains occurs. Notwithstanding the high cost of such controls, these will be found useful in modern office buildings, and other such large energy consuming buildings.

	TRANSPORTATION	FOOD SUPPLY	WATER SUPPLY	WASTE DISPOSAL	COOKING	LIGHTING	VENTILATION	WATER HEATING	SPACE HEATING/ COOLING	ENTERTAINMENT	LAUNDRY/IRONING	REFRIGERATION	COMMUNICATION	VERTICAL TRANSPORTATION	WATER PUMPING
HIGH INCOME URBAN	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
MIDDLE INCOME SUBURBAN	●	●	●	●	●	●	●	●							
LOW INCOME					●	●									

FIG III ENERGY USE IN DOMESTIC BUILDINGS

Energy Conservation and Urban Design

The form of a building or a town determines the efficiency with which they use energy. It has been shown in several studies that our traditional towns, such as Jaiselmer in Rajasthan, provide a fairly comfortable living environment with very little energy expenditure. A few years back, the Delhi Urban Art Commission was exercised over the high-rise buildings that seemed to be coming up all over the city. I was asked to find out if these buildings consume more energy than low-rise buildings. A comparison of maintenance energy consumption was made between two low-rise government buildings with a total floor area of 50,000 sq m, and the Delhi Development Authority (DDA) building, Vikas Minar, which is 23 storeys high. It was found that the taller building consumed about 15 per cent more energy per square meter of floor space per year than the other two. But it could not be established whether this additional energy consumption was due only to the high-rise character of the DDA building. The large number of lifts used in this building consumed only a small portion of the annual energy budget. The main areas of consumption were lighting, ventilation and air-conditioning. As far as embodied energy was concerned, both types of buildings had used similar building materials and construction

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techniques. The only exception was the aluminium glazing used in the DDA building, a material which consumes several times more energy than steel glazing, but the use of aluminium is more a matter of the architect's preference than something that depends upon the height of the building.

Since the two buildings were in very different locations and served very different functions, no meaningful comparison could be made of the energy used in external services. Looking at the transport energy requirements of the DDA building, we found that about two thousand people visited the building every day. If these people travelled from a distance of 10 km each, then the energy consumed in transportation alone amounted to about 100,000 kwh. This is slightly more than 90,000 kwh which was the energy consumed within the building for all purposes. Any energy efficiency in the building itself could be easily wiped out by its improper location and the consequent increase in transportation needs.

However, our major concern is not so much with the actual energy used in building, but with the essential energy needs of efficiently designed buildings. High quality energy intensive materials are essential for high-rise buildings, but it is possible to build low-rise buildings with energy efficient materials, such as brick for load-bearing walls in place of reinforced concrete frame and non-load-bearing walls. All types of solar energy devices (water heaters, air-conditioners, etc.,) require direct sunlight for their operation. They are usually mounted on the roof as that is the only area in a building where uninterrupted sunlight is available. However, the area of the roof in high-rise buildings is too small for this purpose and therefore, they are unable to make use of sunlight as an alternative source of energy. The potential for energy conservation through this means is greater in low-rise than in high-rise buildings.

High density urban areas have been shown to be efficient users of transportation energy when compared to more dispersed layouts. Given these conflicting requirements of energy efficiency in low-rise buildings and in high density urban areas, town planners would naturally ask what kind of layouts are energy efficient keeping in mind the overall energy requirements of a town or a city. Actually, the conflict between low-rise and high density is easy to resolve as has been shown in Figure V. If one looks at three building archetypes — the *pavilion*, the *street* and the *court*, one finds that most of our multi-storeyed layouts can be categorized as pavilions, row-housing as streets and our traditional towns as courts. Lionel March showed that the court is a very efficient system for utilizing urban land and that it is possible to achieve a very high FAR without high-rise construction. To illustrate this principle, we carried out a study

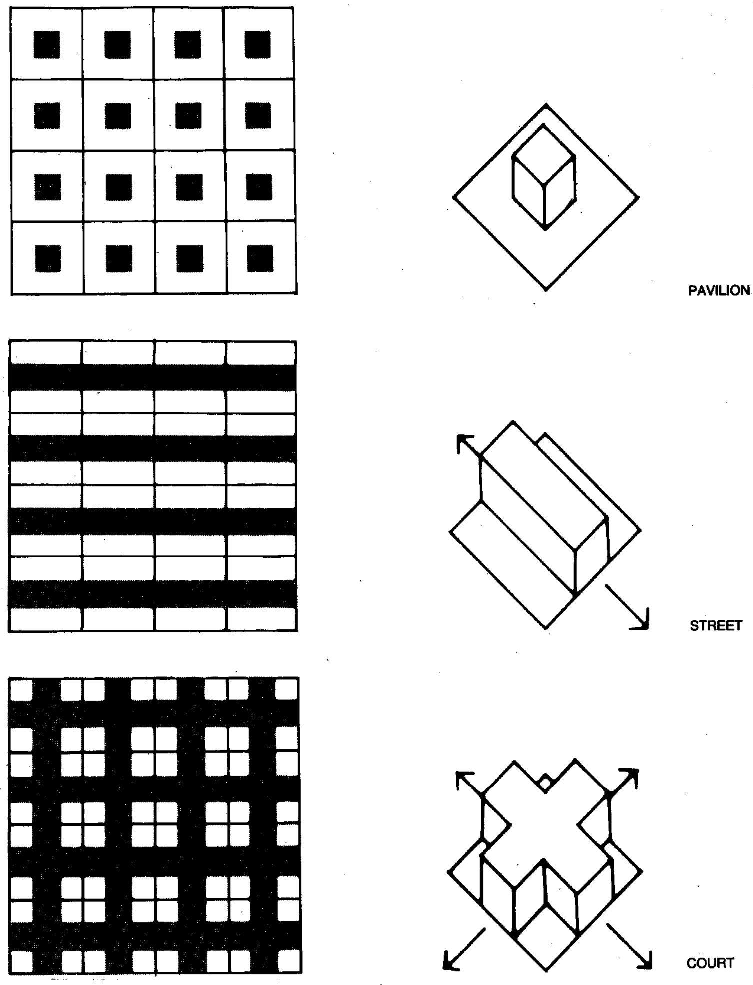


FIG V THREE BUILDING ARCHETYPES (LIONEL MARCH)

of the Central Business District of New Delhi where the FAR is 250 and ground coverage is 26 per cent (Figure VI). The resulting buildings shown in black are 10 floors high.

If the pattern of open space and covered space is reversed (Figure VII), the pavilions are changed to courts and the same FAR is achieved with three and a half floors. The town-planners would, of course, want to know if this high ground coverage would permit enough light and ventilation in the building and enough open space for parking, etc. Looking at the sections in Figure VI and Figure VII it is easy to see that the opportunity for daylighting and ventilation is greater in the courts than in the pavilions, even when an additional floor has been provided for car parking in the former. This analysis is equally valid for housing.

The bye-laws of Delhi now require one to build at 60 dwelling units to an acre which is a very high density and our response to this is far from satisfactory. The typical housing schemes being built today are eight floors high. While these schemes leave 65 per cent

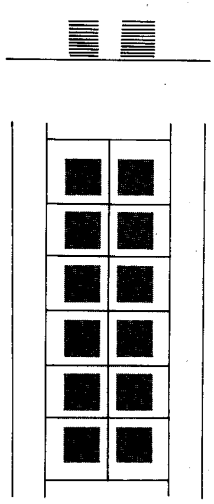


FIG VI PAVILIONS

25% GROUND COVERAGE
10 FLOORS OF OFFICES

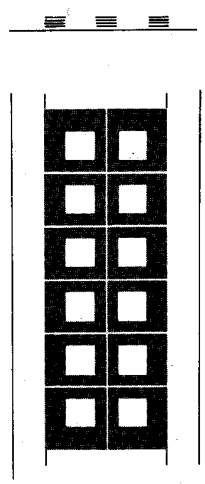


FIG VII COURTS

75% GROUND COVERAGE
3 FLOORS OF OFFICES

of the site as open space, the actual availability and usability of open space is much less than in four floor high schemes that were being built till about five years ago. A study done by students of the School of Planning and Architecture, New Delhi, compared the various possible alternatives for this density and came to the conclusion that it is possible to have buildings no higher than three or four floors with 50 per cent ground coverage and still provide sufficient open space for housing related activities and ensure daylighting and ventilation in all buildings. This would be possible by using the court layout in which peripheral space (normally left as set-backs) gets utilized for buildings.

Passive Solar Architecture

Assuming that we have taken care of the overall layout which can save energy at the town or city level, one can then design energy-efficient buildings with the use of passive solar architecture. Solar energy is available to us as light and heat and therefore its most direct use is for daylighting and for space or water heating. In the Indian plains, the problem is of space cooling rather than of heating and this is not directly possible with solar energy. Passive solar architecture, in this case, therefore means rejecting unwanted solar radiation by appropriate building design. Various techniques available for this purpose involve judicious location, sizing and shading of window openings, the use of reflective finishes on the building exterior, shading of the roof, mutual shading of buildings, insulation of the building envelope and finally, a roof surface sprinkler system for positive cooling of the building. Wind is another natural resource that can be used for natural cooling by proper location, sizing and orientation of window openings. These aspects of passive solar architecture are well-known and sensitive architects do incorporate them in contemporary buildings. The proliferation of window air-conditioners and desert coolers in recent years has now made it possible for architects to design thermally inefficient buildings and yet provide comfortable indoor conditions. In smaller towns, where energy supply is irregular, the opportunity for daylighting and natural ventilation is greater and principles of natural cooling are still followed by architects and builders.

Traditional Designs for Modern Times

Indigenous building design principles evolved over the centuries are useful where the context has remained unchanged, but where lifestyles have changed totally and new building functions have emerged, traditional designs cannot be directly used. Take the example of a simple urban house. The traditional house in Delhi was spread over three floors and the family used each of these floors at a time when each was comfortable to use. The house provided comfort only because a high degree of redundancy and interchangeability of functions was built into it. The same house now belongs to three or more families, each one using only a particular area of the building at all times. With this changed living pattern the house can no longer provide the same degree of comfort and the use of mechanical cooling methods is common. Similar changes have taken place in our office buildings and even in schools. Traditionally, office buildings and schools were used in the cooler hours of the day, that is, only from early morning to midday. Today, school buildings are used in two shifts and offices from 10 am to 5 pm, which hours include the hottest part of the day. The traditional building designs *per se* have no place in this changed situation.

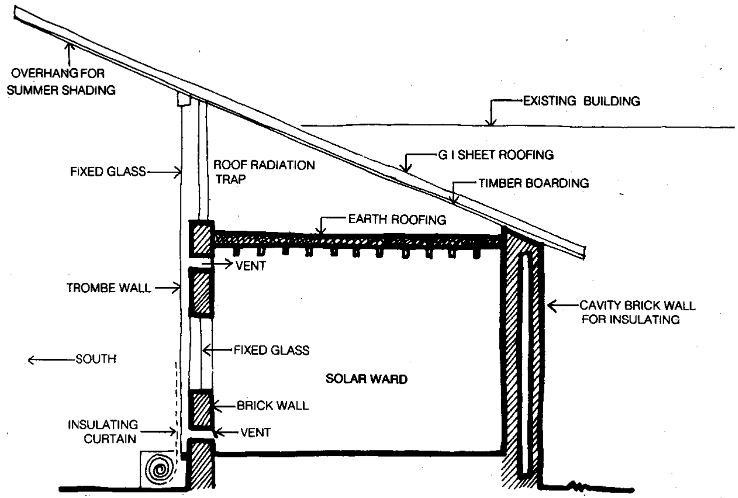
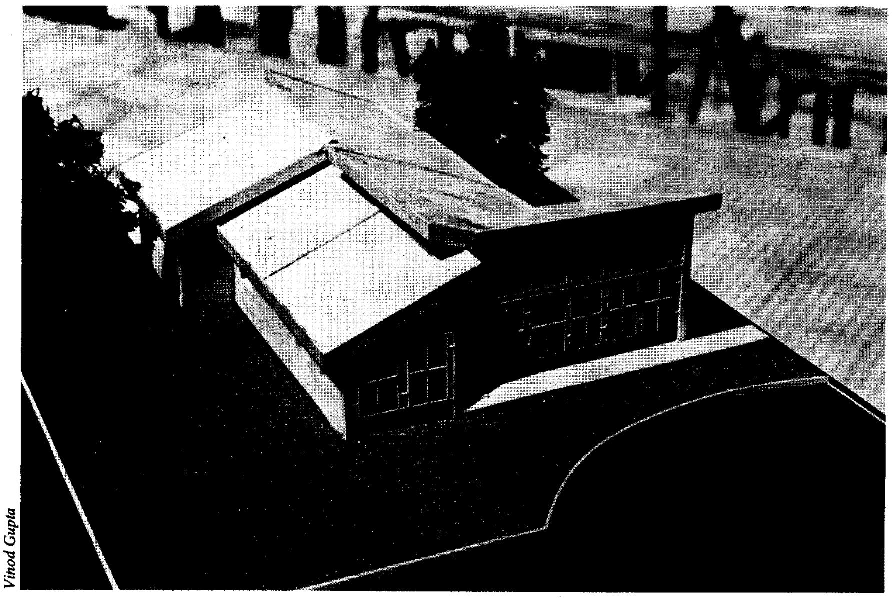


FIG VIII SOLAR HEATED ADDITION TO DISPENSARY AT SRINAGAR



Vinod Gupta

Solar heated addition to dispensary at Srinagar showing the trombe wall

The contemporary architect's job is to marry the traditional building construction methods to modern building technology and provide designs appropriate for contemporary needs. Traditional building materials, such as mud and stone are low energy materials. Their performance can be further enhanced by new insulation materials, sealants and by the careful application of building science principles. Two examples of recently constructed buildings, one in the cold climate of Srinagar, Kashmir, and the other in the hot dry area of Jodhpur, Rajasthan, will illustrate this point.

The traditional urban house in the valley of Kashmir consisted of brick walls and a timber roof covered with a layer of mud. Sometimes a false timber ceiling was also provided. After galvanized iron sheets were

Photo Vinod Gupta

Jodhpur hostel building

introduced in Srinagar, the earth roofs were gradually replaced, to the extent that they are no longer seen anywhere in the city. The GI sheets did solve the problem of roof waterproofing and they also enabled sharper pitched roofs so that snow could slide off by itself, but as compared to earth roofs, this material has practically no insulation value. Consequently, newer buildings require more heating than the traditional structures. This problem has been solved in a solar heated dispensary building of the Regional Engineering College, Srinagar, where GI sheets have been used for their waterproofing qualities and earth for its insulation value (Figure VIII). A trombe wall has been added to the building for solar heating during winter. This consists of a south-facing thick masonry wall painted black on the outside and covered with glass to trap solar radiation. Although no temperature measurements have been taken in this building, it is expected to provide a more comfortable environment than other buildings built according to normal construction practices.

The Jodhpur building is a hostel for junior staff members of the Engineering College of Jodhpur University. It has been constructed almost completely with local stone. The window openings have been shaded with external louvers to cut out unwanted sun in summer and the roof has been specially insulated with the traditional system of inverted earthen pots. For cooling purposes the staircase and water storage tank have been put into a tower which serves as a wind catcher. Each room has an air inlet at the floor level from the wind tower and an outlet at the ceiling level on the leeward side of the building. This ensures a cool draft in the building. The wind tower has a provision for a wet screen at the inlet level. This will further clean and cool the incoming air. The building plan also ensures that each family has an open space either as a courtyard or as a terrace. Solar water heaters have been provided for water heating in winter.

Both of the above buildings use traditional low-energy buildings materials only, but they are able to ensure a better thermal environment by the use of modern building science principles.

The contemporary architect has to do most of his work in urban situations where building bye-laws and constraints of the site make it difficult to use the most efficient energy conserving designs. In smaller towns and villages architects are not normally engaged for designing buildings. The best opportunity for testing energy conservation ideas exists in 'institutional' campuses which are normally built in low density situations. Here the architect has a greater degree of freedom and control. The lessons learnt from these campuses will someday form the basis of design principles that could be adapted to other situations. ◇

Dr Vinod Gupta has specialized in Energy Studies and has his own architectural practice in New Delhi. He has been teaching at the SPA, New Delhi since 1973.

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