"Design decisions for low-cost housing must plan for all available measures to allow for the utilization of energy."

Architecture and Engineering Design for Energy Efficient Low-Cost Housing*

by
Geronimo V. Manahan, F.U.A.P.

The parameters for building design can be categorized to consist of the following:

1. Building materials and components
2. Environment conditions
3. Site conditions
4. Structural frame
5. Architectural and space program, and
6. Cultural attributes

In the evaluation of energy inputs in the design of an energy efficient low-cost house, these same parameters can be applied.

ENERGY IN BUILDING CONSTRUCTION

Studies [1] are beginning to show that up to 70 percent of the energy required in construction is invested in the manufacture of materials and building components. As an example, thatch and timber are low energy materials as compared to metals. The selection of building materials therefore, has greatly influenced the affordability of low-cost housing. However, although this selection procedure can be correlated with the amount of energy invested in the materials, this has rarely influenced decisions. This energy-influencing factor in material selection can be a strong criterion when materials and components, initially as costs of manufacturing, transporting and handling, and ultimately, as maintenance costs where energy inputs of labor are required.

With the growing availability of information on energy inputs in building materials and components, energy content can be included along with other factors in the design considerations for low-cost housing, besides durability, fire protection, thermal mass, labor inputs and installation and service costs.

ENVIRONMENT AND SITE CONSIDERATIONS

An architect's early decision on site planning will strongly influence the type of indoor environment the occupants of the house will experience. If a neutral environment is achieved, without much introduction of mechanical, electrical and sanitary devices which require energy to operate,

* Paper presented at the Seminar-Workshop on Energy Conservation in Building Design, Construction and Maintenance, 17-21 November 1986, Manila, The United Nations Industrial Development Organization.

then the overall consumption of energy can be greatly minimized. If the site is considered by the designer as influenced by its climate and resources such as the sun, wind, water and plants, and also as a part of the overall outdoor environment, then the low-cost house can be designed to approach autonomous conditions in the use of energy. On-site resources can be used not only to reduce the amount of energy needed to maintain indoor comfort, but also to produce outdoor spaces the conditions of which are pleasant. For cramped areas, the use of spaces would be critical.

Site planning can be constrained by economic considerations, building and zoning regulations as well as developments adjacent to the project. These can interfere with the maximization of designing with nature. Nevertheless, if early in the design process the architect is cognizant of the role climate and site can play in the energy efficient design of low cost housing, these factors can indeed bring about energy savings in building operations.

Understanding climatic conditions involves the following principles [2] :

1. Since the sun emits solar radiation, knowing the "path of the sun" can lead to either protecting the building from solar impact or exposing the surfaces to maximize radiant heat. The sun's path can be readily established by the use of graphs and nomograms in as much as the accuracies required in building design are not as precise as the requirements of astronomers.

The solar charts are earth-based views of the sun's apparent movement across the celestial sphere. Essentially, a solar chart is a two-dimensional representation of the celestial sphere projected into a horizontal plane. It can be used as a sun-tracking devise and consequently as a design tool for determining shading patterns. The position of the sun in the sky is defined by two angles. The height above the horizon is called the solar altitude angle. The position of the sun with respect to its projection on a horizontal plane is called the solar azimuth angle. Solar angles change with latitude and time. This is due to the fact that the sun strikes different spots of the earth at different angles. The farther away from the equator, the lower the angle of the sun. Since the sun path varies according to latitude on the globe, different charts will be required for different latitudes.

2. Knowing the intensity and direction of prevailing breezes and harsh winds is another factor to optimize for energy efficient low-cost housing. Designers would want to orient openings of buildings toward prevailing winds especially during the hot summer months. On the other hand, one would like to control the entry of strong harsh winds during the typhoon months. Local data compiled by weather stations do collect measurements on winds. These data can be utilized in site analysis. However, these have to be correlated with the site's terrain and the existence of adjacent vegetation and developments.

Only three principles of air flow are worth remembering in considering where the breezes blow to allow for good ventilation:

a. Air flows from a high pressure to a low pressure area.
b. Air possesses inertia. Once set in motion it tends to continue to flow in its initial direction until some intervening force is met.
c. Air flows through the path of least resistance.

3. Knowing the conditions of dry bulb temperature and relative humidity can establish the base conditions of the environment. These parameters when evaluated can establish whether comfortable conditions will prevail of not. Olgyay [3] has devised a simple chart which simplifies the analysis. This he calls the bioclimatic chart. The key factors of temperature and humidity are correlated to identify critical relationships in the climate. The chart will also show whether comfortable conditions can be attained by additional inputs of air movement or radiant heat. If specific combinations of temperature and humidity fall within the zone of comfort, such condition will not require any corrective measures to attain desirable comfort in the building interior.

4. The exclusion of water from the building interior would require data on rainfall, humidity and temperature. The provision of vapor barriers, weather strips and insulation will be influenced by the direction of driving rain and the condensation phenomena.

RECYCLABLE BUILDINGS

The more a building becomes recyclable, the more energy is recovered. Unless a building structure is designed to recover usable materials during demolition, as in timber construction, or in structures of stone, it becomes more cost effective to reduce the building to rubble and haul the material as fill. However, extensive studies are being made today to look into the possolanic properties of recycled concrete and rubble brick.

Designing for the recycling of building components and frames is a two-stage trade-off. First, the designer must provide for sufficient flexibility of the structure to prolong the useful life of the building. This can be done by allowing for the structure to adapt to changing use. Then, the designer must allow for disassembling certain parts so that the frame can still safely remain while reusable materials and components can be removed.

Such strategy in structural design will call for the ff. considerations:

1. The building frame that is separated from all other building components, and the frame itself can be disassembled easily and safely. This will allow for extensive remodelling possibilities. At the end of the economic life of the structure, the elements can be reused elsewhere for another project.
2. The building's envelope can be allowed to expand or contract as additional floor areas or building frames are added. This will allow for possible expansions without rebuilding, or the designing of columns and footings to support extra floors for vertical expansion.
3. The attributes of climatic conditions of the site should be maximized. The less sophisticated the mechanical, electrical and sanitary systems used, the less obvious will be the obsolesence of the equipment with the passing of time.
4. The articulation of building materials and components should be distinctively established. Combinations which will make recycling of elements difficult must be avoided. Utility lines embedded in concrete are not advantageous for recycling and difficult to repair.

It should be reiterated that even if certain building components are not used "as is", even the reprocessing of these can save energy as compared to using originally, manufactured, virgin material.

DESIGNING THE BUILDING ENVELOPE

Typical to the architect's tools of design is the recognition of the resources that exist on and around the site. The architect has to decide how best to integrate these resources into a functional scheme besides making his design fit into the large pattern of its environment. Usually "bubble diagrams" similar to even diagrams are used. They aid in establishing the best design arrangements of room relations and functions. The architect is in fact optimizing the functions of the plan to best make use of the natural attributes of the site. Sun paths, prevailing winds and shelter from winds are analyzed in relation to place, terrain and views. Noise, odor sources, rainfall and runoff are also included in the scheme. If the third dimension and time are added to the analysis, conditions of privacy, accessibility, daylight, radiation and air motion which change over time and height from the ground are integrated into the scheme. The analysis of the horizontal and vertical layers of the housing design leads to a cost effective means of energy utilization not only in using the building, but also in the course of its erection.

These parameters can be correlated with the aspects of habitability [4] which are considered as a firm technical base having interfaces with behavior in space. The elements of habitability which can be evaluated for design include the following:

1. Architecture covering definitions of volumetric and spatial requirements.
2. Determination of acceptable levels of environment as comfort and crowding are concerned.

3. Definition of personal hygiene and grooming.
4. Extent of mobility indoors and outdoors.
5. Provisions of storage and handling of wardrobe requirements, accounterments, laundring and drying of clothes.
6. Food and water management including their distribution and storage, preparation, serving, dining, cleaning and waste.
7. Housekeeping requirements covering disposal techniques and collection operations.
8. Definition of life-support systems and defensible spaces including security and peace in the home.

THE BUILDING ENVELOPE

The transition space where the exterior forces of the environment are filtered before interacting with the indoors is described as the building envelope. Interactions such as the manner in which solar radiation and daylight is admitted or controlled, or the channeling of air, or the prevention of penetrating water are all controlled by the building envelope. Besides these, the building envelope is characterized to have a fourth dimension. It changes its characteristics with time and orientation. Night and day conditions also affect the envelope. A flexibly designed envelope will allow the occupants to manipulate the conditions of the environment to determine how much of the outside conditions will be allowed to be brought inside the envelope.

COMPONENTS OF THE ENVELOPE

In their more generic terms, the basic components of the envelope are the windows, doors, walls, floors and roofs of the building. These can be an array of components acting singly or in concert in order to allow for a pleasant indoor environment. Norberg-Schulz [5] provides a suggestion in typifying these components in relation to how energy affects the components. These are:

1. Connectors or a means of establishing direct links.
2. Filters as a means of making the connections indirect.
3. Switches as a regulating connector.
4. Barriers as separating elements.

Thus, a stone wall is a filter to heat and cold, but a barrier to light. Windows and other openings have the characteristics of switches. An illustration may make this concept clearer:

In very cold conditions of climate, external influences are not wanted. The architect will consider the building's envelope as a closed shell. He selectively puts the openings in a very limited way, or by special means, provides controls so he can manipulate the building elements. On the other hand, in hot-humid conditions, or in areas with pleasant outdoors, the envelope starts to be an open system. The building skin or curtain walls are designed to modify a limited number of outdoor conditions. This approach when combined with availability of materials and with the influence of culture leads to regionally distinct architecture.

Another typically applied design strategy used by architects who have an awareness of site and environment is to design the envelope as a passively responsive one. When conditions of climate will not allow for passive heating and/or cooling, or for natural lighting, then an active system augments the indoor conditions to support a neutral, pleasant environment. Old structures can be retrofitted by looking at weather stripping, insulation, vapor barriers and window arrangements. This latter component, when retrofitted, may provide for new sizing of openings, operability, shading and/or solar exposure.

ENCOURAGING ENERGY CONSCIOUSNESS

Architects and engineers can aid in the reduction of the amount of energy consumed in a low-cost house not only by means of a deliberate site planning, material specification and envelope design, but also by providing the household with a substantive role in controlling the indoor environment. Through the proper location of switching devices, building occupants are given better opportunities to conserve energy. Several examples can be cited:

1. Daylight consciousness can be encouraged by placing electric light switches close to where natural light penetrates the envelope.
2. Make the user aware of energy consumption by providing attractive alternatives to the use of high energy conveniences. This consciousness can be applied to the energy requirements for laundering, food preparation, waste recycling, elimination of body wastes, personal mobility and space comfort.
3. Procedures for bathing through control of water flow and its heating can provide trade offs that allow for energy conservation.

To keep the occupants aware of consumption of energy, monitoring devices such as meters for water, electricity and fuel consumption can be placed where it will be frequently seen. These can be connected in areas where conservation practices can occur. A growing array of monitoring and control devices are now available which even display the resource savings such as those that contain comparative energy consumption charts. The common experience is that more switches produce more combinations of personal motivations like combinations of adjustable sun shades, small appliances, internal glare control, task lighting, and variable water sprays.

RECYCLING WASTES

The functions of the kitchen, laundry and bathroom are of special interest in residential waste utilization. Their functions have a large requirement for good ventilation. These are areas having a large quantity of moisture and even intense heat for specific periods of use. As such, these areas need evaluation on how water and heat are utilized.

The recycling of solid wastes is another factor which can indirectly influence energy utilization. The separation of dry organic refuse, wet organic garbage and inorganic wastes such as glass, metals, plastics is encouraged in most urban communities. In the house, wet organic garbage can be made into composts. This will require a proper setting to incorporate the accumulation of the community. An outdoor place to redeem and store various recyclables is also a mandatory planning element in the community. The issues in community planning, therefore, covers the allowance of sites for separate storage of recyclable materials and the collection and processing of various categories of garbage.

INTERRELATION BETWEEN ENERGY AND BUILDING DESIGN

Design decisions for low-cost housing must now look ahead and plan for all available measures to allow for the utilization of energy. The future conditions upon which a low-cost house will function can change over the economic life of the building. This has happened when most buildings of the past used wood as a major fuel. Today's buildings may outlast the currently predominant fuels that are used today. At present there are a large number of prospective energy sources that the future house can use. They will have a large impact on how the design of the house will look. In sum the design strategies for an energy efficient low-cost house involves the following considerations:

1. To improve thermal conditions in naturally ventilated buildings by ensuring adequate provisions for the passage of air and roof insulation so as to guarantee the minimal use of mechanical systems providing comfort.
2. To reduce or increase solar heat gain in buildings by the proper orientation and control of the design of the building envelope.
3. To provide adequate access to natural light to reduce the unnecessary use of electricity or other fuels for lighting.
4. To provide adequate space and provisions for the comfortable operations of daily functions in the house by looking at ergonomic and volumetric properties of the space.
5. Set design criteria for thermal transmittance particularly in U-values of the roof.
6. Set design standards for lighting load densities.
7. Set sun shading guidelines.
8. Set design criteria for energy use and water applications in the kitchen, laundry and bathroom.
9. Identify opportunities of optimizing waste handling in the house itself so as to reduce excessive problems in the collection and handling of wastes by the community.

REFERENCES

1. WRIGHT and GARDINER, "Energy and Housing" : *Built Environment,* Volume 5, Number 4, 1979.
2. MANAHAN, GERONIMO V., *Passive Cooling Technology for Hot-Humid Localities,* Manila, United Architects of the Philippines, 3e, 1985.
3. OLGYAY, V., *Design with Climate : Bioclimatic Approach to Architectural Regionalism,* Princeton University Press.
4. LOUVIERE, ALLEN J., "Emerging Aspects of Habitability: Space Flight Considerations", *Ekistics,* 183, February 1971.
5. NORBERG-SCHULZ, CHRISTIAN, *Intentions in Architecture,* Cambridge, MIT Press, 1965.