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Quirouette, R. L.

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by

R.L. Quirouette

Division of Building Research, National Research Council of Canada

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ENERGY SOURCES

In view of the recent energy crisis, a new awareness has forced recognition that research and application of technology in the area of energy and buildings must be expanded as well as accelerated. Energy utilization in buildings results from a general need to provide and maintain a complex balance between climate and occupancy needs through the use of fixed construction and energy-consuming devices. It is most important that the conditions for building operation as well as building design in the next 25 to 50 years should be anticipated now, on the basis that energy sources are going to be depleted or changed in form.

In 1973 the Department of Energy, Mines and Resources published "An Energy Policy for Canada - Phase One". This document forecast the Canadian consumption of energy by product and sectors for the next 25 years. It shows that the commercial, domestic and farm sector consume about a third of our total national energy supply. This energy is used mainly for space heating and heating service water in buildings. It was estimated that the total cost of this energy by the end of 1974 would approach the four billion dollar mark. In the EM&R forecast, which takes no account of the recent crisis, energy demand of the future indicates that oil and natural gas will remain the principal fuels consumed for space heating. Recognizing that supplies are finite, other sources of energy must be developed to take over from oil and gas. The question is what and when.

At present it is recognized that there are alternatives available. Of these alternatives, it is thought that coal, nuclear energy, biomass and solar energy are the most promising sources of the future. The first three are fuels that will need to be processed centrally before distribution can take place. Solar energy is already distributed and needs only to be processed in situ. Technically speaking, biomass and solar energy are fuels that are simple to convert to secondary forms of energy. On the other hand, coal, if it is to be converted to more refined fuels, and uranium (or nuclear energy) require sophisticated and complex technology for conversion to secondary forms. Nevertheless, it is anticipated that changeover should be well under way by the year 2000.

Another well known source of energy is hydropower. Its converted form of course is electric power. At present electric plants are

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substantially hydro, but it is expected that by the year 1990 thermal stations will produce over 50% of the electric power requirements. The modern thermoelectric plant converts about 40% of the energy content of coal into electricity. The remaining 60% of the energy content of coal is converted to heat. If a thermoelectric plant were designed to produce both electric power and heat a total utilization factor of about 80% could be achieved. In Europe, combined plants are being used extensively, and it is likely that this concept will become part of the Canadian scene before the year 2000.

Another source of energy that is attaining increasing significance is biomass. Biomass, to a large degree, is the byproduct of photosynthesis. In view of the very large land masses in Canada, the amount of potential biomass energy is also significant. Examples of biomass would be crop residues, urban solid waste or garbage, animal waste or manure, and forest residues. Interestingly enough, not only is biomass a truly renewable resource, but it is also our only growing resource.

The principal fuel produced from the treatment of organic matter is methane gas. It is estimated that one ton of farm animal waste would produce from 50 to 60 cubic metres of gas, an equivalent to ten Imperial gallons of gasoline (1). Undoubtedly, this may well be one of our principal sources of natural gas in the future. The Mogden sewage treatment plant in London, England, has produced a methane-rich gas since 1935. Current production of the energy-rich gas now totals 8 million cubic feet per day.

A fourth source of energy is solar energy. At present the cost of collecting and storing so-called "free" solar energy is considerably higher than the cost of heat energy obtained from oil or gas. It is expected that the over-all cost of providing solar energy will naturally improve as the price of other fuels rises. The conversion of solar-energy to heat energy is inexpensive and simple, but the capital investment required is high. The major component of cost in solar heating systems is the collector. It is estimated that it varies between 4 and 8 dollars a square foot, and a typical house will likely require about half the floor area in solar collector to supply 50% of the heating requirement. Nevertheless, solar energy research in industralized nations is moving at an unprecedented rate.

Energy Demand

It is well known that the Western Hemisphere is the greatest consumer of energy in the world. If the built environment is representative of the needs and wants of this society, the two most fundamental reasons for this high energy consumption would probably be (1) the high quality control of temperature and humidity for the occupants of these buildings and (2) the provision of technological support services to complement and enhance its activities.

A state of wellbeing from the physiological side requires that the environment be thermally comfortable, that it provide a degree and quality of lighting complementary to the activities of the occupants, and that it provide an acceptable level of air quality and humidity.

Technological support systems are commonly thought of as equipment, machinery, various aids and tools, all those commodities that assist in the increased productivity of man and that promote more efficient and rapid communication.

The thermal comfort of occupants in a building is influenced by the air conditions, the insulative value of the clothing they are wearing, and the nature of the activity that is being performed. It depends on a complex balance of air temperature, velocity, relative humidity, and radiation exchange. Numerous studies have been conducted to determine the effects of varying these factors enabling a comfort standard to be developed. If the outdoor temperature and humidity differ from those indoors, energy will be required to maintain the space conditions at the required level.

Until about 75 years ago, natural light provided most of our lighting except for that provided by candles or gas or oil lamps. Since then an increased quantity and quality of artificial light has been possible through technological developments. Nowadays, daylight is commonly used to provide illumination during the day in residential buildings. It is often overlooked, however, as a means for providing or supplementing artificial illumination in commercial, institutional and industrial buildings. Adequate levels of lighting can be provided by natural light at the building perimeter, but difficulties arise when these levels of lighting must be carried to the interior core of buildings. Natural lighting drops off in intensity quite rapidly as one moves away from a window or exterior opening. Therefore, the demand for uniformly-lit spaces and the attendant difficulties of producing such naturally-lit spaces has resulted in the wider use of artificial illumination.

In Canada, climatic conditions demand that exterior walls of buildings provide a weathertight seal. This necessitates that the interior air supply of buildings will require treatment to maintain adequate levels of oxygen, humidification and the removal of odors and other noxious gases for the occupancy. These conditions are achieved in several ways; in small buildings ventilation within the building is achieved through the natural process of infiltration/exfiltration, as well as by the occupancy activities such as the opening of doors and windows. In larger buildings, particularly in highrise, natural venting is not quite as simple to control. When the temperature in a building or room is different from that outside, pressure differences occur as a result of the differences in air density. Depending on the height of the building and the amount of openings in the building envelope, air will move from the indoor spaces to the outdoor in the upper portion of the building and from the outdoor to the indoor spaces in the lower portion of the building. This is called stack effect. This, combined with the effects of wind, results in high ventilation rates which cannot be controlled adequately by the occupant. The resulting air circulation will not always coincide with desired air flow quantities or patterns. Thus, in practice, it is necessary to seal the exterior envelope of the building and to use mechanical means to obtain desired ventilation.

The cleverness of man to convert energy into useful work has resulted in the development of a vast variety of machinery, equipment, appliances and commodities to support his activities and increase his productivity. This increased productivity, as well as the satisfaction of want and need, has resulted in a technological development momentum which is almost self-perpetuating. It would be an impossible task to list all the items that have been developed to serve man, but to name a few, these would include machinery and equipment used in industrial processes, machinery and equipment used in communication, equipment and appliances to serve every need of operating offices, appliances and gadgetry used in kitchens for the preparation of food, and a multitudinous range of machinery and equipment to handle the processes of building operation, which all demand energy.

The demand for energy is thus clearly established and it is unlikely that this demand will diminish or even level off in the near future. As a matter of fact, EM&R have forecast a substantial growth in demand continuing at least until the year 2000. In view of the possible shortages of the present forms of primary energy sources there are two options to explore in the light of future energy demand. The first option will be to increase the efficiency of utilization by examining, analysing and improving our energy utilization processes, and the second, to search and develop as quickly as possible viable alternative sources of energy.

Energy Utilization

Owing to the Canadian climate, a large proportion of the energy utilized in buildings is directed to their heating and cooling. The primary barrier to heat exchange with the outside environment is the building enclosure. The building enclosure, or envelope, is usually made up of elements such as walls, roof, windows and doors. For most of the opaque elements, heat transfer will take place by transmission and convection. For the clear elements such as vertical windows, skylights and glass doors, heat exchange by radiation will also take place.

In addition to the energy requirements as a result of heat transfer through building elements heat energy is also used to offset the effects of air infiltration/exfiltration in buildings. Air leakage through cracks or other openings is a function of the type of construction, workmanship, condition of the building, as well as its height. The rate of air flow due to infiltration/exfiltration will depend on the magnitude of the pressure difference between the inside and the outside and the size of leakage openings. It is unfortunate that infiltration/exfiltration in buildings has become accepted as an intrinsic feature in buildings to the extent that it is regarded by some as a necessary characteristic, particularly in housing. This component can be substantial, particularly in high buildings exhibiting intricate form and involving numerous joints.

Building enclosure design is an important factor in optimizing energy utilization. Form or shape, orientation, mass, colour and texture, all of these factors affect the heat transfer characteristics of the building. Some of the more energy-conserving forms or shapes optimize the orientation of specific building elements. Mass, and to some extent colour, affects the dynamics of heat-energy utilization.

Within the building, and for reasons previously stated, there are a number of systems, such as heating and cooling systems, lighting systems, and equipment that utilize energy and in the process release a byproduct heat energy, to the interior of the building. In most instances, this byproduct provides a useful heat source during the heating season, but at times, particularly in summer, this heat energy may increase the cooling requirements of the building.

If the objective is to increase the efficiency of utilization of energy, then efforts should be directed to the elements of the building in proportion to their utilization characteristics. First, the heat transfer through walls and roofs is a function of their resistance to heat flow and the surface area enclosing the space in question. Therefore, to improve the energy utilization characteristics of these elements, it would be necessary to increase the resistance of the wall and roof construction as well as minimize the ratio of surface area to volume. Conventional resistance values in single-family-dwelling construction range between 11 and 16 resistance units for electrical heating, and between 8 and 12 units of resistance for other than electrical heating. Increasing costs of energy and concern for conservation will mean increased insulation as well as improved practice in the application of insulation to ensure continuity of the insulating layer.

Windows, on the other hand, offer very little resistance to heat flow. Improving the thermal resistance characteristics of windows is achieved mainly by the use of multiple glazing. A double window with an air space of one half inch has twice the thermal resistance of a single window. Windows in general transfer about five times as much energy as an equivalent area of typical insulated wall construction. It is therefore important in design that the amount, type and location of glazing be carefully considered. Since windows admit solar energy, both in winter and in summer, those facing south are in the most desirable location. They will receive the greatest amount of solar energy during the heating season and they can be shaded most effectively in the summertime. A south-facing window is exposed to direct radiation from about 9 a.m. to 3 p.m. in the summertime. Its peak gain occurs at about noon. This gain is only about half that of an east- or west-facing window because the sun is so high in the sky during midday; therefore, most of the radiation is reflected by the window. In winter the heat-gain picture is completely different. The sun rises later in the morning and remains lower in the sky throughout the day; consequently, a south-facing window gains the most solar heat.

Although the energy demand of each building will be affected differently by windows it can be stated that, in general, windows in Canadian buildings will increase energy consumption. Therefore, to reiterate, one approach to conserving energy is to limit the number of windows used in a building to that which are truly required and to orient them in such a way that heat gain can be maximized in winter and minimized in summer.

Under winter conditions the relative energy losses through the enclosure of a two-storey single detached dwelling would be approximately: walls, 25%; basement, 15%; ceiling, 15%; windows, 25%; and infiltration, another 20%. In calculating net heat energy requirements, it is recognized that the heat from lights, equipment and people may constitute about 10% of the total, with solar gain through windows adding another 10%. This shifts the energy demand curve to a crossover point at some lower temperature, reducing the actual demand directly chargeable to the heating system but increasing the requirements for cooling in summer.

Energy utilization in buildings is also affected by the efficiency of the systems used for the conversion and delivery of energy to the building zones or spaces. In residential buildings, oil, gas and electricity are used with forced air systems comprising 95% of the cases. Their present efficiencies range from 40 to 70% for oil and gas to 100% with electrical heating. Tuning of furnaces is most certainly a wise first step toward improving efficiencies.

In larger buildings more complex systems for heating <u>and</u> cooling are used. The three basic types are all-air, air-water or all-water systems. The all-air systems main merits are low first-cost and ease of maintenance. These systems provide good control over temperature and humidity, but their energy consumption is high when the loads are variable. The air-water system, a combination of both air and water used to transport heat, is controlled by varying the rate of heat transfer between the room air and the water coil either by modulating the water flow rate or restricting the air flow over the coil. The advantages of such systems are: less energy used to transport heat, less energy wasted to achieve temperature and humidity control, and less space needed for ducts. On the other hand, these systems are more expensive, initially, than the simple all-air systems. The third system, the all-water system, is the simplest type of central heating and cooling system. In general, it has fan-coil units in the rooms and only water is circulated throughout the building. The systems are inexpensive as a rule, but they can be noisy as there is a fan right in the room. The energy consumption of such a system is lower, there is no heat wasted in achieving temperature control, and power used to transport heat is minimal. A drawback of the basic fan-coil system is the lack of any positive control over the humidity in the space.

In summary, it can be said that all-air systems provide good control over both temperature and humidity, but this usually involves using heating to offset excess cooling with a consequent high-energy usage. Split systems using both water and air to transport heat, require less space for ducts and less power to circulate heat transport media. Although they are more space-conserving, they do not provide quite as good a control over temperature and humidity in spaces. The choice of systems may well depend on the nature of the humidity requirements and its attendant problems. Controlling humidities to within a narrow range can result in a significant energy consumption since it will involve humidification in winter and dehumidification in summer.

Energy Conservation

Energy conservation in buildings will require that a reduction in total amount of energy required be effected. This will be achieved only through an increase in the efficiency of the utilization of energy. It is possible to incorporate a modernization program to existing buildings that will correct many of the energy-wasteful situations. This might require the replacement or upgrading of older heating systems. New equipment requires less maintenance and consumes less energy for the same output. Similarly, a well-planned and integrated lighting system will conserve both energy supply and energy supply equipment.

A third aspect to the improvement of existing buildings would focus on reducing the air-leakage characteristics. This can be achieved by sealing or weatherstripping joints around windows and doors or by the replacement of components. Finally, a careful study of building operation will provide data for close monitoring, and followup control can effect energy conservation.

New buildings, on the other hand, must involve a more substantial energy conservation program. Such a program should require energy conservation features in the building design, incorporate energy-recovery systems where possible and, in the case of large complexes, be subjected to an energy-performance analysis. In the design of new buildings consideration should also be given to future adaptation to energy sources.

With reference to energy-recovery systems, there are several methods available: utilizing heat storage, central and unitary heat pumps, luminaire recovery and exhaust air recovery. Exhaust air in large buildings can be used to preheat and prehumidify the supply air to the building. There are exchangers that are available that transfer only sensible heat or both sensible and latent heat. Sensible heat recovery is usually sufficient for buildings that are only heated, but fully air-conditioned buildings should use total heat-recovery systems. The economics of energy-saving means is really unique to each building. Each building design must therefore be analysed separately to determine the combination of energy-saving means that produce the most economical design for that building.

Over the last 10 to 15 years there has been considerable development of techniques for the detailed analysis of energy exchanges in buildings notably by the ASHRAE. This has involved the application of computers in calculation and simulation of the total building energy system. At the present time sets of programs are available which can be used as a means for evaluating the energy utilization consequences at various design stages as well as for modelling existing buildings to determine the optimum operating schedules for conservation.

The Department of Public Works of Canada, through the use of such techniques, has analysed a number of existing buildings and prepared a new operating schedule which has resulted in a substantial saving in energy. They are also applying these techniques to the assessment and development of new building designs.

Up to now, first-cost has been the main criteria used by designers. There has not been a great need to evaluate energy consumption consequences of design decisions. This is changing rather quickly. Designers will have to be able to estimate energy consumption both to satisfy code requirements and to justify choices to clients on a life-cycle cost basis.

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