Energy for Building – Improving Energy Efficiency in Construction and in the Production of Building Materials in Developing Countries

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Foreword

Over the past decade there has been a rapid increase in both awareness and concern about the impact of buildings on the global environment. There is concern at one level about the health of the living environment within and around buildings, and there is concern also about the impact of the resource use in buildings on the global environment. There is a growing commitment in some of the industrialized countries to reduce the use in buildings of products whose deterioration will damage the global environment, of hardwoods which are contributing to the loss of the tropical forests, and of energy from non−renewable sources, and the pollution consequences of the use of fossil fuels. These problems are all directly related to energy use or have energy implications, since whatever solutions are found will have some bearing on energy.

In many countries the proportion of the total national energy consumption used in buildings is over 50 per cent and this figure tends to be higher for developing countries. While the largest part of this energy relates to the energy consumption of the building in use, the energy used in the production of buildings is a significant and a growing element of this total energy use.

Of equal concern to the United Nations Centre for Human Settlements (Habitat) is the problem of meeting the need for adequate shelter, especially for the poor in developing countries, as expressed in the Global Strategy for Shelter to the Year 2000. Successive reports by the Centre have detailed the inadequacy of the living standards in those countries. In addition, inadequate housing is a serious problem for a growing proportion of the population in many industrialized countries also.

Increasing the efficiency of energy use in building−materials production is important for three further reasons, apart from the obvious advantage of energy saving: it can help to make durable building materials available at prices which the average poor households can afford; it will help to reduce the environmental degradation caused by the excessive use of biomass fuels, and conserve them for household use; and it will help to reduce the need for imported building materials or production processes. It is, therefore, hoped that this publication will prove useful to building−materials producers, designers, builders and policy−makers in the field of housing and construction, especially in developing countries.

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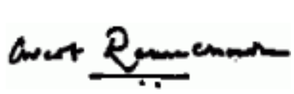

Dr. Arcot Ramachandran
Under−Secretary General
Executive Director

I. Introduction

1.1 Buildings, energy and the environment

The link between the use of energy in buildings and the total energy use is well established. The link between energy production and use and local and global environment is causing increasing concern worldwide. There are thus good environmental reasons for seeking to reduce the energy "embodied" in buildings. In the developed countries there is a growing demand for an environmental impact assessment of all building projects which will include consideration of embodied energy,[1] although this is not yet commonplace.

1/ Royal Institute of British Architects, *Buildings and Health: the Rosehaugh Guide* (London, 1991).

Equally, there is the problem of meeting the need for adequate shelter for the people of the developing countries. Various reports[2] have detailed the inadequacy of the living standards which are being experienced by many millions in those countries. The scarcity and cost of durable building materials is regularly identified as one of the main obstacles to better housing standards. As populations grow and become more urbanized, the soil and vegetable materials on which traditional rural building methods have depended are no longer cheaply or freely available, and they are being replaced by processed or factory−made materials. Many of the well−established technologies for small−scale processing have been inherited from a time when energy, in the form of biomass, was more abundant than it is today or will be in the future, and they are highly energy−intensive. As a result the materials they produce are too expensive for the poor. Likewise the large−scale processing technologies imported from the industrialized countries are energy−intensive and tend to rely on high−grade energy imports.

2/ United Nations Centre for Human Settlements (Habitat), *Global Report on Human Settlements, 1986* (New York, Oxford University Press, 1987).

This publication examines the question of energy efficiency in building materials from the point of view of producers of building materials, building designers and builders. Producers will want to know how they can change their production processes so as to reduce energy consumption (and cost), how energy consumption can be reduced by changing the raw materials, the product mix or specification used, and how energy costs can be reduced by changing to different energy sources. They will also want to know how to go about conducting an energy audit of their operations.

Designers and builders will want to know how the choice of building materials affect the total embodied energy content of a building; how much energy is used in construction and how this can be minimized; how substitutions between materials might be made to save energy without sacrificing performance in other respects; and how building−materials selection affects the lifetime energy consumption of a building, including manufacture, construction, use and maintenance, and demolition. They will want to know how to make estimates of energy consumption for proposed buildings.

All three groups will want to know what techniques are available for application now, and what techniques are currently under development or might become available in the near future. The document is also intended to be of use to policy−makers in the field of housing and construction who will be interested in the conclusions of the report about the most effective actions to be taken by each group.

Chapter II examines the energy use in the production of a range of separate materials which together comprise more than 90 per cent of materials used in building. It looks at the broad characteristics of building−materials production processes. It then examines in greater detail the processes available for producing metals, cements, ceramic materials, and mineral and vegetable materials, identifying the opportunities for improved energy efficiency through the choice of processing technology and plant management. It identifies techniques which are already well−established, and points to some promising developments. Chapter II also looks at the effect of both scale of production and transport costs on total energy consumption in building materials to the point of use, and considers how the optimum strategy for plant location could be developed. It concludes by looking at the possible contribution of recycling to reducing the energy cost of building materials.

Chapter III moves to the energy content of building components. Those who select materials and components for use in a building project −whether as designers or as builders − have the greatest control over the amount of embodied energy used. But they need to know how the energy content of different alternative components or elements of the building compares, rather than the individual materials of which the element is made. This is the sum of the embodied energy in all the materials used plus the energy used in the construction process. The chapter looks in particular at a range of alternatives for binders, for walling materials, and for roofing materials, and attempts to make comparisons between technologies giving comparable performance. It also looks at the energy content of complete building systems, and considers the particular case of insulating materials where increased energy costs in manufacture can be offset by improved energy efficiency in the lifetime use of the building. The opportunities for energy saving for designers by making use of recycled materials (or buildings) is also discussed.

Chapter IV sets out a range of strategies for producers, builders and designers to optimize energy use. For each group it also suggests some strategies for policy−makers, administrators and legislators in the construction industry in developing countries.

1.2 The pollution consequences of energy use in building materials

Pollution arising from the production of building materials arises at three levels. At the local level (under 1 km), pollution is caused by gases produced in the combustion of fuels, causing health risks to workers and local residents. At the regional level (up to 100 km) pollution can cause climatic modification through thermal effects or persistence of particles in the atmosphere. These local and regional effects can normally be controlled by reducing the emission of the substances responsible, and many governments have pollution control or environmental protection regulations setting required standards.

Some of the pollutants emitted in building materials production processes also contribute to pollution on a continental or global scale. Sulphur dioxide resulting from coal−burning, for example, can result in acid rain causing acidification of lakes and destruction of forests. But potentially the most important effect is the phenomenon of global warming caused by increasing concentration of the so−called greenhouse gases in the atmosphere. The gases primarily responsible for this and their approximate contribution are shown in table 1.1. As will be seen, the greatest contribution is made by carbon dioxide emission which is a virtually unavoidable consequence of all combustion processes.

The potential consequences of global warming are so serious at so many levels of human activity that international protocols on reduction of carbon dioxide emissions are certain to be formulated in the near future.[3] These will have implications for all processes involving combustion, and in particular for building materials production processes. The contribution of any process to global warming, unless any other of the gases listed in table 1.1 is emitted, is in direct proportion to the total carbon dioxide produced. This in turn relates to the amount of primary energy used. However, the type of fuel used can affect the greenhouse gas emissions very significantly. Table 1.2 shows some typical values of the carbon dioxide emissions which result from the supply of one gigajoule (GJ) of energy to a process, using different fuels. The important points to note are that electricity produces 2.5 times as much carbon dioxide as coal, while natural gas produces only 60 per cent as much. Fuelwood produces about 10 per cent less carbon dioxide than coal, a similar amount to petroleum.

3/ International Conference on Climate Change.

In any particular region these figures might be slightly different, especially the figure for electricity use which depends on the mix of fuels used to generate electricity in any region. Where a substantial part of this is from either nuclear, hydroelectric or other renewable sources, use of electricity contributes less to carbon dioxide emissions. However, the complex of risks and low−level pollutants associated with nuclear power then becomes a significant issue.

Table 1.1. Contributions to greenhouse warming by various gases

Gas	Contribution to warming (percentage)
Carbon dioxide	50
Methane	19
CFCs	17
Tropospheric ozone	8
Nitrous oxide	4

Source: Henderson and Shorrock (1990).

Table 1.2. Carbon dioxide emissions from various fuels[a]

Fuel	CO_2 emissions, kg/GJ	
	Primary energy	Delivered energy
Coal	91	92
Natural gas	50	55
Oil (petroleum)	69	84
Electricity		231

Source: Henderson and Shorrock (1990).
a/ Figures for delivered energy include overheads of generation and distribution.

The principal measure which can be taken to reduce the energy pollution associated with building–materials processes is to reduce their total primary energy consumption. The many means to achieve this are described in chapter II. Similarly, chapter III discusses how to reduce the embodied energy consumption in a building. In addition to these measures, some reduction in greenhouse gas emissions can also be achieved by fuel substitution in processes. The possible benefits of fuel substitutions in terms of carbon dioxide emissions are shown in table 1.3. Where use can be made of renewable energy sources instead of fossil fuels there is a direct benefit in the reduction of greenhouse gas emissions.

The extent to which biomass fuels can be considered as contributing to atmospheric carbon dioxide accumulation depends on how far the trees or other plants cut are being allowed to regenerate. Where forests or plantations are being managed for continuous energy production, the net production of carbon dioxide will be much less than that produced by one–off cutting for fuel since carbon dioxide is absorbed from the atmosphere by growing trees. Since many small–scale building–materials production processes can make use of biomass fuels, this could provide an additional incentive for using them rather than large factories which use significant amounts of fossil fuels. But it is assumed in this report that reducing the consumption of biomass fuels is just as important as reducing the consumption of other types of fuel.

1.3 Life–cycle energy costing

The idea of life cycle costing of a building is that when design decisions are made, consideration should be given to the total cost associated with each design alternative, over the entire lifetime of the building, including:

- Capital cost of construction
- Annual running and maintenance costs
- Costs of subsequent major refurbishments
- Cost of eventual demolition and waste disposal