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PROMOTING SUSTAINABLE CONSTRUCTION INDUSTRY ACTIVITIES

Background paper*

Prepared by

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* This document has not been edited.

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INTRODUCTION

1. Sustainability is today a key concept in development thinking at all levels. Sustainable development ensures that "it meets the needs of the present without compromising the ability of future generations to meet their own needs".[1] One of the fundamental requirements of sustainable development is that the harmful side-effects of the development process, particularly of construction activities, be arrested so that they do not exceed or overload the assimilative capacity of the biosphere, affecting the sustainability of development.

2. Construction can affect the environement in many ways: through resource deterioration, physical disruption and chemical pollution. Large civil engineering projects can easily destabilize fragile hill slopes. Deforestation associated with construction can cause loss of land by soil erosion, silting of reservoirs and disruption of aquatic ecosystems. Cement, lime and bitumen production pollute the atmosphere, so do the CFCs (chlorofluorocarbons). It is, therefore, imperative that an agenda for action and a manageable policy framework be worked out for the construction sector with a view to effectively, address the requirements of sustainable resource utilization and preservation of eco-systems and control of biospheric degradation caused by adverse effects of construction activities.

3. The purpose of this paper is twofold. First, it attempts to identify in detail the ways in which construction activity contributes to different areas of environmental stress. It uses recent figures to identify existing trends on a global and regional basis, and attempt to assess the contribution of construction to them; it then highlights particular examples of environmental stress resulting from construction activity. Secondly, the paper considers the means available to reduce the environmental impacts through improved technologies, through design or modified practices; and it reviews progress in the development of policies and regulations to implement such measures, both nationally and internationally.

4. One important aspect of sustainability which is not considered in this paper is the direct connection between construction activity and human health. It can be argued

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[1] Report of the World Commission on Environment and Development, 1987

that any construction practice or product of construction which has harmful implications for human health cannot be sustainable. The long-term consequences of atmospheric pollution, discussed in Chapter III are one such implication. However, the relationship between industry, construction, buildings and human health is very complex, which cannot be adequately dealt with in this paper, although occasional references to it are made.

5. Chapter I considers the contribution of construction to the physical degradation of the planet, the conflicts with agriculture, forests and other natural resources. It provides some thoughts and means on how to reduce the deterioration of the physical planet and outlines some policy issues within the industry as well as government to support industry. Chapter II considers the use of non-renewable resources in construction. It elaborates the consequences of the use of non-renewable energy sources in construction and provides some views and means on how to reduce the embodied energy in buildings and how to improve energy efficiency of buildings. After describing the implications of the use of non-renewable materials such as metals and timber in construction, it outlines future policy requirements at both industry and government levels. Chapter III considers the contribution of construction to atmospheric pollution. It describes the relation of construction and atmospheric pollution, pollutions caused by some building materials productions processes, buildings in use and then outlines some ways and means which could reduce atmospheric pollution caused by construction activities.

I. CONSTRUCTION AND DETERIORATION OF THE PHYSICAL ENVIRONMENT

I.1. The dimensions of the problem

7. Rising populations and the consequent exploitation of the natural environment has placed heavy pressure on both global soil resources and tropical forests. New studies show that the condition of both resources is declining more rapidly than was previously thought.

8. According to a new study sponsored by UNEP, an area approximately the size of China and India combined has suffered moderate to extreme soil degradation caused by agricultural activities, overgrazing, deforestation and land conversion over the last 35 years. This area, 1.2 billion hectares, represents almost 11 per cent of the earth's vegetated surface. The way in which this total degradation is distributed among the regions is shown in Table 1.

Region	Total degraded area (million hectares)	Total degraded area (% of vegetated land)
World	1215	10.5
Europe	158	16.7
Africa	320	14.4
Asia	452	12.0
Oceanic	6.2	0.8
North America	78.7	4.4
Central America and Mexico	60.9	24.1
South America	138.5	8.0

Table 1. Areas of moderate to extreme soil degradation, 1945-1990
Source: (World Resource Institute, 1992)

9. Most of this land is agricultural or forest land which has suffered moderate degradation, i.e lost some of its productivity. But about 300 million hectares (3 per cent of the total) shows severe degradation, while 9 million hectares has suffered extreme degradation, i.e. it is unreclaimable and beyond restoration.

10. The study identifies five principal causes of soil degradation: overgrazing, accounting for 35 per cent of all degraded land, deforestation and land conversion, including urbanisation, accounting for 30 per cent, agricultural activities, accounting for 28 per cent, overexploitation for firewood, accounting for 7 per cent, and industrial pollution accounting for about 1 per cent of the total.

11. The study points out that the vast majority of the strongly degraded land is located in Africa and Asia, where a large proportion of the world's poorest inhabitants live, where nutrition levels are currently least adequate, and where population growth rates are also highest.

12. Because of their essential part in the planetary carbon cycle and their biodiversity, the loss of tropical forests is a matter of particular concern. Recent FAO studies have shown that the rate of tropical deforestation has increased dramatically during the last decade. In 1991, FAO found the rate of deforestation to be about 17 million hectares per year, an increase of 50 per cent since the early 1980s. And this does not include forest which has been logged and allowed to regrow, which often leads later to complete deforestation.

13. The extent and distribution of the tropical deforestation between the three tropical regions is shown in Table 2.

Region	Total land area	Forest area 1990	Annual rate of change 1981-90 (per cent)
Total	4, 815, 700	1,714,800	-0.9
Latin America	1,675,700	839,900	-0.9
Asia	896,600	274,900	-1.2
Africa	2,243,400	600,100	-0.8

Table 2. Estimates of forest area and deforestation 1981-90 (thousand hectares) (Source: WRI, 1992)

14. Of the three tropical regions Asia has the highest annual rate of deforestation, followed by Latin America and Africa. But some regional rates are even higher. West Africa has an annual rate of loss of 2.1 per cent, Central America and Mexico 1.8 per cent and continental Southeast Asia 1.6 per cent.

15. The recent report by World Resources Institute (1992) also points to severe environmental stress to the world's freshwater resources and coasts, caused by farming, forestry, industry and human settlements. In several areas water and coastal pollution has reached disastrous proportions, but in many other areas it is increasing without control.

16. Construction activity plays a contributory part in all of these areas of environmental stress. Gross construction output constitutes typically around 8-12 per cent of Gross Domestic Product in many national economies, in both developing and industrialised countries (Wells, 1986), and construction is the destination of many of the materials whose production causes loss or deterioration of land and water resources. Construction activity plays a substantial part in the loss or conversion of agricultural land, both by the extension of human settlements and by the increase in the quarrying and mining used to provide raw materials for construction. And the construction industry worldwide is the principal user of the tropical hardwoods and their products, contributing thereby very substantially to the loss of the tropical forests.

17. The extent to which the responsibility for each of these areas of environmental stress can be allocated to construction activity cannot be easily assessed, as no relevant data exist. Not in many cases, can the subdivision of responsibility between the demands and activities of local construction and those of international trade be quantified. There is a need for considerable further research in these areas.

18. However, some indication of the quantities of materials involved can be obtained by making simplifying assumptions. In terms of volume, the largest by far of the construction materials are mineral aggregates and fill materials. Recent production statistics on the most common types of aggregates for a few developed countries are shown in Table 3 both in terms of gross reported output and output per capita.

Country	Aggregate production (million tonnes)	Tonnes per head of population
France	138	2.45
Japan	190	1.54
Korea	46	1.07
U.K.	319	5.56
USA	1937	7.74

Table 3. Aggregate production for selected countries 1989
(Source: UN Industrial Statistics Yearbook 1989)

19. By contrast, most aggregate production in developing countries is unreported in national statistics, but it is clear that aggregate production rates exceeding 1 tonne per head of population are common, and that this contributes significantly to land conversion rates around major cities. The possible extent of this conversion can be indicated by a simple exploratory calculation. Assuming an aggregate production through shallow quarrying of 1 tonne per head of the global population, about 0.3 million hectares of land might be converted annually; this can be compared with an estimated 1.5 million hectares which is the result of an annual increase of 500 million urban dwellers at 30 m^2 per person. Thus land conversion through quarrying might represent about 20 per cent of the total land loss through urbanisation.

20. A similar study can be made in the case of sawn timber production. Table 4 shows volumetric production of sawn timber in two categories, coniferous and broadleaved, both for selected countries and aggregated world production.

Country	Sawnwood production 1989 (million m^3)	
	Coniferous	Broadleaved
World	373	124
USA		
USSR	86	17
Canada	87	12
Sweden	57	
Finland	11	
Brazil	8	
India		10
Indonesia		14
China		10
Malaysia		9
		8

Table 4. Sawnwood Production, 1989 for selected countries and world totals (Source: UN Industrial Statistics Yearbook, 1989).

21. These calculations are only indicative, in order to show that construction activity certainly makes an important contribution both to land loss and tropical deforestation. The following sections discuss in more detail the ways in which construction activity contributes to environmental stress, and highlights particular examples which have been reported.

I.2. Logging and the loss of tropical forests

22. Timber is not the only economically important product produced from the tropical forests, but it is a very important one, and vital to the economies of a number of low-income countries. In Indonesia, for example, sawn timber and plywood amounted to over 14 per cent of merchandise exports.

23. In principle, timber production from the tropical forests could be made sustainable, but in practice a combination of lack of information, commercial interests, population pressure and bad management are leading to a rapid loss of forests in all the tropical regions, to which the timber industry contributes significantly.

24. The greatest concentrated forest deterioration is occurring in the large rainforests of Amazonia, West Africa and Southeast Asia, which are presently being 'mined' for extraction of selected high-value timber species by international concessionaires with little concern for sustainability. In Africa the 43 million hectares of closed forest which is being logged (20 per cent of the total closed forest) is disappearing at more than 1 million hectares per year (Harrison, 1986). In Kalimantan, the Indonesian Island with the largest timber production, there is now estimated to be an economically harvestable area of only 12 million hectares, as compared with the previously believed 26 million, and by 2000 this is expected to be down to 10 million hectares (Pearce et al 1990: 94). It has been estimated by the International Tropical Timber Organisation that less than 0.2 per cent of tropical moist forests are being managed sustainably for commercial production; and even this small extent of sustainability has recently been questioned (Friends of the Earth, 1992).

25. The reasons for the lack of sustainability of tropical forestry operations are complex, but the following factors are significant;

- government royalties and stumpage fees are very low, not reflecting the true value of the standing trees or even their replacement costs;
- timber royalties are assessed on the basis of the timber actually removed from the forest, rather than the total marketable trees in the forest, leading to highly selective cutting of the best trees, and extensive forest destruction;
- the incentives to the concessionaires to replant the land are extremely poor;
- such replanting as does take place is often with fast-growing softwood species, which cannot replace the current hardwood products in the export market;
- the access roads constructed into the forests for logging operations serve also to open them up for subsequent human settlement, which leads to destruction of the remaining forest;
- current levels of monitoring of the changes in the forests are totally inadequate, so that there is insufficient information on degradation, conversion and deforestation on which to base policy.

26. Importing countries are also in a position to influence the rate of tropical deforestation through the timber trade. Some measures proposed include:

- the imposition of a tropical timber import charge on timber importing countries, the revenue from which would be used to fund projects to promote sustainable forest management;
- creation of an effective labelling scheme to identify the source of all imported timber and to identify timber which has been grown and harvested sustainably;

- banning the use in industrialised countries of all imported hardwoods as in Germany (World Resources Institute, 1992:122), or alternatively of wasteful one-time uses of hardwoods, such as in plywood framework for concrete;
- debt -for-nature swaps to provide funds in debtor countries to support conservation efforts.

27. In Africa the woodlands outside the closed forests totalled 486 million hectares in 1986, and were declining at 2.3 million hectares per year. But this does not include the equally serious but difficult to measure progressive degradation of the woodlands through the thinning out of forest cover (Harrison, 1986).

28. In Nepal, a country heavily dependent on forest resources for economic survival, a recent study showed that although the total forested area was declining rapidly only in the lowland area, the density of the forest in the hill country, where most of the people live, was declining steadily. In the mid-60s 40 per cent of the forest in the hilly regions had more than 70 per cent crown cover; by the late 1970s the proportion with this level of density had fallen to 13 per cent. Attempts over the last decades to bring forests under community management had by the mid-1980s reached less than 6 per cent of the forest area; projections of population pressure and wood use indicate that there will be a wood deficit in the most densely populated areas within 20 years. (Pearce et al, 1990: 168ff)

29. In Sudan, the forests and woodlands in the Northern Savannah region, where most of the population live, are rapidly disappearing. Based on projections of current wood use, it has been estimated that the remaining woody biomass in the Northern region is declining by 5.5 per cent per year. In Khordofan, where 15 per cent of the population live, the rate of loss has been estimated at 25 per cent per year; existing woodlands will totally disappear within a few years (Pearce et al, 1990:117ff).

30. In Bangladesh, bamboo is the most important building material: it is the principal building material used for walls and roofs in about 60 per cent of all dwellings. In 1981 there were about 1.8 million tonnes of mature bamboo culms in the village forests of Bangladesh, which was adequate to supply continuously an annual demand of about 0.8 million tonnes. With the growth of population, urbanisation and the need to replace houses lost in recent flood disasters, demand had risen to 1.4 million tonnes by 1990; and this was coupled with an apparent decline in bamboo production as a result of which most parts of Bangladesh are already experiencing a shortage. The principal reason for the decline in production is pressure on land, leading to overharvesting and use of immature culms, and to disease and poor crop management (SKAT, 1991:60).

31. Whether building is the major use for the forest product, as in the case of bamboo in Bangladesh, or only a minor one as in the case of timber in Nepal and Sudan (where firewood accounts for 93 per cent of all wood use), the implication for building is the same. As forest products become scarcer, their price rises: they also have to be transported longer and longer distances, often leading to several transactions before

they reach the consumer; this further adds to the price the consumer has to pay. In Bangladesh between 1985 and 1990 the real price of bamboo culms increased by about 35 per cent. In Nigeria the real price of building timber increased by nearly 100 per cent between 1981 and 1991. These are clear indications that current use of forest products in building is not sustainable.

I.3. Encroachment of human settlements on agricultural land

32. Another effect of the development of human settlements is that the construction activities they entail uses up agricultural land. Often, because cities have developed in plains this is the best agricultural land. There is no worldwide estimate of the rate of loss of agricultural land in this way. It has been estimated that in some areas urbanisation has been using up 10 per cent of the best agricultural land annually (Ramachandran, 1987), but the contribution to this of construction activity is difficult to disentangle.

33. In India, it has been estimated that some 1.5 million hectares of agricultural land (out of a total of about 170 million) have been taken over in the past 30 years, and a further 0.8 million will be lost at current urbanisation rates by the year 2000. To take one example, the urban area of Delhi has increased from 43.3 square kilometres in 1901 to 660 square kilometres in 1981, absorbing over 100 villages in the process (Centre for Science and the Environment, 1989).

34. The situation is even more severe in Egypt, where virtually the whole population of the country, 57 million people, lives on the only 4 per cent of the land area which can sustain agriculture. During recent years rapid urbanisation has been causing the loss of some 10,000 to 12,000 hectares of fertile land per year, out of a total cropland of 2.5 million hectares (Salem, 1992, WRI, 1992).

35. This land loss is not caused just by the encroachment of the settlement, buildings, roads etc, but also by the impact of these settlements on the hinterland, from which construction materials are removed, by quarrying and excavations for stone, aggregates, brick clays and raw materials for cement and lime production.

36. In the medium sized city of Aligarh in the northern Indian State of Uttar Pradesh (which has a population of about 0.6 million), it has been estimated that the rate of spreading of the boundaries of the city, caused by an increase of 36,000 per year in the population, leads to the loss of 100 hectares of fertile land at the boundary of the city each year (Singh, 1992). But in addition approximately 1 million cubic metres of earth in the form of bricks is needed to construct the new houses built, plus a further 0.5 million cubic metres of earth and other fill materials used as base materials for the roads and building plots. The bricks are supplied from 49 existing brick kilns, located at an average 15 km from the city. The clay pits associated with these brick kilns are relatively shallow, but after use are nevertheless totally lost to agriculture. Farmers also sell soil directly, because of the high price (Rs 10 per m^3) it fetches, leading to total degradation of the land.

37. In some other areas, such as lowland Bangladesh, (SKAT, 1991), potentially agricultural soil is also sold for brickmaking, but it is argued that in this case this is a sustainable practice, because the annual flooding replaces the silt removed for construction.

38. The example of Aligarh is not untypical, but larger cities tend to degrade much larger hinterlands. In the neighbouring states of Harayana and Rajasthan, the growth of industrial, mining quarrying and construction activities have ruthlessly degraded the entire Aravalli hill range, which extends some 500 kms from Delhi to Gujerat. (Roychowdhury, 1992).

39. While the pressure on land is due to Kenya's hostile environment and the high rate of population growth (3.85 per cent), the situation has been worsened by some of man's activities, including construction. The requirements for serviced land in the urban areas, for instance, have increased from 168 hectares in 1988 to 418 hectares by the year 2000. The consequences are that town boundaries have to be extended to include what was previously agricultural land. Similarly, heavy construction activities such as construction of roads, aerodromes, power stations, dams, etc. compete for agricultural land. A typical case can be illustrated by the Third Nairobi Water Project which displaced 499 people in Ndakaini location in Muranga District (Syagga, 1988). A total of 45 hectares of land area was acquired for the purposes of dam construction to supply Nairobi City with water. The area was predominantly a tea zone, and the exercise resulted in loss of production of 65,000 kilogrammes of green leaf tea per year, and unquestionable displacement of families. The money paid for compensation was far below market value and, therefore, could not help the displaced families to reasonably settle elsewhere (Syagga, 1993).

40. Not only quarrying, but also the disposal of wastes uses land which would otherwise be available for agricultural or other uses. Some of these wastes derive from construction activity and demolition, although mostly they are the result of industrial processes, which are only indirectly linked to construction. In China, for example the dumping of *gangue*, or colliery spoil, has already claimed over 4000 hectares of farmland, and increases by 10 per cent per year. (Zhao and Chen, 1987). In India 8 million tonnes of flyash are produced annually by the country's thermal power stations, a good proportion of which is dumped (Sharma, 1987). The significance of this for the construction industry is that much of this waste has potential for reuse as a construction material, which could simultaneously reduce the amount of land required for waste disposal, and reduce the need for quarrying.

I.4. Deterioration of coasts and water resources caused by construction activity

41. In addition to the loss of forests and agricultural land, construction activity can have a seriously detrimental effect on coasts and water resources which in some areas is reaching critical proportions.

42. The most direct and obvious of these impacts are when aggregates or other raw materials are taken directly. In many areas sand and gravel aggregates are removed from beaches or river beds because these are the easiest sources to exploit, though frequently damaging to both wildlife and to their local amenity or tourist value (Navarro, 1992). In parts of India, removal of coral and shells from the coasts for the production of lime and cement has been common, because of their high chemical purity. The use of coral as an aggregate or building stone is also common in parts of India and especially in the Maldive Islands (Saeed, 1987). Marine dredging for construction aggregates has begun to replace quarrying in some countries as the most accessible land quarry sites are used up (Pearce, 1992): this is less obviously damaging to the environment, but has been found to result in increased rates of erosion on nearby coasts.

43. Logging practices can also cause serious damage to water resources. Heavy logging can result in an increase in erosion: increased sediment loads then affect habitats for plant and river organisms downstream. Debris from logging and sawmilling operations can also increase the input into streams of organic material, whose decomposition reduces oxygen in riverwater (WRI, 1992:168). Deforestation has been cited as one of the main causes of changes in runoff, increases in sedimentation and increases in nutrient enrichment worldwide (FAO, 1983).

44. And finally, construction projects such as dams and irrigation schemes can jeopardise coastal waters by blocking the migration of fish, reducing the supply of nutrients to estuaries, and altering salinity. All these alterations can have serious consequences for coastal fisheries which are often not foreseen.

I.5. Means to reduce deterioration of the physical environment

45. In the above account of the impact of construction activity on the environment, some of the effects described were the direct consequences of construction activity, others were more indirect - such as water pollution caused by iron and steel production. In many instances, construction activity is only one, and perhaps a subsidiary factor in the deterioration - as is the case in deforestation, for example. This does not mean that the construction industry can afford to ignore its part in these types of environmental deterioration, since whatever means are used to control them will obviously feed through to the supply and pricing of its inputs. But it does mean that the means of environmental control will have to be exercised externally to the construction industry. This section will briefly consider the range of controls which are available, but will then concentrate on the types of response which are available to the industry itself.

46. Broadly, once undesirable environmental consequences of the use of a natural resource have been identified, there are two types of control which can be exercised: control of the supply and control of the demand. Supply controls could be exercised by means of introducing land-use regulations, pricing of the resource and other measures, to eliminate the indiscriminate exploitation or reduce it to acceptable levels.

Demand side controls aim, by restricting or changing the nature of the activity, to reduce or eliminate the demand for it. In the case of construction activity, which is acknowledged to be essential for virtually every type of development, an increase rather than a decrease is desirable in all developing countries: only in the industrialised countries is it possible to consider a decrease in construction activity overall as a means to control its environmental impact. But there are many ways in which the nature of current construction activity can be changed to make it less environmentally damaging, without reducing the total amount of construction in terms of the built space created or other functions it performs.

These include:

- Improving land-use and pollution emission legislation and control;
- Preconstruction environmental impact appraisals;
- Greater use of demolition and mineral and agricultural wastes in construction;
- Extending the life of and reuse of existing buildings.

47. Some progress has been made in these areas in some developing countries (Ofori, 1992, CIRIA, 1993, Spark, 1991). The greater use of mineral and agricultural wastes as inputs for the construction industry is discussed in the following sections. Some of the other topics are referred to in later sections.

I.6. Utilisation of mineral wastes

48. The potential benefits of greater utilisation of mineral and agricultural wastes as inputs to the construction industry have long been realised. Not only would this reduce the impact of construction on the natural environment by reducing the need for quarrying, mining or logging: it would at the same time reduce the undesirable environmental impacts associated with the disposal of those mineral wastes. Considerable research and development work has been devoted to finding ways to utilise these wastes, both in developing and industrialised countries, and some progress has been made. However, the degree of utilisation of wastes is still very far short of the potential, making this potentially one of the most fruitful ways forward for the construction industry. This section looks at the potential, and also at some of the reasons for the present lack of waste utilisation, and examines means by which this could be increased.

49. Several types of mineral wastes are very widely available in both industrialised and developing countries. These include:

- wastes from coal mining and the mining of other high value minerals;
- wastes from coal-burning power stations;

- blastfurnace and steel slags from iron and steel production;
- demolition and construction wastes.

50. Colliery spoil is the waste material produced in the process of extracting and processing coal. It derives from the layers of sedimentary rock associated with the coal which are extracted at the same time. The percentage of spoil produced per unit of coal extracted increases with the degree of the mechanisation of the mining process. In Germany, it is 80 per cent; in the UK it is about 55 per cent; but in India, where labour intensive mining methods are used, it is much lower, probably less than 10 per cent. Some colliery waste contains a significant proportion of unburnt carbon. In some cases this is left exposed in large tips which use land, and from which poisonous gases can be emitted (Zhao and Chen, 1987). In China, 100 million tonnes per year are produced; in the UK, annual production in the 1980s was about 40 million tonnes. Potential uses for colliery waste are as a fill material, in brickmaking, cement making and in the manufacture of lightweight aggregates. Its value in brick and cement manufacture is that it may combine suitable raw material with some combustible carbon. In China, the colliery waste is allowed to combust spontaneously, which results in volume expansion and the formation of light porous grains which are used as lightweight aggregates in concrete block production. Current utilisation of colliery spoil in construction in China is 20 million tonnes, about 20 per cent of output; in the UK the utilisation rate is only about 10 per cent.

51. Coal-fired power stations produce a high proportion of the world's electricity. These produce large quantities of ash, both in the form of fly ash (or pfa), and furnace-bottom ash. In India 8 million tonnes of ash are produced annually: in the UK about 13 million tonnes are produced. Disposal of this ash can create environmental problems; but both types of ash can be effectively used as aggregates in concrete and concrete block production. Where there is unburnt carbon in the ash, it can effectively be used as a raw material to substitute for clay in brick manufacture. Pfa can be used to manufacture lightweight concrete aggregate; and it can be used, in proportions up to 25 per cent, as a cement extender in the manufacture of Portland cement. In India, a high proportion of the cement produced is of the Portland-pozzolana type, made with pfa admixture. But the present extent of pfa utilisation in the construction industry is generally considerably short of the amount available.

52. In future, coal fired power stations in some regions (e.g. Europe) will be required to install flue gas desulphurisation equipment in order to reduce sulphur dioxide emissions which contribute to acid rain. These will produce gypsum as a byproduct in a form suitable for use in the manufacture of plasterboard.

53. Demolition and construction wastes arise from the demolition of existing buildings or the construction process. Because these often consist of a mixture of materials, including metals, asbestos, broken glass and timber, they are frequently disposed of to landfill waste sites rather than sorted for reuse. In the UK it is estimated that about half of all demolition and construction waste is reused, and only 5 per cent fully recycled. But concrete and masonry waste can effectively be separated and

recycled as aggregates, steel can be separated and returned for recasting into reinforcing bars in small-scale minimills; waste glass can be reutilised in the glass production process. Another type of construction waste with a considerable potential for reuse is asphalt planings, the bitumenised roadstone removed from the surface of roads prior to resurfacing. In the US about 25 per cent of this material is recycled, in Germany 50 per cent.

54. In several countries brick and tile wastes are pulverised or ground for use as slightly pozzolanic fine aggregates in mortars (surkhi in India, semen merah in Indonesia). In Bangladesh where there is a shortage of other aggregate sources, brick bats are satisfactorily used as coarse aggregate in concrete.

55. The potential for the substitution of primary aggregates and fill materials by aggregates from secondary sources is particularly important, because of the vast quantities of aggregates and fill materials needed for today's urban expansion.

56. In most countries, planning authorities have to issue Mineral Extraction Permits for quarrying to be started or extended, but for this means of control to be useful, the amount of quarrying permitted needs to be calculated in relation to some measure of demand, as well as considering environmental impacts. In the UK, the Central Government's Department of the Environment provides guidance to the planning authorities on the expected future demand, regionally, indicating what additional quarrying may be needed. The planners can also, as now in most parts of Europe and North America, impose restoration and after-care conditions or operating restrictions when granting permission for quarrying. These measures can limit the environmental impact of quarrying, but do not appear to have led to much of an increase in the use of secondary aggregates

57. Alternative measures available by government directive are:

- Laws or directions which prohibit the disposal of those mineral wastes which can be recycled (as in Germany and the Netherlands), or alternatively which require that a certain proportion of wastes are recycled;
- Directions requiring that a certain proportion of the aggregates (or other materials) used on construction projects be recycled or waste-based materials.

58. Governments can also assist in promoting greater utilisation of mineral wastes by other means, for instance:

- Provision and distribution of information, and sponsorship of research;
- Initiating the development of new or revised standards;
- The use of grants to demonstrate the use of promising new technologies - such as for example plants for recycling demolition and construction waste.

59. To prevent and to mitigate environmental repercussions in mining and quarrying operations, action must be directed of:

- Mined area rehabilitation and implementation of the environmental management plans concurrently with the on-going mining operations to ensure adequate ecological restoration of the affected areas;
- Rehabilitation of the abandoned mined areas in a phased manner so that scarce land resources can be brought back under productive use;
- Laying down of requisity stipulations for mining leases regarding tenure, size, shape and disposition with reference to geological boundaries and other mining conditions to ensure systematic extraction of minerals along with environmental conservation;
- Upgrading and beneficiation of mineral at the source, to the extent possible inorder to ensure utilisation of low-grade mineral resources and to reduce the cost of transportation, processing and utilisation;
- Environmentally safe disposal of the by-products of mining;
- Restriction on mining and quarrying activities in sensitive areas such as hill slopes, areas of springs and areas rich in biological diversity;
- Discouraging selective mining of high grade ores and recovery of associated lower grade ores during mining; and
- Environmental impact assessment prior to selection of sites for mining and quarrying activities (Gupta, 1993).

60. A third possibility of government action, would be some sort of economic measures, either through levies, or through subsidies. The effect of levies would generally be to raise prices, that of subsidies to lower them, in both cases changing the relative prices of alternatives. In Denmark, for instance, a charge of $0.43 per tonne has been levied for all primary aggregate extraction; and about $20 per tonne on laidfill waste disposal. These additional costs have had a dramatic effect on altering industry practice with regard to demolition and construction waste disposal (Arup, 1992). Subsidies, on the other hand involve increased public expenditure, but have the advantage that they can be targeted on the greater utilisation of specific wastes. A recent study of U.K. practice showed that only 10 per cent of the current 330 million tonnes of aggregates used annually are from secondary sources; it recommended a package of measures to increase waste utilisation including both taxes, levies and other measures. It was estimated that a 15 per cent tax would increase secondary aggregate use by 31 per cent and also have the effect of reducing land use for quarrying and waste disposal by 113 hectares per year (Arup 1992).

I.7. Utilisation of agricultural and organic wastes

61. Mineral wastes tend to be less available in developing countries than industrialised countries, because of lower industrial output. However, developing countries frequently generate comparatively large quantities of organic waste from agriculture and forestry. These are often found to be suitable for further processing for use in construction. There has been considerable experimentation with agricultural wastes in national and regional laboratories, and some successful processes have emerged.

62. Among the more promising developments are:

- *Use of natural fibres as reinforcement in concrete roofing.*

  Fibre concrete roofing (FCR) has emerged during the 1980s as a technically viable and often cheaper competitor to more conventional steel sheet or clay tile roofing. It uses a small proportion - up to 4 per cent by weight - of chopped natural fibres, which can be from waste materials such as coconut coir, or from plantation fibres such as jute, sisal, hemp for which export markets are declining. Small plants for manufacturing FCR have been established in more than 50 countries (Gram et al 1987).

- *Secondary timber species utilisation*

  Efforts by regional forestry research institutes have greatly extended the number of useable and economical timber species which were not previously considered suitable. In Nigeria, for instance, the number of economical timber species was increased from 20 to over 80 over 20 years (Ademiluyi, 1987); the use of these species generally involves the development of low-cost seasoning and treatment plants in which considerable technical progress has been made in recent years (UNCHS 1988). Techniques have also been developed for the constructional uses of poles which enables plantation thinnings to be used (Campbell 1975) in place of sawn timber, with considerable reduction in wastage. Costs can be considerably reduced this way.

- *Rice husk ash cement*

  Rice husk presents a particular disposal problem in many countries and it is often burnt in open heaps. RHA has been shown to have excellent pozzolanic properties, which enables it to be used for the manufacture either of a pozzolanic cement in conjunction with lime or as an extender of Portland cement. Worldwide, more than 60 million tonnes of rice husk are produced annually, giving a potential for 12 million tonnes of pozzolanic material. Several small production plants for lime-rha cement have been established in South Asian countries (Smith, 1983, Spence and Cook, 1983)

I.8. **Policy implications**

63. This chapter has examined the role of construction activity in the deterioration of the tropical forests, agricultural land and water resources. In some cases, such as quarrying for construction material or brickmaking, the loss is directly attributable to construction. In other cases, such as the loss of tropical forests, construction activity contributes to or is part of a larger process, such as urbanisation, which contributes to the losses. There are policy implications both within and beyond the construction industry.

64. Policies primarily within the industry will include policies to promote:

- increased use of secondary and recycled mineral materials in construction;
- increased use of agricultural and organic wastes;
- reduced the use of forest products (particularly tropical hardwoods) which are not sustainably managed;
- reduction in the disposal of wastes, either from materials production or construction activity which cause land dereliction or water pollution.

65. Government policies which are needed to support industry measures will include:

- policies for controlling the exploitation of productive agricultural or forest land for building materials;
- policies for sustainable management of the large tropical rain-forests, partly caused by timber extraction;
- policies for sustainable management of depletion of wood and bamboo resources outside the forests;
- policies to control the extraction of primary minerals for use in construction;
- policies to control the disposal of wastes resulting from construction.

66. The internal and external policies will necessarily interact, and possible overlap with each other, and consequently neither can be carried out in isolation from each other. Where possible, policies should be developed whose effect is in accordance with the 'polluter pays' principle. Some of the possible policy areas have been detailed in the above discussion. There is however considerable interaction between the policies needed to protect forests, land and water resources as discussed in this Chapter and those required to reduce atmospheric pollution (Chapter III), and use of non-renewable mineral resources discussed in the next chapter.

II. USE OF NON-RENEWABLE RESOURCES IN CONSTRUCTION

II.1. Non-renewable resources in the construction industry

67. Construction activity is a major user of the world's non-renewable resources. The use in the construction industry of non-renewable fossil fuels is the most serious concern, both because of the dependency of virtually of all human activities on them at the present time and also because of the current rate of depletion of these fossil fuels. But since burning of fossil fuels also contributes to the global production of greenhouse gases, there is a double urgency about the environmental costs of fossil fuel consumption in and through construction. Energy and fossil fuel use in the construction industry will therefore be the primary focus of this chapter. But the use by the construction industry of certain other minerals with limited reserves is also a matter of concern, and limiting their use will also be considered.

II.2. Use of fossil fuels in construction

68. The rate of increase in the global and regional rates of consumption of fossil fuels are shown in Table 5. The world's commercial energy production has increased globally by 14 per cent in the last decade. In 1989, over 95 per cent of the world's commercial energy was produced by the burning of fossil fuels - oil, gas and coal - while only the remaining 5 per cent was primary electricity produced from geothermal, hydro-electric and nuclear sources. Thus, to the extent that the construction industry uses commercial energy, whether in the form of direct fossil fuel burning or the use of electricity, it is contributing to the depletion of fossil fuels.

	Production, 1989 (GJ x 10^6)	Increase since 1979(per cent)
Fossil fuels and wood (95.4 per cent)		
Solid	95,713	26
Liquid	130,299	-4
Gas	70,497	33
Primary electricity (4.6 per cent)		
Geothermal and wind	141	244
Hydro	7,539	23
Nuclear	6,783	201
Total	310,972	14

Table 5. World commercial energy production, 1989 and increases since 1979.
Source: World Resources Institute, 1992

69. In general it has been found that energy consumption in the production of buildings is a relatively small part of the total lifetime energy use, perhaps 10 to 15 per cent, if a lifetime of about 25 years is assumed. But much of this lifetime energy use, particularly in developing countries, is in the form of cooking energy, over which the initial design has little effect. And even those aspects of the lifetime energy consumption which designers can influence, such as heating and lighting, are controlled by the way the building is used, and can be altered subsequently to some degree. The energy used in the production, the so-called embodied energy, is however totally within the control of the construction industry, the designers, builders and building materials producers. Embodied energy is important for this reason.

70. In the following sections both embodied energy and energy-in-use will therefore be given equal weight in strategies to reduce the consumption of non-renewable energy resources in construction.

II.3. <u>Embodied energy in construction</u>

71. The embodied energy in a buildings is the energy used in all the stages of its production and construction. Figure 1 indicates the locations of these energy uses, identifying four stages: extraction of raw materials, primary materials production, fabrication or secondary building materials production, and the construction process itself. Between each of these stages, there is often some transport of materials, and the energy used in this transport needs to be included.

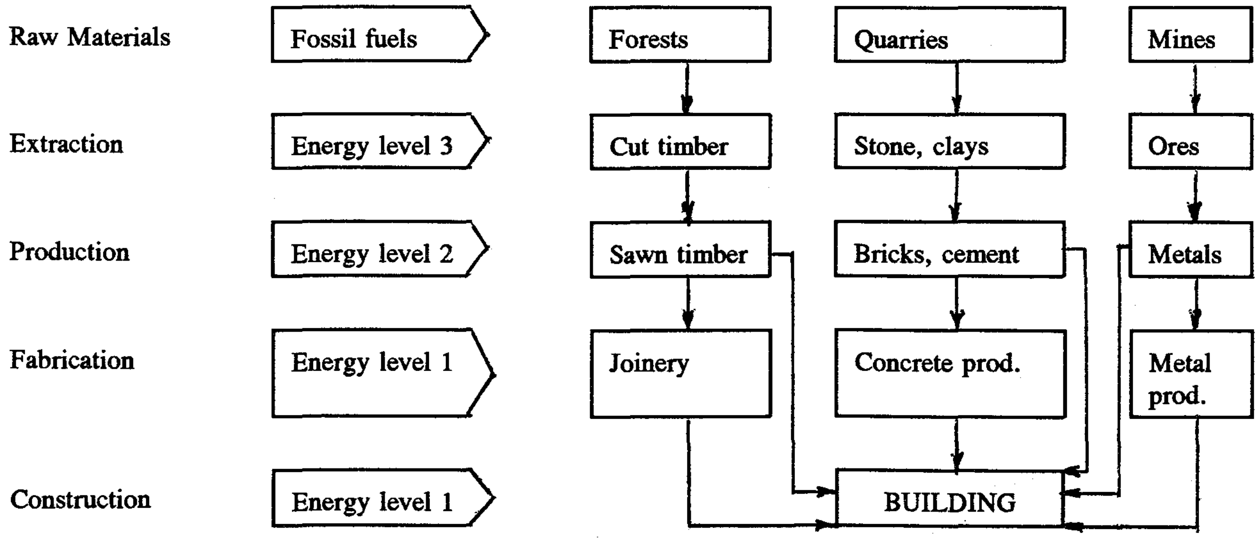


Figure 1. The levels of embodied energy use in building construction

72. Studies of the embodied energy consumption in buildings which have been carried out (UNCHS, 1991a) have indicated that:

- a high proportion of the energy used, about 80-90 per cent, is used in the production and transport of building materials before they are brought to site: only 10-20 per cent of the energy use takes place in the on-site construction process.
- of the energy used in the production of building materials, a high proportion is in the production of a small number of key materials, including concrete and steel, mortar and plaster, and bricks and blocks.

Material	Primary Energy Requirement (GJ/tonne)
Very High Energy	
Aluminium	200-250
Plastics	50-100
Copper	100+
Stainless steel	100+
High Energy	
Steel	30-60
Lead, zinc	25+
Glass	12.25
Cement	5.8
Plasterboard	8.10
Medium Energy	
Lime	3-5
Clay bricks and tiles	2-7
Gypsum Plaster	1-4
Concrete:	
in situ	0.8-1.5
blocks	0.8-3.5
precast	1.5-8
Sand lime bricks	0.8-1.2
Timber	0.1-5
Low Energy	
Sand, aggregate	<0.5
Flyash, RHA, Volcanic ash	<0.5
Soil	<0.5

Table 6. Comparative energy requirements of materials (Source: UNCHS, 1991a)

- there is a very wide variation between the amounts of energy used in the production of different materials per unit weight of the material, which is indicated by Table 6, in which four groups have been distinguished, namely very high-, high-, medium- and low- energy materials. The amount of energy used to produce a tonne of the very high-energy materials is typically more than 100 times that needed for the low-energy materials.

- Similarly, different types of construction systems (sets of materials) can result in considerable differences in the total embodied energy requirements in complete house systems as indicated by the comparison of three houses in Argentina shown in Table 7.

House type	Embodied energy requirement (MJ/m^2)
House made primarily with manufactured materials (hollow brick walls, concrete frame and roof)	1583
House made partly with manufactured materials (clay brick walls, concrete frame, steel sheet roof)	1314
House built primarily with local materials (adobe walls, timber frame, steel sheet roof)	590

Table 7. Comparative energy requirements for three single-storey houses in Argentina (Source: UNCHS, 1991a)

- Among the high and medium energy materials, many (for instance, steel, cement, lime, glass and brick production) use kiln processes for production which are fossil-fuel intensive, and in which there is a considerable difference between the energy consumptions of the processes available.

- Even where elements are being compared on the basis of comparable performance, there are often considerable differences between the energy consumption of the most and the least energy-intensive processes available. Table 8, for example, compares the energy requirements of alternative low-cost roofing assemblies for pitched roofs.

Roof assembly	Embodied energy requirement (MJ/m^2)
Corrugated iron sheets on timber	605
Clay tiles on timber	158
Concrete tiles (12.5 mm)	72
Fibre-concrete tiles (7 mm)	46

Table 8. Comparative energy requirements of alternative roofing assemblies for a pitched roof. (Source: UNCHS, 1991a)

- Building systems which use timber tend to be especially energy-efficient in comparison with alternatives both for walling and roofing systems and for door and window frames. This is particularly so if the source of timber is local forest or woodland.

- In spite of improving energy efficiency, rising energy costs are one of the principal factors causing building materials prices worldwide to rise, creating incentives for technical innovation directed towards greater energy-efficiency and fuel substitution.

II.4. Means to reduce embodied energy in buildings

(a) *Building materials production*

73. The energy use in the production of building materials accounts for over 80 per cent of the total embodied energy in buildings, and, thus, improvement of energy use in production processes is a crucial part of any overall strategy for energy conservation in the built environment. As so much of the energy use in building materials takes place in the manufacture of a few extensively used materials which involve high temperature kiln processes, notably iron and steel, cement, clay bricks and tiles and glass, energy saving strategies should concentrate on these processes. A second area of significant energy use is for mechanical plant used for quarrying, conveying, crushing and grinding materials in manufacturing processes. A third is low temperature processes such as drying and autoclaving. A fourth is in transport of materials both from quarries to the production plant, and from the factory to site or local distributors.

74. Strategies for energy saving in building materials manufacture should therefore include:

- careful study of all kiln processes to assess energy efficiency achieved and opportunities for improved energy efficiency; replacing energy inefficient processes with more efficient ones;

- examining opportunities to use cheaper or non-premium fuels in kiln processes, such as agricultural waste for brick burning, municipal waste for cement production, addition of combustible materials to clays in brick manufacture;

- use of recycled materials in production processes such as scrap iron and steel, recycled glass;

- use of low-energy additives or extenders, such as pozzolanic materials or blast-furnace slag in cement production;

- changing the product mix to produce a higher proportion of low-energy materials such as hollow clay bricks rather than solid bricks;

- energy auditing of all production processes to identify energy end use patterns; upgrading or replacement of energy-inefficient plant; improving maintenance of mechanical plant;

- use of solar energy or waste kiln heat in low temperature operations such as drying (timber, bricks) or water heating;

- selective replacement of mechanical equipment with efficiently used human labour, particularly for loading and unloading, short-distance conveying;

- reduction of transportation energy by appropriate location of production plants, and small-scale production.

75. Because of the high energy intensities of many production processes, larger producers using modern technologies (for example cement producers) are generally aware of the need for energy efficiency, and can be expected to undertake many of these measures without additional incentives, in order to reduce production costs. However, many of the producers of building materials operate at a small scale, using traditional processes, and are slow to respond to changing pressures or alter established practices. Thus policy makers and government departments have a role to assist building materials producers improve their energy efficiency in the ways such as:

- supporting research into methods of improving energy efficiency of traditional energy intensive building materials production technologies, such as brick and tile manufacture, lime manufacture; helping to promote the transfer of improved technologies in the industry through meetings and demonstration projects;

- offering incentives to producers to undertake energy audits;

- supporting studies to examine the effects on materials properties of altering raw materials to reduce energy, for example the replacement of Portland with Portland-pozzolana cement; helping to promote the application of low energy materials by designers and in the construction industry.

(b) *On-site construction*

76. On-site construction activity accounts for a small but important proportion of the embodied energy in buildings, ranging from about 15 to 25 per cent of the embodied energy. A large part of the energy use in construction is related to the use of mechanical plant for transporting, levelling, digging, lifting, compacting, mixing; while a second significant component relates to the energy use in the buildings - both temporary and permanent - used by the builder for the construction activity. Energy embodied in materials used for temporary works - scaffolding and formwork for concrete, for example - forms a third component.

77. Construction efficiency also to some extent affects the total amount of embodied energy in the building, since inefficient site management can result in considerable materials wastage. For example, it has been estimated that in typical urban construction sites in developing countries about 25 per cent more cement is used than would be needed if quality control was improved. In other cases, excess material is used over the amount specified in the design (for example in trench foundations), to reduce time and labour cost.

78. The decisions of the builder may also dictate the sources of supply of the materials used in a building, and hence determine the transportation energy component of the embodied energy, which is often significant.

79. Thus, strategies for improving energy-use efficiency in construction should include:

    - conducting energy audits on typical construction sites to identify energy use and energy saving opportunities; making site staff aware of the energy implications of all site activities, and introducing incentives for energy saving;

    - examining energy efficiency of all mechanical plant used; replacing inefficient plant with more efficient plant; reducing unnecessary use of plant; ensuring that all plant is properly serviced and maintained (poor maintenance can increase energy use by 15-20 per cent): considering the selective replacement of mechanical plant with the use of manual labour;

    - examining energy efficiency of all buildings used in the construction process, and where appropriate upgrading them;

- examining the extent of use of transport of materials etc to and within the site, with a view to reducing journeys and utilising the most energy efficient means of transport available; selecting where possible only local sources of materials supply;

- examining the embodied energy in temporary works, and replacing high-energy materials with lower energy materials in temporary works where possible, for example use of timber and bamboo rather than steel for scaffolding and formwork;

- looking for opportunities to save wastage of materials, such as excessive concrete in foundations, excessive cement in concrete mixes; looking for ways to reduce materials use by the use of closer supervision and quality control;

- separate all waste materials generated to facilitate their recycling.

80. Most of these strategies will prove cost-effective to implement, so it should be possible to persuade builders to implement them without additional financial incentives, once they have been identified. Nevertheless national and local governments have a role in promoting these strategies in a number of ways, such as:

- supporting research into energy consumption in the construction process;

- conducting training events for buildersand construction managers in energy conservation;

- providing incentives to invest in energy saving through for instance replacing or upgrading inefficient plant, or through the use of manual labour in place of mechanical plant.

(c) *Design*

81. In addition to the contributions made by improving the energy-efficiency of the production of building materials and the construction process, there is a major opportunity available to reduce the embodied energy used in building by appropriate choice of materials and technologies in design. Designers can contribute to the reduction of the total energy use in the built environment through strategies such as:

- the use of less materials, particularly high energy materials, in building design; looking for ways to reduce the thickness of walls, finishes, storey heights etc where this can be done without compromising other aspects of performance;

- selection of low-energy materials rather than higher-energy alternatives when these are available, as for instance: use of timber in place of steel or concrete for beams and trusses; use of lime pozzolana mortars in place of cement mortars; use of soil and stabilised soil blocks or sand-lime bricks rather than clay bricks; and use of lightweight aerated concrete blocks rather than dense concrete blocks;

- selection of lower energy structural systems, such as use of load-bearing masonry in place of reinforced concrete or steel frames;
- design of low-rise buildings in place of high-rise buildings wherever the situation permits;
- selection where possible of waste or recycled materials, or manufactured materials which incorporate these; for example portland-pozzolana cements using pfa or blast-furnace slag; asphaltic roof sheets incorporating recycled paper, building boards from agricultural waste, use of second-hand or reclaimed building materials;
- design for long life and adaptability to varying requirements;
- design for recycling; use soft mortars which will allow bricks to be reclaimed; avoid reinforced concrete where alternatives can be used;
- design for the use of materials which are found near to the site and have low transport costs.

82. These strategies will not always be consistent with strategies for saving energy consumption in the use of a building. In such cases it is necessary to examine the total energy consumption over a building's lifetime to determine which is the optimum energy saving strategy.

83. The least energy design may be in some cases not be the least cost solution. Moreover building codes and regulations may in some cases unnecessarily prohibit the use of materials such as stabilised soil, which can offer substantial energy and cost savings. The designer may also be unable to find information to assist in the selection of appropriate materials in a particular locality. Thus, governments and policy-makers have a role in:

- supporting research to provide building designers with detailed information on the energy costs of the entire range of available materials, and typical lifetime energy costs, to assist in materials selection for least energy;
- examining building regulations, standard specifications, and codes of practice to permit the use of low-energy materials, particularly new or unfamiliar ones; utilising them in building projects using public funds;
- sponsoring research into the properties and performance of low-energy materials to enable designers to specify them for an increasing range of applications;

- examining urban plans to find ways to create incentives to limit building heights so that low-energy materials can be used.

84. Although there is less data available on the embodied energy in types of construction other than buildings, it can be inferred that very similar strategies could be adopted by the builders and contractors and the designers of roads, dams, pipelines and other major civil engineering facilities.

II.5. Means to improve energy efficiency of buildings

85. Because of its prominence in energy demand and the widespread fuelwood crisis, considerable attention has been paid to the development and dissemination of energy efficient stoves and other equipment in developing countries (UNCHS 1991) and to alternative sources of energy (UNCHS 1990). These strategies are important, but not directly in the control of the building designer. Alternative strategies with a considerable potential for energy saving are, however, available through building design and construction. Two important options are:

- reduction of heating energy demand through improved standards of insulation of new (and existing) buildings; and

- use of 'passive solar' design approaches to reduce heating loads and or eliminate the need for mechanical ventilation and air-conditioning.

86. Active solar appliances, though not considered further here, can also make a significant contribution, particularly in provision of domestic hot water (UNCHS, 1990).

(a) *Improved insulation*

87. In northern industrialised countries building regulations are requiring progressively higher standards of insulation in all new buildings, with a very significant consequent improvement in the energy-efficiency. The primary energy use for space heating in new buildings in the UK is expected to be cut by half between 1980 and 2000 as insulation standards rise. Many urban areas in low-income countries have a cold season which gives rise to a substantial heating demand, but average insulation standards are very much lower than in western industrialised countries. In the Chinese capital, Beijing, the mean January temperature is -4.6° but most buildings have external walls with thermal transmittance (U) values of 1.5 W/m^2K or worse. New building regulations require maximum U-values of 1.25 W/m^2K for walls and 0.91 W/m^2K for roofs. It is estimated that these and other modest improvements will reduce fuel consumption by 30 per cent (Tu, 1992), and there is potential for much greater savings.

88. Increasing insulation standards have cost implications for building owners, and also increase the embodied energy in buildings. But studies show that the cost and energy pay-back periods of improved insulation standards are very short - months rather than years, in cases where existing standards are low. In most cases, however, government intervention of some form is needed to get improved standards implemented.

89. A contribution which the construction materials industry can make is the development of low-cost insulation materials based on local materials. China currently produces 8 million square metres of insulation materials per year, including mineral wool, expanded polystyrene and foamed concrete technologies, but most of these are expensive materials using imported technologies. Emphasis is now being placed on insulants which use indigenous raw materials such as expanded perlite. Research is also in progess into low-emissivity lining materials and composite panels (CBRI, 1992).

(b) *Passive solar design*

90. Given the high energy consumption of air-conditioned buildings, an important task for building designers working in hot climates is to look for ways to achieve acceptable comfort conditions without resorting to air conditioning and mechanical ventilation. This has a particular importance because buildings designed for air-conditioning cannot easily be adapted afterwards: thus a building which is designed initially with an assumption of air-conditioning is committed to a high-energy requirement throughout its life, or the building becomes useless.

91. Passive techniques for space conditioning are commonly developments of the traditional ways of building in a region, which often evolved design strategies for space, building mass, openings and orientation which effected either cooling or heating in response to the climate. In hot, arid regions, for example, a high building mass is desirable to even out day and night temperature changes: during daytime the building can be closed to prevent hot air entering: at night the building can be opened up to cool its structure. In hot humid regions comfort is most easily maintained by a high ventilation rate to promote cooling, but direct solar radiation should be excluded. A light building mass is desirable, and the orientation, positioning and openings are arranged to maximise ventilation.

92. Such buildings are not expensive. Indeed they may well be cheaper than air-conditioned alternatives on first cost, quite apart from savings in subsequent running costs; but they require skilled design, and the building forms they create, though often similar to the traditional architecture of the region, are often a departure from the modern, urban image.

93. Thus, a strategy for greater utilisation of these techniques must be based on education of the designers, public awareness, and demonstration buildings. But regulations to restrict the use of air-conditioning can also be used to encourage the use of

alternatives, as they already have in some areas. In Denmark, for instance, air-conditioning is not permitted unless the designer can show that comfort conditions cannot be met without it.

II.6. Use of non-renewable materials in construction

94. Fortunately, most of the materials used in construction are both abundant and very widely distributed in the earth's crust. Apart from oxygen, which is present everywhere, silicon, iron and aluminium are the commonest elements in the earth's crust, and they are the main elements used in construction activities.

95. By contrast with minerals, all vegetable materials used in building are in principle renewable, since they can be regenerated. However, current practices of exploitation are such that some of them, notably tropical hardwoods, must also be regarded as non-renewables. These problems are considered in the following sections.

(a) *Disappearing metals*

96. Several metals with limited known reserves are extensively used in construction. The known world reserves, annual consumption and life index of seven leading metals are shown in Table 9. Calculation of reserves is problematical. It involves making assumptions both about the extent of some deposits which have not been fully surveyed, and also about the concentration and location at which the metal can profitably be extracted at today's technology. Extraction and concentrating always involves the use of energy, and thus the latter criterion also depends on energy prices. As the price of a material increases, the incentive to search for new sources is increased, and the amount of known deposits which can be economically extracted also increases - thus reserves will increase.

Metal	Consumption 1990 (thousand tonnes)	Base Reserves 1990 (million tonnes)	Base Life Index (years)
Aluminium (Bauxite)	17,878 (Al)	24,500 (Ba)	225
Copper	10,773	550	62
Lead	5,544	120	36
Nickel	842	109	116
Tin	229	6	28
Zinc	6,973	295	40
Iron Ore	925,000	229,000	265

Table 9. Consumption and reserves of some metals
(Source: World Resources Institute, 1992)

(b) *Non-renewable timber species*

97. Tropical hardwoods are preferred to other materials or many construction and furniture uses because of their durability, colour and texture. Although there are probably in excess of 10,000 different species, the vast bulk of trade, especially international trade, consists of only a few species. Table 10 shows that 60 per cent of the sawn hardwood timber imports to the U.K. in 1988 consisted of just seven species. As explained in Section 2.2, an almost insignificant proportion of the tropical rainforest from which these species are obtained is being managed sustainably, and consequently these species (and a long list of other species which are traded internationally), must be regarded as non-renewable materials.

Type of timber	Principal countries of origin	Imports (m^3)
	Philippines, Indonesia, Malaysia	130,355
Meranti (red)	Brazil, Ghana	103,547
Mahogany	Indonesia, Malaysia	81,817
Keruing	Malaysia, Singapore	27,518
Ramin	Ivory Coast, Ghana, Zaire	22,072
Iroko	Ghana, Nigeria	9,851
Obeche	Indonesia, Burma, Thailand	8,224
Teak	Philippines, Ghana	242,507
Others		

Table 10. Principal tropical hardwood imports to the UK, 1988
(Source: Friends of the Earth, 1988)

II.7. <u>*Means to reduce use of non-renewable materials in construction*</u>

98. There are three principal strategies available to reduce the future use of non-renewable materials, whether mineral or organic in origin, namely: more efficient use, substitution of alternatives, and recycling.

99. Materials - both metals and timber - are frequently used in much greater quantities than are actually required. Scarce materials are often, for example, used for their surface properties. The use of thinner layers can often be made possible by technological advances, whether as timber veneers, or metal coatings. Or simply better design can reduce the quantity required for a particular function.

100. Alternatively, substitution of a scarce material by a more plentiful one is frequently possible to achieve the same property. Among metals, copper can be replaced by polystyrene in plumbing, and by aluminium in electrical wiring, for example. Similarly, there are many substitutions possible for tropical hardwoods. A whole range of temperate timber species, both hardwoods and softwoods, can be substituted for the tropical hardwoods imported into Europe, Japan and North America, for example beech, birch, oak and walnut: and preservative treatments to improve their durability are available.

101. Likewise, the principal tropical hardwoods can be substituted for use in tropical countries by the many lesser-known hardwood species (for which detailed performance data is increasingly becoming available), and by plantation timbers such as coconut and rubberwood. Studies in Philippines have shown that with suitable preservative treatment, coconut wood can be used for structural components, cladding, door and window frames and roofing shingles (Philippines Coconut Authority, 1979). Rubberwood also has a range of constructional uses if proper preservative treatment is applied (UNCHS, 1987).

102. The final strategy for reducing the use of non-renewables is recycling. Often there is considerable potential for recycling components made from scarce non-renewable materials if consideration is given to this at the design stages. A high proportion of lead used for roofing can be recycled, for example, if the lead is not used as a coating for cheaper metals; and similarly timber components can frequently be reused when a building is demolished or refurbished. Recycling has already been discussed as a means to reduce embodied energy in buildings, and as a means to reduce the impact of construction on the physical environment (Chapter I). It can, therefore, be seen as a strategy which has a particularly high pay-off in terms of achieving environmental impact reduction.

II.8. Future policy implications

103. Key policies for the construction industry to improve efficiency in its utilisation of non-renewable resources will include:

- substitution of low-energy intensity materials for high-energy intensity materials;
- encouraging reliable standards of quality for locally produced/low energy materials;
- finding new ways to use recycled and waste materials;
- local sourcing of materials to reduce transportation energy use;
- encouraging efficiencies in design to reduce amount of material used;

- promoting high efficiency technologies and the use of renewable fuel sources;
- promoting design for recycling.

104. The construction industry will need to be supported by suitable government policies. Key policies for governments will include:

- examining opportunities through building regulations etc. to encourage use of low-energy intensity materials;
- examining opportunities in building regulations, standards, energy rating etc. to encourage energy efficiency in building use, and avoidance of air-conditioning;
- examining planning guidelines to encourage both efficient land use and building materials use, for example in appropriate height limits;
- compilation of databases giving information on embodied energy of alternative materials, for use by designers.

Governments can also introduce certain economic incentives through initiation and utilization of environmental taxes to reduce environmental impacts of the use of non-renewable resources in the construction industry.

III. CONSTRUCTION AND ATMOSPHERIC POLLUTION

III.1. Atmospheric pollution and the construction industry

106. Atmospheric pollution is today perhaps the most pressing environmental concern at a global level. Growth in the atmospheric concentrations of several gases has already had severe environmental consequences at regional scales, and the evidence suggests that further regional and global damage is likely, leading even to probable regional climate changes (WRI, 1992). The atmospheric concentration of carbon dioxide, the major 'greenhouse gas' was 354 parts per million in 1990, an increase of 12 per cent on its 1959 level, and an increase of 26 per cent from its preindustrial level. Atmospheric concentrations of the main ozone-depleting gases have increased by between 25 per cent and 200 per cent in the 15-year period between 1975 and 1990.

107. In spite of new international agreements among the nations producing most of these pollutants to limit their emissions, global emissions are still rising steeply at the present time. World carbon dioxide emissions from fossil fuel consumption and cement manufacture increased nearly four-fold from 6,000 tonnes per year to 22,000 tonnes between 1950 and 1989.

Country	Total CO_2 production	Estimated proportion of CO_2 output (%) from:		
	(000 tonnes)	Construction industry	Cement manufacture	Building use
India	651, 936	17.5	3.2	18
Argentina	118,157	7.6	1.9	39
Kenya	5,192	11.9	11.7	25
Germany	641,398	11.8	2.1	51

Table 11. Carbon dioxide emissions for selected countries, 1989, and the estimated contribution from construction, cement manufacture, and building use. (Sources: World Resources Institute, 1992, Wells, 1986)

108. Construction activity, particularly the manufacture of energy-intensive materials, make a significant contribution to carbon dioxide emissions. An estimated 8 to 20 per cent of these emissions in different countries are due to construction and building materials production activities, and a further 2.5 per cent globally results from the chemical reactions taking place in cement and lime production. Examples for four selected countries are shown in Table 11. A further enormous contribution to global emissions results from the energy consumption of buildings in use, up to as high as 50 per cent in northern industrialised countries.

109. Construction activity also contributes significantly to the ozone-depleting gases, as well as to unsustainable levels of other forms of local and regional atmospheric pollution. This chapter therefore examines the ways in which construction activity contributes to atmospheric pollution and the means to reduce it.

III.2. Levels of pollution

110. The pollutant emissions associated with construction arise primarily from the combustion of fossil fuels and are, thus, a product of energy use in the manufacture and transport of building materials and in building operations on site. Some non-energy related pollutants also arise from the industrial processes involved in the production of certain materials, notably in cement manufacture and in metal refining.

111. Much pollution affects air quality; however, pollution of water is also significant, particularly where drinking supplies may become contaminated.

112. The consequences of environmental pollution are experienced at a number of different levels, summarized in Table 12.

Scale	Horizontal extent	Vertical extent	Typical pollutant
Micro	Local: 1mm-1km	1mm-10m	asbestos
Meso	Regional: 1km-100km	10m-1km	particulate matter
Macro	Continental: 100km-hemisphere	1km-20km	SO_2
	Global	above 20km	CO_2

Table 12. Scales of pollution, their vertical and horizontal extent and typical pollutants. Based on Stern et al. (1973).

113. At the local scale, pollution represents an industrial hazard for workers at the production plant and for residents in its vicinity. Risks may be similar in kind to potential health effects on occupants of buildings in which the material is subsequently incorporated: an example is the well-established relationship between asbestos fibre and lung disease (Curwell and March, 1986). Other substances, while not connected with severe health risks, may have a considerable impact on the quality of life in the immediate area.

114. At the regional level, pollution can affect the mesoscale climate, for example by temperature modification ("thermal pollution") or persistence of suspended particulate matter in the atmosphere. Crops and livestock may become contaminated.

115. Macroscale effects cross national boundaries - for example, the acidification of lakes in Scandinavia by sulphur dioxide pollution carried on prevailing winds. Potentially the most far reaching in its consequences is the phenomenon of global warming, caused by the increasing concentration of so-called "greenhouse" gases in the atmosphere. The predicted extent and impact of this build-up was the subject of the report produced in 1991 by the Intergovernmental Panel on Climate Change. Table 13 indicates the relative contributions made by the principal gases.

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

Table 13. Contributions to greenhouse warming by various gases.
Source: Henderson and Shorrock (1990).

116. Organic compounds such as methane make a considerable contribution to the greenhouse effect. A particular concern is in relation to chlorofluorocarbons (CFCs). Although the volumes of CFC emission are low, they are thought to have a disproportionately high impact on climate; not only contributing to global warming but also speeding the decomposition of ozone in the upper level of the atmosphere (the stratosphere). Ozone at a level below 20km (the troposphere) is itself a contributor to the greenhouse effect.

III.3. Pollution emissions from building materials production processes

117. The pollutant potential of processes themselves can be estimated with reference to the cost to industry in meeting anti-pollution regulations. In 1979, approximately 8 per cent of the cost of clean air to US industry was attributed to the quarrying and construction sector (projection by Holum, 1977). The major pollution generators in this sector were producers of cement, lime and asphalt.

(a) *Cement*

118. The production of cement is a highly energy-intensive process, and thus plays an important part in the generation of "greenhouse" pollutants. There is nevertheless considerable scope both for improvements in the efficiency of production methods, and the substitution for cement of less energy-intensive materials (Spence 1988). Additional carbon dioxide is released during the calcining stage of the process: approximately 0.5 tonne per tonne of cement produced. In 1989, this amounted to 557 million tonnes of carbon dioxide, over 2.5 per cent of total carbon dioxide emissions. In some countries, the proportion is much higher - in some West African countries including Togo and Benin, cement production accounts for more than 30 per cent of carbon dioxide emissions (World Resources Institute, 1992).

119. Furthermore, the cement production is frequently a source of airborne particulates. These are generated by the calcining process itself and also in the quarrying, transportation and crushing of limestone to feed the kilns (Awadalla and Yagi 1988).

(b) *Clay brick*

120. The case of the brick industry is interesting in the contribution made to pollutant emissions by constituents of the raw material. In the Fletton brick industry in the UK, carbon compounds in the extracted clay provides 70 per cent of fuel required for firing. The possible impact of primary fuel substitution is, therefore, limited.

121. Elsewhere, however, brick clays typically contain a very low proportion of organic matter, and consequently have a much higher requirement for additional fuel. Powdered coal and other organic substances used as additives to the clay mix can be used to reduce this: Rai (1986) gives an example where a saving of up to 75 per cent in the use of coal for firing has been achieved.

122. A reduction in pollutant output is not automatically achieved by economy in the use of purchased fuels. Table 14 shows energy consumption and estimated carbon dioxide emission for various fuels used in brickworks in the Delhi area.

Fuel	Energy consumption	CO_2 emission	
	MJ/brick	g/MJ	g/brick
Coal	3.9	88	0.34
Coal (70 per cent) and fuelwood	4.8	85	0.41
Rice husks	4.4	72*	0.32
Sawdust	6.4	82*	0.52

*Table 14. Fuel use and estimated CO_2 emission for examples of brickmaking in the Delhi region. *Estimated from calorific value of fuel given by Gandhi (1986).*

123. Efficient modern production techniques may have considerable benefits in terms of pollution, while limiting possibilities for fuel substitution: problems with incomplete combustion and unreliable supply of unconventional fuels may preclude their use (Gandhi 1986). However, many energy-efficient processes require relatively high volume production, leading to increases in the energy and pollution cost of transport from centralized plants.

(c) *Polyurethane foams*

124. There are particular pollution problems, not directly related to energy use, which are associated with certain insulation materials. However, since materials of this kind have an important part to play in reducing energy demand for space heating and cooling, it is relevant to consider their "embodied pollution" cost.

125. Chlorofluorocarbons (CFCs) are used as blowing agents in the production of polyurethane foams - this accounted for 5 per cent of CFC use in 1985.The phasing out of CFCs is discussed in Section 4.5. Replacements are available in forms of insulating materials such as mineral wool which do not require blowing agents . Alternatively, expanded plastics can be produced by other techniques, for instance entrained carbon dioxide. However, a greater thickness of these insulants is required, and there are some situations, for example when rain penetration is likely, for which there are currently no realistic alternatives to extruded plastics produced with CFCs.

(d) *Steel*

126. The iron and steel industry is a major consumer of energy: in Belgium, for example, this sector accounts for 15 per cent of national energy demand (UN Economic Commission for Europe, 1981). Efficiency of fuel use varies greatly depending on the type of processes used for the production of pig-iron and then steel, the proportion of scrap iron used in the steel-making process, and other factors.

127. A correspondingly wide range of fuels can be used: solid fuels predominate in the pig-iron production stage, while oil and electricity are most important in steel-making processes (UN Economic Commission for Europe, 1983). Electric-arc furnaces are an energy-efficient technology, but as shown by Table 16 the use of electrical energy has a high cost in terms of CO_2 emissions. There is considerable potential for fuel substitution.

128. Large quantities of waste products are generated from steel production: nearly 60 per cent by mass of the steel output has been estimated for German production (UN Economic Commission for Europe, 1981). The bulk of this is solid matter such as blast furnace slag, which can be utilized in the construction and civil engineering industries - for example as roadstone and aggregate.

(e) *Aluminium*

129. The production of aluminium is the most energy-intensive process used in the production of a common building material. Over 70 per cent of energy used in the industry is in the form of electricity. The Hall-Heroult electrolytic process used for smelting of alumina derived from bauxite ore is a specific use of electricity which, in the case of some countries, accounts for a large percentage of all generated power (44 per cent in Iceland: OECD 1983).

130. Mining, transportation and grinding of the ore are also energy-consuming processes. On the local scale, the winning of bauxite results in the creation of large quantities of "red mud" slurries (Butcher 1982). The smelting process releases gaseous products such as fluorides, sulphur dioxide and carbon oxides. Depending on the type of process used, these contaminants can be removed from gas emissions with an efficiency of up to 99 per cent (International Primary Aluminium Institute 1982).

131. The high proportion of fuel use in the aluminium industry provided by electricity suggests that CO_2 output is exceptionally high. However, about 51 per cent of the total electricity requirement of the world aluminium industry is provided by hydro-electricity. In some regions it is a much higher percentage: 100 per cent in South America and 83 per cent in Africa (Heindl 1980). It is likely therefore that - unit for unit - the generation of electricity for aluminium smelting results in less pollution than the generation of electricity overall.

132. Furthermore, a considerable proportion of aluminium demand is supplied by recycled material: over 20 per cent in developed countries, and as much as 70 per cent in the UK. The smelting of recycled or secondary aluminium consumes only one fifth as much energy as primary aluminium.

133. An additional saving in energy use may be offered by technological advances in the production process for primary aluminium. For example, the introduction of a process in which aluminium is smelted directly from bauxite could reduce energy demand by 25 per cent (Butcher 1982, Cochran 1987). The high proportion of energy costs in the production process gives the major manufacturing companies a great incentive to explore such possibilities.

(f) *Glass*

134. Glass production requires high temperatures to be attained in glass melting furnaces and subsequently in the formation of glass products. Modern installations make use of a large proportion of recycled energy for preheating input materials, and generating electricity for use in the process, reducing primary energy requirements to around 6000 MJ/tonne (Williams 1989).

135. There is considerable scope for fuel substitution in glass production. Furnace design can be adapted for various fuels - many are already designed for dual use, for example gas and oil. A survey of fuel use in European glass industries in the 1960s showed a wide divergence in fuel mix between countries: coal was predominantly used in Hungary and the UK; oil in France, Spain and Norway; gas in the USSR (UN Economic Commission for Europe, 1967). There has undoubtedly been a general shift towards the use of natural gas supplies in recent years for many of these countries. However, brown coal is still used in the Czechoslovakian glass industry for 35 per cent of furnace fuel (Williams 1987). Electric furnaces have been developed in order to use hydropower supplies in countries such as Switzerland, Sweden and the US. This requires the manufacturing process to be adapted to the use of electricity as fuel, but gives the potential of glass manufacture from a clean source of energy (Doyle 1979).

136. Local pollution effects of glass production include the emission of sulphates and carbonates in flue gases. Particulate emission may include glass particles. The use of red lead as a flux in the production of special glasses may also give rise to pollution problems from lead compounds.

(g) *Asbestos*

137. Asbestos is a naturally-occurring silicate mineral which is mined in a number of forms, including chrysotile, amosite and crocidolite (white, brown and blue asbestos). Energy-intensity for quarrying and processing is, therefore, similar to other naturally-occurring minerals and aggregates, and so macroscale pollution due to energy-use in this industry is relatively low. The use of asbestos fibre as reinforcement in a matrix of cement, bitumen or polymer enables composite materials to be produced which compare favourably with alternative materials such as metallic roofing sheets.

138. Pollution problems result from the release of asbestos particles during processing. Health risks associated with the mining and handling of asbestos have been recognized since the late 19th century. Inhalation of asbestos particles can cause pulmonary fibrosis, lung cancer and other carcinomas such as peritoneal mesothelioma. While these health risks are of greatest concern in relation to asbestos industry workers, there are also risks to the workers' families and the general population in the vicinity of asbestos works (Curwell and March 1986).

139. Risks can be reduced to workers by protective clothing and safety-conscious procedures in the processing of asbestos and production of asbestos products. The more friable types of asbestos, crocidolite and amosite, are considered potentially more harmful than chrysotile. Risks to the inhabitants and users of buildings which incorporate asbestos products are dependent on the likelihood of the material being subject to processes of degradation which will release asbestos fibres. Such processes include weathering, attack by "aggressive" water, abrasion during maintenance, and disposal of the material. It is important that asbestos products are identified as such in order to minimize the risks of careless damage or disposal.

III.4. Pollution emissions from site operations

140. In addition to the pollution arising from the fossil fuel consumption associated with site operations, these site operations have a considerable impact on the local environment during the construction period. Potential problems include:

- Noise pollution. In most cases a temporary nuisance, this can lead to hearing loss in those subjected to high levels for long periods of time. Site workers are particularly at risk.
- Emission of pollutants from materials being worked. Hazardous substances may be released during site operations when the integrity of a materials is disrupted, for example the cutting or drilling of asbestos cement sheets (Awadalla and Yagi 1988).
- Accidental spillage of materials or careless disposal of waste. This directly increases the total energy content of materials required to complete a project. It may also cause considerable harm to the local environment: for example, the discharge of cement slurry into watercourses. Burning of waste materials is a source of carbon dioxide and particulates, and may release quantities of noxious chemicals in an uncontrolled manner.

III.5. Pollution consequences of buildings in use

141. One of the most significant pollutions caused by the buildings in use is the use of refrigerant chemicals, including chlorofluorocarbons (CFCs). The 50 signatories to the 1987 Montréal Protocol and subsequent Declarations (in Helsinki and London) are committed to phasing out 15 CFCs by the year 2000, including the common refrigerant R12 (dichlorodifomethane). Current research is concentrated on investigating replacements such as R134a.

142. Until suitable substances with a low ozone depleting potential become widely available, there are several approaches which will limit the release of CFCs from building systems:

- building design to reduce or eliminate reliance on cooling plant or air conditioning;
- measures to limit CFC release during servicing and maintenance of plant;
- use of alternative refrigeration technologies, for absorption cooling using ammonia or lithium bromide;
- use of alternative desiccant technologies, incorporating silica gel, calcium chloride etc. to improve comfort by dehumidification.

III.6. Means to reduce atmospheric pollution caused by construction activities

143. Since most of the pollution resulting from construction activity is the result of fossil fuel burning, the principal means of reducing pollution is through increased energy-efficiency in all activities. All the ways of improving energy efficiency discussed in Chapter II will reduce pollution as well. Preceding sections have indicated some additional specific pollution-reducing possibilities in particular building materials industries. Further opportunities for pollution reduction in site operations, in transport, and through fuel substitution are discussed below.

(a) Site operations

144. The principal means for reducing atmospheric pollution resulting from site operations are:

- ○ Improving site management efficiency to reduce local sources of pollution such as noise, dust, smoke and release of hazardous materials such as asbestos;
- ○ Reduction of the quantity of site wastes produced through careful delivery schedules, off-site prefabrication, avoidance of accidental damage;
- ○ Systematic separation of all unavoidable construction wastes, to facilitate recycling.

145. All these are matters of site management efficiency, which are increasingly being taken seriously by larger contracting firms in some industrialised countries (CIRIA, 1992; Science Council of British Colombia, 1991). But there is considerable scope for management training to improve performance in all these areas. In some cases, two other options are worth considering: fuel substitution to lower CO_2 outputs associated with a fixed energy consumption; and selective use of human or animal labour in place of mechanical energy.

146. Opportunities for fuel substitution in the use of site equipment are relatively limited: many energy-consuming activities, such as lighting and control of mechanical equipment, are specific uses of electricity for which there is no practical alternative fuel. However, it can be argued that where electricity is generated on site, the primary consumption of energy is less than when the electricity supply is from a mains source - since transmission losses are reduced.

147. In some cases, possibilities may exist for the use of human or animal labour in place of mechanical energy to minimize overall fuel consumption. Operations in which this may be considered include excavation, mixing of materials and transport of components within the site. Low-rise buildings, and those using tradition technologies and relatively small components (e.g. bricks rather than precast concrete wall panels) are most suited to this approach.

(b) *Transportation options*

148. The means of transport is also important: figures in Table 15 suggest that approximately 4 times as much carbon dioxide is emitted by the transportation of a load by road than the equivalent journey by rail or water. Airfreight pollution, per unit weight, is greater by a factor of ten.

149. Emissions from road transport are a major cause of photochemical smog, of which the main components are carbon monoxide, nitrogen oxides hydrocarbons and ozone released by the action of sunlight on organic compounds in the lower atmosphere. An additional source of pollution is dust thrown up from unmetalled roads, and the rubber particulates produced by erosion of vehicle tyres (Hodges 1977).

	grammes per tonne.km			
Emission	Rail	Water	Truck	Air
CO_2	50.00	53.00	220.00	3200.00
CO	0.07	0.08	1.58	22.94
NO_x	0.22	0.02	3.60	2.55
SO_2	0.33	0.02	0.23	0.00
Hydrocarbons	0.05	0.02	0.81	11.76
Particulate matter	0.03	04.00	0.27	3.92

Table 15. Pollutant emissions for various freight options. Based on Hodges (1977).

150. Because of their bulk, and the large quantities moved, building materials brought to site contribute very significantly to the total pollution emissions from transport. It has been estimated that transportation of aggregates alone contributes about one-quarter of all the carbon dioxide emissions due to industrial, commercial and public sector use of road transport in the UK, about 3 million tonnes per year.

151. One way to reduce the use of energy, and the production of pollutants, through transportation is through the establishment of smaller plants nearer to the point of use. But the benefit of this may be offset by the fact that smaller scales of production often require larger amounts of energy, and therefore produce more pollution per unit of output, than larger scales. Studies have shown that the net advantage is more likely to lie with small plants manufacturing for local production when

- the process energy costs are low (sand, earth, timber-based materials);
- transportation is by truck - particularly energy-intensive in hilly country or where roads are poor;
- the demand per head of the population is low;

- population density is low;
- the material has low value for weight.

152. Figure 2 illustrates these arguments by the example of cement production. It shows that when there is a choice of two methods of production at different scales, the best choice in order to minimise overall pollution emissions can be calculated from the *consumption density* of the material, the *average transportation distance* from the production plant to site, and the *mode of transport used.* In a situation like rural Tanzania, where demand is low, where population is scattered, and where roads are poor and truck transportation very costly in energy and pollution terms, it is possible for the total energy and pollution to be considerably reduced if production is scattered in small-scale plants to reduce transportation distance. The argument for reducing transportation costs is strengthened where poor roads lead to damage and wastage of the materials in transit.

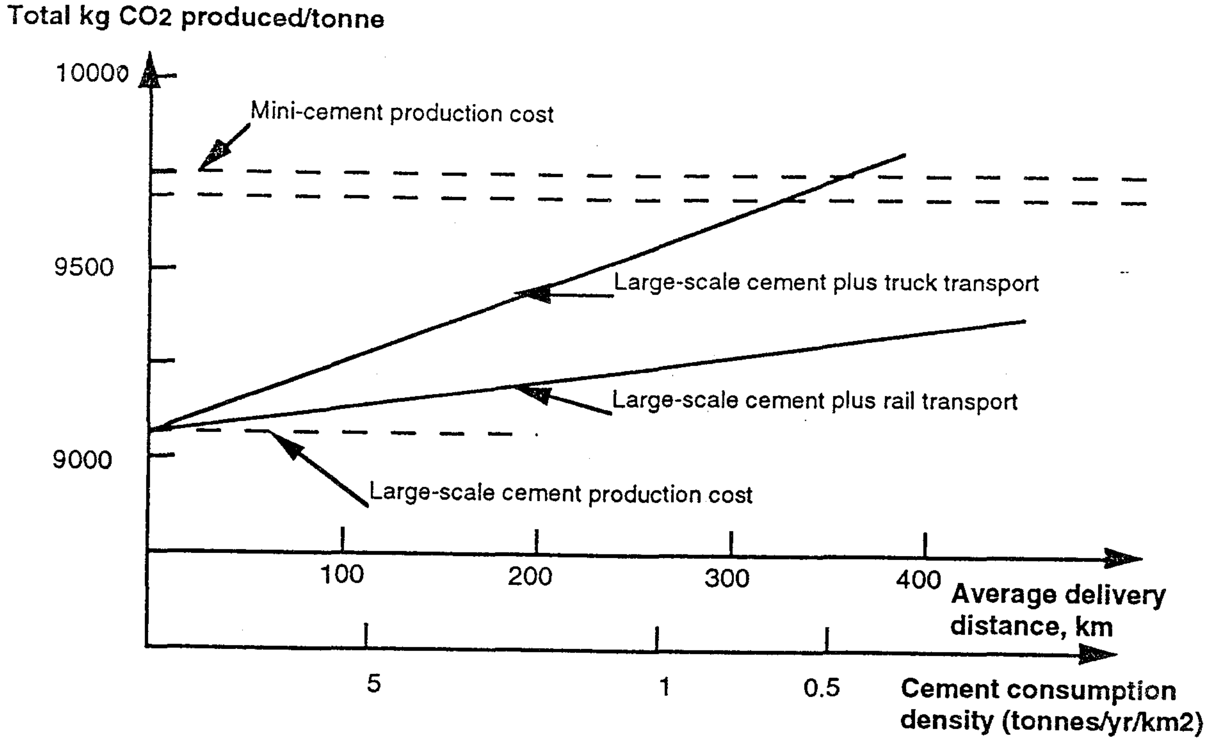


Figure 2. Pollution implications of the choice between small-scale and large scale plants for cement production.

(c) *Options for fuel substitution*

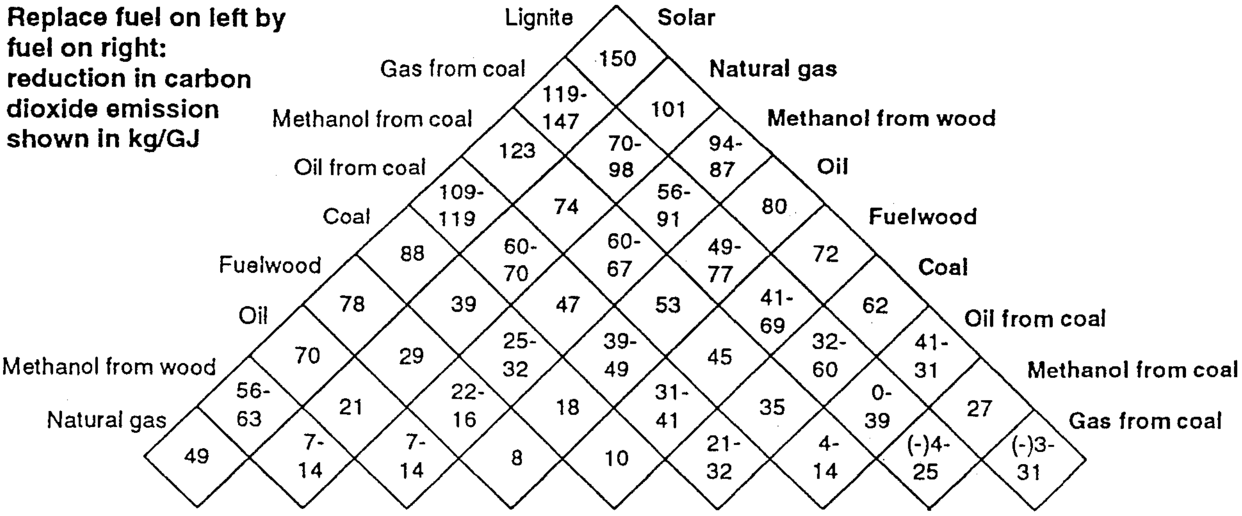
153. The greatest contribution to global warming is made by carbon dioxide, released in the burning of fossil fuels and timber. The actual emission to produce a given quantity of energy is dependent on the fuel used: typical values for the UK are shown in Table 16, although the figure for electricity is a function of the mix of fuels used in the generating industry, which varies over time. Despite the relatively high emissions of carbon dioxide - and other pollutants such as sulphur dioxide - per unit of delivered energy in the electricity supply industry, the fact that these emissions are highly localized means that control is technologically feasible although (in the case of carbon dioxide) expensive at present.

154. A greater reliance on hydropower and/or nuclear fuel would reduce the ratio of carbon dioxide emission to delivered energy. However, such a trade-off would undoubtedly have other environmental impacts (WCED 1987). In the case of nuclear fuel, potential hazards include the accidental release of radioactive contaminants affecting very large areas, as in the Chernobyl disaster of April 1986. The likelihood of such events is difficult to quantify with any degree of accuracy, and many possible effects -for example on genetic material - are poorly understood.

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

Table 16. Carbon dioxide emissions from various fuels: figures for delivered energy include overheads of generation and distribution.
Source: Henderson and Shorrock (1990).

155. The effects on carbon dioxide emissions of other possible fuel substitution are shown in Figure 3.



Replace fuel on left by fuel on right: reduction in carbon dioxide emission shown in kg/GJ

	Solar	Natural gas	Methanol from wood	Oil	Fuelwood	Coal	Oil from coal	Methanol from coal	Gas from coal
Lignite	150	101	94-87	80	72	62	41-31	27	(-)3-31
Gas from coal	119-147	70-98	56-91	49-77	41-69	32-60	0-39	(-)4-25	
Methanol from coal	123	74	60-67	53	45	35	4-14		
Oil from coal	109-119	60-70	47	39-49	31-41	21-32			
Coal	88	39	25-32	18	10				
Fuelwood	78	29	22-16	8					
Oil	70	21	7-14						
Methanol from wood	56-63	7-14							
Natural gas	49								

Figure 3. Reductions in CO_2 emission by fuel substitution. Based on Kellogg and Schware (1984): data from a number of US and European sources.

III.7. Future policy implications

156. Key policies for the construction industry for limiting future atmospheric pollution will be:

- increasing the energy-efficiency, by all the means described in Chapter II;
- encouraging use of renewable energy sources;
- examining opportunities for fuel substitution;
- examining opportunities for fuel substitution in the electricity supply industry, making greater use of renewable energy sources; wind turbines, solar furnaces, photovoltaics etc. Other "clean" sources such as hydro and nuclear power should be assessed on their total likely environmental impact;

- consideration of energy efficiency relative to pollutant output in addition to cash cost: use of free fuel may lead to an increase in pollution;

- local building materials production.

157. Key policies for governments to promote or support industry-based policies include:

  - improving energy-efficiency and emission standards for all construction-related processes and products;

  - actions to comply with the Montréal Protocol and the International Convention on Climate Change;

  - publishing information on pollutant consequences of alternative fuels, and techniques of life-cycle costing in relation to pollutant emissions.

158. In addition, governments can introduce economic incentives to reduce pollution emissions by assisting the industry to acquire technology and know-how for reducing their emissions without increasing the cost of products for the enduress.

CONCLUSIONS

159. Previous chapters have established that construction activities are causing, or contributing significantly to, many of the present processes of deterioration of the natural environment, in particular to:

- loss of soil and agricultural land;
- loss of forests, woodlands and wildlands;
- increases in freshwater and coastal pollution;
- increases in atmospheric pollution at local, regional and global scales;
- depletion of the earth's non-renewable resources.

160. But continued and increasing levels of construction activity are essential to all aspects of development; and indeed only by raising living standards generally will it be possible to reduce or eliminate many of the currently most serious types of environmental deterioration. Poverty is one of the principal causes both of rapid population growth, and also land degradation and loss of the tropical forests.

161. To ensure a sustainable future, it is therefore neither feasible nor desirable for the total level of construction activity overall to be restricted, although in the industrialised countries there may be strong arguments for reducing activity by reusing existing buildings rather than building new ones. In other cases, it is difficult to conceive of construction activity which does not result in some irreversible changes in the natural environment. But sustainable development does not need to imply a complete halt to irreversible change in the natural environment. Economists argue that one essential aspect of sustainable development is that *the world's total stock of 'capital', natural plus man-made capital, should not diminish over time.*

162. Some conversion of natural into man-made capital is clearly acceptable within this definition. Construction of a dam, for example, reduces the existing natural capital of the region in many ways - through forest clearance, quarrying of construction materials, changes in water run-offs and sediment loads, changes in human and wildlife habitats and other ways - but it also creates a lasting asset, which can provide power, irrigation water and other benefits for the immediate future and, if well-designed, for a long time into the future. Similarly, the construction of housing and other buildings uses natural capital - through quarrying, land-conversion, the creation of atmospheric pollution and so on - but compensates for this by increasing the stock of man-made capital which will be passed to future generations. And the materials of which these fixed capital assets are made is still available, though in a less useful form, for reuse in the future. Thus man-made capital is created to compensate for the loss of natural capital.

163. Given the nature of the construction industry which is fragmented, multisectoral and rather complex in character, changes can not be expected to happen in a speedy manner. However, all initiatives will involve changes in technology, commitment towards preserving the natural resources, mitigating the environmental degradation and special investment programmers within the industry: but many of these inputs are unlikely to come about without required stimulus from outside the industry. Therefore, communities, local and national governments, decision makers, international agencies and any other actor involved in the construction sector should be committed to take such measures which would ensure the sustainability of the construction activities, thus, leading to overall social and economic development in all countries.

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