TECHNISCHE UNIVERSITÄT WIEN

VIENNA UNIVERSITY OF TECHNOLOGY

Dissertation

Nachhaltige Bauindustrie, Baupraxis und Gebäudebetrieb:
Die Rolle des Facility Managers

ausgeführt zum Zwecke der Erlangung des akademischen Grades
Doktor der technischen Wissenschaften

unter der Leitung von
Univ. Prof. Dipl.-Ing. Dr. techn. Ardeshir MAHDAVI
Institut für Architekturwissenschaften
Abteilung für Bauphysik und Bauökologie

und
unter der Betreuung von
O. Univ. Prof. Dipl.-Ing. Dr. techn. Hans Georg JODL
Institute für Interdisziplinäres Bauprozessmanagement

eingereicht an der
Fakultät für Bauingenieurwesen

von
Dipl.-Ing. Alireza GHAEMI
Matrikel Nr.: 8026356
Wildgänsegasse 2/1
A-1210 Wien
Österreich

Wien, November 2007

TECHNISCHE
UNIVERSITÄT
WIEN

VIENNA
UNIVERSITY OF
TECHNOLOGY

PhD Thesis

Sustainable building industry, construction practices and building operations:

The role of the Facility Manager

produced for the purpose of obtaining the academic degree of
"Doctor in Technical Sciences"

under the leadership of
Univ. Prof. Dipl.-Ing. Dr. techn. Ardeshir MAHDAVI
Institute for Architectural Sciences
Department of Building Physics and Building Ecology

and
under the guidance of
O. Univ. Prof. Dipl.-Ing. Dr. techn. Hans Georg JODL
Department of Interdisciplinary Building Process Management

submitted at the
Faculty of Civil Engineering

by
Dipl.-Ing. Alireza GHAEMI
Matrikel No: 8026356
Wildgänsegasse 2/1
A-1210 Vienna
Austria

Vienna, November 2007

In Erinnerung an meine verstorbene Gattin
Frau Dr. Susanne Ghaemi-Winkler
widme ich diese Arbeit meinen beiden Söhnen
Arian und Artin

In the memory of my late wife
Dr. Susanne Ghaemi-Winkler
this work is dedicated to my sons
Arian and Artin

Kurzfassung

Die Bauindustrie, in ihrem gesamten Umfang, leistet weltweit signifikante Beiträge zur wirtschaftlichen Entwicklung in jedem Land. Jedoch, während, diese Industrie, als Vervielfachungsfaktor der sozialen und wirtschaftlichen Entwicklung dient, verbraucht sie auf der einen Seite, die natürlichen, nicht erneuerbaren Vorräte des Planeten unnachhaltig und ist auf der anderen Seite, der Hauptverschmutzer unserer Umwelt und die Ursache für globale Sorgen, wie Dezimierung von natürlichen nicht erneuerbaren Energiereserven, sowie Luftverschmutzung und der daraus resultierenden Klimawandel und Erderwärmung.

Zahlreiche Studien haben ergeben, dass beispielsweise, der Anteil des Gebäudebetriebes an CO_2-Emissionen in vielen industrialisierten Ländern über 50% der Gesamt-CO_2-Emissionen aus allen Industrien samt motorisiertem Verkehr ausmacht. Auf Grund derzeitiger Herausforderungen, die als Resultat von regionalen und globalen Umweltschäden und Luftverschmutzung die Erde konfrontieren, sind, jetzt, rigorose Maßnahmen notwendig, so dass die nächsten Generationen der Heutigen keine Nachlässigkeit vorzuwerfen haben.

Es wird davon ausgegangen, dass durch Modifizierung der heutigen Vorgangsweisen, Technologien und wichtiger noch, durch Verlagerung der traditionellen Entscheidungsprozesse hinzu Umweltbewusstsein, die Bauindustrie sich allmählich in Richtung der Nachhaltigkeit bewegen könnte, wie zahlreiche Agenda, Conventionen und Abkommen der Vereinten Nationen definieren.

Tatsache ist, dass durch gigantische Investitionen und Erschaffung von großen Gebäudekomplexen, wie z.B. Bürogebäude, in den letzten Jahrzehnten, eine Substanz von Baulichkeiten entstanden ist, die den heutigen Erwartungen und Anforderungen speziell im Bezug auf den Umweltstandards, Gesundheit und Sicherheit, nicht gänzlich gerecht wird.

In diesem Zusammenhang, kann die Rolle des Facility Managers zur Erreichung der obgenannten Ziele nicht oft genug betont werden, insbesondere bei großen Gebäudekomplexen, die vor 3-4 Jahrzehnten gebaut worden sind. Nahezu alle diese Gebäudekomplexe, die in den letzten 5 bis 10 Jahren keiner wesentlichen Renovierungs- und Sanierungsarbeiten unterzogen worden sind, brauchen dringende Verbesserungsmaßnahmen, sollte effektive Nachhaltigkeit im Bezug auf Umwelt und Energieeinsatz erreicht werden wollen. Faciltiy Manager von solchen Gebäuden könnten die Entscheidungsprozesse eingehend Beeinflüssen, wenn es um die effektive Integration

von ökologischen und ökonomischen Richtlinien und Durchführungsstrategien zur Erreichung der neuen Ziele geht.

Des weiteren, genaue Informationen und Daten im Bezug auf Nutzerverhalten in großen Bürogebäuden sind wichtige Faktoren zur Optimierung der Verwendung von Medien und Energie. Facility Management's Planungen und Strategien können nicht in Isolation durchgeführt werden. Die Art des Verbrauches verschiedener Medien durch die Belegschaft solcher Gebäude muss immer berücksichtigt werden.

Dafür ist die Sammlung von Informationen und Daten und deren Auswertung und Analyse als Eingangsparameter für die Planung und Implementierung, unabdingbar. Es ist nachweisbar, dass dadurch, erhebliche Einsparungen sowohl umweltbezogene als auch kostenmäßige im Verbrauch von Medien erreicht werden können. Mit anderen Worten, Nutzbarmachung von Informationen, sowie Beiträge anderer Beteiligter sollen die Eckpfeiler der Durchführung von umweltrelevanten Modernisierungsprojekten in großen Bürogebäuden sein.

Abstract

The building and construction industry, in general and globally, is one of the significant contributors to the overall economic development in every country. However, this industry, while having a multiplier effect on social and economic development, is on one hand consuming the natural non-renewable resources in a way that it can not be sustainable, and on the other, is a major polluter of the environment and the cause of major concerns on global issues, such as: depletion of natural non-renewable resources, air pollution and resultant climate change and global warming.

Numerous studies have revealed that, for example, the share of building operations to the carbon dioxide emissions in industrialized countries is over fifty per cent of the total carbon dioxide emissions resulting from all industrial activities including motorized transport. In light of the current challenges facing the entire world as a result of regional and global environmental degradation and air pollution, rigorous measures should, therefore, be taken now so that current generation is not blamed by the future ones for its negligence.

It is believed that by modifying the current practices and technologies and, more importantly, by shifting the traditional decision-making processes towards environmental consideration and consciousness, the building and construction industry could gradually approach the goals of sustainability as defined by various United Nations and multilateral Agendas, Conventions, Protocols and/or Treaties.

It is also an obvious fact that through huge investments and creation of large building complexes (e.g. office buildings) over the past few decades, a stock of built environment has been generated, which does not fully meet today's expectations and requirements, particularly when it relates to environmental, health and safety considerations.

In this juncture, the role of facility managers, particularly for large building complexes built 3 - 4 decades ago, in achieving the above-mentioned goals cannot be overemphasized. Almost all of these building complexes that have not undergone any major renovation or refurbishment works in the past 5 to 10 years, need urgent improvements, if the expected sustainability criteria, particularly with regard to environment and energy, is to be met in an effective and efficient manner. In short, facility managers of such buildings could influence the decision-making processes immensely when it comes to the processes of the integration of environmental and

economic policies as well as implementation strategies so that the new goals could be achieved effectively.

Furthermore, accurate information and data on users' behaviors of large office buildings are important inputs for the optimization of the use of resources and utilities (e.g. energy). Facility managers' plans and strategies cannot be implemented in isolation. The way utilities are used by the occupants in such buildings should always be taken into consideration.

As such, collection of information and data and their analysis - to be used as input for planning and implementation purposes - is indispensable. It has been proved that by so doing, considerable savings (both environmentally and financially) in the use of utilities (e.g. electricity for lighting) could be achieved if the above-mentioned issues are taken into consideration by facility managers. In other words, harnessing user information and all other stakeholders' inputs should be the cornerstone for implementing environmental and modernization projects in large office buildings.

List of contents

Part 2

Facility management:
new challenges and opportunities

Part 3

Harnessing user behavior information for building management

Introduction

Building and construction industry and the environment

This work in its part 1 represents a research study on the global impacts of the construction and building industry as well as buildings operations on the environmental resources of the planet.

It describes the current trends, situation and the setbacks of the building and construction industry. It focuses on the consumption patterns of the natural non-renewable resources by the industry and its impact on the environment. It elaborates different approaches and opportunities on how to mitigate the negative impact of the industry on the environment.

Research on facts and problems

The building and construction industry while playing a significant role in economic development in every country, provides, on one hand, direct means to the development and expansion of economic activities and, on the other hand, it is a major consumer of the planet's physical and natural resources and a polluter of the environment.

While having a multiplier effect, the building and construction industry is also one of the most complex industries. The environmental impacts that can arise from the building industry (including operations) are likewise numerous and have a very complex nature.

About 10 per cent of global economy is devoted to construction and operation of residential and office buildings and between 20 to 50 per cent of worlds major resources (energy being the most crucial and polluting one) are consumed by buildings and related industries. Similarly, due to rapid population growth, particularly in the urban areas of fast growing cities, and associated economic development, construction activities are currently growing faster than ever. For example, the total consumption growth in the global construction sector increased by 4.6 per cent from 2003 to 2004 and is expected to exceed 5 per cent annually over the next few years.

For example, unsustainable use of forest timber for construction purposes, which contributes to the loss of forests (particularly tropical forests), extensive use of some metallic minerals such as copper, lead and zinc, which have limited remaining exploitable reserves (between 30 and 60 years), excessive use of fossil fuel as source of energy, which is the most vital input to construction and construction-related industries (e.g. in cement and/or brick industries), indiscriminate use of agricultural land or eco-sensitive zones for construction purposes in the boundary of the cities, removing coral in coastal areas for production of lime and/or sand and gravel from river beds etc. are all, in one way or another, damaging the natural environment that can not be sustainable.

In addition to the above-mentioned unsustainable consumption of natural resources in the construction industry, the residential and office buildings are consuming enormous amounts of energy for their operations, such as heating, cooling, lighting and other purposes during their life time. This extensive use of energy is not only depleting the planets' fossil fuel reserves, it is polluting the atmosphere in a way that can also not be sustainable.

Studies have revealed that, for example, space heating of the residential and office buildings in most industrialized countries is responsible for more than 50 per cent of the carbon dioxides (CO_2) emissions. Similarly the extensive use of chlorofluorocarbons (CFCs) for refrigeration and cooling the buildings is depleting the atmosphere's ozone layer in a way that is another cause for the global warming and resultant climate change.

Tasks and objectives

This research work further elaborates on required actions to minimize the adverse effects of the building industry and operations on the environment and thereby achieving sustainability of the construction industry and buildings operations.

The study pays special attention on the use of non-renewable resources, e.g. energy, in the industry and proposes actions that could reduce the use of energy in the buildings and construction industry. Due to global concerns related to air pollution and global warming processes, special attention has been paid to this issue.

The above-described brief scenario gives a clear indication that sooner or later the current trends in construction practices and in building industry and operations are bound to change in many countries if a better and or even acceptable living condition for our future generations is to be assured in a sustainable manner.

In light of the above, achieving the goals of sustainable human development and resolving the conflicts between the explosively expanding construction industry and the attendant environmental degradation is not an easy task. It requires the ingenuity and resourcefulness of all stakeholders and modification of current and, to some extend malfunctioning strategies, policies and practices. Significant changes will be needed – in decision making at highest levels, and day-to-day behavior by producers and consumers – if we are to reach our goal of development that meets the needs of today without sacrificing the ability of future generations to meet their needs.

It is also clear that the building and construction industry is essential for overall human development, and indeed only by raising living standards it will be possible to reduce or eliminate many of the currently serious types of environmental degradation.

It can be, however, argued that, while the building and construction industry consumes the natural non-renewable resources and contributes to environmental degradation, it generates a stock of human-created capitals, which will be passed on to future generations. This human made built capital can, in fact, lay the foundations for the developmental efforts of our future generations.

With this in mind and in order to ensure a sustainable future and accelerate the process of human development, it is, therefore, neither feasible nor desirable to reduce the levels of building and construction activities just for the sake of preserving the natural resources.

Methods and approaches

In addressing this challenge, and in resolving the, so-called, conflict between human development and the attendant environmental stress, there is need for a change in attitudes, procedures, processes and technologies. However, given the nature of the construction industry, which is fragmented, multi-sectional and complex, changes cannot be expected to happen by themselves and in a speedy manner. It is only through the commitment of the authorities and all other stakeholders that improvement can take place and a sustainable social and economic development can be ensured every where.

Findings and outcomes

The subject study works out general models, which should be applied in the construction industry to achieve the afor-mentioned goals.

In the spirit of foregoing scenario, some of the fundamental recommendations and possible action areas for architects, builders, building material producers and for the users of the buildings could be, among others, the following:

(a) Design buildings for long life and adaptability using low energy content materials as much as possible,

(b) Improve energy efficiency of the production processes, modify the processes to reduce the use of fossil fuels and make use of cleaner technology in the production processes of the building materials,

(c) Increase the use of recycled and waste materials and refurbish or modernize existing buildings instead of demolishing,

(d) Make every effort to replace the use of non-renewable resources with renewable ones,

(e) Promote eco-efficiency and use passive solar architectural methods to reduce the use of non-renewable resources such as energy,

(f) Use heating, cooling and lighting cautiously and save energy as much as possible,

(g) Encourage policy and decision makers to adopt and enforce polluting control measures in the building industry. This can stimulate the industry to use cleaner technologies instead of old and energy intensive ones.

Facility management: new challenges and opportunities

In its part 2 the work elaborates on deficiencies in the ways buildings and particularly large office buildings are operated and develops ways, means and practical models for facility managers to contribute their part to the preservation of the environment and energy resources and thereby to the sustainability of the operations.

This part, while outlining the distinction between traditional and modern facility management practices and approaches, is making attempts to emphasize how important it is to integrate the economic and environmental policies in decision-making processes. It further elaborates on the role of the facility managers, in light of the new and most challenging tasks, that are based on environmental considerations and new policies. Finally, this part describes a number of practical measures that are based on author's own initiatives and experience. Specific and action oriented recommendations are also proposed on how to improve the operations and functions of facility management.

Facts and problems

Evidence has shown that until recent years, the practices and systems of decision-making in the management of many large-scale complexes and facilities (e.g. large office buildings) have tended to separate economic and environmental factors at the policy, planning and implementation levels.

This had influenced the actions of all groups involved in managing such facilities and has had important implications for the efficiency and sustainability of facility development, operations and overall management.

Tasks and objectives

The experience of the past couple of years has shown that facility management can be very influential in mitigating the negative impacts of the buildings and the construction practices on the environment.

An adjustment or even a fundamental reshaping of decision-making, in the light of facility-specific conditions, would be necessary if environment and facility management and/or development are to be put at the center of economic and environmental decision-making and in effect achieving a full integration of these factors.

The facility managers of large-scale buildings have to undertake changes in their institutional structures in order to enable more systematic consideration of the environment when decisions are made on economic, fiscal, energy, and other policies, as well as the implications of policies in these areas for the environment.

Methods and approaches

New forms of dialogue has to be developed for achieving better integration among service providers, governing bodies, scientists and environmental specialists in the process of developing effective approaches to environment and facility management. The final responsibility for bringing about changes lies, however, with the facility managers in collaboration with the governing bodies, all other stakeholders and the users of these facilities.

In this context and in order to improve the decision-making processes in any facility, large or medium in size, facility managers should, among others:

(a) Adopt such policy frameworks that reflect a long-term perspective as the basis for decisions, taking account of the linkages between and within the various economic and environmental issues involved in the facility management,

(b) Establish ways and means to ensure the coherence of economic and environmental policies and instruments, including fiscal measures and the budget. These mechanisms should be applied at various levels and should bring together all interested parties in the decision-making processes,

(c) Monitor the facility management processes and procedures systematically and conduct regular reviews of the potential of the human and financial resources and the state of the environment. This could be complemented by annual environment and development reviews, with a view to assessing the sustainability of the facility functions and its management practices,

(d) Adopt flexible and integrative planning approaches that allow the consideration of multiple goals and enable adjustment of changing needs.

Findings and outcomes

The work introduces, analyses and discusses new and concrete models and the methods for coping with the described challenges. It justifies and proves the positive effects of these models on the environmental, economical and social aspects of the operations of large office building complexes.

Harnessing user behavior information for building management support

The study in its part 3 works out analytical methods applied on the interaction between user control behavior in the offices of a large office building complex and its impact on the energy, costs and thereby environmental aspects and the saving potentials of appropriate reactions to those behavioral patterns.

Facts and problems

Facility management cannot function in isolation. Likewise any policy issue and/or decision-making, even at highest levels, for the improvement of the functions of the buildings, as described in Part 2, cannot be dealt with unilaterally. Users of buildings, particularly large office buildings, are those who by spending 8-10 hours of their daily life inside their offices, can optimally assess the indoor environment of their offices, which could provide the correct inputs to the facility managers in their efforts to improve the functions of the buildings and facilities.

Evidence shows that despite increased awareness creation campaigns and global call on environmental issues such as climate change, etc., there are still individuals working in large office buildings who pay very little or no attention to the importance of saving energy. They do this perhaps even at their own houses, let alone in the offices where they work. They take the supply of, for example, artificial lighting or heating in their offices as granted and do not care about their wastage. In short, they are those who abuse the services provided to them in their offices by negligence and in order to combat this adverse trends and habits, facility mangers of such buildings are facing yet another challenge.

One way of tackling this problem (in addition to awareness creation) is to explore the possibility of using research and application of its results. If, for example, the users of the offices forget to, or do not, switch off the office lights when they leave their offices, then let technology do it. If sufficient daylight is penetrating into the offices and the ambient illuminance is adequate, let technology switch off the lights as long as the illuminance is satisfactory.

Tasks and objectives

The indoor environment consisting of: indoor air quality, such as temperature, humidity ventilation as well as lighting are the main features of any office that have to be adequate and have to meet the requirements and expectations of the majority of the occupants. Notwithstanding the fact that the facility managers may also be in a position to assess the situation and identify the shortcomings, the information and data provided by/from the users are the most important and effective ones that could substantially contribute towards any major decision-making for modification and refurbishment of the office buildings.

Methods and approaches

Various types of data such as: indoor air temperature, humidity, illuminance of the lights, occupancy of the offices, as well as outside parameters such as temperature, humidity, wind speed, global illuminance and irradiation, frequency of the use of the window shades, etc. were collected.

Findings and outcomes

The collected data were analyzed, compared and the results used to find out how the indoor environment of the offices, in particular, the lighting situation could be optimized/improved and in terms of energy-use how can they be made efficient. The results revealed that a saving of up to 70 per cent electrical energy for lighting could be achieved if appropriate measures were taken.

Furthermore, in order to utilize the user assessment and information for improving the indoor climate of any large office building the following general measures should be pursued by facility managers:

(a) Pay attention to each and every request or complain coming from the users and make every effort to understand the specific needs of the users for future improvement,

(b) Conduct regular surveys to enable making accurate and reliable assessment of the situation for future improvement purposes,

(c) Take into consideration that over the past 10 –15 years considerable changes in the type of workplaces in every office have taken place and computers and monitors have replaced the typewriters and papers on the desks. In this context, take special measures to upgrade the lighting conditions of the offices.

(d) With due consideration to the technological changes over the past 1-2 decades, make every effort to persuade the decision-makers and funding-authorities to provide funding for the modernization of the offices in order to make them healthy and environmentally sound working places for the employees.

Part 1

Building and construction industry and the environment

1. The impact of the building and construction industry on the environment

1.1 Overview and problem description

Over the past 25 to 35 years, the environmental impact of human activities has grown dramatically due to sheer increase of world population, excessive consumption of natural resources, changes in lifestyle, technological changes and industrial activities. Thus, the environmental concern of today reflects developments of the past 3 to 4 decades. During this period, the appearance of environmental problems, changes in public awareness, as well as national and international trends have profoundly affected the direction of human development.

The building industry while playing a significant role in economic development in every country, provides, on one hand, direct means to the development and expansion of economic activities and, on the other hand, is a major consumer of the planet's physical and natural resources and a polluter of the environment. According to a study, one-tenth of global economy is devoted to construction and operation of residential and office buildings and one-sixth to one-half of the worlds major resources (energy being the most crucial and polluting one) are consumed by buildings and related industries (1).

While having a multiplier effect, the building and construction industry is also one of the most complex industries. The environmental impacts that can arise from the building industry (including its operations) are likewise numerous and have a very complex nature. There is growing awareness that more must be done to mitigate or avoid the major environmental problems that the building and construction sector activities generate. One element of ensuring and maintaining sustainability in this sector is assuring adequately environmental protection from degradation that could be associated with the buildings and related activities.

Unsustainable use of forest timber for construction purposes, for example, contributes to loss of forests which are valuable natural assets. Tropical hard-wood (which often is produced in an unsustainable manner) is consumed in a way that causes deforestation affecting the eco-system. Studies have revealed that the rate of tropical deforestation in Asia and Pacific region in early 2000s was over 1.8 million hectares per year, which shows an increase of over 80 per cent since the early 1970s (2).

Similarly, extensive use of some metallic minerals such as copper, lead and zinc which have limited remaining exploitable reserves, results in disappearance of these metals in the course of next 30 to 60 years (3). Fossil fuel as source of energy, which is the most vital input to construction and construction-related industries, is also used in a manner that threatens the existing reserves of this key non-renewable source. Very large amounts of energy are used in obtaining raw materials, transporting, processing and manufacturing basic building materials.

Energy is also used for transporting finished materials to the site, assembling and other on-site processes. But greater amounts of energy is consumed for the operation and maintenance of structures. The emissions arising as a result of this energy use represent a major indirect impact of construction on the environment. Since use of energy in construction and in construction-related industries is a major pollutant of the environment (air in particular), this topic will be discussed in more detail in the next chapters.

In addition to above mentioned unsustainable consumption patterns of the natural resources in construction, the industry causes loss of agricultural land and has serious environmental effects on coastal areas and water resources, which in some areas has reached critical proportions. Loss of agricultural land is not caused merely by encroachment of settlements, roads and other facilities, but also by the impact of these facilities on the hinterland, from which raw materials for construction are quarried.

Similarly, the extraction of sand and gravel from river beds and coastal areas has very serious environmental consequences. The removal of coral and shell from the coasts for the production of lime, for example, degrades the marine environment as do also some large civil engineering projects such as dams and irrigation schemes.

In addition to above mentioned major impacts of the construction industry on the environment, the construction and construction-related industries worldwide are major generators of solid and liquid wastes which not only pollute land, water and air, but are also hazardous to human health. Emission of asbestos fibres is one example of such hazard. Thus, the need to introduce environment-friendly and cleaner technology in construction and related industries is becoming an imperative strategy in the context of sustainable development.

Several studies have revealed that on average and globally, building and construction industry accounts roughly for: (4)

- 25 per cent of the forest wood,
- 40 per cent of the raw stone, gravel and sand,
- 16 per cent of world's fresh water,
- 40 per cent of the world's total energy,
- 70 per cent of the sulfur oxide emissions (this is produced by fossil fuel combustion to generate electricity to power our homes and offices), and
- 50 per cent of carbon dioxide emissions (mainly in industrialized countries). This is as a result of operations in buildings-in-use (e.g. heating).

The above figures and statistics give a clear indication that sooner or later the current trends in construction practices and in building industry, in general, are bound to change in many countries if a better or even acceptable living condition for our future generations is to be assured in a sustainable manner.

While in industrialized countries some actions have been, or are being, taken to arrest the implications of resource depletion and environmental degradation caused by construction and building sector, regrettably, in many other countries, these shocking statistics have not been taken very seriously by the building industry and by those involved in it. From one perspective, this is understandable because the sector may not foul oceans and may not kill wildlife as other industries such as chemical or oil industries can do.

But this relatively passive attitude of the building industry (which is changing gradually) does not lessen the extent to which human-made physical assets contribute to the environmental crisis, nor does it reduce the obligation of all stakeholders to steer the industry towards sustainability. This duty is both moral - as we have obligation to provide future generations with a good quality of life - and practical as well as manageable.

The real challenge will, however, lie in ensuring this in a sustainable manner without reducing the rate of building construction activities or bringing some of them to halt. What is needed is the promotion of environment-friendly, clean and energy-efficient technologies and the creation of a policy climate, which would stimulate the sector to implement the innovative initiatives.

1.2 Global growth of the construction sector

The building and construction sector typically provides 5-10 per cent of employment at national level and normally generates 5-15 per cent of gross domestic product (GDP). It literally builds the foundations for sustainable development, including housing, workplace, public and industrial buildings and services, highways and roads, communication, traffic facilities, energy, water and, in short, provides the contexts for social and economic interactions as well as the foundations for well being and livelihood of the society at large. Several studies have also proven the relationship between built environment and public health. (5).

It is also a well-known fact that due to rapid population growth, particularly in the urban areas of fast growing cities, and associated economic development, construction activities are now growing faster than ever. The total consumption growth in the global construction sector increased by 4.6 per cent from 2003 to 2004 and is expected to exceed 5 per cent annually over the next four years or so, with China and India growing fastest, and the construction output is estimated to vary between 3,000 billion and 4,200 billion US Dollars per year (6). Table 1 shows the global construction spending in 2004 and its growth between 2004 and 2005.

Table 1. Global construction spending and growth

Country	Global construction spending in 2004 (Billions US $)	Global construction spending growth 2004-2005 (percentage)
USA	700	4.9
Japan	680	3.8
China	500	8.4
Germany	300	3.7
Italy	190	5.1
France	180	3.7
United Kingdom	180	5.2
Brazil	160	8.0
Spain	140	5.4
Korea (South)	120	6.3
Mexico	90	6.3
Australia	80	6.1
India	40	9.1
Hong Kong	30	7.2
Other countries	720	4.8

Source: Davis Langdon, Reference No. 6

2. Use of natural resources in construction

2.1 The sustainable consumption logic

2.1.1 General remarks

Sustainable consumption means ensuring that the goods and services required to meet every one's consumption needs are delivered without undermining the environmental capital of countries and the world at large. Currently, the unsustainable patterns of production and consumption are depleting the scarce non-renewable resources, degrading or destroying resources that should be renewable (e.g. soils and forests) and generating wastes that are beyond the capacity of natural systems to degrade or absorb without ecological damage. The scale and the gravity of the challenge is such that the industrialized countries may have to reduce their use of environmental capital per unit of output by a factor of four or more over the next half century (7).

The logic of sustainable consumption is geared primarily towards lessening the environmental costs of what we consume. It has two primary tasks. The first is to maintain or enhance the quality of life for those whose consumption needs are met, while reducing the environmental costs. The second is to ensure that the resources required for meeting unmet consumption needs are available while also minimizing the call on environmental capital. As such, sustainable consumption is a central part of the broader goals of sustainable development.

Achieving more sustainable consumption patterns does not necessarily impose costs on consumers or reduce their quality of life. It takes a demand side approach to providing and extending services people need with cost-effective solutions that radically reduce the environmental impacts. There are many 'win-win' areas where measures taken to enhance the eco-efficiency of resource use and minimize wastes can bring economic and environmental benefits.

But the scale of the sustainable consumption challenge means that action will need to go beyond short-term 'win-win' opportunities. Long-term structural changes in policy frameworks, market incentives, technological changes and land-use patterns is also required. This means building up a virtuous cycle of cumulative learning and positive feedback from short-term 'win-win' activities so that the current unsustainable consumption patterns are changed.

2.2 Analysis of international agenda

The United Nations Conference on Environment and Development (UNCED) held in Rio de Janeiro in 1992 underscored the importance of sustainable production and consumption as a means to overall sustainable development. In so doing, it included a distinct section titled "Changing Consumption Patterns" (Chapter 4) in its Agenda 21. Even though Agenda 21 did not define sustainable consumption patterns in detail, it indicated clearly the need to focus policy attention on "the demand on natural resources and......the efficient use of those resources consistent with the goal of minimizing depletion of the environment and reducing pollution". The Rio process considered two key driving forces of sustainability: population growth in developing countries and 'over-consumption' on the part of the industrialized world.

It established all countries' common responsibility for sustainability but pointed out that responsibilities were differentiated. The rich world was given lead responsibility for examining its own levels of consumption. The issue of global inequity was introduced by the Agenda's statement that "measures to be undertaken at the international level for the protection and enhancement of the environment must take fully into account the current imbalances in the global patterns of consumption and production". Thus, a link between unsustainable consumption patterns and current inequities in global resource use and pollution was established.

The Habitat Agenda - the outcome of the second United Nations Conference on Human Settlements, held in Istanbul in 1996 - also emphasized the need for sustainable consumption, particularly, in the urban context. It called on all stakeholders to "manage consumption in ways that would protect and conserve the stock of resources while drawing upon them" (8). It further stated: "cities hold a premise for human development and for protection of the world's natural resources through their ability to support large number of people while limiting their impact on the natural environment...."

"Therefore, an urbanized world implies that sustainable development will depend largely on the capacity of urban and metropolitan areas to manage the production and consumption patterns and the transport and waste disposal systems needed to preserve the environment" (9). "International cooperation, including city-to-city cooperation is both necessary and mutually beneficial in promoting sustainable human settlements development. Depending on the context and the needs of the cities ..... special attention should be paid to the most critical issues, such as changing production and consumption patterns, energy efficiency, sustainable resource and land-use management, water supply and sanitation, waste management and environmental protection......."

The first Oslo Symposium on Sustainable Consumption held in 1994 restated the biological basis of consumption patterns. "Current material flows induce pollution, resource depletion, excessive energy consumption, biodiversity and landscape destruction (which) appear unsustainable by any standard". However, the working definition of sustainable consumption proposed in the Symposium also emphasized inter-generational equity and introduced the notion of quality of life, presumably as a pragmatic response to the infeasibility of policy measures which might appear to threaten western consumers with a reduced standard of living. "[Sustainable consumption is] the use of services and related products which respond to basic needs and bring a better quality of life while minimizing the use of natural resources and toxic materials as well as emissions of waste and pollutants over the life cycle of the services and products...."

This burgeoning policy agenda was reconfirmed at the second Oslo Ministerial Meeting on Sustainable Production and Consumption held in February 1995, where the key working document stated that "sustainable consumption is an umbrella term that brings together a number of key issues, such as meeting needs, enhancing the quality of life, improving resource-use efficiency, minimizing waste, taking a life cycle perspective and taking into account the equity dimension".

2.3 The impacts of construction-sector and urban activities on the environment and natural resources

Urban areas with their dense agglomerations of people and economic activities, including enormous amount of building and construction-sector activities, put different pressures on the environment than do rural settlements. These differences are more pronounced in the developing world because in rural areas there are still primarily primitive villages, where residents are still largely dependent on their own resources for their livelihood (10). The distinction is less clear in the developed world, where rural and urban residents alike tend to benefit from the same modern goods and services, such as piped water, paved roads, electricity etc. (11).

Urban areas affect the environment through major routs, namely: (a) the extraction and depletion of natural resources, (b) the conversion of land to urban uses and (c) the generation and disposal of urban wastes. The nexus of people and economic activity in cities requires resources far in excess of what the local area can supply. Therefore, cities must draw their essential supplies of energy, water, building materials and other commodities including food from distant places. The concentration of wastes in cities is much higher than that in countryside, reflecting the sheer number of people living in a relatively small area and their greater levels of consumption. As a result, urban wastes may quickly overtax the ability of local ecosystems to assimilate them.

The scale of urban consumption and pollution - and the negative impacts associated with them – varies from city to city, depending, in large part, on a city's wealth and size. Not surprisingly, however, the highest levels of resource use and pollution, including waste generation tend to occur in wealthiest cities and among the wealthiest groups within cities (12) (13). Thus, wealthy cities contribute disproportionately to global environmental problems, such as depletion of natural resources, overall pollution and climate change.

2.3.1 Degradation of land

The continuing growth of human population and of industrial activities, including the construction and related industries, place an increasingly heavy demand on the world's finite resources such as land. Land-use conflicts are a growing threat to the environment in many countries. These conflicts, particularly, in developing countries, arise largely because of the lack of coordinated national land-use policies. Each sector, such as mining and forestry, views the production areas as the best resource-base for its development objectives resulting in an intense competition for the same areas, without a mechanism to prioritise competing uses.

In terms of using land for quarrying and extraction of raw materials for construction industry, many national policies are more concerned with licensing exploitation and charging fees for revenue collecting purposes. They are seldom concerned with the appropriateness of the use to which such land is put. For example, in some countries many areas have been licensed for clay or stone quarrying at the expense of the agricultural/livestock sector. Most of these actions have been carried out without prior environmental planning or cost-benefit analysis.

Box 1

Disposal of waste on land

Not only quarrying, but also the disposal of wastes uses land which could otherwise be available for agricultural or other uses. 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 (14). In India, 8 million tons of fly-ash are produced annually by the country's thermal power stations, a good proportion of which is dumped (15).

Source: As indicated in the text.

The increasing spread of human settlements into fragile eco-zones is rapidly destabilizing natural eco-systems in many countries. Occurrences of floods, land and mudslides, etc. in delicate hill slopes and wetlands testify to the vulnerability of the environment to interventions of human activities for the construction and related industries.

Box 2

Transformation of land to other uses

Estimates suggest that 476,000 hectares of arable land in developing countries is being transformed annually to urban uses (16). To compensate for this loss of land, crop production may become more intense. Urban development can push agriculture to less suitable land, with unintended results. In Canada, for instance, replacing the food production from 1 hectare of prime Ontario farmland lost to urban growth requires about 3 hectares of prairie land, thus increasing the rate of land conversion overall (17). As agriculture moves farther from the city, the transportation of food to the city incurs added energy and pollution costs (18). For countries with little unused arable land, such as China and Egypt, the loss of productive farmland may threaten food security (19).

Source: As indicated in the text.

Appropriate land-use policies and planning, specifically, aimed at eco-sensitive zones are very often lacking in many developing countries. One of the main reasons for the lack of clear policies is that data on which to carry out environmental impact assessment (EIA) and cost-benefit analysis are lacking. The assignment of priorities to alternative environmental needs is not a very difficult task to undertake, however, in the ultimate the allocation of land-use priorities would involve an economic decision as between costs and returns and safeguarding the protection of the environment. Rational decision making and implementation of appropriate strategies which are transparent and effective, to solve the conflicts between land use and urban development, are urgent requirements which should be given high priority by decision-makers in many countries.

Box 3

The expansion of urban boundaries

In the medium sized-city of Aligarh in the northern India (with a population of about 0.6 millions), 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. But, in addition, approximately 1 million cubic metres of soil in the form of bricks is needed to construct the new houses built, plus a further 0.5 million cubic metres of soil and other fill materials used as base materials for the roads and building plots.

Source: Reference 20.

2.3.2 Impact on coastal areas and water resources

The degradation of marine environment, caused by removal of coral and shells for production of building lime and for use as aggregates are now attracting increasing attention. Dredging away marine for extraction of aggregates has begun to replace quarrying in some countries as the most accessible land quarry sites are used up. This is obviously less damaging to the environment, but has been found to result in increased rates of erosion of nearby coasts (21). 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 India, in the Maldives and elsewhere (22).

Industry and mining are the principal sources of freshwater pollution by the heavy metals and synthetic organic chemical industries. Often the chemicals are released directly, and sometimes they are leached from solid-waste dumps (23).

2.3.3 Impact on forest resources

Timber, as a major forest product, is not only a very crucial building material but is also very vital to the economies of a number of developing countries. Timber-producing countries gain considerable foreign exchange by exporting timber. Therefore, any loss of forests, for any reason, may provoke potential human, economic and environmental disasters. Timber has been one of the basic building materials for centuries. It has been extensively used both as structural members for buildings and bridges and also for decorative purposes. However, over the past several decades, there has been increasing concern about the destruction of the tropical forest and the adverse impact of this on the environment.

Inefficient commercial logging operations, the use of wood as fuel etc. have resulted in deforestation in many regions. Managing the forests in a sustainable manner so as to minimize the rate of deforestation is, therefore, imperative and should be given highest priority. The greatest concentrated forest deterioration is occurring in the large rain forests of amazons, west Africa and south-east Asia, which are currently being mined for extraction of selected high-value timber species by international concessionaires.

Box 4

Demand for wood

It is estimated that in Philippines, the demand for wood in building construction is likely to increase from 173.000 cubic metres in 1990 to 433.000 cubic metres by the year 2000. In Indonesia the demand for wood in housing construction is likely to exceed nearly 4 million cubic metres. Japan imports 18 million cubic metres of sawn wood for the 1.5 million homes annually built there. In Chile, 60 per cent of the annual production of sawn timber is used in houses and other building construction works. These figures mean that wood is going to be essential building material both for modern structures as well as for traditional building construction in the years to come (24). The rate of deforestation in primary forests in South America and in Asia and Pacific regions in early 1990s was 2.2 million and 1.8 million hectares per year respectively, which shows an increase of approximately 80 per cent since early 1970s in both regions (25).

Source: As indicated in the text.

Box 5

Loss of forests

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 (26). In Kalimantan, the Indonesian area with 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 in few years time this is expected to be down to 10 million hectares (27).

It has been estimated by the International Tropical Timber Organization 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 (28). The World Bank estimates that in few years time, the 33 developing countries that are now net exporters of forest products will be reduced to fewer than 10, and the total developing country exports of industrial wood products are predicted to drop to about 1/3 of their current level (29).

Source: As indicated in the text.

Box 6

Loss of woodlands

In Africa, the woodlands outside the closed forests had an area of 486 million hectares in 1986, and were declining at 2.3 million hectares per year. This does not include the equally serious but difficult-to-measure progressive degradation of the woodlands through the thinning out of forest cover (30). In Bangladesh, bamboo is the most important building material. In 1981 there were about 1.8 million tons of mature bamboo culms in the village forests of Bangladesh, which was adequate for a continuous supply to meet an annual demand of about 0.8 million tons. With the growth of population, urbanization and the need to replace houses lost in flood disasters, demand was grown to 1.4 million tons in early 1990s. 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 over harvesting and the use of immature culms, and to disease and poor crop management (31).

Source: As indicated in the text.

2.4 Consumption trends: looking back, looking to the future

Consumption, specially, of natural resources in urban areas and in construction industry has been the focus of much debate at international and national levels. The environmental consequences of natural resource consumption are often borne by people other than those to whom the benefits of that consumption accrues (32). The people living in industrialized countries, even though a small fraction of the earth's human population, consume, at present, a large share of world's natural resources. From the perspective of developing countries, such consumption, not only deprives them of resources needed for future growth, but also contributes disproportionately to the world's environmental degradation. These issues are controversial and complex.

Renewable resources are often considered to be indefinitely renewable. Yet some are location specific or depend on finite resources such as land. In many areas, exploitation of both biological and physical resources (for example unsustainable exploitation of tropical hardwood) already exceeds the regenerative ability of natural systems. Thus, not only many renewable resources are becoming increasingly scarce, their indiscriminate utilization may damage the underlying systems that sustain or renew them. The near-term economic and human development of many countries could, therefore, be threatened if current consumption patterns continue to remain.

Non-renewable resources, in contrast, are finite. Hence the frequently expressed concern over high-levels of consumption, which will lead to resource depletion and might limit growth or development opportunity. Evidence suggests, however, that the world is not yet running out of most non-renewable resources and it is not likely to, at least in the next few decades. Moreover, new technology is increasingly making possible substitutes for many traditional natural resource-based materials (33). However, with current rate of consumption of non-renewable resources such as fossil fuels and certain metallic minerals, it leaves no doubt that the sustainability of future growth will be faced with severe challenges and barriers.

The following review of the current conditions and trends of the natural resource consumption focus on four critical areas namely: (a) energy and transport, (b) freshwater, (c) mineral resources, and (d) waste generation linked to resource consumption.

2.4.1 Energy and transport

The global primary energy consumption is rising by about 3 per cent annually, and most of this consumption takes place in urban areas. There are however, wide variations in per capita energy use in different regions of the world. On average, the energy used by a person in developed countries is about nine times that in developing countries. Large disparities also exist among developing countries. For example, annual per capita consumption of modern forms of energy in sub-Saharan Africa is less than half the average of that in developed countries.

Several factors contribute to this disparity, notable among them being the level of urbanization and industrial development. With rapid urbanization in low and middle-income countries, this scenario is changing fast. A recent World Bank study estimates that the energy demand in these countries is expected to rise from the current level of one-third of OECD countries to parity with OECD demand by the year 2015. The study concludes that the main factors contributing to this increase in demand will be urbanization, and motorization – a linked urban phenomenon (34).

The rapid growth in energy supply and demand in most developing countries is taking place amid grossly inefficient energy use in the transport sector and in human settlements. The transport sector is the largest single consumer of the commercial energy in cities, accounting for nearly half of all petroleum consumption. In sub-Saharan Africa, it accounts for nearly 80 per cent of commercial energy used.

Energy production and use, in almost every form, generates varying degrees of environmental impacts that effect human health and ecological stability. Transport related air pollution is already threatening the health of some 400 million city dwellers in developing country cities. If current trends continue, in few years time from now, transport related air pollution in many large cities of developing countries will be much worse than the projected levels of major cities in industrialized countries with much higher level of motorization (35).

2.4.2 Freshwater resources

Freshwater is a finite resource, which has to meet the ever-increasing demands from competing users: industry, domestic sector and agriculture. The availability of freshwater is decreasing in many parts of the world notably in the Middle East, Africa, Central Asia, Northern China and many small island states.

Box 7

Problems of freshwater resources

Some 80 countries with about 40 per cent of the world's population are facing acute to chronic water scarcity. The worst affected in the Middle East and North Africa still see their per capita annual renewable freshwater supplies decrease by about 80 per cent between 1960 and 2015 – all in a single lifetime (36). In China, for example, more than 300 cities face water shortage with 100 in acute distress – at an estimated US$ 14 billion in lost economic output each year (37). Ensuring adequate water supply to megacities like Los Angeles and Mexico City has meant that the water authorities have to tap ever more distant watersheds, sometimes with considerable ecological damage.

In developing countries, close to 85 per cent of water is allocated to agriculture, 10 per cent to industry and only 5 per cent for domestic use. Yet, less than 45 per cent of the water for agriculture actually reaches the crops. In addition, cities in the developing countries are also loosing between 30 to 60 per cent of water, produced and treated at high cost for domestic use, through leakage from poorly maintained water supply systems before it reaches the intended consumers (38).

Source: As indicated in the text.

There is also an important equity issue associated with water use, particularly in urban areas. The urban poor in developing countries almost always have to rely on private water vendors and end up paying very high price for their water, often several times more than other affluent neighborhoods do because of having piped water in their homes. Thus the poor, in effect, subsidize water services for the more affluent and continue to suffer water scarcity and a heavy burden of healthcare.

2.4.3 Metallic mineral resources

According to various geological studies, metals - in terms of their existing exploitable reserves - are different. For example, aluminium (bauxite) and iron have a life-index of about 200 years, whereas lead, zinc and copper have a life-index of between 20-30 years at current rate of extraction (39). The known world's economically exploitable resources of some key metals and their life-indexes are shown in table 2.

Table 2. Annual production, reserves and life index of some metals

Metal	Production/year (Million metric tons)	Reserves (Million metric tons)	Life index (Years)
Bauxite (aluminium)	104	23,000	222
Copper	9.3	310	33
Iron ore	930	150,000	161
Lead	3.4	63	18
Nickel	0.9	47	51
Zinc	7.1	140	20
Tin	0.23	6	28

Source: World Resources Institute, Reference 25.

It follows that serious consideration should be given to the increasing replacement of these metals in order to use the existing reserves over a longer period. Copper for example, has already been extensively replaced by other conducting materials, however, zinc, has not been replaced with a proper material and suitable substitute must be found in due course.

Extraction of metallic mineral ores, refining and disposal of wastes from metallurgical industries cause significant local environmental problem and air pollution. Mining can degrade land, create quarries and open pits and a huge amount of solid waste. Air pollution during these processes includes dust from mining, acidic gases, carbon dioxide and other greenhouse gas emissions from smelting, refining and other kiln processes. A careful accounting of environmental impacts from mineral consumption remains to be done. However, preliminary studies suggest that use of heavy metals has left a significant toxic legacy in the soil, eco system and food chains of many industrialized countries (40).

2.4.4 Fossil fuels

The world-wide recognition of the limited supply of fossil fuels has lead to a large-scale effort in search of alternative energy sources such as solar, wind, biomass, hydro and other types of renewable sources of energy. In parallel to these developments, fossil fuels have become more and more precious, and in the long term, many countries will require to conserve energy as a means of self-preservation. In this context, wastage of fuel has to be prevented and the energy efficiency has to gain importance in all urban functions.

Studies have revealed that consumption of fossil fuel has drastically risen during the past three to four decades. Even though in the industrialized countries it has declined to less than 50 per cent of the world's total, consumption has risen dramatically in developing countries (by a factor of 4 over the past 30 years) and substantially, in the countries with economies in transition of Central and Eastern Europe and other CIS countries of former USSR (by a factor of 2.4) (41). Table 3 shows trends of fossil fuel consumption in industrialized, developing and transition countries and table 4 shows the per capita consumption of fossil fuel in developing and industrialized countries.

Coal produced from underground mining, replaced wood as the dominant fuel in the early parts of the twentieth century. The discovery and exploitation of petroleum changed the relative roles of fuels. Coal played a dominant role in electricity generation and, after several decades of decline, has now again emerged as a prime fuel. Gas derived from coal was initially used as a source of lighting and heating.

Again, after several decades of decline, gas and liquid fuels derived from coal are expected to be the major base of future synthetic fuels. Natural gas was initially ignored as being a nuisance and was allowed to burn indiscriminately. Subsequently, it was piped and transported in liquefied form. Because of its relative cleanliness, ease of transport, and convenience of burning, it is now recognized as one of the precious fuels.

Table 3. Fossil fuel consumption trends, ten-year average (petajoules)

Countries	1960-70	1970-80	1980-90	1990-2000
Industrialized	100	125	125	130
Developing	20	30	55	65
Transition	40	55	70	80
World	160	210	250	275

Source: World Resources Institute, Reference 40.

Fossil fuels are expected to have a limited and restricted life, with gradual replacement by nuclear, hydro, geothermal, wind, solar, wave and other energy sources. Countries dependent upon imports of fuel recognize their own high degree of vulnerability, which is leading them to seek for energy independence. The supply, pricing and utilization of fossil fuel has moved from relative insignificance to overriding importance to overall economic development and stability.

Table 4. Fossil fuel consumption (gigajoules/person)

Countries	1960-65	1965-70	1870-75	1975-80	1980-85	1985-90	1990-10 (appx.)
Industrialized	115.82	142.53	166.70	169.52	153.81	160.06	164.00
Developing	7.37	8.26	10.34	12.92	14.53	17.28	20.00

Source: World Resources Institute, Reference 40.

2.5 Waste generation linked to resource consumption

Waste generation, both domestic and industrial, continue to increase worldwide in tandem with growth in consumption. In developed countries, per capita waste generation increased nearly three-fold over the last two decades, reaching a level of five to six times higher than that in developing countries. With increases in population and urbanization, waste generation in developing countries is also increasing rapidly, and may double in volume in current decade. If current trends continue, the world may see a five-fold increase in waste generation by the year 2025 (42).

Most city governments are facing mounting problems with collection and disposal of wastes. In high-income countries, the problems usually center on the difficulties of disposing of the large quantities of solid wastes generated by households and businesses. Land-filling is becoming increasingly costly due to lands scarcity and rising transport costs. In developing countries, many city authorities are unable to collect and transport more than third of the solid waste generated due to limited municipal budgets.

2.6 Recycling

Recycling of waste materials has gained considerable attention in he past 2-3 decades. In developing countries, recycling is normally driven by the need for low-cost materials for industry, high levels of unemployment and the low purchasing power of the large segments of the population. Many developing country cities, particularly in Asia have developed extensive waste economies, structured through waste buyers, waste collectors, small waste shops, second hand markets, dealers, transporters and a range of recycling industries.

Several studies have revealed that recycling can not only reuse the already used materials but can lead to considerable energy savings. Table 5 provides some examples of energy saving if certain building materials are recycled.

In developed countries, however, over the last 2-3 decades, the recycling of waste, including waste generated from demolishing old buildings and other civil engineering outputs, has become very popular. In this context, numerous technologies have been developed in the recent past in the recycling sector and these are all in a bid to reduce consumption of natural resources and to protect the environment. The below boxes illustrate some examples of recycling efforts in the construction industry.

Box 8

Recycling of materials

Most industrialized countries are focusing increasingly on recycling and reuse of both municipal and industrial wastes. Currently, 22-40 per cent of waste aluminum, 27-51 per cent of waste paper and 10-53 per cent of glass are recovered through recycling and reuse in these countries. Several countries are also taxing wastes deposited in landfills. The revenues collected from this tax are earmarked for promoting community recycling programmes (43).

Source: As indicated in the text.

Table 5. Energy requirements for the production of selected materials and possible savings if recycled

Material	Primary Energy requirement (Mj/kg)	Potential energy savings if recycled (Percentage)
Aluminum	130-270	90
Copper	> 100	85
Lead	> 25	78
Steel	20-60	67
Zinc	35-70	58
Cement	4-8	
Glass	12-25	>60

Source: Reference 44.

Box 9

Recycling activities in the construction industry: The case of Austria

Austria's recycling sector within the construction industry has been established through the initiatives of numerous industrial companies, construction enterprises, disposal organizations, gravel plants and the activities of the Austrian Association for the Recycling of Building Materials (BRV). The purpose is to implement new environmental technologies as well as to meet the new sector-specific requirements stipulated in environmental legislation of the country.

Residue building materials amount to approximately 57 per cent of the overall waste volume determined by the Federal Waste Management Plan (June 1998) and "constitutes a volume of considerable significance to waste management". Out of a total mount of 26 million tons per year, 20 million tons are excavated earth, 3.6 million tons mixed mineral building waste, 1.7 million tons road and concrete rubble as well as 1.1 million tons of different construction waste.

In 1993, the "Decree on the separation of materials produced during building work" (Federal Official Journal No. 269/1991) was entered into force. Due to its requirements, anybody commissioning construction work is obliged to process residue-building materials so that it is suitable for recycling, if the waste exceeds a given volume. The Waste Management Act, especially Article 17, Clause 2, in conjunction with the above-mentioned pertinent Decree, forms the legal basis for the separation of residue building materials in line with their intended re-use. The requirement of re-use is stipulated as a principle (Article 3 of the Separation Decree).

In order to implement these principles, the establishment of technical rules has been and is necessary. The most important technical basis is provided by the "Guidelines for recycled building materials" (February 1992) prepared by the Austrian Quality Protection Association for Recycled Building Materials. These Guidelines specify the quality requirements for recycled materials of three quality grades, which are predominantly used in civil engineering. Supplementing the above-mentioned Guidelines, the "Regulation for awarding and carrying the quality mark for recycled building materials" specifies laboratory instructions and guidelines for keeping records adequate to the quality standard. This important basis allows for the implementation of the guidelines: the Quality Protection Association now controls, by means of external authorized laboratories, whether recycled building materials are produced correctly in terms of quality.

Recycled building materials of protected quality

If recycled products comply with the guidelines for "recycled building materials" and have the required properties, they may be used as secondary raw material for the production of:

- Cement-bound base courses,
- Sub-bases and road base-courses in road construction,
- Bottoming and fillers, and
- Aggregates in concrete production or for building with bituminous binders.

Manufacturers of recycled building materials submitting their products for testing to the "Quality Protection Association for Recycled Building Materials" are then awarded the "Quality Mark for Recycled Building Materials", which may be used for recycled building materials for which compliance with the guidelines, test specifications and regulations has been demonstrated.

Guidelines of BRV/GSV

The existing guidelines shall guarantee that only quality-controlled recycled building materials are used. This should make it possible in the near future that even demolition waste from buildings can be recycled on a full scale. Such an approach is, undoubtedly, preferable to land filling for both ecological and economic reasons, and it is in keeping with the goal of recycling building materials as much as possible.

The "Austrian Quality Protection Association for Recycled Building Materials" (Österreichischer Güteschutzverband Recycling-Baustoffe, BRV) aims, in all of its activities, to identify measures to safeguard the quality recycled construction materials in order to increase their market value, to strengthen the recycling industry and enhance its public acceptance. The "Austrian Association for the Recycling of Building Materials" (Österrichischer Baustoff-Recycling Verband, ÖBRV) and the ÖGSV have published five guidelines for recycling of construction materials. They regulate the type and scope of tests performed for recycled construction materials, recovered soil, building units and recovery equipment. They identify requirements for recycled construction materials and cement-bonded substances and stipulate conditions for their further use and new practical applications. The Guidelines are developed in co-operation with the responsible ministries and provincial government offices.

The ÖGSV is authorized to confer a seal on recycled construction materials. The "Quality Mark for Recycled Building Materials", can be used by the manufacturer for promotional purposes. The first award is subject to periodic external and internal quality assurance reviews as specified by the ÖGSV. The existing guidelines shall guarantee that only quality-controlled recycled building materials are used. This should make it possible, that even demolition waste from buildings can be recycled on a full scale.

Recycling companies

The construction industry strongly responded to this new sector. Nationwide, there are 60 active recycling companies represented in the Association for the Recycling of Building Materials, which operate more than 100 plants all over Austria. Approximately 2/3 of the recycling plants are mobile, 1/3 is stationary (year 2000 figures).

Initiation

In 1997, the Vienna University of Technology, in cooperation with the City of Vienna, the Austrian Association for Recycling and Construction Industry, the Construction Industry Association, the Federal Ministries for Economic Affairs and Environment and other related institutions set up a working group concerned with the installation of a Construction and Demolition Recyclable Exchange. A test-run was successfully accomplished in eastern Austria and after several other Federal Governments had joined the project, regular operation began in summer 1998.

Construction and demolishing (C & D) recyclable exchange

The main C & D recyclable exchanges are as follows:

1. Secondary building materials of mineral origin, such as recycled asphalt granules; concrete granules; brick granules; and building construction granules.
2. Construction and demolition waste of mineral origin such as uncontaminated soil; road debris and demolition concrete; and constructions and demolition waste.
3. Humus and composts such as upper soil layer; and organic composting material (quality classes)

The C & D recyclables exchange is not a trading platform for these materials. It only provides information about where, when and what type of material is in supply or demand, and who offers or needs it. The aim of the C & D recyclables exchange is to actively contribute to environmental protection, by reducing landfill quantities and promoting the marketability of recycled building materials. The target group addressed by the C & D recyclables exchange are building societies, recycling companies, forwarding agents, landfill operators, public and private customers, architects and consulting engineers. But also individuals who undertake to build their own houses can check supply and demand on this platform.

BRV in the Internet

Since 1996, the Austrian Association for the Recycling of Building Materials has a homepage in the internet: www.brv.at. For further information, contact can be established at:

Austrian Association for the Recycling of Building Materials (BRV) Karlsgasse 5, A-1040 Vienna, Austria. Email: brv@brv.at, Fax: +43-1-504 15 55

Source: Martin Car, BRV, Reference 45.

2.7 Constraints and barriers to progress

Most urban functions and the related construction-sector activities, at large, still do not apply the 'common sense' of sustainable consumption and the positive effects of it. Many barriers to sustainable consumption are related to the macro-economic frameworks, inadequate institutional structures at the local level, obsolete regulations and most importantly market pressures and lifestyles. Various studies show that the market alone cannot provide the mechanisms for dealing with the optimization and rationalization of production and consumption patterns.

In many instances there is a lack of awareness of the full economic or environmental value of natural resources, such as freshwater or forests. Furthermore, public monopolies in the supply of basic services such as water, energy and transport have often led to misuse of natural resources. These problems are also often compounded by arbitrary and environmentally perverse public subsidies that encourage excessive and inequitable consumption.

Most public policies continue to give priority to a supply-side focus, rather than adopting the sustainable consumption logic and working on the demand side. This supply-side mentality poses real problems in many developing countries which lack the financial resources to invest in increasing supplies – for example in the expansion of electricity generation capacity. Even where eco-efficient options are available and where additional costs can be repaid through lower resource use, the initial capital costs place them beyond the reach of low-income households or under-resourced municipalities.

Unsustainable lifestyles among the world's 'high consumers' also pose a major barrier to progress. To date the rich have not shown much willingness to alter their behavior and create new models of success. In addition, these unsustainable lifestyles are reinforced by marketing and advertising industry. In poorer countries, the tendency to replicate blindly the western lifestyles can lead to the rejection of traditional methods and materials in favor of imported goods, leading to problems related to balance of payments.

Experience has shown that most of the cities that now face water shortage would have avoided this problem if they had applied a commitment to resource efficiency and conservation along the chain, including collection, distribution, use and reuse of water, over the last 20 years. Most cities with inadequate electricity supplies that suffer from frequent losses of power or cuts in supply would also have much reduced this problem, if they had developed electricity supplies along with a commitment to promote efficient use.

Most cities which now suffer serious problems of traffic congestion (and the contribution this makes to air pollution) would also have limited this problem if they had a 30-40 years old commitment to good transport planning and its linking land-use planning as has been done, for example, in Curitiba, Brazil, many European cities and very few other cities (46).

2.8 Ecological footprint

Urban areas are the main sources and consumers of construction industry outputs and the ecological footprint is normally considered only for cities and towns. All cities draw on natural resources produced outside their built up areas. Ecological footprint of any given city is defined as being the natural resource base (land, forests, water, fuel, etc.) outside the city boundaries that provide goods and services to the cities.

Studies indicate that, on average, the total ecological footprint of any city is typically at least ten times more than the area of the city itself. In effect, through trade and natural flows of ecological goods and services, all cities appropriate the carrying capacity of other areas. Expanding ecological footprints of cities pose a special risk because, mostly, the city habitants are unaware of the environmental damage they are responsible for in distant lands, hence they lack the motivation to spur actions to reduce it (47).

Ecologists define the 'carrying capacity' as the population of given specie that can be supported indefinitely without permanently damaging the ecosystem upon which it is dependent. For human beings, the carrying capacity can be interpreted as the maximum rate of resource consumption and waste discharge that can be sustained indefinitely without progressively impairing the functional integrity and productivity of the relevant ecosystem.

Box 10

Big foot

The ecological footprint of London is 120 times the area of the city itself. It is estimated that a typical North American city with a population of 650,000 would require 30,000 square kilometers of land – an area roughly the size of Vancouver Island in Canada – to meet domestic needs without even including the environmental demands of the industry. In comparison, a similar size city in India would require 2,800 square kilometers of land.

Source: International Institute for Sustainable Development, as reported in www.gdrc.org

Regional ecological deficits do not necessarily pose a problem if import-dependent regions are drawing on true ecological surpluses of the exporting regions. In this context a group of trading regions remains within net carrying capacity as long as total consumption does not exceed aggregate sustainable production. However, experience has shown that the prevailing economic logic and trade agreements often ignore the carrying capacity and sustainability considerations. In these circumstances, the terms of trade may actually accelerate the depletion of essential natural resource base, thereby undermining the global carrying capacity.

Box 11

Reducing ecological footprint of cities

Urban agriculture and urban forestry can combine environmental goals such as reducing the ecological footprint of cities and utilizing city wastes with broader economic and social goals. Both generate jobs and livelihood particularly in low-income countries.

Several studies reveal that some cities are already transforming themselves from being only consumers of natural resources into important resource-conserving, health-improving and sustainable generators of resources. A study conducted in Kenya shows that almost two-thirds of 1,500 households questioned in six Kenyan towns produced parts of their food and fuel. In Lusaka, Zambia, vacant, derelict plots next to squatter settlements provide vital food supplements through urban agriculture practiced by more than half of the households in the surveyed low-income areas. In New York, one estimate suggests that about 1,200 vacant lots have been reclaimed for community gardens.

In Calcutta, India, a third of the city's sewage ending up in marches to the east of the city is processed in a most ingenious way. A little over 7,500 acres is taken up by sewage-fed fish ponds 'bheris'. Each year these fisheries produce 7,500 tons of fish. While some of the sewage goes straight to the ponds, some is held for use by the so called "garbage farms". Every day, Calcutta gets 150 tons of vegetables from these farms

Source: UNCHS (Habitat), Reference 48.

2.9 Balancing supply and demand

2.9.1 Supply-side approach

Cities provide excellent opportunities to optimize the use of non-renewable resources. For example in the urban construction sector, energy efficient methods for the production of building materials as well as eco-friendly building designs can considerably reduce the impact of this sector on the environment. This is the broad concept of 'eco-efficiency'. Improving the eco-efficiency of cities and the building and construction industry, will also call for a fresh look at current technologies for resource management from supply-side point of view. Technology will be an important instrument in bringing about efficiency improvements. But the concept of 'appropriate technology' may have to be redefined, giving preference to those that promote 'eco-efficiency', over others, which are more resource intensive.

2.9.2 Demand management measures

While improving eco-efficiency in the construction sector would require some time to slow down the depletion of natural resources, there is growing consensus that fundamental change is required in the current patterns of demand that is closely linked to life-styles and consumer-driven society. Sound urban management (e.g. in transport or energy sectors) could provide a good opportunity for reshaping the current demand patterns and putting it on a sustainable track. Three key elements of demand management strategy can be identified as described below:

2.9.3 Opinion forming

By providing information and demonstrating good practices on the use of alternative products and/or life-styles and their benefits, opinion-forming measures can play a vital role in encouraging sustainable consumption patterns. Such measures can be particularly effective in controlling, e.g. excessive demand for urban mobility, unnecessary use of energy and water in households, etc. The media, advertising and entertainment industry, educational institutions, community groups, etc, can be important partners of the governments in this respect.

2.9.4 Planning and regulations

Planning and development control strategies can also play an important role in e.g. reshaping current land-use patterns. Such measures can particularly be effective in protecting delicate ecosystems in coastal areas and small island states. Greater use of environmental impact assessments (EIA) should be considered in settlement planning and development. Application of EIA techniques should also take into account the ecological footprints of cities.

2.9.5 Economic instruments

Economic instruments and pricing, as policy instruments for demand management are gaining gradual acceptance in many countries in recent years. They can lower the investment burdens of governments on resource conservation and reduce over-reliance on regulations. A range of economic instruments have already been tried such as depletion charges on resource use, emission charges on pollution and deposit-refund schemes to promote recycling and reuse. These experience need to be reviewed and disseminated for wide public and political acceptance.

2.10 Future measures

Despite the apparent 'common sense' of sustainable consumption and environmental consciousness, their principles and practices have still not been applied widely. A review and appraisal of the implementation of Agenda 21 and Habitat Agenda over the past 5-10 years reveals that there is still a long way to go to achieve the ultimate goals of sustainable development, particularly in the urban context.

"Five years after UNCED, the state of the global environment has continued to deteriorate... Some progress has been made.... Overall, however, trends are worsening. Many polluting emissions... greenhouse gases and waste volumes are increasing although in some industrialized countries emissions are decreasing. Marginal progress has been made in addressing unsustainable production and consumption patterns.... At the global level, freshwater, forests, topsoil.... continue to be used at rates beyond their viable rates of regeneration" (49).

In light of above scenario, several key priority measures have been identified which are briefly described below.

2.10.1 Demonstration

Demonstrate the short and long term benefits of applying sustainable consumption logic to local authorities, national agencies and civil society at large. Special focus should be given to the use of energy, water, eco-sensitive land and forest products and the importance of waste minimization by reuse and recycling.

2.10.2 Good practices

Document and share good practices originated both locally or abroad. Learning from experience and good practices is a process needed everywhere. Therefore, rigorous and independent assessment and dissemination should be a common strategy in every city and every human settlement.

2.10.3 Inter-sectoral action

Establish inter-sectoral, a more coherent and integrated approach to improve the situation. Much of the potential for promoting sustainable consumption is currently lost due to traditional systems of decision-making and lack of inter-sectoral interventions at local levels.

2.10.4 Linking technical support with regulatory instruments

Make efforts to link technical support and innovation with appropriate legal, regulatory and institutional frameworks. Technological innovations and research findings are still initiated within a legal and institutional vacuum, ignoring the driven forces that encourage resource depletion and environmental degradation.

2.10.5 Community participation

Facilitate and encourage community participation for decision-making and defining needed strategies. Often communities lack the capacity to mobilize their full potential for promoting sustainable consumption, while local authorities lack the skills or incentives for promoting local partnerships.

2.10.6 Local economic instrument

Develop a better understanding of the use of local economic instruments to promote sustainable consumption. Market forces and prices (including taxes/incentives) are ultimately the main determinants of consumption patterns. There is still enormous untapped potential for exploring the use of economic instruments at local level for changing lifestyles and behavior.

2.10.7 Indicators

Develop appropriate indicators to gauge the current state of production and consumption. Much work has already been done on the development of city indicators as part of local Agenda 21 processes. This could be usefully supplemented by the design of sustainable consumption indicators that meet the information needs of households, communities and enterprises.

2.10.8 Analysis of barriers

Identify the main constraints related to the application of well-known principles of sustainable consumption. Make efforts to analyze them and by defining appropriate solutions try to overcome them by adopting new strategies and practices.

Box 12

Who could do what to save the natural resources (47), (49).

Governments could:

- Introduce natural resource accounting;
- Monitor depletion of resource base;
- Encourage industry to improve efficiency of resource use;
- Promote sustainable consumption through pricing, incentives, taxation, eco-labeling schemes;
- Develop policies that encourage a shift to more sustainable patterns of production and consumption.

City authorities could:

- Manage demand through opinion forming, planning and development control;

- Promote minimization of wastes and encourage recycling and reuse;
- Promote urban agriculture and urban forestry;
- Support initiatives of community groups;
- Formulate and implement local Agenda 21s.

Industry could:

- Lead the drive to achieving eco-efficiency; improving efficiency in material and energy use; minimizing waste in production process; recycling solid and liquid waste and waste water;
- Increase research and development investment for environmentally sound and cleaner technologies.

International community could:

- Assist developing countries in sourcing and acquiring eco-efficient technologies;
- Support exchange of information on best practices and city development indicators;
- Promote energy/material efficiency standards, international protocols and conventions.

2.11 Strategies for optimizing production and consumption (50)

Measures to be undertaken for optimizing production and consumption levels while protecting the environment, must take fully into account the current imbalances in the lifestyle and behaviors of the population in various cities, regions and communities.

Special attention should be paid to the demand for natural resources generated by unsustainable consumption and to the efficient use of those resources consistent with the goal of minimizing depletion and reducing pollution. Although consumption patterns are very high in certain parts of the world, the basic consumer needs of a large section of humanity are not being met.

This results in excessive demands and unsustainable lifestyles among the richer segments, which place immense stress on the environment. The poorer segments, meanwhile, are unable to meet food, health care, shelter and educational needs. Changing consumption patterns will require a multifaceted strategy focusing on demand, meeting the basic needs of the poor, and reducing wastage and careful use of limited natural resources in the production process.

Growing recognition of the importance of addressing consumption has also not yet been matched by an understanding of its implications. Some economists are questioning traditional concepts of economic growth and underlining the importance of pursuing economic objectives that take account of the full value of natural resource capital. More needs to be known about the role of consumption in relation to economic growth and population dynamics in order to formulate coherent international and national policies.

National policies, in general, and sustainable urban development policies, in particular, should have the following broad-based objectives:

(a) To promote patterns of consumption and production that reduces environmental stress and that meets the basic needs of humanity;

(b) To develop a better understanding of the role of consumption and how to bring about more sustainable consumption patterns.

2.11.1 Recommendations and proposed actions

In order to achieve these objectives the developed countries should take the lead in achieving sustainable consumption patterns. This is because most of the unsustainable consumption and production takes place mainly in the developed world. Similarly, developing countries should seek to achieve sustainable production and consumption patterns in their development process. They should guarantee the provision of basic needs for the poor, while avoiding those unsustainable patterns. They should also avoid replication of such unsustainable practices that are currently common in many developed countries.

2.11.1.1 Actions required for promoting research on consumption, data and information collection

In order to support this broad strategy, governmental and/or private research and policy institutes, with the assistance of regional and international economic and environmental organizations, should make a concerted effort to (51):

(a) Expand or promote databases on production and consumption and develop methodologies for analyzing them;

(b) Assess the relationship between production and consumption, environment, technological adaptation and innovation, economic growth and development, and demographic factors;

(c) Examine the impact of ongoing changes in the structure of modern industrial economies away from material-intensive economic growth;

(d) Consider how economies can grow and prosper while reducing the use of non-renewable energy and materials and the production of harmful materials;

(e) Identify balanced patterns of consumption worldwide, which the earth can support in the long term.

In line with above mentioned areas of broad based actions, consideration should also be given to the present concepts of economic growth and the need for new concepts of wealth and prosperity. This will allow better standards of living for every one through changed lifestyles and through less dependence on the earth's finite resources but in harmony with the earth's carrying capacity. This should be reflected in the evolution of new systems of national accounts and other indicators of sustainable development.

2.11.1.2 Developing national policies and strategies

Achieving the goals of environmental quality and sustainable development will require efficiency in production and changes in consumption patterns in order to emphasize optimization of resource use and minimization of waste. In many instances, this will require reorientation of existing production and consumption patterns that have developed in industrial societies and are in turn emulated in much of the world.

Progress can be made by strengthening positive trends and directions that are emerging, as part of a process aimed at achieving significant changes in the consumption patterns of industries, households and individuals. In the years ahead, governments, working with appropriate organizations, should strive to undertake the following (52):

(a) To promote efficiency in production processes and reduce wasteful consumption in the process of economic growth, taking into account the development needs of developing countries;

(b) To develop a domestic policy framework that will encourage a shift to more sustainable patterns of production and consumption;

(c) To reinforce both values that encourage sustainable production and consumption patterns and policies that encourage the transfer of environmentally sound technologies to developing countries.

2.11.1.3 Efficiency in the use of energy and resources

Reducing the amount of energy and materials used per unit in the production of goods and services can contribute both to the alleviation of environmental stress and to greater economic and industrial productivity and competitiveness. Governments, in cooperation with industry, should therefore intensify efforts to use energy and resources in an economically efficient and environmentally sound manner by:

(a) Encouraging the dissemination of existing environmentally sound technologies;

(b) Promoting research and development in environmentally sound technologies;

(d) Assisting developing countries to use these technologies efficiently and to develop technologies suited to their particular circumstances;

(e) Encouraging the use of environmentally sound and renewable sources of energy and natural resources.

2.11.1.4 Minimizing the generation of wastes

Societies need to develop effective ways of dealing with the problem of disposing of mounting levels of waste products and materials. Governments, together with industry, households and the public, should make a concerted effort to reduce the generation of wastes and waste products by (53):

(a) Encouraging recycling in industrial processes and at the consumer level;

(b) Reducing wasteful packaging of products;

(c) Encouraging the introduction of more environmentally sound products.

2.11.1.5 Encouraging environmentally sound purchasing decisions

The recent emergence in many countries of a more environmentally conscious consumer public, combined with increased interest on the part of some industries in providing environmentally sound consumer products, is a significant development that should be encouraged. Governments and international organizations, together with the private sector, should develop criteria and methodologies for the assessment of environmental impacts and resource requirements throughout the full life cycle of products and processes. Results of those assessments should be transformed into clear indicators in order to inform consumers and decision-makers.

Governments, in cooperation with industry and other relevant groups, should encourage expansion of environmental labeling and other environmentally related product information programmes designed to assist consumers to make informed choices.

They should also encourage the emergence of an informed consumer public and assist individuals and households to make environmentally informed choices by:

(a) Providing information on the consequences of consumption choices and behavior so as to encourage demand for environmentally sound products and use of products;

(b) Making consumers aware of the health and environmental impact of products, through such means as consumer legislation and environmental labeling;

(c) Encouraging specific consumer-oriented programmes, such as recycling and deposit/refund systems.

2.11.1.6 Exercising leadership through government purchasing

Governments themselves also play a role in consumption, particularly in countries where the public sector plays a large role in the economy and can have a considerable influence on both corporate decisions and public perceptions. They should therefore review the purchasing policies of their agencies and departments so that they may improve, where possible, the environmental content of government procurement policies, without prejudice to international trade principles.

2.11.1.7 Moving towards environmentally sound pricing

Without the stimulus of prices and market signals that make clear to producers and consumers the environmental costs of the consumption of energy, materials and natural resources and the generation of wastes, significant changes in consumption and production patterns seem unlikely to occur in the near future.

Some progress has begun in the use of appropriate economic instruments to influence consumer behavior. These instruments include environmental charges and taxes, deposit/refund systems, etc. This process should be encouraged in the light of country-specific conditions.

2.11.1.8 Reinforcing values that support sustainable consumption

Governments and private-sector organizations should promote more positive attitudes towards sustainable consumption through education, public awareness programmes and other means, such as positive advertising of products and services that utilize environmentally sound technologies or encourage sustainable production and consumption patterns. In the review of the implementation of Agenda 21, an assessment of the progress achieved in developing these national policies and strategies should be given due consideration.

3. Sustainable energy systems (54)

3.1 The role of energy in the development process

Energy consumption is a measure of human welfare, and there is a close relationship between energy consumption and economic development. Achievement of sustainable global development, therefore, implies realization of a sustainable energy future, especially in meeting the building sector, transport, industrial and household demands.

However, continuation of past patterns of energy-resource use, without due regard for their ecological impact, could lead to a crisis. Profligate production and consumption patterns of certain countries threaten the welfare of the rest of the world, because of the inability of developing countries to obtain sufficient energy to improve their state of development at affordable cost.

For countries with low per capita energy consumption to follow the energy-use pattern of high per capita energy-consuming countries is to hasten the energy and environmental crisis, i.e., create an unsustainable future. The goal of a sustainable future, therefore, imposes an obligation on all countries to implement an energy strategy, which does not jeopardize the development potential of developing countries. Amongst other implications, this might require high-energy-consuming countries to reduce their per capita consumption of energy, especially of energy that is based on fossil-fuel combustion.

The overall problem is how to meet future energy needs of a growing global population, taking into account the potentials of non-renewable and renewable primary-energy sources, and emerging global ecological problems. Current energy paths are dependent, mainly, on the use of coal, oil and natural gas. Their replacement by other sources of energy would be a time-consuming and expensive process, which would also introduce new risks and additional limitations. However, by 2015, the build-up of "greenhouse gases" will require, *inter alia,* some management of the worldwide use of fossil fuels. In such a situation, energy paths that reflect a continuation of current use patterns could not support the development aspirations of many countries.

In developing countries, population growth will have an important impact on energy availability, especially on the demand for traditional fuels, such as biomass. Energy conservation can play a role but only to the extent of making scarce, and depletable energy resources available for an extended time. Hence, energy conservation alone will not suffice. Additional efforts towards developing new energy sources will be a crucial factor in energy-resource sustainability.

3.2 Energy development, efficiency and consumption

Much of the world's energy is currently produced and consumed in ways that could not be sustained if technology were to remain stagnant and if overall energy supply were to increase substantially. The need to control atmospheric emissions of greenhouse and other gases will increasingly need to be based on efficiency in energy production, transmission, distribution and consumption, and on growing reliance on environmentally sound energy systems, particularly new and renewable sources of energy. All energy sources will need to be used in ways that respect the atmosphere, human health, and the environment as a whole.

The existing constraints to increasing the environmentally sound energy supplies required for pursuing the path towards sustainable development, particularly in developing countries, need to be removed. The basic objective of any energy-efficiency measure should be to reduce adverse effects on the atmosphere from the energy sector by promoting policies and strategies to increase the contribution of environmentally safe and sound energy systems, particularly new and renewable ones, through less polluting and more efficient energy production, transmission, distribution and use. This objective should reflect the need for equity, adequate energy supplies and the need to take into consideration the situations that are highly dependent on the consumption of fossil fuels.

3.2.1 Recommendations and proposed actions

Governments at the appropriate level, with the cooperation of the international bodies and the private sector, could (55):

(a) Cooperate in identifying and developing economically viable, and environmentally sound energy sources to promote the availability of increased energy supplies to support sustainable development efforts, in particular in developing countries;

(b) Promote the development at the national level of appropriate methodologies for making integrated energy, environment and economic policy decisions for sustainable development, inter alia through environmental impact assessments;

(c) Promote the research, development, transfer and use of improved energy-efficient technologies and practices, including endogenous technologies in all relevant sectors, giving special attention to the rehabilitation and modernization of power systems, with particular attention to developing countries;

(d) Promote the research, development, transfer and use of technologies and practices for environmentally sound energy systems, including new and renewable energy systems, with particular attention to developing countries;

(e) Promote the development of institutional, scientific, planning and management capacities, particularly in developing countries, to develop, produce, and use increasingly efficient and less polluting forms of energy;

(f) Review current energy supply mixes to determine how the contribution of environmentally sound energy systems as a whole, particularly new and renewable energy systems, could be increased in an economically efficient manner, taking into account respective countries' unique social, physical, economic and political characteristics, and examining and implementing, where appropriate, measures to overcome any barriers to their development and use;

(g) Coordinate energy plans regionally and sub regionally, where applicable, and study the feasibility of efficient distribution of environmentally sound energy from new and renewable energy sources;

(h) In accordance with national socio-economic development and environment priorities, evaluate and, as appropriate, promote cost-effective policies or programmes, including administrative, social and economic measures, in order to improve energy efficiency;

(i) Build capacity for energy planning and programme management in energy efficiency, as well as for the development, introduction, and promotion of new and renewable sources of energy;

(j) Promote appropriate energy efficiency and emission standards or recommendations at the national level, aimed at the development and use of technologies that minimize adverse impacts on the environment.

(k) Encourage education and awareness-raising programmes at the local, national, sub regional and regional levels concerning energy efficiency and environmentally sound energy systems;

(l) Establish or enhance, as appropriate, in cooperation with the private sector, labeling programmes for products to provide decision makers and consumers with information on opportunities for energy efficiency.

3.3 Energy use in industry and commerce (56)

3.3.1 Developed countries

The combined industry and commerce sector is estimated to consume about 34 per cent of world energy production. In developed countries, the industrial sector uses more energy at the national level than any other sector, ranging from 37 per cent in the member countries of the Organization for Economic Co-operation and Development (OECD) to 52 per cent in Eastern Europe. The main fuel used in OECD member countries is oil (30 per cent of energy consumed in the sector), followed by coal (25.5 per cent), gas (24.5 per cent) and electricity (20 per cent). In Eastern Europe, the share of coal and natural gas is more important than that of oil, being about 62 per cent of the energy consumed in this sector.

3.3.2 Developing countries

In developing countries, the sector is estimated to consume 10.5 per cent of world energy production, it is the biggest consumer of commercial energy in Asia (62 per cent in China, 53 per cent in India, 50 per cent in Indonesia), and, in Latin America, the share of the sector is on a par with that of the transport sector (38 per cent, each), whereas, in West Africa, the share (20 per cent) is half that of the transport sector. Oil is the main source of energy, except in China and India, where coal contributes about 70 per cent of the energy needs of the sector.

3.4 Energy use in transport sector (57)

3.4.1 Developed countries

Although the sector consumes 19 per cent of global energy, it is not a large consumer of energy at the national level, except in OECD member countries where its national share is 30 per cent. Elsewhere, the share ranges from a maximum of 13 per cent in the CEE and CIS countries to a minimum of 7.6 per cent in the remaining developed countries. The main fuel in the sector in all countries is oil (97.5 per cent in OECD member countries and 64 per cent in CEE and CIS countries).

3.4.2 Developing countries

The transport sector of the developing countries is a small consumer of global energy (3 to 5 per cent), but there is a wide variation between different regions. In Asia, the sector is not a large consumer of energy (8 per cent of national energy consumption in China, 10 per cent in India, 14 per cent in the Republic of Korea). In Latin America, the share is 38 per cent, and, in West Africa, 44 per cent. The dominant fuel in all countries is oil.

3.5 Energy use in households (58)

3.5.1 Developed countries

The household sector consumes 21 per cent of global energy. At the national level, its importance ranges from a low of 15 per cent in the CEE and CIS countries to a high of 31 per cent in the OECD member countries. The predominant fuel also varies, depending upon the country. In OECD member countries, natural gas and primary electricity are the leading sources of energy for the sector, followed closely by oil and coal (35 per cent natural gas, 30 per cent electricity, 26 per cent oil and 8.5 per cent coal).

3.5.2 Developing countries

The sector consumes about 4 per cent of global commercial energy. Oil, in the form of kerosene, is the most important fuel for lighting and, to a lesser extent, cooking, in most developing countries, ranging from 79 per cent in Indonesia to 51 per cent in China. Coal is an important commercial fuel in some coal-rich countries, such as the Republic of Korea (59 per cent), China (43 per cent) and India (21 per cent). Biomass (fuel wood, agricultural waste and animal dung) is the most important source of energy for the poor. In India, the estimated amount of energy from this source is 104 metric-ton-oil-equivalent (MTOE), 58 per cent of total energy consumed in all the sectors. Although accurate data are not available for other countries, the consumption pattern is known to be similar.

3.6 Future energy demand

3.6.1 Developed countries (59)

According to one study, growth in primary energy demand is expected to slow down to around 0.1-0.5 per cent per annum for at least next 10-15 years. The shares of the various sectors (industry and commerce, transport, and household) are expected to remain constant. These figures are based on the assumption of continued improvements in energy-efficiency as well as a projected slowdown in economic growth in the developed countries. On this basis, the total energy consumption is expected to be between 4030 and 4750 MTOE by the year 2020 compared to about 4200 MTOE in 2000.

3.6.2 Developing countries (60)

3.6.2.1 Industry/commerce

In order to meet the demands of growing populations, the developing countries will have to embark on a great industrialization process. Assuming a continuation of the current trend of energy consumption in the sector, about 1500 MTOE of commercial energy will be required by the sector in the year 2020.

3.6.2.2 Transport

In most developing countries, the key influence on energy consumption by the sector is the growing number of vehicles. The growth rate in the number of vehicles has been exceeding the growth rate in GDP in all developing countries, and the trend is likely to continue, despite the high cost of oil. The sector would thus require about 1000 MTOE of energy by the year 2020.

3.6.2.3 Households

The commercial energy requirements of the sector have to be distinguished between those of the oil-producing countries and those of the oil-importing developing countries. The former group's requirements (about 280 MTOE in the year 2000) will be easily met locally. The latter group's requirements of approximately 150 MTOE will be met by electricity, coal, gas and imported oil. Asian countries of the group will generally turn to maximum use of electricity and direct combustion of coal, supplemented by kerosene. In the African region, oil will play an important role, either for the production of electricity or as fuel (kerosene), especially in countries having indigenous refineries.

The Latin American countries will rely, probably, on electricity, gas and oil to meet the commercial energy needs of the sector. Although all the oil-importing developing countries will face supply/demand problems, Latin American and African countries will, most likely, face the greatest hardship on account of the non-availability of alternative local commercial fuels.

Unless measures are taken to provide alternative fuels, the rural and urban poor will continue to depend on biomass fuels. This dependence has implications for sustainability, as the use of biomass is leading to deforestation, reduction of C02 uptake of forests, soil erosion and desertification. There could, eventually, be a total collapse of the energy-supply system for these segments of the population.

3.7 Energy resources (61)

In the developed countries, oil is expected to remain the largest single contributor to energy production at around 30 per cent in 2020, compared with 38.5 per cent in 1985. The share of coal is expected to rise in this century, and that of nuclear power to double between 1985 and 2020, whereas the contribution of gas is to decline from over 20 per cent in 1985 to around 15 per cent. The contribution of new sources of energy (solar, wind, alcohol etc.) is expected to rise from 1 per cent in the year 2000 to around 3 per cent in 2020.

In the developing countries, solid fuels are expected to maintain a stable share with gradual decline towards 2020. Similarly, natural gas is projected to increase its contribution in the short term but to stabilize or, even, decline slightly by the year 2020. The share of hydropower is expected to rise from 10 per cent of total energy production to about 15 per cent, whilst the contribution of nuclear energy is expected to reach 3-5 per cent by the year 2020. There is likely to be a significant and continued decline in the contribution of oil, from over 57 per cent in 1985 to about 48 per cent in 2020. Similarly, the contribution from non-commercial fuels is expected to decline to below 20 per cent of total energy.

There are varying degrees of exploitation of non-renewable and renewable energy sources. Of all non-renewable energy sources - petroleum, natural gas and coal are the least exploited, especially in developing countries: up to now, petroleum has been in predominant use worldwide. Hence, availability of commercial energy does not appear to be an issue even for the long term: the crucial issue would be affordability, by developing countries, of commercial-energy supplies and environmental degradation associated with fossil fuel use.

However, owing to a combination of factors, such as eventual depletion of sources, increasing difficulties of exploitation of deposits and environmental degradation, it is now generally accepted that attention needs to shift to environmentally acceptable forms of energy. In this context, renewable energy forms come to the fore as complements to and/or substitutes for non-renewable sources in meeting localized and/or low-intensity demands for energy, e.g., in various domestic and industrial uses. Of the renewable forms of energy, biomass is the source most widely used by the urban poor and by rural populations in developing countries. In Asia, the most commonly used biomass is animal waste, whereas, in Africa and Latin America, it is wood-fuel.

3.8 Energy economy and/or substitutability

Although energy-demand projections indicate no particular global problems of resource shortage, ecological requirements might and will bring about the need to:

(a) increase the use of non-conventional fossil fuels;

(b) apply improved energy management;

(c) develop new and renewable energy forms which are environment-friendly; and

(d) spread education on the need for environment-sensitive energy systems.

In addition, energy will have to be conserved through the adoption and use of energy-efficient settlement forms, transport modes and building designs, and by utilization of human settlements byproducts in energy- production systems. For high-energy-consuming countries, it implies a need to reduce per capita energy consumption, and, for low-energy-consuming countries, a need not to generate demand at consumption levels of the former and to adopt technologies for improved production and use of biomass and/or other renewable energy sources.

Energy-conservation or energy-substitution policies are best defined and implemented within an overall resource-management policy, related to specified developmental goals and objectives. A crucial issue is whether these goals and objectives are defined in terms that emphasize consumption and, hence, depletion of natural resources or in terms that emphasize the quality of consumption. If the former, the likelihood is for increasing resource shortages and need for increasing efficiency of resource use. If, however, the emphasis is on quality of consumption, the implication will be for fundamental change in the lifestyles of developed countries and radical rethinking on future expectations by developing countries.

The crisis points in future energy use are different for developed and developing countries. In the first group of countries, the main concerns are the cost of energy, ecological impacts of energy production and use, and reduction of dependence on imported fuels. Nevertheless, except for the global warming factor, energy problems are not likely to reach crisis proportions. Developing countries, however, are already facing an energy crisis in two forms. First, their developmental efforts, aimed at improving the life of their populations, have, so far, been geared to the use of oil as a source of energy, but, with the rapidly increasing costs, most oil-importing countries are now facing the prospect of not being able to afford it.

Some countries such as China, India, the Republic of Korea and several African countries, will probably turn to coal, either as a direct fuel or through the production of oil from coal to replace the unaffordable mineral oil. Nevertheless, for all the oil-importing developing countries including this group, their main hope appears to be in the rapid diffusion of new and renewable technologies.

Secondly, in the absence of an alternative affordable fuel, the rural and urban poor have no choice but to continue using biomass fuels, notwithstanding the depletion of the resources. The fuel wood deficit is estimated to double by the year 2010. Removal of wood cover is already posing a serious ecological hazard, and, as the vast bulk of the world's population survives on biomass, evidently the world is heading for a disaster in the absence of timely appropriate measures. Again, rapid and massive diffusion and use of new and renewable sources of energy appear to be the only solution.

3.9 Ecological impacts of the use of energy resources

The use of non-renewable sources of energy (fossil fuels) causes pollution problems associated with emissions of $C0_2$, methane, etc. (when gas is burnt as a fuel) and particulates: Burning of biomass increases the $C0_2$ emissions in developing countries, and other direct consequences of burning wood fuels are increased desertification and land erosion which, in turn, lead to climate change. An indirect but, nevertheless, possibly harmful effect is that, if trees are felled and not replaced through replanting, there is a reduction of the $C0_2$ uptake of forests and, hence, an increase of $C0_2$ in the atmosphere.

By definition, sustainable development implies minimal use of necessary resources. So, to overcome system constraints, action is necessary on all fronts to reduce global per capita energy consumption, especially of non-renewable fuels. A sustainable energy future might, therefore, be much dependent on the increased availability and use of renewable energy sources - as a means of improving environmental quality and supporting sustainable development.

3.10 New and renewable sources of energy

New and renewable sources of energy include, mainly, hydropower, biomass, solar, wind and geothermal which are the most promising ones. These sources of energy are individually reducible to heat, mechanical and electrical energy and with various forms of transmission processes, it is possible to transmute from one energy mode to another. Unfortunately, the various end-use applications found so far for these forms of energy are location-specific, of low intensity or non-transferable. There are many new and renewable energy technologies undergoing research and development, to make them applicable for worldwide use, including hydrogen and vegetable oils, but these are far from operationally available.

The most viable option for meeting the energy needs of the rural and urban poor is the use of biomass. To this end, conversion of biomass into gas, through the use of digesters, and the use of improved stoves are the most effective ways of using this resource. The technologies of solar photo-voltaic systems offer prospects for meeting the lighting, telecommunications, refrigeration and other power needs of the rural low-income people in a cost-effective and efficient manner in areas that are remote from national electricity grids.

For households in urban areas, the use of low-power energy-efficient appliances and the judicious substitution of cost-effective new technologies for fossil fuels, such as solar water-heaters and other space-heating and-cooling devices, offer opportunities to reduce the cost of energy services, whilst, at the same time, conserving resources.

3.11 Energy policy options

Analysis of currant energy use shows that energy issues are often being tackled randomly or occasionally. Taking into consideration future energy demand, it is evident that a holistic approach, that relates sustainability in food supply, quality of urban and rural life, and possible environmental impacts to the energy-consuming sectors (industry, transport and buildings), must be evolved. The still-evolving industrial structures in most developing countries provide the opportunity to create new patterns of energy utilization, as energy paths are invariably bound to industrial structure. Pricing policies, which reflect full resource costs, will be crucial in creating a sustainable energy path.

3.11.1 Recommendations and proposed actions

3.11.1.1 Recommendations for the developing countries

(a) National action programmes should promote integrated production of agricultural waste and biomass energy outputs, and support reforestation and natural-forest regeneration, with a view to a sustained provision of biomass energy to meet the needs of poor households.

(b) Large-scale dissemination and commercialization of mature renewable energy technologies should be promoted through fiscal measures and internal and external technology-transfer mechanisms, to encourage local manufacturing and commercialization of products which make use of these technologies.

(c) Builders should be encouraged, through building regulations, standards and codes of practice, to use low-energy locally produced building materials.

(d) Information and training programmes, directed at manufacturers and users, should be promoted, with the aim of introducing energy-saving techniques and energy-efficient appliances, such as improved stoves, which will reduce pollution.

3.11.1.2 Recommendations for the developed countries

(a) The central issue of sustainability for most developed countries is excessive use of non-renewable resources and its contribution to 'greenhouse gases and atmospheric pollution as a result of meeting transport and energy demands. Energy- conservation measures are, therefore, urgently required to reduce consumption of these resources whilst maintaining the existing quality of life. In the construction industry, embodied energy in building materials should be reduced.

Recommended energy-conservation measures in the household sector include district heating and cooling, improved insulation, especially of existing buildings, and increased use of new and renewable sources of energy. In the transport sector, the measures include increasing charges on automobile use, e.g., through road and petroleum-products taxes, stringent pollution control of vehicles, speed limits, limitation of private automobile use in congested areas and encouragement of public transport modes. Settlement densities can be intensified and land uses can be arranged, so that transport energy can be economized.

(b) Co-operation should be developed in the related fields of energy conservation, energy pricing and taxation as well as in promotion of technology-oriented joint ventures between consumer and producer interests.

3.11.1.3 Recommendations for the international community

(a) International organizations should assist in preparing resource-management programmes for implementing and monitoring efficient and ecologically sound energy policies.

(b) Developing countries should be provided access to research and development results, to increase energy-use efficiency levels, especially in urban settlements.

(c) International organizations should provide assistance to developing countries, to enable them to apply, on a large scale, renewable-energy technologies, particularly for the use of solar, hydro, wind and biomass sources.

4. Energy consumption in building and construction industry

4.1 Overview

As indicated earlier, the building/construction industry is a major consumer of energy. It uses energy for the production of buildings and civil engineering works as well as for the subsequent use of buildings and facilities. A significant amount of energy is used directly in the building materials production plants and their transportation and of course at the construction sites, whereas that consumed in buildings-in-use (the operational energy of the buildings) is controlled, to a large extent, by the eventual users.

In many countries, the issue of improving efficiency in the consumption of energy for the construction of housing and other type of buildings is gaining special urgency because of rapid urbanization, and adoption of new technologies. In the context of many developing countries, for example, the change from rural to urban settlements is often accompanied with a rapid change from the use of almost no-energy-content materials such as earth, stone and thatch to higher energy-content materials such as cement, steel, aluminium, bricks, concrete and glass.

4.2 Distribution of energy consumption among different building sectors and types (62)

In most countries, residential buildings are responsible for a major part of the energy consumption of the building sector, even if the share of commercial buildings such as offices is also important. Studies indicate that, on average, buildings in Europe account for 36 per cent of the energy use: The non-residential sector accounts for 8.8 per cent and the residential sector for 27.5 per cent of the total (63). The breakdown of the residential and non-residential sector in Europe is presented in table 6.

Table 6. Shares of energy use in different building sectors in the world in percentage of the total energy use

Region	Percentage of total energy use	
	Residential	Commercial and public services
Sub-saharan Africa	54	4
Asia (excl. Middle East)	35	7
Europe	28	10
North America	17	12
Central America and Caribbean	22	5
Middle East and North Africa	20	7
South America	18	3
Oceania	12	4
Developed countries	21	11
Developing countries	33	5

Source: Earth trends 2005, Reference 63.

4.3 Embodied energy in buildings

Energy consumption in the production of buildings is a relatively small part of the total lifetime energy use, perhaps 10 to 15 percent, if a lifetime of about 30-40 years is assumed (64). But much of this lifetime energy use, which is related to heating, cooling and other types of uses is so over which the initial design has little effect. The energy used in the production, the so-called embodied energy, is however totally within the control of the construction industry, i.e. the designers, builders and building materials producers

By definition, the embodied energy of any construction output (buildings and civil engineering facilities) is the total energy used in all stages of the production of these physical assets. These stages, in general, start with the extraction of raw materials, production of building materials and components, transportation, and concludes with on-site construction and completion of the buildings and other civil engineering facilities.

About 80 percent of the total energy requirement in the building and general construction sectors is used in the production and transportation of key building materials to the site and the rest, about 20 per cent, is used in the on-site construction process (65). On the basis of the gross energy requirement for manufacturing a unit weight of building materials, these can be classified in three categories:

(a) Low energy-content materials such as soil, stone and aggregates;

(b) Medium energy-content materials such as lime, gypsum, concrete, clay bricks and tiles, blocks, ceramic tiles; and

(c) High energy-content materials such as aluminium, steel, cement, glass and plastics.

Table 7 shows a classification of major building materials used in construction in terms of energy requirement for their production. As it can be seen, the amount of energy used to produce a unit weight of a high energy-content material is sometimes more than 100 times that is needed for low energy-content materials. Similarly, different types of construction systems (sets of materials) can result in considerable differences in the total embodied energy requirements in a complete house or any other type of building system. Table 8 shows a comparison of three houses using different materials with different energy contents.

Table 7. Comparative energy-requirements of some materials

Material	Primary energy requirement (Gigajoule/ton)
High energy materials	
Aluminium	200-250
Plastics	50-100
Stainless steel	100+
Steel	30-60
Lead, Zinc	25+
Glass	12.5
Cement	5.8
Medium energy materials	
Lime	3-5
Clay bricks and tiles	2-7
Gypsum plaster	1-4
Concrete	0.8-1.5
Timber	00.1-0.5
Low energy materials	
Sand aggregate	<0.5
Soil	<0.5

Source: Reference 64.

Table 8. Comparative energy requirements for three typical single-storey houses

House type	Embodied energy (MJ/sq.m.)
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

Source: Reference 64.

Since most of the high energy-content materials are produced in large-scale facilities using modem technologies, the producers are well aware of the importance of energy efficiency. However, in the context of developing countries, where many of the producers operate at small-scale using traditional processes, it is unlikely that they can respond to changing pressure or upgrade their technologies in a speedy manner and without external support.

The high and medium energy-content materials require the use of kiln processes for production, which are dependent on fossil fuels and in which there are considerable differences between the energy consumptions of the available processes. Even where elements are being compared on the basis of performance, there are often considerable differences between the energy consumption of the most and the least energy-intensive processes available. Table 9, for example, compares the energy requirements of alternative low-cost roofing assemblies for pitched roofs.

Table 9. Comparative energy requirements of alternative roofing assemblies for a pitched roof

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

Source: Reference 66.

In spite of improving energy efficiency, rising energy costs are one of the principle factors causing building materials prices worldwide to rise. This has created incentives and has encouraged scientists to carry out research and introduce innovations directed towards greater energy-efficiency and fuel substitution.

4.3.1 Strategies to reduce the embodied energy of the buildings

Since energy is one of the most costly inputs to the building and construction industries, in general, and the source of most of their polluting effects, improving energy efficiency is one of the most urgent tasks to be addressed. This will call for:

- Design for long life and adaptability, using durable and low maintenance materials,

- efficient use of energy-intensive materials,

- greater use of low energy-content materials,

- improving the energy efficiency of production processes,

- applying low-energy architectural design principles,

- increasing the use of recycled and waste materials,
- modify or refurbish instead of demolishing and constructing new buildings,
- use locally available materials when possible and salvage materials to reduce transport,
- use materials that can be recycled in future.

4.4 Operational energy in buildings

4.4.1 Overview

As mentioned earlier, a considerable amount of energy is used in buildings during their lifetime. This is required for heating, cooling, ventilating, lighting, and other activities. The energy-use patterns inside buildings vary a great deal according to occupant's behaviour, type of the structure and the location of buildings. In residential buildings, urban and rural patterns, for example, tend to be very different. Similarly, household income for residential buildings and climate have major influences both on energy sources and end-use patterns.

Available information on how in residential buildings energy is used is rather poor, and as a result it is difficult to assess accurately efficiency progress in the past and to understand how efficiency patterns could affect future demand. Even where data are available, the economic impact of household energy conservation cannot be assessed, except in very general terms. Without such information, it is impossible for authorities and facility managers to prioritise conservation programmes or allocate funds to those areas that promise the greatest return. So far, many policies have been designed, and much advice has been given on the basis of reasonable "rules of thumb".

Many households, which previously endured a poor indoor climate, are gradually going to install equipment for active climatization as soon as they can afford it. This trend is especially obvious in urban households, which tend to have a better economy and a modern life style compared to their neighbours in hinterland.

Architects and engineers have a crucial role to play in designing buildings to minimize the energy use for active climatization and lighting. A good approach is to take advantage of natural means such as solar radiation and winds and use the building as a collector, storage and transfer mechanism. These so-called passive techniques might be so efficient that in some regions no energy will be required for heating or cooling. The knowledge of passive techniques is well developed, but is unfortunately not yet effectively practiced in many countries.

Many existing buildings were never designed for active climatizartion through heating or air conditioning. The energy performance of such buildings can be improved significantly by increasing air-tightness through sealing of windows or other openings, and by adding thermal insulation materials to the building envelope. The additional cost of such measures pays normally back in few years.

In cold climates where there is a substantial annual heating requirement, various forms of energy sources such as electricity, gas, coal and liquid fuel are used to heat the indoor spaces. A high insulation standard of walls, windows and roofs of the buildings could contribute greatly to reduce the use of energy for heating.

In areas where there is a significant need for cooling, (in hot-dry and hot-humid climates), there is an increasing demand for air-conditioning in work places and in the upper-income urban households. Air-conditioning is inherently energy-intensive in relation to the cooling achieved, since the coefficient of performance is low when compared with heating devises and electricity is the main energy source used. The poor insulation and sealing of many air-conditioned spaces add also to energy demand.

Seen over a building's life time, the ratio between embodied and operational energy will vary considerably, depending on such factors as type of construction, climate and user behaviour. For example, if a building is constructed with high and medium energy materials and no heating or cooling energy is used, the portion of embodied energy will be very high. But if a building has high annual use of energy for heating and/or cooling, the portion of operational energy will be very high, particularly if the building is badly adapted to the climate.

4.4.2 Shares of different energy end-use purposes (67)

The pattern of energy use of a building first and foremost depends on the building type and the climate zone where it is located. In addition, the level of economic development in the area is also influential in shaping the energy use pattern. Currently, one third of the world's population has no access to electricity, more than 80 per cent of whom are located in South Asia and sub-Saharan Africa. (68). In rural areas of sub-Saharan Africa, cooking accounts for between 80 to 100 per cent of the average of the household energy consumption (69). Examples of the shares of different energy uses during the operation phase of the buildings are shown in table 10.

In terms of international average, most residential energy in developed countries is consumed for space heating (60 per cent, although not as important in some developed countries with warmer climate, but in this case the energy is used for cooling purposes) with this application followed in order by water heating (18 per cent) and domestic appliances (6 per cent for refrigeration and cooking and 12 per cent for lighting) with other uses accounting for about 13 per cent.

However, there are substantial variations. In Japan for example, the share for space heating is as low as 28 per cent. In the United States of America, most of the energy used in buildings is due to climatization systems (heating, ventilation and air conditioning – HVAC, totaling to 64 per cent, followed by water heating, 24 per cent and lighting, 12 per cent). (70).

Table 10. Shares of different energy end-use purposes for residential and commercial buildings in selected countries.

Country and type of building	Space heating	Space cooling	Lighting	Water heating	Others
Kuwait Residential	16	23	NA	58	4
India Commercial	9	59	NA	32	NA
India Residential	28	25	NA	46	NA
USA Commercial	38	21	3	8	31
USA Residential	29	NA	20	5	26
China Rural residential	67	NA	NA	2	32
China Urban residential	50	3	4	2	43
Australia Commercial	32	19	NA	5	25
Australia Residential	15	4	20	3	59
Canada Commercial	20	13	8	7	50
Canada Residential	12	3	20	NA	60

Source: Reference 71.

NA: means data not available

5. Atmospheric air pollution

5.1 Overview

Several studies have revealed that much of the atmospheric pollution stems from human activities, economic growth, industrialization, urban transport and almost all other urban functions. Following a number of international interventions such as the adoption of Agenda 21 by the United Nations Conference on Environment and Developments (UNCED) and the United Nations Framework Convention on Climate Change (UNFCCC) and many other agreements and protocols, serious actions are being taken by many nations to reduce these emissions.

However, even with the current declining emissions, greenhouse gases continue to accumulate. The Inter-governmental Panel on Climate Change (IPCC) has estimated that an immediate 60 per cent reduction on emissions of long-lived gases (shorter reductions for short-lived gases) would be required to stabilize atmospheric concentrations (25). As long as concentrations continue to rise, so does the warming potential of the atmosphere and hence the risk of global climate change.

The most recent international intervention was the ratification of the Kyoto Protocol, which represents a vital step forward in nations' efforts to address climate change. The Protocol sets out binding limits on the total greenhouse gas emissions of industrialized countries and establishes an emission reduction target of 5.2 per cent below the 1990 emission levels by 2012. To forward this goal, the Protocol outlines a set of flexibility mechanism, that offer a market-based framework for global cooperation for greenhouse gas reduction and stabilization.

5.2 Protection of the atmosphere

Protection of the atmosphere is a broad and multidimensional endeavor involving various sectors of economic activities. However, as described earlier, most urban functions are, in one way or other, major contributors to atmospheric pollution. The options and measures described in this chapter are recommended for consideration and, as appropriate, implementation by governments and other bodies in their efforts to protect the atmosphere.

It is in this connection that over the past 1-2 decades, major international efforts have been made to arrest the atmospheric pollution at global level. Notable among these initiatives are:

- The 1985 Vienna Convention for the Protection of the Ozone Layer,
- The 1987 Montreal Protocol on Substances that Deplete the Ozone Layer,
- The 1992 Framework Convention on Climate Change,
- The 1997 Kyoto Protocol on Climate Change, and
- Other international, as well as regional, instruments and initiatives.

5.2.1 Improving the scientific basis for decision-making (72)

Concern about climate change and climate variability, air pollution and ozone depletion has created new demands for scientific, economic and social information to reduce the remaining uncertainties in these fields. Better understanding and prediction of the various properties of the atmosphere and of the affected ecosystems, as well as health impacts and their interactions with socio-economic factors, are urgently needed.

In this connection, the basic objective of any policy or action programme area, in any country, should be to improve the understanding of processes that influence and are influenced by the earth's atmosphere on a global scale, including, *inter alia*, physical, chemical, geological, biological, oceanic, hydrological, economic and social processes. It should also build capacity and enhance international cooperation and should improve understanding of the economic and social consequences of atmospheric changes and of mitigation and response measures addressing such changes.

5.2.2 Recommendations and proposed actions

Governments at the appropriate level, with the cooperation of the international bodies and the private sector, could (73):

(a) Promote research related to the natural processes affecting the atmosphere, as well as the critical linkages between sustainable development and atmospheric changes;

(b) Ensure a more balanced geographical coverage of the Global Climate Observing System and its components, including the Global Atmosphere Watch, by facilitating, *inter alia*, the establishment and operation of additional systematic observation stations, and by contributing to the development, utilization and accessibility of these databases;

(c) Promote cooperation in the development of early detection systems concerning changes and fluctuations in the atmosphere, and the establishment and improvement of capabilities to predict such changes and fluctuations and to assess the resulting environmental and socio-economic impacts;

(d) Cooperate in research to develop methodologies and identify threshold levels of atmospheric pollutants, as well as atmospheric levels of greenhouse gas concentrations, that would cause dangerous human interference with the climate system and the environment as a whole, and the associated rates of change that would not allow ecosystems to adapt naturally

(e) Promote, and cooperate in the building of scientific capacities, the exchange of scientific data and information, and the facilitation of the participation and training of experts and technical staff, particularly of developing countries, in the fields of research, data assembly, collection and assessment, and systematic observation related to the atmosphere.

5.3 Air pollution related to industrial development

Industry is essential for the production of goods and services and is a major source of employment, income and development. At the same time, industry is a major resource user and polluter of the atmosphere and the environment as a whole. Protection of the atmosphere can be enhanced, inter alia, by increasing resource and materials efficiency in industry, installing or improving pollution abatement technologies and replacing chlorofluorocarbons (CFCs) and other ozone-depleting substances with appropriate substitutes, as well as by reducing wastes and by-products.

The basic objective of any policy or action programme area should, therefore, be to encourage industrial development in ways that minimize adverse impacts on the atmosphere and by developing new environmentally sound and cleaner technologies.

5.3.1 Recommendations and proposed actions

Governments at the appropriate level, with the cooperation of the international bodies and the private sector, could (74):

(a) In accordance with national socio-economic development and environment priorities, evaluate and, as appropriate, promote cost effective policies or programmes, including administrative, social and economic measures, in order to minimize industrial pollution and adverse impacts on the atmosphere;

(b) Encourage industry to increase and strengthen its capacity to develop technologies, products and processes that are safe, less polluting, and make more efficient use of all resources and materials, including energy;

(c) Cooperate in development and transfer of such industrial technologies and in development of capacities to manage and use such technologies, particularly with respect to developing countries;

(d) Develop, improve and apply environmental impact assessments to foster sustainable industrial development;

(e) Promote efficient use of materials and resources, taking into account the life cycles of products, in order to realize the economic and environmental benefits of using resources more efficiently and producing fewer wastes;

(f) Support the promotion of less polluting and more efficient technologies and processes in industries, taking into account area-specific accessible potentials for energy, particularly safe and renewable sources of energy, with a view to limiting industrial pollution and adverse impacts on the atmosphere.

5.4 Preventing stratospheric ozone depletion

Analysis of recent scientific data has confirmed the growing concern about the continuing depletion of the Earth's stratospheric ozone layer by reactive chlorine and bromine from man-made CFCs, halons and related substances. While the 1985 Vienna Convention for the Protection of the Ozone Layer and the 1987 Montreal Protocol on Substances that deplete the Ozone Layer (as amended in London in 1990) were important steps in international action, the total chlorine loading of the atmosphere of ozone-depleting substances has continued to rise. This can be changed through compliance with the control measures identified within the Protocol.

The objectives of all governments' policy and action programmes in this area should be:

(a) To realize the objectives defined in the Vienna Convention and the Montreal Protocol and its 1990 amendments, including the consideration of those instruments of the special needs and conditions of the developing countries and the availability to them of alternatives to substances that deplete the ozone layer. Technologies and natural products that reduce demand for these substances should be encouraged;

(b) To develop strategies aimed at mitigating the adverse effects of ultraviolet radiation reaching the Earth's surface as a consequence of depletion and modification of the stratospheric ozone layer.

5.4.1 Recommendations and proposed actions

Governments at the appropriate level, with the cooperation of the international bodies and the private sector could (75):

(a) Ratify, accept or approve the Montreal Protocol and its amendments and contribute towards ongoing efforts under the Montreal Protocol and its implementing mechanisms, including making available substitutes for CFCs and other ozone-depleting substances and facilitating the transfer of the corresponding technologies to developing countries in order to enable them to comply with the obligations of the Protocol;

(b) Support further expansion of the Global Ozone Observing System by facilitating - through bilateral and multilateral funding - the establishment and operation of additional systematic observation stations, especially in the tropical belt in the southern hemisphere.

(c) Participate actively in the continuous assessment of scientific information and the health and environmental effects, as well as of the technological/economic implications of stratospheric ozone depletion; and consider further actions that prove warranted and feasible on the basis of these assessments;

(d) Based on the results of research on the effects of the additional ultraviolet radiation reaching the Earth's surface, consider taking appropriate remedial measures in the fields of human health, agriculture and marine environment;

(e) Replace CFCs and other ozone-depleting substances, consistent with the Montreal Protocol, recognizing that a replacement's suitability should be evaluated holistically and not simply based on its contribution to solving one atmospheric or environmental problem.

5.5 Trans-boundary atmospheric pollution (76)

Trans-boundary air pollution has adverse health impacts on humans and other detrimental environmental impacts, such as tree and forest loss and the acidification of water bodies. The geographical distribution of atmospheric pollution monitoring networks is uneven, with the developing countries severely underrepresented. The lack of reliable emissions data outside Europe and North America is a major constraint to measuring trans-boundary air pollution. There is also insufficient information on the environmental and health effects of air pollution in other regions.

The Economic Commission for Europe Convention on Long-range Trans-boundary Air Pollution, and its protocols, have established a regional regime in Europe and North America, based on a review process and cooperative programmes for systematic observation of air pollution, assessment and information exchange. These programmes need to be continued and enhanced, and their experience needs to be shared with other regions of the world. The objectives of this policy and action programme area could be:

(a) To develop and apply pollution control and measurement technologies for stationary and mobile sources of air pollution and to develop alternative environmentally sound technologies;

(b) To observe and assess systematically the sources and extent of trans-boundary air pollution resulting from natural processes and anthropogenic activities;

(c) To strengthen the capabilities, particularly of developing countries, to measure, model and assess the fate and impacts of trans-boundary air pollution, through, *inter alia,* exchange of information and training of experts;

(d) To develop capabilities to assess and mitigate trans-boundary air pollution resulting from industrial and nuclear accidents, natural disasters and the deliberate and/or accidental destruction of natural resources;

(e) To encourage the establishment of new and the implementation of existing regional agreements for limiting trans-boundary air pollution;

(f) To develop strategies aiming at the reduction of emissions causing trans-boundary air pollution and their effects.

5.5.1 Recommendations and proposed actions

Governments at the appropriate level, with the cooperation of the international bodies and the private sector and financial institutions could (77):

(a) Establish and/or strengthen regional agreements for trans-boundary air pollution control and cooperate, particularly with developing countries, in the areas of systematic observations and assessment, modeling and the development and exchange of emission control technologies of mobile and stationary sources of air pollution. In this context, greater emphasis should be put on addressing the extent, causes, health and socio-economic impacts of ultraviolet radiation, acidification of the environment and photo-oxidant damage to forests and other vegetation;

(b) Establish or strengthen early warning systems and response mechanisms for trans-boundary air pollution resulting from industrial accidents and natural disasters and the deliberate and/or accidental destruction of natural resources;

(c) Facilitate training opportunities and exchange of data, information and national and/or regional experiences;

(a) Cooperate on regional, multilateral and bilateral bases to assess trans-boundary air pollution, and elaborate and implement programmes identifying specific actions to reduce atmospheric emissions and to address their environmental, economic, social and other effects.

Box 13

Air pollution and health in the transition economies

Even though the situation is changing rapidly, however, several studies conducted in mid 1990s have revealed that one of the primary challenges for urban areas in transition economies of CEE and CIS countries was/is to clean up the pollution of uncontrolled industrial production - The term CEE and CIS is used for the countries with economies in transition of the Central and Eastern Europe (CEE) and the countries of the Commonwealth of Independent States (CIS) or (the newly independent States) of the former Union of Soviet Socialist Republics (USSR) - (78). Even though since 1989, the region's economic downturn has resulted in reduced industrial production and pollution, annual air pollution rates such as the short and long-term sulfur dioxide exposure still exceed the WHO guidelines in many cities (79). In addition, new threats to air quality are emerging, such as rising emissions of lead and nitrogen oxides as more people gain access to private cars. Many cars are still old, inefficient and use leaded petrol. In Katovice, Poland, for example, 75 per cent of lead emissions come from cars that are 10-30 years old.

Average blood levels among exposed children in many CEE and CIS cities are often greater than 15 micrograms per deciliter and sometimes exceed 40 micrograms per deciliter, especially in city centers with heavy car traffic (80). Whereas in many cities of western Europe where unleaded gasoline is mainly burned, average blood levels among 2- to -3 years old children is roughly 5.3 micrograms per deciliter.

High levels of air pollution have also caused acute or chronic asthma and bronchitis illnesses. In Krakau, Poland, for example, a study has shown that lung cancer risks have increased among residents of the city center (81). The residents of many cities of the region are also facing increasing risks of crumbling infrastructure and deteriorated health services.

In response to this situation, however, many municipalities are implementing broad-based strategies to curb the industrial pollution. In Katovice, Poland, for example, the Ministry of Environmental Protection has prepared a list of the most polluting industries and has ordered them to reduce emissions. The city has also expanded its air quality monitoring system, which now is the most extensive one in Poland (82). Similarly, Novokusnetsk, Russia, has forged a partnership with the US city of Pittsburgh to exchange information about the links between health and pollution and to learn from the experiences of US pollution control measures (83).

Source: As indicated in the text.

Box 14

International action to reduce greenhouse gases and ozone-depleting emissions

Following a number of international interventions, serious actions are being taken by many nations to reduce the greenhouse gas and ozone-depleting emissions. However, even with the current declining emissions, greenhouse gasses continue to accumulate.

The Montreal Protocol ratified by 170 countries in 1987, provides guideline and procedures to eliminate the use of ozone-depleting substances such as CFCs. During the last decade, over US $ 1 billion has been allocated for industrial projects in developing countries to assist them to meet their obligations under the protocol. For example, the United Nations Industrial Development Organization (UNIDO) based in Vienna, is rendering its assistance to close to 600 projects in the relevant industrial sectors (2001 data).

The most recent international intervention was the Kyoto Protocol, which represents a vital step forward in nation's efforts to address global warming. The Protocol sets out binding limits on the total greenhouse gas emissions of industrialized countries and establishes an emission reduction target of 5.2 per cent below the 1990 emissions levels.

The Kyoto Protocol and the reluctance of certain countries to fully implement its recommendations/resolutions has been a cause of global concern in recent years.

Source: United Nations Documents

6. Contribution of the building and construction industry to air pollution

6.1 Different levels of air pollution

The building and construction industry contributes to atmospheric pollution at three levels.

(a) At local level the industry creates air pollution through emissions of dust, fibre, particles and toxic gases from site activities and building materials production processes and transportation,

(b) At regional level it contributes to pollution through emissions of nitrogen and sulphur oxides in building materials production (e.g. cement, lime, glass and metallurgical industries), and

(c) At global level it contributes to atmospheric pollution in two important ways:

(1) By the emission of carbon dioxide and other greenhouse gases from burning fossil fuels;

(2) By the use and release of CFC in the building air-conditioning systems (chillers) and other ozone-depleting substances.

6.1.1 Local level

The most serious air pollutant at local level is suspended particulate matter (SPM) - soot, dust and fibres. The primary source of SPM is the burning of fossil fuels, but there are additional particulate sources deriving from several building-materials industries. Woodworking industries, and cement and lime production are all potential generators of dust and fibre unless abatement methods are used.

A second serious source of pollution is sulphur dioxide. This also arises in the production of building materials, particularly in the burning of high-sulphur coal or oil. International standards define acceptable levels of both SPM and sulphur dioxide, but these are already exceeded in many cities becoming the cause of much debate. According to several studies, more than 500 million urban residents are exposed to unacceptable levels of SPM and some 730 million are exposed to unacceptable levels of sulphur dioxide (84). And finally, output of nitrogen oxides from fuel burning is another growing threat. It will be, therefore, vital for the industry to apply cleaner technology and not to add to these pollution levels further.

6.1.2 Regional level

Air pollution can spread within a larger region in certain atmospheric circumstances. The most common regional effect is acid rain from emissions of $S0_2$ and Nitrogen oxides. These gases can travel long distances from the source, even across country borders, before being brought back to the ground with rain. Acidification harms forests, agriculture and lakes.

6.1.3 Global level

Although not toxic, carbon dioxide (CO_2) is the major greenhouse gas and thus the cause of global warming. An estimated 8 to 20 per cent of these emissions in different countries is believed to be 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. World carbon dioxide emissions from fossil fuel consumption and cement manufacturing increased nearly four-fold from 6,000 tons per year in 1950 to more than 22,000 tons in early 1990s and about 28,000 – 30,000 tons in early 2000s (85).

In addition to pollutants generated from energy-intensive processes, a further enormous contribution to global emission, particularly carbon dioxide, results from energy use in buildings-in-use, for example for space heating. District heating is often poorly controlled and hence inefficient. For example in China about 90 million metric tons of coal is burnt annually for urban heating (86). Table 11 shows the annual carbon dioxide emissions from fossil fuel consumption for four selected countries from 4 continents, which could be generalized for the respective continents representing a global picture.

Table 11. Carbon dioxide (CO_2) emissions for selected countries and the estimated contribution from various industries

Country	Total CO_2 production (1,000 tons/year)	Construction industry (percentage)	Cement manufacture (percentage)	Operation of buildings (percentage)
Argentina	118,157	7.6	1.9	39
India	651,936	17.5	3.2	8
Germany	641,398	11.8	2.1	51
Kenya	5,192	11.9	11.7	25

Source: Reference 87.

The amount of CO_2 emissions depends on the type of fuel shown in table 12.

Table 12. Approximate CO_2 emissions per gigajoule (GJ) for selected fuels

Fuel	CO_2 emissions (Kg/GJ)
Electricity from coal	230
Gas from coal	130
Coal	90
Oil	85
Fuel wood	80
Natural gas	55

Source: Reference 88.

Box 15

Air pollution from cement industry

The cement industry is estimated to contribute up to 5 per cent of all CO_2 emissions. On average, 50 per cent of these emissions stem from chemical changes of the limestone (Calcination), 40 per cent from fuel combustion and over 5 per cent from both electric power consumption and transport (89). There are several ways to produce cement, each using different amounts of energy. A modem dry process, which can use as little as 830 kWh/ton of clinker, is more efficient than a wet process (1,390 – 1,670 kWh/ton of clinker).

Increasing blended cement production, which includes materials that do not require processing in the cement kiln (such as fly ash or slag), reduces the CO_2 emissions as well as energy consumption. Consequently the more widespread use of Best Available Technologies (BATs) could substantially reduce energy consumption and CO_2 emissions. In china for example, where about 40 per cent of the world's cement is produced, there could be significant savings in energy consumption had China used the energy technologies being used for example in Japan.

Source: Reference 90.

Organic compounds, such as methane, also make a considerable contribution to the greenhouse effect. A particular concern is felt with regard to CFCs used in insulation materials, in fire-extinguishing systems and in air-conditioning. Although the volume of CFC emissions is low, they have a disproportionately high impact on climate through their ozone-depleting effects.

As mentioned above, the great majority of processes which lead to the release of contaminating substances into the atmosphere are consumers of energy and, in particular, those requiring the combustion of fossil fuels. The consequences, in terms of pollution, of construction-related operations can, in general terms, be related to the primary energy requirements of these processes. The characteristics of certain processes, however, give rise to particular problems. Some of these are the direct consequence of energy use, while other pollution effects are connected to chemical processes such as generation of additional carbon dioxide from calcination of limestone in cement and lime factories.

Finally, transportation of building materials by trucks to construction sites is also a major contributor to the air pollution. Reducing the transportation distances or by changing the mode of transportation will significantly reduce these emissions and may even cut down the price of products for end-users.

Since air pollution and release of green house gases result in climate change and affect the environment regionally and globally, worldwide reduction of emissions calls for global action.

7. Life cycle approach

7.1 Overview

As mentioned earlier, the building and construction industry is one of the most complex and multi-sectoral industries. While the expansion and/or increase of the construction-sector activity is a major contributor to overall economic and social development in every country, it is, in the mean time, a major consumer of natural resources and a significant contributor to environmental degradation. In this context and in order to assess how different construction materials and components and the operation of buildings influence the environment over a long period of time, it is worth considering a so called "life-cycle approach".

7.2 Life cycle analysis

In general terms, life cycle analysis or assessment (LCA) is meant to assess the performance of manufactured products (for example buildings and/or any civil engineering product) over the entire lifetime of the products and their impact on the environment during that time. The analysis requires information on inputs for the production process such as raw materials and energy. It is also important to know the amount and type of wastes the manufacturing process generates (gases, liquids and solid wastes).

The study of a LCA should lead to a comparison between alternative production processes, look into the possibilities of economizing the use of inputs such as raw materials, particularly, energy and to identify and reduce the wastes and polluting effects of the construction products. Furthermore, the LCA is expected to assess and identify the most suitable and environment-friendly technologies for production and to provide guidance for reducing the adverse effects of the processes on the environment.

In the past couple of years, quite a number of scientists and building research institutions (mainly in the industrialized countries) have made attempts to carry out life cycle analysis / assessments. However, as more life cycle studies have been conducted, their limitations have become apparent. Not surprisingly, because of the complex nature of the task, most life cycle analyses have considered only a small part of the life cycle.

It is also not always possible to obtain the necessary data, as they are often confidential. The results of these analysis have been long tables covering a large number of, rather confusing, data which are difficult to evaluate and process for the purpose of identifying the environmental impacts of the processes (91).

As a consequence, it has proved to be very difficult to make objective life cycle performance comparisons between products and processes. In this context and in an attempt to overcome the prevailing limitations, a number of research institutions are currently involved in setting out a framework for life cycle analysis with the aim of defining a methodology for calculating accurately the embodied energy and emitted carbon dioxide for building materials production (92).

7.3 Life cycle assessment of building materials

The life cycle assessment or analysis of building materials and/or construction elements considers the entire lifetime of the materials/products and their impact on the environment during that time. This includes the following phases:

- Extraction and transportation of raw materials;
- Processing and production;
- Use and installation of materials and/or components;
- Demolition when it is proved to be necessary; and
- Waste treatment or recycling of demolished products.

The environmental impact of the products is evaluated within each of the above-mentioned phases. The environmental parameters that are being taken into consideration normally include:

- **Resource depletion:** energy, materials, water, etc.

- **Human health:** consequences of toxic emissions, impact on work environment, etc.

- **Global and regional pollution:** global warming, depletion of ozone layer, acidification, etc.

- **impact on animals and on vegetation:** biological diversity, etc.

To evaluate a product, its different environmental impacts are scored, and the sum from all phases is added. One difficulty with LCAs is how to weigh different environmental impacts against each other. Existing LCA methods have all different points systems and a comparison between materials often turns out differently depending on the method. Most methods have been developed nationally, and tend to focus on local circumstances and national policies.

Products achieving good ratings in life cycle analysis are based on renewable raw materials, are produced with methods using low amounts of energy and having low pollution, are sound and non-hazardous for the users, etc. If there is a possibility to reuse or recycle the product when a building is demolished, or if the product can be reused, this is considered positive and reduces the total environmental impact considerably.

Many industrialized countries have developed so-called eco-labelling schemes to promote the production of environmentally friendly products. Products that meet the requirements get the eco-label, which works as a "guarantee" to consumers meaning that the particular product is environmentally sound. Given the increasing awareness among consumers of the importance of protecting the environment, eco-labels have become important tools to market products.

Apart from being used to compare building materials, life cycle assessments have long been used by the building materials producers to improve the quality of their products. LCAs are performed to compare alternative production processes, to look into the possibilities to reduce inputs such as energy, and to identify and reduce the wastes and the polluting effects. In many cases LCA is an excellent tool for material producers to make their products more environmentally friendly.

7.4 Life cycle studies of the entire buildings

A limitation with product life cycle assessments is that they normally concentrate on the product itself, and do not include the influence on the energy use in the building during operation. Many thermal insulation materials, which are resource consuming and would not be considered good options in most product life cycle assessments, can reduce energy use in buildings considerably.

Useful approaches, when studying energy use in entire buildings, are life cycle-cost or life-cycle energy analysis. Since energy use is largely linked to environmental impact, the life cycle energy use of buildings, taking into account both the embodied energy in the buildings as well as its operational energy requirement, can be considered a measure of a building's environmental friendliness.

Several countries have already started arranging eco-labelling systems for selected buildings. In the United Kingdom, the Building Research Establishment has developed an "Environmental Standard" to issue a certificate if a building fulfils the requirements of the scheme (91).

8. Buildings materials and health

8.1 Overview

The suitability of certain building materials to human health has been a matter of increasing concern among scientists and building occupants in the recent decades. The health hazards associated with these materials have been subject of discussion in many national and international fora. Given the importance of health as one of the most pressing areas of social concern, a range of studies have been conducted and specific regulations and standards have been produced to mitigate or eradicate the harmful effects of such materials.

Risks to human health result from exposure to harmful environmental conditions in the extraction, production and use of building materials, and the disposal of related wastes.

The harmful conditions include exposure to dust, fumes, gases, and vapors and toxic metals.

The interaction of these factors and human organisms occurs either by absorption through skin, by intake into digestive track by mouth, or by inhalation into the lungs. The results of the interaction can be harmful to human health in a variety of ways, including: respiratory diseases such as asthma, heart diseases, cancer, brain damage or poisoning. The effects of the hazards may be slow, cumulative, irreversible, and complicated by even non-occupational factors such as smoking.

The quality of the built environment (e.g. buildings) too affects its inhabitants in many ways and is dependent not only on the architectural form and specifications, but also on the quality and nature of materials used, the care taken in construction, and the timely and effective maintenance of the building's fabric and support systems.

Some of the health hazards associated with building materials and the built-environment are well documented and programmes to reduce them are in place. Others are and will be the subject of current and future research, therefore, remedial measures are not yet in place. Furthermore the indications, based on present knowledge, that a certain material is harmless to human health does not preclude possible discoveries of health hazards in future, bearing in mind the continuing advances in science and medicine.

There is also low public awareness of the health hazards, and additionally many decision makers are not fully informed or aware of the health implications of building materials. Inadequate information greatly inhibits the ability of the construction industry and other stakeholders in effectively responding to the challenge of controlling the health hazards associated with building materials.

The most critical challenges in promoting practical methodologies for control of hazards associated with building materials include:

(a) Lack of awareness and insufficient knowledge about the nature and severity of health hazards of some materials. It is, therefore difficult to assess the health effects of chronic low-level exposure to many materials;

(b) Manufacturers of building materials have difficulties of balancing the immediate costs of health improvements against long-term benefits;

(c) Designers have a number of conflicting criteria to resolve. They need to balance the risks to health against the cost of providing protection;

(d) Alternative building materials which are often recommended, may have their own unknown health hazards;

(e) There are no regulatory mechanisms on some of the hazards, partly due to lack of information or due to economic considerations.

Given the fact that environmental sustainability and risks to human health rank among the most important areas of social concern today, and given the variety of hazards which need to be addressed, and the different groups exposed to hazards, a range of awareness-creation programmes and control measures need to be established and implemented.

8.2 Health hazards associated with asbestos fibers

Among various building materials, asbestos is, on one hand an excellent material in construction, and on the other, one of the most harmful ones to human health. The term asbestos covers a number of naturally occurring fibrous silicate materials in rock formation widely distributed in the earths crust. The principle varieties of asbestos used commercially are chrysotile, a serpentine mineral (less harmful) and crocidolite and amosite (highly hazardous) both of which are amphiboles.

While the properties of asbestos have been known for more than thousand years, it is only in the past century, that it has been used in building sector on industrial scale, and it is only about three decades now that its harmful effects have become known globally. The main use of asbestos is in the manufacturing of asbestos-cement products such as roofing tiles/sheets, water pipes, building cladding tiles, water tanks, etc. The other source of use of asbestos is for fire protection in buildings, in ships, and many other industrial components as a shield against extreme heat and fire.

Health risks due to exposure to different asbestos types are dependant on the fibrous structure of the material. Thus, asbestos types, which are liable to form fibers less than 3 micrometers in diameter, principally the amphiboles, are most hazardous (96) The fiber length is also important, with fibers longer than approximately 8 microns posing greatest risk. The principal risk is through inhalation of airborne fibers, since there is little chance that fibers will penetrate the skin or be absorbed from the digestive tract.

Epidemiological studies have established that asbestos fibers may be associated with the following diseases:

8.2.1 Asbestoisis

This is a deposition of fibrous tissues in the lung that may cause cardiorespiratory failure. Severity of the disease is related to cumulative exposure to asbestos fibers that have a long latent period, rarely being seen less than 10 years after first exposure to asbestos. It seems that there is a threshold level below which the condition does not occur (93,94,95).

8.2.2 Bronchial carcinoma (lung cancer)

There is a dose relationship but it is uncertain whether there is a threshold level below which there is no risk. The risk to asbestos workers who smoke is ten times as great as to non-smokers.

8.2.3 Mesothelioma

A malignant tumor on the lining of the chest cavity or abdomen. The latent period for the disease is very long – an average of more than 30 years from first exposure. It has a very poor prognosis, being unresponsive to most cancer therapies.

8.3 Factors influencing exposure

Risk groups, which may be exposed to high asbestos levels, are: workers in asbestos manufacturing and processing industries, and maintenance and demolished workers. (97). Risks to construction workers and building occupants occur when the material containing asbestos is subjected to rough mechanical treatment releasing respirable fibers into the air. Installed components, for example, sheet materials which may be sealed by a layer of paint, pose little risk unless degradation occurs by physical abrasion.

The most serious risks to construction workers are likely to be associated with demolishing, or activities related to removal aimed at eliminating asbestos products from a building. There are often problems in identifying components, which contain asbestos, particularly since many are virtually indistinguishable from the substitution materials, which incorporate "man-made mineral fibers" (MMMF).

9. The need for promoting cleaner technology in construction

9.1 Present situation

The building and construction industry covers a wide range of technologies and practices on different scales. Currently, in many countries and particularly in most developing countries, the construction of housing and infrastructure facilities rely either on traditional technologies, which are defective and outdated or, on modern technologies, which are imported at excessive cost. The modern and highly energy-dependent technologies are also, in many developing countries, considered as inappropriate because of the inability of the technology to adapt itself to local conditions and inputs.

Studies have revealed that, in terms of technological advancement, there are great disparities between industrialized countries and the developing ones. The developing countries are technologically dependant on the industrial ones, as they import machinery and elements of technical knowledge, as well as the capacity to use them. This dependence hinders, however, efforts by the former to develop and use indigenous, appropriate and cleaner technologies, which are suitable to local conditions.

Furthermore, the technology systems in most developing countries are characterized by a dualism. The two sectors (traditional and modern) generally operate independently. For example, the modern sector is normally associated with technological progress while the traditional one has remained underdeveloped and undervalued.

This dualism is, in many cases, perhaps, inevitable. However, the lack of linkage between the traditional and the modern sectors and the neglect of the former - which is observed in many developing countries - are undesirable as they hinder the national efforts in improving the traditional technologies to make them cleaner and environment friendly. In this context, upgrading traditional technologies and incorporating innovations in the current practices, with mutually beneficial linkages among various sectors of the construction industry, appear to be the answer to the challenge of meeting environmental consequences of the industry as a whole.

9.2 Technology development

9.2.1 Overview

As the global economy and consequently the consumption of non-renewable resources in construction industry continue to grow, the industry is faced with the challenge of developing and using technologies that consume less non-renewable inputs and have limited impact on the environment – "the cleaner technology". Future developments in the construction technology, which should be based on sustainability principles, would, therefore, require new ways of thinking in planning, manufacturing, operating and maintaining the built environment.

Normally, the pattern of development and application of a new technology passes through various stages such as: an incubation stage, where various ideas are moulded into one successful technology; an introduction stage; and a growth stage, where the production takes up and becomes commercial. When a pioneering enterprise overcomes the teething problems, good reports of its practical application may increase its range of users and its superiority over other technologies.

The challenge here would be to risk being the pioneering enterprise and to apply the newly developed technology in the industry. In this connection, governments and the international community could play an important role in facilitating the introduction of any new technology and in promoting it by various means in any country.

Another important modality for developing and adopting innovative technology would be through regional cooperation, information exchange and technology transfers. Technology development through regional cooperation and exchange of information has proved to be an effective way of improving the performance of the construction sector in many developing countries.

Similarly, technology transfer through acquisition of technical know-how, importation of machinery and equipment, licensing and arranging joint ventures could help needy countries to diffuse innovations in their construction industry. However, in all these cases, the presence and involvement of international and donor agencies are deemed desirable as they can facilitate the cooperation with ease and with some initial financial support.

9.2.2 Choice of technology

Choice of right technology (particularly when it is innovative), is important as it enables long-term and sustainable developmental objectives. It can also help to use resources efficiently while having limited impact on the environment. In this context, the success of any technology adoption would, among others, depend on the (98):

(a) Development of appropriate applications;

(b) Creation of efficient production systems;

(c) Devising of effective marketing systems;

(d) Adaptation of technology to suit the local conditions;

(e) Ability of local labour to handle and maintain the technology; and

(f) Determination to make it succeed.

The problems associated with the ability of many developing countries to choose the most appropriate technology has, often, led to acquisition of polluting technologies, which are already obsolete in many industrialized countries because of strict pollution control legislations. Acquisition of such technologies by developing countries is a wrong step as their eventual replacement by cleaner technologies would prove to be too costly and would hamper the developmental processes of these countries.

Innovative technologies inevitably have weaknesses, defects or drawbacks, are often costly and can only be developed and nurtured through human ingenuity and commitment. Thus, choice of technology relates to a wide range of preconditions, none of which can be taken as granted. It has also very wide implications and its development requires not only an appropriate environment, but also, persistent efforts over time.

9.3 Factors contributing to adoption of cleaner technology in construction

Cleaner technology in building and construction sector cannot be promoted and adopted in isolation. There is a need for persistent efforts, ingenuity and commitment. But this cannot be achieved if all those who are involved in the construction process would not join their efforts and would not provide their inputs in a holistic and coordinated manner. The following sections outline briefly some of the key factors, which could contribute to the promotion of cleaner technology in construction.

9.3.1 On-site construction

Even though the on-site construction operations result in lesser environmental degradation compared to building materials production processes, they can have considerable impact on the local environment during the construction period. Some of the potential environmental problems during on-site operations include:

9.3.1.1 Release of hazardous pollutants

Hazardous substances may be released during site operations if the integrity of the material is disrupted. For examples, cutting, drilling or moving asbestos in construction can affect the health of the workers. Dust and fumes are other common substances, which are released during on-site operations.

9.3.1.2 Accidental spillage of materials or careless disposal of waste

This causes considerable harm to the local environment. For example, the discharge of cement slurry into watercourses or pouring of paint or other chemicals into drainage pipes. Burning of waste materials is also a source of carbon dioxide and particulate and may release quantities of noxious chemicals in an uncontrolled manner

9.3.1.3 Air pollution through burning fossil fuel

In many site operations, fossil fuel is burned for various purposes. For example, kerosene is burned to heat bitumen, which pollutes the air.

In addition to various types of pollution mentioned above, unnecessary work on a construction site increases energy consumption, construction time and cost. Adequate planning of site layout, appropriate storage facilities and careful disposal of wastes and efficient use of energy are measures of minimizing such problems.

The industry in some parts of the world is beginning to address these questions. In the United States of America, for example, the pressure of more stringent environmental regulations and the fact that construction companies have been held liable by courts for hazard resulting from their site practices, even after completion of buildings, are forcing the industry to take these issues seriously. A "Risk Management Procedures" manual produced recently by the Associated General Contractors of America gives a list of hazards for which contractors can be held liable after completion of site operations. These range from emissions of lead paint through emissions and spillages due to construction or maintenance errors causing release of airborne bacteria and/or radon (99).

9.3.2 Machinery and equipment

While the utilization of large-scale, energy- and capital-intensive machinery and equipment might be essential in the construction industry, it might not be appropriate in the housing sector, particularly for non-conventional buildings in developing countries.

However, the recent trend in construction machinery and equipment towards flexibility (i.e., multi-purposes) and small-scale (mini and micro equipment) might make such equipment appropriate for medium-scale construction companies constructing conventional buildings. Powered hand-tools enhance efficiency, and, in some instances, such tools also improve the quality of construction by semi-skilled workers (100).

9.4 Eco-friendly building design

Designers have the responsibility for specifying the materials, which are to be used, and the technical performance standards required for the operation of buildings or any civil-engineering project. Their role in defining architectural layout, the material inputs in construction, technologies and subsequent environmental impact of building operations is, therefore, crucial. Designers can contribute to the promotion of cleaner technology in construction (directly or indirectly) by selecting materials, systems and designs that are less dependent on limited non-renewable resources and energy.

For example, the potential for saving energy in heating and cooling of buildings, through the use of solar architectural principles, is considerable. Solar architecture is ecologically sound and the materials used in solar-architectural construction need not to be different from those used in traditional buildings. Passive-solar architecture systems are directly based on fundamentals of locating and orienting the buildings to make best use of solar energy and of other environmental characteristics, such as topography and trees, to control wind and shade. This approach reaches its ultimate development in earth-sheltered and underground buildings. Generally, it is most effective in hot or cold climates with low humidity (101).

While the professional community with its research efforts is in search for new energy sources, the sun is transmitting continuously vast amounts of energy. Although only one trillionth of the energy reaches the earth, this is still about 10.000 times the total commercial energy used, so that even very modest progress in utilizing solar energy could provide a large part of peoples' energy needs. For example, on a clean day, a surface directly facing the sun receives about 1 kW of solar radiation per square meter (102).

Passive-solar design can be described as satisfying the thermal needs of building occupants by using sun's effect and other natural means. Buildings designed on the principals of passive-solar architecture are those which use the structure of the building (walls, ceiling and floor) as a collector, storage and transfer mechanism with a minimum amount of mechanical equipment, while active-design systems are generally those that are very visible with collectors on roofs, pumps, plumbing, control systems and storage tanks.

Similarly, cooling loads due to solar gains generally represent the main problem in hot regions, but these can usually be avoided through sound architectural design. Shading of windows from direct sun is an essential, especially on the east and west facade. Protection from defused sunlight and reflected sunlight is also important. Solar loads conducted through walls and the roof can be largely avoided by using white or light colours on the exterior and by insulation. Shading by vegetation is particularly effective because the building and the surrounding ground are both shaded and surrounding air is cooled by transpiration. The knowledge of avoiding cooling loads is well developed but is unfortunately not yet effectively practised in many countries (103).

Incorporation of solar-architecture principles and devices in existing buildings is also worth consideration, as it can lead to energy conservation. For example, installation of louvers and insulation, repositioning windows and doors, or even, the sealing of parts of the building can prevent unwanted heat gain or loss. Such modifications are, generally, described as solar retrofitting (104).

9.5 Research and development

Research is essential for developing cleaner technology. It is one of the main ways by which technology development takes place. In fact technology is sometimes described as a product of R&D. In general terms, R&D consists of (105):

(a) Basic research, mainly funded by governments and undertaken by educational institutions, which is largely pursued without any objective of applying the results, and whose main aim is to extend scientific knowledge;

(b) Applied research undertaken in public and private centres putting the results into practical use; and

(c) Development, which refers to the application of research findings to the design and introduction of materials, techniques, equipment and systems, or the improvement of existing ones.

9.6 Building materials

Building materials constitute the single largest and most important construction inputs. In developing countries, building materials constitute approximately 70 per cent of the actual cost of low-cost housing, a significant part of which is accounted for by the cost of energy used for the production and transportation of materials. This imposes enormous demand on the natural-resource base and on the ability of technologies to convert raw materials into construction resources efficiently.

Many developing countries are fortunately endowed with natural resources for the production of basic building materials, e.g., bricks, aggregate, lime, cement and other binders. However, local building materials industries in many of these countries fail to exploit their abundant natural-resource endowment and continue to engage in the production of energy-intensive materials. Broadly, three types of industries can be distinguished requiring different types of inputs, technology application and management (106).

9.6.1 High technology industries

These industries manufacture materials such as steel, aluminium, glass, ceramic tiles, cement, plastics and other types of energy-intensive materials. The knowledge of worldwide technological innovations is spread relatively quickly in these industries. Most of these industries have the ability to assess new technologies and to acquire them from international sources. The transfer of clean, energy-efficient, low-waste technologies or recycling technologies can be promoted in these industries through a mix of regulatory measures and economic incentives.

9.6.2 Intermediate industries

These industries manufacture materials such as clay products, concrete products, timber etc. Technologies range from energy-inefficient and polluting to more modern and environment friendly ones. Many enterprises are not in touch with more recent innovations and are unable to invest in new technologies. Some of the most inefficient users of energy, for instance brick and tile manufacturers fall in this category.

9.6.3 Small-scale traditional industries

These industries, mainly in rural areas of developing countries, produce bricks, lime, roofing tiles, stone, gypsum, pozzolanas, soil-blocks, timber, etc. They use often, rudimentary and outdated technologies, which are also energy inefficient and cause deforestation. A number of international appropriate technology development organizations are supporting these industries in improving their product's quality, in making them energy-efficient, and in introducing new innovations.

9.7 Problems associated with the adoption of cleaner technology in construction

For a variety of reasons, attempts of many countries, particularly the developing countries, to adopt cleaner technology in construction have not succeeded in the past while little effort has been made to upgrade the existing traditional technologies. There are a number of factors which could be attributed to the weakness of the construction industry in developing countries to adopt cleaner technology which include:

(a) Limited recognition by the decision makers, designers and builders to environmental implications of the construction industry;

(b) Limited capacity to import innovative technologies owing to scarcity of foreign exchange earning;

(c) Inability of many countries to attract foreign investment;

(d) A tendency to import large scale, capital intensive facilities, which often remain under-utilized because of problems associated with the supply of inputs such as energy, spare parts and also managerial weaknesses;

(e) Failure to consider science and technology and R&D as integral parts of national development plans;

(f) Lack of well trained personnel, knowledge and experience in innovative technologies.

(g) Insufficient institutional infrastructure and poorly coordinated government support to promote cleaner technology;

(h) Lack of information and inability of government authorities and professionals in obtaining technological information easily;

(i) lack of favourable government policy to encourage designers and builders to adopt environment-friendly technologies in construction; and

(j) Lack of appropriate standards and building regulations and adequate environmental legislation and enforcement mechanisms.

10. International and multilateral action

The international community and multilateral bodies such as the European Union can be very instrumental in helping many countries in combating the environmental degradation caused by the construction activities in four distinct areas namely:

(a) Formulation and monitoring international protocols and conventions for environmental protection;

(b) Technical assistance, transfer of new technologies, networking, information flow and local capacity building;

(c) Multinational funding support for environmental protection; and

(d) Formulation, adoption and enforcement of directives and standards for the reduction of environmental impacts caused by the building and construction industry.

10.1 HABITAT II and the construction sector

Previous sections of this paper provided an insight on various problems in and conflicts between the building and construction industry and the environment. Some recommendations and action areas were also provided for the stakeholders of the industry. In light of the described scenario and through, mainly, international intervention and awareness creation over the past couple of decades, (mainly after the adoption of Agenda 21 at the United Nations Conference on Environment and Development - UNCED - held in Rio de Janeiro in June 1992 and the adoption of Habitat Agenda at the second United Nations Conference on Human Settlements – HABITAT II - held in Istanbul in June 1996) it has become clear that if sustainable development has to be ensured, the current trends and practices of the building sector must be controlled and managed in a way that the natural resource-base is not depleted and the environment is not degraded irrevocably.

In fact, given the importance of the building and construction sector in social and economic development and that the industry is a major cause of environmental degradation, both Agenda 21 and Habitat Agenda of HABITAT II have included distinct sections on construction industry in their Agendas.

The Habitat Agenda, for example, advocates (as far as environmentally sound and cleaner technology in construction is concerned), *inter alia*, a new approach which is based on (107):

(a) **Harmony with environment** - "*.... the impact of construction industry should be brought in harmony with the environment and its contribution towards economic growth should be exploited, all to the advantage of society at large...* " (108)

The Habitat Agenda has also committed itself to the obligation of:

(i) *"promoting locally available, appropriate, affordable, safe, efficient and environmentally sound construction methods and technologies in all countries, particularly in developing countries, at the local, national, regional and sub-regional levels, that emphasize optimal use of local human resources and encourage energy saving methods and are protective of human health"* (109).

(ii) *"Promoting more energy efficient technology and alternative/renewable energy for human settlements, and reducing the negative impacts of the energy production and use on human health and on the environment"* (110).

(b) **Institutional support** – *"...Institutional support should be provided in form of industrial standards and quality control, with particular attention to energy efficiency, health, accountability and consumer safety and protection....."* (111).

(c) **Research and development** – *"Intensify and support research efforts to find substitutes for or optimise the use of non-renewable resources and to reduce their polluting effects, paying special attention to recycling, reuse of waste materials and increased reforestation"* (112).

(d) **Exchange of information** – *"Promote information exchange and the flow of appropriate environmentally sound, affordable and accessible building technologies and facilitate the transfer of technology"* (113).

(e) **Regulatory measures** – *"Encourage and promote the application of low-energy, environmentally sound and safe manufacturing technologies backed by appropriate norms and effective regulatory measures"* (114).

11. Final recommendations

11.1 A strategy for attaining ecological sustainability in building and construction industry

As discussed in the previous sections, the building and construction industry and its practices contribute to many of the processes of deteriorating the natural environment. There are many ways in which the industry could adapt its practices that could reduce the resulting environmental impacts. In view of the very complex and multi-sectional nature of the industry, this can be achieved if strategies and actions are implemented in a coordinated and coherent manner by all stakeholders involved in the sector. In this context, a grouping of the stakeholders have been made which is presented below:

11.1.1 Action by architects, engineers and builders

Architects, engineers and builders can be influential and can facilitate in reducing the use of non-renewable resources and improving the efficiency of energy use by:

(a) Selecting materials, systems and designs, which are less dependent on limited non-renewable resources;

(b) Selecting materials and systems, which have low embodied energy;

(c) Minimizing the total use of materials per unit of built space. For example, constructing cavity walls instead of full brick walls;

(d) Using passive-solar design methods and improved insulation to increase thermal efficiency of buildings;

(e) Avoiding, where possible, air-conditioning by using natural cooling techniques;

(f) Designing for long-life, adaptability and for eventual recycling.

(g) Specifying materials in such a way that would enable the use of secondary, recycled and waste materials.

Architects, engineers and builders can also contribute to the control of atmospheric pollution caused by building and construction industry by:

(a) Optimising the use of fossil fuel for heating the buildings;

(b) Reducing the transportation distances of building materials by using as much as possible locally available materials;

(c) Monitoring and limiting generation of dust, particles and waste gases produced by construction-related operations;

Some of these actions are interlinked and may achieve more than one environmental benefit simultaneously. For example, the selection of recycled and waste materials will often reduce the utilization of primary materials and will reduce embodied energy. In other cases trade-offs will be required. Timber is one of the lowest energy content structural materials available, so, using timber will reduce embodied energy. On the other hand, it may increase deforestation. The appropriate design strategy will therefore, depend on the circumstances, priorities and on economic factors. Implementation of these strategies will require increased environmental consciousness, supervision and quality control.

11.1.2 Action by building material producers

The building materials industry has the greatest contributory role, within the construction sector, in degrading the environment. Although designers and engineers, and to some extent contractors, have the responsibility for selecting the type of materials for any given construction project, the choice and the control of the production technology of materials can have a significant impact on the amount and type of resource consumption and environmental damage resulting from production processes. In this context, the building materials producers can contribute in reducing the environmental damage by:

(a) Minimizing the extraction of primary materials and maximizing the use of recycled materials and wastes;

(b) Improving energy-efficiency in all kiln processes by careful monitoring of all combustion systems and by conducting energy audits;

(c) Substituting fossil fuels by other types of renewable energy sources, where possible, and using waste kiln heat and solar energy for low-temperature operations;

(d) Conducting pollution-emission audits and installing abatement devices such as dust precipitators and desulphurisation equipment in kiln-gas stacks;

(e) Reducing transportation distances of building materials by appropriate locating and scaling of production plants;

(f) Where labour force is abundant (fort example in developing countries) using more labour-intensive technologies;

(f) Increasing the utilization of industrial and agricultural wastes in the production of materials.

11.1.3 Action by building occupants

Building occupants and users of construction outputs have an important role to play in contributing to energy efficiency and reduction of in-door and ambient air-pollution. In this context they can:

(a) Switch from the use of dirty fuels to cleaner ones in households (e.g. gas instead of mineral oil);

(b) Optimise the use of energy for heating and cooling in in-door spaces;

(c) Use energy-efficient and improved household electrical appliances and for heating;

(d) Incorporate polluting control devices on aging coal-fired boilers and convert them, where possible, to gas boilers;

(e) Avoid exposure to air-borne contaminants such as to asbestos fibres;

(f) Use, where possible, solar energy for preheating domestic water to reduce dependence on energy;

(g) Use energy cautiously and turn off electrical appliances when not needed.

11.1.4 The role of the governments

Governments have an important role to play for minimizing the environmental impact of the building and construction industry. Almost all governments are now aware of the unsustainable nature of the current developmental patterns. Many of these are participants in international protocols to limit the carbon dioxide and CFC emissions and are committed to specific targets in that respect. But converting these goals into specific policy sand action plans has not yet, except in few cases, been carried very far. In general, the policies available to governments can be summarized as:

(a) Regulations and controls;

(b) Taxation and economic incentives;

(c) Attitude-formation through education and awareness creation; and

(d) Non-regulatory incentives.

Formulation and enforcement of regulation and controls are the traditional and most effective measures through which governments can contribute in minimizing the environmental impact of the construction sector activities. Important examples of these are regulations to:

(a) Control the extraction of primary material from eco-sensitive zones and coastal areas;

(b) Reduce tropical deforestation;

(c) Promote greater energy efficiency in buildings; and

(d) Reduce pollution resulting from building materials production processes as well as buildings-in-use.

Apart from regulations, governments can apply economic options such as taxation and incentives, which could significantly reduce environmental impact of the construction sector. Some particular forms of environmental taxes include:

(a) Increased royalties for timber extraction;

(b) Charges for pollution; and

(c) Product charges, mainly for those products, which are based on non-renewable resources, are energy intensive and have high polluting effects. Tropical timber, CFC-related products, excessive use of disappearing minerals and metals, etc. are likely candidates for such charges.

The role of governments, however should not only be collecting taxes but providing also incentives through subsidies to producers and consumers of environmentally acceptable products. Examples of incentives could be the exemption of import duties for equipment, which could upgrade the existing energy-inefficient and high polluting technologies.

Finally, the most important non-regulatory measures that governments can take include:

(a) Strengthening the capacities of research institutions;

(b) Providing training, education, information and facilitating awareness-creation;

(c) Formulating and adopting standards and building codes, which would encourage use of environment-friendly techniques and materials;

(d) Establishing eco-labelling schemes; and

(e) Organizing demonstration projects.

12. Final remarks

The environmental problems of the building and construction industries are numerous and have a very diversified and complex nature. These problems are, particularly, acute in the fast-growing cities of many countries, which lack the resources (such as financial, managerial, technological, human, etc.) to improve the situation and rectify their past failures.

Achieving the goals of sustainable human development and resolving the conflict between the explosively expanding construction industry and the attendant environmental degradation is not an easy task. It requires the ingenuity and resourcefulness of all stakeholders and modification of current, and to some extend, malfunctioning strategies, policies and practices. Significant changes will be needed – in decision making at highest levels, and day-to-day behavior by producers and consumers – if we are to reach the goal of development that meets the needs of today without sacrificing the ability of future generations to meet their needs.

It is also clear that the industry is essential for overall human development, and indeed only by raising living standards it will be possible to reduce or eliminate many of the currently serious types of environmental degradation.

It can be even argued that, while the building and construction industry consumes the natural non-renewable resources and contributes to environmental degradation, it generates a stock of human-created capitals, which will be passed on to future generations. To ensure a sustainable future and accelerate the process of human development, it is, therefore, neither feasible nor desirable to reduce the levels of building and construction activities just for the sake of preserving the resource base.

What is required is a change in attitudes, procedures, processes and technologies. However, given the nature of the industry, which is fragmented, multi-sectional and complex, changes cannot be expected to happen by themselves and in a speedy manner. It is only through the commitment of the authorities and all other stakeholders that improvement can take place and a sustainable social and economic development can be ensured every where.

Part 2

Facility management:
new challenges and opportunities

13. Integrating economic and environmental policies and strategies in the facility management

13.1 Overview and problem description

Evidence has shown that until recent years, the policies and strategies related to the management of many large building complexes and facilities have tended to separate economic and environmental factors throughout the planning and implementation levels. The focus has been always to (a) build, (b) put into operation and (c) undertake routine maintenance activities of the buildings and their technical facilities.

This limited focus had influenced the actions of all groups involved in managing such facilities and has had implications on the efficiency and sustainability of facilities' development, operations and overall management. An adjustment or even a fundamental reshaping of policies and strategies, in light of facility-specific conditions, would be necessary if environmental aspects are to be put at the centre of policies and strategies in facilities' management and/or development. In fact, achieving a full integration of environmental and economic aspects in all actions of facility managers has to be pursued.

More and more, in particular in large-scale buildings, facility managers have to undertake changes in their institutional structures in order to enable a more systematic consideration of the environment when policies and decisions are made on economic, fiscal, energy, social and other related measures, as well as the implications of the policies in these areas for the environment.

New forms of dialogue are also being developed for achieving better integration among service providers, governing bodies, scientists, environmental groups in the process of developing effective approaches to environment and facility management. The final responsibility for bringing about changes lies, however, with the facility managers in collaboration with governing bodies, all other stakeholders and the users of these facilities.

Exchange of experience can also be of significant importance. Facility management plans, goals, policies, rules, regulations and the specific situation of different facilities build the overall framework in which the integration of economic and environmental policies and strategies can best take place. In this context, it must be borne in mind that environmental standards may possibly pose severe economic and social costs if they are applied in isolation and without due consideration of other factors.

13.2 Objectives

The overall objective of integrating economic and environmental policies in the facility management should be to improve or restructure the current policy and strategy formulation and implementation processes so that economic and environmental issues are fully integrated.

13.2.1 Required and pre-requisitioned actions

Recognizing that each facility manager would develop her/his own priorities in accordance with its prevailing conditions, needs and programmes, the following general priority actions are proposed so that the objectives and the goals mentioned above could be met in an efficient and effective manner.

(a) Undertake measures and regular reviews of economic and environmental policies and plans in order to ensure the progressive integration of environmental and economic issues in the facility management and developmental goals and its new mandate;

(b) Strengthen institutional structures to allow the full consideration of environmental and facility productivity and performance issues at all levels;

(c) Develop or improve existing mechanisms in order to facilitate the involvement of concerned individuals and all other stakeholders in policy-making regarding the environmental aspects of facility management.

13.3 Strategies for the implementation of new policies

Any facility, large or medium in size, should be accompanied by every effort to define its own strategies that should be in the framework of the above-mentioned integrated policies. This should be done in its pursuit for development and insurance that its programmes and activities would ultimately facilitate achieving its new goals and mandate. In other words, the strategies and programmes should best be based on the below mentioned criteria simultaneously:

(a) economical efficiency,
(b) social acceptability, and
(c) environmental soundness.

13.3.1 Required and pre-requisitioned actions

Based on their own priorities and in accordance with their plans and policies, and in order to improve their strategy-related decision-making processes, facility managers should, among others:

(a) Adopt such strategy frameworks that reflect a long-term perspective as the basis for decisions, taking account of the linkages between and within the various economic and environmental issues involved in the facility management;

(b) Establish ways and means to ensure that the implementation of the programmes would establish coherence of economic and environmental policies and instruments, including fiscal measures and the budget. These mechanisms should be applied at various levels and should bring together all interested parties in the strategy-related decision-making;

(c) Monitor the facility management processes and procedures systematically and conduct regular reviews of the potential of the human, material and financial resources and the state of the environment. This could be complemented by annual environment and development reviews, with a view to assessing the sustainability of the facility functions and its management practices.

(d) Ensure transparency of, and accountability for, environmental and economic implications of the policies.

13.4 Improving planning and management systems

Facility managers, should review the status of the planning and management systems and, where necessary, modify and strengthen procedures so as to facilitate the integrated consideration of the new policies and implementation strategies. To support a more integrated approach to planning and management, the data systems and analytical methods used to support such planning and management processes may need to be improved and/or adjusted accordingly.

13.4.1 Required and pre-requisitioned actions

Based on their own priorities and in accordance with their policies, and in order to improve their planning and management processes, facility managers should, among others:

(a) Improve the use of modem data analysis and information flow at all stages of planning and management, making systematic and simultaneous use of economic and environmental data. Analysis should stress interactions and synergisms and a broad range of analytical methods should be encouraged so as to provide various points of views;

(b) Adopt comprehensive analytical procedures for prior and simultaneous assessment of the impacts of decisions on the management aspects including the impacts within and among the economic and environmental spheres. The analysis should include assessment of costs, benefits and risks;

(c) Adopt flexible and integrative planning approaches that allow the consideration of multiple goals and enable adjustment to changing needs;

(d) Adopt integrated management systems, particularly for the management of inputs to the facilities and the quality and quantity of the outputs. Traditional or well established methods of planning and management should be studied and considered wherever they have proved effective;

(e) Use policy instruments (regulatory and economic) as a tool for planning and management and incorporate efficiency criteria in all managerial tasks. These instruments should be regularly reviewed and adapted to ensure their effectiveness and sustainability;

(f) Delegate planning and management responsibilities to the lower level of facility management members, where possible and feasible, and review regularly their mode of conducts to ascertain efficiency, transparency and accountability.

14. Practical measures

14.1 Potentials and procedures

To demonstrate the potential for supporting the decision-making processes by facility management, and considering the overall and the specific theme of this research study, it was found prudent to elaborate on the practical measures that contribute significantly towards achieving the overall environmental and economic goals of facility management as described in the previous pages.

Due to the age of the old buildings and the wear and tear of the associated structure and installations, major repairs and replacements are necessary. In addition, most of these buildings contain in their various parts and installations health hazardous materials such as PCB, asbestos, etc. Unfortunately, this tremendously important matter has been/is being neglected in the case of many buildings, mostly in light of the enormous costs connected to the eradication of such hazardous materials.

The unavoidable need for these replacements and renovations, however, provides the unique opportunity and challenge, at the same time, to the facility manager, to proceed as follows in brief:

(a) Make a stock take and assessment on the current situation in respect of the shortcomings and needs as well as available resources.

(b) Initiate, develop and execute plans for reorganizing and modernizing both structure and management tools within the facilities management and communication and interaction procedures with the stakeholders and users.

(c) Identify in detail each of the areas, structures and installations that need to be acted on, the resources, the time and the logistics required for each of them.

(d) Initiate and develop plans and technical solutions for each of them always under consideration of their impact on the environment. Estimate the costs associated with each one of the projects.

(e) Prioritise the projects, on one hand based on their effects on the day-to-day operations, health and safety, fulfilling standards, upgrading and modernization works, and on the other hand based on their implications on the costs, environmental soundness and social acceptability.

(f) Put emphasis on the facts related to the "return of investment" for all the environmentally relevant projects.

(g) Present the projects to the governing bodies and stakeholders in all details, together with plan documents, financial and time-schedules.

(h) Present at the same time, innovative approaches as for financing of each of the projects depending on their nature, various sources of funding and financial and administrative instruments required for the effective implementation of the projects.

(i) If all the above is achieved and all the battles won, go ahead and execute the projects in their order of priority, but do not forget at the same time all the other aspects of the day-to-day operations of the complex.

14.2 Large building complexes and facilities

In general, large buildings and/or facilities could be divided into the following four major groups, namely:

- Office buildings,
- Commercial buildings,
- Industrial buildings, and
- Residential buildings

Commercial and industrial buildings have a very specific character and depending on the type of the building and the nature of the natural resources consumed inside them (particularly energy) and their polluting effects cannot be generalized for the purpose of this study. Likewise, large residential buildings that accommodate several apartments have a very unique type of usage and the role of the facility managers are normally limited to maintaining and putting into operation the common areas that are about 10-20 per cent of the entire built areas. As such, the facility managers have almost no control over the environmental and economic parameters related to their functions in the residential buildings and no challenging task can be expected from the facility managers for such buildings.

However, the role of the facility managers for large office buildings that accommodate thousands of employees and have a built area of many-fold of 100,000 square meters has the significant influence in achieving the environmental and economic goals as mentioned earlier in this paper. Furthermore, except very newly built office buildings (built in the past 5-10 years) most of the large office buildings are those built in the 1960s and/or 1970s, which even though partly possessing excellent architectural features do have certain environmental weaknesses that make them fully relevant to the main theme of the present work.

Likewise, in terms of consideration of the user behavior aspects, large office buildings offer the best possibilities and opportunities to optimize the resource consumption and improve the energy/environment performance of the buildings and their technical facilities. It is against this background that for the purpose of demonstrating the practical measures to be taken by facility managers, a typical large office building has been considered most optimal example. In the following sections various practical measures that can be taken by facility managers in a large office building are described in a more detailed manner and should be considered as recommendations made by the author, as they all have been planned, developed and implemented already by the author successfully.

15. Summary of environment, energy and cost efficiency-related measures in large office buildings

Some of the most significant environmentally sound, economically efficient and socially welcomed measures that can be taken by facility managers for large office buildings (built in 1960s or 1970s) that have not undergone any major environmental renovation or refurbishment works in the past 10-15 years are described below:

1. Setting up and putting into operation a new and modern computer-aided Facility Management System (FMS) that rationalizes the managerial and control tasks of the facility management resulting in efficiency and ease of information flow.

2. Upgrading and/or establishment of (if not in existence) a modern and computerized Building Automation Control System (BACS). This facility is, in fact, the nerves of the technical installations of any large building. These highly efficient and computerized new systems monitor and give automatic instructions to the entire technical facility operations round the clock, such as turning off/on automatically the lighting, heating, cooling, humidifying and ventilation systems. They provide also warnings in case of faulty functioning of technical facilities, etc. These measures result, obviously, in considerable energy efficiency and optimization in the operation of the buildings.

3. Undertaking necessary infrastructure and buildings/additions as well as other refurbishments/adaptations, alterations and renovations works, based on facility managers own initiation as well as formulating and developing the projects with regard to new requirements, such as new and modern computer centers and infrastructures, security buildings and installations, last but not least, welfare facilities such as child-care centers.

4. Replacement of the entire façade window glazing of the buildings with state-of-the-art glazing in order to meet today's modern office building standards, and most importantly, to reduce the consumption of energy for heating and cooling as well as

coping with the new security and safety requirements. On average, the surface of the window glazing in such buildings is about 10 per cent of the gross area (m^2) of such buildings.

5. Replacement of the lighting systems with modern ones in the offices in order to reduce the consumption of electricity as well as to meet the today's modern office workplace lighting requirements. Special attendance sensors should also be installed to switch-off the lights of the offices automatically when the office is not occupied (see part 3 of this study). Furthermore, special arrangements could be made to switch-off the lights or at least to reduce the illuminance (by using special dimmers) of the lights automatically when the outside illuminance is high enough and the natural light penetrating into the offices would provide adequate illuminance required for the offices. Needless to emphasize that special arrangement should also be made to switch-off the office lights automatically after working hours. In addition, lighting systems of non-office areas, such as, staircases, corridors, hallways, garages and outdoor areas should be renewed and modernized accordingly.

6. Connection of the sanitary water pipes of the buildings to underground water wells and/or rainwater collecting tanks. The underground water wells installed in the open grounds of large campuses have been normally used only for irrigation purposes. With this very important intervention, the water used in hundreds of toilets in large office buildings would no more be the costly and precious drinking water of the city, but almost a free-of-charge water from the recycled resources. Additional water-consumption-reducing measures, such as air-mixing water tabs, sensor-controlled water tabs, two-stage flushing tanks and waterless toilets could also be considered.

7. Renewing the entire infrastructure, IT and telecommunication cabling, distribution racks as well as outlets in every floor, service shafts and in every single office in order to comply with today's standards, and to eliminate the costly cleaning processes from asbestos and decontamination works wherever applicable.

8. Renewing certain parts of the air conditioning units and systems installed in every office to improve their cooling capacities and overall performance.

9. Various renovations and replacement of equipment in catering areas, restaurants main and mini- kitchen installations.

10. Replacement of the outdated emergency power supply generators, with new ones, including modem synchronized systems. This will result in the reduction of the yearly numerous power cuts for test purposes to a very minimum.

11. Renovation and modernization of elevators to reduce energy consumption and improve their performance as well as their safety features.

12. Installing a completely new and fully extended fire alarm and detection system including its new cabling and the alarm devices.

13. Renewing the floor coverings and replacing them with natural materials such as cork.

14. Insulating the entire enclosure of the buildings thermally. Like the facade window glazing, the envelope of most of the buildings built in 1960s/1970s is thermally very weak. As such, enormous amount of heating and cooling energy is being wasted because of this weakness. In other words, the thermal transmittance (U-value) of the façade structure is very high and every effort must be made to reduce it to acceptable levels. Therefore, these weak enclosures have to be insulated properly in order to reduce the wastage of energy. Studies have revealed that by proper insulation of the façade enclosures of old buildings, a saving of up to 25-30 per cent in the use of heating and cooling energy could be achieved.

15. Using light-reflecting/enhancing paint or coating materials for the surfaces and ceilings of side buildings, such as car park-decks to cope with the stipulated new

lighting regulations in these areas and enabling considerable savings in the use of electricity besides providing a pleasant environment.

16. Detailed description of selected environment and energy efficiency-related projects

16.1 Overview

Large office buildings in which several thousands of employees are working and spending some 8-10 hours of their daily life encompass high-rise buildings, or groups of buildings, with very diverse and often complex functional areas and requirements. These buildings are served likewise by a complex number of energy and environmentally relevant systems. In addition to offices, there are normally numerous other facilities such as meeting and/conference halls, cafeterias and kitchens, library, workshops, medical facilities, bank branches, post office, printing workshops, storage rooms, etc. in such office building complexes.

Large office buildings, with a gross surface area of 300,000 – 400,000 m^2 that accommodate 4,000 – 5,000 employees consume annually on average, over 30,000 MWh heating energy, some 10,000 MWh cooling energy, some 25,000 MWh electricity and about 200,000 m^3 of water. The cost of all these utilities is about Euro 5.0 millions per year (2006 rates). As such, any improvement in the efficiency of the use of these utilities and, particularly, the energy in such large buildings could significantly contribute towards environmental protection as well as savings in financial resources.

The latest European Union Directive on the Total Energy Performance of Buildings (Directive 2002/91/EG of the European Parliament and the European Counsel) requires the member States to set minimum standards in new and existing buildings and to introduce energy certification processes and documents for buildings. Specifically, the member States are required (Article 6) that in case of larger renovation activities for existing buildings with more than 1,000 m^2 net area, the energy performance should be upgraded to the minimum requirement levels (Article 4). The Directive further states that public buildings and buildings with heavy public attendance, with regard to environmental and energy aspects should be models and best practices for others.

16.2 Energy efficiency in space heating and cooling through renewal of façade window glazing

16.2.1 Background

The façade glazing of buildings that were build about 3 - 4 decades ago do not meet today's modern office building requirements with due consideration to energy and environmental issues. Moreover, if the windows of these buildings would be not openable, they need accurate air ventilation to ensure a comfortable indoor air climate. It follows that in such buildings, not only energy is used for heating or cooling, energy is also used for continuous air ventilation. A state-of-the-art façade glazing will, obviously, reduce the wastage of energy and it is for this reason that renewal of the façade glazing in order to improve the energy performance within the buildings should gain more and more attention worldwide.

The insulating façade glass panes used some 3 - 4 decades ago for large buildings in Europe, possess, on average, the following technical characteristics:

(a) Thermal transmittance (U-value) of approximately 3.0 $W/m^2,K$,

(b) Total energy transmission coefficient (g -value) of approximately 0.80, and

(c) Visible light transmission coefficient (τ) of also about 0.80.

The above figures reflect that the technical parameters of the existing glasses in old buildings are far outdated and with due consideration to the advancements in the glass technology over the past 2-3 decades there is an urgent need to renew them if energy has to be saved and if the environment needs to be protected. Furthermore, recent studies, that explored the relationship between the thermal properties of the glazing in the building enclosure and the energy performance of the building, have revealed that considerable amount of energy is wasted daily because of the thermally very weak and outdated façade glazing properties.

16.2.2 Objectives of the project

The objectives of the project would be to:

(a) Achieve efficiency in the use of space heating and cooling energy by replacing the façade window glazing with the state-of-the-art insulating glasses, and
(b) Enhance the safety and security aspects of the facades in cases of explosions (shatter resistant glasses).

16.2.3 Results

Studies conducted over the past 2-3 decades have revealed that replacing the old façade window glasses with new ones possessing the below mentioned technical/thermal properties

$U = 1.1\ W/m^2,K$
$g = 25$ and
$\tau = 50$

will lead to considerable energy savings. The comparative studies have shown that alone the contribution of the new glasses in the heating energy would be a saving of about 14-16 % and in cooling energy about 10-14 % and in monitory terms the total saving would be in the range of 300 – 450 thousand Euros annually (2006 rates) for a building of about 200,000 - 250,000 m^2 net area. It has been also estimated that with the initial replacement investment, the payback period could be somewhere in the range of less than 8 years.

16.3 Energy efficiency through improved and efficient lighting systems

16.3.1 Background

The lighting system of any large office building built during or before 1980s, is normally outdated, inefficient in the use of energy and is not in conformity with today's modern office lighting standards with extensive use of computers in every office. In this context, facility managers should use any opportunity to undertake an innovative measure to renew the lights in the offices. The characteristics and setbacks of the existing lights in the offices of these buildings could be summarized as follows:

(a) They are extremely wasteful in the consumption of energy. The electrical power of the existing lights installed in every office of about 12 - 16 sq.m. is about 380 – 500 Watts and they consume annually between 3.0 and 3.5 million kWh electricity only in the offices (if an occupancy of about 4,000 – 5,000 employees/offices would be taken as the basis), excluding the corridors and common areas in each floor/area. As such, the potential for reducing the electricity consumption is enormous;

(b) They are not suitable for today's modern workplace conditions with extensive use of computers on every desk and are harmful to the eyes of the occupants, especially those of extensive computer users;

(c) The life span of the existing fluorescent bulbs and their starters are relatively short and their continuous renewal is a costly and labor-intensive process. There could be over 50,000 fluorescent bulbs and starters only in the offices of such buildings and replacing them using one full time worker is a costly undertaking, let alone the exorbitant cost of the new fluorescent bulbs and starters, which should replace the burnt ones, as well as the adverse impact on the environment with huge volume of special (hazardous) waste;

(d) The old fluorescent lights are furnished with condensers containing polychlorid biphenyl (known as PCB), which is harmful to human health in case released into the air. The use of PCB as hazardous substance is banned since several years in almost all countries and their disposal (as a hazardous waste) is encouraged everywhere. The removal of PCB in conjunction with the renewal of the existing lights would therefore, contribute towards achieving the goals of having fully healthy, environmentally friendly and safe working places for any office building.

In light of the above circumstances and based on the technological achievements of the recent years, and thanks to the availability of the most advanced office lighting technologies, the renewal of the lighting in these office buildings is highly encouraged.

The new lights based on most recent technologies will have the following characteristics and advantages when compared with the old lights.

(a) Extremely efficient in the use of energy while providing the same and even better luminance. Having a power of about 180 - 240 W for every office (depending on the size of the office), which is almost half of the power of the old lights, the consumption of electricity will be reduced by over 50 per cent – an issue of highest importance, given the escalating cost of electricity worldwide and with due consideration to the negative environmental impacts of excessive use of energy.

(b) Suitability and conformity with today's office workplace requirements. These include among others: improved lighting intensity and equally spread and soft distribution over the workplace areas, appropriate reflection characteristics on the monitors of PCs, improved brightness, glare, etc.

(c) Extreme durability of the bulbs and the starters, thanks to the most advanced technologies in electronically regulated ballasts. The new bulbs and ballasts have much higher life span, which will result in drastic reduction of the renewal processes and savings in material and manpower consumption;

(d) Improved esthetical appearance of the lighting assemblies and the ceilings making the offices more pleasant working areas.

16.3.2 Objectives of the project

The main objective of renewing the office lights in any office building is to reduce drastically the energy consumption for lighting and, at the same time, to improve the quality of lighting of the offices. The ultimate aim would be to comply with the most recent norms and ergonomic standards of computer work places and to create healthy and environmentally friendly office spaces for their occupants.

16.3.3 Results

As indicated earlier, the renewal of the lights will result in savings of about 50 per cent of electricity for lighting in the offices and common areas, while in the meantime it will improve the lighting of the offices tremendously. In monetary terms this saving corresponds to approximately Euro 300,000 per year (2006 rates) for a large office building with 4,000 – 5,000 offices. This amount includes savings related to all offices and the entire common areas in the complex.

16.4 Reducing the use of public water

16.4.1 Background

Another innovative measure that could be taken by facility managers is maximizing the use of underground well or recycled water and reducing the use of precious drinking water. One of the possibilities is to connect the toilet flush tank water pipes to the well water. By this measure, the water used in the toilets will be no more the precious city water.

16.4.2 Objective of the project

The objective of the project would be to reduce the use of public water and contribute towards water conservation in the building and in the city at large as well as cost saviung.

16.4.3 Results

Some 20,000 m^3 of water used annually in flush tanks of such building will no longer be the costly drinking water but almost a free-of-charge water coming from the water wells. In monetary terms, savings of up to about Euro 30,000 per year could be achieved.

Summary: Environment and energy efficiency-related projects

Title	Objectives	Activities	Results	Cost-benefit	Other benefits
Renewal of façade window glazing	To achieve efficiency in the use of space heating and cooling energy.	Renewal of the glazing possibly in conjunction with the execution of the asbestos removal or other renovation work.	Savings of 14-16 % in heating and 10-14 % in cooling energy.	Savings of 300 – 450 thousand Euros annually. Payback period about 8 years.	Enhances the safety and security aspects of the facades in cases of explosions (shatter resistant glasses).
Renewal of office lighting systems	To reduce drastically the energy consumption for lighting and improve the quality of lighting in the offices.	Renewal of the office lights possibly in conjunction with the execution of the asbestos removal or other renovation work.	Savings of about 50 % of electricity consumption	Savings of Euro 300,000 per year. This covers the offices and all common areas for an office building with 4 - 5 thousand employees.	Complies with state-of-the-art and most recent norms and ergonomic standards of computer work - places and creates healthy office spaces.
Reducing the use of public water	To reduce the use of public water.	Connecting the pipes of the toilet flush tanks to underground well water.	Savings of about 20,000 m^3 costly city drinking water annually.	Usage of almost free-of-charge water and savings of about Euro 30,000 per year.	Contributes towards drinking water conservation in the office complex and in the city at large

17. Other environment, health and safety-related measures

17.1 Overview

As described in part 1 of this research study, in addition to the adverse environmental impact of excessive use of natural resources, such as energy, in the buildings, there is a growing concern amongst occupants of buildings, the facility managers and the authorities, which is related to health and safety aspects of old buildings.

Until early 1980s, in many countries asbestos has been used to insulate fire barriers as well as structural elements of the buildings. However, because of the health hazarding characteristics of the asbestos fibers, its use was banned almost everywhere. As such the existence of asbestos (particularly sprayed asbestos) in the buildings have been and are the generators of these concerns.

Evidence has shown that in almost all large buildings (including large office buildings) built in the 1970s or earlier in Europe or elsewhere, asbestos has been used for the purposes mentioned above. As such, one of the most challenging tasks of the facility managers is how to maintain and operate these buildings as well as how to plan and remove the asbestos from them. The complexity and the challenge of this task are often aggravated by the fact that while asbestos has to be removed, the building (s) has/have to remain operational. It means that the asbestos removal procedure should be planned in a manner that employees can continue their daily work. In other words, the entire building can not be vacated but possibly only fractions could be vacated for the purpose of asbestos removal for a pre-determined period of time.

In light of this very challenging task that many facility managers have to undertake sooner or later, the below sections of this paper are devoted to related procedures and processes of asbestos removal, most of which are innovative and are based on the author's own planning, implementation and experience.

18. Asbestos removal project

18.1 Objectives of the project

18.2 Overall objectives

The overall objectives of the project should be to:

(a) Eradicate any possible health hazard or concern that would be associated with the existence of asbestos, asbestos containing materials as well as asbestos contaminated materials (ACM) in the building (s);

(b) Upgrade and refurbish certain parts, functions and installations of the building (s), if needed, feasible and possible, while the building (s), or part of it, is vacant. For example, renewal of the facade glazing, cabling, the lights, the floor covering, etc.

18.3 Specific objectives

The specific objectives of the project should be to:

(a) Remove all asbestos and/or asbestos containing and contaminated materials that may release asbestos fibers in the air at any time, and under any possible circumstances, during the entire life time of the building (s);

(b) Clean and decontaminate all internal surfaces (walls, ceilings, floors, installations such as ducts, cable trays, lights and fixtures, etc...) and any suspicious location in order to ensure that all potential sources of residual asbestos dust due to wear and tear are removed;

(c) Replace the removed asbestos and ACM with other asbestos-free and non-health hazardous materials that have the equivalent performance characteristics (substitution works);

18.4 General features of the project

18.4.1 Legal framework for planning and execution

The legal framework for planning and execution of the project (in Austria) should be all the relevant Austrian rules, regulations, standards and codes of practices. These include, among others, the following:

- Bundesabfallwirtschaftsgesetz (AWG), BGBI. 324/1990
- Asbestverordnung, BGBI. 325/1990
- ArbeitnehmerInnenschutzgesetz, BGBI. 450/1994
- Bauarbeiterschutzverordnung, BGBI.340/1994
- Bauarbeitenkoordinationsgesetz, BGBI. I 37/1999
- OENORM M 9405 - Messung von Asbestfaserkonzentrationen in der Luft, 1. Oktober 1993
- OENORM M 9406 – Umgang mit schwach gebundenen asbesthaltigen Materialien, 1 August 2001

18.5 Planning process

18.5.1 Identification of asbestos localities and ACM

Based on the visual observations the facility managers should undertake a thorough survey in all the buildings with a view to identifying locations of all asbestos and ACM occurrences in the building (s). The results of this survey have to be documented and the locations of all asbestos and ACM have to be indicated in all floor plans of the buildings.

The basis for the production of these plans should not be only the surveys and visual inspections, but also the use of original execution plans of initial construction time of the building(s). These plans should be the basis for the planning process such as the asbestos removing procedures, zoning criteria within a floor, preparation of time schedules, procedures of substitution, etc.

The above mentioned plans should be deemed to be as accurate as possible. However, during the execution of the project any, initially, not identified asbestos or ACM should also be removed to make sure that the building (s) are fully asbestos free.

18.6 Time frame for the execution of the project

In general, the established duration for the execution of the project in each floor should best be based on a sample floor and a pilot project. That means an accurate and reliable time frame can normally be established when the removal works in the first typical floor has been accomplished. Experience has shown that for a floor with a an area of about 2,000 m^2 some 4 – 6 weeks would be enough to remove asbestos and ACM and to decontaminate all areas.

Activities that are carried out in this time period are related to those described in the specific objectives of the project. This time period should start from the day of handing over the vacated floor to the asbestos contractor and finishes on the day when the floor is officially handed over back for occupation and use.

This time period does not include any additional or unforeseen work that might need to be undertaken. If, however any additional/unforeseen work should be executed, a reasonable time should be added to the established time periods. Similarly, this time period does not include the time required for substitution, re-assembly, renewals, refurbishments, and any other building upgrading works that normally is executed by companies other than the specialized asbestos removal company.

18.7 Logistics

One of the most critical and rather complex features of any asbestos removal project is related to its logistics, if the employees have to continue their work while their offices have to be vacated. Normally, the buildings are fully occupied and in order to execute the project floor by floor, they have to be vacated at pre-determined times and sequences.

Each floor or groups of floors have to remain vacant for a pre-planned period of time. For this purpose, special relocation procedures and modalities must be worked out, a brief description of which is given below.

18.7.1 Temporary offices – container office buildings

In order to accommodate the staff during the asbestos removal and refurbishment works in each floor, and facilitate an uninterrupted working condition for them, special swing-spaces (e.g. container office buildings) have to be found/constructed as close as possible to the complex and if space allows on the premises of the office building (s). Depending on the floor vacating plans and other circumstances, these can be 2-4 story container buildings, each floor being more-or-less equivalent the size of the main office floor.

The container buildings should be furnished with the furniture of the main office floors. The furniture of the first floor (if needed also the second and the third floor) should remain in the container buildings for the entire duration of the project. It follows that the furniture required to furnish the floors for the employees returning to their office buildings will be those of the lower floors of the respective buildings. In other words, the first move of the furniture will be external and the rest will be internal (floor to floor).

The alternative office buildings should possess all necessary installations such computer, telephone, power outlets, adequate heating and cooling and all other devices, so that the employees can continue their work without any hindrance. Furthermore, the moves from and to the main office buildings and the connection of all computers and telephones etc. should be carried out only on weekends.

18.8 Technical issues

18.8.1 The concept of buffer zones

In addition to adherence to existing Austrian safety rules and regulations for asbestos and ACM removal, a unique concept of buffer zone is strongly recommended. This concept should be applied in all asbestos and ACM removal floors and should be used as a principle strategy for the execution of the entire project in order to (a) ascertain highest degree of safety and (b) ensure that staff occupying the neighboring areas can continue working without any concem whatsoever.

In general, a buffer floor or "horizontal buffer zone" is a floor between asbestos and ACM removal floor (black zone) and a floor in which employees are working. In few cases where in a given floor both asbestos and ACM removal work has to take place and the employees have to work, a special double-walled "vertical buffer zone" should be erected to ensure that the black zone is fully and hermetically sealed and separated from the employee areas.

During the planning process, every effort has to be made to minimize the number of vertical buffer zones to ensure that no person is working in a floor in which asbestos work is going on. Vertical buffer zones should be made of solid panels, sealed hermetically in all their boundaries and joints to the structure of the building with special adhesive tapes. In a distance of minimum 100-150 cm, a reinforced plastic foil of about 0.5 mm thickness should be attached to a wooden frame specifically constructed for this purpose (black zone side). The foil and its surrounding wooden frame and its internal joints should all be sealed hermetically using special adhesive tapes. Furthermore, as a rule, special smoke tests should be carried out to ascertain the full hermeticity and air-tightness of this type of buffer zones before asbestos or ACM removal work resumes.

18.8.2 Asbestos removal zones in each floor

In order to coordinate the asbestos removal work with the substitution, renewal and upgrading works, every floor should be divided into two or more removal zones. Due consideration should be given to the freight elevators and other logistical aspects when zoning is being planned. Upon completion of the removal work, rough and fine cleaning and after passing satisfactorily the prescribed air measurement tests in the first zone, the removal resumes in the neighboring zone, and so on. By so doing other works such as substitution or upgrading works can start in the first zone while in the neighboring zone still asbestos is removed. This process is repeated until all floors are completed.

18.8.3 Sequence of asbestos and ACM removal and accompanying works

It is recommended to start the execution of the project from the highest floor of each building and proceed downwards. As mentioned earlier, between each floor where asbestos and/or ACM is being removed and upper and lower floors where employees are working, there should be always a buffer floor. Since, at any given time a minimum of 3 floors of each building will be at the disposal of the contractors, the asbestos and ACM related activities will be undertaken simultaneously only in the middle floor. However, non-asbestos related works, such as upgrading works in the upper buffer floor or preparatory work in lower buffer floors can be carried out so that the execution of the entire project is accelerated.

18.8.4 Provisions for asbestos removal works

Before resuming the actual asbestos or ACM removal in any given floor, certain mandatory provisions and arrangements have to be made, which are described below. Even though activities related to these provisions are in full compliance with relevant Austrian rules and codes of practices, some of them are building - specific.

(a) Enclosures of asbestos removal areas (black zones)

All enclosures in which asbestos and/or ACM removal work takes place should be constructed by a 140g/sq.m heavy reinforced plastic foil. This is fixed to a wooden structure and sealed hermetically at its boundaries and internal overlaps by adhesive tape. These enclosures are meant only to separate black and white zones in a given floor. Like buffer zones, smoke tests should be always carried out to ensure the reliability and hermeticity of the enclosures. It should be again mentioned that if in the adjacent area of any black zone employees have to work, the concept of vertical buffer zone as described earlier should be applied strictly.

(b) Air locks

Air locks for the entrance and exit of workers into black zones should be made of stable and solid materials (no plastic foil) and should have three units, namely: white unit, shower, and black unit. Air locks for material and equipment movements into and from black zone should have the same structural features but having only two units, namely: white unit and black unit. The structural as well as safety features of air locks and related enclosures should at any case meet the stipulated standards, technical requirements and adopted practices. The air locks should be cleaned on a daily basis.

(c) Negative air pressure unit (NAPU)

The purpose of negative air pressure units (NAPUs) is to generate negative air pressure inside the black zones. This is designed to ensure that the air inside the black zone can never have the tendency to flow outside the black zone. The NAPUs are in operation at all times (24 hours a day) and shall possess the following technical specifications and criteria:

Inside the black zone and during working hours the NAPUs should generate, compared to outside air pressure, an air pressure difference of at least 20 Pascals. This pressure difference can be a minimum of 10 Pascals outside working hours. Should the pressure fall below these levels, additional NAPUs with automatic starting devices should be available as contingency. The number of air-exchanges per hour within the black zone should be at least 10. All above-mentioned criteria are the basis for determining the number and/or the capacity of each NAPU for any given black zone.

NAPUs are divided into two elements, namely: the filter element and the ventilator connected to appropriate ducts. The filters are integrated in the enclosures directly and the exhaust air flows outside the building. The exhaust air is filtered in a manner to ensure that the inhalable asbestos fiber (IAF) concentration in the exhaust air is not more than 500 per m^3 of air. The exhaust air flows to the outdoor through one or more windows the glasses of which are removed for this purpose.

The effectiveness of NAPUs is checked before starting the work by using smoke generators (no smoke bombs). During the asbestos removal work, three special gauges for monitoring the air pressure and its fluctuation are placed in the:

(a) white zone,
(b) in front of the enclosure or vertical buffer zone, and
(c) in the Facility Management's central automatic control board.

Furthermore, a spare NAPU is provided at all times to be used in case of any emergency or breakdown. In case of any breakdown in electricity power supply, the NAPUs are operated using the emergency electricity supply at each of the areas. All these emergency facilities have to be provided and their functionality tested prior to commencement of asbestos removal in any given black zone.

18.9 Technical aspects of asbestos removal

The sprayed asbestos is removed by wet stripping and direct suction using suitable mechanical, electrical or manual tools. The removed asbestos or ACM is solidified with cement and water, packed in double plastic bags, labeled and signed, transported and stored internally and finally transported to and dumped in specified locations authorized by the respective city authorities.

This arrangement applies also to any other ACM such as the glass wool sheets or the mineral wool fillings at the installation openings and fire retarding apertures and any similar suspicious material. The other types of ACM, such as the asbestos strings on various fire doors or on the elevator portals, or any ACM in all installation shafts, etc. are also removed, packed, transported and dumped in the same manner as described above.

18.10 Decontamination and cleaning

In order to remove any dust (which might, or might not, be contaminated with asbestos fibers), and over-sprays of asbestos or ACM, and to ensure a full decontamination, the entire surfaces of all floor areas have to be cleaned using special methods described below:

(a) Removing and cleaning the asbestos or ACM over-sprays and special paints and coatings around fire insulations, such as on walls around the duct and cable penetrations, cable trays in corridors, the cables themselves, etc.

(b) Removing and disposing the mineral wool fillings and/or in the floor holes of pipes and wet cleaning its surroundings.

(c) Cleaning and removing residual dust from all horizontal and vertical surfaces, corners, inside and outside of all cable channels mounted on the walls or elsewhere, etc. using special vacuum cleaners and suitable methods.

(d) Wet cleaning of all surfaces such as floors, walls, ceilings, windows, doors, heating/cooling units , all ceiling lights and their fixtures, corridor and room ceiling panels, other fixtures and all areas mentioned in (c) above.

(e) Final wet cleaning of all surfaces after all elements/devices have been reinstalled.

(f) Decontaminating all cables situated in the cable trays or elsewhere (that remain in place) by separating them from each other, wet cleaning of each one of them in the whole length, grouping them together again, and replacing them back to the already-cleaned trays/locations. It should be, however, noted that the best and most safe way of eradication of asbestos on the cables and cable trays is their removal and replacement with new and state-of-the-art cablings and associated installations, as elaborated in item 7, section 15 of this part.

(g) Coating rough surfaces such as the concrete columns and beams, concrete ceilings, etc. and/or any other wall with rough surface by a special glue solution. This coating will be done after the final cleaning is over and a confirmation of a satisfactory visual inspection is issued by the supervisors and prior to undertaking clearance air measurement tests.

(h) Cleaning inside surfaces of the airlocks on daily basis.

All above mentioned decontamination and cleaning processes are conducted inside the black zone. However, after removing the enclosures and finalizing all substitution and upgrading works, a very final cleaning is again undertaken and a final air measurement (in accordance with OENORM M 9405) should be conducted before putting the floor at occupation and usage again.

18.11 Air monitoring

18.11.1 General issues

The purpose of monitoring the quality of air is to ensure that the project is progressing safely and that the health of the employees in nearby areas as well as the workers and other persons in or outside the removal site is safeguarded. The air monitoring procedures inside and outside the black zones should be in full conformity with the established standards and codes of practices. Additionally, certain building-specific air monitoring is recommended during the execution of such projects.

As a principle rule, four types of air measurements should be conducted, namely:

(a) quality control air measurements;
(b) clearance air measurements;
(c) final air measurements; and
(d) building-specific air measurements.

18.12 Technical aspects of air measurements

As stipulated in the Austrian Standard OENORM M 9405, all air measurement and analysis should be carried out in accordance with the stipulations of the above-mentioned Standard. The sampling of the air is done by special air measurement equipment specifically designed for this purpose. The air-sucking head of the equipment should normally be 1.5 m above the floor surface and the duration of the sampling (e.i. sucking air) should be 8 hours. The sucked air passes through a special gold-coated filter on which any solid particle of the sucked air is collected. A randomly chosen small part of the filter is then taken to the laboratory to undergo the electronic microscope analysis and identification of the possible asbestos fiber's number and characteristics.

In accordance with the above-mentioned Standard, the measurement of the fibers in the laboratory should be carried out by scanning electron microscopy (SEM) method. This is followed by the energy dispersive X-ray (EDX) microanalysis in order to identify and evaluate the type of the fibers in the specimen. In order to achieve realistic results, all air measurements are carried out under air disturbance and the usage simulation conditions. The permissible limit of the number of inhalable asbestos fiber (IAF) concentrations in one cubic meter of air is recommended to be between 500 and 1000, depending on the usage nature of the building (s).

(a) Quality control air measurements

The purpose of conducting quality control air measurements is to ensure that the areas adjacent to asbestos removal zones, and the environment in general, are not affected by the removal exercise. These measurements are carried out before and during the ACM removal period. They are carried out in the white zones immediately next to black zone enclosures and in the exhaust air leaving the black zone to the outdoors. The number of IAFs should not exceed 500/ m^3 of air.

Should the results exceed 500, asbestos removal work has to be stopped, the NAPUs should be switched to full power, the cause should be clarified, remedy measures undertaken and new measurements should be carried out until satisfactory results are achieved. The asbestos related works can be resumed only when the satisfactory results have been achieved. Additionally, routine air measurements should be carried out in the entrance cabin (white zone) of the air locks, in which case the results could be up to 1000 IAF/ $m^{3.}$

(b) Clearance air measurements

The purpose of clearance air measurements is to ensure that asbestos removal in the black zone has taken place satisfactorily. These tests are executed upon completion of asbestos or ACM removal, decontamination works, cleaning, and satisfactory visual inspection.

These tests are carried out while the NAPU(s) is/are switched off and before the removal of the enclosures.

The temperature inside the enclosure should be above 5 degrees Celsius and the humidity should be less than 70 per cent. The number of IAFs in one cubic meter of air in each and every sample should not exceed 500. Should the result of any measurement be above the stipulated limits, the cause should be clarified, remedy measures undertaken, and after a complete re-cleaning of the area, new measurements should be conducted to achieve the satisfactory results. The number of these new tests in any given black zone should be again the same as those conducted initially.

The number of clearance air measurement tests (initial ones) is dependent upon the number of closed areas (rooms) in a given black zone and also the entire volume of the black zone. This should be in accordance with the criteria stipulated in the relevant standards and norms. Table 13 shows the number of samples as stipulated in the Austrian Standard OENORM M 9406.

Table 13: Minimum number of samples for clearance air measurement

Number of rooms within a removal area (n)	Number of samples
1	1
2	2
3 to 4	3
5 to 6	4
7 to 8	5
9 to 11	6
12 to 14	7
15 to 17	8
18 to 20	9
21 to 30	10
More than 30	n/3

Source: Austrian standard OENORM M 9406 of August 2001

Note:

- For rooms with a volume of more than 500 m^3 and less then 3,000 m^3 – one sample per every 500 m^3
- For rooms having a volume of more than 3,000 m^3 – 6 samples plus one sample for each 1,000 m^3 exceeding 3,000 m^3

(c) Final air measurements

The purpose of the final air measurements is to ensure that all the executed works have met the requirements of the standards and are to the full satisfaction of the supervisory body. These are carried out after the enclosures have been removed, all substitution, accompanying, reinstallation, upgrading works and final cleaning have been completed.

To ensure that there is no contamination inside the already-cleaned zone caused by the removal of enclosure and setting up new enclosure(s) for the adjacent zone (s), 1/3 of the number of measurements are conducted immediately after the removal of the enclosure.

The rest is carried out after all other zones of the floor have been fully cleaned and the entire floor is just ready for re-furnishing and for employees to return to their offices. Again, if any of the measurement results would be higher than 500 IAF/m^3, the cause should be clarified, remedy measures undertaken and the same number of new tests shall be conducted until the expected results are achieved.

(d) Building-specific air measurements

In cases where vertical buffer zones are erected, air measurement tests are carried out in front of the vertical buffer zones (occupied side) to ensure that there is no leakage and release of asbestos fibers from the black zone during asbestos removal. These measurements are carried out randomly as requested by facility management. They are building-specific and their execution is meant to ensure that under no circumstances the health and safety of the nearby persons have been affected negatively.

Should the results of these tests be unsatisfactory, the following measures should be taken immediately:

- Stop asbestos removal work immediately.
- Increase the NAPU(s) function to full power.
- Check the air-tightness of the buffer zone and evaluate the reasons of increased IAFs.
- Undertake any remedy measures required to ascertain the 100 % hermeticity of the vertical buffer zone and carry out a fresh smoke test before resuming the work.
- Continue the asbestos removal work and undertake air measurements simultaneously to ascertain the soundness of the works.

Similarly, if in any asbestos removal floor and the immediate upper/lower floor, no horizontal buffer zone could be provided, air measurement tests should be carried out in the employee occupied floors to ensure that the removal works are carried out satisfactorily. Should the result of any test be above the stipulated limits, the same/similar measures mentioned in the above paragraph should be taken immediately.

18.13 Emergency cases and measures

Emergency cases and related measures that should be taken during the execution of the project could be those associated with:

(a) asbestos related works,
(b) fire emergency.

18.13.1 Asbestos - related emergency

This emergency situation could occur when because of an accident asbestos fibers would be released in the air outside the black zone. In order to mitigate any hazard or danger, all asbestos - related works should be stopped and measures should be taken immediately to avoid further emission of asbestos dust by sealing the enclosure using adhesive tape or any appropriate method.

The NAPU should be switched to full power and any dust entered into the white zone should be immediately sucked in wet condition. After cleaning the area properly, air tests in the affected area should be undertaken to ensure its safety in terms of absence of asbestos fibers above the permitted levels. It should be noted that due to the existence of the buffer zones, even this type of rarely-possible emergency will not have any detrimental effect and/or health hazard to the employees at large. For all such cases, properly planned escape routs are foreseen as well.

18.13.2 Fire emergency

Like in the case of asbestos-related emergency, the fire escape routs should be planned and foreseen well in advance and approved accordingly. In addition to measures described bellow, all the procedures described above are strictly applied in the case of fire emergency.

In all cases, a distinction is made between fire escape routs for employees working in the neighboring areas where asbestos is removed and the workers of the contractor(s). In principle, the escape routs for the employees in all emergency cases should, as much as possible, be the same as those existing ones.

18.13.3 Health and safety

Health and safety in any construction project, in general, and in asbestos removal projects, in particular are very important matters, which require great attention. The contractors and the supervisors have to make every effort to ensure the safety and health of the workers by adhering strictly to the relevant governmental rules and regulations, and by continuously checking the conduct of the workers during their work.

All workers and any person entering the black zone should use special personal protective equipment (PPE) which consists of special overalls (Goretex overalls) and authorized respiratory protective masks. Additionally, the contractor should provide at least ten sets of PPE at the entrance of air locks for emergency cases as well as for use by any other person intending to enter into the black zone.

In order to ensure a full and accurate implementation of the health and safety measures, the special document titled "Safety and Health Plan" should be prepared that will be an important part of the contract documents. This document is based on the relevant country rules and regulations.

18.14 Substitution works

18.14.1 Restoration of fire protection

In the context of asbestos removal project, substitution works mean the replacement of all removed asbestos and/or ACM with non health-hazardous and asbestos-free materials that would possess the same/similar performance criteria as those removed asbestos and/or ACM. Since most of the asbestos and/or ACM used in many office buildings are for the fire protection purposes, the substitution materials shall have the equivalent fire resistance characteristic as asbestos. In other words, the ultimate purpose of substitution works is to reinstate the entire fire protection systems/class of the buildings as they were designed and constructed originally. For the execution of the substitution works, the relevant governmental rules, standards, codes of practices (such as the type of materials, thickness, dimensions, sealing practices, etc.) should be strictly adhered to.

Most of the substitution materials are made of mineral fibers that have the necessary certificates and description of technical specifications issued by the manufacturers and approved by the relevant authorities. Even though a pre-selection of these new materials should be made prior to commencement of the project, the contractor should submit samples and certificates to facility management for final approval, before these are installed. Should, in the course of the execution of the project, new products be used, they follow the same procedures as indicated above.

19. Final remarks

"Facility management" is a new concept or even a new terminology. From one perspective it replaces the traditional "management of buildings", which is an entity in charge of building complexes and entrusted with the task of maintaining and keeping in operation the buildings and their related technical facilities. However, from author's point of view, and as elaborated in this part of the study, the facility management and/or buildings management, should not limit itself to the issues of traditional maintenance and operation of the buildings but should go proactively beyond that.

Evidence has shown that until recent years, the practices and systems of decision-making in the management of many large-scale complexes and facilities have tended to separate economic and environmental factors at the policy, planning and implementation levels.

However, the facility managers of large-scale building complexes have to make efforts to undertake changes in their institutional structures in order to enable more systematic consideration of the environment when decisions are made. New forms of dialogue have to be developed for achieving better integration of economic and environmental issues. The final responsibility for bringing about changes lies with the facility managers, in collaboration with governing bodies and all other stakeholders.

If the sustainability of the building and the construction industry, in general, and those related to the existing "environmentally weak or sick" buildings, in particular, should be ensured, then the traditional facility management systems should reshape their mandate, should revise their policies and decision making-processes, should make every effort to facilitate an integration of economic and environmental policies and should focus on innovative and environment-friendly practices. The availability and the use of new building technologies, innovative approaches and the state-of-the-art materials and components, should not be limited to new construction. They can as well be adapted and utilized in the existing buildings.

The challenge is how to plan, mobilize resources and implement these environmental and modernization measures in large multistory office building(s), which is/are occupied by thousands of employees who cannot stop or interrupt their daily work even for a single day, let alone for several months needed for implementing these measures.

Finally, it should be mentioned that while planning to undertake any environmental and/or innovative measure in any existing building, special attention should be paid to the health and safety aspects of its occupants. Certain building materials, such as asbestos, may cause serious health problems as described in part one of this study. The role of facility managers in eradicating any concern or problem associated with the existence of such hazardous materials in the buildings cannot be overemphasized. Similarly, ensuring a healthy indoor climate such as having: adequate temperature and humidity, clean air, adequate lighting, etc are all issues and requirements of highest priority given the health as one of the most pressing social concerns.

Part 3

Harnessing user behavior information for building management support

20. User control behavior in office buildings: empirical studies and research

20.1 Introduction

In most buildings windows, shades, luminaries, radiators, fans and other control devices can be operated by building occupants. Thus, worldwide, multiple studies have been conducted to collect data on building users' interactions with building control systems and devices (115), (116), (117), (118). Such empirically-based data can bring about a better understanding of control-oriented user behavior in buildings. Specifically, information on user presence and control behavior in buildings is crucial for a number of applications, namely:

(a) Such data helps facility managers to elaborate on and analyze possible deficiencies in the use of energy caused by behavioral patterns of the building users in respect of the media provided to each office and area. The analyzes on these areas enable facility managers to include in their planning such installations and features that would automatically react to user behavioral patterns and help this way to save energy, costs and protect the environment at the same time.

(b) Such information allows the building and facility managers to better understand the motivational background behind user actions and requests. Equipped with such data, building and facility managers can better predict and respond to potential areas of deficit in provision of services to office workers and other building users. In other words, information on behavioral patterns of office users can close the information loop from office occupants to facility mangers and vice versa. As a result, a more smooth and efficient overall building management regime can be expected.

(c) Building systems control professionals (for illumination, heating, cooling, ventilation, and air-conditioning) can make use of user control actions data towards fine-tuning of control procedures of building systems. Specifically, user actions information can be reflected in building control algorithms so that user needs and requirements can be properly anticipated and considered in the execution of building control schemes and sequences.

(d) Upon proper analysis, information collected on user behavior can be communicated back to the office occupants. Thus, users can become better informed regarding their behavioral patterns and their consequences for the indoor climate in and energy performance of the building.

This part describes the effort to observe, over a period of one year, control-oriented occupant behavior in 29 randomly-selected offices of a large high-rise office complex. Specifically, states and events pertaining to occupancy, systems, indoor environment and external environment were monitored. A weather station, a number of indoor data loggers and two digital cameras were used to continuously monitor – and record every five minutes – such events and states (occupancy, indoor and outdoor temperature and relative humidity, internal illuminance, external air velocity and global horizontal irradiance, status of electrical light fixtures and the position of shades).

20.2 Approach

20.2.1 Object

The measurements were conducted in 29 single-occupancy offices in a large high-rise office building. From the selected offices, 15 face north (code: "NO") and 14 face south-west (code: "SW"). The offices are located on the 12th and 13th floor. The office work-stations are equipped with desktop computers and in some cases printers. Both screen-based and paper-based tasks are performed by the occupants.

The offices are typically equipped with the following systems: Three rows of luminaries with 9 or 12 fluorescent lamps (each 36 W) divided into two circuits and manually controlled by two switches near the entrance door; internal manually operated shading; three to four fan coil units under each window for fine adjustment of temperature.

20.2.2 Monitored parameters

The intention for this part of the study was to observe the actions of people toward lighting and shading as well as to monitor the indoor and outdoor conditions under which these actions occur. The change in the status of ambient light fixtures was captured using a sensor mounted under the luminaires. Shading was monitored via time-lapse digital photography. The degree of shade deployment for each office was derived based on regularly taken digital photographs of the façade. Shade deployment degree was expressed in percentage terms (0 %: no shades deployed, 100 %: full shading).

The external weather conditions were monitored using a weather station, mounted on the top of the building. Indoor climate conditions (temperature, relative humidity, illuminance) were measured with autarkic loggers distributed across the workstations. To obtain information regarding user presence and absence intervals, occupancy sensors were applied. All of the above parameters were logged regularly every 5 minutes.

Monitored indoor parameter included room air temperature (in °C), room air relative humidity (in %), ambient illuminance level at the workstation (in lx), luminaire status (on/off) and occupancy (present/absent). Monitored outdoor environmental parameter included air temperature, relative humidity, wind speed (in $m.s^{-1}$), as well as global horizontal illuminance and global horizontal irradiance (in $W. m^{-2}$). Global vertical irradiance incident on the façade was computationally derived based on measured global horizontal irradiance using a procedure described in Mahdavi et al. (119).

The data was collected over a period of one year to cover all seasons and conditions. For the analysis, the range of data was reduced to working days and hours 8:00 till 20:00h (weekends and hours between 20:00 and 8:00 were excluded).

20.2.3 Data processing

The collected data was analyzed to explore hypothesized relationships between the nature and frequency of the control actions on one side and the magnitude and dynamism of indoor and outdoor environmental changes on the other side. Results were processed and visualized primarily in terms of probability and frequency (relative/normalized) distribution graphs.

20.2.4 Electrical energy saving potential for lighting

To estimate the saving potential in electrical energy use for office lighting, the status quo in a sample of offices in each building were monitored. Subsequently, three (cumulative) energy saving scenarios: (a) lights are automatically switched off if the office is not occupied; (b) lights are switched off, if the daylight-based task illuminance level equals or exceeds 500 lx; (c) an automated dimming regime is applied, whereby luminaires are dimmed down so as to maintain a task illuminance level of 500 lx, were considered.

20.3 Rresults

20.3.1 Occupancy

Figure 1 shows the mean occupancy level over the course of a reference day (averaged over the entire observation period). Note that this Figure represents the presence in the user's office and not the complex. Moreover, as Figure 2 demonstrates, the occupancy patterns in individual offices can vary considerably.

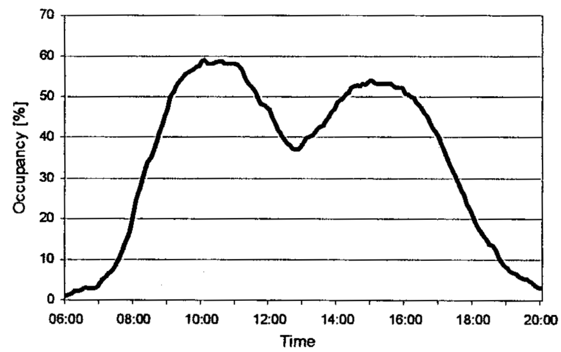

Figure 1. Mean occupancy level in NO+SW over the course of a reference day, averaged over all observed offices

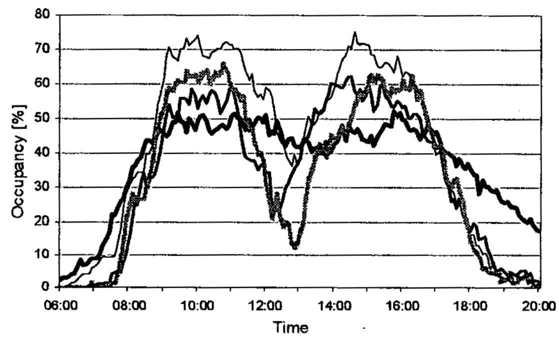

Figure 2. Observed occupancy levels in 4 different offices in NO+SW over the course of a reference day

20.3.2 Lighting

Figure 3 shows the observed effective lighting load in the course of a reference day. Obviously, the information in this Figure is about the general light usage tendency in all observed offices. To provide an impression of the differences amongst individual light usage profiles, Figure 4 and Figure 5 show the lighting operation in each observed office for the entire monitoring period expressed in terms of the ratio of the lighting operation duration to the overall working hours.

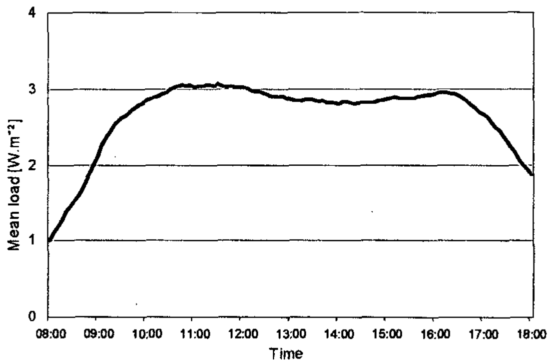

Figure 3.Lighting operation in NO+SW offices

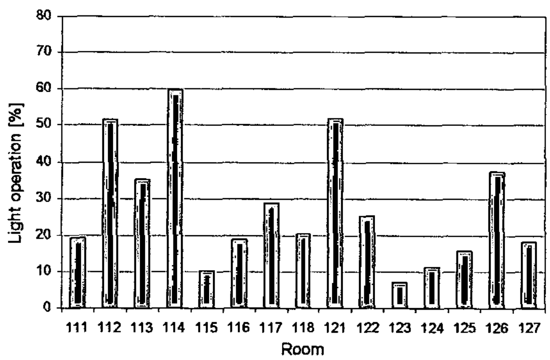

Figure 4. Duration of lighting operation (in percentage of respective overall working hours) in offices of NO

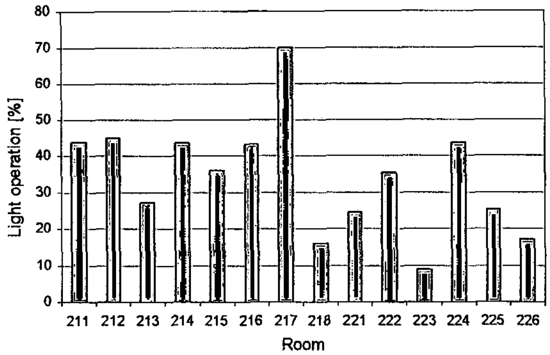

Figure 5. Duration of lighting operation (in percentage of respective overall working hours) in offices of SW

Figure 6 shows the probability that an occupant would switch the lights on, upon arrival in his/her office as a function of the prevailing task illuminance level immediately before the arrival.

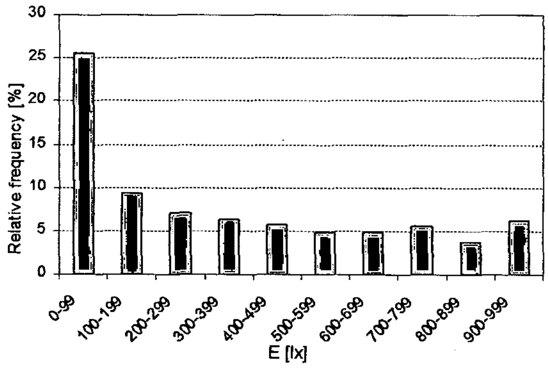

Figure 6.Probability of switching the lights on upon arrival in the office

Figure 7 shows the normalized relative frequency of (intermediate) actions "switching the lights on" by occupants who have been in their offices for about 15 minutes before and after the occurrence of the action as a function of the prevailing task illuminance level immediately prior to the action's occurrence. Normalization denotes in this context that the actions are related to both occupancy and the duration of the time in which the relevant illuminance ranges (bins) applied.

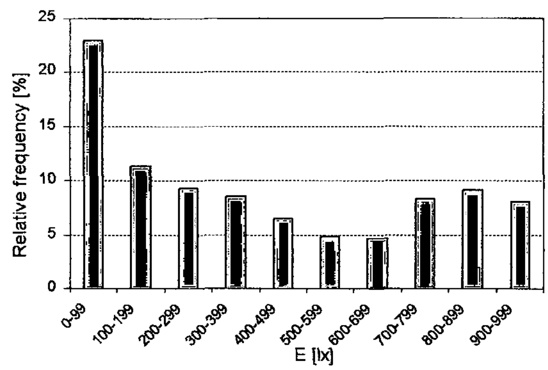

Figure 7. Normalized relative frequency of intermediate light switching on actions in NO+SW

Figure 8 shows the normalized relative frequency of all "switching the lights on" actions (upon arrival and intermediate) as a function of the time of the day together with mean global horizontal irradiance. In this case too, actions are normalized with regard to occupancy.

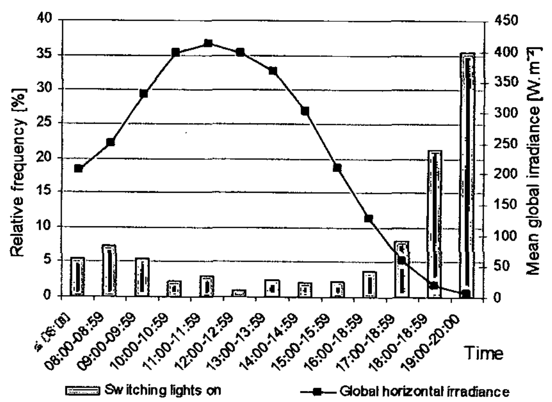

Figure 8. Normalized relative frequency of switching the lights on actions together with mean global horizontal irradiance in NO+SW over the course of a reference day

Figure 9 shows the probability that an occupant would switch off the lights upon leaving his/her office as a function of the time that passes before he/she returns to the office.

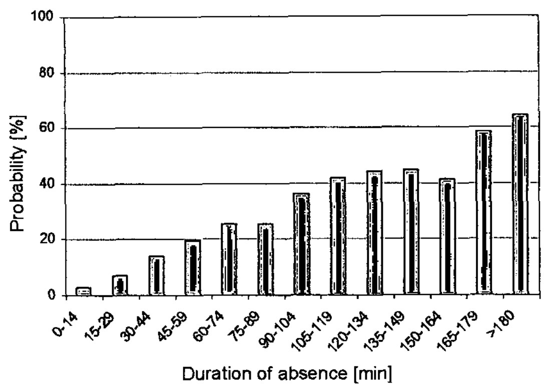

Figure 9. Probability of switching the lights off as a function of the duration of absence from the offices in NO+SW

Shades

Figure 10 represents the mean monthly shade deployment degree in NO and SW respectively.

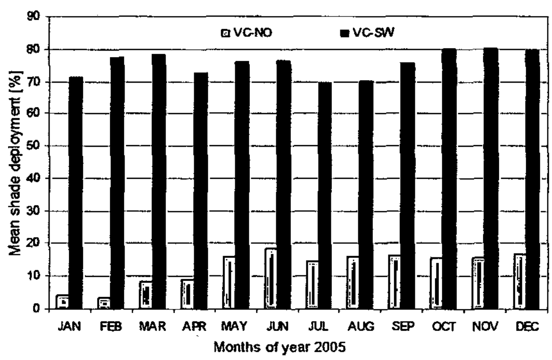

Figure 10. Mean monthly shade deployment degree in NO and SW

Figure 11 shows the normalized relative frequency of "opening shades" and "closing shades" as a function of the global horizontal irradiance in NO+SW. Figure 12 shows the normalized relative frequency of the same actions as a function of the global vertical irradiance. The number of actions is normalized with regard to occupancy and the time during which the respective irradiance bins applied.

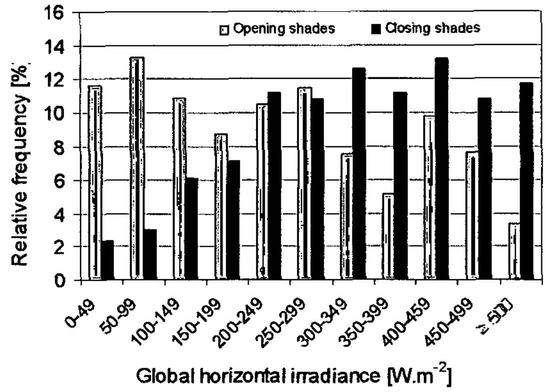

Figure 11. Normalized relative frequency of opening and closing shades in relation to global horizontal irradiance in NO + SW

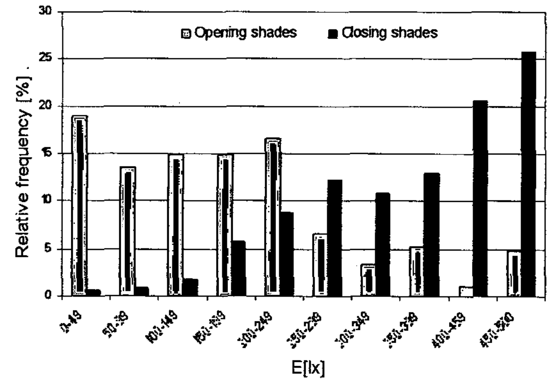

Figure 12. Normalized relative frequency of opening and closing shades in relation to the global vertical irradiance in NO + SW

Figure 13 and Figure 14 show the normalized relative frequency of "opening shade" and "closing shade“ actions together with mean global vertical irradiance over the course of a reference day in SW.

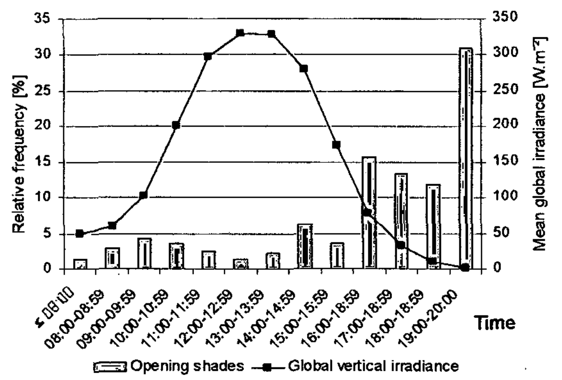

Figure 13. Normalized relative frequency of "opening shade" actions together with mean global vertical irradiance over the course of a reference day in SW

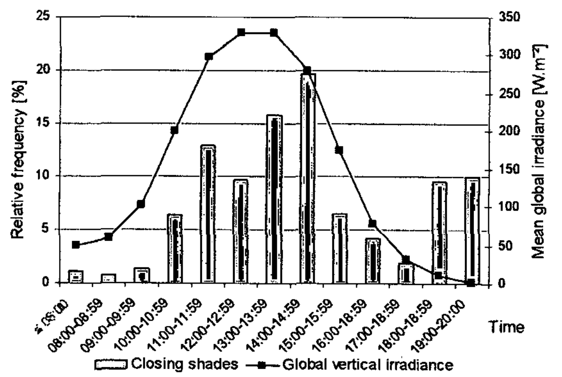

Figure 14. Normalized relative frequency of "closing shade" actions together with mean global vertical irradiance over the course of a reference day in SW

20.3.3 Energy

Figure 15 and Figure 16 illustrate the potential for reduction of electrical energy use for lighting in NO+SW. Thereby, three (cumulative) energy saving scenarios are computationally derived. The first scenario requires that the lights are automatically switched off after 10 minutes if the office is not occupied. The second scenario implies, in addition, that lights are switched off, if the daylight-based task illuminance level equals or exceeds 500 lx. Finally, the third scenario assumes furthermore an automated dimming regime, whereby luminaires are dimmed down so as to maintain a task illuminance level of 500 lx while minimizing the electrical energy use for lighting.

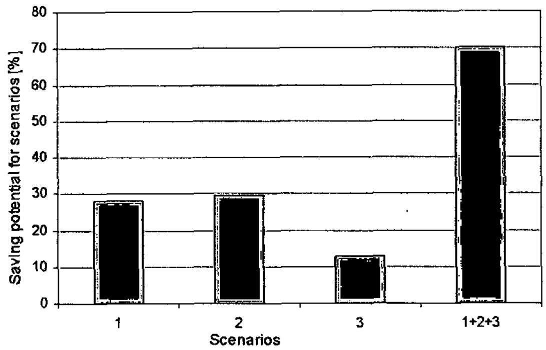

Figure 15. Electricity energy saving potential of luminaires in percentage by scenarios in NO+SW offices

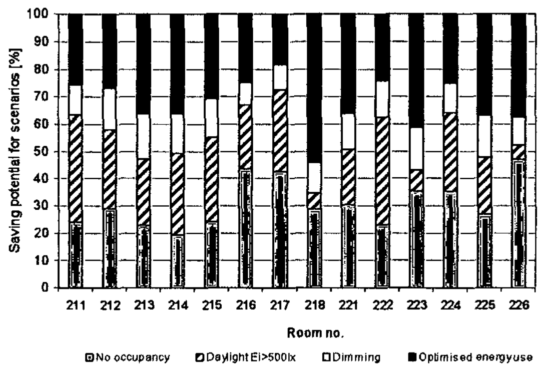

Figure 16. Saving potential in electrical energy use for lighting in 14 offices of SW for the 3 scenarios

20.4 Discussion

The monitored occupancy in NO+SW (Figure 1) and the obviously related people and lighting loads (Figure 3) reveal a pattern similar to that of many other office buildings and as such can be used for simulation runs in terms of corresponding hourly schedules (Figure 17 and Figure 18). Such simulations can be used, for example, to explore the impact of thermal improvement measures on the building's energy use. Moreover, the differences in the both occupancy levels (Figure 2) and lighting operation (Figure 4 and Figure 5) in various offices of NO and SW suggest the possibility of a more realistic simulation scenario using software agents to represent occupancy states in different offices in probabilistic terms.

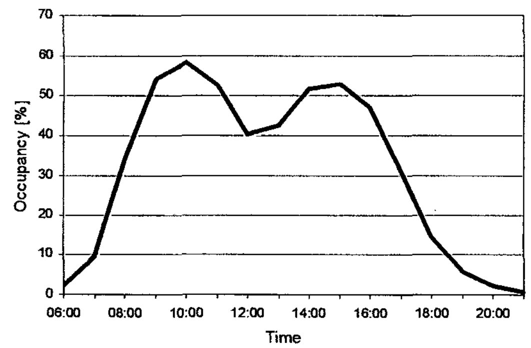

Figure 17. Illustrative simulation input data regarding mean hourly occupancy level for NO+SW

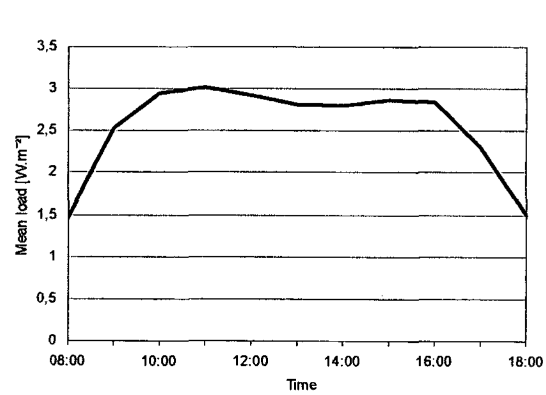

Figure 18. Illustrative simulation input data regarding mean hourly lighting load in NO+SW

Concerning the dependency of the action "switching on the lights" on prevailing illuminance levels (Figure 6 and Figure 7), the clear patterns suggest that only illuminance levels below 100 lx are likely to trigger actions at a non-random rate. However, if the frequency of the action is viewed in terms of the time of the day, a clear pattern is revealed that could be harnessed while modeling the respective behavior in a simulation program (Figure 8).

As to the action "switching the lights off", a clear relationship to the subsequent duration of absence is evident (Figure 9).

The mean monthly shade deployment for each façade depends on the orientation of the offices observed. This explains the higher deployment level of about 65 per cent for SW in comparison to NO (Figure 10). The observation reveals a clear relationship between the frequency of "opening shades" actions and incident radiation on the façade (Figure 12).

The corresponding analysis of the "closing shades" actions shows a significantly higher action frequency once the incident radiation rises above 200 $W.m^{-2}$ (Figure 12). In SW (Figure 13 and Figure 14), which has a south-west orientation, closing actions occur mainly mid-days, while opening actions occur mostly in the afternoons due to the incident radiation on the façade.

The estimated saving potential in electrical energy use for lighting of the sampled offices is significant (Figure 15 and Figure 16). The overall cumulative energy saving potential for all sampled offices is about 70% for NO+SW. This would imply, that annually roughly Euro 140,000 (2006 rates) could be saved by a comprehensive retrofit of the office lighting system toward dynamic consideration of occupancy patterns and daylight availability.

Note that a lighting system retrofit and the resulting electrical energy use reduction would increase the heating loads and decrease the cooling loads. However, as previous studies have shown, given the magnitude of required cooling loads in office buildings, the overall thermal implications of a lighting retrofit are positive both in energetic and monetary terms.

21. Final remarks

This part included a case study concerning user control actions in an office complex.

The results show that:

(a) Actual occupancy degrees are significantly below "design" assumptions, resulting in undifferentiated (and thus inefficient) provision of indoor environmental services;

(b) Only relative low workstation illuminance levels trigger actions of the type "switching on the lights" upon users arrival in their offices;

(c) The likelihood that occupants would turn off the lights in their offices is tightly correlated with the duration of the subsequent absent interval from the office;

(d) Given intelligent occupancy-sensitive and daylight-responsive lighting devices and control systems, up to 70 per cent of electricity energy use for lighting could be saved.

In general, the results imply the possibility of identifying general patterns of user control behavior as a function of indoor and outdoor environmental parameters. The compound results of the ongoing case studies are expected to foster the development of robust occupant behavior models that can improve the reliability of computational building performance simulation applications.

Final conclusions

General remarks

Over the past 30 to 40 years, the environmental impact of human development and the related expansion of the construction and buildings industry, has grown dramatically due to the increase in consumption of natural and energy resources, technological requirements, industrial activities, rapid urbanization and to some extend due to globalization. The environmental concern of today is, therefore, a reflection of the practices and processes taken place in the past 3 - 4 decades. However, during this period, the appearance of environmental problems and increased awareness have led to national and international trends affecting, more and more, the process of overall human development.

In light of the above scenario and through mainly international interventions, particularly after the adoption of United Nations' Agenda 21, Habitat Agenda and the Kyoto Protocol, to mention only a few, it has become now clear that if sustainable human development has to be ensured, the current trends and practices in many developmental, industrial and urban sectors, including the construction and building sector, must be controlled and managed in a way that the natural resource base is not depleted and the environment is not damaged irrevocably.

Even though increased construction and building-sector activities are essential for overall human development, the real challenge for this development will, however, lie in ensuring this without reducing the rate of the construction activities. What is needed is a change in attitudes, modification of the current policies and strategies, the increased use of cleaner technologies, attaching high priority to the environmental considerations and the commitment and resourcefulness of all those involved in the construction and building sector.

The evidence of the past 10 years or so, and the nature of the current initiatives taken by many governments and decision-makers in e.g. reducing the global CO_2 emissions for achieving the goals of the Kyoto Protocol, show that the main focus has been, and is, related mainly to heavy $C0_2$-emiting industries, urban and air transport, non-renewable energy-generating sectors, etc. However, the dramatic environment-damaging and air-polluting effects of the construction and building sectors have, unfortunately, so far not been taken very seriously.

It is against this reality that this research study has been conducted to highlight the role and the importance of the sector in optimizing and/or reducing resource-consumption (such as energy) and in transforming the sector's activities to be in harmony with the environment. The bottom line is that: there is a moral duty and obligation to transfer to the future generations a built environment and physical assets which are sustainable and that their operations do not jeopardize their ability provide good health and possess adequate safety and livelihood.

The overall objective of this research study has been, among others, through intensive desk research work, to provide an analysis and an in-depth insight into the overall nature of the construction and building industry practices, the current global trends, and opportunities. While identifying and highlighting the current setbacks, the study has made every effort to come up with solutions and has proposed priority action areas as to meet the goals of the sustainability in the industry.

The specific aim of the study was, however, to highlight the role of the facility managers of large office and/or public buildings in contributing towards achieving the above-mentioned goals. An analytical case study in harnessing the user behaviors for improving the facility managers operations (with particular focus on optimizing the artificial lighting of large office buildings) is also presented to demonstrate the various possibilities in achieving the overall and, particularly, the specific objectives of this study.

A more detailed description of the final conclusions of all three parts of the study is presented below:

Part 1

The building and construction sector activities are vital for overall economic and social development everywhere. The industry is also heavily dependant on almost all types of natural non-renewable resources (energy in particular) and is in the meantime a main polluter of the environment. As a consequence of this dependence, the environmental problems of the building and construction industry are numerous and have a very diversified and complex nature. These problems are, particularly, acute in the fast-growing cities of many countries, which lack the resources (such as financial, managerial, technological, human, etc.) to improve the situation and rectify their past failures.

In fact, the above reality represents a serious disparity between the construction and building industry and the challenges facing us with regard to protecting the environment. On the one hand, we have to build more and more and have to operate the existing buildings accordingly, and on the other, we have to eliminate, or drastically reduce, the impact of the industry on the environment. As such, achieving the goals of sustainable construction and building industry and resolving the above mentioned conflict is an extremely complex and difficult task.

The study has brought up the results that, for example, in order to optimize the consumption patterns, a demand-side approach would be necessary when compared to the current global supply-side approach. This is a general statement related to lifestyles and excessive materialistic consumption patterns of many wealthy societies. However, if the demand-side approach is applied in the industry, it can make a considerable change in resource consumption of the industry and the protection of the environment.

The study has also revealed that the sector, not only consumes natural non-renewable resources, it has considerable impact on land, coastal areas and on tropical forests. Furthermore, the rational usage of several disappearing metals have been highlighted as means for preserving them for extended periods of usage. The study has found out that by replacing some of these metals with adequate man-made substitutes the lifetime of these metallic minerals could considerably be extended. However, more research is needed in this area.

Since energy is one of the main inputs in the construction and building sector, special attention has been paid in this part to various ways and means on how to reduce the consumption of energy. The study has found out that in order to reduce the embodied energy of the buildings, the planners, architects, building materials producers have to pay attention to this important issue already during the planning and construction phase. They should, for example, use low energy-content building materials as much as possible, use locally available materials to reduce transport, use recycled materials, apply eco-friendly designs, etc.

Another important environment-damaging characteristic of the industry is its contribution to atmospheric air pollution. Even though the air pollution caused by the industry at local level (e.g. dust, soot, fibers, etc.) can, to some extend, be tolerated, the regional and global air pollutions, affecting the global climate change, can no more be accepted let alone tolerated.

The study has shown that the building operations (e.g. heating) in most industrialized countries are responsible for over half of the global $C0_2$ emissions. The major ozone-depleting substances are due to the cooling of the buildings. About 5 per cent of global $C0_2$ emissions are stemming from cement industry, and the list goes on and on. As such, any effort to reduce the air-polluting effects of the industry is not only a moral duty, in many cases, it is even an obligation to be controlled by regulatory initiatives and enforcement machinery.

Furthermore, part one of the study has touched upon yet another important issue, which is related to health hazards of certain building materials. While elaborating the current situation, it has highlighted major actions that should be taken to eradicate health hazards of certain building materials such as asbestos.

Finally, this part of the study, in addition to proposing action-oriented recommendations for each and every environment-damaging aspects of the industry separately, has come up with results that are presented in form of strategic actions for attaining ecological sustainability in the industry. A summary of the selected results are as follows:

- Architects and builders should: select such materials and designs that are less dependant on natural non-renewable resources and have low embodied energy; design and construct for long-life, adaptability and for eventual recycling; and should promote eco-friendly and passive solar designs as much as possible.

- The building materials producers should: minimize the use of primary materials and increase the use of recycled ones; substitute fossil fuels with renewable sources of energy; monitor and conduct pollution-emitting audits; increase the use of industrial and agricultural wastes and improve energy efficiency in all kiln processes of high energy-intensive materials, such as in cement, brick, aluminum, glass, steel and other high energy-intensive industries.

- The building occupants and users should: use heating, cooling and lighting energy consciously; reduce wastage; use solar energy and improve the thermal envelope of their buildings if possible.

- The governments should: initiate and enforce control regulations; provide economic incentives and/or taxation on energy and pollution-related measures; establish eco-labeling schemes; monitor countywide progress; encourage modernization of buildings to reduce the use of energy and strengthen the capacity of research institutions to look into various methods of achieving the sustainability goals of the industry.

In conclusion, it should be mentioned that the findings of this research part could be applied generally and globally towards a more sustainable use of the planets' environmental resources, such as energy, and protection of the environment from adverse impact of the industry.

Part 2

The use of energy in buildings-in-use (the operational energy) which constitutes the major part of the energy used in buildings during their life time can be controlled by the users and, of course, for large public and office buildings, by the facility managers. To that end, awareness creation for the users and modifications of the buildings to be undertaken by facility managers are vital interventions to reduce the operational energy in buildings.

The role of the facility managers, among other actors, directly or indirectly, involved in the building and construction industry, should not be underestimated. In fact, based on recent experiences and achievements, it has been proved that the facility managers could play a vital role in achieving the environmental goals as described in Part 1 of this study.

This work has described, based on author's own research and experience, that until recent years, the practices of decision-making in the management of many large-scale buildings and facilities have focused mainly on economic issues with little, or no, attention to environmental considerations. However, it shows that facility managers of large-scale buildings can undertake changes in their policy-making and institutional structures so as to facilitate the serious consideration of the environment in their strategic activities.

The author has further demonstrated that if the sustainability of the existing buildings needs to be ensured, then the traditional facility management procedures should modify their plans and their mandate, should revise their policies and should enable an integration of economic and environmental policies. The focus should be the use of innovative and environment-friendly practices and technologies.

In order to demonstrate the positive outcome of the above-mentioned restructuring of existing facility management policies and strategies, the study brings about the new knowledge and presents a number of concrete and practical measures and projects to be implemented in large office buildings built about 30 years ago that accommodate up to five thousand employees. Some of the most significant efficiency-measures that could contribute towards achieving the new goals of any facility management and their practical results include:

- Setting up a Computer-aided Facility Management (CFM) system to modernize the operations of the facility management and bring in efficiency;
- Establishing a computer-aided Building Automation Control System (BACS) to monitor the functions of all technical facilities permanently and round the clock;
- Renewing the façade glazing that can reduce the consumption of heating and cooling energy by about 10-16 per cent.
- Renewing the lighting of offices that can result in a saving of about 50 per cent of electrical energy for lighting.
- Reducing the use of public water by increased usage of well water in the sanitary facilities.

The study has finally demonstrated the importance of ensuring health and safety in the existing buildings that have been built 30-40 years ago. Certain building materials, such as asbestos, may cause serious health problems as described in part one of this study. The role of the facility managers in eradicating any concern or problem associated with the existence of such hazardous materials in the buildings cannot be overemphasized. Similarly, ensuring a healthy indoor climate (adequate temperature and humidity, clean air, adequate lighting, etc) are all issues of highest priority given the health as one of the most pressing social concerns.

In this context, the study has provided a brief description of procedures and methods of asbestos removal in a large office building without jeopardizing the smooth functioning of daily office operations and with due consideration to highest safety measures during the asbestos removal. The practical methods initiated, planned and implemented by the author of this study has proved to be most efficient and implementable that could form a solid basis for other facility managers to follow these procedures.

In conclusion it should be mentioned that the practical measures and models worked out in this part of the study are fully relevant and applicable for all office buildings, in particular for large office building complexes. They are valid with some limitations for commercial and industrial buildings and less applicable to residential buildings.

Part 3

This part of the study included a research work on the importance of utilizing the information on users behavior in the offices of a large office building. The work has shown that such information and collected data can help facility managers to elaborate on possible deficiencies in the use of energy caused by behavioral patterns of the users. Such information and the results of their analysis can help the facility managers to better understand the motivational background behind users actions and expectations.

In fact, information on behavioral patterns of the office occupants can not only help the facility managers to improve the functions of the buildings, it will considerably optimize the use of resources, such as energy, in the offices. Hence, another effective approach towards achieving the goals of sustainable building industry as demonstrated in the preceding parts of this research study.

The focus of this part of the study was, by collecting and analyzing necessary behavioral data and information, to improve the efficiency of the office lighting. The results of this research work has revealed that by using intelligent occupancy-sensitive and daylight-responsive devices and control systems up to 70 per cent electrical energy could be saved, which is worth to be taken into consideration by all means.

Finally, it is recommended that in order to harness the user assessment and information for improving the indoor climate of any large-scale office building and improve the functions of facility management, it would be necessary to: conduct regular surveys and assessments; make every effort to upgrade the buildings so that the excessive use of energy is reduced; and improve the indoor climate by modernizing the offices, such as improved lighting systems making them suitable for a modern workplace with extensive use of computers.

In conclusion, it should be mentioned that the results and the models of this part of the study are fully relevant for all office buildings, which typically accommodate thousands of individuals with diverse behavioral patterns regarding the use of the environmental services provided to their offices.

Recommended future research

Future research regarding the issues discussed in this research work could be extended to cover other categories of buildings. Furthermore, the work presented in part 3 of the study on the user control behavior, can be extended to address other environmental services such as air-conditioning, heating, cooling, ventilating, water consumption etc.

Applicability

While applying the results and/or recommended actions presented in this study, attention should be paid to local circumstances and prevailing economic and social conditions of every country or region. The general recommendations and findings presented e.g. in part 1, should/could be adapted to local conditions and should be made compatible with local capacities and capabilities. There are measures and actions, which e.g. could best be suitable and applicable in many developing countries, whereas the same measure(s) may not be fully relevant in the context of many industrialized countries. The ultimate goal should, however, be to pay attention to environmental implications of the decisions and actions in the construction and building industry everywhere and under all circumstances.

Refereces

1. Worldwach Institute, *State of World (1995), Making Better Buildings,* Nicholas Lenssen and David Malin Roodman, p. 95.
2. World Resources Institute, *World Resources 1994-1995,* Oxford University Press, New York.
3. *Ibid.*
4. B. Dimson, *Industry and Environment,* The United Nations Environment Programme (UNEP), 1996, vol. 19, No. 2, p. 2.
5. United Nations Environment Programme (UNEP), *Buildings and Climate change: Status, challenges and opportunities,* ISBN: 978-92-807-2795-1, Nairobi, Kenya, 2007.
6. Davis Langdon 2005, *World construction review/Outlook 2004/2005.*
7. United Nations Centre for Human Settlements - UNCHS (Habitat), *Changing Consumption Patterns in Human Settlements,* HS/449/97, ISBN 92-1-131 330-9, Nairobi, Kenya, 1997, p. 5.
8. United Nations Centre for Human Settlements - UNCHS (Habitat), *Habitat Agenda,* HS/441/97/E, ISBN 92-1-131322-B, Paragraph 29, Nairobi, Kenya, 1997. This is the outcome of the HABITAT II Conference held in Istanbul in June 1996.
9. *Ibid,* Paragraph 101.
10. Ian Douglas, *Human Settlements, Changes in Land Use and Land Cover: A Global Perspective,* Cambridge University press, UK, 1994, p. 155.
11. *Ibid.* p. 154-155.
12. Jorge E. Hardoy, Diana Mitlin and David Satterthwaite, *Environmental Problems in the Third World Cities,* Earthscan, London, 1992, p. 10
13. Gordon McGranahan and Jacob Songsore, *Wealth, Health and the Urban Household: Weighing Environmental Burdens in Accra, Jakarta, and Sao Paulo,* Environment, vol. 36, No. 6, 1994, p. 4-8.
14. G. F. Zhao and B. P. Chen, *The use of gangue in light concrete buildings in Building materials for Low-cost Housing,* E and F. N. Spon, London, 1987.
15. United Nations Centre for Human Settlements - UNCHS (Habitat), *Development of National Technological Capacity for Environmentally Sound Construction,* HS/293/93/E, ISBN 92-1-131-214-0, 1993, p. 14.
16. United States Agency for International Development (USAID), *Urbanization in the Developing Countries.* As cited in, *The Impact of Construction Activities on the Environment,* paper for the Lund University, Lund, Sweden, 1998, p. 7.

17. *Op. cit.* 10. and *The Impact of Construction on the Environment.* Paper for the Lund University, Lund, Sweden, 1998, p. 7.
18. D. W. Jones, *How Urbanization Affects Energy-use in Developing Countries.* 1994.
19. D. E. Dowall and G. Clark, *Making Urban Land Markets Work,* draft paper for Urban management Programme, the World Bank, 1998.
20. A. L. Singh, *Land Degradation Along Aligrah,* International Workshop on Planning Sustainable Urban Development, Cardiff, University of Wales, 1998.
21. F. Pearce, *How Green was our Summit,* New Scientist, July 1992, p. 12-13.
22. M. Saeed, *Maldives Country Paper,* Building Materials for Low-income Housing, E. and F. N. Spon, London, 1987.
23. World Resources Institute, *World Resources 1992-1993,* Oxford University Press, New York, 1993.
24. J. O. Siopongco, *Greater Utilization on a Sustainable Basis of Wood Including CLAS and Plantation Species as a Source of Indigenous Low-cost Building Material,* paper prepared for UNCHS (Habitat), 1990.
25. World Resources Institute, *World Resources 1994-1995,* Oxford University Press, New York.
26. P. Harrison, *The Greening of Africa,* Paladin Grafton, for the International Institute for Environment and Development, 1996.
27. D. Pearce, E. Barbier and A. Markyanda, *Sustainable Development: Economics and Environment in the Third World,* Earthscan, London, 1990.
28. Friends of Earth, *Sustainability and the Trade in Tropical Rainforest Timber,* London, 1991.
29. The World Bank, *World Development Report, Development and the Environment,* Oxford University Press, New York, 1992.
30. *Op. cit.* 26.
31. Swiss Centre for Appropriate Technology (SKAT), *Building Materials in Bangladesh,* Final report, St. Gallen, Swiss, 1992.
32. Parikh Jioti and Parich Kirit and S. Gokarin, *et. al., Consumption Patterns: the Dividing Force of Environmental Stress,* Indira Gandhi Institute of Development Research, Discussion paper No. 59, 1991.
33. *Op. cit.* 93.
34. L.Leitman, *Energy Environment Linkages in the Urban Sector,* UMP, UNCHS/UNDP/The World Bank, 1991.
35 R. K. Pachaury, *Towards Sustainable Energy Development,* 1996,
36. United Nations Centre for Human Settlements - UNCHS (Habitat) sources, 1996-2005.

37 M. Ryan and C. Flavin, *Facing China's Limits, State of the World, 1995,* p. 118.

38. United Nations Centre for Human Settlements - UNCHS (Habitat), *Changing Consumption Patterns in Human Settlements,* HS/449/97, ISBN 92-1-131 330-9, Nairobi, Kenya, 1997, p. 35, and *Op. cit.* 100. p. 35.

39 – 41. *Op. cit.* 25.

42. *Op. cit.* 38, p. 38.

43. *Ibid.*

44 Housing Development and Management, Lund University, *Construction and Environment: Improving Energy Efficiency,* ISSN 1100-9446, ISRN HDM-BI-27-SE, Lund, Sweden, 2001, p.8.

45. M. Car, *Current situation of recycling of building materials in Austria:* United Nations Centre for Human Settlements – UNCHS (Habitat), *Housing and Environment, Report of the Workshop,* Vienna Austria, HS/596/00E, ISBN-92-1-131 456-9, Vienna, 2000.

46. *Op. cit.* 38, p. 13.

47. United Nations Centre for Human Settlements – UNCHS (Habitat), *An Urbanizing World: Global Report on Human Settlements,* HS/383/95/E, ISBN 0-19-823346-9, Oxford University Press, Oxford, UK, 1996, p. 149.

48. *Ibid,* p. 1-18.

49. United Nations, General Assembly, *Report on the Appraisal of the Implementation of the Agenda 21, (Rio+5 special session),* New York, 1997.

50. United Nations Conference on Environment and Development (UNCED), *Agenda 21,* Adopted in Rio De Janeiro, Brazil, June 1992.

51-53. *Ibid.*

54. United Nations Centre for Human Settlements – UNCHS (Habitat), *People, Settlements, Environment and Development: Improving the Living Environment for a Sustainable Future,* Publication produced for the United Nations Conference on Environment and Development (UNCED), Nairobi, Kenya, 1992.

55. *Op.cit. 50.*

56. *Op. cit. 54.*

57. *Ibid.*

58-61. *Op.cit. 54.*

62. United Nations Environment Programme – UNEP, *Buildings and climate change: Status, challenges and opportunities,* ISBN: 978-92-807-2796-1, Nairobi, Kenya, 2007.

63. Earth Trends 2005; ATLAS 2006, as cited in op.cit. 62, p. 8.

64. United Nations Centre for Human Settlements – UNCHS (Habitat), *Development of National Technological Capacity for Environmentally Sound Construction,* HS/293/93/E, ISBN 92-1-131-214-0, 1993, p. 14.

65. *Ibid.*

66. United Nations Centre for Human Settlements – UNCHS (Habitat), *Energy for Building,* HS/250/91/E, ISBN 92-1-131 174 8, Nairobi, Kenya, 1991.

67.*Op.cit. 62. p.12,* 2007.

68. International Energy Agency – IEA, 2002, as cited in Ref. 62, p.12, 2007.

69.S. Karekezi and W. Kitioma, Refered to on 8.5.2006, Part II, Renewables and rural enetrgyin sub-Saharan Africa – An overview, AFREPREN/FWD. (Online) http;//www.afrepren.org/Pubs/bkchapters/rets/part2a.pdf, as cited in Ref. 62, 2007.

70. Earth Trends 2005; ATLAS 2006, as cited in op.cit. 62, p. 12.

71. Al-Said Omar Assam and Al-Ragom 2005, CMIE 2001, *Sustainable Energy Aurthority* Victoria 2004, US Department of Energy 2006, Office of Energy Efficiency, Natural Resources Canada, 2006, as quoted in Ref. 62.

72. *Op. cit.* 50.

73-77 *Op.cit* 50.

78. United Nations Centre for Human Settlements – UNCHS (Habitat), *Housing and Environment, Report of the Workshop,* Vienna Austria, HS/596/00E, ISBN-92-1-131 456-9, Vienna, 2000.

79. European Environment Agency, *Europe's Environment, The Dobris Assessment,* David Stanners and Philippe Bourdeau, *eds.* EEA, Copenhagen, Denmark, 1995, p. 268, as cited in World Resources Institute, *A Guide to the Global Environment,* 1996-1997, Oxford University Press, New York.

80. Clyde Hertzman, *Environment and Health in Central and Eastern Europe,* The World Bank, Washington D.C., 1995, p. 20-25.

81. *Op. cit.* 79, p. 302.

82. Wojciech Beblo, Katowice, *Poland: Industrial Air Pollution and the Air Protection Programme,* Proceedings of the Second Annual World Bank Conference on Environmentally Sustainable Development, I. Serageldin, M. Cohen, and K.C. Siviramakrishnan, The World bank, Washington D. C. 1994, p. 66-69.

83. Viktor Zinovievich Koltun, Institute for Advance Training for Doctors, Novokuznetsk, Russia, 1994 *(personal communication).*

84. Inter-governmental Panel on Climate Change (IPCC), *Climate Change, The IPCC Scientific Assessment,* J.T. Houghton, G. J. Jenkins and J.J. Ephraums, eds., Cambridge University Press, UK, 1990.

85.*Op. cit 15*, p 14.
86. Tu Fenxiang, *Energy use in buildings in China,* 1992, Chinese Building Research Institute.
87. World Resources Institute and J. Wells, 1992.
88. United Nations Centre for Human Settlements – UNCHS (Habitat), *Energy for Buildings,* HS/250/91/E, ISBN-92-1-131174-8, Nairobi, Kenya, 1991.
89. Claudia Kruse, 2004, IIGCC Briefing Note: *Climate Change and the construction sector.* (online):www.iigcc.org/docs/pdf/public/constructionsector_2004.pdf
90. World Business Council for Sustainable Development – WBCSD, *Pathway to 2050, Energy and climate change.* A publication of WBSCD - Facts and Trends series, Switzerland, 2005.
91. C. Arkinson, S. Hobbs, J. West and S. Edwards, *Life Cycle Embodied Energy and Carbon Dioxide Emissions in Buildings,* Building Research Establishment, vol. 19, No. 2, London, UK, April-June 1996.
92. *Ibid.*
93. M. L. Mattison, *Asbestos and Asbestos related diseases* (revised edition), Medical Advisory Group of the Asbestos Information Centre, Widness, United Kingdom. As quoted in UNCHS (Habitat): Building Materials and Health, HS/459/97E. ISBN –92-1-131-338-4, Nairobi Kenya, 1997. p.5.
94. G. B. Leslie and F. W. Lunau, *Indoor Air Pollution: Problems and Priorities,* Cambridge University Press, Cambridge, United Kingdom, 1992 as quoted in UNCHS (Habitat): *Building Materials and Health,* HS/459/97E. ISBN –92-1-131-338-4, Nairobi Kenya, 1997. p.6.
95. S.R. Curwell, C. G. March and R. Venables, *Buildings and Health: The Rosehaugh guide to the design, construction and management of buildings,* RIBA Publications, London, United Kingdom, as quoted in UNCHS (Habitat): *Building Mateeials and Health,* HS/459/97E. ISBN –92-1-131-338-4, Nairobi Kenya, 1997.
96. *Op.cit 93.*
97. IRPTC, Bulletin. Journal of the International Register of Potentially Toxic Chemicals (IRPTC) devoted to Information on Hazardous chemicals, volume 10, No. 1 March 1990, as quoted in UNCHS (Habitat): *Building Materials and Health,* HS/459/97E. ISBN –92-1-131-338-4, Nairobi Kenya, 1997, p.9.
98. H. Karatsu, *Transferring Technology that is Needed,* Intersect, 1990, p. 10-13. As cited in UNCHS (Habitat), *Promoting Cleaner Technology in Construction,* paper for the Seminar on Energy Efficient Technology in Construction, Novosibirsk, Siberia, Russia, December 1998.

99. United Nations Environment Programme (UNEP), *Construction and the Environment: Facts and Figures,* Journal of Industry and Environment, vol. 19, NO. 2, 1996, p. 6.

100. United Nations Centre for Human Settlements – UNCHS (Habitat), *Use of Energy by Households and in Production of Building Materials,* 1991, Report of the Executive Director to the Commission on Human Settlements of the United Nations, Nairobi, Kenya.

101. United Nations Centre for Human Settlements – UNCHS (Habitat), *Housing and Environment,* HS/596/00/E, ISBN 92-1-131456-9, Vienna, Austria, 2000, p. 152.

102. C. Carter and J. De Villiers, *Principles of Passive Solar Building Design,* as cited in ref. 101.

103. United Nations Centre for Human Settlements – UNCHS (Habitat), *Global Overview of Construction Technology Trends: Energy Efficiency in Construction,* 1996, HS/376/95E, ISBN 92-1-131 290-6, Nairobi, Kenya.

104. Reif, D. K. *Solar Retrofit, Adobe, Brick house.* As cited in, UNCHS (Habitat) *Environment-friendly Construction Practices,* Vienna, Austria, 2000.

105. N. Sharif, *Management of Technology Transfer and Development,* ESCAP, Bangalore, Regional center for Technology Transfer., 1998.

106. United Nations Centre for Human Settlements – UNCHS (Habitat), *Transfer of Environmentally Sound Technology, Cooperation and Capacity Building,* Paper produced for the United Nations Commission on Sustainable Development, Nairobi, Kenya, 1994.

107. United Nations Centre for Human Settlements – UNCHS (Habitat), *The Habitat Agenda,* HS/441/97/E, ISBN 92-1-131322-8, , Habitat II, Nairobi, Kenya, 1997.

108. *Ibid,* Paragraph 88.

109. *Op. cit.* 107, Paragraph 40f.

110. *Op. cit.* 107, Paragraph 43o.

111. *Op. cit. 107.*

112. *Op. cit. 107.* Paragraph 92a.

113. *Ibid,* Paragraph 91c.

114. *Ibid,* Paragraph 92b.

115. Bourgeiois, D., Reinhart, C., Macdonald, I. A. 2005. *Assessing the Total Energy Impact of Occupant Behavioural Response to Manual and Automated Lighting Systems,* Proceedings of the IBPSA International Conference - Montreal, Canada (2005), 99 – 106.

116.Newsham, G. R., 1994. *Manual Control of Window Blinds and Electric Lighting: Implications for Comfort and Energy Consumption, Indoor Environment* (1994), 3: 135–44.

117. Hunt, D., 1979. *The Use of Artificial Lighting in Relation to Daylight Levels and Occupancy,* Bldg. Envir. (1979), 14: 21–33.

118. Mahdavi A, Kabir E, Mohammadi A, Lambeva L and Pröglhöf C. 2006a. *"User Interactions with Environmental Control Systems in Buildings";* in: "PLEA 2006 - 23rd International Conference on Passive and Low Energy Architecture, Geneva, Switzerland, 6-8 September 2006 - Clever Design, *Affordable Comfort - a Challenge for Low Energy Architecture and Urban Planning",* R. Compagnon, P. Haefeli, W Weber (Hrg.); Eigenverlag, Genf, Schweiz, 2006, 3-540-23721-6, S. 399 - 404.

119. Mahdavi A, Dervishi S and Spasojevic B. 2006b. *Computational derivation of incident irradiance on building facades based on measured global horizontal irradiance data.* Proceedings of the Erste deutsch-österreichische IBPSA-Konferenz - Munich, Germany (2006), 123-125.

Annexes

List of boxes

List of tables

List of figures