Sol Power

The Evolution of Solar Architecture

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Crisis, What Crisis?
Towards a sustainable future

The concern regarding environmental crises on both the local and global levels reflects a general acceptance that the present form and degree of resource exploitation and our associated consumption practices are unsustainable. The continued disappearance of forest cover, land degradation, the loss of biodiversity, air and water pollution, and the changing chemistry of the atmosphere all clearly reflect the inappropriateness of our present activities and the need for more effective environmental protection.

Concerns over the relationship between human activity and development and their influence on the environment are long-standing. The Earth is rapidly becoming a more crowded place: the less-developed countries experienced exponential growth rates that led to a doubling of global population in just 25 years. In advanced economies, growing evidence of environmental destruction has made people increasingly aware of the potentially irreversible damage being caused as a result of dominant development and consumption practices. The pictures of the Earth transmitted back from American space missions provided a profound symbol of the Earth as an interconnected, dynamic system, yet at the same time illustrated its fragility.

The significance of global interdependence was further highlighted by the energy crisis of 1973: the life-styles that had been fostered by an unhindered rise in energy consumption in advanced economies were directly challenged and called into question. Essentially, the economic rationales which had led to 25 years of continual growth had become problematic. There was an increasing loss of faith in the ability of science and technology to overcome any potential difficulties in the pursuit of progress. Instead of remaining committed to a belief that technological innovation would continue to enable our energy consumption and life-style requirements to be met, it was recognised that we had to come to terms with the realities of finite resource levels and the carrying capacities of eco-systems at both local and global levels.

In the last 20 years, our knowledge of environmental systems, and their interaction and relationship with human activities, has evolved through the development of national and international research programmes and more sophisticated methods of prediction enabled through increasingly accurate modelling techniques. At the same time, environmental devastation has been witnessed first-hand: forest die-back and euthropication of lakes in Scandinavian countries and southern Canada; the occurrence of widespread famine in Africa during the 1970s and 1980s; ongoing poverty and malnutrition for a significant proportion of the world's population; the depletion of rain-forest hardwoods, resulting in the loss of biodiversity and the destruction of traditional shrub woodland due to the pressures of fuel gathering; the increase in the occurrence of skin cancers associated with atmospheric ozone depletion; and the increasing number of asthma sufferers found in congested urban areas linked to low-level ozone and smog pollution.

Despite this, our life-styles and consumption patterns have failed to reflect our concerns. Indeed, although energy efficiency has continually improved, the growth in consumption levels has outstripped any potential gains made in this regard. Although new technologies have enabled fossil fuels to be utilised more efficiently and in cleaner forms, the costs involved in making such improvements have largely put them out of reach for the newly industrialising nations, where the growth in emissions is taking place at the most startling levels. There are difficult issues to be addressed by advanced economies in this regard, as the 1992 Global Summit in Rio highlighted. How do you avoid placing restrictions on, or hindering, economic development yet promote the struggle against environmental destruction?

The potential of nuclear energy, once regarded as the natural successor to fossil fuel, has been curtailed as a result of environmental concerns, and the true costs involved are becoming increasingly apparent. The meltdown at Chernobyl in 1986 and the continued inability to find a resolution to the problems posed by radiated waste disposal have focused public concern on the viability of this energy source. Thus it can be argued that we have reached a moment of transition in both our production and consumption of energy. New technologies must enable us to work with and for the environment rather than be utilised as tools that allow us to conquer and dominate. The notion of sustainable development is increasingly stressed in this connection. Central to this concept is the requirement that current practices and policies should enable (according to the 1987 Brundtland Commission) 'development which meets present needs without compromising the ability of future generations to achieve their needs and aspiration.' In moving towards more sustainable relations between development and the environment, three interrelated components of human impact need to be recognised. Based upon Paul Ehrlich's 1967 formula, this impact may be regarded as a product of population, consumption, and technology, components that exist together everywhere. Thus:

Environmental Impact = Population x Consumption x Technology.

This equation illustrates the actual environmental costs of particular life-styles, making tangible what is so often invisible. Exposing these costs is paramount if people are to be encouraged to move towards more sustainable forms of living.

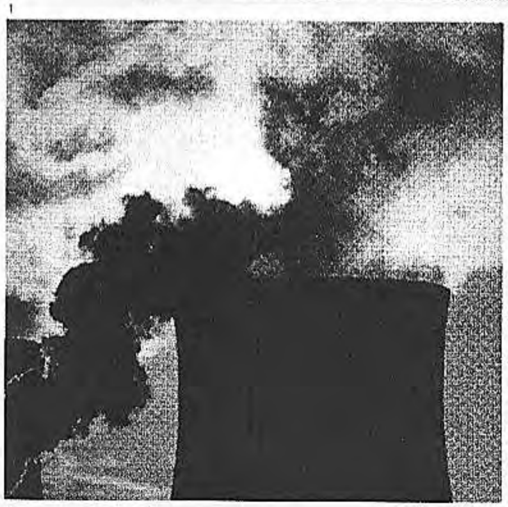
The global environmental crisis is a question of survival. Never before in history have human beings had such an impact on Earth. The resulting problems are a product of the size and growth of population, quantity of consumption, and quality of technology.

1

Deforestation
The gathering of wood for fuel is one major cause of the destruction of savanna tree and scrub forests. Wood is the principal source of energy for most people in poor countries, where women may spend large amounts of their time and energy finding and harvesting it. In many regions, wood harvesting exceeds rates of re-growth.

Pollution
Between 1970 and 1990, whilst sulphur-based emissions declined from 65 to 40 million tonnes per annum in the wealthy OECD countries, emissions from the rest of the world rose from 48 to 59 million tonnes. The future development of these industrialising countries, including the 1.2 billion inhabitants of China with their vast reserves of coal, places the environmental crisis in clear perspective.

Nuclear Waste
Nuclear waste is accumulating at an alarming rate. So far, the problem of waste disposal has not been solved anywhere in the world. Construction costs for nuclear power stations rose from £250 per kWh in 1971 to £2,000 in 1985, reflecting the risk factor involved. Cancer and birth defects are caused by exposure to radiation from nuclear waste.



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Population
New centres of growth

The Population Explosion
Since 1900, the world's population has tripled in size, the world economy has grown 20 times bigger, and industrial production has increased by 5000%. The continuing rise in the world's population today is a major concern.

World Population
The exponential growth of world population is a very recent phenomenon. Before the organisation of agricultural production and the formation of city-states by the early urbanising civilisations, population levels were relatively static for more than 30,000 years. These new forms of social organisation enabled greater numbers to be supported given the resources available (1).

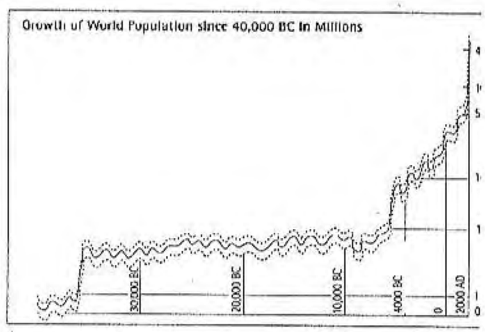
Industrialisation and the large-scale migration to towns and cities from the 17th century on represented a further period of sustained increase. It has only been in the last 40 to 50 years, however, that the pressures of population growth have taken on new dimensions. It is difficult to predict the future; however, the fastest-growing areas show little sign of significant decline in their growth, and those areas where population growth is being reduced already have vast base populations (2).

The rapidity of contemporary demographic change makes it unclear whether the patterns of growth and urbanisation being experienced in the developing world are replicating traditional patterns of industrialised economies or whether they are fundamentally different. Whilst actual and future predictions are hindered by difficulties in collecting accurate data, the environmental consequences and increasing strain placed upon both natural and social resources are becoming clearly apparent.

United Nations projections estimate that total global population by the year 2000 will be between 6 and 6.5 billion persons. To put this into perspective, the total population stood at just 250 million, 2,000 years ago. Until the advent of industrialisation in Europe during the 18th and 19th centuries, population growth was gradual and inconsistent, characterised by high birth and death rates and periods when population levels declined through poor agricultural organisation, famine, and disease. It was not until 1820 that global population reached one billion, and despite European industrialisation, migration, and the resource exploitation and diffusion of new technologies overseas through imperial expansion during the 19th century, it was another hundred years before it reached two billion.

Since 1945, exponential growth has led to a rapid expansion of numbers on an ever-increasing base population. Whilst the rate of population growth has declined and stabilised at very low levels in a number of advanced economies, the fall in death rates but persistence of high birth rates in developing countries has ensured a rapid expansion of global population. Death rates have been reduced through the introduction of modern preventative and curative medicine, including immunisation, water sanitation, and antibiotics, as well as improved agricultural techniques, which have enabled higher crop yields in certain areas of the developing world. Presently, with a growth rate of 1.7%, approximately 190 million births and 95 million deaths occur each year, adding a further 95 million persons to the Earth's population annually. Of these births 95% are in the less developed countries, 20% – 19 million – in India alone.

The growth in population levels is paralleled by the rapid urbanisation taking place in many developing world cities. In 1990, 43% of the world's population was urbanised, comprising 73% of people living in developed countries and 33.6% in developing countries. It is estimated that by the year 2000, the total proportion of urban dwellers will have reached 50%, this increase being almost wholly represented by the growth of cities in the developing world. Forecasts indicate that within 10 to 15 years, few cities in the developed world would feature in a top 20 table of the most populous urban agglomerations. Mexico City and São Paulo already vie with New York and Tokyo and, if they have not already done so, will soon overtake them, as will many others in terms of absolute numbers. The strain such a rapid increase has placed upon the cities' social and physical infrastructures is indicated by widespread un- and underemployment, burgeoning slum districts, and the proliferation of squatter settlements on available land, typically in peripheral locations. It is estimated that a third of the urban population in developing countries live in such conditions; when new dwellings are considered, shanty-type dwellings comprise two-thirds of all new households. Although urban pressures are clearly not as dramatic in advanced economies, many cities, particularly in the more dynamic regions, continue to face urban development pressures as a result of migration and, more significantly, the changing number and form of household structures. Rather than a simple growth in numbers, changing social relations and life-style choices have created a larger number of household units, for example through later marriage, cohabitation, and increasing proportions of divorced and remarrying couples.



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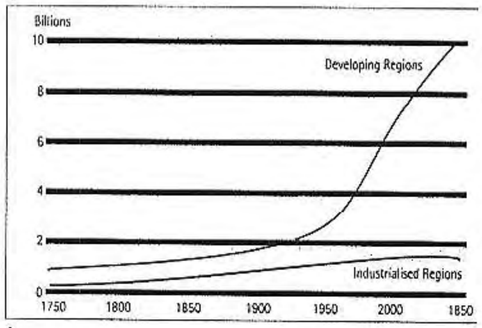

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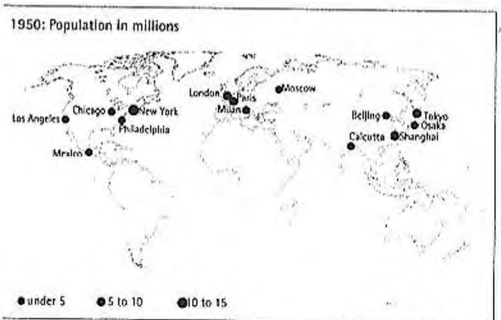
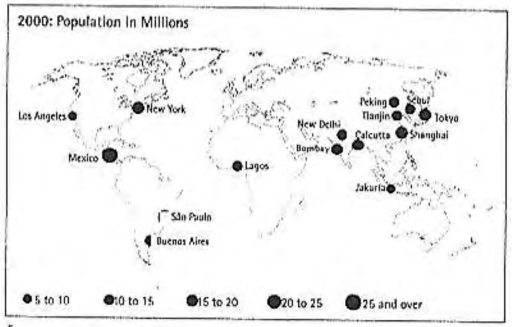
Two demographic trends are presently being experienced at a scale that has no historical precedent: an explosive growth in the total global population, and the increasing urbanisation of that population. The demand for housing for new urban dwellers is greater than ever.

1

Urban Centres
The dramatic growth of population in developing regions is giving rise to a new urban hierarchy and an increasing number of mega-cities with populations of 10 million or more. Indeed, the UN estimates that by 2025, there will be 12 cities with populations greater than 20 million. This growth has not been uniform, and the variation is leading to a profound shift in the urban balance. In 1950, the large majority of the world's largest urban agglomerations were found in developed countries – for example, New York, London, and Paris. By the year 2000, the list of the 25 largest cities will be dominated by rapidly growing cities in the developing regions (4, 5).





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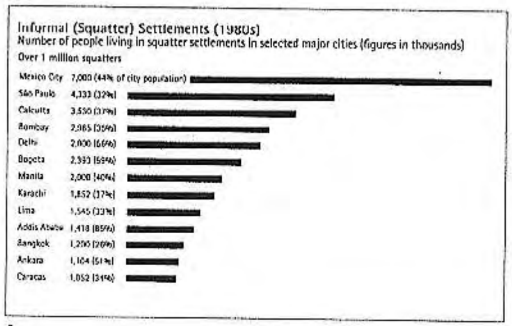

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Housing Demand
Rapid urbanisation of cities in the developing world places great strain upon housing and infrastructure resources (7).

The urbanisation of world population has put enormous pressure on those working in the fields of urban planning and infrastructure. The building construction industries have not yet found solutions for major urban problems (6).

Consumption
A matter of balance

Urban Development
Urban forms help dictate, and are dictated by, changing transport modes. The development of trams and cleaner urban railroads promoted suburban development at the beginning of the 20th century in Europe, Australia, and North America, for example. High-density transit-oriented neighbourhoods were encouraged as new development concentrated upon these linkages. The car has succeeded the tram and train, offering personal mobility at the cost of poor energy efficiency and high levels of pollution. The rise in car ownership and the encouragement of low-density settlements has ensured that households have increasingly become dependent upon the car to negotiate sprawling urban landscapes.

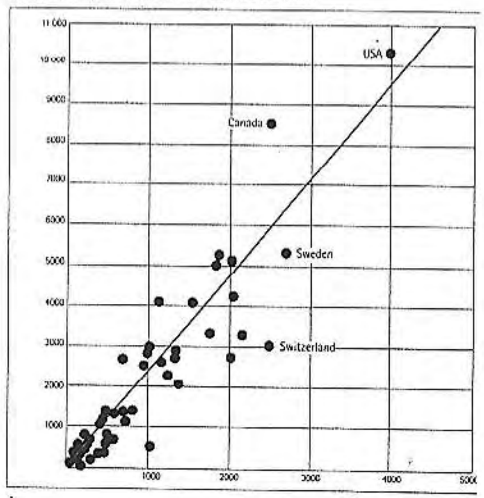
Concern about the pressures applied by exponential population growth to the environment is not simply about numbers, but also recognises the widening disparity in consumption patterns and life-styles between rich and poor. Traditional economic models of development have made explicit the link between progress through industrialisation and increasing levels of energy consumption. Indeed, the direct correlation between per capita energy use and the wealth of nations provides evidence of this association. Industrialisation both necessitates and stimulates greater energy consumption levels, in converting raw materials into manufactured products and in stimulating the development of new products through technological innovation that add to energy demands. For example, whilst the production of electricity was originally intended to provide lighting in buildings and streets after dark, utility owners have searched for ways in which their in-plant investment could be utilised at other times of the day. As standards of living for a large proportion of the population increase, technological innovations gradually become regarded as essential. The telephone, the refrigerator, the car, the television continually increase the energy requirements of the average consumer.

The inequalities recognised between industrialised and developing countries are reflected in their respective energy consumption levels. Economically advanced societies – for example, most European countries – consume approximately a hundred gigajoules of energy per person per year, the equivalent of three and half metric tonnes of coal. In the US and Canada, this figure is closer to 10 tonnes per person per year. At the other end of the scale, countries remaining at low levels of industrialisation typically consume just 0.1 tonnes – 1% of the amount of the highest-consuming societies. If conditions enable developing societies to reach the consumption levels presently recorded in the industrialised nations, then with the vast population bases these countries represent, the implications for global energy requirements are immense.

The energy crises of 1973 and 1979–81 illustrated to industrialised countries the dependency on high levels of energy consumption required to support their life-styles. The message has become more urgent as growing environmental consciousness has recognised the implications of air pollution, ozone depletion, and acid rain for future generations. This greater understanding has translated into support for more sustainable forms of development, which work within environmental constraints rather than trying to overcome them. An important component of this debate has focused upon a re-evaluation of urban form and function and contemporary industrial practices and procedures. In this regard, there has been an increased willingness to recognise the importance of issues such as urban densities in determining energy efficiency and the value of moving towards environmental concerns and the more efficient use of raw materials with less negative output and environmental damage (from cradle to grave).

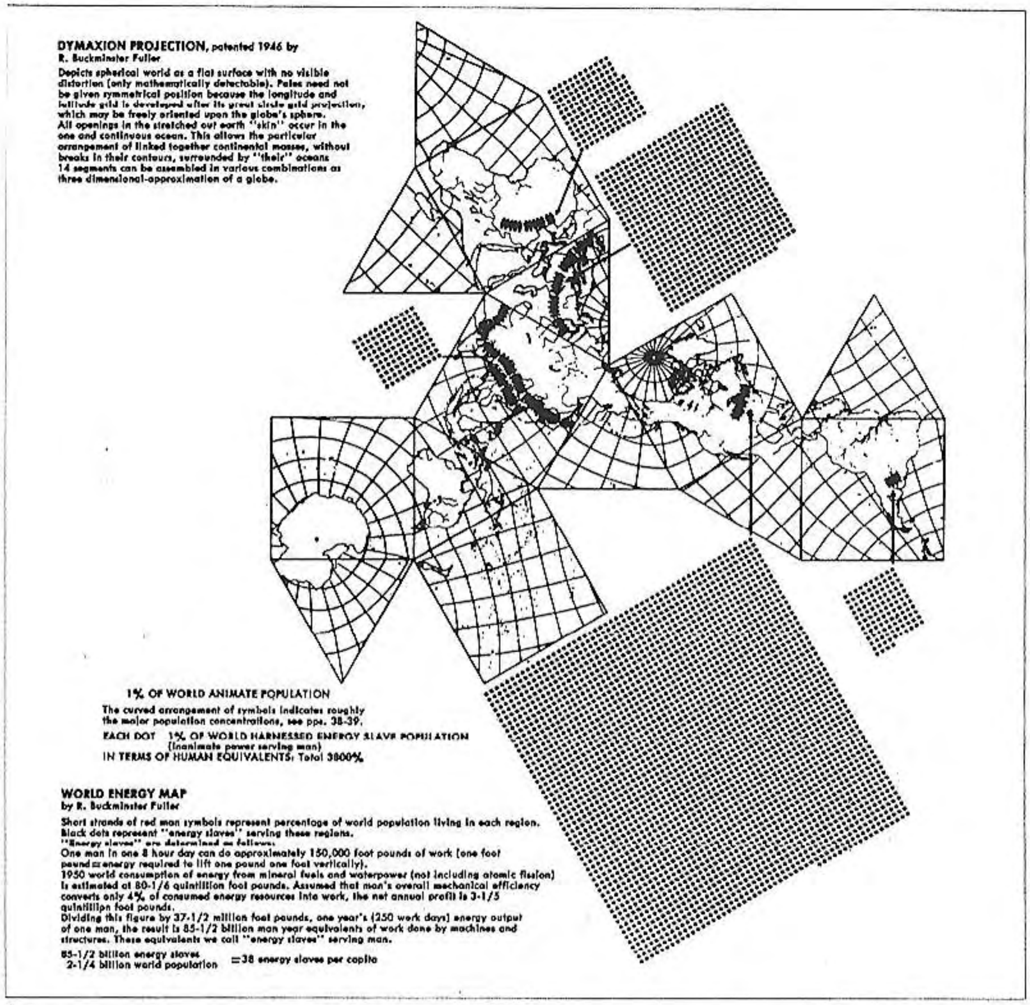
Although public support for environmental issues is often highly vocal, actually translating these beliefs into changing life styles is a more complicated matter. Importantly, this necessitates an understanding of the possible motivations for change: how can an individual's decisions be valued? As dominant economies have placed overriding faith in the principles of the free market, the position of placing value – a private judgement – on the environment, traditionally regarded as a public good, is a complex one. A further paradox is introduced: whilst the global significance of environmental stress is recognised, these issues must be tackled at the local level. Many have argued that our ability to combat problems this complex requires a reassessment of social values and communitarian principles. The environment is a common concern and must be tackled as such.

Energy Consumption in Relation to Gross National Product



1

The Haves destroy the atmosphere through their waste of energy; the Have Nots increase in number and suffer because of the lack of energy. Only through a radical increase of efficiency and a refocusing on renewable energies will it be possible to provide the desired life-style for all people on this planet.



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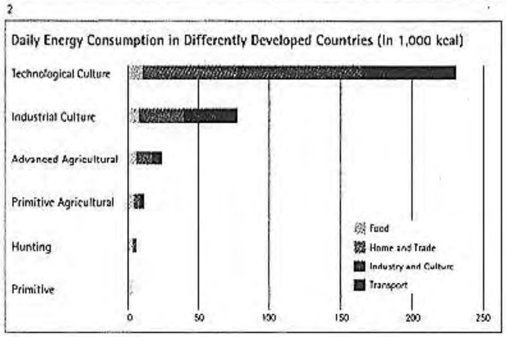
The Haves and Have Nots
Buckminster Fuller's representation of the world (2) illustrates the great inequality between the energy consumption levels of rich and poor nations. The wealthiest 25% account for 75% of total consumption and similar pollution production levels, whilst the other 75%, representing the poorer developing countries, account for just 25% of total world energy use.



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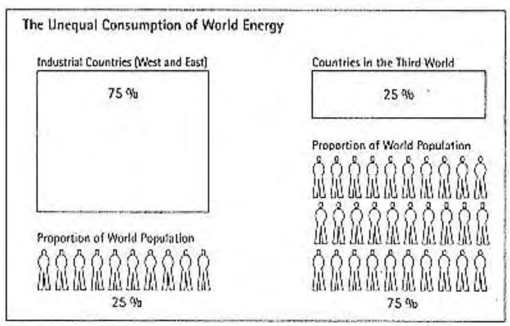


4

Energy consumption and pollution clearly correlate. Countries with high gross national products are the largest producers of fuel-based pollutants, CFC propellants, and nuclear waste (1). Although new technologies have enabled fossil fuels to be utilised more efficiently – for example, through desulphurisation processes – the costs involved in such improvements are largely out of reach for newly industrialising countries (3).

Technology
A question of sustainability

By harnessing energy through agriculture, humans have transformed much of the natural world to suit their requirements. Since energy is neither produced nor consumed, only transferred, all potential energy sources available to us represent a form of solar energy, stored as biomass in trees; as fossil fuels in oil, gas, and coal. Technological innovations have enabled each of these sources to be discovered and utilised, typically leading to a great expansion of production capacities at each stage and promoting new uses and consumption patterns. Dominant forms of energy use reflect an evolution from muscle power through the discovery of fire and the combustion of wood and dung, to the extraction of non-renewable fossil fuels and their conversion to electricity. Muscle power and wood burning still provide a proportion of the energy requirements in the most industrialised societies.

Prior to the Industrial Revolution, our energy sources were primarily renewable. The form and design of towns and cities took into careful consideration characteristics of the local microclimate, typically oriented to take maximum advantage of solar activity. The onset of new forms of industrial organisation during the 18th century was largely enabled by the development of steam-powered engines driven by coal instead of charcoal. The continual refinement of this new technology opened up new vistas for development, increasing the demand for energy even further.

The Industrial Revolution was a fossil-fuel-based revolution: the two went hand in hand. Although it marked a dramatic step in terms of innovative progress, at an early stage the detrimental implications of these technologies were apparent: cities were blackened; the skies continually filled with dense smog; poor health ensued, with children developing bone deficiencies through lack of exposure to sunlight. The pursuit of progress and demand for ever-increasing energy consumption to feed new life-styles has typically offset such concerns.

In the period of reconstruction following World War Two, the role of energy in rebuilding and redefining national industries was paramount. The market for petroleum surged through the growth in car ownership, encouraged by governments and concretised in urban, and increasingly suburban, forms of living. The nuclear industry grew in parallel with militaristic objectives of the Cold War period: electricity suppliers in the US, Britain, and elsewhere were encouraged and subsidised to develop this new technology. In countries with few fossil fuel resources, the pursuit of new nuclear technologies to supply energy needs was vigorous.

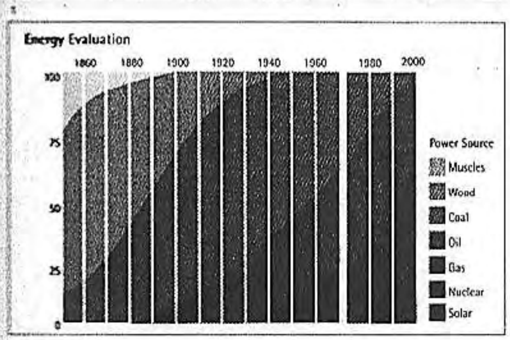
Technologies focusing on the potential to harvest renewable energy remained largely underdeveloped after 1945, when fossil fuels and nuclear power were seen as more economic forms capable of meeting future needs. At present, the crisis in non-renewable energy resources, and the technologies based upon such sources, are not imminent, but can be effectively foreseen. It has become clear that our technological advances have had both global and local environmental consequences. Our over-riding faith in progress through technology is increasingly questioned, as can be seen if we look at nuclear power.

Fossil fuel resources are inevitably finite; conservation represents our best available energy source. Indeed, most of our new sources of energy in the last 25 years have come from improved efficiency, and there remains a great deal of scope for improvement in this regard. An important aspect in moving towards greater energy efficiency is to ensure that the appropriate kind of energy is used for a particular task. For example, the costs of electricity production, once loss in translation and through supply lines is taken into account, are far higher than other forms. The energy wasted in the process each year would provide enough power to heat all the homes in the US. In the longer term, it is by tackling the deeper roots of wasteful patterns of production and consumption that we will resolve the energy crisis, not by creating more energy. It is important that we recognise the importance of changing our values, attitudes, and life-styles in this regard. There must also be a parallel shift in energy production from non-renewable to renewable sources, and from so-called hard technologies – based upon rigid and centralised use of fossil fuels – to softer technologies – those which are environmentally benign and ecologically balanced. The technology to utilise the vast resources of direct solar energy which this planet receives each day already exists and will be a central component in this essential transition back to technology's alignment with nature.

Human history is the history of energy transformation. Every era is marked by its own techniques of energy generation. We are now entering a new solar age.

1

Urban Hotspots
In cities, heat islands reveal themselves as white, red, and yellow areas. These thermograms are a tool to heighten awareness of conservation and to give advice for insulating buildings (1).



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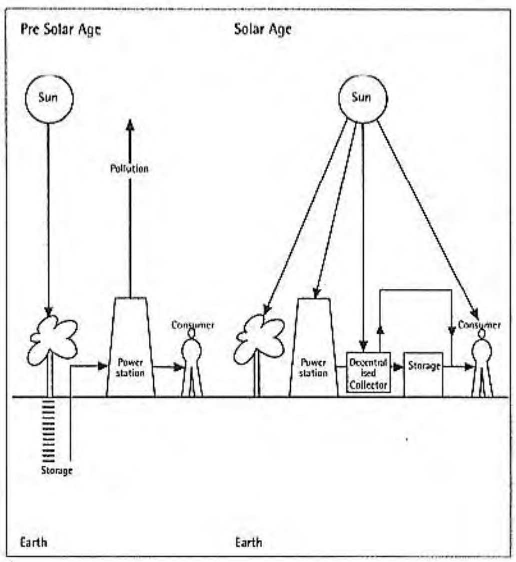

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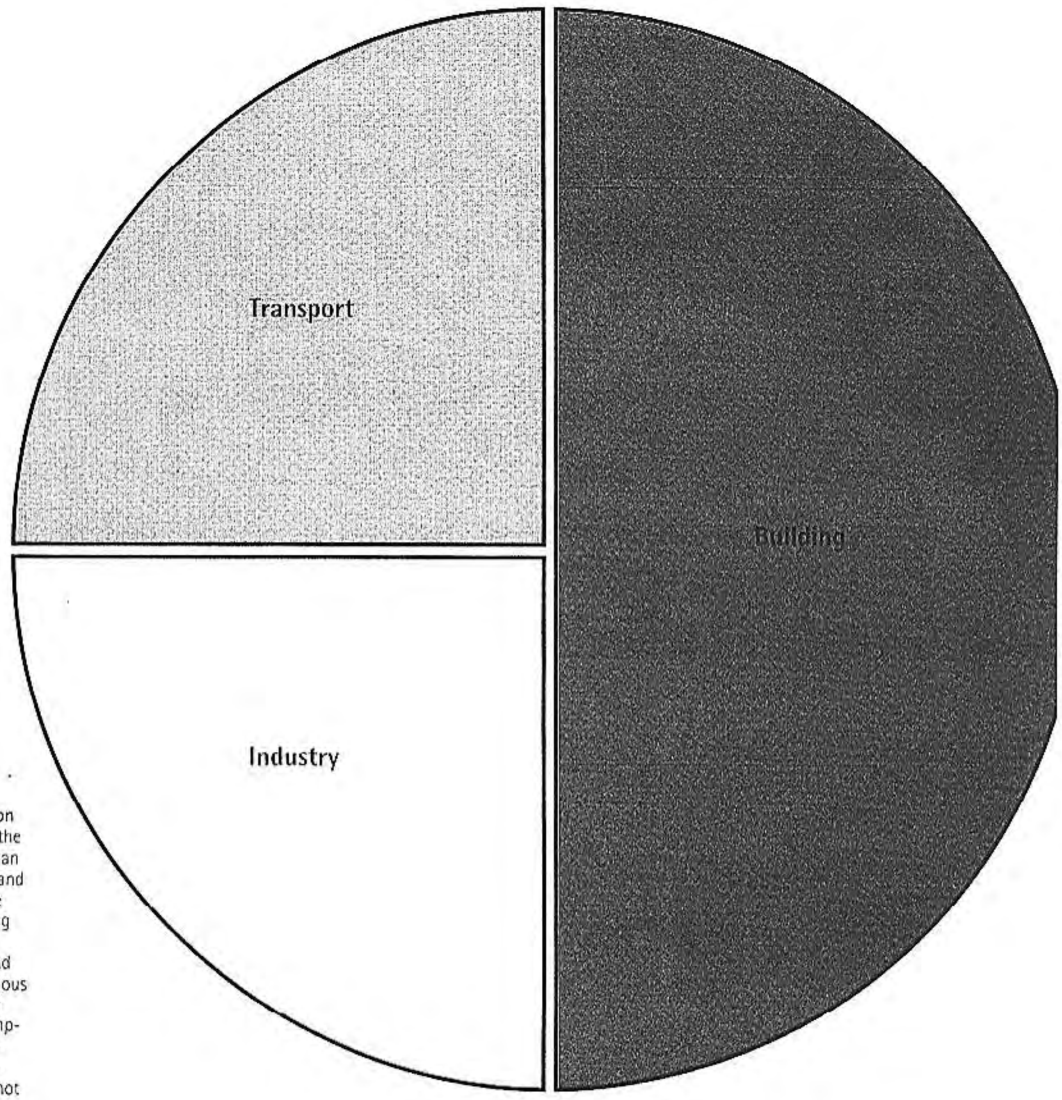
Old and New Solar Energy
The cycle of solar energies on Earth can be divided into solar energy that has been stored underground for thousands of years – old solar energy - and the energy that comes from the sun daily and that can be used directly by passive and active means. We need to develop technologies that use 'fresh' solar energy efficiently.

Architecture and Architects
Renewable energies in architecture and design



World Energy Consumption
Buildings consume half of the energy that is used by human beings. The art of building and consumption patterns have changed dramatically during the last two centuries. The engineering of buildings and the fashioning of homogenous environments have led to a rapid rise in energy consumption. Today, buildings like a typical office block tend to waste the most energy by not allowing the inhabitant and user to participate actively in conservation.

The world's energy consumption can be broken down into three major areas: industrial, commercial, and residential. Most energy is used in the commercial/industrial areas; less goes into residential use.

Architects, engineers, and urban planners are not directly responsible for our built environment, as an increasing number of buildings are built with no care for quality or efficiency and without any architect involved. Nevertheless, architects, engineers, and urban planners are responsible for the energy inefficiency of buildings they design.

Our built environment represents a particular manifestation of technological innovation. Buildings provide shelter, facilitate our activities and interactions, and represent our desires and provide cultural expression. The methods by which we apply technologies in the design and construction of buildings have direct implications for the amount of energy consumed. The enormous amount of energy consumed by buildings reflects a continuing increase in the demands placed upon energy resources and symbolises the problematic relationship between architecture and technology that has emerged during the industrial age. The two have become interdependent, and architectural innovation has increasingly necessitated technological and engineering expertise, coupled with higher energy demands in both construction and operation.

The Industrial Revolution heralded the pursuit of progress and innovation dictated by a human desire to do away with our dependence upon natural constraints and, in so doing, to overcome and dominate nature. Rather than working with particular environmental qualities, buildings have increasingly come to represent enclosed, isolated boxes in which the internal environment is artificially controlled. Structures are maintained at temperatures deemed comfortable according to the purpose of the building: whether the temperature outside is -20 degrees or 35 degrees Celsius, the internal temperature remains constant. Achieving this comfort necessitates considerable energy consumption.

Of course, the level of energy use is largely dependent upon the technologies applied in design and construction, and this may be considered at three levels. Technology determines how much energy is required to operate the services in a building; technology determines what kind of energy is utilised, and how efficiently; technology determines how this energy is generated or harvested. How technologies are employed in building design is the ultimate responsibility of the architect and engineer. They are responsible for dictating the energy requirements of their designs. For example, if structures are designed that use a lot of glazing, then the energy requirements of buildings will necessarily incorporate the costs of artificially maintaining internal conditions against extremes in external temperatures. Likewise, if a building has insufficient window space, energy requirements increase as a result of having to provide artificial lighting.

A number of goals and objectives for more efficient building design can be proposed:

a) Buildings should only need to use artificial mediators inside when the prevailing conditions externally make human activities uncomfortable. As such, buildings can provide a buffer against uncomfortable environmental conditions – for example, extremes in temperature or winds.
b) Buildings should avoid restricting natural conditions reaching their internal spaces that would be of positive benefit to their occupants. For example, buildings should be designed to maximise the use of daylight over artificial light; likewise, buildings should aim to be naturally ventilated with fresh air rather than be controlled through energy-consuming heating and ventilation systems.
c) Buildings should be designed to assist in the collection and storage of received energy sources, particularly solar energy, and then utilise this when and where required. By working with, rather than trying to overcome, the Earth's natural energy cycles, buildings can be designed that consume far less energy.
d) Buildings should also be environmentally responsive to their local surroundings. Not only should they minimise internal energy consumption; they should also aim not to create external demands or induce negative environmental effects. Local energy cycles can be utilised, but should not be altered or used in an unsustainable way.

To facilitate these goals, we need to learn from our pre-industrial history to realise the fundamental importance of the relationship between human activity and nature. Our first building structures provided simple protection from uncomfortable temperature extremes, and until fairly recently a large majority of people spent much of their lives outside, rather than within, buildings. Although the cities of early civilisations altered these trends, lives remained very much dictated by solar and seasonal cycles, instead of trying to homogenise living conditions throughout the year, as modern internal building environments attempt to do.

Throughout the centuries, ingenious use of technology has enabled societies to create highly efficient structures utilising natural or renewable materials in their construction and similar energy sources to enhance their performance. All those who share interest, concern, and responsibility for the built and unbuilt environment should reflect upon successful historical examples and aim to revive and refine many of these forgotten and neglected principles. Recognising the dependency of human activity upon maintaining a sustainable relationship with the natural environment should stimulate greater understanding of constructions in nature. The sophistication and complexity of plant and animal structures – the importance of ordered chaos as seen in skins, shells, and cells – can provide many clues for contemporary research. Through a better understanding of such systems, our ability to adopt an holistic approach to building design, where both local and global environmental implications are taken into full consideration, will be facilitated.