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ENERGY EFFICIENT URBAN DESIGN

A Thesis in

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By

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ABSTRACT

My personal interest to the term "sustainability" comes up with the close examination of the concept of energy efficiency and the clear threats to our environment let me to make an intensive study on the subject.

The aims of this thesis are; to define the problems urban energy consumption causes; to indicate the necessity of reducing this energy consumption; to indicate the importance of planning and urban design to achieve energy efficiency and conservation; to describe energy efficient urban design; to identify energy efficient urban design process and its variables in a convergent manner; and to provide a detailed theoretical supply to serve for further study on this subject.

The theoretical knowledge given in the thesis is based upon a wide, intense and ranged literature survey. On the other hand, the pragmatic approach which is built on the combination of the theoretical pieces with a close look at Izmir example is based on the description of the influences of climate, built environment and development and planning process on energy consumption and energy conservation status of Izmir.

With respect to the climatic data and development pattern of Izmir, it can be said that any attempt to provide energy efficiency should contain reduction of energy consumption both in cooling and heating however the priority differs according to the properties of the site and microclimate. Central areas of the city, due to the existence of heat island, experience overheating, lacking of ventilation. In these areas cooling has priority. Therefore it is required to reduce the heat island effect and the energy used for cooling. On the other hand, new development areas, for instance north growth axis of Izmir, have lower air temperatures because of being not completely developed. Therefore, it is required reductions in energy use for heating. Also in order to prevent the formation of heat island and to provide thermal comfort, it is required cooling strategies in summer.

Energy conservation and efficiency concepts are not common in our planning and design practice. However, energy efficiency must be achieved through a complementary urban planning and design process. The concept should be adopted into master plans and regulations should promote energy conservation.

ÖZ

"Sürdürülebilirlik" terimine olan ilgim, "enerji etkinliği" kavramının derin araştırması ile somutlaşırken, yaşadığımız çevreye yönelik tehdit ve tahriplerin, nitelikleri ve nicelikleri bu konu üzerine yoğun bir çalışma yapmama neden olmuþtur.

Tezin amaçları; kentsel enerji kullanımının neden olduğu problemleri tanımlamak; bu enerji tüketimini azaltmanın gerekliliğini göstermek; planlamanın ve kentsel tasarımın enerji etkinliği ve sakınımı sağlamadaki önemini vurgulamak; "enerji etkin kentsel tasarım"ı tanımlamak; enerji etkin kentsel tasarım sürecini ve değişkenlerini bütüncül bir yaklaşımla ortaya koymak; bundan sonra yapılacak olan çalışmalara kaynak olması için bu konuya ilişkin teorik bilgileri detaylı olarak sunmaktır.

Tezde verilen teorik bilgiler geniş, yoğun ve düzenli bir literatür taramasına dayanmaktadır. Diğer yandan, tezin içerdiği pratik yaklaşım, ki teorik bilgilerin Izmir örneği ile ilişkilendirilmesi üzerine oturtulmuştur, iklim, yapılı çevre ve planlama ve gelişim süreçlerinin, İzmir'in enerji tüketim ve enerji sakınım durumları üzerindeki etkilerini içermektedir.

İklim verileri ve İzmir'in kentsel gelişim dokusu şunu gösteriyor ki; enerji etkinliği sağlamak için yapılacak bir çalışma hem ısıtma, hem de soğutmada tüketilen enerjinin azaltılmasını içermelidir. Isıtma veya soğutmanın önceliği alanın özelliklerine ve mikroklimaya göre değişir.

Merkezi alanlarda ısı adası etkileri yüksek sıcaklıklara ve havalanma yetersizliklerine neden olmaktadır. Bu alanlarda soğutma ön plandadır. Dolayısıyla, ısı adası etkisi ve soğutma için kullanılan enerji miktarı azaltılmalıdır. Diğer yandan, yeni gelişme alanları, örneğin İzmir'in kuzey gelişme aksı, tamamen yapılaşmamış olduğundan daha düşük hava sıcaklıklarına sahiptir. Bu durumda ısıtma için tüketilen enerji miktarının azaltılması gerekirken, aynı zamanda ısı adası oluşumu engellenmeli ve termal konfor da sağlanmalıdır.

Enerji sakınımı ve enerji etkinliği kavramları planlama ve tasarım pratiğimizde henüz yer almamaktadır. Þu bir gerçek ki, enerji etkinliği ve sakınımı bütüncül bir planlama ve tasarım süreci ile sağlanmalıdır. Enerji etkinliği kavramı master planlarda yer almalı ve yapılanma koşulları enerji etkinliği sağlamalıdır.

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Chapter 1

INTRODUCTION

Energy consumption in the developing world has grown tremendously. The increase in consumption depends on many factors, however, urbanization can generally be accepted as a prime cause.

The level of urbanization determines the pattern of energy consumption in the city. The growing population, increasing income has resulted in greater demand for transportation, accommodation and accommodation appliances, especially space conditioning devices.

At that point, it can be said that urban design has a significant effect on the conservation and efficiency of energy. However, the rationale for energy efficient design is not so much the need to conserve energy per se, rather reduction in energy consumption for sustainable environments and for the ecological health of the whole planet.

Any progress towards a sustainable future will require large per capita reductions in the amount of energy required for building conditioning and transportation. Many of the gains to be made in this area lie in the realm of the improved building technologies and improved vehicle efficiencies. Nevertheless, it is certain that site and community design factors can powerfully affect the amount of energy required for space conditioning and transportation.

1.1. The Methodology

The thesis is composed of two approaches; theoretical and pragmatic approaches.

The theoretical approach is based upon a wide, intense and ranged literature survey. The aim is to gather the available theoretical knowledge about energy efficient urban design and to provide a detailed theoretical supply to serve for further studies.

The subject itself is a really an overwhelming study. But because of its wide content, it was hard to make the borders. On the other hand, while doing literature survey, to access the resources which are directly related to the subject was quite difficult as most of the investigations has focused on technical characteristics of energy and some basic resources which were earliest publications are not available.

The pragmatic approach is built on the combination of the theoretical pieces with a close look at Izmir example. Energy consumption is high in Izmir and the city is troubled seriously with this fact such as; cuts in electricity supply, air pollution, climate changes -overheating, heavy rains, flood- etc.

Firstly, in order to determine energy efficient environments and to reduce energy consumption in Izmir, the energy consuming features and energy related problems of the city are considered. These are; sectoral development, urban form and growth pattern, transportation, the relation between the built environment and the urban climate, air pollution, the planning process.

The emphasis is given on the description of the influences of climate, built environment and development and planning process.

The climatic characteristics of the city is expressed according to the data taken from three meteorological stations. The observed values mostly depend on the location of the stations. Güzelyali station is located in the high dense urban area where the effect of heat island is exactly seen. The station in Bornova is also affected by the urban areas around it. However in Çigli, the station is located on an open area where it faces the sea effects.

Any attempt to provide energy efficiency should contain reductions of energy consumption both in cooling and heating however the priority differs according to the properties of the site and microclimate.

First of all, the heating and cooling periods, in other words heating and cooling degree-days of the city are calculated. Every day in which the daily temperature is below 18.3° C is equal to a certain number of HDD units. The calculations characterize the climate of the city by hot long summers and mild winters. In addition, the calculations show that Çigli has higher HDDs and lower CDDs the Bornova and Güzelyali.

At that point two statements are made as the problem definition.

<u>Statement 1:</u> Central areas of Izmir experience overheating, lacking of ventilation due to the existence of heat island. In these areas, in order to achieve energy efficiency the heat island effect should be reduced and/or to reduce heat island effect, energy conservation should be provided.

Statement 2: Locating at the outer zones, new development areas have lower air temperatures than central areas both in summer and winter. Reducing energy consumption for heating has priority.

According to these statements, planning and design guides are established.

Besides microclimatic features and the relation between the built environment and the components of the microclimate, building regulations -legitimate tools- are considered as a variable of energy efficient urban design. Zoning regulations can provide the reduction of energy consumption for space conditioning and promote the use of solar energy. For this reason, the current building regulations are evaluated in the context of energy efficiency.

The angle of coming sunlight is important for the calculation of the amount of required solar access and shading during the day, and moreover during the year. Therefore, at the evaluation of the ordinances related to the location of buildings in relation to each other, the distance between buildings, setbacks, building heights; in accordance with the solar time in Izmir, the sun angle values and shadow depths for buildings of 15.50m.and 24.50m. in height are calculated. The winter and summer solstice represent extreme conditions such as the highest or the lowest position of the sun so the longest or the shortest shadow of the year.

The review of the current building regulations show that they do not encourage providing energy efficiency.

Finally, a check-list is formed. The purpose of this table is to test the efficiency of an existing settlement or a project under the influence of pre-defined variables and/or to lead the designers and developers for new developments with the aim of energy efficiency. Egekent -2 Mass Housing Area is evaluated according to this check-list as an example.

The aim of the evaluation is not to say whether the selected area is energy efficient or inefficient., however to determine at which points the area or the plan provide efficiency or at which conditions it is inefficient.

The reason for choosing Egekent-2 is that Egekent-2 Residential Area is located on the north growth axis of Izmir. This axis has not completely developed yet. Its microclimate has not entirely affected by the urbanization. Therefore, a study on this region may take attention and be a reference for new developments.

Chapter 2

ENERGY IN THE NATURE AND ENERGY IN THE WORLD

2.1. Energy In The Nature: Finite Limitations of the Use of Earth Ecosystem

The earth and the biosphere, the system that we and all other living things live in, can be considered a "closed material system" with a finite mass. Ecologically, the earth can be conceived as a unit.

This spatial unitness formed by the interactions of both the biological and physical environment can be termed as "ecosystem". The functions in the ecosystem include the transformation, circulation and accumulation of matter and the flow of energy through natural processes. (Yeang, 1995)

It is known that the formation of all mineral deposits, whether fuels, metals or others have taken time and we, people are consuming them faster than they are being naturally regenerated. " The availability of resources at any particular time is the result of the interaction among the nature and size of human requirements, the physical occurrence of the resource and the economic cost of extracting, producing and recovering it. This is further related to people's standard of living and the extent of the patterns of need that they demand." (Yeang, 1995; pp: 101)

The use of earth's ecosystems, energy and material resources requires a conservation conscious design approach.

" The physical substance and form of the present built environment are constructed from the renewable and non-renewable energy and material sources which are derived from the earth's mantle and its ambient environment" (Yeang, 1995; pp: 97). So the designer must be aware of non-renewable resources used in the realisation, operation and disposal of the built environment and of the efficiency with which these sources are utilized.

The built environment must be designed to minimize consumption of these resources and to minimize wastes, to optimize use, to be more dependent on the renewable and recoverable, to conserve the resource and to provide the potential and flexibility for its future use.

2.1.1. Natural Resources and Sustainable Energy

In the first subtitle, it is said that the physical substance and form of the present built environment are constructed from the renewable and non-renewable energy and material resources. The sources of energy and materials from the earth are termed natural resources. Natural resources are classified according to their availability and regenerability; replaceable and irreplaceable resources. (Table 2.1)

Table 2.1. Classification of natural resources

INEXHAUSTABLE RESOURCES	examples are air, water and solar energy.
REPLACEABLE and MAINTAINABLE RESOURCES	examples include water in place and flora and and fauna populations. The production of resources is primarily a function of the environment and if environmental conditions are suitable, the resource in question will continue to be produced. The impairment of the environment will result in reduced production of the resource.
IRREPLACEABLE RESOURCES	examples include minerals, soil,fossil fuels, land and landscape in the pristine condition. These resources are generally considered irreplaceable in relation to the rate and type of human exploitation. The more that is used now, the less there will be available for the future.

(cont.)

(Table 2.1. cont.)

METALLIC MINERAL RESOURCES	Abundant metals	Scarce metals
	iron, aluminum	copper, lead
	chromium, manganese	zinc, tin, tungsten
	titanium, magnesium	gold, silver, platinum
		uranium, mercury

NONMETALLIC MINERAL RESOURCES		
minerals for chemical fertilizers and special uses	mainly building use	water
sodium, chloride, phosphates	cement, sand, gravel	lakes, rivers
nitrates, sulfur, etc.	asbestos, gypsum, etc.	groundwater

ENERGY RESOURCES	Limited and nonrenewable energy sources	continuous-flow energy sources
	fossil fuels; coal, oil,	
	natural gas, oil shale	
	materials capable of	
	nuclear fission or fusion.	

direct utilization	indirect utilization
down-flow of precipitated water	photosynthesized energy (e.g.wood)
tidal response of water	waste products used as fuel
geothermal	
wind pressure	
climate energy	

(Source: adapted from Yeang, 1995)

2.1.1.1. Sustainable Energy

The term " sustainable energy" refers a number of practises, policies and technologies which seek to provide us with the energy use need at the least financial, environmental and social cost. Sustainable energy can be divided into two major groupings: energy efficiency and renewable energy. (DOE, 1996)

Energy Efficiency;

Energy efficiency encompasses the policies or practices which help to evaluate the full cost of energy choices and to get more output from a unit of energy. Energy efficiency includes:

- demand-side management: practices or policies undertaken by energy planners that encourage users to employ energy more efficiently

- integrated resource planning: practices that help evaluate the total costs and benefits of both supply-side (generation) and demand-side (end-use efficiency) options, in order to employ the mix which will provide energy at the least financial and environmental cost.

- generation, transmission and distribution efficiency: practices that improve the efficiency with which electricity is generated and delivered to end-users.

- end-use efficiency: practices that improve energy efficiency at the level of the final user. This category includes nearly all electricity using and thermal technologies, such as motors, lighting, heating, ventilating, air conditioning and appliances. It also includes technologies that help conserve or better use of energy.

Renewable Energy;

Renewable energy includes sources of power that are replaceable and often locally accessible. It includes;

- solar power: solar power includes active, passive and photovoltaic technologies and practices.

- biomass power: biomass refers to biological sources of energy like wood and agricultural waste. Biomass energy technologies may burn these fuels for heat or power generation or convert them to liquids (such as alcohol) or gas (such as methane) for later combustion.

- other technologies like wind power, hydro-electric generator and geothermal power

2.2. Energy In the World and In Turkey

Energy is the convertible currency of technology. Without energy the whole fabric of society as we know it would crumble; the effect of a 24 hour cut in electricity supplies to a city shows how totally dependent we are on that particularly useful from of energy.

Computers and lifts cease to function, hospitals sink to a care and maintenance level and the light go out. As population grow, need for more and more energy is exacerbated. Enhanced lifestyle and energy demand rise together and the wealthy industrialized economies which contain 25 percent of the world's population consume 75 percent of the world's energy supply.

Unfortunately this insatiable desire for more and more energy can be met by burning the world's reserves of fossil fuels or wood. Ninety percent of world energy is provided by burning one hydrocarbon fuel or another and the inescapable result is to add more carbon dioxide to the already burdened atmosphere and so increase global warming with its attendant destabilizing effect on the weather machine. The insulating effect of the carbon dioxide blanket is causing the world warm up.

Acid rain, largely arising from the combustion of fossil fuel for electricity generation is also contributing to the degradation of our environment. Dying forests, sterile lakes and corroded building are all now bearing witness to the folly of unrestrained combustion of our fuel reserves.(Dunderdale,1990)

Using energy is not an aim however it is a tool. There is a requirement for sufficient energy as a result of a certain services and there are many kinds of alternative technologies and energy sources to meet that need.

There is an essential relationship between development and energy consumption. Energy is the basic input of economic and social development. Technological innovations affect social and economic life in a way, cause increase in energy consumption.

2.2.1. Energy Use In the World

In resent years, the energy circumstances of the world have been changing in fundamental rather than superficial ways. For most of the countries, the era of low cost energy had ended. Energy growth based on existing energy-supply systems, end-use technologies and end-use patterns begin to create greater marginal costs than marginal benefits.

Few analysts expect that, the increase in energy use would be less cause for concern, if future energy demand could largely be met with sources whose environmental impacts were relatively benign. And it is also thought that the prices would not be much more than today's prices over the next two decades as the oil reserves of the Middle East are huge, gas resources are thought to be larger than once believed and the resources of relatively low-price coal are large.

However, "...the costs of fossil fuel use are rising faster than prices. The environment is absorbing more damage, and costs are also being imposed on future generations. Some of the costs are not yet known, especially those connected with the greenhouse effect. Nor do we understand the capacity of the environment to continue to absorb insults without damaging effect." (Schipper and Meyers, 1992; pp:331)

The advanced industrial nations are rich enough and technologically capable enough to master most of the problems. If they chose, these countries could tolerate low or even negative energy growth and they could afford to pay considerably higher energy prices to finance a transition to energy supply technologies that are less disruptive environmentally.

However, the situation is difficult in the less developed countries. They have to industrialize the way the rich did on cheap energy. But such a development requires higher energy costs - whether imposed by the world oil market or by a transition to cleaner costs as a necessary trade for meeting basic human needs and generating economic growth.

Today, the share of the world energy use in the less developed countries is modest, however their population size and growth rates and also their economic aspirations represent a huge potential for future energy growth. If this demand is met with fossil fuels, it will generate huge additions to the atmospheric burdens of carbon dioxide and other pollutants of regional and global concern.

The less developed countries are much more affected by global environmental changes; they have smaller food reserves, more marginal diets, poorer health and more limited resources of capital and infrastructure. Global climate change brought on by carbon dioxide and other greenhouse gases could have devastating consequences for them, such as; more dry season heat and drought, more wet season floods and storm victims, more famine and disease.

On the other side, although having greater capacities to adopt and adjust, the industrial countries will also suffer from the direct effects of climate change as the world is too interconnected by trade, investment, finance, resource interests, politics, porous borders,... (Schipper, and Meyers, 1992)

In developed countries, the current understanding of market economy forces people to consume more and more. That fact brings up a life style that consuming energy sources without pity. Cities, buildings and all equipment aer shaped according to this consuming life style.

The solution of that problem requires a fundamental change in all consumption habits and production structures. In short, that consuming life style should be changed.

That kind of change could be difficult, but possible. However, such a change in the production area could be the end of economic vitality. In that case, the short-term solutions are implemented without giving any harm to the market conditions. At the same time, the energy crisis is evaluated as a fashion and the fashionable products are distributed into the market as a new profit. Shortly, the market economy continues its vitality by using energy crisis as an advertisement equipment.

In undeveloped countries, the situation is different. Energy is limited like other sources and there is a regional unbalanced use of energy. In those countries, at the production level, foreign dependent policies are preferred.

One of the main consideration in energy-environment-development predicament is the population. The population cannot be frozen. Without a global effort at population limitation, the population of the planet could soar to 14 billion or more by the year 2100. When today's circumstances is compared with future; "supplying 5.3 billion people in 1990 with an average energy use rate of 2.5 kilowatts per person - a total of 13.2 terrawatts - was placing severe strains on the planet's technological, managerial and environmental resources and crucial human needs were going unmet. Yet for every billion people added to the world's population at the same level of energy use per person, new energy supplies capable of sustaining an additional continuous drain of 2.5 terrawatts must be mobilized, paid for and their environmental impacts somehow absorbed." (Schipper and Meyers, 1992; pp:36)

2.2.1.1. Human Activity, Structural Change, Lifestyle

As population grows and economies expand, the level of energy using activities will increase. In a time period, the importance of different types of activities change according to the technology, lifestyles and consumption habits, certain activities can decline in importance in some regions or increase in others. However, it is absolute that the increasing activity will determine the future energy use.

Besides activity and population growth, the properties of population have an additional impact on world energy consumption. (Schipper and Meyers, 1992)

The aging of the population with respect to continuing decline in birth rates and rising life expectancy will affect energy use in all sectors. Such kind of change will shape the type of goods that are produced and the services that are provided. In addition, it will affect where and how people live. The future elderly may be more likely to retire in warmer locations where the need for heating is less. The elderly tend to spend more time at home and maintain higher levels of indoor comfort than younger people. The higher life expectancy of women relative to men and changing family structures may lead to further increase in the share of single-person households, which would increase energy use per capita.

When we consider "lifestyle", a key issue is whether people conduct activities at home or travel away from home to accomplish them. However, the energy used in traveling is almost always much higher than the energy consumption at home, even if travel uses modes with low energy intensity. For example, including the energy consumption in space conditioning, the process of preparing a meal at home requires less energy than driving to eat out or pick up already prepared food.

On the other hand, the home is increasingly becoming a place of work. This trend will be fostered by the introduction of new information technology. This will increase energy use in the home for office equipment and for heating and cooling but will reduce commuting.

"While providing a comfortable work environment for 100 people in an office requires much less energy than if those 100 people each worked at home, the relatively high energy intensity of commuting usually results in much greater overall energy use." (Schipper and Meyers, 1992)

Another issue is that how people will use their leisure time, while the aging of the population and innovations in home electronics could lead to a higher share of leisure time at home, out-of-home leisure activities would increase energy demand for transportation.

In the less developed countries, the urbanization, income distribution and the mass media will affect the lifestyle, in other words consumption patterns as well as demand for energy using goods such as appliances and motor vehicles.

2.2.2. World Energy Consumption Since 1970

World primary energy use grew by over one third between 1970 and 1990. The average increase over these two decades, which hides periods of growth and stagnation is 2.3 % per year. In the 1974 - 1975 and 1980 - 1983, the world energy use was steady because of higher prices and slowing of economic activity. However, after each period of stagnation, when the real prices declined, the growth continued. Between 1983 and 1989 the growth was rather steady (averaging 2.8 % per year) and in 1990, there was a little increase. (Schipper and Meyers, 1992)

Most of the increase in energy use has been in the less developed countries. Their share of the total energy use grew from 20 % to 31 % over two decades. The share of the OECD countries fell from 60 % to 48 % and the increase in the share of Formal East Bloc was only 1 % (from 20 % to 21 %) because of being insulated from the effect of higher oil prices. The average annual growth in energy use between 1970 and 1990 was 1.3 % in the OECD countries, 2.4 % in the Former East Bloc and 4.5 % in the less developed countries.

There are some reasons for these changes in energy use; first of all, the population grew faster in the less developed countries. Further, in the process of economic development, in the less developed countries, the use of commercial energy tent to grow faster than GDP due to development of manufacturing and basic infrastructure. On the other side, structural change in economic activity and maturation of physical infrastructure has contributed to decline in the energy/GDP ratio. In addition to these changes, in the concept of energy efficiency, most less developed country energy users have had far less information, technology and capital to improve energy efficiency than OECD users.

Figure 2.1 shows the evolution of world energy use by type. The decline in the share of oil is seen in the graphic (from 41 % to 36 %), but total oil consumption in 1990 was over one-third higher than in 1970. The share of natural gas has grown from 17 % to 20 % and coal has fallen from 28 % to 25 %. Nuclear energy has seen the most rapid growth, the share is 5 % of total energy use in 1990.

When the shares of different sectors in total consumption is considered, it can be seen that the decline in energy consumption is only in manufactoring sector (from 36 % of the total to 27 %). Passenger travel increased from 19 % to 22 %, while the share of freight transport rose from 7 % to 10 %. The residential and service sector share grew slightly which is 1 %. (Fig. 2.2)

Energy use for transportation has grown rapidly as a consequence. In 1988, around 64 % of total world transportation was accounted for by the OECD countries. The shares of the Former East Bloc and the less developed countries were only 14 % and 23 %.

The total reserves of the world's fossil energy sources are approximately 900 million to petroleum equivalent. The reserved coal sources are 75 percent of the total value and the rest of the reserves are petroleum and natural gas.

A great amount of coal reserves exist in eastern countries and petroleum reserves are mostly in the Middle East countries.

52 percent of the commercial energy consumption take place in developed OECD countries. And USA, where the population is 5 % of the world's population, consumes ¼ of the total demand of energy.

With this rate of consumption and production of existing sources, petroleum reserves can serve 40 years, natural gas can serve 60 years and coal reserves 240 years.

Energy demand estimations show that, in 2010's, the average annual increase of primary energy demand will be in the rate of 2 %. Among fossil fuels, natural gas has the greatest demand value (annual increase of the demand will be 2,5 %). In spite of being environmental hazardous, the demand for coal will increase at a rate of 1.8 % in the near future and also the increase in demand for electricity will be 2,8 %. (Sahin, 1994)

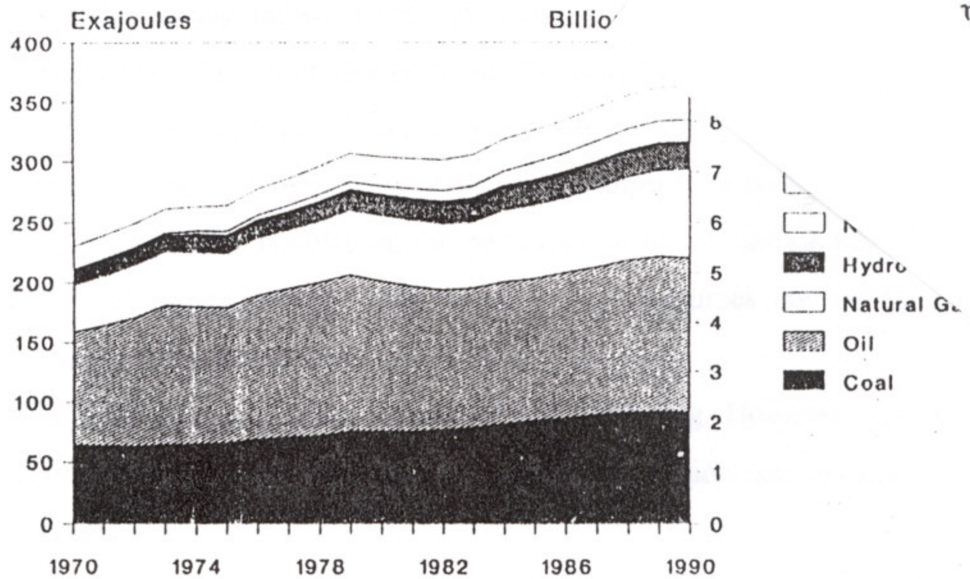

Fig. 2.1. The evolution of world energy use by type (Schipper and Meyers, 1992; pp:74)

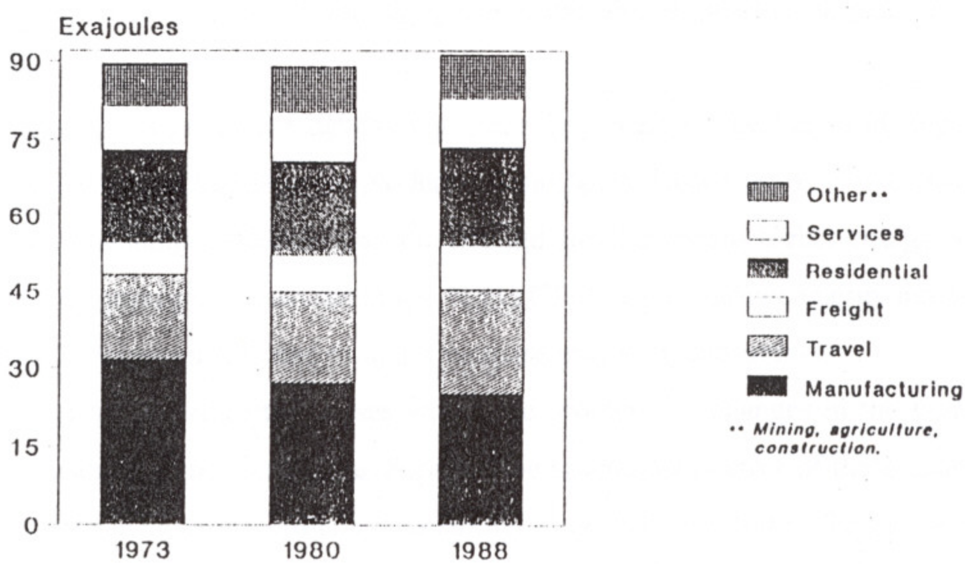

Fig. 2.2. The shares of different sectors in total consumption (Schipper and Meyers, 1992; pp:79)

2.2.3. Energy Efficiency: Steps Toward A Sustainable Future

"A sustainable supply and use of energy is one that does not reduce, over time, the quantity and quality of goods and services that the planet's environmental, economic and social system are able to provide." (Schipper and Meyers, 1992; pp:328)

The three most basic determinants of the global impacts of civilization's energy use are the size of the human population, the per capita levels of various activities and the sophistication of the technology with which energy resources are obtained and transformed to support those activities.

The efficiency of energy using technologies is improving. However, the rate of this improvement cannot balance the growth in global population and increase in per capita activity levels.

Between 1973 and the mid 1980s, a stimulating improvement in energy efficiency occurred because of higher energy prices and concern over the security of oil supplies. "Real energy prices today are somewhat higher than they were in 1970, but their current impact on OECD economies has been largely mitigated by the improvements in energy efficiency." (Schipper and Meyers, 1992; pp:329) In most sectors, especially in manufacturing, where technological progress is relatively independent of change in energy prices, OECD intensities will likely continue to decline. In addition, historic and current energy efficiency policies and programs have also a positive impact on the improvements.

On the other side, in the developing countries, energy efficiency will improve with stock turn-over and use of more modern technologies. However, as it is explained before, they have to industrialize the way the rich did and that means higher energy costs and their growing population, increase in per capita GDP, rise in various energy intensive activities, and urbanization will lead to major increase in energy consumption.

Emission of CO_2 and other gases will cause problematic changes in the world's climate is increasingly gaining credence. Some of the crucial parameters of these changes are uncertain and the costs are difficult to quantify. However, restraint in the increase of fossil fuel use or an absolute decline has been identified in every study as a key element in dealing with the threat of climatic change. The idea that improving energy efficiency should be an important part of the energy strategy of developing countries is being

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The three most basic determinants of the global impacts of civilization's energy use are the size of the human population, the per capita levels of various activities and the sophistication of the technology with which energy resources are obtained and transformed to support those activities.

The efficiency of energy using technologies is improving. However, the rate of this improvement cannot balance the growth in global population and increase in per capita activity levels.

Between 1973 and the mid 1980s, a stimulating improvement in energy efficiency occurred because of higher energy prices and concern over the security of oil supplies. "Real energy prices today are somewhat higher than they were in 1970, but their current impact on OECD economies has been largely mitigated by the improvements in energy efficiency." (Schipper and Meyers, 1992; pp:329) In most sectors, especially in manufacturing, where technological progress is relatively independent of change in energy prices, OECD intensities will likely continue to decline. In addition, historic and current energy efficiency policies and programs have also a positive impact on the improvements.

On the other side, in the developing countries, energy efficiency will improve with stock turn-over and use of more modern technologies. However, as it is explained before, they have to industrialize the way the rich did and that means higher energy costs and their growing population, increase in per capita GDP, rise in various energy intensive activities, and urbanization will lead to major increase in energy consumption.

Emission of CO_2 and other gases will cause problematic changes in the world's climate is increasingly gaining credence. Some of the crucial parameters of these changes are uncertain and the costs are difficult to quantify. However, restraint in the increase of fossil fuel use or an absolute decline has been identified in every study as a key element in dealing with the threat of climatic change. The idea that improving energy efficiency should be an important part of the energy strategy of developing countries is being increasingly accepted by public officials, multilateral development banks and bilateral donoes. Implementation of energy efficiency strategies is well behind the recognition of their importance, but there are signs of progress.

Some key steps for stimulating more careful use of energy. (Schipper and Meyers, 1992)

- Rationalization in energy pricing and internalization in environmental externalities;

Without addressing reform of energy prices, promoting energy efficiency is difficult. Environmental costs should be internalized into prices through both regulation and taxation. Governments should begin with those costs that are most clear and agreed upon. Uncertainty about costs is inevitable, but is not a reason to putt off some degree of internalization.

- Improvement in present energy using capital; The key areas to address are building retrofit and industry. Utility programs can do much to encourage electricity saving measures.
- Implementation of energy efficiency standards or agreements for new products and buildings; Such kind of standards and agreements can give the market a societal perspective as well as provide clear signals to manufacturers and builders.
- Encourage higher energy efficiency in new products and buildings.
- Promote international cooperation and technology transfer; Transfer of technologies and policy approaches among developing countries should be encouraged by strengthening communications and institutional linkages.
- Adjust policies that encourage energy intensive activities; It is necessary to adjust policies that artificially stimulate or subsidize travel, automobile use, large-single family dwellings, urban sprawl and energy intensive industries. Discouraging energy intensive activities or encouraging less energy intensive ones can have larger impacts on energy use than many energy efficiency policies. Land use planning can also play a major role in reducing travel distances and reliance on the automobile.
- Promote population restraint worldwide;

"People, not machines, make the decisions that affect energy use. Insight into the human dimension of energy use is key to better understanding future energy trends and how to act effectively to manage them." (Schipper and Meyers, 1992; pp:350) Energy efficiency problems are closely connected to broader issues of economic and social development. "How the built environment, transportation and communication infrastructures and agriculture and industrial sector of economies evolve means as much, if not more, to energy demand and energy efficiency as the efficiencies of individual technologies." (Schipper and Meyers, 1992; pp:350) This is especially important in the developing countires, where much of the future energy using infrastructure is still to be built.

2.2.4. Energy Use In Turkey

In Turkey, the situation was that, the sources of the country had not been efficiently used although the coal and water sources were sufficient to meet the energy requirement. In spite of evaluating its own resources, importing petroleum was accepted as an energy policy.

Being in the development process, in electricity generetion, industry and space heating, consuming more petroleum has began. Giving weight on land transportation and increasing car ownership resulted as more requirement for petroleum. And in 1970's, with national subvention, the petroleum prices were kept low and that caused increase in consumption, too.

During the same period, when the world wide increase in petroleum prices joined with the unfair national energy policies, the energy crisis was felt enormously in Turkey. In that tremendous crisis, the taken decisions as a solution were electricity restriction and importing electricity. In addition, energy scarcity brought energy saving. However, high income groups continued to consume while middle and low income groups had to do energy saving because of high prices and scarcity.

In due time, two regulations about energy saving were published. The aims of those regulations were, to protect air pollution in big cities and to provide fuel saving in heating systems. So, according to those regulations, some precautions had to be taken in both existing and new buildings. Those precautions were, to limit the heat diffusion coefficient of external walls, to reduce heat loss, to increase operational efficiency and to improve the quality of personnel who works in the heating system. (Birkan,1980)

However, those regulations were published by Ministry of Energy and Natural Resources for that reason neither public sector nor municipalities took them into consideration.

In the past, more than half of the population was living in the rural areas. In those areas, the location of the settlements, the arrangement and the form of buildings were affected by climatic conditions. The form of the buildings was also influenced by the restricted energy sources.

Today, with the increasing migration from rural areas to the cities, the "gecekondu" areas grow rapidly. In those gecekondu areas, people construct their own houses, however that built up sites are not convenient to the natural environment as in the rural areas. Because the migrants come across with different climatic conditions and the area where they have to settle have unsuitable physical conditions. And the construction materials that thay found are the ones which they are not used to use them and also those material have low quality in insulation and in heat storage capacity. Fortunately, by considering the orientation, by having few and small openings and having small living areas and being crowded at the house, they can solve their heating and insulation problems. Electricity is used only for lighting and coal and wood for heating. However, despite all disadvantages, those kind of areas are more convenient to the natural environment than the planned areas.

In the planned areas where high and middle income groups live, energy consumption is higher. Because in those areas the orientation is out of consideration, the buildings are not well insulated and are large in size.

Houses are produced by privately and then sold in the market. In fact, the number, quality and the size of the houses have no relations with the requirements. The consumer has to buy what he finds, not what he needs or wants. And in the market, there is no public control. Municipalities only control whether the building has plans or not or whether the plan is appropriate to the regulations and building codes.

Besides not having beneficial orientation and receiving sufficient daylighting, the quality of construction and heating systems are also low. In that circumstances, energy efficiency can not be provided in the housing sector.

There were approximately 4 million old buildings which were built before 1984. And while constructing those buildings some energy saving precautions were taken.

However, 2 million TEP of energy saving potential can be achieved with roof insulation, double glass and reducing leakage.

Buildings which were constructed after 1984 has been accepted as appropriate to the regulations of Ministry of Public Works and Settlements (16 January 1985). However, according to these regulations, seasonal heat loss from windows and external walls, in different cities being at the same climatic regions differs from each other. For that reson, while determining average acceptable heat loss of buildings, degree days should be taken into consideration in order to remove the difference between the regions. If present regulations were prepared according to the European standards, the reduction in energy consumption would be higher. (Keskin, 1994)

Besides, insulation improvements, with the saving potential of operational improvement in using stove and central heating and efficient electric apparatus and lighting systems, total energy saving potential of the country reaches the amount of 4,7 million TEP. And this amount is equal to the 30 % of the total energy consumption in housing sector in 1991 which is 16,2 million TEP.

2.2.4.1. Energy Production and Consumption In Turkey

The energy reserves of Turkey can be neglected among world's reserves because of their quantity and quality.

Hydraulic power and lignite reserves are potential energies to use. But the geographical location of lignite reserves are scattered, low in quality, high in cost and environmentally hazardous. At the same time, the reliability of hydraulic reserves are low as they are dependent on precipitation and they require higher costs while improving. However, today, lignite and hydraulic power meet 75 percent of total commercial energy production.

Lacking to meet the primary energy demand with domestic production, the amount of imported energy has increased in the coarse of time. The amount of imported energy is 46 %.

In the past 40 years, the average annual increase in energy consumption has been 5,3 %. In 1960, 65 % of energy was consumed in housing, 15 % in transportation and 10 % in industry. During the following periods, while the consumption share of industry and power stations had been increasing, the share of housing sector had decreased. (Şahin, 1994)

In 1990, in the concept of energy consumption, housing sector has again taken the first place but with a low rate as 28 %. The share of industry sector has been 20 % and transportation sector's share has been 17 %. (Table 2.2.)

In the following tables (Table 2.3) , the shares of consumption of primary energy sources are shown. There is a decline in the share of coal (from 15.4 % to 10.9) while the share of petroleum is still high. Petroleum has the highest share in the total energy consumption which is 46.6 % in 1993. The share of nuclear energy has grown from 0.1 % to 7.6 % and lignite from 9.2 % to 16.9 %. The hydraulic share grew from 1.4 % to 4.8 %.

All these energy consumption values show that energy is used inefficiently and densely in Turkey.

2.2.5. Energy Status of Izmir

Today, in Izmir, a large portion of the energy utilized is derived from fossil burning. Except electricity; lignite, kerosene, motorin, fuel-oil and LPG are used in space heating in Izmir. Among these, especially lignite and fuel-oil affect the air quality of Izmir adversely as local lignites have low quality in use such as having low heating value and having high ash content and high sulphur bearing and fuel oils as being undesulfurized petroleum product.

"In 1995, approximately 1.200.000 tons of lignite coal has been burned within the metropolitan area. Of this two thirds have been consumed by the industry and one third by the households. About 100.000 tons of the household lignite combustion takes place in central heating systems." (Towards an Agenda 21 in Izmir, 1996)

According to data taken from DIE, the fuel consumption in Izmir between 1980-1989 is determined by corresponding the urban population with fuel consumption. The annual fuel consumptions are given in the table 2.4.

During year 1993, 115.673 tons of petroleum,23.535 tons of kerosene, 151.341 tons of LPG, 306.579 tons of diesel fuel and 153.988 tons of gasoline are burned.

Table 2.2. The shares of sectoral energy consumption

YEARS	HOUSING	INDUSTRY	TRANSP.	AGRICULT.	OTHER	FINAL CON.	TRANSF.	TOTAL
1970	45.8	21.9	17.0	2.7	1.8	89.2	10.8	100
1971	43.7	21.8	17.1	3.3	1.9	87.7	12.3	100
1972	43.6	21.5	17.4	3.2	1.7	87.3	12.7	100
1973	41.5	21.2	17.6	3.0	1.8	85.1	14.9	100
1974	41.8	21.4	18.2	2.8	1.3	85.5	14.5	100
1975	40.3	23.0	18.8	2.5	1.9	86.5	13.5	100
1976	40.5	22.9	19.4	2.6	2.0	87.3	12.7	100
1977	38.1	24.8	19.2	2.7	2.1	87.0	13.0	100
1978	37.9	24.5	18.9	2.9	2.2	86.4	13.6	100
1979	39.0	25.2	17..1	2.6	2.0	85.8	14.2	100
1980	40.0	24.9	16.4	3.0	1.7	86.0	14.0	100
1981	39.6	25.0	16.6	3.1	1.8	86.1	13.9	100
1982	39.4	24.8	16.5	3.5	1.8	86.0	14.0	100
1983	38.7	23.9	16.5	3.6	2.0	84.7	15.3	100
1984	37.1	25.2	16.4	3.9	2.1	84.8	15.2	100
1985	36.3	25.0	15.8	3.8	2.1	83.0	17.0	100
1986	34.7	24.1	16.2	4.0	2.4	81.3	18.7	100
1987	33.7	25.8	16.3	3.9	2.6	82.4	17.6	100
1988	33.5	26..4	17.1	3.8	2.1	82.8	17.2	100
1989	31.8	26.2	16.2	3.6	1.7	79.6	20.4	100
1990	29.4	27.3	16.4	3.7	1.9	78.7	21.3	100
1991	29.8	27.8	15.2	3.6	2.2	78.6	21.4	100
1992	29.9	27.1	15.0	3.5	2.5	78.0	22.0	100
1993	28.7	27.1	17.1	4.0	2.9	79.7	20.3	100

(Source: Türkiye 6. Enerji Kongresi, Enerji İstatistikleri, İzmir, 1994, pp: 190)

Table 2.3. The shares of primary energy sources in total energy consumption

YEARS	COAL	LIGNITE	ASPHALTIT	PETROL	N.GAS	HIDROLIC	ELECTRIC	SUN	WOOD	AG. WASTE
1970	15.4	9.2	0.1	42.2		1.4			20.4	11.3
1971	14.2	9.5	0.0	46.2		1.1			18.2	10.7
1972	12.8	9.9	0.3	47.9		1.2			18.1	9.8
1973	11.5	9.4	0.5	51.5		0.9			17.0	9.2
1974	12.4	9.6	0.7	50.0		1.1			17.1	9.1
1975	11.0	9.8	0.7	51.8		1.9			16.0	8.8
1976	10.3	10.0	0.6	53.1		2.4			14.9	8.5
1977	9.6	9.6	0.6	55.8	0.1	2.3			13.9	8.0
1978	8.9	10.7	0.4	54.9	0.1	2.5			14.1	8.3
1979	9.7	11.6	0.3	50.7	0.1	2.9			15.2	9.2
1980	8.9	12.4	0.8	50.4	0.1	3.1			14.8	9.3
1981	8.6	13.1	0.8	49.5	0.0	3.4			15.0	9.1
1982	8.9	13.5	1.1	49.4	0.1	4.6			14.7	8.5
1983	9.0	14.9	0.9	49.3	0.0	2.7			14.4	8.2
1984	9.5	17.2	0.3	47.9	0.1	3.1	0.1		13.9	7.4
1985	9.8	20.3	0.6	46.3	0.2	2.6	0.0		13.3	6.5
1986	9.4	21.0	0.6	46.5	1.0	2.4	0.1		12.5	6.2
1987	9.8	19.7	0.6	47.9	1.4	3.4	0.1		11.4	5.5
1988	11.0	16.6	0.6	47.4	2.3	5.2	0.1		11.1	5.5
1989	9.4	20.2	0.3	45.3	5.7	3.1	0.1		10.6	5.1
1990	12.2	18.3	0.2	44.8	5.8	3.7	0.1		10.1	4.8
1991	12.6	19.4	0.1	42.7	7.0	3.6	0.1		9.9	4.6
1992	11.9	18.8	0.1	43.6	7.4	4.0	0.1	0.1	9.5	4.4
1993	10.9	16.9	0.1	46.6	7.6	4.8	0.1	0.1	8.9	4.1

(Source: Türkiye 6. Enerji Kongresi, Enerji İstatistikleri, İzmir, 1994, pp: 112)

The above paragraphs, including the level of energy consumption, show that like many of cities, Izmir is dependent on non-renewable energy resources. On the other hand, the Metropolitan Area of Izmir has a considerable potential of renewable energy resources such as wind power, solar energy, etc. But the use of these resources does not go beyond small scale utilizations. However, being a renewable resource, geothermal energy become popular day by day in Izmir.

The richest geothermal sources known in Turkey locate within the Seferihisar-Narlidere-Balçova triangle. It is estimated that the thermal sources in Balçova and Narlidere have a potential enough to heat about 100 thousand residents. There exists a potential for 9 thousand residents in Çesme. In the case that optimist results rise in the capacity in Çigli and Yamanlar, also Çigli, Bostanli and Karsiyaka would utilize the geothermal energy in the future. (MMO, 1996)

Table 2.4. Annual Energy Consumption in Izmir

	Lignite	Fuel oil	Kerosene	LPG	Diesel oil	Benzin
1980	158.245	86.091	21.413	37.566	59.975	35.419
1981	144.261	105.503	16.695	40.935	61.821	36.458
1982	157.810	94.560	18.068	43.197	70.714	36.979
1983	167.412	62.924	14.626	48.343	66.744	29.912
1984	158.925	85.873	17.252	51.684	107.648	53.194
1985	210.058	98.683	17.390	61.489	138.190	73.148
1986	178.620	88.550	17.609	70.255	175.809	82.684
1987	227.592	102.715	23.630	85.536	197.494	100.544
1988	225.368	108.300	24.835	110.285	207.281	105.819
1989	224.438	114.499	20.359	131.332	216.945	114.302
1990	230.221	-	-	-	-	-
1991	242.456	-	-	-	-	-
1992	252.351	-	-	-	-	-
1993	267.551	115.673	23.535	151.341	306.579	153.988

(Source: Müezzinoğlu, 1995; pp:168)

2.3. Summary

The ecosystem -the spatial unitness formed by the interactions of both the biological and physical environment- have functions including the transformation, circulation and accumulation of matter and the flow of energy through natural processes. And in this process, the formation of all mineral deposits, whether fuels, metals or others have taken time and we, people are consuming them faster than they are being naturally regenerated. Therefore, the use of earth's ecosystems, energy and material resources requires a conservation conscious design approach. The built environment must be designed to minimize consumption of these resources and to minimize wastes, to optimize use, to be more dependent on the renewable and recoverable, to conserve the resource and to provide the potential and flexibility for its future use.

In addition, the energy consumption trends in the world point out the necessity of energy conservation. The scale of human energy use today is considerably larger than in 1970. As a result of higher energy use, the environmental costs are being increasingly perceived at local, regional and global levels. In the future, with the growing number of people and expanding volume of activities, there appears to be a significant potential that impacts associated with energy supply and use will seriously harm human and ecological well-being.

On the other hand, while Turkey -having not enough and efficient energy production and contrarily experiencing higher amounts of consumption- suffering on the cost side from paying too much for energy, the country is also paying in the forms of excessive environmental impacts. The city of Izmir has some potential of renewable energy but still depending on non-renewable energy. Moreover, currently, the residents of the city suffer from cuts in electricity supply. However the city requires having local energy policies including energy efficiency and conservation both at production and consumption level.

Key words; **ecosystem, conservation conscious design, non-renewable energy, renewable energy, sustainable energy and energy efficiency, energy use.**

Chapter 3

ENERGY CONSUMPTION AND ENERGY CONSCIOUS URBAN DESIGN

This chapter includes the concept of urban energy consumption, and the goal of energy conscious urban design.

3.1. The Need For Energy Conscious Urban Design

Does energy really matter in urban design? Or do we need energy conscious urban design? The effects of a dramatic increase in energy prices, during the oil crisis, in the early 1970's, were making themselves felt in many ways. So, the answer to this question seemed obvious. When the crisis was over, the prospects for energy conscious urban development have receded and the incentive use of resources efficiently removed. It was thought that the crisis was not sustained and that no lasting energy constraints have actually been experienced. (Owens, 1987)

However, in today's condition, acid rains, nuclear accidents, environmental hazards, global warming, pollution, ozone hole, etc. constantly reminds us of the non-monetary costs of energy consumption. In addition, if present consumption rates continue, petroleum reserves will run out some time in the 21st century. This means that, long before the reserves are entirely depleted, the prices of fossil fuels will probably rise to levels at which few can afford to buy them. (Lyle, 1994)

" It is clear that, energy consumption in the developing world has grown tremendously over the past years. Although many factors are cited as causes for the increase in consumption, it is generally agreed that urbanisation is the prime cause." (Emmanuel, 1995; pp:59) Then, the pattern of energy consumption in developing countries suggests that urban design related decisions have a significant impact on the consumption of energy. At that point, the energy conscious urban design comes into existence.

3.2. The Goal Of Energy Conscious Urban Design

Considering the significance of energy in urban development, the goal of energy conscious design is to reduce urban energy consumption and the problems that this consumption causes while population continues to increase.

Transportation and space conditioning are the two factors which must influence energy demand at the urban scale. So, any progress toward a more sustainable future requires large per capita reductions in the amount of energy required for space conditioning and transportation while at the same time providing the comfort level.

The range of options to save energy in any size of the urban scale is very wide; land use arrangements to cut transportation costs, site and community design factors, building design that emphasis conservation, improved vehicle efficiencies, the use of other renewable energy sources and technologies.

3.3. Space Conditioning and Energy Efficient Urban Design

Energy conscious design requires careful analysis of the natural benefits and problems of the site. " One of the fundamental tenet of energy conscious planning is that the climate can be modified using the natural features of the site, thus reducing or in some cases eliminating the need for artificial conditioning. The site is a complex interaction of many factors; orientation, slope, elevation, surface materials, topography, the velocities and direction of prevailing winds, temperature patterns, humidity, precipitation, vegetation, the presence or absence of water, the seasonal availability of sunlight and especially in urban areas, the influence of other buildings.

" The primary focus of the site analysis is to ensure that the land is used efficiently and that the building fit appropriately into the service infrastructure. The way in which a building is sitting, however relative to other buildings or to natural features of the landscape, can be a major determined of its energy efficiency." (Mackenzie, 1991; pp:38)

Designing for energy efficiency involves an integrated approach. These approaches are; to minimize the impact of the external environment and to use directly the effect of the sun and natural ventilation to minimize the need for heating and cooling systems.

In a climate, where protection is needed from cold and wind, the designer would consider maximizing solar exposure, using extensive paved and masonry surfaces to increase the absorption of radiation and using existing or creating new windbreaks in the form of trees or walls. However, in a hot climate, to make the microclimate cooler, the options would include positioning buildings for maximum ventilation by prevailing winds, using shade trees, vines and planted ground covers, pruning lower growth for increased air circulation and allowing for evaporative cooling from sprinklers, pools, ponds or lakes. In cities, the positioning of surrounding buildings is important as this can determine the flow of wind currents and therefore the temperature. (Anderson,1990)

Urban form, land use arrangements and density also affect the energy efficiency. By planning residential buildings in area which can benefit from solar gain, while storage buildings or parking areas are located in areas receiving little sun is an energy efficient arrangement.

3.4. Transportation and Energy Efficient Urban Design

Transportation is a significant factor in energy consumption. It can be examined in such ways, in the context of energy efficiency; One is that the use of petroleum; a great amount of this non-renewable energy is used in transportation. This situation causes some urban problems. We need using renewable energies for reducing the consumption.

Another fact is that, an increase in the fuel prices affect the energy consumption. But in the short to medium terms it seems that energy does not matter very much. Marginal adjustments of trip patterns, especially social trips are associated with only small changes in petrol consumption. In the medium term, people try to revert to their former trip patterns and will resort to other methods without loss of mobility. (Owens,1987)

Increasing the importance of transport costs in the trip decision, the result is the closer association between different activities and the reduction of total amount of travel.

At that point, the effect of urban form, land use and density in energy consumption come into existence.

The availability of energy and hence mobility has been an important premise for the changes from the ancient, pedestrian cities to the present, sprawling automobile cities.

It does not seem unreasonable to assume that developmental patterns facilitated by a high mobility, actually require more transportation than developmental patterns more similar to those of ancient, low mobility centre. In accordance with this, that compact and concentrated development could save considerable amount of energy. (Naess, 1995)

Some researchers suggest that any correlation between urban variables and energy use in transport can disappear when controlling for social and economic factors like income, car ownership, vehicle efficiency, household structure, etc. (Naess,1995) However, these socio-economic factors and urban form should considered together for consumption of energy.

Besides the compactness and mixing land use, a high urban density has an energy saving effect. A high density implies shorter average distances between residences, workplaces and service functions and also shorter walking distances to public transport stops.

On the other hand, in the context of energy consumption, the transport modes have also importance. In determining the appropriate mode, scale is the most significant factor.

The smallest scale of transportation is the scale of a small community or neighborhood which can cover on foot or by bicycle. At these scales, biomass is the appropriate energy source. At the next level of scale, which might be that of a large town or small city, hydrogen, electrical power and biofuels can replace some portion of the petroleum that fuels car. A combination of mass transit and small, highly efficient vehicles will be needed for urban use. Charged by photovoltaic cells, such carts could be an appropriate mode for individual movement. At the scale of larger cities and regions, mass transit systems using trains and buses are far more suitable than individual modes, which occupy too much energy. Intercity mass transit uses less than 1/10 as much fuel energy per passenger mile as automobiles and intracity transit uses less than one-sixth as much. (Lyle, 1994)

3.5. Summary

Although the energy crisis is still with us and a substantial body of knowledge and studies related to structural energy efficiency was consequently developed, very little was actually implemented. Since energy prices will continue to be cheap, designers should concentrate on areas other than energy efficiency. However, it should be remembered that the rationale for energy efficient design is not so much the need to conserve energy per se, rather reduction in energy consumption for the ecological health of the whole planet. The world with its teeming energy hungry millions will continue to consume more energy and the ecological consequences of such high consumption are beyond the collective wisdom. Energy efficient urban design guidelines should perhaps guided by this concern for ecological health of the earth and just by quantitative gains in energy efficiency.

Therefore, the goal of energy conscious design is to reduce energy consumption and the problems that this consumption causes. Transportation and space conditioning are the two factors which influence urban energy demand. So, any progress toward a more sustainable future will require large per capita reductions in the amount of energy required for space conditioning and transportation.

Key words: **urban energy consumption, energy conscious urban design, transportation,** and **space conditioning.**

Chapter 4

CLIMATE: A FUNDAMENTAL CONSIDERATION IN REDUCING ENERGY CONSUMPTION

If a purpose of planning is to reduce energy consumption and to save energy, "climate" is one of the fundamental consideration.

The most obvious facts of climate are; the annual, seasonal and daily ranges of temperature (these variations happen according to the conditions of latitude, altitude, exposure, vegetation and proximity to weather modifiers as water bodies, ice masses or desert); the amount of precipitation the form of dew, rainfall, frost or snow; humidity; the duration of sunlight in hours per day; the direction and velocity of the winds; the geologic structure with soil types and depths; the existing vegetation and wild-life; etc. All of these physical elements work together as an ecological system. (Simonds, 1993)

There are four climatic regions in the earth; the cold, the cool temperate, the warm-humid and the hot-dry. Each of these climatic regions have their distinctive characteristics. It is hard to define the boundaries of the regions or the zones precisely however there are considerable variations and these influences the site development. Nevertheless, the designer is particularly interested in the microclimate. Microclimate is the detailed modification of the general climate.

4.1. Microclimate

The properties of microclimate elements which influence the energy consumption are given at below subtitles.

4.1.1. Effects Of Topography In Microclimate

The slope, slope direction of the ground has an climatic effect. The orientation of the ground with respect to the sun, and the way in which the topography affects air movement, are the principal influences. (Fig. 4.1)

4.1.1.1. Sun Angle

The angle formed between sunlight approaching the earth's surface and the surface itself is called the sun angle. Maximum radiation is received by a surface that is perpendicular to the direction of the sun. Smaller angles have weaker solar intensities.

The sun angle for any latitude and date can be computed in three basic steps. First, the declination of the sun must be known. This is the latitude where the sun angle is 90° on a given date. Then, the zenith angle must be determined.

Zenith angle is the angle formed between a vertical line and the position of the sun in the sky. (Fig. 4.2) The last step is the subtraction of zenith angle from 90° . This gives us the sun angle. (Marsh, 1991)

For example:

Location	: 50 degrees north latitude (given)
Date	: June 15 (given)
Declination of the sun	: 23 degrees
Zenith angle, ZA	: 27 degrees
Sun angle, SA	: 90 degrees - ZA
Sun angle, SA	: 63 degrees

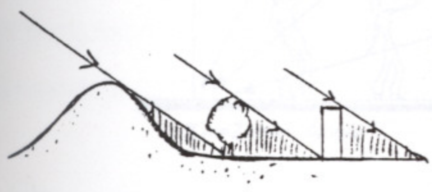
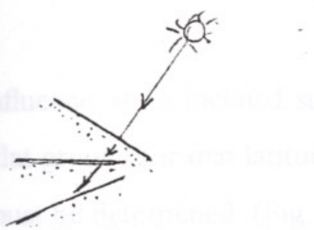
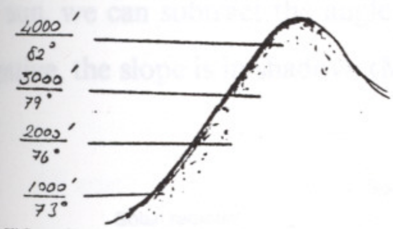
<table>
<tr><td></td><td>SLOPES WITH SOUTHERLY EXPOSURE RECEIVE THE MOST HOURS & GREATEST INTENSITY OF SOLAR HEAT EACH DAY</td></tr>
<tr><td></td><td>TOPOGRAPHICAL FORMS, TALL BUILDING, TREES OR OTHER OBJECTS MAY REDUCE THE TOTAL HOURS OF DAYLIGHT. DEPENDING UPON THE CLIMATIC SITUATION, FULL SUN MAY OR MAY NOT BE DESIRABLE</td></tr>
<tr><td></td><td>THE MORE PERPENDICULAR A SLOPE TO THE RAYS OF THE SUN, THE WARMER THE SURFACE TEMPERATURE</td></tr>
<tr><td>
</td><td>TEMPERATURES VARY WITH ELEVATION BY ABOUT 3°F FOR EACH 1000 FEET IN THE DAYTIME. NIGHTTIME DIFFERENTIALS ARE GREATER</td></tr>
<tr><td></td><td>THE GLARE FROM WATER, SAND OR OTHER REFLECTIVE SURFACES CAN INCREASE HEAT LOADS.</td></tr>
</table>

Fig. 4.1. Topography affects the microclimate (Simonds, 1983, pp: 86)

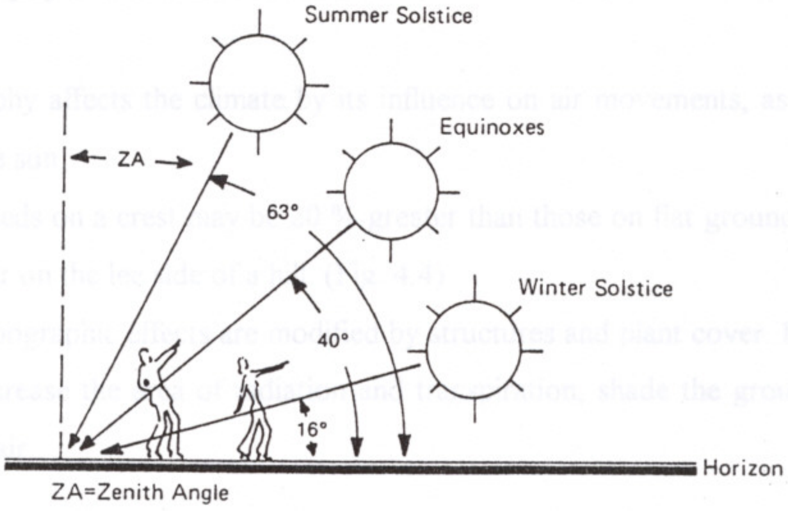


Fig. 4.2. The annual changes in sun angle for 50 degrees north latitude (Marsh, 1991; pp:214)

The influence of an inclined surface on local sun angle can also be computed. The sun angle on flat ground for that latitude, the direction in which the slope faces and the angle of the slope must be determined. (Fig. 4.3) If the slope faces the noon sun, the angle on the slope is equal to the flat ground angle plus the angle of the slope. If the slope is away from the sun, we can subtract the angle of the slope from the angle of the sun. If the product is negative, the slope is in shadow. (Marsh, 1991)

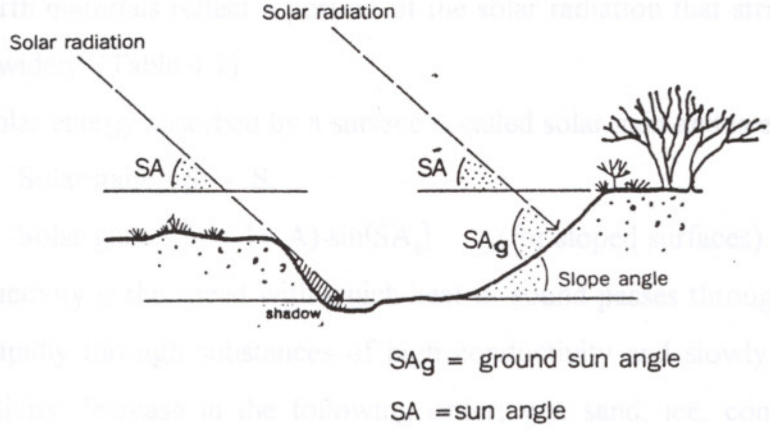


Fig. 4.3. Ground sun angle (Marsh, 1991;pp:215)

4.1.1.2. Topography and the Air Movement

Topography affects the climate by its influence on air movements, as well as by its orientation to the sun.

Wind speeds on a crest may be 20 % greater than those on flat ground and the wind is generally quiter on the lee side of a hill. (Fig. 4.4)

These topographic effects are modified by structures and plant cover. Plants alter the surface form, increase the area of radiation and transpiration, shade the ground, brake and trap the moving air.

4.1.2. Effects of Albedo, Conductivity and Turbulence In Microclimate

Heat is exchanged by radiation, conduction and convection. There are three corresponding characteristics; albedo, conductivity and turbulence. The reflective capacity of a surface is termed as "albedo". The percentage of incoming solar radiation reflected back instead of being absorbed.

$$A = \frac{S_o}{S_i} * 100$$

A = albedo, S_i = incoming solar short-wave
S_0 = outgoing solar short-wave

All earth materials reflect a portion of the solar radiation that strikes them, but their albedos vary widely. (Table 4.1)

The solar energy absorbed by a surface is called solar gain and is equal to;

$$\text{Solar gain} = S_i - S_o$$

$$\text{Solar gain} = S_i\ (1 - A)\sin(SA_g) \quad \text{(for sloped surfaces)}$$

Conductivity is the speed with which heat or sound passes through a given material. Heat flows rapidly through substances of high conductivity and slowly through those of low. Conductivity decrease in the following order; wet sand, ice, concrete, asphalt, still water, dry sand or clay, wet peat, fresh snow, still air. (Lynch, 1994)

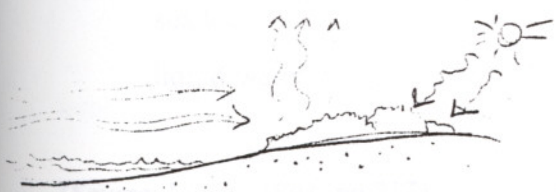
	FULL EXPOSURE TO WINTER WIND
	WIND DEFLECTED BY GROUND CONFORMATION
	WIND DEFLECTED BY TREES
	SMOOTH FORMS INDUCE THE SMOOTH FLOW OF AIR
	A MILD SUMMER BREEZE CAN BE AMPLIFIED BY THE VENTURI EFFECT OF WELL-PLACED BULDINGS, WALLS, HEDGES OR MASS PLANTINGS
	ABRUPT FROMS CAUSE UNPLEASANT AIR TURBULENCE
	AS THE DAYTIME SUN HEATS THE LAND SURFACE AND WARM AIR RISES, THE COOL MOIST AIR FROM ADJACENT WATERBODIES MOVES LANDWARD TO FILL THE VOID

Fig. 4.4. Topography affects air movement (Simonds, 1983; pp:87)

Table 4.1 . Albedos for various surfaces

Material	Albedo (%)
Soil	
dune sand, dry	35 - 75
dune sand, wet	20 - 30
dark, topsoil	5 - 15
gray, moist	10 - 20
clay, dry	20 - 35
sandy, dry	25 - 35
Vegetation	
broadleaf forest	10 - 20
coniferous forest	5 -15
green meadow	10 - 20
tundra	15 - 20
brown grassland	25 - 30
crops	15 - 25
Synthetic	
dry concrete	17 - 27
blacktop, asphalt	5 - 10
Water	
fresh snow	75 - 95
old snow	40 - 70
sea ice	30 - 40
liquid water	30 - 40

(Source: Marsh, 1991; pp:217)

Convection is the distribution of heat and sound by fluid movement. The significant factors are speed and turbulence.

The ground has a low albedo and high conductivity produces a mild and stable microclimate. Excess heat is quickly absorbed and stored and as quickly released when the temperature drops. If the ground has high albedo and low conductivity the exchange of heat do not help to balance the swings of the general climate. A high density of artificial structures or a substantial area of paving increases the albedo and this results in higher summer temperatures. On a day, when the general temperature is 25 C, the surface of a concrete walk in the sun may be 35 C. (Lynch, 1994)

The slope and albedo are very important in the solar heating of a varied landscape. For example, the location is at 45 degrees north latitude, the profile of the landscape is given in the figure 4.5. The rates of solar heating at noon on the equinox would be as follows: (Marsh, 1991)

Example:

	Building roof	Concrete wall	Plowed field	Sandstone
slope	45°	30°	5°	25°
orientation	south	north	south	south
albedo	10%	27%	22%	40%
SA	90°	15°	50°	70°
S	.78	.78	.78	.78
S	.78(1-.10)sin90	.78(1-.27)sin15	.78(1-.22)sin50	.78(1-.40)sin70
	.70	.15	.47	.44

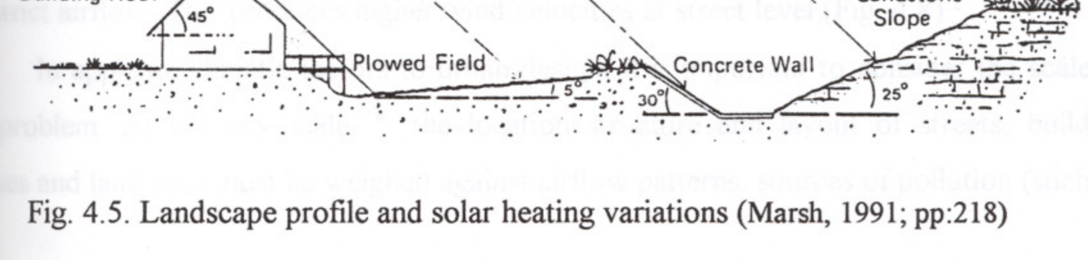


Fig. 4.5. Landscape profile and solar heating variations (Marsh, 1991; pp:218)

4.2. Urban Climate

Urbanization transforms the landscape into a complex environment characterized by forms, materials and activities.

" The flow of energy in the urban landscape is different. As a whole, the receipt of solar radiation is substantially lower, while the generation of sensible heat at ground level is greater in cities. Furthermore, the rate of heat loss from the urban atmosphere through convective and radiant flows is lower." (Marsh, 1991; pp:228). Urban climate is warmer, less well lighted, less windy, foggier, more polluted and often rainier than the region wide climate. (Fig. 4.6)

The spatial pattern of higher air temperature in urban areas produces "heat island" (Fig. 4.7). The absorption of a given quantity of radiation and in turn, heat the overlying air faster provides higher temperature. Furthermore, because of a higher carbon dioxide content, the atmosphere retains more heat. In addition, having lower wind speeds at ground level, the heated air tends not to be flushed away.

The elevated topography of urban environment that consists of size, spacing and height arrangements of buildings determine the nature of air flow, wind speeds. " In the case of an individual building, the structure represents an obstacle to airflow and in order to satisfy the continuity of flow principle, wind must speed up as it crosses the building." (Marsh, 1991; pp:232)

In a two dimensional model, the windward brow of the building and roof tops are the places where the wind reaches the highest speed. Air is also deflected from the brow down the face of the building, speeds decline on the leeward side and spread out with some descending to the ground. streets bordered by a mass of tall buildings have the character of canyons. The canyons, if aligned in the direction of prevailing winds, tends to channel and constrict airflow. This produces higher wind velocities at street level (Fig. 4.8)

In applying climatic factors to urban design, it is important to consider the scale of the problem. At the city scale, "...the location structure and layout of streets, building masses and land uses must be weighed against airflow patterns, sources of pollution (such

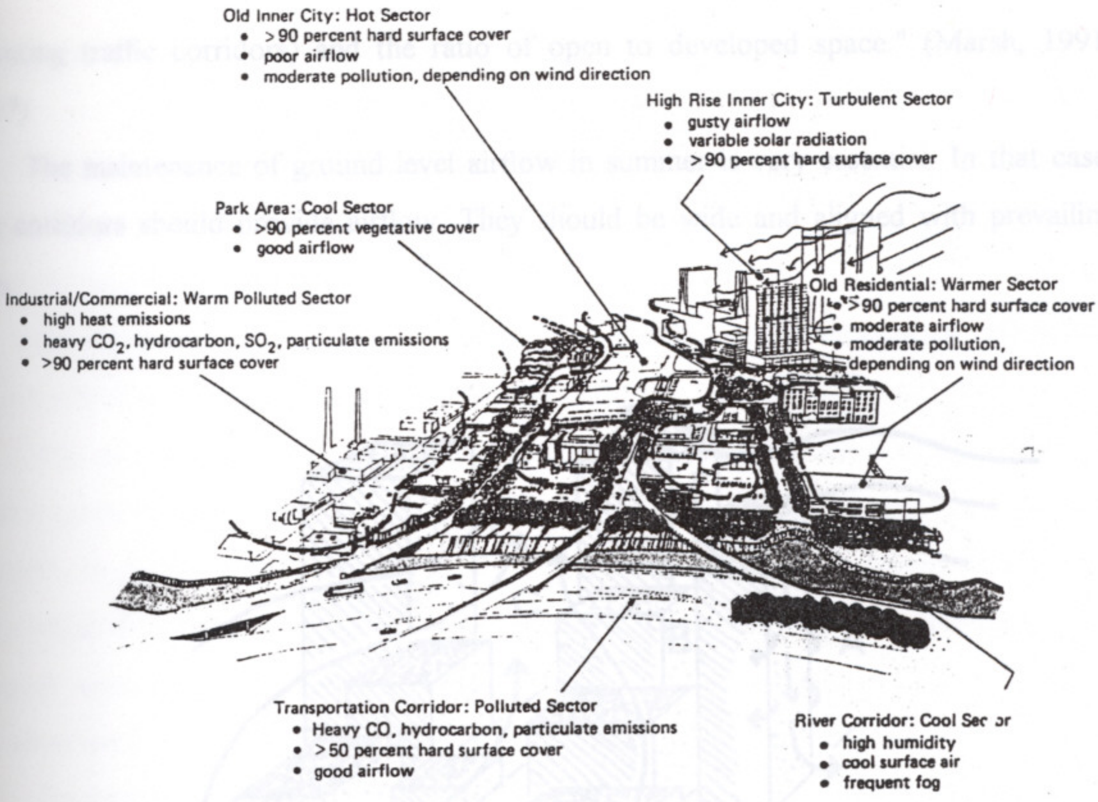


Fig. 4.6. Urban climate conditions associated with different sectors of a city (Marsh, 1991; pp:228)

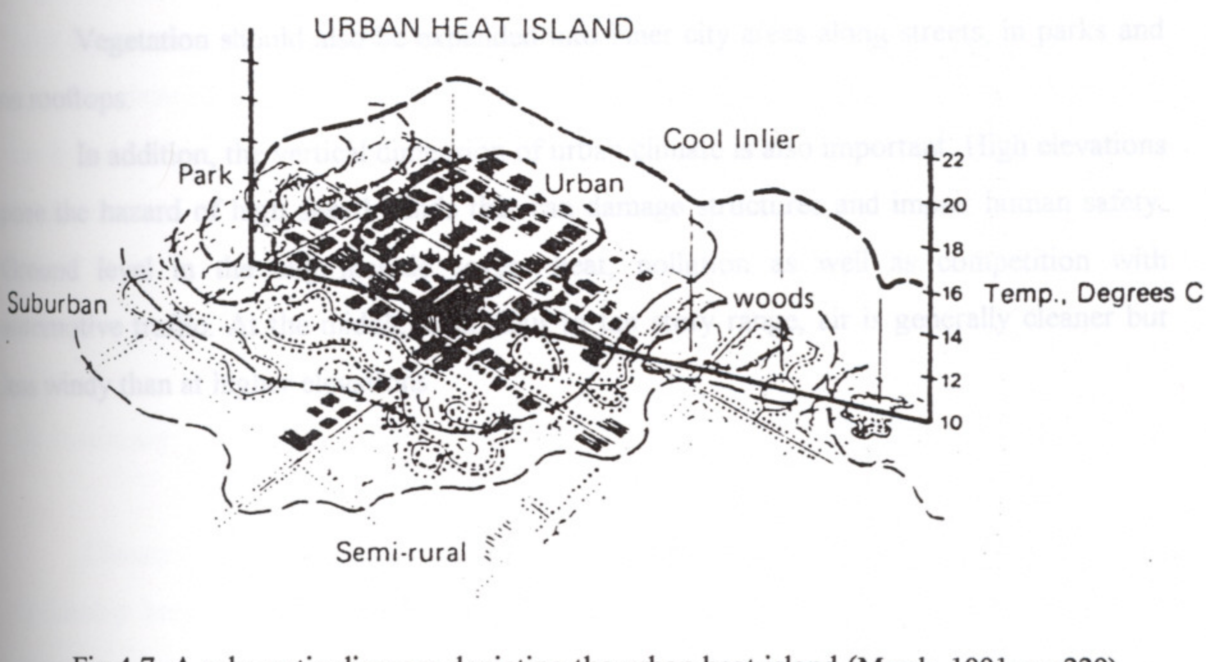


Fig.4.7. A schematic diagram depicting the urban heat island (Marsh, 1991; pp:229)

as existing traffic corridors) and the ratio of open to developed space." (Marsh, 1991; pp:237)

The maintenance of ground level airflow in summer is very essential. In that case, street corridors should provide airflow. They should be wide and aligned with prevailing winds.

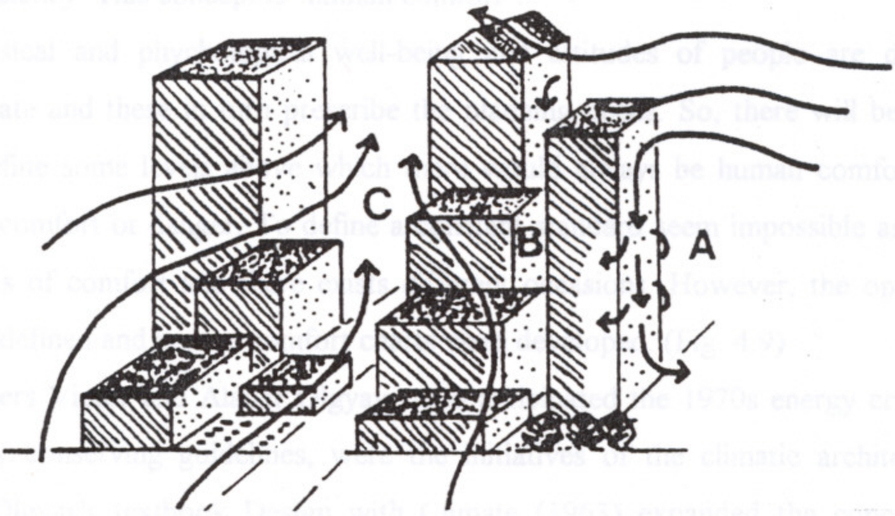


Fig. 4.8. Airflow over and around buildings (Marsh, 1991; pp: 232)

Vegetation should also be expanded into inner city areas along streets, in parks and on rooftops.

In addition, the vertical dimension of urban climate is also important. High elevations pose the hazard of high speed winds that can damage structures and impair human safety. Ground level in the city include severe heat, pollution as well as competition with automotive traffic. At the middle level, four to ten story range, air is generally cleaner but less windy than at higher elevations.

4.3. Human Comfort

Some elements of microclimate and their modifications are considered in the current chapter. The reason to modify the microclimate elements is to achieve comfortable and energy efficient environments.

At that point, it is required to explain the concept which determines the level of comfort and efficiency. This concept is "human comfort".

The physical and phychological well-being and attitudes of people are directly affected by climate and these in turn prescribe the planning needs. So, there will be some standards, to define some levels above which there would always be human comfort and below which discomfort or danger. To define a constant standard seem impossible as there are many aspects of comfort and there exists different occasions. However, the optimum conditions were defined and human comfort charts were developed. (Fig. 4.9)

Researchers Victor and Aladar Olgyay who anticipated the 1970s energy crisis by published energy conserving guidelines, were the initiatives of the climatic architectural design. Victor Olgyay's textbook Design with Climate (1963) expanded the concept of climatic design to include urban form and, as such, remains the basic reference for most energy conscious architects and planners. So, the basis of the developed standards and charts for comfort is the principles of Olgyay.

An example for comfort conditions cn be given as follows: In the temperate zone, the one in light clothing, sitting in shaded indoors can feel quite comfortable at temperature ranges between 18° and 26° C (65°and 80° F) as long as the relative humidity lies between 20 and 50 %. As humidity increases, the same people can begin to feel uncomfortable at lower temperatures. (Lynch, and Hack, 1994).

4.4. Summary

Climate is a fundamental consideration in energy efficient planning and design. The relationship between outdoor and indoor conditions determine the energy consumption. It can be accepted that if the exterior condition is very similar to the desired interior condition, no extra energy is required for space conditioning. But if there is a significant difference between outdoor and indoor condition, large amounts of energy are needed. At that point it can be said that, the amount of energy consumption can be reduced by a modification of the microclimate. The knowledge of prevailing climate conditions, the understanding of the microclimate elements which most affect energy use and the the understanding of the ways in which objects-built environment affect the climate to create microclimate maintain providing energy efficient environments.

Key words; **climate, microclimate, microclimate elements, urban climate, human comfort**.

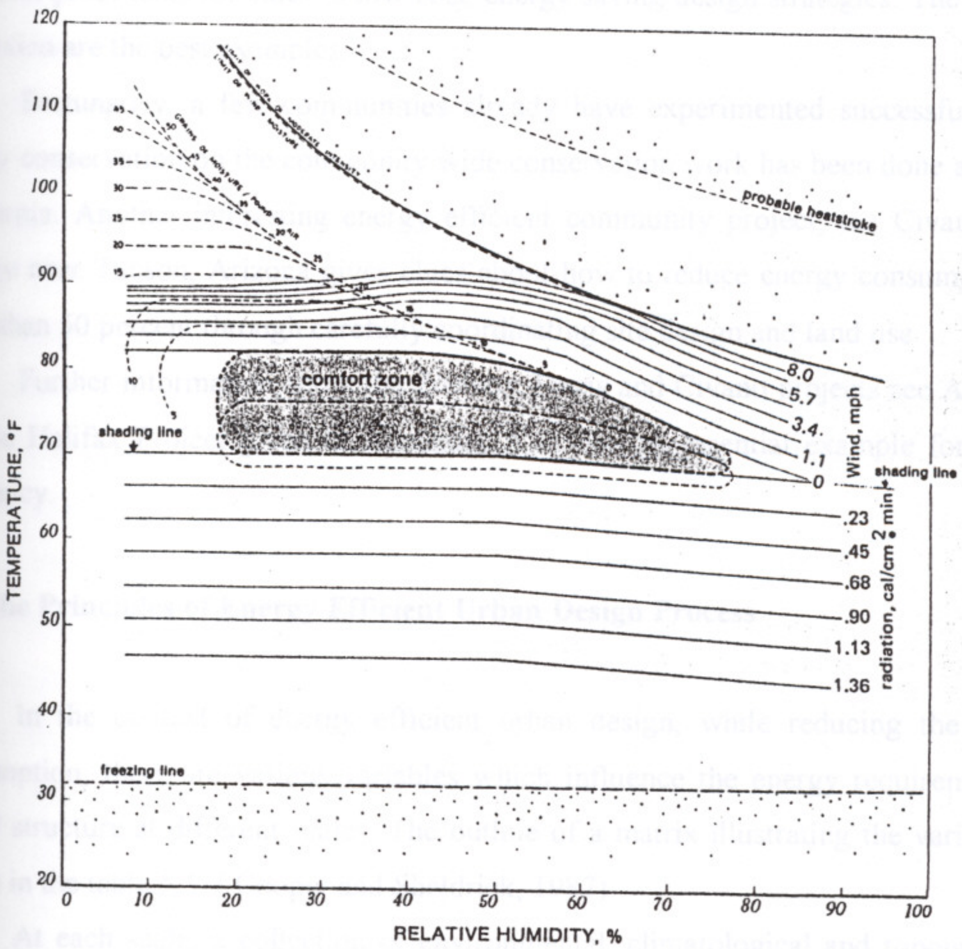


Fig. 4.9. Climate comfort chart that can be used to test urban environments for their suitability for humans. (Marsh, 1991; pp: 212)

Chapter 5

ENERGY EFFICIENT URBAN DESIGN

There has been lots research about the energy conservation and energy efficiency but much of the investigation has focused on the technical characteristics of energy using machinery such as vehicles, space conditioning systems and industrial processes. However, there has been relatively little research about the effects of urban design on energy consumption and conservation.

A common ground for the attitudes to save energy was to examine successful historical precedents for clues to low cost, energy saving design strategies. The Pueblos in Mexico are the best examples.

Fortunately, a few communities already have experimented successfully with energy conservation on the community wide conservation work has been done at Davis, California. Another interesting energy efficient community project, the Civano Solar Village near Tucson, Arizona gives clues about how to reduce energy consumption by more than 50 percent through carefully coordinating site design and land use.

Further information about the Pueblos, Davis and Civano projects see Appendix A. The Halifax Project given in Appendix A is also an essential example for energy efficiency.

5.1. The Principles of Energy Efficient Urban Design Process

In the context of energy efficient urban design, while reducing the energy consumption, there are various variables which influence the energy requirements of spatial structure at different scales. The outline of a matrix illustrating the variables is shown in the table 5.1. (Cooper and Sheldrick, 1987)

At each scale, a collection of environmental, climatological and topographical data is required. In order to achieve the best results and most beneficial effects, all possible aspects of climate, natural and built environment should be taken into consideration at all levels of planning and design. Obviously, to give the most comprehensive advice, all collected data should be evaluated and analysed in the context of energy efficiency. And finally, the integration of energy efficiency of energy efficiency. And finally, the integration of energy efficiency considerations at all levels of planning; from site selection down to the final stage of building design should be done.

We are much concern about settlement and building scale. The two major factors, are reducing the transportation and space conditioning energy needs in urban energy consumption can generally be considered at these scales. At each factor and scale, there are variables related to energy efficiency to be taken into account. These variables are defined in the table 5.2.

5.2. The Variables of Energy Efficient Urban Design - Settlement Scale

The variables related to settlement scale are; urban form, land use, density, site selection and orientation, street layout, wind, external shading and landsaping.

5.2.1. Urban Form

Urban form characteristics favourable for the minimizing of transport energy requirements, also seem to be favourable for energy conservation in space conditioning.

An energy conscious city form will help direct individual buildings and sites to be properly oriented, shaded or exposed, ensure ventilation. etc.

" There has been insufficient examination of what an energy efficient urban form is actually composed of and how such a state can be reached given the present arrangements". (Newman and Kenworthy, 1989; pp:24) In order to achieve a solution and identify an energy efficient urban form, it is useful to distinguish between energy efficient characteristics of urban form and the forms themselves, since once the desirable characteristics have been identified, they can be found in more than one form. (Owens, 1987). Energy efficient characteristics of urban form are;

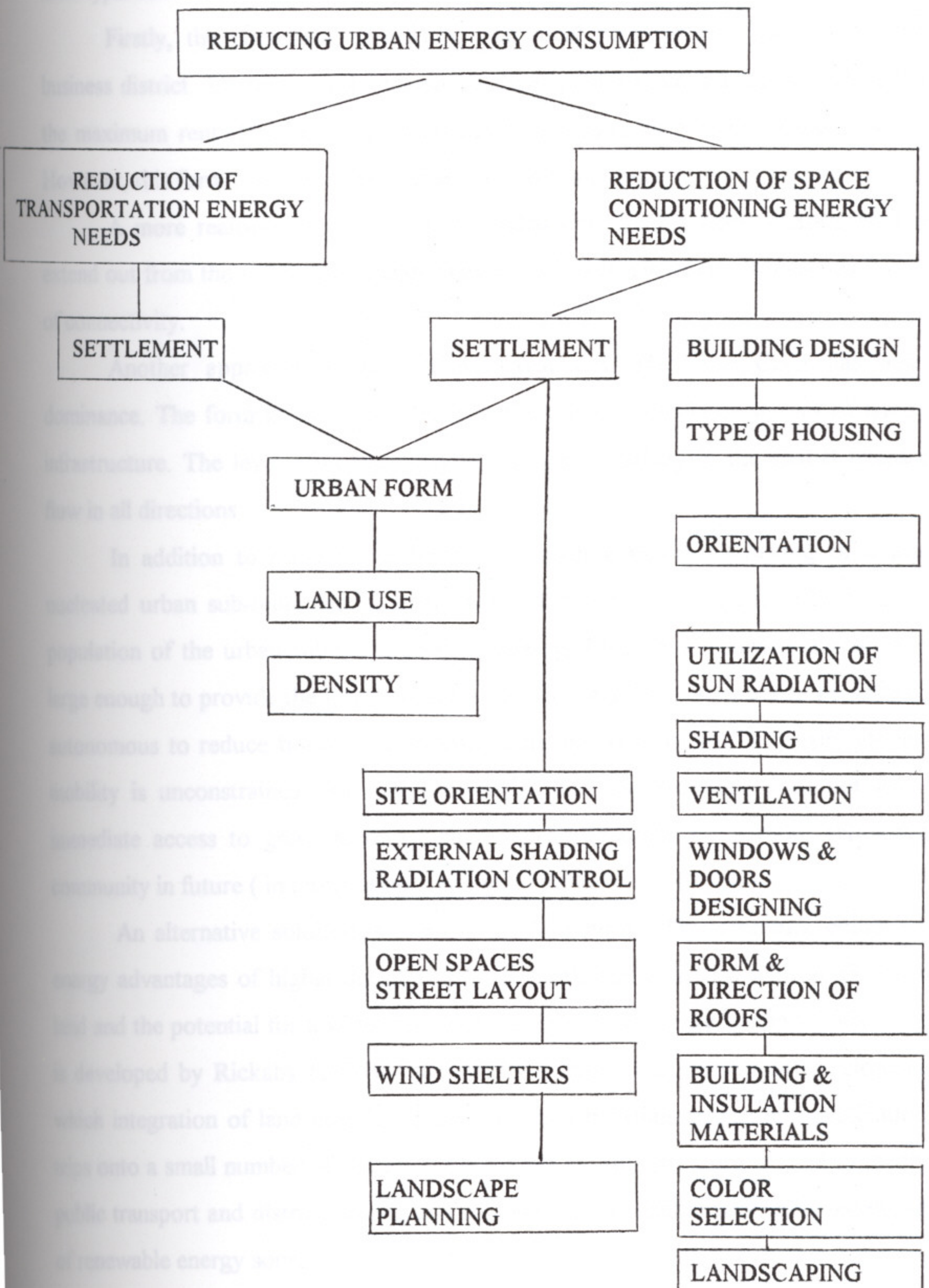
* the encouragement of facilities within walking and cycling distances or readily accessible by public transport. This is the main tenet of most energy efficient patterns;

* the need to site and orientate groups of building so as to take maximum advantage of microclimate and especially to make use of passive solar energy.

Table 5.1. Variables including the energy requirements of spatial structures at different scales (adapted from Owens, 1985, Energy and urban Built Form, pp:189)

STRUCTURAL VARIABLE	***SCALE***	***LEVEL OF ACTIVITY***
Settlement pattern (e.g. rank-size, geometrical arrangement etc.)	Regional	
Communication network between settlements	Sub regional	
Size of settlements (area)		
Shape of settlement (circular, linear etc.)		Land use planning
Communication network within settlement (radial, grid, etc.)	Individual settlement	
Interspersion of land uses	Neighborhood	
Degree of centralization of facilities		
Density	Building	
Layout (estates etc.)		
Orientation (of buildings or groups of buildings)		Building design
Siting (in relation to microclimate)		
Design		

Table 5.2. Variables of energy efficient urban design (adapted from Bitan and Oded, 1995)



5.2.1.1. The Archetypal Forms

In order to understand different possibilities for urban form, the simple archetypal forms can be examined. (Fig. 5.1) (Anderson *et al.*,1996)

Firstly, the concentric city form; The focal point of the form is the central business district. There exists the maximum density, maximum number of trip ends and the maximum rent. Land uses are segregated into concentric zones around the CBD. However, this form assumes a very dense transport network.

A more realistic assumption is the radial city. In this case, sectors, land uses extend out from the CBD along major lines of transport. However, this causes low level of connectivity.

Another approach is the multinucleated city. Here the CBD has lost its dominance. The form is more complex and there is a hierarchical system of transport infrastructure. The level of connectivity in the city is higher, so the spatial interaction flow in all directions.

In addition to these urban forms, an urban structure consisting of compact, nucleated urban sub-units can be examined in the context of energy efficiency . The population of the urban sub-units, having walking distances or bicycle scales must be large enough to provide the threshold for a range of facilities if they are to be sufficiently autonomous to reduce travel requirements. This pattern may not be energy efficient if mobility is unconstrained. Another problem is that this structure does not give the immediate access to green areas which might be desirable for a more self-sufficient community in future (in terms of both energy and food)

An alternative solution is a linear grid structure . This structure combines the energy advantages of higher densities and integration of activities with access to open land and the potential for a wider range of life styles and energy systems. This structure is developed by Rickaby (1979). " It permits a high linear density of development in which integration of land uses is achieved by concentrating origins and destinations of trips onto a small number of routes" (Owens, 1987). This structure is ideal in theory for public transport and district heating and it would be compatible with quite extensive use of renewable energy sources.

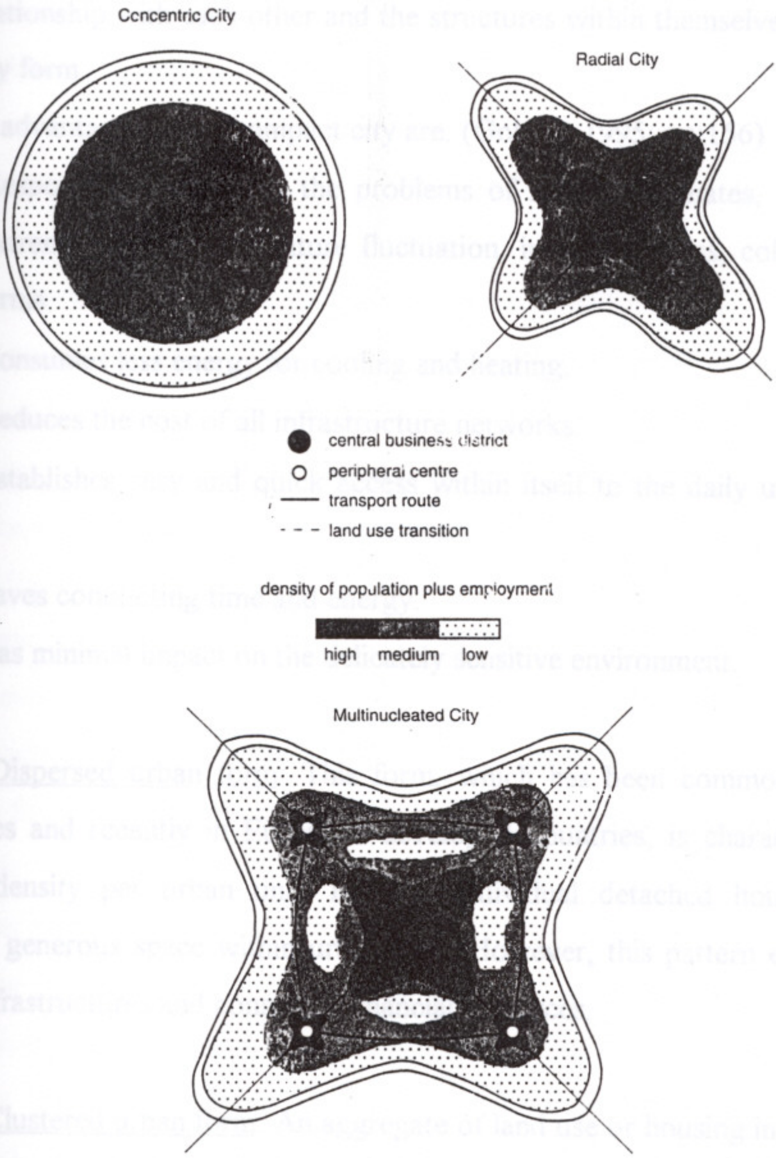


Fig. 5.1 The archetypal forms (Anderson et al., 1996; pp:11)

5.2.1.2. Compact, Dispersed, Clustered, Combined Urban Forms

Urban forms can also be classified as compact, dispersed, clustered and combined form. The properties of these forms are:

- Compact urban form: Compact city morphology responds positively to the stressful climates. The concentrated and firmly unified land uses in a close and tight physical relationship with each other and the structures within themselves constitutes the compact city form.

The advantages of the compact city are: (Golany, 1995; pp:156)

1. Responds to and eases the problems of stressful climates, such as; intense radiation, extreme diurnal temperature fluctuation, intense dryness, cold or hot winds, and dust storms.
2. Consumes less energy for cooling and heating.
3. Reduces the cost of all infrastructure networks.
4. Establishes easy and quick access within itself to the daily use, services and business.
5. Saves commuting time and energy.
6. Has minimal impact on the delicately sensitive environment.

- Dispersed urban form: This form, which has been commonly used in the United States and recently in European developed countries, is characterized by low population density per urban unit, low-rise individual detached housing units and provision of generous space within urban land. However, this pattern extends utilities, roads and infrastructures and consumes financial resources.

- Clustered urban form: An aggregate of land use or housing in relatively small urban units, integrated within very close proximity of each other constitutes the clustered form. These forms can carry within them an integrated land use or segregated land use as well. Clustered form also responds favorably to stressful climates.

• Combined urban form: This is an aggregate of different forms brought together to establish a type of dispersed form and becomes a cohesive part of the urban pattern.

The archetypal and above urban forms help us while thinking about energy issues in cities. However, urban form is complicated issue. The most desirable urban form can not be determined only on the basis of energy efficiency. Urban form evolves over long periods according to the events, technologies, policies and politics.

5.2.2. Land Use

Land use pattern have a major impact upon energy consumption and energy efficient development. Energy systems influence spatial structure and land use patterns in part determine levels of energy consumption. (Owens, 1986)

How intensively a city uses its land is the essential factor in energy efficiency. Studies have shown that, " the more intensive the land use, the shorter the distances of travel, the greater the viability of transit (more people per stop and hence better service), the greater the amount of walking and biking, the higher the occupancy of vehicles, and the less need for a car." (Newman and Kenworthy, 1989; pp:25)

A dense, compact form with mixing land uses - housing, commercial, business, schools and even light industrial areas- bringing all within walking or at least bicycling distance provides energy conservation. When land use is sufficiently concentrated, the opportunities for more walking and biking can be greatly encouraged by improvement of facilities. This can include establishing pathways and bike lanes and particularly pedestrianizing central cities.

On the other hand, the location of activities according to the climatic and environmental conditions reduce energy consumption and environmental hazards. The south location of residential areas in order to benefit from solar gain, the location of storage or parking areas, in areas receiving little sun and also the location of industrial areas related to prevailing winds.

5.2.3. Density

Density is another variable that can be taken into account in energy efficiency.

Higher densities make walking, bicycling and mass transit much more feasible modes of transportation thus reducing the use of automobiles and consumption of energy. (Fig. 5.2)

Clustered dwellings are much more efficient in their use of land and can be more efficient in their use for facilities by sharing amenities.

Ralph Knowles suggests that " the higher the density development, the more energy efficient the buildings will be. Buildings clustered tightly together can share half or more of their exterior walls and roof, thus presenting less than half as much surface for the gain or loss of heat." (Lyle, 1994; pp:124)

However, research results on energy consumption are mixed. For example, a study carried out by the Florida Solar Energy Center showed that a single family detached households used almost twice as much energy per dwelling unit as single family attached households. On the other hand, when we calculated on a per occupant, per square basis, it can be seen that the consumption in the attached units was only slightly lower. At that point, for conventional buildings, levels of energy consumption may be more closely related to the size of dwellings than to their density. (Lyle, 1994)

In the above paragraphs, it is said that higher densities are more energy efficient as density allows efficient use of infrastructure and enhance sustainability. On the other hand, when low urban densities are considered, it can be suggested that low densities increase automobile use, however make solar heating more feasible and provide possibilities of generating renewable energy resources and food on site. (Grant, et.al; 1996)

On the other hand, at any level of density liveability and sustainability require integration of buildings and landscape. If the landscape does not work with buildings in controlling energy flow, energy consumption will be high.

Fig. 5.2 Higher densities prevent heat gain and heat loss (WMO, 1996; pp:19)

5.2.4. Site Selection and Orientation

The energy consumption in space conditioning is very much effected by the site. Energy efficiency can be achieved by site selection and orientation.

It was well known that a south slope is warmer and has the largest growing season. A south slope is the best for most building types. The south slope receives the most solar energy as it most directly faces the winter sun (Fig. 5.3.). Also the south slope will experience the least shading as the cast of objects is shortest on south slopes. (Fig. 5.4). (Lechner, 1991)

With different slope orientations occurs variations in microclimate. These slope orientations and variations are shown in the figure 5.5.

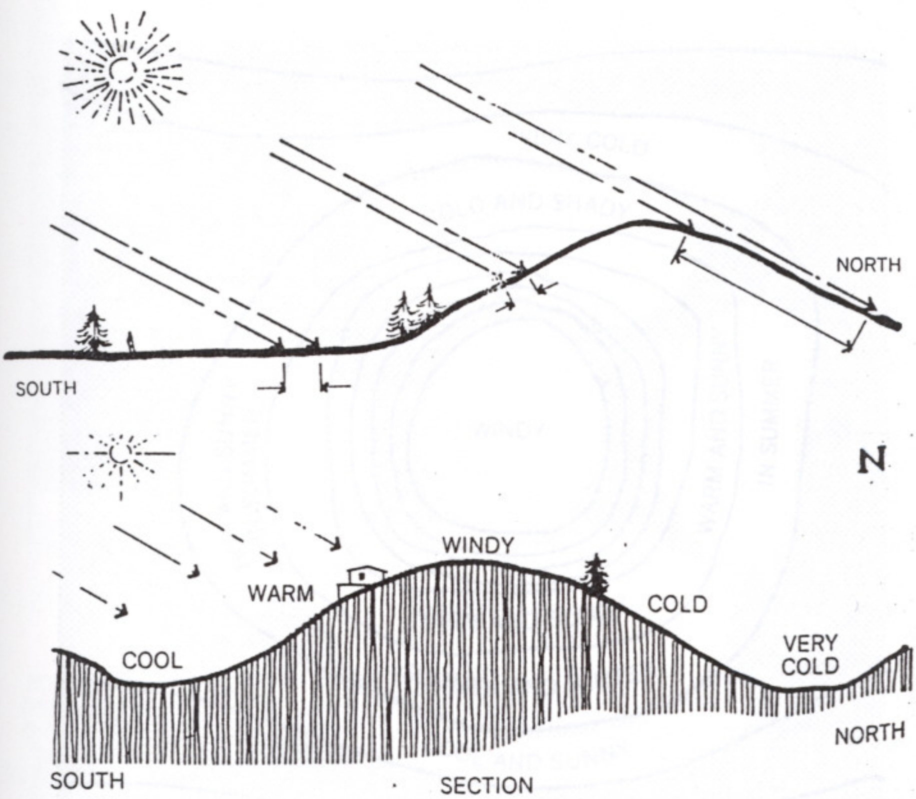


Fig. 5.3. In winter, south sloping land receives the most sunshine (Lechner, 1991; pp:211)

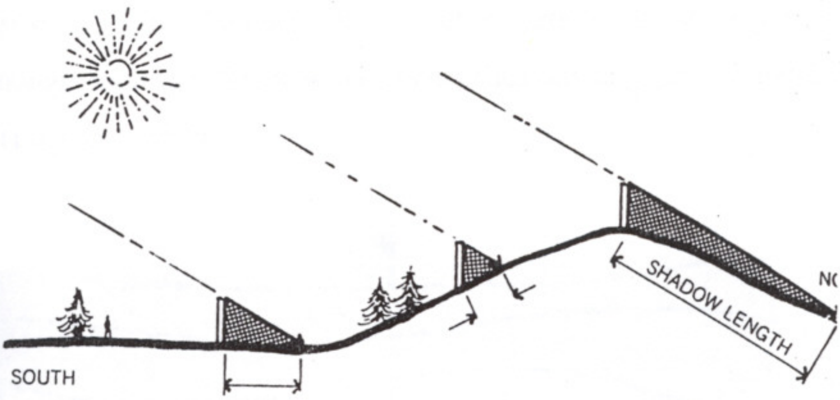


Fig. 5.4. Shade on the south sloping land (Lechner, 1991; pp:212)

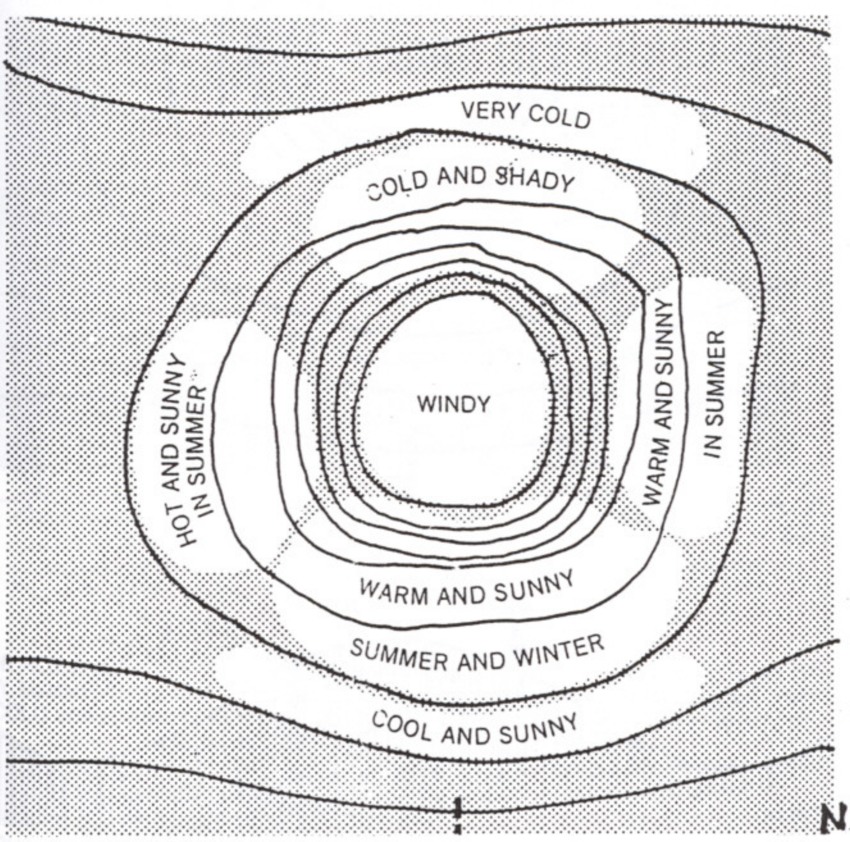


Fig. 5.5. Slope orientations and variations in microclimate (Lechner, 1991; pp:212)

The south slope is the warmest in the winter while the west slope is the hottest in the summer. The north slope is coldest and the shadiest. The hilltop is the windiest while low areas are cooler.

The best site for a building depends on both climate and building type.

For buildings such as residences and small office buildings, the climatic conditions are; (Fig. 5.6) (Lechner, 1991)

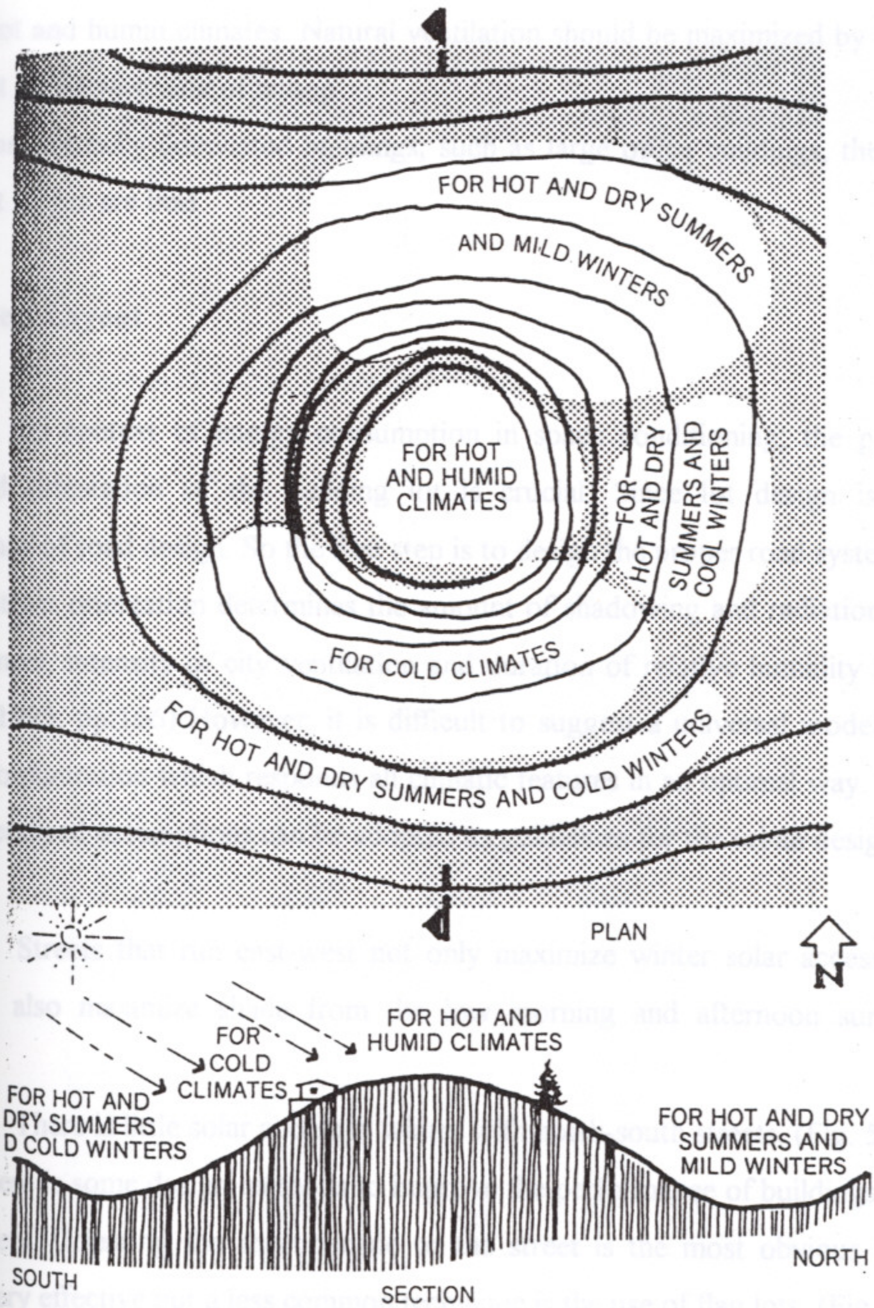


Fig. 5.6. Preferred building sites around a hill (Lechner, 1991; pp:213)

Cold climates: South slope maximize solar collection and provides from cold northern winds. Avoid the windy hilltops and low lying areas that collect pools of cold air.

Hot and Dry climates: Low lying areas that collect cool air are suitable for location. If winters are very cold then bottom of south slope is preferable. Location on north or east slopes is also suitable if winters are mild but the west slopes are not preferable.

Hot and humid climates: Natural ventilation should be maximized by building on hilltop but avoid west side of hilltop.

For internally dominated buildings, such as large office buildings, the north and north-east slopes are best.

5.2.5. Street Layout

In the context of energy consumption in space conditioning; the proper size, shape and orientation of the building lot is crucial. Since lot design is largely a consequence of road design. So the first step is to design the proper road system.

"Street orientation determines the amount of shadowing and radiation, light and air movement, intensity of city ventilation and duration of relative humidity in the air." (Golany, 1995; pp:166) However, it is difficult to suggest a universal model of streets and city configuration which responds all climatic features in an optimal way. Therefore, some generalized assumptions can be adopted as guidelines for the urban design of street layout.

- Streets that run east-west not only maximize winter solar access from the south but also maximize shade from the low morning and afternoon summer sun. (Fig. 5.7)
- There is little solar access in winter with north-south streets. (Fig. 5.8)

There is some design methods to improve the performance of buildings on north-south streets. Orienting the short facade to the street is the most obvious technique. Another very effective but a less common technique is the use of flag lots. (Fig. 5.9 a and b)

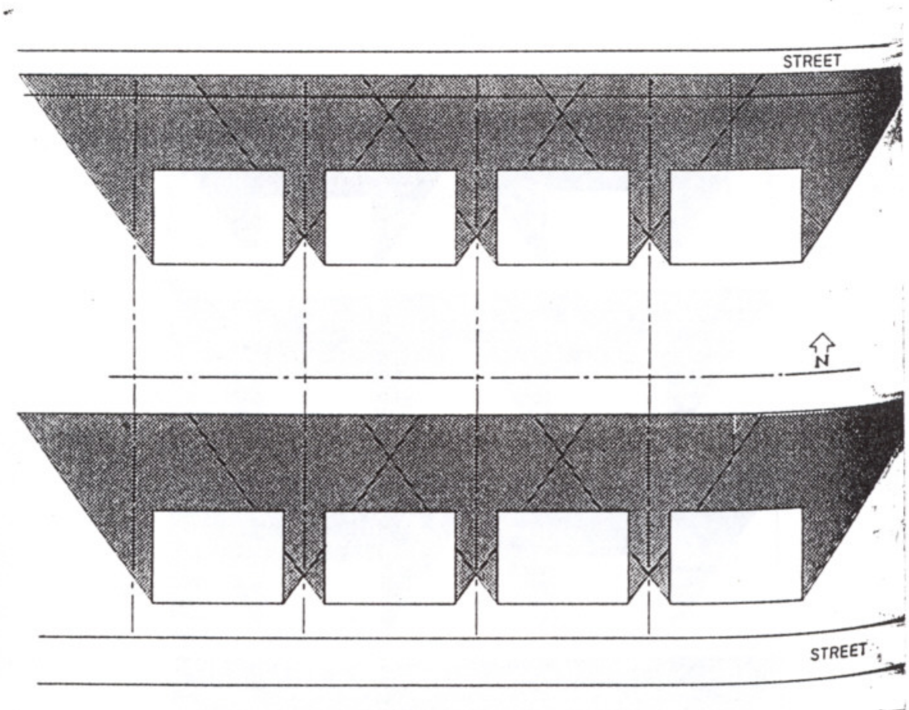


Fig. 5.7. East-west streets (Lechner, 1991; pp:222)

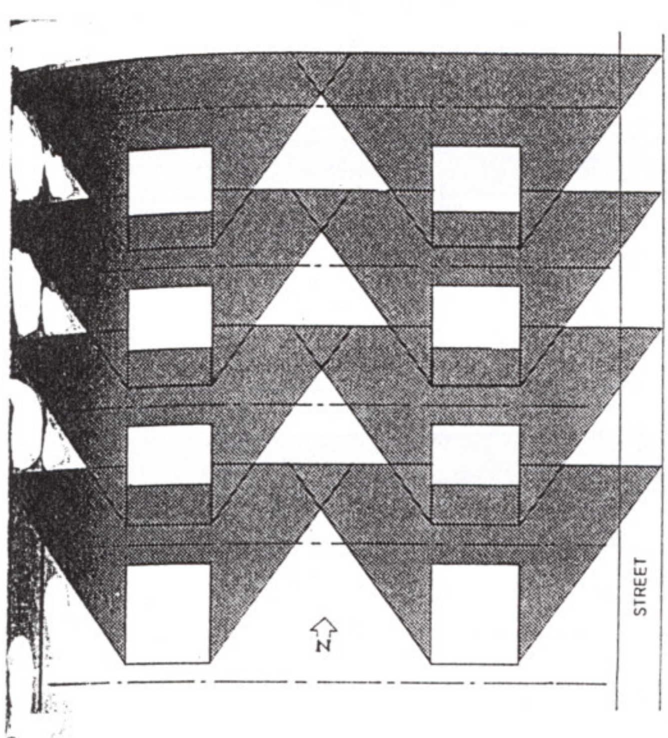


Fig. 5.8. North-south streets (Lechner, 1991; pp:223)

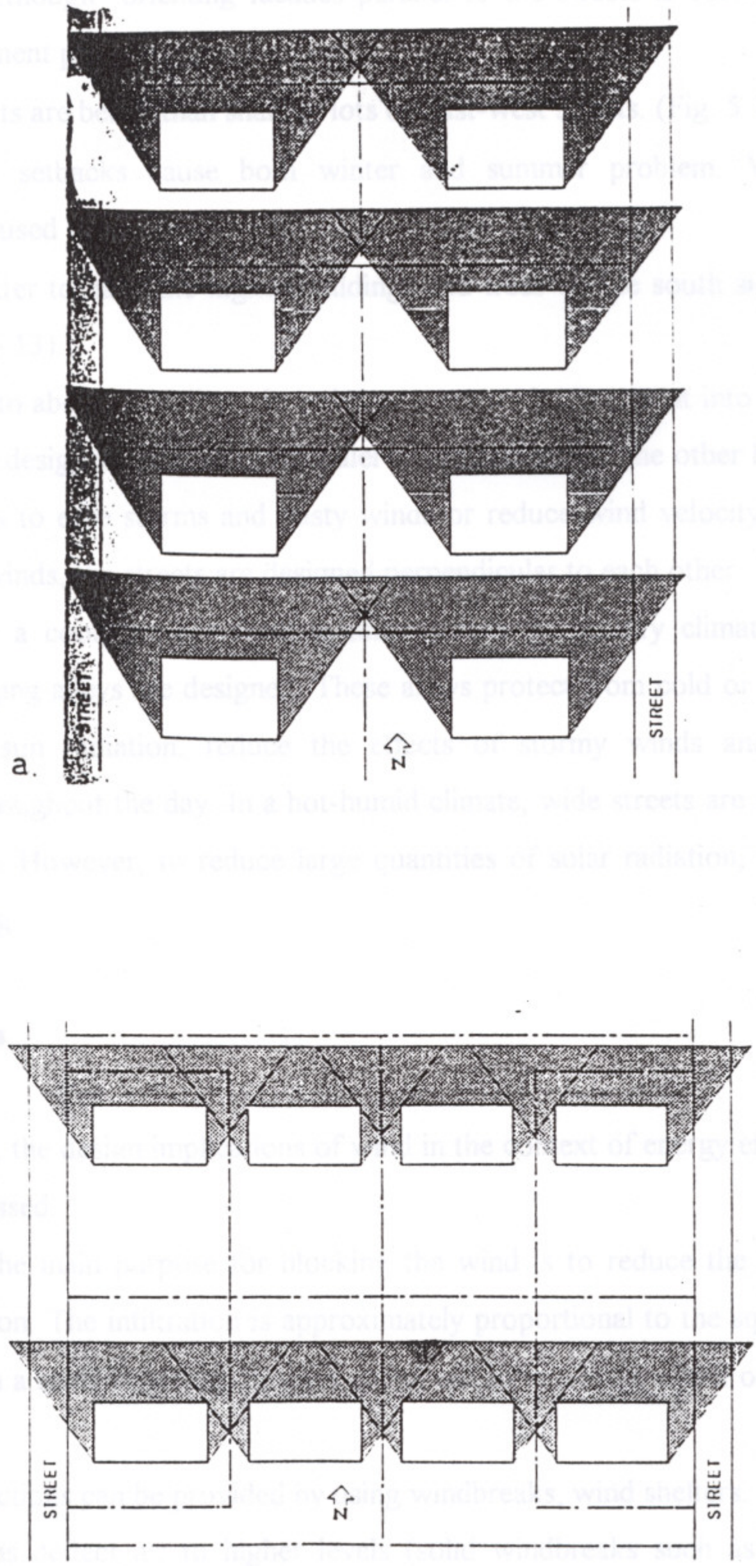


Fig. 5.9.(a) Orienting the short facades to the north-south street, (b) the use of flag on north-south streets (Lechner, 1991; pp:223)

- If the buildings are rotated to the south, the orientation will be achieved on diagonal streets. Although orienting facades parallel to the streets is convenient, this alternative arrangement provides benefits. (Fig. 5.10)
- Deep lots are better than shallow lots on east-west streets. (Fig. 5.11)
- Uneven setbacks cause both winter and summer problem. Very small setbacks especially used in row housing can be acceptable. (Fig. 5.12)
- It is better to have the higher buildings and trees on the south side of east-west streets. (Fig. 5.13)

In addition to above guidelines, in order to support air movement into and within the city, streets are designed straight and parallel to each other. On the other hand, if the desired condition is to ease storms and dusty winds or reduce wind velocity and bring cooler or warmer winds, the streets are designed perpendicular to each other.

To provide a cool and comfortable microclimate in hot-dry climate; narrow, winding or zigzagging alleys are designed. These alleys protect from cold or hot winds, receive minimum sun radiation, reduce the effects of stormy winds and establish shadowed space thoughout the day. In a hot-humid climate, wide streets are required to support ventilation. However, to reduce large quantities of solar radiation, these wide streets need shading.

5.2.6. Windbreaks

In this part, the design implications of wind in the context of energy efficiency on site design is discussed.

In winter the main purpose for blocking the wind is to reduce the heat losses caused by infiltration. The infiltration is approximately proportional to the square of the wind velocity, then a small reduction in wind speed will have a large effect on heat loss. (Fig. 5.14)

These reductions can be provided by using windbreaks, wind shelters.

Windscreens deflect air to higher levels (solid windbreaks such as buildings), create turbulence (solid windbreaks), absorb energy (porous windbreaks such as trees).

The height and the porosity of a windbreak determine the performance of wind protection. (Fig. 5.15)

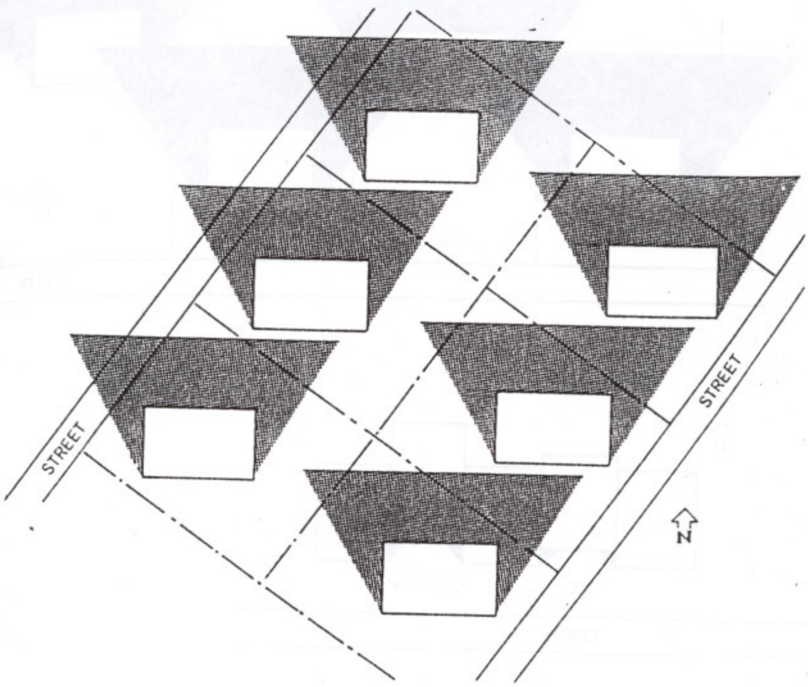


Fig. 5.10 South related buildings on diagonal streets (Lechner, 1991; pp:224)

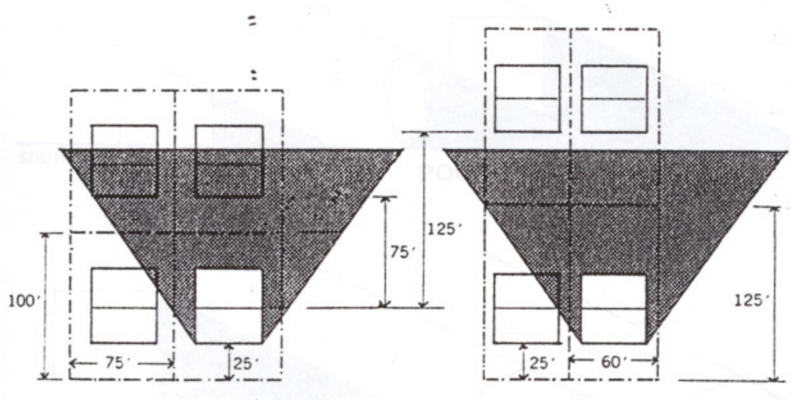


Fig. 5.11 Deep lots are better on east-west streets (Lechner, 1991; pp:225)

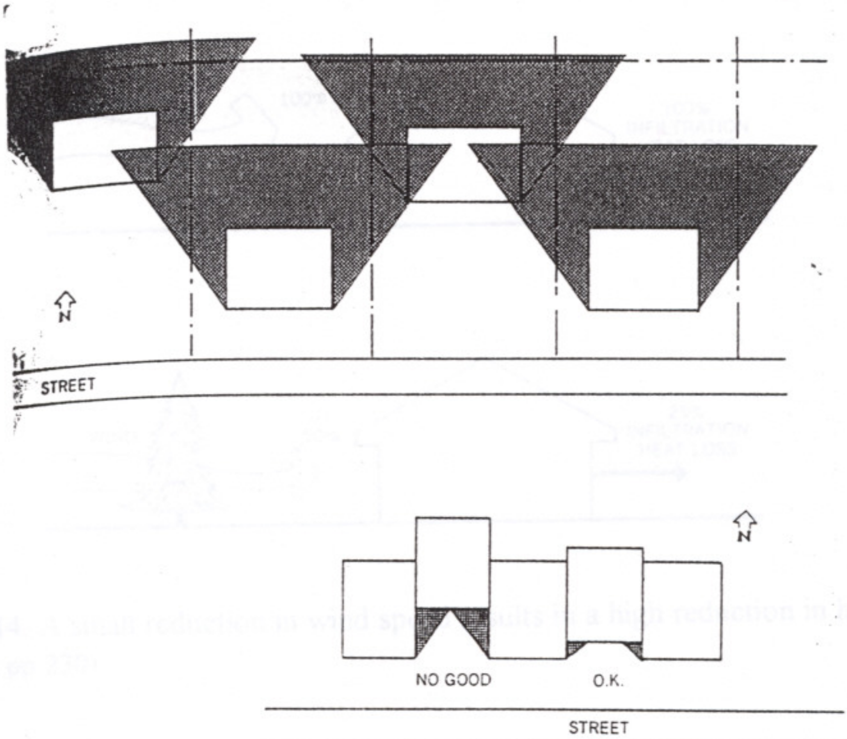


Fig. 5.12 Uneven setbacks cause problems (Lechner, 1991; pp:225)

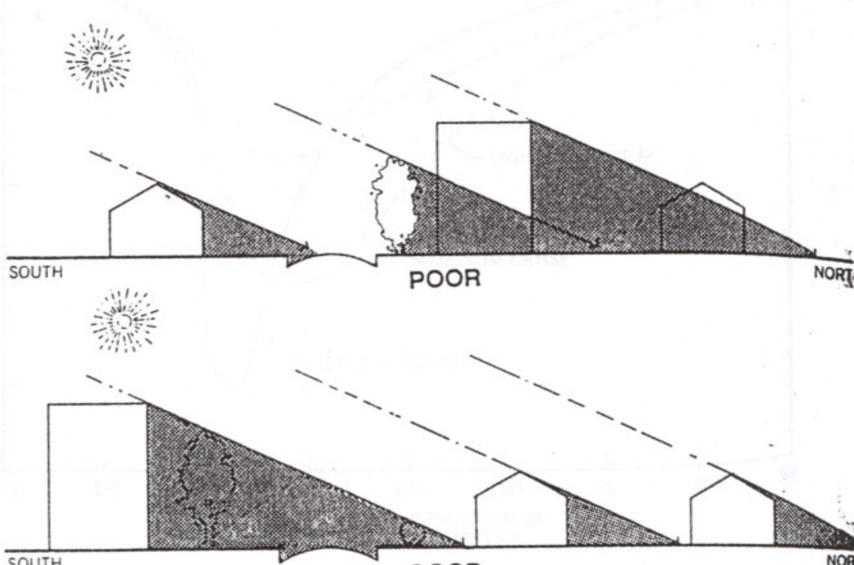


Fig. 5.13 Higher Buildings and trees on south side of east-west street (Lechner, ›1; pp:226)

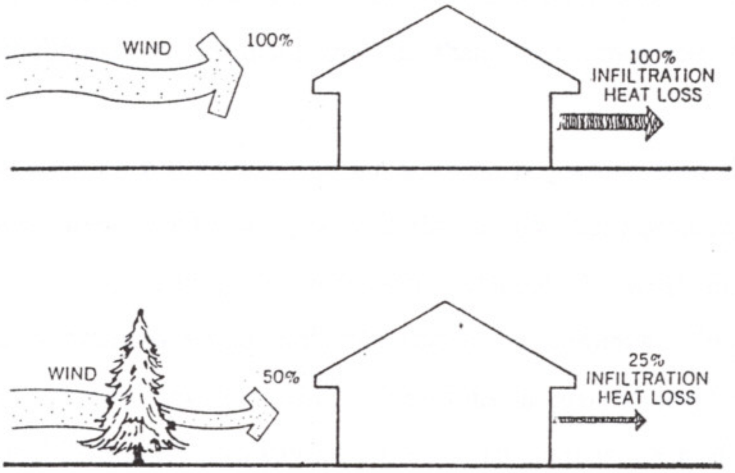


Fig. 5.14. A small reduction in wind speed results in a high reduction in heat loss. (Lechner, 1991; pp:230)

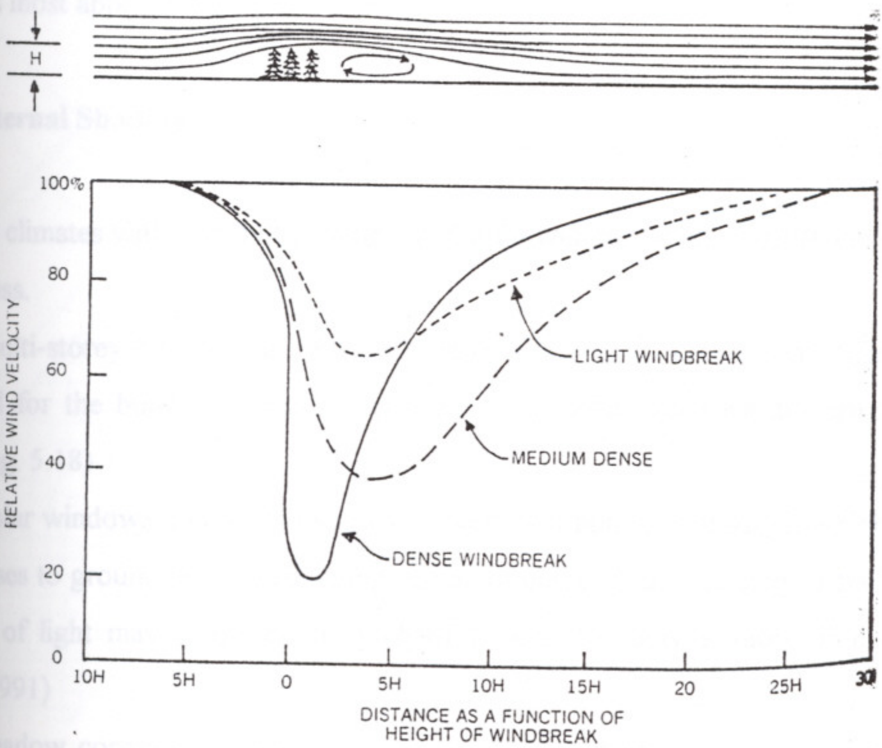


Fig. 5.15 The performance of windbreak (Lechner, 1991; pp:230)

The depth of wind protection is proportional to the height of the wind break. The densest windbreak results in the greatest reduction of air velocity but also has the smallest downwind coverage. It's better to use dense windbreaks on small lots and medium dense windbreaks at distances greater than four times the height of the windbreak.

At gaps or ends of windbreaks the air velocity is greater than the free wind. (Fig. 5.16) This phenomena can be acceptable in the summer but not in the winter. This undesirable situation occurs in cities when buildings channel the wind along streets. A similar situation also happens when buildings raised on columns . In addition, tall buildings will often generate severely windy conditions at ground level . However, a building extension will deflect winds away from ground level areas. (Fig. 5.17)

Taller buildings placed toward the north not only protect from the cold winter winds but also allow better solar access. When the climate is warm and humid, cross ventilation is very desirable. The benefit of natural ventilation can be maximized by building far apart and by eliminating low vegetation that would block the cooling breezes. Where the priority is protection from the cold winter winds, row or cluster housing is most appropriate.

5.2.7. External Shading

In climates with very hot summers and mild winters, shade is more desirable than solar access.

Multi-storey buildings are built on narrow streets to create shade both for the street and for the buildings. Shadow corridors and solar windows are created in the cities. (Fig. 5.18)

Solar windows are narrow spaces between tall buildings through which the solar beam passes to ground level. Depending on the orientation and spacing of the buildings, the shaft of light may illuminate a patch of ground for only a short time each day. (Marsh, 1991)

Shadow corridors are elongated zones, bordered by a continuous ridge of tall buildings that block the sun. Direct solar radiation is never received in such

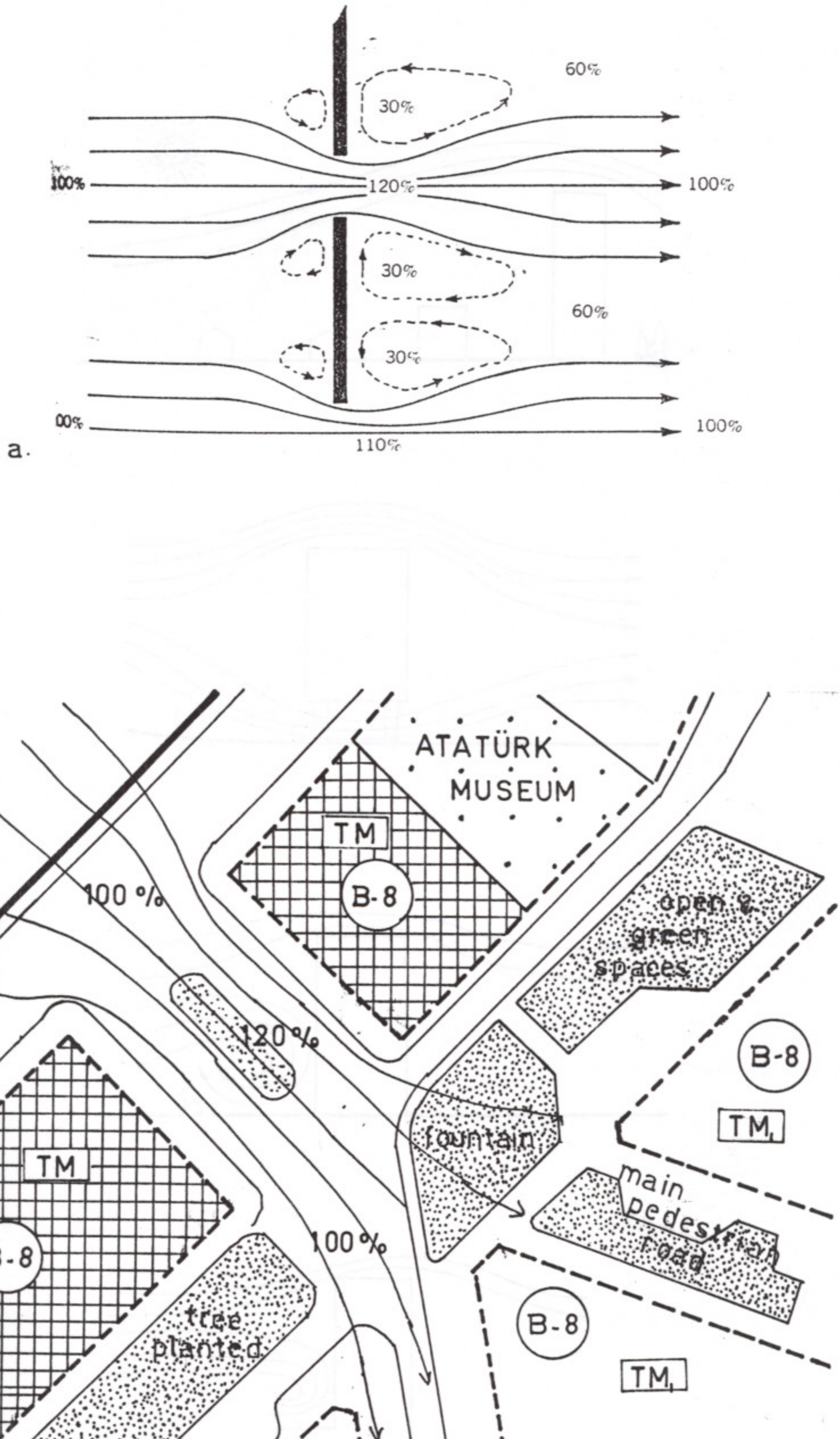


Fig. 5.16 (a) At gaps or ends of windbreaks the air velocity is greater than the free wind (Lechner, 1991; pp:231), (b) an example from Kordon Road, Izmir (scale: 1/1000)

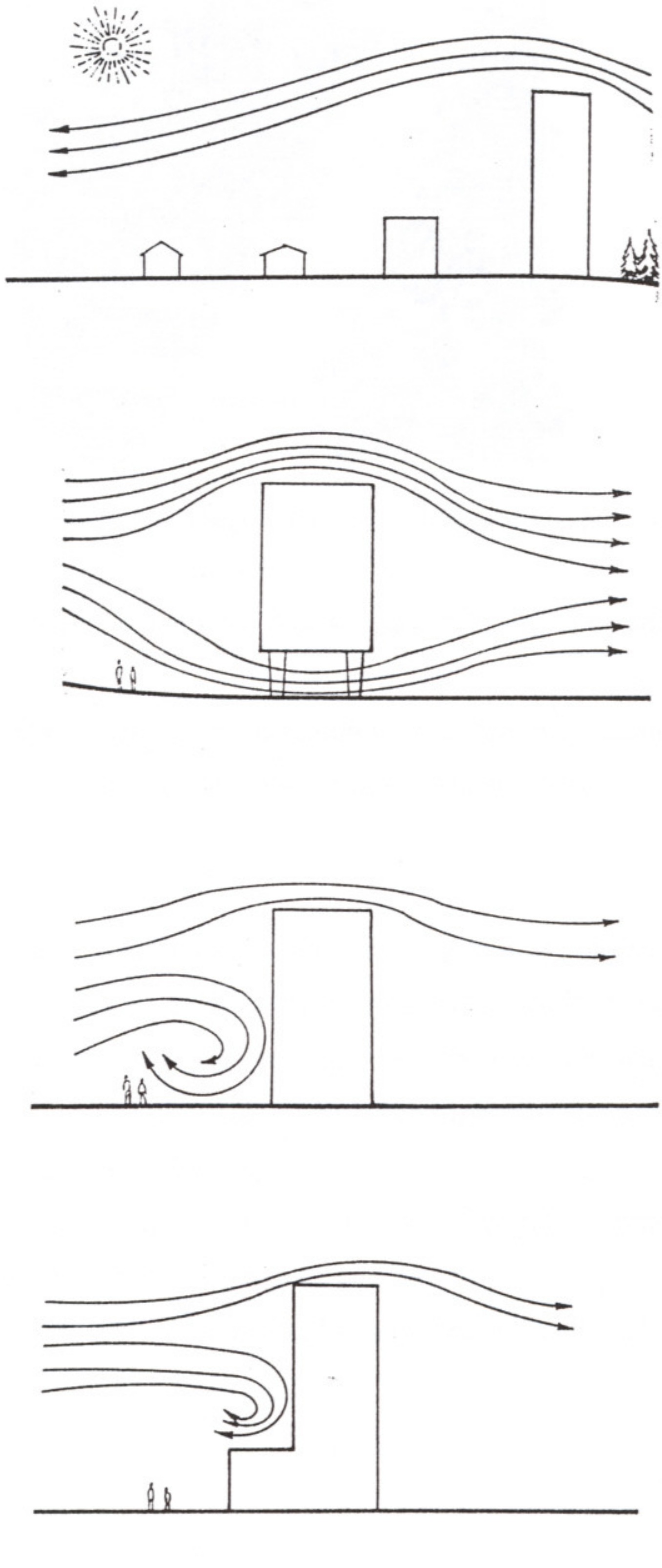


Fig. 5.17 Buildings act as a windbreak (Lechner, 1991; pp:231)

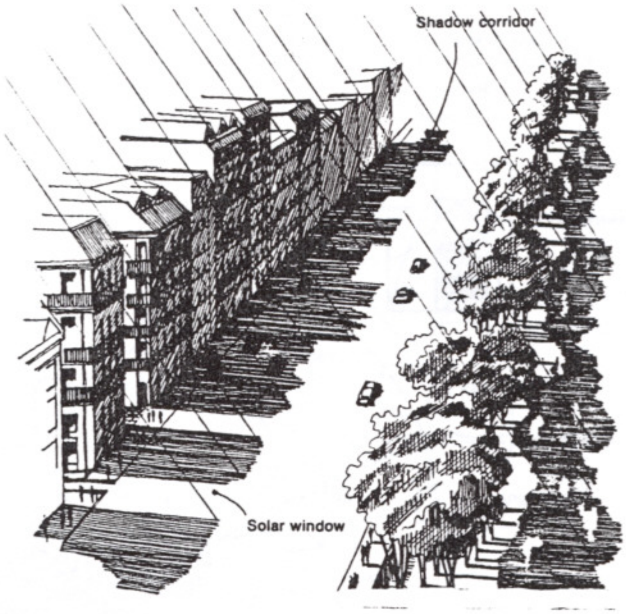


Fig. 5.18 Solar window and shadow corridors (Marsh, 1991; pp:221)

environments the only light comes from diffused sky radiation and radiation reflected from nearby buildings.

The length of a shadow cast by a building or a tree in horizantal surface is a function of the height of the object and the sun angle. (Marsh, 1991)

$$S = \frac{h}{Tan(SA)}$$

This formula is traditionally used in site planning in areas of excessive heat and intensive solar radiation because it is necessary to provide shade in pedestrian areas, parking lots, on building faces, plazas and the like. The need for shade is generally greatest in the hours between 11 a.m. and 4 p.m. when high solar intensities are coupled with high air ground temperature. (Fig. 5.19)

On the other hand, streets can have their own shading systems. Arcades and colonnades are used for protection from rain as well as sun.

Trellis, pergolas and arbors can be used as an outdoor shading elements.

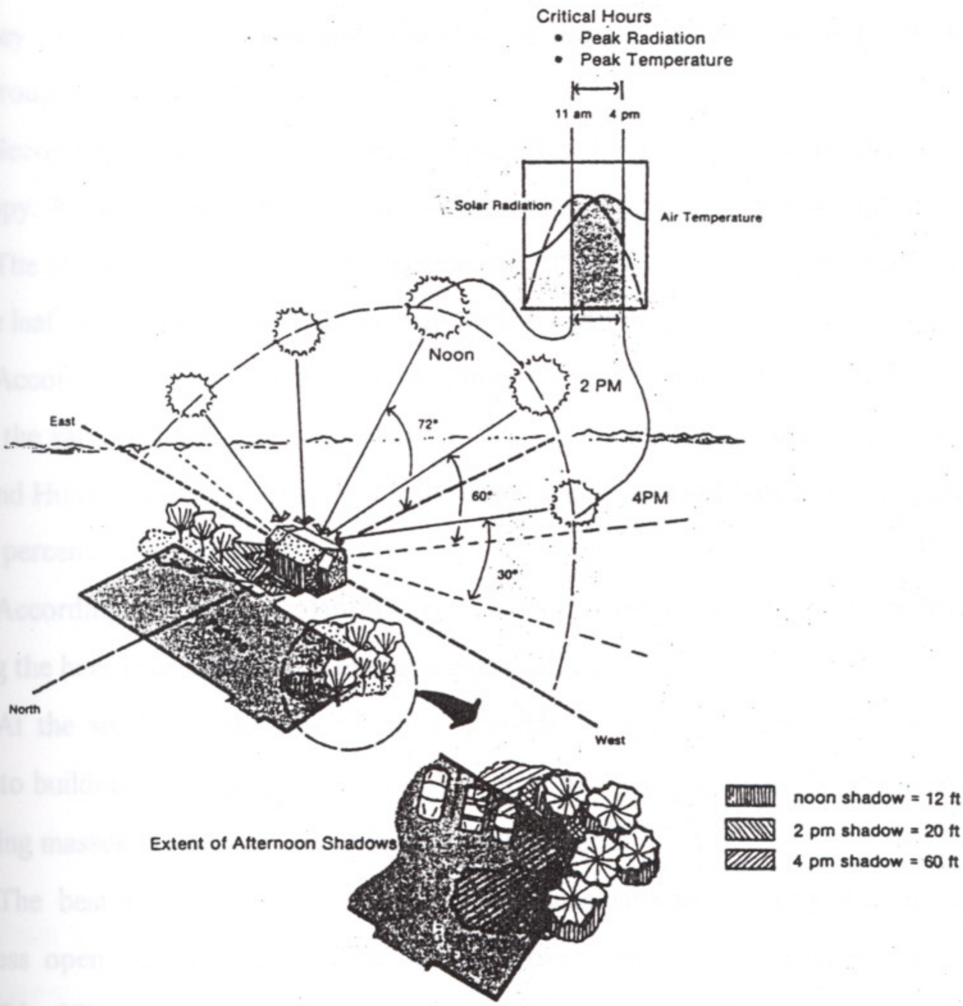


Fig. 5.19 Shadow patterns (Marsh, 1991; pp:223)

5.2.8. Landscaping

Urban areas are several degrees warmer than vegetated areas as most buildings and paving surfaces tend to retain and release more heat and also heating and air conditioning equipment releases a great deal of heat.

Tree cover can moderate this heat island effect, helping to control microclimate in three different ways.

The first way is by absorbing and reflecting solar radiation. " A tree in full leaf intercepts between 60 and 90 percent of the radiation that strikes it, depending on its canopy." (Lyle, 1994; pp:102) This creates a cool shade. And in winter time, a deciduous tree reflects 25 % - 50 %. Thus, clusters of trees can reduce ambient summer temperature in large areas. When placed adjacent to buildings on the south east and west sides, they can reduce incoming solar radiation in summer and if deciduous, allow it to pass thorough in the winter.

Secondly, trees moderate the heat island effect by creating zone of calm air under the canopy. A band of air turbulence occurs around the edges of a tree canopy.

The third way is the cooling mechanism. The release of cooling water vapour from the leaf surfaces of trees through evaporation and transpiration.

According to data developed by Pinkard, (Lyle, 1994) " one large tree can provide the same cooling effect as 10 room-size air conditioners working 20 hours per day.", and Hutchinson added that "...a well placed planting could reduce cooling costs by over 50 percent." (Lyle, 1994)

According to these calculations, tree planting is the most cost effective means of reducing the heat island effect and energy consumption.

At the smaller scale, effectiveness depends on specific location of plants with respect to buildings and other use areas. And at larger scales it depends on the location of planting masses in relation to regional climatic patterns.

The best trees are those that have a dense summer canopy and an almost branchless open winter canopy. The branches even without leaves create significant shade. (30 - 60%)

Trees are more effective than grass in controlling air temperature because they also provide shade along with the evaporative cooling. Shade from trees are more effective that the man-made shade structures. At night it is warmer under trees as trees block the outgoing heat radiation.

When trees are not available, bushes can be used.

Besides outdoor shading structures such as trellis, pergolas and arbors, allees, pleached allees and hedgerows can be used.

Allees are garden walks bordered with bushes and trees. They control air movement. In pleached allees closely spaced trees or bushes form a tunnel like structure. They create cool shady walkways. The hedgerow is a row of bushes, shrubs or trees forming a hedge. Depending on the orientation, they can be used for shading, wind protection or wind funnelling. (Fig. 5.20)

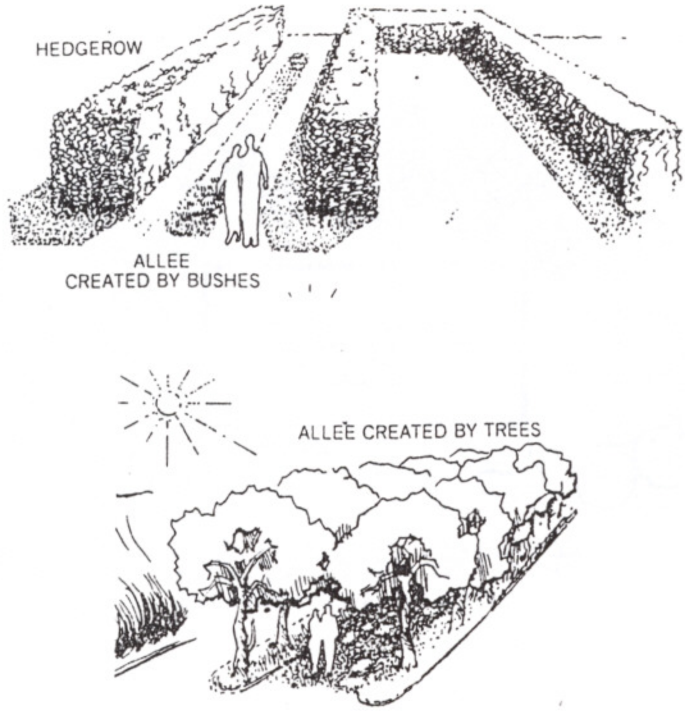


Fig. 5.20 Allees, hedgerows (Lechner, 1991; pp:245)

From figure 5.21 to figure 5.24, landscaping techniques appropriate for four climates are presented. Fig. 5.25 illustrates tree plantation principles in different climates.

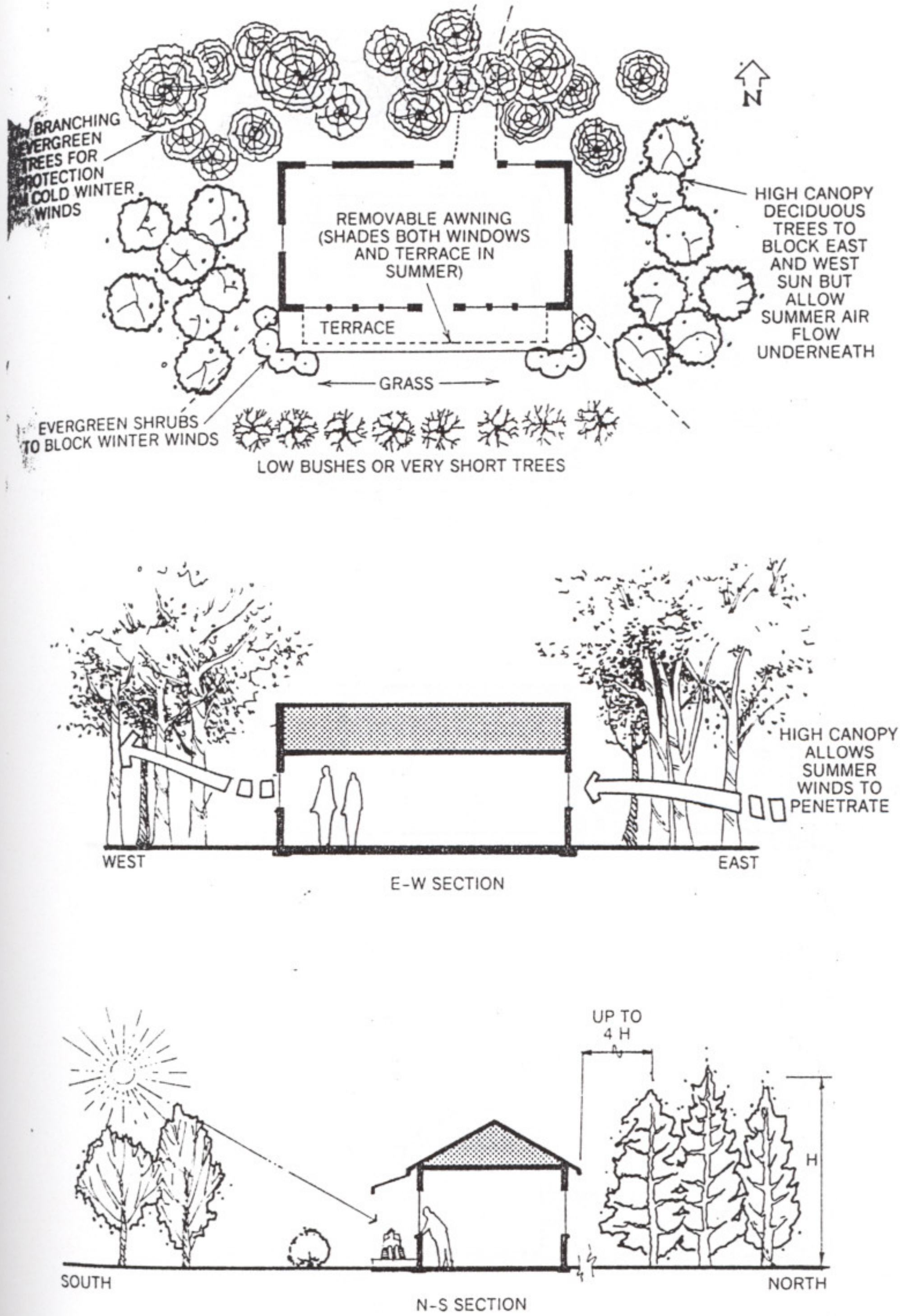


Fig. 5.21. Landscaping technique for a temperate climate (Lechner, 1991; pp:241)

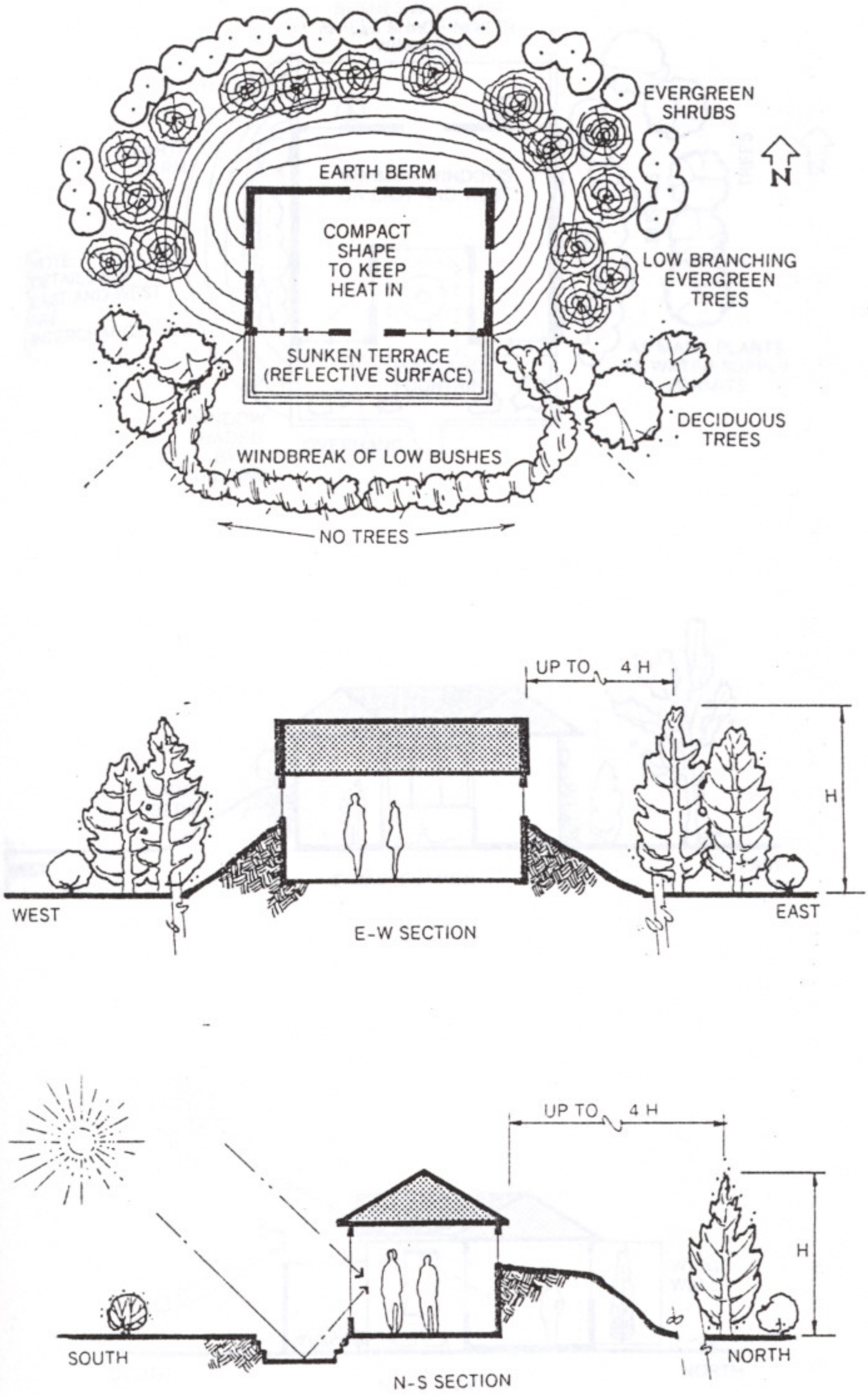


Fig. 5.22 Landscaping technique for very cold climate (Lechner, 1991; pp:242)

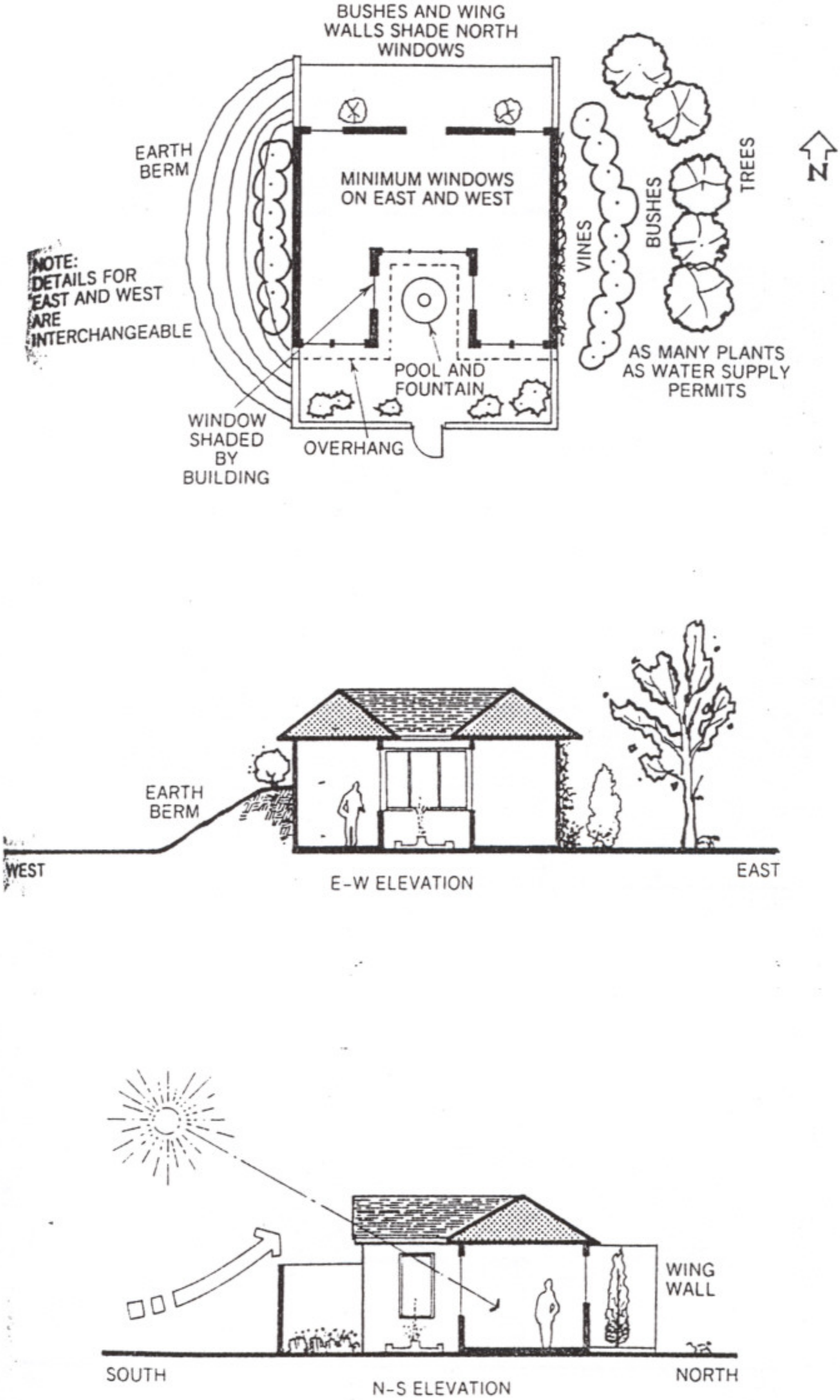


Fig. 5.23 Landscaping technique for hot and dry climate (Lechner, 1991; pp:243)

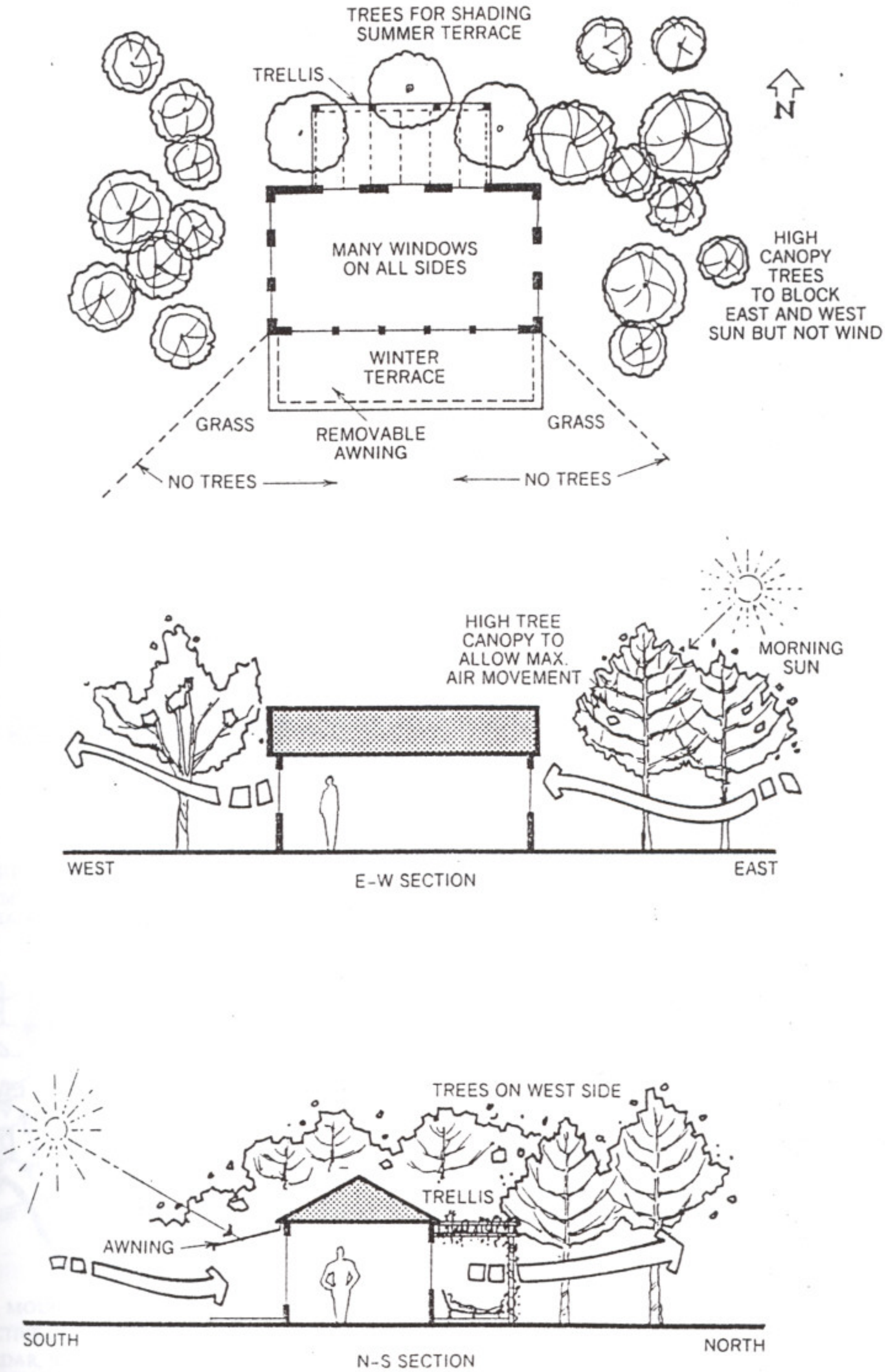


Fig. 5.24 Landscaping technique for hot and humid climate (Lechner, 1991; pp:244)

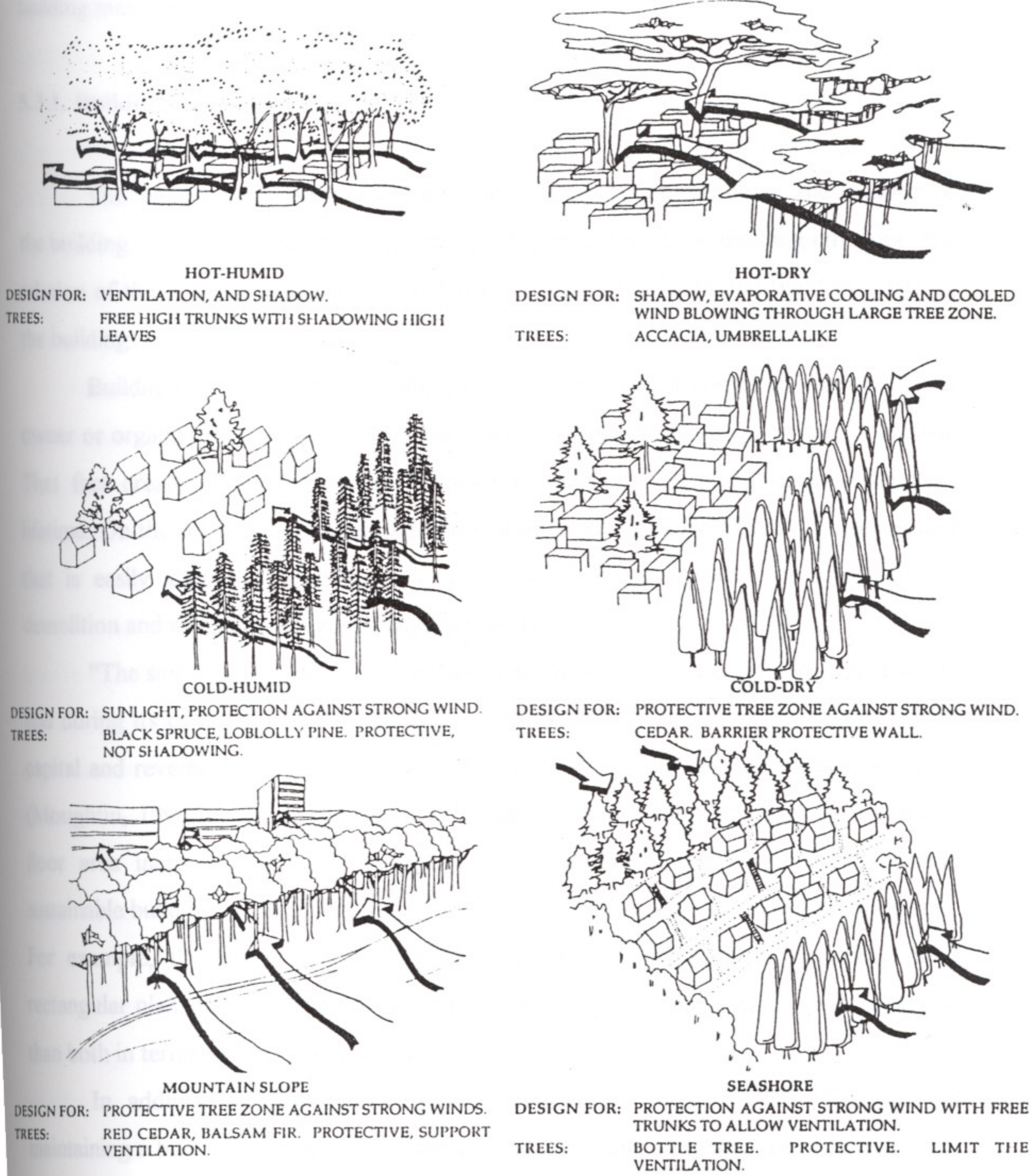


Fig. 5.25 Tree plantation principles (Golany, 1995; pp: 168)

5.3. The Variables of Energy Efficient Urban Design - Building Scale

The variables related to building scale are; building geometry, building form, housing types, utilization of sun, openings, ventilation and cooling, shading, lighting, and building materials.

5.3.1. Building Geometry

The energy efficiency consideration in building design can be as; the location of the building in relation to the means of access, the geometry of the building envelope, the relation of the building to its site and the ways in which the users and builders relate to the building.

Buildings that are usually designed to meet the requirements of one particular owner or organization, become specialized and they accommodate specialized activities. That fact creates difficulties while adapting buildings to changing needs during its lifetime. On the other hand, a building that can be used for many different purposes and that is easily adopted to serve many activities, eliminates or reduces the need for demolition and rebuilding to serve changing needs.

"The sustainable building is one which uses least capital energy in its construction and during its occupation has minimum energy revenue requirements. Both the energy capital and revenue costs of the building are related to its geometry in a similar way." (Moughtin, 1996; p:29) As the ratio of the area of the building envelope to the usable floor area increases, both types of energy costs tend to increase. Therefore, the sustainable building is one where its envelope is the smallest for a given usable floor area. For example, the single-story square plan has an advantage over the exaggerated rectangular plan shape. However, two, three and four story buildings are more effective than both in terms of energy conservation.

In addition to Moughtin's statement, Knowles suggests that "the cost of maintaining a built arrangement is a function of the amount of energy required to sustain the desired steady internal state while the external environment goes through its cyclic variations." (Knowles, 1974; pp:63) In order to explain his statement he uses the terms "stress" and "susceptibility". Stress can be measured in terms of the amount of energy necessary to maintain the built arrangement and the amount of maintenace energy is a function of the variation in force effect upon the arrangement. And the term susceptibility can be described as a function of the ratio between exposed surface and contained volume. The more the exposed surface for the contained volume, the more susceptibility the arrangement. This surface-to-volume ratio (S/V) or the coefficient of susceptibility can be correlated with the stress range on a site.

The correlation between size and S/V can be explaines by an expanding cube. A unit cube, -ones face in contact with te ground- exposes five unit surfaces, while its volume is one, thus S/V = 5. If the edge dimensions of that cube are doubled, then S/V =2,5 (its surfaces total 20, volume is 8). According to those ratios, it can be said that the smaller cube is more susceptible to environmental stress than the larger as big things have smaller surface-to-volume ratios than small things.

When the cubes are rearranged into eight unit volumes, that will produce a higher S/V in each case. For example, if the eight unit volume is arranged in a row so that eight faces are in contact with the ground plane, then S/V is 3,25. (Fig.5.26a) And if they are rearranged into a tower shape, then S/V =4,12, which is higher than the row and the cube of equal volume.

In addition, complexity of a shape also affects S/V. Complex shapes generally have a higher S/V. (Fig.5.26b) So size and shape together determine the coefficient of susceptibility by determining S/V. "Large and simple shapes have a lower S/V and are less susceptible. Small and complex shapes are much more susceptible, with a higher S/V." (Knowles, 1974; pp:67)

5.3.2. Building Form

Building form has an important effect on energy efficiency and building morphology can significantly reduce the heating load. Controlling the heat balance of a building is a matter of guiding the reflection, absorption and release of heat and the movement of the air. And the building forms guide this flow of energy in different ways.

For example, a rectangular shaped house with the length not more than 1,5 times the width and elongated the east-west direction would minimize heat loss in winter and overheating in summer. (Garg, 1987) This is because of that east and west faces receive more radiation in summer and should have less area while south faces receive more radiation in winter and should have larger area.

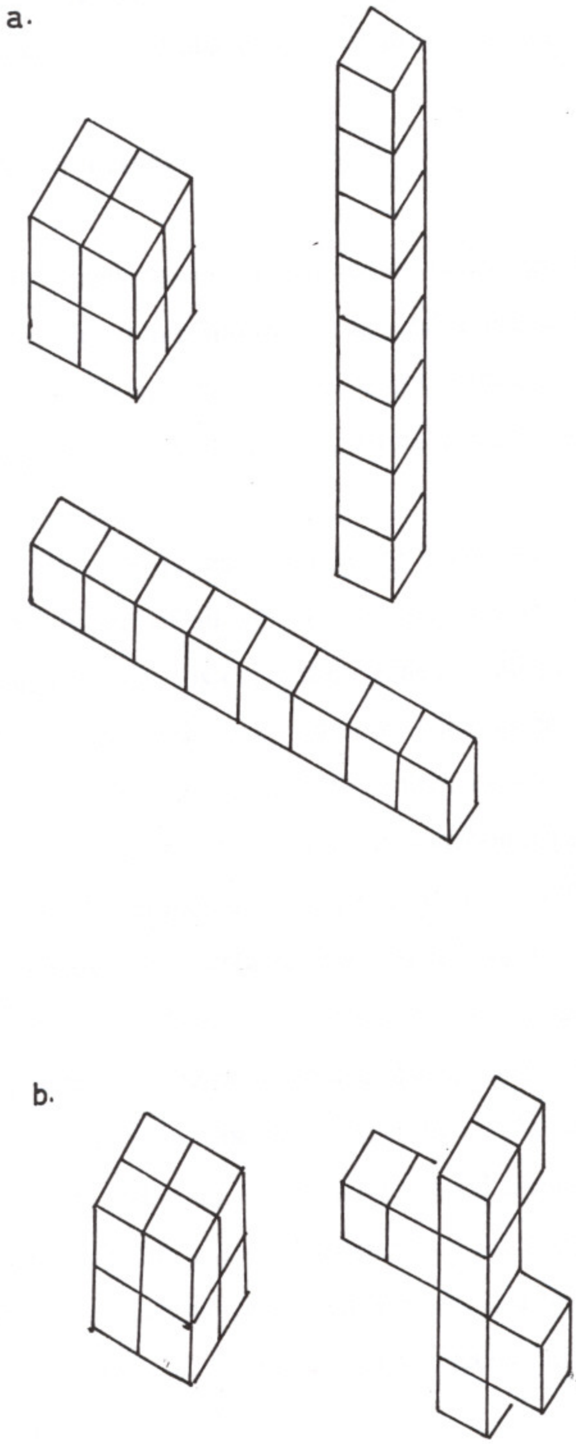


Fig.5.26.(a) The shape of the formhas an effect on its surface-to-volume ratio
(b) Simple shapes generally have a lower surface-to-volume ratio

And also multi-storeyed buildings should be preferred than the single storied building with the same volume since it would have less exposed area and therefore comparatively less heat loss. If a part of the building is sunken in the ground, it will also be energy efficient, since the temperature in the underground at a 3m. depth remains constant and is generally equal to the annual average of air temperature. (Garg, 1987)

5.3.2.1. Building Forms As Archetypes

Three basic forms as archetypes use the principles of energy flow in three quite different ways. Each type developed in response to the need to create living space within specific climatic conditions, works in ways quite different from each other. (Fig. 5.27) Together, through the shaping of shelter, they illustrate a wide range of means for controlling energy flow.

The first building form is the raised structure, or building on stilts. The strategy of this form is to allow movement of air all the way around the structure. When the structure is raised, a shaded cool zone is created underneath and this helps to keep the floor of the building cool and serves also as an outdoor living space. Air moving around the structure helps to prevent pockets of warm air from forming and the movement of air generally keeps the structure somewhat cooler than its surroundings. Raised structures are most commonly found in the tropics as they are much more effective in creating a cooler interior in a warm climate than in creating a warm interior in a cool climate.

The second form is the earth-sheltered structure, which is dug into the earth becoming part of it and sharing in its thermal balance. These structures use the earth as a kind of thermal governor. A few feet below ground level, the temperature is fairly constant at about 12° to 15° C and being below ground level creates an insulation from temperature extremes. In that frame, the earth sheltered structures are able to release heat to the ground through conduction when their interiors are warmer and draw heat from it when they are cooler. These structures are most effective in areas where climatic extremes either very hot or very cold or both.

The third form is the sunspace, which is a portion of a building specifically shaped to collect and store solar radiation. The sunspace works like a greenhouse. It has a sizable area of south facing glass through which short-wavelength solar radiation flows when the building needs warming. (Lyle, 1994)

These all archetypes represent a distinctly different means of controlling energy flow. However, they can be combined in one structure. A structure on stilts can incorporate a sunspace or at least use the sunspace principle in providing south facing glass for its interior spaces. Shortly, these three basic concepts of energy / earth forms can be used in various ways and almost unlimited combinations. (Lyle, 1994)

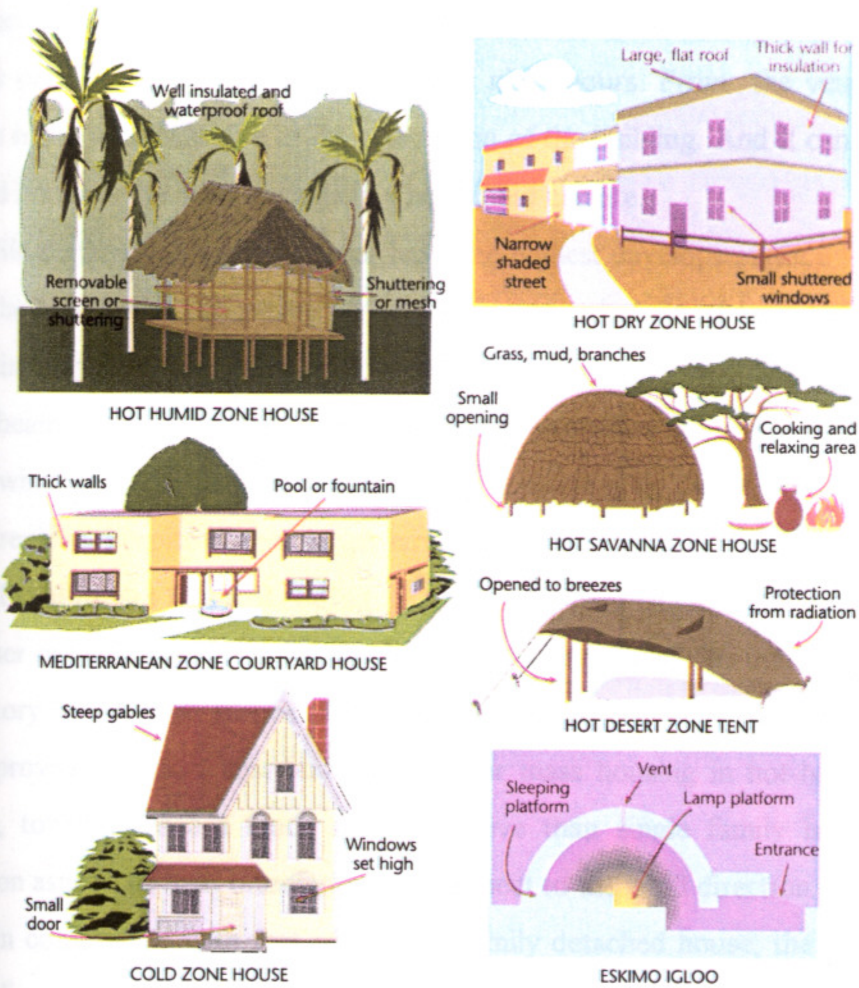


Fig. 5.27 Housing in different climatic zones (WMO, 1996; pp:17)

5.3.3. Housing Types

Another variable of energy efficient urban design is the housing types. There is a considerable effect of housing types in providing natural ventilation, orientation, etc. Different types of housing represents different sensitivities to the climatic features.

The housing types and their properties which are to be given in this subtitle are explained in the context of hot-humid and hot-dry climate conditions.

Detached Single Family Houses: Detached houses, exposed to the outdoor air on all sides, provides good potential fo rnatural ventilation. For a given thermal resistance of the envelope the expected indoor comfort during the daytime hours would not be worse than in more compact buildings. A detached house will cool down faster than other types of buildings, providing better comfort when the outdoor wind usually weakens or subsides during the evening and night hours. From the ventilation aspect, this type is the least sensitive to the orientation of the building. And it can be said that, a detached house is the most suitable in a hot humid climate.

Single family detached houses have the highest envelope surface area among the various building types. Therefore, in hot dry regions, the rate of temperature rise during the daytime hours in single family houses is the fastest. So this building type exhibit the highest heating load in winter. Being less sensitive to orientation with respect to the sun and the wind direction, detached single family house may be the most appropriate type in hot-dry regions, in spite of their larger envelope surface area.

Townhouses (Row Buildings): A set of several single family units, attached to each other on their sidewalks, forms a row of dwelling units. The units can range from a single story up to three stories. From the climatic aspect, after detached houses, town houses provide the next best building type for mass housing in hot-humid regions. In addition, townhouses are much more sensitive than single family houses, from the ventilation aspect, to their orientation with respect to the wind direction.

In comparison with that of a single family detached house, the exposed area of the building envelope is smaller. In a hot dry climate this factor reduces the rate of temperature rise during the daytime hours, while if the building is designed for effective cross ventilation, its cooling rate in the evenings may not be affected by the fact that the dwelling has only two external walls. In hot-dry climate, a north-south orientation for the external walls will minimize the exposure of the townhouse to the sun in summer and maximize its potential for solar heating in the winter.

Multi-Story Apartment Buildings: Multi-story apartment buildings have the smallest surface area of the envelope of all building types. Therefore their rate of heat gain in summer and of heat loss in winter is also the lowest. However, multi-storied apartment buildings may present difficulties in providing cross ventilation. (Cook, 1991)

5.3.4. Utilization of Sun

Utilization of sun is another parameter for energy efficiency. In order to improve the comfort of the inhabitants indoors and outdoors and to reduce the energy demand of the buildings for heating in winter and for cooling in summer, the achievement and the regulation of solar access is significant.

Buildings can act as a barrier for solar access and air movement because of their heights, their locational relation with each other and the distances between them. On the other hand, two factors influencing building interaction are slope and orientation. A particular slope and orientation characteristics form an area of influence. When the slope increases, the area of influence increases in dependent of orientation.

Knowles suggests that "The area of influence, which is based on a unit height, must be converted into a dimensional relationship between height and the area influenced. This is done by means of the height-to-area ratio (H/A). This conversion required several descriptive steps leading to a building increment." (Knowles, 1974; pp:77)

A land increment can place some initial limitations on the plan dimensions of the building increment. But another requirement would be a height limitation. While the development of building, height criteria may seem unnecessary. However, what seems reasonable is that buildings should not shade each other unduly. The result is a height-to-area ratio (H/A) that limits building height and area of influence as a function of slope and orientation. Within the height and area limits of building increment, buildings may be placed in relation to one another. The ultimate purpose is to produce a system that represents some balanced response to nature.

5.3.4.1. Distance Between Buildings

It can be said that, besides building heights, the utilization of the solar radiation as passive heating or air conditioning is also the function of open spaces between buildings. When sun radiation strikes to a surface, then there occurs a shaded area. The dimensions of that shaded area alters according to the sun angle. If the preferred condition is receiving maximum direct solar radiation then the distance between buildings should be equal or more than the highest depth of shaded area.

On the other hand, varying of angular position of the sun with respect to the directions, the acceptable distances between buildings differ in accordance with the orientation of the buildings.

Tha alteration of the distances in the direction of prevailing wind, also differs the velocity of the wind that affect the building facades. In that case, the distance between buildings should be determined also by considering the wind velocities which affects the building facades.

A method in determination of suitable distances between buildings:

To receive maximum direct solar radiation, the distance between buildings should be equal or more than the highest depth of shaded area. The shaded facades are only under the effect of diffused solar radiation. Unshaded facades receive both the direct and diffused solar radiation. (Ak, 1994)

The factors in determining the distance between buildings are:

- latitude
- climate
- site orientation
- topography, slope angle
- orientation
- building form and heights
- profile angle

The method is;

1. Determination of the characteristics of the day which the heating is preferred,

2. Determination of the profile angles,

3. Evaluation of the depth of shaded area,

In evaluating the depth of shaded area (u); the latitude and the height of the building is used for any time of the day. (Fig. 5.28)

$u = \cot\Omega \,.\, h$

In sloped areas, the depth of shaded areas is evaluated according to the orientation of the site and facades, time and profile angle and also heights of back and front facades. In addition to that, the shade which the buildings create perpendicular to the slope direction shold be evaluated.

The evaluation of the shaded area with respect to the front height: (Fig. 5.29)

Ω = profile angle

h_f = front height

h_b = back height

s = angle of the slope

u = depth of shaded area

$\tan s = a / u \qquad a = u \,.\, \tan s$

$\tan \Omega = b / u \qquad b = u \,.\, \tan \Omega$

$h_f (b-a) = u \,.\, (\tan \Omega - \tan s)$

$$u = \frac{1}{(\tan \Omega - \tan s)} \,.\, h_f$$

If $s = \Omega$ then $u = \infty$

If $s > \Omega$ then $u = \infty$ (Fig. 5.30)

When the depth of the shaded area is evaluated according to the back height;

$$u = \frac{1}{(\tan \Omega + \tan s)} \,.\, h_b$$

Determination of the proper values for distances between buildings:

Proper values for distances between buildings should be defined in accordance with the depth of shaded area. The limit values can be defined according to the direct solar radiation which affects the surfaces during the hours after sun rise.

Profile angles, which alters according to the hours, also changes the depth of shaded area with respect to the each direction (N-S, NNW-SSE, NW-SE, WNW-ESE, W-E, WSW-ENE, SW-NE)

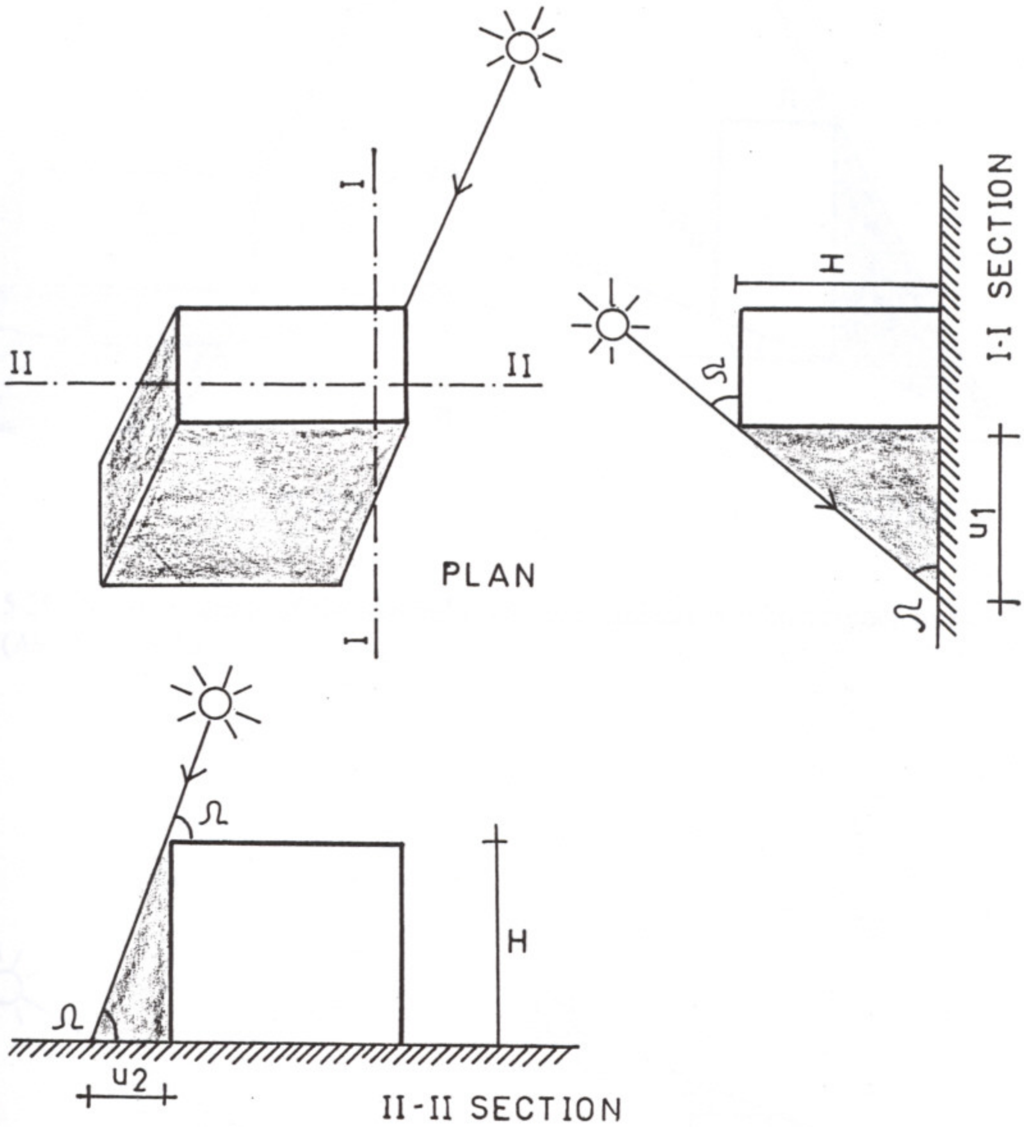


Fig. 5.28 Evaluating the depth of shaded area (Ak, 1994, pp:52)

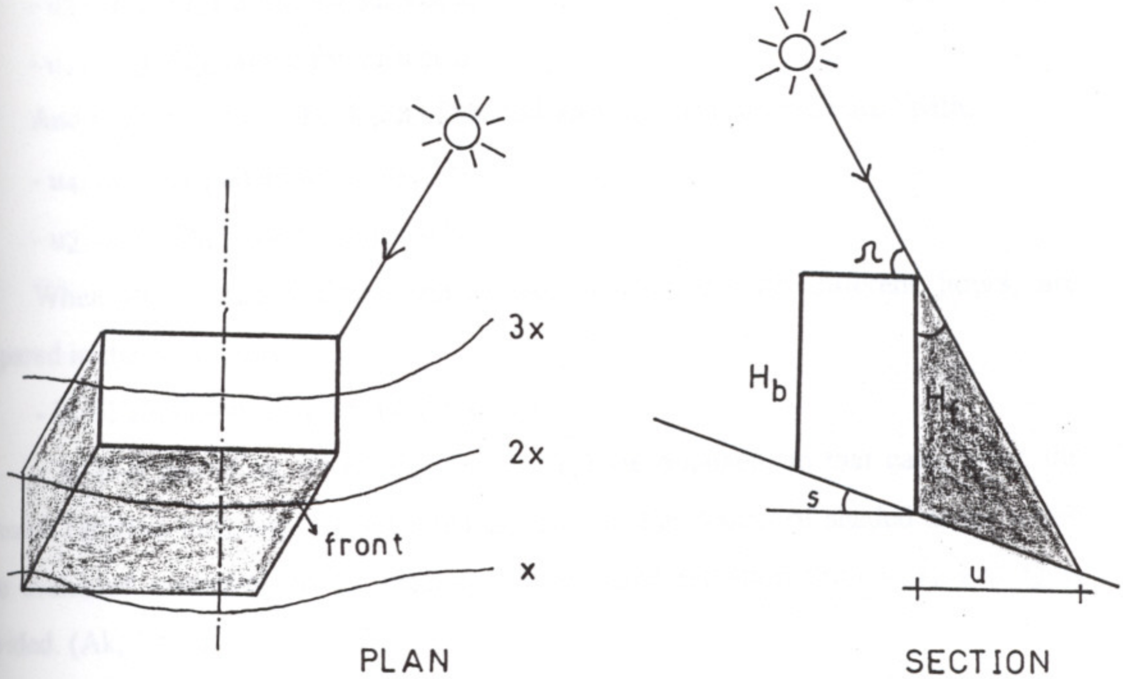


Fig. 5.29 The evaluation of the shaded area in sloped areas with respect to the front height (Ak, 1994, pp:53)

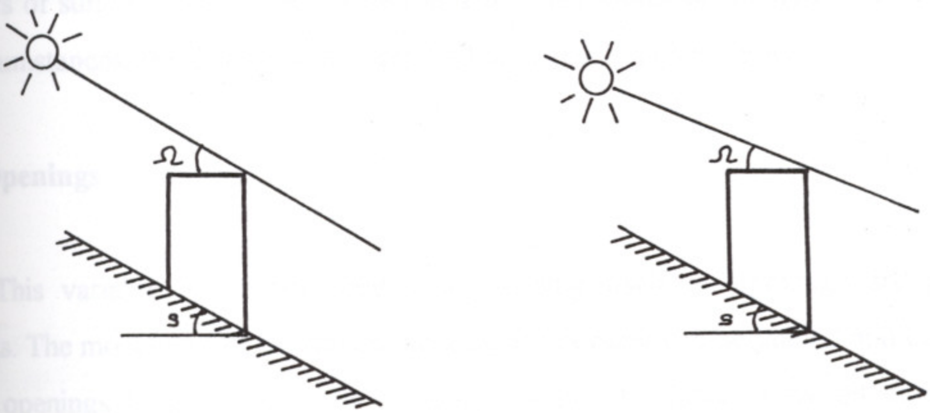


Fig. 5.30 The condition of having infinite shade (Ak, 1994, pp:54)

As it is shown in the figure 5.31, in I-I section, the depths of shaded area (u_3, u_1) can be evaluated with;

- u_3, in t_1, Ω_{a1} angle for surface a;

- u_1, in t_2, Ω_{a2} angle for surface a

And in II-II section, the depth of shaded area (u_4, u_2) can evaluated with;

- u_4, in t_1, Ω_d angle for surface d

- u_2, in t_2, Ω_b angle for surface b

When these shaded areas, which were evaluated with different hours, are compared in the conditions of;

- In I-I condition, u_1 (in t_2) > u_3 (in t_1)

- In II-II condition, u_2 (in t_2) > u_4 (in t_1) are obtained. In that case, when the distances between buildings are accepted as equal to the depths of shaded areas which were evaluated according to t_2, receiving direct solar radiation both in t_1 and t_2 is provided. (Ak, 1994)

The day-hour number of receiving direct solar radiation of the surfaces which are oriented towards different directions, differs according to the directions and the days.

Being under the effect of solar exposure when the intensity of the direct solar radiation is maximum, is preferable from the point of heating economy, in cold and cool climate regions. However to provide that maximum solar radiation, the depths of shaded area and so the distances between buildings should be determined in accordance with the lowest profile angles. The profile angles for E, ESE and SE directions should be taken in the hours of sun rise and for W, WSW, and SW directions, in the hours of sun set. In that circumstances, the distances between buildings reach higher values.

5.3.5. Openings

This variable is directly related to building itself as openings are parts of buildings. The movement of air, thus of heating and cooling can be guided and controlled by the openings in a structure. Air movement can be induced by either pressure differences or temperature differences. Therefore, the significance is the movement of air. Air movement both in indoor and outdoor has relationship with each other. However, in this subtitle, interior air movement is considered.

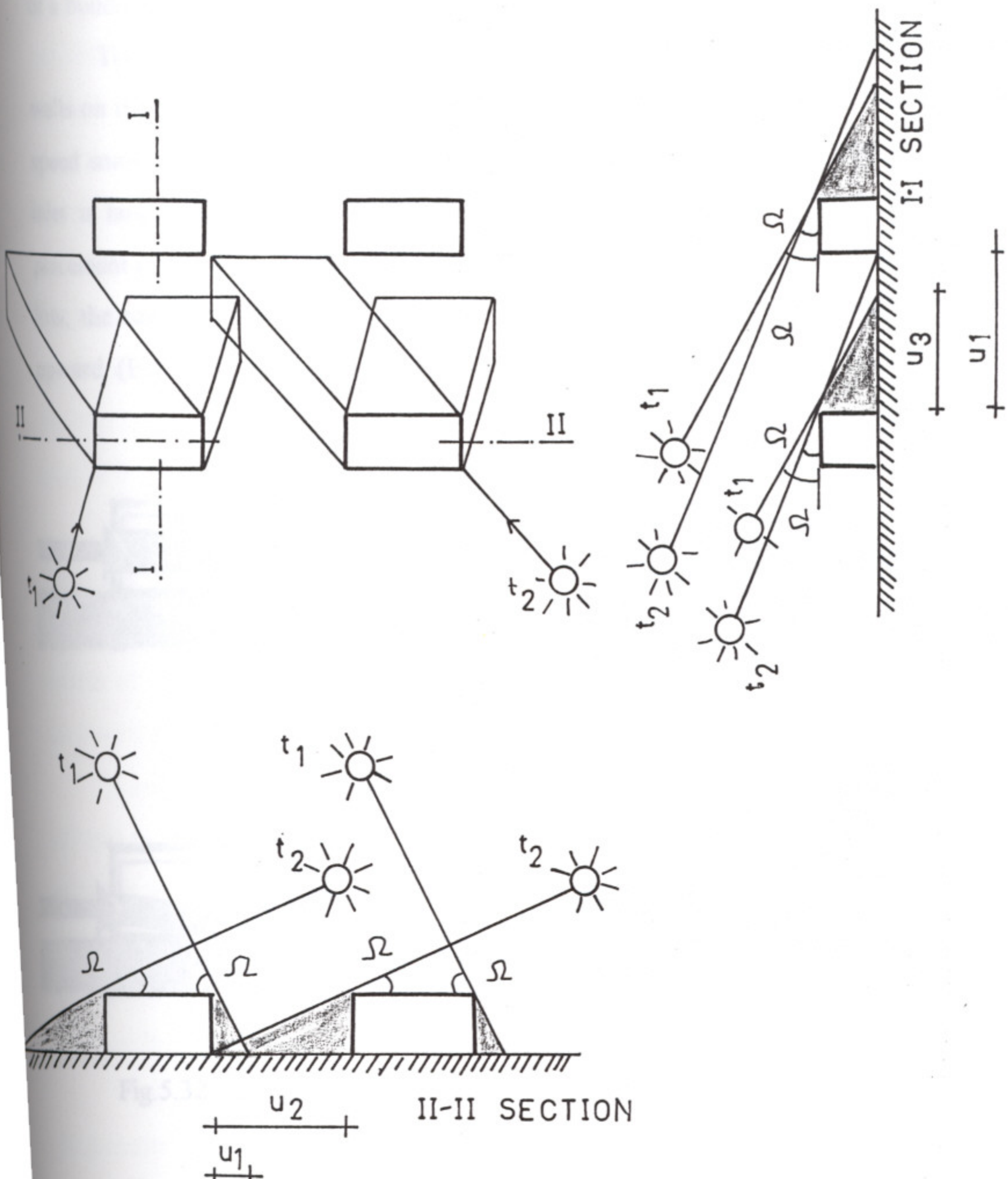


Fig. 5.31 Alteration of the depth of shaded area according to the different hours
(Ak, 1994; pp:56)

"The most common condition of interior air movement is cross-ventilation, in which the movement of air is enhanced by the built up of pressure on the windward side of a building relative to the low pressure area on the leeward side." (Lyle, 1994; pp:108)

The difference in pressure causes movement of air if openings are located in the walls on the two opposite sides. The volume of air flowing through will be large and its speed somewhat greater than the inlet, if the openings are large and equal in size. If the inlet is larger than the outlet, the flow will tend to dissipate between the two. The placement of the inlet is much more important than the outlet. If the placement of inlet is low, the result is downward movement of air. A higher placement causes air to move upward. (Fig.5.32)

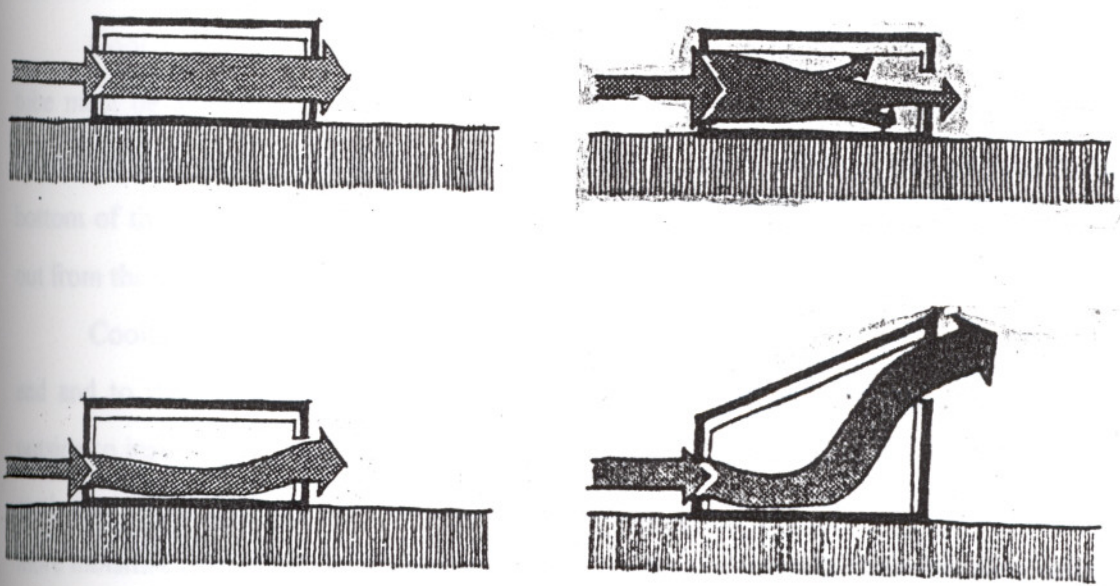


Fig.5.32 Interior air movement (Lyle, 1994; pp:108)

The other principle of air movement is that of warm air rising. The air tends to move from bottom to top, when inlets are located close to the ground and outlets located high. the greater the height difference and the larger the temperature difference, the faster will be the air movement. Heat chimneys are extreme examples of the applications of this basic principle. The high ceilings commonly seen in warm climates follow the same principle.

5.3.6. Ventilation and Cooling

In the previous subtitle, the principles of air movement related to interior ventilation are explained. Thus, in this part, the architectural forms that use these principles of interior energy flow to induce cooling effect are going to be mentioned.

Windscoops, which were already used several thousands years ago in Egypt and are still found in the Middle East today, are used to maximize ventilation. When there is a strong prevailing wind direction, the scoops are all armed in the same direction. (Fig. 5.33) In areas, where there is no prevailing wind direction, windtowers with many openings are used as in Dubai on the Persia Gulf. The mashrabiya is another wind-catching feature in the Arabic Middle East. (Fig. 5.34) These delicate wood screens kept most of the sun out yet allowed the breeze to blow through. (Lechner, 1991)

Cool tower are large vertical tubes used to cool outdoor or indoor spaces. the tube must be at least 25 feet above ground. In the top of the tube, there is a water-soaked air fitter that cools air that passes through it. After cooling, the air falls to the bottom of the tower, where it flows out through a large opening. The cool air spreads out from the opening to cool the surrounding space. (Fig. 5.35)

Cooltubes are buried in the earth and open to the interior of a structure at one end and to the outside air at the other. As air moves through the tube, pulled from outside to inside either by a fan or by a flow induced by rising warm air, the surrounding earth cools it through its own relatively constant temperature. Since warm air can hold more moisture than cool air, it loses water on the journey through the tube, thus helping to reduce humidity within structure.

These are simply long tubes which are usually 8 to 24 inches diameter. However, the diameter and length of the tubes depends on the calculated need for cool air within the structure.

a.

b.

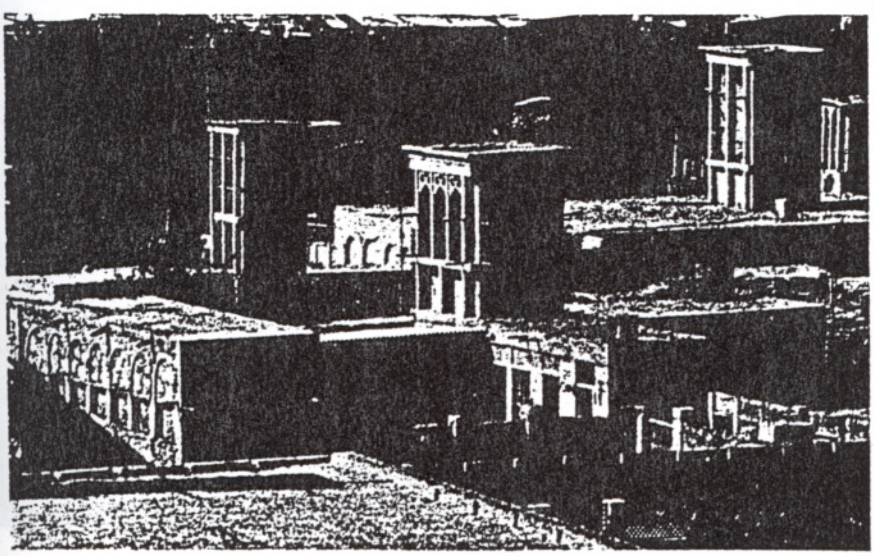


Fig.5.33 The windtowers in Hyderabad, all face the prevailing wind and the windtowers in Dubai, catching the wind from any direction. (Lechner, 1991; pp:175)

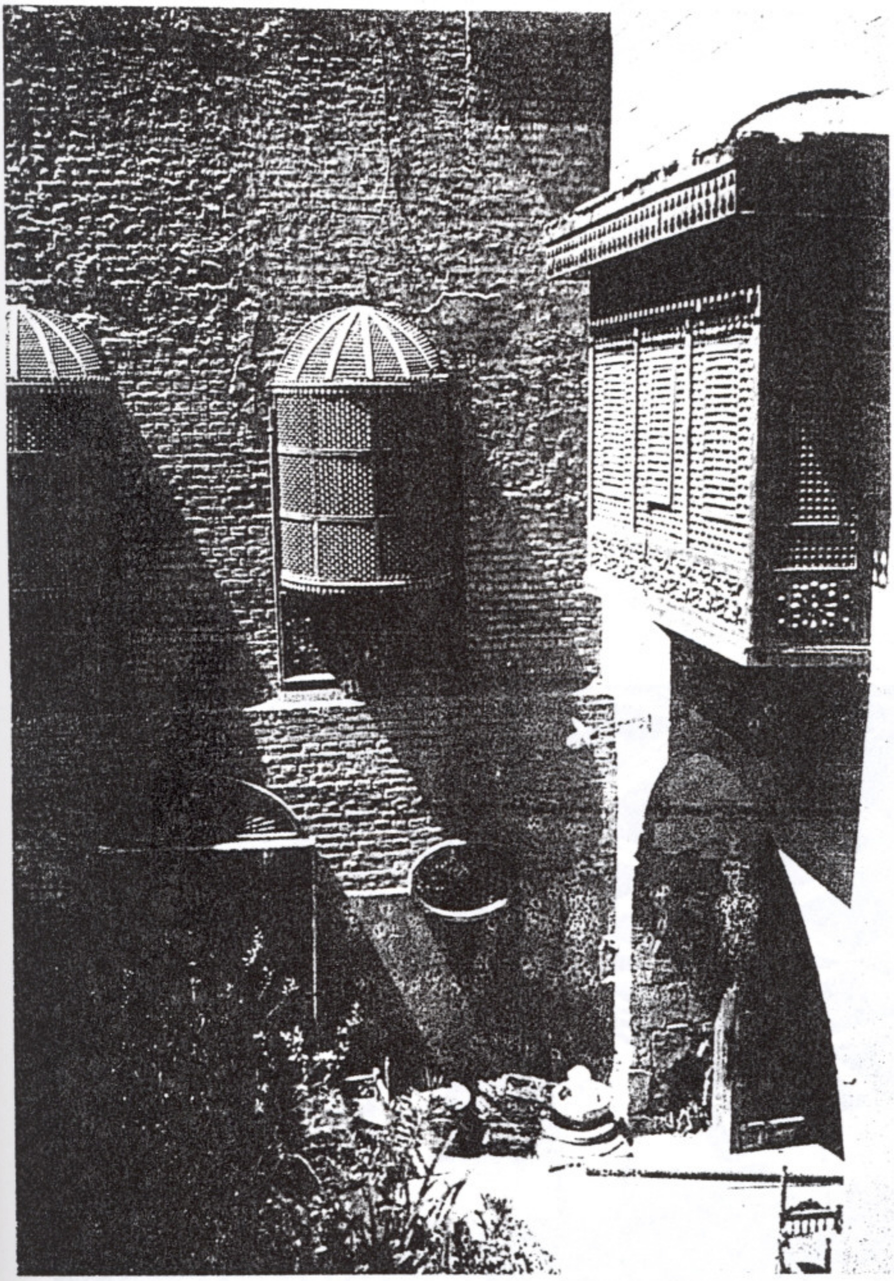
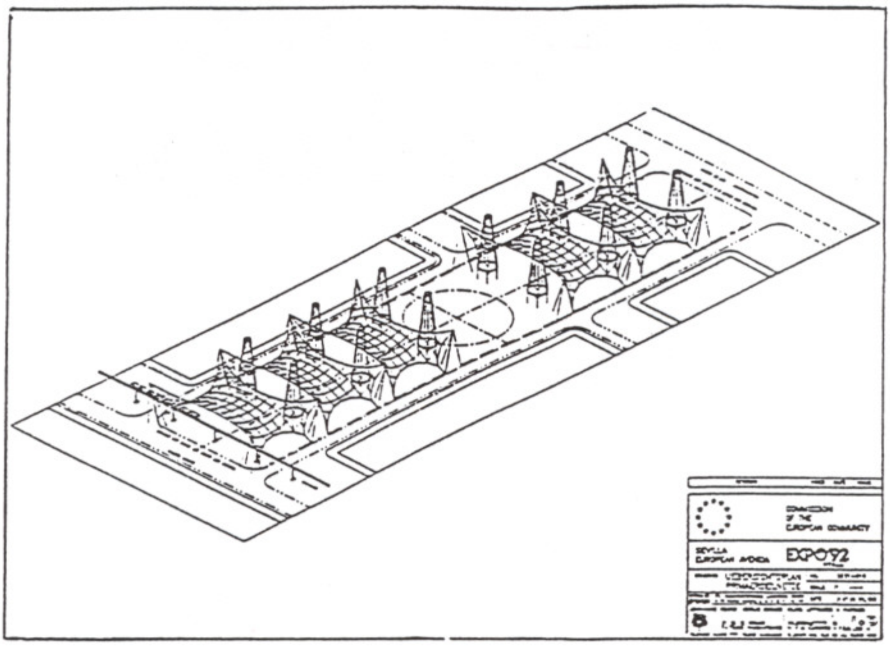


Fig. 5.34 The mashrabiya, Cairo, (Lechner, 1991; pp:176)

(a)



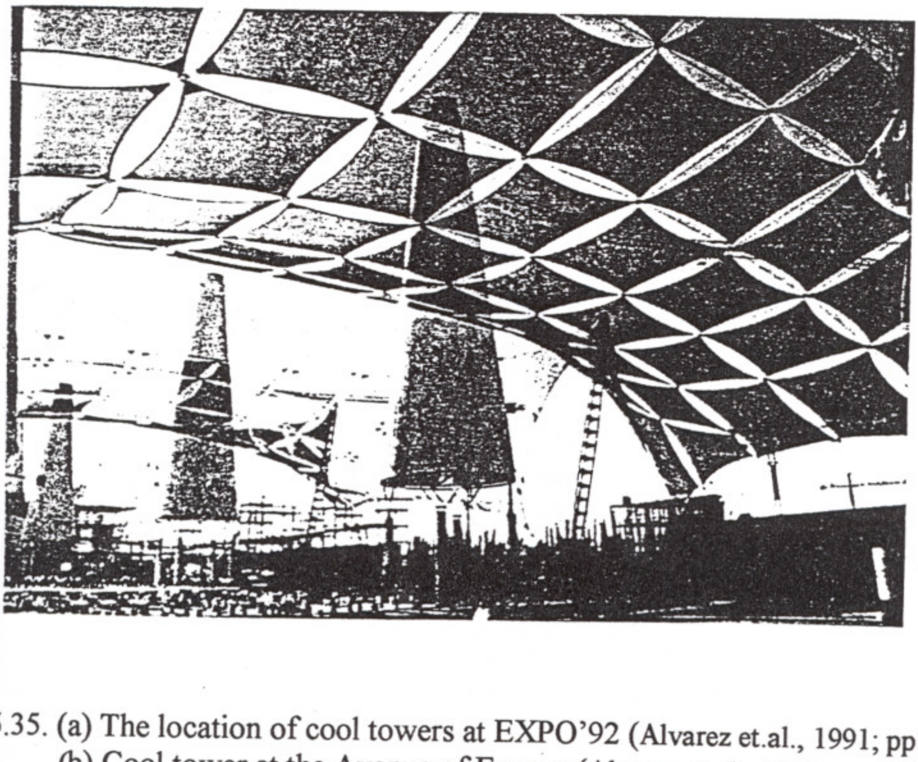
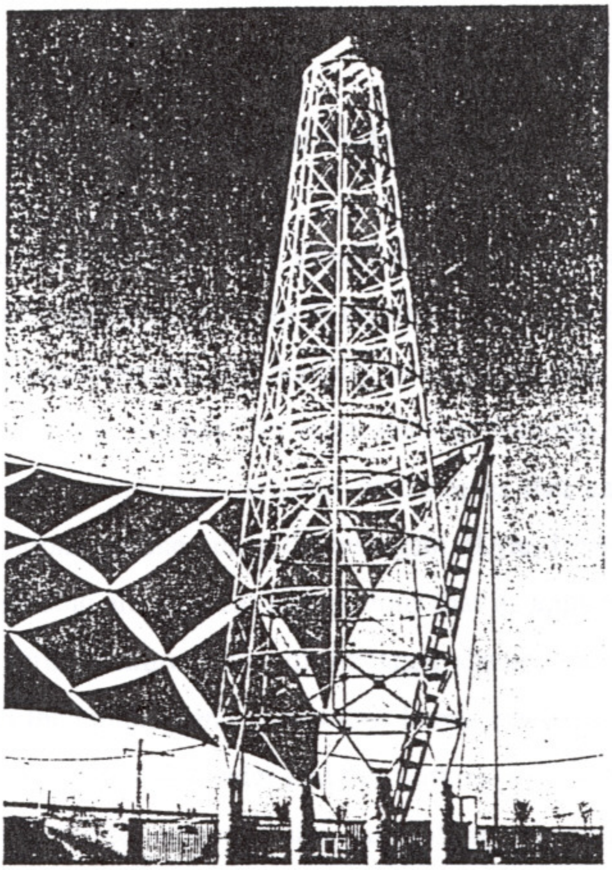


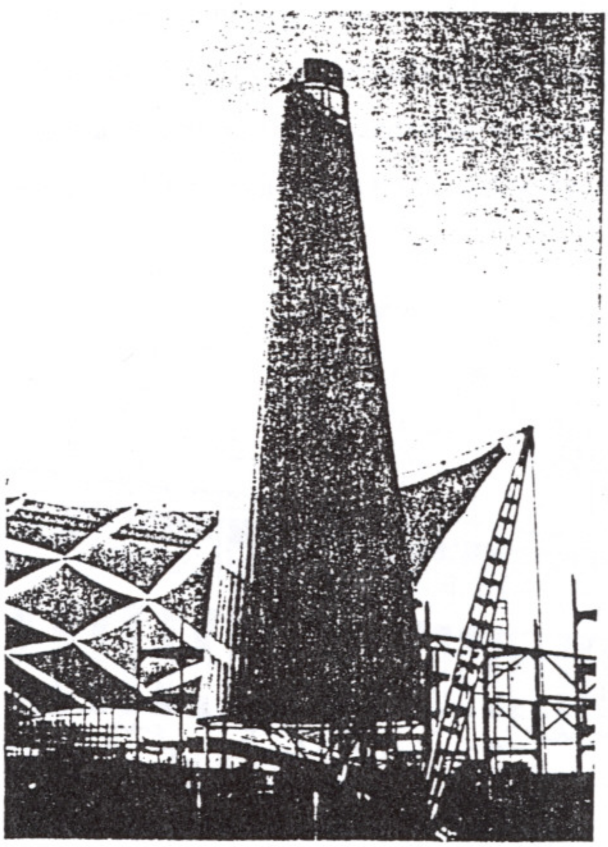
Fig. 5.35. (a) The location of cool towers at EXPO'92 (Alvarez et.al., 1991; pp:196)
(b) Cool tower at the Avenue of Europe (Alvarez et.al., 1991; pp:197)

(cont. next page)

(Fig. 5.35. continue)

(b)





5.3.7. Shading

Shading is mentioned before as external shading. In this subtitle, it is going to be explained at building scale.

There are times, when the heat gain should be maximized, and times, when it should be minimized, and a great many times in between. It is possible to design fixed overhangs and other shading elements of a building to allow the sun to shine in during the winter and exclude it in the summer. Movable shading elements can provide much more flexible and responsive control. Overhangs or canopies that can be retracted or removed to different positions for fine tuning the heat gain. (Lyle, 1994)

The benefits of shading are so great and obvious that its applications can be seen throughout history and across culture. Many of the larger shading elements had the dual purpose of shading both the building and an outdoor living space. In ancient greek and Roman buildings, the portico and colonnades had this purpose as a part of their function. Later, in south America the Greek revival architecture offered shading also as symbolic and esthetic benefits. Building elements are usually multifunctional. The greek portico also protects against the rain while providing solar control. (Fig. 5.36) There is a rich supply of historical examples like; the porch, veranda (from India), balcony, loggia, gallery, arcade. In Japanese architecture, the veranda-like element called the engawa (large overhangs), protected the sliding wall panels that could be opened to maximize

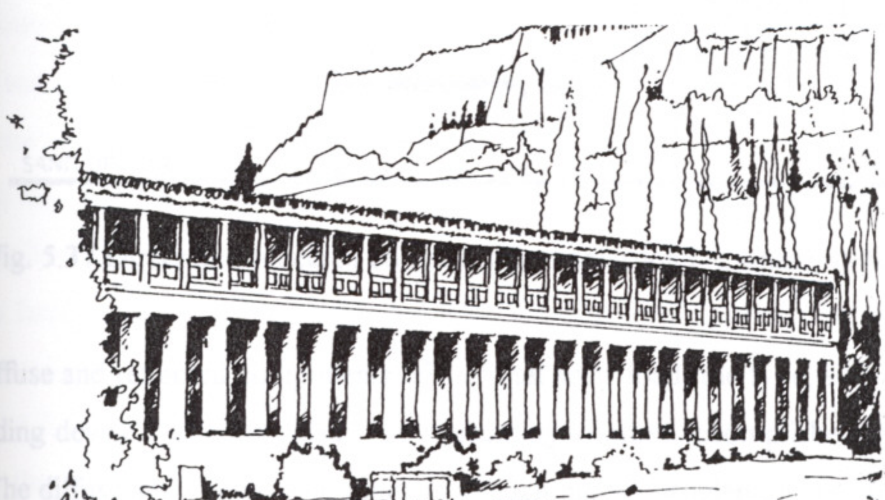


Fig. 5.36 Colonnades and porticoes in ancient Greek architecture (Lechner, 1991; pp:134)

access to ventilation, light and view. When the panels are closed light enters through a continuous translucent strip window above. Many great architects have understood the importance of shading and used it to create powerful visual statements. Le Corbusier is most closely linked with an aesthetic based on sun shading. For him the aesthetic opportunities were as important as the protection from the sun. He invented the fixed structural sunshade now known as "brise-soleil" (sun breaker). (Lechner, 1991)

Direct, diffuse and reflected radiation are the three components of the total solar load. When passive solar heating is not wanted, a window must always be shaded from the direct solar component and often also from the diffuse sky and reflected components. (Fig. 5.37) In humid regions, the diffuse sky radiation can be as significant as the direct radiation. And in that regions, dust or pollution can also create much diffuse radiation. On the other hand, reflected radiation can also be an essential problem where intense sunlight and high reflectance surfaces often co-exist. In urban areas, this problem occurs where highly reflective surfaces be quite common. Concrete paving, white walls and reflective glazing can all reflect intense solar radiation. Depending on the size of the direct

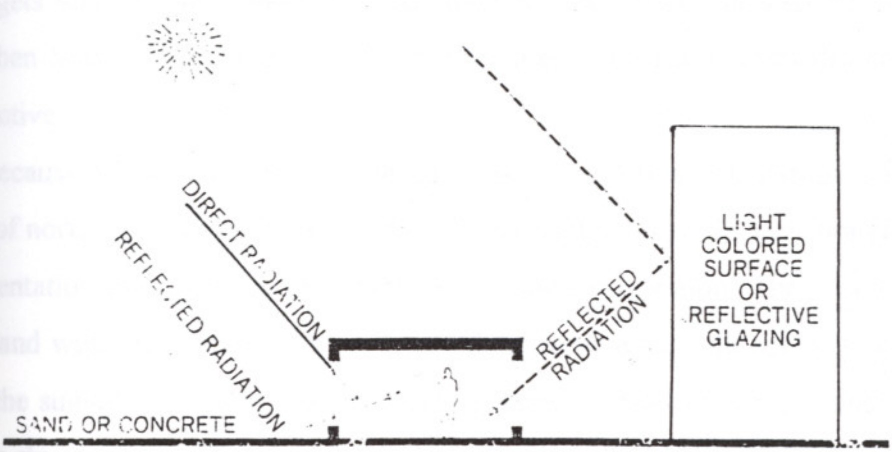


Fig. 5.37 Direct and reflected components of solar load (Lechner, 1991; pp:139)

direct diffuse and reflected components of the total solar load, the type, size and location of a shading device will be decided. The reflectivity is often accomplished by the use of plants. The diffuse sky component which is a much harder problem, is usually controlled by indoor shading devices or shading within glazing. The direct solar component is best controlled by exterior shading devices. The ideal shading device will block a maximum of solar radiation while still permitting views and breezes to enter a window.

5.3.8. Lighting

Lighting is a significant energy user, although the amount is considerably less than the amount used for heating and cooling. In addition, lighting is the least efficient common use of energy, about 95 % of the energy used dissipates as heat.

Energy used for lighting and for heating and cooling are closely interrelated with each other. Admitting solar light rays means the less need for electric lighting and it means admitting heat energy as well.

Designing for both daylight and thermal energy flow, a window should be located so as to guide ar movement and provide daylight and to do both where they will be most effective. (Lyle, 1994)

The orientation and form of the building are critical factors in a successful daylighting. The south orientation is usually best for daylighting.The south side of a building gets sunlight throughout the day and the year. This will also be desirable in winter when heating effect is required. On this orientation sun control devices are also most effective.

Because of the constancy of the light, the second best orientation is north. The quantity of north light is rather low, however the quality is high. In very hot climates the north orientation may be even preferred to the south orientation. The worst situations are, east and west orientations. These orientations receive sunlight for only half of each day and the sunlight is at a maximum during summer instead of winter. And also being low in the sky, east and west sun creates glare problem. The horizantal orientation is not always applicable. When applicable, horizantal openings allow fairly uniform illumination over very large interior areas and also horizantal opening receive much more light than vertical openings.

The form of the building not only determines the mix of vertical and horizantal openings that is possible, but also how much of the floor area will have access to daylighting.

Generally, in multi-storey buildings a 15 feet perimeter zone can be fully daylit and another 15 feet beyond that can be partially daylit. (Lechner,1991) The figure 5.38 shows the availability of daylight according to the variations of a multi-storey office buildings. Each building has the same area. The core area of the rectangular plan receives no daylight, but it still has a large area that is only partially daylit. The atrium is able to have all of its area daylit.

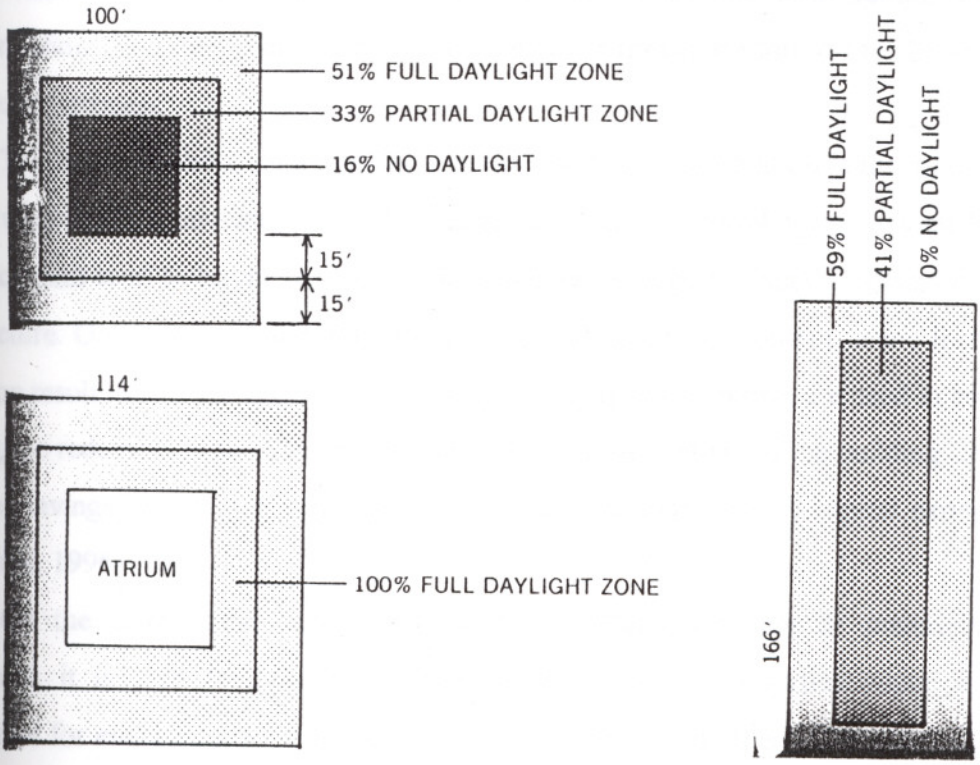


Fig. 5.38 The availability of daylight according to the variations of building types. (Lechner, 1991; pp: 321)

5.3.9. Building Materials

The reasons of determining building materials as a variable of energy efficieny are that they involve a considerable amount of energy use in their manufacture and they have thermo-physical properties which are of importance for energy conservation in buildings.

All building materials originate in the earth; some require only man's effort to make a structure. Building from earth does the least damage to the environment. Being close to the building site, it does not involve transport energy costs and when no longer needed the building decomposes naturally without giving any harm to the earth.

When non-renewable energy is used, pollution results from its extraction, refining and fabrication. And they require additional energy for transportation to the site and for construction process.

Therefore, in choosing a building material the first consideration is the amount of energy used in its manufacture. The material close to its natural form, having lower energy content tend to be the least polluting since less energy has been involved in their manufacture. On the other hand, though they are high in energy content, some forms of insulation result in a lower energy density. If these insulating materials are used in correct manner, the reduction in the energy demand will be during lifetime of the building. In that case, the savings in energy revenue are greater than the extra energy capital expended. (Moughtin, 1996)

On the other hand, when the thermo-physical properties of materials are considered, it is seen that there are three thermo-physical properties which are of importance for energy conservation in buildings. Those are; the thermal resistance, heat capacity and solar absorption of surface.

A building material or a combination of building materials for walls, roofs, floors and internal partitioans should provide a high thermal resistance together with a high heat capacity. The thick and heavy structure of walls and roofs supress the amplitude of the external temperature, smooth out variation in inside temperature and stores sufficient amount of heat. "In this respect 'Trombe Wall' which is high mass wall on the south side of the house, blackened and glazed, will be very useful which not only serves as solar energy collector but also as storage and built in radiant heating panel" (Garg, 1987; pp:10)

5.3.9.1. Transparent Materials And Thermal Mass

Transparent materials allow the short wavelengts of solar radiation to pass through. "After striking interior surfaces, the reflected rays are long in wavelength and these do not pass through so readily. This way of trapping of heat is called the greenhouse effect." (Lyle, 1994; pp:107)

Nevertheless, transparent materials are poor insulators. They readily lose heat by exchange with outside air. Transparent surfaces may lose more heat than they gain. However, a careful sizing and placement of transparent surfaces maintains the balance between incoming and outgoing heat to keep interiors within the comfort zone.

Thermal mass is to store the heat and reradiate it when solar radiation is no longer coming in. In this process storage capacity is essential for operation and is often the limiting factor for effectiveness of the system. Thermal mass absorbs a great deal of heat rapidly and releases it slowly.

"Materials vary greatly in their capacity for storing heat. Brick, stone and water make excellent thermal mass, wood, wallboard and most metals do not. The most effective thermal mass tends to be dense, heavy, bulky and relatively expensive." (Lyle, 1994; pp:107)

Since energy consumption first became a matter of concern in the 1960's, the technology of thermal storage materials has shown improvements. The use of phase-change materials such as Glauber's salt is among the more interesting developments. These phase-change materials absorb a large amount of heat in passing from a solid to a liquid state and then release the heat when they reverse the change and return to the solid state. During the warm hours of the day, these materials change to a liquid and during a cooler period they return to a solid.

The amount of translucent surface and the volume and surface area of thermal mass are in close relation. The larger the transparent surfaces, the more thermal mass is needed to absorb the incoming heat. The ratio of thermal mass surface to transparent surface usually should be at least 3 to 1.

5.4. Summary: Urban Design For Hot-Humid and Hot-Dry Regions

As a summary of the previous subtitles, including the variables of energy efficient urban design, which climatic modifications should be taken into consideration and what urban design should aim in hot-humid and hot-dry regions are going to be made clear in this part.

The reason for choosing the hot-humid and hot-dry regions among other climatic regions is that; in such climatic areas or regions, to modify the climatic characteristics, to improve the comfort of the inhabitants outdoors and indoors and to reduce the energy demand of the buildings for cooling in summer are harder. Most of the countries in the hot-humid areas are developing countries and vast majority of people cannot afford air conditioning. Therefore thermal stress should be minimized primarily by appropriate urban and building design details which do not involve high cost. Also desert climates provide the maximum opportunity for bioclimatic design on an urban scale. In addition, the project site, Izmir, which is going to be studied in the context of this thesis, has the climatic features of hot-humid regions.

5.4.1. Hot-Humid Regions

The street layout, to provide good ventilation conditions for pedestrians in the street and good ventilation of the buildings along the streets are the main climatic objectives in hot-humid regions.

When the urban temperature reaches its maximum during the afternoon hours, the best ventilation within the streets and the sidewalks is achieved when the streets are parallel to the direction of the prevailing winds. (Givoni, 1991) As it is very common in many towns in developing countries, streets perpendicular to the wind direction, with closely spaced long buildings along them, block the wind in the whole urban area. Wide main avenues oriented at an oblique angle to the prevailing winds (between 30° and 60°) enables penetration of the wind into the heart of the town. The buildings along such avenues are exposed to different air pressures on their front and back facades. The upwind wall is at a pressure zone while the downwind wall is at a suction zone, thus providing the potential for natural ventilation.

As well as the urban temperature, urban density is among the major factors which determine the urban ventilation conditions. The higher the density of buildings in a given area, the poorer will be its ventilation conditions. However, for a given density, the urban ventilation conditions can differ according to the particular configuration of buildings by which the density is obtained.

In an urban configuration, in hot-humid regions, high long buildings, of about the same height, perpendicular to the wind direction should be avoided as much as possible. Thus, this configuration blocks the wind and creates poor ventilation conditions both in the streets and for the buildings. The urban ventilation is enhanced by an urban profile of variable building height, where buildings of different height are oblique to the wind.

5.4.2. Hot-Dry Regions

In hot-dry regions, the typical daytime summer temperatures are in 32°-36° range while in hotter regions they may experience above 40° and up to 45° and even higher.

In that circumstances, the urban design in hot-dry regions should aim; (Givoni, 1991)

- to choose locations with the most favorable climate, mainly lower summer temperatures,
- to minimize urban temperature elevation above the surrounding level,
- to enable good ventilation potential for the buildings, especially in the evenings and in the open spaces,
- to provide shade in summer in the streets, over sidewalks and in open spaces,
- to provide solar access in winter for the buildings and in open spaces, especially in regions with cold winters,
- to minimize the dust level.

Lower summer temperatures and ventilation conditions especially in the evenings and at night should be considered while choosing a location for a town or a neighborhood. On the other hand, the wind is sometimes undesirable because the outdoor air temperature is above skin temperature and the wind increases the convective heat gain of the body. Therefore, the main concern in hot-dry regions is how to provide the potential for evening and night ventilation for the buildings.

When urban design is considered, it can be said that the density of the built up area in hot-dry climate may have both positive and negative effects on human comfort outdoor and indoors, depending on the details of the urban physical configuration. "With proper design of the individual dwelling units a building can be cross-ventilated even when openings are provided only in the northern and southern walls. In this case, the distance between the buildings along the east/west axis can be minimized, thus minimizing also solar radiation in summer on the sensitive eastern and western walls and windows." (Givoni, 1991; pp:27)

The effect of urban density on urban air temperature is another consideration. If the city is large enough and built densely enough it will be possible to achieve a daytime air temperature at the street level that is lower than in the surrounding areas. With the high density of buildings and white roofs, a large fraction of the solar radiation will be reflected upwards. The longwave radiant loss from the large roof's area can then exceeds the absorbed solar radiation even on a clear day in mid summer. Under these conditions the average temperature of the roof surfaces will be lower than the average regional air temperature.

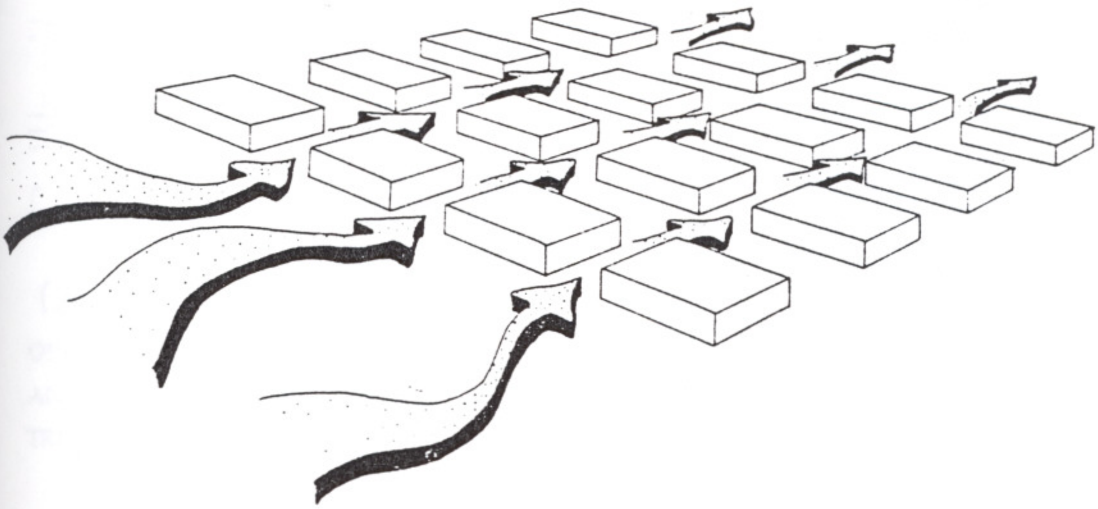
In table 5.3, basic urban design guidelines related to hot-humid and hot-dry regions are given.

In figure 5.39, the street configurations suitable for hot-dry and hot-humid is shown. Figure 5.40 illustrates the open space patterns.

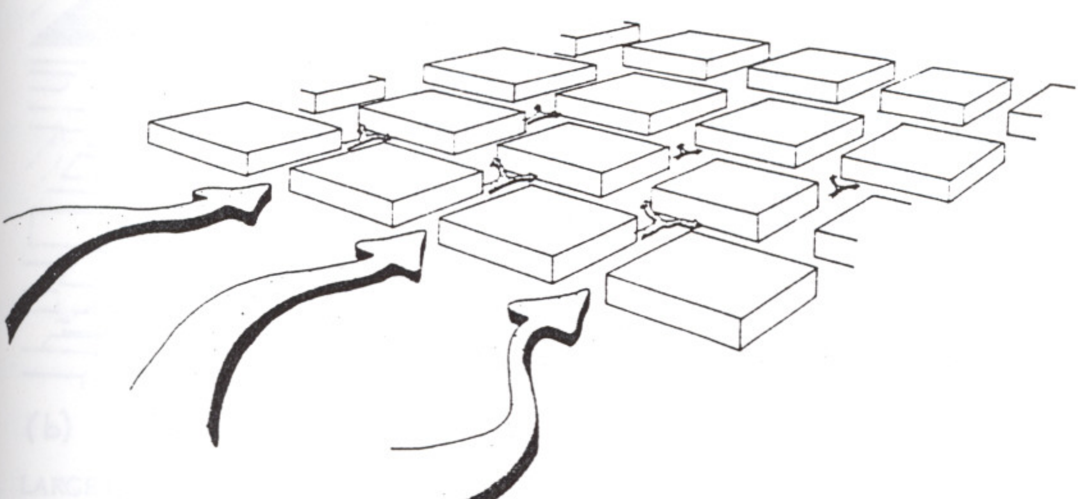
Table 5.3. Basic urban design guidelines

MAIN CLIMATIC TYPES	MAJOR PROBLEMS / ISSUES	BASIC URBAN DESIGN RESPONSES
HOT-HUMID	Excessive heat High humidity	Ventilation: open ends and dispersed form. Widely open streets to support wind movement Extensive shadow Dispersion of high-rise buildings to support ventilation Combined variation of building heights Wide yet shadowed open spaces Shadowing, planned tree zones
HOT-DRY	Excessive dryness combined with high day temperature Dusty and stormy	Compact forms Shadowing Evaporative cooling Protected urban edges from hot winds Windward location near a body of water Narrow winding neighbourhood roads and alleys Mix of building height to shadow the city Small, dispersed and protected public open spaces Circumferential and intersecting tree zones Use of geo-space city concept

(Source: Golany, 1995; pp:164)

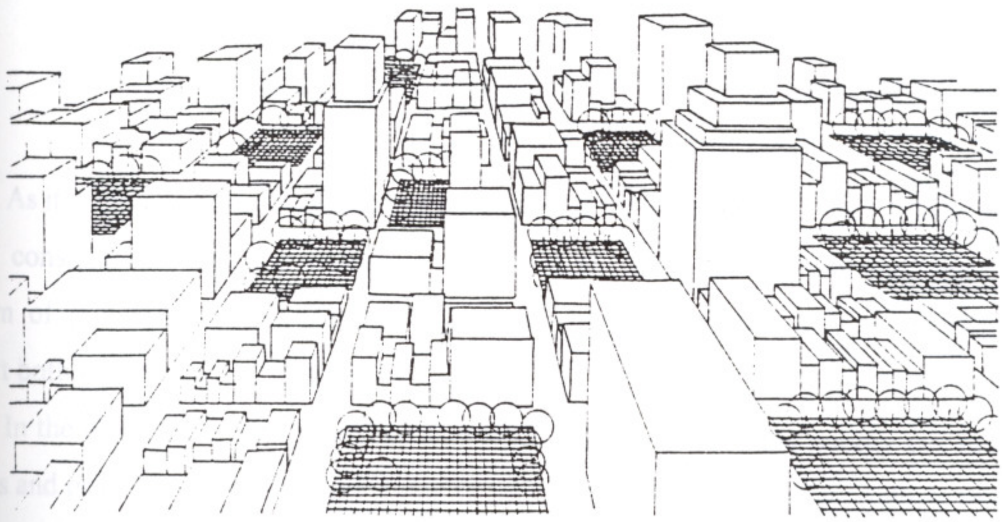


A.



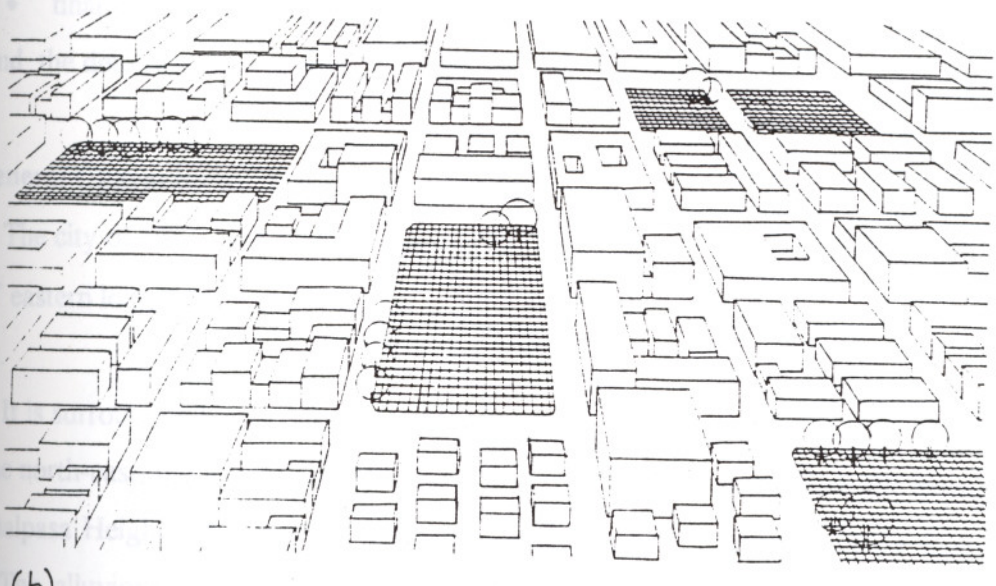
B.

Fig. 5.39 Street configuration (a) in hot-humid and (b) in hot-dry regions (Golany, 1995; pp:164)



(a)

OPEN SPACE GENERATES STAGNATED COLD AIR IN THE WINTER AND HUMID AND HOT AIR IN THE SUMMER. THEY SHOULD BE COVERED WITH HIGH TRUNK TREES TO PROVIDE SHADOW AND VENTILATION.



(b)

LARGE OPEN SPACES ARE INTOLERABLE SINCE THEY GENERATE DUSTY AIR, HIGH TEMPERATURE AT DAYTIME (AFTERNOON), AND COLD TEMPERATURE AT NIGHT (STAGNATED AIR), AND CONSUME LARGE QUANTITIES OF WATER TO MAKE THEM GREEN.

Fig. 5.40. Open space patterns (a) in hot-dry and (b) in hot-humid regions (Golany, 1995; pp:169)

Chapter 6

ENERGY EFFICIENT URBAN DESIGN IN IZMIR

As it is explained that, the goal of energy efficient urban design is to reduce urban energy consumption. Such a reduction will lead to healthier environment, ease the problem of pollution and congestion to a considerable degree and provide thermal comfort both in outdoor and indoor.

In the chapter of "energy efficient urban design in Izmir", the energy consuming features and problems of the city are going to be considered and design guidelines related to the problems are going to be determined.

The method used is;

- the collection of data including climatic and environmental (natural and built)
- the evaluation of all collected data in the context of energy efficiency
- the determination of energy consuming features of the city
- finally, the integration of energy efficiency considerations at urban design scale and the determination of design guidelines.

6.1. General Characteristics of Izmir

The city of Izmir whose geographic coordinates are 37° 45' northern latitude and 28° 20' eastern longitude, has developed around a natural bay which is the biggest one in Turkey.

It is surrounded by the Yamanlar Mountain from the north, the Manisa Mountain from the north-east, the Kemalpasa Mountain from the east and south-east, the extension of Kemalpasa Heights, the volcanic mass of Kadifekale and Tekke Mountain from the south. The alluvions carried by the Gediz River had formed Karşıyaka-Çiğli alluvial plains. On the east of the gulf exists the sediment plain of Bornova. This plain expands from the gulf to the east with a small slope. (Fig. 6.1)

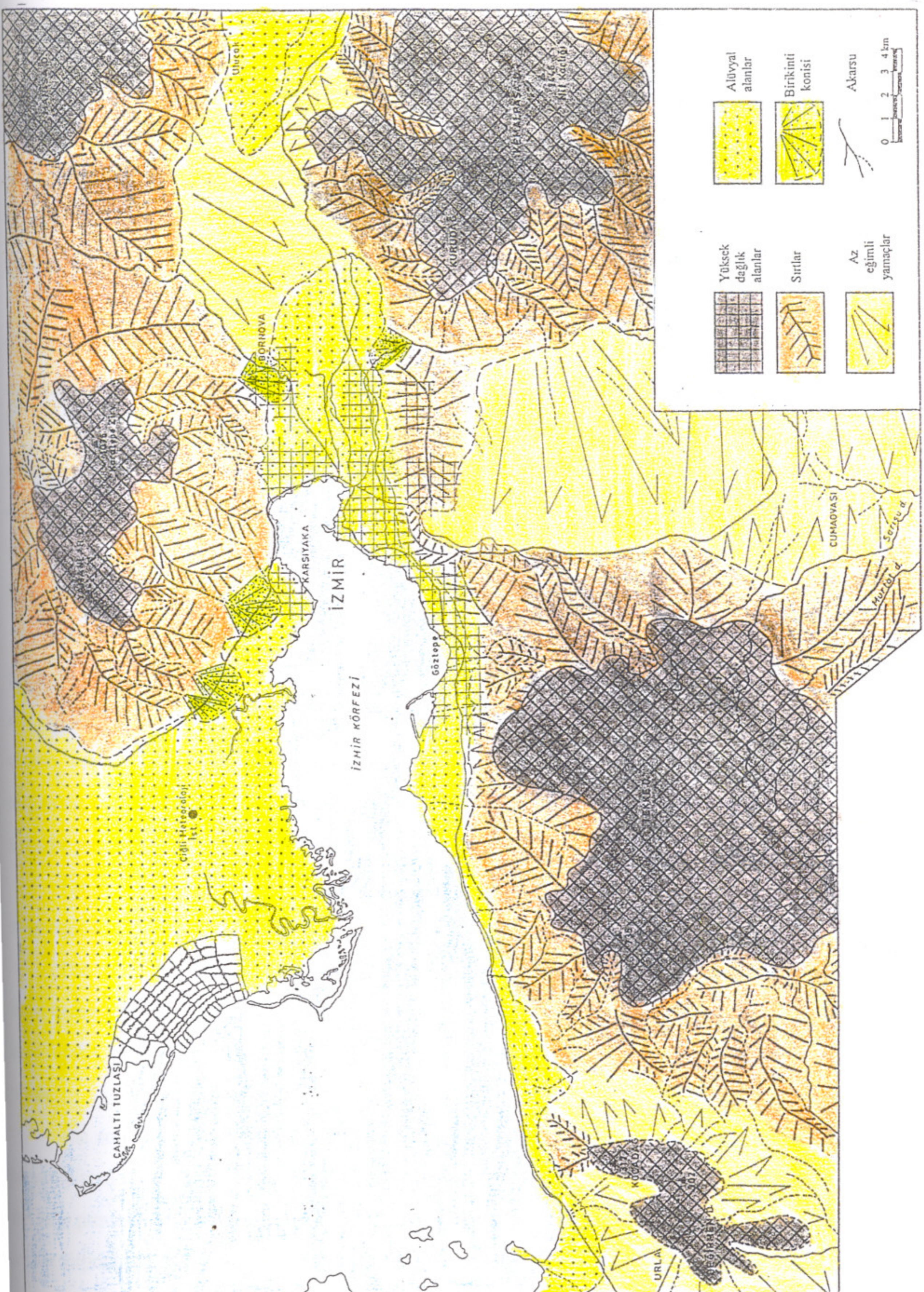


Fig. 6.1 The geomorphological map of Izmir (Kılınç, 1996; pp:16)

Izmir is a metropolis in which regional trade, industrial and agricultural decisions are taken and in which those are organized and controlled. After Istanbul, the Greater Izmir Area has the second essential industrial zone. In the regional production, the share of Izmir is 76 %. And Izmir is responsible for the 11 % of the national market. Its commercial capacity increasingly expanded as its port has grown.

Izmir has developed with Konak as its center (CBD), and has grown along the four main roads that connect Izmir with the other part of the country and due to the topographical characteristics of the city. The growth axis along the roads coincide with the valleys which permitted easier transportation and encourage the spread of the settlement along them. Therefore, the shore of the bay and its surrounding with hill chains and valleys have given Izmir its spatial for of an elongated finger growth with densely settled shores and valleys. The rapid population growth and economic conditions have pushed settlements up to the hills as secondary growth tendencies.

On the north axis, the first organized industrial zone of Izmir (Atatürk Organized Industrial Zone) has been developed. Besides industrial potential, the region accommodates the collective residential areas. These residential areas are separate clusters scattered along the Izmir-Menemen road and have relatively low densities comparing to the other growth axis. Agricultural villages on the northern corridor are also now part of the metropolitan limit.

The east axis has the growth potential of industry. The industrial area is extending in the region of Kemalpasa.

The west axis is the most densely occupied part of Izmir. The region, showing a linear extension parallel to the shore ends with the recreational areas. There are also large forests on the south. In addition, Balçova Baths are the special features of the region.

The south axis, where industrial and residential areas have developed together, has completed its available extension area. The forests and agricultural areas are factors that have prevented development. The other land-uses that have taken place in the south are the airport, the duty free region due to the existence of the airport and the Tahtali Dam. (Fig. 6.2)

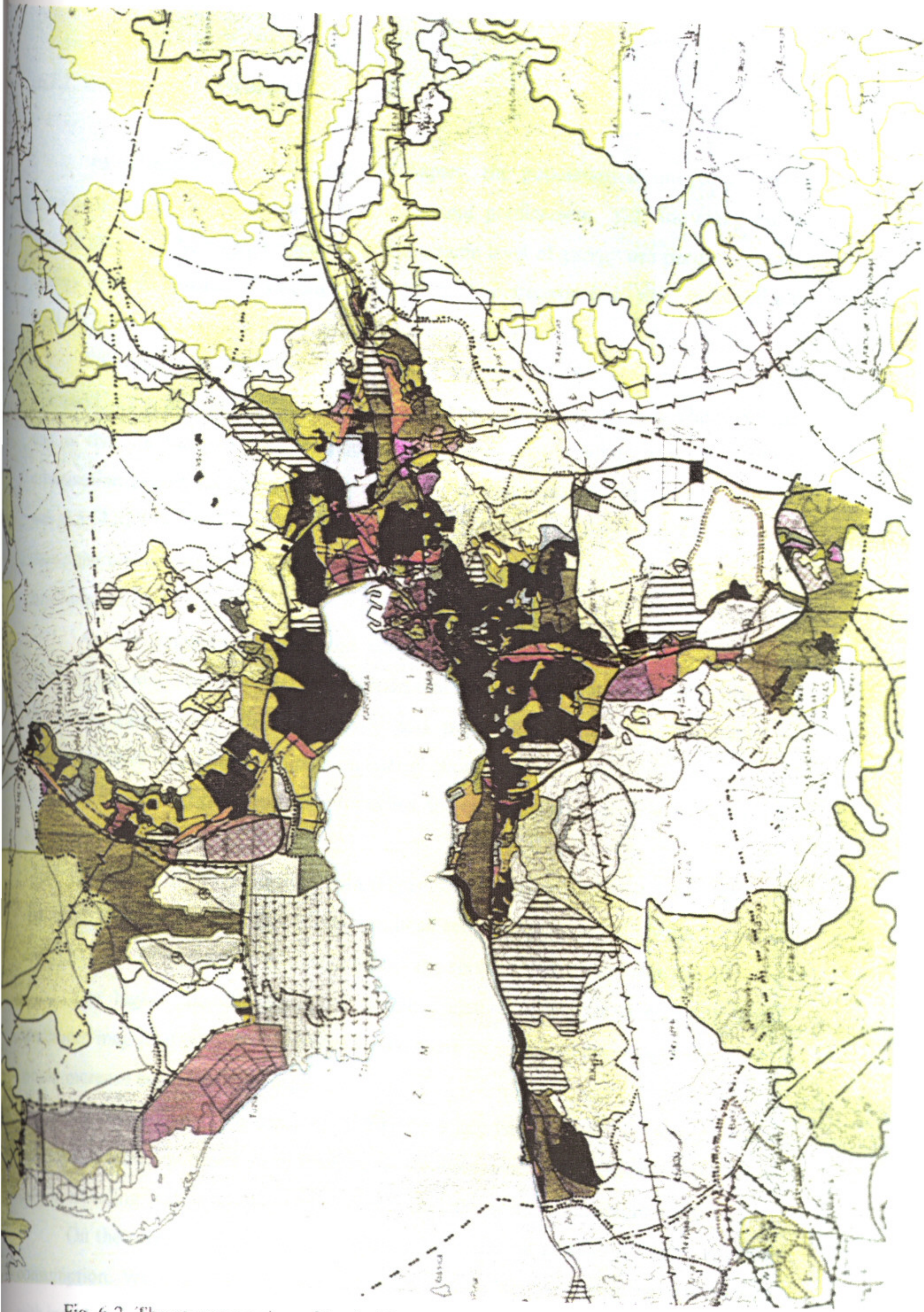


Fig. 6.2. The structure plan of Izmir (Greater municipality of Izmir, scale: 1/100000)

6.1.1. Demographic Structure

As it was stated in the second chapter, the population is one of the main consideration in energy-environment-development predicament. Yet, for every billion people added to the world's population at the same level of energy use per person, new energy supplies capable of sustaining an additional continuous drain must be mobilized, paid for and their environmental impacts somehow absorbed.

Following the statement above, when the demographic structure of Izmir is examined, it can be said that it displays a magnificent population increase. The reason for this is that its being a metropolitan and a region of development where a rapid urbanization occurs are the attractive forces for the migrants. The population of Izmir was 2.317.829 in 1985 and in 1990 it became 2.694.770 (Table 6.1). The table 6.2 shows the population by province, annual increase rate, area and population density. The population shared by districts is shown at table 6.3a and b.

As the population grows and economies expand, the level of energy using activities will increase. However, it is certain that the increasing activities will determine the future energy use. Besides activity and population growth, the properties of population have an additional impact on energy consumption.

In the context of population properties, the city population is given by sex and by age groups at table 6.4.

The aging of the population with respect to continuing decline in birth rates and rise of life expectancy will affect energy use in all sectors. Such kind of change will shape the type of goods that would be produced and the services that would be provided.

The higher life expectancy of women relative to men and changing family structures may lead to further increase in the share of single-person households, which would increase energy use per capita.

Moreover, when we consider "lifestyle", a key issue is whether people conduct activities at home or travel away from home to accomplish them. However, the energy used in traveling is almost always much higher than the energy consumption at home.

On the other hand, the state of literacy have also an additional effect on energy consumption. We can relate the state of literacy with lifestyle considerations and also with income levels. When the number of literate people increases and the level of literacy

Table 6.1. Population growth in Izmir

	1955	1960	1965	1970	1975	1980	1985	1990
IZMIR	910.496	1.063.490	1.234.667	1.427.173	1.673.966	1.976.763	2.317.829	2.694.770

(DIE, 1990)

Table 6.2. Population by province and annual increase rate

1985			1990			Annual Increase Rate (%)		
Total	Population of province and district center	Population of sub-districts and villages	Total	Population of province and district center	Population of sub-districts and villages	Total	Province and district center	Sub-districts and villages
2.317.829	1.809.924	507.905	2.694.770	2.134.816	559.954	30.14	33.02	19.51

Table 6.3. (a) Order of district center by population and annual increase rate
(b) City and village population, area and density by province and district

a.

District center	1990 (population)	1985 (population)	Annual Inc. Rate (%)
KONAK	866.700	808.434	13.92
KARŞIYAKA	418.724	342.944	39.93
BORNOVA	272.860	200.603	61.53
BUCA	199.130	137.791	73.64

(DIE, 1990)

b.

	TOTAL			CITY POP.			VILLAGE POP.				
	Total	Male	Female	Total	Male	Female	Total	Male	Female	AREA	DENSITY
BORNOVA	278.300	145.008	133.292	272.860	142.059	130.801	5440	2949	2491	203	1371
BUCA	203.383	103.752	99.631	199.130	101.512	97.618	4253	2240	2013	103	1975
KARŞIYAKA	424.196	211.695	212.501	418.724	208.250	210.474	5472	3445	2027	214	1982
KONAK	874.597	449.948	424.649	866.700	445.805	420.895	7897	4143	3754	243	3599

(DIE, 1990)

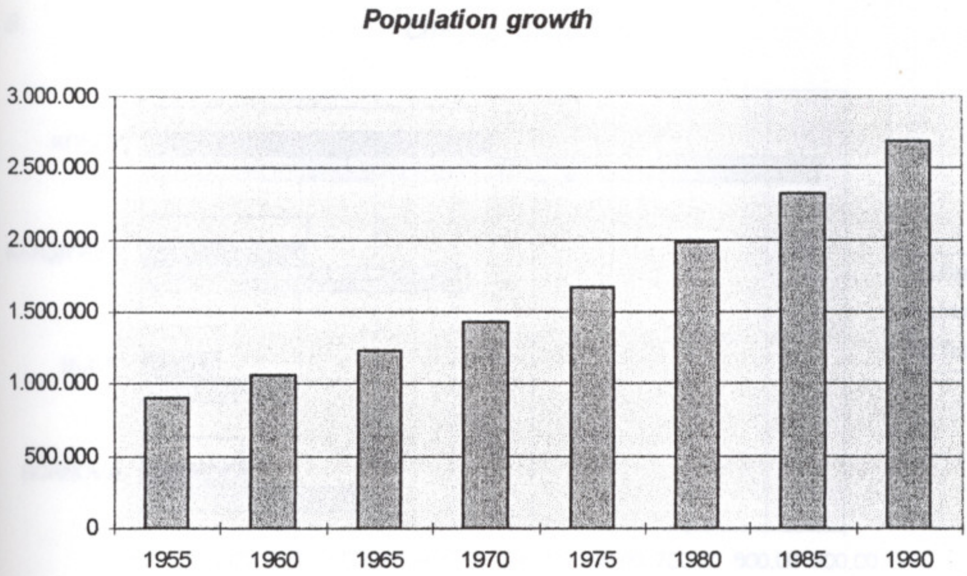


Fig. 6.3. Population growth in Izmir

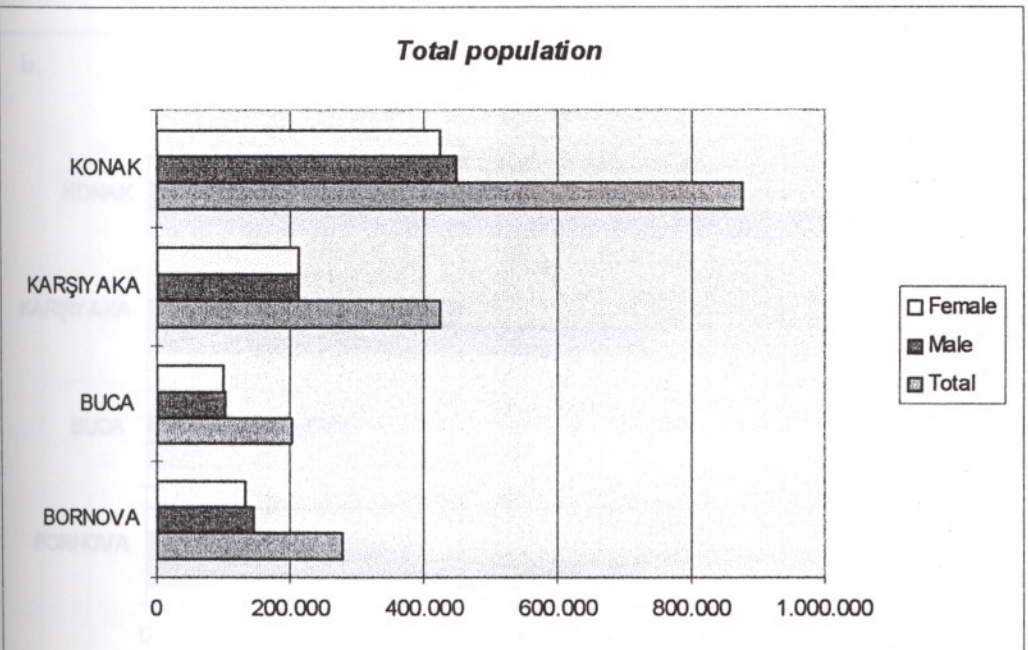
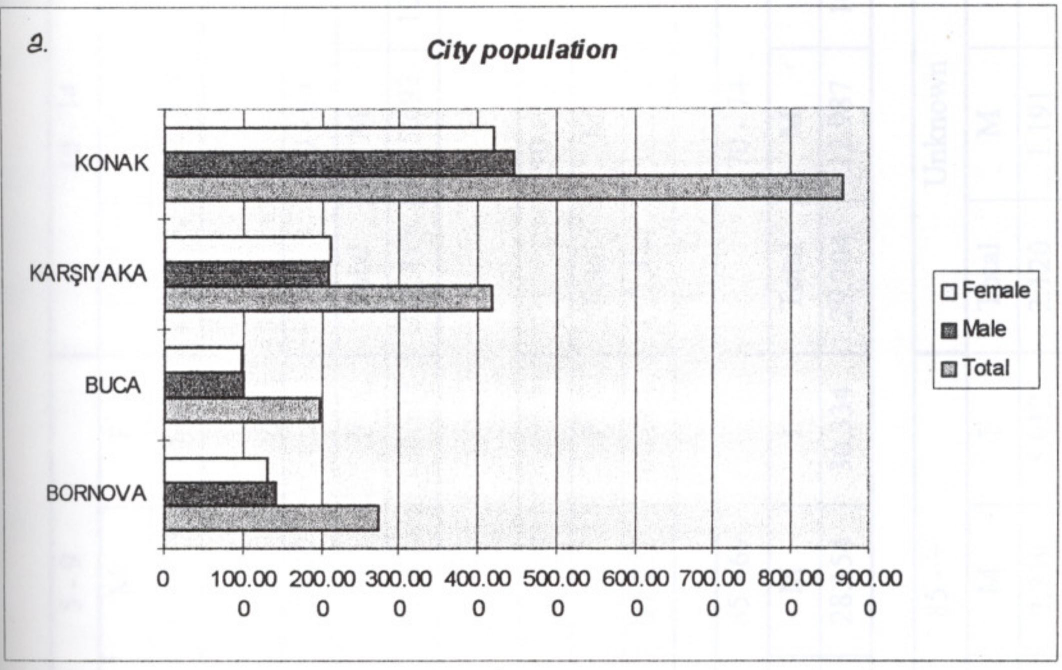


Fig. 6.4. Total population by province



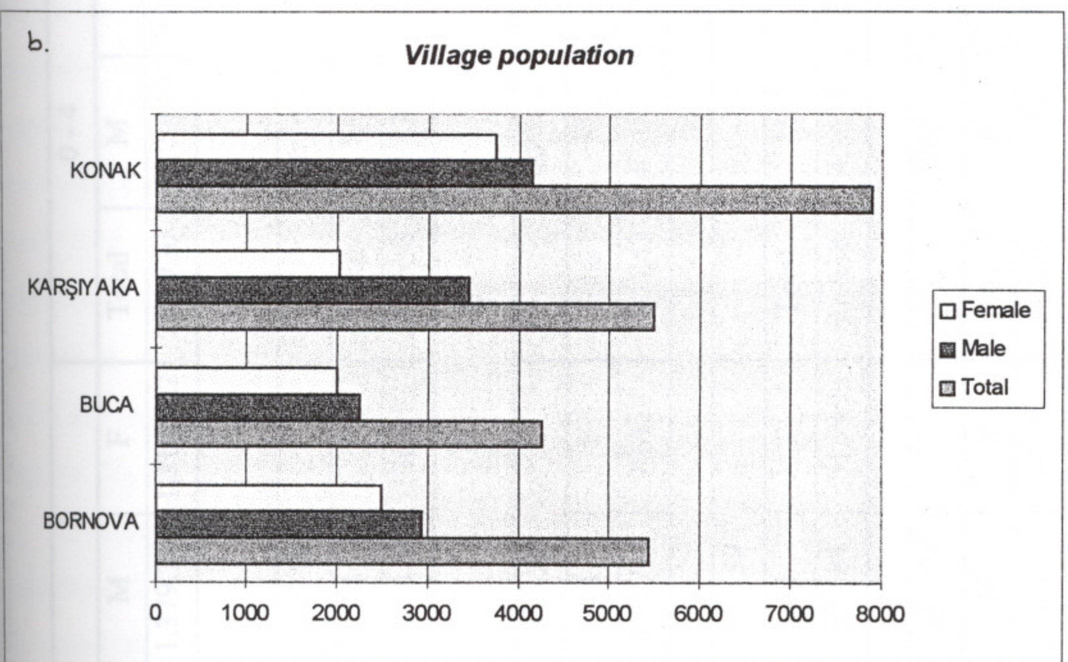


Fig. 6.5 (a) City population, (b) village population by province

Table 6.4 Population by age groups and sex

			0 - 4			5 - 9			10 - 14		
Total	M	F	Total	M	F	Total	M	F	Total	M	F
2.694.770	1.379.778	1.314.922	219.720	112.480	107.240	257.765	131.654	126.111	279.913	143.988	135.925

15 - 19			20 - 24			25 - 29			30 - 34		
Total	M	F	Total	M	F	Total	M	F	Total	M	F
277.209	147.156	130.053	257.538	137.727	119.811	246.786	126.675	120.111	223.419	115.692	107.727

35 - 39			40 - 44			45 - 49			50 - 54		
Total	M	F	Total	M	F	Total	M	F	Total	M	F
199.171	102.717	96.454	160.242	83.081	77.161	125.586	64.922	60.664	112.444	56.210	56234

55 - 59			60 - 64			65 - 69			70 - 74		
Total	M	F	Total	M	F	Total	M	F	Total	M	F
104.533	52.684	51.849	91.638	43.578	48.060	58.488	28.154	30.334	29.704	12.987	16.717

75 - 79			80 - 84			85 - +			Unknown		
Total	M	F	Total	M	F	Total	M	F	Total	M	F
25.573	11.011	14.562	14.270	5.132	9.138	8.651	2.739	5.912	2.120	1.191	929

becomes higher, and also when the income level increases, the lifestyle of the population changes in a manner which causes an essential energy consumption with respect to increasing energy using activities. The table 6.5 shows the state of literacy in Izmir.

In short; Izmir, a metropolis and the third greatest city in Turkey presents a significant potential of development. It should be accepted that energy is the basic input of this economic and social development that takes place in the city of Izmir. And the population size, growth rates and population properties and the economic aspirations of Izmir represent a huge potential for future energy consumption. And today, it is known that a large portion of the energy is derived from fossil burning.

6.1.2. Residential Density

Izmir has a concentric density distribution. The population density is at maximum at the old city center, and decreases towards outer parts. One of the basic reason that causes this is the high concentration of residential units and buildings.

The highest density appears in the Alsancak district with 1857 person/ha. On the other hand, the density on the both sides of the İkiçeşmelik Street is 1300 person/ha while the density on the both sides of the Mithatpaşa Street is about 1000 person/ha. The commercial sections and the business areas (CBD) and Konak, in which partially residential purposes mingle with, has a density of around 80 person/ha. The gecekondu areas which are around the Greater Municipality have very low densities. The density around the districts like Salhane, Çınarlı, Halkapınar especially which are characterized by the industrial sections except the residential sections in the East is very low; around 20 person/ha. By the virtue of their topographic nature, Yeşilyurt, Karabağlar, Uzundere districts are among those which have low densities. In those places, the density is 30 person/ha. (Ege-Koop, 1993)

In Izmir, different social structures and their distribution patterns in space have caused the different patterns in residential areas. For example, in the western part of the city, Güzelyalı has an organic relationships between the education, income and profession levels. In this district people are relatively literate, identified with the middle class, white-collar jobs. Towards the inland from Güzelyalı, Balçova, Güzelbahçe and Narlıdere districts have identical social characteristics in terms of education level, income

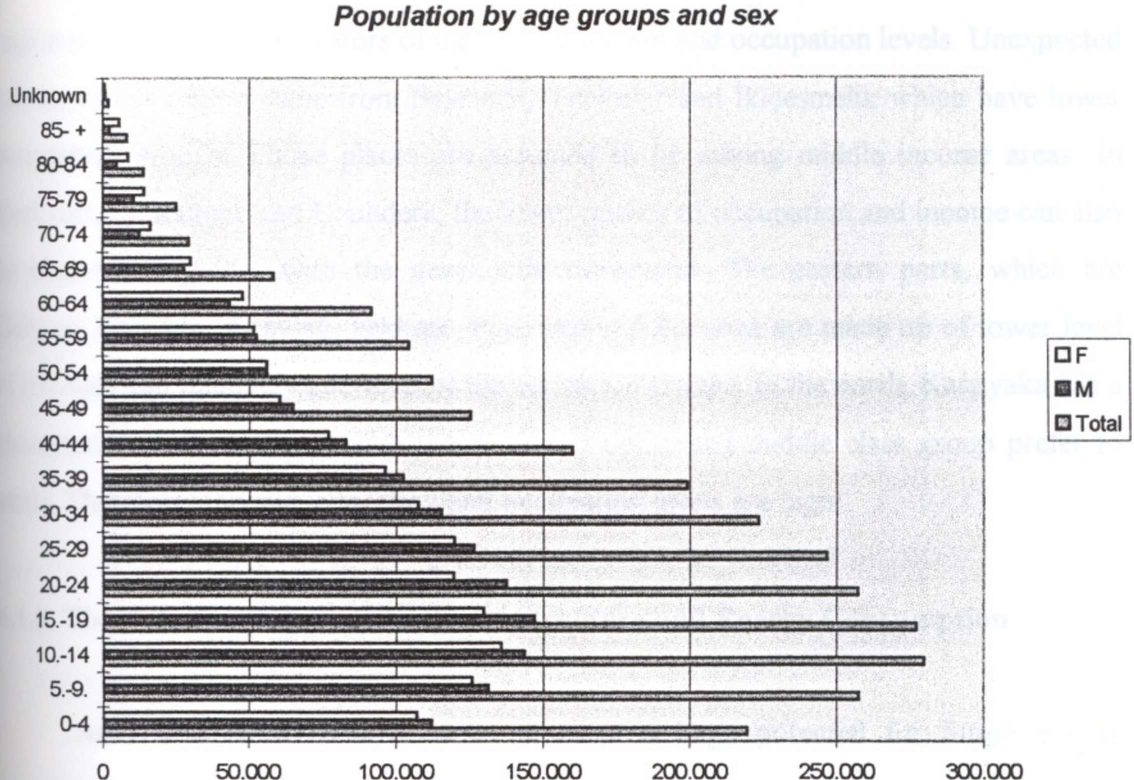


Fig. 6.6 Population by age groups and sex

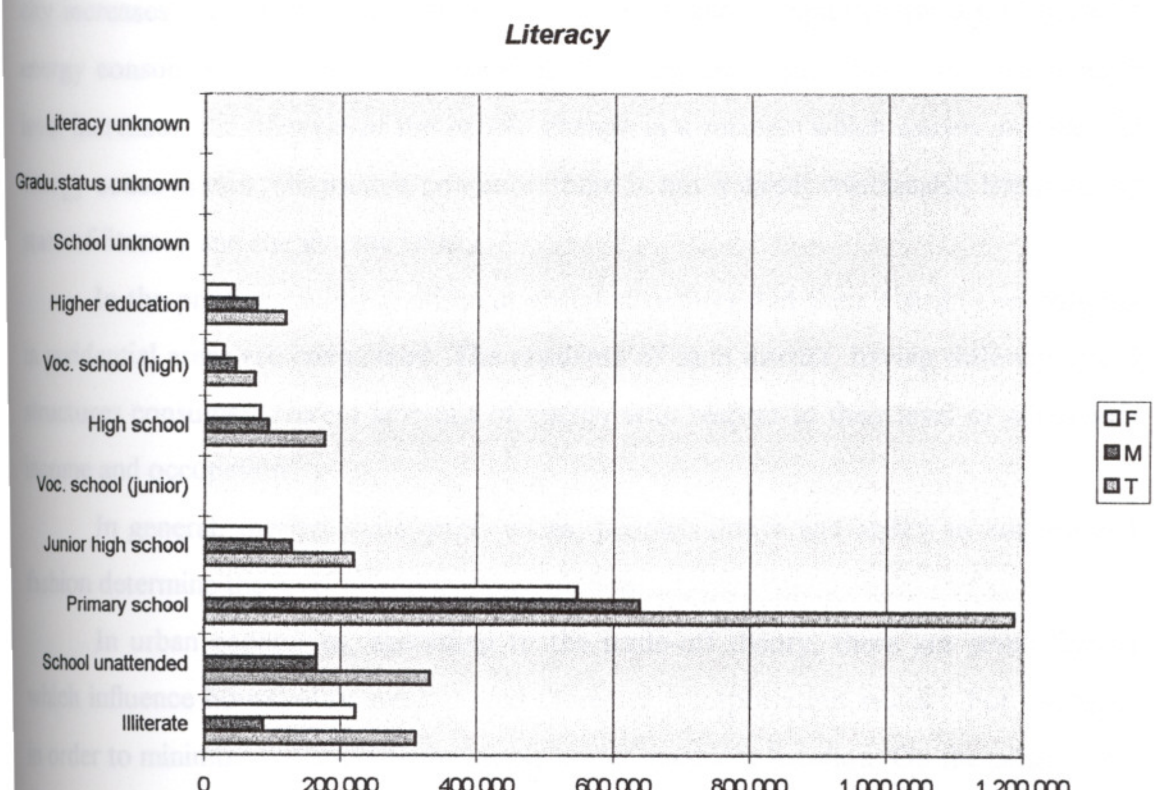


Fig. 6.7. The state of literacy

and occupation. However, the living standards are quite low in İnciraltı. The Alsancak region has the highest indicators of income, education and occupation levels. Unexpected values, in this region came from Basmane, Yenişehir and İkiçeşmelik which have lower occupation groups. Those places are assumed to be among middle income areas. In Yeşilyurt, Limontepe and Uzundere, the lower quality of occupation and income can also be observed together with the gecekondu movement. The eastern parts, which are Gültepe, Çamdibi, Altındağ, Işıkkent, Pınarbaşı and Bornova are made up of lower level of incomes and relatively mid-level of the education groups. In the north, Karşıyaka has a characteristics of residential area where mostly upper and middle class group prefer to settle. Therefore, income, education and occupation levels are high.

6.1.3. The Relation Between the Social Structure and Energy Consumption

As it was ststed before Izmir represent a huge potential for future energy consumption due to its population size, growth rates, population properties.

When the graph of population by age groups is examined, it is seen that Izmir has a young population. This means, as the population becomes younger, the activity in the city increases. The increase in the number, velocity and complexity causes increase in energy consumption. When the level of literacy becomes higher and when the income level increases, the lifestyle of the people change in a manner which causes an essential energy consumption. (In today's condition there is not a direct relationship between the state of literacy and the income level.)

In the previous subtitle, different social structures and their distribution patterns in residential areas are considered. The residents of each district, having different social structures consume different amounts of energy with respect to their level of education, income and occupation.

In general, the individual preferences, people's desire and ability to acquire and fashion determine the level of energy consumption.

In urban economics, according to the trade-off theory, there are some factors which influence household's location and therefore transportation system. For example, in order to minimize transport costs people prefer inner city location. On the other hand, if household wants a large amount of space, they have to locate further from the center.

This demand is mostly motivated by income. When household's income increases, their demand for space increases too.

The inclination in Izmir is that, the new residential developments for both high and middle income groups are taken place at the outer zones on north and west axis, as the inner city is densely occupied. Besides individual preferences urban economics, social interactions, planning process and transportation system and investments encourage such kind of development. The result is increase in the number of private vehicles, therefore more fossil-fuel consumption. In addition, large amount of space requires more energy consumption for space conditioning.

Under these circumstances, it is required that the consumer, the developer, the government and the planner should have energy conservation consciousness.

6.2. Climatic Features of Izmir

Depending on the natural characteristics and mainly on climatic conditions, location of settlements, economic and cultural developments have taken place on the plains of Aegean Subregion which are located among the mountains and throughout the Aegean coastal zone.

In general the climate of Izmir is mild Mediterranean climate and be called as half-humid.

In Izmir, there are three stations where the meteorological data is gathered. These are; the one, which has served as Izmir's meteorological station since 1929, locates in the urban area in Güzelyalı. The second one, which is smaller than Güzelyalı station is located in the research area of Agricultural Faculty in Bornova. Generally, it serves for the scientific researches of Aegean University. The third station in Çiğli is under military use, however in recent years it has began to serve also for civic use.

The climatic characteristics of Izmir is going to be expressed according to the data taken from those stations. The other main source which was used for in establishing this part is a master thesis "The Wind Properties in Izmir", prepared by Ercan Kılınç in Aegean University, Department of Geography.

In accordance with the data taken from 3 meteorological stations;

The annual temperatures are 16,8° C (Çiğli), 17,5° C (Güzelyalı) and 17,2° C (Bornova). The minimum monthly average temperatures occur in January (Bornova 8,1° C, Çiğli 8,2° C and Güzelyalı 8,6° C). After May, the temperature becomes higher than the annual average temperatures and reaches its highest value in July (Bornova 27,2° C, Çiğli 26,9° C and Güzelyalı 27,5° C). Till October, the temperature remains over the annual average temperature and then begins to decrease. During the cold period, the monthly average temperatures are about 9°-10° C however, it sometimes come up to 21° C. On the other hand, the temperatures in summer sometimes increase over 40° C. The observed highest temperatures were; 42,9° C in July, 1973 (Bornova), 42,7° C in August, 1958 (Güzelyalı) and 41,7° C in June, 1973 (Çiğli). In addition to highest degrees, the observed lowest temperatures were; -8,2° C in January, 1942 (Güzelyalı), -7,6° C in 1964 (Bornova) and -5,6° C in 1973 (Çiğli). These values related to average monthly and annual temperatures are given in table 6.6a, 6.6b and 6.6c. (Fig. 6.8)

The table 6.7 shows the monthly average temperatures which were observed in 4 stations. The values taken from Çiğli station is given with the standard deviations. According to the table, when the monthly average temperatures in 4 different sites are compared, the situation is that, the observed temperature values mostly depend on the location of the meteorological stations. Güzelyalı station is located in the high-dense urban area where the effect of heat island is exactly seen. The station in Bornova is also affected by the urban areas around it. However, in Çiğli, the station is located on an open area where it faces the sea effects. There is approximately 1° C difference between temperatures in Güzelyalı and Çiğli.

Izmir, like many other large cities, has experienced through the years, the increase of its temperature which is because of heat island effect.

It is known that the formation of heat islands in cities depends on the amount of sun radiation received, the amount of evaporation, ventilation and other climatic features and also on the city morphology and configuration, population, activities taken place, etc.

The increase in temperatures with respect to heat island effect in Izmir can be demonstrated by the graphics of annual average minimum and maximum temperatures and daily temperature changes.

Table 6.6. Average values of climatic features (a) Güzelyalı station (1938-1993), Bornova station (1959-1993), (c) Çiğli station (1974-1993)

	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Annua
Average air pressure (mb)	1016.5	1014.3	1012.4	1010.1	1009.7	1007.8	1006.7	1006.9	1010.9	1014.2	1014.9	1015.5	1011.7
Average temperature (C°)	8.5	9.2	11.1	15.4	20.4	25	27.5	26.7	22.9	18.5	14.2	10.2	17.5
Maximum temperature (C°)	21.4	23.9	30.2	32.5	37.6	40.3	41.9	42.7	38.7	33.4	30.3	24.7	42.7
Minimum temperature (C°)	-8.2	-5.2	-3.8	0.7	4.3	9.5	15.4	15	10	3.6	-2.9	-4.7	-8.2
Average relative humidity (%)	74	71	69	65	62	55	54	54	59	67	73	74	65
Average vapor pressure (mb)	8.3	8.3	8.9	11.2	14.3	16.7	18.3	18.1	15.9	13.5	11.4	9.5	12.9
Average wind speed (1984-1993)	2.7	3	2.8	2.7	2.8	2.9	3.1	2.9	2.6	2.5	2.5	2.6	2.7
Wind direction (1984-1993)	ENE	ENE	WNW	WNW	WNW	WNW	W	W	WNW	WNW	SSE	SSE	WNW
Average wind speed (1938-1993)	4.2	4.2	4.5	3.9	3.6	3.8	4.4	4	3.7	3.4	3.5	4.2	4
Highest wind speed (1938-1993)	32.5	31.8	31.5	27.7	23.7	24.8	20.6	20	27.8	28.3	26.4	29.4	32.5
Wind direction (1938-1993)	S	N	SE	S	ESE	SE	N	N	SSW	SSE	NNE	ESE	S
Highest wind speed (1984-1993)	20.1	28.3	19.8	22.8	17.6	16.5	18.6	14.3	16.8	21	20.7	26.9	28.3
Wind direction (1984-1993)	W	SE	SW	E	N	SSW	NNE	WNW	WNW	SSE	S	SSW	SE
Average rainfall (mm)	142.1	101.5	72.1	43.8	32.8	8.7	2.8	2.3	11.8	46.7	89.9	144.4	689.9

(Kılınç, 1996; pp:21)

(a)

(cont. next page)

b.

	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Annua
Average air pressure (mb)	1013.2	1012.6	1011.9	1009.7	1010	1008.7	1006.7	1007.3	1010.6	1013.5	1014.4	1014.2	1010.7
Average temperature (C°)	8.1	8.9	11	15.1	20.2	24.9	27.2	26.6	22.8	17.7	13.1	9.9	17.1
Maximum temperature (C°)	23.6	24.6	31.2	32.9	38.4	41.3	42.9	41.5	39.2	34.4	28.4	25.2	42.9
Minimum temperature (C°)	-7.6	-6.1	-4	0	4.8	10.4	11.4	13.2	8.6	3	-1.6	-4.5	-7.6
Average relative humidity (%)	69.8	68.4	66.9	63	57.4	50.1	48.1	51.5	57.3	63.5	68.9	70.7	61.3
Average vapor pressure (mb)	7.9	8.1	9.3	10.8	13.6	15.6	17.3	17.8	15.6	12.8	10.7	9	13.3
Average wind speed (1984-1993)	1.4	1.5	1.2	1	1.2	1.3	2.2	1.9	1.6	1.5	1.4	1.3	1.5
Wind direction (1984-1993)	ENE	NE	NE	NE	ENE	NE	NE	NE	NE	NE	NE	NE	NE
Average wind speed (1959-1993)	2.9	2.7	2.6	2.1	2	2.3	2.9	2.9	2.5	2.2	2	2.6	2.7
Highest wind speed (1959-1993)	24	25	24	21	18.8	16.8	19.6	18.4	15	24	20.4	17.8	25
Wind direction (1959-1993)	SW	NE	NE	E-SW	SW	SSW	NE	ENE	NE	SW	S	NE	NE
Highest wind speed (1984-1993)	15.6	16.4	15.2	19.5	18.4	7.8	7.8	7.6	13.9	14.6	15.4	16.2	19.5
Wind direction (1984-1993)	NE	SW	SE	SW	SW	NE	NE	NNE	NE	NE	NE	NE	SW
Average rainfall (mm)	123.5	90.9	65.2	51.9	33.1	11	3.2	2.7	13.2	43.3	79.3	123.9	641.2

(Kılınç, 1996; pp:22)

(cont. next page)

	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Annua
Average air pressure (mb)	1016.4	1015.5	1014.5	1012.3	1012	1010.8	1009.8	1010	1012.5	1015.1	1016.3	1015.8	1013.8
Average temperature (C°)	8.2	8.5	10.3	15	20.3	24.8	26.9	26.4	22.8	16.8	12.7	9.3	16.8
Maximum temperature (C°)	22.5	23.3	29.8	31.4	36	41.7	41.2	40	37.5	33.4	25.6	22.2	41.7
Minimum temperature (C°)	-5.6	-6.2	-4.6	1	10.3	11.3	13.2	13.6	8.6	2.4	-2	-4.2	-6.2
Average relative humidity (%)	76	74	72	71	65	57	54	56	61	70	74	76	67
Average vapor pressure (mb)	8.4	8.4	9.3	12.3	15.8	18.1	19.3	19.6	16.9	13.8	11	9.2	13.5
Average wind speed (1984-1993)	2.4	3	2.7	3.1	2.7	2.9	3.2	2.9	2.5	2.5	2.8	3.1	2.8
Wind direction (1984-1993)	N	N	N	ESE	N	N	N	N	N	N	N	N	N
Average wind speed (1974-1993)	4.2	4.2	4.5	3.9	3.6	3.8	4.4	4	3.7	3.4	3.5	4.2	4
Highest wind speed (1974-1993)	32.5	31.8	31.5	27.7	23.7	24.8	20.6	20	27.8	28.3	26.4	29.4	32.5
Wind direction (1974-1993)	S	N	SE	S	ESE	SE	N	N	SSW	SSE	NNE	ESE	S
Highest wind speed (1984-1993)	20.1	28.3	19.8	22.8	17.6	16.5	18.6	14.3	16.8	21	20.7	26.9	28.3
Wind direction (1984-1993)	W	SE	SW	E	N	SSW	NNE	WNW	WNW	SSE	S	SSW	SE
Average rainfall (mm)	98.9	64.1	60.7	37	25.9	8.8	2.8	1.1	6.4	40.1	62	74	481.8

(Kılınç, 1996; pp:23)

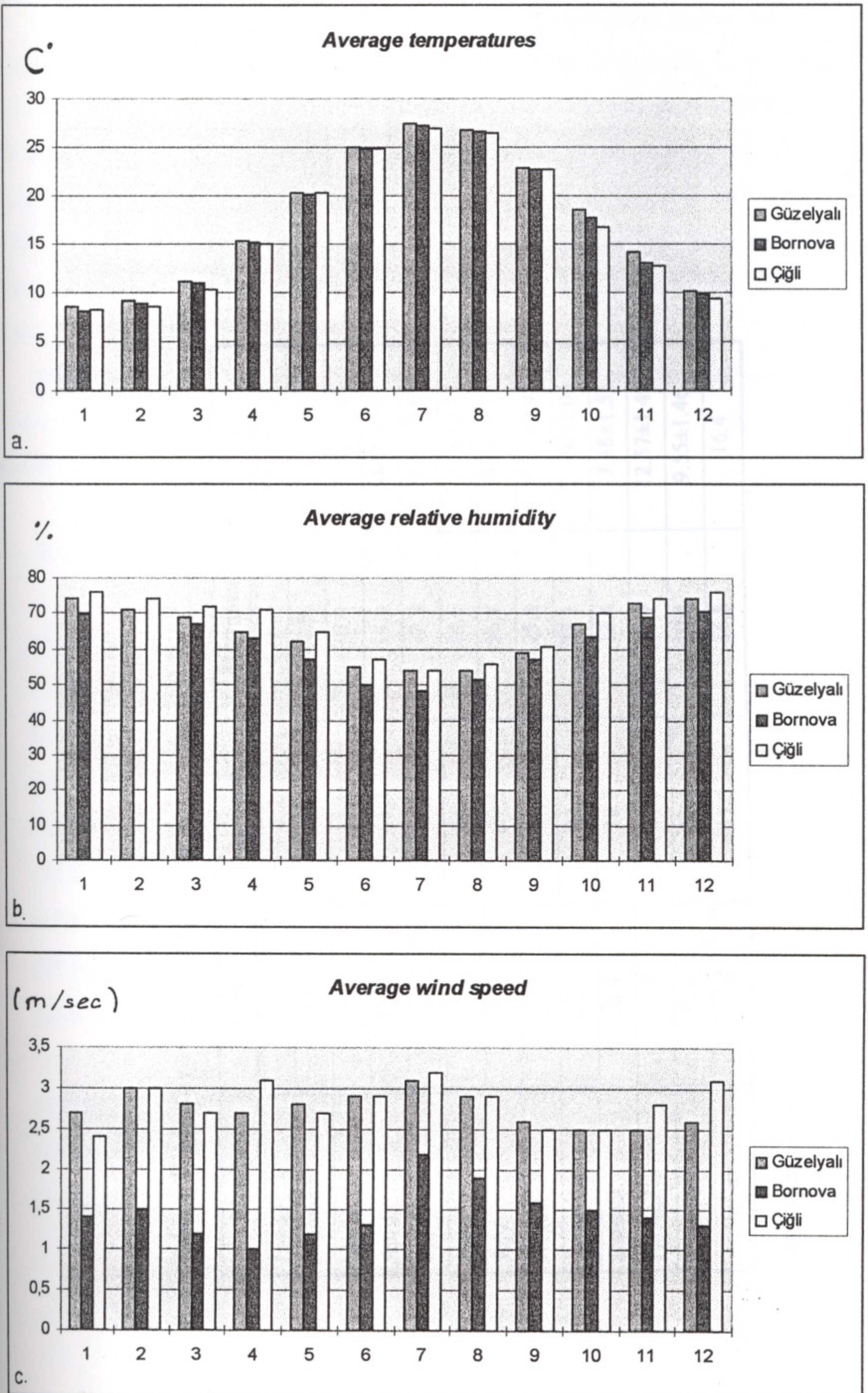


Fig.6.8. (a) average temperatures, (b) average relative humidity, (c) average wind speed

Table 6.7 . Monthly average temperatures

Months	Güzelyalı	Bornova	Menemen	Çiğli
January	8.6	8.2	7.4	7.6±0.92
February	9.6	8.8	8.9	8.24±2.00
March	11.1	11.1	10.9	10.75±1.00
April	15.5	15.3	14.6	14.46±0.83
May	20.4	20.1	19.8	19.23±0.81
June	25.0	24.7	24.6	24.20±0.77
July	27.6	27.5	26.7	25.96±0.71
August	27.3	27.0	25.8	25.05±0.92
September	23.3	22.7	22.1	21.60±1.06
October	18.4	18.3	17.4	17.38±1.55
November	14.3	13.9	13.7	12.57±1.49
December	10.6	10.4	10.4	9.55±1.46
Annual av.	17.6	17.3	16.8	16.4

(ITO,1995)

In the graph of annual minimum temperature, the linear trend shows that there has been an increase in temperatures for 62 years (Fig. 6.9a). According to the figure 6.9b the annual maximum temperatures, the maximum values of temperature has become higher as years go by because of the rapid urbanization. And in the figure 6.9c, that the daily temperature changes are illustrated, the linear trend shows that the distance between daily temperatures becomes lower in 62 years time period. In general, the lowest distances between day and night temperatures occur in summer and transition seasons.

If the solar radiation, sun angle values and sun shine in Izmir is considered; The sun angle values for Izmir are as below: (Table 6.8) (Şengöz, 1995) And the figure 6.10 illustrates these angles.

Table 6.8 The solar angle values for Izmir at noon time.

Day of the year	Altitude(h)	Azimuth(θ)
(15.1.1995) 15	30.28°	59.72°
(15.2.1995) 46	38.26°	51.74°
(15.3.1995) 74	48.77°	41.23°
(15.4.1995) 105	60.98°	29.06°
(15.5.1995) 135	70.29°	19.71°
(15.6.1995) 166	74.81°	15.19°
(15.7.1995) 196	73.03°	16.97°
(15.8.1995) 227	65.31°	24.69°
(15.9.1995) 258	53.74°	36.26°
(15.10.1995) 288	41.95°	48.05°
(15.11.1995) 319	32.40°	57.60°
(15.12.1995) 349	28.21°	61.79°

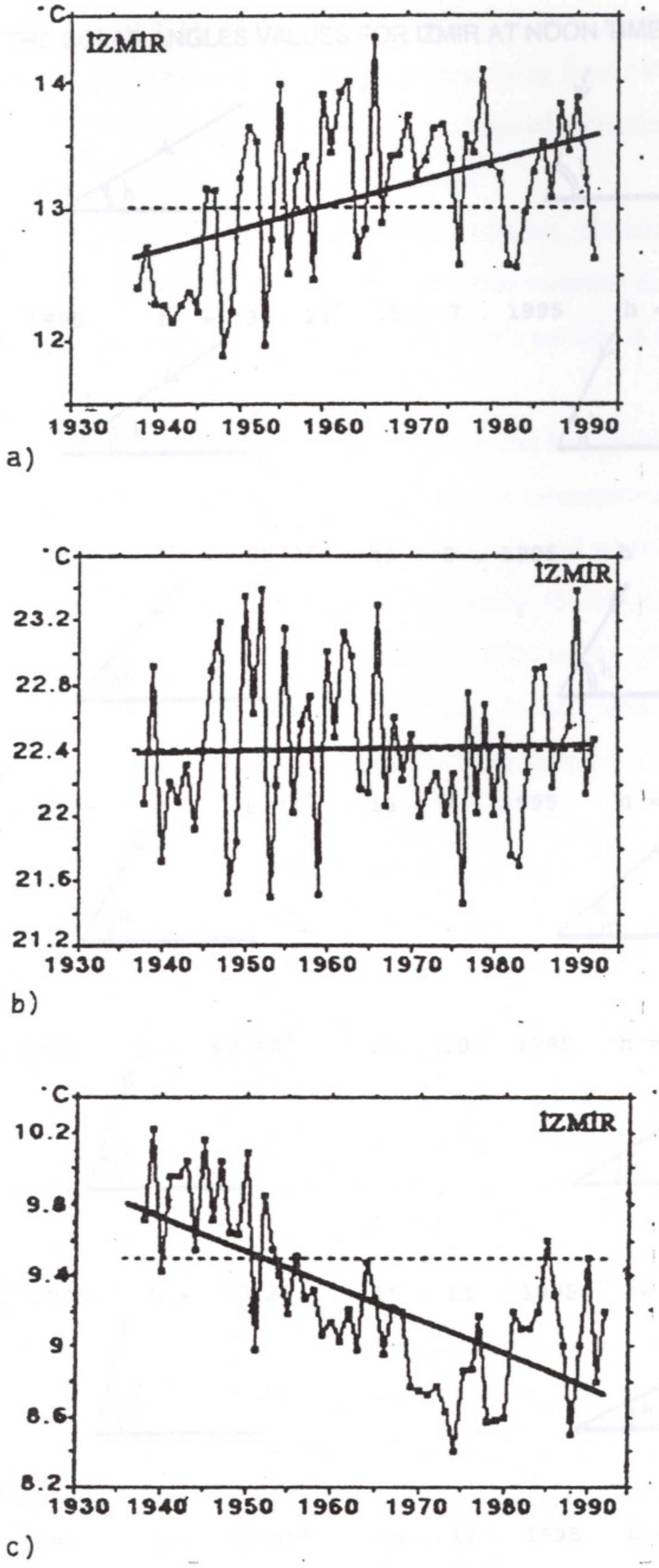


Fig. 6.9 The graphics of (a) annual average minimum and (b) maximum mperatures and (c) daily temperature changes (Temuçin, 1995; pp:84,86,88)

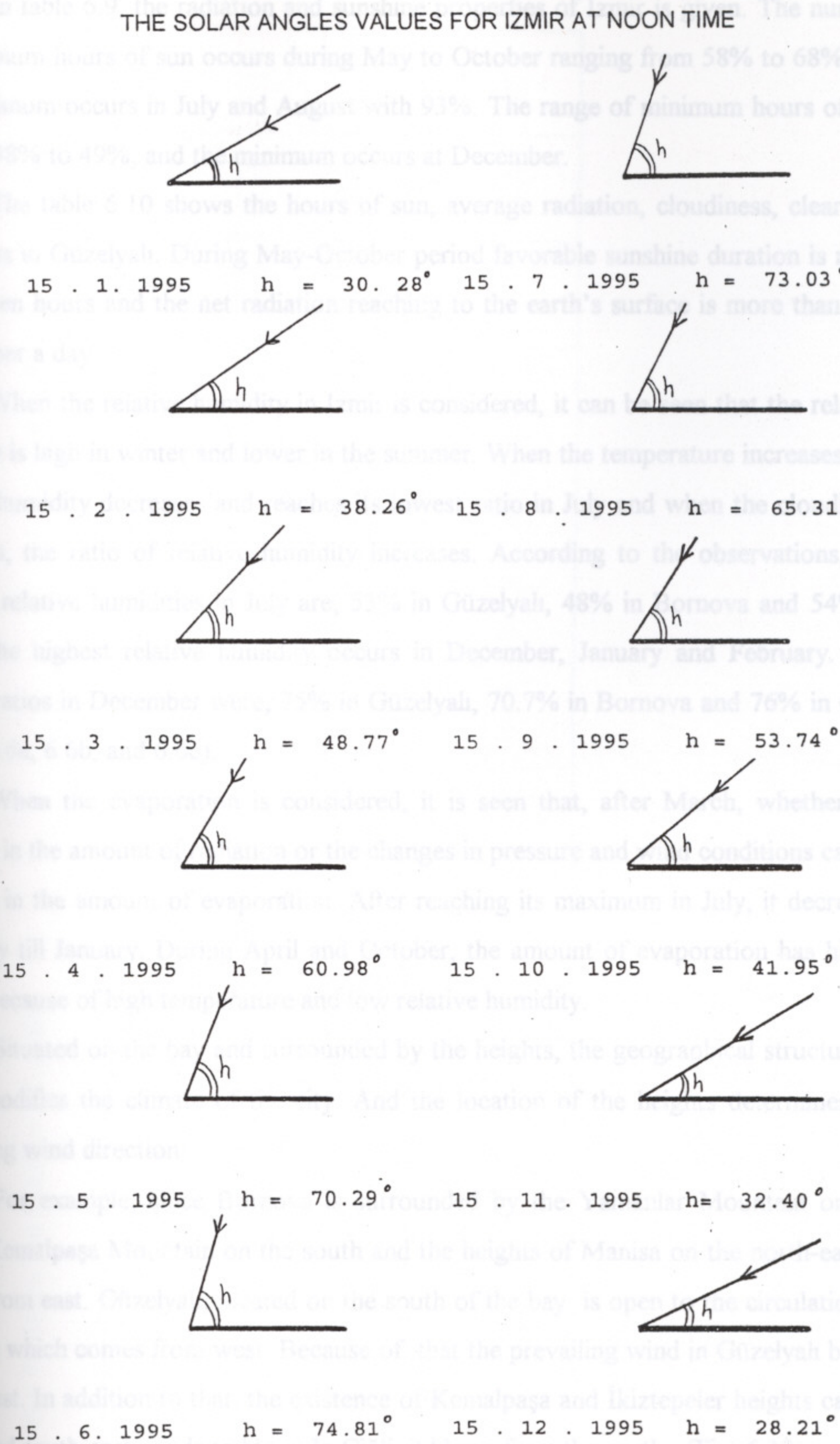


Fig. 6.10. Solar angle values (Şengöz, 1995)

In table 6.9, the radiation and sunshine properties of Izmir is given. The number of maximum hours of sun occurs during May to October ranging from 58% to 68% and the maximum occurs in July and August with 93%. The range of minimum hours of sun is from 38% to 49%, and the minimum occurs at December.

The table 6.10 shows the hours of sun, average radiation, cloudiness, clear and dark days in Güzelyalı. During May-October period favorable sunshine duration is more than seven hours and the net radiation reaching to the earth's surface is more than 100 cal/cm^2 per a day.

When the relative humidity in Izmir is considered, it can be seen that the relative humidity is high in winter and lower in the summer. When the temperature increases, the relative humidity decreases and reaches its lowest ratio in July and when the cloudiness increases, the ratio of relative humidity increases. According to the observations, the average relative humidities in July are; 53% in Güzelyalı, 48% in Bornova and 54% in Çiğli. The highest relative humidity occurs in December, January and February. The highest ratios in December were; 75% in Güzelyalı, 70.7% in Bornova and 76% in Çiğli (Table 6.6a, 6.6b, and 6.6c).

When the evaporation is considered, it is seen that, after March, whether the increase in the amount of radiation or the changes in pressure and wind conditions causes increase in the amount of evaporation. After reaching its maximum in July, it decreases gradually till January. During April and October, the amount of evaporation has higher values because of high temperature and low relative humidity.

Situated on the bay and surrounded by the heights, the geographical structure of Izmir modifies the climate of the city. And the location of the heights determines the prevailing wind direction.

For example; since Bornova is surrounded by the Yamanlar Mountain on the north, Kemalpaşa Mountain on the south and the heights of Manisa on the north-east, it blows from east. Güzelyalı, located on the south of the bay is open to the circulation of air mass which comes from west. Because of that the prevailing wind in Güzelyalı blows from west. In addition to that, the existence of Kemalpaşa and İkiztepeler heights causes south and south-east winds to blow. In Çiğli, it blows from the north. (Fig. 6.12)

When an evaluation is made among the prevailing winds, it can be seen that, the WNW wind in Güzelyalı blows with the frequency of 15.6%, and W wind blows 14.0%.

Table 6.9 : Sun Radiation and Sunshine Properties

	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Ann.
Hours of sun (T) h/m	9.38	10.35	11.44	13.00	14.06	14.39	14.24	13.28	12.14	10.58	9.53	9.21	12.11
Real hours of sun (R)	3.05	3.55	4.42	6.14	7.28	10.33	12.32	11.59	9.40	6.35	5.14	3.11	7.13
Ratio of sunshine (T/R)	43.0	41.2	46.4	49.0	58.3	78.2	92.3	92.6	82.5	67.5	48.0	38.6	61.8
Declination angle deg/min	30°37’	38°35’	49°07’	60°57’	70°20’	74°38’	72°43’	64°59’	53°46’	41°56’	32°38’	28°29’	-
Net radiation cal/cm^2/	11.0	54.8	116.1	186.3	248.5	296.0	307.3	263.9	173.6	84.5	25.4	1.1	147.3

(Koçman, 1993; pp: 19)

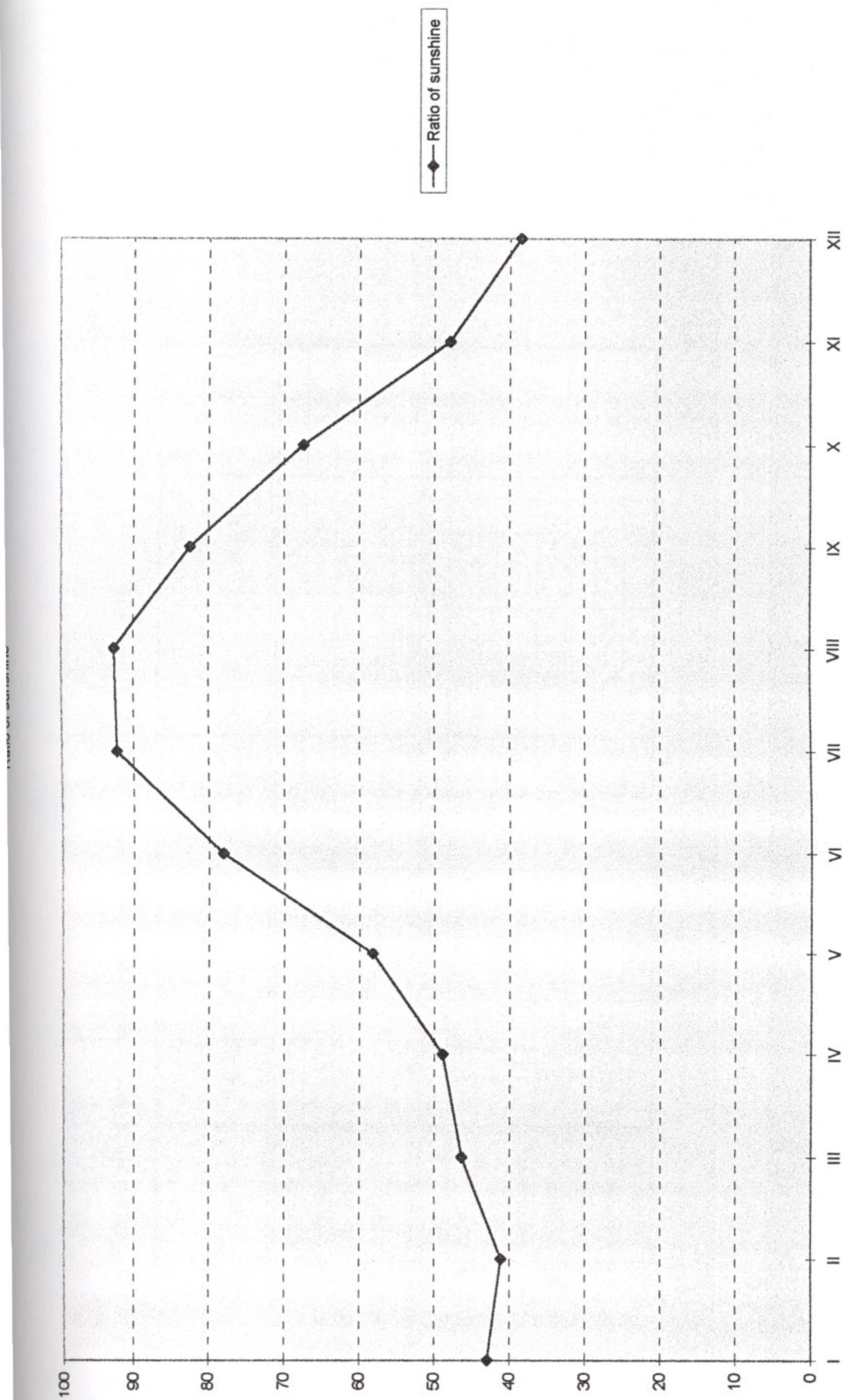


Fig. 6.11. Ratio of sunshine

Table 6.10. Climatic features observed in Güzelyalı station (1939-1993)

Months	Average number of daylight hours	Average radiation	Average cloudiness	Number of clear days	Number of cloudy days	Number of dark days
January	4.4	189.07	5.6	5.3	17.3	8.4
February	4.9	243.40	5.4	4.8	16.9	6.5
March	6.4	339.23	5.1	6.2	18.2	6.4
April	7.5	411.60	4.6	6.6	18.6	4.8
May	9.5	477.03	3.7	9.4	19.4	2.2
June	11.3	538.13	2.0	17.5	12.0	0.5
July	12.2	541.76	0.8	26.5	4.5	0.1
August	11.8	485.32	0.8	26.6	4.3	0.2
September	10.3	415.66	1.5	21.6	8.1	0.4
October	7.5	285.15	3.3	12.5	16.0	2.4
November	5.4	190.36	4.7	6.7	18.4	4.9
December	4.2	141.16	5.5	5.2	17.7	8.0
Annual av.	7.9	290.51	3.6	12.4	14.3	3.7

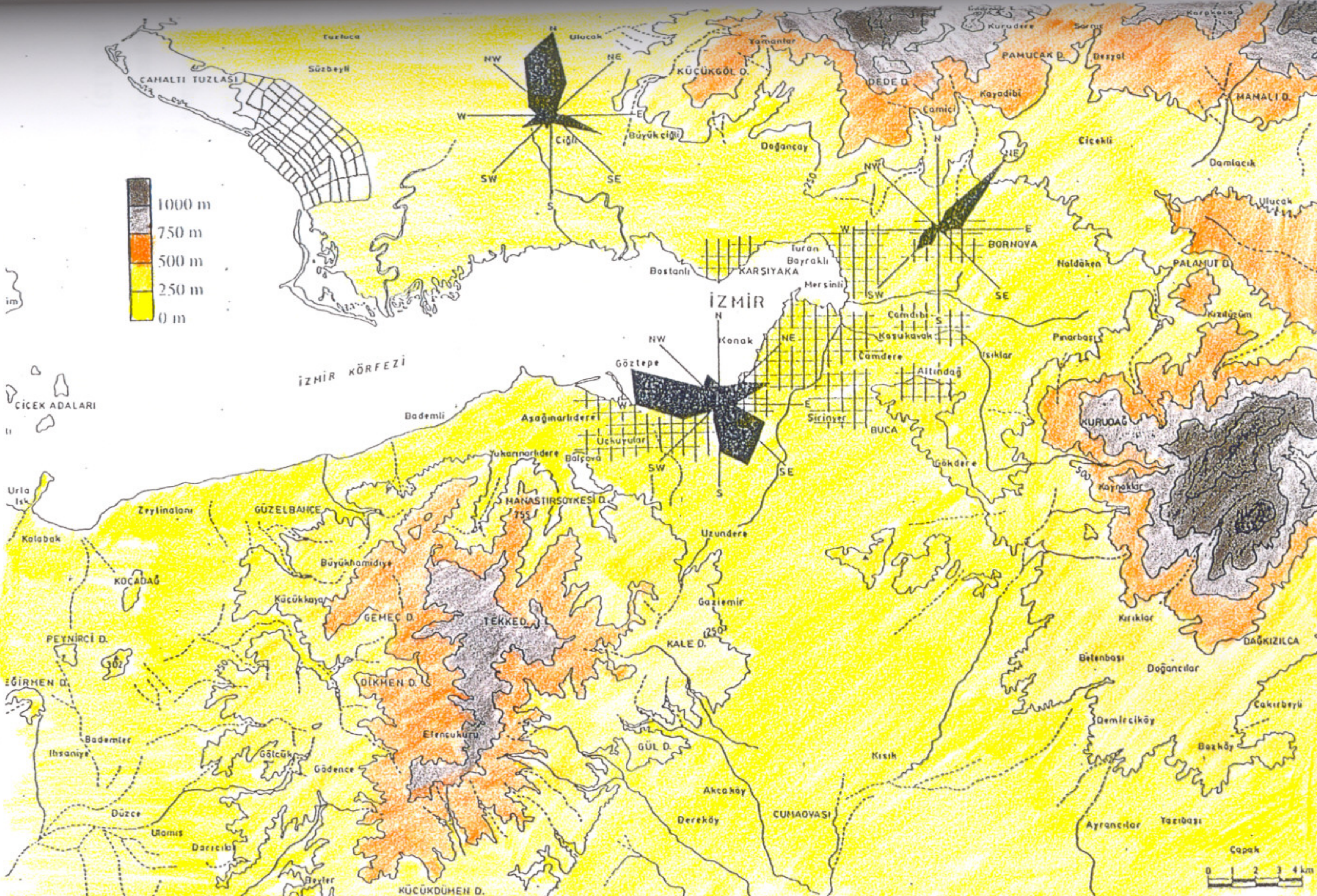


Fig. 6.12 Prevailing wind directions (Kılınç, 1996)

In Bornova, the frequency of NE winds is 32.2%. North winds blow with the frequency of 22.9% in Çiğli (Table 6.11a, 6.11b, 6.11c)

The wind blows with its highest speed in the afternoon when the temperature is highest and blows with lower speeds during night and morning hours. The observations show that, the highest wind speed occurs at 14:00 in Izmir. (Table 6.12)

On the other hand, it is observed that in general, the wind speeds are not too high in Izmir. Annual average wind speed in Çiğli is 2.8 m/sn. and the lowest annual average wind speed in Bornova is 1.5 m/sn. and the annual average wind speed in Güzelyalı is 2.7 m/sn.

Heating and Cooling Degree-Days:

Heating and cooling degree-days are calculated to determine whether heating or cooling is required.

Every day in which the daily temperature is below 18.3°C is equal to a certain number of HDD units. * The table 6.13 shows the HDD and CDD of Izmir.

The calculation of
heating degree-days: (18.3°C - monthly ave. temp.) × number of days in a month

In accordance with the heating and cooling degree-days, table 6.14 shows the thermic periods.

The charts belong to Bornova, Çiğli, and Güzelyalı show the total number of degree-days for each month with heating degree-days above the zero line and cooling degree-days below. It is thus easy to visually determine both heating and cooling periods. (Fig. 6.13)

Table 6.11. The frequencies of the winds (a) in Güzelyalı, (b) in Bornova and (c) in Çiğli

(a)

Güzelyalı		N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
January	# of blow	31	27	60	115	30	56	76	94	90	20	4	17	45	87	28	38	818
	frequency	3.8	3.3	7.3	14.1	3.7	6.8	9.3	11.5	11.0	2.4	0.5	2.1	5.5	10.6	3.4	4.6	100.0
February	# of blow	49	19	53	93	18	62	56	82	87	19	9	16	40	73	35	44	755
	frequency	6.5	2.5	7.0	12.3	2.4	8.2	7.4	10.9	11.5	2.5	1.2	2.1	5.3	9.7	4.6	5.8	100.0
March	# of blow	21	38	33	54	21	77	83	108	78	38	16	80	79	116	27	39	908
	frequency	2.3	4.2	3.6	5.9	2.3	8.5	9.1	11.9	8.6	4.2	1.8	8.8	8.7	12.8	3.0	4.3	100.0
April	# of blow	5	5	12	33	17	57	102	96	95	28	11	30	111	115	38	32	787
	frequency	0.6	0.6	1.5	4.2	2.2	7.2	13.0	12.2	12.1	3.6	1.4	3.8	14.1	14.6	4.8	4.1	100.0
May	# of blow	32	24	28	32	17	61	50	61	38	33	23	85	157	169	27	42	879
	frequency	3.6	2.7	3.2	3.6	1.9	6.9	5.7	6.9	4.3	3.8	2.6	9.7	17.9	19.2	3.1	4.8	100.0
June	# of blow	29	42	25	38	15	69	32	38	30	12	16	85	175	187	31	47	871
	frequency	3.3	4.8	2.9	4.4	1.7	7.9	3.7	4.4	3.4	1.4	1.8	9.8	20.1	21.5	3.6	5.4	100.0
July	# of blow	37	30	48	54	10	18	9	5	13	7	9	70	303	106	49	48	816
	frequency	4.5	3.7	5.9	6.6	1.2	2.2	1.1	0.6	1.6	0.9	1.1	8.6	37.1	13.0	6.0	5.9	100.0
August	# of blow	14	58	40	75	6	19	16	26	14	14	15	146	197	256	30	49	975
	frequency	1.4	5.9	4.1	7.7	0.6	1.9	1.6	2.7	1.4	1.4	1.5	15.0	20.2	26.3	3.1	5.0	100.0
September	# of blow	11	32	49	69	9	30	36	45	56	23	18	51	188	225	50	40	932
	frequency	1.2	3.4	5.3	7.4	1.0	3.2	3.9	4.8	6.0	2.5	1.9	5.5	20.2	24.1	5.4	4.3	100.0
October	# of blow	20	26	45	87	22	53	54	109	84	33	14	32	108	139	30	49	905
	frequency	2.2	2.9	5.0	9.6	2.4	5.9	6.0	12.0	9.3	3.6	1.5	3.5	11.9	15.4	3.3	5.4	100.0
November	# of blow	21	14	46	87	17	81	122	151	97	27	7	23	37	88	27	39	884
	frequency	2.4	1.6	5.2	9.8	1.9	9.2	13.8	17.1	11.0	3.1	0.8	2.6	4.2	10.0	3.1	4.4	100.0
December	# of blow	23	23	53	74	25	112	124	184	73	25	11	17	24	68	29	43	908
	frequency	2.5	2.5	5.8	8.1	2.8	12.3	13.7	20.3	8.0	2.8	1.2	1.9	2.6	7.5	3.2	4.7	100.0
Annual	# of blow	293	338	492	811	207	695	760	999	755	279	153	652	1464	1629	401	510	####
	frequency	2.8	3.2	4.7	7.8	2.0	6.7	7.3	9.6	7.2	2.7	1.5	6.2	14.0	15.6	3.8	4.9	100.0

(Source: Kılınç, 1996; pp:42)

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(Table 6.11. continue)

b.

Bornova		N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
January	# of blow	0	3	91	235	27	59	28	25	13	10	22	18	6	11	9	6	563
	frequency	0.0	0.5	16.2	41.7	4.8	10.5	5.0	4.4	2.3	1.8	3.9	3.2	1.1	2.0	1.6	1.1	100.0
February	# of blow	0	17	217	92	43	21	30	11	15	18	22	17	14	7	6	4	534
	frequency	0.0	3.2	40.6	17.2	8.1	3.9	5.6	2.1	2.8	3.4	4.1	3.2	2.6	1.3	1.1	0.7	100.0
March	# of blow	1	31	198	24	48	5	23	5	8	32	77	14	20	3	18	0	507
	frequency	0.2	6.1	39.1	4.7	9.5	1.0	4.5	1.0	1.6	6.3	15.2	2.8	3.9	0.6	3.6	0.0	100.0
April	# of blow	0	3	50	84	17	12	7	16	4	10	60	69	32	21	9	16	410
	frequency	0.0	0.7	12.2	20.5	4.1	2.9	1.7	3.9	1.0	2.4	14.6	16.8	7.8	5.1	2.2	3.9	100.0
May	# of blow	2	30	117	10	29	5	17	5	5	41	88	57	31	11	18	6	475
	frequency	0.2	8.8	24.8	2.1	6.1	1.1	3.6	1.1	1.1	8.7	18.6	12.1	6.6	2.3	3.8	1.3	100.0
June	# of blow	1	42	116	4	29	6	21	3	2	53	89	47	22	12	22	6	475
	frequency	0.2	6.4	24.8	2.1	6.1	1.3	4.4	0.6	0.4	11.2	18.7	9.9	4.6	2.5	4.6	1.3	100.0
July	# of blow	0	62	240	82	70	24	13	2	0	39	53	39	12	10	26	15	687
	frequency	0.0	9.0	34.9	11.9	10.2	3.5	1.9	0.3	0.0	5.7	7.7	5.7	1.7	1.5	3.8	2.2	100.0
August	# of blow	3	86	245	14	59	6	17	0	0	38	72	35	25	17	31	12	660
	frequency	0.5	13.0	37.1	2.1	8.9	0.9	2.6	0.0	0.0	5.8	10.9	5.3	3.8	2.6	4.7	1.8	100.0
September	# of blow	1	38	223	27	25	6	6	1	1	26	63	38	38	16	40	2	551
	frequency	0.2	6.9	40.5	4.9	4.5	1.1	1.1	0.2	0.2	4.7	11.4	6.9	6.9	2.9	7.3	0.4	100.0
October	# of blow	1	53	241	18	54	5	18	1	5	30	65	27	33	7	27	0	585
	frequency	0.2	9.1	41.2	3.1	9.2	0.9	3.1	0.2	0.9	5.1	11.1	4.6	5.6	1.2	4.6	0.0	100.0
November	# of blow	2	38	208	21	68	9	29	4	15	12	47	9	9	6	21	4	502
	frequency	0.4	7.6	41.4	4.2	13.5	1.8	5.8	0.8	3.0	2.4	9.4	1.8	1.8	1.2	4.2	0.8	100.0
December	# of blow	48	154	264	60	74	21	32	4	8	32	31	2	11	8	54	122	925
	frequency	5.2	16.6	28.5	6.5	8.0	2.3	3.5	0.4	0.9	3.5	3.4	0.2	1.2	0.9	5.8	13.2	100.0
Annual	# of blow	59	557	2210	671	543	179	241	77	76	341	689	372	253	129	281	193	6871
	frequency	0.9	8.1	32.2	9.8	7.9	2.6	3.5	1.1	1.1	5.0	10.0	5.4	3.7	1.9	4.1	2.8	100.0

(Source: Kılınç, 1996; pp:43)

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(Table 6.11. continue)

c.

Çiğli		N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
January	# of blow	113	54	12	11	25	60	29	7	8	3	5	8	6	9	31	76	457
	frequency	24.7	11.8	2.6	2.4	5.5	13.1	6.3	1.5	1.8	0.7	1.1	1.8	1.3	2.0	6.8	16.6	100.0
February	# of blow	96	44	15	2	16	50	21	8	13	12	10	4	10	13	15	71	400
	frequency	24.0	11.0	3.8	0.5	12.5	12.5	5.3	2.0	3.3	3.0	2.5	1.0	2.5	3.3	3.8	17.8	100.0
March	# of blow	80	43	8	5	13	61	18	8	9	22	15	27	15	32	28	76	460
	frequency	17.4	9.3	1.7	1.1	2.8	13.3	3.9	1.7	2.0	4.8	3.3	5.9	3.3	7.0	6.1	16.5	100.0
April	# of blow	66	16	6	9	25	72	30	11	19	34	14	32	22	16	33	44	449
	frequency	14.7	3.6	1.3	2.0	5.6	16.0	6.7	2.4	4.2	7.6	3.1	7.1	4.9	3.6	7.3	9.8	100.0
May	# of blow	78	33	5	3	10	37	14	3	7	18	21	58	17	52	28	73	457
	frequency	17.1	7.2	1.1	0.7	2.2	8.1	3.1	0.7	1.5	3.9	4.6	12.7	3.7	11.4	6.1	16.0	100.0
June	# of blow	89	26	3	3	8	26	6	4	3	20	17	53	27	28	48	78	439
	frequency	20.3	5.9	0.7	0.7	1.8	5.9	1.4	0.9	0.7	4.6	3.9	12.1	6.2	6.4	10.9	17.8	100.0
July	# of blow	165	42	1	3	0	2	6	2	2	4	2	35	9	32	60	96	461
	frequency	35.8	9.1	0.2	0.7	0.0	0.4	1.3	0.4	0.4	0.9	0.4	7.6	2.0	6.9	13.0	20.8	100.0
August	# of blow	134	61	8	3	2	6	2	1	0	2	10	29	14	44	74	67	455
	frequency	29.5	13.4	1.8	0.7	0.5	1.3	0.4	0.2	0.0	0.4	2.2	6.4	3.1	9.7	16.3	14.7	100.0
September	# of blow	126	46	5	2	8	16	2	4	0	7	20	43	18	24	43	81	439
	frequency	28.7	10.5	1.1	0.5	1.8	3.6	0.5	0.9	0.0	1.6	4.6	9.8	4.1	5.5	9.8	18.5	100.0
October	# of blow	87	36	6	5	27	56	6	24	9	14	10	43	12	27	32	73	448
	frequency	19.4	8.0	1.3	1.1	6.1	12.5	1.3	5.4	2.0	3.1	2.2	9.6	2.7	6.0	7.1	16.3	100.0
November	# of blow	104	35	7	6	47	102	17	8	11	10	4	14	7	12	28	53	445
	frequency	23.4	7.9	1.6	1.3	10.3	22.9	3.8	1.8	2.5	2.2	0.9	3.1	1.6	2.7	6.3	11.9	100.0
December	# of blow	108	53	9	11	181	95	21	9	7	5	8	3	6	8	20	46	456
	frequency	23.7	11.6	2.0	2.4	3.4	20.8	4.6	2.0	1.5	1.1	1.8	0.7	1.3	1.8	4.4	10.1	100.0
Annual	# of blow	1246	489	85	63	207	583	172	89	88	151	136	349	163	297	440	834	5366
	frequency	23.2	9.1	1.6	1.2	2.0	10.9	3.2	1.7	1.6	2.8	2.5	6.5	3.0	5.5	8.2	15.5	100.0

(Source: Kılınç, 1996; pp:44)

Table 6.12. Average wind speeds in different hours

			I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Annual
Güzel-yalı	Observation period 1984 - 1993	7.00	2.6	2.6	2.2	2.2	2.0	2.2	1.9	1.7	2	2.4	2.7	2.2	2.2
		14.00	2.9	3.3	3.5	3.6	4.0	4.5	4.6	4.6	3.9	3.4	2.9	2.9	3.7
		21.00	2.9	2.5	2.5	2.3	2.3	2.3	2.5	2.2	2.2	2.2	2.2	2.3	2.4
		Mean	**2.7**	**3.0**	**2.8**	**2.7**	**2.8**	**2.9**	**3.1**	**2.9**	**2.6**	**2.5**	**2.5**	**2.6**	**2.7**
	1938 - 1993	Mean	**3.7**	**4.0**	**3.7**	**3.3**	**3.0**	**3.1**	**3.4**	**3.2**	**2.9**	**2.8**	**3.1**	**3.6**	**3.3**
Bor-nova	Observation period 1984 - 1993	7.00	1.4	1.2	1.0	0.7	1.0	1.0	2.1	1.8	1.5	1.5	1.4	1.3	1.3
		14.00	1.7	1.9	1.7	1.6	2.1	2.4	2.9	2.5	2.4	2.0	1.6	1.5	2.0
		21.00	1.1	1.2	0.8	0.5	0.6	0.6	1.7	1.4	1.0	1.2	1.1	1.0	1.0
		Mean	**1.4**	**1.5**	**1.2**	**1.0**	**1.2**	**1.3**	**2.2**	**1.9**	**1.6**	**1.5**	**1.4**	**1.3**	**1.5**
	1959 - 1993	Mean	**2.9**	**2.7**	**2.6**	**2.1**	**2.0**	**2.3**	**2.9**	**2.9**	**2.5**	**2.2**	**2.0**	**2.6**	**2.7**
Çiğli	Observation period 1984 - 1993	7.00	2.0	2.4	2.2	2.5	1.5	1.6	1.7	1.6	1.4	1.9	2.6	2.7	2.0
		14.00	3.0	3.9	3.8	4.5	4.6	5.0	5.3	4.5	4.4	3.8	3.6	3.7	4.1
		21.00	2.1	2.8	2.1	2.3	1.8	2.0	2.7	2.6	1.8	1.9	2.3	2.8	2.2
		Mean	**2.4**	**3.0**	**2.7**	**3.1**	**2.7**	**2.9**	**3.2**	**2.9**	**2.5**	**2.5**	**2.8**	**3.1**	**2.8**
	1959 - 1993	Mean	**4.2**	**4.2**	**4.5**	**3.9**	**3.6**	**3.8**	**4.4**	**4.0**	**3.7**	**3.4**	**3.5**	**4.2**	**4.0**

(Kılınç, 1996; pp:56)

Table 6.13. Degree-days

	GÜZELYALI	BORNOVA	ÇİĞLİ
January	303.8	316.2	313.1
February	254.8	263.2	274.4
March	216	219	240
April	87	96	99
May	-65.1	-58.9	-62
June	-201	-198	-195
July	-285.2	-275.9	-266.6
August	-260.4	-257.3	-251.1
September	-138	-135	-135
October	-6.2	18.6	46.5
November	123	156	168
December	251.1	260.4	279
HDDs	**1235.7**	**1329.4**	**1420**
CDDs	**955.9**	**925.1**	**909.7**

* Heating Degree-Days (HDDs):

1. Areas with more than 5500 HDDs per year are characterized by long cold winters
2. Areas with less than 2000 HDDs per year are characterized by very mild winters.

Cooling Degree-Days (CDDs):

1. Areas with more than 1500 CDDs per year are characterized by long hot summers and substantial cooling requirements.

2. Areas with less than 500 CDDs per year are characterized by mild summers and little need to mechanical cooling. (Lechner, 1991)

When the climatic data of Izmir is summarized;

The climate of Izmir is relatively temperate. Although summers are very hot and winters are somewhat cold, spring and fall are generally quite pleasant, however very short. The annual sunshine is 61.8 %. The region is characterized as half-humid and the humidity is at the comfort range during the year.

CLIMATIC DESIGN PRIORITIES:

In climates with very hot summers and mild winters, cooling strategies are more essential than heating strategies, and therefore shade is more desirable than solar access.

- Protect from the summer sun;
- Use natural ventilation for summer cooling;
- Keep hot temperatures out during the summer;
- Let the winter sun in;
- Keep the heat in and the cool temperatures out during the winter.

Table 6.14 Thermic periods

Thermic	Dates	Daily ave.	Number of	Annual rate
Cold - cool	21 Nov - 28 Mar	7.4 °C -13.6° C	128	35.1
Tepid	29 Mar - 28 Apr	14.0° C -17.0° C	31	8.5
Hot	29 Apr - 10 Jun	17.8° C -24.2°C	43	11.8
Very hot	11 Jun - 28 Aug	25.0° C -28.5° C	79	21.6
Hot	29 Aug - 19 Oct	24.9° C -18.2° C	52	14.3
Tepid	20 Oct - 20 Nov	10.3° C -17.4° C	32	8.7

* "Ege Ovalarının İklimi", Prof.Dr. Asaf Koçman, İzmir,1993

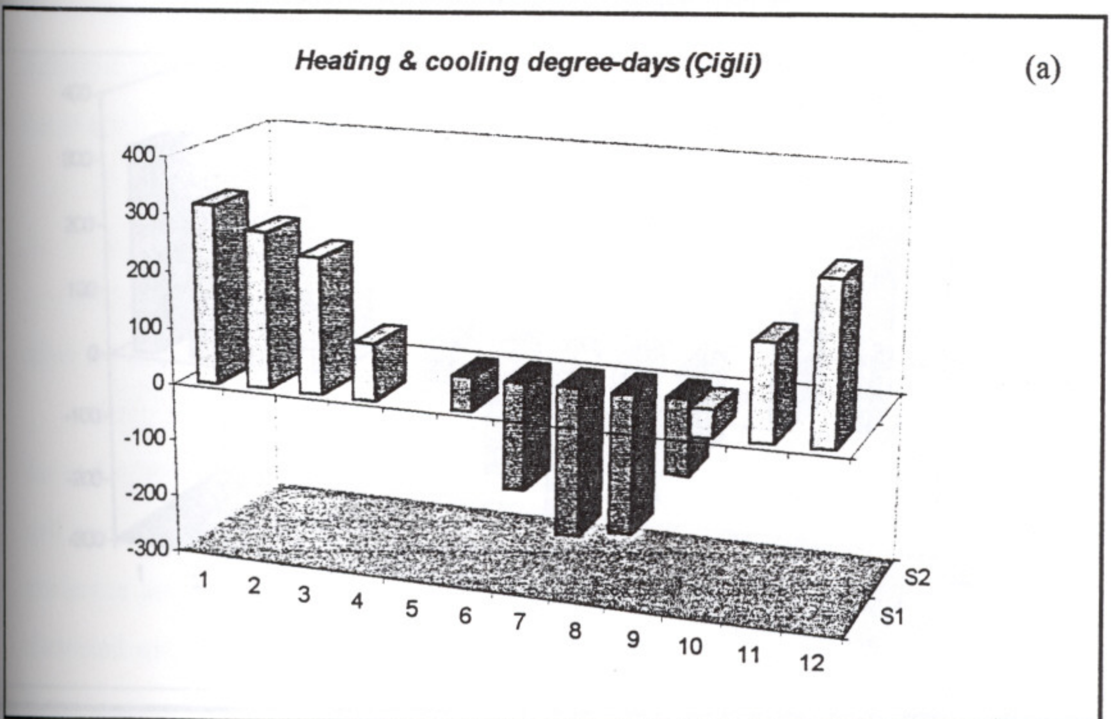
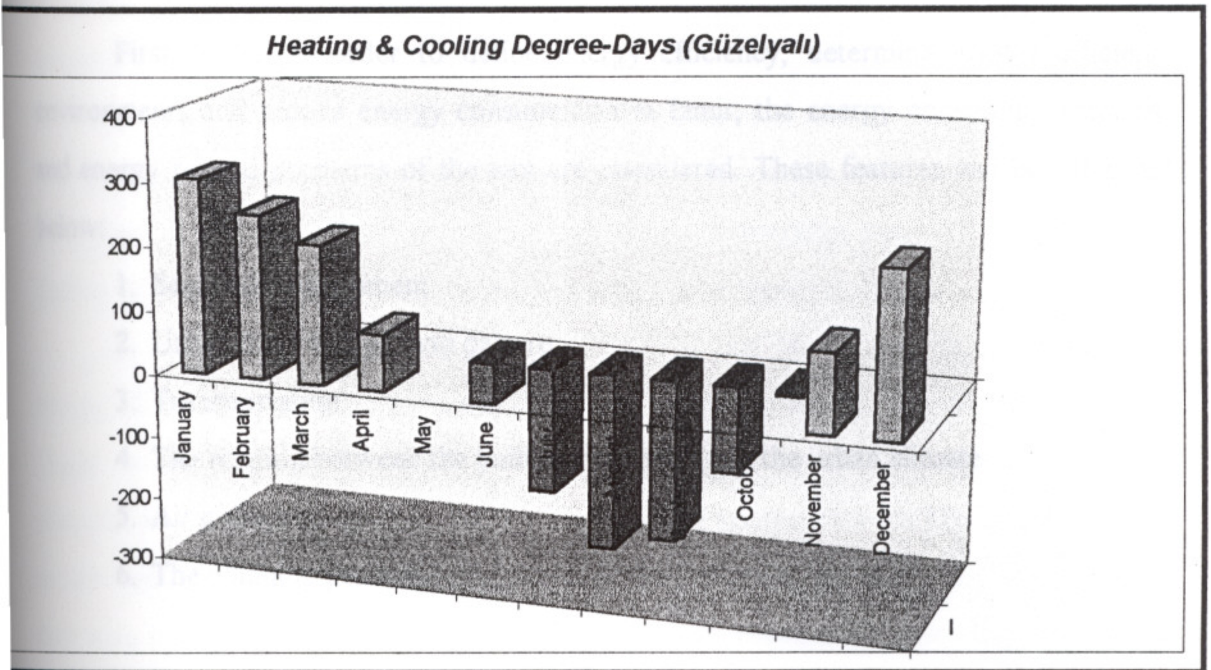


Fig. 6.13. Degree days (a) of Çiğli, (b) of Güzelyalı, (c) of Bornova

(cont. next page)

(Fig. 6.13. cont.)



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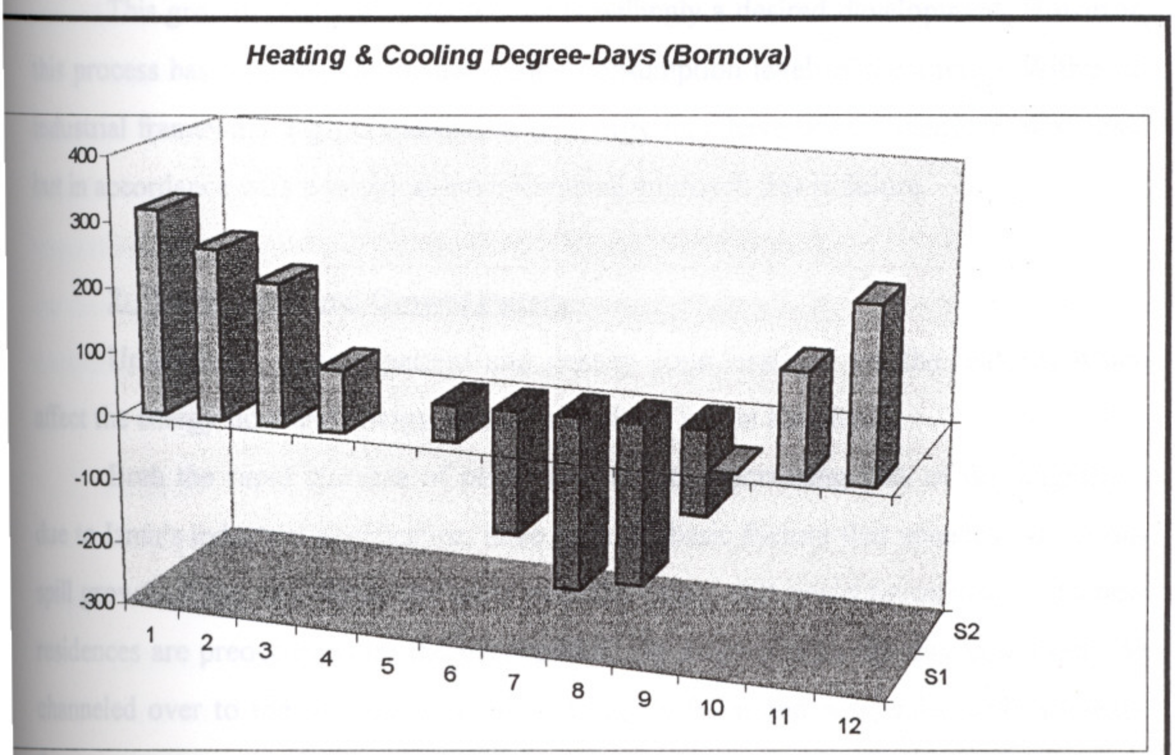


c)

6.3. Energy Consuming Features and Energy Related Problems of Izmir

First of all, in order to define energy efficiency, determine energy efficient environments and reduce energy consumption in Izmir, the energy consuming features and energy related problems of the city are considered. These features can be listed as below:

1. Sectoral development
2. Urban form and growth pattern
3. Transportation
4. The relation between the built environment and the urban climate
5. Air pollution
6. The planning process

1. <u>Sectoral Development</u>

Izmir is a metropolis in which regional trade, industrial and agricultural decisions are undertaken and in which those are organized and controlled. Its commercial and industrial capacity is increasingly expanding continuously.

This growth potential in all sectors is willingly a desired development. However, this process has a significant impact on the consumption level of the energy. Within an industrial framework high consumption of energy may have been a measure of success but in accordance with ecological-environmental approach this is failure.

2. <u>Urban Form and Growth Pattern</u>

Urban form, growth pattern and density considerations are the features which affect the energy flow and energy consumption level within the city.

Both the rapid increase of population and the increasing rate of the migration, due to Izmir's industrial significance, have been the basic factors that speeded up the oil-spill growth of the city. Since the areas near the center that could be opened up to new residences are preoccupied by the gecekondus, the migration to the city could only be channeled over to the remote places like Bornova, Buca and Karşıyaka with the leap-frog.

Therefore, this dispersed form has resulted in a demand for more roads which translates into more and longer journeys, more congestion and yet more fuel consumption.

On the other side, the spread new settlements have grown with lower densities which require more infrastructure costs. Low density residential areas make solar heating more feasible and provide possibilities of generating renewable energy. However these factors have not been considered during the planning process yet.

In contrast to lower densities, it is assumed that high urban densities enhance energy efficiency as density allows efficient use of infrastructure. The city of Izmir has higher densities but this does not indicate that Izmir is an efficient city. Because the technical and social infrastructure of the city does not compensate the higher densities. It is also accepted that higher densities allow efficiency from the points of heat loss and heat gain however, the building within the city is not necessarily depending on certain factors i.e. climate.

In addition, related with the urban pattern and density, the ratio of open to developed areas, is low in the city. The solid-void ratio is significant for air movement. Open spaces among the settlement encourage and direct the air movement. Low ratios and unbalanced pattern cause lack of ventilation, therefore thermal control.

Moreover, the current growth pattern of the city affects the environment in an undesired manner. As the settlement and transport areas expand on the north and west axis, the nature and landscape are increasingly fragmented and destroyed, wetlands filled, vegetation stripped off and the productive capacity of the land is undermined. In short, the clearing, grubbing and building activities are interfering with the energy flow and the ecosystem of the city.

3. Transportation

Transportation sector is an essential activity and land-use in Izmir, thus a magnificent energy consumer.

Private transportation:

People travel for a variety of reasons. The number of trips that people make is conditioned by their life-styles and preferences, their income, the cost of travel, the amount of time available for travel and time needed to accomplish the trip. In addition, the choice of mode for traveling is shaped by the factors such as; purpose of journey, distance of trip, availability and cost of mode, income and preferences. All these considerations determine the travel demand.

Today, Izmir -like many other cities- has responded to travel demand by expanding the transportation supply. This means building more road to accommodate an ever growing number of vehicles, instead of improving the mobility of urban residents and the efficiency of the existing transportation system. Therefore, the costs of increasing dependence on cars are becoming apparent such as; expensive road building and maintenance, clogged and congested streets, high levels of energy consumption with its attendant economic and environmental costs.

Public transportation:

When the public transportation system of Izmir is taken into account, it can be said that the present system does not meet the needs of the developing city and its residents. And the system runs inefficiently.

The system contains segregated usage of different transport means while urban transportation problems require integrated solutions. Lacking of integration lessens the benefits of the rail and sea transport systems in Izmir. Another fact that reduces the opportunities of the rail and sea transport is the heavily widening of land network by giving weigh on bus transportation. According to the research made by the Izmir Greater Municipality in 1989, the share of the sea transport in Izmir's mass transportation is only 2 %. It seems that today's share is not more than this percentage though the private sea transportation has began to serve since last year. In addition to these, it can be accepted that the informal transit services -dolmuş, minibuses- are an important part of the city transportation. Although they tend to contribute to congestion, the vehicles, which operate without timetables, provide more frequent services than municipal buses.

The above considerations show that the system is highly a fuel consumer so an air pollutant.

The more critical thing is that such a public transportation system does not persuade drivers to leave their cars at home. While giving weigh on bus transportation, as long as buses run on the same congested streets as private vehicles, they will never be an attractive alternative for people who can afford a car.

Lastly, the investment of rapid transit system is a positive enterprise for the urban mass transportation. Whether there are still some physical and technical problems and uncertainties about the system, it is expected that this rapid transit system will increase the efficiency. However, in reality the system should have been constructed some twenty years ago.

Infrastructure:

The condition of the transportation infrastructure is important from the point of energy consumption. In Izmir, the transportation infrastructure including roads, sidewalks, crossroads and also railways is seriously deficient. There exists poor road surfaces which lead to safety hazards, congestion, vehicle aging, as well as increased fuel consumption and pollution.

Pedestrianization:

Within the framework of efficiency, it is important to improve the mobility of pedestrians. There has been some pedestrianization studies in Izmir in order to improve pedestrian movement. Wide pedestrian roads were opened in activity centers like Konak, Alsancak and in the other parts of the city.

In this part, the implemented studies are investigated from the point of microclimate and human comfort.

In Konak, the wide pedestrian road provides linkage between business and shopping areas with heavy pedestrian usage however it does not provide thermally comfortable movement. Widely open streets to support wind movement is desirable but there has to be also shading. The arcaded sidewalk is preferred by pedestrians in order to protect themselves from sun. Shading and landscaping for thermal control is deficient. The examples of pedestrianization in Alsancak are relatively more successful. The east-west oriented pedestrian road that connects the 1.Kordon and 2.Kordon, is providing ventilation as being perpendicular to the sea with an open end. The street is shadowed by buildings on both sides and the plantation balances the thermal conditions. Sevgi Road, the tree lined street is a good example. Trees provide shading, ventilation and fresh air. The road behind the Gazi primary school is another pedestrian oriented implementation with landscaping. The street is exposed to sun radiation from afternoon till early evening. The surface materials and building facades cause reflection and increase in the amount of radiation.

4. The Relation Between the Built Environment and the Urban Climate

The climate of Izmir is not so stressful although there are overheated periods during daytime hours in summer. However, the physical structure of the city, which has formed without considering the climatic features thoroughly, causes extreme conditions both in summer and winter.

When the old structure of the city is examined, it is seen that the city was generally climate responsive. The streets were generally narrow and covered with the balconies or overhangs and the eaves of the two-storied houses on both sides. While those covered narrow streets provided shading, there might be lack of ventilation. However, the houses were designed in order to provide both solar access and ventilation. The long galleries and the terraces at the second floor let the zephyr-the sea breeze in. Moreover, it is known that those houses had no chimneys and fireplaces. In cold days, the charcoal was burned in a container for heating.

Today's city morphology does not offer an opportunity like that in the past. Although the winter is mild in Izmir, high levels of energy is consumed for heating because of heat losses. On the other hand, it can be suggested that the energy requirement for cooling is much above the amount required for heating.

In the physical structure of the city, the blocks are parallel to the sea thus the high buildings are elongated continuously along the shore like a wall. Therefore, the microclimatic wind patterns from the sea are not made use of, and the air corridors through the inner city are not created or undesirable situations occur at distance between buildings. In general, there is not a combined variation of building heights, types and sizes. Five and eight storied apartment blocks and 3 m. side distances are dominant in the city. So the result is lacking of direct solar access, lacking of air movement and accordingly, the existence of air pollution. When the sea breeze slows down in the early hours of morning and lately in the evening during autumn and winter, the air pollution reaches higher values in the settlement. As the buildings become higher and dense, and the green and open spaces become scarce, the pollution threats the city more seriously.

As the urbanization increases, each square kilometer of the urban land becomes a more intensified heating area. The intensity of heat island depends on factors, such as the absorption of heat caused by land cover, the trapping of heat by buildings because of their mass and geometry and the reduction in vegetation.

When the climatic data taken from 3 different meteorological stations are compared, it is seen that the urban temperatures in Bornova and Güzelyalı are higher than the temperatures in Çiðli during both in summer and winter. Because Güzelyalı and Bornova are densely urbanized centers; on the other hand Çiðli, locating on the north growth axis, has still got rural properties. In addition, if the last 60 year's results are taken into consideration, the observed situation is that air temperatures have been increasing. While maximum temperatures in summer and minimum temperatures in winter are both increasing and the wind speeds are decreasing.

Such comparisons show the increasing intensity of heat island in Izmir. Therefore, it is required to reduce that heat island effect.

Increase in temperatures and in greenhouse effect cause changes in local climate. The city of Izmir has experienced the results of global warming with severe weather events such as flooding (November,1995).

The relation between heat island effect and energy efficiency in space conditioning and transportation constitutes the basis of the study. It is required to look for the possibilities of mitigating the negative impacts of heat island effect and energy consumption related to urbanization by designing urban areas.

5. Air Pollution

Air pollution is another energy related problem of Izmir. There is an important relationship between the heat island effect, energy efficiency in space conditioning and transportation.

It was observed that in some cities the air pollution reduces 15% -20% of sun radiation. Some portion of this amount of lost energy is absorbed by the atmosphere and layer above the city. Therefore, the temperature in the city is higher than its periphery. In the seasons when the temperature and the relative humidity gets higher, the transformation of SO_2 to sulfate aerosols occurs faster and with photochemical reactions, the formation of smog process increases. The smog over the city causes increase in the air temperature. (Temuçin, 1995)

When the breeze slows down in the early hours of morning and lately in the evening during autumn and winter, the air pollution reaches higher values in Izmir. The observed values can define the level of air pollution. The average, maximum and minimum values of air pollution in 1993 is given in the table 6.15.

Table 6.15. Air pollution

Station	Average SO2	Max. / Min.	Average PM	Max. / Min.
Balçova	134	439 / 56	102	400 / 30
Bornova	127	448 / 38	92	522 / 29
Çamdibi	130	792 / 47	92	855 / 23
Buca	139	584 / 50	110	1330 / 29
Karşıyaka	154	721 / 56	123	1003 / 26
Konak	142.5	715 / 56	100	719 / 30
Güzelyalı	161	499 / 63	74	379 / 27
Gürçeşme	137.5	832 / 10	87.5	979 / 28
İzmir (Aver.)	141	832 / 10	99	1330 / 26

(Source: İzmir'in Hava Kirlenmesi, Prof. Dr. Aysen Müezzinoğlu, 1995)

According to the regulation for air quality, the limitations of air pollution values are approximately 250 microgram/m^3 for SO_2 and 200 microgram/m^3 for PM. In the table, the average values of SO_2 and PM show that the limits were not spoiled in the year 1993. However, in the same regulation, the short-term limit values for 24 hour averages are determined as 400 microgram/m^3 for SO_2 and 300 microgram/m^3 for PM.(ITO, 1995) It is seen that the limits are exceeded during the day of the year.

On the other hand, the annual SO_2 and PM emissions from heating are considerably high in total emissions. The table 6.16 shows the annual SO_2 and PM emissions from different sources in Izmir.

Table 6.16 The annual SO_2 and PM emissions

Sources	SO_2 (ton/year)	PM (ton/year)
Fuels from heating	25537	4138
Industrial	7750	3000
Total emissions	33287	7138

(Source: İzmir'in Hava Kirlenmesi, Prof. Dr. Aysen Müezzinoğlu, 1995)

In addition to domestic fuel consumption, power use is also an important cause for air pollution. The thermal lignite fired power plants have not enough control technologies. Besides the quality of fuel, the combustion equipment also create air pollution. "In imperfect combustion systems, fuel burning creates unburned gases and particles as well as hazardous components such as polynuclear aromatic hydrocarbons. (Towards and Agenda 21 in Izmir, 1996)

6. <u>The Planning Process</u>

The current situation in Izmir is the haphazard development. The planning process is far beyond the development process. First the investment decisions are taken and then the plan is produced in a way neglecting the planning principles and not depending on a scientific basis.

In order to solve the problems, it is expected that the transportation master plan and the structure plan of the city to be complementary, but the planning decisions are taken without considering each other. The production of the plans and restrictive zoning and density ordinances are very time consuming and rigid, and are more and more outdated at completion time as it has been overtaken by events in the rapid urban growth. The enforcement of the plans, on the other hand is also often beyond the capacities of the implementing agencies and therefore puts into question their efficiency.

6.4. Energy Efficient Urban Design in Izmir

<u>**Goal:**</u>

To reduce urban energy consumption and its negative impacts and to provide energy efficient urban environments.

<u>**Objectives:**</u>

To reduce energy consumption in transportation.

To reduce energy consumption in space conditioning.

The related data (general characteristics of the city, climatic data, energy consuming features,) were given in the previous sub-titles. Next step is the utilization of the gathered data through energy efficiency considerations in order to achieve the objectives and therefore the goal.

In the context of the study, the more emphasis is given to reduce energy consumption in space conditioning. However, to ensure the energy efficiency in transportation, generalized guidelines are defined below. The study is enhanced by the evaluation of building regulations and a case study. The evaluation of the building regulations will provide a rational and legitimate approach for solving energy efficiency related problems in planning and design. On the other hand, the case study which will be introduced in the next sub-titles does not involve a complete urban design project, however it will assist a framework for the evaluation of energy efficiency in urban areas.

6.4.1. Objective 1: Reducing Energy Consumption in Transportation

- <u>Compact or clustered urban form</u>: In new developments, instead of dispersed urban form with low densities, compact or clustered urban form with high density should be encouraged. In these forms, the integrated land-use supports proximity. This proximity reduces the length of infrastructure, the journeys, the dependency on motor vehicles; shortly reduces energy consumption.
- <u>Mixed land-use development</u>: Instead of encouraging residential areas as primary land-use in new development areas, mixed development should be allowed, reducing the need for travel.

• The mobility of urban residents: The mobility of urban residents should be improved by pedestrian oriented implementations and public transport. Least priority should be given on cars.

• Improved transportation system: Instead of expanding the transportation supply, the existing transportation system should be improved for responding to travel demand.

• Efficient mass transportation: The efficiency of the mass transportation system should be improved by integrated use of transport means. More significance should be given on sea transport. Its share in mass transportation should be increased. The existing railway network should be improved. The rapid transit system should be completed as soon as possible and integrated with the existing mass transportation system.

• Improved transportation infrastructure: The transportation infrastructure including roads, sidewalks, crossroads, etc. should be improved for reduction in energy consumption.

6.4.2. Objective 2: To Reduce Energy Consumption in Space Conditioning

The evaluation of the climatic data shows that the climate of Izmir requires heating and cooling during the year.

Therefore, any attempt to provide energy efficiency should contain reduction of energy consumption both in cooling and heating however the priority differs according to the properties of the site and microclimate.

Statement 1 : Urban centers of Izmir experience overheating, lacking of ventilation and air pollution due to the existence of heat island.

Consequently, in order to achieve energy efficiency, the heat island effect should be reduced, and/or to reduce heat island effect, energy conservation should be provided in urban centers.

<u>Statement 2</u> : Locating at the outer zones, new development areas have lower air temperatures than the central areas. The microclimate of the site is mainly affected by its orientation, its topographical features and its natural landscape. The site is fully open to direct solar access and wind movements.

In these circumstances, during development process, the plan should provide the utilization of solar access for passive heating, the suggested physical configuration should direct air movements for both summer and winter conditions. The suggested plan and the site design should prevent the formation of heat island.

<u>The first statement demonstrates a situation which requires resolving problems in the existing structure:</u>

• We do not have the ability to change the present structure. However, after the evaluation of the present structure and the identification of the problems, the existing conditions can be improved by small scale urban design studies. In fact, the scale of the design and its variables depend on the inherent characteristics of the site. Besides the physical properties of the site, the user profile, for what reason and when-the time periods (hours, days, seasons, years) that the site is used are important. Nevertheless, the design process should involve the following basic understandings; the components of microclimate which can affect the use of space and can be modified through design, the effects that objects can have on microclimate components, the effects of microclimate on people and buildings and therefore on energy consumption.

• When the Izmir situation is considered, it is assumed that the proposed design studies in the activity centres will require **the prioritizing of shading to prevent solar radiation and maximizing the air movement for natural ventilation.**

<u>The second statement is much more related with the new development areas:</u>

When the future population of the city and the amount of energy they will demand are estimated, and the capacity of the non-renewable energy resources and the truth of limits and also negative impacts of the consumption to the environment are carefully thought about, the importance of energy conservation through planning and design comes into existence.

- At the regional scale, the potential of renewable and non-renewable energy resources of the region can be determined and renewable energy resources can be recommended for future use.

The Aegean region has the potential of solar energy, wind power, geothermal energy, etc. however they are not in common use. With the determined locations and capacities, the resources should be utilized as soon as possible within the region.

- At the structure plan level, the potential of domestic energy resources and their locations can be identified and then utilized. At the same time, the structure plan scale provides to manage and control the urban growth pattern, the urban form, the density, the land-use allocation by an understanding of energy-resource conservation and energy efficiency. Such a sensitive planning approach will provide not only reduction in resource consumption but also a significant attempt for a sustainable future.

- Site planning and urban design are important initiatives for reducing depletion of non-renewable energy resources and for encouraging renewable energy resources such as sun power. A modification of the microclimate through planning and design can reduce the amounts of energy required. When the microclimate around a building is very similar to the desired interior conditions, little or no extra energy is needed. But, if the interior and exterior conditions are seriously different from each other, large amount of energy is required.

In that case, besides micoclimatic features and the relation between the objects and the components of microclimate, building regulations -legitimate tools- can be considered as variables of energy efficient urban planning. Zoning regulations can provide the reduction in energy consumption for space conditioning and promote the use of solar energy. The evaluation of current building regulations is given in the next subtitle.

• Besides influence of planning and design process to energy efficiency, municipalities should develop policies to promote renewable energy sources both in public buildings and private developments. Solar heating, wind power, geothermal energy are all possible renewable energy sources for domestic uses.

• Communities should also encourage residents to use efficient heating and cooling systems. Most of the buildings within the city have interior heating sources of stoves (which are burned with coal, wood, fuel or electricity) or other individual heating equipment, instead of central heating system as the weather is not too cold in the winter, in Izmir. However, such individual heating equipment does not provide a satisfactory heating due to the quality of the equipment or the resource and the level of insulation in buildings.

• Moreover, land policies and regulations could encourage developers to design for energy efficiency. Houses can be built to be highly energy efficient. A well insulated wall and ceiling can reduce heat loss to very low levels. However, the majority of the dwellings in Izmir have absolutely low levels of insulation and have leaky joints between walls and windows, doors.

• In Izmir situation, the new development areas on the growth axis should provide the utilization of solar access for passive heating. The new physical configuration should direct air movement for both summer and winter conditions. In short, while developing, the essence should be given to energy efficiency implementations and the new developments should prevent the formation of heat island.

6.4.3. Solar Access Right

Before the evaluation of the current building regulations in Turkey, it would be preferable to understand the relation between the zoning regulations and energy considerations such as; promoting renewable energy resources, reducing energy consumption or providing energy conservation. Also, at that point, to introduce the concept of "solar access right" would be stimulating for the progress of the research. Solar access right; to prevent one property owner from blocking sunlight to another.

The orientation of future design to assure solar access will be a significant contribution to development of the use of solar energy and this is entirely dependent on the legal framework in connection with existing structures as well as concerning future development. (Coplan, 1981)

In order to protect solar access as a local option, it is required to incorporate a concern for solar access into the regular planning procedure. Building and zoning regulations can promote the use of renewable energy resources-solar energy: What is important here is to assure solar access. In the urban context, obviously not every building can face south, southeast or southwest and access to sun becomes even more of an issue when the density of urban development increases. In that case, besides zoning regulations concerning energy conservation, solar access rights, right-to-light laws are proposed and explored in Japan and California. (Stephens, 1980) (Appendix B)

However, today, most countries -so does our country- do not as yet have solar easement statutes. However, buildings could be designed so that each property owner respects the accessibility of others to solar right. Being a legitimate tools, zoning regulations an be suggested for assuring this solar access-solar right. It is clear that zoning is mostly concerned with height and setback requirements, however these building heights, plot and building densities, building lines and setbacks directly affect the solar access and energy consumption in space conditioning. Therefore, the regulations should promote the use of solar energy and the reduction of energy consumption. While encouraging the reduction of energy consumption and the use of solar energy, urban planning codes and building regulations should limit individual rights in order to achieve benefits for the common good. In that circumstances, having such an enforcement, the orders related to building should incorporate the considerations local topography and the climate as well as land-use and density, height and setback requirements.

6.4.4 Evaluation of Building Regulations and Planning Implementations

When the building regulations at Urban Development Act No.3194 are generally taken into account, it is seen that there is no regulation about solar access and orientation is even not mentioned. There is also no regulation requiring landscaping be an integral part of the physical structure. The table 6.17 contains the current building regulations in Turkey.

What's clear is that the regulations yield a common building form in all around the country, in seven different regions and climates. The apartment buildings having constant 3 m. side distances are all the same in Ankara, Erzurum, Adana and İzmir, with also their architectural forms. The identity of the cities which had formed by the culture and the domestic properties of the site throughout the history, has been diminishing because of insensitive implementations. The architecture and planning turn into matters of industrial production and fashion.

The cost of that kind of development has been high in terms of energy and material consumption. Whatever the domestic situation is, with mass production and transportation -powered by fossil fuels- it became possible to use the same materials everywhere and the desired constant interior thermal conditions are maintained by mechanical heating and cooling apparatuses which are also driven by fossil fuels.

<u>The evaluations and suggestions</u>:

After the generalized evaluation at the above two paragraphs, following is the details, including suggestions.

Table 6.17. The current zoning regulations

Item 13: The lot sizes

The minimum width and lengths of the lots resulted from the (ifraz)s will be determined by adding the dimensions of the building which is to be built to the garden and setback distances with reference to the related codes of the regulation. In the application of this code, 6m. is regarded as the minimum building facade length.

Item 17: The width of the lot

In the residential and commercial areas;

- where construction is permitted up to 4th floor (4th is included), the width of the plot must;

- in attached form	: not be less than 6.00 m,
- at the corner of the blocks	: not be less than side distances+6.00 m,
- in detached form	: the sum of all side distances+6.00 m.

- up to 9th floor (9th is included), the width of the plot must;

- in attached form	: not be less than 9.00 m,
- at the corner of the blocks	: not be less than side distances+9.00 m,
- in detached form	: the sum of all side distances+9.00 m.

- where permitted up to 10th floors or more;

- in attached form	: not be less than 12.00 m,
- at the corner of the blocks	: not be less than side distances+12.00 m,
- in detached form	: the sum of all side distances+12.00 m.

Parcel depth:

In the residential and commercial areas, the depth of the plot must;

- in the form without front garden: not be less than 13.00 m,

- in the form with front garden: not be less than the front garden distance+13.00 m.

Item 26: Floor area ratio

In the residential areas where the block or detached building code is complied and where no any measure of total floor area is issued by the plan, the floor area ratio must not exceed 40 % in any place.

(cont. next page)

(Table 6.17 cont.)

<u>Item 28: Building depths</u>

As a result of the use of the formula, if the depth of the building was determined to be less than 10.00 m., it can be up to 10.00 m. unless the backside(rear) distance is less than 2.00 m.

<u>Item 29:</u>

In the implementation plans, the number of floors or the heights of the buildings and their corresponding number of floors are to be determined but not to exceed the quantities shown below:

- for on the roads up to 7.00 m. : up to 6.50 m. of building height and max. 2 of floors except the basement,
- for on the roads of 7.00 m. and wider: up to 9.50 m. of building height and max. 3 of floors,
- for on the roads of 9.50 m. and wider: up to 12.50 m. of building height and max. 4 of floors,
- for on the roads of 12.00 m. and wider: up to 15.50 m. of building height and max. 5 of floors,
- for on the roads of 14.50 m. and wider: up to 18.50 m. of building height and max. 6 of floors,
- for on the roads of 17.00 m. and wider: up to 21.50 m. of building height and max. 7 of floors,
- for on the roads of 19.50 m. and wider: up to 24.50 m. of building height and max. 8 of floors

- the front yard distances: the front and the side distances to the street should be at least 5.00 m. for the buildings to be constructed in the residential areas.
- side distances: side distances should be at least 3.00 m. for the buildings permitted up to 4 floors (4 is included). If more than 4, the side distances will be increased by 0.50 m. for each floor added.

The number of floors considered in the calculation of the side distances can be found by dividing the height of the building into 3. In this calculation, the surplus value exceeding 2.50 m. corresponds to a one floor.

(translated from Urban Development Act No.3194)

• First of all, **each city or planning region should have its own zoning regulation with respect to the development regulations at Urban Development Act No:3194.** These local regulations should be based on the local properties of the site especially on the climatic features, concerning energy conservation. The neglected sun and air movement factors should be included by the zoning regulations in order to achieve energy efficiency.

To base the arrangement of the zoning regulations on such a concept may seem rather specific however that kind of approach can provide a rational step towards a development philosophy, which has sustainability as its ultimate goal. The plan notes can contain these local building codes which are developed by energy conservation consciousness. However, it is required another ordinance for assuring that each plan should include the above considerations.

• At Urban Development Act, No:3194, an item declares that; "as long as it is not against the regulations for implementation plans at 3194, it is the municipalities that is fully authorized to take decisions for the conditions that are not mentioned in the regulations, considering the necessities and the characteristics of the site."

Therefore, if the municipalities are licensed to take decisions, they should be aware of the importance of energy conservation and assuring solar access as a renewable energy. They should determine the location of buildings, their densities, heights, setbacks, building lines, etc. by considering the site characteristics, climatic features, orientation and the sun angles in order to achieve energy efficiency.

With the purpose to make the considered application obligatory, the regulations for development plans at Urban Development Act, No. 3194 should include an item which insists on energy conservation, such as; **as long as it is not against the regulations at Urban Development Act, No 3194, the municipalities are fully authorized to take decisions for assuring solar access and energy conservation, considering the necessities and the characteristics of the site and the climate,** or shortly; **energy conservation and the use of sun as a renewable energy should be provided at all scales of planning.**

There are two concepts suggested at the above statement; assuring solar access and energy conservation. Although the concept of energy conservation includes the use of sun, it is required to separate them. The concept of assuring solar access provides the use of sun power as a renewable energy for passive heating. On the other hand, receiving full sun can sometimes be undesirable in the regions that has long and hot summers and can result higher energy consumption for cooling. At that point, as the priority is given to cooling, the necessity of shading and ventilation come into existence. Therefore the decisions about street layout, location of building in relation with each other, building heights, setbacks, etc. should provide reduction in solar radiation and provide natural ventilation. Controlling air movement is also essential for winter conditions from the point of heat losses.

• Furthermore, besides climate properties, the land-use characteristics can also directly affect the decision on building regulations and whether solar access or shading is prior. It is known that an urban center has higher air temperatures and lacking of air movement. In order to reduce these negative impacts, shading and natural ventilation should be provided in those areas. Moreover, it is assumed that in urban centers, energy demands for commercial and business centers are higher for lighting than for heating. A greater dependence on artificial lighting means that building need to use more energy for cooling and proportionately less for space heating.

On the contrary, receiving sun throughout the day is always desirable in residential areas. Besides heating effect, receiving sunlight is very significant for physical and mental health of the people. However, in today's cities dwellings which does not capable of receiving sunlight has a quantity that can not be underestimated.

As a result, it can be said that **the building codes should be given according to the different land-uses**.

• There is a parameter which has great influence on providing energy efficiency and solar access and which has not even mentioned in the current zoning regulations. This parameter is the orientation; proper site, lot, building or street orientation to the sun or to the prevailing wind. In that case, the proper orientation should be determined for the city. It is not possible to define a constant orientation for lots and streets. However a proper orientation for buildings can be provided by arrangements within the lot. In one of the previous chapter (chapter 5), the subtitle 5.2.5. includes some examples of the arrangements for proper building orientation. Zoning regulations should provide to have such arrangements and building lines should provide the suitable orientation. Therefore, **zoning regulations should include the proper orientation and building lines should be defined by considering the proper orientation.**

• The determination of suitable orientation for Izmir;

First of all, it is observed that in Izmir's situation the west orientation creates the worst conditions. (Fig. 6.14) Therefore, a plan note can have an item that does not allow west orientation. On the other hand, it is seen that south, southeast and southwest are suitable orientations. The figure 6.14, illustrates the amount of solar radiation loads of different orientations. When the radiation loads of different orientations are compared, it can be said that the range for suitable orientations in Izmir are south, south-southeast and southeast. Southeast orientation reduces more sun radiation load than southwest orientation in the summer. If buildings need to warm up quickly in the morning particularly after a cold night, orientation of the buildings to the southeast would most effectively harness solar heating in the winter.

• Furthermore, in order to provide the most appropriate circumstances, the building codes for different land-uses should be given by considering the sun angle values. The angle of coming sun light is important for the calculation of the amount of required solar access during the day, and moreover during the year. The location of building in relation to each other, the distance between them, setbacks, building heights, etc. should be determined according to the position of the sun. By using the sun angle values, the shadow depths of buildings or any other object in a given design area can be calculated and the design decisions can be taken according to the shadow depths and positions. (Table 6.18 and Fig. 6.15)

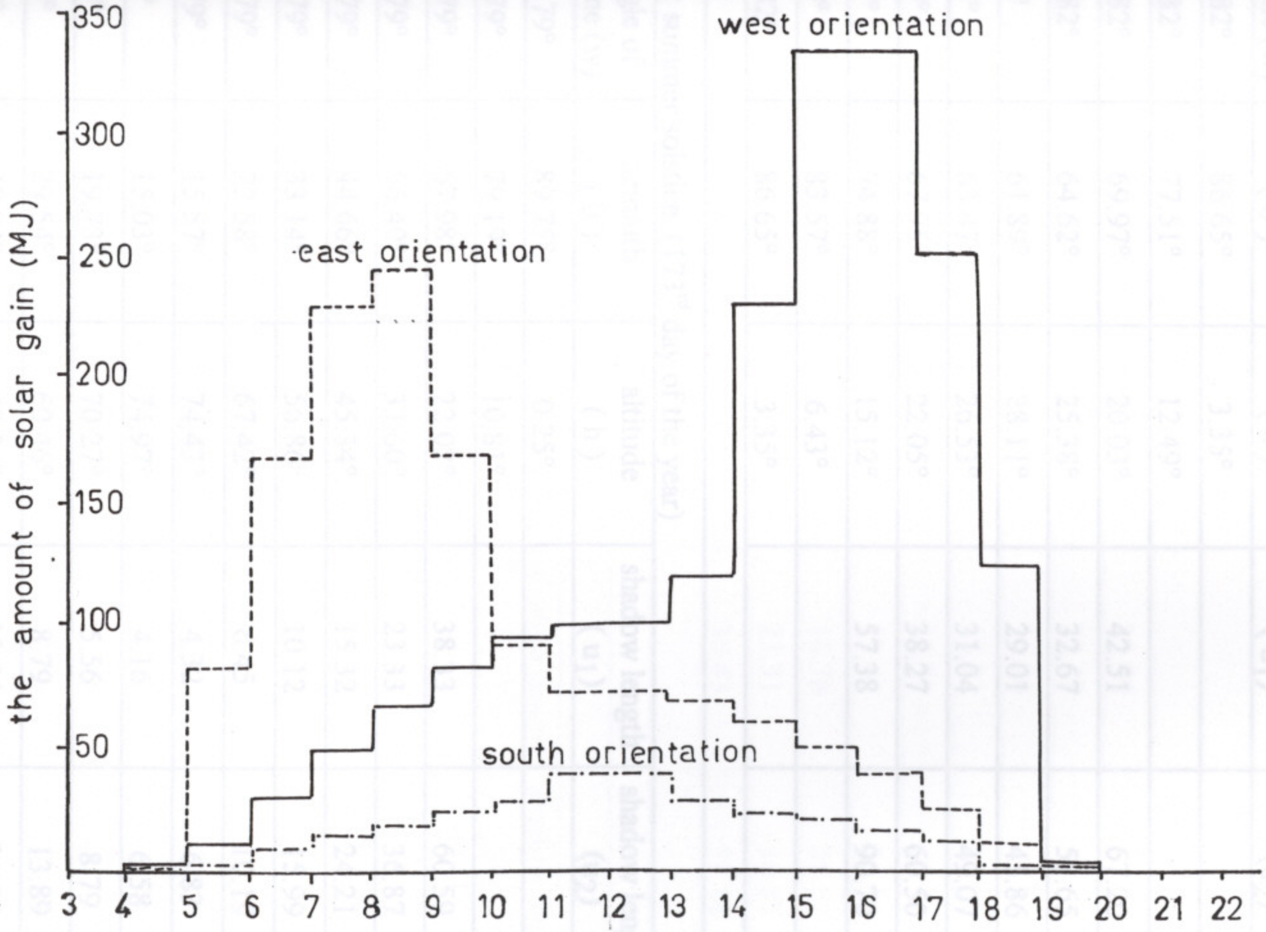


Fig. 6.14. The amount of solar radiation loads of different orientations (Atagündüz, 1989; pp:83)

Table 6.18 Sun angle values

December 21: winter solstice (356th day of the year)				
the angle of solar time (w)	azimuth (θ)	altitude (h)	shadow length (u_1)	shadow length (u_2)
-64.82°	86.65°	3.35°		
-49.82°	77.51°	12.49°		
-34.82°	69.97°	20.03°	42.51	67.20
-19.82°	64.62°	25.38°	32.67	51.65
0°	61.89°	28.11°	29.01	45.86
15°	63.47°	26.53°	31.04	49.07
30°	67.95°	22.05°	38.27	60.50
45°	74.88°	15.12°	57.38	90.70
60°	83.57°	6.43°		
64.82°	86.65°	3.35°		

June 21: summer solstice (173rd day of the year)				
the angle of solar time (w)	azimuth (θ)	altitude (h)	shadow length (u_1)	shadow length (u_2)
-109.79°	89.75°	0.25°		
-94.79°	79.19°	10.81°		
-79.79°	67.98°	22.02°	38.33	60.59
-64.79°	56.40°	33.60°	23.33	36.87
-49.79°	44.66°	45.34°	15.32	24.21
-34.79°	33.14°	56.86°	10.12	15.99
-19.79°	22.58°	67.42°	6.45	10.19
-4.79°	15.57°	74.43°	4.32	6.83
0°	15.03°	74.97°	4.16	6.58
15°	19.73°	70.27°	5.56	8.79
30°	29.54°	60.46°	8.79	13.89
45°	40.94°	49.06°	13.44	21.25
60°	52.65°	37.35°	20.31	32.11
75°	64.32°	25.68°	32.23	50.95
90°	75.67°	14.33°	60.68	95.91
105°	86.47°	3.53°		
109.79°	89.75°	0.25°		

(cont. next page)

(Table 6.18 cont.)

March 21: equinox (81st day of the year)				
the angle of solar time (w)	azimuth (θ)	altitude (h)	shadow length (u_1)	shadow length (u_2)
-88.07°	88.49°	1.51°		
-73°	76.76°	13.24°		
-58°	65.49°	24.51°	33.99	53.73
-43°	55.06°	34.94°	22.19	35.07
-28°	46.27°	43.73°	16.20	25.61
-13°	40.27°	49.73°	13.31	20.76
0°	38.46°	51.54°	12.31	19.46
15°	40.86°	49.14°	13.41	21.19
30°	47.27°	42.73°	16.78	26.52
45°	56.38°	33.62°	23.31	36.85
60°	66.95°	23.05°	36.43	57.58
88.07°	88.49°	1.51°		

September 23: equinox (267th day of the year)				
the angle of solar time (w)	azimuth (θ)	altitude (h)	shadow length (u_1)	shadow length (u_2)
-91.76°	92.25°	-2.25°		
-76.76°	80.56°	9.44°		
-61.76°	69.20°	20.80°	40.80	64.49
-46.76°	58.60°	31.40°	25.39	40.14
-31.76°	49.43°	40.57°	18.11	28.62
-16.76°	42.76°	47.24°	14.33	22.65
0°	39.87°	50.13°	12.95	20.46
15°	42.20°	47.80°	14.05	22.22
30°	48.47°	41.53°	17.50	27.66
45°	57.44°	32.56°	24.27	38.37
60°	67.91°	22.09°	38.19	60.36
75°	79.21°	10.79°		
91.76°	92.25°	-2.25°		

- The above table shows the azimuth and solar angle values at the winter and summer solstice, and equinoxes in accordance with the solar time in Izmir.

- Each 15° represents one hour.
- The solar time values are taken from "Güneş Enerjisi temelleri ve Uygulamaları" by Prof.Dr. Ing.Gürbüz Atagündüz.

- The azimuth and altitude values are calculated by the formula below:

$\cos \theta = \sin \phi * \sin \sigma + \cos \phi * \cos \sigma * \cos \omega$

σ = declination

$\sigma = 23.45 * \sin(360 *(284 + n) / 365)$

$\phi = 38,46$

- By using the formula ($u = H / \tan h$), the shadow lengths for buildings of 15.50 m (u1) and 24.50m (u2) in height are calculated.

- To represent extreme conditions such as the highest or the lowest position of the sun and so the longest or the shortest shadow of the year, the winter and summer solstice are used.

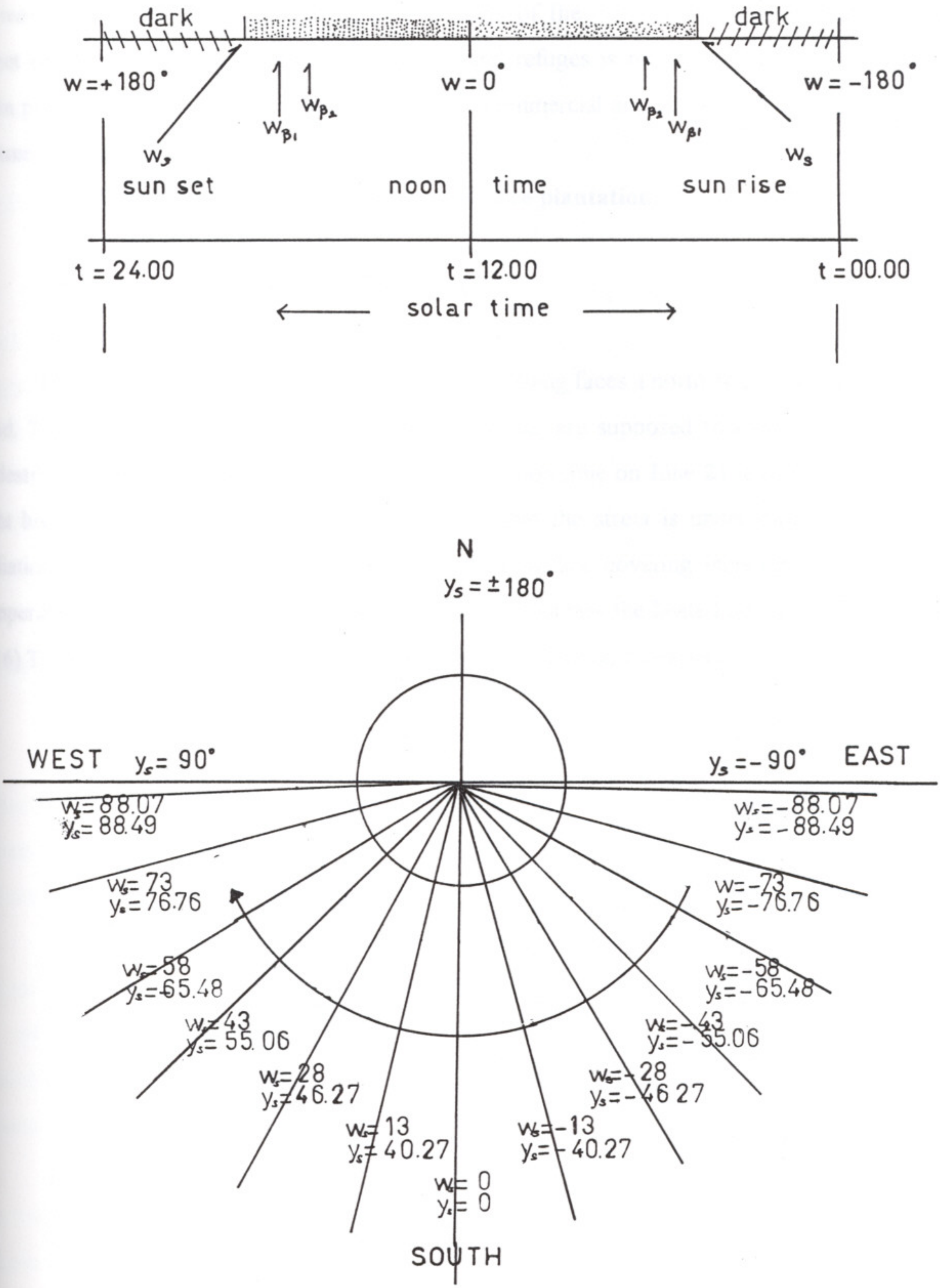
- In design process, such values given at the table can be useful in estimating the required solar radiation or shading at key times of the day or of the year.

- A combination of the regulations yield a minimum situation like that;

The minimum permissible plot size is 78 m^2, with 6 m. minimum plot width and 13 m. minimum plot depth. In relation with these measures, the building size is 60 m^2 (6m.10m.). With a depth of 3 m. back garden, the resultant form is a wall-to-wall strip development. Such a form, having 2 or 3 stories seems quite energy efficient. Let consider the other items.

- According to item 29, the building heights (number of floors) are determined correspondent to the width of the road on which the building faces. It is known that the width of the road is determined according to the traffic load that it carries and its characteristics within the transportation system. But the logic to determine the building heights correspondent to the width of the road is not clear.

When the building heights and road widths are compared, the resultant situation seems not unfavorable from the points of solar access and air movement. However, in different microclimates and orientations, the given measures may cause undesirable conditions. In the places where summers are long and too hot, these wide roads are under direct solar radiation but they provide ventilation. On the other hand, in the places where wind blows with higher speed, the roads parallel to the prevailing wind may have stormy, cold conditions.



6.15. Solar time and sun angles (adapted from Atagündüz, 1989)

The existing correlation between the road width and building height is accepted. However, in order to reduce the negative impacts of the correlation, besides proper street orientation, tree plantation on sidewalks and refuges is required. Especially the main pedestrian roads and the sidewalks on wide commercial and activity zones should be tree planted.

Therefore, **the regulations should include tree plantation**.

In the following there are some examples,

<u>Example 1</u>: The situation is that a 8 storey building faces a north-south elongated road. The sidewalks, approximately 4 or 5 m. in wide, are supposed to carry a heavy pedestrian movement throughout the day. It is the noon time on June 21 and there is a light breeze in the air: The resultant condition is that the street is under direct solar radiation. The sidewalks are not shaded. The hard surface covering increases the air temperature. So, the breeze has no cooling effect as it carries the heated air. (Fig. 6.16) Tree-plantation is needed for both cooling and shading on sidewalks.

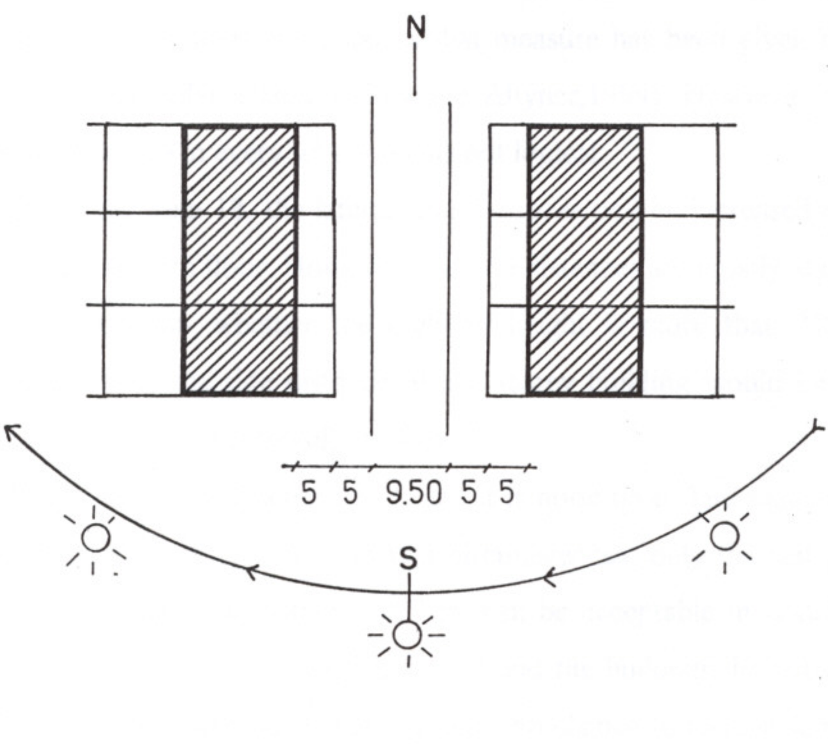


Fig. 6.16. Example 1: The street is under direct solar radiation

Example 2: This time 8 storey attached buildings face east-west elongated street.

The angle of the incoming sun ray is 75° at noon time and the shadow depth of the 8 storey building is 6.6 m. (Table 6.18) (Fig. 6.17a). At noon time, only the left garden is under shade. If the building has no front garden, the left sidewalk will be shaded by the building entirely. (Fig. 6.17b) Figure 6.18 illustrates the conditions at 14:00

Example 3: The third example is from an existing situation in Kordon. (Fig. 6.19) The buildings on the block which is parallel to the sea are attached in form and the sea oriented buildings that also faces 20.00 m. road have 8 floors, at the back side facing the 10.00 m. secondary road the buildings are 15.50 m. in height.

Such implementation is convenient to the regulations however the resultant form provides the worst orientation and at the same time, the building masses along the shore blocks the sea breeze and do not let the air enter through the hinterland.

Therefore, **orientation to the sun and to the prevailing wind should be considered while determining building heights**.

• Moreover, the item 18 refers to the lateral side distances. The 3 meters side distance for two storey buildings is logical as that measure has been given by German planners for assuring full solar access. (Akay and Altýner,1994). However, to use that value as a constant distance in every where seems not logical.

According to the item 18, the lateral side distances will be increased by 0.50 m. for each floor added after 4th floor. However, the side distances are mostly accepted as 3 m. -which is the minimum- whether the building height is more than 12.50 m. In accordance with the item, the side distance of a 8 storey building would be 5 m. The distance between two buildings is therefore 10 m.

Example 4: The day is December 21, and it is noon time. The shadow depth of the 5 storey building is 29 m. in Izmir. In that circumstances, only the last two floors receive sun light. However, that distance of 7 m. can be acceptable in Izmir's climatic conditions. But if the block is north-south oriented and the buildings have back garden which is only 3 meters, the north sided buildings have no chance to receive sun. (Fig. 6.20)

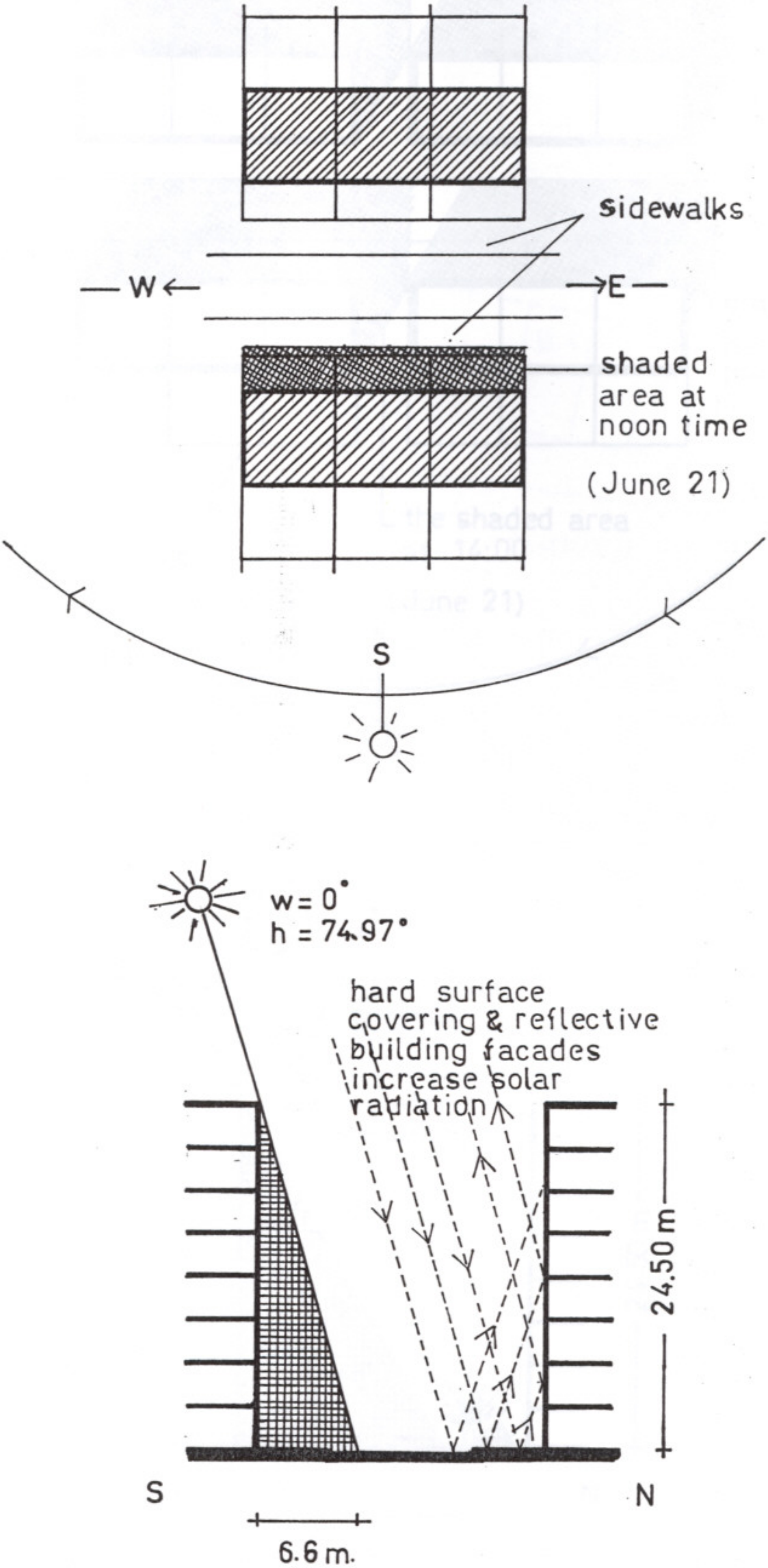
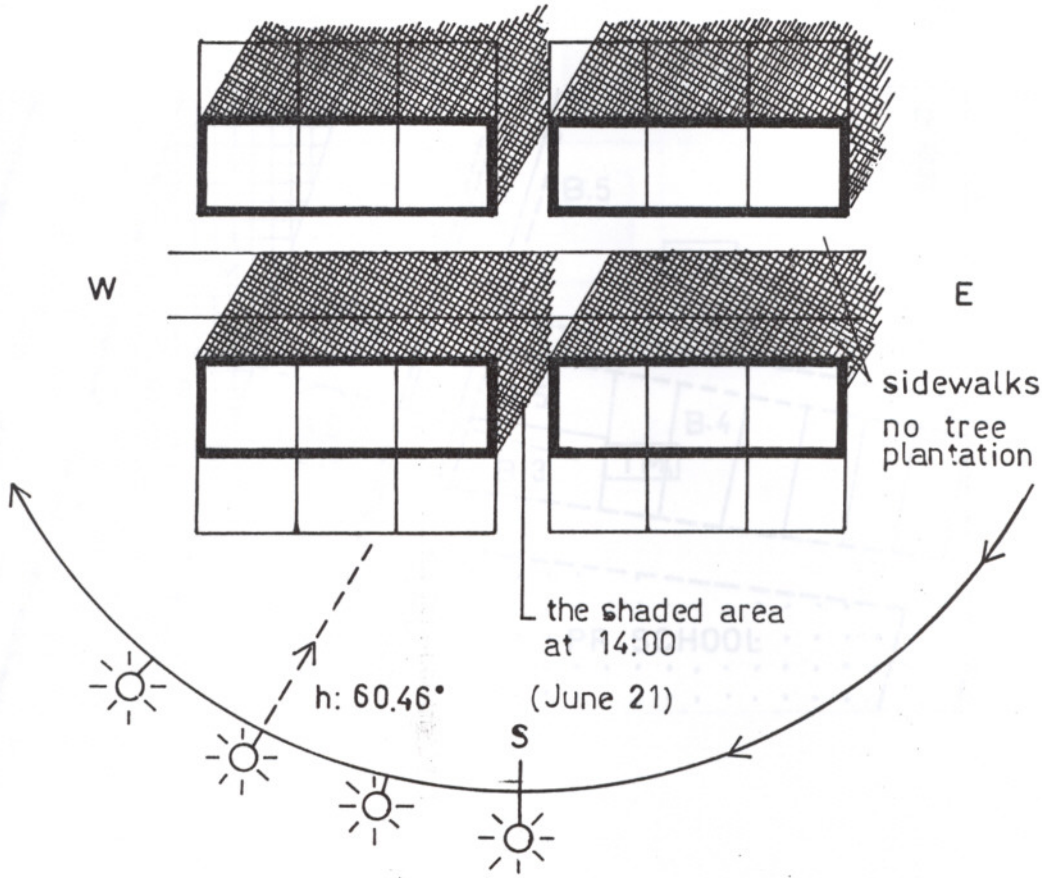


Fig. 6.17. Example 2: Plan and section



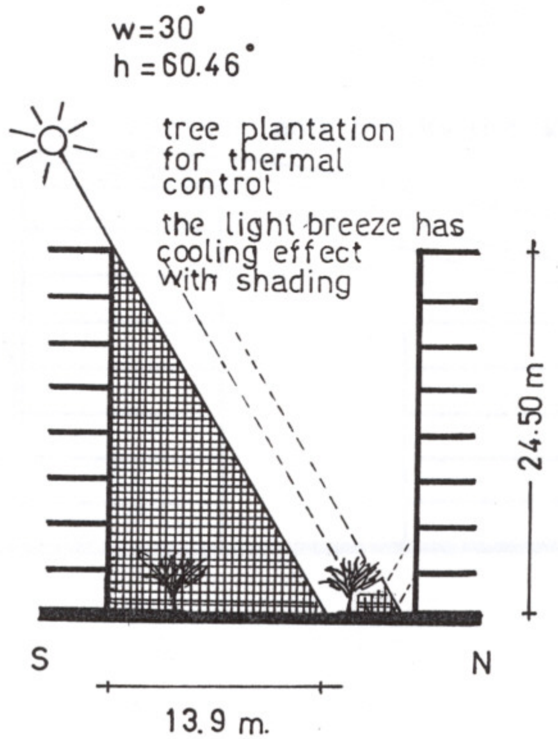
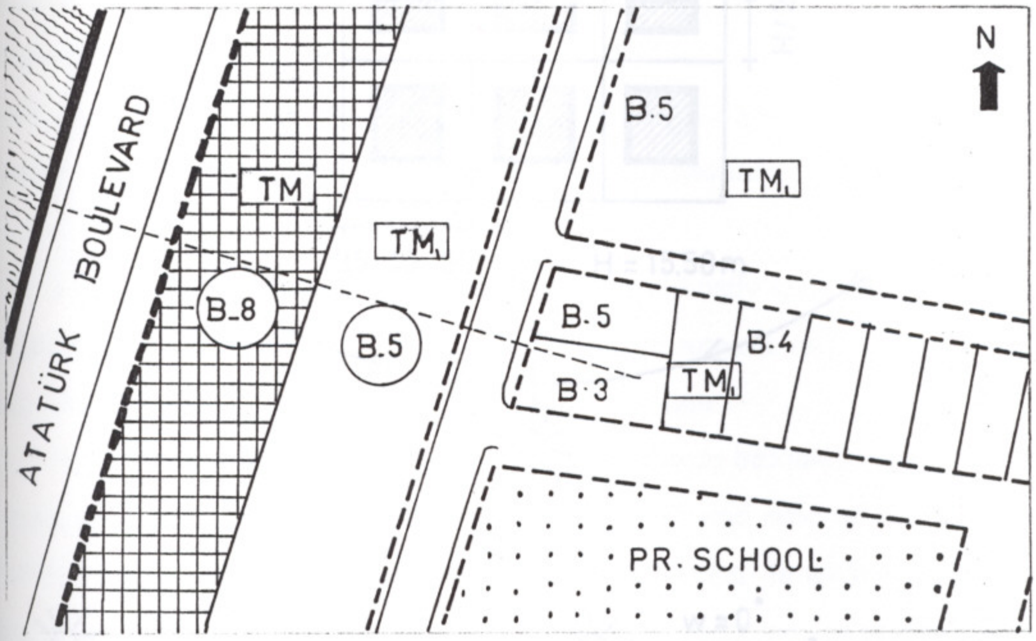
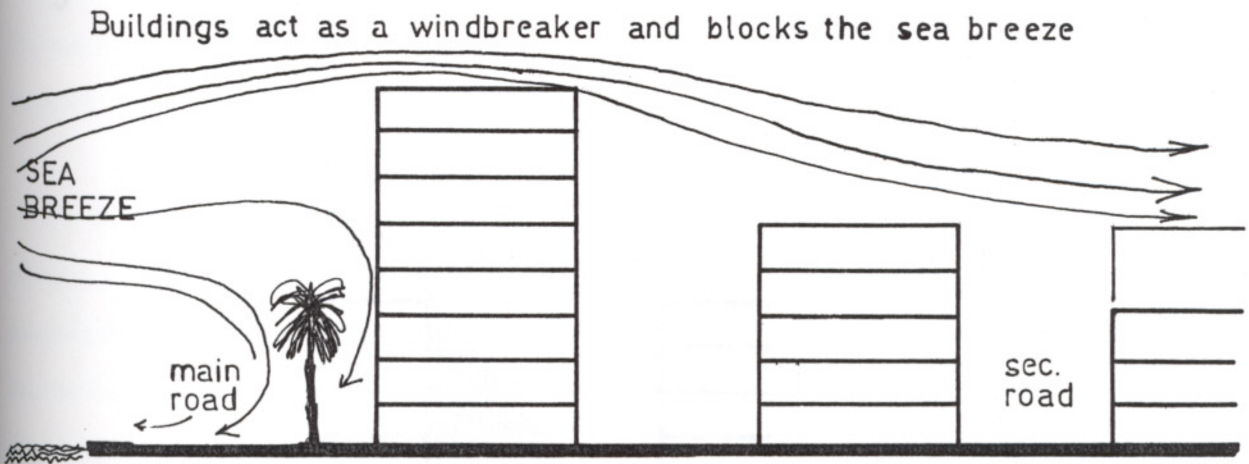


Fig. 6.18. Shadow patterns at 14:00



PLAN (1/ 1000)



WEST

SECTION

Fig. 6.19. Orientation to the sun and to the prevailing wind should be considered while determining building heights.

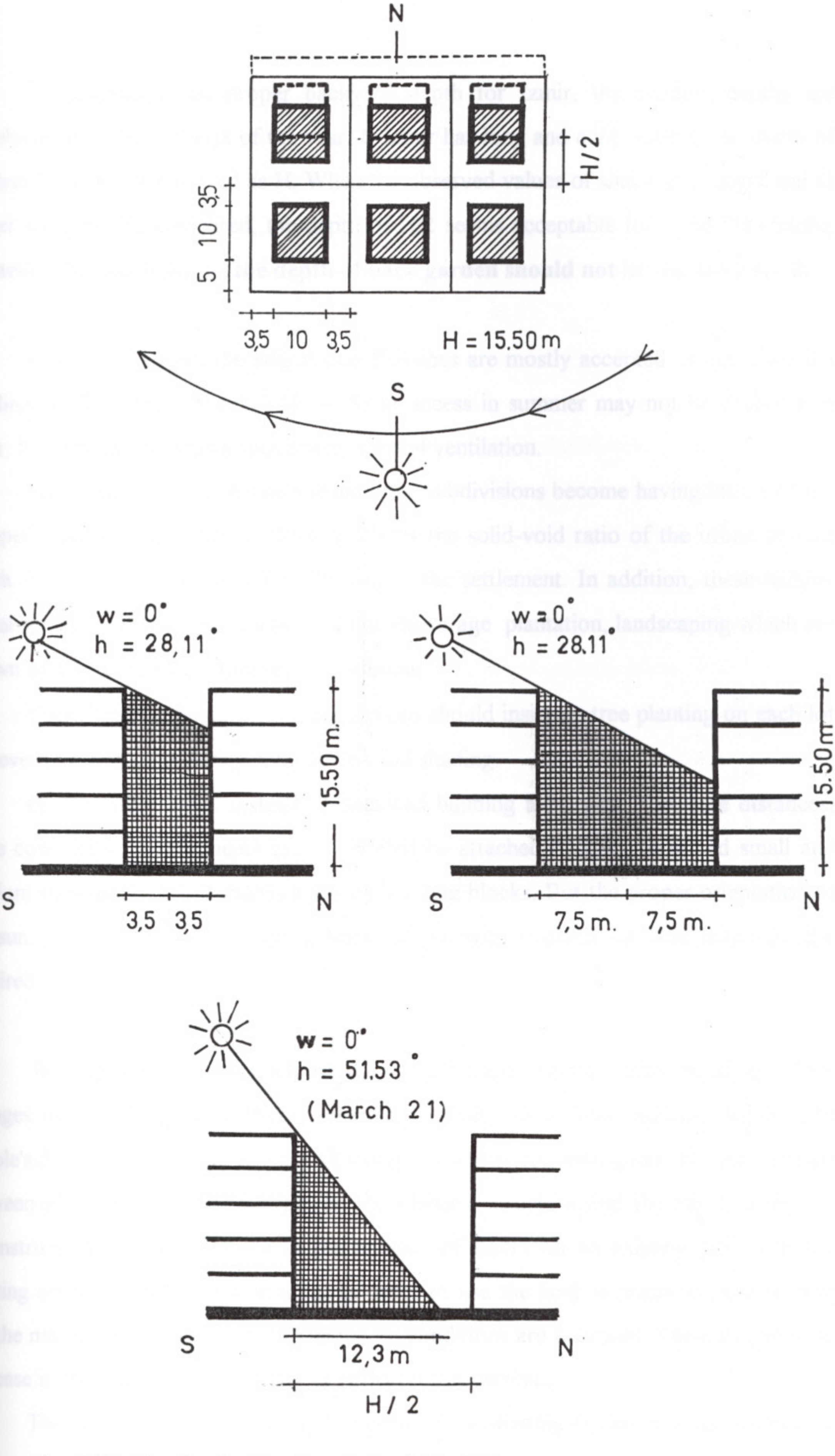


Fig. 6.20. The depth of backyard should be H/2

To determine the proper backyard depth for Izmir, the shadow depths are calculated for different days of the year. If Izmir has long and cold winters, the depth of backyard should be accepted as H. When the observed values of shade at equinox and at winter solstice are compared, the depth of H/2 seems acceptable for Izmir. Therefore, **whatever the condition is, the depth of back garden should not be less than H / 2.**

•As it was stated, the lateral side distances are mostly accepted as 3m. even the building height is more than 12.50 m. Solar access in summer may not be desirable in Izmir, but what about the air movement, natural ventilation.

With that 3 m. lateral side distances the subdivisions become having little or truly no open spaces. This situation directly affects the solid-void ratio of the urban pattern which is very significant for air movement in the settlement. In addition, these narrow lateral spaces and small backyards does not encourage plantation, landscaping which are known as natural tools for thermal conditioning.

Therefore, the plan notes or regulations should insist on tree planting on each lot however in a way considering solar access and shading.

On the other hand, instead of detached building form with 3 m. side distances, more convenient environments can be created by attached building form and small and medium sized open, green spaces between building blocks. But the proper orientation to the sun and prevailing wind and a back garden with a depth not less than H/2 are required.

In fact, the problems related to side distances mostly occur because of the changes on the plan. Land prices, urban economics, production process, fashion and people's desire and ability to acquire all struggle with the common good. The interactions between above factors make stress on the physical structure and the result is shortly reconstruction and the increase in the number of floors on an existing plot with the existing amount of construction area. In order to use the land as much as possible and get the maximum construction, the minimum conditions are accepted. The outcomes are increase in the density, insufficiency in infrastructure services.

The reconstruction or the replacement of the existing structure process can also be examined in the context of the main theme as below.

It is known that existing buildings embody quantities of energy capital. They require energy capital in terms of maintenance, new equipment or insulation. On the other hand, a new construction replacing an old one requires energy for demolition and rebuilding. If the new building is constructed as energy efficient, super insulated or served by solar heating, passive cooling, there may be a tangible energy capital gain. If not, the result is more energy and resource consumption.

- The use of sun for passive heating;

In practise, a high residential density, especially for buildings over 5 storeys, can not provide passive heating. In that circumstances, the passive solar concept can be excluded from development of urban design projects, defining the exact location and orientations of buildings, their shapes and their mutual relationship.

On the other hand, low densities provide solar access for passive heating. **While developing with lower densities the plan should insist on providing solar heating**. The design of the site with setbacks, building heights, etc. should prevent one property owner from blocking sunlight to another.

6.4.5. Case Study: Egekent-2

In this part, for evaluating the energy efficiency, an existing residential area is taken as an example. This sample area is Egekent-2.

First of all, the aim is not to say whether the selected area is energy efficient or inefficient however to determine at which points the area or the plan provide efficiency or at which conditions it is inefficient. Such a determination can help to make the energy efficient urban design process clear.

On the other hand, the reasons for studying single example are; firstly, if there are some examples of energy efficient planning or design implementations, in order to compare their efficiencies, two-or-more samples could be chosen. But there exists no development area which has been planned and designed with the aim of efficiency. When the number of examples increases, the number of variables for comparison increases too. However, as long as each sample area has different characteristics, to get rational results from comparison is not possible.

The reason for choosing Egekent-2 is that Egekent-2 Mass Housing Area is located on the north growth axis of Izmir. This axis has not completely developed yet. It's microclimate has not entirely being affected by the process of urbanization. Therefore, a study on this region may take attention and be used as guidelines for new developments on this axis.

At the beginning of the study a check-list is developed. This check-list can used to test and modify the design as required to achieve the energy efficiency. It will also assist to meet the requirements and provide outlines for preparing preliminary and final plans for new developments. The check-list is given in table 6.19.

6.4.5.1. The Evaluation of the Sample Area

<u>**The general properties of the site**</u>: A mass housing area. 16 ha. In size. Its population is approximately 4800. Its net residential density is app. 400 per/ha. It is located on Izmir-Menemen Road and it is 30 km. away from the center. The land is flat. Its climatic features are given in the subtitle 6.2. in detail. It provides accommodation for middle income group.

Urban form: The site is a part of leapfrog development. But the area itself is clustered in form. Clustered form provides efficiency from the point of space conditioning.

Accessibility: Accessibility depends on private transportation. Public transportation is in sufficient. Therefore, accessibility is the major problem of the site. Public transportation should be improved.

Density: Its density is 400 per/ha. And therefore it can be classified as high density development.

Land-use: A residential dominated area. Mixed land-use is preferred for efficiency.

Orientation: Blocks and buildings have generally proper orientation to the south, southeast and southwest.

The evaluation of shading and ventilation conditions for cooling requirements:

- **Location of buildings** prevents shading in summer. (Disadvantage)
- **Shading elements** such as arcades, pergolas, etc. do not exist. (Disadvantage)
- **Location of buildings** provides natural ventilation in summer. (Advantage)
- **Street layout** parallel to the prevailing winds encourages air movement. (Advantage)
- **Building heights** are uniform. This may block the prevailing wind. (Disadvantage)
- **The ratio of open to developed spaces** is appropriate for natural ventilation. (Advantage)
- **Landscaping for cooling** is not enough. (Disadvantage)
- **Surface covering** is hard. This decreases the albedo. (Disadvantage)
- In buildings, **number of surface area exposed to sun radiation** can be accepted as low. However this factor differs according to type of housing. (Advantage)
- **Number of surface area exposed to west orientation** is low, as most of the buildings in the site face south, southeast and southwest. (Advantage)

- **<u>The opening configuration (windows, doors) of buildings</u>** provides interior cross-ventilation. (Advantage)

The evaluation of solar access and wind protection conditions of the site:

- **<u>Distance between buildings</u>** provide solar access. (Advantage)
- **<u>Location of buildings in relation with each other</u>** provide solar access. (Advantage)
- **<u>Openings (windows,doors) of buildings</u>** face south and let the sun in. (Advantage)
- **<u>Uniform height buildings</u>** act as a windbreaker. (Advantage)
- In buildings, **<u>number of surface area exposed to the wind</u>** is high. (Disadvantage)
- **<u>Openings</u>** of buildings are facing the winter winds. (Disadvantage)
- **<u>Landscaping for wind protection</u>** do not exist. (Disadvantage)
- **<u>Landscaping</u>** provide solar access. (Advantage)
- **<u>Community spaces</u>** between buildings are sunny and protected but the open spaces, playgrounds are cold and windy spaces.

The variables are also illustrated on plans. (Fig. 6.21, 6.22, 6.23, 6.24)

With respect to climatic properties of the site energy efficiency in space conditioning concept or simply heating and cooling requirements of the site can be evaluated like that below; (Table 6.20)

The plan and design properties of the site provide advantage from the point of natural ventilation in summer. However, it is seen that solar radiation control by shading is not provided. Lack of shading and landscaping, and having hard surface covering cause increase in the air temperature. The air movement within the site has lost its cooling effect.

In winter, the site has advantage of solar access but it is required wind protection. North, cold winds cause increase in heat loss in buildings and cause stormy, cold exterior conditions.

Generally, being far away from the city center, depending on private transportation and having insufficient mass transportation are disadvantages of the site. On the other hand, the physical configuration and orientation provide considerable advantages from the point of space conditioning.

In the existing situation, reducing winter wind effects has the priority. But when we consider the future development with current policies, the surrounding of the site will entirely develop. In that case, the velocity of winds both in summer and winter will slow down and the air temperatures will increase because of the urbanization. Therefore energy consumption for heating and cooling will also increase within the site.

However for today's condition, the best way to control winter winds and solar radiation is proper landscaping. In addition, while deciding on individual implementations at building scale, it is required rational measurements for heat loss and heat gain.

Chapter 7

CONCLUSION

Does energy really matter in urban design? Do we need energy conscious urban design?

The effects of a dramatic increase in energy prices during the oil crisis in the early 1970s, were making themselves felt in many ways. When the crisis was over, it was thought that the crisis was not sustained and no energy constraints have actually been experienced. Thus, the prospects for energy conscious development have receded and the incentive use of resources efficiently removed.

However, the energy consumption trends in the world point out the necessity of energy conservation. The amount of human energy use today is considerably higher than in 1970s. We are consuming energy and material resources faster than they are being naturally regenerated and the environmental costs are being increasingly perceived at local, regional and global level. In addition, if present consumption rates continue, long before the reserves are entirely depleted, the prices of fossil fuels will probably rise to levels at which few can afford to buy them.

This means, in the future, with the growing number of people and expanding volume of activities, there appears to be a significant potential that impacts associated with energy supply and use will seriously harm human and ecological well-being.

Under these circumstances, and while it is generally agreed that urbanization is the prime cause for the increase in energy consumption, what can we do as planners and designers of the built environment to anticipate the inevitable next energy shortage? It may not be too late to seriously consider while we still have the chance. We should search for a balance between resource use and conservation in the designs and plans that we propose.

Therefore, the goal of energy conscious design is to reduce urban energy consumption and the problems that this consumption causes. The rationale for energy efficient design is not so much the need to conserve energy per se, however reduction in energy consumption for the ecological health of the whole planet.

Transportation and space conditioning are the two major factors which influence energy demand at the urban scale. Any progress toward a more sustainable future require large per capita reductions in the amount of energy required for space conditioning and transportation.

The range of options available to save energy in a project of almost any size is very wide; Urban form, growth pattern decisions, land-use arrangements to cut transportation costs, density considerations for lower per unit infrastructure costs, site planning for passive heating and cooling, building design that emphasizes conservation, the use of other renewable energy resources such as solar energy, wind power, geothermal energy, etc.

But which alternative or combination of alternatives can be applied to a project depends on the unique characteristics.

Climate is one of the fundamental consideration in reducing energy consumption. The microclimate, which is made up of weather, landforms and other natural conditions, determine the design strategies. In addition, the microclimate of a site is also made up of a great many social, institutional and economic factors. These factors may also influence the site's efficiency.

In short, the site characteristics determine, the techniques and methods to be applied and the variables of design process.

On the other hand, energy efficiency or conservation should not be confined only to individual projects. Because, for example; in a project site, if all new housing developments were highly energy efficient but located farther and farther from city center, the energy saving would be overwhelmed by the additional transportation energy consumption. Furthermore, consider that in a development area, the use of alternative energy resources is accepted as a policy, but if the patterns of growth and development are not addressed along with specific planning, design and architectural measures, then the use of alternative energy sources will mean little. The form and density of housing, the land-use patterns can result more energy saving than e.g. any solar application.

Therefore, energy efficiency or conservation must be achieved through a complementary urban planning and desing process and it must be achieved through a carefully coordinated resource management plan on either the municipal or regional level.

The very adoption of an energy conservation and efficiency concepts into master plans can lead to greater public awareness and to increased support for legal alternatives reducing energy consumption.

Adopting ordinances to promote energy conservation in almost every aspect of the community, from building performance standards to the reduction of energy used for transportation provide putting energy consciousness into standard development practice at the most fundamental level.

It is required zoning regulations to be drafted in accordance with a comprehensive land-use plan and the plan must consider and promote conservation of energy resources and reasonable access to solar energy.

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APPENDIXES

CASE STUDIES

The reality of energy crisis led the architects, designers, and planners to an attitude about energy responsibility. Examples of those energy responsive approaches are going to be introduced as case studies.

A common ground for these diverse attitudes to saving energy was to examine successful historical precedents for clues to low cost, energy saving design strategies. For that reason, at the beginning of the case studies, the old settlements are given as examples.

The further studies are about solar villages and eco-cities. Today's terms such as "bio-climatic design", "green design", "solar design", "sustainable design", and "ecological design" have already the same main purpose of which a balance between nature and the built environment, and a balance between resource use and conservation in the proposed designs and plans. So the energy-efficiency is the common feature of all.

A.1. Prehistoric Pueblos

Before the examples old settlements, from Jeffrey Cook's paper, an introductive paragraph about "the Pueblo" is given :"There are over 25 000 Anasazi settlement sites in Arizona, with as many in New Mexico and lesser numbers in Colorado and Utah. Anasazi is the Navajo word for "the ancient ones". It can also mean "the other ones" or even "the aliens". Their best known and admired stone cities are Pueblo Bonito at Chaco Canyon and Acoma. The Anasazi invention of the pueblo form was the basis of their distinctive architecture. We may call them urban villages or miniature cities, these multi-functional mega-structures of stone and mud. Within a single articulate building were accommodations for day to day life, for the storage of wealth and for the social and spiritual activities that ultimately shelter and succor any society. Thus the pueblo was not only an impressive architectural unit, it was a confirmation of land planning philosophy, of community responsibility and a concretization of culture." (Cook, 1991; p:145)

A.1.1 Acoma Pueblo, New Mexico

Acoma Pueblo, that placed a top of a flat and nearly inaccessible mesa that rises 400 feet from the plain, at 35° north latitude, is an example of man-made arrangement. The Pueblo appears to have been continuously occupied for over a thousand years and a greater number of houses exist today. The climate is generally desert-like, but ambient air temperatures are modified by the mile-high attitude.

The plan of the pueblo contains (Fig.A.1), parallel rows of buildings extending for about a thousand feet at just a few degrees off an east-west axis and terminating at the steep slopes of the mesa, and gaps between housing groups which are in different width from minor walkways to major spaces. The individual houses of the rows share a common wall suggest a modular construction in which units were regularly added in a line using common walls to extend in the east-west direction and these parallel rows define the streets which were also extended to the east and west.

The Acoma house steps down, exposing broad areas of roof and vertical wall to the south. The ground floor extend its greatest length in a north-south direction of the plan and is generally twelve to fifteen feet height. The second floor is stepped back and eight to nþne feet in height. The house also contains spaces in addition to a terrace upon the roof of the space below. (Fig.A.2) The walls are composed of adobe-covered rubble for the first story and adobe-covered brick for the stories above. Floors and roofs are adobe packed on grass or sticks that are laid over small wood members that span timbers. All doors and windows originally opened off south facing terraces.

"Both the regularity of the plan and the southerly orientations of the sections suggest a significant relation between the building arrangement and the sun." (Knowles, 1974, pp:30) The terraces and south walls of a unit generally receive the first light of morning and the last at evening during most of the year. Upon the roofs and terraces the summer sun is more direct, while the winter sun favors the vertical south facing walls. "It is possible to imagine that a people for whom the sun is so important might achieve such a delicate interaction among the parts of their building arrangements that no vertical portion of one building ever shades the work areas of surrounding buildings." (Knowles, 1974; p:30)

The dynamics of possible interaction suggest that, by 5:15 a.m. all faces of the upper two stories are light. By 7:00 a.m. the light is directed down the streets from the east and is just beginning to select details from the south walls, still to the interior because of the extreme height of the summer sun and until 4:00 p.m. when all light disappears from the south walls, the openings remain in shadow. After that time, only west and north walls are lighted. When shadows subdue the streets, only the upper stories are punctuated with evening brightness. The south walls are more directly served by the winter sun. By 8:15 a.m., light falls directly on every south facing surface above the first floor. By 9:30 a.m. even the south faces of the ground floors are in the light and remain so until 300 p.m. when shadows begin to rise up from the darkened street below. From that time, until sunset, the upper floors remain in bright sun.

In order to understand what the Acoma model has offered, a comparison with different arrangements of six volumes from the energy profile viewpoint can be made. The required situation is the equalizing of energy profiles between summer and winter. The results of the alternatives are; An energy profile of the section with terraces to the south shows a summer increase of 187 percent over the winter. (Fig.A.3a) When the tiered section is reversed so that all work surfaces face north, there occurs a loss with a 33,3 percent for the winter energy profile, however, during the summer the loss is only about 4,5 percent. Although the same incident energy is maintained during the hot months of the summer, the northern orientation causes decrease in the winter energy profile (Fig.A.3b). A third alternative would have been to lay all six volumes down on the ground. This horizontal exposure results in am 88,4 percent increase in the summer profile over the original section while the winter gain is only 26,7 percent (Fig.A.3c). Lastly, the arrangement that stacks all six volumes vertically, exposing a large surface to the south offers a 52 percent reduction in the summer energy profile when compared with the original section and a 17 percent increase in the winter profile. This arrangement is the most appropriate which equalizes the seasonal energy profiles. However, it was technically difficult for the Acoma culture to attain (Fig. A.3d).

In that circumstances, the Acoma's choice was the best. Further investigation about the Acoma structure is the efficiency of the form. Efficiency is taken to be a ratio between the energy reduced by the form (Ei) and the energy that could be received by all exposed surfaces (Em). The ratio Ei / Em is expresses as percent efficiency. According to the studies, the form is 32,5 % less efficient in the way surfaces are exposed to incident energy during the winter compared to summer (Fig. A.4a and 4b).

"Since the summer sun is more direct upon horizontal surfaces and the winter sun is more direct upon the south facing walls of the tiered section, it would have been most reasonable if the vertical walls receiving winter sun had a high transmission co-efficient and a high heat storage capacity." (Knowles, 1974; p:31) Conversely, the horizontal receiving their maximum energy in the summer should exhibit a low thermal transmission co-efficient and a low heat storage capacity. As a result; the pueblo is an efficient energy system that tends to equalize internal energy profiles over the extremes of season and day. By its shape and materials, it provides an internal consistency, a steady state.

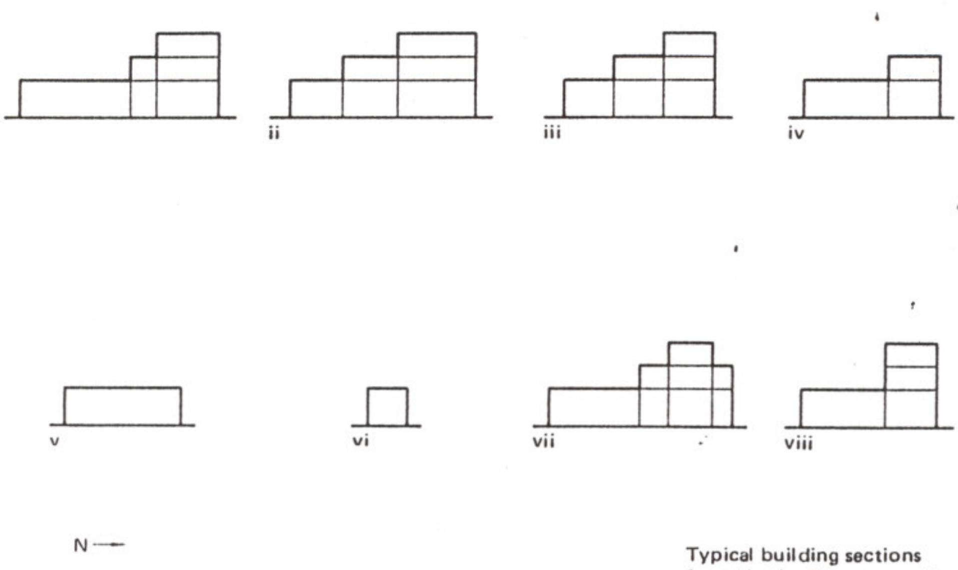
A.1.2. Pueblo Bonito, Chaco Canyon, New Mexico

Pueblo Bonito locates at 36° north latitude and lies about 100 feet south of the sheer rock cliffs of Chaco Canyon. The mile-high elevation modifies a generally hot and arid climate so that the winters are cool and extended. The old pueblo was literally a curved version of Acoma. It had three tiers and opened to the southeast (Fig. A.5).

The author Ralph Knowles has explained the construction of the old pueblo as; "this simple combination of small houses built together in a crescent made use of relatively primitive methods of construction. The walls were made of single blocks of sandstone ranging to a thickness of three feet. The outside walls were almost twice as thick as at their base as they were at the top. Roofs and floors consisted of crude assemblages of cottonwood, pine or juniper logs covered with a mud or adobe." (Knowles, 1974; p:35)

Plan of Acoma based on U.S. Geological Survey photograph (1956). Map prepared at the University of Southern California by P. Canelo, R. Gallagher, R. Kauffman and R. Nickum (1967).

Fig.A.1. Plan of Acoma



Typical building sections found in the Acoma pueblo. The tiered section usually contains six rooms separated by bearing walls (vertical lines) and floors (horizontal lines). North is to the right thus exposing tiers to the south.

Fig.A.2. Typical building sections

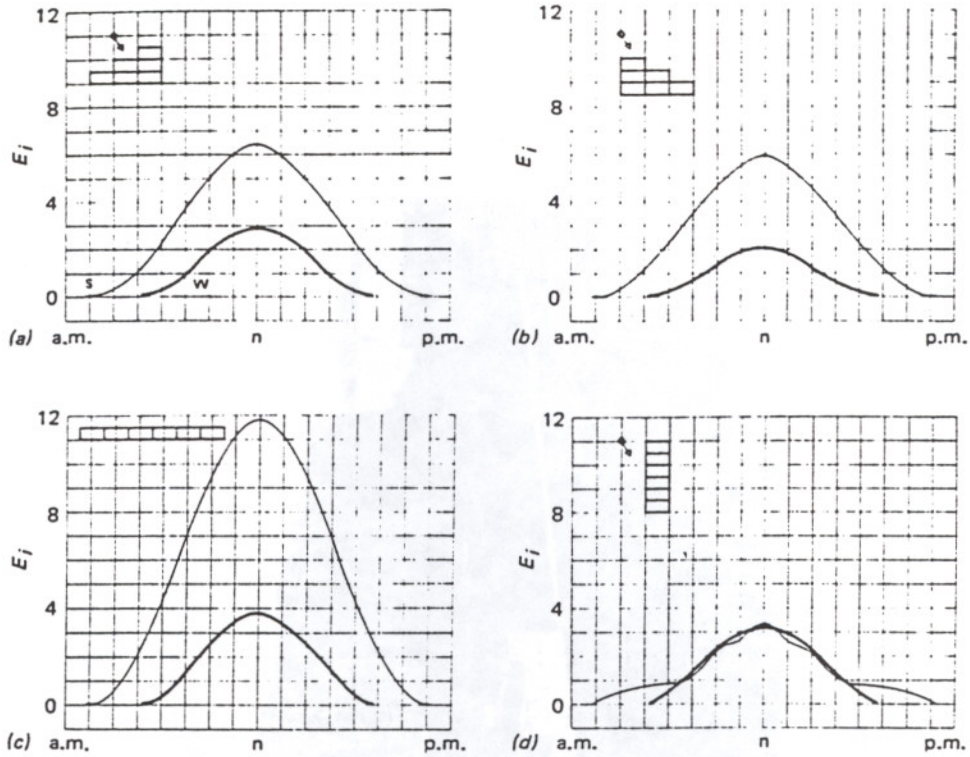


Fig. A.3. A comparison of seasonal energy profiles for various arrangements of the six volumes comprasing a housing unit (Knowles, 1974; pp:32)

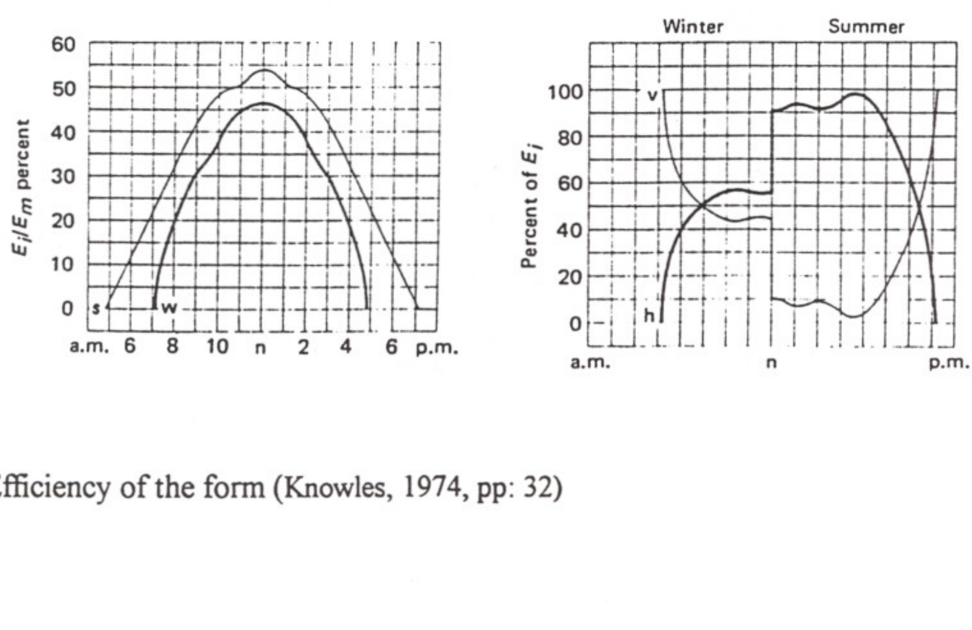


Fig. A.4. Efficiency of the form (Knowles, 1974, pp: 32)

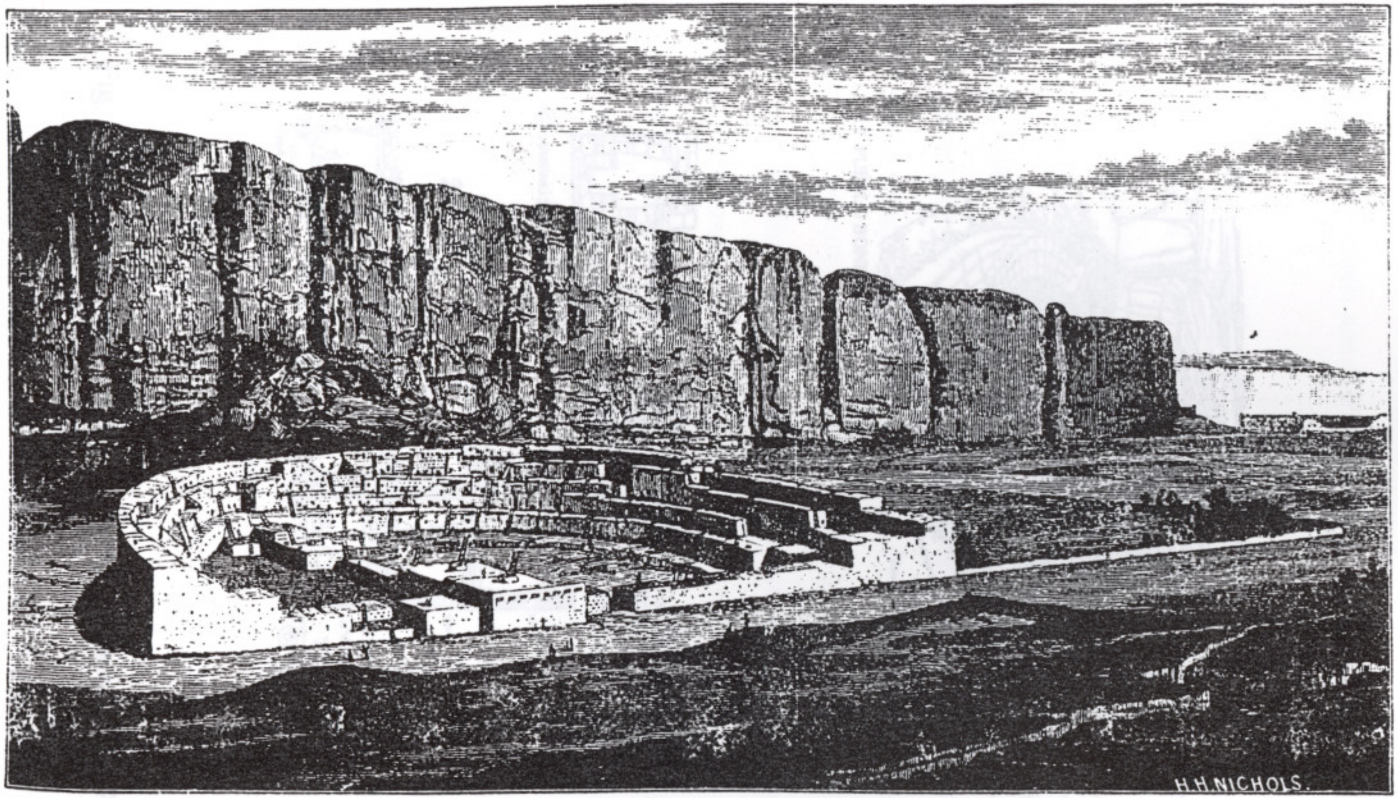
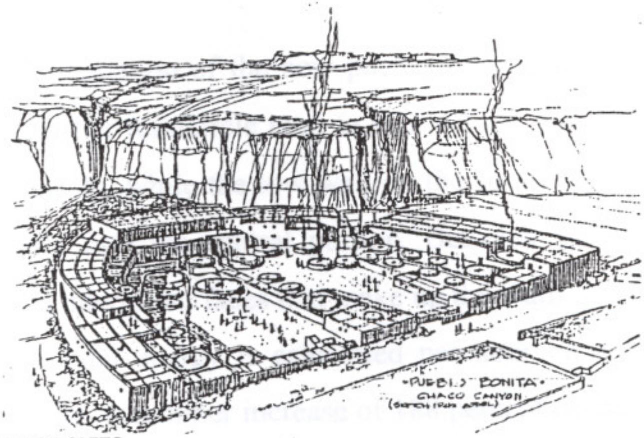


Fig. A.5. (a)Pueblo Bonito, Chaco Canyon (Lechner, 1991; pp: 105)



3.2 PUEBLO BONITO

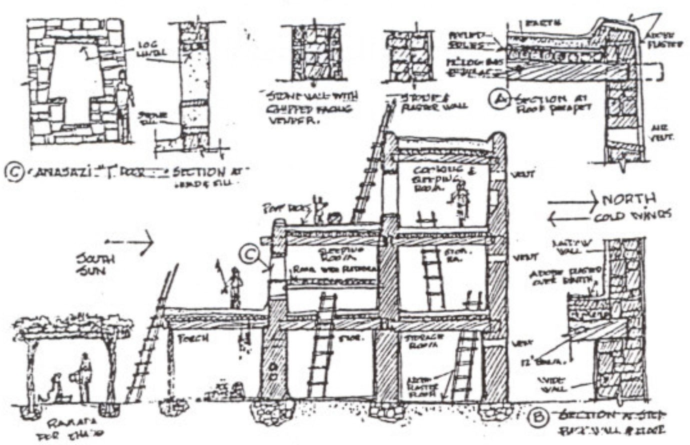


Fig. A.5. (b) Life was oriented to the sun (Alvarez et.al. 1991; pp:149)

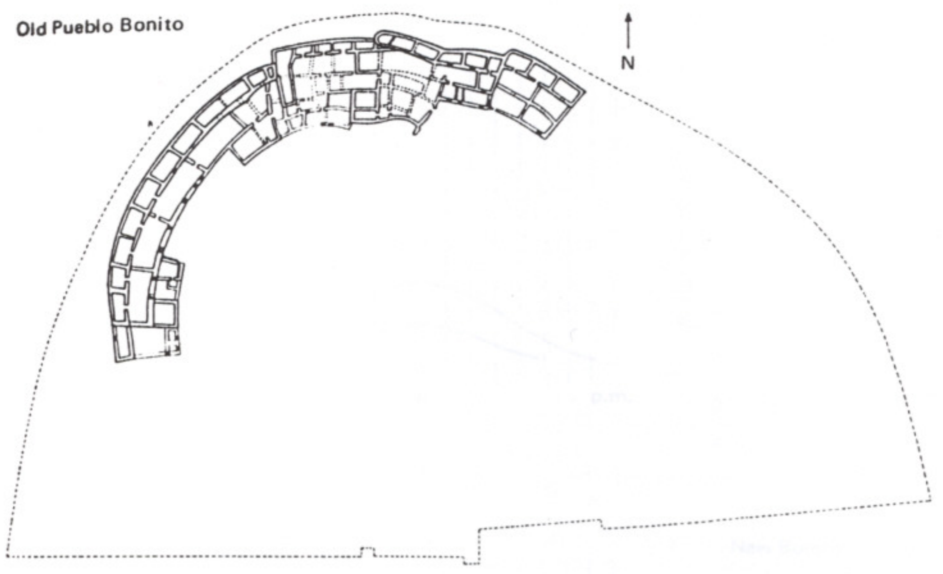
This early constructions has been dated at A.D. 919. Around A.D. 1050 - 1060, strangers moved into the region, represented an unknown and quite different culture and constructed the new Pueblo Bonito. (Fig. A.6) The open orientation to the southeast, the gap placed in the northern wall of the third tier, and the cutaway western corner are the aspects of the old pueblo which are distinctive and responsible for the relationship to the sun.

In comparison, the orientation of the new pueblo is directly to the south. The high walls around the outside of the semicircle tend to shut off the summer sunrise and sunset from the interior of the pueblo, while the low wall on the south tends to admit the winter sunrise and sunset directly into the central portion. Between sunrise and sunset at all seasons, the sun strikes the interior surfaces that make up the walls and terraces.

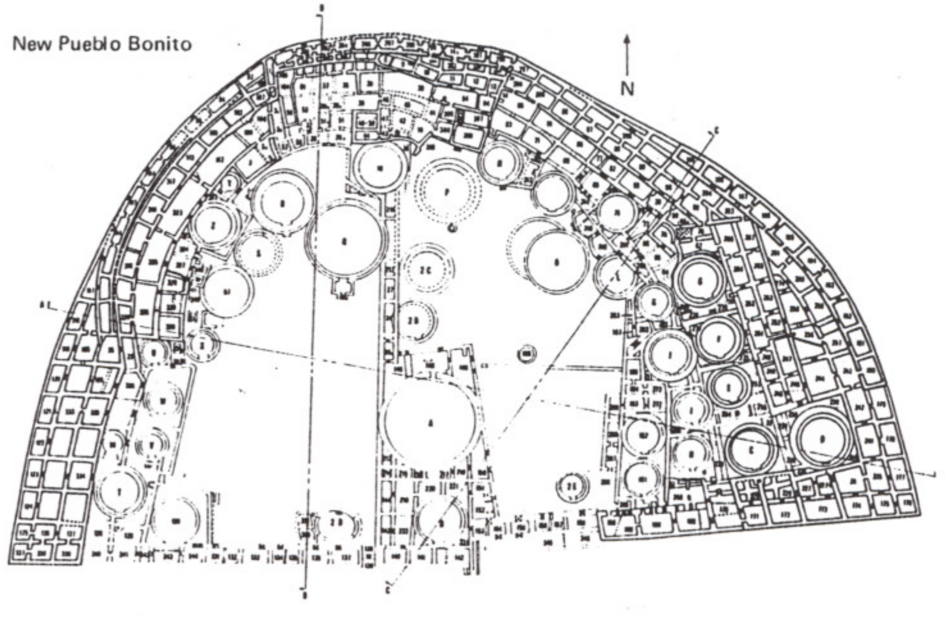
When the direct incident energy is calculated per hour on both the old and new pueblos; the old pueblo shows a summer increase of 188 percent over winter while the new pueblo increases 233 percent in summer (Fig. A.7). The energy profile of New Bonito is generally higher, as New Bonito has a much larger surface area. However, with respect to incident energy per unit area, the two factors act somewhat alike. All external surfaces on the two forms tend to act with nearly equal efficiency. The new form's efficiency is only 5 percent to 7 percent higher over the year than the old form. In fact, the summer increase for New Bonito is 5 percent less than it is for the crescent of Old Bonito.

Like Acoma, both old and new Bonito show a considerably higher percentage of their total energy gain on the verticals during the winter and on the horizontals during the summer. They both use materials on each of the surfaces that would tend to balance the seasonal conditions regarding transmitted energy to the interior spaces.

The quantification of the interactions of the sun, the crescent and the site in energy terms suggests that the Bonitians were aware of the relationships between the form of their constructions and the dynamics of earth and sun. Knowles says that; "they must have worked from a fairly distinct mental image or even from a two or three dimensional physical model of forms." (Knowles, 1974; p:44)There is a very strong visual recognition of the special times of day in the old pueblo. Sunrise and sunset of both extreme seasons



Plan of Old Bonito. A tier arrangement of two and three stories opening in a crescent to the southeast. The crude construction of monolithic sandstone walls with logs and mud used for floors and roofs has been dated at A.D. 919. Heavier lines represent higher tiers. *Source:* Neil M. Judd, *The Architecture of Pueblo Bonito,* figure 3.



Plan of New Bonito. A vastly expanded, tiered arrangement containing 800 rooms built around Old Bonito during a remarkably short time of twenty years, A.D. 1060-1080. The construction showed a high degree of sophistication in the use of materials. The materials used in the walls were differentiated and roof timbers displayed fine craftsmanship. Heavier lines represent higher tiers. *Source:* Neil M. Judd, *The Architecture of Pueblo Bonito,* figure 2.

Fig. A.6. Plans of Old and New Bonito (Knowles, 1974, pp: 38)

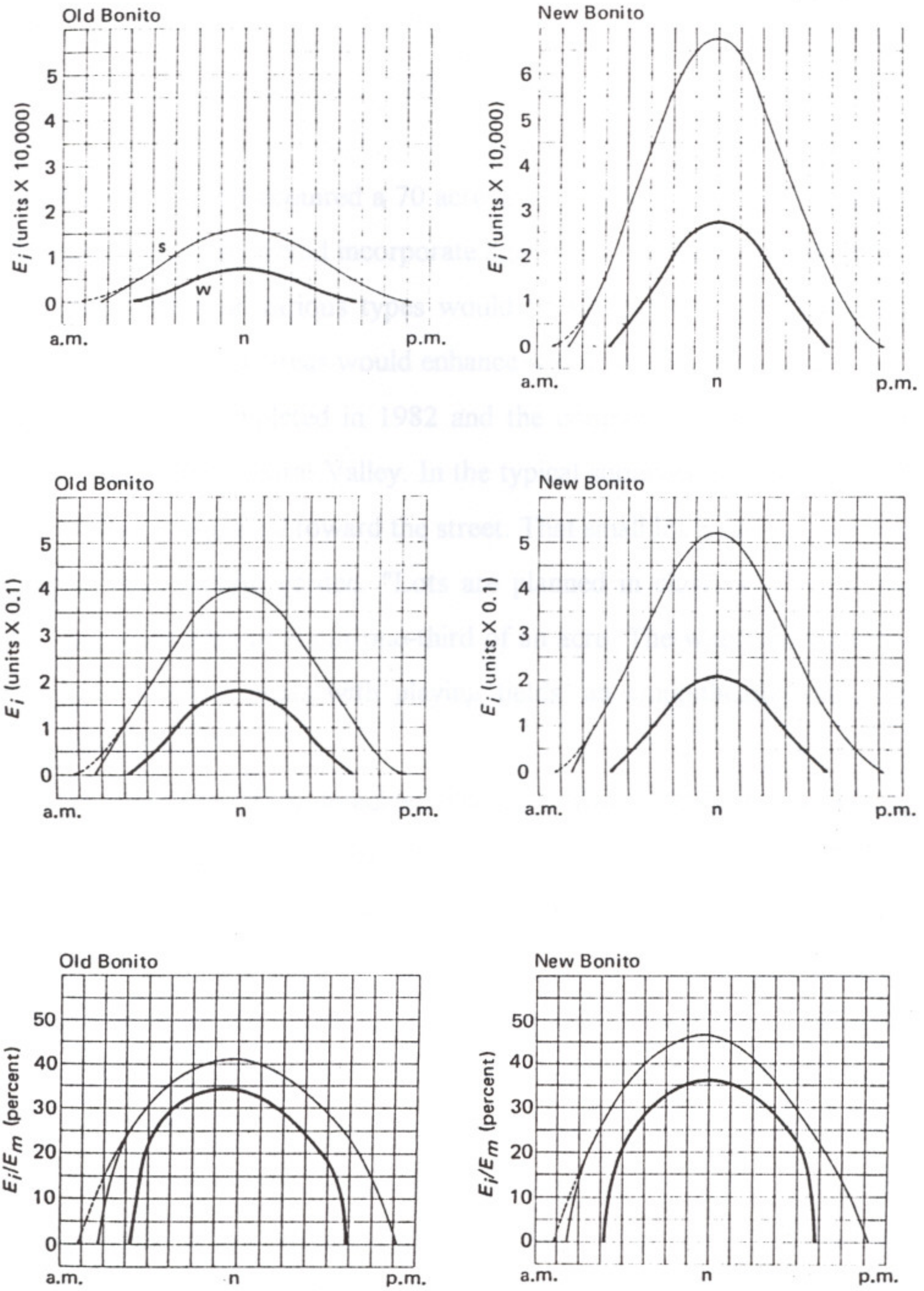


Fig. A.7. Incident energy in summer and winter, incident energy per unit area and efficiency (Knowles, 1974, pp: 40) are clearly emphasized in the way the sun strikes key surfaces. There is a higher efficiency of both forms regarding transmitted energy to the interior volumes in the winter.

A.2. Villages Homes

In 1973, Michael Corbett acquired a 70 acre site in Davis, California. His plan was to design a model community that would incorporate aggressive energy conservation with solar energy. Residential clusters of various types would be interspersed with commercial and agricultural uses, while common areas would enhance social interaction.

Villages Homes was completed in 1982 and the community has become one of the most desirable in California's Central Valley. In the typical subdivision, small lots, averaging about 3800 square feet, are graded toward the street. That small lot is enough for an average sized house and a small private garden. "Lots are planned in clusters of eight with each cluster sharing a common area of about one-third of an acre. The whole community of 220 homes shares larger common areas with playing fields, an amphitheater and community gardens." (Lyle, 1994; p:125).

Most homes are single-family detached. There are also some duplexes and one co-op building. With a few earth-sheltered homes, styles vary from New Mexican and North-western wood to California modern. To maximize solar exposure, houses are oriented north-south along the street. The streets of Village Homes run east to west and feed out to an adjacent minor arterial street. To discourage traffic and allow trees to shade the road during the intense summer heat, streets are much narrower than conventional subdivision. Compared with the standard for the area which is 44 feet, the width of the streets are 22 feet. Parking is not directly on the streets but in parking bays provided at intervals along their lengths. That results in less pavement to collect heat during the day in that very warm climate and more area for planting for microclimate control.

In the circulation system of the Village Homes, much emphasis is given to pedestrian and bicycle paths as to streets. Movement within the community is intended to be entirely by foot and bicycle. Michael's view about the circulation system is, "When you minimize the use of automobiles to conserve fossil fuels, for example, this also reduces noise, conserves land by minimizing streets and parking, beautifies the neighborhood and makes it safer for children." (Browning, 1996)

The additional benefit of the narrower streets is that the air temperature over the street is 10 to 15 degrees lower than surrounding neighborhoods, during the hot summer months. That is attributed both to a reduction in the heat-soaking asphalt mass and the mature trees, which shade more of the street area than would occur in a typical development. Furthermore, between 50 % and 75 % of heat needs of villagers are contributed by solar energy. All the houses have 60 % or more of their glazing on the south side. And the most basic solar features on south facades are the overhangs which shade the houses in the summer but allow sun in the winter. The houses have extra insulation in roofs and for thermal mass they have a concrete slab construction. And also they have solar hot water systems with collection panels on the roof. So the passive devices range from a few south facing windows to architect Jim Zanetto's earth-sheltered solar house, which has never used any fossil fuel. (Lyle, 1994; p:125) In Davis, less than 10 % of the houses have mechanical air conditioning.

When the drainage system is considered, it is seen that running through the common areas is a natural alternative to expensive and wasteful storm drains. Lots, grading away from the street, the rainwater trickling off roads and lawns finds its way into shallow swales landscaped like seasonal stream beds with rocks, bushes and trees. Runoff from the streets goes directly into these larger channels. Small check dams help slow the flow and prevent surges downstream. (Fig.A.8)

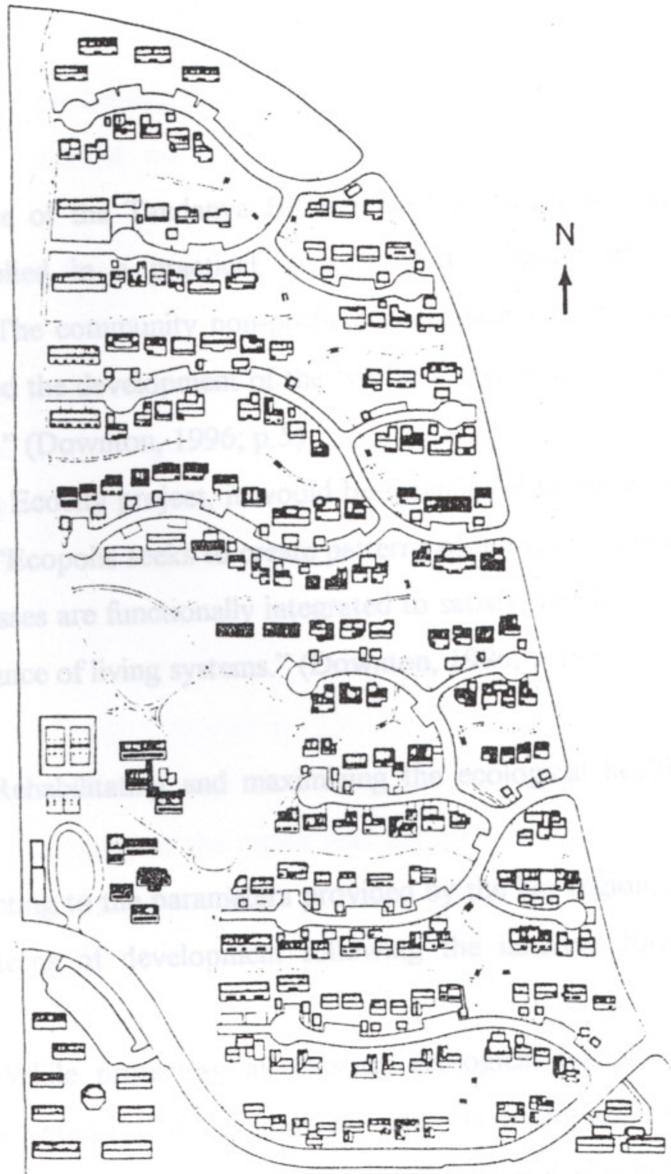
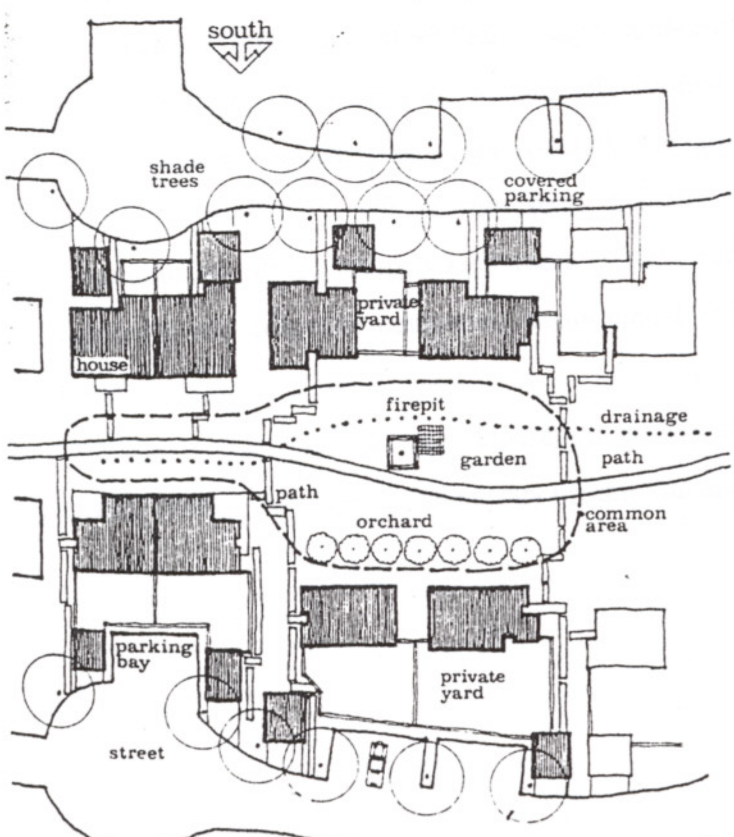


Fig. A.8 Village Homes



A.3 The Halifax Ecocity Project

"In the Mediterranean climate of the Tandanya Bioregion of South Australia, the Ecopolis philosophy is being applied in a practical, two-pronged program of urban redevelopment and rural renewal. The community non-profit organization Urban Ecology Australia Inc. (UEA) has co-initiated the development of the 'world's first piece of ecocity' in the centre of the city of Adelaide." (Downton, 1996; p:5)

Before explaining the Halifax Ecocity project, it would be meaningful to demonstrate the Ecopolis Development briefly. "Ecopolis seeks to create patterns of human settlement in which built form and natural processes are functionally integrated to satisfy human needs as part of the dynamic ecological balance of living systems." (Downton, 1996; p:19)

Objectives;

1. Restore degraded land: Rehabilitating and maximizing the ecological health and potential of land.

2. Fit the bio-region: Respecting to the parameters provided by the bio-region, fitting into the landscape with the patterns of development following the inherent form and limitations of the land.

3. Balance development: While protecting all existing ecological features, there should be a balance between the intensity of development and the ecological carrying capacity of the land. And also, the built form should integrate the diverse elements of a community to form a whole place rather than a single land-use.

4. Halt urban sprawl: Developing human habitation at relatively high density within green belts of natural landscape with the overall development density constrained by ecological limits. The Halifax project represents a major increase in inner-city density associated community infrastructure which reduces the need for further suburban sprawl with its expensive and resource consuming requirement for land, services and transport infrastructure.

5. Optimize energy performance: Operating at low levels of energy consumption, using renewable energy resources, local energy production and techniques of resource reuse,

minimization of energy demand by passive heating and cooling of buildings, with high levels of insulation and extensive use of thermal mass, emphasis on public transport, easy pedestrian movement and cycling.

6. Contribute to the economy: Supporting and promoting appropriate economic activity.

7. Provide health and security: In the context of an ecologically resilient environment, employing appropriate materials and spatial organization to create safe and healthy places. The Halifax project creates a range of public and private spaces with secure separation to private spaces and visible and accessible public spaces enhancing security.

8. Encourage community.

9. Promote social equity.

10. Respect history.

11. Enrich the cultural landscape.

12. Heal the bio-sphere: Contributing to the repair and improvement of air, water, soil, energy, biomass, food, biodiversity, habitat, ecolinks, waste recycling.

The Halifax project Ecopolis, which is opposed to sub-urbanity, promotes a return to the measure of human bodies rather than machines - 10 minutes walk rather than 10 minutes drive.

Running in great parallel lines across the site of what was once a toxic scar in the middle of a young colonial city, there are walls of 400 mm. thick rammed earth. The earthquake resilient walls, spanned by reinforced concrete floors extend the technology of earth architecture. Roof gardens alternate with steel and copper roofs and more than a thousand solar collectors make hot water or export electricity to the grid. Buildings range in height from two storeys to five, with passive cooling belvederes carrying water tanks, stairs and lifts.

The planning grid is square. Apartment blocks enclose square courtyards and the square, with the occasional intervention of a circle. Repetition is avoided. No two plans are quite the same, no courtyard is enclosed by the same profiles and every elevation is unique, being designed with input from the households.

The solar facing north and shaded southern facades change over the days and years as shutters, stained glass panels, flyscreens, paint and stains come and go with the flux of life in the dwellings they light, shade, warm and cool. The east and west facing earth walls have less apertures for light, vision and ventilation. Each building has an insulation made from recycled cellulose or wool blankets to keep summer heat out and sun-trapped winter warmth inside. On the other hand, to protect people from increasing UV, verandahs, pergolas, tents and trees are used.

Moreover, the falling water on the myriad roofs, solar panels, paths, balconies and verandahs, is collected and piped to underground tanks, then pumped up and filtered through reedbeds and aerated through public fountains and water sculptures cooling the air on hot days. "Some stormwater is directed to rainwater tanks. All of it is stored on-site and mixed with the filtered gray water from sinks, showers and basins to irrigate the roof gardens and balconies and sustain the edible landscape, permaculture plantings and ecological corridor threading across the site." (Downton, 1996; p:6 However, the sewage will be treated by biological processes in the solar aquatic greenhouse in a year or two. In addition to that, all the water on the site will be recycled within a few short years.

Besides some on-site parking, cars are practically invisible as parking is provided mostly below ground. Having no through traffic, the pedestrian is in control. Also, the paths and trafficable areas capture stormwater run-off through impermeable or semi-permeable surfaces. Surface carparks, with sheltering pergolas carrying vines and solar panels like the ones on the roof gardens are designed as courtyards for people rather than autos. rehabilitating and maximising the ecological health and potential of land.

As a conclusion, the key features of the architecture and urban design of the Halifax Ecocity Project are given as items below:

- Energy efficient townhouses
- Apartments and townhouses
- Apartments over craft workshops

•Low / middle income co-housing

•Apartments and offices

•Middle income co-op town houses

•100 % solar townhouses

•Apartments over shops

•Building forms designed for natural heating and cooling

•Mixed use, cultural and commercial focus enhances community identity

•Meeting hall

•Cafe's and coffee shops

•Shops, clinics,etc.

•Ecology center - education and agitation

•Entryways, public and private spaces are clearly defined

•Relatively formal street frontages respect the city's planning heritage

•Verandahed pedestrian street

•Verandahs and balconies reflect both colonial traditions and an appropriate response to climate

•Verandahs provide vital protection from increasing levels of UV

•Community shade tents - UV protection

•Native vegetation planted on contaminated site to de-toxify soil and create wildlife habitat

•Canopy, understorey and ground cover plantings create the beginnings of an ecological corridor.

•Village square open space integral to stormwater control, no stormwater runoff to surrounding streets

•Rain water tanks

•Stormwater and grey water used to irrigate onsite vegetation and roof gardens

•Rooftop and balcony gardens contribute to food supply and solar thermal control of buildings

•Heritage chimney retro-fitted for use as a cool tower (Chimney now most likely to be used to ventilate the underground carpark)

•Street trees provide shade, filter the air and are irrigated by water harvested from the street

•Excess power from solar electric devices is exported to main grid

•Clean, quiet, comfortable public transport reduces private car dependency

•Advanced traffic management results in safer, narrower roads and pedestrian friendly street.

Site Plan

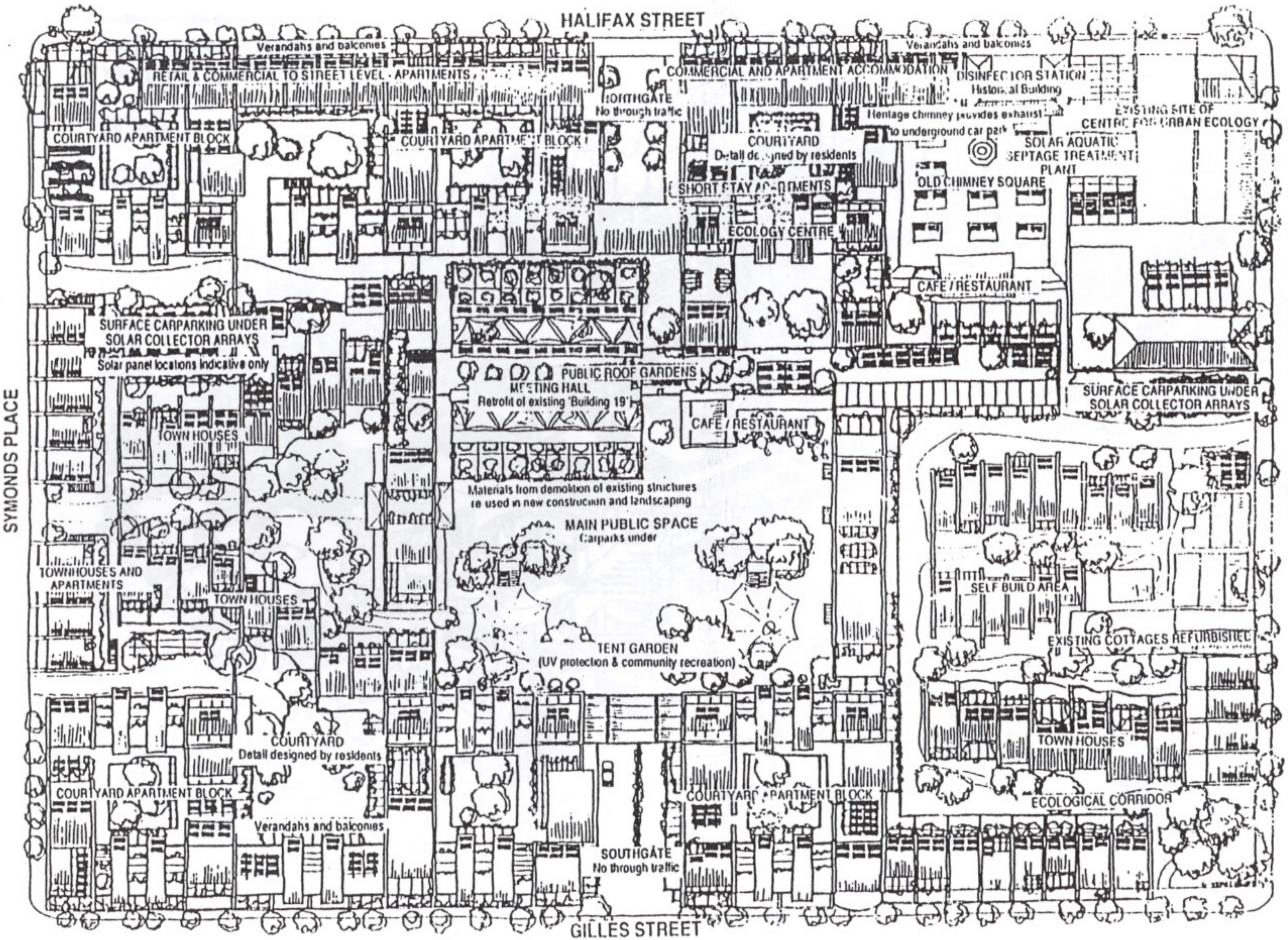


Fig. A.9 Site plan of the Halifax Ecocity

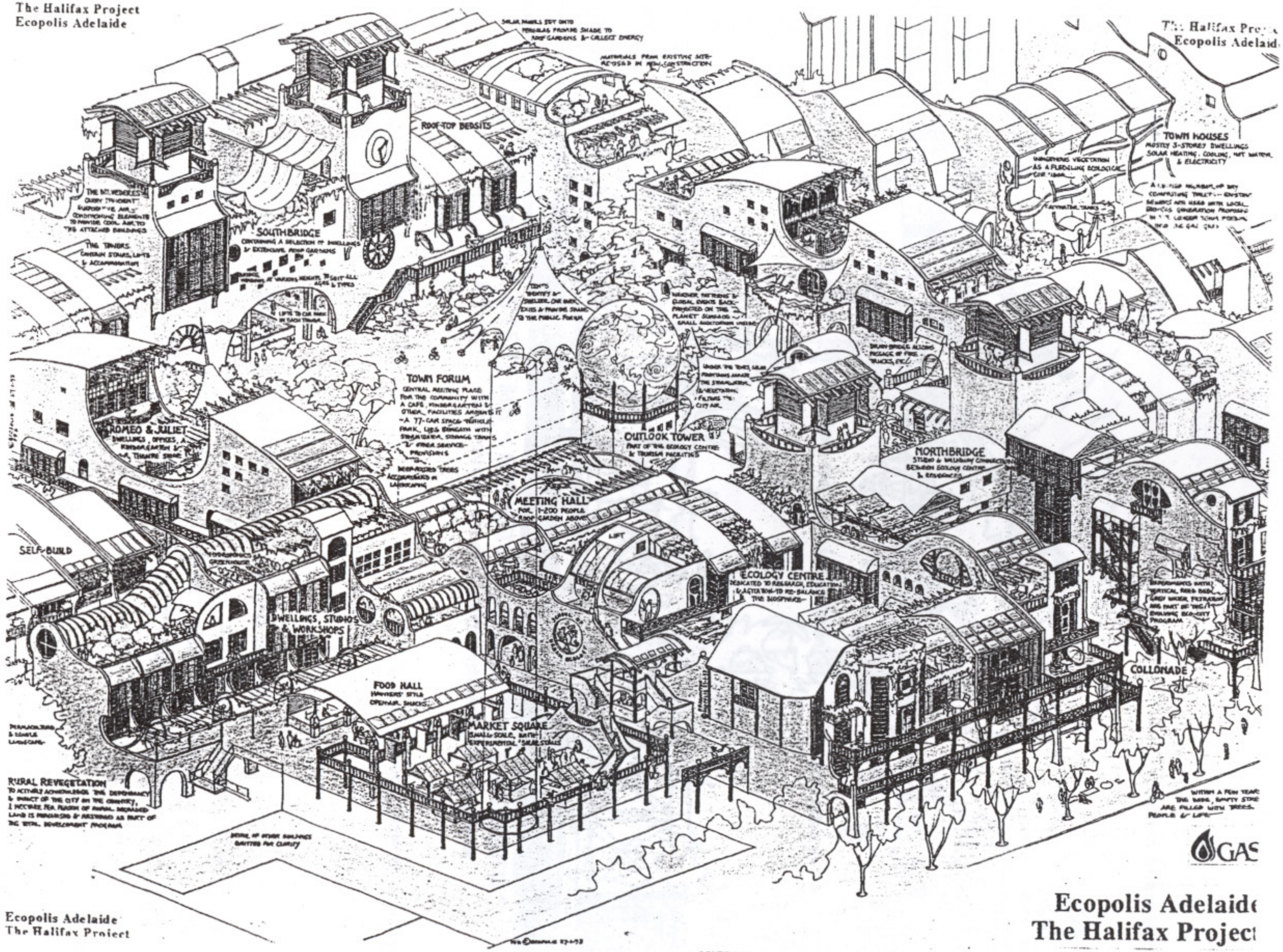
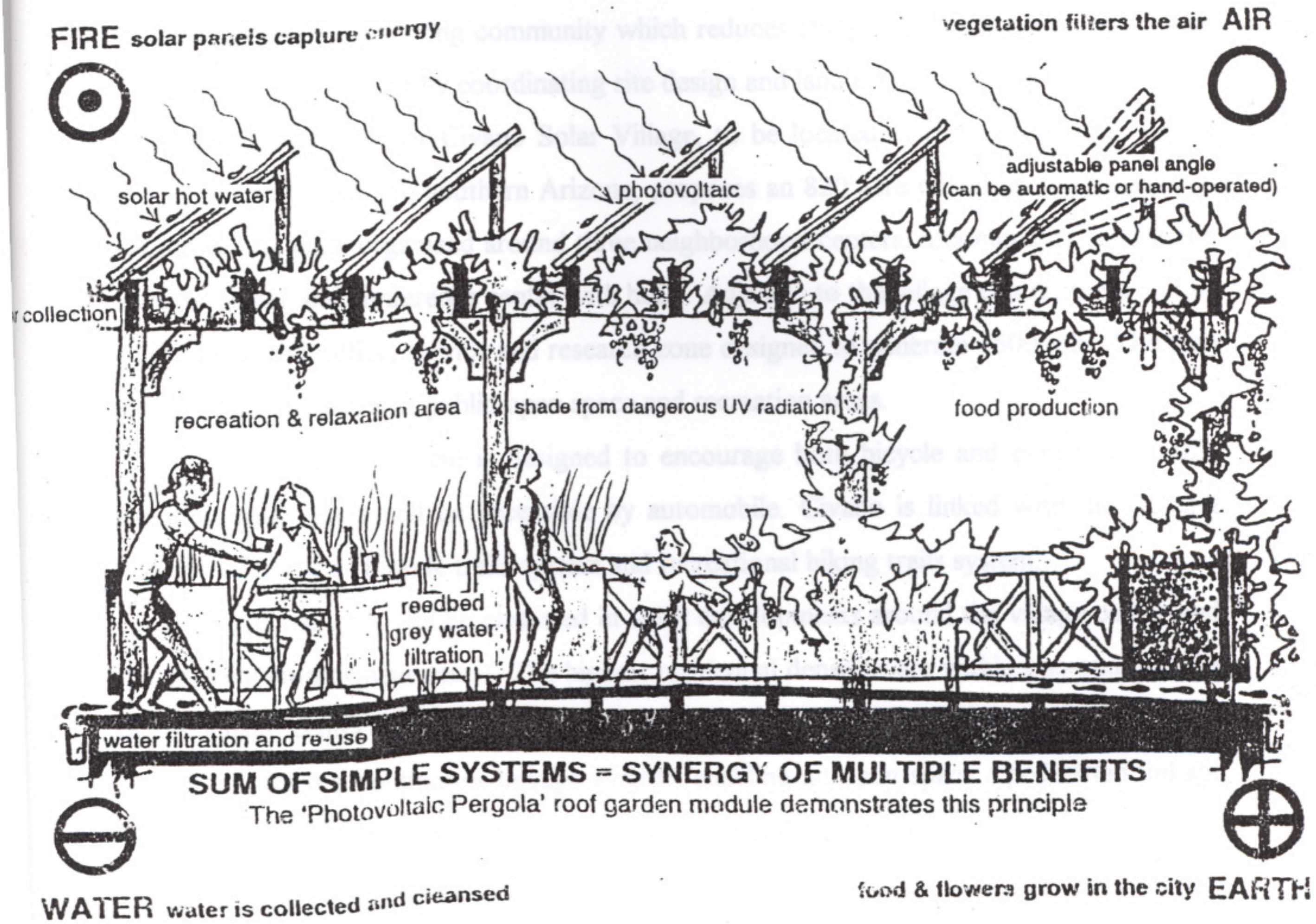


Fig. A.10. Sketch from Ecopolis



The whole is greater than the sum of the parts...

Photosynthesis is only about 1 - 2 % efficient. An engineer would never design a tree! that is exactly what the Ecopolis design philosophy is all about – each element may not be 100% ficient in itself, but all the elements together add up to something with a rich, organic integrity.

Fig. A.11. A detail from the Ecopolis project

A.4. Civano: Tucson's Solar Village

The guiding plan for Civano Solar Village can be expected to be the premier example of a resource-based planned community when completed. It will be one of the most interesting energy conserving community which reduces energy consumption by more than 50 percent through carefully coordinating site design and land use.

The master plan for Civano Solar Village, to be located at the eastern edge of the Tucson Basin in semiarid southern Arizona, proposes an 820 acre mixed use community of 2500 dwelling units organized around three neighborhood centers, a community school and a visitor center and conference center with hotel. Adjacent to the village center, there will be a light industrial, office, service and research zone designed to generate 1500 jobs. The plan incorporates 400 acres of public open space and recreation areas.

The circulation system is designed to encourage both bicycle and pedestrian traffic although each parcel will be accessible by automobile. Civano is linked with the existing regional bus system, bicycle trails system and recreational hiking trails system.

Residential units will be clustered in small developments around the village center and the adjacent employment center. The highest residential densities are within one-quarter mile of the village center to one per acre at the periphery of the development. An open space system will form a continuous linkage system, enabling an open space / pedestrian linkage between each residential unit, the commercial center and all civic uses.

The community will contain a balance of land uses at all stages. Land use is distributed so that 50 % of the residents and 70 % of the jobs are within one-quarter mile of the village center. Pedestrian, bicycle and public transportation systems will be conveniently located to origins and destinations in Civano, reducing the need to rely on personal automobiles.

The residential development is oriented to maximize southern and northern exposures and access to natural breezes, thus maximizing the use of passive solar design for summer cooling and winter heating. In addition, photovoltaic solar arrays for energy production will be used to shade parking areas, large rooftops.

The major performance targets about specific energy and resource conservation are:

- reduce energy consumption by 75 %
- reduce water consumption by 65 %
- reduce air pollution by 40 %
- reduce solid waste production by 90 %

State initiatives to ensure solar access[a]

Colorado	1975	CH 326	Creates solar easements
California	1978	CH 1154	Creates solar easements Removes restrictive covenants Mandates passive design in subdivisions
		CH 1366	Creates solar shading/nuisance provisions
Connecticut	1978	PA 314	Enables solar access in planning/zoning
Florida	1978	CH 309	Creates solar easements
Georgia	1978	A 1446	Creates solar easements
Idaho	1978	CH 294	Creates solar easements
Kansas	1977	CH 227	Creates solar easements
Maryland	1977	CH 934	Creates solar easements Enables solar access restrictions
Minnesota	1978	CH 786	Creates solar easements Enables solar access considerations in planning/zoning
New Jersey	1978	A 561	Creates solar easements
New Mexico	1977	CH 169	Creates "sun rights" provisions
North Dakota	1977	CH 425	Creates solar easements
Oregon	1973	ORS 197	Mandates local comprehensive land use planning (which includes consideration of renewable energy sources).
Virginia	1978	CH 323	Creates solar easements

[a] Key: solar access, access to incident sunlight necessary for solar utilization; solar easement, any easement defining solar skyspace for the purpose of ensuring adequate exposure for a solar energy system.

B. Solar Access Rights

Communities with energy-efficient development regulations[a]

Category and county	Type of Regulation	Date accepted	Provision
Reducing Heating and Cooling Needs			
1. Port Arthur, TX	Subdivision requirements for passive solar orientation	Sept. 1979	Mandatory
2. Sacramento County, CA	Resolutions and administrative procedure for passive solar orientation	1977	Voluntary
3. Dade County, FL	Site plan view criteria for energy-efficient site design	1975	Voluntary
4. Boulder, CO	Incentives for energy-efficient site design	Aug. 1977	Incentive
5. Douglas County, KS	Zoning amendment to permit underground housing	March, 1979	Removes regulatory barrier
6. King County, WA	Regulations to permit and encourage townhouse development	Dec. 1979	Removes regulatory barrier/encourages
7. Davis, CA	Zoning amendment to permit flexible siting of fences and hedges for solar heating	1979	Removes regulatory barrier
8. Davis, CA	Zoning amendment to permit greater use of shade control devices	1979	Removes regulatory barrier
9. Davis, CA	Landscaping requirements for energy conservation	1979	Mandatory
Reducing Transportation Needs			
10. Boulder, CO	Incentives for energy-efficient location of development	Aug. 1977	Incentive
11. Windsor, CT	Incentives and requirements for energy-efficient location of development	1976	Incentive/mandatory
12. Davis, CA	Zoning amendment to expand use of home occupations	Apr. 1979	Removes regulatory barrier
Reducing Embodied Energy			
13. Windsor, CT	Reduced subdivision standards for street widths	1974	Removes regulatory barrier
14. King County, WA	Reduced subdivision standards for street widths	Proposed	Removes regulatory barrier
15. Davis, CA	Reduced subdivision standards for street widths	Proposed	Removes regulatory barrier
Using Alternative Energy Sources and Systems			
16 San Diego County, CA	Mandatory use of solar water heaters in new development	1979	Mandatory
17. San Diego County, CA	Protection of solar access in new development	1979	Mandatory
18. Albuquerque, NM	Zoning provisions to protect solar access	1976	Mandatory
19. Los Alamos, NM	Zoning provisions to protect solar access	1977	Mandatory
20. Lincoln, NB	Incentives for protecting solar access	Oct. 1979	Incentive
21. Imperial County, CA	Overlay zoning provisions to manage geothermal energy development	1972	Manages and facilitates
22. Davis, CA	Deregulation of clotheslines "solar dryers"	1977	Removes regulatory barriers

[a] Within each category the examples are not listed in any particular order, except that similar techniques are grouped together. Source: American Planning Association, "Energy-Conserving Development Regulations: CURRENT PRACTICE" (ANL/CNSV-TM-38) U.S. Department of Energy and Argonne National Laboratory, Chicago, IL, May, 1980, p. 14.