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Energy Conservation and Its Implication for Architectural Design and Town Planning in the Hot-Arid Areas of Saudi Arabia and the Gulf States

Abd-El-Hamid M. Khair-El-Din
Associate Professor, Department of Architecture College of Architecture and Planning, King Saud University, Riyadh, Saudi Arabia

Abstract. The energy crisis has had adverse effects on the national development plans of Saudi Arabia and the Gulf States, even though they are oil-rich countries. Sooner or later fossil fuels will be in short supply. At the moment they are abundant and will still be the main source of National Income for the foreseeable future so they should be used wisely and not wastefully. These fossil fuels must be used economically and skillfully and only for the progress and development of the nations dependent on them.

The whole of the energy needs should be examined with a view to reducing the demand on oil and making better use of solar energy. Can we reduce the demand for oil in transport and for air conditioning in the cities? Can we create an awareness that fossil fuels are not renewable and that solar energy is free? A better understanding of our climatic conditions and the use of passive solar energy in building techniques by simply grouping buildings better would save energy. We need to do research into building materials with a higher thermal capacity and insulation value, that are durable and maintenance free. Our towns and communities should be so laid out that travel requirements are reduced to a minimum. Transport modes should be suitable and efficient.

Hopefully a pleasant living environment can be created for the people of the Arab Gulf despite the harshness of the climate while at the same time conserving their national wealth.

Introduction

All over the world almost two-thirds of all the total energy produced is consumed in conditioning the environment of buildings and in transporting people and goods between them [1].

Residential buildings are major consumers of energy. About one third of the total U.S. energy consumption is consumed by residential and commercial buildings, with about 70% of this total used for heating and cooling [2].

A survey in 1980 of a number of developed nations indicates that the commercial and domestic buildings sector together consume on average 37% of the total primary energy used [3]. For this reason the standards of buildings and energy performance are receiving increased attention with a view to regulating the energy demand of this sector.

In developing countries, approximately 35% of total energy is used for heating of buildings in areas where winter heating is a problem [4].

In a recent survey in Riyadh, Saudi Arabia, it was discovered that about 60% of the total electricity consumed in the summer was used in the conditioning of the environment within buildings [5]. Therefore, the use of energy to create a better living environment within buildings is causing serious problems for both developing and developed countries alike. The demand for energy here is causing great stress to national economies at the expense of industrial and agricultural productivity.

There is, therefore, a great responsibility incumbent upon those who design, plan and manage the living environments of people to consider ways of substantially reducing the demand for energy and in doing so assist the national economy. Owing to the magnitude of this problem this paper aims at indicating the scope for the promotion of a more efficient use of energy in the living environments of people within the Gulf States (Fig. 1) and especially in hot-arid areas, with the objective of conserving energy for the more productive areas of industry and other sectors relevant to our development.

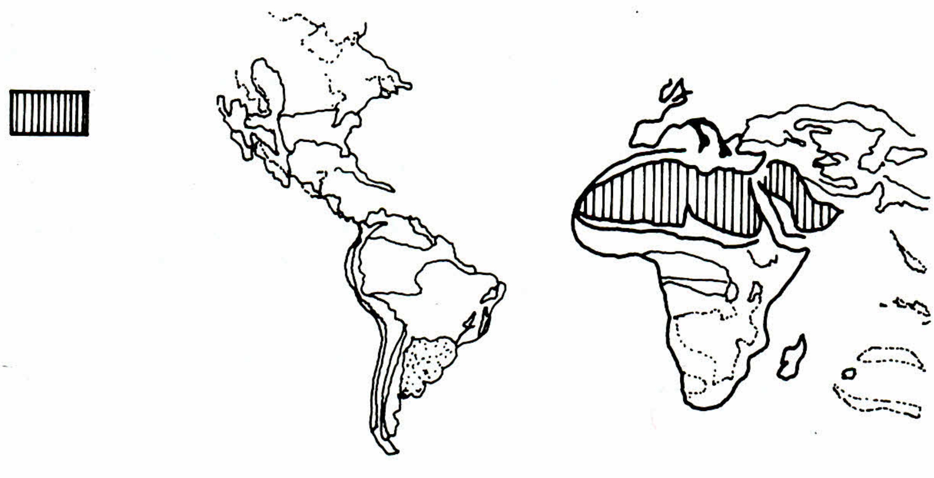


Fig. 1. The Gulf States and North Africa are in the hot arid area [6, p.19]

Measures to Improve the Efficiency of the Built Environment

Generally speaking, for the assessement of the total range of factors which should be considered in seeking to reduce the energy demand for our living-built environment, working spaces, recreation and movement, there are seven measures which should be identified as the ones which have high potential [1].

1- The reduction of the conduction and ventilation losses of the individual building. This will require durability of materials which need management, maintenance, legislation and building regulations to ensure their durability.

2- The improvement of the fuel conversion efficiency of the individual vehicle. This has a potential which is very cost-effective and is dependent on the application of thermodynamics to mechanical techniques. This is beyond the scope of this paper. (The other five measures are more interesting to us as architects and planners, all are related to building materials, form, orientation, layout and the location of development and how the need for transport, generated by the development, is met.)

3- The massing or grouping of buildings.

4- Design with regard to climate.

5- The provision of a better way of conditioning our environment.

6- The use of energy-efficient transport modes.

7- The location of developments that will reduce travel requirements.

I will now elaborate and discuss these points further.

1 – Durability and maintenance

In recent years payments for management, maintenance and service have accounted for an increasing part of total building costs. New materials, products and designs have sometimes been introduced without sufficient knowledge of their long term properties and service lives. We still need to learn much about plastics, metal work, glazing, wall papers, cladding, floor finishing, sanitary fittings and landscaping. Even components made of traditional materials present problems. Wooden windows are insufficiently durable, they rot; mud and stone works are expensive to maintain and replace.

The undesirable consequence of introducing untested techniques and materials are now becoming evident in Saudi Arabia and the Gulf states.

Considering these facts building legislation and regulations to ensure durability of structural elements should be introduced, keeping in mind safety, energy conservation and the health of the occupants. The main points of such building regulations should be concerned with durability, replaceability, accessibility, operation and maintenance instructions while at the same time aiming to secure the most desirable living environment [3].

2 – (As stated above this point is beyond the scope of this paper. Ref. "The improvement of the fuel conversion efficiency of the individual vehicle".)

3- The massing or grouping of buildings

The compactness of buildings is one of the pivotal issues in determining the thermal characteristics of building forms. Many researchers have drawn attention to valid facts that designers can adopt to save energy (Figs. 2,3,4)

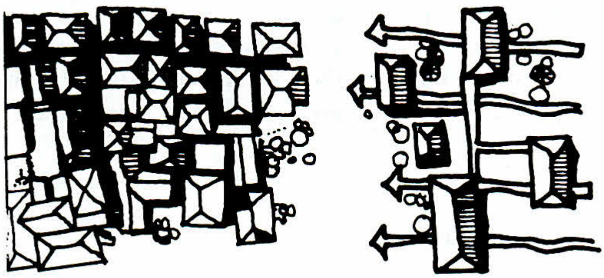


Fig. 2. The compact housing solution in hot-dry areas will reduce the nuisance of sand and sand storms. Free flow of wind is required in hot-humid area [6, p.49].

Fig. 3. Compact buildings and narrow square courts are recommended in hot-desert areas [8]

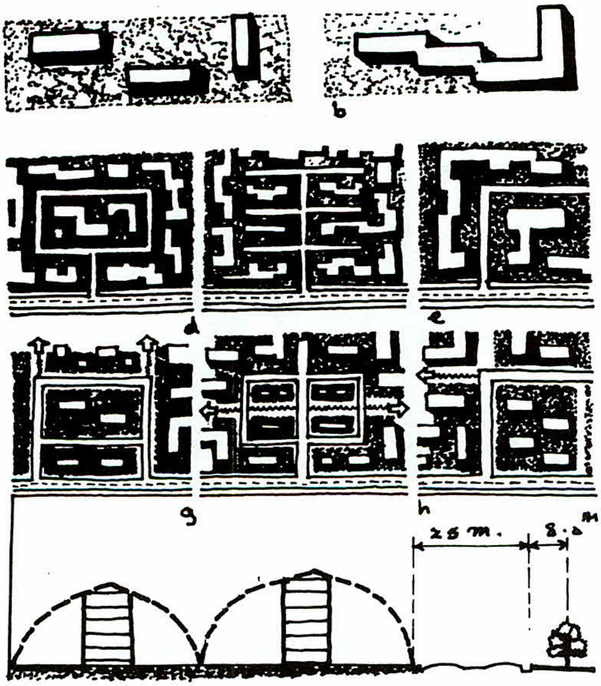


Fig. 4. In hot-arid area, avoid tall-narrow buildings. It should not be too thin in plan or elevation. Round, square hexagonal, octagonal or wide rectangular buildings are recommended [6, p.84].

A- A mid-floor flat of the same volume and the same surface area of exposed glazed walling as an equivalent detached house is likely to have about one third of space cooling and heating requirements [1]. For this reason multi-level buildings or apartments are more energy saving than individual housing.

B- If buildings are grouped close together in hot-dry climates, the same as our ancestors did, they will give some shade to each other and provide shady narrow streets with little space in between [6]. The use of arcades, colonnades, shading devices, small enclosed top-covered courtyards, inward-looking and introvert spaces are desirable (Figs. 5,6,7,8). Natural cooling system such as fountains, waterfalls, vegetation etc. will alleviate the harshness of the lack of humidity in a hot-dry climate (Fig. 9,10), [6. p. 35].

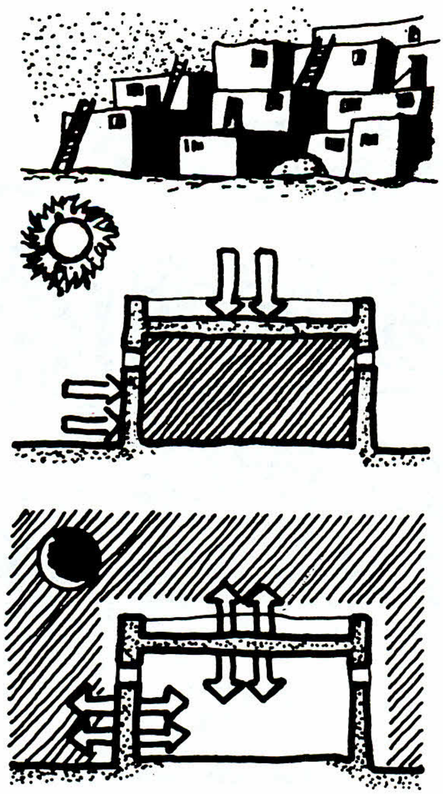


Fig. 5. Buildings in hot-dry zones are traditionally constructed with thick walls and roofs and with very small opening [6, p.42].

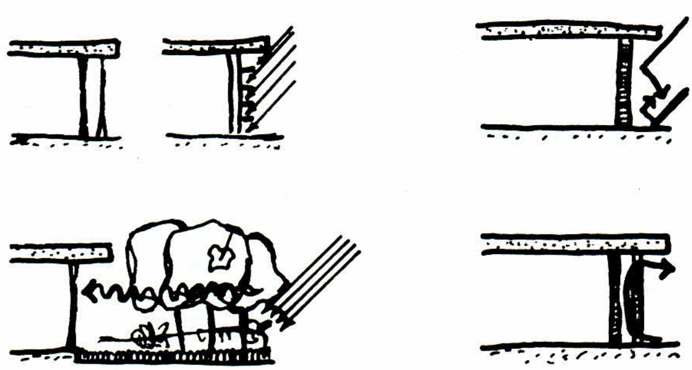


Fig. 6. Shading devices, cavity walls, roof with air space in between will provide a resistance to heat flow [9].

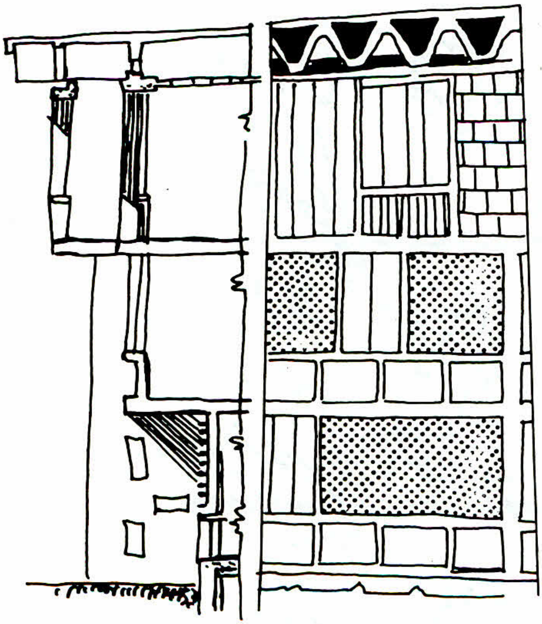


Fig. 7. Shading devices with free circulated air around them will release the absorbed heat and prevents its radiation inside the building [8, p.101].

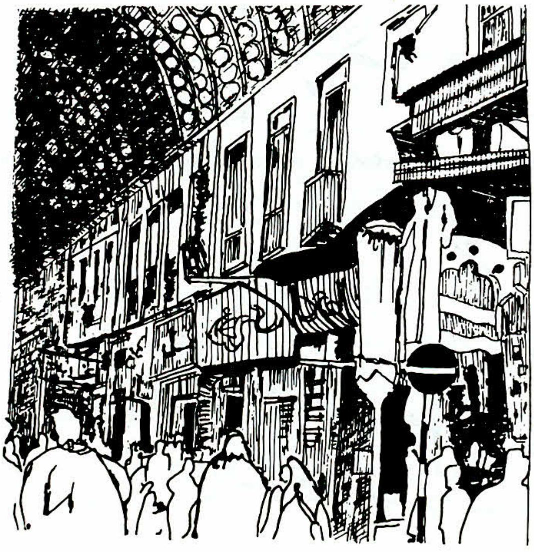


Fig. 8. The use of arcades, colonnades, small enclosed top-covered cortyards, streets will alleviate the harshness of the lack of humidity in a hot-dry climate [8, p.67].

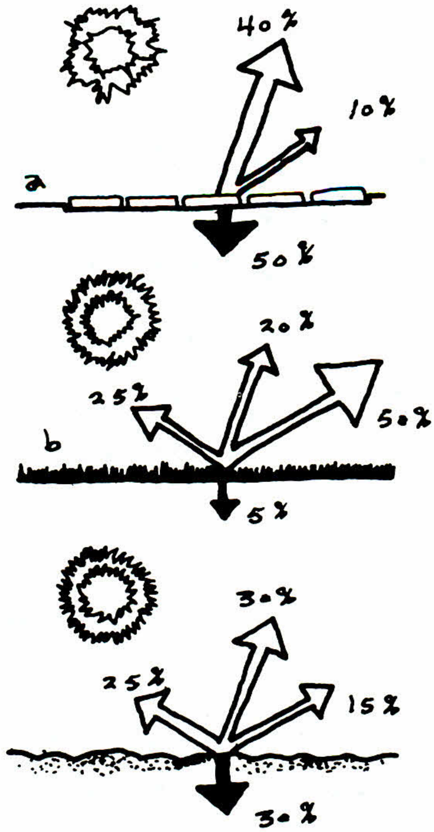


Fig. 9. Absorption of heat by different surface materials: (a) paving, (b) grass, (c) bare ground [6, p.35].

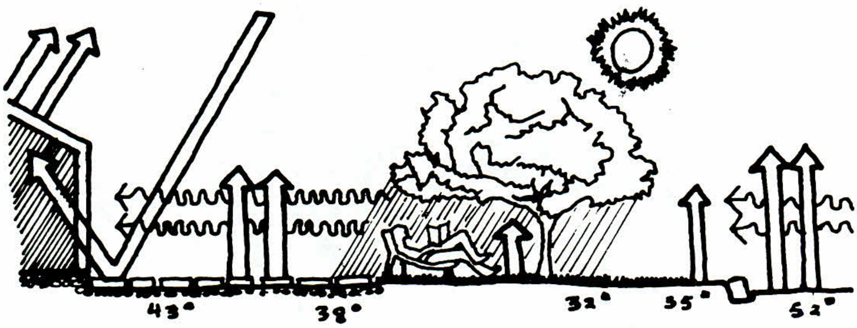


Fig. 10. The temperatures in and around building can be tempered by the nature of surrounding surfaces. Temperatures shown were recorded in hot-dry climate when the air temperature was 40°C [6, p.35].

C- The compact housing solution in dry hot areas will reduce the nuisance of sand and dust storms which cause discomfort and irritation to the eyes, nose and throat and a great deal of extra cleaning work (Figs. 2, 3). (Wind-blown sand is often the cause of damage to wood, metals, paints, galvanising and other exterior surfaces). A square central courtyard offers good protection from wind-blown sand. Rectangular courtyards with long axes parallel to the wind are not recommended [6].

4 – Design with regard to climate

This include both macro-climate (the altitude and latitude at which development takes place), and micro-climate (the effects of urban heat islands, resulting from the sun's radiation and light reflection) and exposure to winds [1].

A- The shape, orientation, grouping and landscaping of development can alter micro-climate, including the excessive heat from the sun and can produce the very desirable coolness from a breeze.

B- The layout must allow for the free flow of the natural elements, such as wind, especially in hot-humid areas (Fig. 2). Dead-end streets and built-up street corners should be avoided to reduce heat radiation (Fig. 4).

C- Techniques are being studied on how to use landforms and the planting or vegetation to modify micro-climate (Figs. 9 and 10). Innovation in the use of infrared aerial photography to survey heat loss in buildings may enable progress to be made in assessing such heat loss.

D- Passive solar heating and cooling should deliberately have priority in design and planning for our community. The use of solar energy has the potential to further significantly reduce the energy consumption of residential buildings.

E- By using earth-sheltered houses we can reduce the energy cost by between 25% and 80% below that of the conventional house [7]. In hot-arid areas underground structures prove to be comfortable (Fig. 11). At a depth of about 2.5 m. below ground level, the temperature of the earth is remarkably even and remains close to the average temperature of the region, so providing warmth in the winter and coolness in the summer. Soil temperatures are not only moderate at this depth but they also change very slowly with the maximum and minimum temperatures occurring up to three months later than those on the surface Page. [6].

F- Building materials and their insulation values

The air is one of the best insulators. Materials which enclose or contain air have low heat transfer characteristics and are generally light in weight. Walls, roofs and building components are often made up of two or more layers separated by air space which provide a resistance to heat flow (Fig. 6). the amount of this resistance

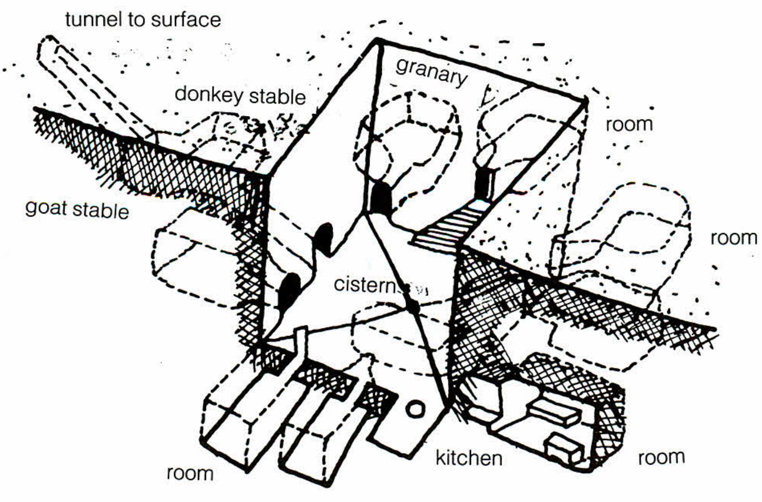
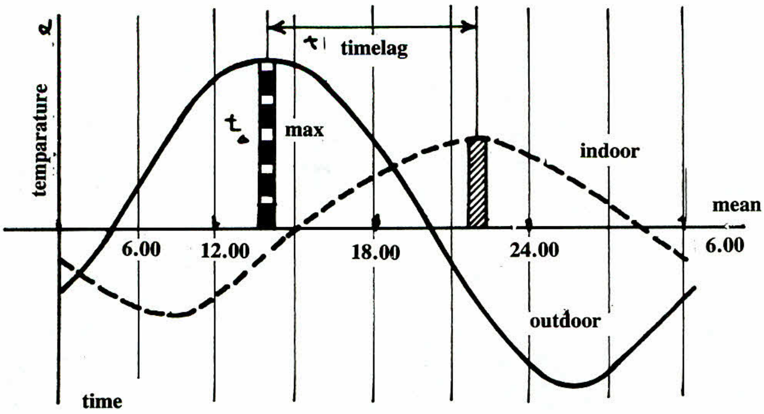


Fig. 11. Underground buildings are so well insulated against the scorching desert days and chilly nights. Over the past 40 years whole towns and villages-including not only dwellings but also factories, schools, hotels and offices have been built entirely underground in the Loess (silt) bed of northern China [6, p.99].

depends not only on the width of the air space but also on the characteristics of the enclosing surfaces, as heat transfer across these spaces takes place mainly by radiation from one surface to another. For this reason highly reflective materials, such as metal foil, used in air spaces can reduce their thermal conduction by over two or three fold in some instances Page [6]. Heat exchange by conduction and convection in air space depends on whether the space is horizontal or vertical, on its width and on the direction of the heat flow (upwards, downwards, or horizontal) and on the free movement of air in between to release the heat absorbed by the exposed surface.

G- Materials and the thermal capacity of the heat storage value

The larger this is, the slower the temperature change that is propagated through the material. This delay is called the "time lag" of the construction (Figs. 12, 13). Materials with large time lags are usually dense in quality and heavy in weight. Solar radiation affects buildings in two ways. It is either absorbed by the walls and roof surfaces and then re-radiated into the building or it enters directly through glazed areas which transmit solar or short-wave radiation with very little loss in heat energy. As a result we have the greenhouse effect. Glass allows the short-wave solar radiation to pass through but not the long-wave radiation emitted by objects or surfaces in a room. The heat which enters through glazed areas is trapped and can increase the indoor temperature to far above that of the air outdoor (Figs. 14, 15). The indiscriminate use of glass in hot climate areas can, therefore, not be recommended [6].



Timelag decrement factor

Fig. 12. **The earth above underground structure protects the interior from radiation and provide a huge thermal mass to stabilise air temperatures. Soil temperatures change slowly with the maximum and minimum temperatures occuring up to three months later than those on the surface. Such time-lag will provide relative warmth in winter and coolness in summer in such structures [6, p.112].**

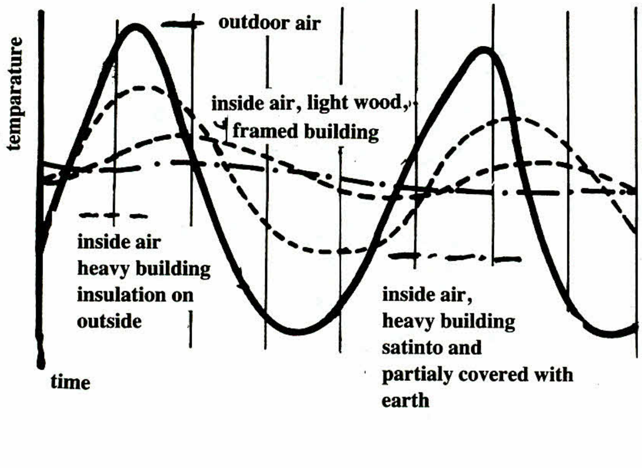


Fig. 13. **Different materials have different thermal capacity or heat storage value. The larger this is, the slower the temperature change that is propagated through the material. This delay is called the "time-lag" of the construction. Materials with large "time-lags" are usually dense in quality, heavy in weight and preferable in hot-dry areas [6, p.112].**

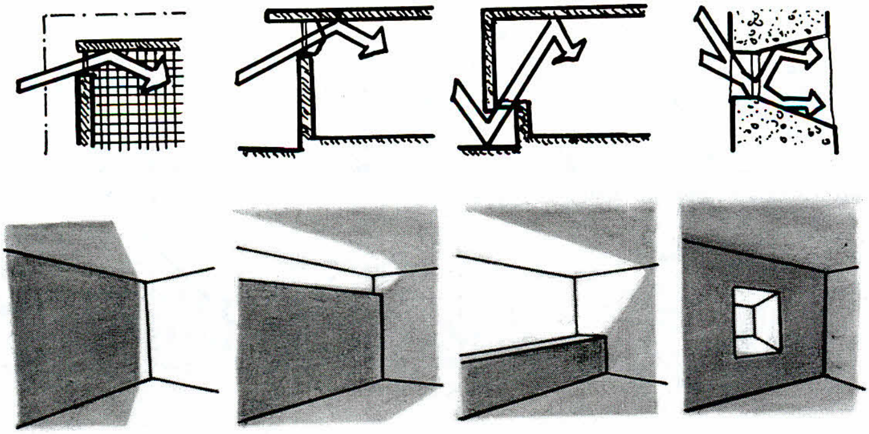


Fig. 14. In hot-dry areas, reflected glare from the ground and other surfaces is a problem and small carefully positioned windows, will reduce the glare in such areas [6, p.50].

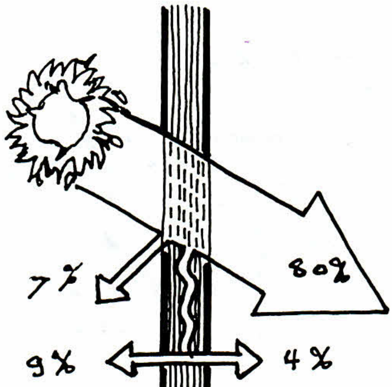


Fig. 15. Solar radiation enters through glazed areas which transmit solar or short-wave radiation with very little loss in heat energy. By greenhouse effect, the heat enters through glazed areas in trapped and can increase the indoor temperature to far above that of the air outdoors [6, p.41].

Presently, a wide range of special heat-absorbing and heat-reflecting glasses are available in the market, but most of them are limited in their effectiveness because either their own temperature is raised, which increases the heat convected and re-radiated into the internal space, or they tend to reduce even more light than heat.

To modify the extremes of the diurnal range and to insulate the interior from the blistering heat outside, buildings in the hot-dry zones are traditionally constructed with thick walls and roofs and with very small openings. The thick exterior walls and roofs (built of clay or stone) absorb solar radiation during the daylight hours and slowly re-radiate it during the night. In this way the external temperatures are damped, and internal temperatures stabilized, being cooler in daytime and warmer at night (Fig. 5). In regions where diurnal and seasonal variations are not so large and the intense direct and reflected radiation is the main source of discomfort, the wall mass is often reduced with the outside surfaces painted white or some other light colour, to reflect a minimum of the radiant heat [6].

5- The provision of a better way of conditioning our built-environment by combining cooling, heating and power, and district conditioning

Here we need to assess the cost-effectiveness of large scale conditioning schemes based on centralized boilers or chillers. Some of these could be fuelled by municipal refuse and by using the waste heat from either new or existing generating stations [1].

6- The use of energy-efficient transport modes

Conservationist enthusiasts have strongly advocated more energy-efficient modes of transport for a long time. More use of bicycles, a reduction in the number of short cold-start car trips and more use of public transport will save large amounts of energy.

7- The location of development can help to reduce transport requirements

This can be achieved by clustering activities sufficiently close to each other primarily to reduce trip lengths. At the same time this can enhance the possibility of walking or cycling.

The neighbourhood unit with schools, shops and social facilities near homes can reduce the overall need for travel and so save energy.

Avoiding the dispersal of activities will create social cohesion and will have a positive economical outcome as well; it will save energy.

Conclusions

1- To save energy we need to assess all the factors which influence our built-environments, we also need to study the travel patterns of people within our cities, regions and nations.

2- We need to select suitable building materials with a high thermal capacity and heat insulation value to withstand the rigours of our climate.

3- New technology and building materials should be tested and evaluated before applying them as structural elements and building components in our development.

4- Elaborate research should be carried out to evaluate the traditional building materials for further development and improvement.

5- Solar energy, which is a rich and permanent resource, should be used in all our development. Awareness of this resource can be developed by individuals, by contractors, by financial institutions or by the state.

6- Passive solar systems should be used at all levels. We must consider the proper orientation of buildings, their form, shading devices, vegetation and landscaping and earth sheltered settlements.

7- Community facilities should be centralized and not dispersed, to create harmony, save time and energy.

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توفـير الطاقة وتأثيرها على التصميم المعماري وتخطيط المدن في المناطق الحارة الجافة في المملكة العربية السعودية ودول الخليج

عبدالحميد محمود خيرالدين
أستاذ مشارك، كلية العمارة والتخطيط، جامعة الملك سعود، الرياض، المملكة العربية السعودية

ملخص البحث. من السهل أن يلمس الإنسان أن مشكلة الطاقة لها تأثيراتها المعوقة لخطط التنمية القومية في المملكة العربية السعودية ودول الخليج وذلك بالرغم من أنهم جميعًا من الدول الغنية بالبترول. وعاجلا أو آجلا، فإن الوقود الأحفوري المستخرج من حفريات الأرض سوف يصبح نادرا وليس بالوفرة الآنية.

وفي وقتنا الحاضر، فإن هذا الوقود متوافرا، وسيبقى كذلك لمستقبل قريب. ولهذا السبب بعينه، فإنه يجب استعماله بحكمة وترشيد وليس بإسراف وتبديد. مثل هذا الوقود الأحفوري، يجب أن يستغل بطريقـة اقتصـادية، وبحذق ومهارة فائقتين، وأن يوجه فقط لخدمة التقدم الاقتصادي والتنمية القومية للدول المعتمدة عليه.

كما أنه يجب أن تطرق كل السبل لتوفير الاحتياجات من مصادر الطاقة، آخذين في الاعتبار تقليل الطلب على البترول خاصة، ومستغلين الطاقة الشمسية كأحسن وأرخص مصادر الطاقة عامة.

فهل في إمكاننا بعد كل هذا التقليل من الطلب على البترول بترشيد وسائل النقل وأعمال تكييف الهواء داخل مدننا. . ؟ وهل في إمكاننا أن نذكي الوعي الاقتصادي عند المستهلك، موضحين له بأن الوقود الأحفوري ليس متجددا تجددا مطلقا. . وإلى الأبد وأن نبيّن له بأن الطاقة الشمسية هي أفضل ما يمكن الحصول عليه بدون مقابل؟.

ولـذا فإنـه بالمعرفة التامة والوعي الكامل بكل ظروفنا المناخية والعمل بهذه المعرفة لتوفير الحلول المعمارية والتخطيطية المناسبة. فإنه يمكننا الاستفادة من الطاقة الشمسية أقصى استفادة. . وذلك بحسن تجميع المباني. وباختيار أفضل التكوين المعماري لها. وبتوجيهها التوجيه التخطيطي المناسب. . بالتالي سوف يوفر هذه الطاقة ويجعلها في خدمة سكان المنطقة.

وفضـلا عن ذلـك، فنحن في أشـد الحـاجة إلى أن نجري الأبحاث على مواد البناء والتي تتميز بالاحتفاظ بطاقة حرارية عالية أو التي تتميز بقيمة كبيرة في عملية العزل الحراري داخل المباني أو التي لها صفة الدوام وتكاليف صيانتها غير باهظة. كما أننا نحتاج إلى أن تكون تخطيطاتنا لمدننا وتجمعاتنا الحضرية والسكانية بالشكل الذي يجعل متطلبات السفر ونفقاته ميسرة، ويمكن تحقيق ذلك بالاهتمام بوسائل وطرق المواصلات والتي يجب أن تكون مناسبة وعلى قدر من الكفاءة العالية.

وبعد كل ذلك نأمل توفير بيئة معيشية ممتعة لسكان المملكة العربية السعودية ودول الخليج بالرغم من قسوة الظروف المناخية بها ـ وفي الوقت نفسه يمكن أن تحتفظ بالبترول «الثروة القومية بالمنطقة».