

VERNACULAR ARCHITECTURE AND CONTEMPORARY DESIGN IN OMAN: CHALLENGES IN A CHANGING CLIMATE

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ABSTRACT

The buildings sector accounts for a considerable proportion of global energy and resource use and anthropogenic CO₂ emissions. In Oman, the widespread introduction of mechanically air-conditioned and energy-inefficient buildings accompanied rapid economic growth and modernisation during the 1970s. Primary energy use continues to escalate and the supply of electrical power to residential buildings is the principal end-use sector. The vernacular architecture of the region illustrates economic means for creating comfortable environments utilising only natural, renewable forms of energy. However, the feasibility of incorporating traditional cooling techniques in contemporary buildings will depend upon the acceptance of cycles and variations in indoor climates and crucially on what is considered the upper limits of comfortable thermal conditions by occupants. The lack of energy performance targets is a barrier to improving the energy performance of the future housing stock in Oman. Buildings need to be assessed according to the added demands they place on local and global ecosystem services with reference to acceptable environmental limits of performance.

INTRODUCTION

“Traditional wisdom and lore in building, using renewable resources and indigenous skills, may still offer wisely managed, economically effective and culturally appropriate solutions to the world’s increasing housing needs”. Thus, Paul Oliver asserts the relevance of vernacular architecture to contemporary design and construction challenges (Oliver, 1997). This paper explores current development trends and drivers of energy use and carbon emissions in Oman, located on the eastern tip of the Arabian Peninsula, and reviews the passive and low energy approaches to providing comfort in the vernacular buildings of hot dry desert climates. The relevance of these traditional building techniques to the design of contemporary buildings is appraised, and potential barriers to improving the energy performance of the future housing stock in Oman are identified.

ENVIRONMENTAL LIMITS AND SUSTAINABLE DEVELOPMENT

Living within acceptable environmental limits, and demonstrating stewardship of the Earth’s finite natural resources for future generations, is integral to sustainable development or “development that meets the needs of the present without compromising the ability of future generations to meet their own needs” (United Nations, 1987). This implied concern for inter-generational equality – the intrinsic normative essence of sustainable development – logically and ethically extends to a concern for intra-generational equality, and, in particular, meeting the “essential needs of the world’s poor” (ibid.). However, in the context of predicted population growth and the wide disparity of wealth and resources, achieving sustainable development presents a particular challenge to current development patterns.

Furthermore, at a conceptual level, environmental limits are not easily defined and in this respect it is useful to distinguish between ‘limits’ and ‘thresholds’ (Haines-Young *et al.*, 2006). A limit refers to a “critical point” or “level of some environmental pressure, indicator of environmental state or benefit derived from the natural resource system” beyond which further change is deemed unacceptable (*ibid.*, p. 19). A ‘threshold’ is a more precise term that describes “situations in which a distinct regime shift between alternative equilibrium states exists, which may or may not be reversible” (*ibid.* p. 11).

LIFECYCLE ENVIRONMENTAL IMPACTS OF BUILDINGS

The built environment has significant and diffuse environmental impacts on natural habitats. For buildings, these impacts occur throughout its life, during the processes associated with raw material extraction and acquisition, energy and material production and manufacture, construction, operation, maintenance and demolition. Globally, it is estimated that 60% of all resources go into construction (Edwards, 2005).

Concentrating on the operational energy use of buildings, a study of world-wide energy use in 2004 (de la Rue de Can and Price, 2008) indicates that buildings are responsible for approximately 38% of global energy use and 34% of indirect carbon emissions after reallocation of the energy used for conversion to the end-use sectors. The study identifies the following determinants of buildings energy demand (*ibid.*):

- Population growth;
- Economic development;
- Diffusion level of energy use equipment;
- Size of households;
- Square metres of building areas; and
- Behavioural factors.

To this may be added the seasonal and annual climatic factors which affect heating and cooling requirements in buildings.

There are significant regional variations in the characteristics of energy use in buildings, reflecting the relative weight of these drivers at a regional scale. For example, the vast majority of rural populations in developing countries (approximately half of the world’s population) are dependent upon traditional wood fuel for cooking and water heating, and hence in 2004 biomass accounts for 40% of total energy use in residential buildings globally. In developed countries natural gas and electricity are the principal sources of energy in residential buildings (*ibid.*).

BUILDINGS, ENERGY USE AND DEVELOPMENT IN OMAN

Figure 1 illustrates the growth of total primary energy supply in Oman from 1971 to 2006. During this 25 year period, total primary energy supply increased by an average of 23% each year, or by a factor of 173 over the whole period. Some supplementary trends may be observed further to this rapid growth of energy use. Oman is currently a net exporter of crude oil and natural gas and its domestic energy mix is reliant upon these fossil fuel sources of energy; increasingly natural gas (67.6% of total primary energy supply in 2006). Fossil fuel combustion and industrial processes are the principal anthropogenic causes of increasing atmospheric CO₂ concentrations (Raupach *et al.*, 2007), and as energy use has escalated in Oman so have CO₂ emissions.

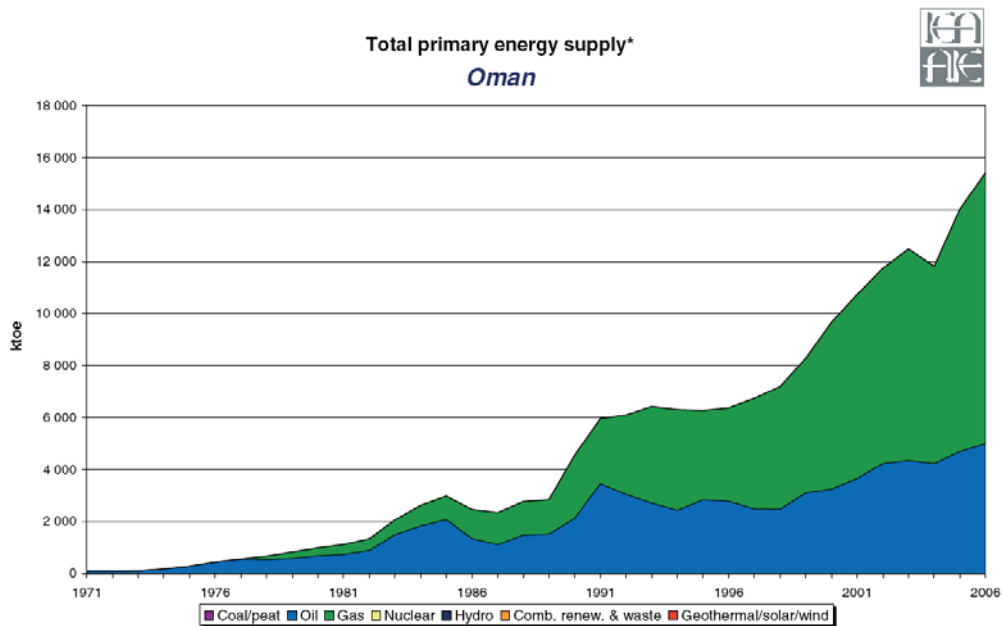


Figure 1: Total primary energy supply in Oman 2006 (International Energy Agency, 2006)

A more detailed analysis of the drivers of CO₂ emissions is revealed by evaluation of the terms of the Kaya identity:

$$CO_2 = \underbrace{population}_{\text{Activity drivers}} \times \underbrace{\frac{GDP}{population}}_{\text{Economic drivers}} \times \underbrace{\frac{Energy}{GDP}}_{\text{Energy intensity}} \times \underbrace{\frac{CO_2}{Energy}}_{\text{Carbon intensity}}$$

Table 1: Evaluation of the Kaya Identity for Oman in 2006 relative to a 1971 baseline (IEA, 2009)

| <i>Kaya Identity</i> | Total CO₂ emissions | Population | GDP/population | Energy/GDP | CO₂/Energy |
|-------------------------------------------|-------------------------------------------------|-------------------|----------------------------------------|-------------------|------------------------------|
| Oman 2006 data | 29.45 Mt CO ₂ (sectoral approach) | 2.55 million | \$15,930 per capita (2000 US\$ PPP) | 15.89 MJ/\$ | 45.6 t CO ₂ /TJ |
| Oman 1971 data | 0.25 Mt CO ₂ (sectoral approach) | 0.77 million | \$6,360 per capita (2000 US\$ PPP) | 0.76 MJ/\$ | 67.97 t CO ₂ /TJ |
| Increase relative to 1971 baseline | 11700% | 231% | 150% | 1990% | -32% |

Table 1 shows the absolute values of the terms of the Kaya Identity for Oman in 2006 and also how these have increased relative to a 1971 baseline. The rapid increase observed in total primary energy use and CO₂ emissions has occurred in the context of several development trends:

- From 1971 to 2006, the population of Oman more than tripled. Thus, total energy use increases as there are more people who need to meet their energy needs.
- During the same period, the economy showed raised levels of activity with a GDP per capita increase of 150%. This economic growth has been energy intensive, indicated by a twenty-fold increase in total primary energy supply per GDP.
- The carbon intensity of energy production in Oman has reduced over the same period, reflecting a transition from diesel fuel and crude oil to natural gas for electricity generation.

These recent patterns of development in Oman are mirrored in other oil-producing Gulf states, although rates of development in the region vary widely. There has been substantial investment in ambitious buildings and infrastructure projects in those states that have achieved rapid economic growth, and to an extent the contemporary architecture reflects the aspirations and growing confidence of a region asserting its economic and cultural position in world affairs. However, social norms have been less quick to adapt and tensions have arisen between the expectations of a traditionally Islamic society and recent urban developments (Al-Hemaidi, 2001).

In contrast to the ostentatious architectural statements that have been raised in locations such as Abu Dhabi and Dubai, contemporary developments in Oman have preserved a more understated idiom. This position is supported by the present leader, Sultan Qaboos, whose ‘Diwan’ of Royal Court Affairs circulated a pattern book for architects ‘Elevational Guidelines for buildings in Oman’ recommending they “look to the existing buildings of the city and its environs as their models, in order to ‘impart an Omani character’” (Lasdun, 2006). These traditional exterior stylings, however, conceal very modern attitudes towards providing thermal comfort in buildings, and more and more people rely on mechanical air-conditioning systems (Al-Ismaily & Probert, 1997).

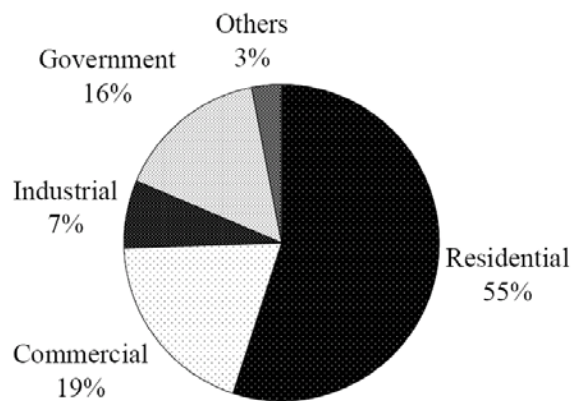


Figure 2: Electrical power use by sector in Oman 2007 (Sultanate of Oman Ministry of National Economy, 2009a)

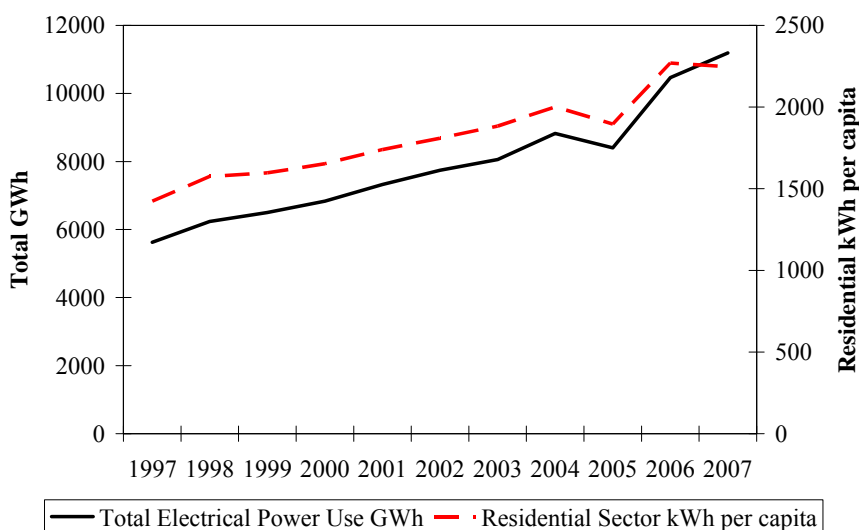


Figure 3 Total electrical power use and per capita consumption in the residential sector in Oman 1997 to 2007 (Sultanate of Oman Ministry of National Economy, 2009a)

Figure 2 illustrates the breakdown of electrical power use by sector in Oman for 2007. The residential sector is the principal consumer accounting for 55% of total electrical power use. Furthermore, there are significant daily and seasonal variations in electrical energy demand: the average summer demand is more than double of the average winter demand (Al-Badi *et al.*, 2009), and the daily system load is characterised by a peak of more than 50% compared with the minimum load (Al-Ismaily & Probert, 1997). These demand fluctuations correspond with peak air-conditioning loads, and result in poor load factors and significant under-utilisation of the total power generation capacity.

In the context of increasing total electrical power use, per capita consumption in the residential sector increased by 66% during the period from 1997 to 2007 as shown in Figure 3. This suggests a trend towards increasingly energy-intensive lifestyles.

In summary, recent development patterns in Oman are coupled to rapidly increasing levels of primary energy use, and the supply of electrical power to residential buildings is the principal end-use sector. Returning to the concept of living within acceptable environmental limits and the objectives of sustainable development, one measure of the cumulative environmental impact of human activities is the ecological footprint (Wackernagel, 2009). In a WWF (2008) study using 2005 data, the ecological footprint of Oman is equivalent to 4.7 global hectares (gha) per person compared to a global biocapacity of 2.1 gha per person. Thus, national consumption of ecological resources in Oman exceeds relative global biocapacity by a factor of 2.2, primarily due to its carbon footprint. According to this analysis Oman is therefore in 'ecological deficit'.

The continuing immoderate exploitation of finite fossil fuel reserves in Oman is incompatible with sustainable development, and the need for diversification of the production base of the Omani economy to reduce reliance on oil is identified as a priority in the Sultanate's Long Term Development Strategy 1996 – 2020 (Sultanate of Oman Ministry of National Economy, 2007, section 2-6-4). Complementary measures to reduce energy use and carbon emissions include policies which promote demand management, increase energy efficiency and the diversification of energy sources to improve security of supply and encourage cleaner, renewable forms of energy. Historically, buildings relied upon natural, renewable forms of energy to provide comfort. The vernacular architecture of hot dry desert regions is reviewed in the following sections to appraise the relevance of traditional building techniques to inform the design of contemporary low energy buildings in Oman.

VERNACULAR ARCHITECTURE AND CONTEMPORARY DESIGN

The innate local wisdom embodied in vernacular architecture is praised by the Egyptian architect Hassan Fathy:

“Thousands of years of accumulated expertise has led to the development of building methods using locally available materials, climatization using energy derived from the local natural environment, and an arrangement of living and working spaces in consonance with social requirements” (Fathy, 1986, p. xx)

This is a continuing source of inspiration to architects and engineers today (Richardson, 2001). The passive and low energy approaches to providing comfort in the vernacular buildings of hot dry desert regions were of particular interest to Fathy as prototypes of building methods compatible with the prevailing climate conditions. However, not all vernacular architecture is climatically responsive; “sometimes

cultural determinates dominate and overshadow the needs from climate” (Cook, 1996, p. 277). This statement is equally applicable to the contemporary challenges of low energy building design, and this issue is explored in further depth following a review of the climate characteristics and passive cooling techniques employed in the vernacular architecture of hot dry desert regions.

CLIMATE CHARACTERISTICS OF HOT DRY DESERT REGIONS

Hot dry desert and hot dry maritime desert climates predominate in Oman according to the Atkinson System of tropical climate classification for building needs (Koenigsberger *et al.*, 1974). Two marked seasons occur; a hot and a somewhat cooler season. In hot dry desert regions, high daytime temperatures with large diurnal range, clear skies and intense direct and indirect solar radiation, and dusty winds are typical climate parameters to be considered. To achieve comfort in these conditions, it is desirable to lower the indoor air temperature and the temperatures of internal surfaces in buildings compared to ambient climate conditions in summer. It is also necessary to provide shade and moderate the microclimate around the building, in the adjacent public spaces and streets (Givoni, 1998). Maritime zones experience a similar climate to that described above, but higher humidity tends to reduce the diurnal temperature variations and moderate temperatures. This increases the importance of air movement for achieving comfort.

Table 2: Monthly weather data (Sultanate of Oman Ministry of National Economy, 2009a)

| MUSCAT (2007) | | | | | | | | | | | | | | |
|-------------------|------|-----|------|----|----|------|----|------|----|----|-----|----|--------------|----|
| Climate Parameter | J | F | M | A | M | J | J | A | S | O | N | D | Peak values | |
| Temp °C | Max. | 29 | 34 | 35 | 41 | 45 | 43 | 43 | 41 | 41 | 37 | 34 | 30 | 45 |
| | Min. | 12 | 15 | 15 | 19 | 25 | 23 | 28 | 26 | 21 | 18 | 18 | 16 | 12 |
| R.H. % | Max. | 92 | 96 | 97 | 96 | 91 | 99 | 95 | 98 | 97 | 97 | 96 | 91 | 99 |
| | Min. | 24 | 20 | 10 | 8 | 6 | 12 | 16 | 24 | 8 | 9 | 27 | 35 | 6 |
| Precipitation mm | 2 | 0.2 | 48.4 | 0 | 0 | 257 | 0 | 0 | 0 | 0 | 0 | 0 | Total: 307.6 | |
| SALALAH (2007) | | | | | | | | | | | | | | |
| Climate Parameter | J | F | M | A | M | J | J | A | S | O | N | D | Peak values | |
| Temp °C | Max. | 30 | 32 | 36 | 35 | 35 | 34 | 31 | 30 | 31 | 38 | 38 | 33 | 38 |
| | Min. | 15 | 19 | 20 | 22 | 25 | 25 | 25 | 24 | 23 | 18 | 18 | 17 | 15 |
| R.H. % | Max. | 83 | 86 | 91 | 91 | 93 | 92 | 91 | 94 | 94 | 88 | 85 | 80 | 94 |
| | Min. | 6 | 11 | 8 | 20 | 45 | 56 | 60 | 70 | 55 | 8 | 12 | 9 | 6 |
| Precipitation mm | 0 | 0 | 23.4 | 0 | 42 | 50.4 | 0 | 20.5 | 1 | 0 | 8.8 | 0 | Total: 146.1 | |

Mahoney Tables

Sketch design recommendations for Muscat, the capital of Oman on the north coast, and Salalah on the south coast may be generated through use of the Mahoney Tables and the summary monthly weather records presented in Table 2. A detailed explanation of the Mahoney Tables is presented in Koenigsberger *et al.* (1974). As an overview, the process consists of collating temperature, humidity and rainfall statistics, assessing this data against climate indicators, and reading off corresponding design recommendations for the building and elements.

The resulting remedial actions recommended by the Mahoney Tables for Muscat and Salalah illustrate the contrasting climatic design requirements for these two locations as shown in Table 4. Compact planning, with buildings organised around small courtyards, is identified as a preferable urban layout for Muscat, whereas for Salalah it is recommended that buildings are broadly spaced for breeze penetration. This indicates the added importance of providing air movement during the persistent hot-humid conditions experienced in Salalah during the hot season. More generally, the

varied climate of Oman provides a context for a range of climatic design solutions reflecting the local conditions.

Table 3: Extract of the recommended building design specifications for Muscat and Salalah generated by the Mahoney Tables

| Recommended Specifications | Muscat | Salalah |
|-----------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Layout | Buildings planned around small courtyards if thermal storage is required for most of the year. | Building should be orientated on an east-west axis, the long elevations facing north and south, to reduce exposure to the sun. |
| Air movement | If air movement is never essential, or is desirable for not more than a month, rooms can be double banked and there is not much need for cross-ventilation. | Rooms should be single banked with windows in the north and south walls, to ensure air movement by ample cross-ventilation. |
| Spacing between buildings | Compact planning is recommended if the air movement requirement is insignificant. | If wind penetration is only needed for part of the year, buildings should be broadly spaced for breeze penetration but with provision for protection from cold or dusty hot winds. As a rough guide: space between long rows of building should not be less than five times the height. |
| Openings | Very small, between 10 and 20% of the wall area. | Small, between 15 and 25% of the wall area. |

PASSIVE COOLING TECHNIQUES IN HOT DRY DESERT REGIONS

The preceding analysis of climate data for Muscat and Salalah utilising the Mahoney Tables identified two passive cooling strategies:

- Compact planning to reduce the rate of solar heat gains by providing shading for buildings and the adjoining streets; and
- Layout of buildings to encourage wind-driven ventilation: this may be used to provide cooling for a space either by directing air movement across the occupants and increasing convective and evaporative heat transfer from the body, or indirectly by removing heat stored in the building fabric and reducing the ambient temperature.

Both approaches have precedents in the traditional built landscape of Oman.

Settlements with compact clusters of enclosed, inward-looking buildings organised around a central courtyard are a characteristic response to climatic regions where a combination of high temperatures and low humidity predominates for most of the year. The courtyard functions as a “reservoir of coolness” (Fathy, 1986, p. 63) and creates an exterior space which is more quiet, clean and private than the street thus improving the microclimate for the surrounding interior spaces it interacts with (Ratti *et al.*, 2003). Although Givoni (1998) cautions that the actual microclimate within an internal patio will depend greatly on its design details and treatment, the cool deep courtyards that existed in Salalah are described as being “witness to the efficiency of the courtyard’s cooling effect” (Oliver, p. 464). However, the Oman Census in 2003 (Ministry of National Economy, 2009b) indicates that villa-type houses are now the most popular typology for new residential buildings. The introduction of setback provisions in building regulations governing the distance between adjacent plots and increasing levels of car ownership are barriers to compact urban planning configurations.

The wind towers traditionally found along the north Al Bāṭinah coast of Oman were used to capture cool daytime sea breezes: “the tower projects above roof level to catch cooler, and usually less dusty, high-level air, which is then channelled down into rooms below” (Oliver, 1997, p. 461). The cooling effect of wind towers may be further augmented through evaporative cooling by guiding incoming air over water-filled porous pots to provide a significant reduction in the temperature of the air before it enters the interior. These porous water jars have also traditionally been mounted within window apertures to cool air and water (Oliver, 1997). Bahadori (1994) describes the limitations of traditional wind tower designs, including the admission of dust and insects into the building. However, there has been a contemporary resurgence of interest in techniques that combine natural ventilation with direct evaporative cooling including a number of small buildings in Arizona that incorporate downdraught towers with wetted cellulose pads (Ford, 2001). Cooling of the envelope may also be facilitated by wetting external surfaces. Spraying water on floors and on the surfaces of the narrow lanes was a daily task for many of the inhabitants of the mountainous regions of Oman (Al-Hinai *et al.*, 1993). A water pool or fountain located in the central courtyard is another traditional evaporative cooling feature (Fathy, 1986). Cool, shaded environments are also provided by the incorporation of vegetation in buildings and the surrounding landscape.

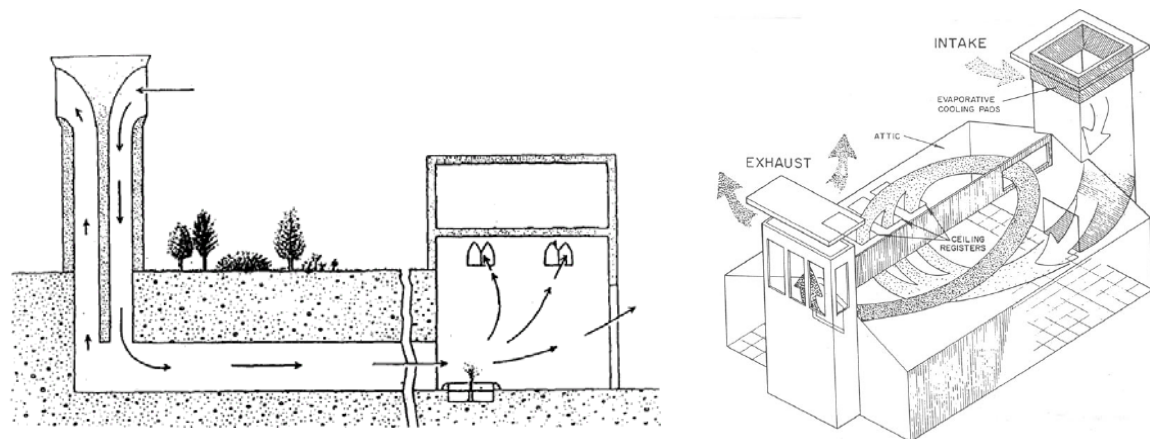


Figure 4: Traditional (left: Gallo, 1994) and contemporary (right: Ford, 2001) cooling towers

Compact settlement patterns, courtyard buildings and devices which encourage air movement and cool incoming air are combined with other elements of building design to provide passive cooling in the vernacular architecture of hot dry desert climates. Overall, the roof of the building receives the highest proportion of incident solar radiation at subtropical latitudes and is also the surface most exposed to the clear night sky. The domed roof – the “great tradition for roofing in desert regions” (Konya, 1984, p. 43) – distributes the incident solar radiation over a larger surface area in comparison to a flat roof, and is thus more effective at reducing radiative heat gains during the day and maximising re-radiation at night. An additional benefit of domed or vaulted roofs are that they have greater convective cooling potential as air speed increases over the curved surface rendering cooling winds more effective at reducing the temperature of the roof (Fathy, 1986). With respect to materials, a combination of high thermal resistance and high heat capacity of the envelope elements is advantageous in hot dry desert climates to minimise conductive heat flow into the building and reduce indoor peak temperatures respectively (Givoni, 1998). Traditional building materials in hot dry desert regions are clay and stone. These

materials have a relatively high heat capacity and are used to construct the thick exterior walls and roofs characteristic of the vernacular buildings in these climates (Konya, 1984).

The passive cooling principles employed in the vernacular architecture of hot dry desert climates are inherently low energy and require little or no maintenance, however little has been incorporated as standard practice in contemporary building design in Oman. Mechanical air-conditioning permits buildings that are an inappropriate response to the prevailing climate to be made habitable, whereas passive design requires a holistic approach that shapes the form, construction and details of the building. The availability of the requisite design and construction skills is therefore critical for the successful application of passive cooling strategies in Oman.

CHANGING NEEDS IN A CHANGING CLIMATE

In the context of the growing and unsustainable demands currently placed on ecosystem services, there is an intuitive appeal to the economies of living which shaped the vernacular architecture of hot dry desert regions. Nonetheless, the rejection of traditional forms of building is observed to be a pervasive phenomenon: “vernacular buildings are seen by politicians and populace alike as representative of a backward past opposed to their modern ideas and expectations” (Oliver, 1997, p. xxiii). It may be argued that the reintroduction of traditional building forms is therefore incompatible with contemporary aspirations and urban lifestyles, and that “the more removed the vernacular is from the urban experience, the more it becomes an idealized vehicle for expressing a sense of dislocation” (Richardson, 2001, p. 16).

The widespread introduction and use of mechanically air-conditioned, concrete-block buildings followed the rapid modernisation of Oman in the 1970s (Al-Hinai, *et al.*, 1993). Often highly energy inefficient, these buildings have housed increasingly energy profligate lifestyles. However, Oman may be receptive to recovering its architectural heritage as the publication of a Royal pattern book for architects would indicate. The application of traditional passive cooling techniques in buildings presents a significant opportunity for energy savings. However, the acceptance and feasibility of such systems will depend crucially on what is considered the upper limits of thermal comfort. The proliferation of mechanical air-conditioning systems and expectations of controlled environments may be a barrier to the acceptance of cycles and variations in indoor climates – a psychological adaptation analogous to the concept of habituation in psychophysics (Fountain *et al.*, 1996).

HOUSING, ENERGY REGULATIONS AND BUILDING RATING SCHEMES

The Omani population is predicted to grow from 2.507 million in 2005 to 3.865 million by 2030; an increase of 54% (United Nations Department of Economic and Social Affairs, 2006). Thus, there is likely to be an increased future demand for new housing. Currently, there are no mandatory targets for energy performance in Omani building regulations. This omission is a regulatory barrier to improving the energy performance of the future housing stock.

One possible mechanism for implementing low energy building principles in Oman is the establishment of a building rating scheme. As a concluding remark, the two most widely adopted existing building rating schemes – the Building Research Establishment Environmental Assessment Methodology (BREEAM) and Leadership in Energy and Environmental Design (LEED) – have been criticised for being overly prescriptive and complex (Fenner & Ryce, 2008). An additional concern is the lack

of flexibility in these assessment schemes to reflect the local social, economic and environmental context of buildings. The Pearls Design System is a building rating methodology currently under development by Abu Dhabi Urban Planning Council which aims to reflect “the unique cultural, climatic and economic development of the region” (Abu Dhabi Urban Planning Council, 2009). Returning to the opening theme of this paper, these schemes share a fundamental conceptual barrier to providing a meaningful assessment of building performance with respect to sustainable development objectives. It is argued here that buildings need to be assessed according to the added demands they place on local and global ecosystem services with reference to acceptable environmental limits of performance. In the absence of this performance baseline, the scoring systems of existing building rating methodologies remain essentially arbitrary. This is not to undermine the value of such schemes for furthering the adoption of current industry best practice. However, the definition of what constitutes a ‘sustainable’ or ‘green’ building can not be framed outside of the hypothesis that we need to live within acceptable environmental limits.

CONCLUSION

Human demand on ecosystem services continues to increase with deleterious social and environmental consequences although a wide global disparity of wealth and resources remains. The lifecycle environmental impacts of buildings are significant and diffuse, and account for a considerable proportion of energy and resource use and anthropogenic CO₂ emissions. The drivers of buildings energy use include population growth, economic development, diffusion level of energy use equipment, size of households, square metres of building areas and behavioural factors. Seasonal and annual climatic factors are additional determinants. There are significant regional variations in the characteristics of energy use in buildings, reflecting the relative weight of these drivers at a regional scale.

In Oman, recent development patterns have been coupled to rapidly increasing levels of primary energy use, and the supply of electrical power to residential buildings is the principal end-use sector. Rapid modernisation in the 1970s accompanied the widespread introduction and use of mechanically air-conditioned, concrete-block buildings. Often highly energy inefficient, these buildings have housed increasingly energy profligate lifestyles. By contrast, the economies and ingenuity of the vernacular architecture of the region illustrates both culturally and climatically appropriate solutions for creating comfortable environments utilising only natural, renewable forms of energy. The application of traditional passive cooling techniques in contemporary buildings presents a significant opportunity for energy savings. However, the feasibility of traditional cooling techniques depends crucially on what is considered the upper limits of thermal comfort. The lack of energy performance targets is a barrier to improving the energy performance of the future housing stock in Oman. Buildings need to be assessed according to the added demands they place on local and global ecosystem services with reference to acceptable environmental limits of performance.

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