Chapter 9

Towards Near Zero Energy Home

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Additional information is available at the end of the chapter

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Abstract

In the context of building design, as investment in the built-environment continues to grow, the requirement to deliver low-energy buildings will become ever more pressing as natural resources dwindle and consumer energy costs increase. Energy efficiency awareness and regulations continue to rise in the Gulf Cooperation Council (GCC) countries but the majority of building stock of which the larger share in energy consumption has not been designed for energy efficiency. The design and construction of buildings in hot humid climates require high-energy consumption typically for air conditioning due to higher thermal loads. Regionally, there is a rising concern on the current rate of energy consumption due to air conditioning. The global sustainability assessment system (GSAS), a performance-based system raised the bar of efficient design by the development of stringent energy passive design benchmarks on the thermal cooling need in buildings. This chapter introduces the simulation measures undertaken to reduce the cooling need using a 'showcase' house or the 'near Zero Energy Home' (nZEH), which is currently under construction. The chapter presents and discusses the Be Lean, Be Clean and Be Green strategies that used to reduce the cooling demand by more than 80% and the overall energy consumption by 75%.

Keywords: energy efficiency, zero energy home, renewables, solar cooling, climate change

1. Introduction

As the population continues to grow, there will be increased pressure and demand for energy resources. Considering the wider impacts of carbon emissions on our climate, effective energy efficiency solutions are necessary in order to achieve the overall goal of reducing these emissions.

Qatar and in particular the Gulf Cooperation Council (GCC) countries, in general, can be characterised by an extreme set of climatic conditions regarding the challenges under consideration. These conditions relate, among others, to aspects identified in the literature [1–3]. Extreme climatic conditions impose a heavy reliance on cooling, mostly electricity-based, and thus a strong and structural dependency of a high-energy resource. Hourly outdoor dry temperature variations during a year in Doha, Qatar are shown in **Figure 1**. The average of highest outdoor temperatures during a year is 37.03°C, however, high-temperature values that exceed 46°C could be observed in summer. As shown in **Figure 2**, the temperature exceeds 40°C for more than 300 hours, which is anticipated to be doubled when considering Doha climate change, by 2025.

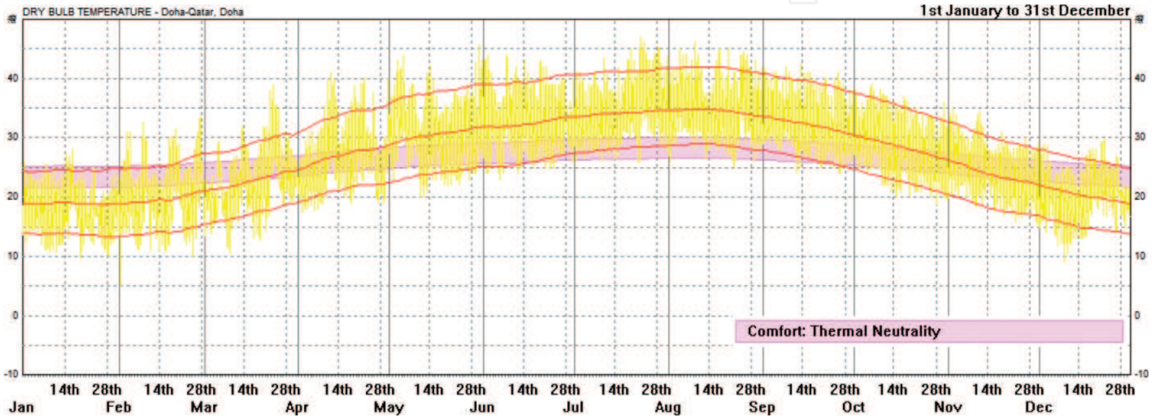


Figure 1. Outdoor dry bulb temperature variations.

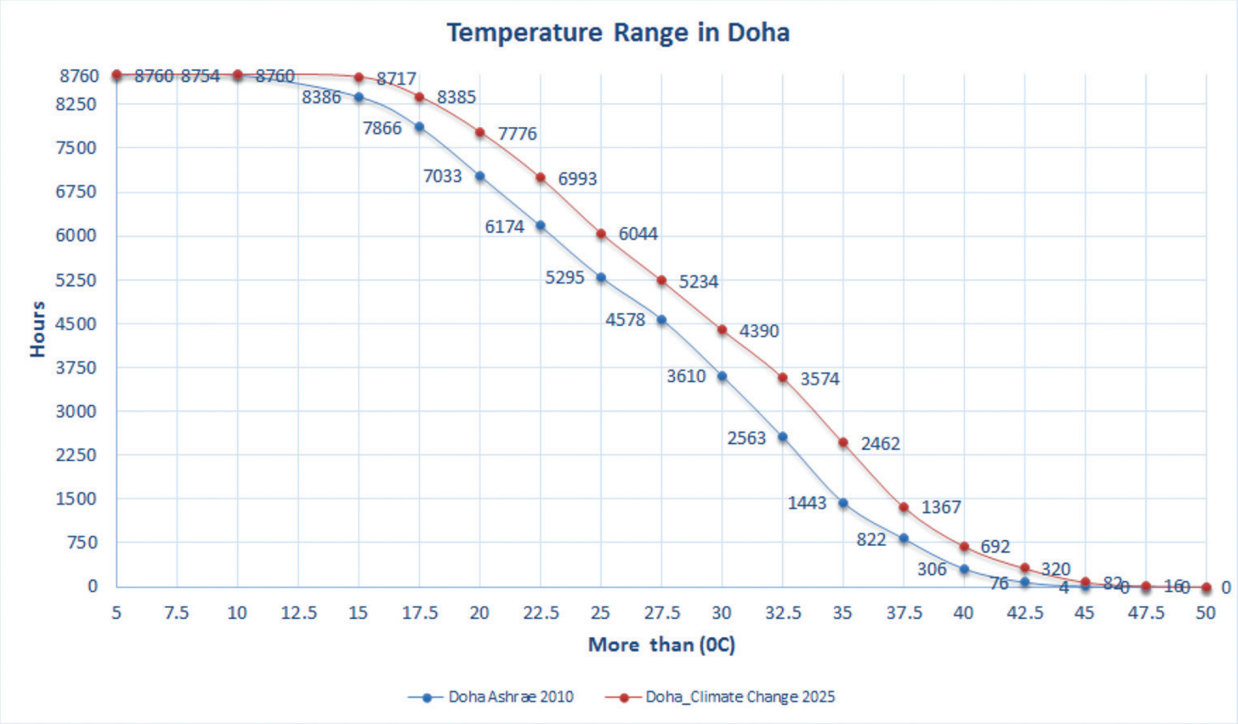


Figure 2. Temperature range in Doha.

The hourly outdoor air relative humidity (RH) variation is shown in **Figure 3**. The data show that the daily average RH is always greater than 40%, and the daily maximum RH often goes above 80%. Dehumidification by air-conditioning is required all year round.

Figure 4 shows solar radiation by different orientations. Annual cumulated solar radiation amounts from different orientations are different. The data show that the west and south walls of a building receive the most solar radiation, less than the roof with an annual average of 54%.

Many buildings in the GCC have been constructed following international models that are not fit for the particular conditions imposed by the local context. For instance, the design of modern high-rise buildings, with unfortunate high glazing to wall ratio, increased dramatically the energy consumption due to high solar gains. In addition to insufficiently insulated building skins, a lack of passive design measures for energy consumption control such as glazing and shading features and an excessive proneness to overheating result in an excessive

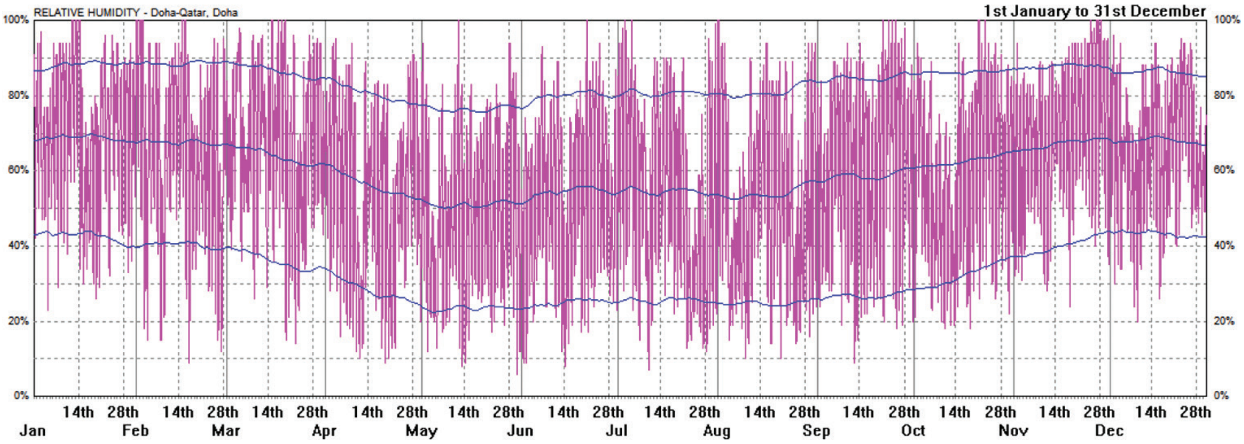


Figure 3. Relative humidity.

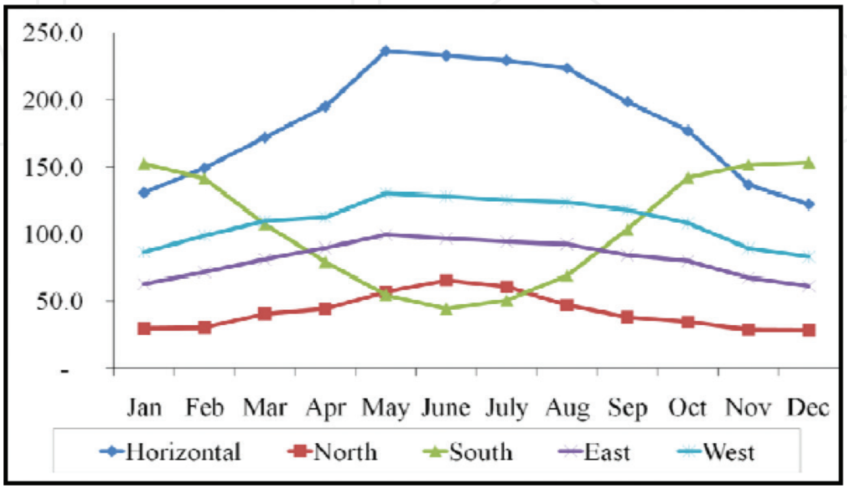


Figure 4. Global solar radiation per month in all orientations (kWh/m^2).

reliance on active indoor climate control. Air conditioning counts for more than 60% of the electricity consumption in the GCC countries [4]. Moreover, this lack of responsiveness to the local climatic conditions also leads to problems of indoor air quality, user comfort and user productivity.

With energy being cheaply available, the incentive for building users to save on their energy consumption is weak. This is moreover the case for three major contributing factors at the same time: building skins, HVAC installations and user behaviour. As a consequence, extremely high-energy consumption and greenhouse gas emission figures. According to the IEA records, Qatar has both the highest CO_2 emissions and energy consumption per capita in the world [3].

In Qatar and the GCC, not only the total annual energy consumption in buildings is very high, but peak demands for electricity also put a heavy burden on the infrastructures needed to respond to such demand pattern. In this context, building energy efficiency strategies can help to realise peak shaving by load reduction and load shifting.

As stated earlier, rapid population growth increases the stress on the energy infrastructure system, and is particularly related to the peak load and installed capacity problem.

Thermal regulation of the indoor spaces can be accomplished by simple passive design methods to utilise the natural sources of energy, such as the sun and the wind to provide domestic hot water (DHW), cooling, ventilation and lighting and to contribute to responsible energy use. During recent years, building construction continued to bloom in the Gulf region. However, the hot and humid climate of the region makes homes demand large quantity of energy for air-conditioning to achieve an acceple thermal comfort level. On a yearly basis, the cooling load dominates the building thermal load, while the heating load can be negligible for the energy use estimation in buildings. The weather in Qatar is moderate only during 3 months, while in most of the other months, it is warm/hot or even very hot and humid [1].

The concentration of carbon dioxide and other greenhouse gases in our atmosphere is now recognised as the driver of global warming and climate change. The Intergovernmental Panel on Climate Change (IPCC) advised that cut of 25–40% by 2020 would be necessary, compared to a 1990 baseline, to limit the global atmospheric average temperature rise to 2°C. Despite these publications, global emissions have increased to 40% above the 1990 baseline by 2009 and the concentration of atmospheric CO_2 is now believed to be at its highest for at least 800,000 years [5].

Energy benchmarks were introduced for several new building types in Qatar by the Global Sustainability Assessment System (GSAS) [6], as given in **Figure 5**.

The worldwide drive towards curtailing carbon emissions and improving the sustainability of our social, economic and cultural networks is now well underway. Considering that cooling in buildings accounts for two-thirds of all energy consumption in buildings, the use of passive design to limit the need for cooling, and thus the electrical consumption associated with cooling, is likely to lead to a significant overall reduction in carbon emissions.

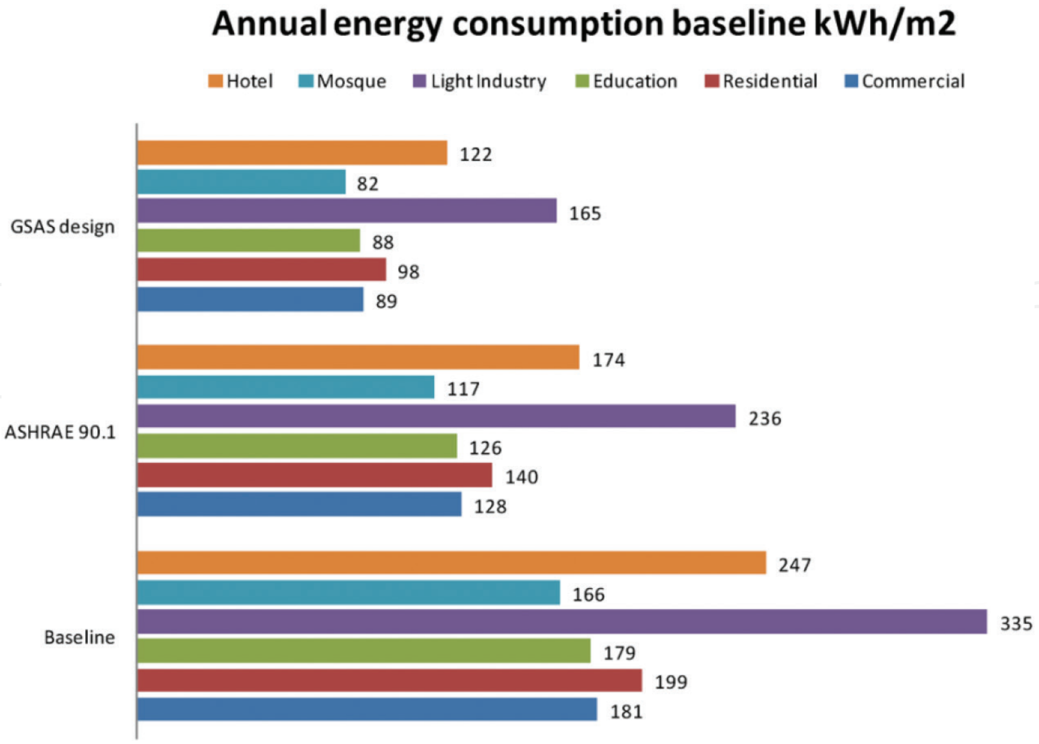


Figure 5. Energy consumption baseline for different new build in Qatar (kWh/m^2/year) [6].

There has been a very little work available about the design of zero energy home in hot/tropical regions [7, 8]. The literature lacks in providing similar examples from the MENA region and hot arid climates. Sustainability venture presents obstacles and it appears to be challenging, especially to find data on several countries [9]. Therefore, this chapter is coming to bridge the gap through a comprehensive study of dynamic design. Simulation studies and analysis, calculations and a real demonstrative building are developed. In particular, the near zero energy home (nZEH) project will try to focus on efficient design solutions for residential buildings as well as the design considering the influence of the local climate, the endogenous energy resources and the local economic conditions. Emphasis will be given to the bioclimatic design of the house and the renewable energies utilisation in order to achieve objective towards nZEH.

2. Background

Conventionally, the main energy generation methods are by the combustion of fossil fuels which are limited resources on the Earth. Excessive burning of fossil fuels also intensifies the global greenhouse gas content, which accelerates the global warming effect. As a result, a novel building-design concept namely, net or near net zero energy building (NZEB) has emerged, which aims to reduce the energy demands of buildings from fossil fuels resources and to magnify the utilisation of renewable energy in buildings.

In general, NZEB is defined as a building with zero net energy consumption, which means that the total amount of energy consumed by the building is roughly equal to the amount of renewable energy generated on the building site on a year-round basis [10, 11]. More definitions of NZEB based on different evaluation principles and across different countries were presented [12]. A strategic goal of the building technologies program of the US Department (DOE) is to accomplish 'marketable zero energy homes in 2020 and commercial zero energy buildings in 2025' [13]. In Europe, in the recast of the EU Directive on energy performance of building (EPBD), it was specified that all new buildings shall be 'nearly zero energy building' by the end of 2020 [14]. *Furthermore, since October 2008, a panel of experts from International Energy Agency (IEA) has initiated a project entitled 'Towards Net Zero Energy Solar Buildings' [15] which was intended to analyse exemplary buildings that were near a zero-energy balance in order to develop methods and tools for the planning, design and operation of such buildings*.

More efforts should be put on the research of near zero energy home (nZEH) in hot climate geographical location, especially in the Gulf region as it *is lacking* comprehensive research in near zero energy buildings.

Unfortunately, the lack of a common approach for this new type of buildings results in misunderstandings, endless discussions and different solutions per project [16]. Recent studies note that; despite the *exciting* phrase of 'zero *energy*', near zero energy building definition often lacks a clear and widely accepted explanation of what this term *actually* means. Researchers indicate that the definition of zero energy buildings concept can be constructed in several ways, depending on the project goals, intentions of the sponsors, concern about the climate changes and greenhouse gas emissions and finally, the energy costs [11, 17]. Smart technologies, efficient structure *design* and innovative materials should follow a robust legislation contributing to healthier and more *efficient* living.

Improving the energy efficiency measures has taken the attention of researchers in *hot*, humid climate in the Gulf region. Experimental and theoretical studies were conducted recently to improve building fabric efficiency and promote enhanced indoor air quality in *hot*, humid climates [18–20]. Energy and carbon framework model has been developed and implemented in the Gulf region [1], as shown in **Figure 6**. Passive design of high-rise buildings attracted researchers from different parts of the world [21–25].

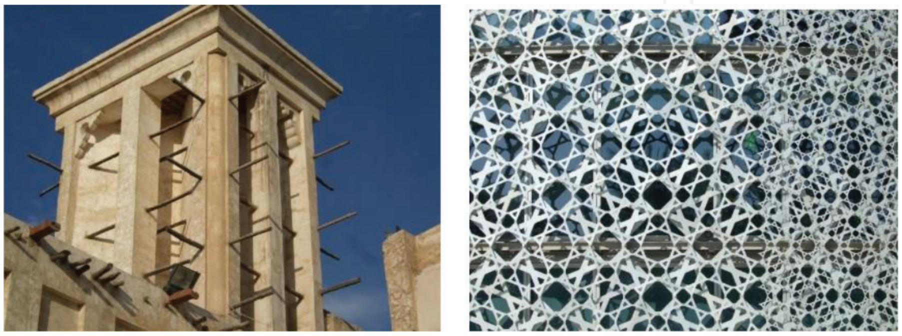


Figure 6. Proposed energy and carbon model structure [1].

In China, passive design zones for different climates in18 cities representing the 5 major climate types *were developed*. A bioclimatic approach was adopted in which the comfort zone and 12 monthly climatic lines were determined and plotted on the psychrometric chart for each city. The potential use of nine passive design strategies *was assessed* and passive design strategy zones were identified [26].

Another study presented an integrated approach to explore how energy consumption could *be minimised* in residential buildings by optimising seven passive design measures for 25 representative cities. The study showed that, with *optimisation*, the passive design could reduce *annual* thermal load of building considerably and could replace air-condition systems in winter for the areas with high solar radiation [27]. Within a system transition, for nZEH, a complex interplay between technical and non-technical challenges emerges. Consequently, a holistic approach is fundamental for success when it comes to practical implementation.

Technical challenges concern the best trade-off between available passive design solutions, the development of new concepts, the integration with technical installations and energy and mobility systems at different scale levels (building, neighbourhood, region or state), and the interplay with indoor environmental requirements (air quality, thermal comfort, health and productivity). Relying more on passive design measures and reducing the share of active climate control is another technical challenge, which however also has a strong cultural component. Financial aspects may be considered as another set of technical parameters. Life cycle cost or net present value will be important aspects to consider, both for selecting the economically most promising options and for providing decisive arguments to the potential investor. The identification of feasible business models is crucial for any development to become successful in reality.

Non-technical challenges concern, for example, supporting energy efficiency uptake by policy measures such as regulation or subsidising, training building sector actors to assimilate new techniques and passive design concepts, and educating the public at large about the benefits of energy efficiency and building renovation.

Socio-cultural aspects are another important, non-technical matter of concern. As nZEH, in particular in the residential sector, intervenes deep into the life of citizens, it shall be sensible to this two-sided challenge. Reconnecting with the environmental wisdom and cultural roots of traditional architecture may deliver unique concepts in the Qatari or the GCC context. We can see that this tendency is emerging in new architecture (such as the Burj Doha tower, the Msheireb and Lusail developments in Doha or the Al Bahar Towers in Abu Dhabi).

Researchers in the Gulf region [1, 4, 6] developed an energy hierarchy and integrated multi-level approach that connects sustainable developments from the national level to the project level to reduce the carbon emissions in Qatar, see **Figure 7**. The implementation of the strategy in a city in Qatar forecasted more than 30% reduction in CO_2 emissions compared to the existing standards, see **Figure 8**.

Previous research [28] showed that the average annual solar radiation falling on the Arabian Peninsula was about 2200 kWh/m^2. Other researchers [29] also concluded that Saudi Arabia, a

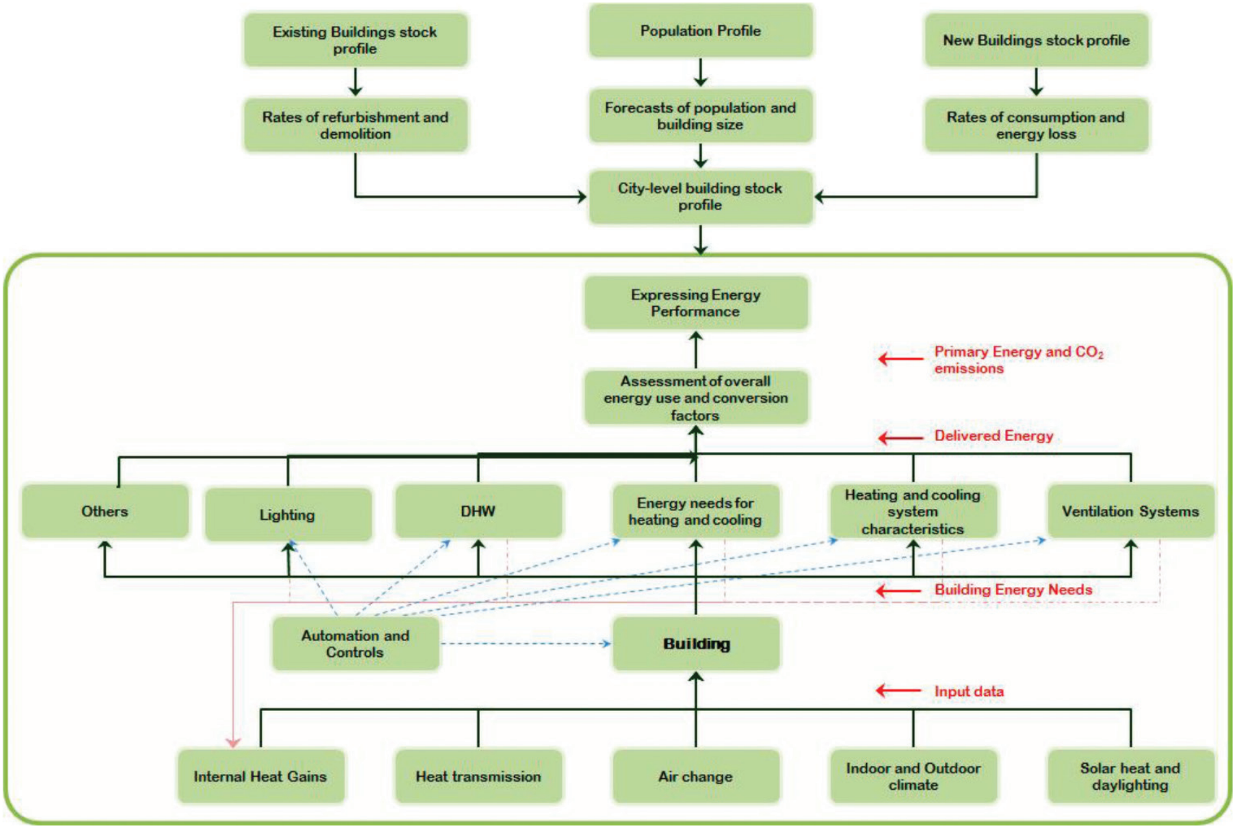


Figure 7. Passive climate design measures have always been a fundamental asset of traditional architecture.

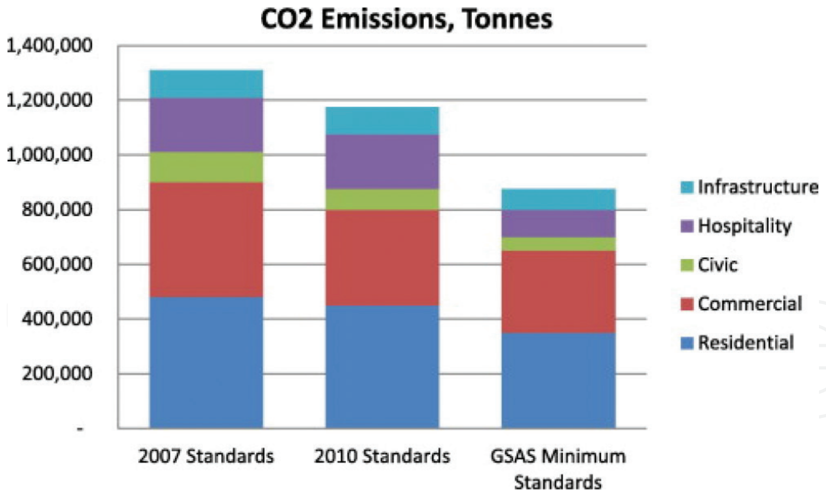


Figure 8. Forecast impact of GSAS standard on CO_2 emissions from new cities in Qatar by 2020 [1].

country located in the Gulf region and adjacent to Qatar has great natural potential for solar power generation and economic incentives to develop renewable energy to meet domestic electricity demand. Both studies further consolidate the fact that solar energy is abundant in Qatar and the Gulf region. This implies that under proper design, the energy generated from solar energy is possible to cover part to full demand in a residential unit.

An experiment of passive-house with dynamic insulation was performed in the Gulf region [4, 18, 19]. The experiment results revealed that dynamic insulation could reduce 17% of cooling energy demand as compared with a static insulation. The findings are adequately encouraging to continue the research and development activities of dynamic insulation technologies, which can be applied into the nZEH.

Apart from the dynamic facade, a novel titled solar liquid desiccant regeneration system, which potentially reduces the cooling demand of an indoor space, was also studied [30, 31]. The study provides a good reference for such system to be employed in the nZEH. Simulation studies on the performance of solar absorption cooling system in another country in the Gulf region (UAE) were performed [32]. The simulation results showed that the solar absorption cooling system was operated at optimum COP and the chilling capacity was sufficient throughout the year except June–September. The insufficient cooling capacity over the June–September period could be improved by increasing the gross area of the solar collectors. Therefore, solar absorption cooling system may also be a desirable option to be utilised in the nZEH. Detailed literature reviews and descriptions of the evaluation methods for net zero energy building can also be found [33].

In the current state of affairs indeed, buildings are more and more becoming smart entities operating in smart networks, in particular when it comes to renewable energy provision and the deployment of smart grid infrastructures. Buildings hereby become an agent in the energy infrastructure, consuming, producing or buffering different forms of energy in order to arrive at optimal functioning both at the building level and the district level. Accommodation of intermittent renewable energy production, smart control algorithms, demand side management and buffer capacity are some of the main pillars of this new energy paradigm. A good example for the Qatari context would be the deployment of fourth generation smart cooling grids based on renewables like the Sun or geothermal energy, in combination with adiabatic cooling conversion.

It is important to note that recent experiences in the GCC indicate that in a smart and renewable energy infrastructure paradigm, energy efficiency turns out to be a critical factor for the feasibility of the former [34]. Energy demands and peak loads tend to be so high that, in order to fulfil all demands with renewable sources, energy efficiency remains paramount. Unlike the NZEB approach of temperate climates, extra energy consumption for indoor space cooling is expected for the nZEH in the Gulf region.

3. The nZEH description and energy hierarchy

To this end, the aim is to present an exceptional prototype building that may support the future building sector towards nearly zero energy solutions. The proposed home design concept will be a progression form of passive and bioclimatic sustainable design. A performance measure for the nZEH will be implemented during the design process and a real-time performance indicator will be derived. The operation process after the completion of the construction will be measured and monitored using a smart metering solution. This dynamic

Figure 9. The eco home perspective.

measurement can be integrated on seasonal or yearly basis to show the overall performance. The eco-house will be a landmark project that will reinforce Qatar's reputation as a leading advocacy of sustainable development and will drive in a new generation of nZEH building in the region. This house will offer a genuinely sustainable, smart and healthy living environment for residents. A number of methodologies will be carried out through this 5-year project duration in order to achieve the aim of the nZEH.

Public and private sector of Qatar already have started the implementation of strategies towards minimising the carbon footprint of the building sector and improving the quality of life. GSAS, a performance-based sustainability rating system, is developed by the Gulf Organisation for Research and Development [35]. GSAS is studying the local situation in the Gulf region, the weather, the local standards and practices and many more, leading to the formulation of value statements and will help the project throughout the whole design and construction process to include the most efficient strategies and techniques [36]. GSAS limited the maximum annual cooling demand for new-build housing compliance in Qatar to 125 kWh/m^2 however, conventional designs exceed 250 kWh/m^2. The project will develop a comprehensive design and market search in this direction, which will lead in a financially acceptable, feasible and totally successful project. **Figure 9** shows that the architectural language reflected in the villa designed to award a modern interpretation of the timeless traditional Qatari architecture, reflecting the culture and heritage of Qatar.

The nZEH, a detached family home, was designed in the hot-humid climate in Qatar as a 'showcase' study using the following strategies: Be Lean; Be Clean and Be Green as shown in **Figure 10**.

3.1. Be Lean strategy: reduce energy need

The envelope has an impact on cooling load and day lighting considerations. It was modelled as a climate modifier rather than solely a means of excluding external climatic conditions. It consists of structural materials and finishes that make up the exterior of the building and separate the inside from the outside. The envelope will have the ability to minimise solar heat gain and avoid overheating, also to use window shading and thermal mass to attenuate heat

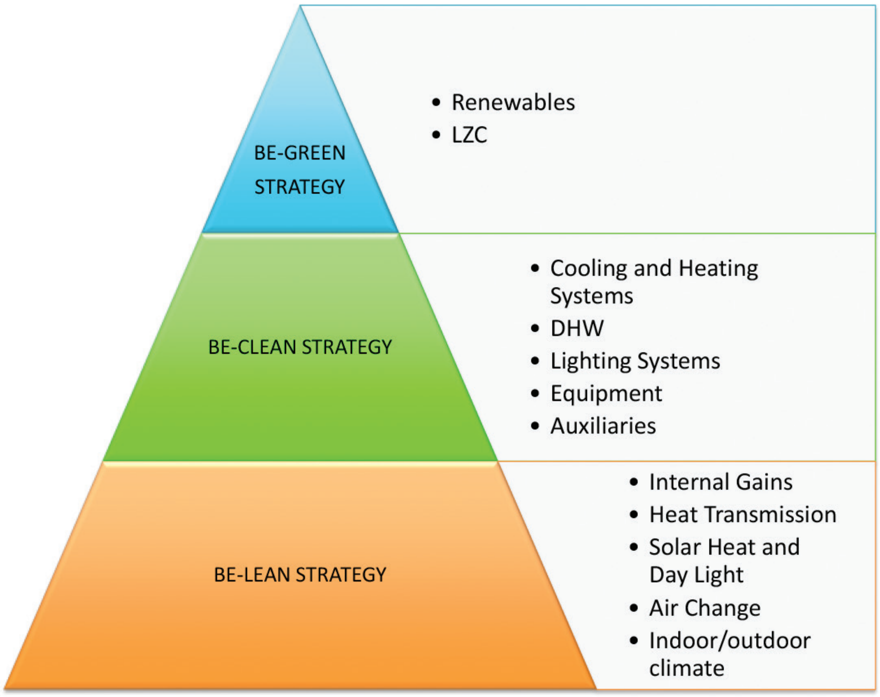
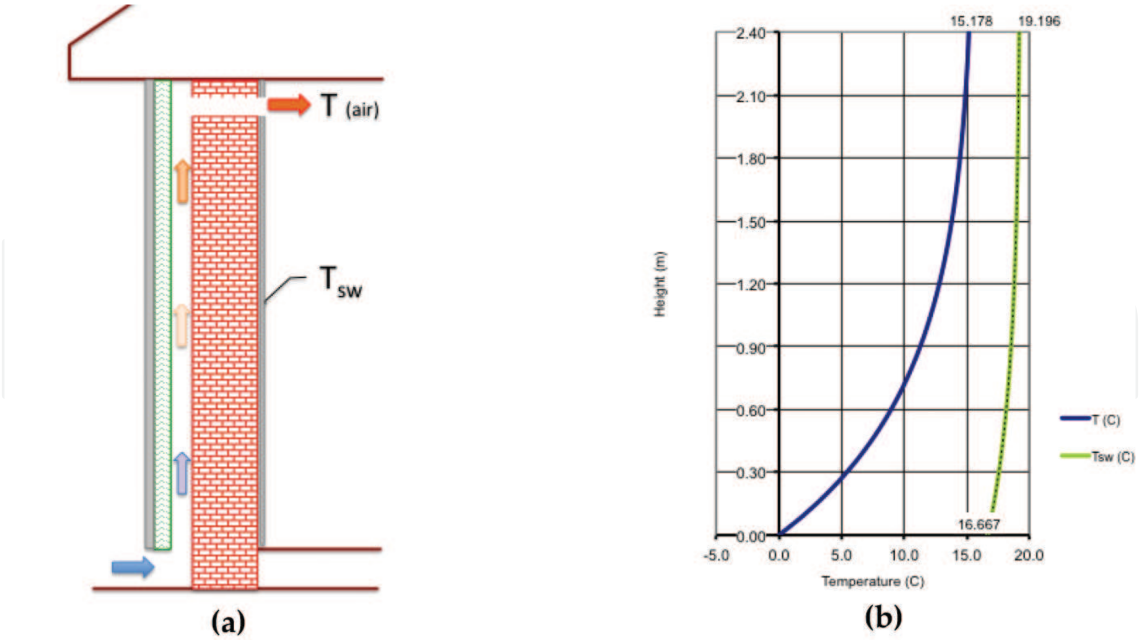


Figure 10. The nZEH strategies used in the nZEH showcase.

gain; to allow optimum levels of natural ventilation and day-lighting. It is worth noting that higher humidity ratios and dust are the main barrier of using natural ventilation, hence it is essential to use mechanical or a hybrid ventilation system in several cities within the Gulf region. A novel façade design approach has been modelled and will be implemented in the nZEH. It will have a compact design to reduce the influence of the external environment and may also benefit by need of less space for the distribution of horizontal and vertical services, particularly for air ductwork. Assemblies of air permeable adaptive insulation cells will be fitted internally over the available wall area and sealed in place using an independent, self-supporting gypsum board lining system that contain and protect the cells. As the name suggests, adaptive insulation permits the flow of air through the cells to facilitate the recovery of building fabric heat or, as in the present case, cool loss to ventilation air. Dynamic insulation uses the fabric as a heat exchanger. It either captures the heat loss from the envelope via the ventilation air in cold climates or rejecting the heat gain via the exhaust air in hot climates. Under steady state conditions, the heat loss through a conventional 'static' wall is the same entering as leaving the wall, its magnitude determined by the resistance to heat flow of the materials used to build the wall. By contrast, the parietodynamic wall in **Figure 11a** shows cold outdoor air being drawn in through the void created by the insulation layer and pre-heated by fabric heat loss, recovering part of that heat loss to the building as tempered air. Use of the wall to exhaust chilled indoor air provides an effective means of rejecting wall heat gain in the hot climate, to deliver precisely the same reduction in wall *U*-value as a function of airflow rate.

Researchers [37, 38] reported the results from the first field trial of dynamic insulation in Abu Dhabi. They also investigated the use of dynamic insulation in a building facade for local zonal insulation and ventilation [38].



(a) (b)

Figure 11. Solid wall system using 50 mm eps sheet (a) Sectional schematic. (b) Air and surface temperatures.

The height-averaged dynamic *R*-value of a dynamic wall or building façade can be estimated using the following steady-state expression [39]:

$$R_d = \frac{1}{U_d} = \frac{(T_i - T_o) \times N R_o}{(M - T_o)(e^{-N} + N - 1)}$$

where

$$M = \frac{R_o T_i + R_i T_o}{R_o + R_i}$$

$$N = \frac{R_o + R_i}{Rh o_a C_a V_u R_i R_o}$$

T_i and T_o are indoor and outdoor temperatures, R_o and R_i are the aggregated thermal resistances (*R*-values) between the void space and the cladding to ambient and indoor interfaces respectively, Rho_a the air density, C_a the specific heat capacity of air and V_u the volume flow rate of air per unit width of wall. Equation ignores radiation, convection, thermal inertia and secondary void space effects.

A study for a dynamically insulated villa showed that the dynamic *U*-value is 0.125 kWh/m^{2}K while the static is 0.24 kWh/m^{2}K based on the conditions shown in **Figure 12** [40].

3.2. Be Clean strategy: reduce energy consumption

The use of efficient systems and effective means of control is vital to reduce the energy consumption. A study showed that the energy saving of a building heating system by adopting model predictive control (MPC) could reach the range of 15–28% [41]. At times when ventilation

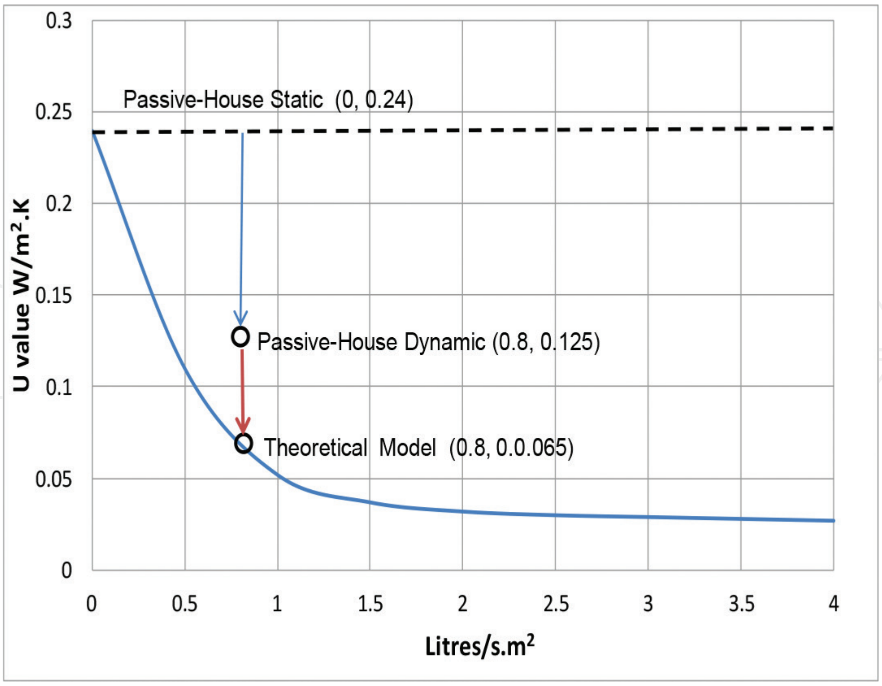


Figure 12. Dynamic *U*-values (W/m^{2}K) [40].

and daylight cannot alone meet the needs of occupants, the building services should meet the remaining demands as simply and effectively as practicable, in harmony with the occupants and the building as a whole. An essential part of the integrated design is to ensure that the energy supply and monitoring strategy is as coherent and environmentally sustainable as possible.

Figure 13 shows about 83% of the ambient weather conditions are not in the comfort zone, therefore, the following strategies are used to design a high efficient cost-effective system.

The innovative efficient system design includes:

- Variable frequency drive, two-stage indirect evaporative air conditioner coupled with liquid desiccant dehumidifier and the energy recovery system
- Low-grade heat driven 17.6 kW absorption chiller (input temperature range of 75–85°C), coupled with 35.2 kW variable refrigerant flow (VRF).
- Controls play the vital role for the sequence and operation of the system especially when coupled with the dynamic façade and the HVAC system as stated above.

3.3. Be Green strategy: renewables

There have been numbers of high-energy efficiency system installations coupled with the building to potentially generate and store useful energy from renewable energy sources for the occupants. The 17.6 kW ‘All in One’ absorption chiller is fully driven by renewables. The solar absorption chiller is fully integrated with a hybrid cooler and a thermal store. Flat plate solar collectors, 50 m^2, are used to charge the thermal store (75–85°C) in addition to 4 kWp photovoltaic for lighting auxiliaries and small power. The nZEH includes smart meters and sub-metering to ensure that future building performance can be continually monitored by the building operator.

The preliminary data that provide a draft description of the nZEH are presented in **Table 1**.

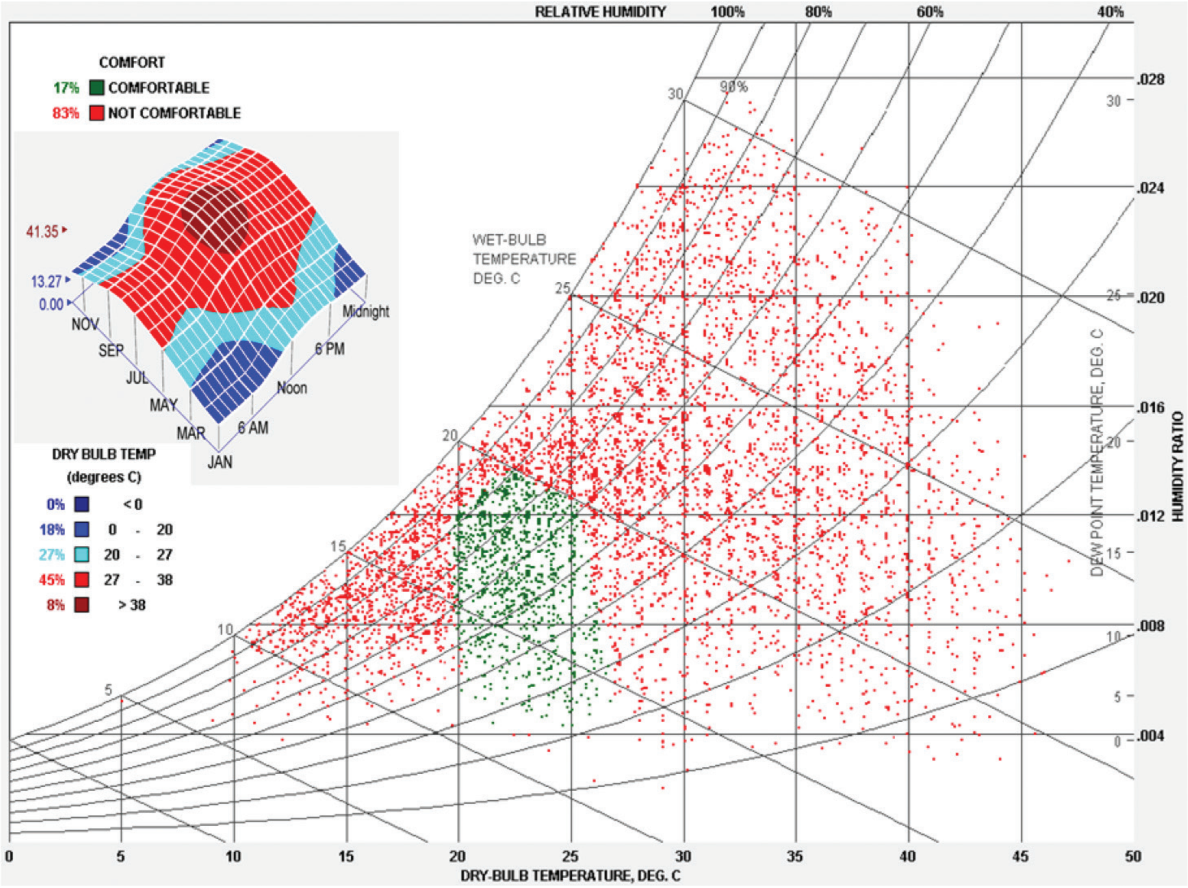


Figure 13. Extreme weather conditions of Doha city.

Gross area (m^2)		**733 m^2**
Number of bedrooms/occupants		7 persons
Space cooling design		VRF (35.2 kW), solar absorption chiller (17.6 kW)
Water heating design		Solar water heating, 50 m^2
Renewable energy		PV panels, 4 kWp
Lighting features		LED, 4.5 W/m^2
Ventilation		Controlled demand, maximum 400 L/s
Building Envelope Characteristics	**Roof**	*U*-values: 0.1 [$W/(m^2k)$]
	Walls	*U*-values: 0.24 static, 0.07 dynamic [$W/(m^2k)$]
	Windows	*U*-values: 1.3 [$W/(m^2k)$], SC = 0.25, external shading
Other Features		Socio-cultural, energy monitoring and control
GSAS rating target		6 stars

Table 1. Home specifications.

4. Results and discussion

All year round energy performance of the nZEH can be estimated by integrating the component modules of the associated system with the architectural design of the nZEH in the simulation platform. The design parameters' values of the associated systems and of the residential unit, as well as the control strategies which result in an energy balance of energy generation and energy consumption throughout a year, can also be obtained via the simulation exercises.

Figure 14 summarises the strategies undertaken to reduce the building's cooling need. The baseline is based on ASHRAE 90.1 and 90.2 (2010) and current local authority's regulations. Implementing conventional materials to the proposed design, the annual cooling need is about 180 MWh (246 kWh/m^2). This figure is in agreement with the literature (250 kWh/m^2). Applying the dynamic façade strategy will reduce the cooling need by 6.9%. Solar radiation is very critical, optimising the window to wall ratio, orientation, providing proper shading and the use of high-performance glazing can reduce the cooling need by 20%. The super-efficient design can reduce the cooling need by almost 50%. **Figures 15** and **16** compare the baseline and super-efficient hourly and monthly cooling demand. The passive measures reduced the peak dramatically and the loads are almost flattened.

Further to the passive design, efficient cooling systems and proper controls can be applied to reduce the need for electricity. As shown above, the passive measures reduced the cooling need by almost 50%. The most used air conditioning system for single residential homes in Qatar and the GCC countries is the split direct expansion unit with a typical coefficient

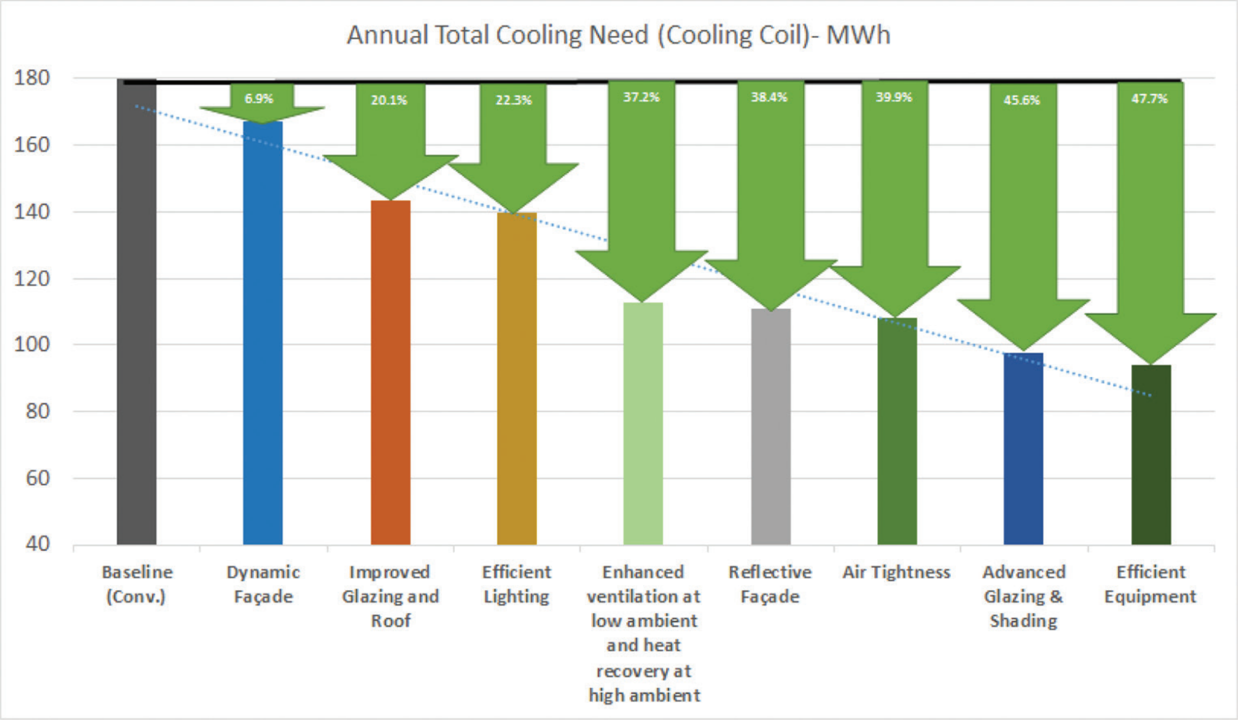


Figure 14. Annual total cooling need (cooling coil) MWh.

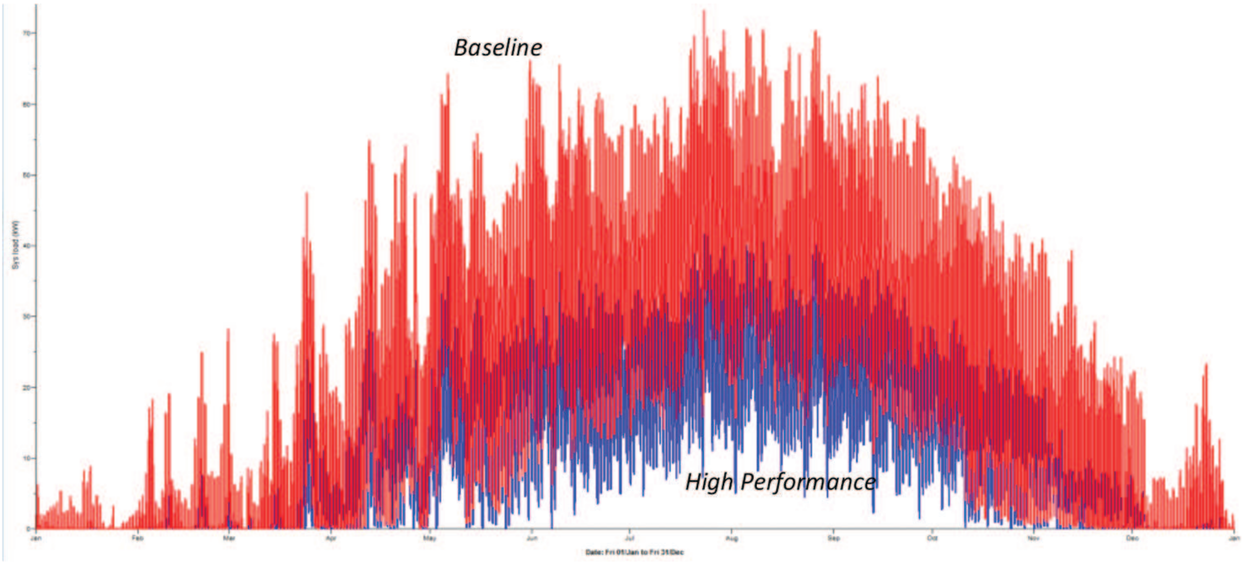


Figure 15. Hourly cooling loads (kW).

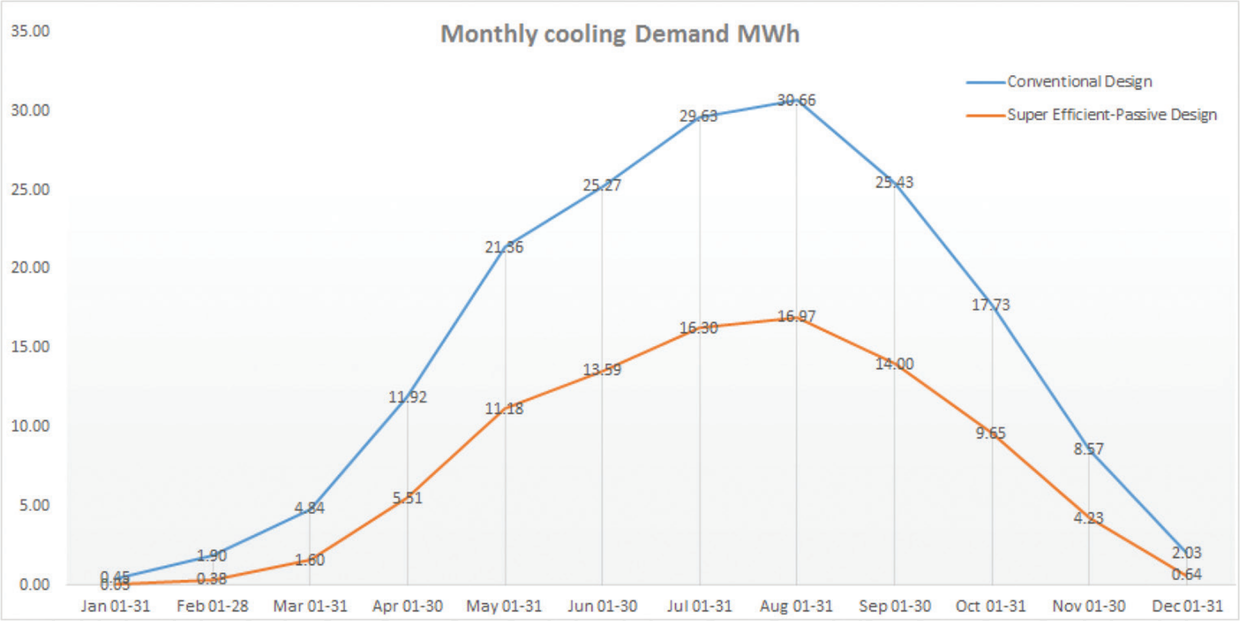


Figure 16. Monthly cooling demand (MWh).

of performance (COP) of 2. Moving to more efficient systems such as package systems or variable refrigerant flow will result in higher COP and hence reduce further the electrical demand. As shown in **Figure 17**, the use of VRF reduced the electrical need by 12%. It is anticipated that the energy performance of the nZEH can be further improved by the advancement of the control system. Model predictive control (MPC) with weather prediction is a high potential option to be applied in the continuation study. In the nZEH, indirect-direct

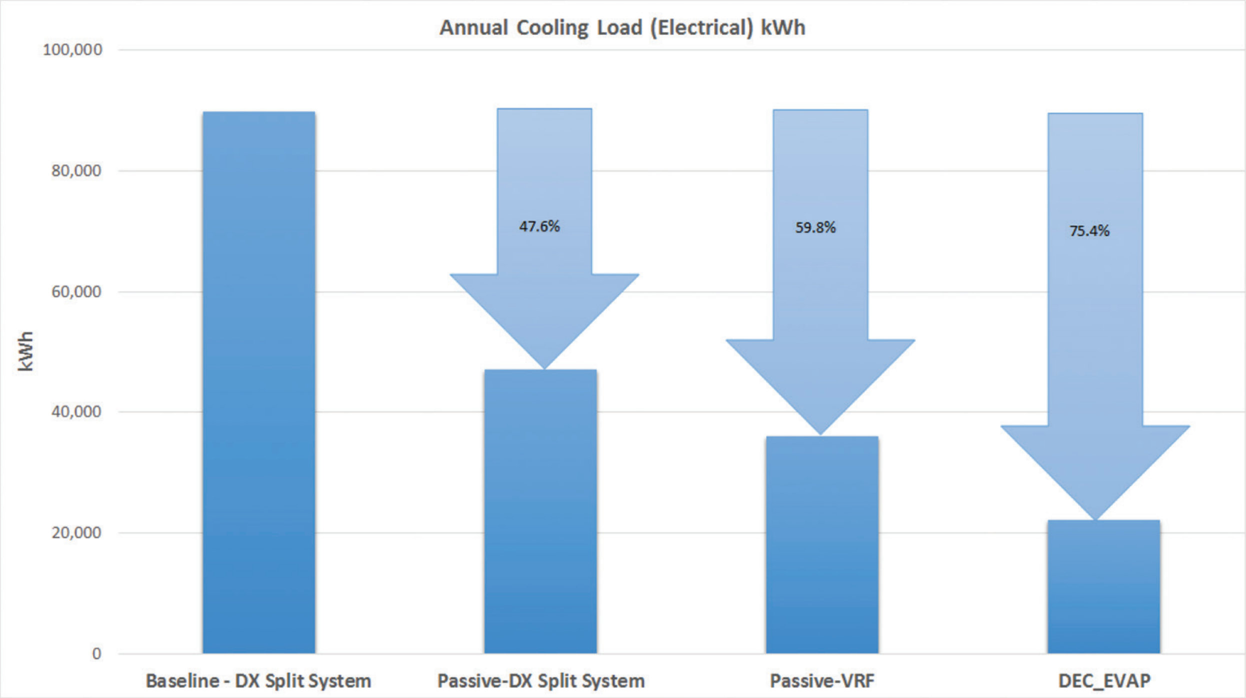


Figure 17. Annual cooling load (electrical) kWh.

evaporative cooling coupled with a desiccant system (DEC_EVAP) will be used to cool the house during certain periods. Also, it will be used to dehumidify the air when the humidity is high. Coupling such system will reduce the cooling loads by further 15% without compromising the thermal comfort. Such savings could be much higher if a new comfort zone is defined.

As shown in **Figure 18**, the use of low-grade heat 5TR (17.6 kW) solar absorption chiller (SAC) driven by 50 m^2 of solar water heater will reduce the cooling load by 8.5%. The integration of SAC with the domestic hot water demand will also reduce the needs of electricity to produce hot water, see **Figure 19**. Initially, the use of water efficiency measure (low flow fixtures) reduced water demand by more than 60%. As shown in **Figure 19**, the DHW is fully driven by the solar system.

Further for a clean strategy, renewable energy systems have to be applied in order to generate the remaining energy.

As shown in **Figures 20** and **21**, the use of 4 kWp to drive the auxiliaries and other small power is feasible. This will contribute an additional 3% reduction in annual energy consumption and an overall reduction of 75% compared to the baseline. Consequently, the house can be considered as near zero energy home (nZEH).

On the other hand, offsetting the 25% by renewables is not realistic and needs a lot of considerations. The house requires an extra 25 kW from renewables in order to achieve the net zero energy building, NZEB. In such case, the use of photovoltaic panels will require more than 200 m^2 of land or roof area which is not feasible.

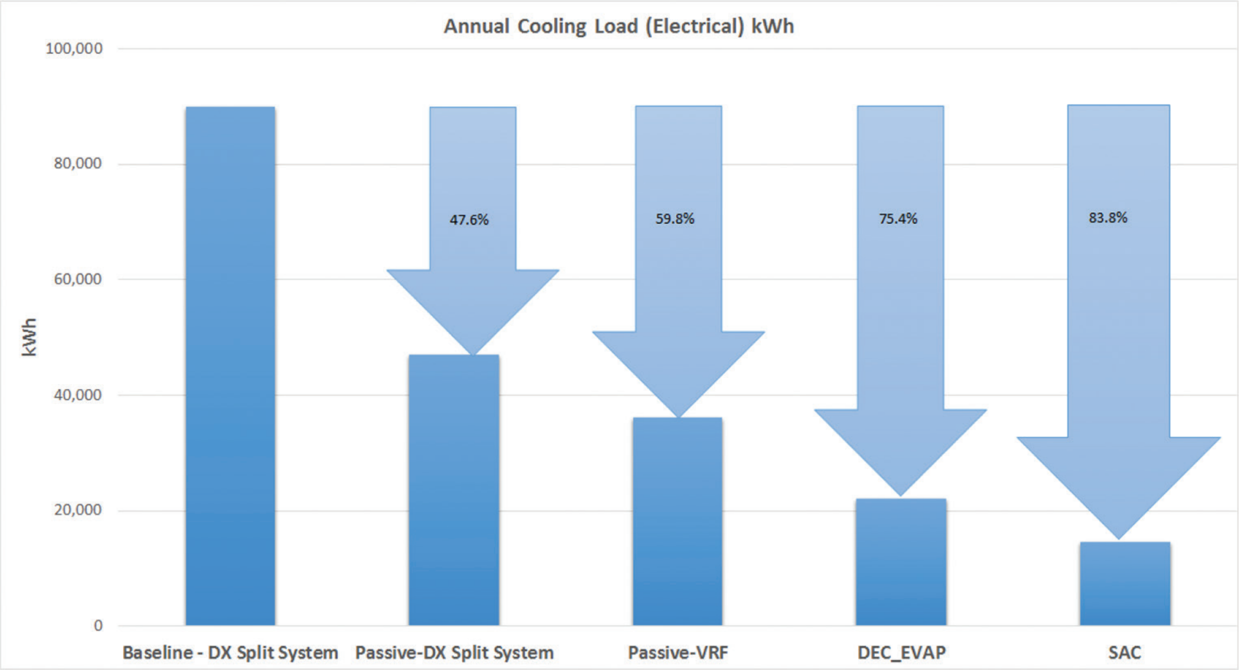


Figure 18. Annual cooling load (electrical) kWh.

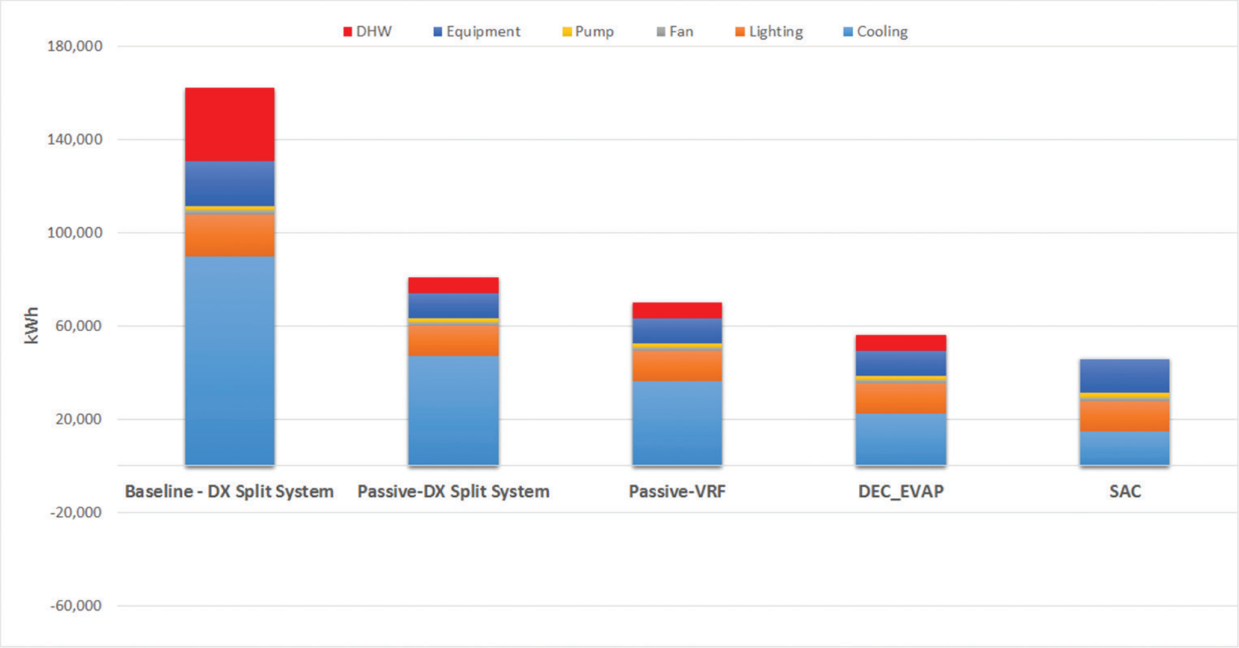


Figure 19. Total annual energy consumption by type using different strategies (kWh).

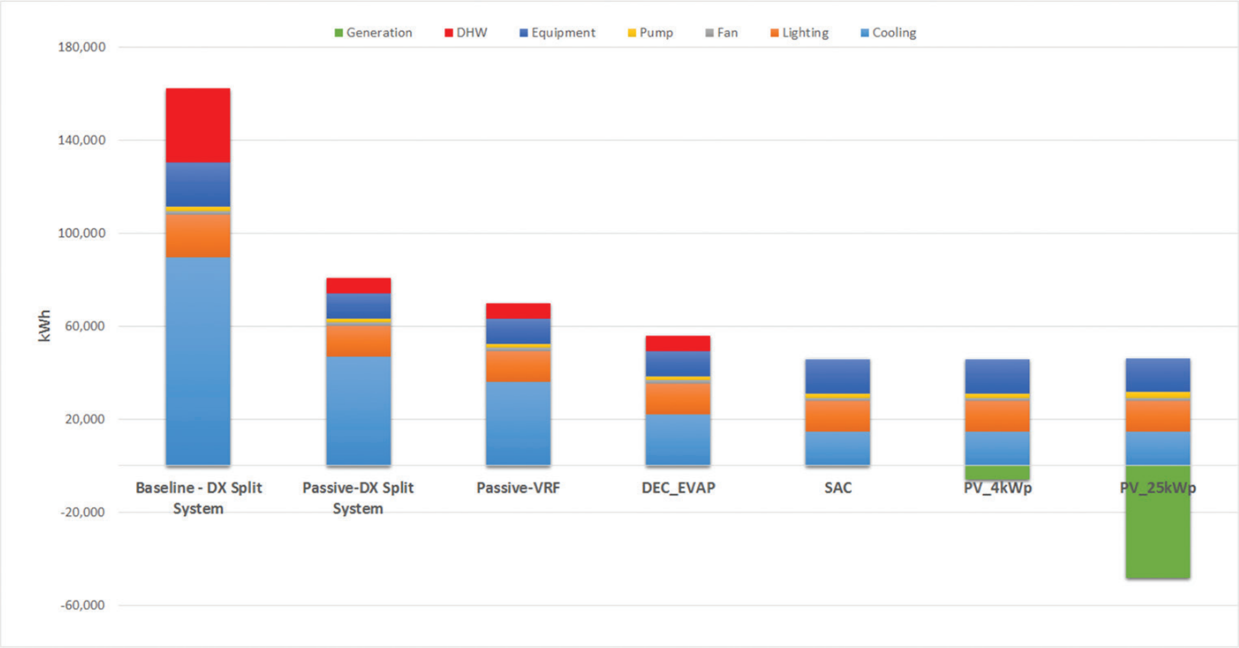


Figure 20. Total annual energy consumption by type using different strategies with renewables (kWh).

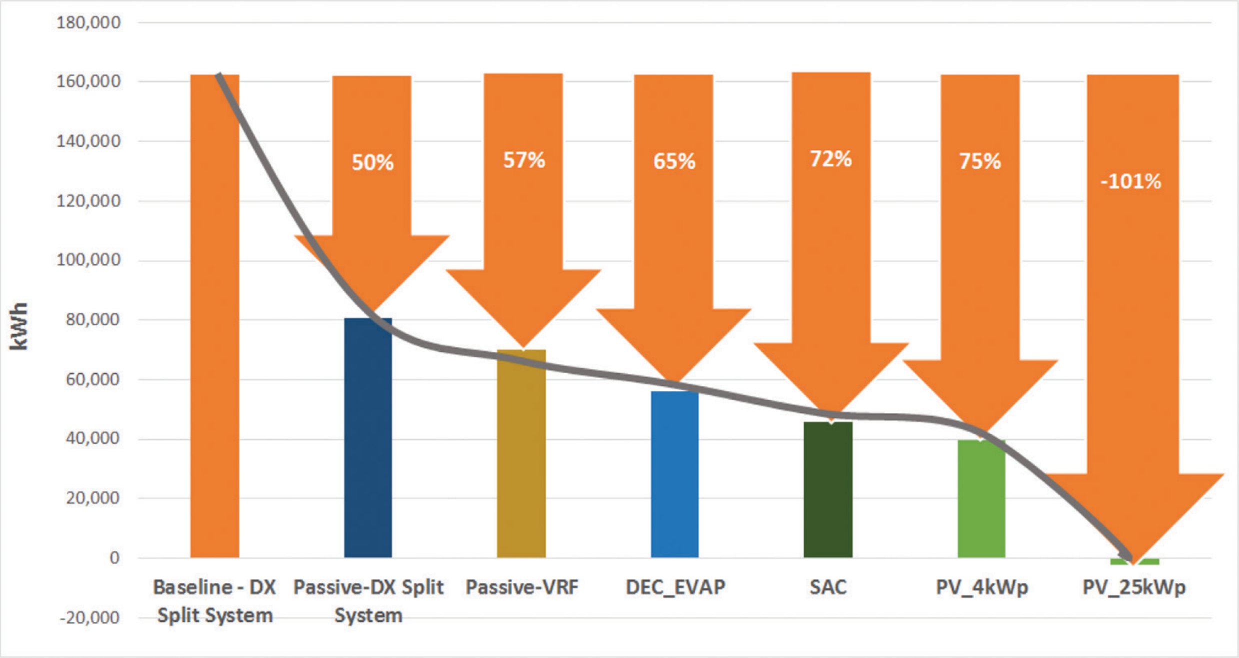


Figure 21. Total annual energy consumption with renewables (kWh).

5. Conclusion

This chapter presented the drivers, challenges and innovative technologies used to design the 'showcase' or the near zero energy home (nZEH) in Qatar (hot-humid climate). Several energy reduction strategies, using a defined energy hierarchy, are presented. The Be Lean or passive design measures are implemented comprehensively to reduce the needs for cooling. *This is* not limited to using high-performance multi-functional insulated façade, high performance glazing with *extensive* shading, the provision of day-lighting and energy efficient lighting without compromising the indoor environmental quality, *in order to* reduce the thermal loads. These measures contributed in reducing the cooling needs by 48%. The Be Clean strategies incorporated 'all-in-one' efficient cooling technologies that integrated desiccant cooling, integrated with indirect-direct evaporative cooling, absorption *cooling* and VRF system. The 5TR solar driven (50 m^2 solar collectors) absorption chiller is used to offset the cooling loads and the photovoltaic (4 kWp) is used to run auxiliaries and small power. The overall energy reduction is found to be 75%. In order to have a net zero energy building, it is necessary to upgrade the photovoltaic to 25 kWp, which means more than 200 m^2 of area is required which is not feasible. Although the nZEH is in the initial construction stage, it is anticipated that some minor changes into the design may occur. The monitoring results will be reported to the industry and community which will provide the pathway to the net zero energy building.

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