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An 80-year projection of nZEB strategies in extreme climatic conditions of Iraq

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Purpose
The Middle Eastern terrain is expected to encounter unprecedented climatic conditions emanating from extreme heat waves that exceed the critical threshold of inhabitable conditions before the turn of the next century (circa. 80 years). This threatens to cause a significant challenge that is only further exacerbated by a gap between supply and demand of affordable energy. Therefore, the purpose of this study is to investigate the potential of utilising nearly zero energy buildings (nZEB) to improve the performances of residential buildings in Iraq and the Middle East.

Design/methodology/approach
This study uses Iraq as a case study because of its breadth of climatic conditions experienced across its wide-reaching territory and recent critical infrastructural challenges following a geo-political crisis. Three virtual buildings were simulated for Baghdad, Mosul and Basra cities to narrow the confines of the region to achieve nZEB under current and future climatic weather scenarios of 2080.

Findings
The findings showed that all three cases studies buildings located within various climatic region in Iraq can achieve significant annual energy reductions and nZEB standards ranging from 41% to 87% for current climatic conditions and 40% to 84% by 2080. An operational cost analysis has also been carried out for the three case study cities which revealed significant operational cost savings achievable through nZEB buildings.

Originality
There currently remains a paucity of studies that investigate such positive potential for nearly zero energy buildings (nZEB) strategies under current and predicted future climatic scenarios in the Middle East.

Keywords: *Nearly Zero Energy Buildings; Residential Buildings; Middle East; Building Performance Simulation; Hot Arid Climate.*

INTRODUCTION

Climate change poses an epidemic threat to health, safety and the environmental conditions for the global population by increasing the rate of infectious diseases, mortality and degrading the quality of air (Ebi et al., 2017; WHO, 2017). Scientific evidence points to the excessive anthropogenic greenhouse gas (GHG) emissions that contribute to current manifestations of climate change and are projected to have further impact upon potential future climatic scenarios (IPCC, 2000). Faced by such threats the UN General assembly responded by adopting Sustainable Development Goals (SDGs) in 2015 which are consisted of of 17 goals, including: i) ensuring healthy lives; ii) promoting well-being for all, iii) ensuring access to affordable, reliable, sustainable and modern energy for all; and iv) making cities and human settlements inclusive, safe, resilient and adaptable to climate change(Lee et al., 2016). Residential dwellings cover an all-encompassing facet of SDG for future of daily life, human survival and adaptability. Hence, improving building energy efficiency and onsite renewable energy production can go a long way to achieve many of the SDG's goals in developing countries faced with extreme inhabitable climatic conditions such as Iraq.

Typically energy consumption within the built environment is responsible for about 30% of the world's total GHG emissions and about 40% of world's primary energy consumption (UNEP, 2017). These emissions have reached unprecedent levels in developing countries. For instance, As such, residential buildings in Iraq consume 82% of total building related energy consumption, with nearly 69% used for cooling and heating with rest of 31 % consumed for other domestic purposes (Hasan, 2012). The residential sector presents a significant challenge and opportunity in terms of energy and carbon reductions. Presently, the weak building regulations have accounted for such a lack luster approach to building energy efficiency in developing countries. UN habitat report stated that Iraq's current construction codes lack adequate sustainable and environmental measures that regulate energy use in buildings, a common phenomenon experienced by many countries in Middle East (Un-Habitat, 2006). Subsequently, developing nZEB standards can improve the prospect of establishing a benchmark for buildings that aim to reduce the carbon's footprint for buildings significantly. Extreme dry-bulb maximum temperature (T_{max}) occurrences exceeding 60 ◦C are projected to become the norm in most low-lying cities of the gulf region including Iraq by 2070-

20100 (Pal and Eltahir, 2016). Reaching such high dry bulb temperatures would pose a significant threat into human health by causing heart stroke and hydration (Ibid).

Previous studies on the rising average temperatures in the Middle East have pointed towards the benefits of climate change mitigation measures in accordance with IPCC Representative Concentration Pathway (RCP) via testing multiple simulation scenarios (Feitelson and Tubi, 2017; Nematollahi et al., 2016). The overheating and high indoor temperatures in Iraq are exacerbated by the shortfall supply of electricity during peak demands in summer. It was estimated that Iraq's electricity generation in 2011 produced only 9 GW, whilst peak demands were estimated to be 15 GW, resulting in a shortage of 6 GW (IEA, 2012). Currently, the shortage of energy demand is met by using private diesel generators owned by the building occupants.

The imminent need to achieve energy and significant reductions in carbon emissions, has led many countries to establish a nZEB standards around the world (Aldossary et al., 2017; Alrashed and Asif, 2015; Taleb and Sharples, 2011). Most developed countries established a definition of low energy buildings based on: efficiency of the building fabric; climatic conditions; occupants' profile and integrated renewable technologies.

Iraq presently does not hold a standardized specifications to achieve nZEB design. Establishing a strategy for achieving nZEB in Iraq considering current and future weather scenarios may start the energy conscious revolution required in the building sector. In addition, achieving nZEB standards will eliminate the existential threat posed on human survival in Iraq.

Therefore, this study examines the nZEB strategies for reducing energy consumption for residential buildings through nZEB standards and principles using IESV analysis software. Digitally simulated weather scenarios and building design performance analysis of IESV offers a vignette of suitable building design measures that can be tested over the next 80-years period. The energy performance of the buildings will be assessed and reported through the following KPIs: (1) energy use intensity (kWh/m^2.year); (2) carbon dioxide emissions ($KgCO_2/m^2$.year), (3) and the monthly operational cost ($). The aim of this study is therefore to develop a suitable specifications for nZEB strategies for residential buildings in Iraq for building lifecycle .years. The wider implications of the study is to lay the foundation for improved building performance such as zero energy and energy positive buildings in Middle East and southeast Asia.

Definitions OF LOW ENERGY BUILDINGS

Innovative zero energy buildings provide an exciting future and an ambitious quest to mitigate the adverse impacts of climate change. Despite its wider use across various regions in the world, there has been no consensus on their definitions by policy makers. The concomitants definitions for these buildings were:

- **Nearly Zero Energy Building (NZEB)**: a building with high energy performance that has lower or very little energy consumption annually, which is maintained by the use of on/offsite renewable energy sources (European Commission, 2017);
- **Zero Energy Homes (ZEH)**: a building with an annual primary energy consumption that is offset by positive on-site energy production(ASBEC, 2011);
- **Carbon Neutral Design (CND):** a building that use no fossil fuel to operate the heating, cooling and lighting (American Institute of Architects, 2012);
- **Climate positive:** a building that produces far more renewable energy compared with its consumed energy for varies purposes such as: heating, cooling, domestic hot water and lighting (ASBEC, 2011).

defining these buildings demand setting the targets for future energy consumption of buildings. For example, the European commission mandated all new buildings to achieve zero energy target by 2020, others such as 'Architecture 2030' (a non-profit organization) demanded all buildings to achieve a minimum of 90% carbon emission reduction by 2025 and zero carbon buildings by 2030 (Architecture2030, 2019).

Zero Energy Buildings in Hot Climates

Myriad studies have implemented nZEB strategies in hot climates of Middle East, albeit none have demonstrated the impact of nZEB strategies on energy consumption for current and future weather scenarios. Other studies have used optimisation algorithms to improve energy consumption and carbon emissions of buildings located in hot and warm climate with focus on the Middle East region as a case study (ALqadi et al., 2018; De Wolf et al., 2017). For instance, Aldossary et al. (2014) identified energy consumption patterns for domestic buildings in Saudi Arabia and they were able to achiev 21 to 37% reductions in primary energy through improving their buildings' fabrics and installing renewable energy sources on-site. Similarly, AlAjmi et al. (2016) tried to achieve net zero energy for educational building in Kuwait, by comparing the energy consumption on-site with the simulated model.

Their findings recommend the implementation of on-site renewables such as PV and solar cooling to achieve net zero energy targets on a monthly and yearly basis. Other researchers, Stazi et al.(2014) and Ascione et al. (2016) discussed designing nZEB with multi-objective optimisation criteria (e.g. simulation methods, cost, life cycle impact and thermal comfort) to evaluate their optimum design solution. Other studies focused on investigating the buildings to to withstand the catastrophic climate changes in future (Jentsch et al., 2008; Robert and Kummert, 2012). There have been scant studies in literature that discuss the implementation of zero energy and low energy buildings in Iraq. Abbood et al. (2015) investigated the use of off-site manufacturing as potential solution to reduce the energy consumption for residential buildings. The implemented solution reduced energy consumption by 61%. Almusaed and Almssad (2015) demonstrated the environmental impact of ecological buildings materials on vernacular buildings in Basra city. While (Naji et al., 2019) simulated existing buildings with multiple materials to reduce the high cooling demand in summer. All previous studies discussed use of using energy simulations with alternative materials in Middle East and Iraq in particular, however, they didn't address the impact of future weather scenarios on existing buildings to achieve zero energy building standard. Hence, this paper aims to answer the fundamental question of whether nZEB can be attenable not only for the current weather scenario but rather during the whole life cycle of the building.

Zero Energy Buildings Standards and Codes

Globally set benchmarks and standards for nZEB are summarised for brevity in Table 1. The table lists codes and requirements for achieving nZEB in warm climatic regions across the world including european countries and USA. In addition, UK's nZEB standard was included in Table 1, because it was one of the first countries that introduced a zero carbon home standard in 2007 (Zero Carbon Hub, 2017). The requirements for nZEB vary for each country, with a primary energy consumption recorded between 20 kWh/m^2.year and 120 kWh/m^2.year for residential buildings. According to Table 1, it appeared that the average primary energy consumption was 39.3 kWh/m^2.year. Additionally, and unlike other energy codes, the UK specifies the carbon emissions per building while other countries use vague indicator to measure renewables on site through determining the percentage of renewables.

Hence the UK standard was chosen as reference to investigate the implementation of nZEB in Iraq. Specifying the carbon emission per year is a better indicator for renewables implementation on-site compared with specifying the percentage of renewables, as the building might achieve a very low carbon emissions annually without the need to implement renewable design solutions to offset these emissions.

Country	Requirements and energy indicators	Renewable energy requirements
Croatia	For coastal region: 33.40 kWh/m^2.year	Not specified
Cyprus	Not defined	25% of primary energy consumption must be provided through renewable energy
France	Primary energy for new residential buildings should be no more than 50 kWh/m^2.year;	Demonstration of using renewable energy though one of the following options: Provision of on-site solar panels for hot water purposes; 50% of renewable energy supplied through district network; Renewables energy production on-site should contribute to EPC energy consumption of 5 kWh as minimum
Italy	Under development 26 kWh/m2.year	Renewable energy should be 50% of total energy consumption for cooling, heating and hot water
Malta	Primary energy for residential buildings should be no more than 40 kWh/m^2.year	Not specified
Spain	Not specified 41	Not specified
UK	The building regulation did not provide full definition for zero carbon home; however, the zero-carbon hub provided a requirement for zero energy homes, in which energy used for heating and cooling should be equal or no more than: 39 kWh/m^2.year for mid-terraced/attached house; 46 kWh/m^2/year for end-terraced and detached house; 39 kWh/m^2/year for apartments	The onsite renewables use is determined for each building type as: 10 $KgCO_2/m^2$.year for detached house; 11 $KgCO_2/m^2$.year for mid-terraced house, end-terraced house 14$KgCO^2/m^2$.year for apartment blocks The remaining carbon emission should offset using off-site renewable energies
USA	For California: all new homes to achieve zero net energy by 2020	All renewables employed on site must produce energy equivalent to the energy needs of the building to achieve zero primary energy

Table 1-Various energy standards established by different countries adopted from (ASBEC, 2011; European Commission, 2017; ZEBRA2020, 2018)

CURRENT AND FUTURE CLIMATE OF IRAQ

Iraq has a total area of 438 320 km^2 and it is sharing borders with Turkey, Iran, Syria, Jordan, Saudi Arabia and Kuwait. Its geographical regions are divided into three distinctive parts (FAO, 2017), as shown in Figure 1 and summarised as follows:

(1) Northern region with Mediterranean climate, which have mild summer and cold winter—its territory starts from south of turkey and ends in south of Mosul in Iraq;

(2) The desert region which lay and extends from north of Baghdad to the south-west border of Jordan and Saudi Arabia respectively. The region identified as hot arid climate;

(3) The irrigated area that lay between the two main rivers, Tigris and Euphrates. It extends from north of Baghdad to the south of Basra.

Three main cities (Baghdad, Mosul and Basrah) have been therefore selected for this study as representative case studies, which covers the three distinguished climates regions in Iraq. These climate conditions are used to evaluate the energy performance of the buildings using Integrated Environment Solutions (IESV). Typical metrological year for each city has been generated using Metonorm database (Meteonorm, 2017).

Future weather scenarios for 2080 year were generated based on (A2) scenario developed by the intergovernmental panel on climate change (IPCC). The A2 weather scenario assumes significant GHG emission increases which were set out for 2080 year using the 'CCweatherGen' weather generator tool (Jentsch et al., 2008). It is estimated that the average building lifespan is around 60-90 years (Birkeland, 2002); therefore, 2080 weather scenario was chosen to test the performance of the building in the future to cover the duration of the building lifespan. Hence, the current and future weather scenarios generated for the three case study cities were implemented and tested using Integrated Virtual Environment (IESVE) for energy simulation.

Figure 1 – Map of Iraq adapted from (Google maps, 2019) and modified by the author to depict Iraq's climatic regions

Weather variables were generated and reported in Table 2 for current and future weather scenarios. The results showed that under current and future weather scenarios, Iraq has three climatic regions based on ASHRAE climate classification. The climate classifications are based on heating degree days (HDD) and cooling degree days (CDD). All three climatic regions have very similar heating and cooling degree days. Mosul is the only city with a climate that changed slightly in 2080 from 3B Warm dry into 1A very hot Humid, while Baghdad and Basra are expected to maintain the same classification in the future. Heating degree days (HDD) were predicted to decrease for all cities in the future weather scenario, while cooling degree days (CDD) were predicted to increase in the future. Highest CDD were recorded for Basra in 2080, while the highest HDD were recorded in Mosul under current weather.

City & weather file	**Climate Classification**	**Temperature**		**Heating & Cooling**		**Precipitation**	**Wind**		**Annual solar resource**
		Max	Min	HDD	CDD	Annual rainfall	Annual speed	Direction	
Basra typical weather file	1B Very hot and dry	48.5 °C	2.9 °C	478.8	5577.7	140.6 mm	3.3 m/s	E of N 337.5°	2049.9 kWh/m^2.year
Basra in 2080	1B Very hot and dry	50.0 °C	5.5 °C	187.3	7070.3	140.6 mm	3.3 m/s	E of N 337.3°	2066.9 kWh/m^2.year
Baghdad typical	1B Very hot dry	50.1 °C	2.7 °C	475.7	5646.9	140.6 mm	3.5 m/s	E of N 321.8°	1930.7 kWh/m^2.year
Baghdad 2080	1B Very hot dry	50 °C	6.9 °C	138.7	7462.9	323.7 mm	3.5 m/s	E of N 322.1°	1942.6 kWh/m^2.year
Mosul typical weather	3B Warm dry	43.8 °C	-3.8 °C	1574.3	3376.5	323.7 mm	3.1 m/s	E of N 191.3°	1835.2 kWh/m^2.year
Mosul in 2080	1A Very hot Humid	50.0 °C	-0.8 °C	893.8	5043.4	710.4 mm	3.1 m/s	E of N 191.7°	1881.9 kWh/m^2.year

Table 2-Climate variables for typical year and 2080 for three Iraqi cities (Baghdad, Basra and Mosul)

METHODOLOGY

This study investigates the possibility of implementing nZEB in hot and arid climate, particularly within Iraq microclimatic regions. In theory, the successful utilisation of nZEB in various developed countries proofed to be achievable, however, the building requirements for achieving such standards is still unknow and untested in Iraq. Therefore, this study uses a case study approach, applying the principles of nZEB design on mid-terraced house. The selection of mid-terraced house represents the most predominate housing type in Iraq with an average area of 177 m2 according to a housing survey conducted by Un-Habitat to assess the housing market in Iraq (Un-Habitat, 2006). As such, an existing mid-terraced house with internal floor area of 178 m^2, as shown in Figure has been chosen as a base model to test the nZEB strategies via the use of IES-VE simulation.

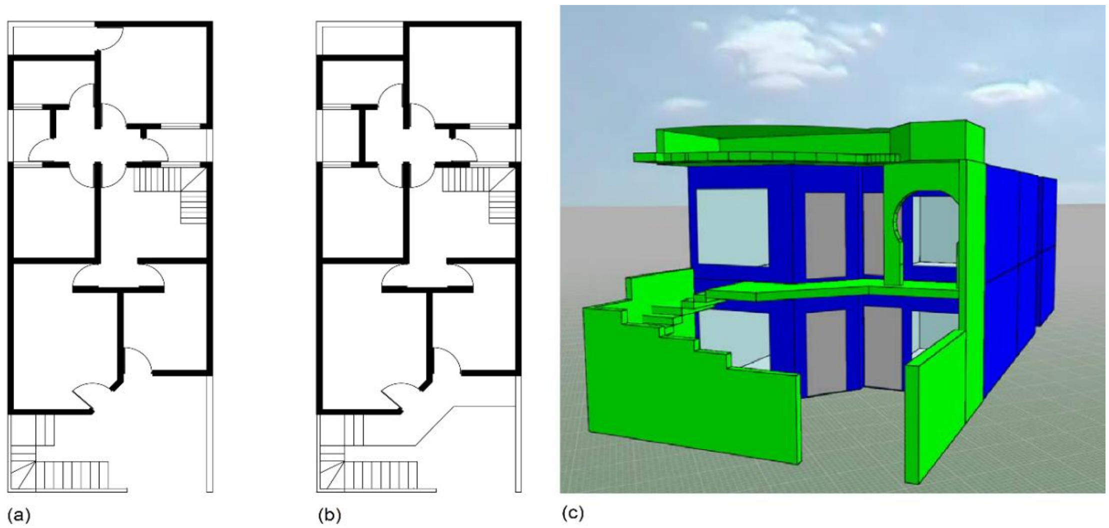

Figure 2-Represents (a) ground floor, (b) first floor, (c) isometric view of the case study

Various studies in the literature used IES-VE simulation as a method to test and validate various energy design strategies for buildings (Alrashed and Asif, 2015; Taleb and Sharples, 2011). Similarly, this study uses simulation as a main method to test the applicability of nZEB in Iraq for current and future weather scenarios. The steps followed in this research are illustrated in Figure 3, and further explained below:

1- Identifying the base case model for residential building in Baghdad;
2- Setting the model's simulation parameters (e.g. internal heat gains, building envelope, cooling and heating set points, etc.);
3- Validating the simulation through comparing the simulated primary energy consumption of the case study building against its actual energy consumption for the average residential building in Iraq;
4- Duplicating the simulated case study building in Baghdad for Basra and Mosul after confirming the validation of the model in previous step;
5- Calculating the primary energy consumption and carbon emissions for each case study building (Baghdad, Mosul and Basra) under current and future weather scenario to determine if current buildings qualify for nZEB standards. The simulated building should meet the nZEB standards which include: (a) heating and cooling energy equal to or less than 39.3 kWh/m^2.year; (b) carbon emission equal to or less than 11 KgCO_2/m^2.year for all climatic regions in Iraq.

6- If the buildings don’t qualify for nZEB standards, design interventions were incorporated into the building to reduce its primary energy and carbon emissions to achieve the desired nZEB standard;

7- Operational costs were calculated for each simulated scenario to provide a better insight to the actual cost associated with operational performance for nZEB in Iraq;

8- Final recommendations for designing nZEB were provided based upon the findings of the simulations for the case study buildings located in three cities.

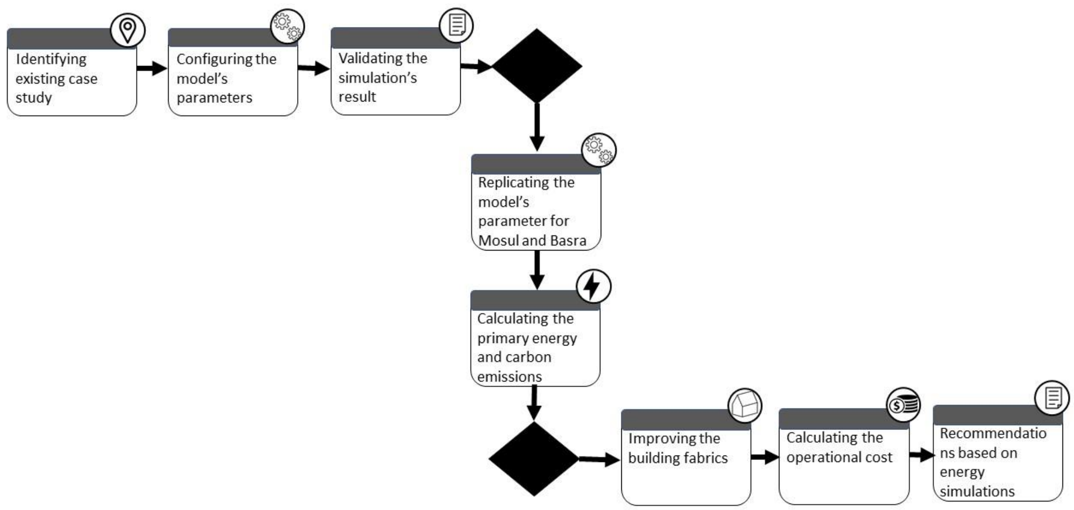

Figure 3-The methodological steps followed in this study

Case study and model parameters

To emulate a real-life scenario of typical residential dwellings in Iraq, an anonymised residential building was used as a case study. The selected case study building is an existing 5-bedrooms mid-terraced house occupied by 6 residents in Baghdad, Iraq. The main façade is facing the south western orientation, the building construction is comprised of load bearing brick walls and a concrete flat roof. It is worth noting, that some simulation parameters were approximated during the energy simulation of the case studies. For instance, the air infiltration rate was assumed to be 1 Air Changes per Hour (ACH) akin to Kuwait, which is a neighboring country to Iraq that holds very similar construction methods for residential buildings as suggested by (Al-ajmi and Hanby, 2008). We argue that such values are representative of typical airtightness in developing regions , particularly in Middle East, therefore the same value was assumed for Iraq. U-values were automatically calculated for the representative materials using materials and components database within IESVE system software. IESVE consists of built-in thermal properties such as density, specific heat capacity and thermal conductivity of relevant construction materials. Heat gains were calculated after identifying assumed equipment (e.g. electronic devices, appliances and number of occupants) available in the case study model. Relevant thermal properties of building model materials and simulation parameters are summarised in Table 3.

House key areas	Description
Land area including the built-up area	127.22 m^2
Ground floor area +first floor area	187 m^2
First floor area	80 m^2
Roof floor area	66.2 m^2

Building envelope	Construction Materials	U-Value ($W/m^2.K$)
External wall	(20 mm stucco + 130 mm brickwork + 20 mm plaster)	2.78
Ground floor	(25 mm floor tiles+ 25 mm screed+ 100 mm sandstone+ 100 mm reinforced concrete+ 5 mm asphalt+ 50 mm concrete deck+ 150 mm stone+ 2 mm earth)	2.14
Roof	(4 mm concrete tiles+ 2 mm sand+ 5 mm polyurethane board+ 2 mm asphalt+ 20 mm cast concrete+ 13 mm plaster)	2.70
Doors	(40 mm wooden door)	2.29
Windows	(6 mm single glazing)	6.39
Infiltration	1 ACH	
Buildings systems and internal gains		
HVAC system	Flow rates= 8 l/s/person	
Domestic hot water	0.95 efficiency	
Auxiliary ventilation	Bathroom and kitchen = 64 l/s	
Heating set point	20.0 °C	
Cooling set point	24.0 °C	
Bedrooms internal gains	Max power consumption of (Lighting + miscellaneous) =6.58 W/m^2	
Kitchen internal gains	Max power consumption of (Lighting + miscellaneous) =33.28 W/m^2	
Reception internal gains	Max power consumption of (Lighting + miscellaneous) = 6 W/m^2	
Office internal gains	Max power consumption of (Lighting + miscellaneous) = 6 W/m^2	
Living area	Max power consumption of (Lighting + miscellaneous) = 7 W/m^2	

Table 3-Thermal properties for building envelope and parameters used for simulation

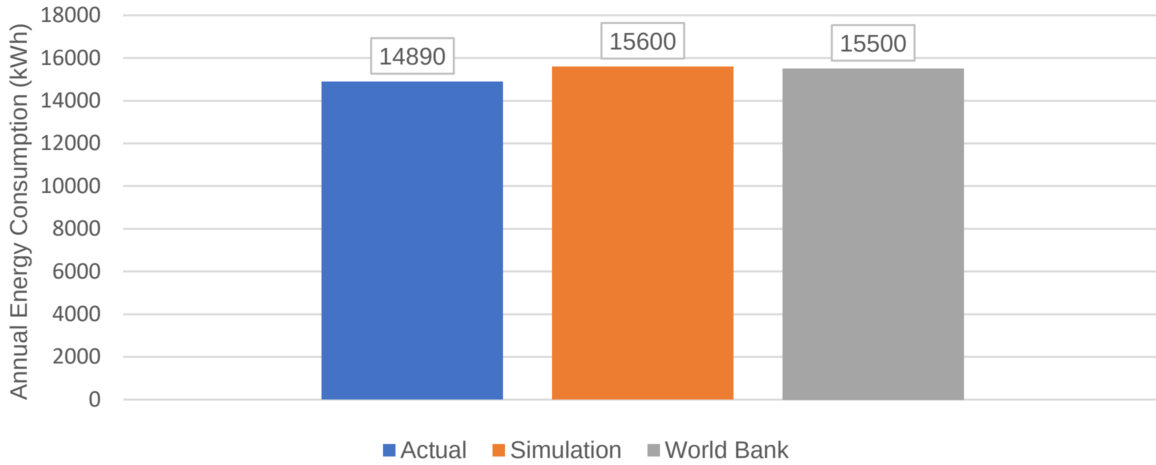

Figure 4-Comparisons between the actual consumed energy and the simulated one in kWh

VALIDATION OF SIMULATION

In order to validate the energy consumption for the simulation in IES-VE, the base model was validated using actual annual electricity consumption data collected from electricity bills for the real case study building in Baghdad.. compares the total simulated energy consumption with an actual annual electricity bill for the case study building. The total annual energy consumption for the simulated building was 15600 kWh.year compared with the actual electricity consumption obtained from the electricity bills which was 14890 kWh.year; the comparisons, showed a variance of 16% between actual and simulated electricity consumption. In addition, the annual simulated electricity consumption was within 1% of error margin when compared with the World Bank estimation of energy consumption for average houses in Iraq, which accounted for 15500 kWh.year (World Bank, 2017). Therefore, it is reasonable to suggest that the simulation has predicted the energy consumption of the building with reasonable accuracy, showing very close agreement with both actual annual electricity consumption and the average house energy consumption indicator by the World Bank.

RESULTS AND DISCUSSIONS

Base model in Baghdad with no intervention

The simulated results for Baghdad base model within the current climate scenarioshowed the primary energy consumption was 88.20 kWh/m^2 and 67.97 kWh/m^2 was used for heating and cooling. A parametric design evaluation was carried for optimum orientation of the building, which when south facing shows a reduction of primary energy to 85 kWh/m^2 and 62.35 kWh/m^2 for heating and cooling. It was thus deemed that the southern orientation was an optimum choice for the rest of the case study simulations in Basra and Mosul. This base model in Baghdad was then simulated for 2080 weather scenario, showing a primary energy usage of 99.43 kWh/m^2 with 11% increase in total energy consumptions compared with current climate simulation (See **Error! Reference source not found.**). Conversely, the calculated carbon dioxide emission for the current climate scenario was 53.97 KgCO_2/m^2.year while the total annual emission for 2080 was predicted to be as high as 65.42 KgCO_2/m^2.year. **Error! Reference source not found.** shows that the pattern of energy consumption in future scenarios was heavily influenced by the cooling demands of the summer months. More importantly though, the results demonstrated that the current and future energy consumptions did not meet the nZEB standard threshold.

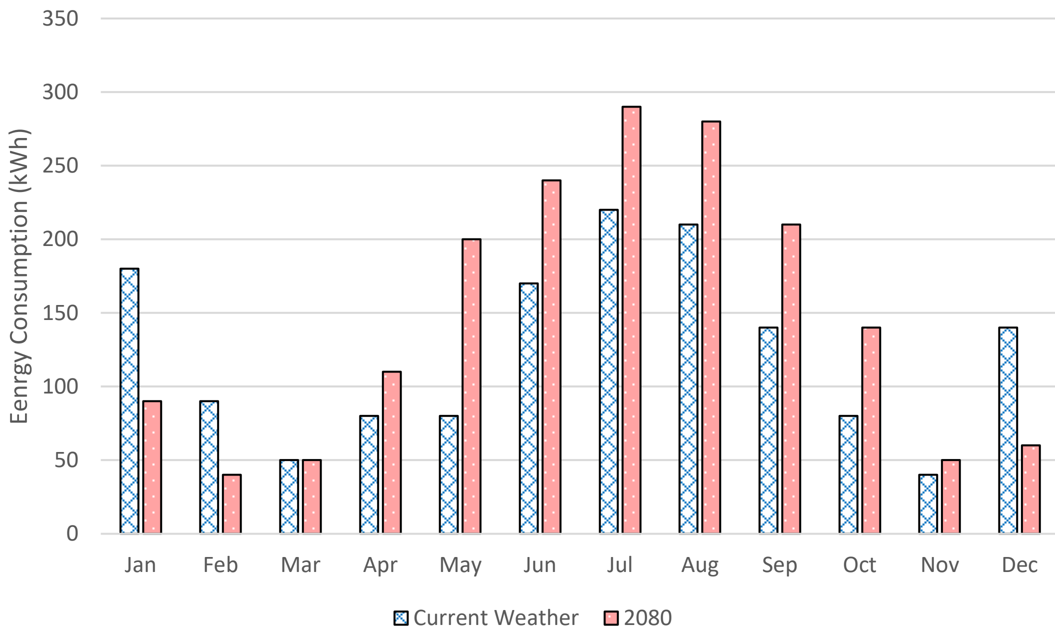

Figure 5- Current monthly vs. future monthly energy consumption comparison for Baghdad without interventions

Base model in Basra

The base model of the residential dwelling validated for Baghdad was geo-located and simulated for Basra under current and predicted future weather scenarios. The total primary energy consumption for current conditions showed slightly higher energy consumption compared with the same model for Baghdad. As such, the primary energy consumption was accounted for 85.39 kWh/m^2.year, while same consumption increased for 2080 by 12% as shown in Figure .

The cooling demands were predicted to significantly increase under 2080 weather scenario, whereas during winter seasons heating demands were predicted to be 26% lower in 2080. As such, the energy consumption for heating and cooling were 65.16 kWh/m^2 and 76.40 kWh/m^2 for current and future weather scenarios respectively. Carbon emissions for the current and future scenarios were predicted to be 52.80 $KgCO_2/m^2$.year and 62.47 $KgCO_2/m^2$.year respectively. Similar to Baghdad's simulation, the hypothetical simulated model for Basra failed to achieve nZEB threshold.

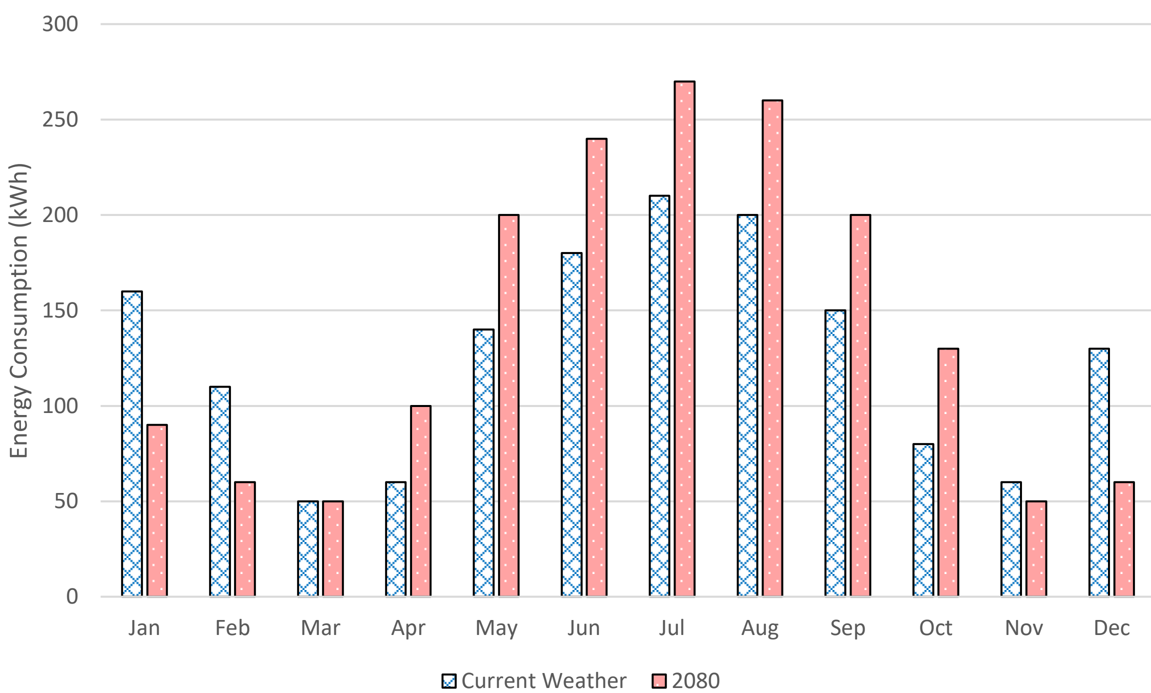

Figure 6-Current monthly vs. future monthly energy consumption comparison for Basra

Base model in Mosul

The simulated model in Mosul showed a higher primary energy consumption in comparison with Baghdad and Basra, with a primary energy consumption of 104.49 kWh/m^2.yearand 101.68 kWh/m^2.yearfor current and 2080 weather scnearios (See Figure). Importantly, the nature of the weather in the northern Iraq and particularly Mosul are dogged by higher heating demands under current weather conditions. The cooling energy consumption was projected to increase while heating energy consumption was expected to decreases slightly under 2080 conditions, therefore the energy consumption for the current year was higher than the same simulated model for 2080. The simulated results showed similar pattern of heating and cooling demands which predicted to be 84.26 kWh/m^2.year and 80.89 kWh/m^2.year for current and future weather scenarios respectively. Carbon emissions in a similar vein were higher with 58.34 $KgCO_2/m^2$ and 60.50 $KgCO_2/m^2$ for current and 2080 weather scenarios..

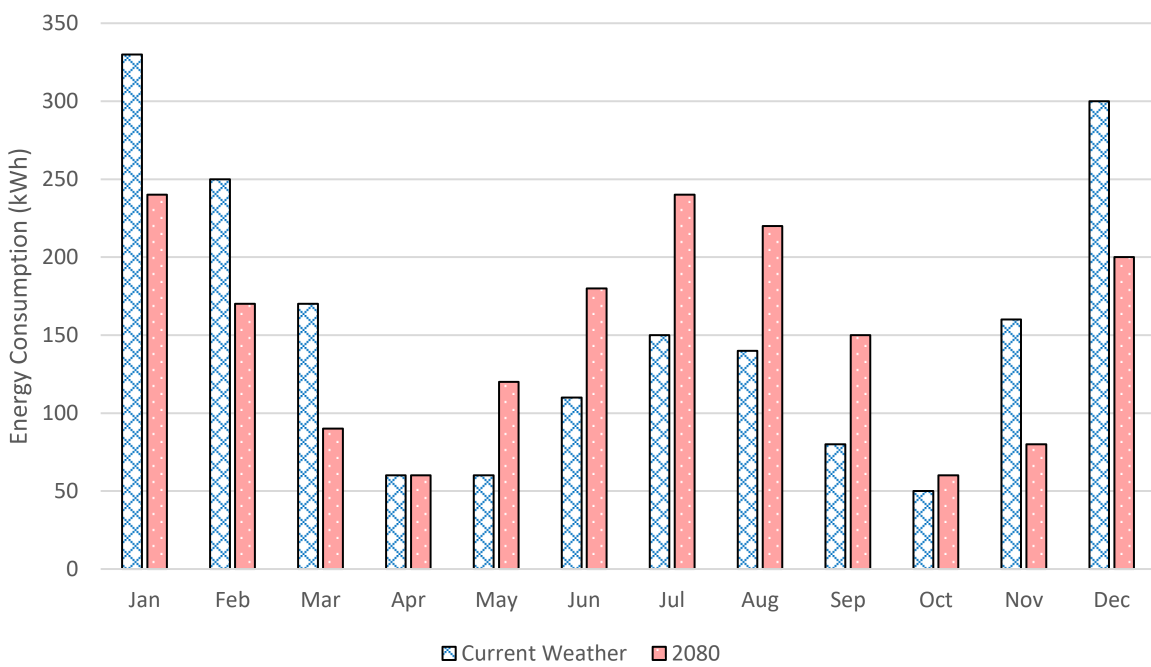

Figure 7-Current monthly vs. future monthly energy consumption comparison for Mosul

ACHIEVING nZEB FOR CASE STUDIES

Building Performance Improvement

The simulated energy consumption and carbon emission results for three building case studies suggests that the simulation did not meetnZEB standards, due to the following reasons: (1) higher energy consumed for heating and cooling which exceeds 39.3 kWh/m^2.year; (2) higher carbon emissions > 11 $kgCO_2/m^2$.year. Therefore, the following building performance improvements have been proposed:

1. Building fabric efficiency improvements as suggested in Table 4;
2. Building air tightness improvements;
3. The installation of on-site renewable energy (south facing Monocrystalline silicon PV);

The changes have been implemented within the IESVE model and simulated for the three case studies.

Construction U-value	**Description**
Ground Floor	(750 mm London clay+ 250 mm brickwork+100 cast concrete+50 mm insulation+50 chipboard+ 10 mm synthetic carpet) U-value= 0.27 W/m^2. K
External wall	(15 mm plaster+175mm brickwork+275mm ploystyrene+20 render) U-value=0.13 W/m^2. K
Roof	(20 mm asphalt +120 mm insulation+89 vapor barrier+ 50 screed+220 concrete deck+12 mm cavity+12.5 mm plasterboard) U-value=0.13 W/m^2. K

Table 4-Optimised thermal properties of the building envelope for the case study buildings

Interventions for Baghdad's model

After implementing the building fabric efficiency values, several air infiltration values were tested with the optimum air infiltration rate of 0.4 ACH for which the building can achieve the nZEB threshold standard. The building primary energy consumption reduced down to 47.19 kWh/m^2 and 56.17 kWh/m^2 representing a 44% reduction for both current and 2080 weather scenarios, as shown in Figure .

The predicted annual energy consumption for heating and cooling were 27.52 kWh/m^2 and 37.07 kWh/m^2 for currrent and future weather scenarios respectively. The value of carbon emissions were reduced below the required target of <11 $KgCO_2/m^2$ for nZEB standards. The results showed that the building improved the annual carbon emissions with 9.4 $KgCO_2/m^2$ and 9.68 $KgCO_2/m^2$ for current and 2080 upon installation of a south facing Monocrystalline PV (installed at a tilt of 34° with an area of 34m^2 and 48m^2).The PV's values were configured for the optimal design of simulation after iterating through range of values to find the optimal values. It is worth noting that the primary energy consumptions were predicted to significantly reduce after the PV interventions by up to -3.58 kWh/m^2.year and -43.47 kWh/m^2.year for current and weather scanrios comapred with the base model prior to the design interventions. The results showed that there was potential increase in PV performance under future weather scenarios, the reason for the excellent performance in 2080 PV energy production was owed to the increase of the annual solar energy in 2080 for Baghdad as illustrated in Figure .

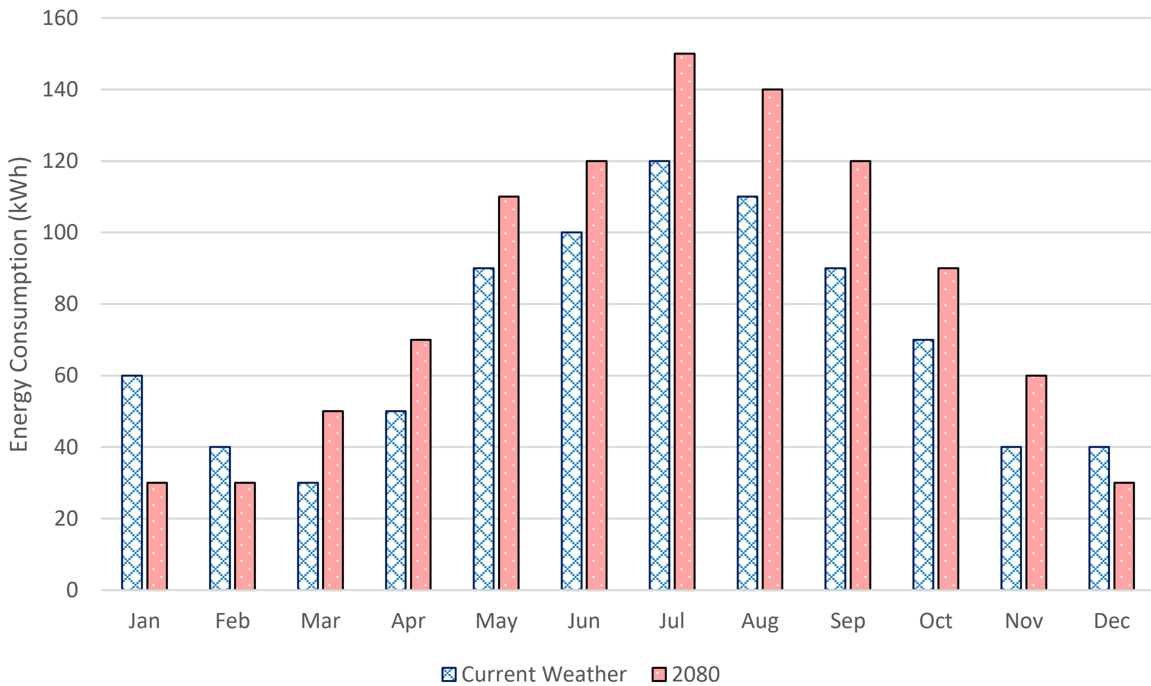

Figure 8-Current monthly vs. future monthly energy consumption comparison in Baghdad with design interventions

Interventions for Mosul's model

Predicted simulations for Mosul showed a significant reduction in primary energy consumptions for heating and cooling after implementing the design interventions. The design interventions included the utilisation of air infiltration values ranged from (0.6 – 1.0) ACH in conjunction with enhanced U-values for the building envelop. The primary energy consumptions in Mosul were reduced by 55% and 46% for current and future weather conditions respectively (See Figure). As such, the heating and cooling energy demands for current and future conditions were projected to be 33.70 kWh/m^2 and 34.26 kWh/m^2. To keep the carbon emissions within the narrow confines of nZEB threshold, an additional 37m^2 of PV were added to achieve 9.36 KgCO$_2$/m^2 of annual carbon emissions. For 2080 weather scenario, an increase in primary energy consumption were anticipated therefore, to offset this, an additional of 40m^2 PV were added to the model to achieve 10 $KgCO_2/m^2$. Following the addition of PV in the reported annual energy consumptions for were 4.83 kWh/m^2.year and 13.14 kWh/m^2.year for current and future weather scenarios.

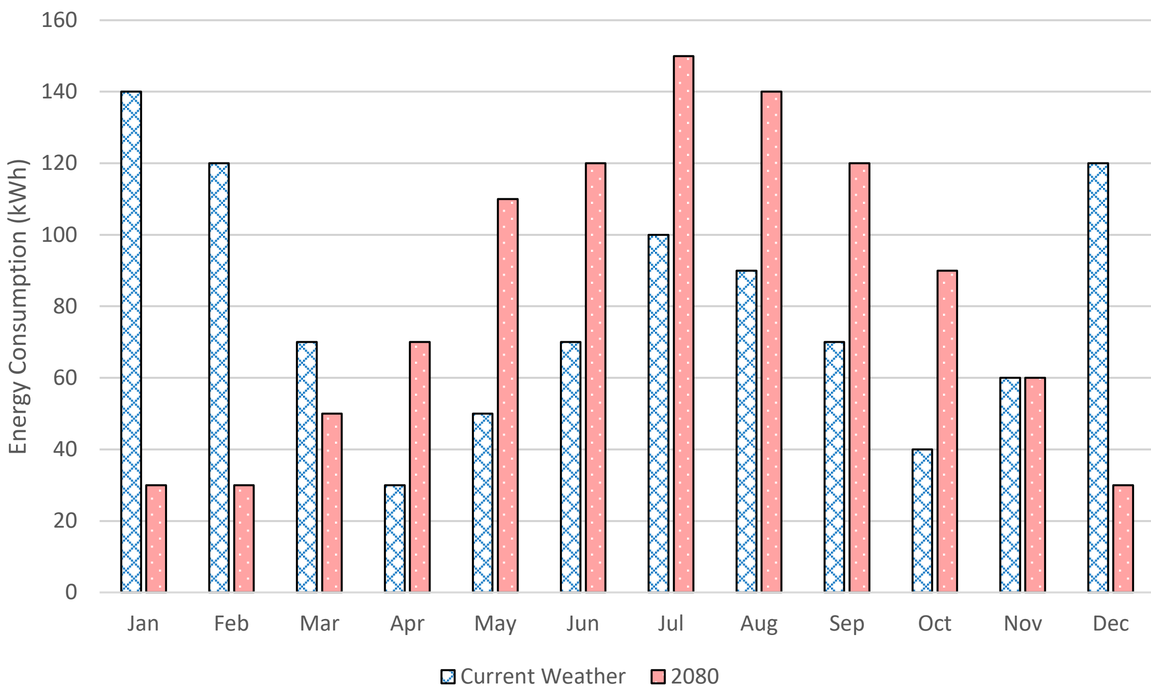

Figure 9-Current monthly vs. future monthly energy consumption comparison in Mosul with design interventions

Interventions for Basra's model

The design interventions implemented for the simulated model in Basra were comprised of low U-value and airtightness values ranged from from (1 to 0.7) ACH. These interventions contributed to reducing the annual energy consumptions to 50.56 kWh/m^2 and 58.42 kWh/m^2 representing 41% and 40% for current and 2080 weather scenarios (as shown in Figure). Whilst the heating and cooling energy have been found to be 30.33 kWh/m^2.yearand 38.20 kWh/m^2.yearunder similar weather scenarios. On the other hand, the carbon emissions were found to be within the less than the required threshold of nZEB. The total carbon emissions for current were reported as 9.90 $KgCO_2/m^2$ with 35m^2 area of utilised Pv on-site. While the carbon emissions for 2080 were projected to be 11 $KgCO_2/m_2$ with an area of 45m^2 of PV. The energy performance of buildings improved significantly after the installations of PV, which subsequently led to improvement in primary energy consumptions for 2080 with 5.22 kWh/m^2.year compared to 16.70 kWh/m^2.year for a current weather scenario.

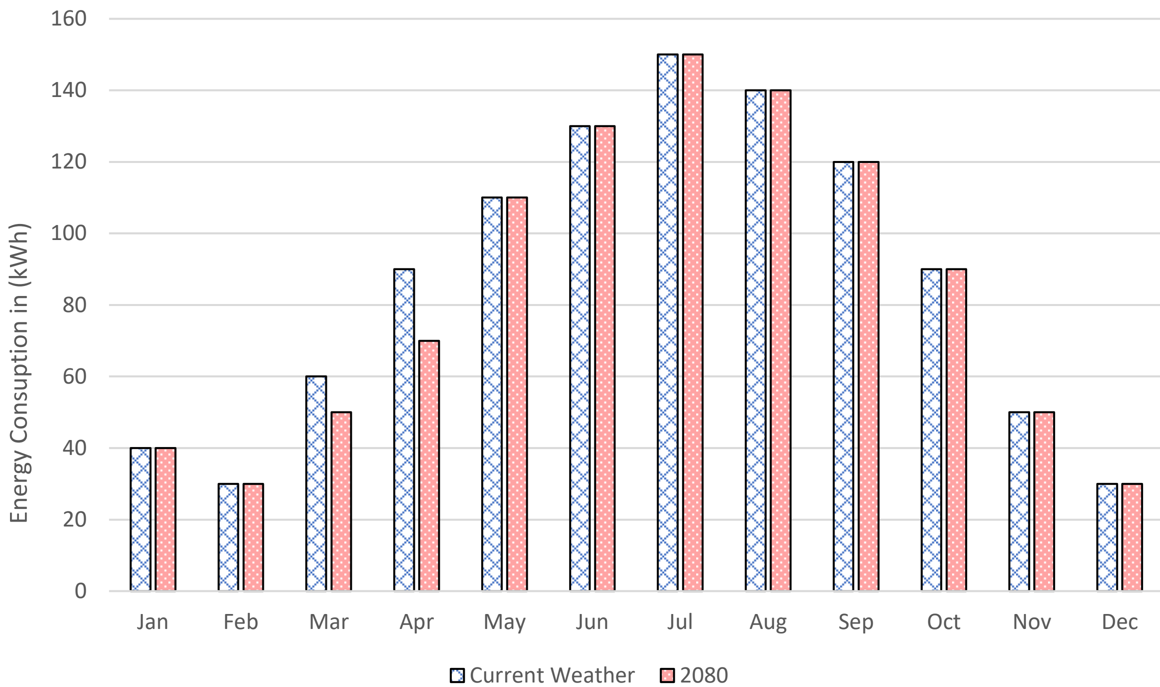

Figure 10- Current and future monthly energy consumption for the house model in Basra with design interventions

Operational cost analysis and savings

The operational costs of all simulated scenarios were analysed for the three case studies: Baghdad, Mosul and Basra. The calculations for the operational costs were determined through comparing the monthly energy consumptions of kWh recorded for each simulated scenario with electricity price quotation from the Iraqi ministry of electricity (Shafaaq, 2016). In some of the simulated scenarios the generated energy from the PV exceeded the building energy consumption, therefore, a numerical value of 0 was assigned to these months to indicate the building with no energy consumption from the national grid. There is currently no policy or established mechanism for selling electricity to the national grid in Iraq, therefore, the cost of selling the excessive energy to the grid has not been considered yet. The analysis for for the base case model in Baghdad showed the highest operational cost for 2080 with an estimated cost of $228.71. However, improving the building fabric and utilising the PV on the roof contributed to reduce the energy consumption significantly for 2080 scenario in Baghdad, as demonstrated in Table 5.

Month	Baghdad typical year (south orientation) and no intervention	Baghdad typical year (south orientation) with building envelope intervention	Baghdad typical year with building envelope intervention and PV	Baghdad in 2080 with no intervention	Baghdad in 2080 with building envelope intervention	Baghdad in 2080 with building envelope intervention and PV
Jan	34.52	4.32	4.32	8.63	4.32	0.00
Feb	8.63	4.32	0.00	8.63	4.32	0.00
Mar	4.32	4.32	0.00	4.32	4.32	0.00
Apr	8.63	4.32	0.00	8.63	8.63	0.00
May	17.26	8.63	4.32	34.52	17.26	4.32
Jun	34.52	8.63	4.32	34.52	17.26	4.32
Jul	34.52	20.71	8.63	34.52	17.26	8.63
Aug	34.52	18.99	4.32	34.52	17.26	4.32
Sep	17.26	7.77	4.32	34.52	17.26	4.32
Oct	8.63	6.04	4.32	17.26	8.63	4.32
Nov	4.32	3.45	0.00	4.32	8.63	0.43
Dec	17.26	3.45	0.00	4.32	4.32	0.00
Total	224.39	94.94	34.52	228.71	129.46	30.64

Table 5-Operational cost represented by electricity bill in USD for Baghdad's simulated scenarios

The operational energy costs for all scenarios in Mosul were shown in **Error! Reference source not found.**, the highest annual operational cost was reported as $250 for current weather condition using the base model. The building fabric and PV interventions reduced the current annual operational energy by 55% and a further 81% accordingly. It was apparent from the compared operational values that the lowest energy consumption was recorded in 2080 scenario with an estimated annual cost of $18.78, which was 92% less compared with the base model prior to the design interventions. The reason behind achieving that low operational cost for 2080 was mainly caused by reducing the heating demands in winter while increasing the surface area of PV as shown in **Error! Reference source not found.**.

Month	Mosul's model for typical year with no intervention	Mosul's model for typical year with building envelope intervention	Mosul's model for typical year with building envelope intervention and PV	Mosul's model for 2080 with no intervention	Mosul's model for 2080 with building envelope	Mosul's model for 2080 with building envelope intervention an PV
Jan	34.52	17.26	8.63	34.52	2.59	0
Feb	34.52	17.26	8.63	17.26	2.59	0
Mar	8.63	8.63	4.32	4.32	4.31	0
Apr	8.63	4.32	0.00	8.63	6.03	0
May	17.26	4.32	0.00	17.26	18.96	2.23
Jun	17.26	8.63	4.32	34.52	20.68	2.77
Jul	34.52	8.63	4.32	34.52	25.86	5.28
Aug	34.52	8.63	4.32	34.52	24.13	4.31
Sep	17.26	8.63	0.00	17.26	20.68	2.78
Oct	4.32	4.32	0.00	4.32	7.76	0.95
Nov	4.32	4.32	4.32	4.32	5.17	0.46
Dec	34.52	17.26	8.63	34.52	2.59	0
Total	250.28	112.20	47.47	245.97	141.35	18.78

Table 6-Operational cost represented by electricity bill in USD for Mosul's simulated scenarios

The simulation for Basra on the other hand, showed that annual operational costs for typical year with no building interventions were the highest compared with Mosul and Baghdad. Employing PV on the roof as well as optimising the building fabric for Basra reduced the operational cost for current scenarios by 78% which was the lowest cost recorded among all scenarios for this city as illustrated in Table 7.

Month	Basra model with no intervention for typical year	Basra's model for typical year with building envelope interventions	Basra's model for typical year with building envelope interventions and PV	Basra's model for 2080 with no intervention	Basra's model for 2080 with building envelope intervention	Basra's model for 2080 with building envelope intervention with PV
Jan	3.45	8.63	4.32	8.63	4.32	0
Feb	8.63	4.32	0.00	8.63	4.32	0
Mar	4.32	4.32	0.00	4.32	4.32	0
Apr	8.63	4.32	0.00	8.63	8.63	4.32
May	17.26	8.63	4.32	34.52	17.26	4.32
Jun	34.52	17.26	4.32	34.52	17.26	8.63
Jul	34.52	17.26	8.63	34.52	17.26	8.63
Aug	34.52	17.26	8.63	34.52	17.26	8.63
Sep	17.26	17.26	4.32	34.52	17.26	8.63
Oct	8.63	8.63	4.32	17.26	8.63	4.32
Nov	8.63	4.32	0.00	4.32	4.32	0.00
Dec	17.26	4.32	4.32	4.32	4.32	0.00
Total	197.64	116.51	43.15	228.71	125.14	47.47

Table 7-Operational cost represented by electricity bill in USD for Basra's simulated scenarios

Comparisons with energy codes

It was imperative to compare all three simulations due to the various codes and international nZEB standards from (ASBEC, 2011; Taleb and Sharples, 2011) study. Some of these countries with nZEB standards have not specified the target for the primary energy consumptions that ought to be achieved in the near future. Whereas, some countries such as Ireland and Austria focused on increasing the percentage share of renewable resources with 35% and 56% to offset the energy consumptions. Little is known on how these standards affect the buildings of the near future. Therefore, a comparison was established to highlight the variance between these nZEB codes. The level of improvements for the international standards ranged from (0 to 120 kWh/m^2.year) for current weather conditions with an average of 60 kWh/m^2.year as shown in **Error! Reference source not found.**. The implemented solutions for Baghdad, Basra and Mosul showed achieving nZEB standards was possible in Iraq can even having a positive climatic effect by producing more energy than consumed in some simulated scenarios, as shown in Figure 11. Hence implementing the suggested solutions for nZEB buildings in hot climates particularly in Middle East (with similar construction materials used in Iraq) can improve the buildings energy performance and transform them into a climate positive building in the future weather scenarios.

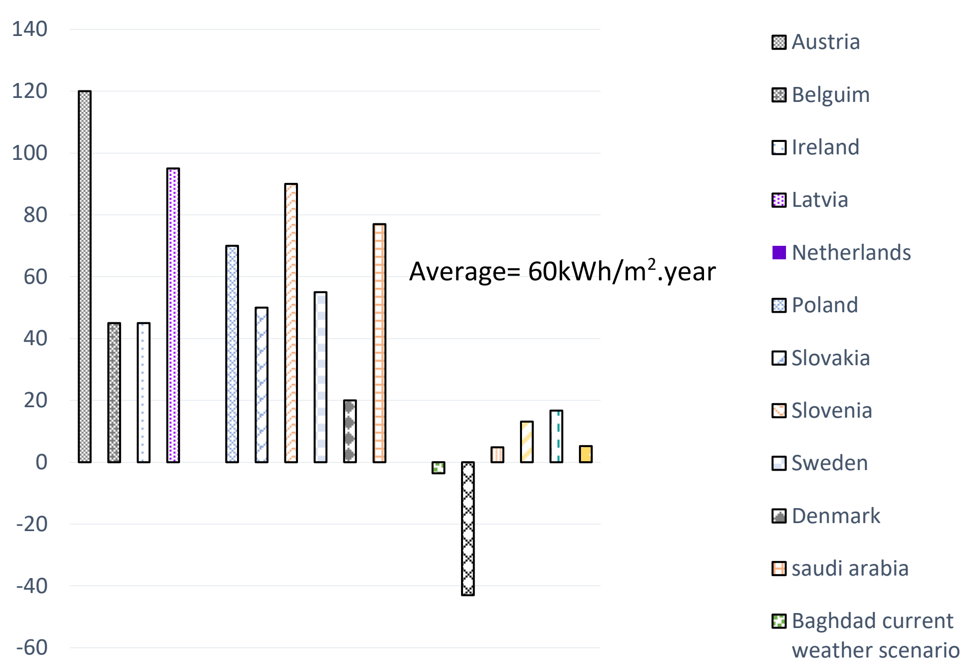

Figure 11-Comparisons of established international nZEB codes in the world

CONCLUSION

For Middle-Eastern territories improving building energy efficiency and onsite renewable energy production can go a long way to achieving many of the UN's outlined SDG's particularly in countries such as Iraq facing unprecedented heat waves in the next 80 years. Iraq has had significant economic social and environmental ailments least of which includes an energy demand crisis. Iraq, dogged to incrementally develop in the aftermath of conflict and an energy crisis, requires new measures to enable more sustainable and self-reliant energy efficient residential dwellings in the near future to withstand extremities of temperature increases. Such future dwellings of Iraq can be achieved by simple measures of building design to achieve nZEB standards to enable more self-reliant dwellings.

Under current and projected future climatic conditions - this paper examined hypothetical and simulated thermal modelling strategies for attaining nZEB standard of building performance improvements in three climatic zones in Iraq. With an absence of low-energy rating system or guidance for nZEB application in Iraq this study has sought to create the early standard guidelines for such in a typical residential dwelling in Iraq.

An existing case study building in Baghdad has been used as a basis for developing the typical dwelling as a virtual model within IESVE software and geo-locating this model to two other Iraqi cities, of Mosul and Basra. Energy performance analysis has been carried out for the current and future climatic conditions of 2080. After the recommended improvements, the predicted results reveal that under current climatic conditions the primary energy consumption for nZEB in the three climatic zones of Iraq ranges from 16.70 kWh/m2.year to –3.58 kWh/m2.year which suggests that it is feasible to achieve nZEB standard and positive energy buildings under current climatic conditions in all three zones. The overall energy consumption for 2080 climate ranges from 13.14 kWh/m2.year to -43.47 kWh/m2.year, demonstrating the possibility to achieve nZEB target under both current and projected future climatic conditions.

The findings from the study demonstrate that to achieve a unified nZEB building standard for Iraq, the following considerations should be made during design and construction based on the corresponding geographical location:

1. Building envelope in all three cities should have (roof U-value= 0.27 W/m^2. K, external wall & roof U-value= 0.13 W/m^2. K for);
2. The optimum air infiltration for all three cities should be (0.6 ACH for Mosul, 0.7 ACH for Basra and 0.4 ACH for Baghdad);
3. PV oriented to the south and tilted to 34° with for all three cities based on its geographical location and orientation to meet the carbon target for the nZEB standards;
4. Glazing U-value for all three locations should be 0.8 W/m^2. K

The estimated operational cost reveals that all buildings with current construction materials have high operational costs, the highest operational cost being in Mosul under current climatic conditions due to high heating demands in winter. All annual operational costs showed significant reductions for all cities after improving the building envelope efficiency and the application of on-site PV systems. The estimates of operational costs assume that all residents rely upon grid electricity, however presently majority of building residents use on-site diesel or petrol generators to overcome shortage of electricity in Iraq. This study provides an embryonic roadmap for future building owners and policy makers to implement and specify nZEB standards for residential developments in Iraq. In achieving this aim, more sustainable and resilient residential buildings can be introduced to these regions to withstand current and potential future climatic changes. This study has inherent methodological limitations, albeit it forms as bourgeoning research in nZEB strategies for three climatic regions in Iraq. Key limitation of this study include the exclusion of any social, economic and political factors that may influence future adoption of nZEB in Iraq. Authors hope to establish a nascent movement of research in this domain to motivate policy makers and building owners and occupants to take active measures in applying best practice from nZEB to craft more energy efficient and resilient buildings in Iraq, a country with an already fragile resource scarcity.

However, even nZEB standards alone cannot guarantee total immunity for residential dwellings from extreme climatic conditions of the near future in the Middle-East so future research is required to: improve understanding of policy change in developing countries facing growing energy demands in extreme climates; address the specific operational changes in residential dwellings currently plausible in Iraq; address the current dependency upon on-site diesel or petrol generators; analysis of social, economic and political barriers to nZEB in Iraq; and consolidate greater international oversight of Middle-Eastern residential construction methods and design of new build developments.

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