Future Cities and Environment

Energy Optimization for Affordable Housing via Microclimate and Energy Simulation, Case Study: Bashayer El Kheir 1, Alexandria, Egypt

TECHNICAL ARTICLE

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ABSTRACT

Nowadays, the residential sector consumes around 47% of all electricity production. The current need is to maximize the energy efficiency on the affordable housing, while the Egyptian government is focusing on constructing a large concrete block without concerning the environmental impact or energy efficiency. Combining the microclimate and building energy simulation results by testing them in the existing and futuristic climatic conditions. For microclimate scenarios the blue infrastructure shows the maximum air temperature reduction by 1.05 OC in the existing climatic conditions and 2.65 OC with the highest values of relative humidity, the combination of blue and green infrastructure shows average reduction by 1.02 OC in and 2.05 OC in existing and futuristic climatic conditions respectively, and the green infrastructure has the least effect of reduction by 0.7 OC and 1.30 OC. according to the building energy simulation, the tested retrofitting scenarios shows the highest energy reduction value by 11.34% for the wall insulation, 7.30% for double glazing, 6.65% by improving air infiltration, 5.07% for solar shading and 3.20% for the roof insulation. Estate developers required to present these settlements as Competitions for specialists in different fields respecting all the environmental aspects and the aesthetic values regardless the social levels.

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INTRODUCTION

Reducing the overall energy required for a building's functioning is the aim of energy-efficient construction. High-performance buildings are designed to improve the comfort of its inhabitants in regards to temperature, lighting, and sound. Identifying ideas and techniques to enhance building energy efficiency and general building performance can be aided by measurable estimations (Aksamija, 2012).

In a congested metropolis, a building's energy efficiency is quite influenced by its environment. At the Urban Canopy Layer, the influence of the built environment, along with anthropogenic heat gains from transportation and building HVAC exhaust, influences the exterior ambient conditions (Jianxiang Huang et al., 2020). The ability of current building energy models to accommodate for the micro-scale fluctuations in the urban microclimate, which can drastically alter a building's energy performance in large metropolitan areas, is restricted (Rajashree Kotharkar, 2016).

In order to evaluate the time-varying energy performance of a group of constructions and the coupled thermal mass to the exterior space from direct and reflected solar radiation, traffic, and the exhaust from Ventilation systems in a metropolitan cities, the Urban Building Energy and Climate (UrBEC) model, a coupled urban microclimate model (UMM) and building energy model (BEM), has been developed (Asser Elsheikh et al., 2021).

Building energy modelling (BEM) tools have undergone significant improvements over the past twenty years, including improved interconnectivity, convenient default data input, and increased template usage. These changes were made to address challenges faced by architects and expand the use of BEM tools in the field of architecture (Mahgoub, 2020). Thus, a seamless data exchange mechanism between chosen Building Information Modeling (BIM) tools for architects and preferred BEM tools for engineers is required. Furthermore, if a smooth data exchange method is implemented between BIM and BEM systems, a significant duration and expenditure savings could be accomplished (US Department of Energy, 2022).

Object-Oriented Modeling techniques have been developed to facilitate the ability to employ multi-domain simulations effectively. The modelling of dynamic behaviors utilizing differential algebraic equation (DAE)-based calculations is facilitated by employing OOPM, a rapidly expanding study field that offers structured and equation-based modelling tools (Fritzson, 2014). The goal of the OOPM technique is to provide virtual prototyping for the quick evaluation of various concepts based on adding models or extracting subsystem models from the building energy systems [8]. OOPM approach aims to support virtual prototyping for the rapid evaluation of different concepts based on quickly adding models or extracting subsystem models in the building energy systems.

Although it has been proven and is still being developed, it is still challenging to consistently produce high-quality BEM with the tools available today. Even though a large portion of the process is automated, users can nevertheless simplify models, select among representations with slight variances, and fix errors (Zahra Pezeshkiet al., 2019).

CASE STUDY METHODOLOGY

Generating methodology of the case study applied in four phases. By combining the microclimate model ENVI-met with the building energy model Design builder. This methodology applied through the methodology workflow as shown in Figure 1.

1. Phase one: Climatic data formulating through two different softwares. First software is "weatherShift™" tool in order to generate the futuristic weather data. Second software is climate consultant tool in order to generate the existing weather data. Selecting California Energy Code Comfort Model, 2013.
2. Phase two: Micro climate simulation through ENVI-met software, visualizing the results through LEONARDO (employs by ENVI-met headquarter), simulating the boundary layer. Applying three different scenarios compared to the existing situation.
3. Phase three: Building Energy Simulation using Designbuilder, which employs Energyplus, analysing the results through two main axis the first axe is the energy outputs and the second axe is the meteorological axe. Applying five different retrofitting scenarios.
4. Phase four: Testing the most energy efficient retrofitting scenarios through feasibility study of Life cycle cost analysis by the NPV tool of energy consumption In order to fulfil the triple constraints in project management to achieve the ideal acquisition Cost model

CASE STUDY DESCRIPTION

Bashayer El Khier (1) is a residential complex attached with many social services located in Gharb district in Alexandria, Egypt (31°10`27.66"N, 29°53`48.86"E). The complex purpose is to replace a slum area located in "Ghett El Ennab" neighborhood in Gharb district. Bshayer El Khier (1) designed and implemented by the Engineering Authority for the northern military region (EA NMR) in Alexandria from 2014 to 2016 as shown in Figure 2. The complex meets the political and national vision for

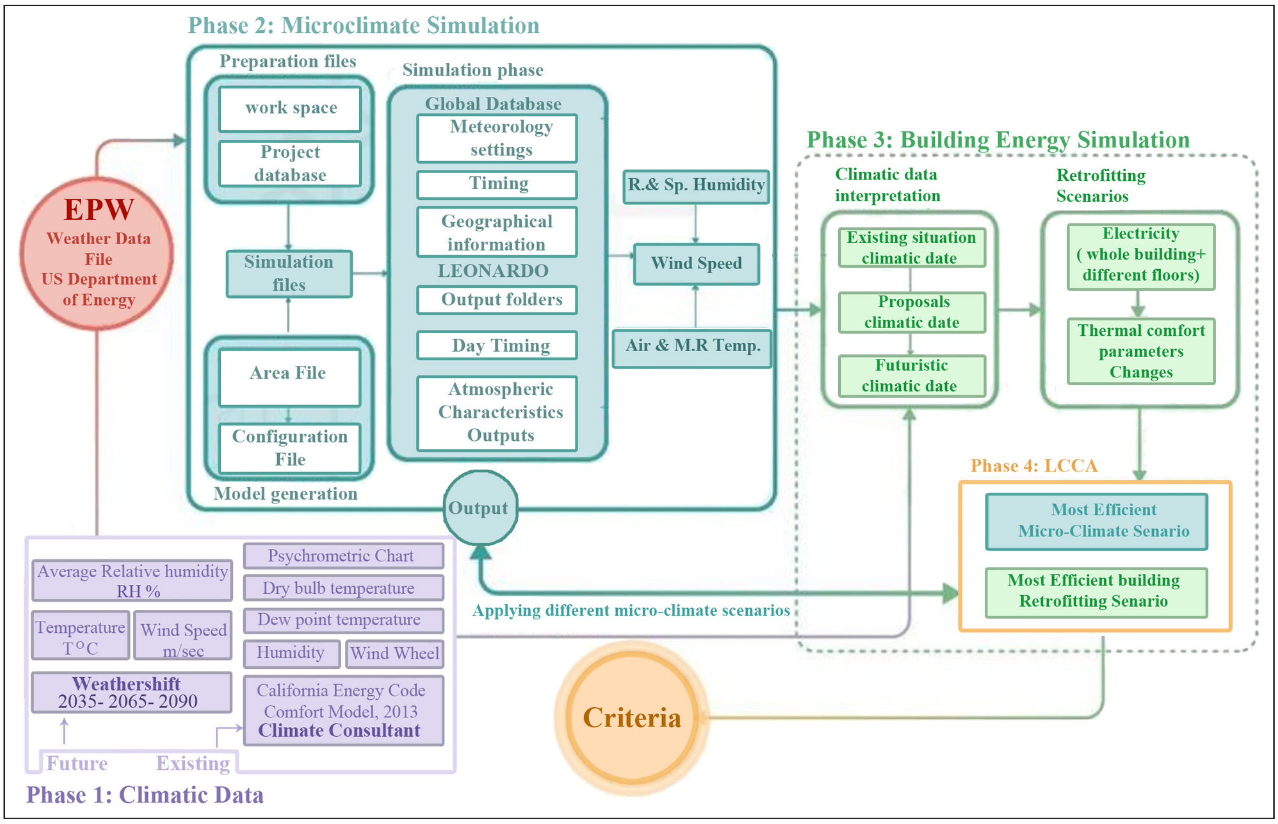

Figure 1 Workflow of methodology description.

Figure 2 Ghett El Ennab befor development (Left side), Bashayer El Kheir 1 (Right side).

demolishing slums and mobility of the residents into a planned complex affordable for low-income citizens.

Bashayer El Khier (1) consists of two main zones, first one is the residential zone that overlooks from north on a residential area, primary schools and preparatory schools and the second one is the service zone that overlooks from north on the extension of Bashayer El khier (2), also these zones overlays between El-Mahmoudia highway from north that is currently under development while the canal backfilled and planned to be a highway and the water stream delivered through pipes beneath it which has been done by 2018, and from south overlooks on a goods railway, From east overlays on a farz street with width of 17 m that overlooks on the rest of Bashayer el khier (2) and Armed Forces yard in Ghett El Ennab.

From west Bashayer el khier (1) over looks on a vacant land on which there are disputes between ministerial bodies on it and still not planned as shown in Figure 3.

Bashayer El Khier (1) total area is 51,743 m², the residential complex is about 70% of the total area which is 36,280 m², contains 17 block, consist of ground floor level and 11 floors all blocks have the same layout. Blocks (1, 2 & 3) ground floor level dedicated for Charity work (Real estate office, orphanage, nursery, special needs association, post office, project management and maintenance office). The total area of the residential blocks is 90 m² × 1632 which is equal 146,880 m² with footprint 35% of the residential complex area and the other 65% represent site configurations (green spaces, pass ways and asphalt roads).

Each block area is 720 m² divided into two buildings with area 360 m² and each building consist of 4 apartments each one consists of 3 bedrooms, kitchen, toilet and reception with total apartment area 90 m² as shown in Figure 4, the total number of apartments in each block is 96 unit, the whole units at Bshayel El Khier

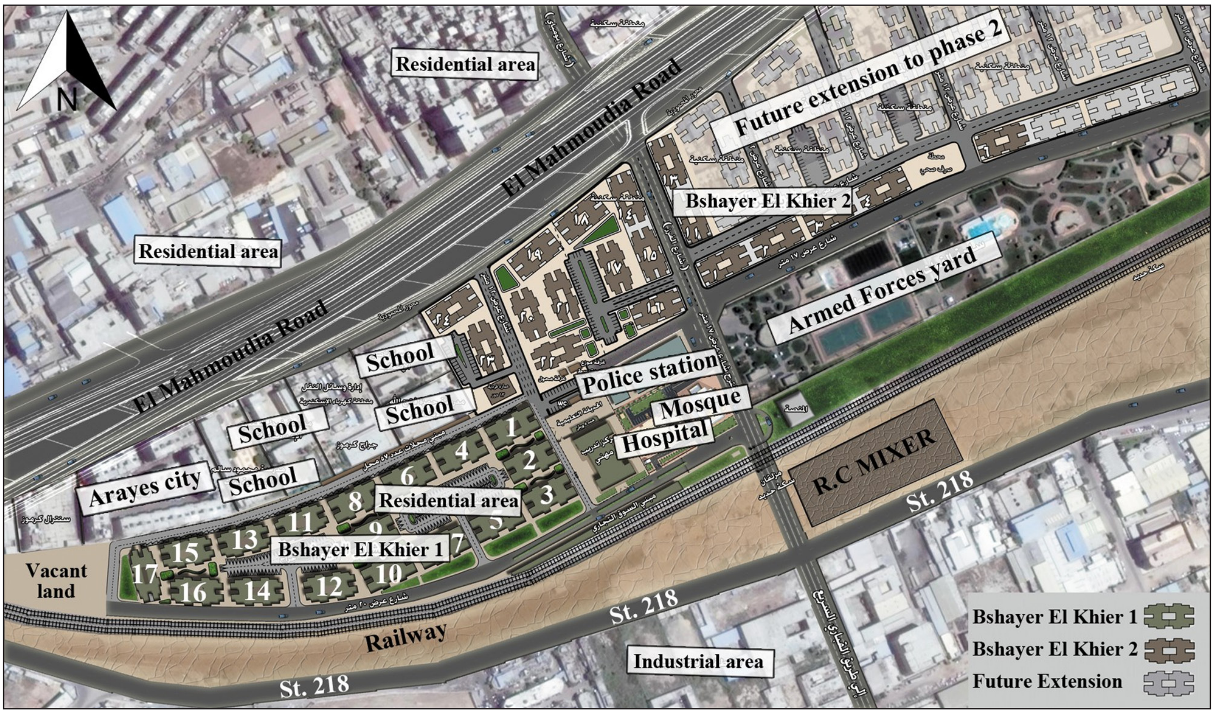

Figure 3 Master plan for Bashayer El Khier (1&2) and the future extensions.

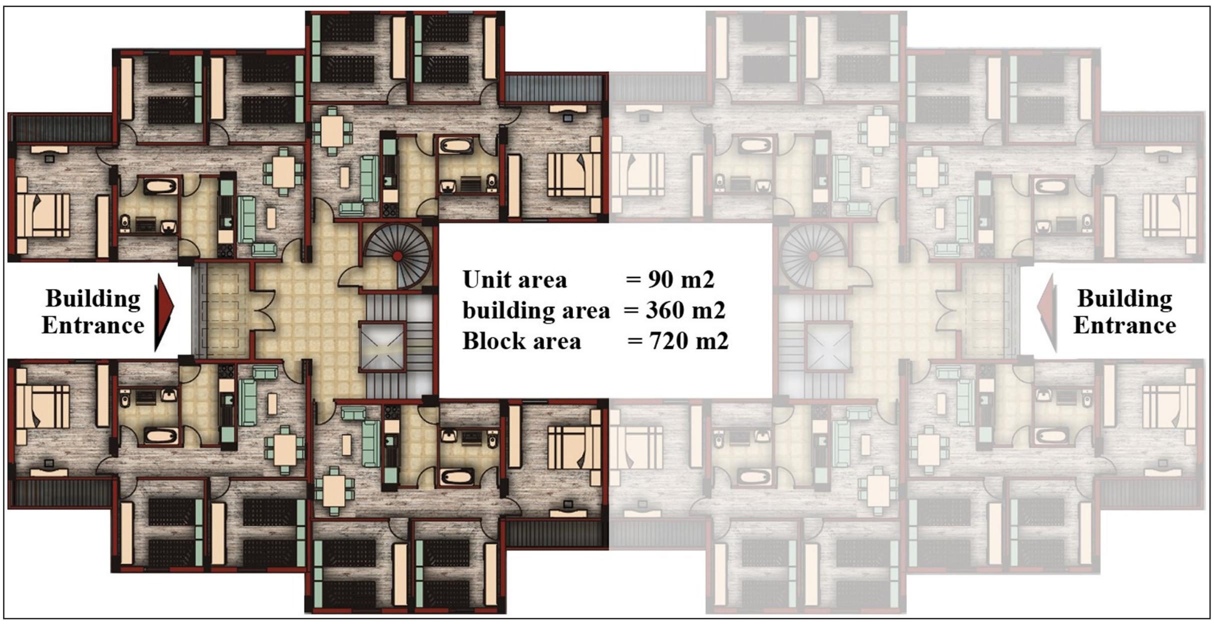

Figure 4 Bshayer El Khier (1) inner and aerial views.

(1) is 1632 unit all occupied with expected capacity for each unit is 5 person/family. That makes the whole area population Capacity 8160 person with urban density 1/4.8 (P/m^2) from the whole area and 1/2.9 (P/m^2) from the residential zone.

PHASE ONE: CLIMATIC DATA

Building and infrastructure built today will experience significantly different weather patterns over the course of the 21st century due to the impact of climate change. Weather data in the EPW (Energy Plus Weather) file format downloaded from the US Department of Energy's EnergyPlus site applied on two different softwares in order to get the futuristic and existing weather data.

FUTURISTIC WEATHER DATA

Generating the Futuristic weather data using the "weatherShift™ tool" through online website which is available at (http://www.weather-shift.com/), using data from EPW file, applying the RCPs 8.5 (Representative Concentration Pathways) which are greenhouse gas emission scenarios for the 21st century that result in the CO_2 equivalent atmospheric concentrations, that would be an additional 8.5 W/m^2 of heating in 2100. The scenarios were created by the Intergovernmental Panel on Climate Change (IPCC) as a basis for the climate projections done for its Fifth Assessment (AR5).

Alexandria is characterized as a hot arid climate and located in northern coast climatic zone according to the Egyptian Residential Energy Code, the average temperature with approximately 25°C that drops to 17°C at February and reaches to 30°C at August at the present, also WeatherShift™ tool generated a future predicted weather till 2090 showing the increasing of temperature by average 2°C for each quarter century.

As Alexandria is a coastal city, it extends about 32 km along the Mediterranean Sea, the level of Relative Humidity is relatively high representing an average of 70% within the range between (55% – 80%) at the present however the sea breeze keeps the moisture reachable to a comfort level, also showing a slightly decreasing of humidity percentage till 2090 between (60% – 72%).

EXISTING WEATHER DATA

Generating the existing weather data using climate consultant software using same data from EPW file, selecting one of four Comfort models. Each one has its own Criteria and modifies the way comfort is shown on the Psychrometric Chart.

By selecting California Energy Code Comfort Model, 2013, For the purpose of sizing residential heating and cooling systems the indoor Dry Bulb Design Conditions should be between (20°C) to (23.9°C). No Humidity limits are specified in the Code, so 80% Relative Humidity and (18.9°C) Wet Bulb is used for the upper limit and (–2.8°C) Dew Point is used for the lower limit.

Prevailing wind direction in Alexandria is north–west, with average wind speed (4.7 m/sec), there is also a phenomenon wind blows across the country in spring from south east also known as (khamasin) this wind carrying a large amount of dust and sand came from the desert, it's speed could reaches up to 38.9 m/sec that appears between February to June each year consists of 5 to 6 waves. Alexandria lies on 13m above sea level. About 183 mm|18 cm of precipitation falls annually. January is the wettest month, and on average, August is the driest month.

Psychrometric chart generated by the climate consultant software shows the areas of occupant's thermal comfort highlighted by different colours as shown in Figure 5, also showing the relation between the dry bulb temperature on X-axis and humidity ratio on

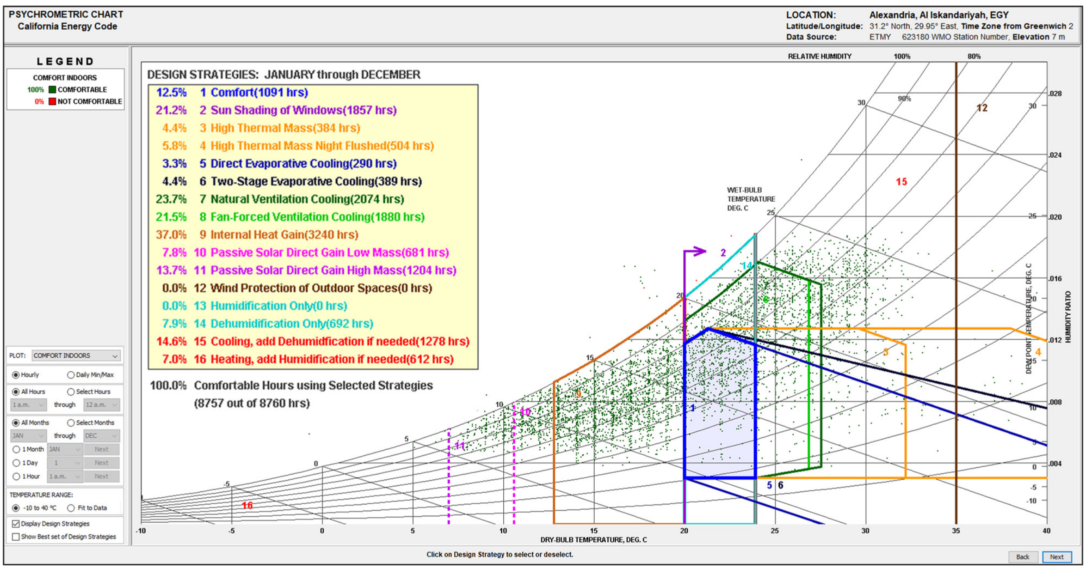

Figure 5 California Energy Code Comfort Model, 2013.

Y-axis, also shows the relative humidity as a curves and a wet bulb temperature on a diagonal lines.

Climate consultant offers a various design strategies based on the EPW file, all strategies have a percentage based on the comfortable hours through the 8760 hour of the year with the highest percentage is 37.0% internal heat gain, 23.7% for natural ventilation cooling, 21.5% fan forced ventilation cooling, and 21.2% sun shading of windows.

PHASE TWO: MICROCLIMATE SIMULATION

According to Energy simulation, the Second phase as mentioned before, the case study area was simulated through different scenarios considering the vegetation, landscape and water bodies, using ENVI-met software, the simulations take part through the Boundary layer quantified by a time series records of air temperature, these scenarios tested via same strategic method as shown in Figure 6.

Envi-met software requires the preparation files to specify the work space through main two folders. Also it needs creating of main two input files, an area file (.INX) to define the study area buildings, plants, soil and sources and the second file is the configuration file (.CF) that includes the area file combining with the Global Database s and settings.

AREA FILE INDEX DESCRIPTION

The case study area file model created based on the received drawings for the satellite image and the site design with the surroundings from the EA NMR. The total model area 450 m × 310 m that divided into three main zones first zone Bashayer El Khier (1) and the extention for Bashayer El Khier (2), Second zone for the educational services and a residential complex in the north of the first zone, and the third zone is El-Mahmoudia spine. All these zones create with x-Grids: 225 and the y-Grids 155 grid with grid size and structure in main area dx = 2.00 m and dy = 2.00 m creating margin grids recommended by the software, as for the height to include the canopy layer under the umbrella of the boundary layer (as described at chapter two 2.4.1) the maximum building heights 36 m, doubling the maximum building height to 108 m modeled with z-Grid: 27 with grid size of dz = 4.00 m. These numerical statistics defined in order to be below the maximum acceptable grid number for simulation settled by the ENVI-met software which is (250 × 250 × 30 grid).

The geographic properties defined the latitude by 31.13 and the longitude 29.57 also the reference time zone and location for Alexandria/Egypt, the area file through the spaces Component of the ENVI-met headquarter allows to be create the model grid by grid, each grid defined though different characteristics as building, vegetation with two categories of sample plants and 3D plants finally soil and surfaces which

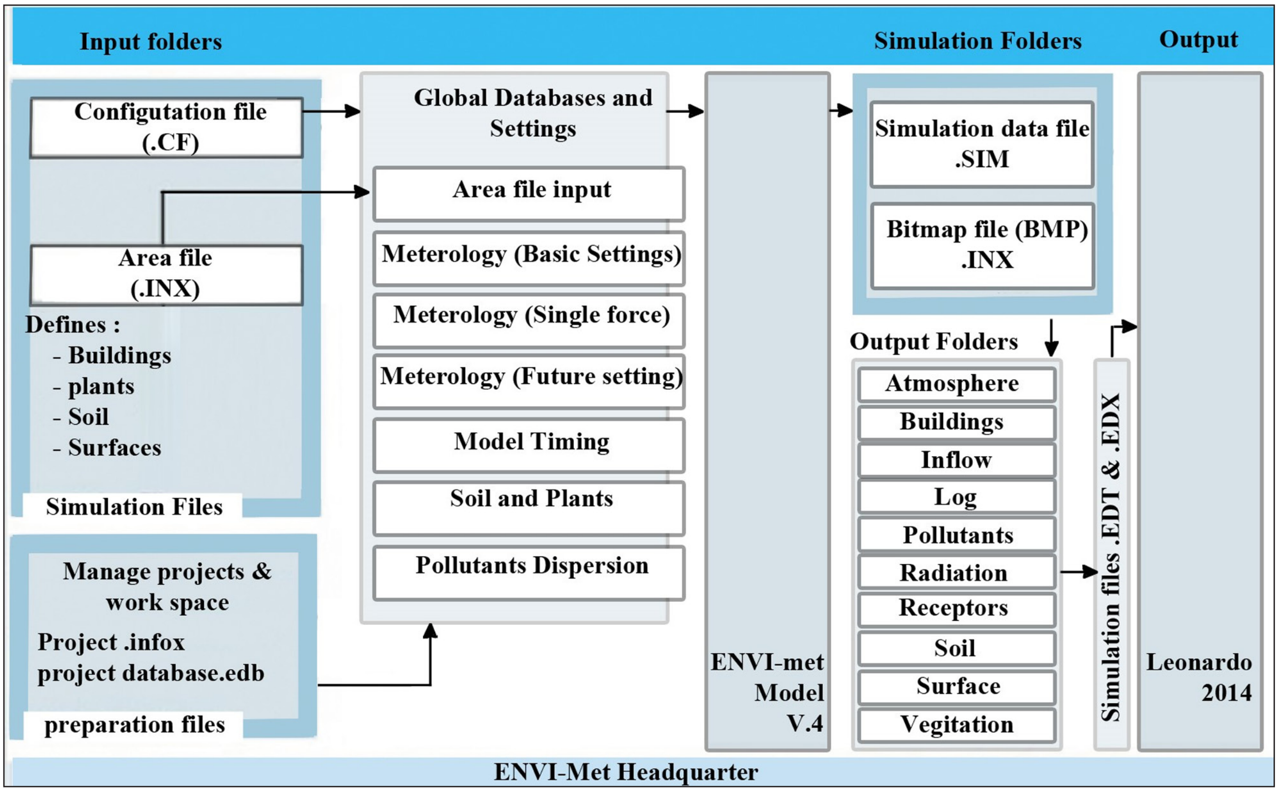

Figure 6 Strategic workflow method via ENVI-met Software.

consists of different profiles such as natural surfaces, roads and pavements, decorative, special surfaces and water. These elements descried in the study area model as shown in Figure 7 for the area existing situation as base case.

MICROCLIMATE RETROFITTING SCENARIOS

A total of 8 scenarios were simulated first 4 in the climatic existing characteristics and other 4 scenarios simulated with the futuristic climatic characteristics, the first proposal is the existing situation of 2020 which represents the base case ($G_{E.X}$). Represents the existing scenario where El Mahmodeya canal covered with Asphalt roads and some loamy and sandy soil, the whole spine is about 85 m width from north to south a 16 m. wide one way asphalt road, 25 m. loamy and sandy soil backfilling, a 32 m. wide two ways asphalt road and 12 m. one way asphalt road.

The second scenario is to replicate the situation before the backfilling of the canal combining the green and water ($G_{G.W}$) to test the effect of backfilling on the urban microclimate, were estimate the green spaces as 1/1.0 (person/m²) on both sides of water canal as ratio of 1:4:1, The third scenario is to replace the 25 m spine with green (G_G) whish estimated as the minimum rate regulated for green open spaces per person according to the Egyptian building law no. 118 of 2008 as 1/3.5 (person/m²). The fourth scenario is to use a water stream (G_W) for the full spine and the two sides are loamy soil, these scenarios shown in Figures 8, 9, 10, 11.

PHASE THREE: BUILDING ENERGY SIMULATION

The selected blocks for this research are blocks 8, 9 and 10, all Bashayer El Khier (1) blocks have the same architectural plans but these three blocks represent a sample for all the 17 blocks as shown in Figure 12.

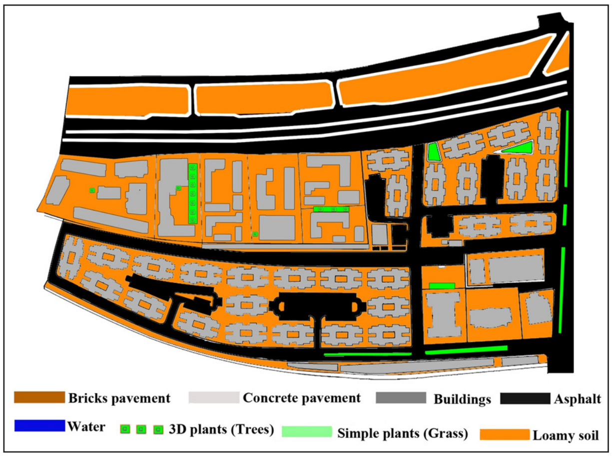

Figure 7 The base case study area existing situation modelled in ENVI-met.

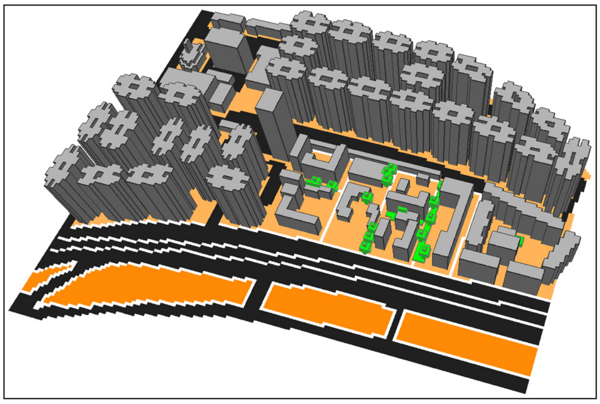

Figure 8 Scenario 1 ($G_{E.X}$) the existing situation of 2020 which represents the base case.

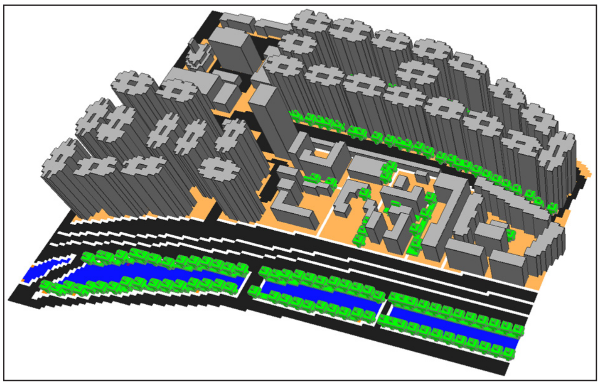

Figure 9 Scenario 2 ($G_{G.W}$) combining the green and blue infrastructures, the green spaces as 1/1.0 (person/m²), with ratio of 1:4:1.

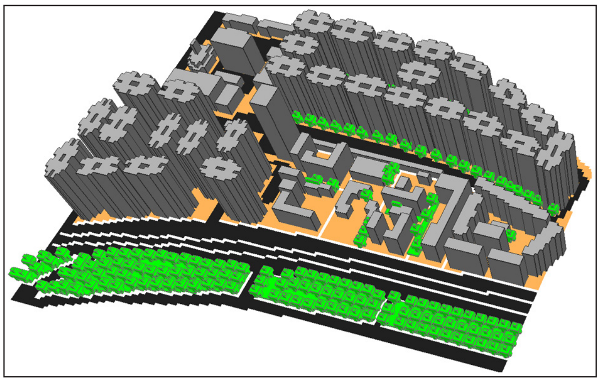

Figure 10 Scenario 3 (G_G) the 25 m spine with green spaces as 1/3.5 (person/m²).

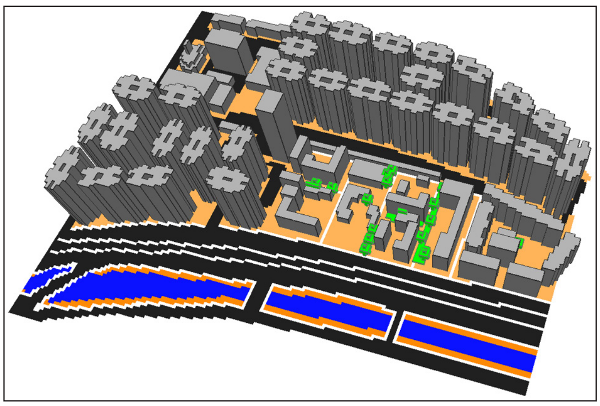

Figure 11 Scenario 4 (G_W) using a water stream with two sided loamy soil.

Figure 12 Selected block for energy simulation.

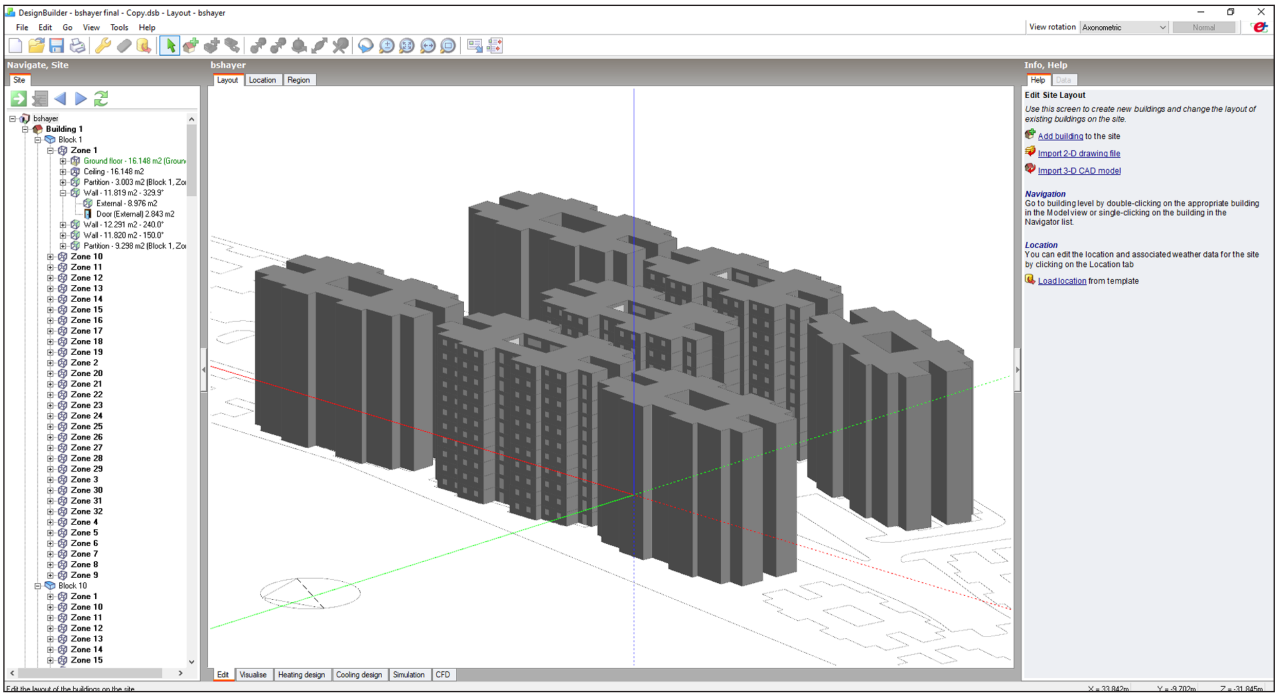

Figure 13 Blocks 8, 9 & 10 with solid surrounding blocks on Designbuilder software.

BLOCK DESIGN DESCRIPTION

According to Energy simulation first pillar as mentioned before, Building shapes and orientation: all blocks in rectangular shapes. Block 8 has 4 apartments facing the north and the other 4 apartments facing the south with a gap between the southern façade of block 8 and the northern façade of block 9 between (7.5 m to 10.5), and the southern façade of block 9 has the same gap with the northern façade of block 10, the last 4 apartment of block 10 facing the south.

Designbuilder software used to Model these three blocks as shown in Figure 13, with the surrounding blocks to test the effect of shading and wind on those blocks' energy consumption.

BLOCK CONSTRUCTION CHARACTERISTICS

All blocks is a typical reinforced concrete skeleton buildings, the external walls are 20 cm brick wall with 2 cm inner plaster and 3 cm outer plaster, the inner partitions are 10 cm brick walls with 2 cm both sides plaster.

Building construction characteristics used in modelling are based on the EA NMR, with their thermal transmittance (U-value) and thermal resistance (R-value), except the doors, windows and floor finishing based on the site observation, all windows are single aluminium framed with 6mm transparent glass with no solar shading elements. All doors are wooden flush doors except the apartment entrance door is a wooden panelled doors and the main building entrance is a steel, glass door.

BUILDING RETROFITTING SCENARIOS

According to Energy simulation first pillar as mentioned before, the building envelope has a significance role affecting the Energy consumption. Simulating the existing situation ($S_{E.X}$) as the model base case. Different retrofitting scenarios are tested as shown in Figure 14.

The tested retrofitting scenarios are: first to reduce the heat transmittance through Exterior wall insulation ($S_{W.I}$), second testing different glazing types ($S_{D.G}$), third adding solar shading devices ($S_{S.S}$) for south and west block facades, fourth enhancing the air infiltration rates ($S_{A.I}$) These retrofitting scenarios applied on the selected 3 blocks, on the block as a whole and on the blocks' ground floor, fifth floor which representing a typical floors. Also adding the roof thermal insulation for the last floor (roof).

MICROCLIMATE AND BUILDING ENERGY OUTPUTS

Using ENVI-met for the micro-climate simulation (M.C.S) and design builder for Building energy simulation (B.E.S) testing different scenarios on each software then combining the results to propose the most energy efficient scenarios, The scenarios results divided into 4 Sets each one consist of 2 groups each set is a combination of M.C.S and B.E.S, the first group in each set testing the existing situation results from ENVI-met to the different Desingbuilder proposals results, as shown in Table 1.

Set A is testing the results of the existing and futuristic results of micro-climate on the study area with no development as it is in 2020, with different building envelope retrofitting scenarios. Set B is testing the results of the green and water effect if it applies on the existing

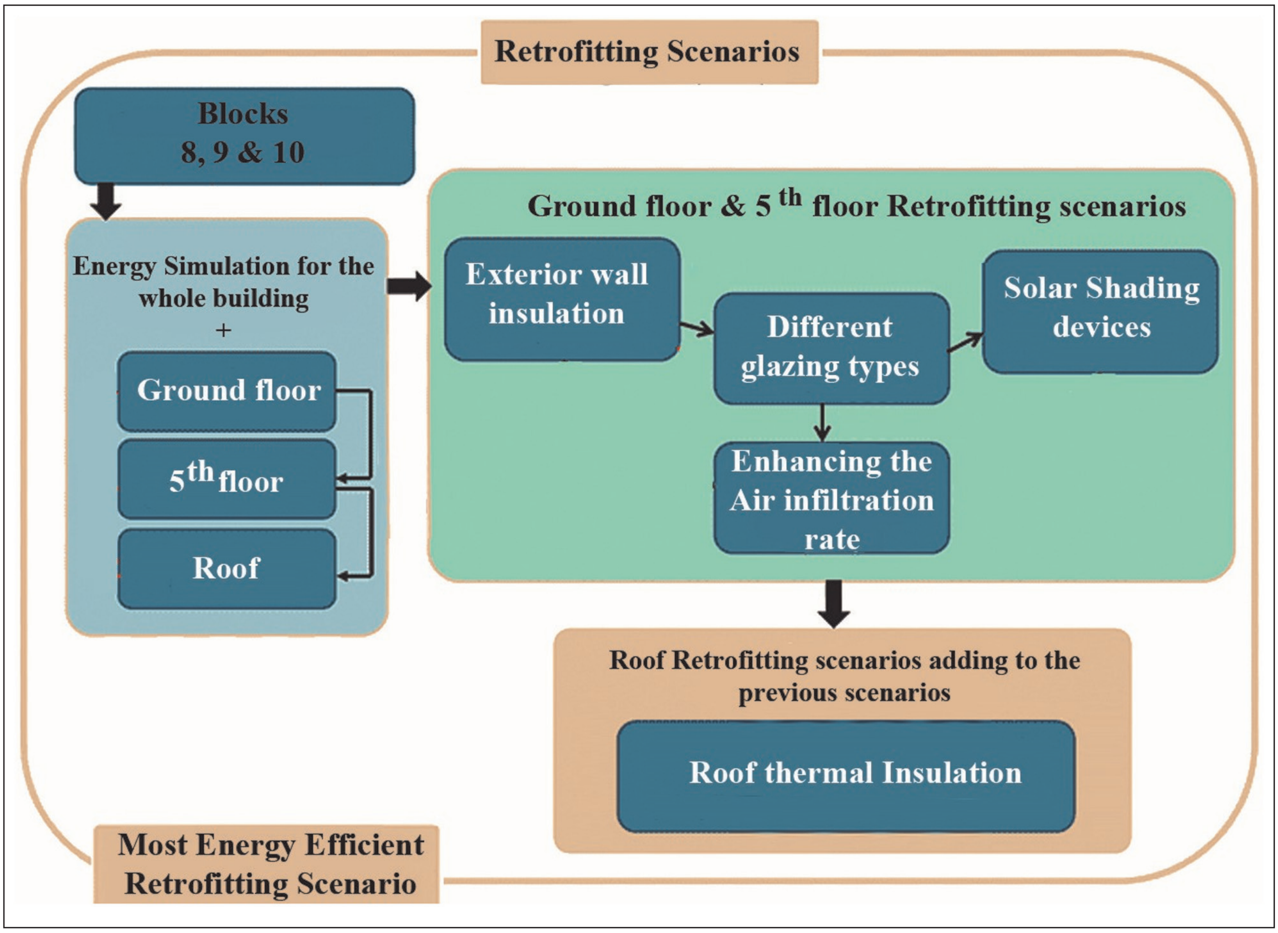

Figure 14 Different retrofitting scenarios applied on blocks 8, 9 & 10.

			SCENARIOS RESULTS COMBINATION					
			SE.X	SW.I	SD.G	SS.S	SA.I	SR.I
Set A		$G_{E.X}$	$G_{E.X}+S_{E.X}$	$G_{E.X}+S_{W.I}$	$G_{E.X}+S_{D.G}$	$G_{E.X}+S_{S.S}$	$G_{E.X}+S_{A.I}$	$G_{E.X}+S_{R.I}$
	$F_{E.X}$		$F_{E.X}+S_{E.X}$	$F_{E.X}+S_{W.I}$	$F_{E.X}+S_{D.G}$	$F_{E.X}+S_{S.S}$	$F_{E.X}+S_{A.I}$	$F_{E.X}+S_{R.I}$
Set B		$G_{E.X}$	$G_{G.W}+S_{E.X}$	$G_{G.W}+S_{W.I}$	$G_{G.W}+S_{D.G}$	$G_{G.W}+S_{S.S}$	$G_{G.W}+S_{A.I}$	$G_{G.W}+S_{R.I}$
	$F_{E.X}$		$F_{G.W}+S_{E.X}$	$F_{G.W}+S_{W.I}$	$F_{G.W}+S_{D.G}$	$F_{G.W}+S_{S.S}$	$F_{G.W}+S_{A.I}$	$F_{G.W}+S_{R.I}$
Set C		$G_{E.X}$	$G_{G}+S_{E.X}$	$G_{G}+S_{W.I}$	$G_{G}+S_{D.G}$	$G_{G}+S_{S.S}$	$G_{G}+S_{A.I}$	$G_{G}+S_{R.I}$
	$F_{E.X}$		$F_{G}+S_{E.X}$	$F_{G}+S_{W.I}$	$F_{G}+S_{D.G}$	$F_{G}+S_{S.S}$	$F_{G}+S_{A.I}$	$F_{G}+S_{R.I}$
Set D		$G_{E.X}$	$G_{W}+S_{E.X}$	$G_{W}+S_{W.I}$	$G_{W}+S_{D.G}$	$G_{W}+S_{S.S}$	$G_{W}+S_{A.I}$	$G_{W}+S_{R.I}$
	$F_{E.X}$		$F_{W}+S_{E.X}$	$F_{W}+S_{W.I}$	$F_{W}+S_{D.G}$	$F_{W}+S_{S.S}$	$F_{W}+S_{A.I}$	$F_{W}+S_{R.I}$

Table 1 Simulation scenarios results Combination.

situation and its effect on the existing and futuristic climatic conditions characteristics. Set C is testing the results of the green effects. Set D is testing the results of the water effects.

ENVI- met simulation running times takes from (20 – 24 days) to simulate all the configuration output files in the best case it will takes 160 days for all the scenarios with all the configuration files, this study is depending on the atmospheric conditions file which takes a simulation running time about 40 hours for each scenario (1.67 days) of total 320 hours which is about (13.3 days) on a 4 processors of intel® core ™ i7-6700HQ CPU @ 2.60GHz and NVIDIA® GeForce GTX 960M.

DISCUSSION OF MICROCLIMATE RESULTS

ENVI-met showed different sensitivity levels across the tested parameters. These parameters are the main indicators for occupants' thermal comfort. These meteorological parameters tested through different scenarios with different environmental aspects, by merging the water and green elements to emulate the previous situation before backfilling of El-Mahmodya canal with improvements to fulfill the legal requirements according to the Egyptian building law no. 118 year 2008, then testing the effect of each one separately as green and blue infrastructure, Simulations take part through the futuristic and existing climatic conditions from EPW weather file for Alexandria, Egypt. According to all scenarios simulated for date 1st August 2020 for all scenarios, the following figures show the meteorological parameters (air temperature, relative humidity, and wind speed) for time 2:00 pm as shown in Figures 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, illustrates Scenario 1 ($G_{E.X}$), Scenario 2 ($G_{G.W}$), Scenario 3 (G_{G}), and Scenario 4 (G_{W}) respectively. These outputs visualized by Leonardo 2014 through ENVI-met headquarter.

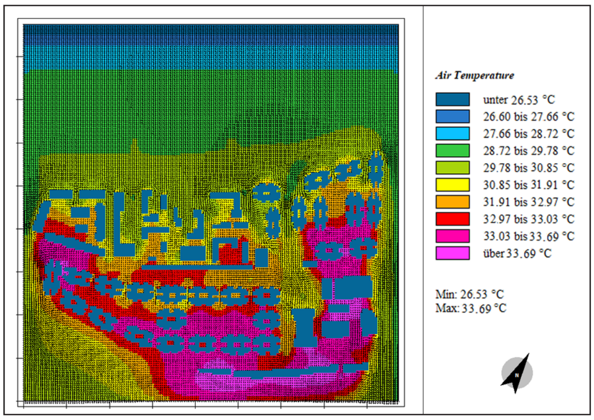

Figure 15 Air temperature for Scenario 1 ($G_{E.X}$).

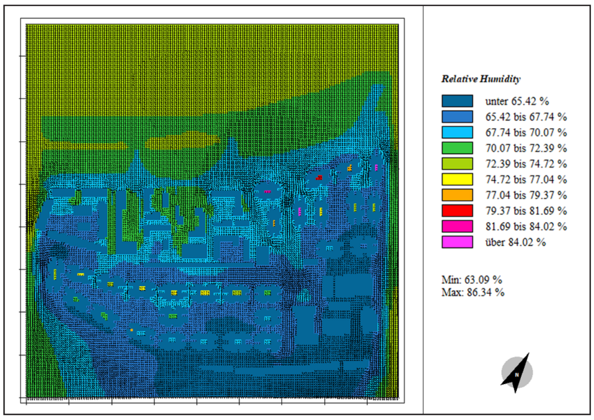

Figure 16 Relative Humidity for Scenario 1 ($G_{E.X}$).

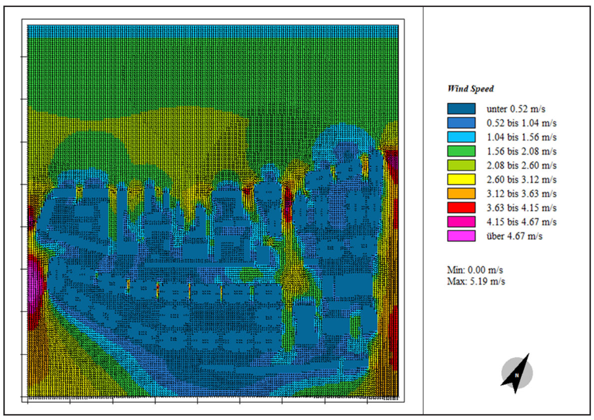

Figure 17 Wind Speed for Scenario 1 ($G_{E.X}$).

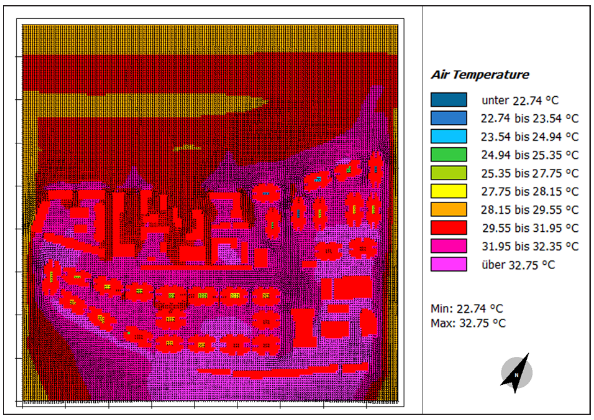

Figure 18 Air temperature for Scenario 2 ($G_{G.W}$).

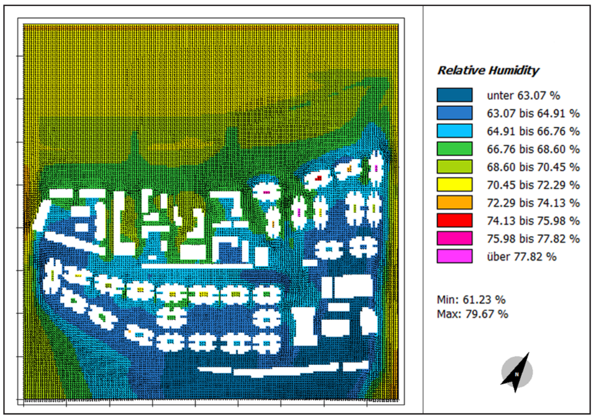

Figure 19 Relative Humidity for Scenario 2 ($G_{G.W}$).

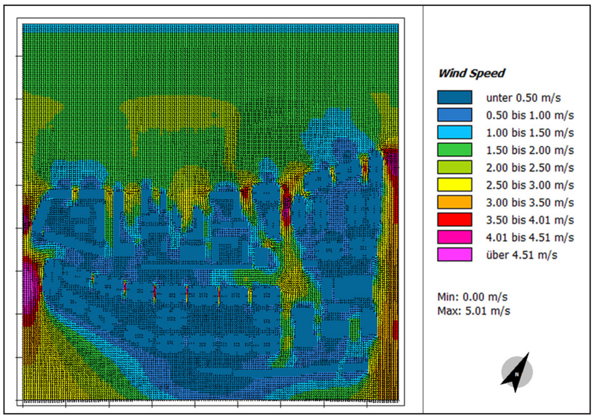

Figure 20 Wind Speed for Scenario 2 ($G_{G.W}$).

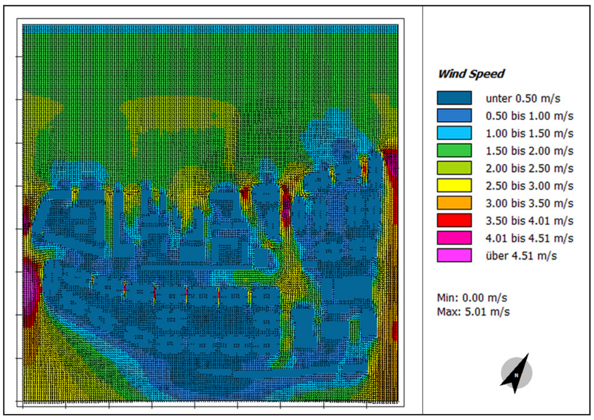

Figure 21 Air temperature for Scenario 3 (G_G).

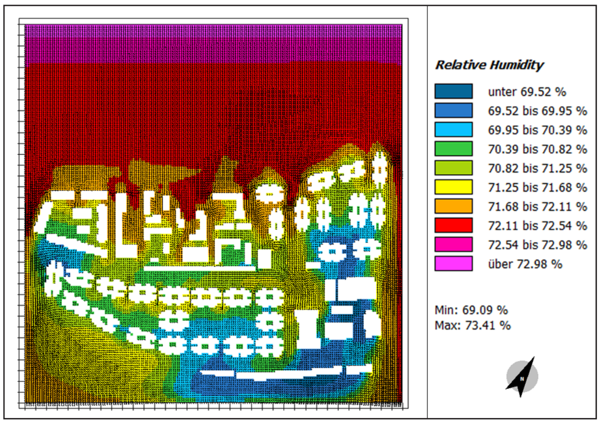

Figure 22 Relative Humidity for Scenario 3 (G_G).

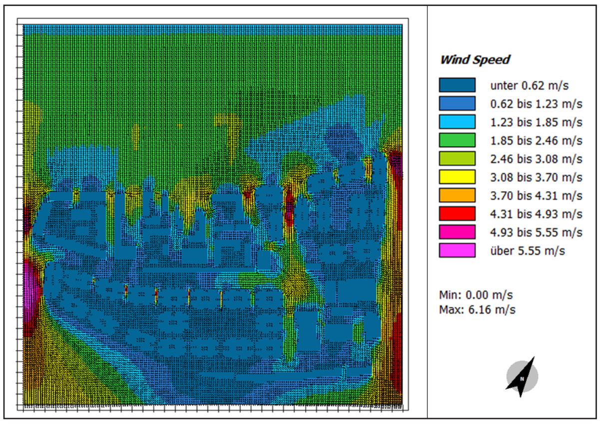

Figure 23 Wind Speed for Scenario 3 (G_G).

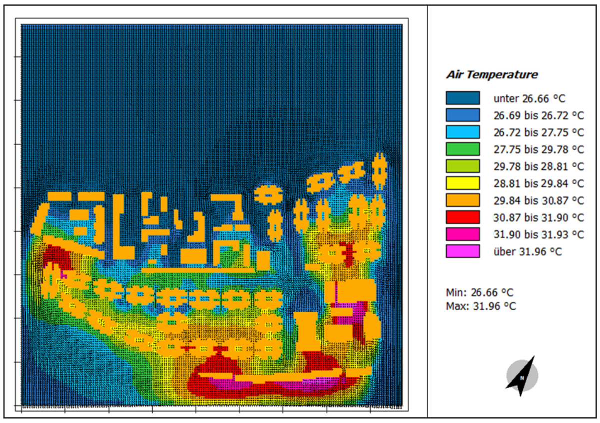

Figure 24 Air temperature for Scenario 4 (G_W).

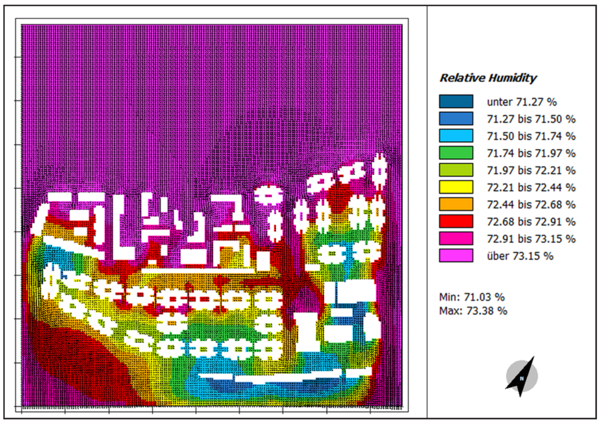

Figure 25 Relative Humidity for Scenario 4 (G_W).

The previous values presenting the values changes for the different scenarios, also to demonstrate the actual values as a qualitative data as shown in Table 2. Avrage (Avg.) presents the values for the overall climatic conditions and zone demonstrate the measured values at the centre of the residential complex of Bashayer El Khier (1).

Based on the previous analysis considering the zone section, Scenario 3 (G_G) the effect of green infrastructure provide a small changes in air temperature values in comparison with Scenario 1 ($G_{E.X}$) the existing situation, however scenario 1 shows a reduction of relative humidity values with an average of 3%. Scenario 4 (G_W) the effect of the blue infrastructure shows the minimum air temperature comparing to all other scenarios, however scenario 2 ($G_{G.W}$) the effect of combining the green and blue infrastructure shows the most nearest air temperature values, also scenario 2 has a significant relative humidity values which less than scenario 4 with an average of 7.0% due to the effect of the green infrastructure for reducing the amount of moisture in air. Scenario 2 ($G_{G.W}$) showing the most acceptable meteorological values to be chosen to apply in building Energy simulation in order to reach the least micro-climate effects on the buildings.

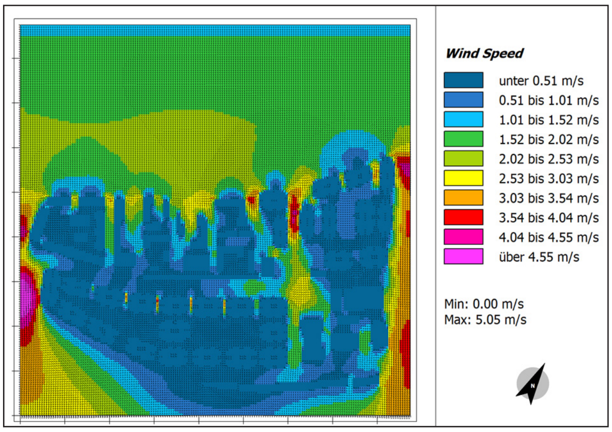

Figure 26 Wind Speed for Scenario 4 (G_W).

DISCUSSION OF BUILDING ENERGY SIMULATION RESULTS

Designbuilder outputs showed different response to different retrofitting scenarios with high sensitivity levels of the main two axis the energy outputs and the meteorological parameters, all these five scenarios tested in comparison with the existing situation in order to determine the most energy efficient retrofitting scenario that also provide the thermal comfort through the meteorological parameters. The following Table 3 shows the average monthly energy consumption reduction for each scenario the most energy efficient scenario is scenario 1 ($S_{W.I}$) which is the Exterior wall insulation then followed by Scenario 2 ($S_{D.G}$) the double glazing with argon gas, the third one in Scenario 4 ($S_{A.I}$)

		SCENARIO 1 (G_{E-X})		SCENARIO 2 ($G_{G.W}$)		SCENARIO 3 (G_G)		SCENARIO 4 (G_W)	
METROLOGICAL PARAMETERS		**MIN.**	**MAX.**	**MIN.**	**MAX.**	**MIN.**	**MAX.**	**MIN.**	**MAX.**
Air Temperature (°C)	Avg.	26.53	33.16	22.74	32.75	26.54	33.17	25.66	31.96
	Zone	26.85	33.09	25.55	32.35	26.00	32.09	25.69	31.87
Relative Humidity%	Avg.	63.06	70.07	61.23	79.67	69.09	73.41	71.03	73.38
	Zone	65.42	70.07	63.07	66.76	69.52	71.68	71.74	71.91
Wind Speed (m/sec)	Avg.	0.00	5.19	0.00	5.01	0.00	6.16	0.00	5.05
	Zone	0.52	1.04	0.50	1.00	0.62	1.23	0.51	1.01

Table 2 Metrological parameters average values for Bashayer El Khier 1.

	BLOCK 8		BLOCK 9		BLOCK 10	
	ENERGY CONSUMPTION	**ENERGY REDUCTION**	**ENERGY CONSUMPTION**	**ENERGY REDUCTION**	**ENERGY CONSUMPTION**	**ENERGY REDUCTION**
Scenario 1 ($S_{W.I}$)	13901.66	11.80%	14101.53	10.40%	14029.79	11.82%
Scenario 2 ($S_{D.G}$)	14563.11	7.60%	14662.19	6.84%	14720.59	7.47%
Scenario 3 ($S_{S.S}$)	14941.38	5.20%	15.019.91	4.57%	15042.42	5.45%
Scenario 4 ($S_{A.I}$)	14689.20	6.80%	14728.10	6.42%	14837.87	6.74%
Scenario 5 ($S_{R.I}$)	15256.59	3.20%	15234.68	3.20%	15400.62	3.20%

Table 3 Retrofitting scenarios effect on average monthly energy consumption and reduction.

improving air infiltration. All these three scenarios helping to reduce the internal heat gain as recommended by the climate consultant software output described in the Psychrometric chart as mentioned before.

Scenario 5 ($S_{R.I}$) roof insulation has the least effect on energy consumption reduction and has similar reduction values on the three block because they all facing the same environment. Scenario 3 ($S_{S.S}$) solar shading having the least effect on block 9 because the north and south facades fully shaded by blocks 8 and 10, the west and east facades have a small window to wall ratio smaller than the other facades.

In order to fulfil the triple constraints in project management to achieve the ideal acquisition cost model through applying the life cycle cost analysis on the retrofitting scenario 1 ($S_{W.I}$), scenario 2 ($S_{D.G}$), and scenario 4 ($S_{A.I}$).

PHASE FOUR: LIFE CYCLE COST ANALYSIS FOR RETROFITTING SYSTEMS

In order to apply the LCCA through the Net Present Value NPV, by identifying the estimated initial cost for retrofitting systems, expected life of each system, average annual expenses for maintenance, operation, and other overheads under Expenses parameter, finally the estimated energy cost through the operating life.

The estimated Energy consumptions show that the average apartments consumption are between the second and third category of energy consumption categorized by the Egyptian Ministry of Electricity and Renewable Energy, as the whole block consumption is 15909.73 kWh over 88 apartment each one around 180.80 kWh, using the third category as a default value for all apartments, the value of energy bill will increase 30% annually as from 2019 to 2020 (50 P/kWh to 65 P/kWh) in order to remove the Governmental financial support by 2025.

Using the polystyrene foam as a thermal insulation for walls from CHEMA PRO Company, that determine the 1.00 m^2 of the thermal insulation cost between 30 –70 L.E using the simulated one which costs 32.5 L.E, also attached the catalogue at the appendix, for the scenario 3 ($S_{D.G}$) using a double glazing window from the future PVC windows which determine the 1.00 m^2 of windows cost between 1200–1400 L.E, also for Scenario 4 ($S_{A.I}$) using window sealing from FLEX TAPE using a strong rubberized waterproof seal black tape 4” of total length 3.00 m cost between 80 – 100 L.E. these values applied on the block 10 to determine the life cycle parameters as shown in Table 4.

As the total block envelope walls area 5123.94 m^2 while the WWR is 10% so the total glazing area is 512.39 m^2 subtracted from total walls area to get the insulated walls area which is 4611.55 m^2. Also needs a 171 bucket of sealing to cover all the openings frames. Applying the equations for Life cycle cost analysis through Net present value for the energy consumption for each scenario.

Scenario 1 ($S_{W.I}$) shows that through the first 13 years from the expected life there will be a reduction of the amount of loss of money due to the implementation of the wall insulation, then at the year 14 (2032–2033) it shows a slightly increasing of benefits that means the amount of energy savings by applying this scenario becomes benefits, and keep increasing from this point forward. The life cycle cost of scenario 1 equals 161,252.13. Which shows an increasing of the value of the initial investment by 7.05%.

For scenario 2 ($S_{D.G}$) it shows the worth values in order its keeping losing through the expected life, however it decreasing the amount of loss. Which needs to get a different glazing type prices in order to reach the beak-even point as scenario 1. The life cycle cost of scenario 2 equals 185,862. Which shows a huge decreasing of the value of the initial investment cost by 76.66%.

For scenario 4 ($S_{A.I}$) it shows that break-even point will be at second year (2021–2022) which means an early benefits, also between (2027–2028) it shows the end of the expected life 8 years with the minimum benefit value

		SCENARIO 1 ($S_{W.I}$)	SCENARIO 2 ($S_{D.G}$)	SCENARIO 4 ($S_{A.I}$)
Expected life in years		16	16	8
Initial cost	**Material cost**	149,875.38	796,107	1537.1
	Expenses 2%	2,997.51	15,922.14	307.43
Total Initial Cost		152,872.89	812,029.14	15679.13
Replacement Cost		–	–	15679.13
Annual Inflation rate (5%) 2020/2021		145,229.25	771,427.68	18,895.18
Annual Energy Cost 2020/2021		10,341.32		
Annual Energy Saving Cost 2020/2021		1222.34	772.50	697.00

Table 4 Life cycle cost analysis for block 10.

in order to replace a new sealing tapes. The life cycle cost of scenario 3 equals 162,594.67. Which shows a huge increasing of the value of the initial investment cost by 88.38%.

CONCLUSION

The Egyptian government has made clear efforts in the recent period in eradicating informal settlements and establishing economic housing projects, but unfortunately most of these projects do not take into account the planning, environmental, energy efficiency buildings and architectural standards also lack of the minimum aesthetic values.

Replacing slum areas into towers for storing people is something that must be changed in the future. Billions are spent in producing typical human stores with a population density of more than 500 individuals/acre. This is not the best option for human life.

Egypt continues to establish housing projects that lack of proper standards and considers them a historical achievement. As Ghett El Ennab projects (Bashayer El Khier 1,2), reaching the New Al-Alamein City, passing through the new administrative capital, it pursues the same thought in packing people inside large concrete blocks and establishing cities far from any studies.

This study using the coupling method by combining the micro climate model ENVI-met with the building energy model Designbuilder, which employs Energyplus. Using the Weather data in the EPW (Energy Plus Weather) file format downloaded from the US Department of Energy's. Testing all the results through the existing weather data exported from the climate consultant software and futuristic weather data exported from "weatherShiftTM" tool.

The ENVI-met software for micro climate simulation results concluded to the following:

- The blue infrastructure shows the maximum values of air temperature reduction by 1.05°C in the existing climatic conditions and 2.65°C in the futuristic climatic conditions with the combination of green and blue infrastructure, however it has the highest relative humidity even higher than the existing situation;
- The combination between the green and blue infrastructure shows at average the air temperature reduction by 1.02°C in the existing climatic conditions and 2.05°C in the futuristic climatic conditions, also represents the minimum values for relative and specific humidity;
- The green infrastructure is the least effective on the air temperature which decreasing the values by average 0.7°C in the existing climatic conditions and 1.30°C in the futuristic climatic conditions, however it has increased the relative humidity over the existing situation but below the blue infrastructure situation.

The Designbuilder software for building energy simulation result concluded the following:

- The thermal wall insulation of polyethylene foam 5.00 cm shows the highest value of energy reduction by 11.34% comparing to the existing situation;
- The double glazing of 6.00mm glass with gap 13.00mm filled with argon gas is the second scenario of energy reduction by average 7.30%;
- Improving the air infiltration rete by using sealing around the openings reducing the energy consumption by average 6.65% as a third choose of retrofitting scenario;
- Solar shading is the fourth choice reducing the energy consumption by average 5.07%;
- Roof insulation by polyethylene foam 5.00 cm shows the least effect on energy reduction by 3.20%.

The feasibility study through life cycle cost analysis concluded the following:

- The net present value of improving air infiltration by sealing tapes shows the best value of money by increasing the value of the initial cost by 88.38%. Also shows the earliest break-even point by second year of expected life.
- The second choice is the wall thermal insulation that shows an increasing of the initial cost by 7.05%. Also represent the break-even point by year 13 of all 15 years as expected life of investment.
- The double glazing shows the worst value for money by reducing the initial cost value by 76.66%. With no break-even point at the first 15 years of the expected life.

As a discussion, in order to achieve the occupants' thermal comfort by temperature reduction through Scenario 4 (G_W) water infrastructure, and achieving energy efficiency building by applying Scenario 1 (Exterior wall insulation).

RECOMMENDATIONS

Through the combination of the qualitative and quantitates criteria which representing the previous conclusion, this study recommends the following:

- The government and those responsible for developing slums must present these projects in planning and architectural competitions in order to reach the best designs at the lowest possible cost.

- Considering the planning, environmental, energy efficiency buildings and architectural standards also the aesthetic values of these residential complex Regardless the social levels for appropriate development.
- Revising the Egyptian building law no. 118 of 2008 especially under the open green areas section compared to the international standards as the long term plan and for the short term plan is to applying the law on the private and governmental sectors in the construction industry.
- Studying the micro climate effect before implementing of any project as the backfilling of El-Mahmodya canal had a huge effect as mentioned through the study.
- Investigating for the environmentally friendly techniques for both architectural and civil techniques.
- Before implementing any project or technique all the studies should be completed and connected also applying the feasibility study for them to strengthen the choose and the ability of this choice.

DISCUSSION

The study's findings highlight the significant implications for the construction industry in Egypt. The lack of proper planning, environmental considerations, energy efficiency, and architectural standards in many housing projects can have adverse effects on the well-being of residents and the environment, for example; inadequate insulation or poor ventilation can lead to uncomfortable indoor temperatures, air pollution and increased energy consumption, resulting in higher costs for residents and greater strain on the power grid.

The study recommends the use of a coupling method to combine micro climate and building energy models to assess the performance of buildings accurately. This approach enables policymakers and designers to evaluate the impact of different building materials, energy-saving technologies and urban design strategies on both energy consumption and thermal comfort.

The study's results indicate that green and blue infrastructure can have a significant impact on reducing air temperature, which can improve thermal comfort in urban areas and mitigate the urban heat island effect. Additionally, adequate insulation, double glazing, and improved air infiltration can enhance energy efficiency and reduce energy consumption in buildings.

However, the study has limitations. The futuristic weather data is not a solid result due to frequent changes in environmental conditions. The micro climate data is sensitive to surrounding urban contexts, so the results may not be applicable to other studies in different locations. The study only tested one type of retrofitting scenario, and the simulation of energy consumption is not a solid value as there are no bills for electricity, only a pre-paid service. Lastly, the feasibility study focused on the available financial offers, which could affect the expected life of the scenarios.

In conclusion, the study highlights the importance of considering both environmental and energy efficiency factors in housing construction and recommends the implementation of proper planning, architectural standards, and sustainable building practices. The coupling method provides a valuable tool for assessing the performance of buildings and identifying effective solutions for enhancing thermal comfort and energy efficiency. Adopting these measures can improve the quality of life for residents, reduce energy costs, and contribute to sustainable development in Egypt.

COMPETING INTERESTS

The authors have no competing interests to declare.

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