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BIM & BEM for a Net Zero Energy house model Case Study: A Housing Unit in Riyadh, SA

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BIM & BEM for a Net Zero Energy house model Case Study: A Housing Unit in Riyadh, SA

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***Abstract*-: Net Zero Energy Buildings (NZEB) are becoming more and more important with the global sustainability movements and energy crisis which increase the need to reduce carbon emissions and energy consumption. The development of Building Information Modelling (BIM) and Building Energy Modelling (BEM) techniques and applications increase its capabilities to support designers in their trials to cope with such movements during the design process and proved its benefits in the Architecture, Engineering and Construction (AEC) industry and used in multiple purposes efficiently. However, the status of the documented trials to achieve a NZE is in its modest situation. This represents a research gap and the intensive for this study that aim to invest the capabilities of BIM and BEM applications to reach a NZE house model in Riyadh, Saudi Arabia. The study adopted a descriptive and experimental approach to apply the NZE concepts on a house model using Revit, Green Building Studio and Insight applications. The reached model could reduce the normal yearly energy combined consumption by about 40% and proved that the building could produce more energy than it consumes.**

***Keywords*— Building Information Modelling (BIM), Building Energy Modelling (BEM), Net Zero Energy Buildings (NZEB), Building Performance Simulation (BPS).**

I. Introduction

The Kingdome of Saudi Arabia has a 10% annual growth in energy consumption, 75% of energy consumed is by built environment, and 50% of that energy is consumed by Residential Sector. More than half of this enormous amount of energy is dedicated for cooling and conditioning buildings in Riyadh city due to the harsh environments, as shown in Figure (1) and (2) [1] , [2] and [3], All this statistics represent the energy crisis in KSA that need to be well considered.

A. *BIM, BEM and the Sustainable Design*

Despite the correlation between thermal comfort and energy expends in housings, enhancing the quality of building sustainability and minimizing energy consumption is a goal that should not be disregarded no matter how daunting the obstacles may be, hence, to design such buildings architects should have the tools that helps them make informed decisions [4]. Moreover BIM technology can improve building performance and help to predict energy utilization [5] through analyzing the activity of multiple building specifications such as HVAC systems, Building envelope, heating and cooling loads, and BIM have the ability to predict the thermal performance and the Overall Thermal Transfer Value OTTV through them in order to improve existing built or unbuilt environments [6].

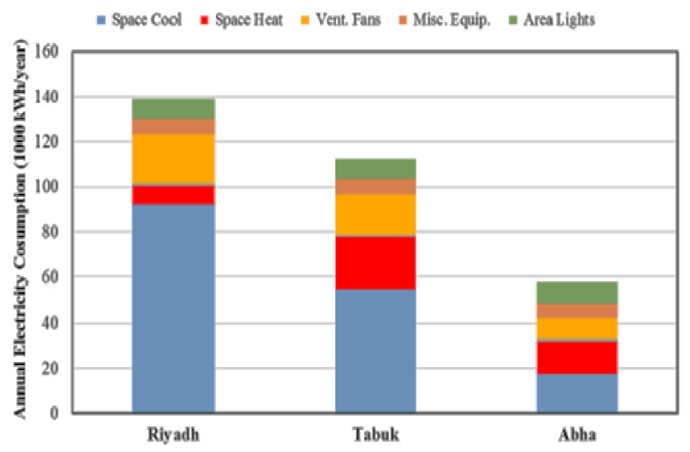
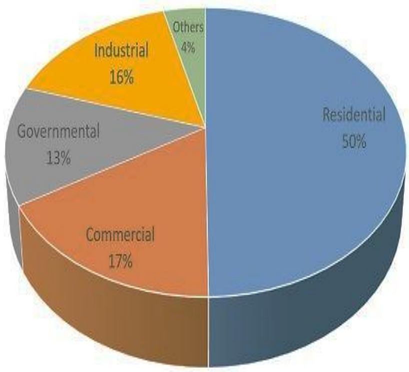
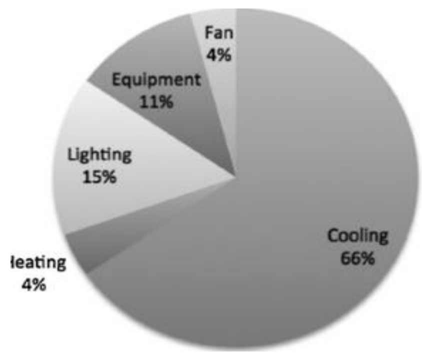


Figure 1. Annual energy consumption in villas located in the KSA [1]



(a)



(b)

Figure 2. (a): Energy consumption by sector [2]
(b): Energy end-use consumption distribution [3]

BIM is an intelligent technology that provides digital, object-based representation and considered as a rich information environment. BIM Applications can produce 3D geometric models that produce 2D and 3D drawings and more specific information that can be used in building analysis. However, to get accurate interoperability a design phase should provide detailed geometry and information to get an error-free accurate thermal performance simulation analysis. [7]. A complete BIM model is an integrated multidisciplinary database that could be exchanged between designers and engineers to work more synergistically and achieve sustainable design. BIM models are also include information regarding energy and thermal comfort and used with applications that simulate building performance to making sustainability analysis and simulation an easy part of the design stages [8].

A BIM model supports Building Sustainability Assessment BSA through automation and integration methods that are immensely crucial with the rising demand for sustainable Architecture [9]. It helps architects and designers in early design stages to achieve sustainable NZEH [10]. Moreover, according to [11], such energy simulation is important to conduct sensitivity analysis in order to identify the most important factors that influence thermal performance of buildings. Simulation tools linkage to BIM can be as add-ons, plugins and interfaces. [7] and [11] have conducted a research to study building's orientation impact on energy consumption using Revit for BIM model that was exported through a gbXML format to Green Building Studio and Ecotect.

Autodesk Revit© is a program that applies BIM technology through entering information related to the 3D geometry to get a parametric model. This model can be used to produce various documentations such as, plans, sections, elevations, perspectives, details, and schedules [6], [12]. Additionally, BIM have developed methods to help in designing sustainable buildings, thus is classified as Green BIM. [13] also defines Green BIM as "a model-based process of generating and managing coordinated and consistent building data that facilitates the accomplishment of established sustainability goals".

BIM's most commonly used modeling tool in the AEC industry have been proven to Autodesk Revit by the National Building Specifications (NBS) since 2012 [14]. Through Revit it is possible to export the model to Green Building Extensible Markup Language "gbXML" [15] . In addition to other exchange format such as COBie and ODBC, IFC and GBxml are the most common exchange tools across databases. However, GBxm can perform better in sensing information [16].

B. *BIM, BEM and the Net Zero Energy Homes (NZEH)*

The Net Zero Energy Homes (NZEH) doesn't mean that it doesn't consume energy, but able to achieve a balance between the consumed energy and the generated energy. The process of designing NZEH is very complicated due to the tremendous amounts of calculations that should be done in an accurate manner, to satisfy Green Building Assessment Schemes GBAS such as BREEAM, BEAM Plus and LEED. GBAS have seen a global attention the field.

BIM technology applications can help with these calculations by simulating a data rich 3D model to achieve GBAS criteria illustrated in Figure 3. [16] and [17] also notes that there are several uses of BIM in energy analysis such as energy modelling automation, storing and organizing building's data, enhancing existing data in libraries, and good presentation of energy-related outputs.

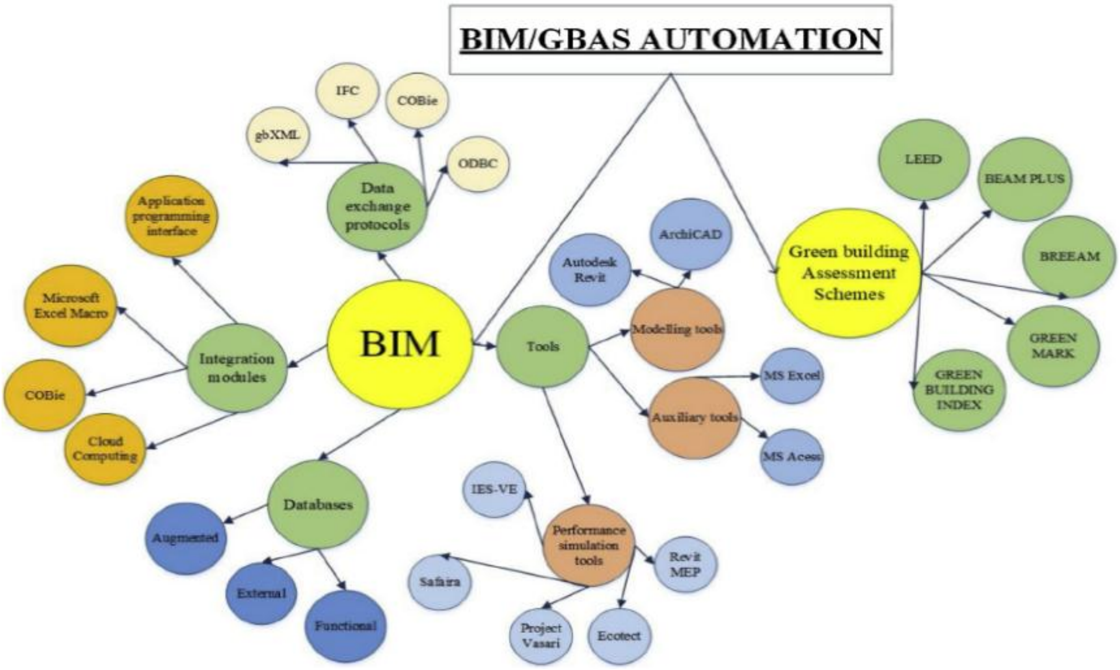


Figure 3. BBIM modelling, exchange protocols and simulation tools [16]

In addition to energy reduction, there is a need to generate energy from renewable sources. In some cases, the energy consumption of the building as a whole can be compensated by the renewable energy generated at the site or obtained nearby [18].As per [19], Zero energy can be achieved in buildings through applying four strategies or steps, three of which are in the design phase which are: minimize building loads (building massing/orientation/envelop, passive strategies and daylighting), maximize Energy Efficiency (HVAC and Efficient Lighting and control) and utilize on-site renewable energy Production (photovoltaic panels, solar water heating and wind turbine). The fourth strategy is in the operation stage and is related to every action that could minimize building energy consumption this include Heating and cooling set points, Operable window (kill switches), User group awareness and education, Equipment limitations/policy change and Energy star equipment.

II. Research Problem, Objective and Methodology

A. Research Problem

Despite the fact that there are wide range of technologies and applications that could support architects and engineers to reach a sustainable houses and even NZEHs designs, the recent statistics issued by Saudi general authority for statistics revealed that percentage of consumed energy in the Saudi residential sector reach 47.58% [20]. This represent the research problem in the view of the global energy crises, sustainability, and green architecture movements.

B. Research Objective

The research aims at proposing a model for a NZEH by investing the capabilities of BIM and BEM applications in modelling and simulations of a number of alternative proposals for the house elements that could reduce energy consumption from one side, and investing the available natural renewable energy to make the balance between the house consumed and generated energy.

C. Methodology

The study adopted a descriptive and experimental methodology to achieve its objectives through a number of procedures, illustrated in Figure (4), started with data gathering and Literature review about BIM, BEM and NZEH, Selecting the BEM Simulation application for modelling the case study, selecting energy simulation application so that energy model can be exported into for further analysis. Then the simulation will be done to discuss the result of the simulation of ordinary to reach the target NZE house in Riyadh.

III. About the BEM Applications

A. Procedures of Selecting the BEM Applications

The first step in selecting the suitable Building Energy Modelling (BEM) application was to search for the "top simulation applications" in specialized web sites where fifteen applications where collected. The authors explored its main features, work flow, ratings, video links, benefits and interoperability with BIM and weather applications. The review included some literatures about such applications. The applications selected in the first round were: HAP from Crrier, Ecotect, Equest, Energy plus, Design Builder, BuildSmithHub, DIAL, Comfie, Sefaira, Open Studio, AK Warm, IES, HEED, Green Building Studio, and Insight.

Based on the previous review, three applications were selected based on the suitability with the case study objectives, the general review of the website of each application, its ranking from specialized websites. A comparison was compiled for these three applications, as shown in table (1), based on the five main criteria (as the study concentrate on the conceptual design stage, the accuracy criteria was not considered as a major criteria) [21], [22], and [23]:

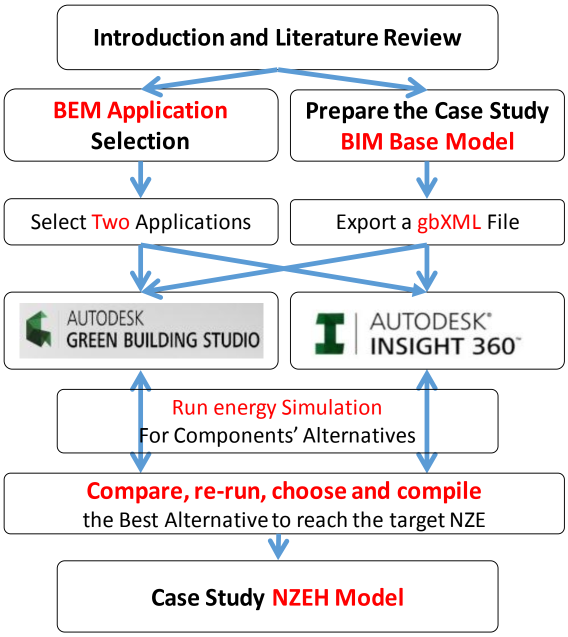


Figure 4. Methodology used for comparative simulation study between Base Model and NZEH Model in Riyadh (By authors)

Figure 5. The 15 Simulation Applications reviewed by the authors.

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Figure 6. GBS Workflow (Autodesk, 2021)

- **The inputs** included criteria are related to the conceptual design stage and included building type/function, building geometry, orientation, climatic/ weather data, building envelop and HVAC types.
- **The outputs** criteria included Energy Analysis, Carbon-Emissions, Natural Ventilation Analysis, Photovoltaic Collection, Thermal Analysis, Solar Analysis, Daylight Analysis, Heating/Cooling Loads Breakdown, LEED credit assistance, Water Usage and Graphical Reports.
- **The Interoperability** criteria included The import from other applications such as Revit, Archicad, and Sketch Up, and from major format such as DXF Import, and gbXML.
- **The Usability** criteria included Simple User Interface, Provides Extensive Weather/Climate Data, available Default Libraries, Requires Minimal Expertise, the rich of Help File, User Tutorials/Online Support, Potential for Customization, and Provides Feedback for Potential Design Changes to Improve Energy Efficiency.
- **The Speed** Criteria included the amount of time needed to perform simulations of energy usage, daylighting, and natural ventilation under 1 hour and 10 minutes.

The comparison showed that that the IES and GBS are very similar except for the speed. Based on the context of the study, and considering that the GBS is related to the same brand of "Auto Desk" product that mean it is 100% compatible and interoperable with Autodesk Revit BIM Application. Therefore, Autodesk's Green Building Studio application was selected as the BEM application for this study.

Table 1. Comparison between the Selected three BEM Applications (Thomas Reeves, 2015), (Rallapalli, 2010), & (Autodesk, 2022)

Application / Comparison Criteria Average Scores	AUTODESK GREEN BUILDING STUDIO GBS	EnergyPlus	IES
Inputs (in Conceptual Design)	100%	66%	100%
Inputs (in Conceptual Design)	100%	66%	100%
Outputs	95%	55%	95%
interoperability	80%	20%	100%
Usability	75%	50%	63%
Speed	100%	--	50%
Overall Average Scores	92%	51%	85%

As the Insight applications is included in the Autodesk with the GBS, parallel analysis in GBS and Insight was done, to ensure the best design alternatives are chosen, that is because choosing design alternatives and running them consumes tremendous time and effort because there is no graphical or any representation to what might be the best option for the project at hand, thus choosing design options by the name necessitates in-depth background information on each system and its impact on buildings. While also creating and running design alternatives with all the options and comparing them is time consuming. On the other hand, insight helps designers and architects through visual graphical that show each design decision effects on the buildings and enables for easier and less time-consuming analysis to reach optimum design.

B. Green Building Studio (GBS) Workflow and interoperability

Green Building Studio is a built-in tool in Revit that simulates the energy use, HVAC, PV information, carbon emissions and natural weather, sun exposure and the thermal comfort inside a building, the GBS workflow is shown in Figure 6.

C. Green Building Studio (GBS) Interoperability

Interoperability refers to the ability of two separate systems or applications to communicate and exchange data with each other. The advantage provided by the seamless transfer of data is to remove the redundancy of data generation in the analytical models, and to ensure that sustainable features are incorporated into the initial design stages. Bahar study of the interoperability reviewed current trends in thermal simulation, identifying key criteria for evaluating building thermal simulation tools based on specifications and capabilities in interoperability, and discussed the details of the workflow and data exchange for multiple thermal analysis (Bahar, 2013). As shown in Figures (7), the energy used can be analyzed in both conceptual and detailed building information models through Autodesk tools: building elements, conceptual masses, and gbXMl exports.

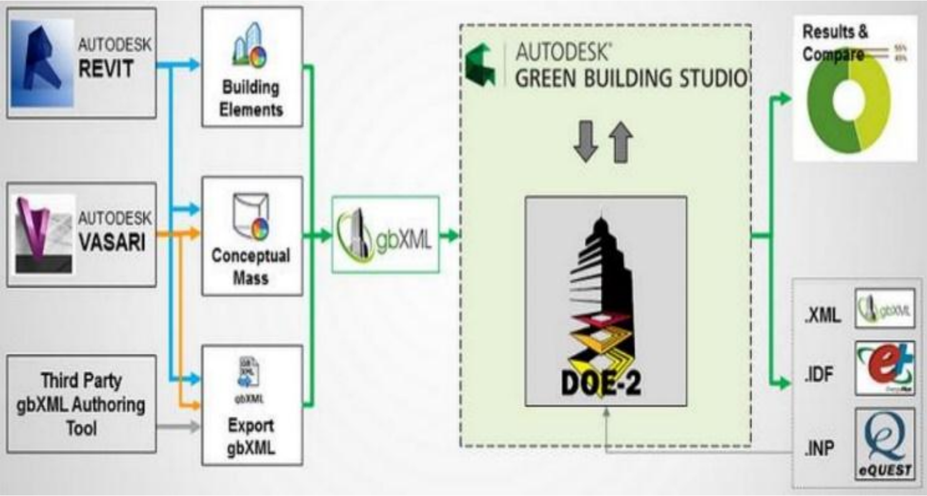

Figure 7. GBS Energy work flow, inputs & outputs (Autodesk, 2022)

Figure 8. Site Location of Case Study in Riyadh City (Google Maps)

IV. About The Case study

A. The Site

The selected case study is a mid-sized housing unit in Saudi Arabia, Riyadh city, Al Yasmine neighborhood with Site area of 880.6m2" as shown in figure 8.

B. Riyadh Weather Basic Data

The climate of the city of Riyadh is desert and harsh, hot and dry in summer, rainy and humid sometimes and moderate in autumn, cold and humid and rainy sometimes in winter, and warm and rainy in spring. July is the warmest month of the year with an average temperature of 43.5 degrees Celsius, and in On the other hand, the coldest month of the year is January, when the average temperature is wet (9 degrees Celsius), summer lasts between May to September, autumn between October and November, winter between December and January and February, and spring between March and April.

As for the rains in the city of Riyadh, like other desert cities, it is characterized by its extreme precipitation and very abnormalities from the average. A year (151%) was recorded above the average, and the following year did not record any rain drop, and rains in general were little and irregular, and precipitation was recorded in the city of Riyadh More in the spring, i.e. in the months (March and April) of each year, according to the table below, where approximately (51%) of the annual rate falls in these two months only.

The prevailing winds in the city of Riyadh are generally considered to be the northern winds, specifically the northeastern ones, and when they blow actively in the summer or spring, they are dusty, and contribute to moderating the temperature, while reducing the temperature a lot, reaching up to Sometimes below zero if it blows from this direction in the winter season, and the average total of dust days in the year reaches (5.4) days, and the month of April is considered one of the most dusty months of the year, with an average of approximately two days per month.

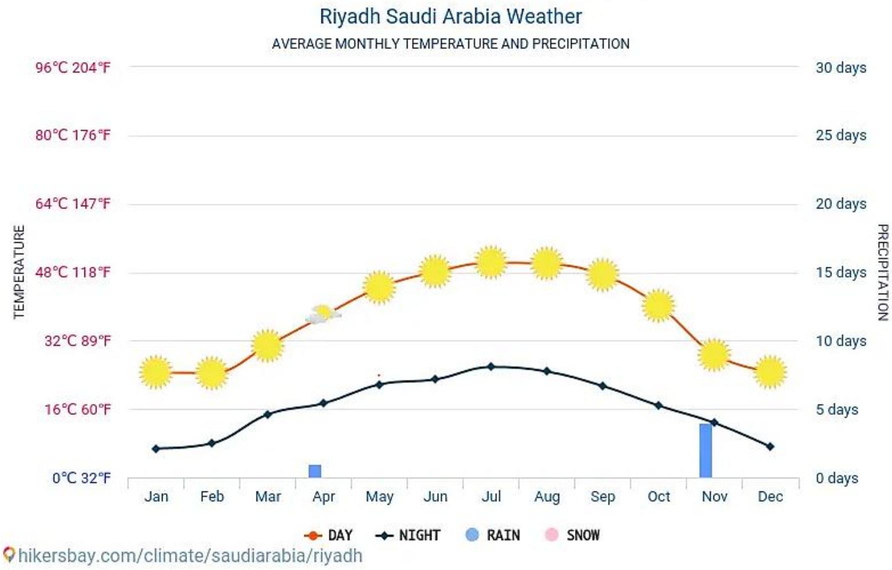

Figure 9. Riyadh City Weather Data (http://hikersbay.com/climate/saudiarabia/riyadh)

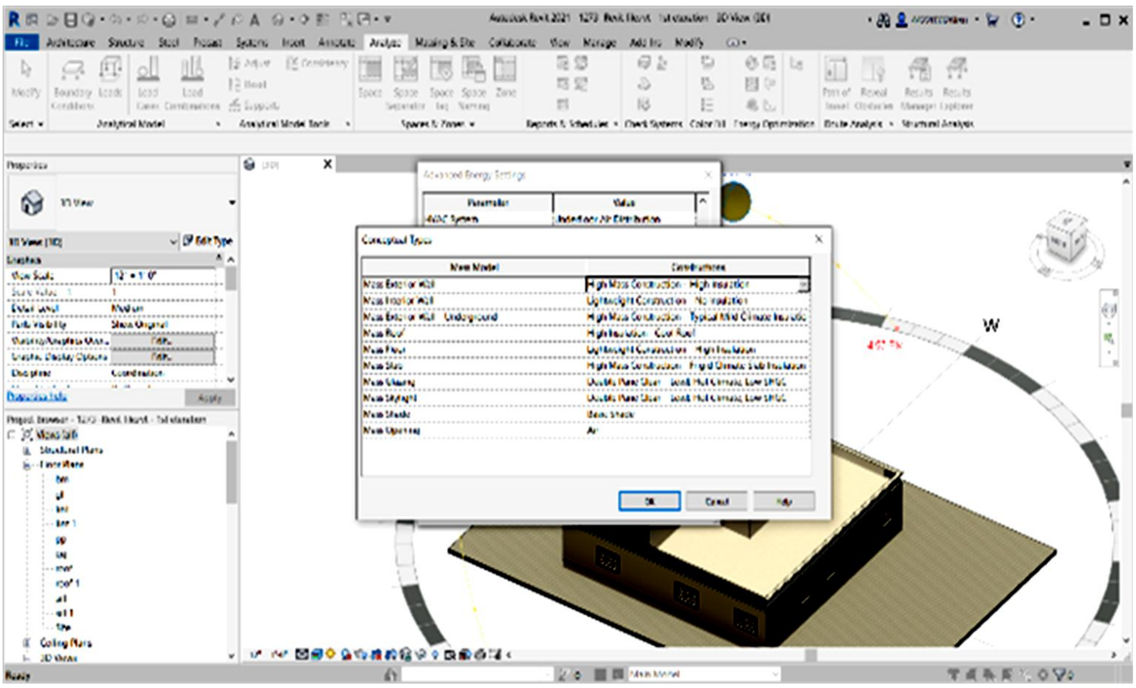

Figure 10. Base Model setting in Revit Application

C. Case Study Modelling Considerations / Procedures

- Building type is residential
- Modeling the components of the building with its specifications and thermal properties
- Definition of Revit Architectural program with architectural spaces (Rooms) in terms of name, area, volume, use, and the number of people/m2 for each space.
- Determining the air conditioning systems and the specifications of the devices used.
- Using the application tools to calculate the thermal loads for spaces, cross check before preparing the energy simulation model
- Export the model in gbXML format to import it to the BEM applications (GBS).

D. Case Study modelling and base run Simulation

The case study taken for this research is a normal house in Saudi Arabia, Riyadh city, Al Yasamin neighborhood with area of 880.6m2.

The Revit model have been set in the analysis, as in figure (10), to a single-family housing with Residential 14 SEER/0.9 AFUE Split/Packaged Gas <5.5-ton HVAC system and standard operation schedule system. The exterior walls are Lightweight Construction – Typical Mild Climate Insulation, and the interiors are Lightweight Construction – No Insulation the roof is No Insulation - Dark Roof. Then the model was exported as an energy mass in gbxml format to GBS.

After running the project, the information shown in figure (11) and table (2A&2B) are illustrated stating that the Base model for the house that spends 7,580 SAR (2021 US$) on energy costs annually and have an equal to 8.29 USD/m2 /year consumption for each m2 yearly.

Energy, Carbon and Cost Summary	
Annual Energy Cost	7,580 SAR
Lifecycle Cost	103,239 SAR
Annual CO_2 Emissions	
Electric	0.0 tons
Onsite Fuel	5.5 tons
Large SUV Equivalent	0.5 SUVs / Year
Annual Energy	
Energy Use Intensity (EUI)	97 kBtu / ft² / year
Electric	54,168 kWh
Fuel	947 Therms
Annual Peak Demand	22.3 kW
Lifecycle Energy	
Electric	1,625,049 kW
Fuel	28,404 Therms

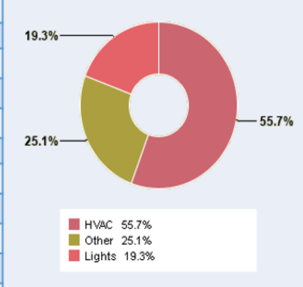

Figure 11. (A) Energy Base run results of the base Model

V. RESULTS OF ALTERNATIVE SIMULATION

A. Simulation analysis of Building Orientation

At this stage the model variables are fixed except for the rotation angle. The annual energy cost and cost saving could be analyzed, as shown in table 2.

Table 2A: Base Case Indoor water Consumption

Indoor Water Consumption	Total	Male	Female	Efficiency	% of indoor usage (%)	Gallons per year	Annual cost savings (USD $)
Toilets	5	2	2	Standard	0	0	0
Sinks	6	2	3	Standard	0	0	0
Shower	5	2	3	Standard	0	0	0
Clothes washer	1			Standard	0	0	0
Dishwasher	1			Efficient	0.1	339	0.5
Total Efficiency Savings					**0.1%**	**339**	**0.5 $**

Table 2B: Base Case Outdoor water Consumption

Outdoor Water Consumption		Annual Rainfall (m3)	Catchment Area	Surface Type	Gallons per year	Annual cost savings (USD $)
Rainwater Harvesting	No	4.43194	2843	Gravel/Tar	0	0
Native Vegetation Landscape	Yes				3.707	2.67 $
Greywater Reclamation	No				0	0
Site Potable water Sources	No	Yield	50	Gal/Day	0	0
				Total Net-Zero Saving	**3.707**	**2.67$**

Table 2. Building Orientation Alternatives and its effect on annual cost

App.	Orientation Alternatives	HVAC	Annual Energy total Cost		
			Base run	Alt.	Difference
GBS	15	HP, ASHRAE 90.1-2010, 9.5 EER, COP 3.2 Electric Heat, 75F economizer	7,580 SAR 2021.33 US$ ($8.29/m2)	2,409.33$	Cost More 9.87 $/m2
	30			2,102.93$	Cost More 8.62 $/m2
	45			2,106.40$	Cost More 8.63 $/m2
	60			2,109.07$	Cost More 8.64 $/m2
Insight	90	ASHRAE Package Terminal Heat Pump	7,580 SAR 2021.33 US$ ($8.29/m2)		Saves $27.12/m^2

Table 3. Lighting and Power Alternatives and its effect on annual cost

App	Efficiency	Lighting Control	Annual Energy total Cost $		
			Base run	Alt.	Difference
GBS	LPD 50% Less than base-run	Occupancy Sensors	7,580 SAR 2021.33 US$ ($8.29/m2)	1757.60$	Saves 7.20 $/m2
		Occupancy + Daylighting Sensors & Control		1757.60$	Saves 7.20 $/m2
Insight	3.23 W//m2 + 6.46 W//m2 for Plug load	ASHRAE Package Terminal Heat Pump	7,580 SAR 2021.33 US$ ($8.29/m2)		Saves $11.32/m2

B. *Simulation analysis of Lighting*

In the lighting analysis in Green Building studio and Insight, it shows that the occupancy sensors and the daylighting sensor with the occupancy sensor together have a little effect on energy consumption. The Insight option was better with $11.32 USD/m2/yr savings, as shown in table 3.

C. *Simulation analysis for roof deck construction*

In the roof analysis department 3 design alternatives have been established in GBS all saved energy but the best option was found in Insight that saves $15.44 USD/m2/year as shown in table 4.

D. *Simulation analysis of Southern Walls*

Analysis was done to analyze the construction of the southern walls of the building envelope. The alternatives applied for construction, glazing type, shade length and window to wall ratio. And it was found that the optimum window to wall ratio in the southern walls are 15 with ½ of the window height shaded and Super Insulated 3-pane Clear Low-e glazing on an Insulated Concrete Form wall (ICF), 14" thick form wall. This achieve a yearly cost saving of 0.06$/m2/year, as shown in table 5.

E. *Simulation analysis of Photovoltaic*

Through analysis in table 7 it was found that GBS have limited options related to photovoltaic analysis and that there is emerging technology that needs to be added to the program in order to get full benefit of the new technologies.

Such as in Insight there shows that there is a photovoltaic system with 20.4% panel efficiency that can produce in the given area about 48,780 kw/h (which saves 1821 $). With the ability to add electric battery the extra energy produced from the photovoltaic system can be either sold to make profit of saved for later uses, as shown in table 6.

Table 4. Roof Deck Construction Alternatives and its Effect on Annual Cost

App.	Roof Const. Type	Annual Energy Cost $/year		
		Base run	Alt.	Difference
GBS	Continuous Roof Deck with Super High Insulation	7,580 SAR 2021.33 US$ ($8.29/m2)	1,505.07$	Saves 6.17$/m2
	Continuous Roof Deck with Code Compliant Insulation		1,497.33$	Saves 6.14$/m2
	Cool Roof - R50 continuous ins. over roof deck		1,531.73$	Saves 6.28$/m2
Insight	Roof Deck – R60	7,580 SAR 2021.33 US$ ($8.29/m2)		Saves $15.44/m2

Table 5. Building Southern walls Alternatives and its effect on annual cost

App.	Wall Const.	Glazing Type	Shade	WWR	Annual Energy Cost $/m2/year		
					Base run	Alt.	Diff.
GBS	Insulated Concrete Form (ICF) Wall, 14" thick form	Super Insulated 3-pane Clear Low-e	1/2 of the Window Height	15%	7,580 SAR 2021.33 US$ $8.29/m2	$2,006.13	Saves 8.22$/m2
			2/3 of the Window Height	15%		$2,013.33	Saves 8.25$/m2
			1/3 of the Window Height			$2,008.27	Saves 8.23$/m2
		Insulated Clear Low-e Hot Climate	1/2 of the Window Height			$2,013.6	Saves 5.25$/m2
Insight	14-inch ICF	Trp.-LoE	1/2 of the Window Height	BIM 11%	$2021.33		Costs ($0.33/m2)

Table 6. Simulation analysis of adding Photovoltaic and its related energy production and payback period

App.	Area	Installed panel area	Panel Type	Annual energy production (kw/h)	Payback period
GBS	880.6 m2	531 m2	Single Crystalline- 13.8% efficient	33,005	28
			poly Crystalline- 12.3% efficient	29,418	28
			Thin film- 7.5%efficient	17,938	28
Insight	880.6 m2	90%	20.4% efficiency solar panel	48,790	30

Table 7. Indoor Water Efficiency Analysis

Updated Indoor Water Consumption	Total	Male	Female	Efficiency	% of indoor usage (%)	Gallons per year	Annual cost savings (USD $)
Toilets	5	2	2	Low-Flow	14.8	52,445	85
Sinks	6	2	3	Low-Flow	1.7	5,860	9.6
Shower	5	2	3	Low-Flow	6.1	21,647	35.2
Clothes washer	1			H. Axis	8.1	28,929	46.9
Dishwasher	1			Efficient	0.1	339	0.5
Total Efficiency Savings					**30.8%**	**109.221**	**177.2 $**

Table 8. Outdoor Water Efficiency Analysis

Outdoor Water Consumption		Annual Rainfall (m3)	Catchment Area	Surface Type	Gallons per year	Annual cost savings (USD $)
Rainwater Harvesting	Yes	4.43194	2843	Asphalt/Conc.	7,069	4.8 $
Native Vegetation Landscape	Yes				6,810	4.8 $
Greywater Reclamation	Yes				5,006	8 $
Site Potable water Sources	No	Yield	50	Gal/Day	0	0
				Total Net-Zero Saving	**18,885**	**17.6 $**

F. Simulation analysis of Water Efficiency

Indoor Water

Through making the (toilets, and showers) low- flow and enhancing the sinks with hands free technology that is (sensors that sense the existence of the hands to open the water and closes automatically when the hands are away) and enhancing the efficiency of dishwashers and, making the cloth washer a horizontal-axis washer, saves 30.8% of indoor water usage which calculates a total of 109,221 gallons per year saving $665, as shown in table 7.

Outdoor Water

By incorporating rainwater harvesting and native vegetation landscaping and grey water reclamation 18,885 gallons of water can be saved per year, as shown in table 8.

G. Summary of Simulation Results

As shown in table 9, the energy cost saving reach more than 100% with about 85% percentage share in the energy generation from photovoltaic (equal to 1,821$). The negative percentage of the annual energy cost saving is (- 5.13%) means that the house can produce more energy than it consumes, i.e. a nearly Net Zero Energy House (NZEH).

Table 9. Summary of all Simulation results

No.	Alternative Item.	Annual Energy Cost
1	*Simulation analysis of Building Orientation*	27.12
2	*Simulation analysis of Lighting*	11.32
3	*Simulation analysis for roof deck construction*	15.44
4	*Simulation analysis of Southern Walls*	57.00
5	*Simulation analysis of Photovoltaic*	1,821
6	*Simulation analysis of Water Efficiency Indoor Water*	177.00
7	*Simulation analysis of Water Efficiency Outdoor Water*	17.60
	Total Annual Energy Cost Saving based on proposed Alternative	**2,126.48 $**
	Original Annual Energy Cost for the base case	**2,021.33 $**
	Percentage of Annual Cost saving	**- 5.13 %**

VI. Conclusions and Recommendations

A. *Conclusions*

This paper tried, through the use of BIM and BEM applications, to reach NZEH in locations with climate as harsh as Riyadh, in the KSA. Autodesk can be helpful for designers on small scale projects such as houses with Revit, GBS and Insight, which can run several simulations.

Previous studies have suggested plans for achieving less energy as well as the incorporation of renewable energy resources into existing structures.

Based on the results, it is possible to infer that:

- Adequate planning and design will enhance energy clean production and decrease energy usage and using the appropriate materials can make the design a long-term, cost-effective home.
- The total annual cost of energy as well as the total combined consumption of energy can be reduced from 8.29 USD/m2 /year to -13.83 USD/m2 /year meaning the building can produce more energy than it consumes.
- The various project analysis criteria indicate that the energy use achieved in design phase can be enhanced, and lead to construction energy efficient.
- The use of BIM/BEM applications support different users in facilitating energy simulation and calculations to simulate and calculate the energy in buildings more easily and quickly.

B. *Recommendations*

The main recommendations of this research are directed to four agents: educational institutions, regulators, users of BIM/BEM, and Media as follow:

- **Educational Institutions**: to include BIM and BEM applications in the curriculum.
- **Regulators**: to include the four strategies of the NZEHs in building Code.
- **Saudi Electricity Company (SEC)**:
  - Make available in the local market different types of battery systems that are compatible with photovoltaic.
  - Encourage residents using such batteries with Photovoltaic system to store extra generated energy and either use it later or buy it to SEC.
- **Users of BEM/BIM applications**:
  - update the sustainable strategies to incorporate them and get more efficient results.
  - Produce renewable energy while setting the necessary policies from the early design stages for all building types.
- **Media:** Increasing efforts to raise the culture of rationalization of consumption and optimal use of energy.

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