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Energy Efficiency improvement in School Buildings

[1]Chro Hama Radha and *[2] Husein Husein

[1] Breuer Marcell Doctoral School, Institute of Architecture, Faculty of Engineering and Information Technology, University of Pécs, Boszorkány u. 2, H-7624 Pécs, Hungary
[2] Faculty of Engineering, Department of Architecture Koya University, Iraq

Abstract:
High energy consumption is one of the most serious problems globally faced today. The building sector is known to be the largest energy consumer. Energy performance in school buildings is very significant, for ascertaining the health and productivity of students and teachers. Analysis of previous studies shows that school buildings present a poor indoor air quality due to the high occupant density of school buildings, especially in classrooms, with approximately four times the occupant density of office buildings, if compared. School buildings also consume a large amount of energy due to the lack of energy saving measures applied to the buildings. The purpose of this study is to improve indoor environment and reduce energy consumption of school buildings, through analysing, evaluating and improving energy efficiency of a secondary school typology in Sulaimani. Based on the measurements in the school and IDA ICE simulation model, several improvement options were investigated, including window ratio, thermal insulation, and infiltration. An improved model was presented and the results were compared via IDA ICE software 4.7.1. The results revealed that the optimum model performed better in both indoor environment and energy consumption than the existing school model.

Keywords: Energy efficiency, indoor environment, IDA ICE energy simulation, building improvement.

1-Introduction:

Worldwide energy demand for building sector is predicted to grow by more than 50% from 2010 to 2050 [1]. School building constitutes an important part of the non-residential building stock [2]. School-age students spend much of their time in school buildings. The sustainability of these buildings should be a priority as better comfort with a high indoor air quality contributes to an improvement in the conditions for learning. [3]. The indoor environmental and energy performance in these buildings is important for assuring the health and productivity of students and teachers [2]. One of strategies for reducing energy consumption is providing natural light from the sun, in addition, it improve student performance. A study shows that students with the best day lighting in their classrooms progressed 20% faster on math tests and 26% faster on reading tests in one year than those with minimal day lighting [4].
The objective of this study is to analyse the energy performance of the typical school plan, then investigate the major deficits in buildings to provide improvement suggestions lowered energy consumption and improved indoor environment based on the parametric analyses. The effects of

different parameters which affect the energy performance and indoor environment of the school building were studied via the commercially available building simulation software IDA ICE.

2- Case study description:

The case study was a secondary school typology located in Sulaimani, Iraq. The building has a total area 3343.5 m^2. It consists of two floors with 18 classrooms, 2 laboratories, computer rooms, a draft hall, a multipurpose hall, a cafeteria, teachers' rooms, water drinking spaces, and toilets. It also has a capacity for 600 pupils.

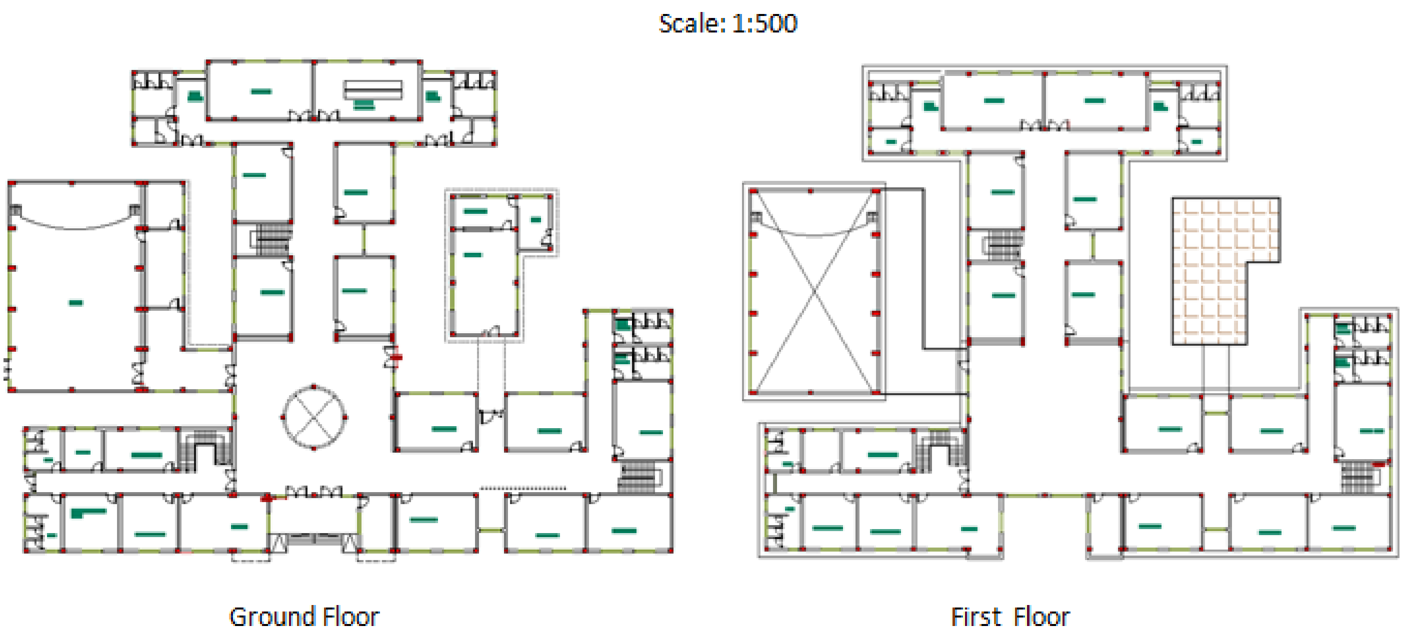

Figure 1. Shows the plans of Secondary school typology [6].

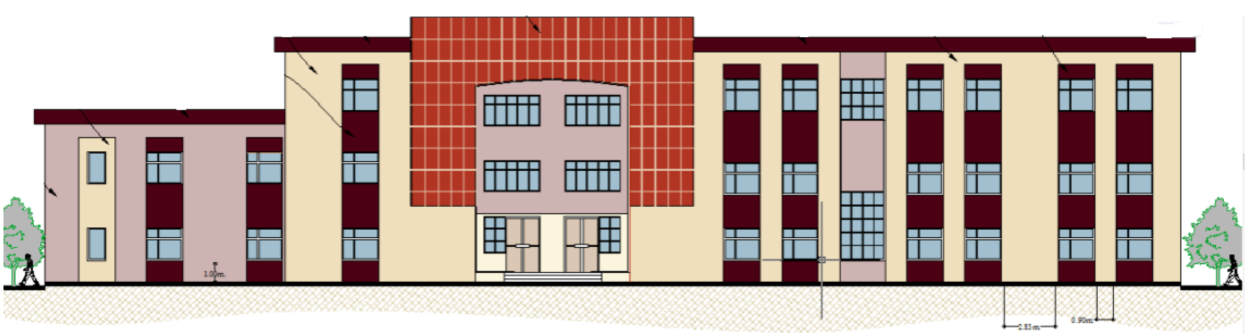

Figure 2. Shows the elevation of Secondary school typology [6].

3- Building energy simulation model:

Building energy simulation is the analysis of the energy performance of buildings using computer modelling and simulation techniques [5]. To investigate the energy performance of the school building, the simulation software IDA ICE 4.7 has been used. In order to get results in reasonable time, simplification of the architectural layout is needed before importing into IDA ICE. Then, information on the materials used for constructing walls, roofs, and floor, their thickness, as well as window panes and building services system, were taken from the construction plans. In addition, PRN weather file which created by Meteonorn software 7, was used that consisted of 6 parameters: dry -bulb temperature, relative humidity, direct normal radiation, diffuse radiation, wind speed, and wind direction, the air temperature was measured at a height of 10m. Based on the school information, fuel was used for heating the school, while for cooling and Domestic Hot Water (DHW), eclectic were used. The basic parameters used for energy simulations are given in Table 1. Furthermore, the software facing difficulties handling non-perpendicular walls, so avoiding these is necessary by transforming the layout into an approximate state, while keeping the original building physics related dimensions.

Table 1. Description of the school building

Construction	Material	Layer	Thickness (cm)	U value W/m2*K
External wall	Hollow concrete block	1	20	
	Cement plaster	1	2	2.562
	Gypsum plastering	1	2	
Internal wall	Hollow concrete block	1	20	2.13
	Double gypsum	2	4	
Internal floor (Internal slab)	Reinforced concrete	1	15	
	Fine sand	1	5	2.4
	Tile	1	2	
Roof	Reinforced concrete	1	15	
	Air gap	1	10	0.82
	Gypsum board	1	1	
External floor	Reinforced concrete	1	15	
	Fine sand	1	5	2.4
	Tile	1	2	
Glazing	2 panes glazing	2	1	2.9
Generator Efficiencies:				
Heating	Fuel			
Cooling	Electric			
Domestic Hot Water (DHW)	Electric			

4- Energy analysis:

The simulation result as shown in table 2, that the total energy demand for the typical school building for one year period was 783667 kWh. A predominant characteristic in the energy consumption is fuel heating, electric cooling and hot water and the rest of energy consumption are for lighting and other purposes.

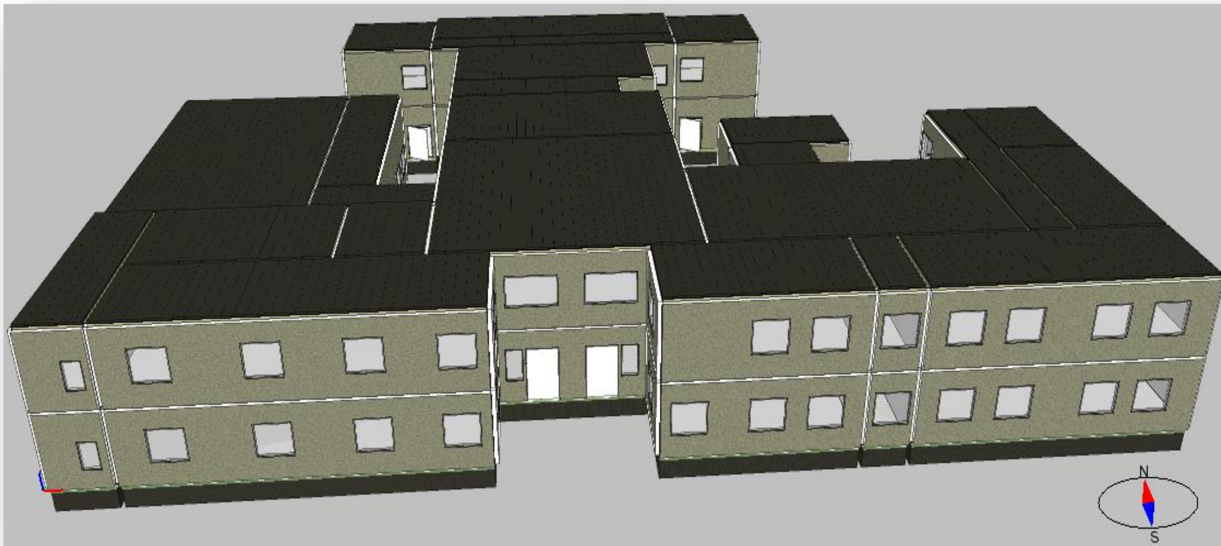

Figure 3. Shows IDA ICE model for typical secondary school building

Table 2. Delivered Energy report from IDA ICE for one year period.

		Purchased energy		Peak demand
		kWh	kWh/m^2	kW
■ (yellow)	Lighting, facility	49080	14.7	16.79
■ (cyan)	Electric cooling	224777	67.2	347.0
■ (cyan)	HVAC aux	0	0.0	0.0
■ (orange)	Electric heating(DHW)	118740	35.5	13.55
	Total, Facility electric	392597	117.4	
■ (red)	Fuel heating	391070	117.0	227.7
	Total, Facility fuel*	391070	117.0	
	Total	783667	234.4	

5- Improvement:

Based on the simulation model several improvement options were investigated. In order to compare the different scenarios, the energy efficiency and indoor environment were evaluated, the focus of the improvement was to minimize the heating and cooling demand.

In the next step four different scenarios have been defined based on the add of thermal insulation and reducing the window ratio, reducing the infiltration. The fifth scenario was applied for getting optimum model, as presented in table 3.

Table 3. Scenarios detailed descriptions

Scenarios	Description
Scenario (1)	Adding 20cm thermal insulation to the building envelope
Scenario (2)	10% Window Ratio reduction of the reference model.
Scenario (3)	20% Window Ratio reduction of the reference model.
Scenario (4)	An infiltration reduction from 10 (as in the reference model) to 5.
Scenario (5)	Optimum model (applying (1), (3), and (4) scenarios together

6- Result analysis:

After simulation all scenarios for the school building, the energy consumption for fuel heating, electric cooling loads, DHW, electric lighting facility were compared with the reference model. In order to clarify the result analysis for the scenarios, one zone (class room-1) was investigated. The result represented through different scenarios that the total energy consumption was reduced 44.81% by adding 20cm insulation for the building envelope ,while by reduction infiltration from 10 to 5, the total energy reduction was 1.68%. In addition, in the third and fourth scenario, the whole window ration of the school was reduced by 10%, 20% from the reference case, the total energy consumption was reduced 0.41%, 1.08% sequentially, as shown in table 4.

Table 4. Shown the energy consumption reduction in four scenarios.

Secondary School Zone: Class Room-1 Orientation: South		Reference	1 Insulation 20cm	2 Infiltration	3 Window Ratio 10%	4 Window Ratio 20%
Electric Cooling	kWh	227617.0	158449.0	225088.0	223016.0	217285.0
Fuel Heating	kWh	387667.0	105709.0	377034.0	389043.0	389991.0
DHW	kWh	119052.0	119052.0	119052.0	119052.0	118740.0
Lighting facility	kWh	49212.0	49225.0	49202.0	49225.0	49098.0
Total Energy	kWh	783548.0	432435.0	770376.0	780336.0	775114.0
Percentage of reduction		0.0	44.81%	1.68%	0.41%	1.08%

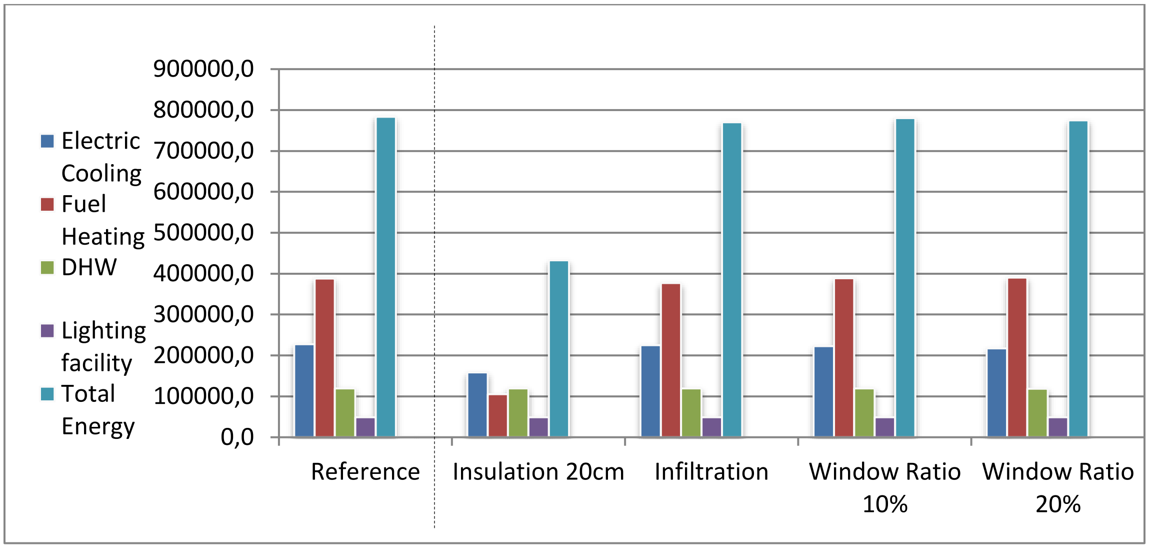

Table 4. Shows annual energy consumption through all scenarios based on compared with the reference model.

Through different scenarios, the amount of CO_2, daylight, and thermal comfort were also investigated to insure that the indoor air quality inside the school building. On the other side to ensure daylight and CO_2 level abide the regulation of the setpoint of IDA ICE. In addition, thermal comfort, CO_2 level, and day lighting were compared to the reference model.

From the table 5, it can be observed that adding 20 cm of thermal insulation to the building envelope leads to an increase in daylight level and reduce the CO_2 level slightly while reducing the window ratio and infiltration reduced the daylight and increase the CO_2 level in a way that didn't affect the efficiency of the indoor environment of the school building.

Table 5. Shows daylight, CO2 level, and thermal comfort through four scenarios based on comparison with the reference model.

Secondary School Zone: Class Room-1 Orientation: South		Reference	1 Insulation 20cm	2 Infiltration	3 Window Ratio 10%	4 Window Ratio 20%
Daylight	Lux	2017.5	2017.6	2017.0	1748.2	1283.9
CO2	ppm	830.5	816.4	937.2	862.9	951.1
Thermal comfort	Hour	1570.0	1450.0	1570.0	1571.0	1566.0

To get the optimum model, three scenarios are used, including 20cm thermal insulation, reduction of infiltration, 20% window ratio reduction. The final results of implementing three scenarios a significant decrease of energy consumption for conditioning school by 49.31%, as shown in table 6.

Table 6. Shows optimum model for the school building typology and its reduction by

comparing with the reference model.

Zone: Class Room-1 Orientation: (South)		Reference model	Optimized model
Electric Cooling	kWh	227617.0	134815.0
Fuel Heating	kWh	387667.0	94513.0
DHW	kWh	119052.0	118740.0
Lighting facility	kWh	49212.0	49090.0
Total Energy	kWh	783548.0	397158.0
Percentage of reduction		0.0	49.31%

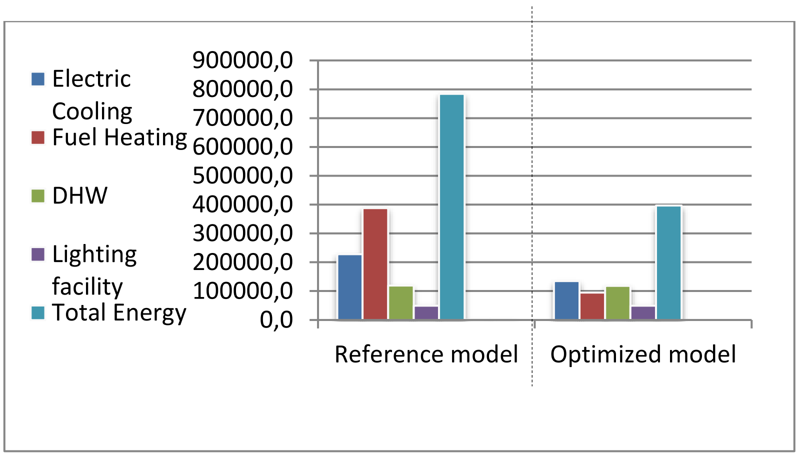

Figure 5. Shows the comparison between optimum model and reference model.

7- Conclusion:

Five energy measures on building envelope as four scenarios were defined and implemented in a typical school building in Sulaimani, Iraq.

The simulations showed that the most important improvements were the reduction of window area, infiltration, and thermal insulation that based on the simulations were obtained. The improved school performed better in both thermal indoor environment and energy consumption than the reference case, the yearly energy consumption in the optimized model was reduced by 49.31 % compared to the reference building. It may enable the schools to obtain economic advantages and make larger financial sources available for educational purposes.

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