Energy Efficient Optimization in a Typical School Building: Kurdistan Typical School Buildings as a Case Study

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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 in Kurdistan. The purpose of this study is to improve the indoor environment and energy performance of school buildings, through analysing, evaluating and improving the indoor environment and energy efficiency of a secondary school typology in Sulaimani city in northern Iraq. Based on the measurements in the school building and the simulation model (using Indoor Climate and Energy (IDA ICE) software 4.7.1) several improvement options were investigated, including window to wall ratio, thermal insulation, and infiltration. As a result an optimal solution model in terms of thermal comfort and energy efficiency was proposed. The optimum model was also simulated and the results were compared with the reference model. 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

The energy and environmental issues in recent years have become increasingly important in the world, thus it's increasingly urgent to cope with the steady increase in energy demand and to reduce emissions of greenhouse gases to a level that will stop the global warming (Zanni et al., 2015). Worldwide energy demand for building sector is predicted to grow by more than 50% from 2010 to 2050 (Yousefi, Yousefi & Yousefi, 2015). School building constitutes an important part of the non-residential building stock (Rospi et al., 2015). The school-age students spend much of their time in school buildings. Thus, 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, (Dall'O et al., 2013). Furthermore, the indoor environmental and energy performance in these buildings is important for assuring the health and productivity of students and teachers (Rospi et al., 2015). One of the strategies for reducing energy consumption is providing natural light from the sun, in addition, it improves student performance. A study shows that students with the best daylighting in their classrooms progressed 20% faster on math tests and 26% faster on reading tests in one year than those with minimal daylighting (NREL, 2011).

The objective of this study is to analyse the energy performance in the typical school building, and investigate the major defects to provide indoor environment and energy consumption reduction suggestions based on the parameter analysis. The study also addressed the different parameters which effect on the energy performance and indoor environment in the school building based on the commercially available building simulation IDA ICE software.

2. Literature Review

School buildings in particular, are important among other kinds of buildings, where students can learn correct patterns of energy consumption and inspire by energy efficiency. This issue currently is an increasing concern in several countries and made authorities to take some measures towards more saving and energy efficiency in schools (Yousefi et al., 2015). Several authors have published about the indoor air quality and energy efficiency in the school building. Rospi et al. (2015) presented the outcome of a study on the energy performance in five different school buildings which located in Matera city (South Italy). The improvement was performed into two strategies; the first strategy was considering the envelope and the replacement of windows frames. The second strategy was considering the improvement on the thermal system and replacing the existing heat generator with a condensing one with high efficiency. Based on the result analysis the first improvement provides a total energy reduction of 35 %, while the intervention on the system provides 30% saving energy for heating. Yousefi et al. (2015) investigated the energy performance in the nine typical school buildings in three cities (Yazd, Tabriz and Ilam) in Iran. They pointed out adding thermal insulation to the external walls and roofs in the surveyed school buildings can reduce energy consumption 42% in Yazed, and 37%, 31% in Ilam and Tabriz respectively. They also explain the effects of windows glazing replacement on the energy reduction.

Dias, Ramos and Manzano (2013) analyzed the quality of the actual internal environment and energy efficiency of the upper school building at the Polytechnic Institute Leiria in Portugal, through direct measurements and questionnaires conducted during one year of the classroom. Based on the results, they explained that school buildings have a poor indoor environment, due to the high density of students in the classroom. They stated that the behavior of the occupants and ventilation is very important to reduce energy consumption and improve indoor air quality in the school building.

Kang et al. (2015) presented a study to reduce the energy used in the school building in Seoul, Korea, based on passive and active strategies comparison. The results showed that the energy efficiency increased 32% when the design was improved based on passive strategies. Kang proved that passive design strategies are more efficient in terms of energy savings than active strategies. In order to investigate the indoor air quality and energy performance in the school buildings, a typical secondary school building was chosen and the data was collected from the Directorate of Education in Sulaimani (DES).

3. Case Study Description

The case study is a secondary school typology located in the Sulaimani city in northern Iraq. The building has a total area 3343.5 m2. It consists of two floors with 12 classrooms, 2 laboratories, computer rooms, a draft hall, a multi-purpose hall, a cafeteria, teacher's rooms, water drinking spaces, and toilets as shown in Figures 1and 2; besides it receives a capacity for 400 students.

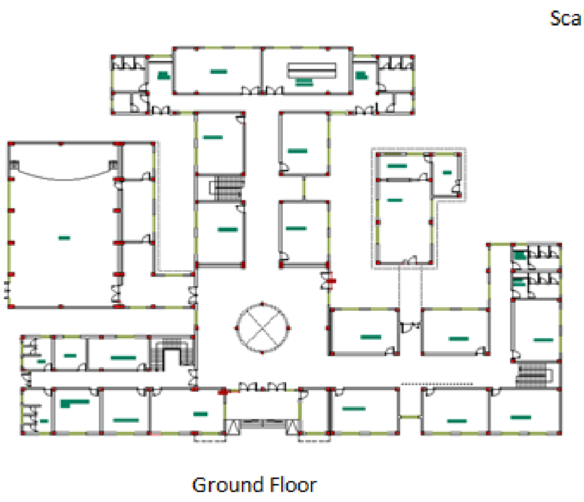

Figure 1: The plans of secondary school typology DES (2015)

Figure 2: The elevation of secondary school typology DES (2015)

4. Building Energy Simulation Model

Building Energy Simulation is the analysis of the energy performance of buildings using computer modelling and simulation techniques (Dragicevic et al., 2013). To investigate the energy performance in the school building, the dynamic 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, floors, and their thickness, as well as window glazing 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 electric were used for cooling and Domestic Hot Water (DHW).

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	
	Double gypsum	2	4	2.13
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			

The basic parameters which were used for energy simulations are given in Table 1. Furthermore, the software is facing difficulties handling non-perpendicular walls. Therefore, it is necessary to avoid this by transforming the layout into an approximate state, while keeping the original building physics related dimensions. After setting up all the parameters, the IDA ICE, model can be created as shown in Figure 3. Running one-year simulations will provide results for energy analysis.

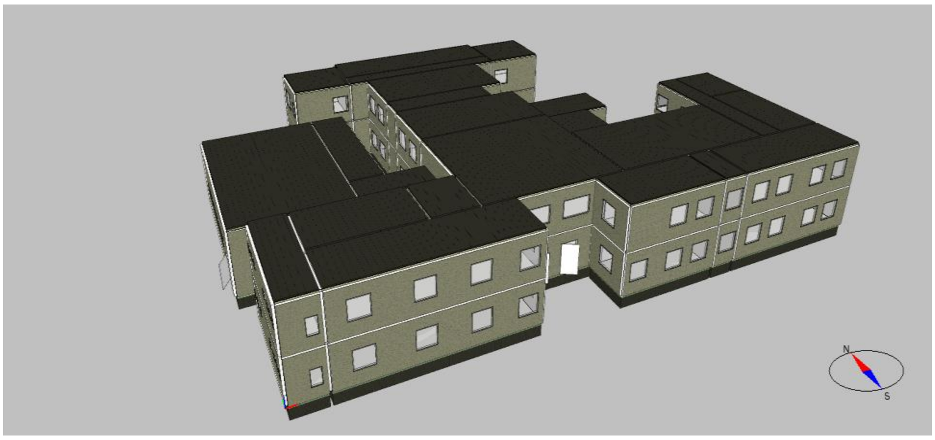

Figure 3: IDA ICE model for typical secondary school building

5. Energy Analysis

The simulation result as shown in Table 2 revealed that the total energy demand for the typical school building for one year period was 783667 kWh. Based on the result analysis the greatest user of energy is for heating (fuel). The second largest use is for cooling (electricity) followed by domestic hot water (electricity), plug loads, and other uses. Indeed, 78% of the consumed energy stands for indoor air conditioning (heating and cooling).

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

		Purchased energy kWh	Purchased energy kWh/m²	Peak demand kW
	Lighting, facility	49080	14.7	16.79
	Electric cooling	224777	67.2	347.0
	Electric heating (DHW)	118740	35.5	13.55
	Total, Facility electric	392597	117.4	
	Fuel heating	391070	117.0	227.7
	Total	783667	234.4	

A predominant characteristic in the energy consumption is fuel heating, electric cooling and domestic hot water (DHW), and the rest of energy consumption is for lighting and other purposes, as shown in Figure 4.

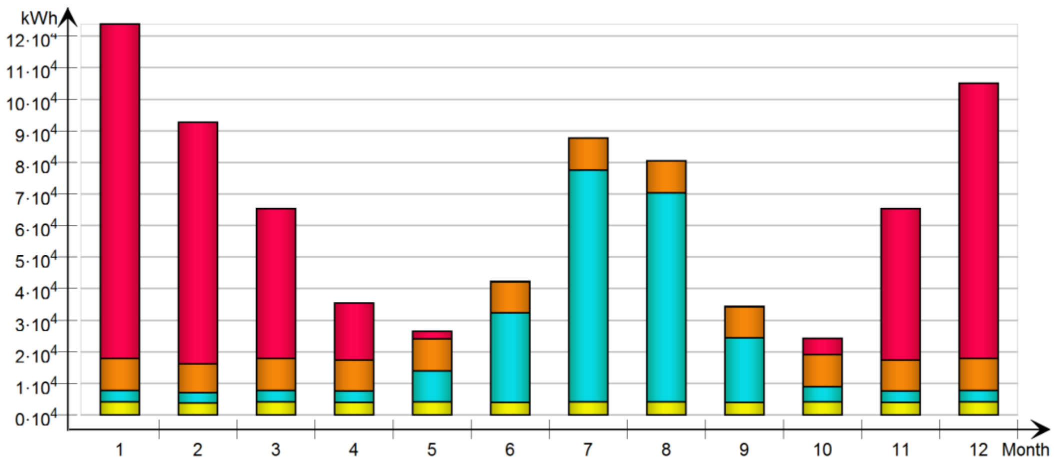

Figure 4: IDA ICE energy report, the predominant characteristic is fuel heating and electric cooling

6. 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 including; thermal insulation, cutting back the window to wall ratio, and decrease the infiltration. The fifth scenario was applied for getting the optimum model, presented as in Table 3.

Table 3: Scenarios detailed descriptions

Scenarios	Description
Scenario (1)	Adding 20cm thermal insulation to the building envelope
Scenario (2)	10% Window to wall Ratio reduction of the reference model.
Scenario (3)	20% Window to wall Ratio reduction of the reference model.
Scenario (4)	Reducing infiltration of the reference model from 10 ACH to 5 ACH.
Scenario (5)	Applying the most effective scenarios together.

7. Result Discussion

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 that the total energy consumption was reduced 44.82% by adding 20cm insulation for the building envelope, while by reduction infiltration from 10 ACH to 5ACH, the total energy reduction was 1.70%. In addition, in the third and fourth scenario, the window to wall ratio of the school building was reduced by 10%, 20% from the reference case, the total energy consumption was reduced 0.43%, 1.09% sequentially, as shown in Table 4.

Table 4: 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	224777	158449	225088	223016	217285
Fuel Heating	kWh	391070	105709	377034	389043	389991
DHW	kWh	118740	119052	119052	119052	118740
Lighting facility	kWh	49080	49225	49202	49225	49098
Total Energy	kWh	783667	432435	770376	780336	775114
Percentage of reduction		0.0	44.82%	1.70%	0.43%	1.09%

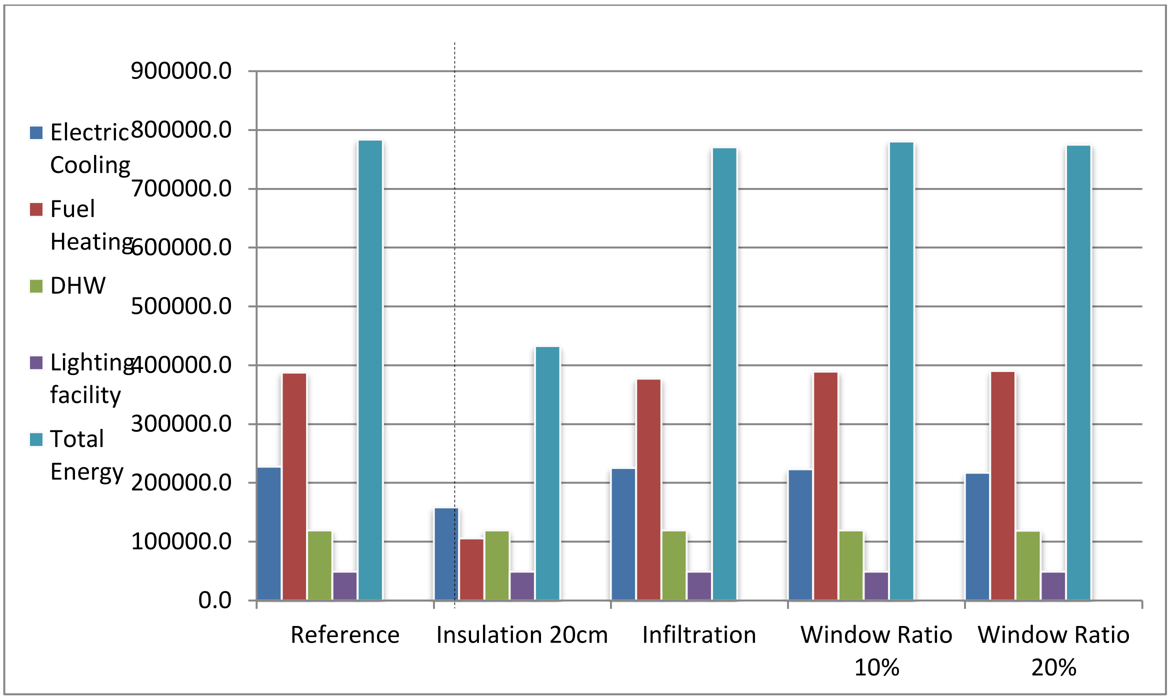

Figure 5: Annual energy consumption through all scenarios based on compared with the reference model

Through different scenarios, the amount of CO2, daylight, and thermal comfort were also investigated to ensure the indoor air quality inside the school building. On the other side to ensure daylight and CO2 level abide the regulation of the set point of IDA ICE. In addition, thermal comfort, CO2 level, and day lighting were compared to the reference model. From Table 5, it can be observed that adding 20 cm of thermal insulation to the building envelopes has increased the daylight level and reduced the CO2 level slightly, while reducing the window to wall ratio and infiltration were lead to reduce the daylight level and increase the CO2 level in a way that didn't affect the efficiency of the indoor environment of the school building.

Table 5: 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

Thus, in order to propose an optimal model, based on the result analysis, three scenarios have been integrated: including 20cm thermal insulation, reduction of infiltration, and 20% window to wall ratio reduction. The optimum model has been simulated and compared with the reference model. The results showed that the optimum model has a significant decrease in energy consumption for conditioning school 49.32%, as shown in Table 6.

Table 6: The optimum model for the school building and its comparison with the reference model

Zone: Class Room-1 Orientation: (South)		Reference model	Optimized model
Electric Cooling	kWh	224777	134815
Fuel Heating	kWh	391070	94513
DHW	kWh	118740	118740
Lighting facility	kWh	49080	49098
Total Energy	kWh	783667	397158
Percentage of reduction		0.0	49.32%

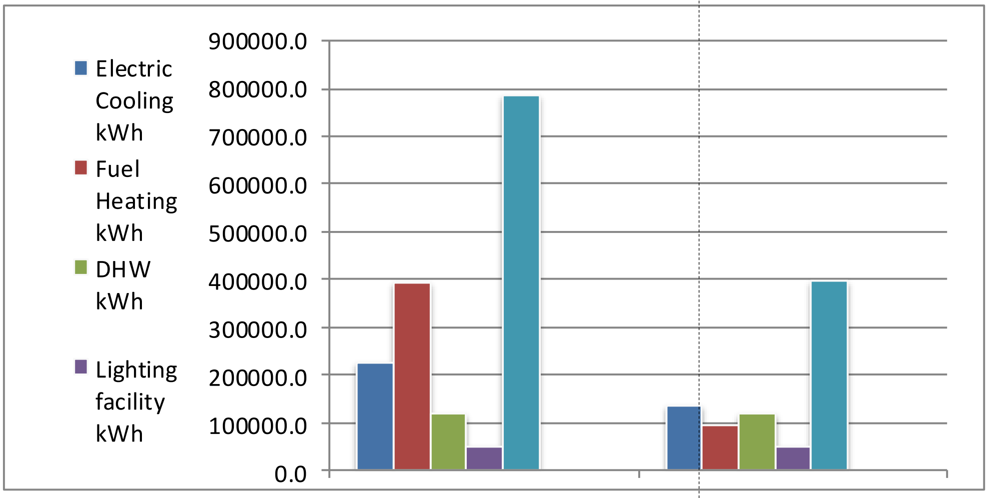

Figure 6: The comparison between optimum model and reference model

8. Conclusion

This study investigated the energy and indoor environment optimization in a typical school building in Sulaimani, Iraq, through simulation several scenarios. The simulation results showed that the most significant improvements occurred while adding thermal insulation to the building envelopes. Thus, the improved model performed better than the reference model in terms of indoor environment and energy consumption. The yearly energy consumption in the optimized model was reduced by 49.32 % compared to the reference building. Furthermore, it may enable the schools to obtain economic advantages and make larger financial sources available for educational purposes.

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