

# EVALUATING INDOOR ENVIRONMENTAL QUALITY AND ENERGY DEMAND IN ERBIL'S PUBLIC SCHOOL CLASSROOMS: A SIMULATION-BASED ASSESSMENT BASED ON CLASSROOM ORIENTATION

DOI: [https://doi.org/10.18485/arh\\_pt.2025.10.ch5](https://doi.org/10.18485/arh_pt.2025.10.ch5)

## \_ Dedar Salam Khoshnaw

PhD Student, University of Pecs - Faculty of Engineering and Information Technology - Marcel Breuer Doctoral School, Pecs, Hungary. Koya University - Faculty of Engineering, Department of Architectural Engineering, Erbil, Iraq, [dedar.salam@koyauniversity.org](mailto:dedar.salam@koyauniversity.org), [0000-0002-2752-9022]

## \_ Tamás János Katona

PhD, Professor Emeritus, University of Pécs - Faculty of Engineering and Information Technology, Department of Building Structures and Energy Design, Institute of Architecture, Hungary, [katona.tamas@mik.pte.hu](mailto:katona.tamas@mik.pte.hu) [0000-0001-5888-832X]

## \_ Bálint Baranyai

PhD, Assistant Professor, University of Pécs- Faculty of Engineering and Information Technology, Energy Design Research Group, Institute of Architecture, Pécs, Hungary, [baranyai.balint@mik.pte.hu](mailto:baranyai.balint@mik.pte.hu), [0000-0002-9523-535X]

## ABSTRACT

The quality of the indoor environment is crucial for establishing comfortable and energy-efficient learning spaces within schools. This study assesses the indoor environmental quality (IEQ) and energy demands of public school classrooms in Erbil, Iraq, by comparing simulation results from IDA ICE 5.1 software with international standards. The research focuses on the influence of classroom orientation on essential environmental factors, including thermal comfort, daylight availability, and indoor air quality (IAQ). A frequently constructed school model in Erbil was selected for analysis, with simulations conducted for classrooms oriented to the north, south, east, and west.

The results indicate that north-facing classrooms provide the most stable thermal conditions, optimal daylight, and reduced cooling energy requirements, while south- and west-facing classrooms experience higher thermal gain and energy consumption. Analysis of IAQ suggests that cross-ventilated designs maintain superior air quality in accordance with ASHRAE 62.1 standards. The study recommends energy-efficient strategies, including passive cooling techniques, enhanced insulation, optimised ventilation, and the integration of renewable energy, to promote sustainability in Erbil's public schools. These findings serve as a foundation for policy recommendations and future improvements in school design that effectively balance comfort, energy efficiency, and environmental sustainability.

**KEYWORDS** \_ *Indoor environment quality, Energy demand, school classrooms, IDA ICE simulation, Erbil*

## INTRODUCTION

The quality of indoor environments in classrooms is crucial for students' health, well-being, and academic success. Factors such as thermal comfort, air quality, lighting, and acoustics significantly impact concentration and learning outcomes. Poor IEQ can lead to discomfort, reduced cognitive abilities, and increased absenteeism (Dorizas, Assimakopoulos, and Santamouris 2015). Additionally, the energy demands of school buildings are a growing concern due to rising costs and sustainability goals (Jaouaf, Bensaad, and Habib 2024). Therefore, ensuring compliance with IEQ standards while achieving energy efficiency is vital for optimal learning environments. Erbil, the capital of the Kurdistan Region of Iraq, faces challenges in maintaining IEQ due to rapid urbanization and a lack of consideration for modern standards in public school construction (Zewar 2024; Aziz et al. 2023). With significant climate variations, striking a balance between indoor comfort and energy consumption is crucial. This study aims to evaluate the IEQ and energy use of Erbil's public school classrooms through simulation-based analysis, comparing the results to international and regional standards. It will identify areas for improvement and propose strategies to enhance both IEQ and energy efficiency. The paper includes a literature review, methodology, results and analysis, recommendations, and a conclusion.

## LITERATURE REVIEW

### Indoor Environmental Quality (IEQ) in Classrooms

IEQ significantly affects occupant comfort and productivity, encompassing thermal conditions, air quality, lighting, and acoustics. In classrooms, poor IEQ can hinder students' concentration, health, and academic performance (Wargocki and Wyon 2007).

- a. **Thermal comfort:** Temperature and humidity are crucial for focus. ASHRAE recommends classroom temperatures between 20-24°C in winter and 23-26°C in summer. (Bienvenido-Huertas et al. 2024). Extreme temperatures can decrease cognitive performance.
- b. **Air Quality:** Effective ventilation is essential. Elevated CO<sub>2</sub> levels, often above 1,000 ppm in crowded classrooms, can cause fatigue. WHO and ASHRAE suggest keeping CO<sub>2</sub> below 800 ppm for optimal learning (Persily and de Jonge 2017).
- c. **Lighting conditions:** Natural and artificial light impacts vision and engagement. Insufficient light can lead to eye strain. The Illuminating Engineering Society recommends a minimum of 300 lux for classrooms (van Bommel 2019).
- d. **Acoustics:** Background noise can hinder communication. Ideally, classroom noise levels should not exceed 35 Db(A) for clear interaction (Zannin and Zwirtes 2009).

### Energy demand in school buildings

Energy consumption in school buildings is influenced by climatic conditions, materials, HVAC systems, and occupancy patterns. In hot areas like Erbil, cooling demands significantly increase energy use. Research shows that passive design strategies—such as improved insulation, shading, and natural ventilation—can effectively reduce energy consumption

- a. **HVAC and Ventilation:** HVAC systems are major energy consumers in schools. Energy-efficient solutions, like demand-controlled ventilation and high-efficiency air conditioning, are recommended to promote sustainability
- b. **Passive Design Strategies:** Employing thermal mass, reflective materials, and proper window orientation can enhance thermal comfort and reduce energy demand, with some case studies indicating cooling load reductions of 20-30% in hot climates.

This literature review emphasizes the importance of IEQ and energy efficiency in schools, underscoring the need for a comprehensive assessment of public classrooms in Erbil. The following section outlines the methodology for a simulation-based evaluation of these aspects.

## METHODOLOGY

### Study Methodology and Case Selection

This research employs simulation-based methods, utilising IDA ICE 5.1, to assess the IEQ and energy demands of public school classrooms in Erbil. A typical school building commonly found in the region was selected as the case study to accurately represent standard design and construction practices (see Figure 1).



Figure 1: public school in Erbil

### Classroom Orientations and Assessment Parameters

To evaluate the influence of classroom orientations on indoor environmental conditions, four orientations (North, South, East, and West) were modelled. The classrooms were assessed based on essential IEQ and energy parameters, including:

- Thermal comfort: evaluated by analysing temperature variations throughout the year.
- Daylight availability: examined based on the daylight factor and illumination levels.
- IAQ: measured in terms of CO<sub>2</sub> concentrations and ventilation efficiency.

### Simulation Configuration in IDA ICE 5.1

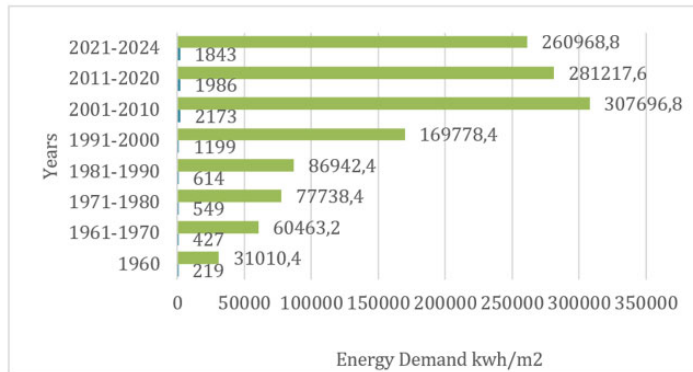
The IDA ICE 5.1 software was used for dynamic simulations, which included:

- Building design: modeled after actual school construction specifications from Erbil.
- Weather data: incorporated local meteorological data for realistic conditions
- Occupancy schedules: standard classroom occupancy patterns were used.
- HVAC systems: simulations included both natural and mechanical ventilation.

## RESULTS AND DISCUSSION

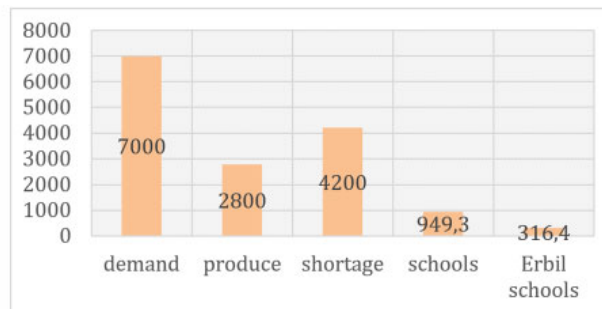
### Energy Demand Trends in Erbil's Schools (1920-2024)

A review of schools and their energy consumption from 1920 to 2024 shows a significant increase in both. Figure 3 illustrates the link between the growth in the number of schools and their energy demand over the years.



**Figure 3:** correlation between the growth in the number of schools and their energy demand over the years

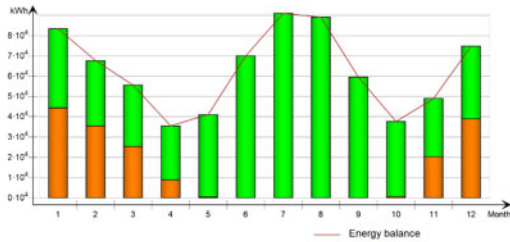
Since the 1990s, rapid urbanisation and population growth in Erbil have expanded the public school system, increasing energy consumption for heating and cooling. Schools significantly contribute to the rising energy demand in the Kurdistan region. Analysing this, it's clear that schools in Erbil are taking up a larger share of the total energy supply, emphasising the urgent need for energy-efficient school buildings to lower electricity and fuel use.



**Figure 4:** annual energy demand mw/year, generally and for schools in the Kurdistan region, highlighting Erbil's contribution

### Simulation Outcomes of Classroom Orientations

The IDA ICE 5.1 software simulated the orientations of four classrooms (north, south, east, and west) to assess their impact on thermal comfort, daylighting, IAQ, and energy efficiency. Figure 5 shows a monthly summary of primary energy totals for a typical school in Erbil.



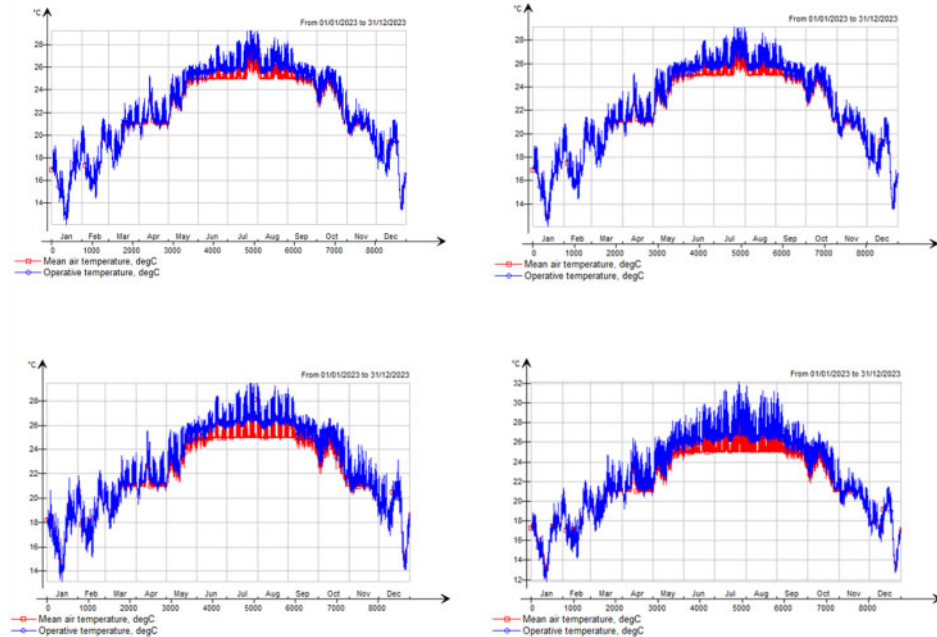
**Monthly Total primary energy**

		Total	
		kWh	kWh / m <sup>2</sup>
■	Purchased by facility (el)	579834.0	108.9
Total Electricity		579834.0	108.9
■	Purchased by facility (fuel)	174315.2	32.7
Total Fuel		174315.2	32.7
Overall energy performance		754149.2	141.6

**Figure 5: monthly summary of primary energy totals**

**Thermal Comfort Analysis**

Classroom temperature fluctuations varied by orientation. South-facing rooms experienced the highest thermal gain in summer while north-facing classrooms maintained more stable temperatures throughout the year. East and west orientations experienced greater variations due to morning and afternoon solar exposure. ASHRAE Standard 55 advises keeping classroom temperatures between 20-24°C in winter and 23-26°C in summer for comfort (Standard 1992). Simulation results show that north-facing classrooms needed less cooling in summer, enhancing their energy efficiency see Figure 6.



**Figure 6: a. East façade; b. North façade; c. South façade; d. West facade**

## Daylighting Analysis

Daylighting is essential for reducing reliance on artificial lighting and improving students' cognitive performance. South-facing classrooms receive the most natural light but may experience glare and overheating. In contrast, north-facing classrooms offer consistent, diffused daylight, enhancing visual comfort see Figure 7.

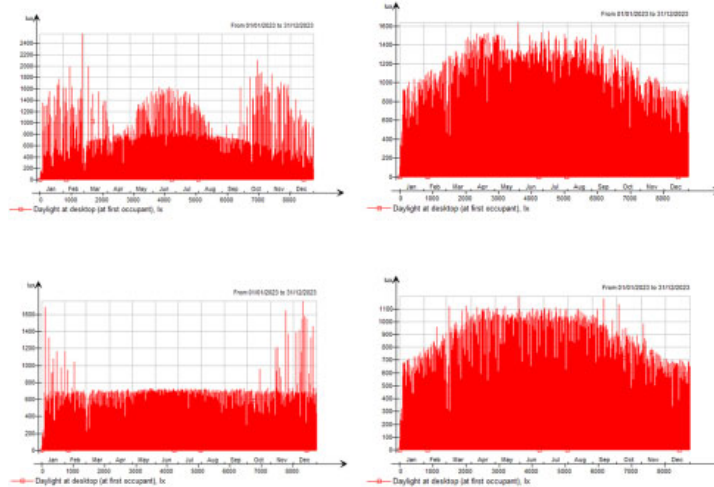


Figure 7: a. East façade; b. North façade; c. South façade; d. West façade

## Indoor Air Quality

CO<sub>2</sub> concentration levels were evaluated to assess ventilation efficiency, based on ASHRAE Standard 62.1, which states classrooms should keep CO<sub>2</sub> below 800 ppm for good indoor air quality (Carrasco, Molina, and Jones 2023). The results showed:

- North- and south-facing classrooms maintained CO<sub>2</sub> levels within acceptable limits.
- East- and west-facing classrooms displayed slightly elevated CO<sub>2</sub> levels due to variations in ventilation effectiveness (see Figure 8).

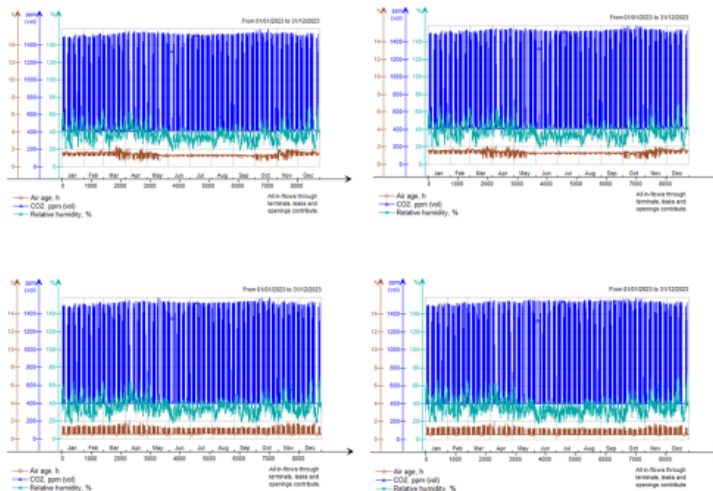


Figure 8: a. East façade; b. North façade; c. South façade; d. West façade

## **Interpretation and Implications**

### ***Optimal Classroom Orientation***

North-facing classrooms provide the best balance of thermal stability, natural daylight, and energy efficiency. In contrast, south-facing classrooms receive ample natural light but require additional cooling to mitigate heat gain.

### ***Energy Demand Reduction Potential***

Implementing passive cooling strategies like shading, improved insulation, and optimised ventilation can reduce cooling needs by 20-30% (Zomorodian, Tahsildoost, and Hafezi 2016). This is significant for lowering energy consumption in schools, especially with the rising electricity demand in Erbil's educational facilities.

## **RECOMMENDATIONS AND STRATEGIES**

Based on the study's findings, several recommendations can enhance IEQ and energy efficiency in Erbil's public school classrooms. These focus on optimising building design, improving ventilation, and integrating energy-efficient solutions to create healthier, sustainable learning environments.

### **Optimal Classroom Orientation and Design**

1. North-Facing Classrooms: Prioritize north-facing classrooms for better thermal stability, consistent natural light, and lower cooling needs.
2. Shading Devices: Use adjustable external shading, like louvres and blinds, on south and west-facing classrooms to reduce overheating and glare.
3. Building Envelope Improvements: Employ high-performance glazing and insulated walls to regulate indoor temperatures and minimise heat gain or loss.

### **Policy and Implementation Recommendations**

1. Green Building Standards: Local authorities must enforce energy efficiency regulations for new schools, aligning with international standards like LEED and BREEAM.
2. Awareness and Training: School staff should receive training in energy conservation techniques.
3. Maintenance and Monitoring: Schools should conduct regular energy audits and indoor air quality assessments to ensure compliance with safety standards.

## **CONCLUSION**

This study assessed the IEQ and energy demand of public school classrooms in Erbil using IDA ICE 5.1 simulations. Key findings include:

- North-facing classrooms had stable temperatures, optimal daylight, and the lowest cooling loads.
- South and west-facing classrooms faced higher thermal gains, increasing cooling energy needs.
- CO<sub>2</sub> concentrations and ventilation efficiency varied by orientation, with cross-ventilated designs performing best.
- The growing energy demand in Erbil's public schools highlights the need for energy-efficient strategies.

To tackle these challenges, passive design methods, enhanced ventilation, and renewable energy solutions are crucial. Implementing these measures will enhance student comfort, promote energy savings, and foster sustainability. Further research should focus on long-term classroom performance monitoring and adaptive thermal comfort models, alongside policy development for energy-efficient educational buildings.

## REFERENCES

- Aziz, Shuokr Qarani, Shamal Ali Othman, Payam Ismael, Shuokr Q Aziz, Shamal A Othman, Jwan S Mustafa, and Payam I Abdulrahman. 2023. 'Evaluation of Construction Materials and Environmental Situation Management in School Buildings Throughout a Half-Century (1970 to 2021) in Erbil City'. *Article in Academic Journal of Nawroz University* 12 (4): 2023. <https://doi.org/10.25007/ajnu.v12n4a1652>.
- Bienvenido-Huertas, David, Daniel Sánchez-García, Blanca Tejedor, and Carlos Rubio-Bellido. 2024. 'Energy Savings in Buildings Applying ASHRAE 55 and Regional Adaptive Thermal Comfort Models'. *Urban Climate* 55 (May):101892. <https://doi.org/10.1016/J.UCLIM.2024.101892>.
- Bommel, Wout van. 2019. 'Lighting Quality and Standards'. *Interior Lighting*, 389–406. [https://doi.org/10.1007/978-3-030-17195-7\\_16](https://doi.org/10.1007/978-3-030-17195-7_16).
- Carrasco, Nicolás, Constanza Molina, and Benjamin Jones. 2023. 'Investigating Uncertainty in the Relationship between Indoor Steady-State CO2 Concentrations and Ventilation Rates'. <https://www.aivc.org/resource/investigating-uncertainty-relationship-between-indoor-steady-state-co2-concentrations-and>.
- Dorizas, Paraskevi Vivian, Margarita Niki Assimakopoulos, and Mattheos Santamouris. 2015. 'A Holistic Approach for the Assessment of the Indoor Environmental Quality, Student Productivity, and Energy Consumption in Primary Schools'. *Environmental Monitoring and Assessment* 187 (5): 1–18. <https://doi.org/10.1007/S10661-015-4503-9>.
- Jaouaf, Salaheddine, Bourassia Bensaad, and Mustapha Habib. 2024. 'Passive Strategies for Energy-Efficient Educational Facilities: Insights from a Mediterranean Primary School'. *Energy Reports* 11 (June):3653–83. <https://doi.org/10.1016/J.EGYR.2024.03.040>.
- Persily, A., and L. de Jonge. 2017. 'Carbon Dioxide Generation Rates for Building Occupants'. *Indoor Air* 27 (5): 868–79. <https://doi.org/10.1111/INA.12383>.
- Standard, ASHRAE. 1992. 'Thermal Environmental Conditions for Human Occupancy'. *ANSI/ASHRAE*, 55 5. <https://cir.nii.ac.jp/crid/1574231875437564672>.
- Wargocki, Pawel, and David P. Wyon. 2007. 'The Effects of Moderately Raised Classroom Temperatures and Classroom Ventilation Rate on the Performance of Schoolwork by Children (RP-1257)'. *HVAC&R Research* 13 (2): 193–220. <https://doi.org/10.1080/10789669.2007.10390951>.
- Zannin, Paulo Henrique Trombetta, and Daniele Petri Zanardo Zwirtes. 2009. 'Evaluation of the Acoustic Performance of Classrooms in Public Schools'. *Applied Acoustics* 70 (4): 626–35. <https://doi.org/10.1016/J.APACOUST.2008.06.007>.
- Zewar, Sardar Suwar. 2024. 'Contribution to School Design through Assessment of Corridor Conditions in Foundation Schools in Erbil, Iraq'. *Buildings* 2024, Vol. 14, Page 2678 14 (9): 2678. <https://doi.org/10.3390/BUILDINGS14092678>.
- Zomorodian, Zahra Sadat, Mohammad Tahsildoost, and Mohammadreza Hafezi. 2016. 'Thermal Comfort in Educational Buildings: A Review Article'. *Renewable and Sustainable Energy Reviews* 59 (June):895–906. <https://doi.org/10.1016/J.RSER.2016.01.033>.