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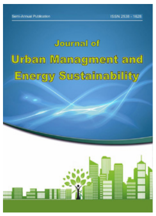

ORIGINAL RESEARCH PAPER

A comparative study of the effects of window features on energy efficiency

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ABSTRACT

Today, solutions to reduce the energy consumption of buildings are fundamental to protecting non-renewable energy sources. A sustainable solution to protect non-renewable resources is the optimal use of renewable resources, such as bringing as much daylight into the building as possible. The use of daylight, in addition to reducing the consumption of electrical energy, minimizes the load on the cooling system of the building. The optimal dimensions of windows are one of the important elements of the building, which is very effective in saving electricity and heat consumption. This study aims to optimize the consumption of electrical energy using daylight sensors. In this regard, the effect of daylight in reducing lighting consumption and reducing energy consumption has been investigated. This study was conducted in Tehran city. The simulation method uses Energy Plus software to simulate and analyze the data. The results showed that the use of daylight, in addition to reducing the consumption of electrical energy, minimizes the load on the building's cooling system: The amount of total energy consumption by energy carriers in the first stage (without using the Delight Sensor) is 72165.06 kWh and in the second stage (using the Delight Sensor) it is 53413.22 kWh, which reduces their energy consumption by almost 26%. A decrease of 66% was observed using the daylight sensor in the southern zone, while in the northern zone, it reached 76%. According to the ASE distribution diagram, the amount of glare near the windows, in the southern zone, was more than 2000 lux. According to the parametric analysis, the optimal ratio of the opening window to the surface is 20% in the southern zone and 30% in the northern zone.

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Running Title: The effects of window features on energy efficiency

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INTRODUCTION

Achieving affordable energy is one of the important goals of achieving sustainable development (Rezaei et al., 2019; Madurai Elavarasan et al., 2021; Hessari & Seyf shojaee, 2021). Recently, the reduction of natural resources and technological advances have caused a decrease in energy efficiency in buildings (Sharp et al., 2014; Danesh Pajouh et al., 2020). Energy-saving techniques have made buildings reduce energy consumption to a great extent (Marszal et al., 2011; Sarbu & Sebarchievici., 2013; Laaroussi et al., 2020). Concerns about building energy consumption can be addressed by incorporating passive solar techniques (PST) into the building to take advantage of daylight (Krüger & Zannin., 2004). Studies have shown that these PSTs are economical solutions for building energy efficiency (Kwon & Lee., 2018; Freewan & Dalala., 2020). Due to the importance of renewable energy sources, recently much research has been conducted on the development of optimal clean energy technologies (Kumar et al., 2020; Madurai Elavarasan et al., 2020; Grosjean & le Baron, 2022).

Historically, buildings have been designed to use daylight efficiently. However, the technological advancements of buildings became completely dependent on electrical energy for lighting (Leslie, 2003). Due to the frequent use of air conditioning and artificial lighting systems, non-residential buildings account for a significant part of their electricity consumption. (Ibañez et al., 2017; Webb, 2022). Since among the functions of the building, the largest amount of energy consumption includes lighting, therefore, the use of daylight in buildings as the main source of light for the environment reduces the demand for lighting energy in buildings (Heschong et al., 2002; Hua et al., 2011). Daylight harvesting systems are a useful solution to improve energy efficiency (Pandharipande & Newsham., 2018). Daylight harvesting systems (DHS) make it possible to offer the greatest energy savings (Williams et al., 2012). Reported energy savings for DHS typically range from 20 to 60 percent (Galasiu et al., 2013), Therefore, their practical use is not common yet (Galasiu & Reinhart., 2008). The double-glazed window reduces the energy consumption of the building in the heating sector by 12% and in the cooling sector by 17% (Eiraji & Elmkhah, 2021). Exterior windows, although providing views and daylight, came at the cost of thermal and visual comfort (Costanzo et al., 2017; Rashidzadeh & Heidari Matin, 2023).

Sunlight, as an unlimited and free source, can create lighting effects inside the building, and while creating lighting effects in the interior space, it can save energy (Heschong, 2002; Van Bommel & Van den Beld., 2004; Galasiu & Reinhart., 2008; Kilic & Hasirci., 2011; Wang & Boubekri., 2011; Bellia et al., 2013; Brotas & Pajares., 2013; Ramli et al., 2013; Wilkins, 2016; Ghonimi, 2017; Ko et al., 2020). The parameters that determine the quality of indoor spaces are temperature, light, indoor air quality, the ability to control daylight, and solar gain (Choi et al., 2012; Othman & Mazli., 2012; Barrett et al., 2013; Barrett et al., 2015). For this purpose, various indicators are used to measure the building's energy performance. (Mihai & Iordache., 2016). Some of these indicators include indoor air quality, thermal comfort, and lighting (Winterbottom & Wilkins., 2009; Boyce, 2010; Haverinen-Shaughnessy et al., 2015; Kuijsters et al., 2015; Heydarian et al., 2016; Vilcekova et al., 2017; Allan et al., 2019). Recently, daylight-dependent lighting control techniques have been reliably used to improve building energy efficiency (Pandharipande & Newsham., 2018; Karamouzian et al., 2021). Building lighting control techniques is one of the ways to achieve energy savings in cities (Dubois & Blomsterberg, 2011). The most common indoor lighting control systems are based on automatic artificial lighting technology, space management, time scheduling, and daylight harvesting (Ul Haq et al., 2014).

Daylight design strategies play an important role in green building rating systems (Giarma et al., 2017; Asojo et al., 2019). To ensure the effectiveness of energy efficiency, sustainability goals should focus on different daylighting approaches (Andersen, 2015). The design of the spaces directly affects the energy efficiency and the quality of the interior light of the building (Hill & Epps., 2010; Ahmadpoor Samani, & Ahmadpoor Samani., 2012; Shafaghat et al., 2015; Andargie et al., 2019). Windows provides the amount of sun radiation heat, daylight, and also natural ventilation for indoor spaces. Among the different fronts of the building, the light-transmitting surfaces on the south front show better thermal performance. Research studies have shown the positive effect of using the potential of natural environments on humans and energy efficiency (Mantler & Logan., 2015; Kim & Miller., 2019; Mavoa et al., 2019; Huang et al., 2020; Martin et al., 2020; Choe et al., 2020). The change in lifestyle and the presence of more residents in indoor spaces has increased the preoccupation of designers with using daylight for building energy efficiency (Frontczak & Wargocki., 2011; Hwang & Kim., 2011; Pathak et al., 2015). Daylight is a combination of direct and indirect sunlight during the day that includes direct light, scattered light, and light reflected from the ground and other surfaces (Figure 1).

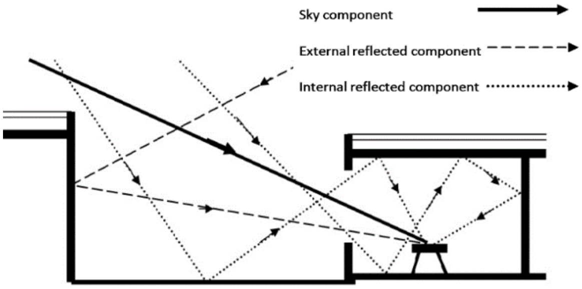


Fig 1: Daylight factor components (Lechner, 2009)

The factor of daylight is defined as the ratio of light inside the space of the light of its outside and in cloudy sky conditions. In other words, daylight factor is the sum of direct radiation reflected from internal and external surfaces that can be calculated for a point or the average of the whole space. Glare is one of the important factors in improving daylight and includes con-trolling the difference in brightness of interior surfaces and controlling it causes visual comfort of the environment by creating a balance between direct and indirect lighting (Figure 2).

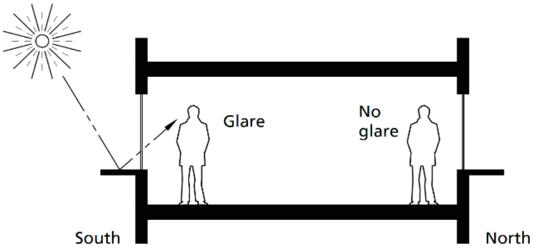


Fig 2: Glare of direct south light and light without glare of the north (Lechner, 2009)

The window, as the weakest part of the building shell, provides natural visibility, light and ventilation, and directly affects thermal comfort and energy consumption. Skylights work well to collect daylight. One of the advantages of these windows is the reduction of energy consumption in the lighting sector, but, heat loss in winter and heat transfer in summer are its disadvantages. The use of skylights provides uniform light. The greater distance of this window from the floor, the less dazzling will be. The dimensions and area of the window, in addition to affecting the amount of light, also affect the amount of cooling and heating load on the building. Therefore, in determining the appropriate dimensions of the window, in addition to the quality of space lighting and saving energy consumption, lighting, cooling and heating should be considered. The optimal ratio of window surface to wall should be designed in the early design stages and in coordination with the form, orientation and dimensions of the window. This ratio should reduce the total energy required for heating, cooling and lighting. The ratio of window to wall surface affects the energy consumption of the building and the comfort conditions of users by changing the rate of heat transfer from the shell, solar heat radiation, unwanted air leakage and received daylight. Among the items studied in determining the optimal ratio of window to wall ratio, solar gain, visibility and heat transfer, as well as climatic conditions.

MATERIALS AND METHODS

In the first step of the research, parametric analysis has been done to find the optimal location of the building. Then, two analytical models were performed: first, simulation without sensor daylight and then with sensor daylight. According to the information obtained in the simulation analysis, the most optimal direction is 20 degrees southwest. The simulation method is done by using Design Builder software to simulate and analyze the data.

The part of the plan that was considered as a module has been simulated in two zones, north and south. Both zones receive natural light through a 3-meter-long window from the terrace. Each room measures 4.2 x 8.7 meters. The materials used in the walls are common in construction. The parametric analysis method has been used in this research to investigate the effect of building orientation on energy consumption in an office-commercial building in Tehran city and to obtain the optimal orientation of an office-commercial building. According to the information obtained in the simulation of this section, the most optimal direction is 200 degrees (20 degrees southwest).

In the following, the annual daylight transaction diagram is considered in the overall plan, and ASE and SDA parameters are examined.

Annual Sunlight Exposure (ASE): The number of hours during a year that a point on the work surface receives more direct sunlight than a certain threshold. This criterion is usually used along with SDA to measure the probability of visual discomfort due to high brightness and is used as part of the daylight evaluation in the standard.

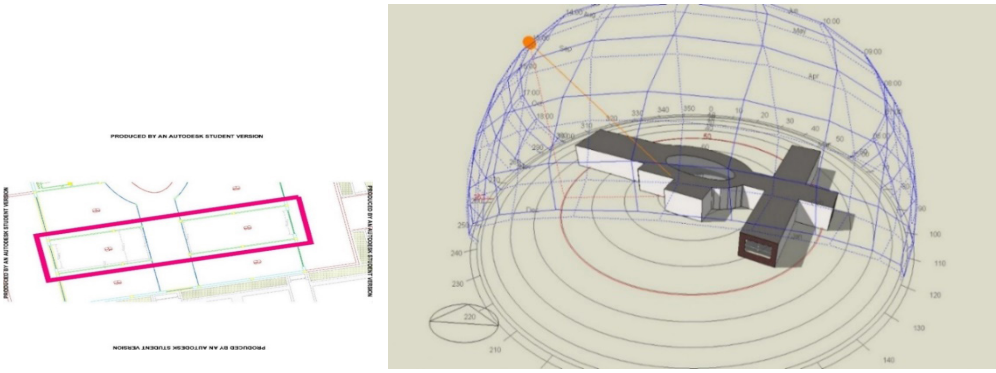


Fig 3: Simulated sample plan

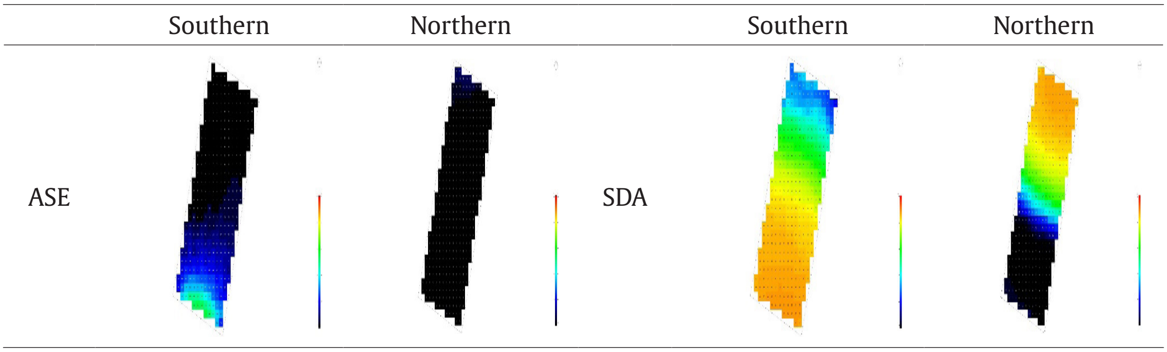


Fig 4: ASE and SDA distribution chart in Design Builder software

Spatial Daylight Autonomy (SDA): This criterion shows how long the minimum brightness of a work surface (300 (lux)) can be maintained only by daylight. This index is defined as a percentage of people's attendance during a year. In other words, SDA determines how much an area has access to enough daylight so that the anticipated activities can be carried out without artificial lighting. When the default settings are used, the output shows the percentage of the surface that has a brightness greater than 300 lux at least 50% of the time.

According to the ASE distribution diagram, the amount of glare near the windows, in the southern zone, was more than 2000 lux. That is, during the year, in some parts of the room, 1717 hours of glare were observed. The more we move away from the windows, the fewer these hours will be. To the extent that in some areas, glare almost disappears. In the southern zone, the most hours of glare were 1717. In the northern zone, this value was much less, so the maximum duration of glare was 261 hours.

The window area on different fronts of the building is one of the architectural factors affecting the energy consumption of the building.

DISCUSSION AND FINDINGS

Daylight sensor is not used in the building in the first stage of simulation: In the first stage of the research, internal benefits, temperature, heat in the south and north zones, and the total energy consumption of the building is calculated without using the daylight sensor (Figure 6, 7). Figures show the amount of heat absorbed by the building. The diagram includes different parts of thermal energy that are absorbed in the building and includes the following items: 1) The heat that is created through artificial lighting; 2) The heat consumed by equipment; 3) The heat that is generated by residents; and 4) The Solar Gains Exterior Windows that is absorbed through the sunlight on the windows in the building.

4.2. Daylight sensor is used in the building in the second stage of simulation: In the second stage, internal benefits, temperature, heat in the south and north zones, and the total energy consumption of the building are calculated using the daylight sensor (Figure 8, 9).

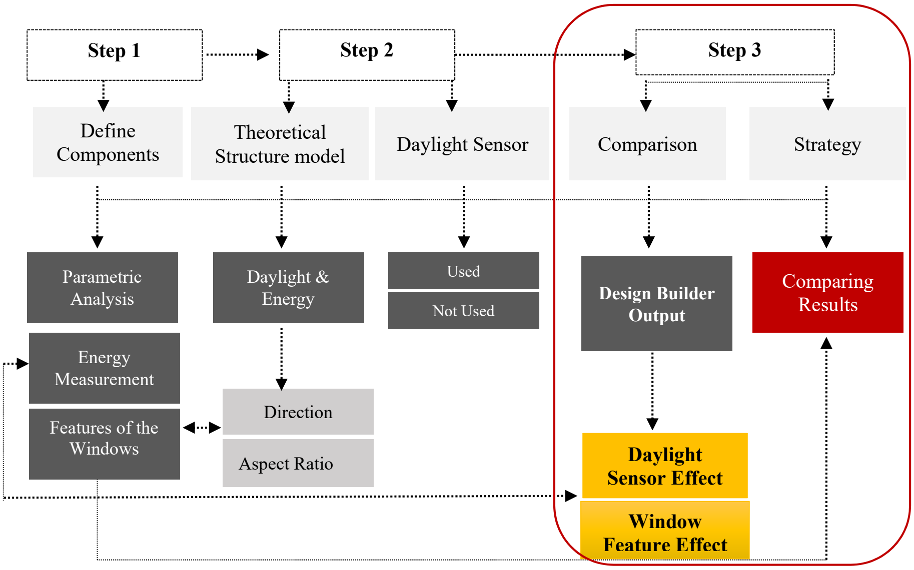
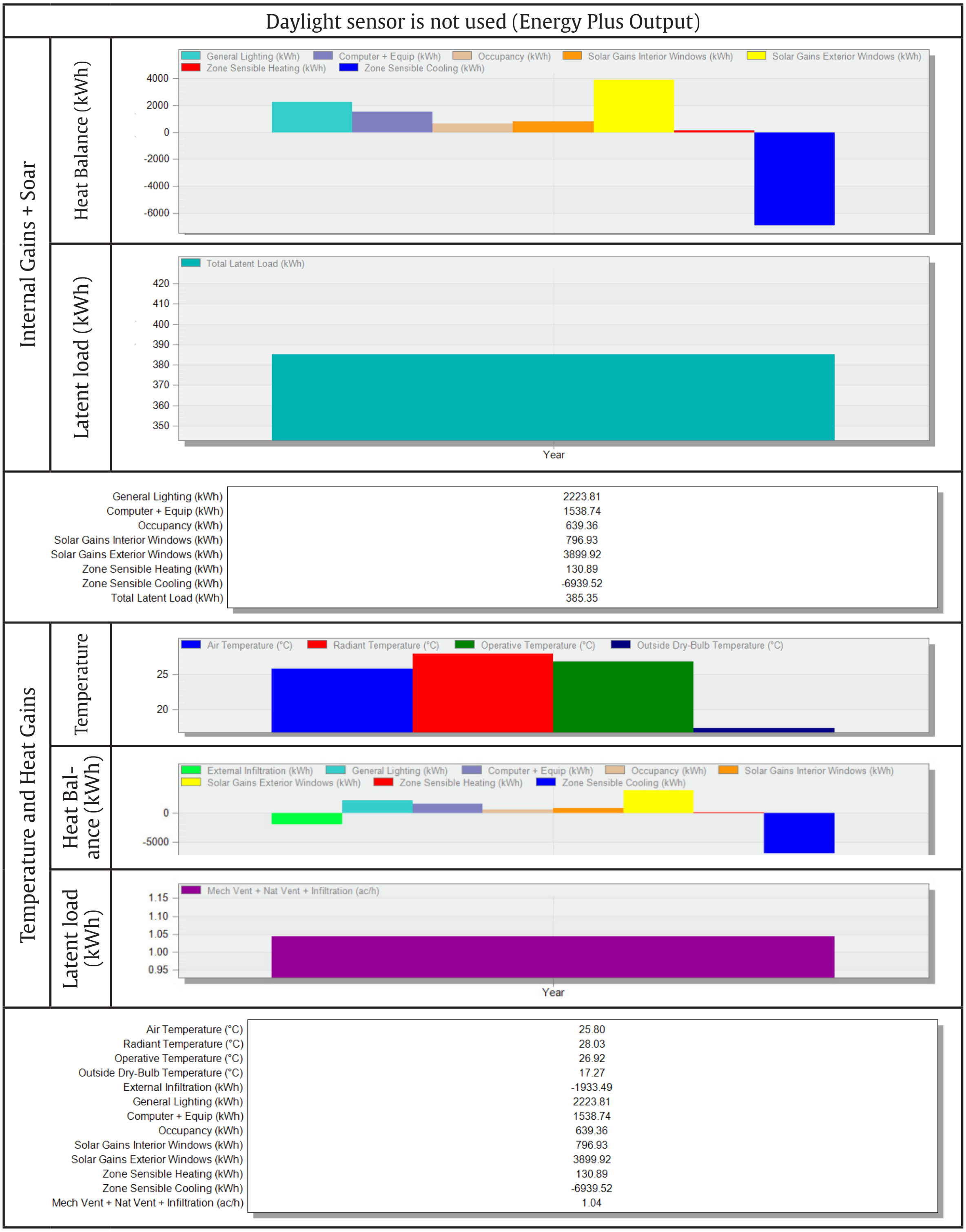


Fig 5: Research framework



General Lighting (kWh)	2223.81
Computer + Equip (kWh)	1538.74
Occupancy (kWh)	639.36
Solar Gains Interior Windows (kWh)	796.93
Solar Gains Exterior Windows (kWh)	3899.92
Zone Sensible Heating (kWh)	130.89
Zone Sensible Cooling (kWh)	-6939.52
Total Latent Load (kWh)	385.35

Air Temperature (°C)	25.80
Radiant Temperature (°C)	28.03
Operative Temperature (°C)	26.92
Outside Dry-Bulb Temperature (°C)	17.27
External Infiltration (kWh)	-1933.49
General Lighting (kWh)	2223.81
Computer + Equip (kWh)	1538.74
Occupancy (kWh)	639.36
Solar Gains Interior Windows (kWh)	796.93
Solar Gains Exterior Windows (kWh)	3899.92
Zone Sensible Heating (kWh)	130.89
Zone Sensible Cooling (kWh)	-6939.52
Mech Vent + Nat Vent + Infiltration (ac/h)	1.04

Fig 6: Internal Gains: Daylight sensor is not used in the building (Energy Plus Output)

Finding

In the case where the daylight sensor is used, the amount of artificial light decreases in the fuel breakdown diagram due to the increase in heating. Due to the reduction of the heat emitted from the artificial light, the amount of heating increases. That is, utility systems must work more to heat the environment, but the reduction in electricity consumption is so much that the benefits and optimization require using the sensors (Table 1 and Figure 10).

According to the consumption simulation results, the total energy by energy carriers when the Daylight Sensor is not used is 72165.06 kWh, but when the Daylight Sensor is used, it is 53413.22 kWh, which represents a 26% reduction in energy consumption. That is, the appropriate direction chosen for the establishment of the building as well as the use of daylight sensors are the factors in reducing energy consumption.

According to the simulation results in the northern and southern zones, table 2 has been extracted, in which the amount of illumination using daylight sensor and without using daylight sensor has been shown.

Tab 2: Comparison table of general Lighting without and with Delight sensor

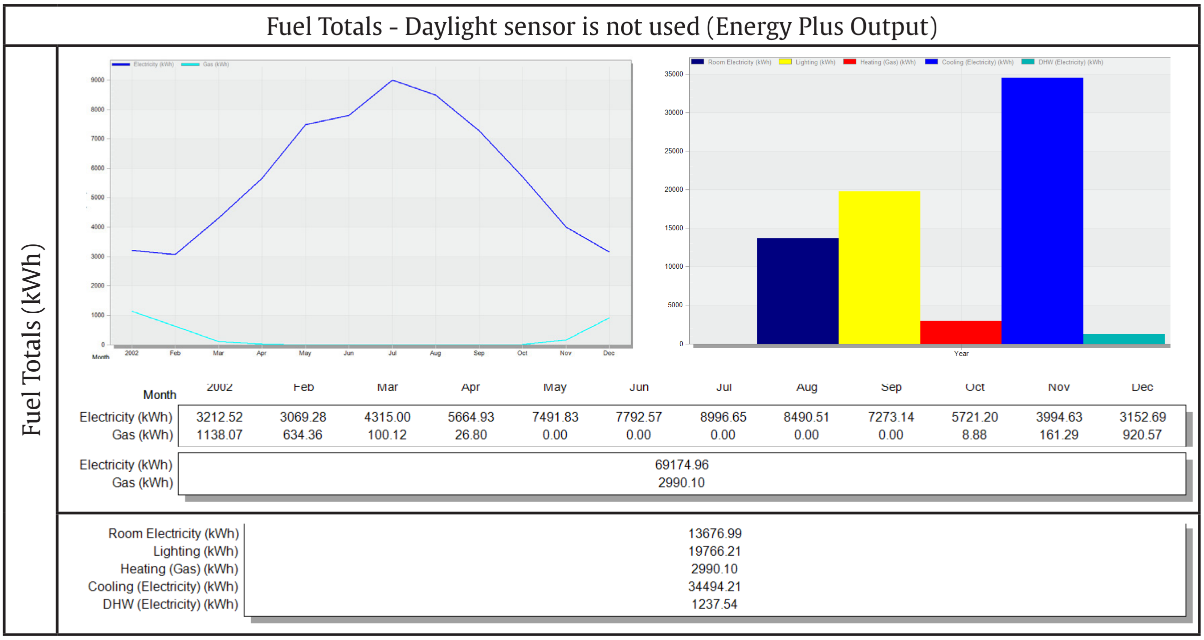
Zone	Daylight Sensor	Internal Gain General Lighting
Southern Zone	Without	2223.81
	✓ Using	748.31
Northern Zone	Without	2498.62
	✓ Using	583.63

In the southern zone, a decrease of approximately 66% is observed using the Daylight sensor. In the northern zone, this reaches 76%.

In the southern zone, a decrease of approximately 66% is observed using the Daylight sensor. In the northern zone, this reaches 76%. According to the parametric analysis, the optimal ratio of the opening window to the surface is 20% in the southern zone and 30% in the northern zone.

RESULT AND CONCLUSION

In this research, the effect of daylight in reducing lighting consumption and reducing energy consumption was investigated. The sim-



Fuel Totals - Daylight sensor is not used (Energy Plus Output)

Fuel Totals (kWh)

Month	2002	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Electricity (kWh)	3212.52	3069.28	4315.00	5664.93	7491.83	7792.57	8996.65	8490.51	7273.14	5721.20	3994.63	3152.69
Gas (kWh)	1138.07	634.36	100.12	26.80	0.00	0.00	0.00	0.00	0.00	8.88	161.29	920.57

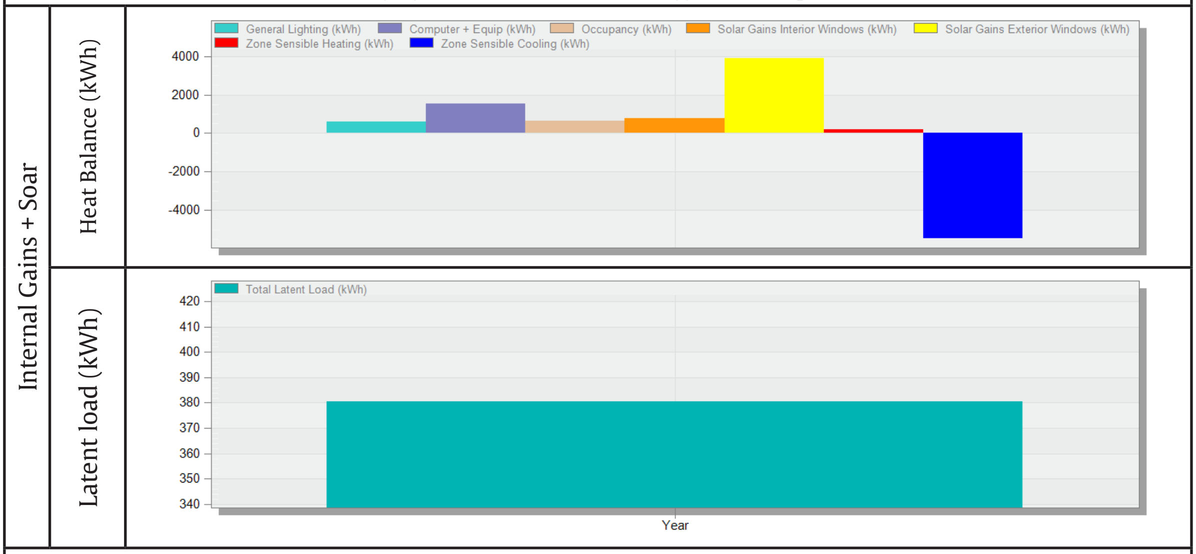
Electricity (kWh)	69174.96
Gas (kWh)	2990.10

Room Electricity (kWh)	13676.99
Lighting (kWh)	19766.21
Heating (Gas) (kWh)	2990.10
Cooling (Electricity) (kWh)	34494.21
DHW (Electricity) (kWh)	1237.54

Fig 7: Total energy consumption: Daylight sensor is not used (Energy Plus Output)

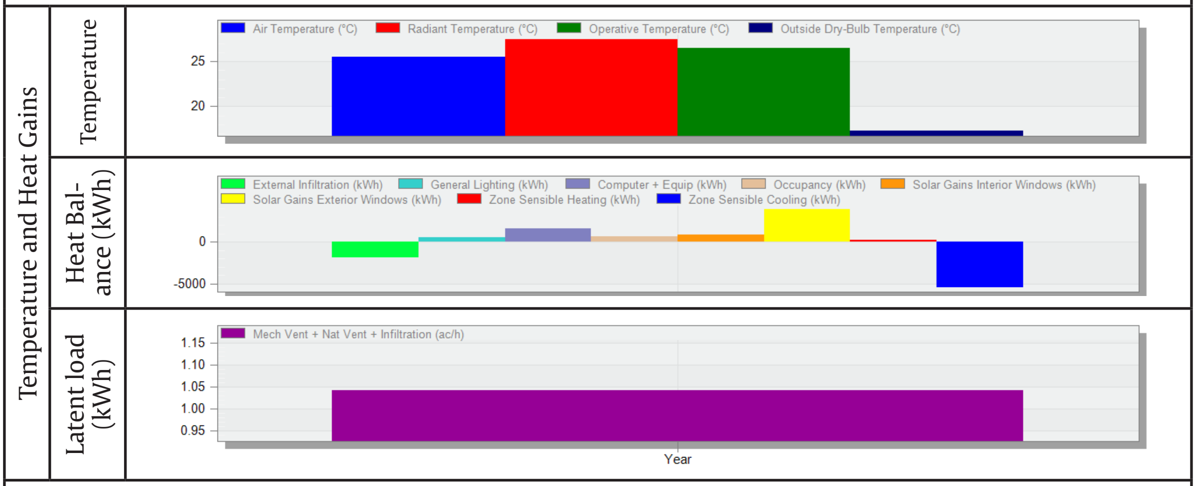
Daylight sensor is used (Energy Plus Output)

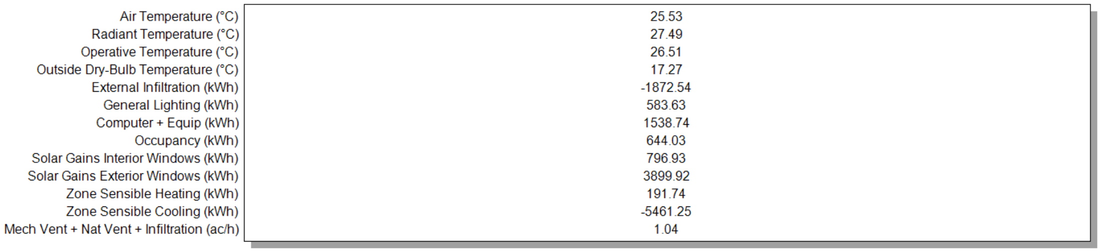
Internal Gains + Soar



General Lighting (kWh)	583.63
Computer + Equip (kWh)	1538.74
Occupancy (kWh)	644.03
Solar Gains Interior Windows (kWh)	796.93
Solar Gains Exterior Windows (kWh)	3899.92
Zone Sensible Heating (kWh)	191.74
Zone Sensible Cooling (kWh)	-5461.25
Total Latent Load (kWh)	380.67

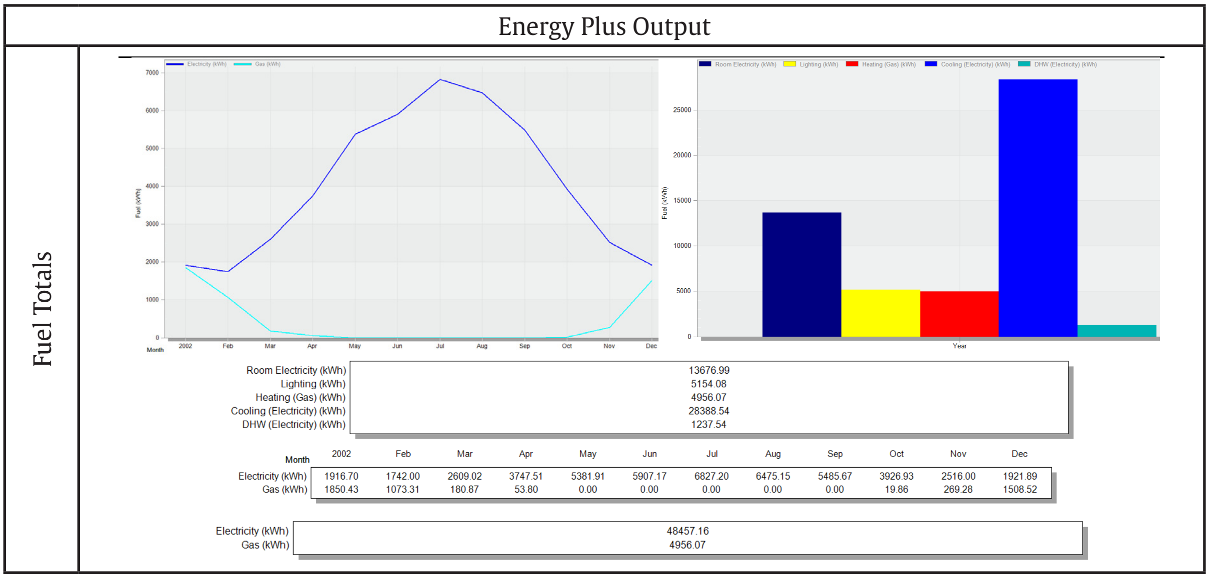
Temperature and Heat Gains





Air Temperature (°C)	25.53
Radiant Temperature (°C)	27.49
Operative Temperature (°C)	26.51
Outside Dry-Bulb Temperature (°C)	17.27
External Infiltration (kWh)	-1872.54
General Lighting (kWh)	583.63
Computer + Equip (kWh)	1538.74
Occupancy (kWh)	644.03
Solar Gains Interior Windows (kWh)	796.93
Solar Gains Exterior Windows (kWh)	3899.92
Zone Sensible Heating (kWh)	191.74
Zone Sensible Cooling (kWh)	-5461.25
Mech Vent + Nat Vent + Infiltration (ac/h)	1.04

Fig 8: Total energy consumption: Daylight sensor is used (Energy Plus Output)



Room Electricity (kWh)	13676.99
Lighting (kWh)	5154.08
Heating (Gas) (kWh)	4956.07
Cooling (Electricity) (kWh)	28388.54
DHW (Electricity) (kWh)	1237.54

Month	2002	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Electricity (kWh)	1916.70	1742.00	2609.02	3747.51	5381.91	5907.17	6827.20	6475.15	5485.67	3926.93	2516.00	1921.89
Gas (kWh)	1850.43	1073.31	180.87	53.80	0.00	0.00	0.00	0.00	0.00	19.86	269.28	1508.52

Electricity (kWh)	48457.16
Gas (kWh)	4956.07

Fig 9: Internal Gains: Daylight sensor is used in the building (Energy Plus Output)

Tab 1: Comparative table of energy analysis charts

Energy measurement	Fuel total				
	Gas (kwh)	Electricity (kwh)	Lighting (kwh)	Heating (kwh)	Cooling (kwh)
Without daylight sensor	2990.10	69174.96	19766.21	2990.10	34494.21
Using daylight sensor	4956.07	48457.16	5154.08	4956.07	28388.54

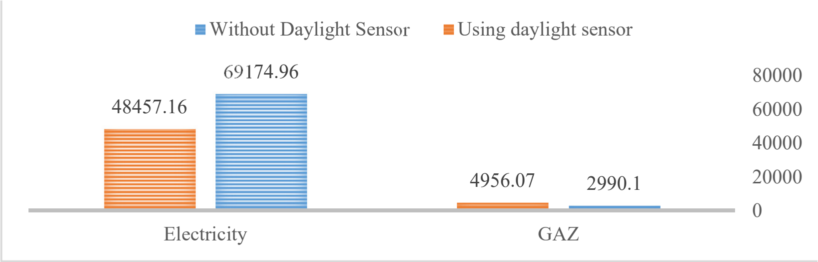


Fig 10: Comparative chart of total energy consumption by energy carriers in the building (Energy Plus Output)

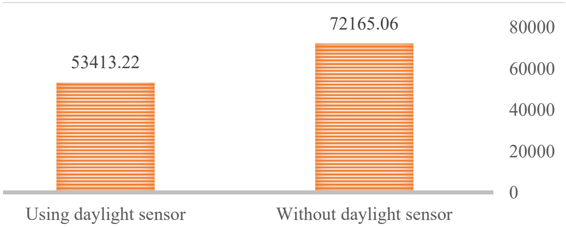


Fig 11: Comparative chart of total energy consumption in the building (Energy Plus Output)

ulation was carried out on the module with administrative use in two zones, north and south, and the results are as follows:

The amount of total energy consumption by energy carriers in the first stage (without using the Delight Sensor) is 72165.06 kWh and in the second stage (using the Delight Sensor) it is 53413.22 kWh, which reduces their energy consumption by almost 26%. That is, the appropriate direction chosen for establishing the building and using daylight sensors were the factors in reducing energy consumption. A decrease of 66% was observed using the daylight sensor in the southern zone, while in the northern zone, it reached 76%. According to the ASE distribution diagram, the amount of glare near the windows, in the southern zone, was more than 2000 lux. That is, during the year, in some parts of the room, 1717 hours of glare were observed. The more we move away from the windows, the fewer these hours will be. To the extent that in some areas, glare almost disappears. In the southern zone, the most hours of glare were 1717. In the northern zone, this value was much less, so the maximum duration of glare was 261 hours. According to the parametric analysis, the optimal ratio of the opening window to the surface is 20% in the southern zone and 30% in the northern zone.

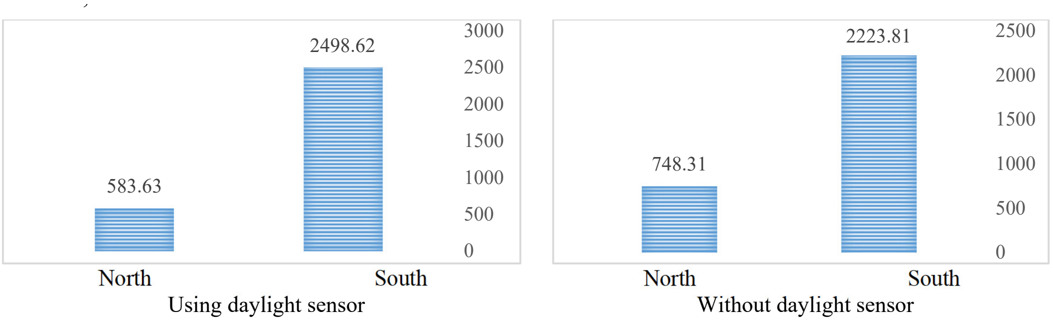


Fig 12: Comparison diagram of Internal Gain in General lighting diagram for south and north zone (Energy Plus Output)

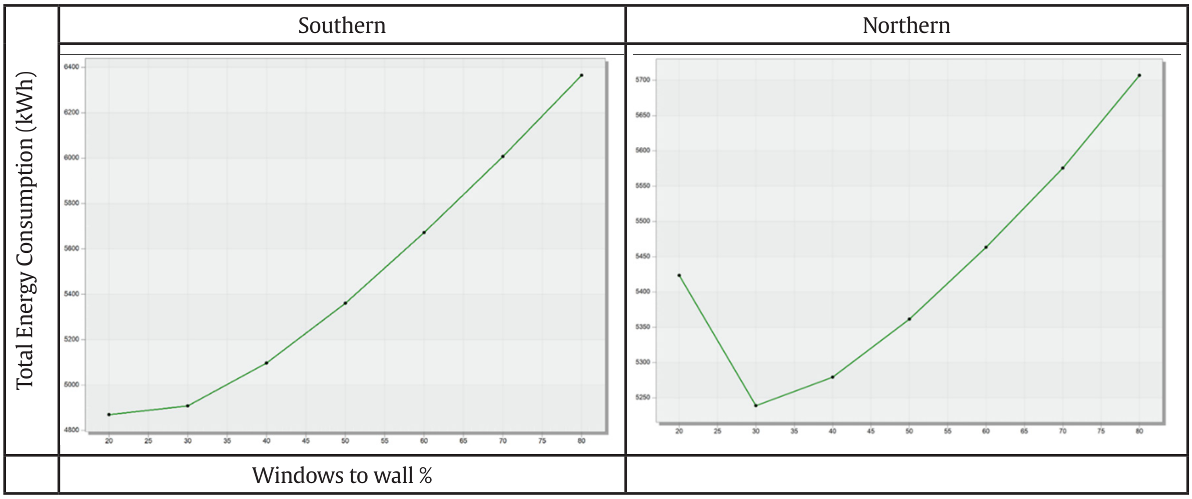


Fig 13: Parametric analysis diagram of the optimal ratio of the opening wall to the surface (Energy Plus Output)

References

Ahmadpoor Samani, S., & Ahmadpoor Samani, S. (2012). "The Impact of Indoor Lighting on Students' Learning Performance in Learning Environments: A knowledge internalization perspective", International Journal of Business and Social Science, vol. 3, no. 24, pp. 127-136. https://ijbssnet.com/journals/Vol_3_No_24_Special_Issue_December_2012/14.pdf

Allan, A. C., Garcia-Hansen, V., Isoardi, G., & Smith, S. S. (2019). "Subjective Assessments of Lighting Quality: A Measurement Review," LEUKOS, vol. 15, no. 2–3, pp. 115–126, https://doi.org/10.1080/15502724.2018.1531017.

Andargie, M. S., Touchie, M., & O'Brien, W. (2019)"A review of factors affecting occupant comfort in multi-unit residential buildings," Building and Environment, vol. 160, p. 106182. https://doi.org/10.1016/j.buildenv.2019.106182.

Andersen, M. (2015). "Unweaving the human response in daylighting design," Building and Environment, vol. 91, pp. 101–117, https://doi.org/10.1016/j.buildenv.2015.03.014.

Asojo, A. O., Bae, S., & Martin, C. S. (2019). "Post-occupancy Evaluation Study of the Impact of Daylighting and Electric Lighting in the Workplace," LEUKOS, pp. 239-250, https://doi.org/10.1080/15502724.2019.1602778.

Barrett, P., Davies, F., Zhang, Y., & Barrett, L. (2015). "The impact of classroom design on pupils' learning: Final results of a holistic, multi-level analysis," Building and Environment, vol. 89, pp. 118–133, https://doi.org/10.1016/j.buildenv.2015.02.013.

Barrett, P., Zhang, Y., Moffat, J., & Kobbacy, K. (2013). "A holistic, multi-level analysis identifying the impact of classroom design on pupils' learning," Building and Environment, vol. 59, pp. 678–689, https://doi.org/10.1016/j.buildenv.2012.09.016.

Bellia, L., Pedace, A., & Barbato, G. (2013). "Lighting in educational environments: An example of a complete analysis of the effects of daylight and electric light on occupants," Building and Environment, vol. 68, pp. 50–65, https://doi.org/10.1016/j.buildenv.2013.04.005.

Boyce, P. R., (2010). "Review: The Impact of Light in Buildings on Human Health," Indoor and Built Environment, vol. 19, no. 1, pp. 8–20, https://doi.org/10.1177/1420326X09358028.

Brotas, L., & Pajares, G. M., (2013). "Improving daylighting in architecture The SunBlocc prototype" in PLEA 2013, Munich, Germany.

Choe, E. Y., Jorgensen, A., & Sheffield, D. (2020). "Does a natural environment enhance the effectiveness of Mindfulness-Based Stress Reduction (MBSR)? Examining the mental health and wellbeing, and nature connectedness benefits" Landscape and Urban Planning, vol. 202, 103886. https://doi.org/10.1016/j.landurbplan.2020.103886.

Choi, J-H., Loftness, V., & Aziz, A. (2012). "Post-occupancy evaluation of 20 office buildings as basis for future IEQ standards and guidelines," Energy and Buildings, vol. 46, pp. 167–175, https://doi.org/10.1016/j.enbuild.2011.08.009.

Costanzo, V., Evola, G., & Marletta. L. (2017). "A Review of Daylighting Strategies in Schools: State of the Art and Expected Future Trends" Buildings 7, no. 2: 41. https://doi.org/10.3390/buildings7020041.

Danesh Pajouh, H., Majedi, H., & Zarabadi, Z. (2020). Explanation of Urban Morphology Evaluation methods and Tool in Sustainable Energies Approach. Journal of Urban Management and Energy Sustainability, 1(3), 62-75. https://doi.org/10.22034/ijumes.2017.18.12.023

Dubois, M.-C., & Blomsterberg, Å. (2011). "Energy saving potential and strategies for electric lighting in future North European, low energy office buildings: A literature review," Energy Build., vol. 43, no. 10, pp. 2572–2582. https://doi.org/10.1016/j.enbuild.2011.07.001

Eiraji, J., & Elmkhah, S. (2021). Studying Energy Consumption in Built Educational Spaces with Approach of Sustainability and Optimization. Journal of Urban Management and Energy Sustainability, 2(4), 69-85. https://doi.org/10.22034/jumes.2021.560771.1083

Freewan A. A. Y., & Al Dalala, J. A. (2020). "Assessment of daylight performance of Advanced Daylighting Strategies in Large University Classrooms; Case Study Classrooms at JUST," Alexandria Engineering Journal, vol. 59, no. 2, pp. 791–802, https://doi.org/10.1016/j.aej.2019.12.049.

Frontczak, M., & Wargocki, P. (2011). "Literature survey on how different factors influence human comfort in indoor environments," Building and Environment, vol. 46, no. 4, 922–937. https://doi.org/10.1016/j.buildenv.2010.10.021.

Galasiu, A. D., & Reinhart, C. F. (2008). "Current daylighting design practice: a survey," Building Research & Information, vol. 36, no. 2, pp. 159–174, https://doi.org/10.1080/09613210701549748.

Galasiu, A. D., Newsham, G. R., Suvagau C., & Sander, D. M. (2013). "Energy Saving Lighting Control Systems for Open-Plan Offices: A Field Study" LEUKOS, vol. 4, no. 1, 7–29. http://dx.doi.org/10.1582/LEUKOS.2007.04.01.001

Ghonimi, I. (2017). "Assessing Daylight Performance of Single vs. Double Skin Façade in Educational Buildings: A Comparative Analysis of Two Case Studies," JSD, vol. 10, no. 3, p. 133, https://doi.org/10.5539/jsd.v10n3p133.

Giarma, C., Tsikaloudaki, K., & Aravantinos, D. (2017). "Daylighting and Visual Comfort in Buildings' Environmental Performance Assessment Tools: A Critical Review," Procedia Environmental Sciences, vol. 38, pp. 522–529, https://doi.org/10.1016/j.proenv.2017.03.116.

Grosjean, A.; le Baron, E. (2022). Longtime solar performance estimations of low-E glass depending on local atmospheric conditions. Sol. Energy Mater. Sol. Cells, 240, 111730. https://doi.org/10.1016/j.solmat.2022.111730

Haverinen-Shaughnessy, U., Shaughnessy, R. J., Cole, E. C., Toyinbo, O., & Moschandreas, D. J. (2015). "An assessment of indoor environmental quality in schools and its association with health and performance," Building and Environment, vol. 93, pp. 35–40, https://doi.org/10.1016/j.buildenv.2015.03.006.

Heschong, L. (2002). "Daylighting and Human Performance," ASHRAE Journal, p. 65-67.

Heschong, L., Wright, R. L., & Okura, S. (2002) "Daylighting Impacts on Human Performance in School," Journal of the Illuminating Engineering Society, vol. 31, no. 2, pp. 101–114, https://doi.org/10.1080/00994480.2002.10748396.

Hessari, P., & Seyf shojaee, M. (2021). Evaluation of the optimal form of educational building based on energy consumption (Case study: Torbat Heydarieh city). Journal of Urban Management and Energy Sustainability, 2(4), 58-68. https://doi.org/10.22034/jumes.2021.558191.1081

Heydarian, A., Pantazis, E. J., Carneiro, P., Gerber, D., & Becerik-Gerber, B. (2016). "Lights, building, action: Impact of default lighting settings on occupant behavior," Journal of Environmental Psychology, vol. 48, pp. 212–223, https://doi.org/10.1016/j.jenvp.2016.11.001.

Hill M. C., & Epps, K. K. (2010). "The Impact of Physical Classroom Environment on Student Satisfaction and Student Evaluation of Teaching in the University Environment," Academy of Educational Leadership Journal, vol. 14, no. 4, p. 65-79.

Hua, Y., Oswald, A., & Yang, X. (2011). "Effectiveness of daylighting design and occupant visual satisfaction in a LEED Gold laboratory building," Building and Environment, vol. 46, no. 1, pp. 54–64, https://doi.org/10.1016/j.buildenv.2010.06.016.

Huang, Q., Yang, M., Jane, H., Li, S., & Bauer, N. (2020). "Trees, grass, or concrete? The effects of different types of environments on stress reduction," Landscape and Urban Planning, vol. 193, 103654. https://doi.org/10.1016/j.landurbplan.2019.103654.

Hwang, T., & Kim, J. T. (2011). "Effects of Indoor Lighting on Occupants' Visual Comfort and Eye Health in a Green Building," Indoor and Built Environment, vol. 20, no. 1, 75–90. https://doi.org/10.1177/1420326X10392017.

Ibañez, C. A., Zafra, J. C. G., & Sacht, H. M. (2017). "Natural and Artificial Lighting Analysis in a Classroom of Technical Drawing: Measurements and HDR Images Use," Procedia Engineering, vol. 196, 964–971, https://doi.org/10.1016/j.proeng.2017.08.037.

Karamouzian, H., Zanganeh Shahraki, S., & Farhoodi, R. (2021). Explanation of the energy consumption mechanism model-based in urban morphology context. Journal of Urban Management and Energy Sustainability, 2(3), 23-31. https://doi.org/10.22034/jumes.2021.249026

Keshtkar Ghalati, A., & Ahmadian, M. (2024). "Effects of Window and Light Shelve Configurations on Energy Consumption and Daylight Illuminance in Classrooms". Renewable Energy Research and Applications, 5(1), 107-119. https://doi.org/10.22044/rera.2023.12563.1194

Keshtkar Ghalati, A., & Amiri, N. (2022). "Urban Flood Management Using the Green Roof System (Case study: Tehran City) ". Journal of Urban Management and Energy Sustainability, 3(1), 58-68. https://doi.org/10.22034/jumes.2021.558168.1080

Keshtkar Ghalati, A., & Taromsari, F. M. (2023). "Integration of photovoltaic modules to optimize energy usage in residential buildings". Asian Journal of Civil Engineering 24, 2179–2191. https://doi.org/10.1007/s42107-023-00634-0

Kilic, D. K., & Hasirci, D. (2011). "Daylighting Concepts for University Libraries and Their Influences on Users' Satisfaction," The Journal of Academic Librarianship, vol. 37, no. 6, pp. 471–479, https://doi.org/10.1016/j.acalib.2011.07.003.

Kim G., & Miller, P. A. (2019). "The impact of green infrastructure on human health and well-being: The example of the Huckleberry Trail and the Heritage Community Park and Natural Area in Blacksburg, Virginia" Sustainable Cities and Society, vol. 48, 101562. https://doi.org/10.1016/j.scs.2019.101562.

Ko, W. H., Schiavon, S., Zhang, H., Graham, L. T., Brager, G., Mauss, I., & Lin, Y.-W. (2020). "The impact of a view from a window on thermal comfort, emotion, and cognitive performance," Building and Environment, vol. 175, p. 106779, https://doi.org/10.1016/j.buildenv.2020.106779.

Krüger E. L., & Zannin, P. H. T. (2004). "Acoustic, thermal and luminous comfort in classrooms," Building and Environment, vol. 39, no. 9, pp. 1055–1063, https://doi.org/10.1016/j.buildenv.2004.01.030.

Kuijsters, A., Redi, J., de Ruyter, B., & Heynderickx, I. (2015). "Lighting to Make You Feel Better: Improving the Mood of Elderly People with Affective Ambiences," PLOS ONE, vol. 10, no. 7, pp. 1–22, https://doi.org/10.1371/journal.pone.0132732.

Kumar, N.M., Chopra, S.S., Chand, A.A., Elavarasan, R.M., & Shafiullah, G.M. (2020). Hybrid Renewable Energy Microgrid for a Residential Community: A Techno-Economic and Environmental Perspective in the Context of the SDG7. Sustainability, 12, 3944. http://doi.org/10.3390/su12103944

Kwon C., & Lee, K. (2018). "Integrated Daylighting Design by Combining Passive Method with DaySim in a Classroom," Energies, vol. 11, no. 11, p. 3168, https://doi.org/10.3390/en11113168.

Laaroussi, Y., Bahrar, M., El Mankibi, M., Draoui, A., & Si-Larbi, A. (2020). "Occupant presence and behavior: A major issue for building energy performance simulation and assessment," Sustainable Cities and Society, vol. 63, p. 102420. https://doi.org/10.1016/j.scs.2020.102420.

Lechner, N. (2009). Heating, Cooling, and Lighting: Sustainable Design Methods for Architects. Third edition, by John Wiley & Sons, Inc.

Leslie, R. P. (2003) "Capturing the daylight dividend in buildings: why and how?" Building and Environment, Volume 38, Issue 2, 381-385. https://doi.org/10.1016/S0360-1323(02)00118-X.

Madurai Elavarasan, R., Selvamanohar, L., Raju, K., Rajan Vijayaraghavan, R., Subburaj, R., Nurunnabi, M., Khan, I.A., Afridhis, S., Hariharan, A., & Pugazhendhi, R. (2020). A Holistic Review of the Present and Future Drivers of the Renewable Energy Mix in Maharashtra, State of India. Sustainability, 12, 6596. http://doi.org/10.3390/su12166596

Madurai Elavarasan, R., Pugazhendhi, R., Jamal, T., Dyduch, J., Arif, M.T., Manoj Kumar, N., Shafiullah, G., Chopra, S.S., & Nadarajah, M. (2021). Envisioning the UN Sustainable Development Goals (SDGs) through the lens of energy sustainability (SDG 7) in the post-COVID-19 world. Appl. Energy. 116665. http://doi.org/10.1016/j.apenergy.2021.116665

Mantler, A., & Logan, A. C. (2015). "Natural environments and mental health," Advances in Integrative Medicine, vol. 2, no. 1, 5–12; https://doi.org/10.1016/j.aimed.2015.03.002

Marszal, A.J., Heiselberg, P., Bourrelle, J.S., Musall, E., Voss, K., Sartori, I., & Napolitano, A. (2011). "Zero Energy Building – A review of definitions and calculation methodologies," Energy and Buildings, vol. 43, no. 4, pp. 971–979, https://doi.org/10.1016/j.enbuild.2010.12.022.

Martin, L., White, M. P., Hunt, A., Richardson, M., Pahl, S., & Burt, J., (2020). "Nature contact, nature connectedness and associations with health, well-being and pro-environmental behaviors," Journal of Environmental Psychology, vol. 68, 101389. https://doi.org/10.1016/j.jenvp.2020.101389.

Mavoa, S. M., Lucassen, S., Denny, J., Utter, T., Clark, & Smith, M. (2019). "Natural neighborhood environments and the emotional health of urban New Zealand adolescents," Landscape and Urban Planning, vol. 191, 103638. https://doi.org/10.1016/j.landurbplan.2019.103638.

Mihai T., & Iordache, V. (2016). "Determining the Indoor Environment Quality for an Educational Building," Energy Procedia, vol. 85, pp. 566–574, https://doi.org/10.1016/j.egypro.2015.12.246.

Othman A. R., & Mazli, M. A. M. (2012). "Influences of Daylighting towards Readers' Satisfaction at Raja Tun Uda Public Library, Shah Alam," Procedia - Social and Behavioral Sciences, vol. 68, pp. 244–257, Dec. 2012, https://doi.org/10.1016/j.sbspro.2012.12.224.

Pandharipande, A., & Newsham, G.R. (2018). Lighting Controls: Evolution and Revolution. Lighting Res. Technol. 50, 115–128. http://doi.org/10.1177/1477153517731909

Pathak, P., Dongre, A., & Shiwalkar, J. (2015). "Lighting design as a function of user comfort and performance in Indian work spaces," Journal of architectural and planning research, vol. 32, pp. 168–180.

Ramli, N. H., Ahmad, S., & Masri, M. H. (2013). "Improving the Classroom Physical Environment: Classroom Users' Perception," Procedia - Social and Behavioral Sciences, vol. 101, pp. 221–229, https://doi.org/10.1016/j.sbspro.2013.07.195.

Rashidzadeh, Zh., & Heidari Matin, N. (2023). "A Comparative Study on Smart Windows Focusing on Climate-Based Energy Performance and Users' Comfort Attributes" Sustainability 15, no. 3: 2294. https://doi.org/10.3390/su15032294

Rezaei Rad, H., Rafieian, M., & Sozer, H. (2019). Evaluating the effects of increasing of building height on land surface temperature. Journal of Urban Management and Energy Sustainability, 1(1), 37-42. https://doi.org/10.22034/ijumes.2019.01.01.002.

Sarbu I., & Sebarchievici, C. (2013). "Aspects of indoor environmental quality assessment in buildings," Energy and Buildings, vol. 60, 410–419. https://doi.org/10.1016/j.enbuild.2013.02.005.

Shafaghat, A., Keyvanfar, A., Ferwati, M. S., & Alizadeh, T. (2015). "Enhancing staff's satisfaction with comfort toward productivity by sustainable Open Plan Office Design," Sustainable Cities and Society, vol. 19, pp. 151–164, https://doi.org/10.1016/j.scs.2015.08.001.

Sharp, F., Lindsey, D., Dols, J., & Coker, J. (2014). "The use and environmental impact of daylighting," Journal of Cleaner Production, vol. 85, 462–471. https://doi.org/10.1016/j.jclepro.2014.03.092.

Ul Haq, M. A., Hassan, M. Y., Abdullah, H., Rahman, H. A., Abdullah, M. P., Hussin, F., & Said, D. M. (2014). "A review on lighting control technologies in commercial buildings, their performance and affecting factors," Renew. Sustain. Energy Rev., vol. 33, pp. 268–279. https://doi.org/10.1016/j.rser.2014.01.090

Van Bommel W., & Van den Beld, G. (2004). "Lighting for work: a review of visual and biological effects," Lighting Research & Technology, vol. 36, no. 4, pp. 255–266, https://doi.org/10.1191/1365782804li122oa.

Vilcekova, S., Meciarova, L., Burdova, E. K., Katunska, J., Kosicanova, D., & Doroudiani, S. (2017). "Indoor environmental quality of classrooms and occupants' comfort in a special education school in Slovak Republic," Building and Environment, vol. 120, pp. 29–40, https://doi.org/10.1016/j.buildenv.2017.05.001.

Wang, N., & Boubekri, M. (2011). "Design recommendations based on cognitive, mood and preference assessments in a sunlit workspace," Lighting Research & Technology, vol. 43, no. 1, pp. 55–72, https://doi.org/10.1177/1477153510370807.

Webb, M. (2022). Biomimetic building facades demonstrate potential to reduce energy consumption for different building typologies in different climate zones. Clean Technol. Environ. Policy, 24, 493–518. https://doi.org/10.1007/s10098-021-02183-z

Wilkins, A. (2016). "A physiological basis for visual discomfort: Application in lighting design," Lighting Research & Technology, vol. 48, no. 1, pp. 44–54. https://doi.org/10.1177/1477153515612526.

Williams, A., Atkinson, B., Garbesi, K., Page, E., & Rubinstein, F. (2012). "Lighting Controls in Commercial Buildings," LEUKOS, vol. 8, no. 3, 161–180. http://dx.doi.org/10.1582/LEUKOS.2012.08.03.001

. Winterbottom M., & Wilkins, A. (2009). "Lighting and discomfort in the classroom," Journal of Environmental Psychology, vol. 29, no. 1.

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