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The Evaluation of Ceiling Depth Impact on Lighting and Overall Energy Consumption of a Building with Top-lighting System

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Abstract The purpose of this study was to evaluate the variation in building energy predictions caused by simulation settings related to building envelop thickness. The study assessed the ceiling depth impact on skylight energy performance through OpenStudio integrated Radiance and EnergyPlus simulation programs. A ceiling as deep as 1.5 to 3m was analyzed for skylight to roof ratios from 1% to 25%. The results indicated that the building ceiling depth negatively affected the capability of skylights to significantly reduce building energy consumption. Through a parametric analysis, the study concluded that 8%, 9%, 10% and 11% skylight to roof ratio were optimal in terms of total building energy consumption for a ceiling depth of 1.5m, 2m, 2.5m and 3m, respectively. In addition, the results showed that the usually recommended 5% skylight to roof ratio was only efficient when no ceiling depth was included in the simulation model. Furthermore, the study indicated that the building energy saved by the optimal skylight of each ceiling depth decreased as the ceiling depth deepened. The highest total building energy reduction was 9%, 7%, 5% and 3% for a ceiling depth of 1.5m, 2m, 2.5m and 3m, respectively. This study induced that the solar heat gains and daylight visible transmittance by ceiling depth were crucial in the predictions of skylight energy performance and should not be neglected through building simulation simplifications as it is commonly done in most simulation programs' settings.

Keywords: skylights, energy efficiency, EnergyPlus, Radiance, lighting critical region

1. INTRODUCTION

Building sector consumes about 36 % of the global final energy and artificial lighting has been reported to be among major energy consumers. The energy used for arti-ficial lighting alone is around 5-15 % of the total building energy consumption (Ryckaert et al. 2010). Due to the ongoing energy crises in many countries, researchers have done extensive investigations on various ways to reduce building energy consumption. The use of natural light is among the best strategies recommended to effectively reduce building energy consumption especially for commercial and public buildings. Yun, Hwang and Kim (2010) have reported that when a building is adequately designed for daylight, its energy consumption can be reduced up to 20-40 %. Beside its potential to reduce building energy consumption, daylight has been proven to improve occupants' mood, relieve stress and therefore enhance productivity (Al-Ashwal and Hassan, 2018).

There exist various strategies to bring daylight into buildings, and they can be categorized into two categories: side-lighting and top-lighting. The former refers to the daylighting system where natural light is brought into the building through side openings such as windows or light shelves while the latter refers to a system where daylight is designed to reach into the deep area of the space through the top building envelop as in the case of skylights. The h system in rchitecture istory of top-lighting indicates that there have been some drawbacks on its application such as roof water leakage, noise, excessive light and heat ex-change. With today's advancement in technology, noise and roof leakage can be mitigated by selecting the right skylight materials (Lawrence & Crawley, 2008). However, in order to avoid excessive light and heat gain, it is im-portant to analyze how top-lighting system affect building overall energy demand.

Top-lighting system is widely used due to its ability to provide daylight with fairly homogeneous illuminance distribution in

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space lacking facades or deep rooms where daylight from side lighting system cannot sufficiently reach to the rear area of the space. Besides, top-lighting system can be preferred for both the aesthetical and energy efficiency purposes (Gago et al. 2015; Li, Cheung, Chow, & Lee, 2014). Furthermore, a study by Adahi, Saghafi and Tahbaz (2017) has reported that the usefulness of top-lighting is expected to raise with today's urbanization rate as the buildings tend to cluster together.

Skylights, described as a sloping or lateral opening at the top of a building, have been widely studied and the literature holds a good number of discussions and findings on the role of skylights in building sustainability. Given their convenience and easy manipulation of the study variables, building simulations tools such as Lightscape, Daysim, Radiance and EnergyPlus have been widely used in top-lighting investigations. For instance, Acost et al. (2013) investigated the impact of reflector shape on day-lighting performance of lightscoop skylights. The study proposed a lightscoop skylight of 4:3 height-to-width ratio as an optimum lightscoop in terms of daylight factor and no significant impact of reflector shape was observed as only the overcast sky condition was considered in the study. Al-Obaidi et al. (2015) analyzed the influence of skylight size and glazing material on indoor air tempera-ture and daylight factor under hot climate of Malaysia. Through IES-VE (integrated Environmental Solution- Virtual Environment) software program, the study concluded that a skylight of polycarbonate glazing and 3% skylight-to floor area was optimal in terms of natural light distribution and cooling loads.

Through EnergyPlus and Radiance simulation tools, Fang and Cho (2018) studied the effects of skylights and clerestory on building energy performance, concluding that 3% skylight-to-ceiling ratio was the optimal skylight. The results of this study were in agreement with previously reported findings by Motamedi and Lied (2017), which concluded that skylight opening ranging from 3% to 14% of the ceiling ratio could reduce building energy consumption by up to 19%. More investigations were carried out using computer simulations on various skylights related parameters such as the shape and configuration (El-Abd et al. 2018) and the size, glazing properties and orientation (Laouadi, Atif, and Galasiu, 2002).

Unlike side-lighting systems, skylights are accommodated in a deep layering scheme containing various building functioning systems; thus, building envelope becomes crucial with top-lighting system. Considering the settings of most building energy simulation programs that apply building envelop thickness only to heat transfer and thermal mass calculations, the skylights performance could be different from the predictions in previous studies and more investigations are still needed to predict skylights benefits with consideration of the context in which they are installed. The purpose of this study was to parametrically analyze the impact of ceiling depth on the energy efficiency of horizontal skylight considering both lighting and overall building energy consumption.

2. RESEARCH METHODS

(1) Study Variable

A common public space of 9mx9mx4.5m, representing a small scale of a vast open rooflit space of a single-story building or a top floor of a multistory building, was modeled and analyzed. The model dimensions were chosen from a previous study on lightscoop skylights (Acosta, Navarro, & Sendra, 2013) in order to generate general re-sults pertinent to the literature. The model included a horizontal skylight with no side-opening. This was purposely done for the predictions of building energy consumption to be merely governed by the skylight features (skylight opening area and ceiling geometry). In addition, the space was modeled free of any interior structures such as columns, interior partitions, etc. in order to avoid any complication that could alter the simulation results either slightly or substantially.

The building materials optical properties used in this study were defined based on IESNA (Illuminating Engineering Society of North America) (DiLaura et al. 2011). The reflectance values of 30%, 50%, and 70% were used for floor, walls, and ceiling, respectively. The model thermal properties were chosen according to Korean Energy-Saving Design criteria for office and commercial buildings (Oh et al. 2018). The U-values [W/m2K] of the floor, walls, and ceiling were 0.513, 0.429, and 0.192, respectively.

The glazing material used in this study was Flat-styled CoolOptics manufactured by SunOptics. This glazing type has the advantage of high visible daylight transmittance with less building thermal exchange and it was selected for this study following a previous study that reported its energy efficiency when used for horizontal skylight in five different climatic conditions (Yoon et al. 2008). The thermal and optical properties of the glazing material were: 1.98 W/m2K, 0.37 and 0.67 for U-value, shading coefficient and visible transmittance, respectively. The optical and thermal properties of the simulation model are summarized in Table 1.

Depending on the building size, type and equipment hosted in the ceiling, a ceiling can be as deep as 1.52 m and 2.74 m (Ghobad, Place, & Hu, 2012). Therefore, a ceiling depth of 1.5 m to 3 m was analyzed in this study and the Figure 1 shows the simulation model details and study variables.

Table 1. Model optical and thermal properties.

Surface	Material	Reflectance	U-value [W/m2K]
Floor	Brick+ heavyweight concrete+ insulation	0.3	0.513
Walls	Heavy concrete+ insulation	0.5	0.429
Ceiling	Lightweight concrete+ insulation	0.7	0.192
Glazing	Flat-styled CoolOptics		1.98

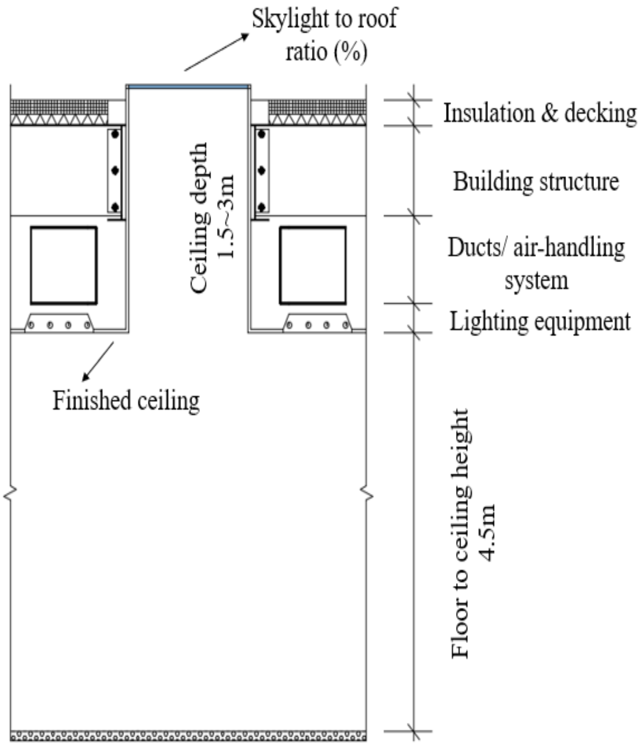


Figure 1. Typical horizontal skylight installation into a building ceiling.

(2) Simulation Tools and Modeling Conditions

This study was carried out using OpenStudio's integrated Radiance and EnergyPlus to avoid isolated daylighting and building energy simulations which could lead to inaccurate predictions (Guglielmetti, & Ball, 2016). Through OpenStudio SketchUp plugins, a 3D model was created with all the necessity to generate relevant predictions with the light-backward ray-tracing hybrid approach used by Radiance. The model was then exported to OpenStudio program, where additional modeling was performed to satisfy all the input requirements (thermal properties, equipment and operational schedule) for whole building energy simulation by EnergyPlus.

The integrated daylighting and energy simulations are carried out into two phases. The simulation starts by Radiance creating an indoor illuminance schedule from the hourly outdoor illuminance values contained in the weather file; then, a new artificial lighting schedule is created. The new lighting schedule is then sent to be used by Ener-gyPlus during the phase of whole building energy simula-tion.

The IWEC (International Weather for Energy Calcula-tion) Ulsan weather file, approved by ASHRAE (American Society of Heating Refrigerating and Air-conditioning Engineers) to represent the typical long-term weather patterns (Crawley, 1998), was used in this study. The model was simulated as a single thermal zone and the annual energy consumption for lighting, cooling, heating and ventilation was calculated considering internal loads from people and lighting. The air infiltration, occupancy and lighting power density were set to 2.19 m3/hr.m2, 9.3 m2/person and 11.34 W/m2, respectively (Kim, Oh, & Jeong, 2016). The space was considered to be in operation from 9am to 5pm during weekdays. A simplified HVAC system was designed, and it contained the outdoor air mixing box, coil cooling DX single speed, coil heating gas, a fan and air terminal. The cooling system used electricity with COP (Coefficient of Performance) of 3 while natural gas was used for heating system with COP of 0.8. Table 2 summarizes the major simulation input and conditions used in this study.

(3) Artificial Lighting Control

In this study, one photo sensor was used to dim or turn off the artificial lights according to daylight availability. The sensor for lighting control was located at the occupiable space area with the least daylight level to ensure sufficient lighting for the whole space. In order to determine the area with the lowest daylight level, UDI (Useful Daylight Illuminance) was used. UDI is a climate-based daylight metric that indicates the percentage of occupied hours when the daylight illuminance received at a point is in the range of useful daylight level. Generally, a daylight illuminance greater than 100 lux but lower than 2000 lux is considered useful (Cantin, & Dubois, 2011). The model was divided into 4 daylight zones and Table 3 shows the UDI variation for illuminance points from wall to the center of the space. To make sure that the entire space was provided with sufficient light, the sensor for artificial lighting control was located in daylight zone 1 at the point where the least daylight illuminance occurred.

Figure 2 shows the illuminance map containing 81 measurement points used for daylight qualitative analysis, a sensor point for artificial lighting control of the total space and the area under skylight aperture (1% to 25% SRR). The number and layout of the illuminance measurement points were defined based on adequate daylighting evaluation. Nabil and Mardaljevic (2006) recommend-ed that daylight illuminance points should be positioned in a way that 0.5 m is left between contour points and side walls and 1 m between two consecutive illuminance points. Continuous dimming control with 3 steps was used and the system controlled 100% of artificial lighting of the room. IES (Illuminating Engineering Society) recommendation of a suitable lighting for general open space (300 lux) was used as illuminance set point.

The study was carried out through three steps:

- Step 1: The energy performance of different skylight-to-roof ratios (SRR) was evaluated with no ceiling depth included in the simulation models and energy efficient skylights were determined.
- Step 2: All the predefined energy efficient SRR (from step 1) were re-modeled with a ceiling depth of 1.5m to 3m included in the simulation model.
- Step 3: A parametric analysis of the variation of lighting and overall energy consumption according to the ceiling depth.

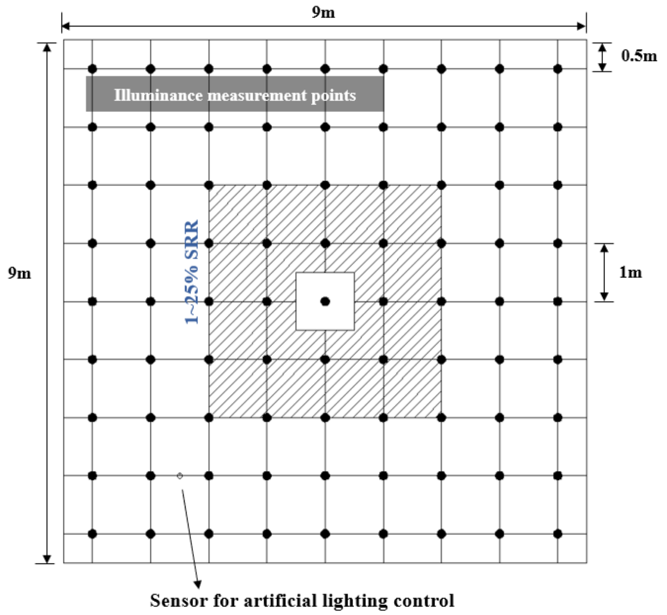


Figure 2. Illuminance measurement points and location of lighting control sensor.

Table 2. Simulation input and conditions.

Category	Input	Values
Set points	Lighting	300 lux
	Cooling	240C
	Heating	200C
Internal loads	Lighting density	11.34 W/m2
	Occupancy	9.3 m2/person
	People load	117.2 W
COP	Cooling system	3
	Heating system	0.8
Infiltration		2.19 m3/hr.m2
Operation hours	9am- 5pm	
Lighting control	Continuous dimming (3 steps)	

Table 3. Daylight zone and variation of UDI.

Daylight zone	Distance from wall [m]	UDI100-2000
Zone 1	0.5-1.5	25-44 %
Zone 2	1.5-2.5	56-65 %
Zone 3	2.5-3.5	70-85 %
Zone 4	3.5-4.5 (center)	100%

3. RESULTS AND DISCUSSION

Adding a skylight to a building decreased its lighting energy consumption with an increase of solar heat gain and thermal conductance. Thus, for a skylight to be energy efficient, it should be able to outweigh the increased thermal exchange by the reduction of lighting energy and internal heat gain from artificial lighting. Therefore, in this study, the skylight energy performance was evaluated based on the total building energy consumption which included the energy used for lighting, cooling, heating and ventilation. A skylight was considered as energy efficient if its energy was less than the base model which had the same dimensions and material properties but did not in-clude any skylight. In addition, lighting energy consumption was separately analyzed to clearly identify the direct influence of the skylight features on the building lighting.

(1) Energy Efficiency of Skylight

Although there are a number of factors that can influence skylight energy performance, the first and foremost is the size of the opening. Thus, the energy simulations for SRR ranging from 1% to 25% were carried out and for this step, no ceiling depth was included in the simulation model.

The total building energy consumption dropped by adding a skylight until it reached its minimum at 6% SRR (Figure 3). Starting at 7% SRR, the increase in the energy used for space cooling, heating and ventilation (which were considered in this study) began to outweigh the lighting energy reduction and as a result, any widening of skylight lead to an increased building energy consumption.

Although increasing the SRR above 6% started to minimally increase the total building energy, any SRR below 20% was energy efficient. The results indicated that 6% SRR was optimal with 69% energy reduction for lighting and 18% total building energy reduction. These predictions were compared with previously reported findings to ensure their accuracy Motamedi and Lield (2017) reported that a building with a skylight of 3 to 14% skylight-to-roof ratio was more energy efficient than the same building without skylight and the optimal skylight-to-roof ratio was 5.5-6%. Regarding building energy reduction, the study concluded that an optimal skylight could reduce the overall building energy up to 19%. Therefore, the simulation results of this study were verified to be in good line with the literature.

(2) Skylight and Lighting Energy Critical Region

It is a common practice for architects and designers to increase the size of an aperture (window or skylight) in order to reduce electric lighting energy consumption by providing more natural light. However, at some point, the widening of building aperture loses its potential for weighty electric energy reduction. A study by Ochoa et al. (2012) has reported that a critical region for artificial lighting energy consumption was observed from a WWR (window to wall ratio) of 70% in a temperate climate, making any opening larger than 70% WWR counterproductive.

A similar special behavior for lighting energy consumption was noticed in this study. The lighting energy reductions were greater for skylight smaller than 10% SRR. Any increase in the skylight size from 10% SRR stopped bringing significant lighting energy reduction (less than 5%). This particular characteristic of energy reduction can be explained by the fact that as the skylight aperture size increases, more daylight is admitted making the interior space more saturated with natural light. Thus, augmenting the amount of daylight does insignificant to no improve-ment on the building lighting energy efficiency.

(3) Ceiling Depth and Skylight Energy Efficiency

Each of the predefined energy efficient SRR was re-modeled with a ceiling depth included in the simulation model and its energy performance was reevaluated. Figure 4 shows the variation of skylight performance with the increase of the ceiling depth. As expected, the skylight potential to reduce the building energy consumption decreased as the ceiling depth increased. The SRR alternatives for energy efficient skylight were 1-17% for 1.5m ceiling depth, 5-17% for 2m ceiling depth, 7-17% for 2.5m ceiling depth and 9-17% for 3m ceiling depth.

The results indicated that the impact of building ceiling depth on the skylight energy performance was greater for small skylights than it was for larger skylights. This was attributed to the fact that more daylight bounced off the ceiling vertical section for smaller apertures than they happened for larger openings. Consequently, as the ceiling depth increased, smaller skylight apertures failed to bring significant lighting energy reduction to counterbalance the thermal exchange of skylight.

The total energy curve in Figure 4 illustrates a concave upward with a minimum energy consumption at optimum SRR. To allow a close look on how skylights energy performance varied depending on ceiling depth, monthly energy consumption from the calculated hourly energy consumption for cooling, heating, ventilation and lighting are presented in Appendix A. However, due to a big number of SRRs simulated in this study, detailed energy consumption by category for only 3 SRRs at the concave part on the total energy graph (optimal SRR and one SRR before and one after the optimal) for each ceiling depth are displayed in the appendix with the optimal SRR in grey shade.

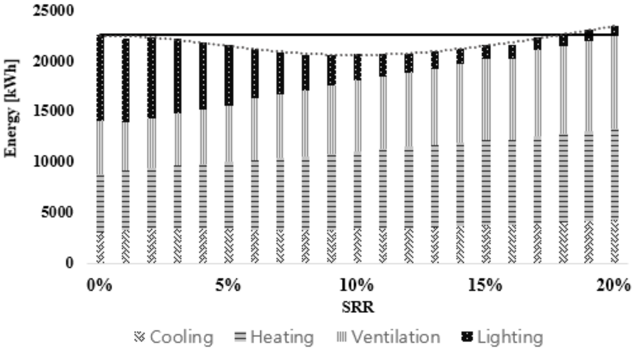
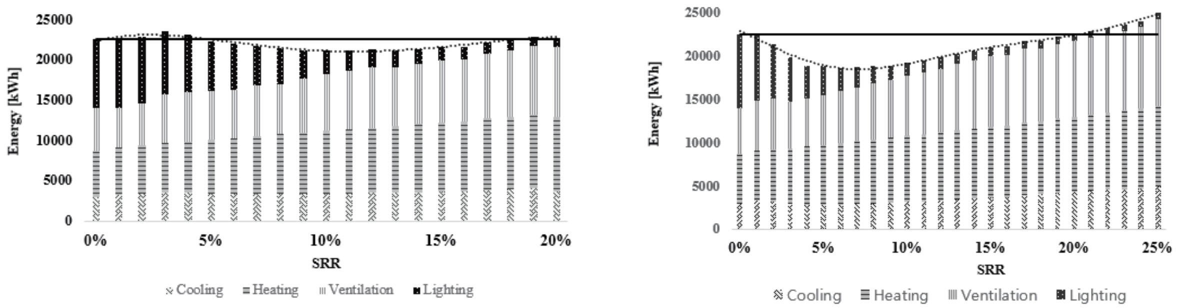


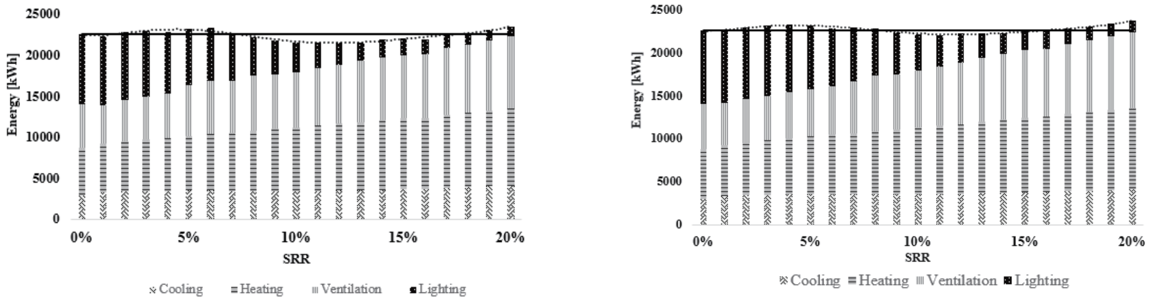
Figure 3. Energy performance of different SSRs.

The optimum SRRs in terms of the total building energy con-sumption were 8%, 9%, 10% and 11% for a ceiling depth of 1.5m, 2m, 2.5m, and 3m, respectively. In addition, including the ceiling geometry into the simulation model did not only alter the optimal skylight but also the capacity of the skylight to reduce building energy consumption was affected. The total building energy consumption was reduced by 9%, 7%, 5%, and



(a) Ceiling depth: 1.5m

(b) Ceiling depth: 2m



(c) Ceiling depth: 2.5m

(d) Ceiling depth: 3m

Figure 4. Predicted skylight energy performance according to actual building ceiling depth.

3% for the ceiling depth of 1.5m, 2m, 2.5m, and 3m, respectively.

Solar heat gain, thermal conductance and lighting energy reduction are at the base of energy performance of skylights. Ghobad et al. (2012) and Motamedi (2017) analyzed the dynamics of top-lighting system and the associated lighting and thermal loads. Both studies reported that heating loads were increased regardless of the skylights size while variations in cooling loads primarily depended on the climate conditions and skylight size.

Although, previously conducted studies agree that adequate skylight design can reduce lighting energy consumption and overcome possible thermal negative impacts, the total building energy reduction is highly influenced by the geometry of the ceiling accommodating skylights. Ceiling depth reduces indoor daylight from skylights through multiple light reflections, and as a result significant lighting energy can be saved for only a certain SRR threshold. With the knowing the extend to what a skylight performance is altered by ceiling depth, designers can better orient their focus on other aspects such as the applicability of possible ceiling adjustments and the cost involved.

4. CONCLUSION

This study examined to what extend the simulation settings in most building simulation programs affect the predictions on the skylight energy performance. Through a parametric analysis the study concluded that the recommendations of optimal skylights (5-6 % skylight to ceiling ratio) commonly reported in the literature were efficient only when no ceiling depth was included in the simulation model. The study induced that the building ceiling depth had great influence on the overall energy performance of skylights, therefore should not be excluded from top-lighting related scientific investigations.

1% to 25% skylight to roof ratios installed in 1.5m to 3m ceiling depth were analyzed and the results indicated that the impact of the ceiling geometry on the skylight energy performance decreased as the size of the aperture increased. The optimal skylight to roof ratio for a ceiling depth of 1.5m, 2m, 2.5m, and 3m was 8%, 9%, 10%, and 11%, respectively. The total building energy reduction for the optimal skylight was 9%, 7%, 5% and 3% for 1.5m, 2m, 2.5m, and 3m ceiling depth, respectively; indicating that ceiling depth negatively influences the ability for skylights to reduce building energy consumption.

Furthermore, it is important to mention that there are other factors such as building characteristics and functioning systems (HVAC system, operational schedules, etc.), that can influence the evaluation of skylight energy performance. Therefore, more investigations are needed to establish the sensitivity of the simulation predictions and the detail level of building physical features and functioning systems included in the simulation model; and this is part of the author's future work.

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Appendix A. Predicted monthly energy consumption by category.

Ceiling depth	SRR	Category	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total [kWh]
No depth	5%	Cooling	-	-	-	-	69.96	220.24	258.42	709.24	376.84	-	-	-	
		Heating	4226	3053.8	1705.66	275.44	-	-	-	-	-	77.8	873.34	3147.58	
		Ventilation	166.99	150.83	166.99	161.6	166.99	161.6	166.99	166.99	161.6	166.99	161.6	166.99	
		Lighting	115.02	101.03	93.87	57.63	57.79	68.5	82.07	58.57	84.66	76.91	107.86	113.41	
															17976.8
	6%	Cooling	-	-	-	-	117.98	313.8	704.84	881.86	562.86	-	-	-	
		Heating	4056	2977.6	1658.8	138	-	-	-	-	-	64.46	240	3006.9	
		Ventilation	154.06	139.15	154.06	149.09	154.06	149.09	154.06	154.06	149.09	154.06	149.09	154.06	
		Lighting	105.98	72.28	77.22	50.08	47.51	55.78	70.7	49.06	77.26	72.98	96.95	100.81	
															17413.64
	7%	Cooling	-	-	-	-	62.36	216.66	512.24	695.16	370.94	-	-	-	
		Heating	4138.16	3024.48	1676.4	277.44	-	-	-	-	-	70.32	849.9	3077.24	
		Ventilation	160.58	145.04	160.58	155.4	160.58	155.4	160.58	160.58	155.4	160.58	155.4	160.58	
		Lighting	97.47	65.19	66.12	42.43	39.13	43.53	57.2	39.32	65.98	65.07	91.69	91.45	
															17626.58

Ceiling depth	SRR	Category	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total [kWh]
1.5m	7%	Cooling	-	-	-	-	84.36	256.3	567.4	764.74	424.2	-	-	-	
		Heating	4302.28	3141.8	1723.24	263.8	-	-	-	-	-	64.46	850	3188.6	
		Ventilation	173.33	156.55	173.33	167.74	173.33	167.74	173.33	173.33	167.74	173.33	167.74	173.33	
		Lighting	144.61	103.26	110.12	78.05	77.5	89.96	103.05	81.88	110.47	107.22	131.49	143.23	
															18952.84
	8%	Cooling	-	-	-	-	79.54	251.66	560.26	753	425.8	-	-	-	
		Heating	4202.6	3077.24	1682.22	259	-	-	-	-	-	64.46	814.72	3106.6	
		Ventilation	170.31	153.83	170.31	164.82	170.31	164.82	170.31	170.31	164.82	170.31	164.82	170.31	
		Lighting	135.11	94.36	98.82	69.44	70.32	82.37	95.55	72.98	99.61	95.55	123.32	134.39	
															18454.2
	9%	Cooling	-	-	-	-	85.28	252.58	566.88	773.74	422.94	-	-	-	
		Heating	4419.52	3229.64	1770.2	275.44	-	-	-	-	-	70.32	896.8	3294.1	
		Ventilation	180.86	163.36	180.86	175.03	180.86	175.03	180.86	180.86	175.03	180.86	175.03	180.86	
		Lighting	114.58	76.93	82.2	55.46	52.19	61.77	76.28	54.94	83.08	78.25	105.66	111.28	
															19139.56

Ceiling depth	SRR	Category	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total [kWh]
2m	8%	Cooling	-	-	-	-	88.48	262.28	580.18	787.14	438.22	-	-	-	
		Heating	4425.38	3235.5	1770.2	269.6	-	-	-	-	-	64.46	879.2	3288.26	
		Ventilation	180.61	163.13	180.61	174.79	180.61	174.79	180.61	180.61	174.79	180.61	174.79	180.61	
		Lighting	140.97	104.64	106.45	74.42	77.82	91.1	104.39	79.73	105.75	107.69	128.65	138.14	
															19475.21
	9%	Cooling	-	-	-	-	83.7	260.12	574.66	772.62	429.62	-	-	-	
		Heating	4331.58	3159.3	1735	269.86	-	-	-	-	-	58.73	849.92	3212.06	
		Ventilation	173.02	156.28	173.02	167.44	173.02	167.44	173.02	173.02	167.44	173.02	167.44	173.02	
		Lighting	130.43	91.71	97.18	65.83	66.2	77.78	91.27	67.74	96.64	96.42	120.2	129.3	
															18905.05
	10%	Cooling	-	-	-	-	93.68	263.54	586.56	801.14	439.06	-	-	-	
		Heating	4531	3317.6	1811.2	281.5	-	-	-	-	-	70.34	926.12	3382	
		Ventilation	187.76	169.59	187.76	181.71	187.76	181.71	187.76	187.76	181.71	187.76	181.71	187.76	
		Lighting	117	77.29	84.08	56.86	55.57	64.01	78.78	57.48	84.89	79.74	104.55	113.5	
															19688.24

Ceiling depth	SRR	Category	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total [kWh]
2.5m	9%	Cooling	-	-	-	-	90.68	265.82	588.5	804.42	440.4	-	-	-	
		Heating	4560.18	3346.86	1846.34	287.2	-	-	-	-	-	70.34	920.24	3399.62	
		Ventilation	179.39	162.03	179.39	173.6	179.39	173.6	179.39	179.39	173.6	179.39	173.6	179.39	
		Lighting	141.91	104.2	107.15	77.46	82.66	95.66	108	84.03	107.48	107.44	129.31	140.18	
															20018.24
	10%	Cooling	-	-	-	-	91.72	271.48	591.88	798.88	444.9	-	-	-	
		Heating	4454.68	3253.08	1787.8	269.58	-	-	-	-	-	64.46	879.2	3311.7	
		Ventilation	176.18	159.13	176.18	170.5	176.18	170.5	176.18	176.18	170.5	176.18	170.5	176.18	
		Lighting	131.4	87.81	92.13	64.17	64.94	75.62	88.88	66.78	93.04	88.15	116.47	131.6	
															19394.74
	11%	Cooling	-	-	-	-	94.68	269.48	596.08	817.58	444.58	-	-	-	
		Heating	4671.54	3411.34	1875.64	287.2	-	-	-	-	-	70.34	961.26	3499.26	
		Ventilation	185.55	167.59	185.55	179.56	185.55	179.56	185.55	185.55	179.56	185.55	179.56	185.55	
		Lighting	114.4	78.43	84.35	57.38	55.96	66.36	80.19	56.79	84.79	78.45	103.16	110.25	
															20154.17

Ceiling depth	SRR	Category	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total [kWh]
3m	10%	Cooling	-	-	-	-	95.44	277.52	608.14	831.5	460.5	-	-	-	
		Heating	4689.12	3423.06	1875.64	287.2	-	-	-	-	-	64.46	949.54	3510.98	
		Ventilation	186.53	168.48	186.53	180.52	186.53	180.52	186.53	186.53	180.52	186.53	180.52	186.53	
		Lighting	147.62	113.84	117.56	79.61	80.19	94.74	107.51	83.21	114.75	118.1	137.7	145.39	
															20609.59
	11%	Cooling	-	-	-	-	92.98	277.94	605.22	820.84	465.96	-	-	-	
		Heating	4571.9	3329.28	1817.04	269.62	-	-	-	-	-	64.46	890.92	3405.48	
		Ventilation	179.26	161.91	179.26	173.47	179.26	173.47	179.26	179.26	173.47	179.26	173.47	179.26	
		Lighting	126.92	93.19	100.24	67.46	67.11	80.27	93.73	69	99.33	99.97	115.24	121.77	
															19856.48
	12%	Cooling	-	-	-	-	99.36	276.98	610.68	841.78	459.5	-	-	-	
		Heating	4771.18	3499.26	1922.54	293.06	-	-	-	-	-	70.32	978.84	3563.74	
		Ventilation	191.23	172.73	191.23	185.07	191.23	185.07	191.23	191.23	185.07	191.23	185.07	191.23	
		Lighting	122.07	80.57	86.02	58.21	57.62	67.41	81.15	58.57	86.31	83.41	109.42	123.05	
															20652.67

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