Selecting the Optimum Window Elements of Several WWRs without Prejudicing the Energy Consumption

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Abstract

In this study, a simulation-based optimization technique (SOT) has been used to find optimum window elements that allow the architects and owners to choose their preferences without sacrificing the energy efficiency. In order to implement the SOT, Evolutionary Algorithm (Genetic Algorithm, GA) was linked with a simulation program (EnergyPlus) using the (jEplus+EA) tool. EnergyPlus used to model a west-facing living room on a ground floor of a residential building. The design parameters of the modeled zone were window's glazing and frame materials, overhang projection and inclination, room depth, and side-fins projection for window-to-wall-ratios (WWRs) from 10 to 50%. Such set of parameters with their bounds turns into 0.778 million possible solutions for each WWR. The outcomes of this study showed that WWR up to 40% could be utilized to design a house window with an excess energy less than 5% compared to that at WWR=10%.

Introduction

Residential buildings are part of the main energy consumers worldwide; they consume 20-40% of the generated energy in the developed countries (Pérez-Lombard et al., 2008). For example, in the United States, the residential sector consumes 20% of all primary energy resources; while in Europe it accounts for about 30% of the total European energy consumption (Nejat et al., 2015). Windows features of residential buildings, including size, materials, and attachments are playing a major role in controlling the heat gain in and out of the house. The high burden resulted from this large consumption on economy, environment, and energy makes residential sector noteworthy.

Buildings consumption in hot climate countries has even a more critical energy situation. For example, buildings in Kuwait account for 70% of the electrical power consumed at peak time on a hot summer day (ME, 2005). Most of the existing buildings in Kuwait are residential as a rapid increase in these buildings takes place in recent years (MEW, 2007). However, solar gain through windows affects the energy consumption of air conditioning systems (Hamad, et. al., 2011) substantially.

Building design in Kuwait is usually carried out by the owner preference. Window configuration and its effect on energy use are rarely concerned during the design stage. Such decisions which are ignored at an early stage are hard to change later. Buildings owners are fascinated by how transparent their buildings are; regardless the impact of solar irradiance penetrated through openings and glazing.

The area of the window is represented in terms of its area to the wall area. Window-to-wall-ratio (WWR), has a great impact on the heat gain in and out of the building and also on the daylight availability and occupant visual comfort. Therefore, selecting the optimum window's elements such as glazing and frame materials, and window' attachment elements (overhang and side-fins), forms an efficient window design. This also enhances the stability of the indoor air temperature and air mixing leading to a better thermal comfort. Therefore, optimum window selection ensures the building sustainability since these elements are influential on the building energy consumption along its lifespan.

There are many studies that investigate the effect of WWR for different climates. Goia (2016) has examined several WWRs for many European climates in respect of saving energy. The study showed an optimum WWR for most cases between 30-45%. Peel et al. (2007) carried out a study of mid-size residential building. The authors found a quite large variety of WWR (20-90%) that can be selected based on the climate. However, other research outcomes proclaimed that the lower the WWR is, the lower energy consumption (Ozkan and Onan, 2011; Kheiri, 2013; Lee et al., 2013; Echenagucia et al., 2015).

Therefore, the influence of the window system has to be evaluated completely from an energy perspective and visual comfort. This is achieved by minimizing energy use for heating, cooling, and artificial lights and increasing the natural light (daylight) to its maximum possible availability. Such approach requires particular coupling of a building simulation program and an optimization algorithm (simulation-based building optimization, SOT). Thus, in this study "state-of-the-art" EnergyPlus (Crawley et al., 2001) is linked with Genetic Algorithm (GA). The input variables to the simulation program in this study represent the window design elements such as glazing and frame materials, overhang, and side-fin projection. Simultaneous changing of these parameters will lead to different possible solutions. These possible solutions (search space) can be searched systematically by an optimization method. The search space in this study had been constrained by the amount of illuminance and visual comfort while the main objective is minimizing energy use or cost.

In this paper, the simulation-based optimization technique (SOT) is utilized to get optimum window's elements for several WWRs. The research outcomes should give room to architects and owners to select their preferred WWR without prejudicing the energy performance.

Simulation-based Building Optimization

Many researchers have proven that simulation-based building optimization approach can improve building energy efficiency and indoor environment (Caldas and Norford, 2001; More and Wright, 2003). In order to implement a simulation-based optimization technique (SOT); an optimization algorithm has to be coupled with a building simulation program such as EnergyPlus, BSIM, and DOE-2. In this research, the Genetic Algorithm was selected as an Evolutionary Algorithm (EA) to implement the search while, EnergyPlus was chosen to simulate the building.

Evolutionary Algorithm (Genetic Algorithm)

In natural law, strong genes will survive for many generations. Similarly, in artificial creatures, a random set of chromosomes (population) is initiated first, which represents initial solutions to the studied problem. Then, an evolution to that initial population takes place, using reproduction operators: selection, crossover, and mutation (Goldberg, D.E., 1989). A selection operator is invoked to create a new intermediate population of parents, where the probability for each individual to survive is in linear proportion to its fitness value. Basically, above average individuals will be most likely to have more copies in the intermediate population, while below average individuals will be at risk of being discarded. After the population of parents has been selected, a reproduction operator is applied to produce the new offspring. Then a fine alteration of the new chromosomes is invoked by what is called a mutation operator; GA process is illustrated in Fig. 1.

From the above description, the reproduction looping will keep continuing forever, forming an infinite loop. However, this process is terminated if one of the following four conditions is satisfied: a) a good solution is found, b) a certain number of generations or function calls have been reached, c) a set time has elapsed, or d) no improvement has taken place in the solution.

Initially, different population sizes have been tried to ensure the search not trapped on local optimum solutions. Ultimately, a GA of the mid-size population (size 20) with a high reproduction rate, 100% crossover, and 20% mutation rate, were used for a fixed number of generations (300). Such GA configuration agreed with the findings of Alajmi and Wright (2014).

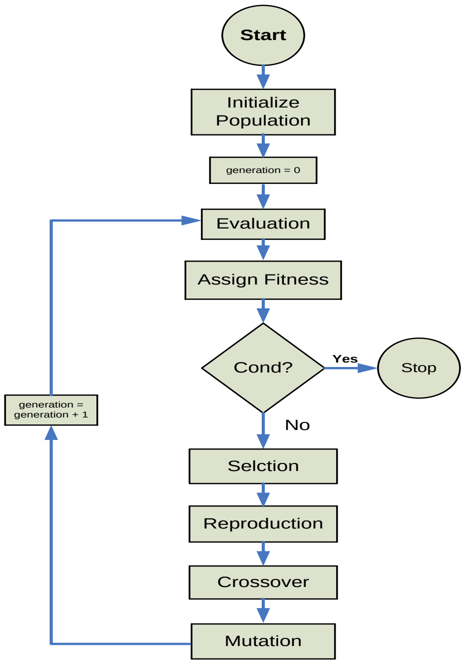

Figure 1: Basic Genetic Algorithms (GAs) flowchart.

Building Simulation Program (EnergyPlus)

This new-generation building energy simulation program is the outcome of more than two decades of developments by the U.S. Department of Energy (Crawley et al., 2001). One of the major features of EnergyPlus is the integration between the building loads, system and plant. This feature allows accurate space temperature predictions using the Predictor-Corrector Method. This method predicts the mechanical system load needed to maintain the zone air set point and simulates the mechanical system to determine its actual capacity. Then, it recalculates the zone air-heat balance to determine the actual zone temperature. Numerous research projects have validated the performance and accuracy of the EnergyPlus (Olsen and Chen, 2003).

In this study, the program calculates the heating, cooling, lighting, and equipment consumptions and visual comfort.

Research Methodology

Optimizing any scientific problem requires an extensive evaluation of the objective function. In the case of building optimization problem, a massive number of building simulations are required to be evaluated. This may be one of the main obstacles to using the simulation-based technique. For instance, in this research eight design parameters are assigned to be varied on different step size (bounds); this turned into 777,600 possible solutions for each WWR.

To overcome such an obstacle many approaches could be implemented: a) using parallelized method through the network, b) evaluated solution is saved in a database or virtual memory so as not to re-evaluate the similar solutions, c) simplifying the objective function and/or its constraints.

In this study, all the above approaches were considered. Precisely, the most effective approach is the parallel function calls (building simulations). This requires a high-performance computing machine. Therefore, a server of 48 threads (ENSIMS X3200) powered by 2x Intel Xeon 2.5GHz with a memory size of 64GB RDIMM was allocated to accomplish the computation. This powerful machine (server) enables multi-tasking simulations, up to 56 at the same time.

Design Parameters

The design parameters need to be selected carefully because the high number of design parameters can lead to an increase in the computational time.

The selected design parameters in this study are the room depth (4-6 m) where a linear lighting control is located in the middle of the zone depth (ZD). The overhang projection was set up to 100% of the window height (H) and its tilt from 90° (horizontal) to 145°. The side-fins was chosen to be (0-80%) of the window width (W). In addition, glazing materials were 6mm-clear, 6mm-green, 3 and 6mm-bronze, and 3mm-low-e. The air gap was either 6 or12mm. Also, frame and divider materials are either aluminum or PVC. A list of these design parameters is given in Table 1. These design parameters generate a 777,600 possible solutions (search space) for each case of WWR.

Table 1: Design parameters values.

Index	Variable	Based Value	LB	UB	step
1	Zone depth, ZD (m)	-	4	6	0.25
2	Daylighting sensor location (m)	ZD/2	-	-	-
3	Overhang tilt (°)	-	90	145	5
4	Window overhang projection (%)	H	0	100	5
5	Window side-fins projection (%)	W	0	80	5
6	Glazing materials	Clear, Green, 3 and 6mm Bronze, 3mm clear Low-e			
7	Air gap thickness	6 and 12 mm			
8	Frame and Divider	Aluminum & PVC			

Objectives Functions and Constraints

In this study, the first objective function is to minimize the annual cooling and heating consumptions of the studied room. The second objective function is to increase the daylighting illuminance to reduce the artificial lighting. The objective functions of the annual energy consumption, $f(x)$ and $f(y)$, can be expressed as follows:

$$f(x) = \left[Q_c(x) + Q_h(x)\right] / 3.6\times10^6 \quad (1)$$

$$f(y) = \left[E_{Daylighting}(x)\right] \quad (2)$$

In equation 1, $Q_c(x)$ and $Q_h(x)$ are the room' annual cooling and heating energy consumptions (J), respectively. The denominator is a factor to convert the energy to kWh. $E_{Daylighting}(x)$ is the room' daylighting (lux).

The two competing objectives are; minimizing the heating and cooling consumptions, and maximizing the natural light (daylighting). The relation is formed in Eq. 3.

$$f(xy) = f_{\min}(x) + f_{\max}(y) \quad (3)$$

Two constraints have been provided to limit the search space (possible solutions). The first was the illuminance level, allowed at the middle of the room which was set at 500 lux and the second is the glare index which was set to 19 (Carlucci, 2015).

$$c_{1,2}(x) = \sum_{i=1}^{n} z_i / n \quad (4)$$

where,

$$z_i = \begin{cases} NH_{lux}, & \text{if } \left(NH_{lux} > 500\right) \\ NH_{glare}, & \text{if } \left(NH_{glare} > 22\right) \end{cases}$$

where, NH_{lux} and NH_{glare} is the exceeded number of hours over the set values of illuminance and glare index, and n is the total number of hours that the occupants' presence in the zone. The limit of the constraints set to 10% of the total number of hours.

Therefore, in this research, a solution is feasible only if $c(x)$ is less than 10% of the total number of hours. The occupants are assumed to be looking at 90° from the window side.

The Modelled Zone

It is true to say that the building facade has the largest windows area. Nevertheless, when the residential buildings are free from the four sides (has no neighborhood buildings contact), windows can be existing in any directions.

It is well known that the geographic location and the orientation of the building have a profound effect on the solar gain by the windows and walls. The façade that received the largest amount of radiation is dependent on the latitude and longitude angles and depends on the season under consideration. Since the cooling load is the main electrical consumption in hot climate countries, the focus is given to the façade that received the maximum radiation from the sun during long days of summer. In the northern part of the equator, the facade facing west receives the largest solar radiation, during the summer season whereas the façade facing south receives the largest solar radiation during winter and full year.

The space considered in this study is a living room on the ground floor of a residential building, in the State of Kuwait. The dimensions of the representative room that used to optimize window system elements are illustrated in Fig. 2. The window dimensions: width (W) and height (H) are changed in accordance to WWR of the studied base wall. The exterior wall was fixed to be 4m wide and 3.5m heights and facing west. Selection of the west-facing room is based on preliminary runs on all orientations, which show that the west-facing is the most challenging one, particularly during the summer season. The WWR has been changed from 10 to 50% in a step of 5%.

For the glazing feature, a double glass was used (the common practice construction for residential building) with a different configuration. The options are from the most transparent (double clear glazing) to the most energy-efficient (low-e glazing). The indoor temperatures were set at 21°C and 24°C for the winter and summer seasons, respectively.

Local Weather Data

In this work, the weather data for Kuwait City (29.22° Latitude, 47.98° Longitude, and 55m elevation) has been selected as the external weather of the simulated building. The design days of summer and winter seasons in Kuwait, as per the Energy Conservation Code of Practice (MEW-R-6, 2014), are given in Table 2.

Table 2: Design days in Kuwait.

Design Day	Dry-bulb temp. (°C)	Daily Range Temp. (°C)	Month/ Day
Summer	48	13	7/21
Winter	5.6	7	1/21

The data of these design days, together with the design supply temperatures, are used to automatically size the heating, ventilating, and air conditioning (HVAC) systems using EnergyPlus simulation program. However, building response to the auto-sized HVAC system is considered over a complete meteorological year, in order to accurately calculate the total building energy consumption. In this study, the ideal load template available in EnergyPlus is used “HVACTemplate: Zone: IdealLoadsAirSystem” to calculate the required heating and cooling demands on each calculating step for the zone with a design factor of 1.25 for heating and 1.15 for cooling.

Set-up of Numerical SOT Process

The EnergyPlus building simulation program is utilized in this study to simulate the zone load. An EnergyPlus input file (IDF) that represents the baseline model is developed and tested. The results of this model are used after that to evaluate optimum solutions. The search for solutions is started by setting the upper and lower limits and the stepwise in the considered design variables. This is done using the jEPlus tool (Zhang, 2009), which allows changing the values specified for each of the design parameters within their limits. Values of these parameters are fed automatically to the IDF file.

Once the project is defined in jEPlus, the tool (jEPlus+EA) was used to perform the Genetic Algorithms, GA, optimization process (Zhang, 2012). The jEPlus+EA process was executed remotely through the allocated server. The entire process is illustrated in Fig. 3. The steps of research methodology that are used in this numerical simulation can be summarized as:

1) Define the studied zone using EnergyPlus to create the IDF file with the following inputs:
    a) weather file
    b) zone dimensions
    c) window dimensions
    d) internal load
    e) constructions materials
    f) occupant activity and internal load schedules
    g) daylighting and glare set values
2) Set the lower bound (LB), upper bound (UB) and the stepwise of the design parameters using the jEPlus tool.
3) Set the initial window-wall-ratio (10%) as the reference optimum with the two different ratios (0.8 and 1.2) of width to height of the window.
4) Find the optimum solutions within the search space using the jEPlus+EA tool.
5) Repeat the procedures for a new WWR (10-50% in a step of 5%) for the two stated widths to height ratios of the window (0.8 and 1.2), see Fig 4.

The optimization run was performed using the Non-dominated Sorting Genetic Algorithm II (NSGA-II) implemented in jEPlus+EA. The specifications of the algorithm settings include:

1. Integer encoding of the design variables
2. Population size 20
3. Binary tournament selection
4. Hybrid (single point, uniform, and arithmetic) crossover operator, with 100% crossover rate.
5. Random mutation with 20% mutation rate.
6. Pareto archived elitism operator
7. Evolution is limited to 300 generations for each run.

The selection of algorithm settings is dependent on the characteristics of the problem. Based on the experience of optimization problems in building design, and the results of pilot runs, this setting is considered to perform well (Wright and Alajmi, 2016).

Results and Discussion

Although two objective functions are set for the optimum solutions obtained by the SOT process, the optimum solutions should not be dominated by one of the objective functions. When the SOT process converged with no domination of either objective functions, the solution is called Pareto-front solutions (Deb, 2001). These solutions are presented by red points in Fig. 5. Pareto-front solutions are survived for many generations during the SOT process. On the other hand, the blue points (Fig. 5) are those solutions produced for the last generation run. They are not totally matched the Pareto-front solutions produced by the SOT process. It should be noted that the zone depth has a negative effect on minimizing the energy consumption. Thus, most of the optimum solutions preferred the shortest zone depth (4m) as can be seen in Fig. 5.

The results showed that some design parameters were always the same on the optimum solutions such as the window glazing (3-mm low-e), air gap of 12mm thickness and PVC window’s frame material. The remaining design parameters that affect the optimum solutions were the overhang and side-fin projections and the overhang's tilt.

Table 3 lists the optimum solutions of all examined WWR from 10 to 50%. The narrower WWR of 10% and W/H=0.8 has been selected as the optimum reference solution that requires the lowest energy consumption, see Table 3. Various optimum solutions at WWR of 10% attain energy consumption higher than the reference optimum by 0.2-1.4%. All solutions with energy consumption larger than that for the optimum reference solution by more than 5% are excluded. The rejected solutions are listed in Table 3 and marked by underlined red color. WWR of 15% showed 0.1 to 1.5% higher energy consumption than the optimum reference solution. This is surprisingly close to the consumption of WWR=10%. The other WWRs, i.e. 20, 25, 30, 35, 40, 45, and 50% showed differences on energy consumption of 0.9-2.3, 1.2-3.0, 1.8-4.6, 2.3-4.5, 2.8-6.6, 3.5-6.9, and 3.4-9.0 respectively. Interestingly, the optimum solutions that satisfy the consumption conditions exist even at WWR=50%.

Table 3 indicates that the average cooling consumption, for the optimum solutions, is about 84% whereas the lighting load represents about 13.3% of the total consumption. In all solutions, the heating load is lower than 3% of the total consumption. Therefore, energy consumption in such hot climate is dominated by the cooling load even for optimum window design.

Visual comfort was considered as constraints for the optimum solutions in terms of illuminance level and glare index. The number of hours that exceeded the illuminance value and glare index is listed in Table 3. There are optimum solutions without any visual discomfort, for all WWR. Those solutions have zero hours exceeding the glare index and illuminance level. However, annual discomforted hours for the other valid optimum solutions are equal or less than 73hrs for glare index and 68hrs for illuminance level. Thus, the annual duration of visual discomfort for these solutions is lower than 1% of the total annual hours. In general, the higher W/H ratio had some hours where the glare index went beyond the set value (19). Nevertheless, the lower W/H ratio had a higher number of hours that exceeded the daylighting limit (500 lux) than higher W/H ratio.

The proposed approach may be used for large and small projects by a qualified person. In sophisticated large projects, a qualified design team may do a guided simulation based on the results of the present work. On the other hand, the designer, for small projects, may use the outcome guidelines of the present work or similar. This work led to providing guidelines for the optimum design of windows on the tough façade. The results confirmed some window' elements such as the frame and divider materials, the glass type and thickness, and the air gap between double glazing panes. In addition, the results indicated that small room depth is better for more daylighting. More work on this topic should provide architects with more guidelines to design cost-effective and energy-efficient windows for facades in all orientations.

Conclusion

The main objective of this paper was to demonstrate the possibility of manipulating several WWRs with different window's design elements such as glazing materials, overhang, and side-fin projections. Thus, more room is given to architects and owners to select among the various WWRs without prejudicing the energy consumption. The results showed an abundant number of selections of different WWR (15-40%) with an insignificant effect on its energy efficiency. Slightly less efficient window's design options were found with higher WWR (45-50%). This work proved that the worst facade orientation on hot climate could have large windows if optimum window's elements are used.

Future Work

Daylighting distribution of the optimum solutions needs to be looked at closely in a post-process analysis. Also, the effect of including interior blinds might enrich the analysis. In addition, other orientations of the windows are worthy to be included in the future work.

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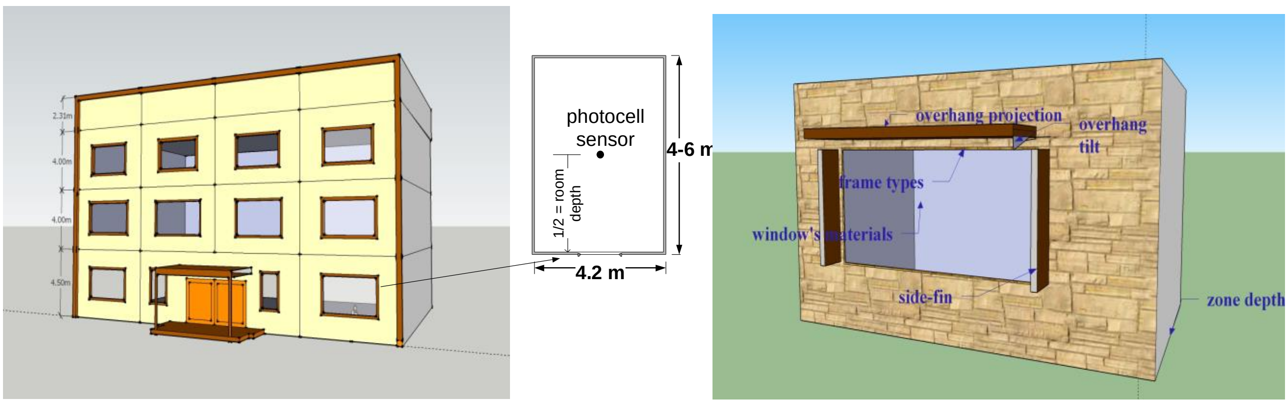

(a) (b) (c)

Figure 2: Schematic of the common residential houses layout (a) Front view of the house (b) Plan view of ground-floor living room (c) zone's axonometric view

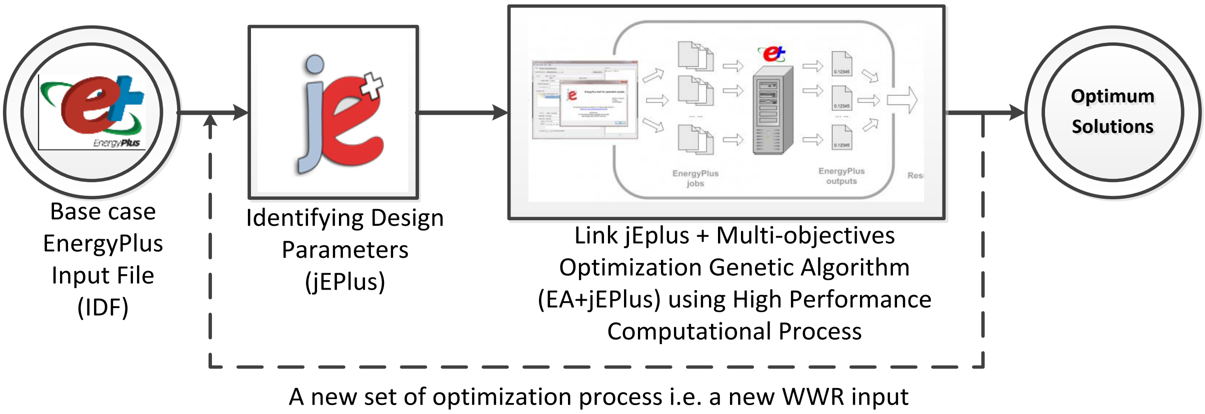

Figure 3: Numerical SOT process set-up

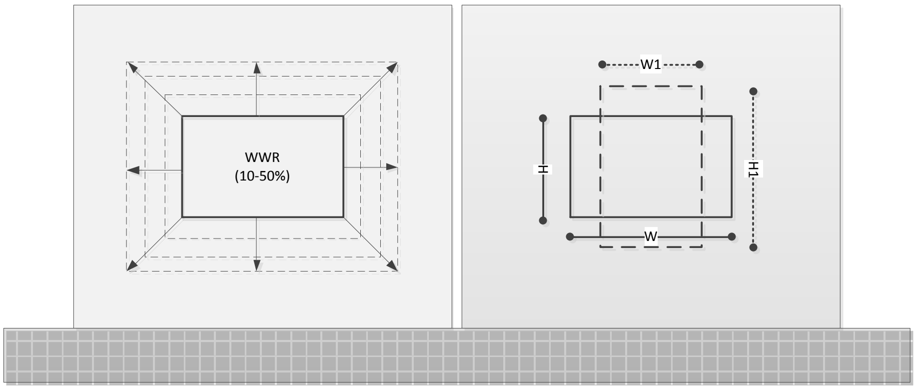

Figure 4: WWR and W/H window for each SOT set.

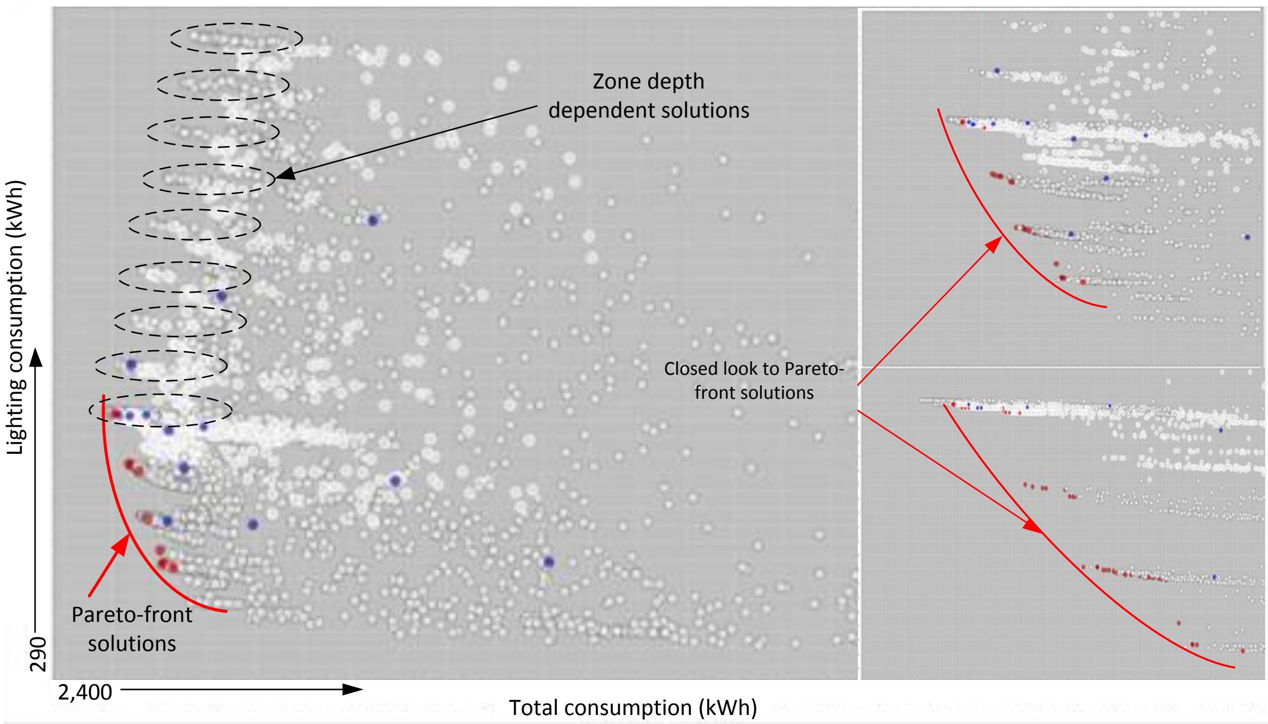

Figure 5: Pareto-front of optimum solutions of the two main objectives shown in red dots.

Table 3: Three optimum design parameters solutions for each SOT WWR and W/H ratio

Index	Width (m)	Height (m)	Width/ Height Ratio	Overhang (m)	Overhang Tilt Angle (°)	Side-fins (m)	Glare Index Exceed. (Hrs)	Illumin. Exceed. (Hrs)	Heating Cons. (kWh)	Cooling Cons. (kWh)	Lighting Cons. (kWh)	Total	Diff. %
WWR 10%													
A1	1.1	1.3	0.8	1.3	145	0.8	0	0	50.7	2522.4	425.8	2998.9	0.0
A2	Reference Optimum Solution			1.3	125	0.6	0	0	49.0	2531.5	424.6	3005.1	0.2
A3				0.5	90	0.6	0	68	46.0	2573.2	422.1	3041.2	1.4
B1	1.3	1.1	1.2	1.1	145	1.0	0	0	50.1	2531.8	424.9	3006.9	0.3
B2				0.9	120	1.0	0	0	48.9	2542.3	423.5	3014.7	0.5
B3				0.6	95	1.0	0	3	47.5	2554.1	422.2	3023.9	0.8
WWR 15%													
A1	1.3	1.5	0.9	1.4	135	0.70	0	0	51.2	2527.5	424.4	3003.1	0.1
A2				1.4	125	0.65	0	0	51.4	2540.5	424.3	3016.1	0.6
A3				1.4	95	0.70	0	0	49.7	2556.7	422.7	3029.1	1.0
B1	1.5	1.3	1.2	1.3	145	0.70	0	0	56.1	2536.0	424.9	3017.0	0.6
B2				1.3	120	0.70	0	0	54.2	2551.3	424.6	3030.1	1.0
B3				1.2	95	0.70	0	0	52.4	2568.6	422.5	3043.5	1.5
WWR 20%													
A1	1.5	1.8	0.8	1.8	145	1.1	0	0	61.9	2535.9	424.5	3022.4	0.8
A2				1.8	125	0.8	0	0	58.5	2555.2	423.5	3037.2	1.3
A3				1.2	95	1.1	0	27	55.7	2600.6	421.2	3077.6	2.6
B1	1.8	1.5	1.2	1.5	145	1.3	0	0	62.3	2537.3	425.4	3025.0	0.9
B2				1.4	120	0.9	0	0	58.6	2563.1	423.0	3044.7	1.5
B3				1.5	90	1.4	0	0	57.0	2587.5	422.1	3066.6	2.3
WWR 25%													
A1	1.7	2.0	0.9	2.0	145	1.3	0	0	67.5	2543.5	425.1	3036.2	1.2
A2				1.8	125	1.3	0	0	64.8	2563.6	423.4	3051.7	1.8
A3				2.0	90	0.5	0	3	55.7	2632.7	419.8	3108.2	3.6
B1	2	1.7	1.2	1.7	145	1.4	0	0	68.1	2542.3	424.4	3034.8	1.2
B2				1.4	125	1.1	33	0	64.0	2571.6	422.3	3057.9	2.0
B3				1.6	90	1.4	38	1	60.9	2609.6	421.0	3091.5	3.1
WWR 30%													
A1	1.9	2.2	0.9	2.2	145	1.4	0	0	73.0	2551.5	424.6	3049.1	1.7
A2				2.0	125	1.3	0	0	69.4	2576.2	422.6	3068.3	2.3
A3				2.2	90	0.5	0	17	58.4	2661.1	418.6	3138.1	4.6
B1	2.2	1.9	1.2	1.9	145	1.5	0	0	73.4	2553.7	425.1	3052.2	1.8
B2				1.7	125	1.7	20	0	70.3	2577.3	423.4	3071.0	2.4
B3				1.9	95	0.7	70	0	61.0	2648.9	420.6	3130.5	4.4
WWR 35%													
A1	2	2.4	0.8	2.4	145	1.4	0	0	78.3	2561.8	425.2	3065.3	2.2
A2				2.2	125	1.4	0	0	74.3	2588.9	422.7	3085.9	2.9
A3				2.2	95	1.4	0	1	68.9	2641.8	420.0	3130.7	4.4
B1	2.4	2	1.2	2.0	145	1.8	0	0	78.9	2564.0	425.2	3068.1	2.3
B2				2.0	125	1.0	50	0	73.6	2594.9	422.7	3091.2	3.1
B3				1.9	95	1.7	20	0	69.9	2642.5	421.4	3133.8	4.5
WWR 40%													
A1	2.2	2.5	0.9	2.5	140	1.4	0	0	83.0	2573.9	425.2	3082.1	2.8
A2				2.3	125	1.3	0	0	78.2	2605.1	423.1	3106.3	3.6
A3				2.4	90	0.7	0	17	65.9	2712.0	418.1	3196.0	6.6
B1	2.5	2.2	1.13636	2.2	145	1.9	0	0	84.3	2574.7	424.8	3083.7	2.8
B2				2.2	125	1.1	27	0	78.8	2608.2	422.7	3109.7	3.7
B3				2.1	95	1.8	34	0	74.1	2662.0	420.5	3156.6	5.3
WWR 45%													
A1	2.3	2.7	0.9	2.6	140	1.6	0	0	87.4	2591.5	425.2	3104.1	3.5
A2				2.6	125	1.6	0	0	84.4	2610.6	423.0	3118.0	4.0
A3				1.8	95	1.6	0	43	76.1	2711.9	417.9	3205.8	6.9
B1	2.7	2.3	1.17391	2.3	140	2.0	0	0	89.1	2588.9	425.8	3103.8	3.5
B2				2.3	125	0.7	73	0	79.5	2646.2	422.2	3147.9	5.0
B3				2.2	95	1.9	34	0	78.3	2682.4	420.7	3181.4	6.1
WWR 50%													
A1	2.4	2.8	0.9	2.7	140	1.6	0	0	92.5	2601.4	423.5	3117.4	4.0
A2				2.7	125	1.6	0	0	88.6	2625.6	421.1	3135.3	4.6
A3				2.0	90	1.6	0	74	78.8	2743.0	416.4	3238.2	8.0
B1	2.8	2.4	1.16667	1.9	145	1.1	27	0	80.8	2598.0	422.7	3101.5	3.4
B2				2.3	125	0.6	74	0	82.2	2672.6	420.6	3175.3	5.9
B3				2.3	90	0.6	154	5	72.3	2780.4	416.8	3269.4	9.0