Daylightophil Approach towards High-Performance Architecture for Hybrid-Optimization of Visual Comfort and Daylight Factor in BSk

Mohammadjavad Mahdavinejad, Hadi Yazdi

Abstract—The greatest influence we have from the world is shaped through the visual form, thus light is an inseparable element in human life. The use of daylight in visual perception and environment readability is an important issue for users. With regard to the hazards of greenhouse gas emissions from fossil fuels, and in line with the attitudes on the reduction of energy consumption, the correct use of daylight results in lower levels of energy consumed by artificial lighting, heating and cooling systems. Windows are usually the starting points for analysis and simulations to achieve visual comfort and energy optimization; therefore, attention should be paid to the orientation of buildings to minimize electrical energy and maximize the use of daylight. In this paper, by using the Design Builder Software, the effect of the orientation of an $18m^2(3m*6m)$ room with 3m height in city of Tehran has been investigated considering the design constraint limitations. In these simulations, the dimensions of the building have been changed with one degree and the window is located on the smaller face (3m*3m) of the building with 80% ratio. The results indicate that the orientation of building has a lot to do with energy efficiency to meet high-performance architecture and planning goals and objectives.

Keywords—Daylight, window, orientation, energy consumption, design builder.

I. INTRODUCTION

DAYLIGHTING means the use of natural light, to meet the visual and thermal demands of building occupants. Daylight and views relate a strong connection between place and time. They reflect healthy circadian rhythms, reduce stress, and result in better productivity, attentiveness, and mood. Although many studies have been done to quantify the human benefits (employee retention, reduced absenteeism, and improved student testing scores), accurate research is still not available [1]. Daylighting is a simple concept to control natural light and reduce the use of electric lights. Electric lighting is not only responsible for huge amounts of the electrical load on a building, but it also can cause excessive cooling pans.

Utility costs of a building can be lower when daylighting is perfectly designed to replace electric lights. A good daylighting design means using ways of addressing the climatic conditions of the building location. When there are more cooling requirements, designers should find ways to reduce solar and conductive heat gain while maximizing natural light [2]. On the other hand, zones needing more heating requirements have to balance the heat waste from lower artificial lighting and conduction with necessary heat that is gained from daylighting [3].

Nowadays, finding efficient sources of energy is a challenge for developing countries like Iran. This can possibly lead to improve the design and has a major role to decrease the energy waste and improve the daylight exploitation [1]. Energy consumption has gained more attention in the building sector, and consumers have to do their best to improve their performance and prevent energy waste [4]. The limitation of energy resources and their wide-spread use in Iran, compared to the universal average, has increased the necessity of efficiency in energy consumption of this country. In recent years, housing and commercial sectors have gained the largest ratio (37%) of energy consumption, so designing the best pattern is one of the appropriate solutions [5]. There are some attributes which affect the daylighting ratio of the buildings, such as the size and materials of windows. But there is a significant attribute such as the orientation that describes the angle of the orientation of the building in the specific site [6]. These attributes vary parametrically.

A parametric representation of a design is where selected values within the design model are variable. So, the objective of this study is to analyze the use of simulating design method in an office building, with a variable orientation angle. To effectively design daylight in buildings, daylight availability data are necessary. Although there is a great potential of daylight energy in Iran, its use is hindered by the absence of measured data [7], [8]. Thus, this design is to find the optimized orientation angle to minimize the energy consumption and maximize the daylight use in the climatic condition of Tehran [9], [10]. It is worth noting that, energy efficient adoption of natural ventilation [11], [12], recombinant materials [13] and new geometry [14] can be utilized [15] in architectural design especially in the building form and composition. Tehran is located in a semi-arid position, and its climate is extremely defined by its geographical location, with Alborz Mountains in the north and the central desert in the south. Tehran is generally described as mild in the spring and autumn, hot and dry in the summer, and cold and wet in the winter.

Fig. 1 shows the monthly average high and low temperature of Tehran.

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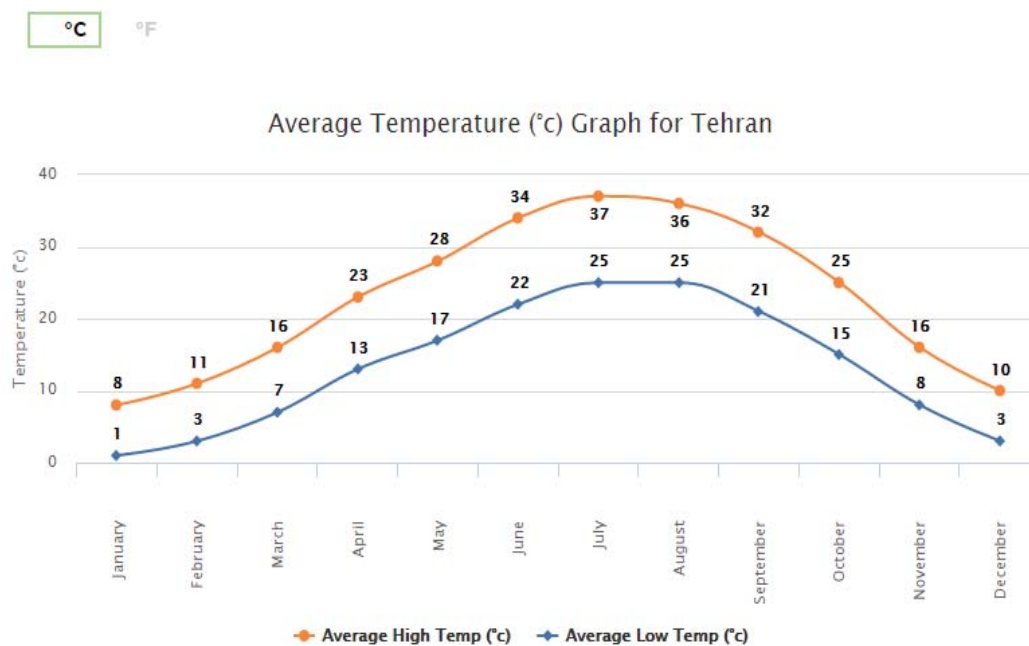
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Fig. 1 Average Temperature (°c) Graph for Tehran [16]

II. METHODOLOGY

Design Builder Application for Architects ensures that designs meet performance goals at the early design steps by supplying precise and valid energy and daylighting behavior data. The Building Simulation Collections (Design Builder) help architects to use BIM (Building Information Modeling) solutions, analyze solar shading, use better technology and consider facade options in one comprehensive application [17].

Energy Plus is the best modular building energy simulation program developed by the US Department of Energy, in order to modelize building heating, cooling, lighting, ventilation and other energy flow systems, which have been under constant development. It is built on BLAST and DOE-2's most well-known features and possibilities, but at the same time it has many innovative features such simulation time in less than an hour, heat transfer balanced zone simulation, multi zone air conditioning system, thermal comfort and photo-voltaic systems. Energy Plus is a simulation program with a user friendly and graphical interface. Design Builder has created magnificent and easy to use interface to Energy Plus [18].

III. MODELING

The exploitation of daylight, commonly referred to as 'daylighting', is recognized as an effective means to reduce the artificial lighting requirements of non-domestic buildings [19]. The design model is an office building with $18m^2(3m*6m)$ dimensions (Fig. 2). The orientation of the model varies from 1° from north to 360° located in Tehran, Iran (Fig. 3). The height of the building is 3 meters and the glazing ratio is 80%. The building has one window on the small wall. The design is to find the best orientation to minimize the energy consumption and maximize the daylight use.
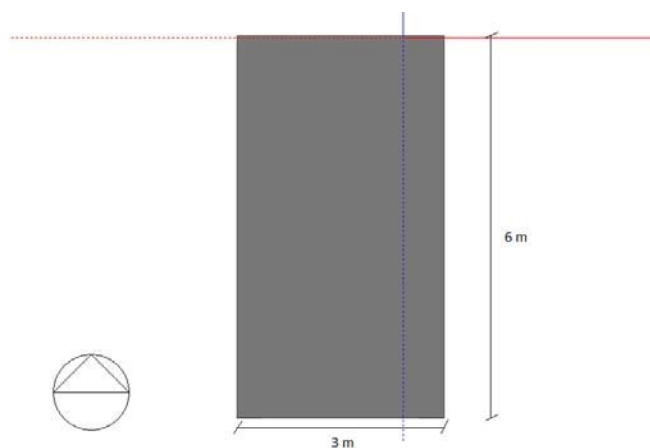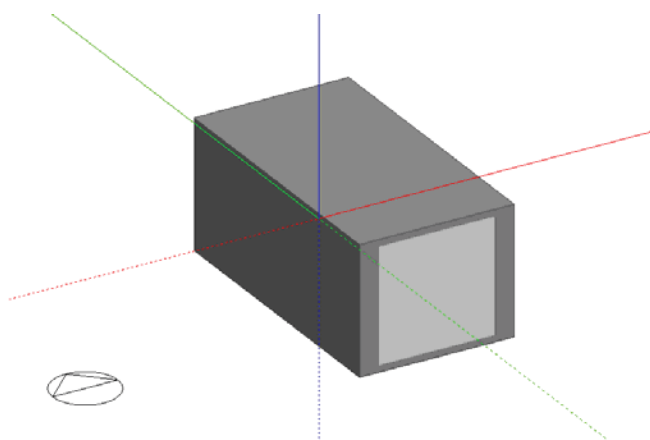

Fig. 2 The Plan of the Office Building

Fig. 3 The Geometry of the Office Building

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IV. EXPERIMENT

The cooling and heating energy is measured in kWh. For superior Air loads, this is the sum of sensible and latent heat that should be erased. For distributed Open Studio systems such as Packaged Terminal Heat Pumps (PTHP), electrical

energy should be used for each zone. For central Open Studio systems, this output should be a single list of chiller electrical energy for the whole building [20]. The electric lighting energy necessary for office building in kWh was estimated by means of the following developed procedure:
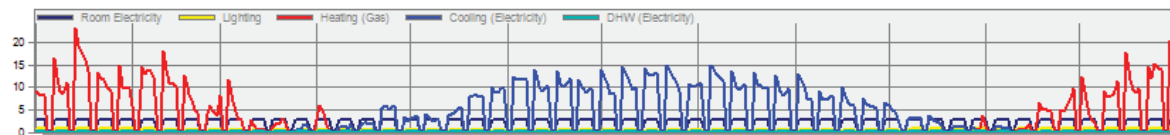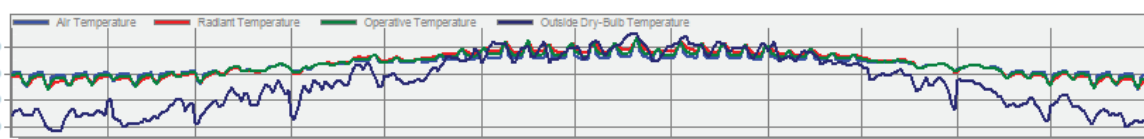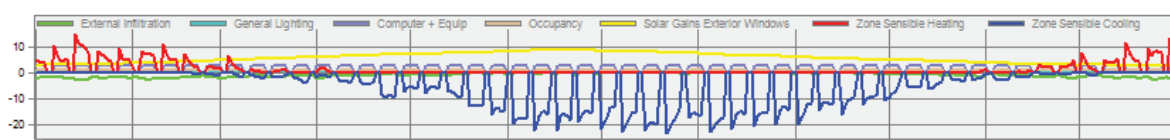
Fig. 4 Fuel [kWh]
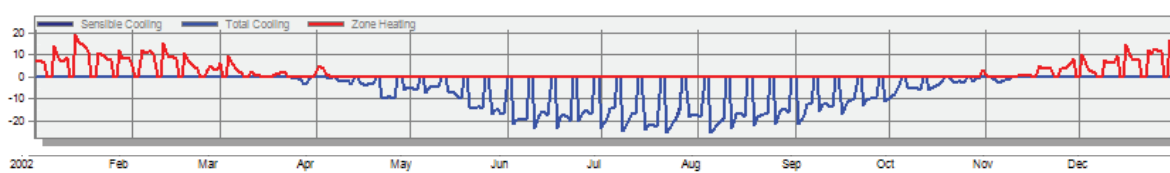

Fig. 5 Temperature [°C]

Fig. 6 Heat Balance [kWh]

Fig. 7 System Load [kWh]

TABLE I
SITE AND SOURCE ENERGY

	Total Energy [kWh]	Energy Per Total Building Area [kWh/m²]	Energy Per Conditioned Building Area [kWh/m²]
Total Site Energy	3633.46	200.65	200.65
Net Site Energy	3633.46	200.65	200.65
Total Source Energy	7793.40	430.38	430.38
Net Source Energy	7793.40	430.38	430.38

TABLE II
BUILDING AREA

	Area [m²]
Total Building Area	18.11
Net Conditioned Building Area	18.11
Unconditioned Building Area	0.00

The researchers calculated the annual average of total energy, the cooling energy, the heating energy, and the electric light energy for orientation angles from 1° to 360° (360 angles) (Fig. 8). According to Fig. 8, the minimum amount of the total energy (the electricity, cooling, and heating energy) respectively occurs at 360°. And with changing the orientation angle from 1° to 360°, the electric light energy remains

constant with the range of ±8.62 kWh.

TABLE III
END USES

	Electricity [kWh]	Natural Gas [kWh]	Additional Fuel [kWh]	District Cooling [kWh]	District Heating [kWh]	Water [m3]
Heating	0.00	0.00	0.00	0.00	711.26	0.00
Cooling	0.00	0.00	0.00	1923.68	0.00	0.00
Interior Lighting	145.75	0.00	0.00	0.00	0.00	0.00
Exterior Lighting	0.00	0.00	0.00	0.00	0.00	0.00
Interior Equipment	784.86	0.00	0.00	0.00	0.00	0.00
Exterior Equipment	0.00	0.00	0.00	0.00	0.00	0.00
Fans	0.00	0.00	0.00	0.00	0.00	0.00
Pumps	0.00	0.00	0.00	0.00	0.00	0.00
Heat Rejection	0.00	0.00	0.00	0.00	0.00	0.00
Humidification	0.00	0.00	0.00	0.00	0.00	0.00
Heat Recovery	0.00	0.00	0.00	0.00	0.00	0.00
Water Systems	0.00	0.00	0.00	0.00	67.91	1.06
Refrigeration	0.00	0.00	0.00	0.00	0.00	0.00
Generators	0.00	0.00	0.00	0.00	0.00	0.00
Total End Uses	930.61	0.00	0.00	1923.68	779.17	1.06

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TABLE IV
THE ORIENTATION ANGLE OF THE BUILDING TO MINIMIZE THE ENERGY CONSUMPTION

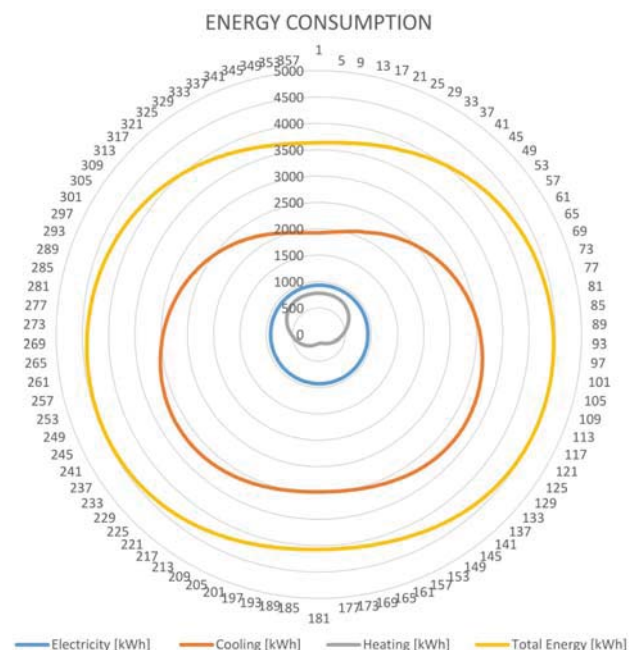| Energy Analysis	Total Energy	Cooling	Heating	Electricity
Angle	360°	360°	173°	267°

Fig. 8 The Annual Average Energy Simulation for Orientation Angle from 1° to 360°

V. CONCLUSION

The research indicates the significance of orientation in energy efficiency as part of architectural design and form configuration. By using the Design Builder, in daylight, heating, and cooling analysis, the result was automatically optimized. From the perspective of minimizing the total energy consumption, electricity, heating and cooling, the best orientation angle is 360°, even though the best orientation angle for the minimizing heating consumption is 173° and for the electricity consumption is 267°. The results of the paper show that the use of simulation analysis can improve the design quality (as mentioned in literature review [21]) by means of lower energy consumption and optimal daylight use.

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