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Internal gain profiles for building energy modeling
Comparison of different standards and OSIM software

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Abstract

Energy consumption in the building sector has an important portion in total energy consumption in the world. Occupancy is an important factor driving building performance. Static and homogeneous occupant schedules, commonly used in building performance simulation, contribute to issues such as performance gaps between simulated and measured energy use in buildings. Stochastic occupancy models have been recently developed and applied to better represent spatial and temporal diversity of occupants in buildings [1]. In this thesis, a new method of acquiring occupancy profile has been developed by Occupancy Simulator software which is a web-based program by Lawrence Berkeley National Laboratory (LBNL). this software considers movement and presence of occupant generate the realistic occupancy schedules of zones in the simulation and provides a dynamic profile [2]. This profile can be used as the input of internal gain simulation such as lighting, appliances and people gain. Thanks to IESVE software by using VEScript plugin, CSV profile created by OSIM software can be imported into IESVE and applied to the case studies. Three different case studies have been modelled and OSIM profiles of each case study have been applied to achieve the internal gain of building. Moreover, in order to get the sensitivity of these dynamic profiles, a complete comparison among OSIM software and static standards' profiles of ASHRAE, ISO 17772-1-2017 and ISO 18523-1-2016 for office buildings has been developed. For this purpose, all profiles of equipment gain, people gain, and lighting gain are also applied in the IESVE software for each case study. Then, the results of internal gains taken from OSIM profiles are compared with each standard. Overall, it can be concluded that OSIM software, by using sensitive simulations, provides a rational results of internal gain loads which is an average in general among ASHRAE, ISO 17772-1-2017 and ISO 18523-1-2016 standards. This means that OSIM software can be incorporated with IESVE in order to do a complete and dynamic simulation of internal load in building energy simulation instead of application of standards' profiles of internal loads. Further research can be implemented to do optimization in OSIM occupancy pattern profiles.

Introduction

Buildings are responsible for the largest proportion of both final energy use (36%) and energy-related CO 2 emissions (39%) [3]. Multifarious factors have impact on energy use and emissions by buildings such as layout of the building, window operation, internal gain which include occupant gains, lighting gains and appliances gains, ventilation and mechanical heating and cooling systems [4].

Occupancy is an important factor for building performance. Different factors have an impact on occupants gain like presence and movement patterns and their interaction with the building. These factors play a fundamental role in building energy simulation [3][4]. Traditionally, in building performance simulation (BPS), occupancy schedule inputs are static and homogeneous, leading to a lower accuracy in predicting building energy performance [5]. But in reality, the occupancy pattern and their building energy use in buildings may differ significantly from each other [6]. To model the influence of human behaviors on building energy consumption and the indoor environment accurately, the occupancy schedule inputs should provide realistic information on the presence and absence status, the number of occupants in rooms, their break time, their meeting schedule and the diversity of occupant behavior patterns. This issue of realistic representation of occupancy schedules used in building performance simulation has been a recent topic of study and discussion. [2] One of the recent methods to provide occupancy pattern is the Occupancy Simulator [7]. It is a web-based program developed by Lawrence Berkeley National Laboratory (LBNL), which was employed to simulate movement and presence of occupants and generate the realistic occupancy schedules of zones. The Occupancy Simulator is developed based on a stochastic Markov Chain model, which takes occupant movement as probabilistic according to occupant's work profiles. Luo et al. [2] validated the performance of the program by measurements, showing that the generated occupant schedules by Occupancy Simulator accurately represent the realistic temporal and spatial variations of occupancy [8].

In general, office buildings energy consumption is an important part of building energy consumption and occupancy pattern has changed from fixed pattern to dynamic based as it was expressed before due to recent conditions of COVID and implementing of smart work. Thus, these dynamic profiles could be essential to control the heating and cooling needs of the building and respectively balance the waste of energy in office buildings. In the framework for this thesis, four typical profiles of occupant behavior models are identified for three different case studies. ISO 17772-1-2017, ASHRAE, ISO 18523-1-2016 and Occupancy Simulator (OSIM) which is the dynamic profile pattern of occupants. For this purpose, the profiles for each standard and OSIM software are applied in the layout model of building for each case study and the results are taken from IESVE software. Then, all gains regarding lighting, occupant, equipment and total internal gain are compared with each other in order to find the difference in values for the same case study.

literature review

There are different methods in order to analyze occupancy pattern in the buildings. By generalizing a stochastic model for the occupancy simulation utilizing weekly presence probability statistics and a mobility parameter relating state change of presence and absence, Page et al. suggested a probabilistic model to predict and simulate occupancy in single-occupation offices [9]. The model provides a time series of the state of presence (present or absent) of each tenant in each room inside a building by conceptualizing occupant presence as an inhomogeneous Markov chain, interrupted by occasional periods of protracted absence. An occupant-based energy consumption prediction model was developed by Wang and Ding using the stochastic characteristics of occupant behavior discovered through an examination of the connection between occupant behavior and equipment energy consumption [10]. In order to determine the occupancy pattern in office spaces using a decision tree model and acquire consistent patterns of occupancy schedule in order to anticipate future occupancy schedules, D'Oca and Hong utilized a data mining framework [11]. Azar and Menassa developed an agent-based model to simulate the interaction of occupants with different energy consumption habits [12]. In addition, Yang and Wang investigated a multi-agent-based intelligent control system to achieve effective energy and comfort management in a building environment [13]. Lee and Malkawi proposed a novel approach using agent-based modeling to simulate occupant thermal comfort in commercial buildings [14]. Building upon previous models, Langevin et al introduced an agent-based model of occupant thermal comfort and environmental adaptation using a standard protocol [15]. A probabilistic occupancy model for occupants' lengthy vacant activities was also given by Stoppel et al. It might be further linked with BPS models [16]. The daily occupancy rates of rooms and buildings in their simulation findings include long vacant activities like training, vacations, and other building underutilization. To simulate the stochastic movement of occupants, an agent-based building occupancy simulation model based on the homogeneous Markov chain model was introduced. It incorporates the idea of using occupant profiles and specific occupant properties to generate corresponding occupancy schedule output [17]. With detailed building and occupant profile as inputs, the model can be integrated in simulation tools to generate time series location for each occupant and the occupancy of each space in the building [18]. The Occupancy Simulator, a web-based tool for occupancy simulation, utilizes this agent-based algorithm to mimic the stochastic occupant presence and building mobility, representing the range of spatial and temporal occupancy [19]. The performance of the occupancy simulation models was evaluated using a wide range of assessment indicators in previous research in order to measure the results' accuracy when compared to actual ground truth data. In a study, Tahmasebi and Mahdavi compared the outputs of the occupancy model with the actual occupancy levels at the building level to support the stochastic realization of occupant profiles as a representation of inhabitants' presence patterns [20].

Methodology

As explained in the previous section internal gain plays an important role in building energy simulation and subsequently in building energy optimization. In order to obtain internal load, parameters such as lighting, occupancy, and energy consumption of building equipment like computers are examined. The consumption pattern of each of the above items is in the form of profiles based on time, in the standards, and by entering these profiles in the building energy modeling software, the annual consumption of each of these parameters can be achieved. In this section, we will fully discuss the details of the investigated profiles, the steps taken in order to obtain internal gains and make a comparison among them.

OSIM software

The occupancy simulation software (OSIM) is based on occupant behavior in the building. Wang et al. introduced a novel approach for building occupancy simulation based on the Homogeneous Markov chain model to simulate occupants' stochastic movement process. OSIM provides the location of occupants and the occupancy of each defined space in the software at a specific time step [3].

This App is an agent-based occupancy simulator, and it is a web application running on a server and simulates occupant movement in a building using the Markov-chain model. The following parameters should be defined as the input of the App: Area of the office building, Space type, area of each space, number of occupants in each space, working days of each type of occupants, arrival departure and break time and holydays. Then the profile of occupants for each day of the year is generated by the App. These schedules can be downloaded and used for building simulation [3].

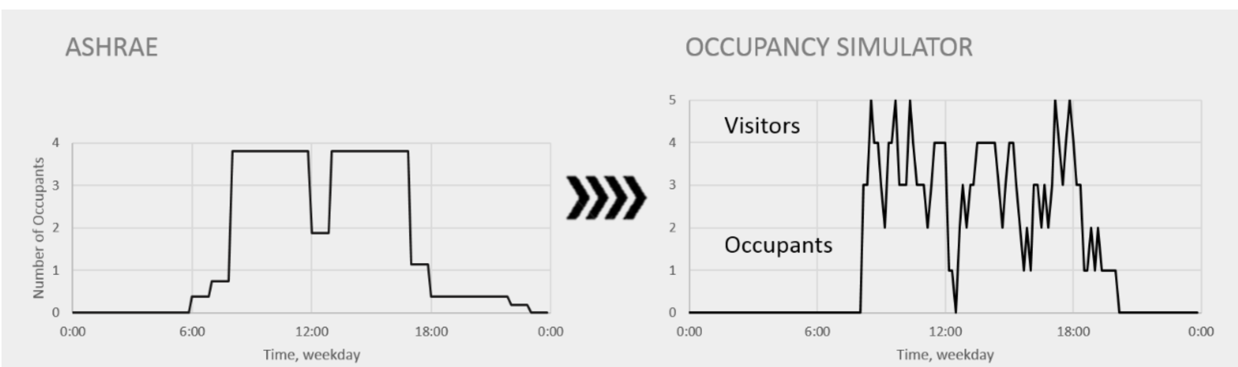


Figure 1. Static and Occupancy Simulator profiles [21]

ISO 17772-1-2017

ISO 17772-1-2017 also defines a profile for occupant schedule and internal loads that can be used as input to calculations of energy use in a building. Single office, Landscape office and meeting room reference are chosen for the documents and profile table from the ISO 17772-1-2017. [12] In single office and landscape tables, for the working days the profile of occupant, lighting and appliances are similar and for the weekends (Saturday and Sunday) everything considered as zero which means there is no internal load in those days. But for meeting room there are different profiles not only for the working day and weekend but also among occupant, lighting, and appliances. The details of the profiles are as following tables:

h	**Energy calculation for single office**					
	Weekdays			**Weekends**		
	Occupants	Appliance	Lighting	Occupants	Appliance	Lighting
1	0	0	0	0	0	0
2	0	0	0	0	0	0
3	0	0	0	0	0	0
4	0	0	0	0	0	0
5	0	0	0	0	0	0
6	0	0	0	0	0	0
7	0	0	0	0	0	0
8	0	0	0	0	0	0
9	0	0	0	0	0	0
10	1	1	1	0	0	0
11	1	1	1	0	0	0
12	1	1	1	0	0	0
13	0	0	0	0	0	0
14	1	1	1	0	0	0
15	1	1	1	0	0	0
16	1	1	1	0	0	0
17	0	0	0	0	0	0
18	0	0	0	0	0	0
19	0	0	0	0	0	0
20	0	0	0	0	0	0
21	0	0	0	0	0	0
22	0	0	0	0	0	0
23	0	0	0	0	0	0
24	0	0	0	0	0	0

Table 1. Single office profile - ISO 17772-1-2017

h	Energy calculation for landscape office					
	Weekdays			**Weekends**		
	Occupants	Appliance	Lighting	Occupants	Appliance	Lighting
1	0	0	0	0	0	0
2	0	0	0	0	0	0
3	0	0	0	0	0	0
4	0	0	0	0	0	0
5	0	0	0	0	0	0
6	0	0	0	0	0	0
7	0	0	0	0	0	0
8	0.2	0.2	0.2	0	0	0
9	0.6	0.6	0.6	0	0	0
10	0.6	0.6	0.6	0	0	0
11	0.7	0.7	0.7	0	0	0
12	0.7	0.7	0.7	0	0	0
13	0.4	0.4	0.4	0	0	0
14	0.6	0.6	0.6	0	0	0
15	0.7	0.7	0.7	0	0	0
16	0.7	0.7	0.7	0	0	0
17	0.6	0.6	0.6	0	0	0
18	0.2	0.2	0.2	0	0	0
19	0	0	0	0	0	0
20	0	0	0	0	0	0
21	0	0	0	0	0	0
22	0	0	0	0	0	0
23	0	0	0	0	0	0
24	0	0	0	0	0	0

Table 2. Landscape office profile - ISO 17772-1-2017

h	Energy calculation for Meeting room					
	Weekdays			Weekends		
	Occupants	Appliance	Lighting	Occupants	Appliance	Lighting
1	0	0	0	0	0	0
2	0	0	0	0	0	0
3	0	0	0	0	0	0
4	0	0	0	0	0	0
5	0	0	0	0	0	0
6	0	0	0	0	0	0
7	0	0	0	0	0	0
8	0.2	0.2	0.2	0	0	0
9	0.6	0.6	0.6	0	0	0
10	0.6	0.6	0.6	0	0	0
11	0.7	0.7	0.7	0	0	0
12	0.7	0.7	0.7	0	0	0
13	0.4	0.4	0.4	0	0	0
14	0.6	0.6	0.6	0	0	0
15	0.7	0.7	0.7	0	0	0
16	0.7	0.7	0.7	0	0	0
17	0.6	0.6	0.6	0	0	0
18	0.2	0.2	0.2	0	0	0
19	0	0	0	0	0	0
20	0	0	0	0	0	0
21	0	0	0	0	0	0
22	0	0	0	0	0	0
23	0	0	0	0	0	0
24	0	0	0	0	0	0

Table 3. Meeting room profile - ISO 17772-1-2017

ASHRAE

The next standard which is evaluated is ASHREA profiles. In ASHRAE the profiles are divided into three parts: working days, Saturdays, Sundays and holidays and others. Moreover, the profile for occupant, lighting and equipment are different from each other. In the following tables all profiles are shown.

h	**Energy calculation for Lighting**		
	Weekdays	**Saturday**	**Sunday, holiday, other**
1	0.05	0.05	0.05
2	0.05	0.05	0.05
3	0.05	0.05	0.05
4	0.05	0.05	0.05
5	0.05	0.05	0.05
6	0.1	0.05	0.05
7	0.1	0.1	0.05
8	0.3	0.1	0.05
9	0.9	0.3	0.05
10	0.9	0.3	0.05
11	0.9	0.3	0.05
12	0.9	0.3	0.05
13	0.9	0.15	0.05
14	0.9	0.15	0.05
15	0.9	0.15	0.05
16	0.9	0.15	0.05
17	0.9	0.15	0.05
18	0.5	0.05	0.05
19	0.3	0.05	0.05
20	0.3	0.05	0.05
21	0.2	0.05	0.05
22	0.2	0.05	0.05
23	0.1	0.05	0.05
24	0.05	0.05	0.05

Table 4. Lighting profile - ASHRAE

h	Energy calculation for Equipment		
	Weekdays	**Saturday**	**Sunday, holiday, other**
1	0.4	0.3	0.3
2	0.4	0.3	0.3
3	0.4	0.3	0.3
4	0.4	0.3	0.3
5	0.4	0.3	0.3
6	0.4	0.3	0.3
7	0.4	0.4	0.3
8	0.4	0.4	0.3
9	0.9	0.5	0.3
10	0.9	0.5	0.3
11	0.9	0.5	0.3
12	0.9	0.5	0.3
13	0.8	0.35	0.3
14	0.9	0.35	0.3
15	0.9	0.35	0.3
16	0.9	0.35	0.3
17	0.9	0.35	0.3
18	0.5	0.3	0.3
19	0.4	0.3	0.3
20	0.4	0.3	0.3
21	0.4	0.3	0.3
22	0.4	0.3	0.3
23	0.4	0.3	0.3
24	0.4	0.3	0.3

Table 5. Equipment profile - ASHRAE

h	Energy calculation for Occupant		
	Weekdays	**Saturday**	**Sunday, holiday, other**
1	0	0	0
2	0	0	0
3	0	0	0
4	0	0	0
5	0	0	0
6	0	0	0
7	0.1	0.1	0.05
8	0.2	0.1	0.05
9	0.95	0.3	0.05
10	0.95	0.3	0.05
11	0.95	0.3	0.05
12	0.95	0.3	0.05
13	0.5	0.1	0.05
14	0.95	0.1	0.05
15	0.95	0.1	0.05
16	0.95	0.1	0.05
17	0.95	0.1	0.05
18	0.3	0.05	0.05
19	0.1	0.05	0
20	0.1	0	0
21	0.1	0	0
22	0.1	0	0
23	0.05	0	0
24	0.05	0	0

Table 6. Occupant profile - ASHRAE

ISO 18523-1-2016

ISO 18523-1-2016 also provides profile for internal loads. Daily schedules are divided into three different parts. The daily schedules a, b and c are allocated to weekdays except for Saturdays, Saturdays and Sundays/holidays, respectively [22].

Daily schedule	Total
a	244
b	49
c	72
Total number of days	365

Figure 2. Daily schedule - ISO 18523-1-2016

The categories of space or zone for buildings is expressed by detail in ISO 18523-1-2016 in figure 3. For the case study, "Office room", "office room with heavy electrical load", "Meeting room", "Corridor", "Lavatory", and "Kitchen" profiles are chosen to be applied. Then, for each space there are three profiles of "Occupant", "Appliances", and "Lighting" which are applied to each space. The detail of each profile is explained in the following tables 7 till 19.

Of-1 **Office room**
Of-2 **Office room with heavy electrical load**
Of-3 Meeting room
Of-4 Tea room
Of-5 Canteen
Of-6 Central monitor room
Of-7 Changing room
Of-8 Corridor
Of-9 Lobby
Of-10 Lavatory
Of-11 Smoking room
Of-12 Kitchen
Of-13 Indoor parking garage
Of-14 Machine room
Of-15 Electric room
Of-16 Kitchenette with hot water server
Of-17 Storage room
Of-18 Printing room
Of-19 Garbage storage

Figure 3. Categories of spaces - ISO 18523-1-2016

h	Energy calculation for Office room - Occupant		
	Weekdays	**Saturday**	**Sunday, holiday, other**
1	0	0	0
2	0	0	0
3	0	0	0
4	0	0	0
5	0	0	0
6	0	0	0
7	0	0	0
8	1	0	0
9	1	0	0
10	1	0	0
11	1	0	0
12	0.6	0	0
13	1	0	0
14	1	0	0
15	1	0	0
16	1	0	0
17	1	0	0
18	0.5	0	0
19	0.3	0	0
20	0.2	0	0
21	0	0	0
22	0	0	0
23	0	0	0
24	0	0	0

Table 7. Office room - Occupant profile - ISO 18523-1-2016

h	Energy calculation for Office room - Lighting		
	Weekdays	**Saturday**	**Sunday, holiday, other**
1	0	0	0
2	0	0	0
3	0	0	0
4	0	0	0
5	0	0	0
6	0	0	0
7	0	0	0
8	1	0	0
9	1	0	0
10	1	0	0
11	1	0	0
12	0.5	0	0
13	1	0	0
14	1	0	0
15	1	0	0
16	1	0	0
17	1	0	0
18	1	0	0
19	1	0	0
20	0.8	0	0
21	0	0	0
22	0	0	0
23	0	0	0
24	0	0	0

Table 8. Office room - Lighting profile - ISO 18523-1-2016

h	Energy calculation for Office room - Appliances		
	Weekdays	**Saturday**	**Sunday, holiday, other**
1	0.25	0.25	0.25
2	0.25	0.25	0.25
3	0.25	0.25	0.25
4	0.25	0.25	0.25
5	0.25	0.25	0.25
6	0.25	0.25	0.25
7	0.25	0.25	0.25
8	1	0.25	0.25
9	1	0.25	0.25
10	1	0.25	0.25
11	1	0.25	0.25
12	0.8	0.25	0.25
13	1	0.25	0.25
14	1	0.25	0.25
15	1	0.25	0.25
16	1	0.25	0.25
17	1	0.25	0.25
18	1	0.25	0.25
19	0.5	0.25	0.25
20	0.5	0.25	0.25
21	0.25	0.25	0.25
22	0.25	0.25	0.25
23	0.25	0.25	0.25
24	0.25	0.25	0.25

Table 9. Office room - Appliances profile - ISO 18523-1-2016

h	Energy calculation for Landscape office - Occupant		
	Weekdays	**Saturday**	**Sunday, holiday, other**
1	0	0	0
2	0	0	0
3	0	0	0
4	0	0	0
5	0	0	0
6	0	0	0
7	0	0	0
8	1	0	0
9	1	0	0
10	1	0	0
11	1	0	0
12	0.6	0	0
13	1	0	0
14	1	0	0
15	1	0	0
16	1	0	0
17	1	0	0
18	0.5	0	0
19	0.3	0	0
20	0.2	0	0
21	0	0	0
22	0	0	0
23	0	0	0
24	0	0	0

Table 10. Landscape office - Occupant profile - ISO 18523-1-2016

h	Energy calculation for Landscape office - Lighting		
	Weekdays	**Saturday**	**Sunday, holiday, other**
1	0	0	0
2	0	0	0
3	0	0	0
4	0	0	0
5	0	0	0
6	0	0	0
7	0	0	0
8	1	0	0
9	1	0	0
10	1	0	0
11	1	0	0
12	0.5	0	0
13	1	0	0
14	1	0	0
15	1	0	0
16	1	0	0
17	1	0	0
18	1	0	0
19	1	0	0
20	0.8	0	0
21	0	0	0
22	0	0	0
23	0	0	0
24	0	0	0

Table 11. Landscape office - Lighting profile - ISO 18523-1-2016

h	Energy calculation for Landscape office - Appliances		
	Weekdays	**Saturday**	**Sunday, holiday, other**
1	0.25	0.25	0.25
2	0.25	0.25	0.25
3	0.25	0.25	0.25
4	0.25	0.25	0.25
5	0.25	0.25	0.25
6	0.25	0.25	0.25
7	0.25	0.25	0.25
8	1	0.25	0.25
9	1	0.25	0.25
10	1	0.25	0.25
11	1	0.25	0.25
12	0.8	0.25	0.25
13	1	0.25	0.25
14	1	0.25	0.25
15	1	0.25	0.25
16	1	0.25	0.25
17	1	0.25	0.25
18	1	0.25	0.25
19	0.5	0.25	0.25
20	0.5	0.25	0.25
21	0.25	0.25	0.25
22	0.25	0.25	0.25
23	0.25	0.25	0.25
24	0.25	0.25	0.25

Table 12. Landscape office - Appliances profile - ISO 18523-1-2016

h	Energy calculation for Meeting room - Occupant		
	Weekdays	Saturday	Sunday, holiday, other
1	0	0	0
2	0	0	0
3	0	0	0
4	0	0	0
5	0	0	0
6	0	0	0
7	0	0	0
8	0	0	0
9	1	0	0
10	1	0	0
11	1	0	0
12	1	0	0
13	1	0	0
14	1	0	0
15	1	0	0
16	1	0	0
17	1	0	0
18	0	0	0
19	0	0	0
20	0	0	0
21	0	0	0
22	0	0	0
23	0	0	0
24	0	0	0

Table 13. Meeting room - Occupant profile - ISO 18523-1-2016

h	Energy calculation for Meeting room - Lighting		
	Weekdays	**Saturday**	**Sunday, holiday, other**
1	0	0	0
2	0	0	0
3	0	0	0
4	0	0	0
5	0	0	0
6	0	0	0
7	0	0	0
8	0	0	0
9	1	0	0
10	1	0	0
11	1	0	0
12	1	0	0
13	1	0	0
14	1	0	0
15	1	0	0
16	1	0	0
17	1	0	0
18	0	0	0
19	0	0	0
20	0	0	0
21	0	0	0
22	0	0	0
23	0	0	0
24	0	0	0

Table 14. Meeting room - Lighting profile - ISO 18523-1-2016

h	Energy calculation for Meeting room - Appliances		
	Weekdays	**Saturday**	**Sunday, holiday, other**
1	0	0	0
2	0	0	0
3	0	0	0
4	0	0	0
5	0	0	0
6	0	0	0
7	0	0	0
8	0	0	0
9	1	0	0
10	1	0	0
11	1	0	0
12	1	0	0
13	1	0	0
14	1	0	0
15	1	0	0
16	1	0	0
17	1	0	0
18	0	0	0
19	0	0	0
20	0	0	0
21	0	0	0
22	0	0	0
23	0	0	0
24	0	0	0

Table 15. Meeting room - Appliances profile - ISO 18523-1-2016

h	Energy calculation for Corridor - Occupant		
	Weekdays	**Saturday**	**Sunday, holiday, other**
1	0	0	0
2	0	0	0
3	0	0	0
4	0	0	0
5	0	0	0
6	0	0	0
7	0	0	0
8	1	0	0
9	1	0	0
10	1	0	0
11	1	0	0
12	1	0	0
13	1	0	0
14	1	0	0
15	1	0	0
16	1	0	0
17	1	0	0
18	1	0	0
19	1	0	0
20	1	0	0
21	0	0	0
22	0	0	0
23	0	0	0
24	0	0	0

Table 16. Corridor - Occupant profile - ISO 18523-1-2016

h	Energy calculation for Corridor - Lighting		
	Weekdays	**Saturday**	**Sunday, holiday, other**
1	0	0	0
2	0	0	0
3	0	0	0
4	0	0	0
5	0	0	0
6	0	0	0
7	0	0	0
8	1	0	0
9	1	0	0
10	1	0	0
11	1	0	0
12	1	0	0
13	1	0	0
14	1	0	0
15	1	0	0
16	1	0	0
17	1	0	0
18	1	0	0
19	1	0	0
20	1	0	0
21	0	0	0
22	0	0	0
23	0	0	0
24	0	0	0

Table 17. Corridor - Lighting profile - ISO 18523-1-2016

h	Energy calculation for Bathroom - Occupant		
	Weekdays	**Saturday**	**Sunday, holiday, other**
1	0	0	0
2	0	0	0
3	0	0	0
4	0	0	0
5	0	0	0
6	0	0	0
7	0	0	0
8	1	0	0
9	1	0	0
10	1	0	0
11	1	0	0
12	1	0	0
13	1	0	0
14	1	0	0
15	1	0	0
16	1	0	0
17	1	0	0
18	1	0	0
19	1	0	0
20	1	0	0
21	0	0	0
22	0	0	0
23	0	0	0
24	0	0	0

Table 18. Bathroom - Occupant profile - ISO 18523-1-2016

h	Energy calculation for Bathroom - Lighting		
	Weekdays	**Saturday**	**Sunday, holiday, other**
1	0	0	0
2	0	0	0
3	0	0	0
4	0	0	0
5	0	0	0
6	0	0	0
7	0	0	0
8	1	0	0
9	1	0	0
10	1	0	0
11	1	0	0
12	1	0	0
13	1	0	0
14	1	0	0
15	1	0	0
16	1	0	0
17	1	0	0
18	1	0	0
19	1	0	0
20	1	0	0
21	0	0	0
22	0	0	0
23	0	0	0
24	0	0	0

Table 19. Bathroom - Lighting profile - ISO 18523-1-2016

IESVE

IESVE is an energy modeling software allowing design of the geometry of building and defining multifarious aspects of that such as HVAC and loads, SunCast and Airflow analysis based on the location, compliance, energy, and carbon [23].

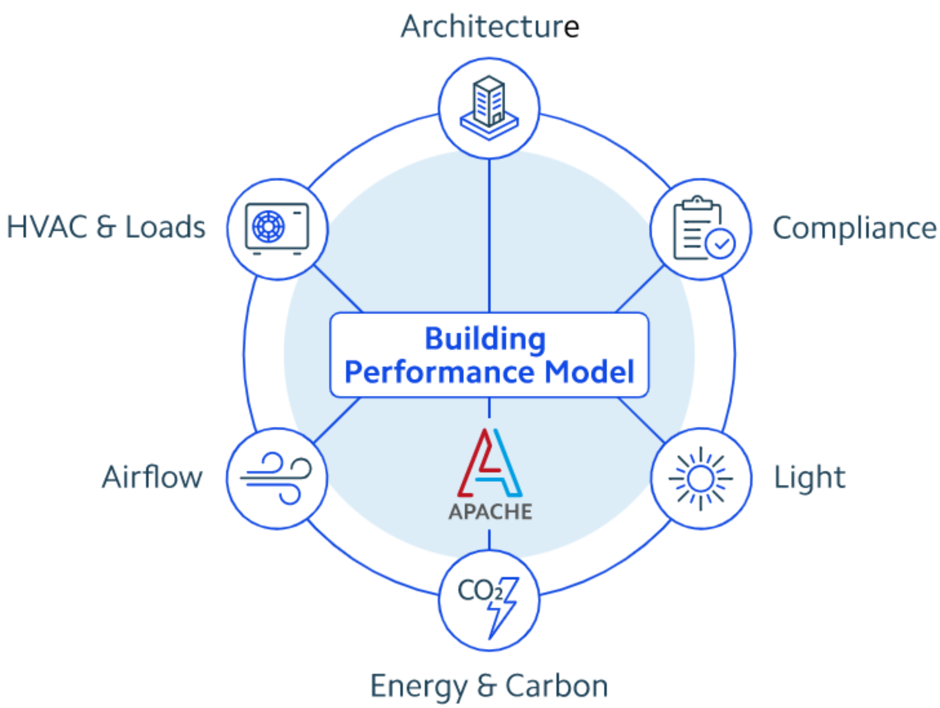


Figure 4. IESVE modeling parts

In this thesis, the research is specifically implemented on “internal gain’ profile and the results are based on “people gain”, “equipment gain”, “lighting gain” and “total internal gain” [24].

Case study 1

The chosen building for case study 1 is a one-story office building with the total area of 880 m2 occupied by 16 people. The rooms are divided as following plan (figure 5):

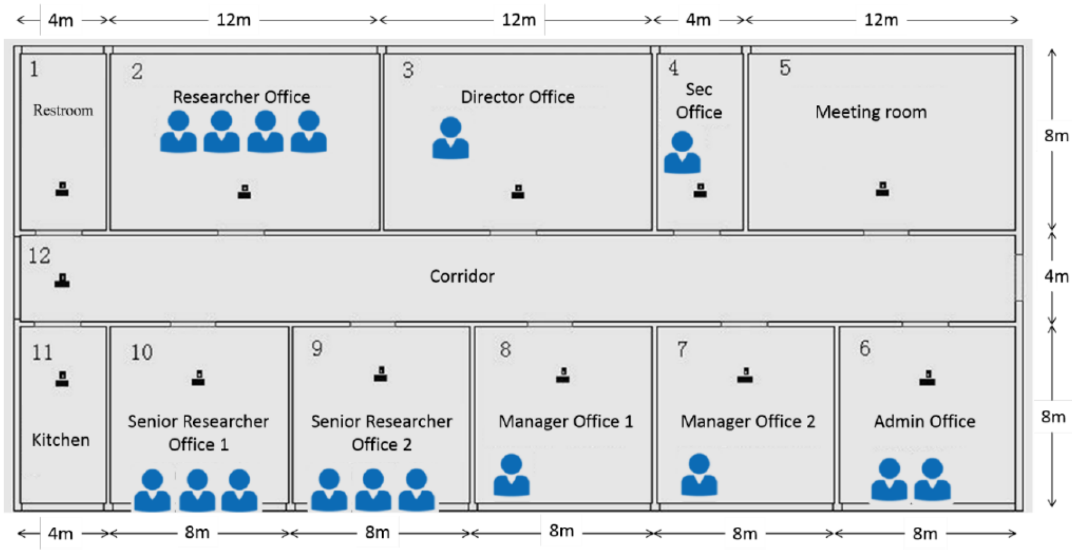


Figure 5. First case study layout of building

In the next step, the geometry of the building is modeled in IESVE software (figure 6). The weather file is chosen as Milano Linate airport for the location definition. Then, the model is ready to apply internal gain profiles.

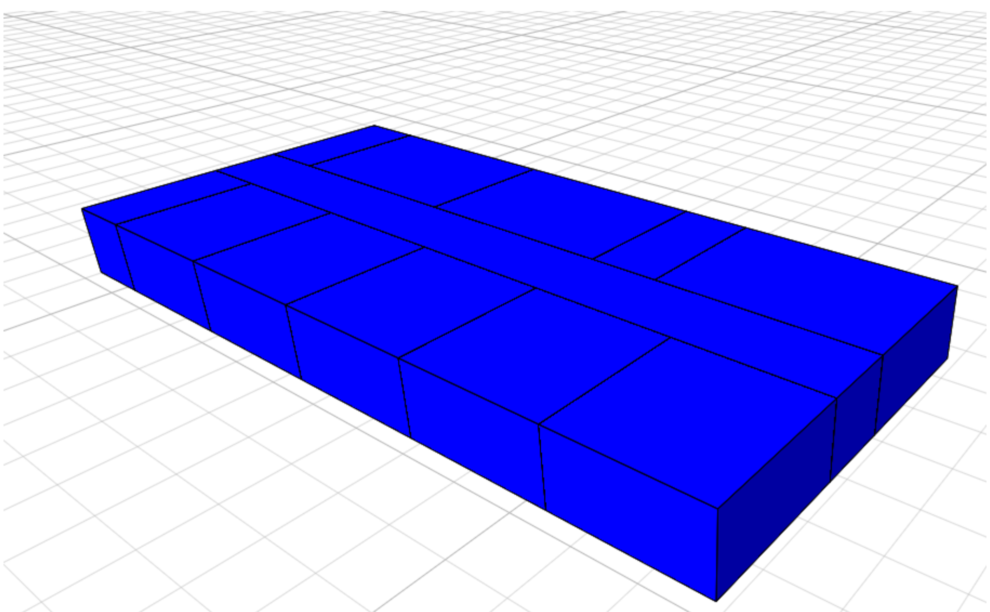


Figure 6. First case study IESVE geometry

The first profile that should be inserted in IESVE is the annual occupancy pattern profile of OSIM software. The required steps are explained in detail to acquire the CSV profile from OSIM.

- **Step 1: The Start New Page**

In this step, the building type and the area should be provided, which are “Office – Small” with 880 m2 in this case. The other building types available are “Office – Large” for office buildings with a floor area of more than 3000 m2 and “Other” for all other types of buildings [21].

- **Step 2: The Spaces Page**

Then, the name of all spaces should be chosen and the number of each space in the building and the area of each space should be inserted based on the case study plan (table 20).

Name	Space type	Area [m2]	Space multiplier
Researcher Office	Office - Researcher	96	1
Meeting Room	Meeting Room	96	1
Director Office	Office - Director	96	1
Manager Offices	Office - Manager	64	2
Restroom and Kitchen	Auxiliary	32	2
Corridor	Corridor	176	1
Sec Office	Office – Admin and Sec	32	1
Admin Office	Office – Admin and Sec	64	1
Senior Research Offices	Office – Senior Researcher	64	2

Table 20. First case study - OSIM space properties

- **Step 3: The Space Type Page**

In this page, the name of the spaces is defined, and its occupant type should be selected then its density is inserted based on m2/person (table 21). For example, if the area of the ‘researcher office’ is 96 m2 and there are 4 people in this space, the occupant density for this space is 24 m2/person. Also, For the “Meeting room” space type, users can define the meeting events for selected day of week, number of people per meeting and the probability percentage of duration of meeting based on 30 minutes, 60 minutes, 90 minutes, and 120 minutes. In this case study, the meeting days are every day except Saturday and Sunday with the minimum number of 2 and maximum number of 8 people and its duration probability is 13%, 70%, 12% and 5% respectively. For the kitchen and bathroom, usage should be chosen as “others” which does not need any information. It is worth noting that for Offices occupant percentage of people who are working in that space is 80% and 20% for secretary moving in their spaces.

Name	Usage	Occupant density
Office - Researcher	Office	24
Meeting Room	Meeting Room	-
Office - Director	Office	96
Office - Manager	Office	64
Auxiliary	Others	-
Corridor	Others	-
Office – Admin and Sec	Office	32
Office – Admin and Sec	Office	32
Office – Senior Researcher	Office	21

Table 21. First case study - Occupant density specification in OSIM software

- **Step 4: The Occupant Type Page**

In the following page, the occupant type should be specified with their working days, arrival and departure time and short-term leaving events such as lunch or coffee break with its duration. The arrival time is considered as 8 am and for the departure it is 17:30 pm with the variation of 15 minutes for working days. For the break, one hour of lunch time with the variation of 30 minutes at 12 pm is defined. The space occupancy is specified as following table 22:

Location	Own office	Other office	Meeting room	Auxiliary room	Outdoor
Average use time [percentage]	50	5	30	5	10
Average stay time [min]	60	20	60	10	20

Table 22. First case study - usage time in OSIM software

- **Step 5: The Simulate Page**

Finally, the simulation year with its start and end dates is determined with the time step of 10 minutes. Holidays based on the country are selected. in this scenario, simulation year is 2015. By clicking on the Simulate button, the simulation starts, and it takes about one minute to run an annual simulation [21].The results can be viewed on the Simulate page, with the customization of results period and the choices of spaces / whole building (Figure 15). Users can also download the occupancy results in CSV and EnergyPlus IDF formats, and further use them in building performance simulation [21]. The summary of all process is mentioned in figure 7.

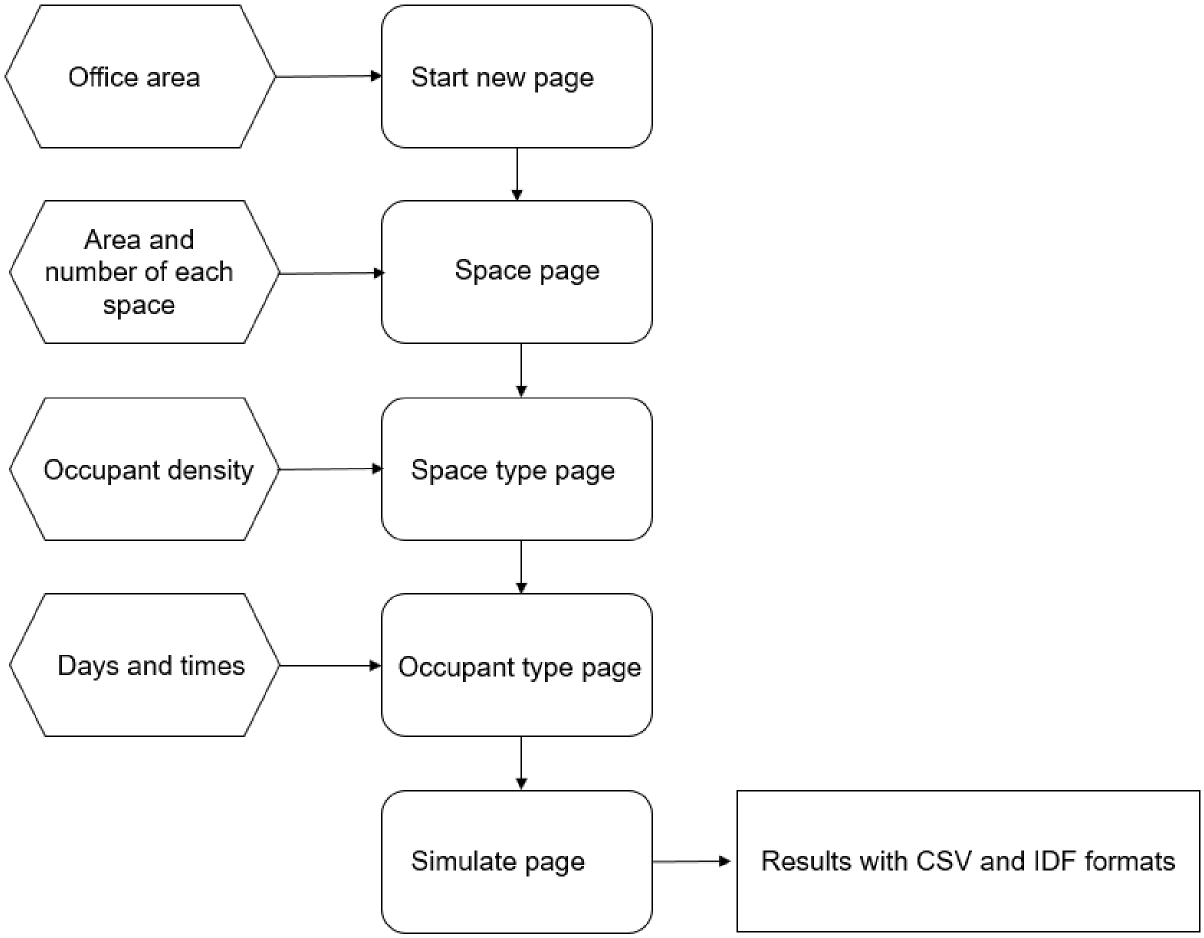


Figure 7. OSIM software process diagram

The daily profiles, weekly profiles and annual profile are respectively shown in figures 8,9,10.

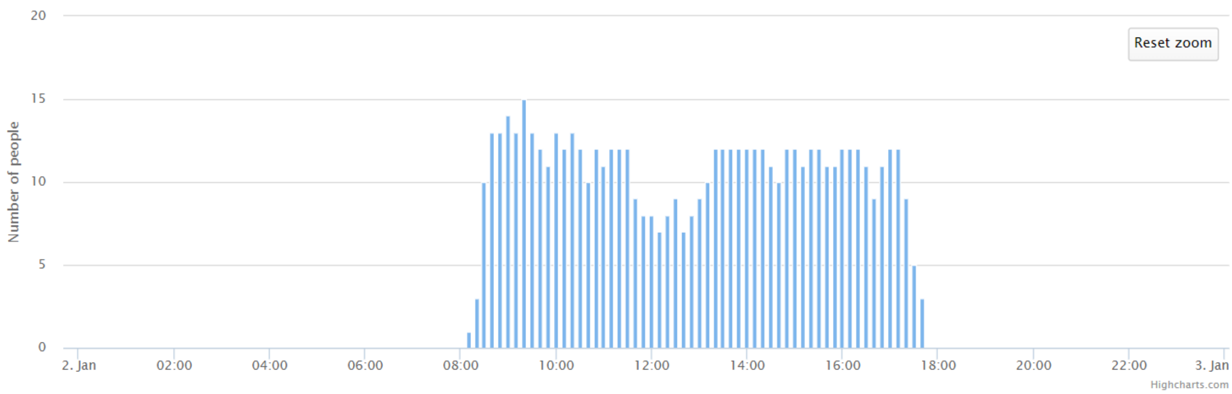


Figure 8. First case study - Daily profile of OSIM

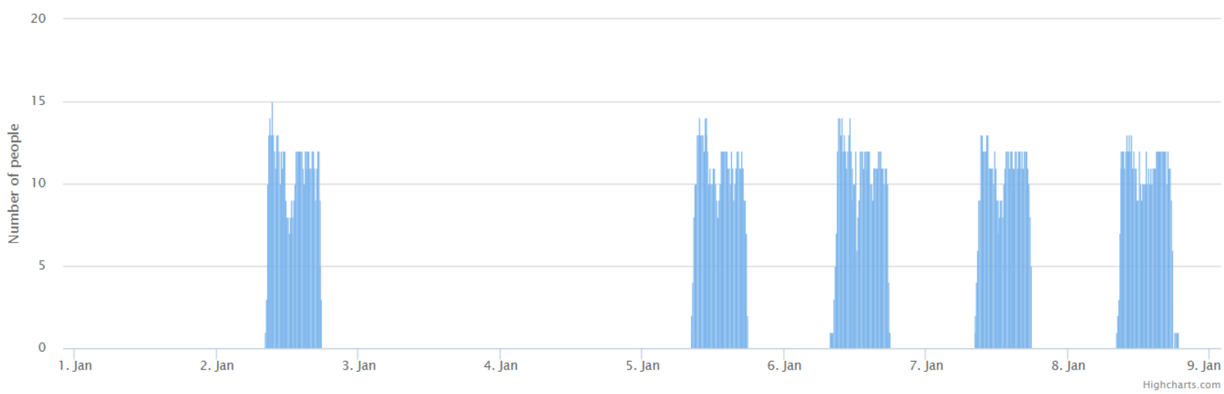


Figure 9. First case study - Weekly profile of OSIM

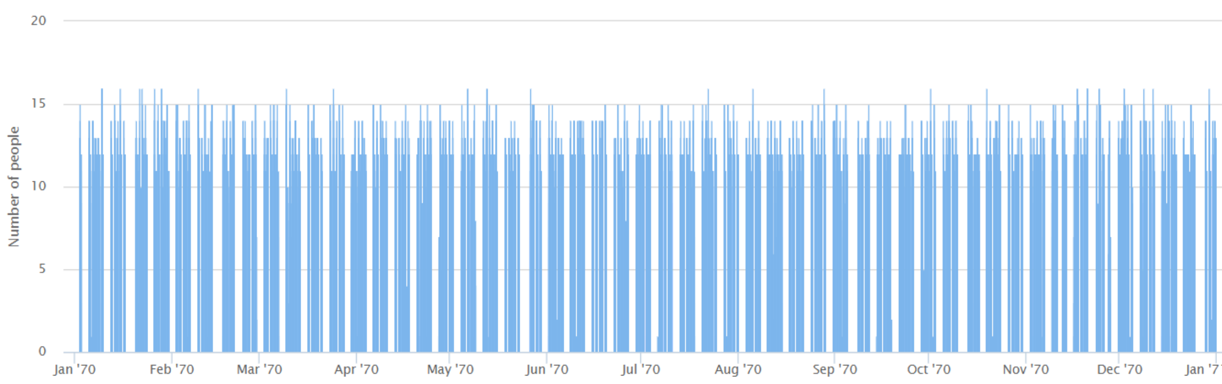


Figure 10. First case study - Annual profile of OSIM

The results are taken in CSV format and then it should be post produced by using Excel. In this case, one number between -1 to 12 is assigned to each person and if the number is higher than 1, it should be counting as 1 occupant in the time step of 10 minutes. For example, table 23 is the numbers assigned to each person in the time step of 8:30 am for the date of 26^{th} of January. As it was mentioned above the numbers higher than 1 should be considered as the person is present. Thus, it can be concluded that "director_officer_O1", "Manager_office_O1", "Sec_O1", "Admin_office_O1", "Senior_research_office_O1" have the number higher than 1 and they are present at this time. As the result, total number of occupants in this time step is 5 people.

Occupant ID	Number
Researcher_office_O1	1
Researcher_office_O2	1
Researcher_office_O3	1
Researcher_office_O4	-1
director_officer_O1	3
Manager_office_O1	-1
Manager_office_O1	5
Sec_O1	9
Admin_office_O1	10
Admin_office_O2	0
Senior_research_office_O1	-1
Senior_research_office_O2	-1
Senior_research_office_O3	-1
Senior_research_office_O1	12
Senior_research_office_O2	-1
Senior_research_office_O3	-1

Table 23. CSV format result of OSIM software

Then all number of occupants will be achieved for the whole year in the time step of 10 minutes. These numbers are absolute numbers which should be converted to modulating numbers in order to be imported in IESVE. For this reason, all numbers of occupants will be divided into 16 which is the total number of members in the office in this case study. In addition, the modulating numbers should be based on 1 hour instead of 10 minutes for IESVE. To satisfy this requirement two strategies are implemented. In the first strategy, an average of one hour of modulating occupancy intensity and in the second condition the maximum value of occupancy intensity is considered as the hourly value to be imported into IESVE.

Finally, a CSV file produced of month, day, hour, min and maximum and average value of occupancy intensity is exported from the Excel and ready to be imported into IESVE to provide Free form profile. In this regard, thanks to VEScript of python plugin, by picking up the CSV created file, the free form profile (FFD) is created and inserted automatically in the software (figure 12).

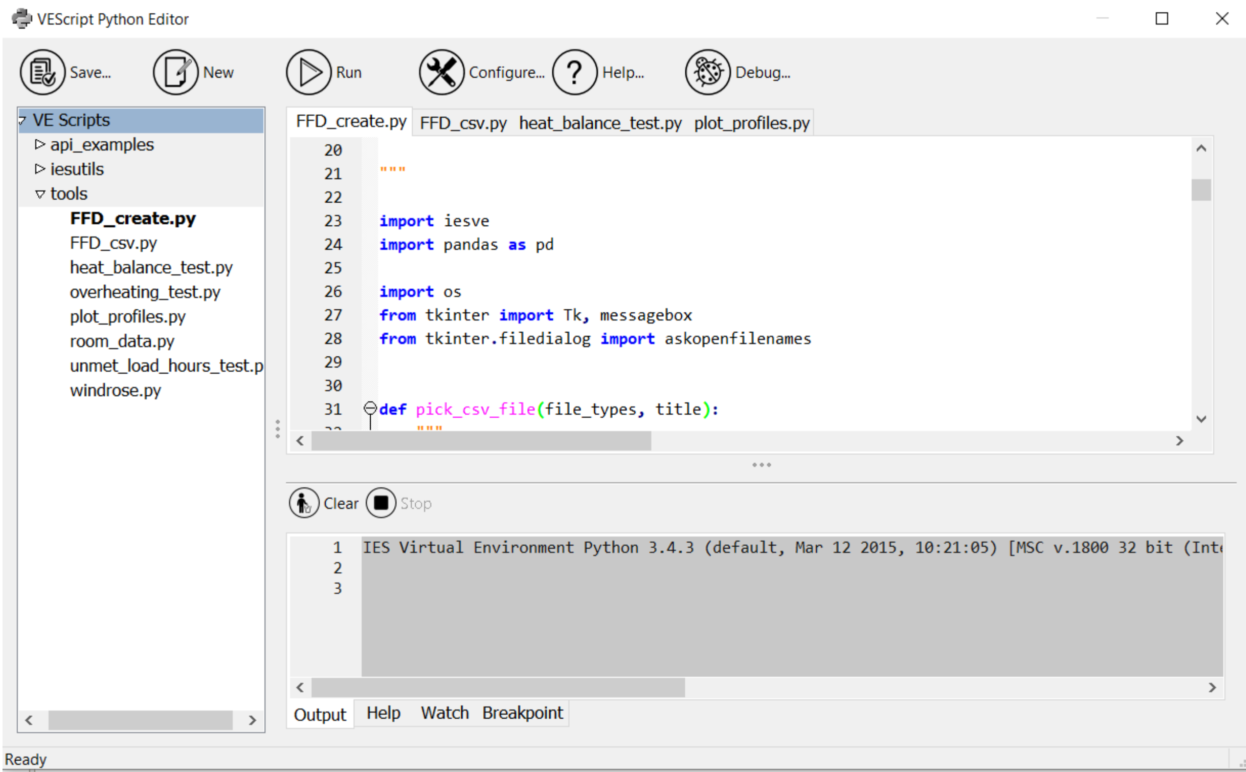


Figure 11. VEScript python editor to create FFD file from CSV

After this step, by clicking on "Building template manager" the annual profile of OSIM software can be noticed in the list of internal gain profiles which is the starting point for doing the calculations of internal gain based of OSIM results.

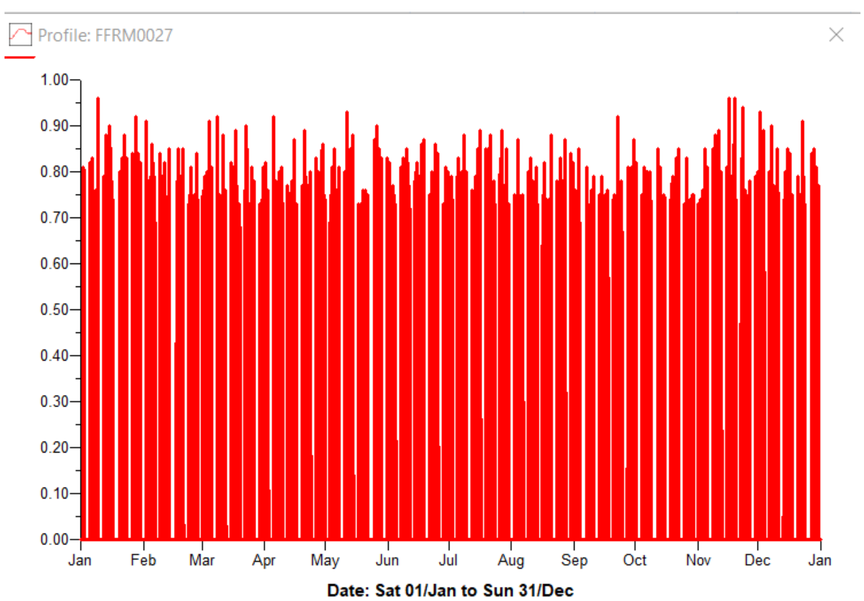


Figure 12. First case study FFD created profile in IESVE

For the first simulation, OSIM profile for both maximum and average condition is assigned to internal gain containing the people, lighting, and computers (equipment). In Building template manager part, the zones are divided into five templates, "Single office", "landscape office" , " Corridor" , " Kitchen and bathroom" and " Meeting room". For each room specific value regarding its consumption is defined based on ISO 17 and ISO 18 as the figure 14 [22], in Apache section of IESVE each defined template is assigned to proper zone in geometry then by clicking on ApacheSim, the dynamic simulation is calculated and the results appears on VistaPro section. Because the profiles are different every day and room by room, The 14th of January and researcher office are chosen as the example date and location to demonstrate the results of different approaches.

In figure 15 total internal gain and its compositions are shown for the OSIM maximum and average profiles. The peak value for internal gain in OSIM average and max is respectively 2.25kW and 2.6 kW.

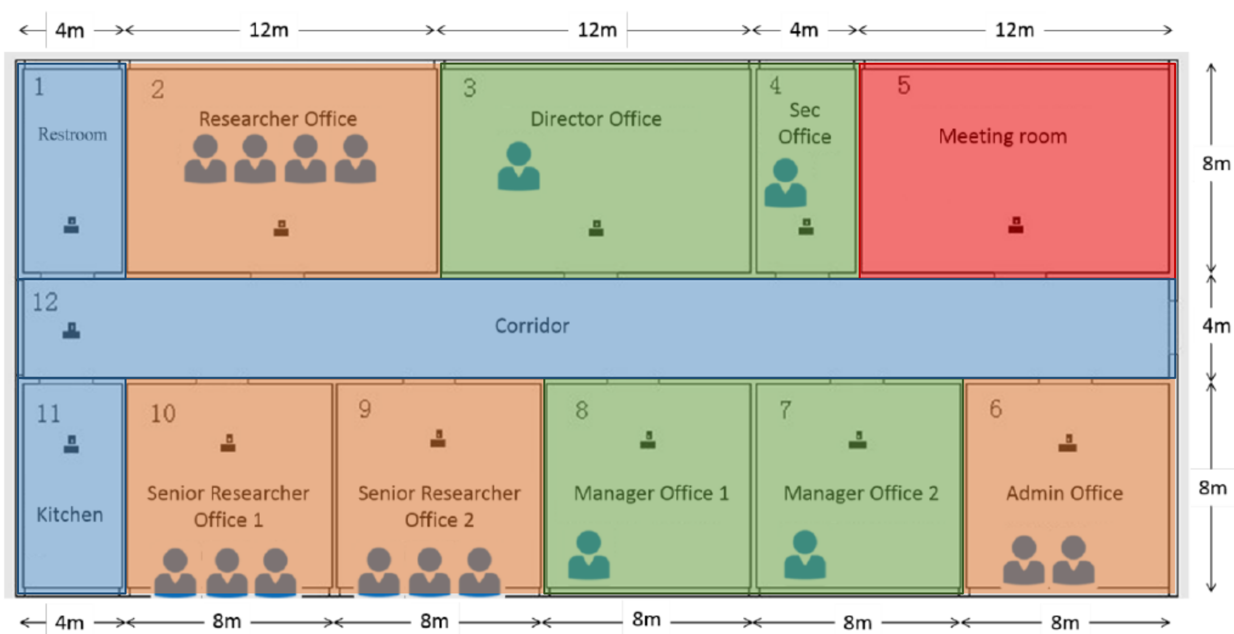


Figure 13. First case study layout division of OSIM

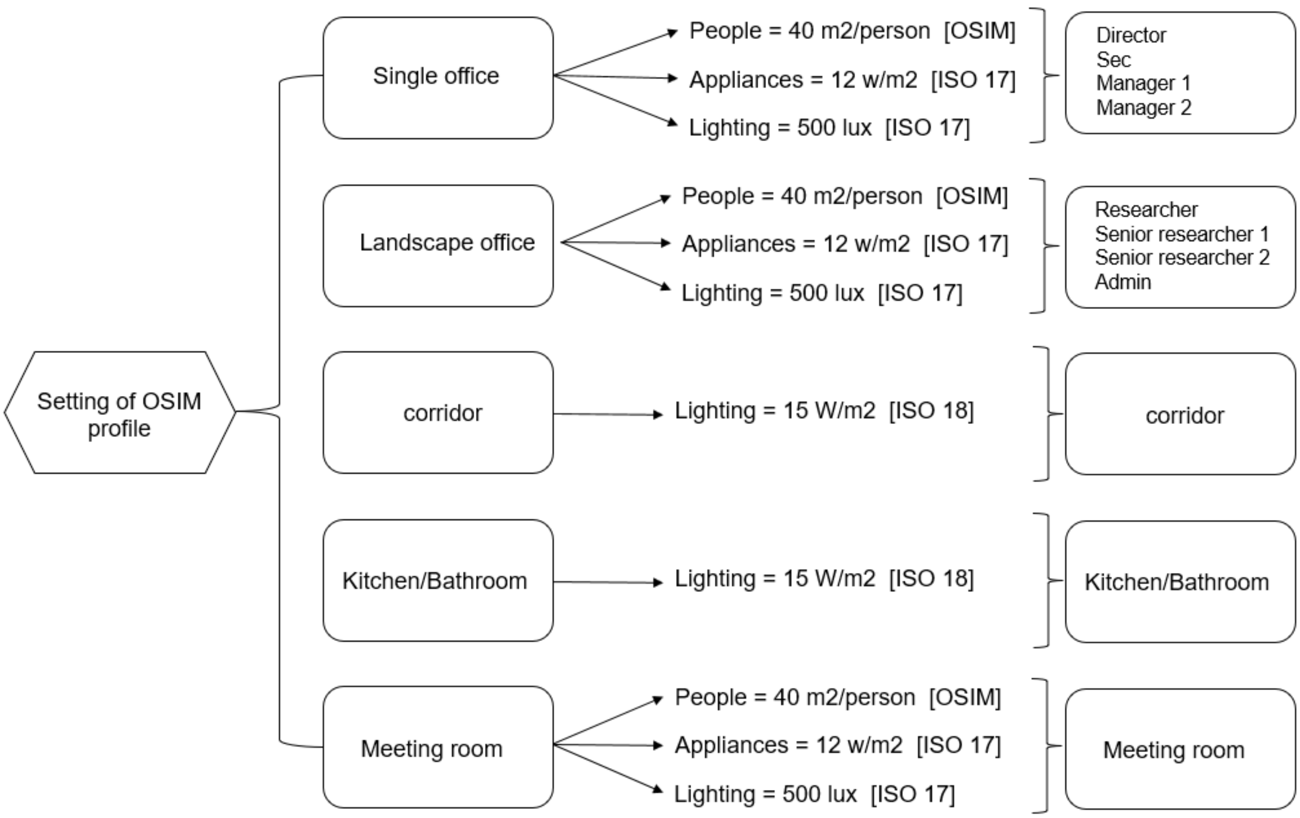


Figure 14. First case study consumption specifications for OSIM simulation

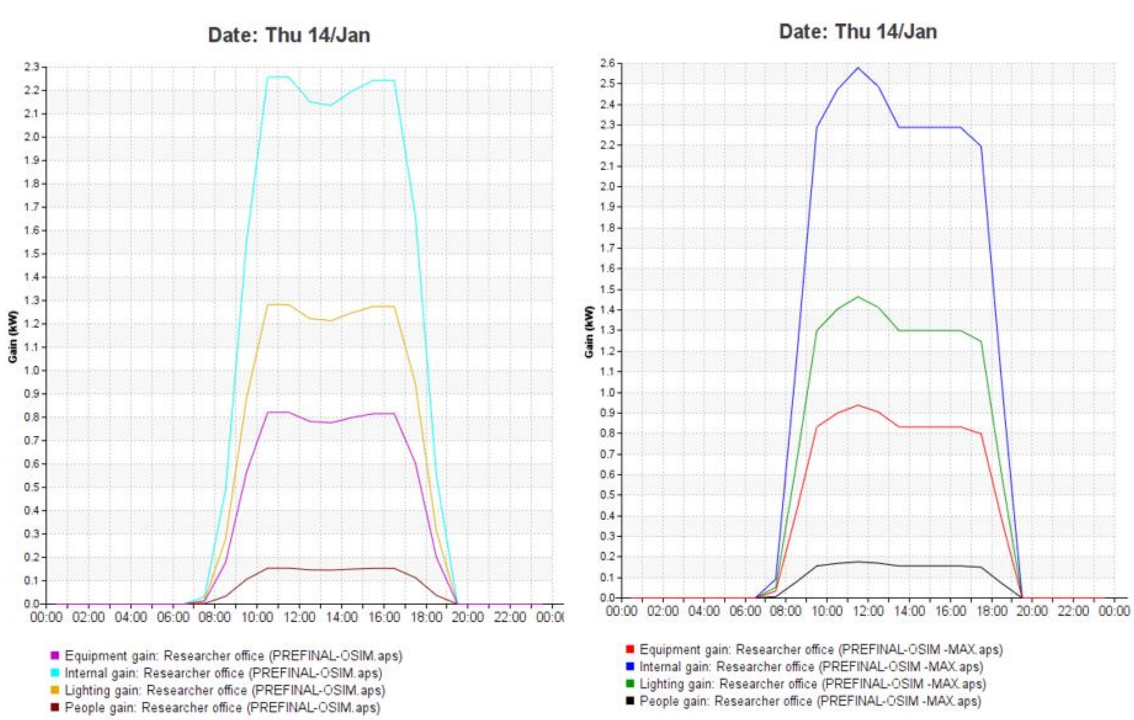


Figure 15. First case study internal gains of OSIM max and average for the researcher office

For the second simulation, ISO 17772-1-2017 profiles are defined in "building template manager" part by inserting daily profile based on the tables mentioned in methodology section. Then weekly profile is made of daily profile. Similar to OSIM, internal gain consists of people, lighting and computers is selected and the results taken from VistaPro. The division of the spaces in this case just considered for the single offices, landscape offices and meeting rooms as figure 16. For the rest of the spaces in the building no internal gain exists based on ISO 17772-1-2017. Details of value for each space is mentioned in chart 17.

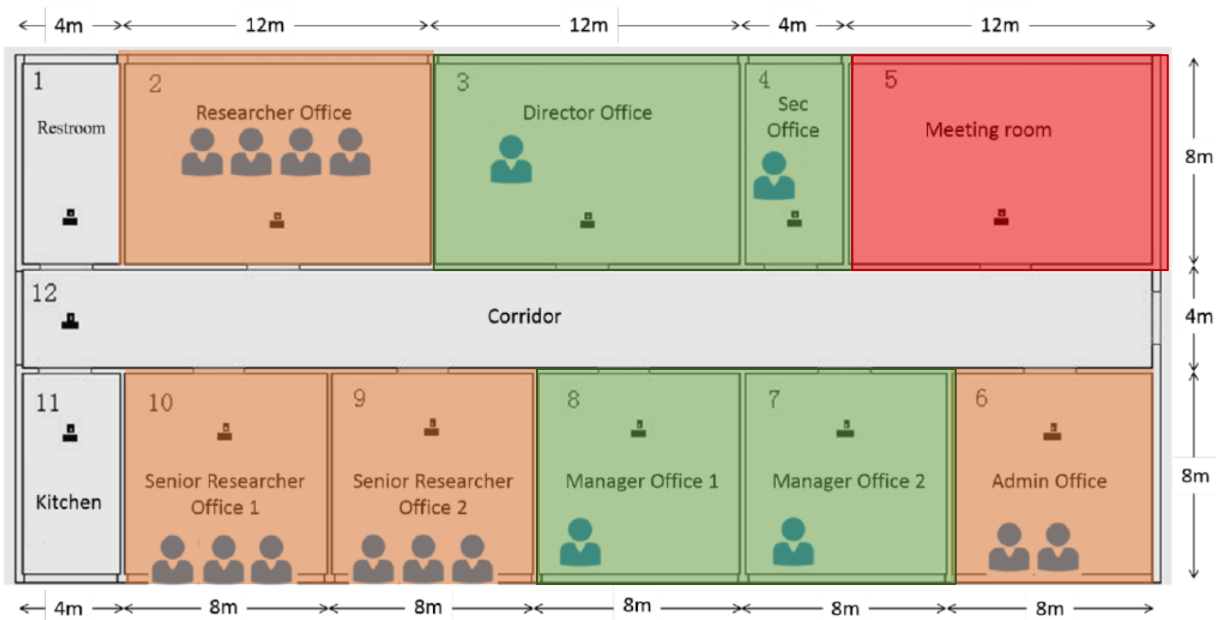


Figure 16.First case study layout division of ISO 17772-1-2017

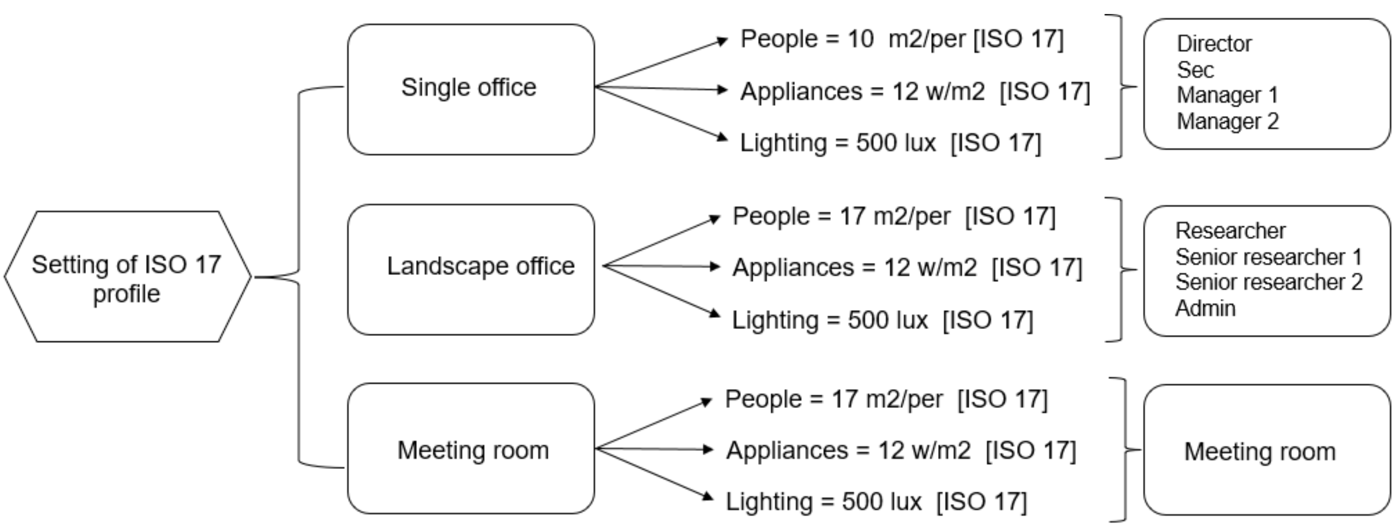


Figure 17.First case study consumption specifications for ISO 17772-1-2017 simulation

Single office profile

	Daily Profile:
Monday	ISO 17 - single [DAY_0033]
Tuesday	ISO 17 - single [DAY_0033]
Wednesday	ISO 17 - single [DAY_0033]
Thursday	ISO 17 - single [DAY_0033]
Friday	ISO 17 - single [DAY_0033]
Saturday	Always Off (0%) [OFF]
Sunday	Always Off (0%) [OFF]
Holiday	Always Off (0%) [OFF]
Heating-Rm	Always Off (0%) [OFF]
Cooling-Rm	Always Off (0%) [OFF]
Heating-Sys	Always Off (0%) [OFF]

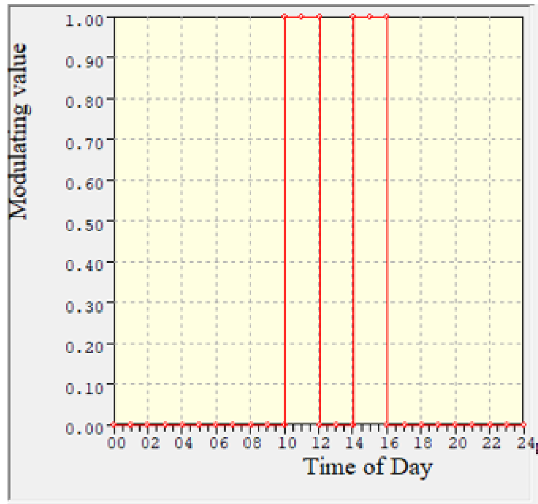


Figure 18. First case study single office profile of ISO 17772-1-2017

Landscape office and meeting room profiles

	Daily Profile:
Monday	ISO 17 - Landscape [DAY_0021]
Tuesday	ISO 17 - Landscape [DAY_0021]
Wednesday	ISO 17 - Landscape [DAY_0021]
Thursday	ISO 17 - Landscape [DAY_0021]
Friday	ISO 17 - Landscape [DAY_0021]
Saturday	Always Off (0%) [OFF]
Sunday	Always Off (0%) [OFF]
Holiday	Always Off (0%) [OFF]
Heating-Rm	Always Off (0%) [OFF]
Cooling-Rm	Always Off (0%) [OFF]
Heating-Sys	Always Off (0%) [OFF]

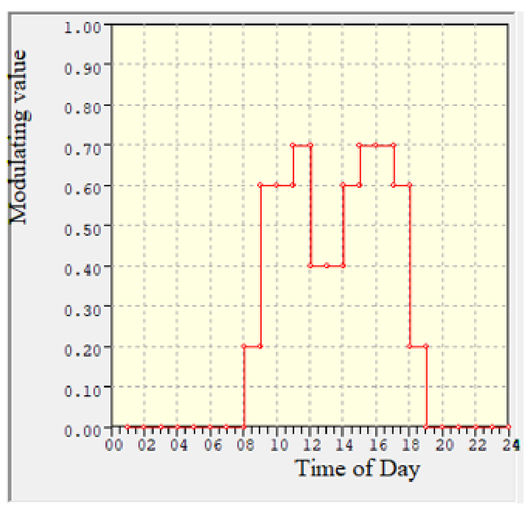


Figure 19. First case study landscape office and meeting room profiles of ISO 17772-1-2017

In figure 20 there is an example of all internal gain consisting of lighting gain , equipment gain and people gain in the date of 14th of January for the researcher office room. The minimum value is regarding people gain and the maximum value is for lighting gain with the peak value of 1.2 kW.

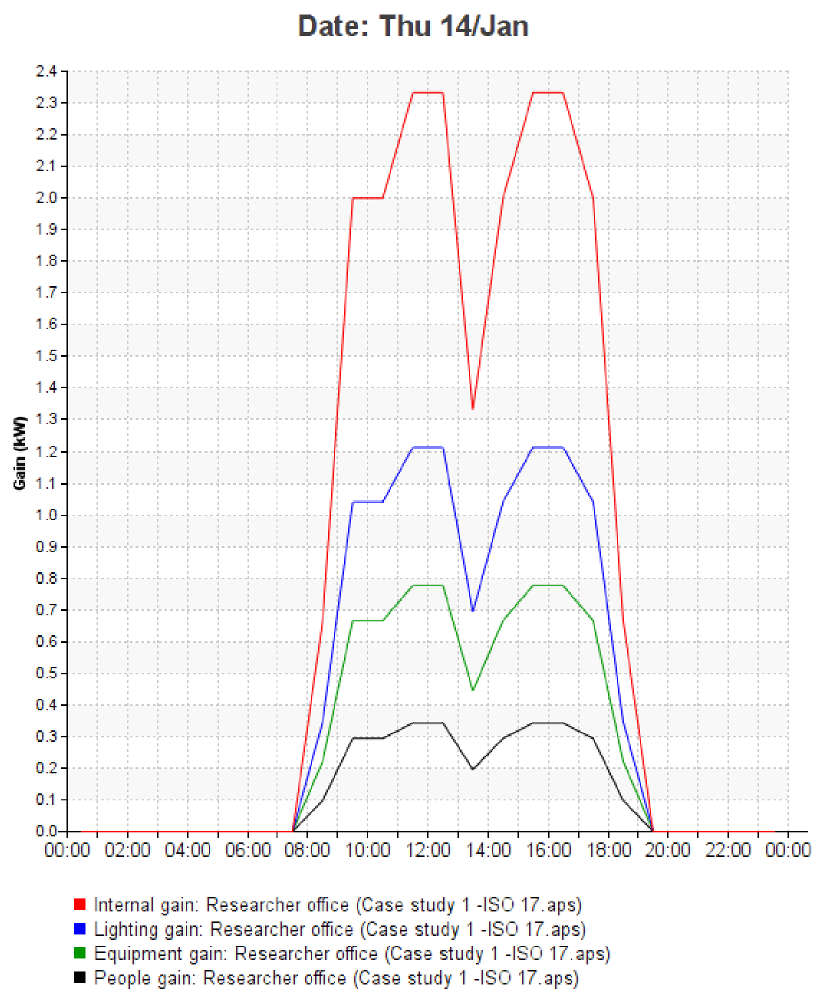


Figure 20. First case study internal gains of ISO 17772-1-2017 for the researcher office

The third simulation is based on ASHRAE profiles. As explained in ASHRAE section in methodology, in this standard the profiles for people, lighting and equipment are different from each other. In addition, for each section, the profiles of working day, Saturday and Sundays/holidays/others are separated. Thus, in every part separated daily and weekly profiles should be determined. The Value regarding people, appliances and lighting system are taken from ASHRAE standard which is based on "Core" and "Perimeter" areas in the office building. Core areas and Perimeter spaces are respectively assigned to Offices and corridor/bathroom/ kitchen area as expressed in graph 22. The final profiles taken from VistaPro for the researcher office in 14th of January is demonstrated as the example date in figure 26.

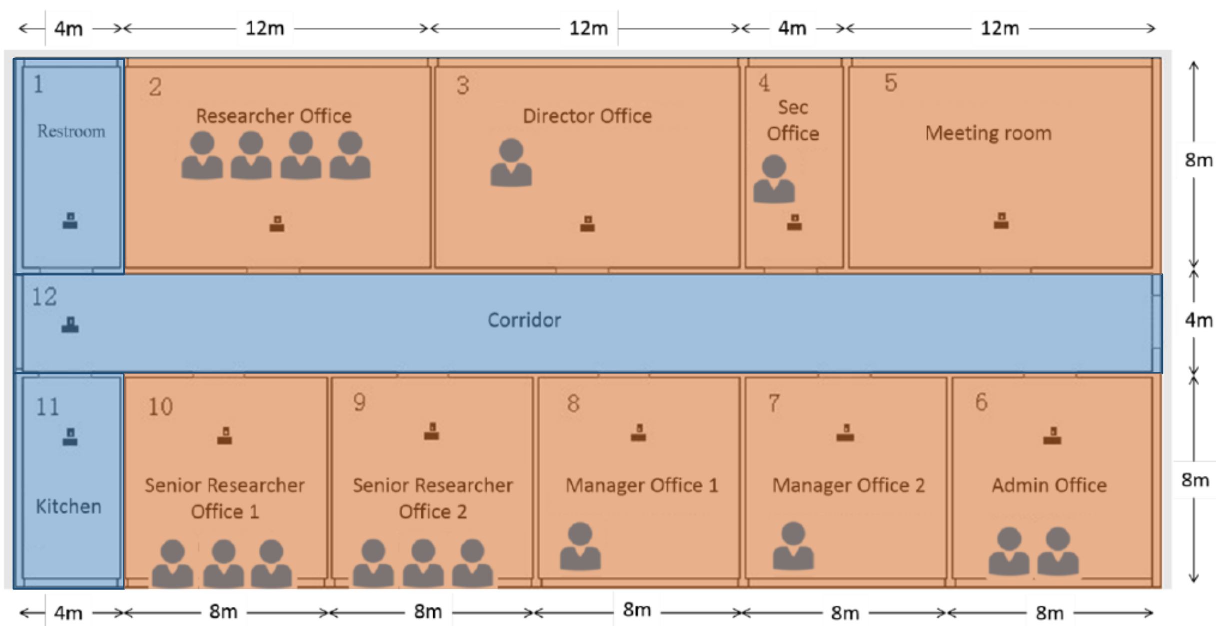


Figure 21. First case study layout division of ASHRAE

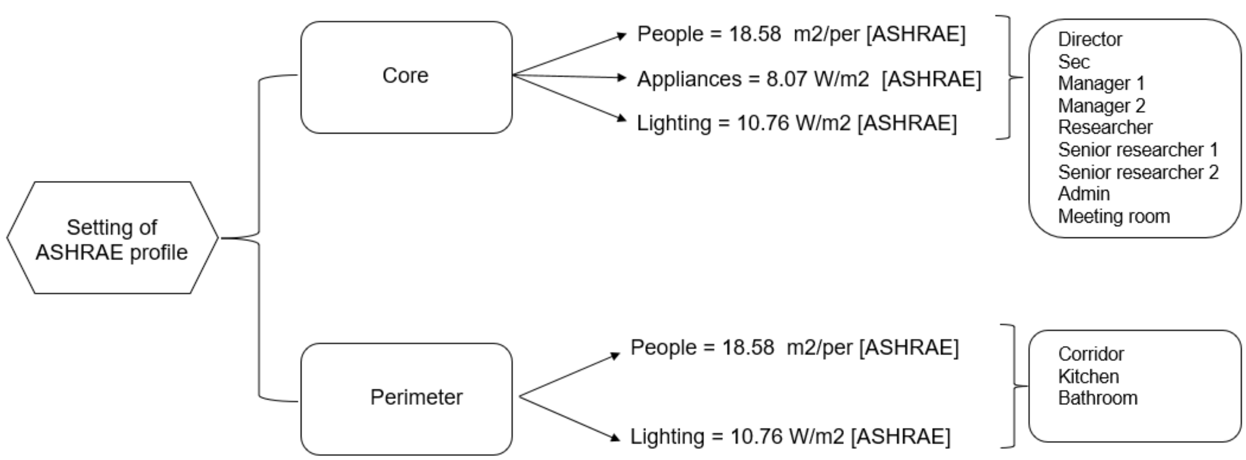
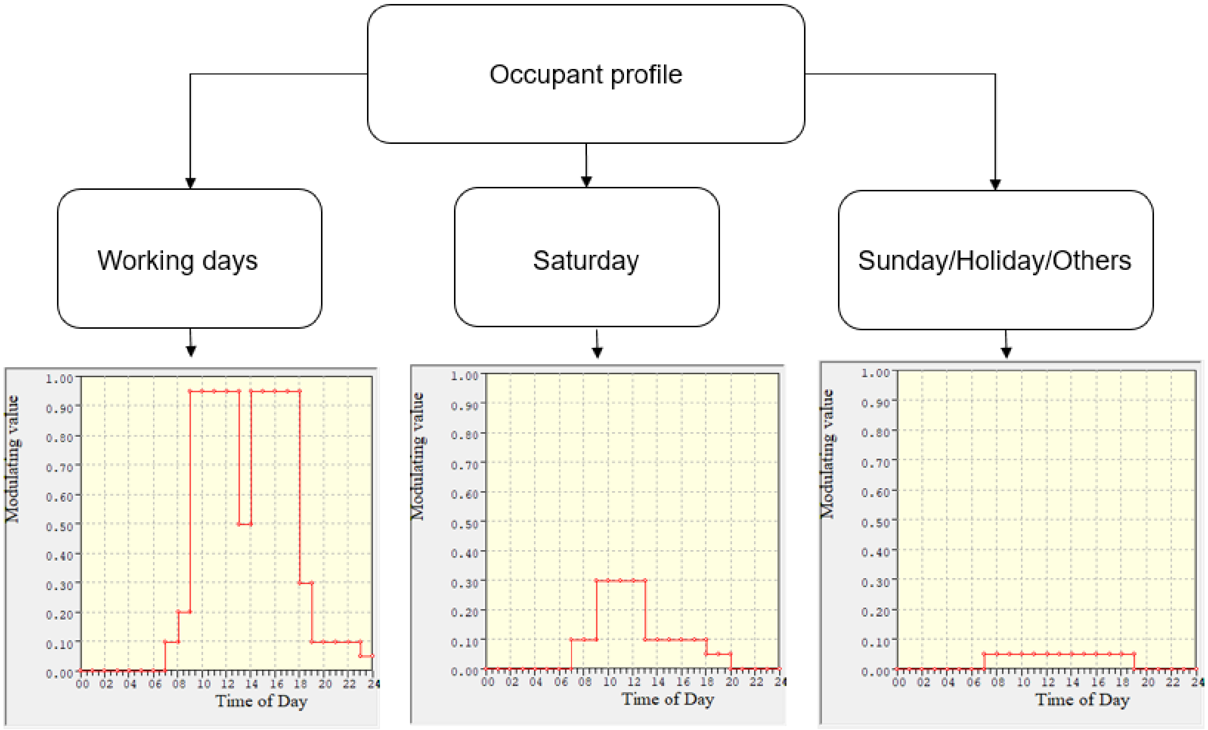
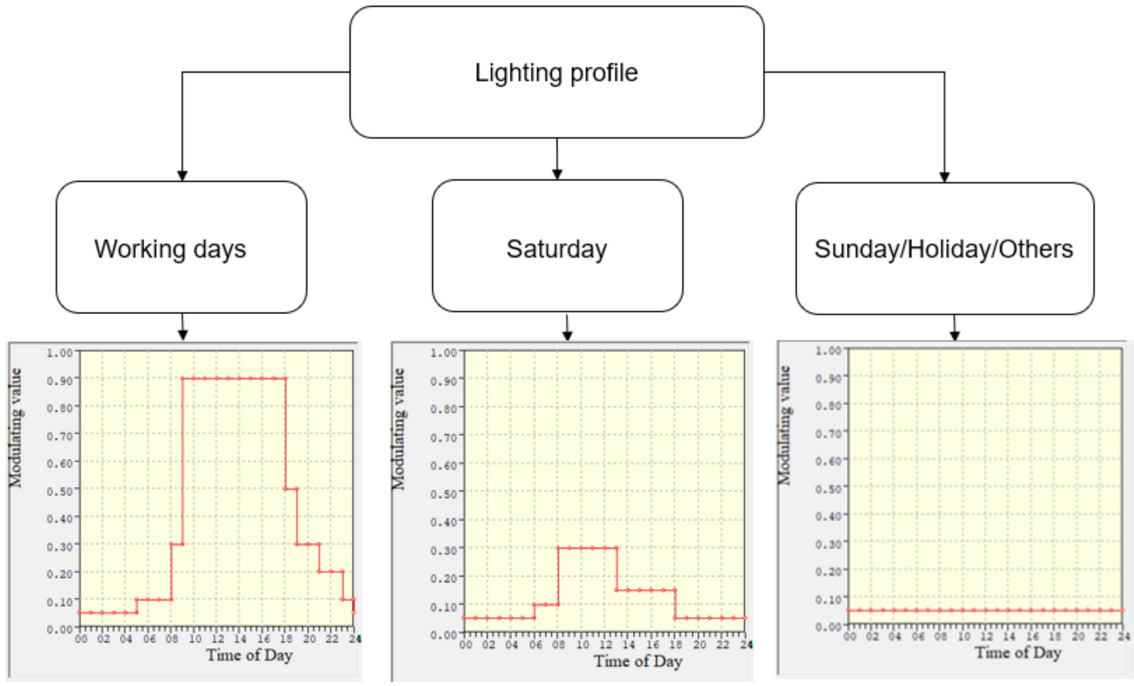


Figure 22. First case study consumption specifications for ASHRAE simulation



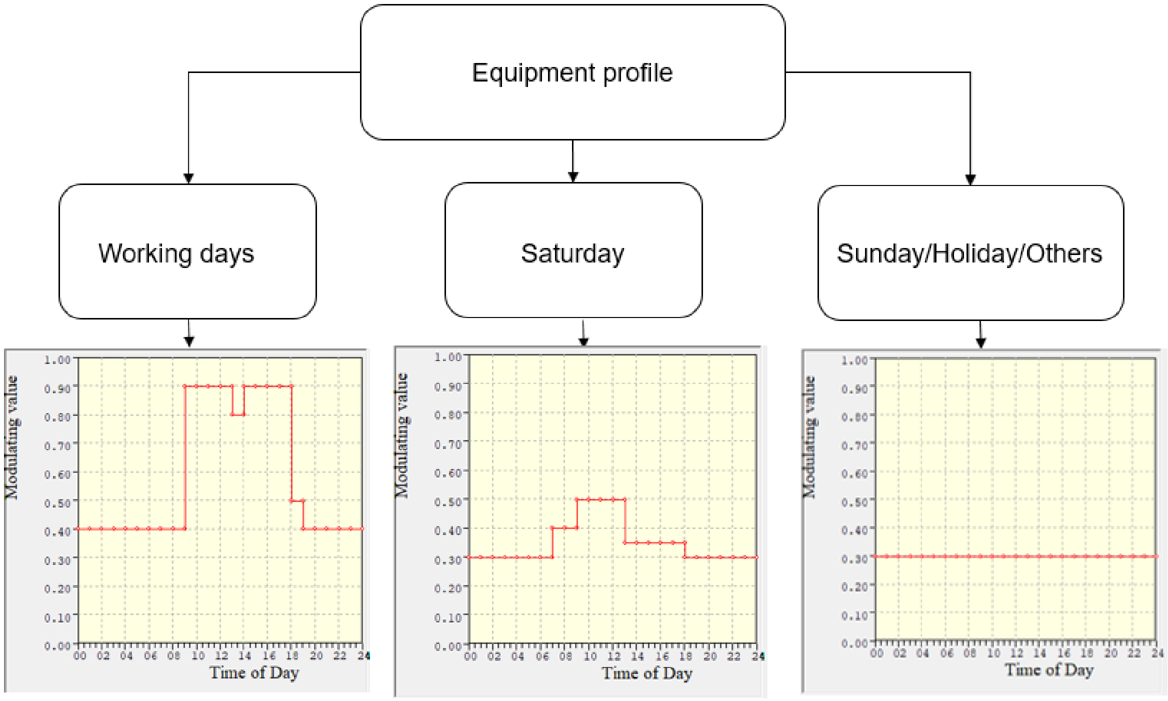
	Daily Profile:
Monday	ASHREA-People-WD [DAY_0030]
Tuesday	ASHREA-People-WD [DAY_0030]
Wednesday	ASHREA-People-WD [DAY_0030]
Thursday	ASHREA-People-WD [DAY_0030]
Friday	ASHREA-People-WD [DAY_0030]
Saturday	ASHREA-People-Sat [DAY_0031]
Sunday	ASHREA-People-Sun [DAY_0032]
Holiday	ASHREA-People-Sun [DAY_0032]
Heating-Rm	ASHREA-People-Sun [DAY_0032]
Cooling-Rm	ASHREA-People-Sun [DAY_0032]
Heating-Sys	ASHREA-People-Sun [DAY_0032]

Figure 23. First case study occupant profile for ASHRAE



	Daily Profile:
Monday	ASHREA-Light-WD [DAY_0025]
Tuesday	ASHREA-Light-WD [DAY_0025]
Wednesday	ASHREA-Light-WD [DAY_0025]
Thursday	ASHREA-Light-WD [DAY_0025]
Friday	ASHREA-Light-WD [DAY_0025]
Saturday	ASHREA-Light-Sat [DAY_0023]
Sunday	ASHREA-Light-Sun [DAY_0026]
Holiday	ASHREA-Light-Sun [DAY_0026]
Heating-Rm	ASHREA-Light-Sun [DAY_0026]
Cooling-Rm	ASHREA-Light-Sun [DAY_0026]
Heating-Sys	ASHREA-Light-Sun [DAY_0026]

Figure 24. First case study lighting profile for ASHRAE



	Daily Profile:
Monday	ASHREA-Equip-WD [DAY_0027]
Tuesday	ASHREA-Equip-WD [DAY_0027]
Wednesday	ASHREA-Equip-WD [DAY_0027]
Thursday	ASHREA-Equip-WD [DAY_0027]
Friday	ASHREA-Equip-WD [DAY_0027]
Saturday	ASHREA-Equip-Sat [DAY_0028]
Sunday	ASHREA-Equip-Sun [DAY_0029]
Holiday	ASHREA-Equip-Sun [DAY_0029]
Heating-Rm	ASHREA-Equip-Sun [DAY_0029]
Cooling-Rm	ASHREA-Equip-Sun [DAY_0029]
Heating-Sys	ASHREA-Equip-Sun [DAY_0029]

Figure 25. First case study Equipment profile for ASHRAE

The figure 26 is the example of all internal gain in the date of 14th of January for the researcher office room. The maximum gain among people, lighting and equipment gains belongs to lighting gain with 0.9 kW. It worths to mention that for equipment the minimum value of gain is 0.3 kW because in the profile of appliances, some appliances are considered as always on even during the nights and weekends.

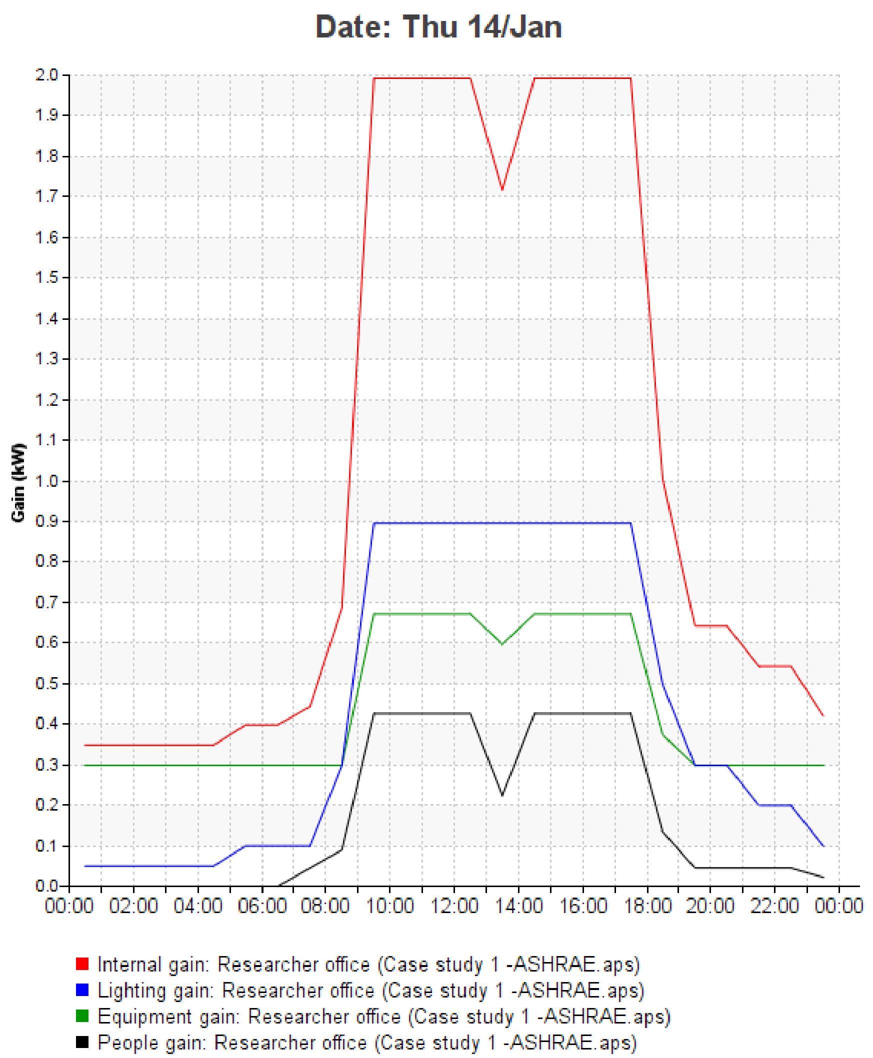


Figure 26.. First case study internal gains of ASHRAE for the researcher office

The last simulation is regarding to ISO 18523-1-2016. In order to define the setting of simulation, the specific coefficients regarding to occupants, lighting and appliances are inserted for each type of space's profile as chart 28 and final results of profiles are achieved by VistaPro in IESVE.

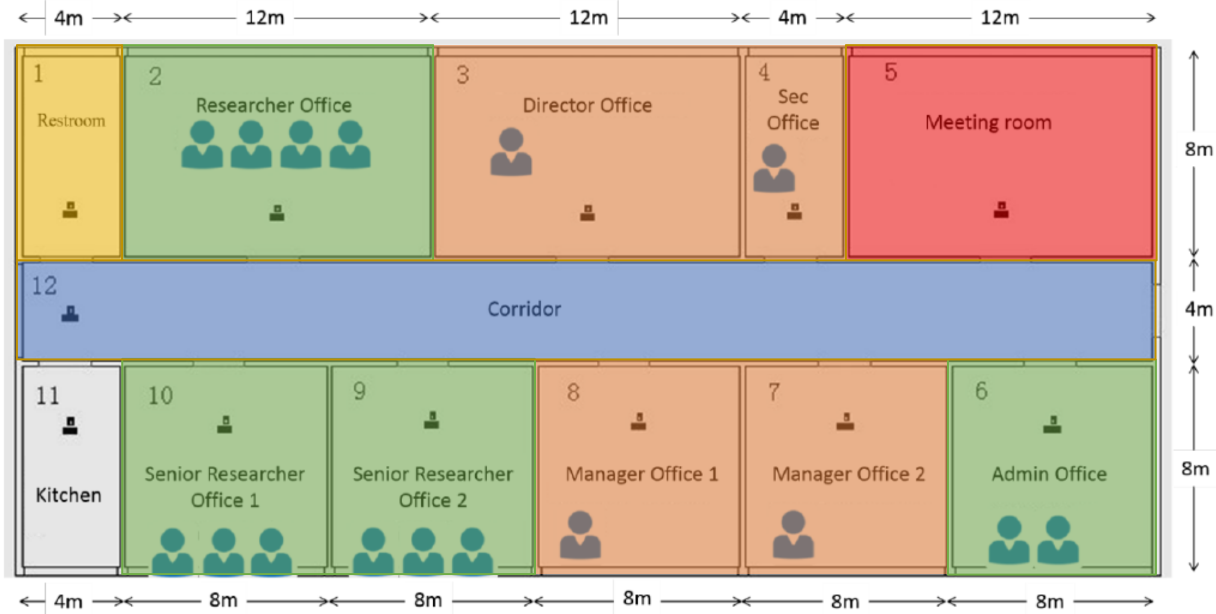


Figure 27.First case study layout division of ISO 18523-1-2016

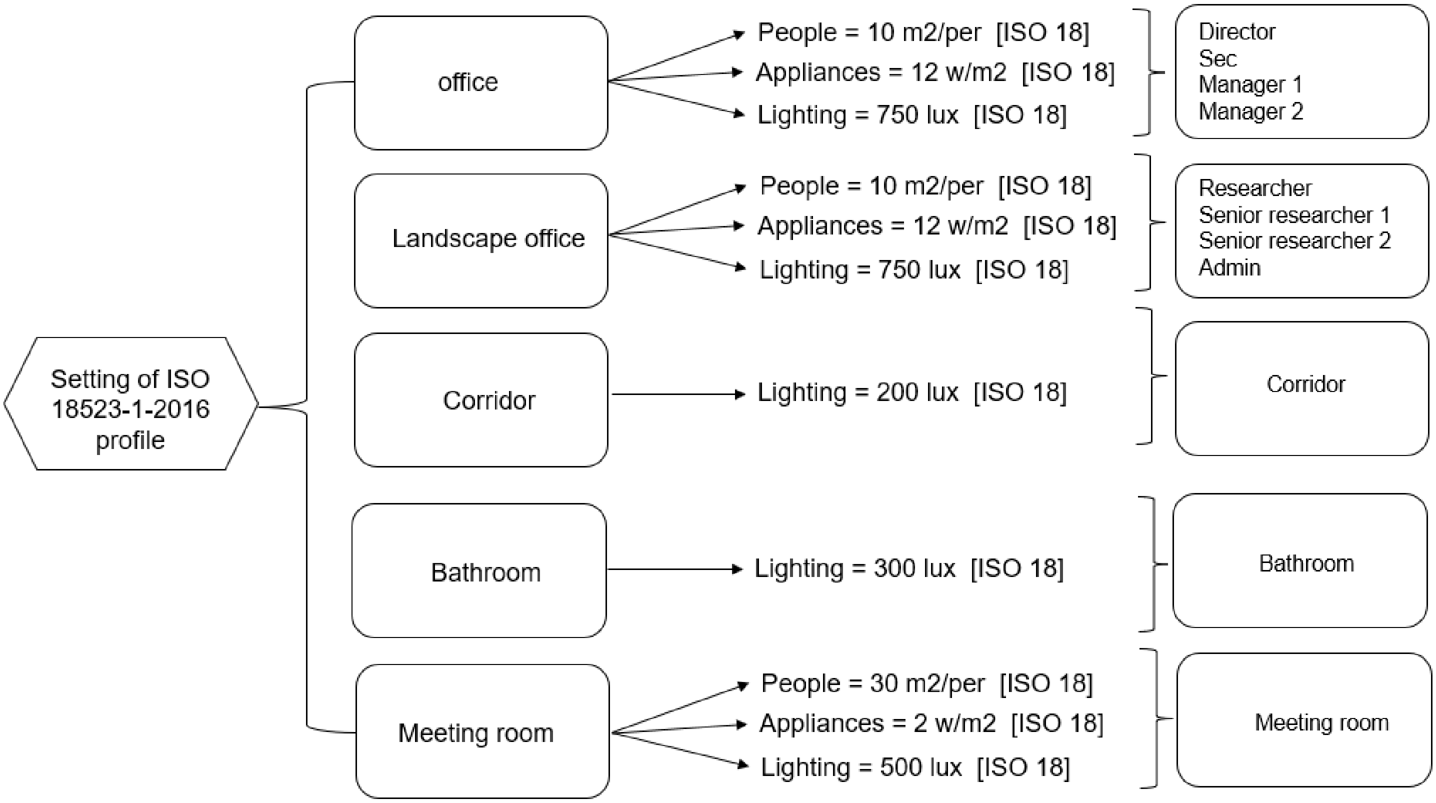


Figure 28. First case study consumption specifications for ISO 18523-1-2016

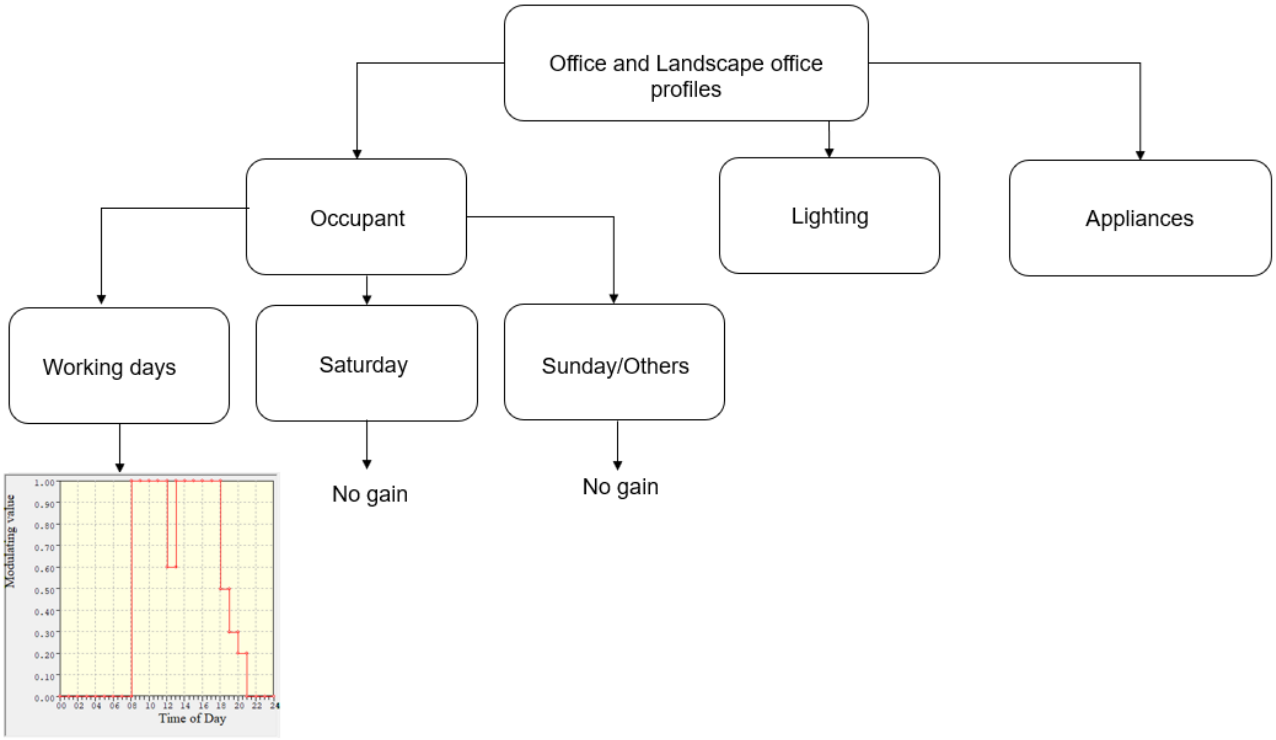


Figure 29. First case study office and landscape office profiles of occupants for ISO 18523-1-2016 simulation

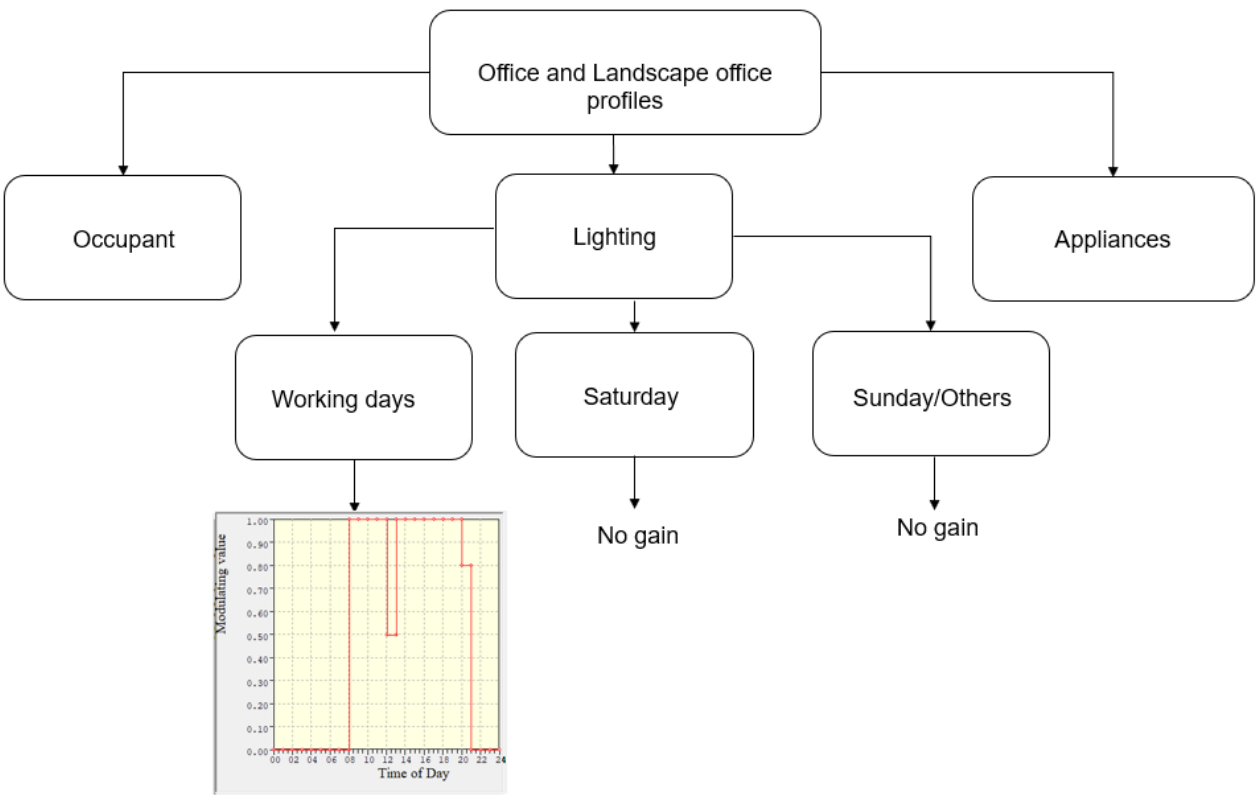


Figure 30.First case study office and landscape office profiles of lighting for ISO 18523-1-2016 simulation

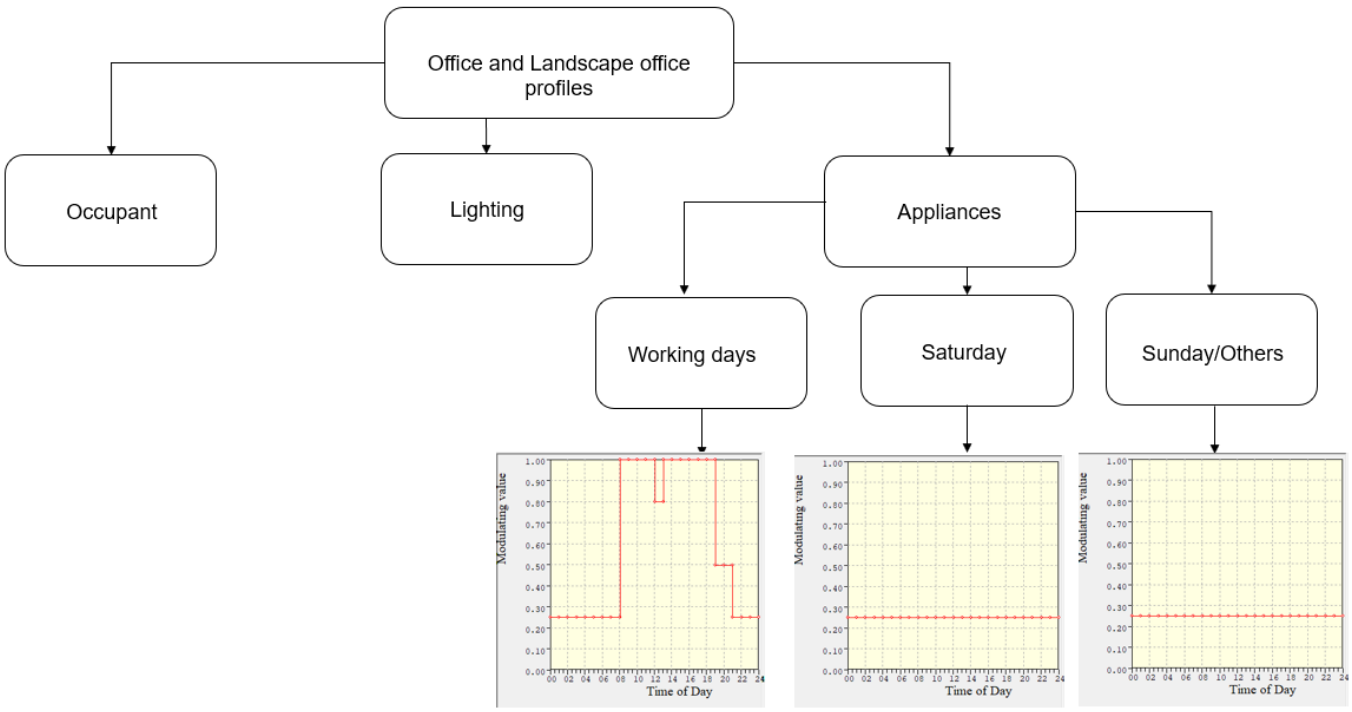


Figure 31.First case study office and landscape office profiles of appliances for ISO 18523-1-2016 simulation

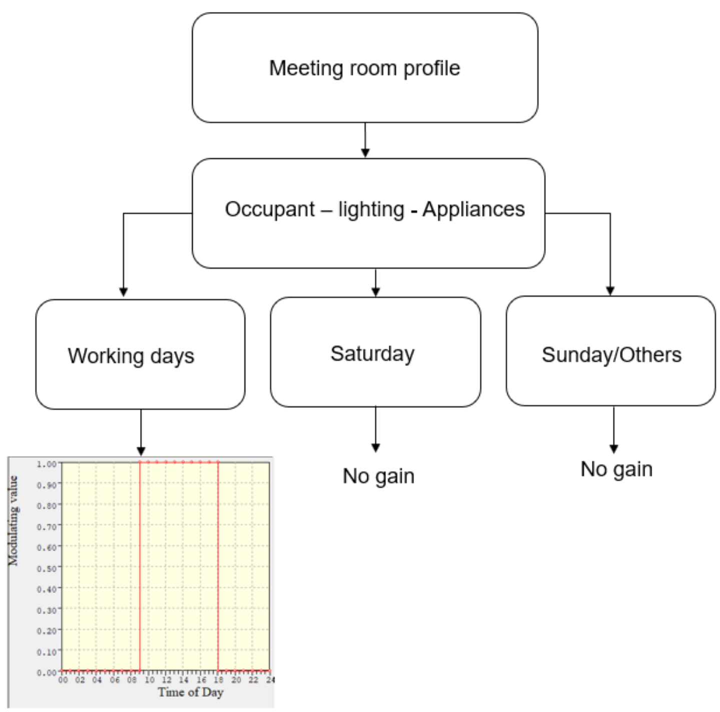


Figure 32.First case study meeting room profile for ISO 18523-1-2016 simulation

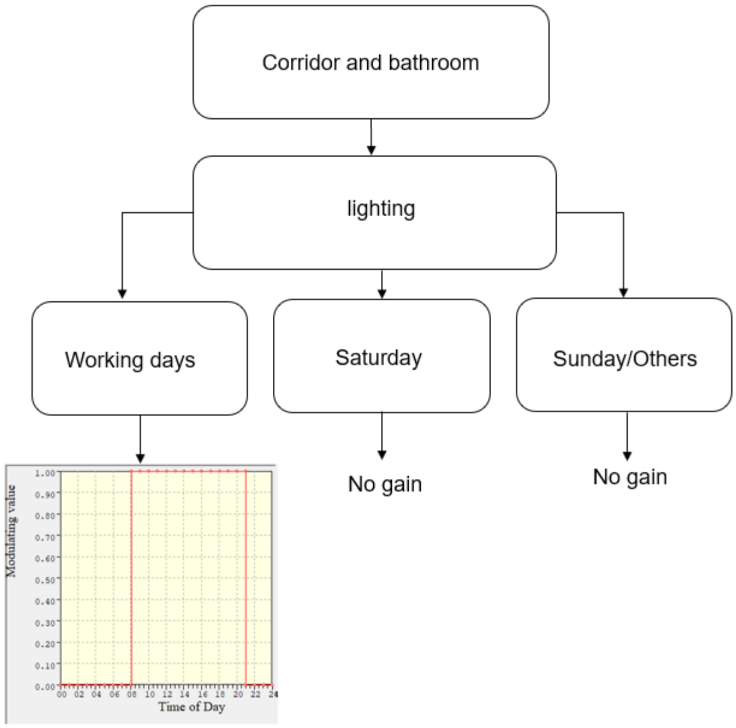


Figure 33.First case study corridor and bathroom profile for ISO 18523-1-2016 simulation

After inserting all profiles and running the simulation in IESVE, internal gain loads for each standard and also OSIM software in case study 1 can be obtained.

Case study 2

The Second building for case study 2 is a one six story office building with the total area of 5000 m2 Based on ISO 18523-1-2016 office building layout. The rooms are divided as following plans (figure 34,35,36):

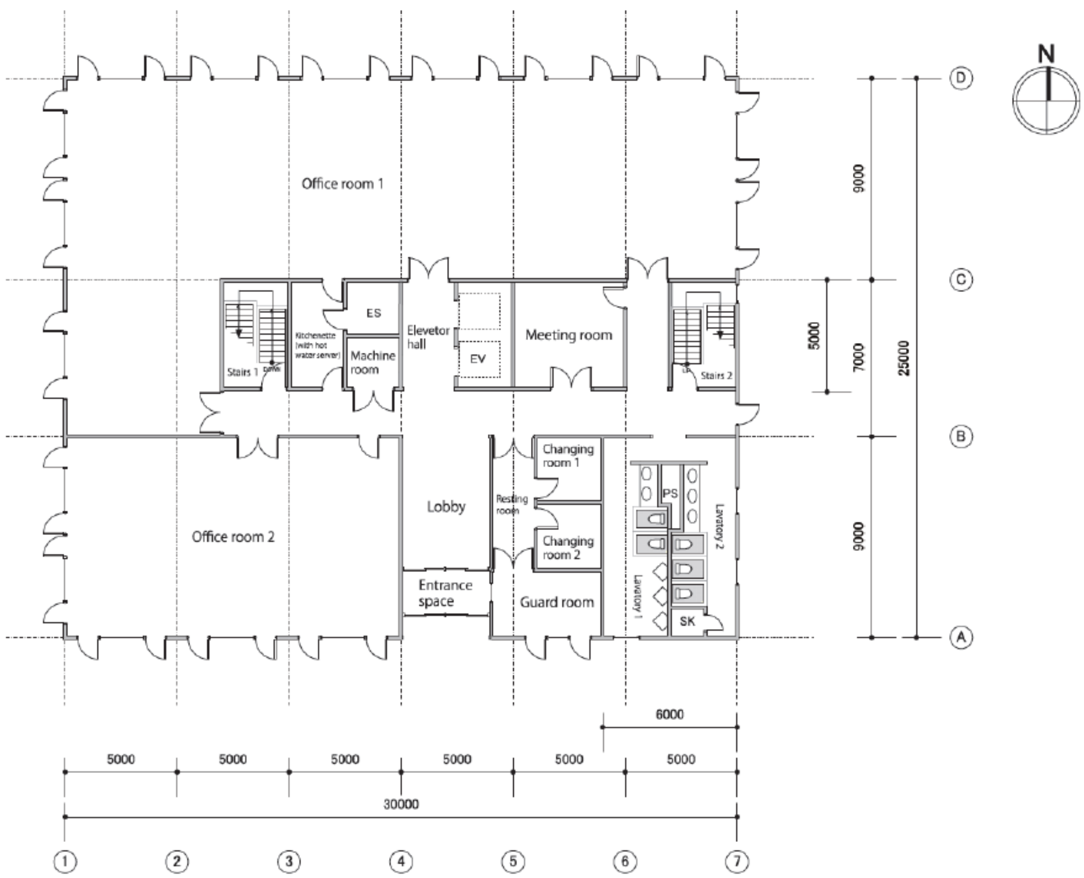


Figure 34. Second case study layout of building - Ground floor - ISO 18523-1-2016

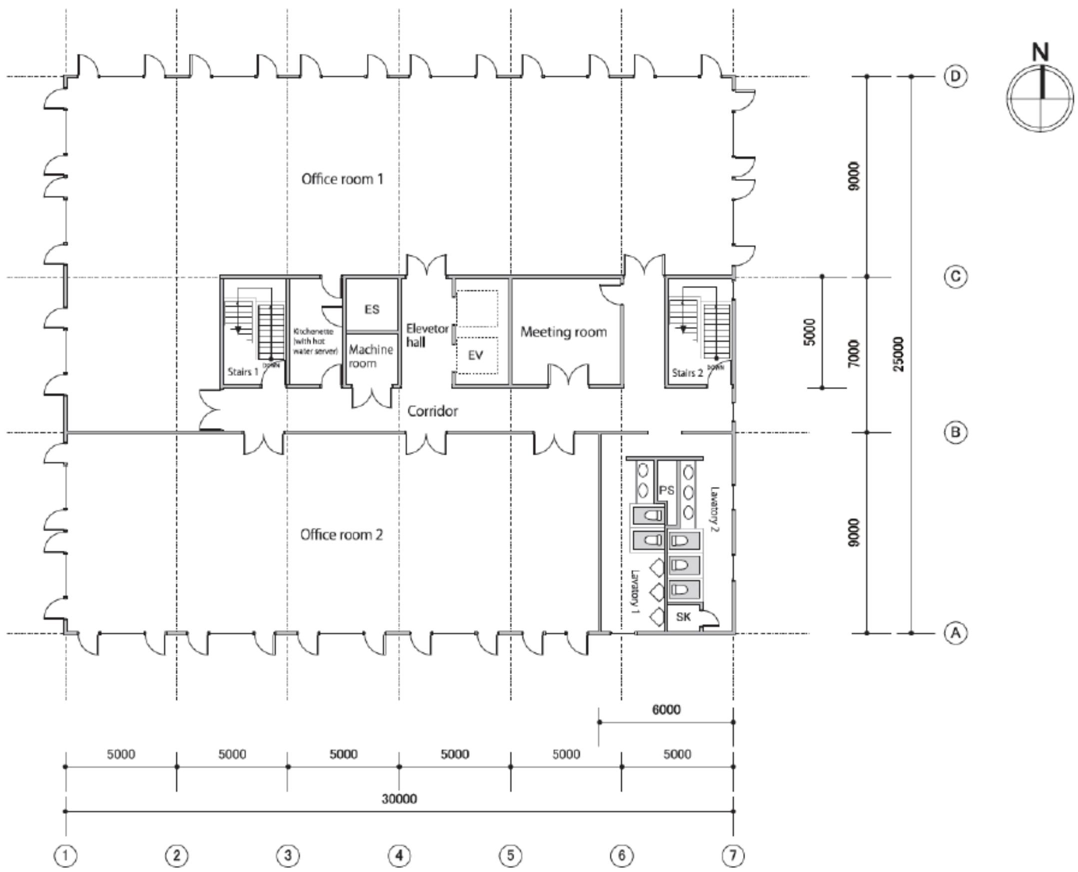


Figure 35.Second case study layout of building - 1st to 6th floor - ISO 18523-1-2016

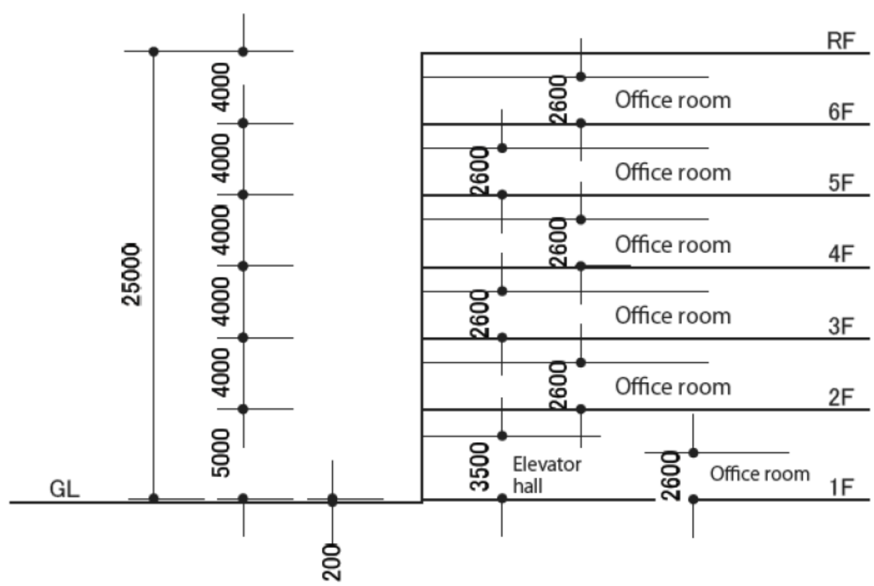


Figure 36.Second case study layout of building – Section - ISO 18523-1-2016

Same as the first case study the geometry is modeled in IESVE with the same weather file location of Milano Linate airport (figure 37).

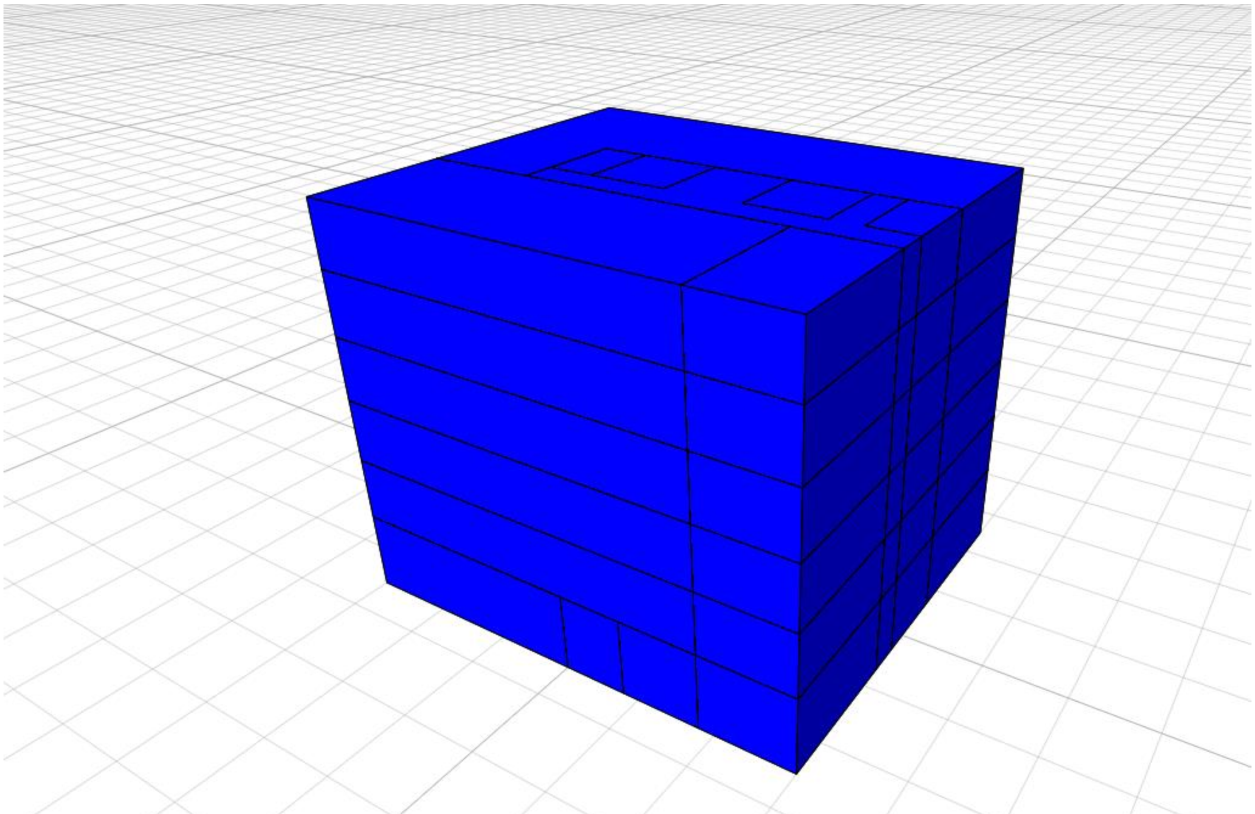


Figure 37.Second case study IESVE geometry

- **Step 1: The Start New Page**

Large office chosen because the area is 5000 m2

- **Step 2: The Spaces Page**

Then, the name of all spaces should be chosen and the number of each space in the building and the area of each space should be inserted based on the case study plan (table 24).

Name	Space type	Area [m2]	Space multiplier
office type 1	Landscape office	319	6
Office type 2	Single office	216	5
Office type 3	Ground floor office	135	1
Kitchen	kitchen	25	6
bathroom	bathroom	54	6

Meeting room	Meeting room	25	6
corridor	corridor	81	6
Changing room and guard room	Single office	45	1
Lobby	corridor	36	1

Table 24. Second case study - OSIM space properties

- **Step 3: The Space Type Page**

In this page, the name of the spaces is defined, and its occupant type should be selected then its density is inserted based on m2/person. Also, For the “Meeting room” space type, users can define the meeting events for selected day of week, number of people per meeting and the probability percentage of duration of meeting based on 30 minutes, 60 minutes, 90 minutes, and 120 minutes. In this case study, the meeting days are every day except Saturday and Sunday with the minimum number of 2 and maximum number of 10 people and its duration probability for the time is 13%, 70%, 12% and 5% respectively. For the kitchen and bathroom, usage should be chosen as “others” which does not need any information. It is worth noting that for Offices occupant percentage of people who are working in that space is 100% .

Name	Usage	Occupant density $m^2/person$
office type 1	Office	15*
Office type 2	Office	10
Office type 3	Office	10
Kitchen	Others	-
bathroom	Others	-
Meeting room	Meeting room	-
corridor	Others	-
Changing room and guard room	Office	10
Lobby	Others	-

Table 25. Second case study - Occupant density specification in OSIM software

- **Step 4: The Occupant Type Page**

In the following page, the occupant type should be specified with their working days, arrival and departure time and short-term leaving events such as lunch or coffee break with its duration. The arrival time is considered as 9 am and for the departure it is 18 pm with the variation of 15 minutes for working days. For the break, one hour of lunch time with the variation of 30 minutes at 12 pm is defined and one coffee break with the duration of 20 minutes at 3 and variation of 10 min. The space occupancy is specified as following table 26:

Location	Own office	Other office	Meeting room	Auxiliary room	Outdoor
Average use time [percentage]	70	10	10	5	5
Average stay time [min]	60	20	60	10	20

Table 26. Second case study - usage time in OSIM software

The daily profiles, weekly profiles and annual profile are respectively shown in figures 38,39,40.

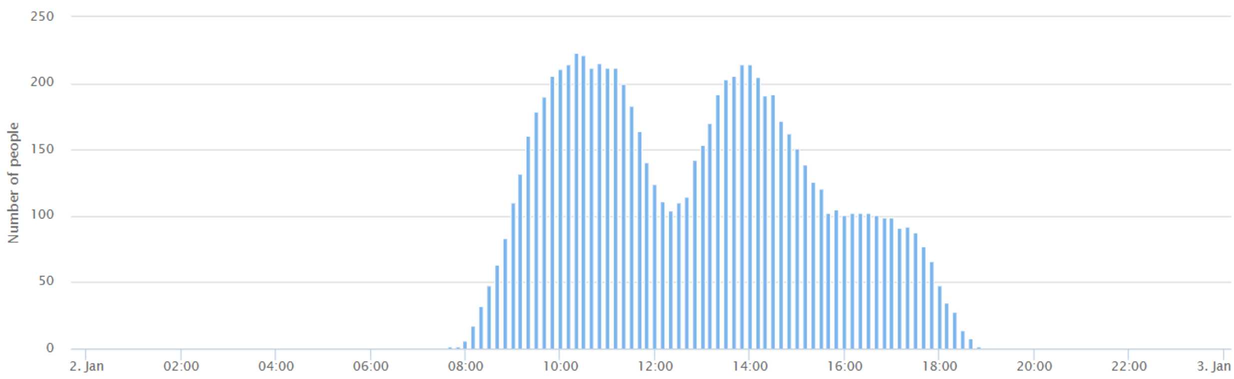


Figure 38. Second case study - Daily profile of OSIM

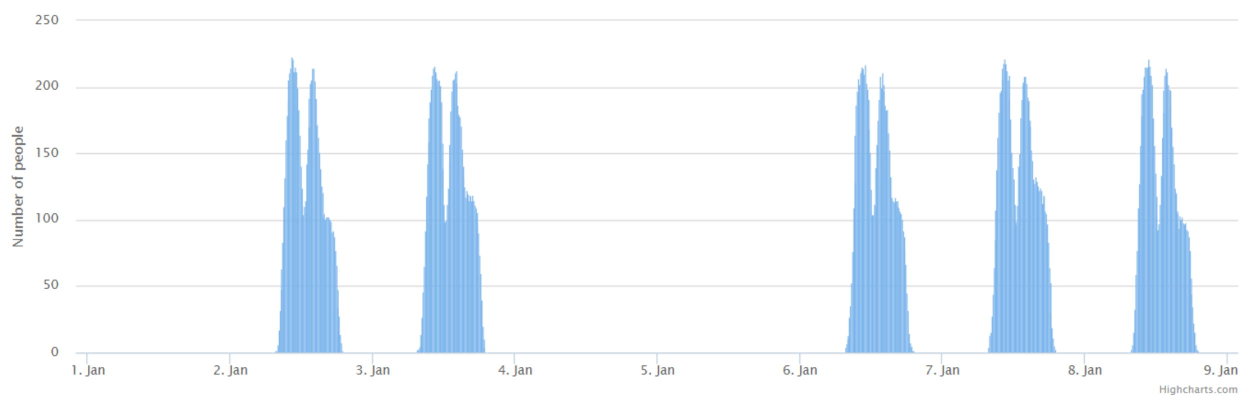


Figure 39. Second case study - Weekly profile of OSIM

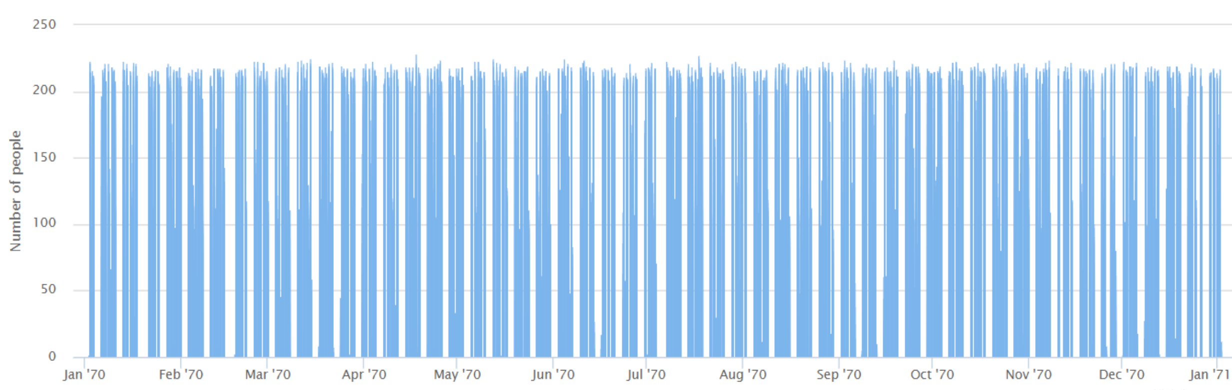


Figure 40. Second case study - Annual profile of OSIM

The results are taken in CSV format and all postproduction has been applied to achieve the FFD format in IESVE same as previous section in caste study 1.

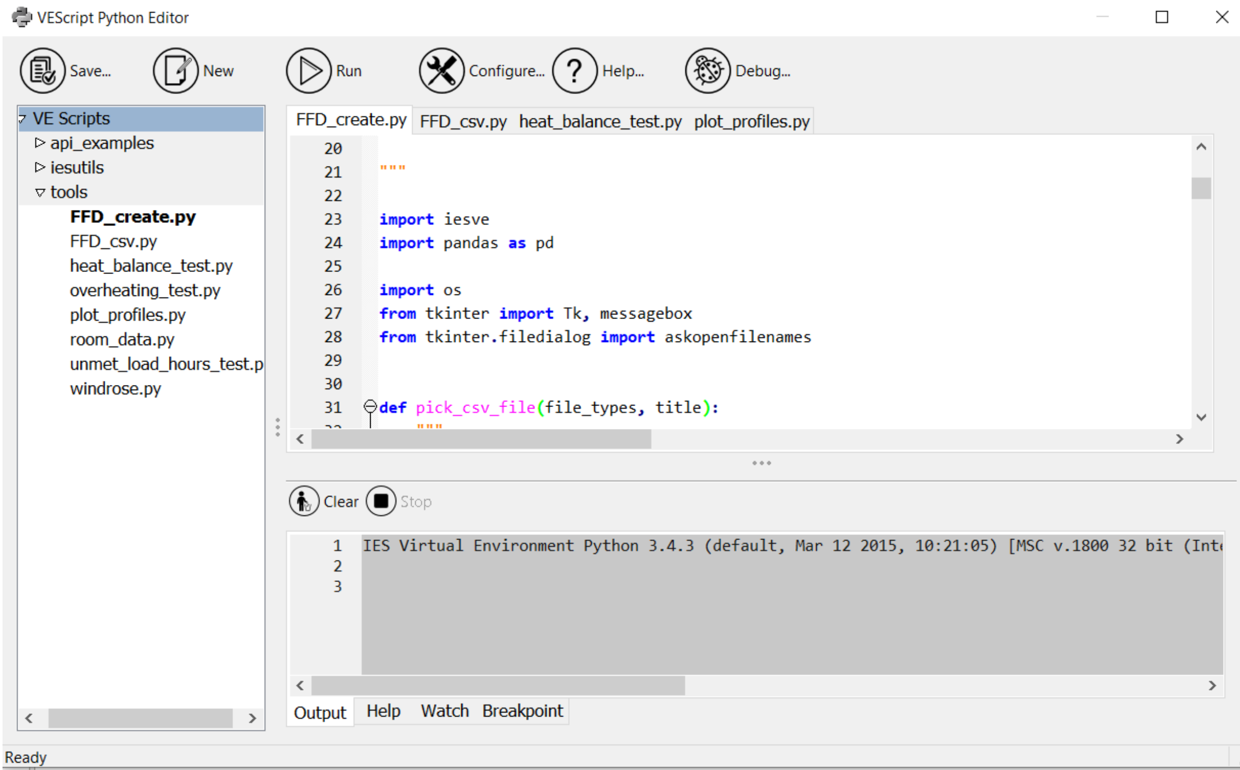


Figure 41 VEScript python editor to create FFD file from CSV

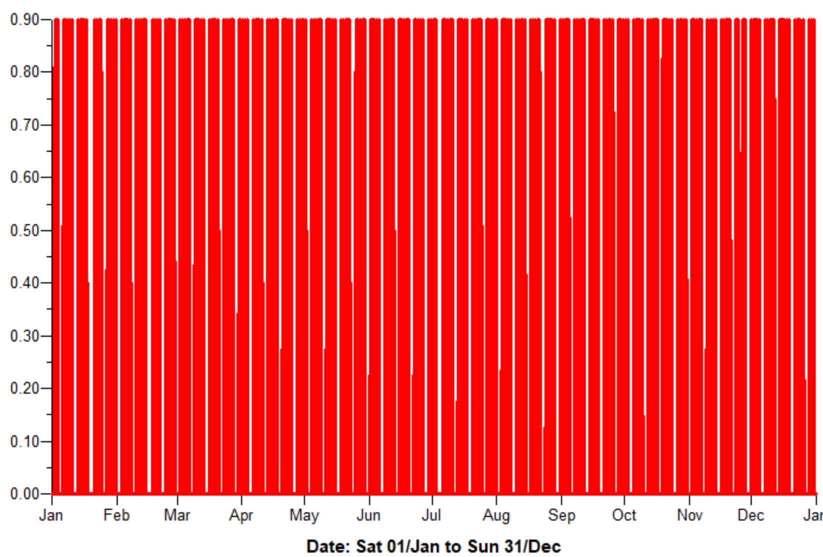


Figure 42.Second case study FFD created profile in IESVE

In the first simulation OSIM profiles is used in maximum and average hourly intensity of people condition. Division of spaces is as following chart 45. For each room specific value regarding its consumption is defined based on ISO 17 and ISO 18 [22]. After running dynamic simulation, the results are taken from VistaPro in IESVE. Due to difference in daily profiles, The 14th of January and “office room 2” in the ground floor are chosen as the example date and location to demonstrate the results of different approaches in figure 46.

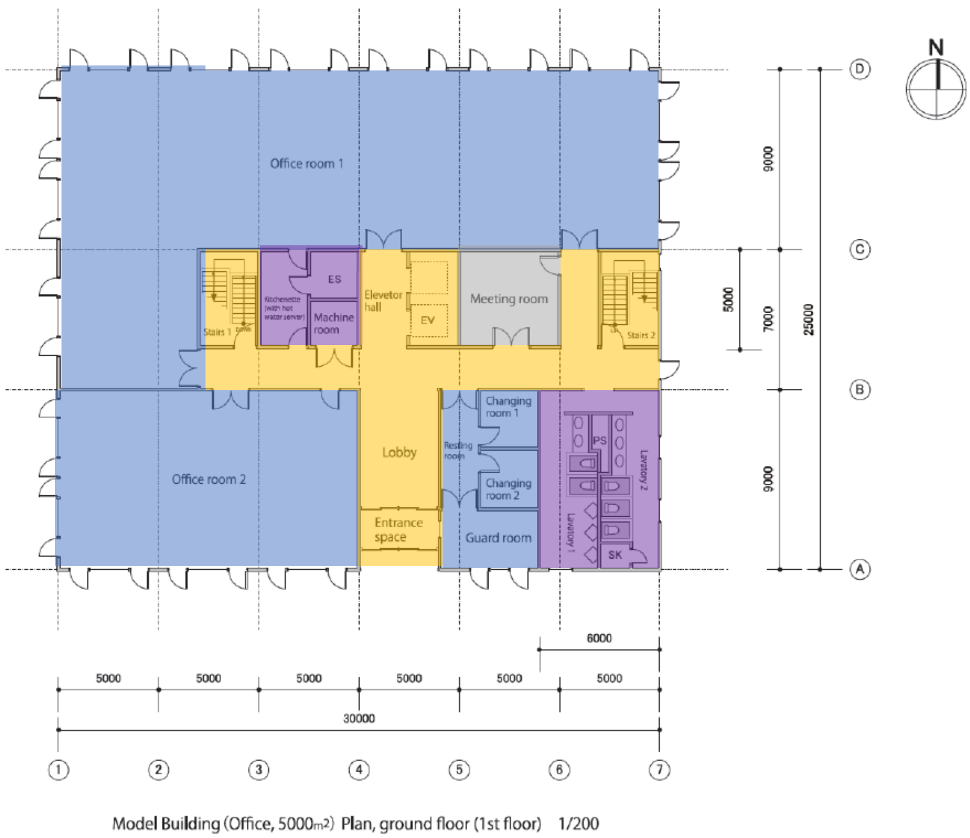


Figure 43. Second case study layout division of OSIM - Ground floor

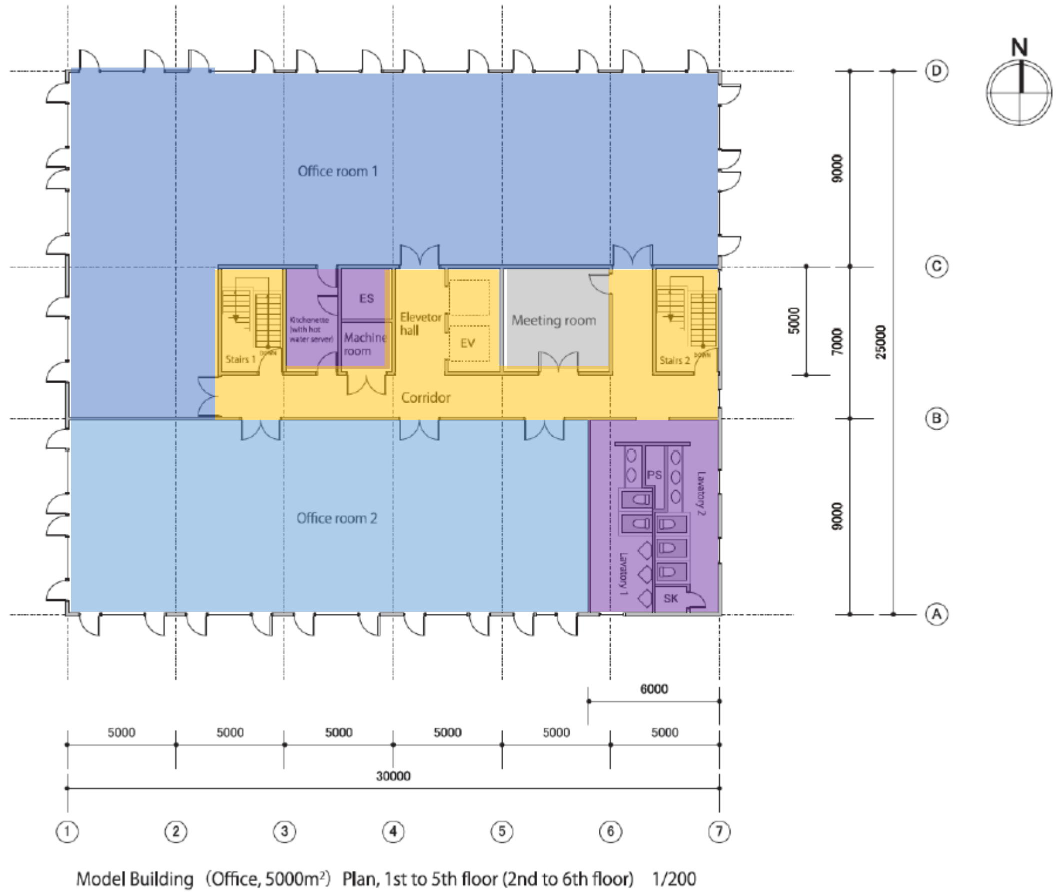


Figure 44. Second case study layout division of OSIM - 1st to 6th floor

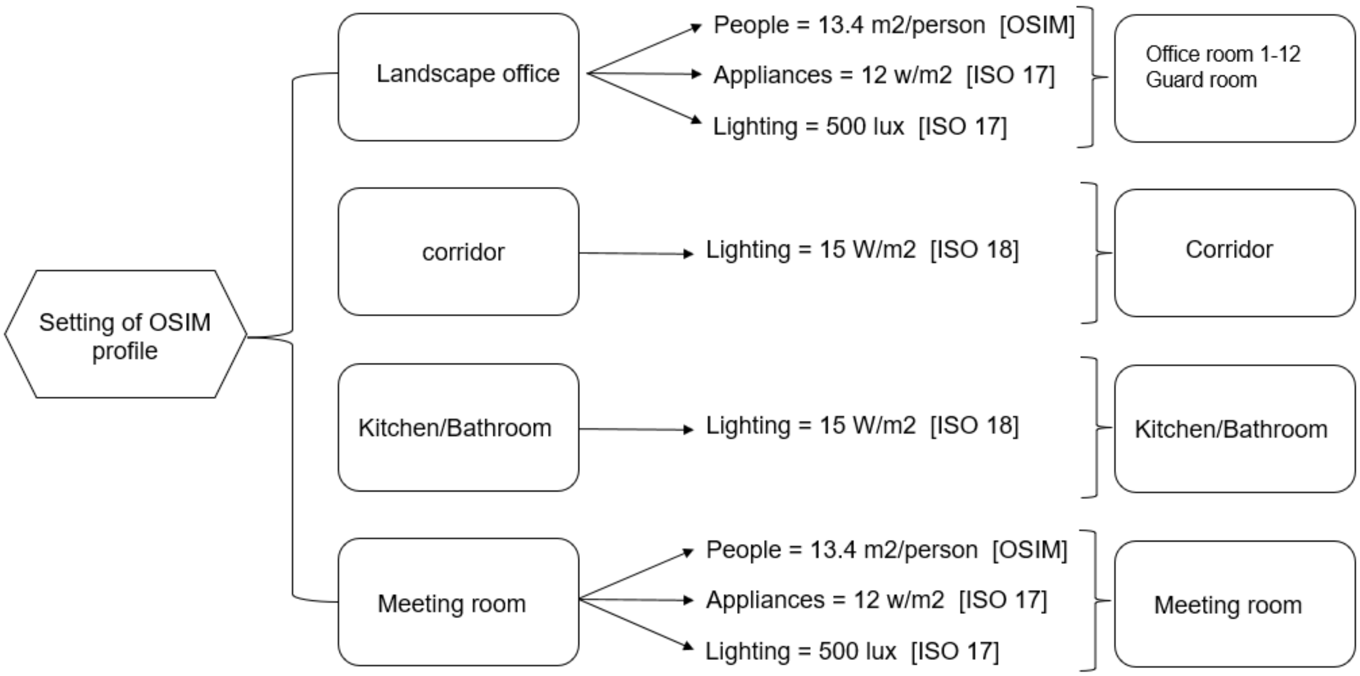


Figure 45. Second case study consumption specifications for OSIM simulation

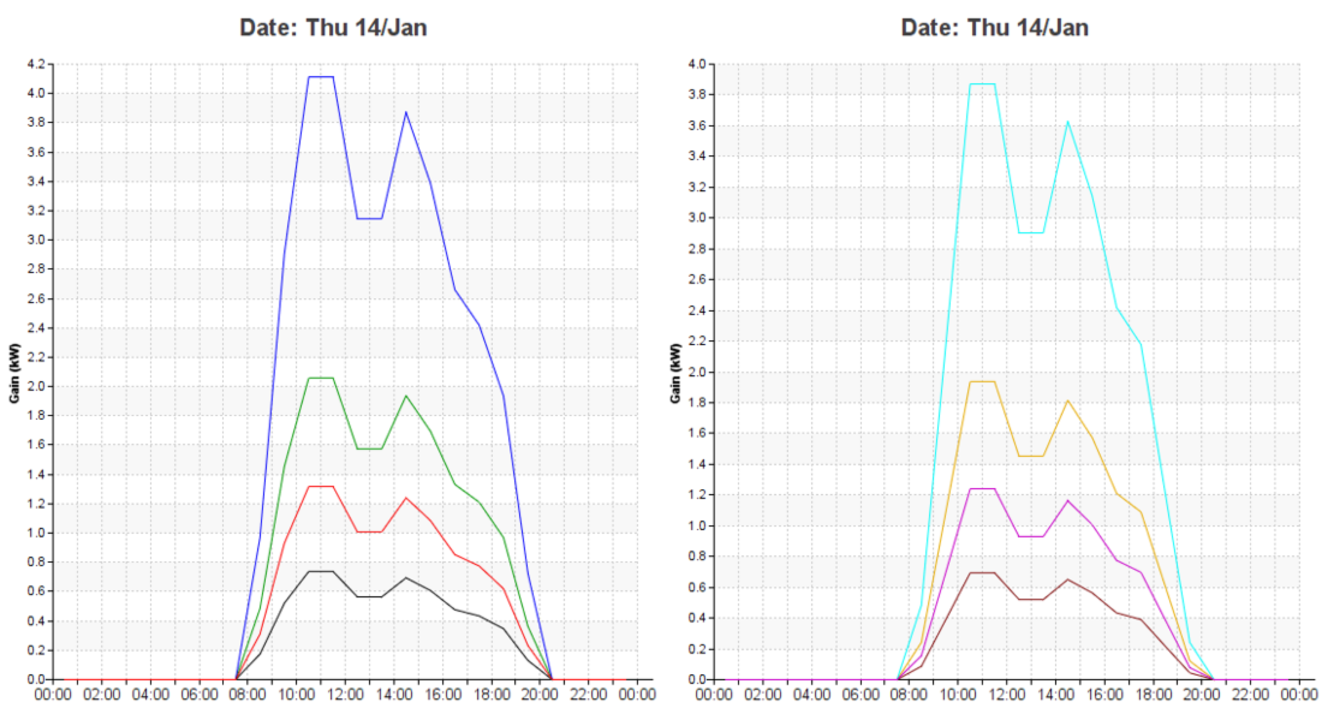


Figure 46. Second case study internal gains of OSIM max and average for the office room 2

The second simulation, ISO 17772-1-2017 profiles are defined in “building template manager” part like case study 1 in IESVE. Daily and weekly profiles are inserted with the standard value of people density in scenario 1 of case study 2 and actual number of people in scenario 2 of case study 2. Then internal gain consists of people, lighting and computers is selected and the results taken from VistaPro. The division of the spaces in this case is landscape office and meeting room and the rest of spaces like bathroom and corridor there is no internal gain based on ISO 17772-1-2017. The example profile of “office room 2” in the ground floor is chosen in date 14th of January in figure 50.

Figure 47. Second case study layout division of ISO 17772-1-2017 - Ground floor

Figure 48. Second case study layout division of ISO 17772-1-2017 - 1st to 6th floor

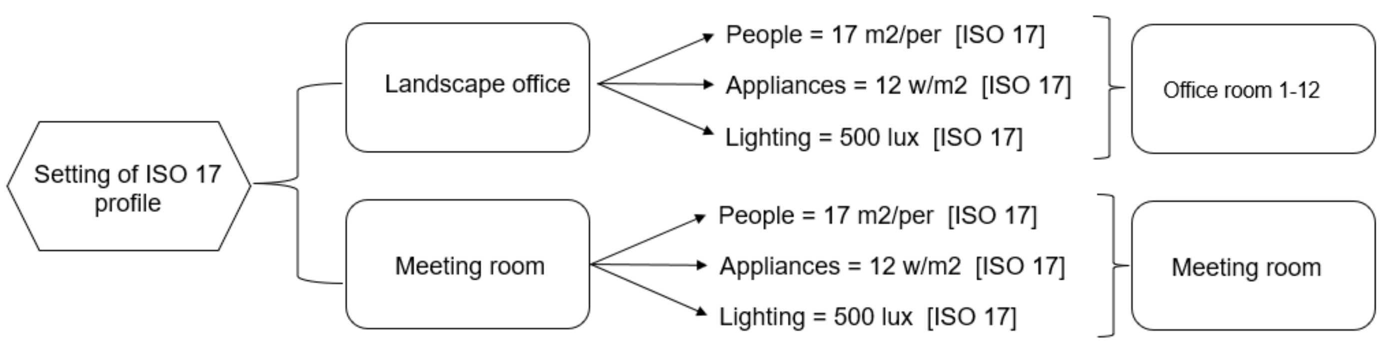


Figure 49. Second case study consumption specifications for ISO 17772-1-2017 simulation

Landscape offices and meeting room profile are similar to figure 19 in case study 1.

Similar to case study 1, the highest value refers to lighting profile with the peak value of 1.7 kW and the minimum value belongs to people gain people gain profile. Total internal gain has the peak value of 3.25 kW (figure 50).

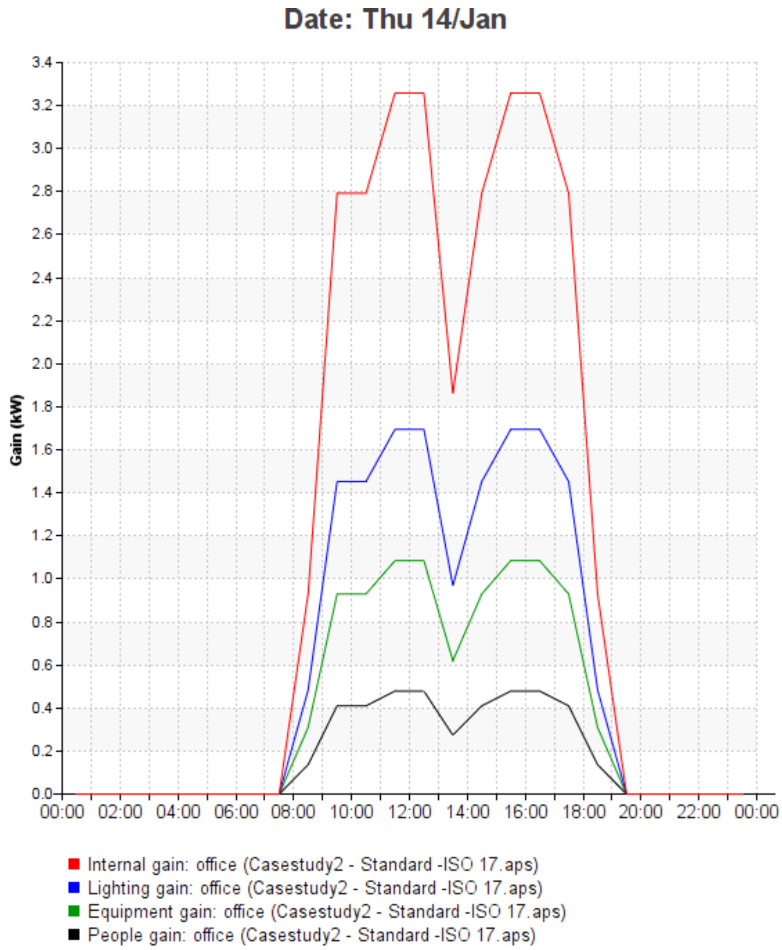


Figure 50. Second case study internal gains of ISO 17772-1-2017 for the office room 2

The third simulation is based on ASHRAE profiles. Schedule profiles are same as case study 1. As it was explained in case study 1, the value of people, appliances and lighting system are taken from ASHRAE standard is based on “Core” and “Perimeter” areas in the office building. Core areas and Perimeter spaces are respectively assigned to Offices and meeting rooms and corridor/bathroom/ kitchen/ guard room areas. The example date is 14th of January for the “Office room 2” on the ground floor in figure 54.

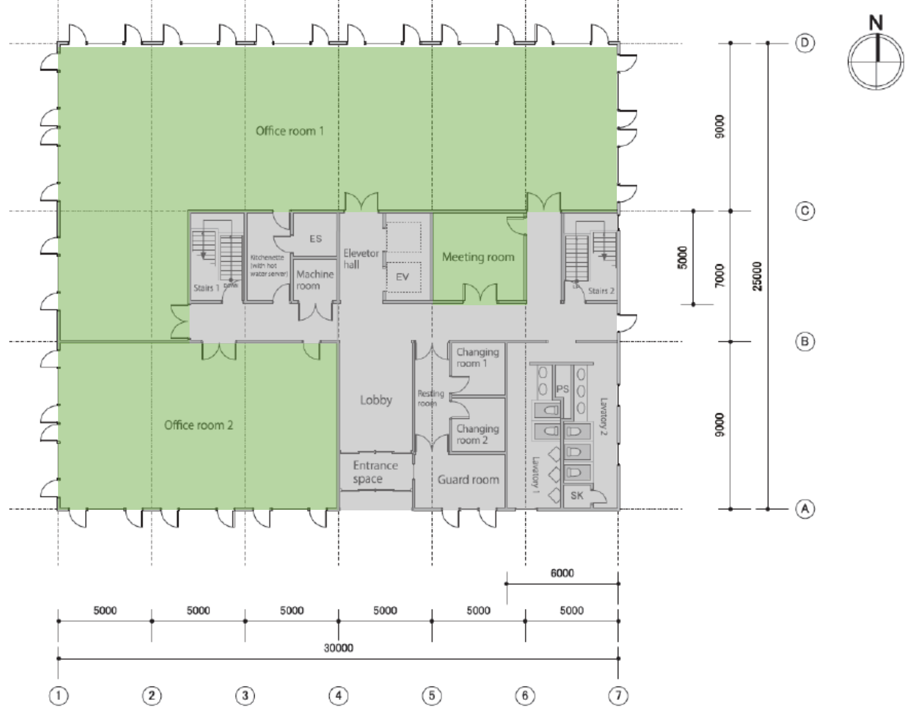


Figure 51. Second case study layout division of ASHRAE – Ground floor

Figure 52. Second case study layout division of ASHRAE - 1st to 6th floor

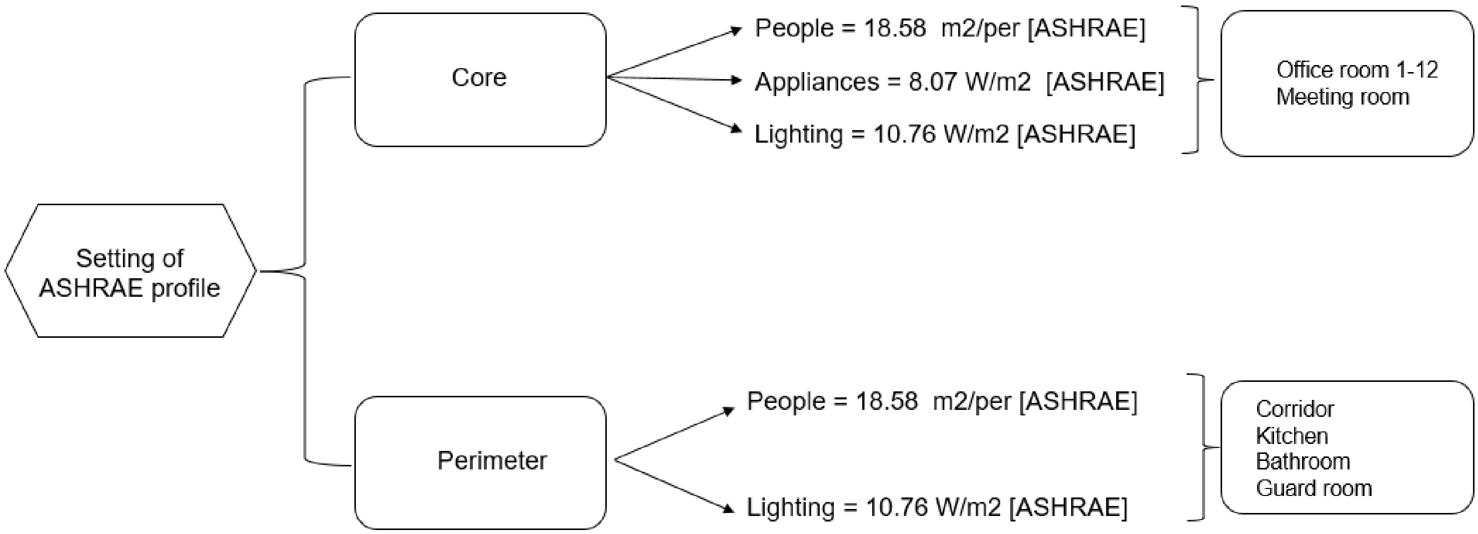


Figure 53. Second case study consumption specifications for ASHRAE simulation

The occupant, lighting and equipment profiles of ASHRAE are expressed in figure 23, 24, and 25 in case study 1.

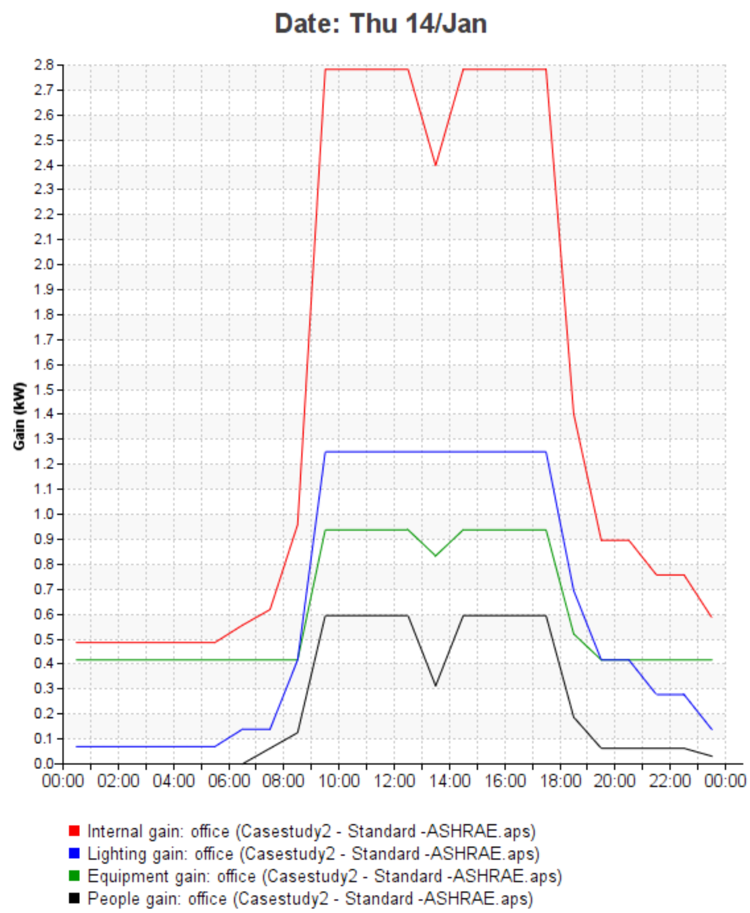


Figure 54. Second case study internal gains of ASHRAE for the Office room 2

The final simulation is based on ISO 18523-1-2016. Space division and coefficient for occupants, lighting and equipment is demonstrated in chart 57. Same as previous standards, “Office room 2” on ground floor is the sample of different profiles on date 14th of January. In figure 55 And 56 different spaces are shown graphically. The profiles are figures 29 till 32 in case study 1.

Figure 55. Second case study layout division of ISO 18523-1-2016 - Ground floor

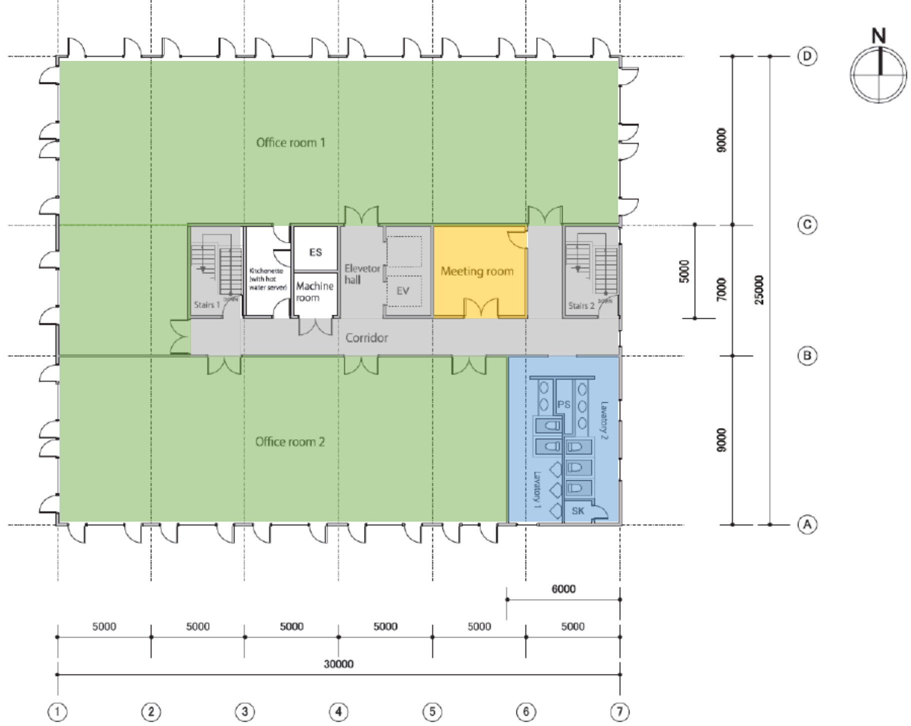


Figure 56. Second case study layout division of ISO 18523-1-2016 - 1st to 6th floor

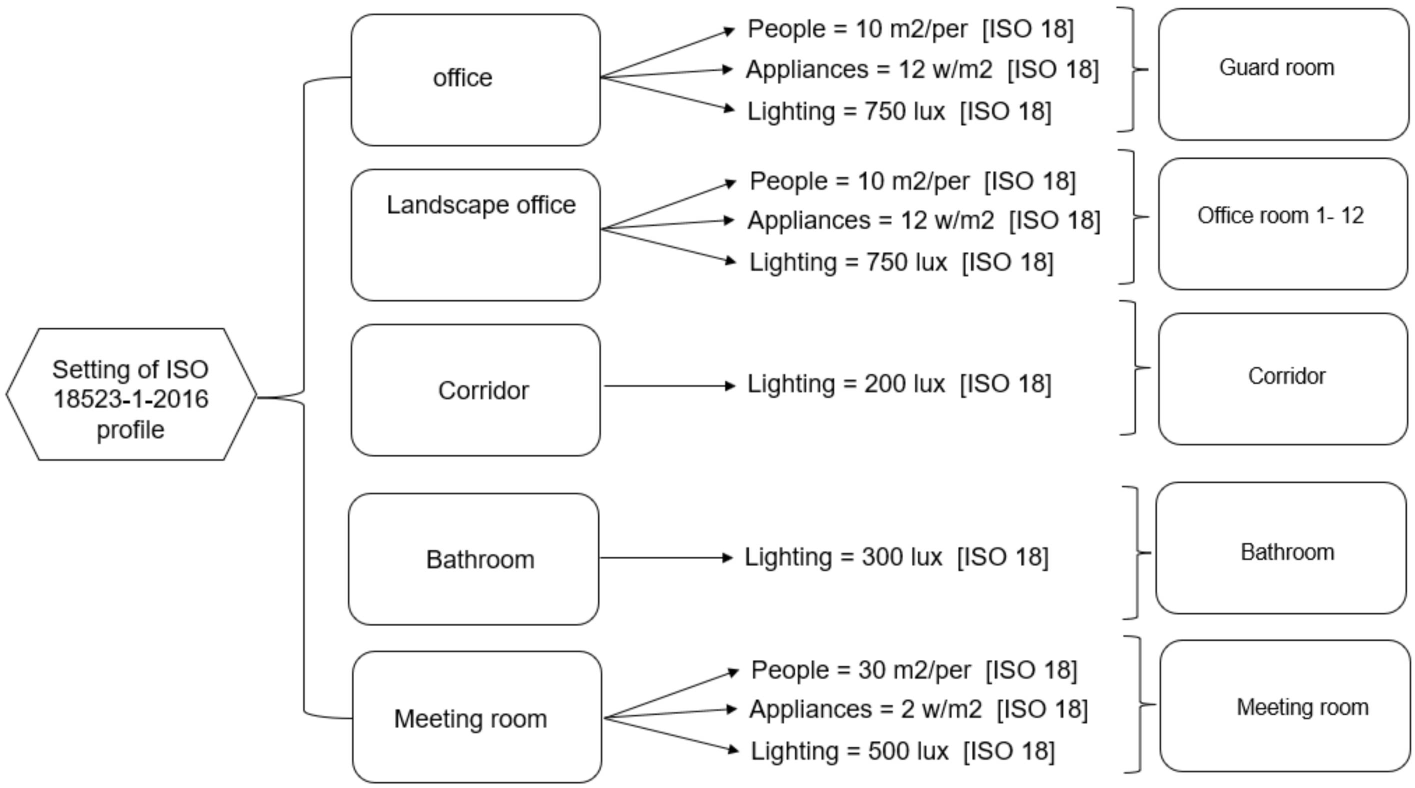


Figure 57. Second case study consumption specifications for ISO 18523-1-2016

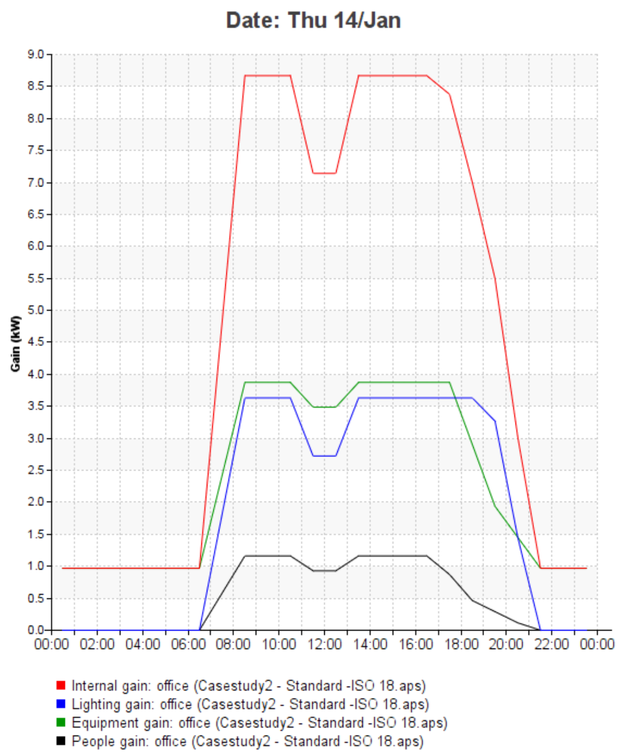


Figure 58. Second case study internal gains of ISO 18523-1-2016 for the Office room 2

Case study 3

The third building for case study 3 is first floor of building 15 Politecnico di Milano with the total area of 840 m2. The rooms are divided as following figure 59:

Figure 59. Third case study layout of building - First floor

In figure 60 The modeling of the building in IESVE is demonstrated with the weather file location of Milano Linate airport.

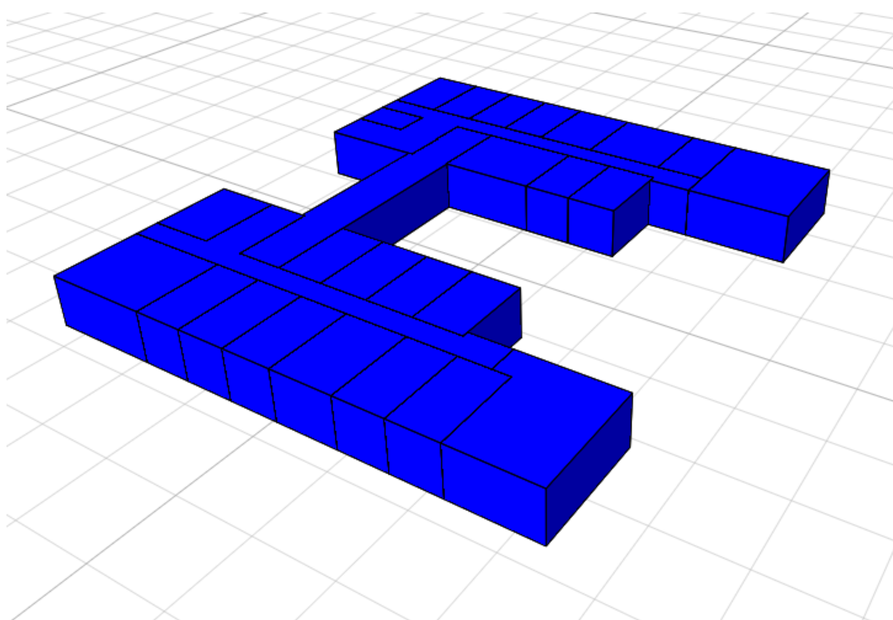


Figure 60. Third case study IESVE geometry

- **Step 1: The Start New Page**

Large office chosen because the area is 840 m2

- **Step 2: The Spaces Page**

Then, the name of all spaces should be chosen and the number of each space in the building and the area of each space should be inserted based on the case study plan (table 27).

Name	Space type	Area [m2]	Space multiplier
Single office type 1	Single office	20	15
Single office type 2	Single office	24	3
Single office type 3	Single office	30	1
Landscape office 1	Landscape office	40	2
Landscape office 2	Landscape office	46	1
Landscape office 3	Landscape office	56	1
Bathroom 1	bathroom	10	1
Bathroom 2	bathroom	20	1
corridor	corridor	206	1

Table 27. Third case study - OSIM space properties

- **Step 3: The Space Type Page**

In this page, the name of the spaces is defined, and its occupant type should be selected then its density is inserted based on m2/person. For the bathroom, usage should be chosen as “others” which does not need any information. It is worth noting that for Offices occupant percentage of people who are working in that space is 100% .

Name	Usage	Occupant density m^2/person
Landscape office	Office	10
Single office	Office	15
bathroom	Others	-
corridor	Others	-

Table 28. Third case study - Occupant density specification in OSIM software

- **Step 4: The Occupant Type Page**

In the following page, the occupant type should be specified with their working days, arrival and departure time and short-term leaving events such as lunch or coffee break with its duration. The arrival time is considered as 9 am and for the departure it is 17 pm with the variation of 30 minutes for working days. For the break, one hour of lunch time with the variation of 30 minutes at 12 pm is defined and one coffee break with the duration of 20 minutes at 3 and variation of 10 min. The space occupancy is specified as following table 29:

Location	Own office	Other office	Meeting room	Auxiliary room	Outdoor
Average use time [percentage]	50	0	0	5	45
Average stay time [min]	60	0	0	10	50

Table 29. Third case study - usage time in OSIM software

The daily profiles, weekly profiles and annual profile are respectively expressed in figures 61, 62 and 63.

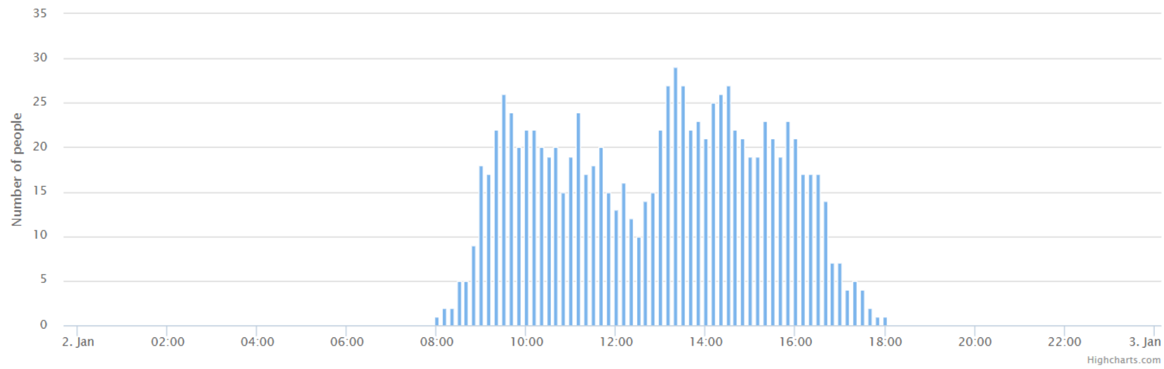


Figure 61. Third case study - Daily profile of OSIM

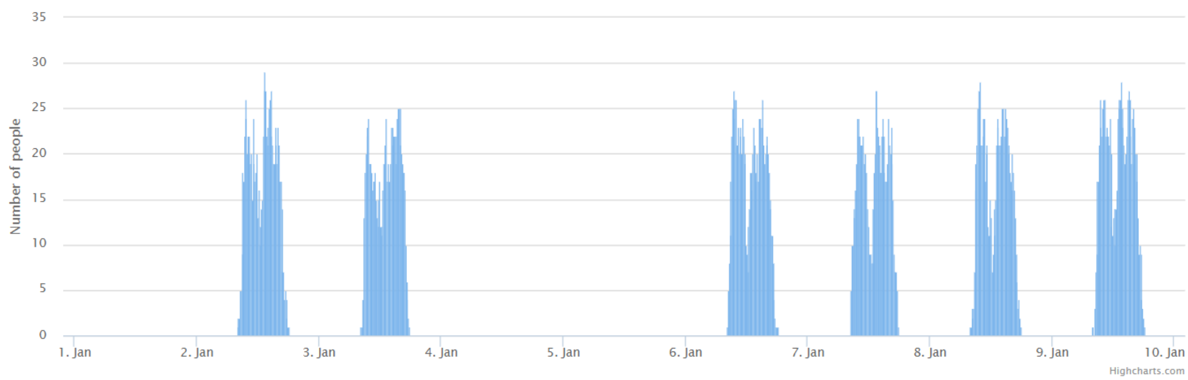


Figure 62. Third case study - Weekly profile of OSIM

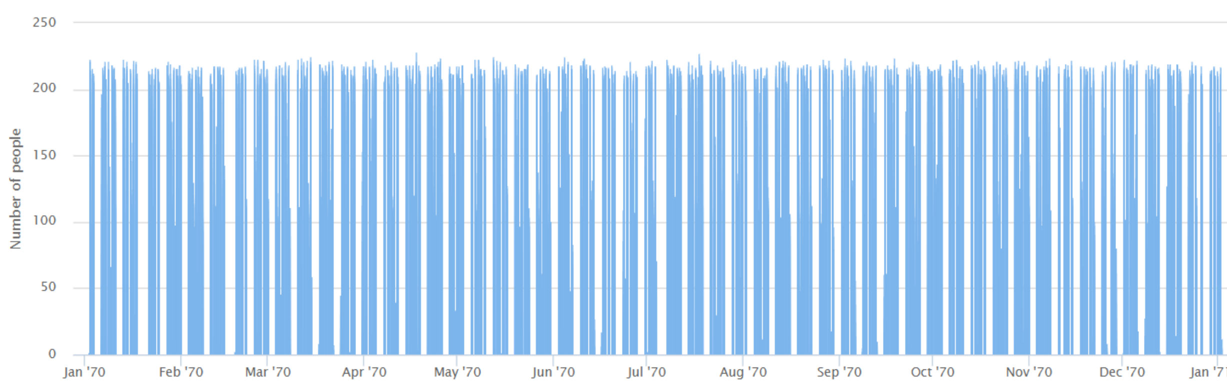


Figure 63. Third case study - Annual profile of OSIM

The CSV results are post produced as expressed in case study 1 and it has been imported in IESVE to acquire FFD annual profile figure 65.

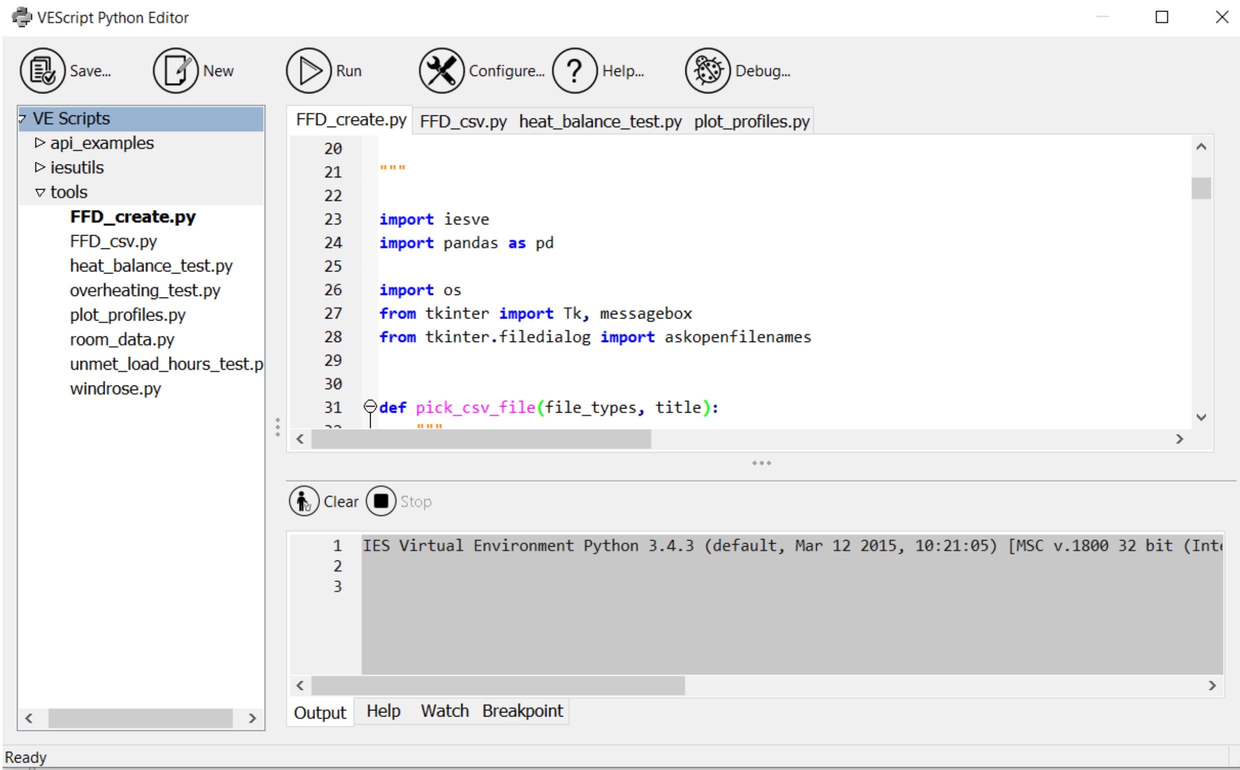


Figure 64. VEScript python editor to create FFD file from CSV

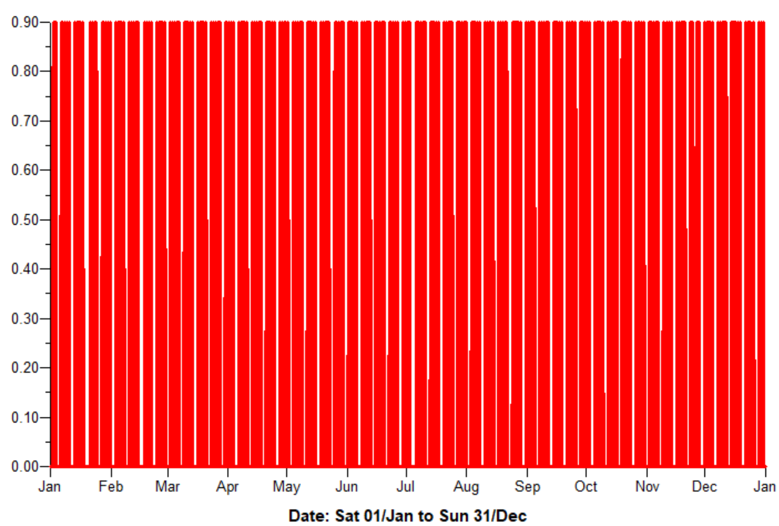


Figure 65. Third case study FFD created profile in IESVE

The first simulation is applying OSIM profile considering the average and maximum modulating value of intensity for people. Space division is explained in figure 66. consumption specification is also shown in chart 67 After doing the simulation, the results has taken from VistaPro in IESVE.

Figure 66. Third case study layout division of OSIM

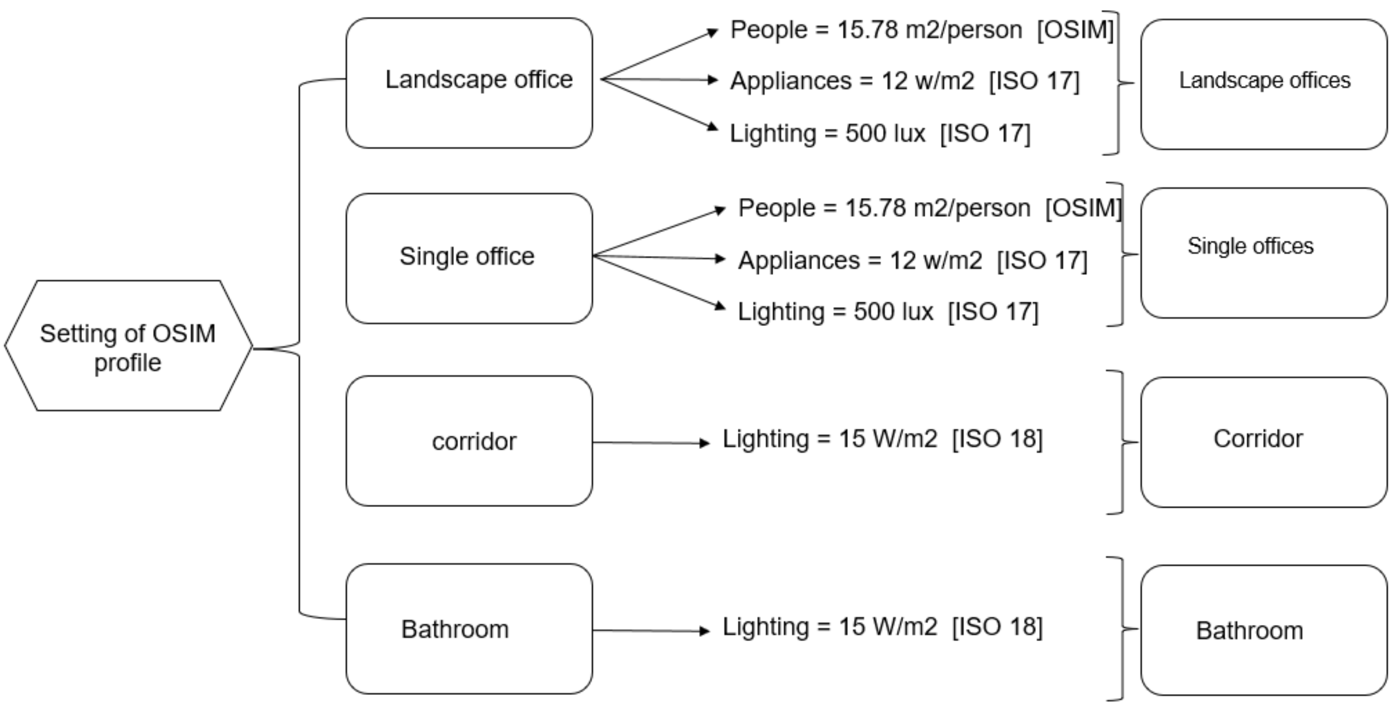


Figure 67. Third case study consumption specifications for OSIM simulation

In the second simulation, ISO 17772-1-2017 profiles of single office and landscape office are used in IESVE. The other spaces like bathroom and corridor have no internal gain based on ISO 17772-1-2017. Single office and landscape office profiles are similar to figure 18,19 in case study 1.

Figure 68. Third case study layout division of ISO 17772-1-2017

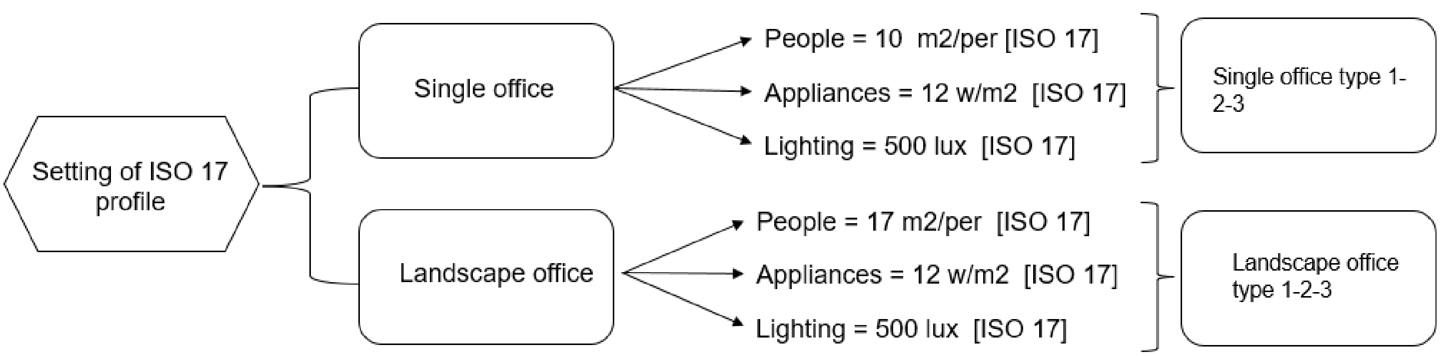


Figure 69. Third case study consumption specifications for ISO 17772-1-2017 simulation

The third simulation is based on ASHRAE profiles based on "Core" and "Perimeter" areas in the office building. Core areas and Perimeter spaces are respectively assigned to Offices and corridor/bathroom areas. The chart 71 corresponds to detail of space values. Space division is expressed in figure 70. Profiles are in figure 23, 24, and 25 of case study 1.

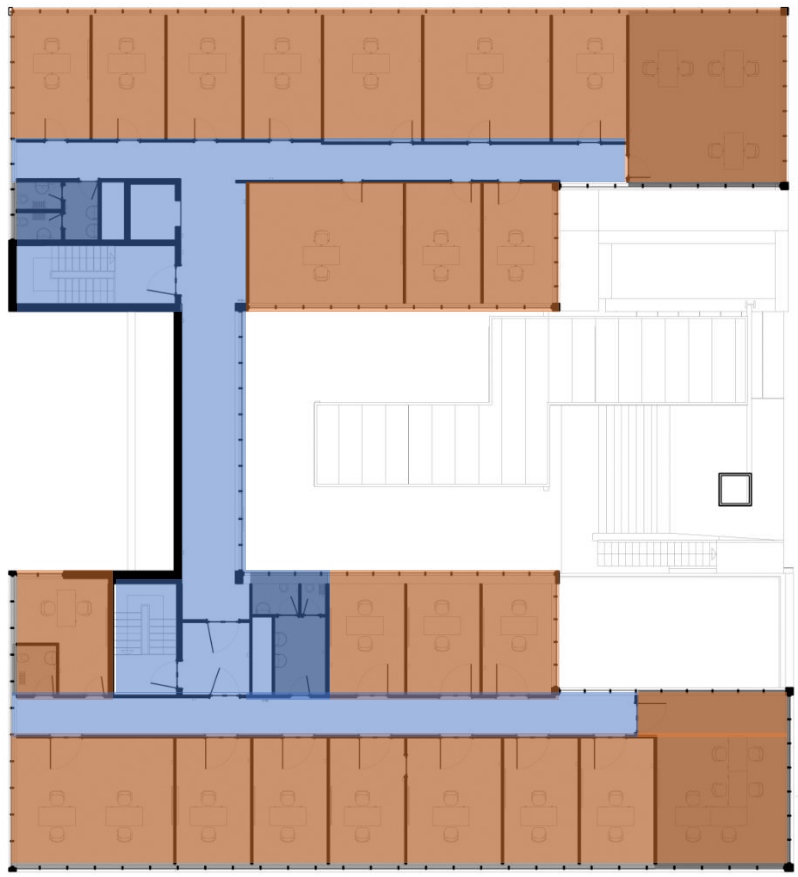


Figure 70. Third case study layout division of ASHRAE

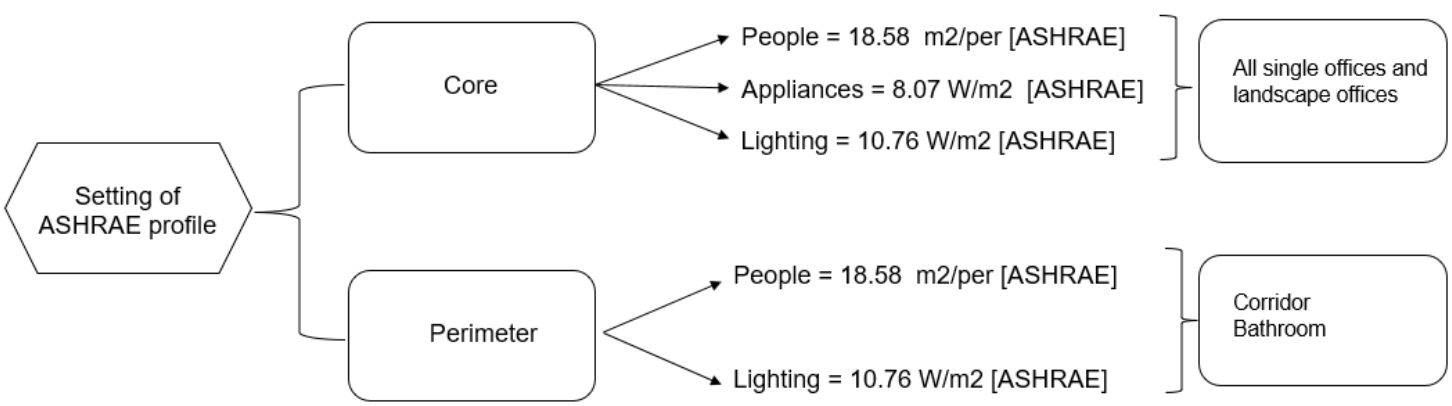


Figure 71. Third case study consumption specifications for ASHRAE simulation

The last simulation is ISO 18523-1-2016. The internal layout is demonstrated in figure 72. And all information regarding simulation is expressed in figure 73. Profiles are expressed in figures 29 till 32 of case study 1.

Figure 72. Third case study layout division of ISO 18523-1-2016

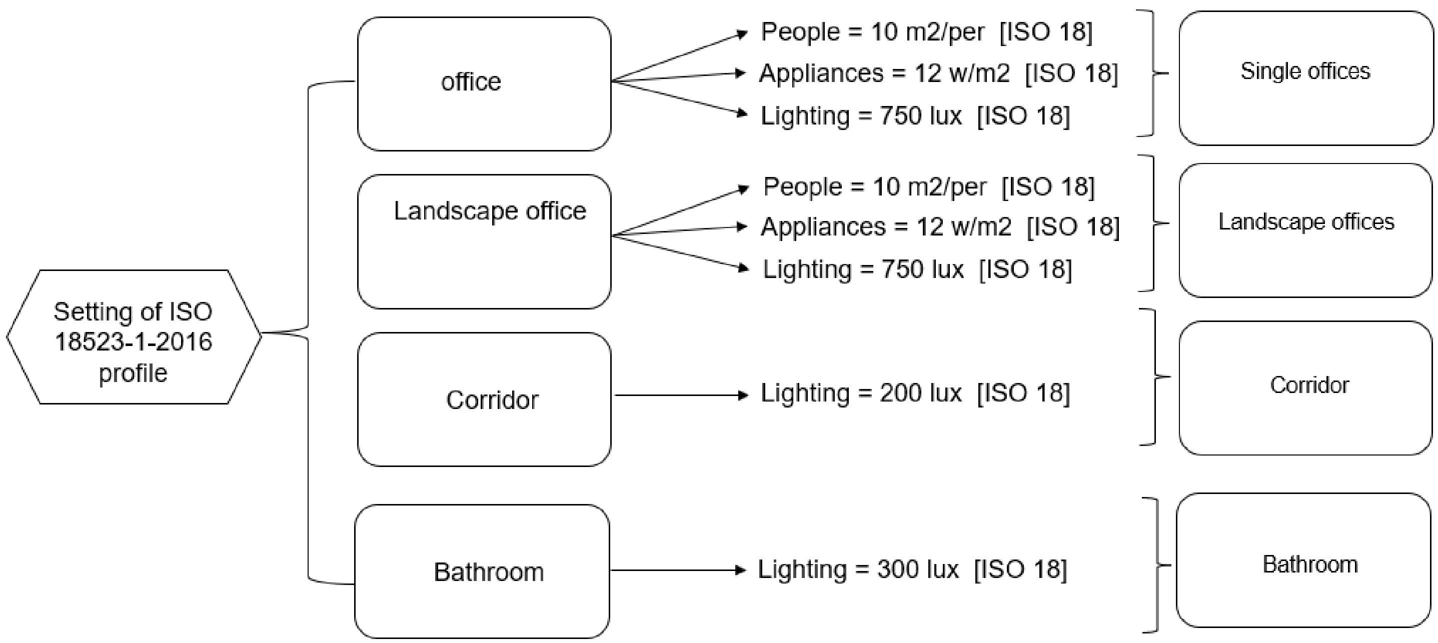


Figure 73. Third case study consumption specifications for ISO 18523-1-2016

Result

Case study 1 – Scenario one and two:

As it was expressed in previous sections, internal load includes sensible and latent load of people, load of lighting system and loads regarding equipment. So, in this section all results from simulation of internal gain profiles are taken from IESVE for two different scenarios. The results are exported as tables including each space gains with the time step of one hour for the entire year. By summing up the value of gains for all spaces in one hour, the hourly rate of internal loads for the whole building is achievable. Finally, yearly rate of each internal gain of the building is calculated by sum up the hourly value. The same date as previous example (14th of January) is taken as the example date for the researcher office.

The results are taken from two scenarios. As it was expressed before, in the first scenario the internal loads are based on standards density of people and in the second condition internal loads of occupants set with exact number of people.

In following, gain comparison of standards and OSIM software for people, lighting, equipment, and total internal gain are demonstrated. In addition, the comparison of number of people in each room based on different standards density are expressed in table 30 as the first scenario.

In the second scenario, the same approach as first scenario for getting the results is followed. The actual number of people is expressed in table 31. In this case, the equipment and lighting gain is similar to scenario 1 because there is no change neither in the profiles nor in the values. But for people gain and consequently for general internal gain the values and profiles acquired from IESVE are different due to changing the number of people from m2/person to actual number of people in each room.

	Number of occupants			
Space	**OSIM**	**ISO 18523-1-2016**	**ISO 17772-1-2017**	**ASHRAE**
Researcher Office	2.4	9.6	5.6	5.1
Meeting Room	2.4	3.2	5.6	5.1
Director Office	2.4	9.6	9.6	5.1
Manager Office 1	1.6	6.4	6.4	3.4
Manager Office 2	1.6	6.4	6.4	3.4
Restroom	-	-	-	1.7
Corridor	-	-	-	9.4
Sec Office	0.8	3.2	3.2	1.7
Admin Office	1.6	6.4	3.7	3.4
Senior Research Office 1	1.6	6.4	3.7	3.4
Senior Research Office 2	1.6	6.4	3.7	3.4
Kitchen	-	-	-	1.7
Total number	16	57.6	47.9	46.8

Table 30. First case study number of occupants based on standard density of people

In the second scenario, all simulations have been repeated with actual number of occupants with unit of "people" in each standard instead of implementing given density of people by "m2/person". This means that the number of occupants are the same for each space in all standards. Following table 31 demonstrates the details:

	Number of occupants			
Space	**OSIM**	**ISO 18523-1-2016**	**ISO 17772-1-2017**	**ASHRAE**
Researcher Office	4	4	4	4
Meeting Room	-	-	-	-
Director Office	1	1	1	1
Manager Office 1	1	1	1	1
Manager Office 2	1	1	1	1
Restroom	-	-	-	-
Corridor	-	-	-	-
Sec Office	1	1	1	1
Admin Office	2	2	2	2
Senior Research Office 1	3	3	3	3
Senior Research Office 2	3	3	3	3
Kitchen	-	-	-	-
Total number	16	16	16	16

Table 31. First case study number of occupants based on actual number of people

It can be concluded that for OSIM in both scenario there are 16 people because the density of people defined in this software is achieved by dividing the area by number of people. On the other hand, for the standards of ISO 17772-1-2017, ISO 18523-1-2016 and ASHRAE the standard density of people is higher than the actual number of people due to difference in the standard and actual conditions. By decreasing the number of occupants in IESVE simulation, the people gain reduced in all standards, but it remains the same of OSIM simulation. All details of yearly values are shown in table 32. For OSIM comparison, we have two options of OSIM max and average which are considering max intensity of people among time steps of 10 minutes for one hour and average intensity of people among time steps of 10 minutes for one hour respectively. The value regarding OSIM max is chosen as the sample of OSIM for occupant gain comparison.

	Occupant gain comparison							
Space	**OSIM max Density [kWh]**	**OSIM max Actual [kWh]**	**ISO 18523 Density [kWh]**	**ISO 18523 Actual [kWh]**	**ISO 17772 Density [kWh]**	**ISO 17772 Actual [kWh]**	**ASHRAE Density [kWh]**	**ASHRAE Actual [kWh]**
Researcher Office	395.53	684.56	2302.35	995.976	766.50	563.76	1130.22	908.40
Meeting Room	389.87	0	642.21	0	755.54	0	1113.70	0
Director Office	395.53	171.15	2302.35	248.994	868.81	140.94	1130.22	227.10
Manager Office 1	262.97	171.15	1529.92	248.994	577.33	140.94	750.99	227.10
Manager Office 2	262.97	171.15	1529.92	248.994	577.33	140.94	750.99	227.10
Restroom	0	0	0	0	0	0	355.73	0
Corridor	0	0	0	0	0	0	2090.95	0
Sec Office	130.27	171.15	757.78	248.994	285.95	140.94	371.83	227.10
Admin Office	257.30	342.28	1497.01	497.988	498.48	281.88	734.73	454.20
Senior Research Office 1	262.97	509.36	1529.92	746.982	509.44	422.82	750.99	681.30
Senior Research Office 2	262.97	509.36	1529.92	746.982	509.44	422.82	750.99	681.30
Kitchen	0	0	0	0	0	0	355.73	0
Total value	2620.4	2634.2	13621.4	3983.9	5348.8	2255.0	10287.1	3633.62

Table 32. First case study yearly occupant gain comparison

	people gain standard density[kWh]	people gain actual number [kWh]	Difference percentage [%]
ASHRAE	10287.14	3633.62	-64.7 %
OSIM Max	2620.42	2634.2	-
OSIM Average	2185.31	2164.88	-
ISO 17772-1-2017	5348.85	2255.04	-57.8 %
ISO 18523-1-2016	13621.45	3983.9	-70.8 %

Table 33. First case study total annual people gain - standard density and actual number of people

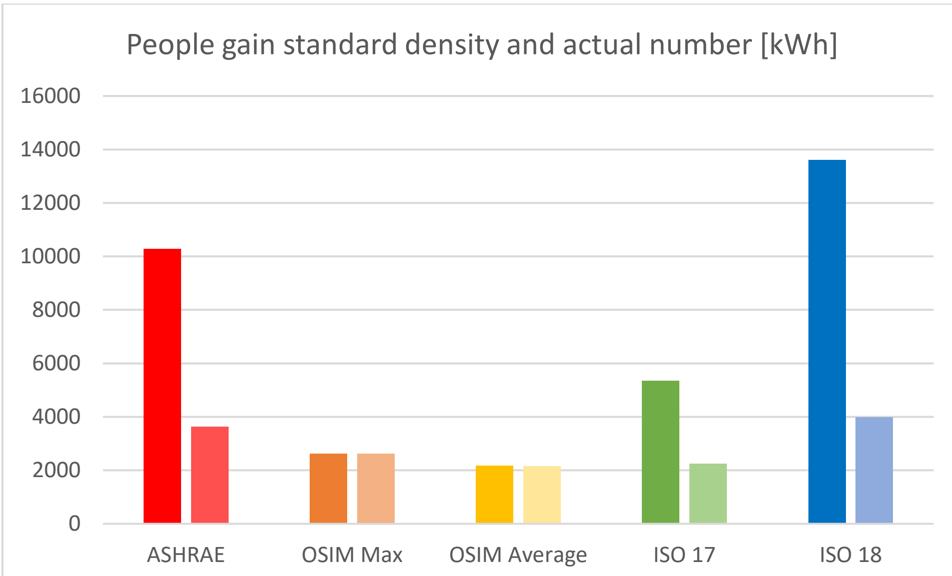


Figure 74. First case study total annual people gain - standard density and actual number of people

In table 33, annual people gain of first case study for each standard and also for OSIM max and average condition considering standard density of people and actual number of people are shown (first scenario and second scenario). The highest value of occupant gain belongs to ISO 18523-1-2016 with the value of 13621.45 kWh and the minimum value is for OSIM average condition with 2164.31 kWh figure 74.

By reduction the number of occupants in actual number of people scenario (second scenario), the results of people gain for each standards become close to each other and the only reason of difference in the value of annual people gain is due to different profiles of different standards which are applied during the simulation in IESVE software. So, it can be achieved that determination of accurate number of people plays a key role to acquire precise results.

Total yearly lighting and equipment gain comparison for each room based on its coefficient is shown in tables 34 and 36 respectively. As it was explained previously, lighting gains and equipment gains are the same for both first and second scenario (standard density of people and actual number of people). The lighting installed power density is 3.750 W/m2/100 lux and the maximum sensible gain and maximum power consumption are 18.750 w/m2.

	Lighting gain comparison							
Space	**Coef**	**OSIM [kWh]**	**Coef**	**ISO 18523-1-2016 [kWh]**	**Coef**	**ISO 17772-1-2017 [kWh]**	**Coef**	**ASHRAE [kWh]**
Researcher Office	500 lux	3296.78	750 lux	8348.40	500 lux	2714.95	10.76 W/m^2	2959.27
Meeting Room	500 lux	3249.20	500 lux	4013.74	500 lux	2675.80	10.76 W/m^2	2916.71
Director Office	500 lux	3296.78	750 lux	8348.40	500 lux	1809.98	10.76 W/m^2	2959.27
Manager Office 1	500 lux	2190.78	750 lux	5548.05	500 lux	1202.79	10.76 W/m^2	1966.95
Manager Office 2	500 lux	2190.78	750 lux	5548.05	500 lux	1202.79	10.76 W/m^2	1966.95
Restroom	15 W/m^2	830.25	300 lux	1110.87	-	-	10.76 W/m^2	931.81
Corridor	15 W/m^2	4879.19	200 lux	4353.22	-	-	10.76 W/m^2	5474.83
Sec Office	500 lux	1085.05	750 lux	2747.70	500 lux	595.71	10.76 W/m^2	974.36
Admin Office	500 lux	2143.46	750 lux	5427.96	500 lux	1765.12	10.76 W/m^2	1924.10
Senior Research Office 1	500 lux	2190.78	750 lux	5548.05	500 lux	1804.24	10.76 W/m^2	1966.95
Senior Research Office 2	500 lux	2190.78	750 lux	5548.05	500 lux	1804.24	10.76 W/m^2	1966.95
Kitchen	15 W/m^2	830.25	-	-	-	-	10.76 W/m^2	931.81
Total value	28374.10		56542.49		15575.62		26939.96	

Table 34. First case study yearly lighting gain comparison

	Lighting gain [kWh]
ASHRAE	26939.96
OSIM Max	28374.10
OSIM Average	23662.97
ISO 17772-1-2017	15575.62
ISO 18523-1-2016	56542.49

Table 35. First case study total annual lighting gain

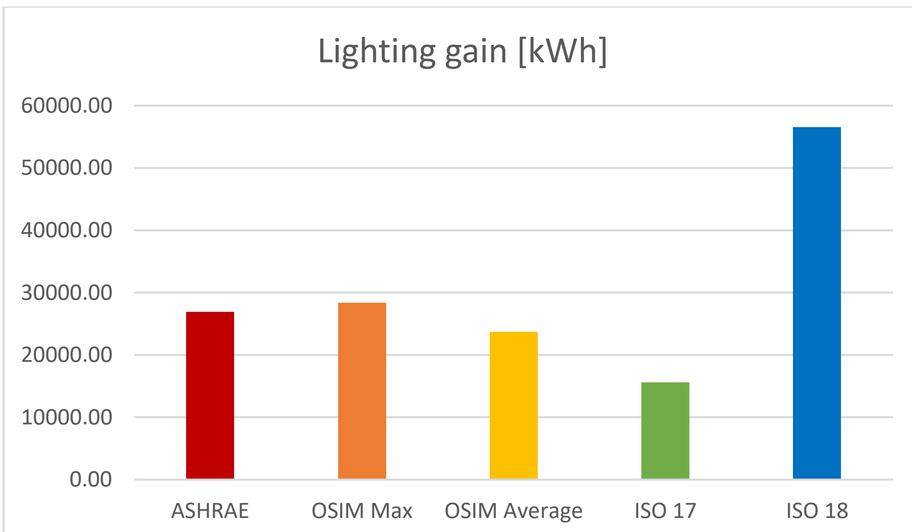


Figure 75. First case study total annual lighting gain

For lighting gain ISO 18523-1-2016 has the highest value because in this standard the acceptable value of illuminance for the office rooms are 750 lux while in other standards the acceptable range is 500 lux for offices. On the other hand, ISO 17772-1-2017 possesses the minimum value of lighting gain due to the fact that this standard considers no lighting gain for corridors, kitchens and bathrooms (figure 75 and table 35).

	Equipment gain comparison							
Space	**Coef**	**OSIM [kWh]**	**Coef**	**ISO 18523-1-2016 [kWh]**	**Coef**	**ISO 17772-1-2017 [kWh]**	**Coef**	**ASHRAE [kWh]**
Researcher Office	12 w/m^2	2109.7651	12 w/m^2	4905.87	12 w/m^2	1737.4248	8.07 w/m^2	3353.5603
Meeting Room	12 w/m^2	2109.7651	2 w/m^2	428.2227	12 w/m^2	1712.5776	8.07 w/m^2	3305.0068
Director Office	12 w/m^2	2109.7651	12 w/m^2	4905.87	12 w/m^2	1158.318	8.07 w/m^2	3353.5603
Manager Office 1	12 w/m^2	1402.2291	12 w/m^2	3260.7141	12 w/m^2	769.8456	8.07 w/m^2	2228.7395
Manager Office 2	12 w/m^2	1402.2291	12 w/m^2	3260.7141	12 w/m^2	769.8456	8.07 w/m^2	2228.7395
Restroom	-	-	-	-	-	-	-	-
Corridor	-	-	-	-	-	-	-	-
Sec Office	12 w/m^2	694.448	12 w/m^2	1614.7605	12 w/m^2	381.2688	8.07 w/m^2	1103.5221
Admin Office	12 w/m^2	1402.2291	12 w/m^2	3189.9693	12 w/m^2	1129.7124	8.07 w/m^2	2180.6394
Senior Research Office 1	12 w/m^2	1402.2291	12 w/m^2	3260.7141	12 w/m^2	1154.7684	8.07 w/m^2	2228.7395
Senior Research Office 2	12 w/m^2	1402.2291	12 w/m^2	3260.7141	12 w/m^2	1154.7684	8.07 w/m^2	2228.7395
Kitchen	-	-	-	-	-	-	-	-
Total value	14034.89		28087.55		9968.53		22211.25	

Table 36.First case study yearly equipment gain comparison

	Equipment gain [kWh]
ASHRAE	22211.24
OSIM Max	14034.88
OSIM Average	10064.20
ISO 17772-1-2017	9968.52
ISO 18523-1-2016	28087.54

Table 37. First case study total annual equipment gain

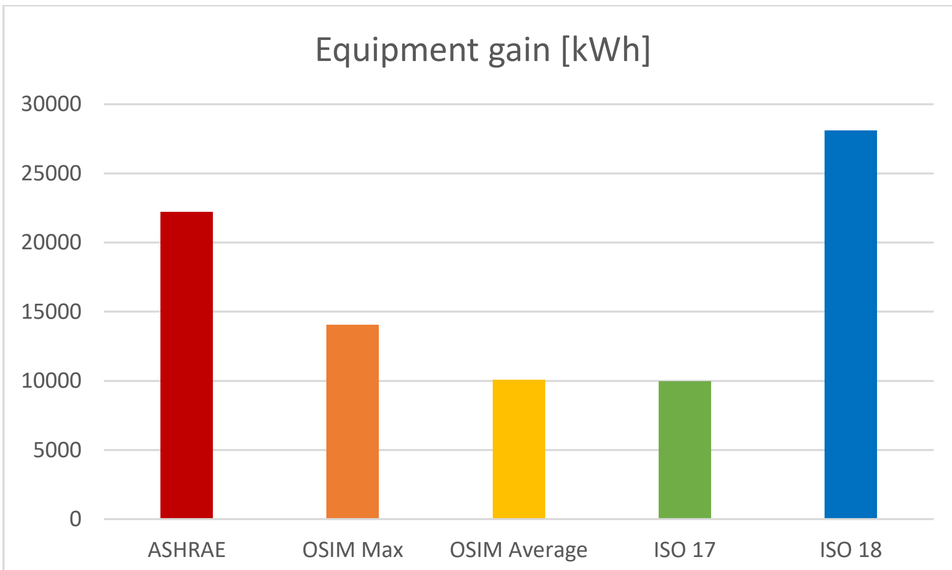


Table 38. First case study total annual equipment gain

Total internal gain of standard density of people and actual number of people for each standard and OSIM software are expressed in table 39.

	Total internal gain comparison							
Space	**OSIM max Density [kWh]**	**OSIM max Actual [kWh]**	**ISO 18523 Density [kWh]**	**ISO 18523 Actual [kWh]**	**ISO 17772 Density [kWh]**	**ISO 17772 Actual [kWh]**	**ASHRAE Density [kWh]**	**ASHRAE Actual [kWh]**
Researcher Office	5802.0	6091.06	15556.6	14250.2	5218.98	5016.1	7442.87	7208.15
Meeting Room	3812.2	3422.38	5084.17	4441.95	5144.07	4388.4	7335.45	6208.95
Director Office	5802.0	5577.67	15556.6	13503.2	3837.11	4593.3	7442.87	6526.85
Manager Office 1	3855.9	3764.11	10338.6	9057.75	2549.97	3099.8	4946.18	4413.70
Manager Office 2	3855.9	3764.11	10338.6	9057.75	2549.97	3099.8	4946.18	4413.70
Restroom	830.25	830.25	1110.86	1110.86	0	0	1287.47	927.73
Corridor	4879.1	4879.19	4353.21	4353.21	0	0	7565.76	5450.78
Sec Office	1909.7	1950.65	5120.25	4611.43	1262.92	1606.4	2449.78	2300.76
Admin Office	3772.4	3857.54	10114.9	9115.92	3393.31	3176.7	4839.45	4550.45
Senior Research Office 1	3855.9	3468.37	10338.6	9555.74	3468.45	3281.7	4946.18	4867.90
Senior Research Office 2	3855.9	3468.37	10338.6	9555.74	3468.45	3381.7	4946.18	4867.90
Kitchen	830.25	830.253	0	0	0	0	1287.47	927.73
Total value	43062.0	41904.02	98251.4	88613.8	30893.2	29744.	59435.8	52664.6

Table 39. First case study yearly internal gain comparison

	Internal gain standard density [kWh]	Internal gain Actual number [kWh]	Difference percentage [%]
ASHRAE	59435.87	52664.65	-11.4%
OSIM Max	43062.07	42542.03	-
OSIM Average	35912.46	36054.54	-
ISO 17772-1-2017	30893.26	29744.38	-3.7%
ISO 18523-1-2016	98251.44	88613.86	-9.8%

Table 40.First case study total annual internal gain – standard density and actual number

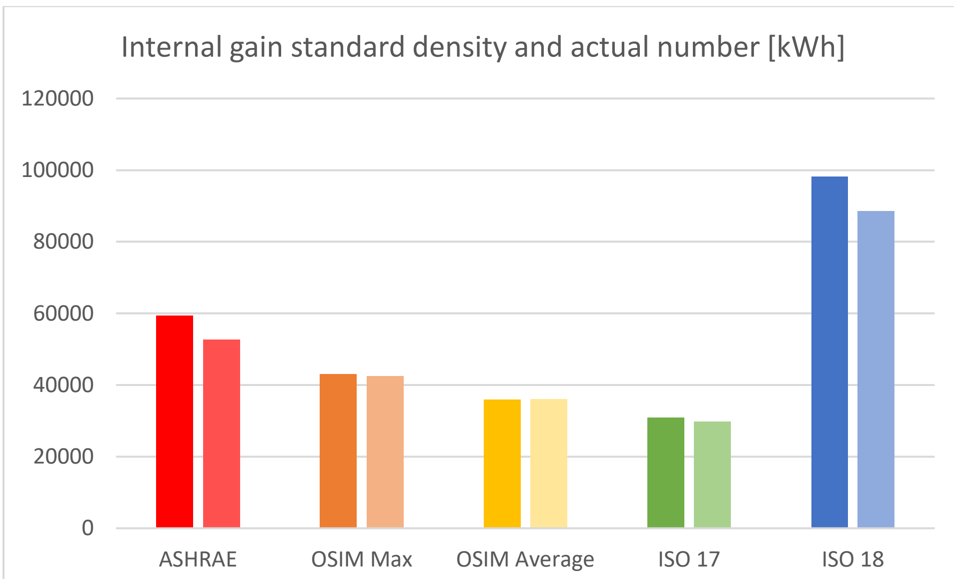


Figure 76. First case study total annual internal gain – standard density and actual number

Highest value of total internal gain refers to ISO 18523-1-2016 with the value of 98251.44 kWh for the total year. (table 40 and figure 76). It is due to the fact that in ISO 18523-1-2016, people gain, equipment gain, and lighting gain have the highest value also and total internal gain is taken from summing up all of the gains mentioned before. Because of the impact of people gain on total internal gain, by reduction in people gain, total internal gain also reduces.

Case study 2 – Scenario one and two:

Similar to case study one, results regarding internal gain, lighting, equipment gain, and people gain are compared with each other in two scenarios. The first scenario is with standard density of people and the second scenario is regarding to Actual number of people in the rooms. The annual results' time step is one hour and then they are summed up for the whole building. Thus, yearly rate of gains for the building is achieved. In table 41 the number of occupants based on standard density is expressed. The value regarding each room is multiplied by the number of same rooms in the whole building.

	Number of occupants			
Space	**OSIM**	**ISO 18523-1-2016**	**ISO 17772-1-2017**	**ASHRAE**
Office 1-3-5-7-9-11	23.8 * 6 = 142.8	31.9 * 6 = 191.4	18.8 * 6 = 112.6	17.16 * 6 = 103
Office 2	10	13.5	7.9	7.2
Office 4-6-8-10-12	80.6	21.6 * 5 = 108	12.7 * 5 = 63.5	11.62 * 5 = 58.1
Bathroom * 6	-	-	-	2.9 * 6 = 17.4
Meeting room * 6	1.8 * 6 = 11.25	0.8 * 6 = 5	1.47 * 6 = 8.8	1.34 * 6 = 8
Kitchen * 6	-	-	-	1.34 * 6 = 8.0
Corridor	-	-	-	37.76
Guard room	3.35	4.5	-	2.4
Total number	248	322.4	192.8	241.8

Table 41. Second case study number of occupants based on standard density of people

Same as case study one, in the second scenario, all simulations are based on actual number of occupants with unit of "people" instead of "m2/person". All details are expressed in table 42.

	Number of occupants			
Space	**OSIM**	**ISO 18523-1-2016**	**ISO 17772-1-2017**	**ASHRAE**
Office 1-3-5-7-9-11	21 * 6 = 126	21 * 6 = 126	21 * 6 = 126	21 * 6 = 126
Office 2	13	13	13	13
Office 4-6-8-10-12	21 * 5 = 105	21 * 5 = 105	21 * 5 = 105	21 * 5 = 105
Bathroom	-	-	-	-
Meeting room * 6	-	-	-	-
Kitchen	-	-	-	-
Corridor	-	-	-	-
Guard room	4	4	4	4
Total number	248	248	248	248

Table 42. Second case study number of occupants based on actual number of people

Similar to case study 1. OSIM occupant numbers are similar in first and second scenarios. While in standard density of ASHRAE and ISO 17772-1-2017 there are less people than actual number which means the real occupant gain is higher than the one considered just by standard density value. For ISO 18523-1-2016 actual number of people are less than standard density. Thus, people gain will reduce in this case.

	Occupant gain comparison							
Space	**OSIM max Density [kWh]**	**OSIM max Actual [kWh]**	**ISO 18523 Density [kWh]**	**ISO 18523 Actual [kWh]**	**ISO 17772 Density [kWh]**	**ISO 17772 Actual [kWh]**	**ASHRAE Density [kWh]**	**ASHRAE Actual [kWh]**
Office 1-3-5-7-9-11	3571.8 * 6 = 21431.25	18570.1	7624.75 *6 = 45748.5	5228.8 * 6 = 31373.2	2538.72 * 6 = 15232.3	2959.7 * 6 = 17758.4	3742.82 * 6 = 22456.9	4769.132 * 6 = 28614.79
Office 2	1506.4	1807.3	3215.62	3236.92	1070.64	1832.2	1578.65	2952.32
Office 4-6-8-10-12	2425.3 * 5 = 12126.5	16367.3	5177.40 * 5 = 25887.0	5228.87 * 5 = 26144.3	1723.93 * 5 = 8619.65	2959.7 * 5 = 14798.7	2541.44 * 5 = 12707.2	4769.132 * 5 = 23845.66
Bathroom	-	-	-	-	-	-	615.69 * 6 = 3694.18	-
Meeting room * 6	282.92* 6 = 1697.54	-	171.0 * 6 = 1026.04	-	201.07 * 6 = 1206.44	-	296.41 * 6 = 1778.51	-
Kitchen	-	-	-	-	-	-	296.41 * 6 = 1778.51	-
Corridor	-	-	-	-	-	-	8199.44	-
Guard room	502.95	520.14	1073.44	995.976	-	563.76	526.944	908.406
Total number	37264.64	37264.7	76950.6	61750.4	26129.0	34953	52720.4	56321.17

Table 43.Second case study yearly occupant gain comparison

	People gain standard density [kWh]	People gain Actual number [kWh]	Difference percentage [%]
ASHRAE	52720.45	56321.17	+6.8 %
OSIM Max	37264.87	37264.87	-
OSIM Average	32277.74	32277.74	-
ISO 17772-1-2017	26129.07	34953.12	+33.8 %
ISO 18523-1-2016	76950.63	61750.51	-19.8 %

Table 44. Second case study total annual people gain - standard density and actual number of people

By increasing the number of occupants, the people gain, and total internal gain are increased except for OSIM results which has almost similar results in two conditions (table 44 and figure 77).

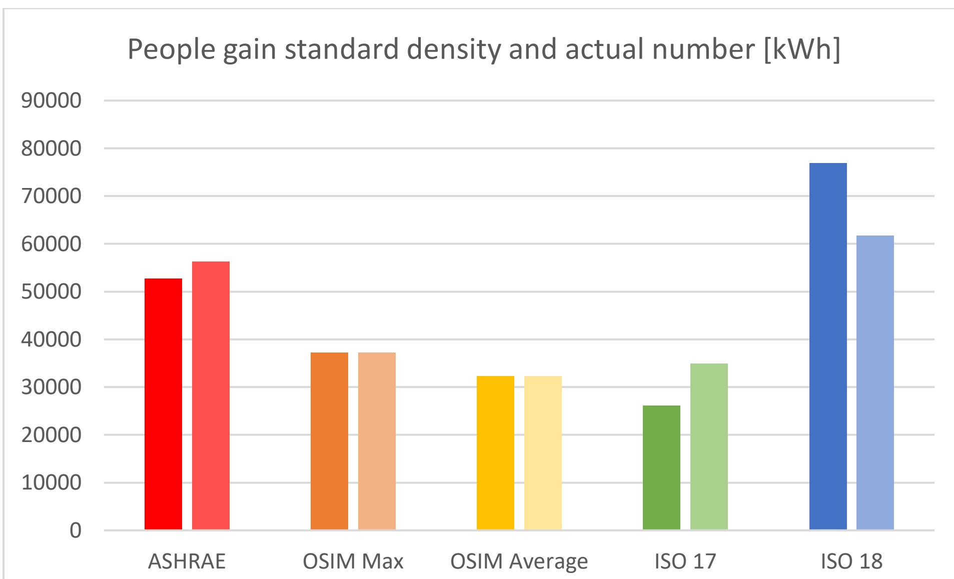


Figure 77. Second case study total annual people gain - standard density and actual number of people

As it was mentioned before, in OSIM simulations total annual people gain is the same in both first and second scenarios due to similar number of occupants. ASHRAE and ISO 17772-1-2017 people gain increases from 52720.45 kWh to 56321.17 kWh and from 26129.07 kWh to 34953.12 kWh respectively base on table 44. The value of ISO 18523-1-2016 decreases from 76950.63 kWh to 61750.51 kWh.

Tables 45 and 47, respectively, provide the total annual lighting and equipment gain comparison for each room based on its coefficient. The lighting installed power density is 3.750 W/m2/100 lux and the maximum sensible gain and maximum power consumption are 18.750 w/m2.

	Lighting gain comparison							
Space	**Coef**	**OSIM max [kWh]**	**Coef**	**ISO 18523-1-2016 [kWh]**	**Coef**	**ISO 17772-1-2017 [kWh]**	**Coef**	**ASHRAE [kWh]**
Office 1-3-5-7-9-11	500 lux	59829.65	750 lux	165894.2	500 lux	53948.86	10.76 W/m^2	58547.9
Office 2	500 lux	4205.422	750 lux	11660.78	500 lux	3792.017	10.76 W/m^2	4115.311
Office 4-6-8-10-12	500 lux	33854.38	750 lux	93869.17	500 lux	30526.69	10.76 W/m^2	39755.84
Bathroom * 6	15 W/m^2	7872.45	300 lux	11534.84	-	-	10.76 W/m^2	9629.389
Meeting room * 6	500 lux	4739.146	500 lux	6409.951	500 lux	4273.771	10.76 W/m^2	4638.818
Kitchen * 6	15 W/m^2	3790.876	300 lux	3703.12	-	-	10.76 W/m^2	4638.818
Corridor	15 W/m^2	17474.05	200 lux	17068.5	-	-	10.76 W/m^2	14746.52
Guard room	500 lux	1403.787	750 lux	3892.502	-	-	10.76 W/m^2	1373.875
Total number	133169.8		314033.1		92541.34		137446.5	

Table 45. Second case study yearly lighting gain comparison

	Lighting gain [kWh]
ASHRAE	137446.46
OSIM Max	133169.75
OSIM Average	115349.28
ISO 17772-1-2017	92541.33
ISO 18523-1-2016	314033.05

Table 46. Second case study total annual lighting gain

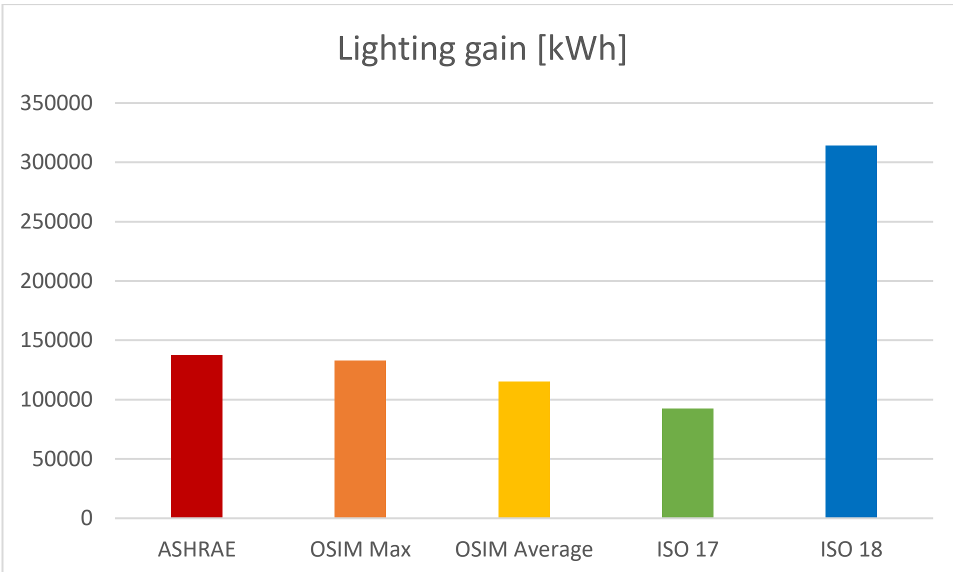


Figure 78. Second case study total annual lighting gain

	Equipment gain comparison							
Space	**Coef**	**OSIM [kWh]**	**Coef**	**ISO 18523-1-2016 [kWh]**	**Coef**	**ISO 17772-1-2017 [kWh]**	**Coef**	**ASHRAE [kWh]**
Office 1-3-5-7-9-11	12 w/m^2	38291.18	12 w/m^2	97488.24	12 w/m^2	34527.32	8.07 w/m^2	66633.15
Office 2	12 w/m^2	2691.54	2 w/m^2	6852.776	12 w/m^2	2427.065	8.07 w/m^2	4683.755
Office 4-6-8-10-12	12 w/m^2	21667.04	12 w/m^2	55163.31	12 w/m^2	19537.02	8.07 w/m^2	37703.82
Bathroom * 6	-	-	-	-	-	-	-	-
Meeting room * 6	12 w/m^2	3033.276	2 w/m^2	683.559	12 w/m^2	2279.574	-	-
Kitchen * 6	-	-	-	-	-	-	-	-
Corridor	-	-	-	-	-	-	-	-
Guard room	12 w/m^2	898.399	12 w/m^2	2287.149	12 w/m^2	810.1179	-	-
Total value	66581.44		162475		59226.90		109020.7	

Table 47. Second case study yearly equipment gain comparison

	Equipment gain [kWh]
ASHRAE	109020.72
OSIM Max	66581.44
OSIM Average	57671.98
ISO 17772-1-2017	59226.90
ISO 18523-1-2016	162475.03

Table 48. Second case study total annual equipment gain

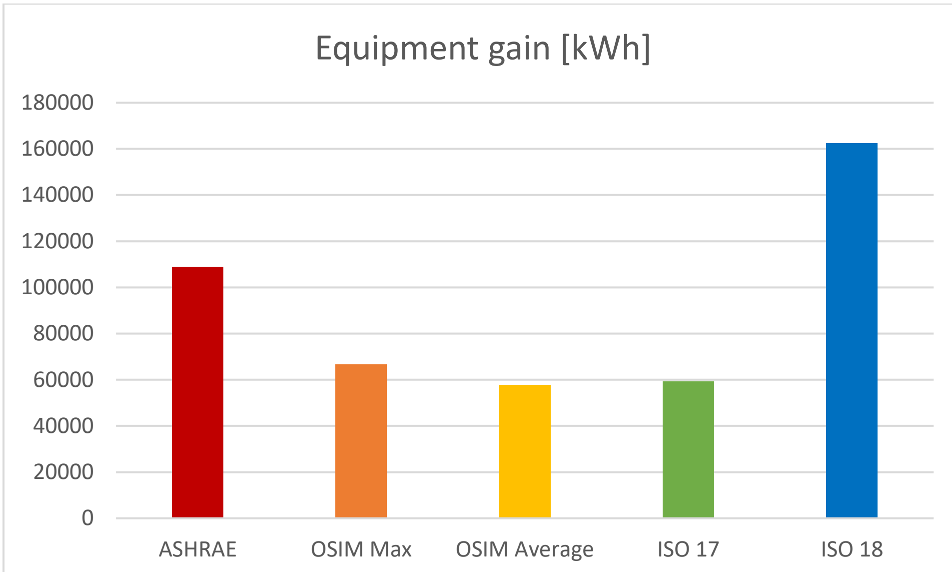


Figure 79. Second case study total annual equipment gain

As it was explained before, equipment gains depend on two factors: standard profile and appliances coefficient of usage. Considering these two factors, it can be concluded that ISO 18523-1-2016 has highest value of appliances gain with the value of 162475.03 kWh (table 48 and figure 79).

	Total internal gain comparison							
Space	**OSIM max Density [kWh]**	**OSIM max Actual [kWh]**	**ISO 18523 Density [kWh]**	**ISO 18523 Actual [kWh]**	**ISO 17772 Density [kWh]**	**ISO 17772 Actual [kWh]**	**ASHRAE Density [kWh]**	**ASHRAE Actual [kWh]**
Office 1-3-5-7-9-11	119552	117814.9	309130.6	294755.4	103709.3	106234.9	147637.5	153795.8
Office 2	8403.37	8928.895	21729.1	21750.4	7289.73	8051.3	10377.3	11751.11
Office 4-6-8-10-12	67647.9	71933.15	174919.5	175176.9	58683.3	64862	83540.4	94679.22
Bathroom * 6	7872.45	7872.45	11534.84	11534.84	-	-	13323.5	9629.389
Meeting room * 6	9469.91	7772.258	8119.55	7093.51	8215.07	7008.1	6417.08	4638.818
Kitchen * 6	3790.87	3790.876	3703.12	3703.12	-	-	6417.08	4638.818
Corridor	17474.0	16600.97	17068.5	17068.5	-	-	29572.1	21372.51
Guard room	2805.11	2302.176	7253.07	7175.57	810.11	2639.6	1900.76	3845.657
Total value	237015	237015	553458	538258.	177897	188796	299185	304351.3

Table 49. Second case study yearly internal gain comparison

	Internal gain standard density [kWh]	Internal gain Actual number [kWh]	Difference percentage [%]
ASHRAE	299185.78	304351.32	+1.7 %
OSIM Max	237015.67	237015.67	-
OSIM Average	205298.74	205298.74	-
ISO 17772-1-2017	177897.46	188796.72	+6.1 %
ISO 18523-1-2016	553458.38	538258.24	-2.7 %

Table 50. Second case study total annual internal gain – standard density and actual number

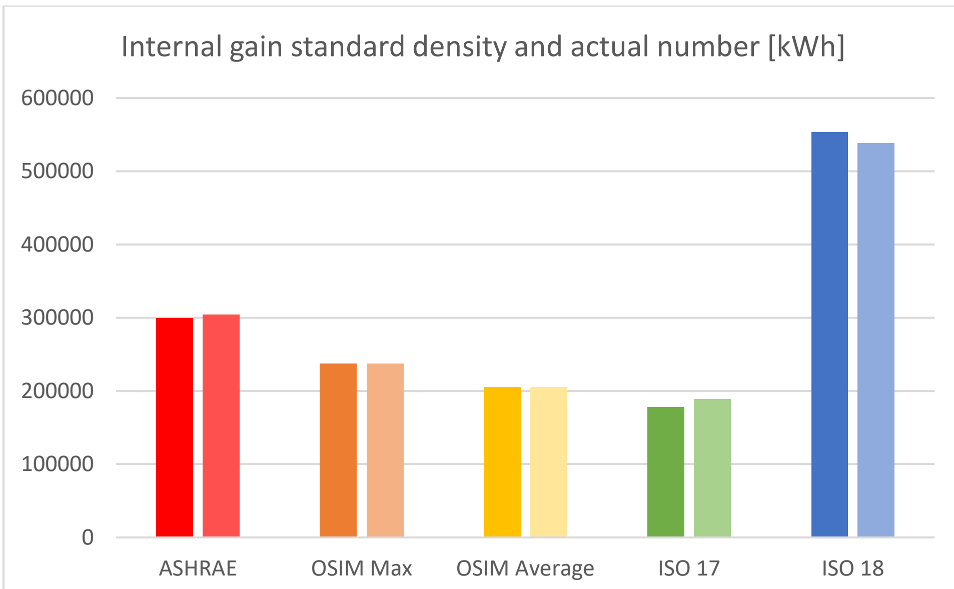


Figure 80. Second case study total annual internal gain – standard density and actual number

Total internal gain value for ASHRAE in first scenario by considering standard density of people is 299185.78 kWh and in second scenario by increasing the number of occupants is 304351.32 kWh (table 50 and figure 80). In ISO 17772-1-2017 also the total internal gain in first scenario (standard density of people) is 177897.46 kWh and in second scenario (actual number of people) it is 188796.72 kWh. OSIM simulations have similar internal gain and ISO 18523-1-2016 has reduction from 553458.38 kWh to 538258.24 kWh.

Case study 3 – Scenario one and two:

For both situations of standard density and actual number, the last case study results for internal gain, lighting, equipment, and people gains are expressed below. The time step for the annual results is one hour, and they are then totaled for the entire building. As a result, the building's annual gains rate is attained.

	Number of occupants			
Space	**OSIM**	**ISO 18523-1-2016**	**ISO 17772-1-2017**	**ASHRAE**
Single office type 1	1.26 * 15 = 19	2*15 = 30	2*15 = 30	1*15 = 15
Single office type 2	1.52 * 3 = 4.6	2.4*3 = 7.2	2.4*3 = 7.2	1.3 * 3 = 3.8
Single office type 3	1.9	3	3	1.6
Landscape office 1	2.53 * 2 = 5.1	4*2 = 8	2.3*2= 4.7	2.15 * 2 = 4.3
Landscape office 2	2.9	4.6	2.7	2.4
Landscape office 3	3.54	5.6	3.3	3
Bathroom 1	-	-	-	0.5
Bathroom 2	-	-	-	1
corridor	-	-	-	11
Total number	37	58.4	50.9	42.6

Table 51. Third case study number of occupants based on standard density of people

in the second scenario, all simulations are based on actual number of occupants with unit of "people" instead of "m2/person" (table 52). OSIM has same number of people and the other standards have less people in actual scenario compared with standard density of occupant.

	Number of occupants			
Space	**OSIM**	**ISO 18523-1-2016**	**ISO 17772-1-2017**	**ASHRAE**
Single office type 1	15*1 = 15	15*1 = 15	15*1 = 15	15*1 = 15
Single office type 2	1*3 = 3	1*3 = 3	1*3 = 3	1*3 = 3
Single office type 3	2	2	2	2
Landscape office 1	4*2 = 8	4*2 = 8	4*2 = 8	4*2 = 8
Landscape office 2	4	4	4	4
Landscape office 3	5	5	5	5
Bathroom 1	-	-	-	-
Bathroom 2	-	-	-	-
corridor	-	-	-	-
Total number	37	37	37	37

Table 52. Third case study number of occupants based on Actual number of people

Space	Occupant gain comparison							
	OSIM max Density [kWh]	**OSIM max Actual [kWh]**	**ISO 18523 Density [kWh]**	**ISO 18523 Actual [kWh]**	**ISO 17772 Density [kWh]**	**ISO 17772 Actual [kWh]**	**ASHRAE Density [kWh]**	**ASHRAE Actual [kWh]**
Single offices	2875.14	2091.02	9070.42	4979.88	5134.26	2818.8	4452.75	4542.03
Landscape offices	1318.3	2117.36	4158.80	4232.89	1384.78	2395.9	2041.54	3860.725
Bathrooms	0	0	0	0	0	0	320.410	0
Corridor	0	0	0	0	0	0	2354.72	0
Total value	4193.44	4208.38	13229.2	9212.77	6519.04	5214.7	9169.43	8402.75

Table 53. Third case study yearly occupant gain comparison

The number of people in ISO 18523-1-2016 is reduced by 21.4 people. Thus, there is a decrease in occupant gain from 13229.2 kWh to 9212.77 kWh. In ISO 17772-1-2017 the reduction is 13.9 people leading to 1304.34 kWh reduction in people internal gain. The third simulation for ASHRAE also has a difference of 766.68 kWh by reduction of 5.6 people. Finally, OSIM results has similar value because the number of people inside stays about the same.

	People gain standard density [kWh]	People gain Actual number [kWh]	Difference percentage [%]
ASHRAE	9169.43	8402.75	-8.4%
OSIM Max	4193.44	4208.38	-
OSIM Average	3416.31	3454.24	-
ISO 17772-1-2017	6519.04	5214.78	-20.0%
ISO 18523-1-2016	13229.22	9212.77	-30.4%

Table 54. Third case study total annual people gain - standard density and actual number of people

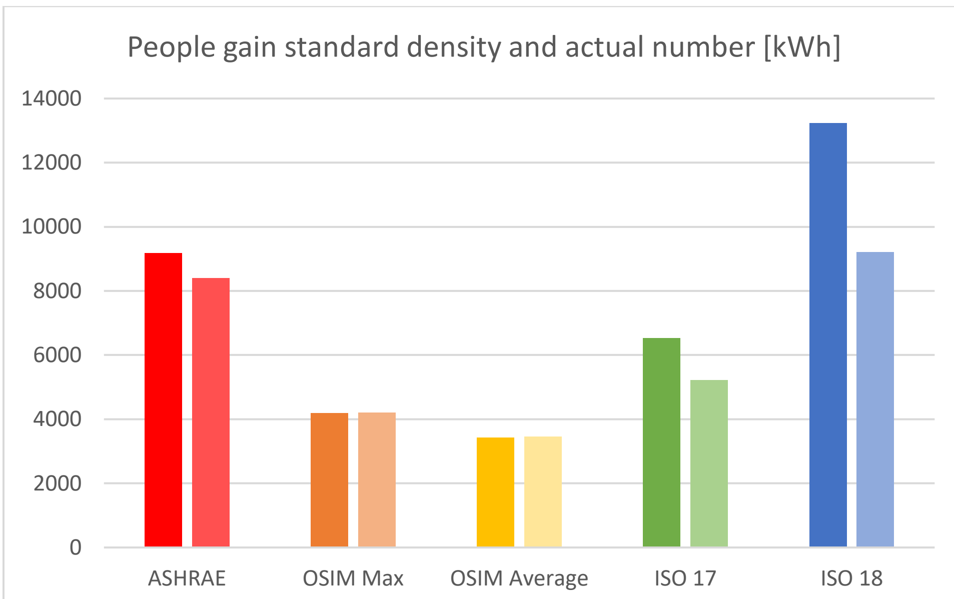


Figure 81.Third case study total annual people gain - standard density and actual number of people

The lighting installed power density is 3.750 W/m2/100 lux and the maximum sensible gain and maximum power consumption are 18.750 w/m2.

	Lighting gain comparison							
Space	**Coef**	**OSIM max [kWh]**	**Coef**	**ISO 18523-1-2016 [kWh]**	**Coef**	**ISO 17772-1-2017 [kWh]**	**Coef**	**ASHRAE [kWh]**
Single offices	500 lux	9452.58	750 lux	32891.17	500 lux	10696.67	10.76 W/m2	11607.88
Landscape offices	500 lux	4334.07	750 lux	15081.02	500 lux	4904.373	10.76 W/m2	5322.88
Bathrooms	15 W/m^2	544.32	300 lux	1000.596	-	-	10.76 W/m2	835.50
Corridor	15 W/m^2	3999.056	200 lux	4902.546	-	-	10.76 W/m2	6138.77
Total value	18330.03		53875.33		15601.04		23905.06	

Table 55. Third case study yearly lighting gain comparison

	Lighting gain [kWh]
ASHRAE	23905.05
OSIM Max	18330.03
OSIM Average	14932.81
ISO 17772-1-2017	15601.04
ISO 18523-1-2016	53875.33

Table 56. Third case study total annual lighting gain

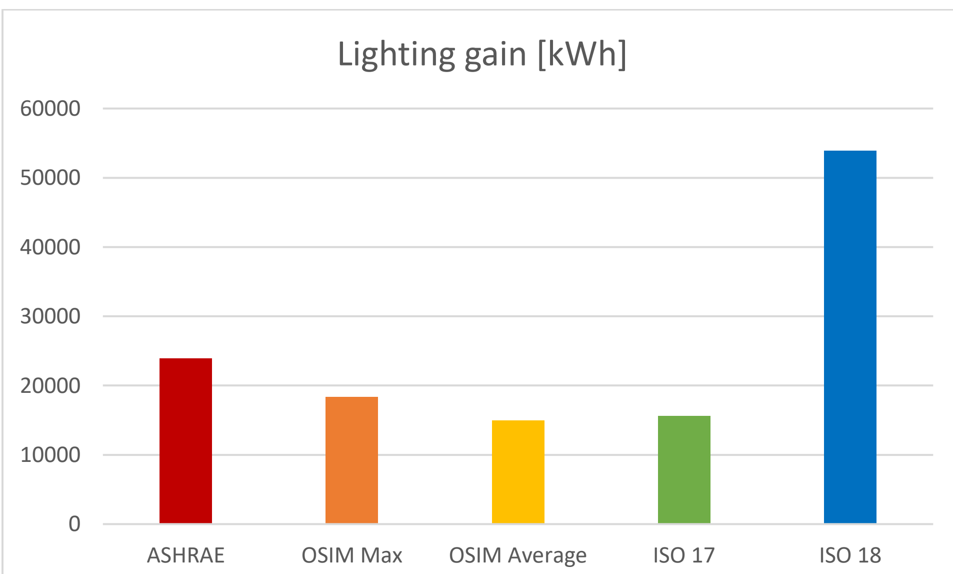


Figure 82. Third case study total annual lighting gain

	Equipment gain comparison							
Space	**Coef**	**OSIM [kWh]**	**Coef**	**ISO 18523-1-2016 [kWh]**	**Coef**	**ISO 17772-1-2017 [kWh]**	**Coef**	**ASHRAE [kWh]**
Single offices	12 w/m2	6049.87	12 w/m2	19329.63	12 w/m2	6846.03	8.07 W/m2	13210.67
Landscape offices	12 w/m2	2773.88	12 w/m2	8862.60	12 w/m2	3138.78	8.07 W/m2	6057.986
Bathrooms	-	0	-	-	-	-	-	-
Corridor	-	0	-	-	-	-	-	-
Total value	8823.75		28192.24		9984.81		19268.66	

Table 57. Third case study yearly Equipment gain comparison

	Equipment gain [kWh]
ASHRAE	19268.65
OSIM Max	8823.75
OSIM Average	7188.28
ISO 17772-1-2017	9984.82
ISO 18523-1-2016	28192.23

Table 58.Third case study total annual Equipment gain

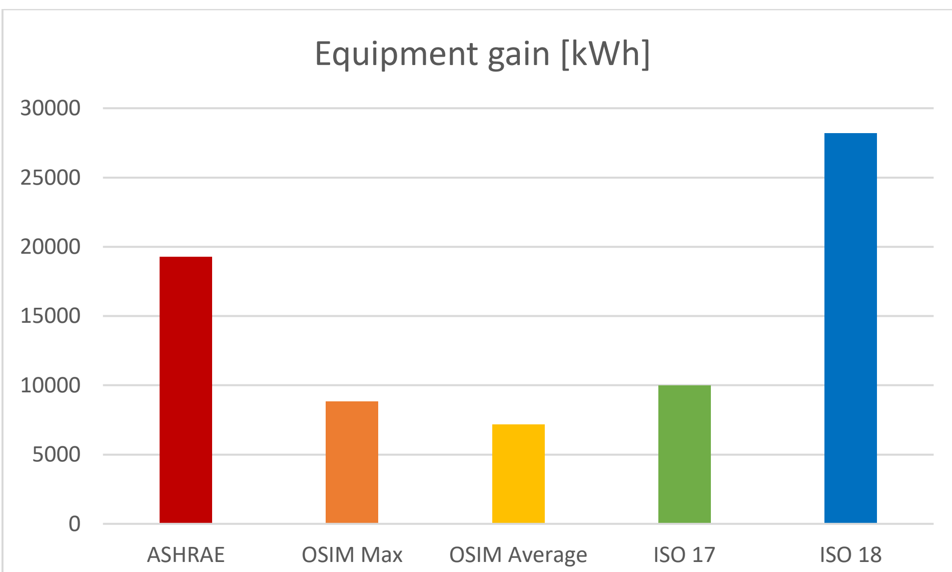


Figure 83. Third case study total annual Equipment gain

	Total internal gain comparison							
Space	**OSIM max Density [kWh]**	**OSIM max Actual [kWh]**	**ISO 18523 Density [kWh]**	**ISO 18523 Actual [kWh]**	**ISO 17772 Density [kWh]**	**ISO 17772 Actual [kWh]**	**ASHRAE Density [kWh]**	**ASHRAE Actual [kWh]**
Single offices	18377.6	17993.57	61290.9	57200.4	22676.7	20361	29271.4	29360.88
Landscape offices	8426.38	9225.34	28102.2	28176.5	9428.18	10439	13421.7	15241.1
Bathrooms	544.32	544.32	1000.59	1000.59	-	-	1155.76	835.5083
Corridor	3999.05	3999.056	4902.54	4902.54	-	-	8493.44	6138.77
Total value	31347.4	31762.2	95296.3	91280.1	32104.9	30800	52342.4	51576.26

Table 59. Third case study yearly internal gain comparison

	Internal gain standard density [kWh]	People gain Actual number [kWh]	Difference percentage [%]
ASHRAE	52342.40	51576.26	-1.5%
OSIM Max	31347.40	31762.29	-
OSIM Average	25537.21	25875.25	-
ISO 17772-1-2017	32104.95	30800.53	-4.1%
ISO 18523-1-2016	95296.35	91280.16	-4.2%

Table 60. Third case study total annual internal gain – standard density and actual number

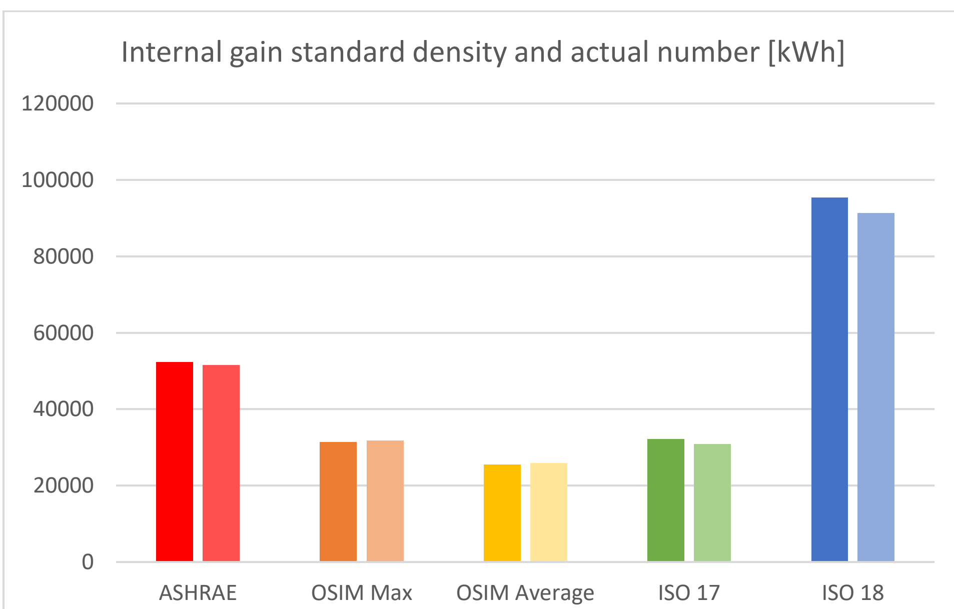


Figure 84.Third case study total annual internal gain – standard density and actual number

Discussion and conclusion

Static profiles of internal gain in multifarious standards for internal load calculations of building loads is the typical method used in building energy modeling. But nowadays, dynamic profiles considered as more precise method of energy simulation due to the fact that it has proposed realistic situation specially for people movements and presence. OSIM software is a new web-based software which can produce dynamic profile of occupants. These profiles can be used in energy modeling software such as EnergyPlus and IESVE. The aim of this thesis is to investigate a complete comparison of different standards' profile and OSIM dynamic profile for internal gain loads in three different office buildings. For this purpose, each standard's profile and consumption coefficient of appliances and lighting and people is applied for each case study. Simultaneously, the dynamic profile of OSIM software also applied in the case studies and the results are compared with each other.

As it is explained in table 61 and figure 85 of case study 1, for equipment gain highest value is 28087 kWh in ISO 18523-1-2016 and the second highest value refers to ASHRAE standard with the value of 22211.24 kWh. The minimum value is 9968.52 kWh for ISO 17772-1-2017. OSIM max and OSIM average have the average value among the other standards with values of 10064.1 kWh for average intensity and 14034.88 kWh for maximum intensity. For lighting gain again highest value is for ISO 18523-1-2016 with the value of 56542.49 kWh and minimum value which belongs to ISO 17772-1-2017 is 15575.62 kWh. In lighting gain OSIM max has higher value than ASHRAE and OSIM average. But OSIM average has the value of 23662.97 kWh which again is the average value among other standards. For people gain OSIM max and OSIM average has the minimum value because it considers actual number of people of the case study. Other standards have higher value because they consider standard density of people which leads to a greater number of people in standard density condition. As it is shown in the figure 85 considering actual number of people scenario (scenario 2) all values regarding people gain in different standards are close because of having same number of people. Obviously, those values are not equal due to differences in the profiles of occupant in each standard. In general, total internal gain should be considered as the conclusion for the case study because it includes all the gains together for the whole building. Based on the table 61, maximum value of internal gain refers to ISO 18523-1-2016 88613.86 kWh and the second highest value is for ASHRAE with the number of 52664.65 kWh. Minimum value goes to ISO 17772-1-2017 which is 29744.38 kWh. OSIM has an average value among others which is 42542.03 kWh and 36054.54 kWh for OSIM max and average respectively.

As it was mentioned before, standard density is the scenario in which people density coefficient [w/m2] that is multiplied into the profile of space is based on the standard not actual number of people in the case study. On the other hand, actual number scenario is when the exact number of people for each space in the case study is multiplied into the profile of the space. Because there is a difference in number of people considering standard density scenario and actual number scenario, the people gain in these two scenarios are different. Finally total internal gain which includes people gain will be multifarious in each scenario.

Case study 1						
	people gain standard density [kWh]	people gain actual number [kWh]	lighting gain [kWh]	equipment gain [kWh]	internal gain standard density [kWh]	internal gain actual number [kWh]
ASHRAE	10287.14	3633.62	26939.96	22211.24	59435.87	52664.65
OSIM Max	2620.42	2634.2	28374.1	14034.88	43062.07	42542.03
OSIM Average	2185.31	2364.88	23662.97	10064.2	35912.46	36054.54
ISO 17772-1-2017	5348.85	2255.04	15575.62	9968.52	30893.26	29744.38
ISO 18523-1-2016	13621.45	3983.9	56542.49	28087.54	98251.44	88613.86

Table 61. First case study - summary of all gains in different standards

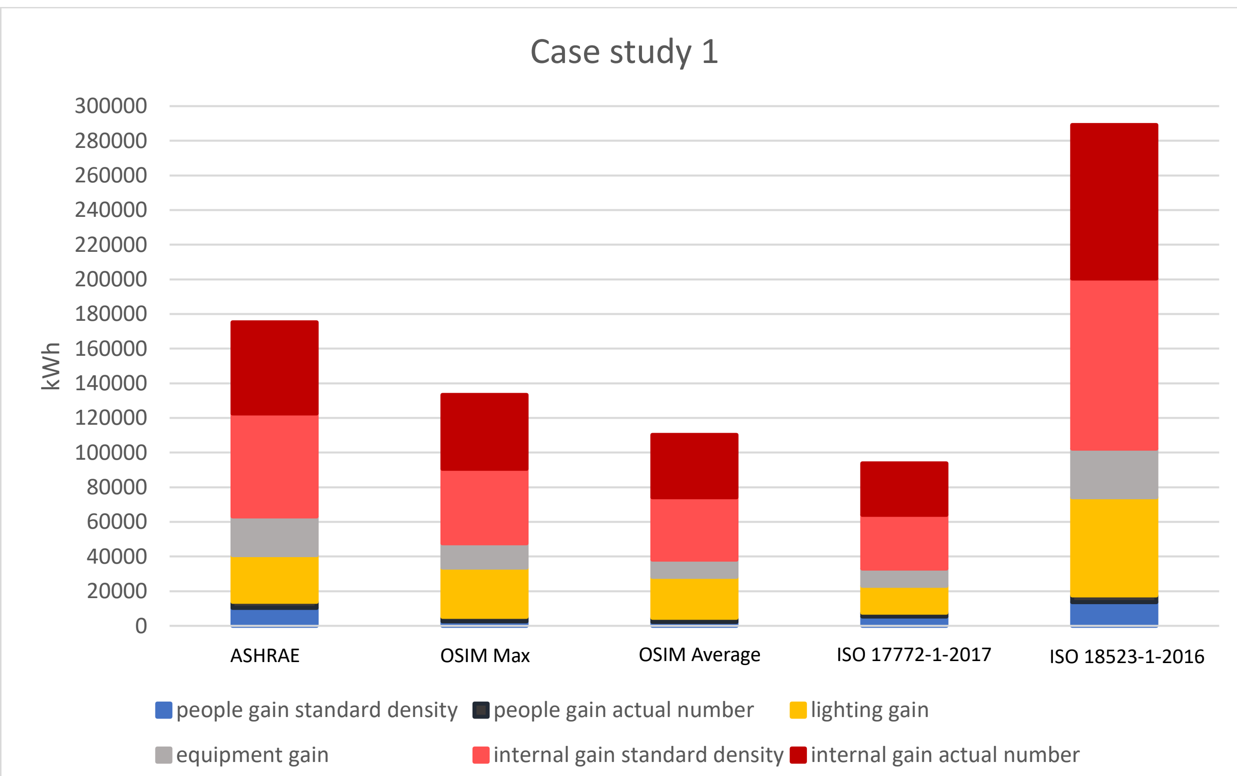


Figure 85. First case study - summary of gains in different standards

Case study 1		
Standard	**Internal gain standard density value [kWh]**	**Percentage**
ISO 18523-1-2016	98251.44	100 %
ASHRAE	59435.87	60.49 %
OSIM Max	43062.07	43.83 %
OSIM Average	35912.46	36.55 %
ISO 17772-1-2017	30893.26	31.44 %

Table 62. First case study - total internal gain percentage comparison

Table 62 represents the percentage of each standard based on considering the highest value of ISO 18523-1-2016 as 100%. The minimum percentage refers to ISO 17772-1-2017 which is 31.44%. OSIM max and average present the percentage of 43.83 % and 36.55 % respectively.

In case study 2, similar to case study 1, internal gain represents sum of all gains in the building. The highest value of internal gain belongs to ISO 18523-1-2016 that is 553458.38 kWh. The second highest value is for ASHARE with the number of 299185.78 kWh. OSIM max is 237015.67 kWh and OSIM average is 205298.74 kWh. Minimum value is 177897.46 which refers to ISO 17772-1-2017. Table 63 and figure 86 represent details of all gains for case study 2.

Case study 2						
	people gain standard density [kWh]	**people gain actual number [kWh]**	**lighting gain [kWh]**	**equipment gain [kWh]**	**internal gain standard density [kWh]**	**internal gain actual number [kWh]**
ASHRAE	52720.45	56321.17	137446.46	109020.72	299185.78	304351.32
OSIM Max	37264.87	37264.87	133169.75	66581.44	237015.67	237015.67
OSIM Average	32277.74	32277.74	115349.28	57671.98	205298.74	205298.74
ISO 17772-1-2017	26129.07	34953.12	92541.33	59226.9	177897.46	188796.72
ISO 18523-1-2016	76950.63	61750.51	314033.05	162475.03	553458.38	538258.24

Table 63. Second case study- summary of gains in different standards

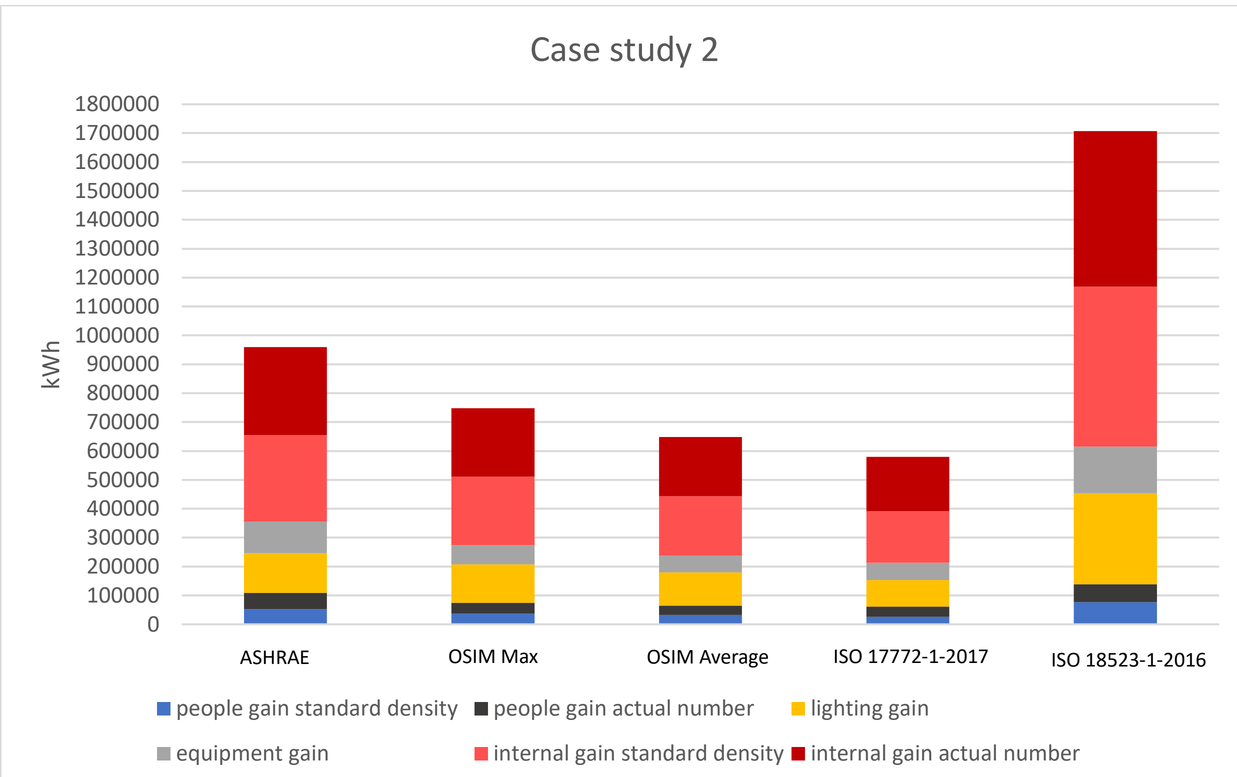


Figure 86. Second case study- summary of gains in different standards

Case study 2		
Standard	**Internal gain standard density value [kWh]**	**Percentage**
ISO 18523-1-2016	553458.4	100 %
ASHRAE	299185.8	54.06 %
OSIM Max	237015.7	42.82 %
OSIM Average	205298.7	37.09 %
ISO 17772-1-2017	177897.5	32.14 %

Table 64. Second case study - total internal gain percentage comparison

Based on table 64, ISO 18523-1-2016 represents the percentage of 100%. ISO 17772-1-2017 has minimum percentage of 32.14%. OSIM is representative of 42.82% and 37.09% which is the average value among other standards.

By evaluating of all gains and internal gain in case study 3, ISO 18523-1-2016 again has the highest value and ASHRAE represents the second highest value of gain. Unlike to previous case studies, in case study 3 the minimum value of internal gain goes to OSIM average with the value of 25537.21 kWh. ISO 17772-1-2017 and OSIM max have close value which are 32104.95 kWh and 31347.4 kWh respectively (table 65 and figure 87).

Case study 3						
	people gain standard density [kWh]	**people gain actual number [kWh]**	**lighting gain [kWh]**	**equipment gain [kWh]**	**internal gain standard density [kWh]**	**internal gain actual number [kWh]**
ASHRAE	9169.43	8402.75	23905.05	19268.65	52342.4	51576.26
OSIM Max	4193.44	4208.38	18330.03	8823.75	31347.4	31762.29
OSIM Average	3416.31	3454.24	14932.81	7188.28	25537.21	25875.25
ISO 17772-1-2017	6519.04	5214.78	15601.04	9984.82	32104.95	30800.53
ISO 18523-1-2016	13229.22	9212.77	53875.33	28192.23	95296.35	91280.16

Table 65. Third case study- summary of gains in different standards

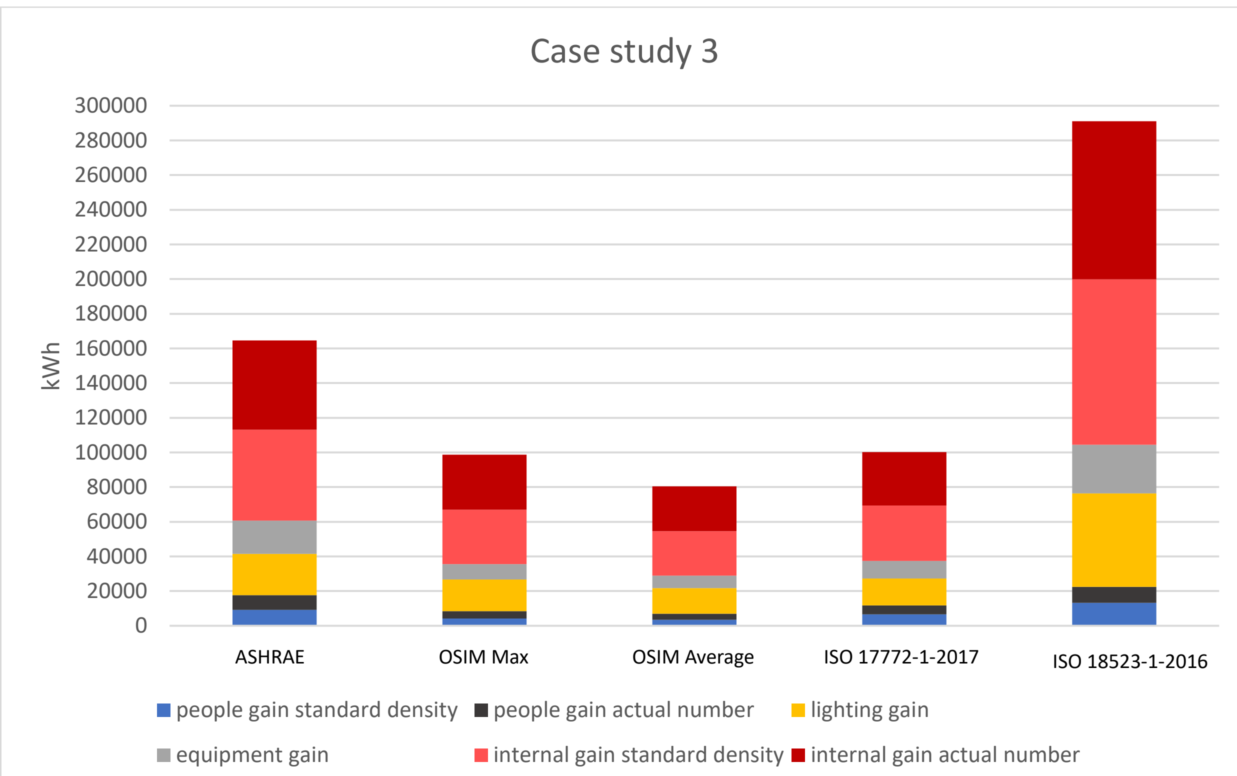


Figure 87. Third case study- summary of gains in different standards

Case study 3		
Standard	**Internal gain standard density value [kWh]**	**Percentage**
ISO 18523-1-2016	95296.35	100 %
ASHRAE	52342.4	54.93 %
ISO 17772-1-2017	32104.95	33.69 %
OSIM Max	31347.4	32.89 %
OSIM Average	25537.21	26.80 %

Table 66. Third case study - total internal gain percentage comparison

Based on the results taken from IESVE, it can be concluded that ISO 18523-1-2016 profile expresses the highest value regarding internal gain load in all sectors of people, lighting, and equipment. ASHRAE profiles has the second highest value of internal gain. On the other hand, ISO 17772-1-2017 profile represent the least value for internal loads. The average results of OSIM software are closed to ISO 17772-1-2017 standards. But the maximum results of OSIM software is more conservative compared to ISO 17772-1-2017 and average results of OSIM.

In general, it can be concluded that by considering different standard for the same case study, achievement is various based on the profile of the standard which is applied and coefficients of lighting, appliances usage and people density of people. Therefore, each factors have an important role to acquire accurate results. Applying OSIM software profiles not only provides dynamic simulation of people which considers movement and presence of people, but also by comparing the results it can be defined as an average profile among ISO 17772-1-2017, ISO 18523-1-2016 and ASHRAE standards. This means that OSIM software supply a reasonable and sensitive profiles which is suitable to get internal gain loads in more realistic situation which leads to precise heating and cooling load calculations for buildings.

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