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ASSESSING THE IMPACT OF GREEN ROOF ON THE BUILDING PERFORMANCE A CASE STUDY OF OUTPATIENT PEDIATRIC CLINICS IN LEBANON

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Keywords: Beirut; Design Builder; Building Performance Simulation; Green Roof; Heat Gain/ loss;

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Abstract

Several studies have proved that incorporating the use of green roofs can optimize overall building performance and increase the building's energy efficiency. This review targets different scenarios of green roof as a solution in addition to studying its various types and their effect in order to better optimize the results. With a structured analysis and cohesive interpretations through simulations and analytical cooling design extracted from EnergyPlus modeler, findings were assessed, and a conclusion was set to choose the best scenario. In addition to, other parameters that were taken into consideration which specifies the level of the green roof covered area along the whole space. This paper is a mere motive to demonstrate that simple changes that are innovative and sustainable can affect the long-term energy efficiency of the building. By Such, the simulated five scenarios demonstrated and tested showed that covering basic roof with 70% of total roof area with green intensive roof, was proven to increase the zone sensible cooling from an average of -49.478, scenario one, to -24.47 kW, scenario five, in the main waiting area.

Keywords

Beirut; Design Builder; Building Performance Simulation; Green Roof; Heat Gain/ loss;

1. Introduction

1.1 Assessing building performance specifically addressing the heat gain/ loss in addition to the heat balance of the main waiting space with Green Roof vs. Non-Green Standard Roof.

Green roof installation has been used as a sustainable approach for many years in order to reduce the adverse environmental effects imposed on the total building performance. This technique's implementation is being more advised recently, by the developed countries, on the new ongoing design projects, where new laws are set for building projects due to its environmental and economic effects on the environment in both urban and rural areas. This study presents the variations that are taking place in my main waiting hall such as the heat balance, due to having this floor's roof exposed directly to the exterior environment. Choosing green roof as an example for this simulation, having that it being a suitable choice when the green to build- up area ratio is quite low.

1.2. Literature Review

The review of the literature was based on publications indexed to the web of science. Advanced search tools were used, and the search terms selected were "Green Roofs" and "Passive Roof Solutions". Such research topic was firstly discussed dating back to the late 1980s named "Thermal performance of - still on roof- system", where the paper discussed heat flux of the roof on the interior space and it was conducted in Delhi, India. By far, around 5,370 publications on the presented topic where published online (1980 -2020), having most of them discuss the effects of green roof implementation and its effect on the building performance.

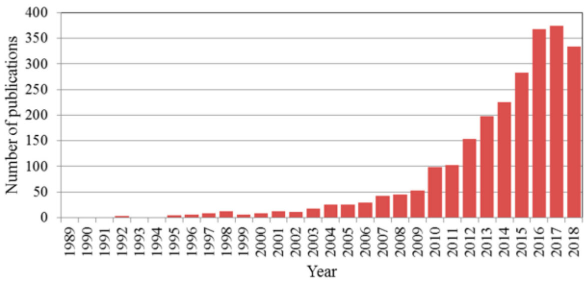


Fig.1: Percentage of academic publications per country Source: Suszanowicz, et. al.,2019

In the past 40 years, USA scores the highest number of research papers published on the respective topics (over 20% of all globally published works), followed by China and Italy. It is also important to note out, that others represent the total 64 countries of the world that were not mentioned in the adjacent graph 1. Green roof components with rock wool showed low thermal transmittance values (Kotsiris, et. al, 2012). Moreover, semi-intensive green-roof are more efficient compared with full-extensive for outdoor temperature and cooling demand reduction. (Morakinyo, et. al, 2017). Green Roof in cities absorbs the air pollutants and improve the oxygen production and the roof surface insulation (Suszanowicz, et. al., 2019). It is also worth mentioning that numerous authors have issued results of simulations of model behavioral studies on green roofs. Kumar, V. (2017) has assessed the impact of soil depth, plant height, leaf reflectivity on the green roof performance using Design builder software. Green infrastructural strategy reduces the outdoor air temperature by 4 to 5 PET°C and can mitigate the urban heat island in Beirut which has been optimized using ENVI met urban modelling tools (Mohsen, et. al., 2016).

2. Methodology and data sources

2.1. Experimental setup / Input Data

This parametric study is carried out on a small sized roof top (of 1800 m2 roof footprint) of an outpatient clinic two story building. This prototype was modeled as a code compliant building using energy model simulation software – Design builder- following the ASHRAE Standard 90.1-2016, for building envelope information. The input database scenarios (Table A), were defined for the type of roofs used, in addition to the coverage percentage area of the given roof space. Adiabatic buildings, for the surrounding context, were situated into the building context as well, yet they are not the included as an objective to be studied in this study in particular.

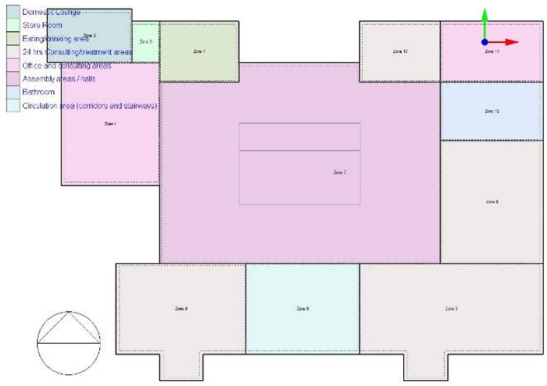


Fig.2: Ground Floor Activity

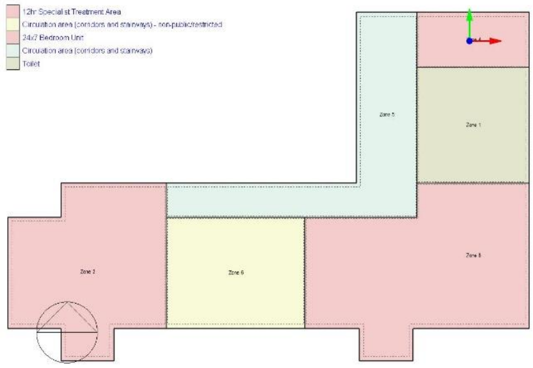


Fig.3: First Floor Activity

The model was divided into thermal zones, with additional setting up of the activity that is taking place in each thermal zone – figures 2,3, such activities ranged from 6 clusters of clinics with their respective waiting area, main gathering hall, cafeteria, storages, and working offices. In addition, fenestrations were distributed along the building envelope as mentioned according to the ASHRAE Standard 90.1-2016, with a skylight 60 m_2 centered in the main waiting space.

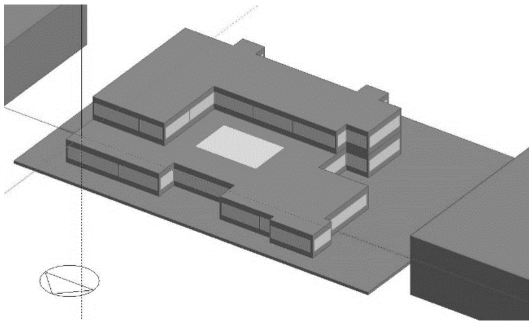


Fig. 4: Modeled Block Perspective

* A. 70 % was taken as a full covering green percentage of ground floor since the skylight takes around 30% from the Total roof area, totaling both up to 100 percent.

B. The study was carried out during mid- summer days where temperature and outdoor heat reach its peak. That is why, the future design suggestions will be designed according to the peak timing.

2.2. Simulation Scenarios

Table 1: Scenarios' Technical Information

Scenario Name	Description	Variables properties
Scenario 1	Flat Roof - Energy Code Standard – Medium Weight Concrete	Reinforced Concrete slab
Scenario 2	50% Covered Green Roof	50% Area Green roof
Scenario 3	70% Covered Green Roof	70% Ares Green roof
Scenario 4	Intensive - Non- Vegetated Green Roof	More Layered Green roof
Scenario 5	Extensive - Vegetated Green Roof	Less layered Green Roof

The base case scenario is having a regular medium weight concrete roof which is widely popular and applicable in Lebanon, having it being regularly insulated. This case is suggested to represent the minimal effort when it comes to building energy saving that most of consultant and engineering firms are doing. And, to compare, later, these results with the results of a green roof solution.
The first three scenarios mentioned (in the above Table 1), where assessed and evaluated independently at first. The best scenario of the second and third addressed, which lead to the most effective cooling benefits, was then optimized and used to increase its efficiency with studying two more varying parameter which is the intensive and the extensive Green Roof system.

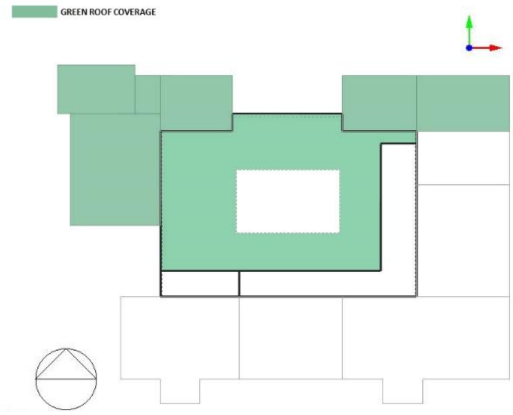


Fig.5: 70% Green Roof Area Coverage

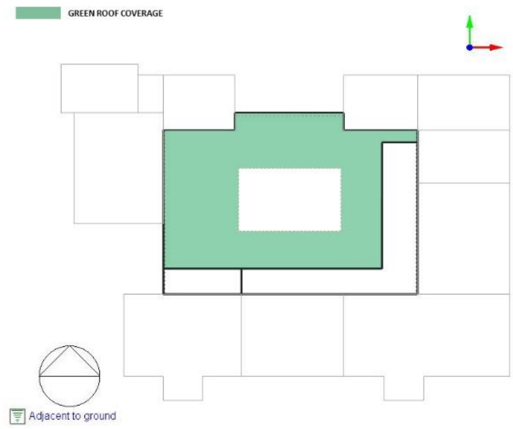


Fig. 6: 50% Green Roof Area Coverage

The input of intensive and extensive green roof was for the sake of studying the depth of roof and its effect imposed on the cooling design. Where, Extensive green roofs are thin-film systems, typically low weight, and are characterized by low maintenance demands. Intensive roofs, however, have a thick layer of substrate suitable for almost all types of plants and can be used for recreation and other purposes. [2]
Additionally, the flow of this experimental studies will be moving according to the following chart, starting with prototyping the model, comparing between the different scenarios, choosing the best result and optimizing it's efficiency based on the simulation's result, and finally analogy and conclusion.

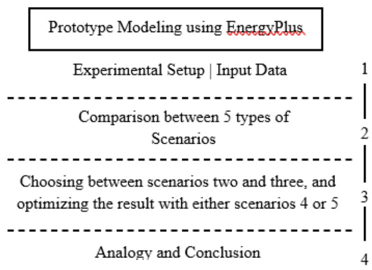


Fig.7: Methodology Flow Chart

3. Results and Discussion

3.1. Scenario 1 | Base Case Scenario

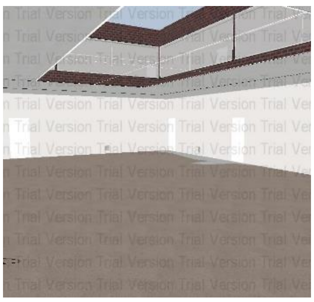


Fig.8: Zone 7 Interior Shot

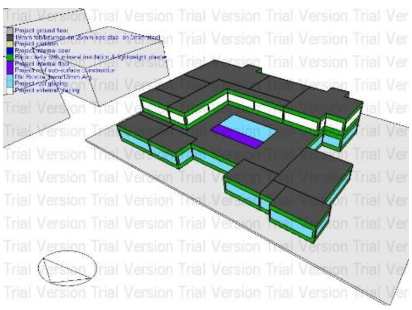


Fig.9: Scenario one Model Data

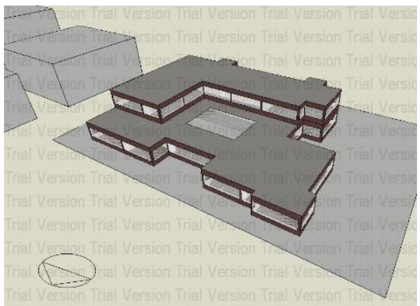


Fig.10: External Shot

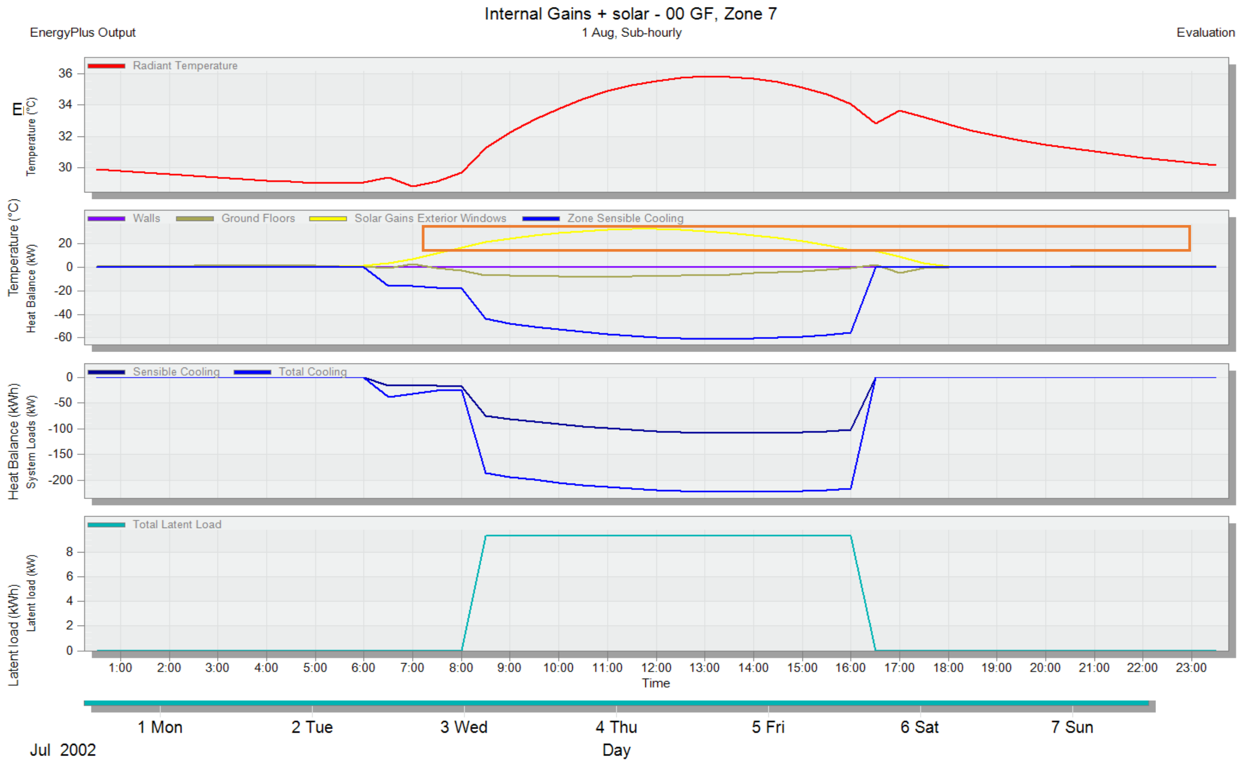


Fig. 11: Scenario 1 - Summer Design Data for Pediatric Clinic, 00 GF, Zone 7

Table 2: Scenario 1 - Simulation Data for Pediatric Clinic, 00 GF, Zone 7

Internal Gains + solar - 00 GF, Zone 7

EnergyPlus Output — 1 Aug, Sub-hourly — Evaluation

Time	2:00	4:00	6:00	8:00	10:00	12:00	14:00	16:00	18:00	20:00	22:00
Radiant Temperature (°C)	29.58	29.19	29.07	29.70	33.78	35.55	35.69	34.09	32.75	31.48	30.66
Walls (kW)	0.29	0.27	0.22	0.27	-0.23	-0.30	-0.20	0.03	-0.02	0.16	0.24
Ground Floors (kW)	1.07	1.17	0.58	-2.57	-7.80	-7.56	-5.12	-0.73	-0.01	0.38	0.67
Solar Gains Exterior Windows (kW)	0.00	0.00	1.48	16.92	29.33	32.60	27.38	14.65	0.74	0.00	0.00
Zone Sensible Cooling (kW)	0.00	0.00	0.00	-18.06	-53.08	-59.65	-60.83	-55.77	0.00	0.00	0.00
Sensible Cooling (kW)	0.00	0.00	0.00	-18.06	-91.77	-104.60	-109.03	-102.47	0.00	0.00	0.00
Total Cooling (kW)	0.00	0.00	0.00	-24.52	-204.62	-218.75	-223.31	-215.65	0.00	0.00	0.00
Total Latent Load (kW)	0.00	0.00	0.00	0.00	9.33	9.33	9.33	9.33	0.00	0.00	0.00

Table 3: Scenario 1 - Simulation Data for Pediatric Clinic, 00 GF, Zone 7

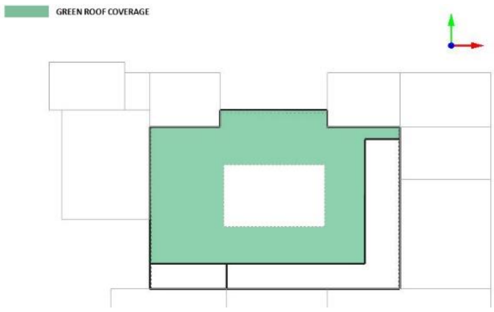
Internal Gains + solar - 00 GF, Zone 7

EnergyPlus Output — 1 Jul - 31 Aug, Daily — Evaluation

Day							
Radiant Temperature (°C)	31.10	31.29	30.87	30.81	31.21	32.05	32.60
Ground Floors (kWh)	-41.19	-42.43	-32.12	-37.90	-44.09	-54.06	-51.71
Solar Gains Exterior Windows (kWh)	279.27	279.85	268.29	275.09	277.04	278.46	277.87
Zone Sensible Cooling (kWh)	-479.79	-492.24	-463.04	-467.61	-480.42	-497.68	-513.97
Total Latent Load (kWh)	74.68	74.68	74.68	74.68	74.68	74.68	74.68

- Radiant temperature of the main waiting space reaches its peaks where it reaches 31 and 32 degrees in mid-summer days of July and august where outdoor temperature reaches its utmost.
- In addition, we can view that the values of solar gains are somehow staying at a constant value, though varying with a slight change, yet they are maintaining the 260 – 275 value.

3.1.2. Scenario 2 | 50% Green Roof Coverage



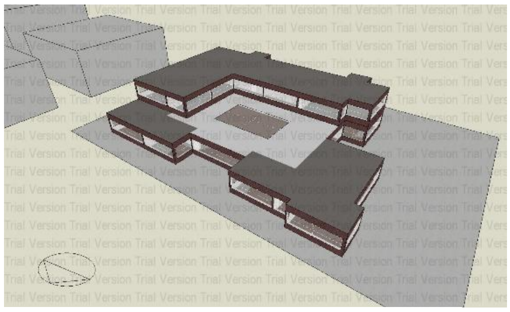


Fig. 12: Presence of 50% Green Roof Fig. 13: 50% Green Roof Area coverage

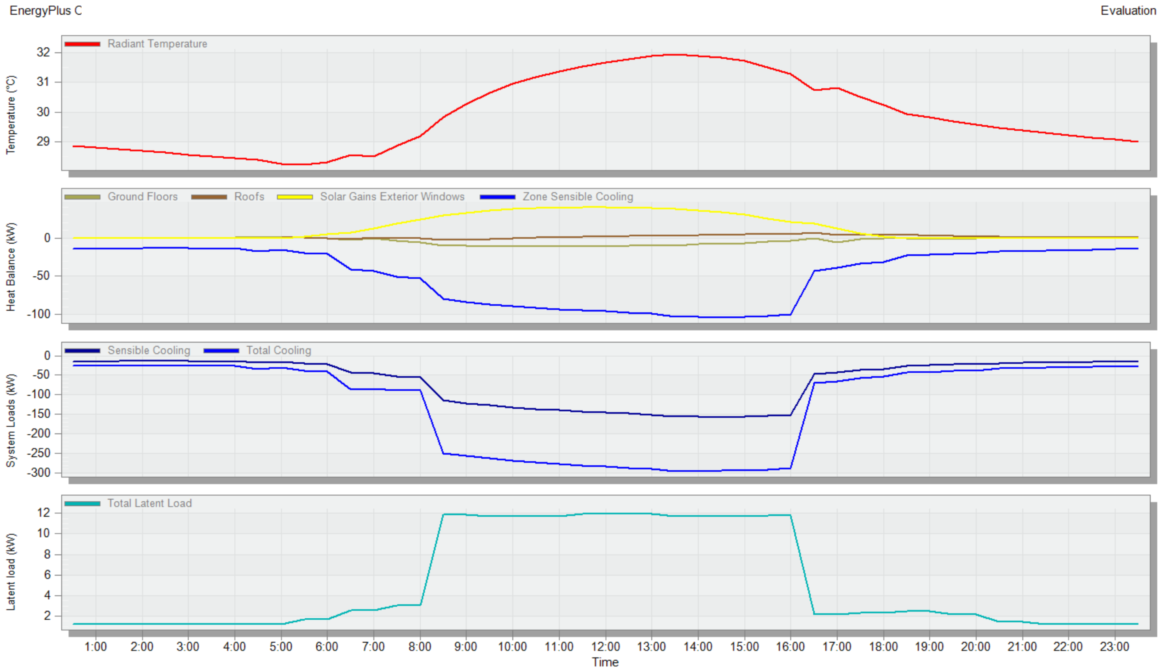


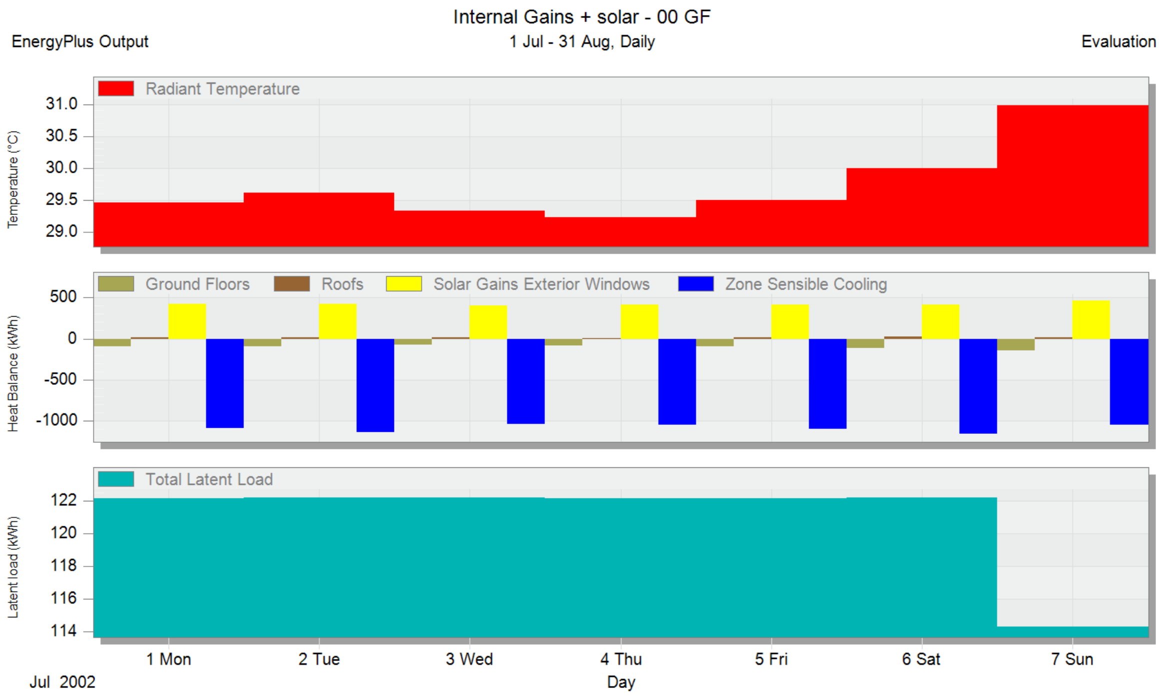
Fig.14: Scenario 2 -Summer Design Data for Pediatric Clinic, 00 GF

Table 4: Scenario 2 - Simulation Data for Pediatric Clinic, 00

Internal Gains + solar - 00 GF

EnergyPlus Output 1 Aug, Sub-hourly Evaluation

Time	2:00	4:00	6:00	8:00	10:00	12:00	14:00	16:00	18:00	20:00	22:00
Radiant Temperature (°C)	28.68	28.43	28.31	29.18	30.95	31.66	31.90	31.28	30.23	29.58	29.22
Ground Floors (kW)	-0.25	0.12	-0.72	-6.02	-11.34	-10.74	-8.44	-3.44	-1.00	-1.04	-0.76
Roofs (kW)	-0.14	-0.10	-0.70	-0.34	-0.73	2.01	4.04	5.05	4.03	1.71	0.53
Solar Gains Exterior Windows (kW)	0.00	0.00	4.74	24.60	37.81	39.86	35.92	20.80	1.73	0.00	0.00
Zone Sensible Cooling (kW)	-13.87	-13.78	-20.43	-52.94	-89.49	-96.16	-103.53	-99.54	-31.17	-20.06	-16.45
Sensible Cooling (kW)	-14.62	-14.44	-21.27	-55.63	-131.77	-145.70	-156.51	-150.85	-34.46	-22.24	-17.58
Total Cooling (kW)	-25.92	-26.15	-39.98	-88.38	-267.82	-283.68	-294.86	-287.58	-54.50	-37.90	-29.65
Total Latent Load (kW)	1.24	1.24	1.68	3.08	11.74	11.92	11.74	11.75	2.29	2.16	1.25



GF

Fig. 15: Simulation Data for Pediatric Clinic, 00 GF

Table 5: Simulation Data for Pediatric Clinic, 00 GF

Internal Gains + solar - 00 GF

EnergyPlus Output — 1 Jul - 31 Aug, Daily — Evaluation

Day							
Radiant Temperature (°C)	29.46	29.61	29.33	29.23	29.50	30.00	30.98
Ground Floors (kWh)	-92.84	-95.97	-77.95	-85.02	-96.42	-111.23	-144.45
Roofs (kWh)	12.99	19.22	11.13	9.81	16.86	21.57	14.23
Solar Gains Exterior Windows (kWh)	418.58	419.49	404.69	412.94	415.40	417.05	465.58
Zone Sensible Cooling (kWh)	-1089.65	-1135.16	-1034.69	-1045.64	-1100.05	-1154.85	-1052.36
Total Latent Load (kWh)	122.18	122.19	122.20	122.18	122.18	122.20	114.27

As noticed, the temperatures reach their minimum of 29.23 degrees and a maximum of around 31 degrees on non-working weekends.

Moreover, the roof heat balance is on increase with the progress of time, where heat balance got achieved when energy expenditure is equal to energy intake, resulting in minimal changes in the zone 7 body mass energy.

3.1.3. Scenario 3 | 70% Green Roof Coverage

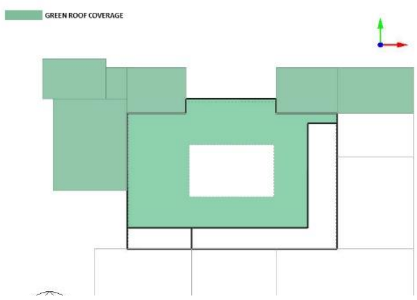


Fig. 16: Presence of 70% Green Roof

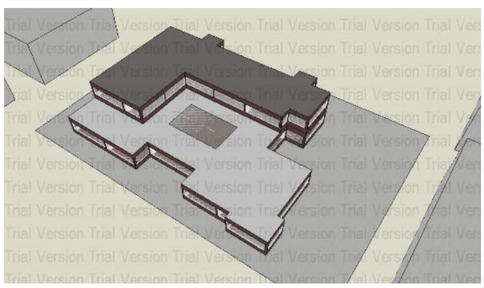


Fig. 17: 70% Green Roof Area Coverage

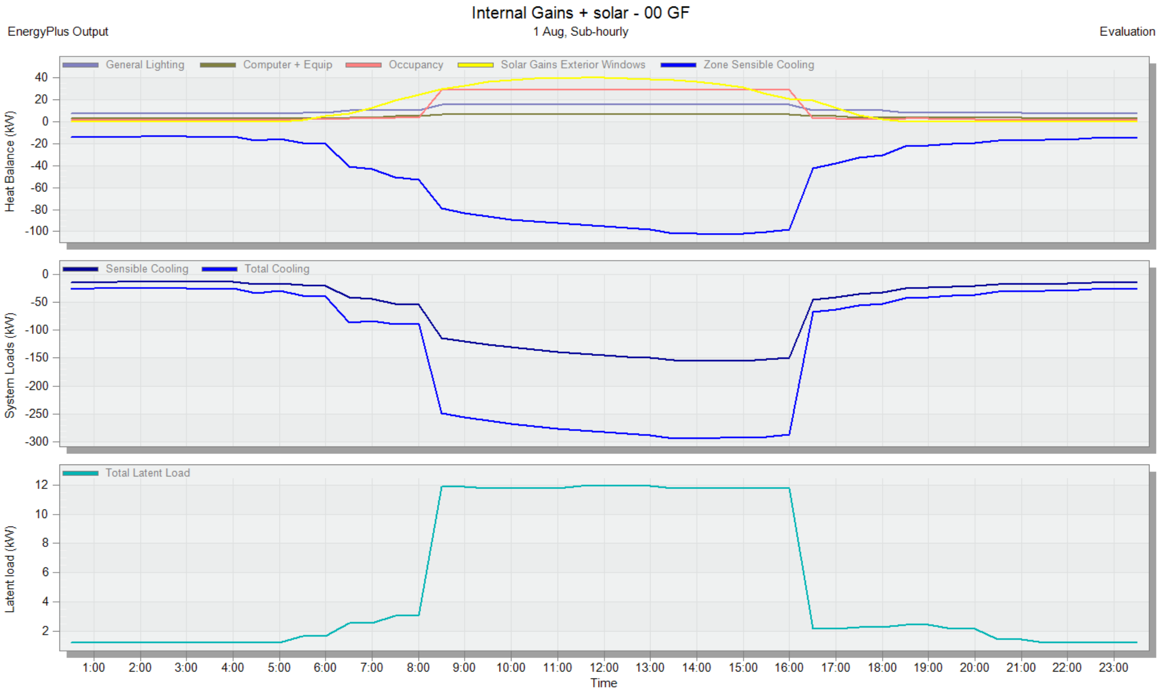


Fig. 18: Scenario 3 - Simulation Data for Pediatric Clinic, 00 GF

Table 6: Scenario 3 -Simulation Data for Pediatric Clinic, 00 GF

Internal Gains + solar - 00 GF

EnergyPlus Output — 1 Aug, Sub-hourly — Evaluation

Time	2:00	4:00	6:00	8:00	10:00	12:00	14:00	16:00	18:00	20:00	22:00
General Lighting (kW)	7.28	7.28	7.68	10.47	15.32	15.32	15.32	15.51	10.34	7.87	7.47
Computer + Equip (kW)	3.09	3.09	3.09	4.97	6.58	6.58	6.58	6.62	3.79	3.79	3.16
Occupancy (kW)	1.33	1.33	1.77	3.37	28.63	28.79	28.63	28.65	2.44	2.15	1.35
Solar Gains Exterior Windows (kW)	0.00	0.00	4.74	24.60	37.81	39.86	35.92	20.80	1.73	0.00	0.00
Zone Sensible Cooling (kW)	-13.86	-13.79	-20.46	-52.77	-88.91	-95.25	-102.12	-98.28	-30.33	-19.81	-16.36
Sensible Cooling (kW)	-14.62	-14.45	-21.30	-55.46	-131.19	-144.79	-155.10	-149.59	-33.62	-21.98	-17.50
Total Cooling (kW)	-25.91	-26.17	-40.03	-88.17	-267.18	-282.65	-293.41	-286.25	-53.57	-37.58	-29.56
Total Latent Load (kW)	1.24	1.24	1.68	3.08	11.74	11.92	11.74	11.75	2.29	2.16	1.25

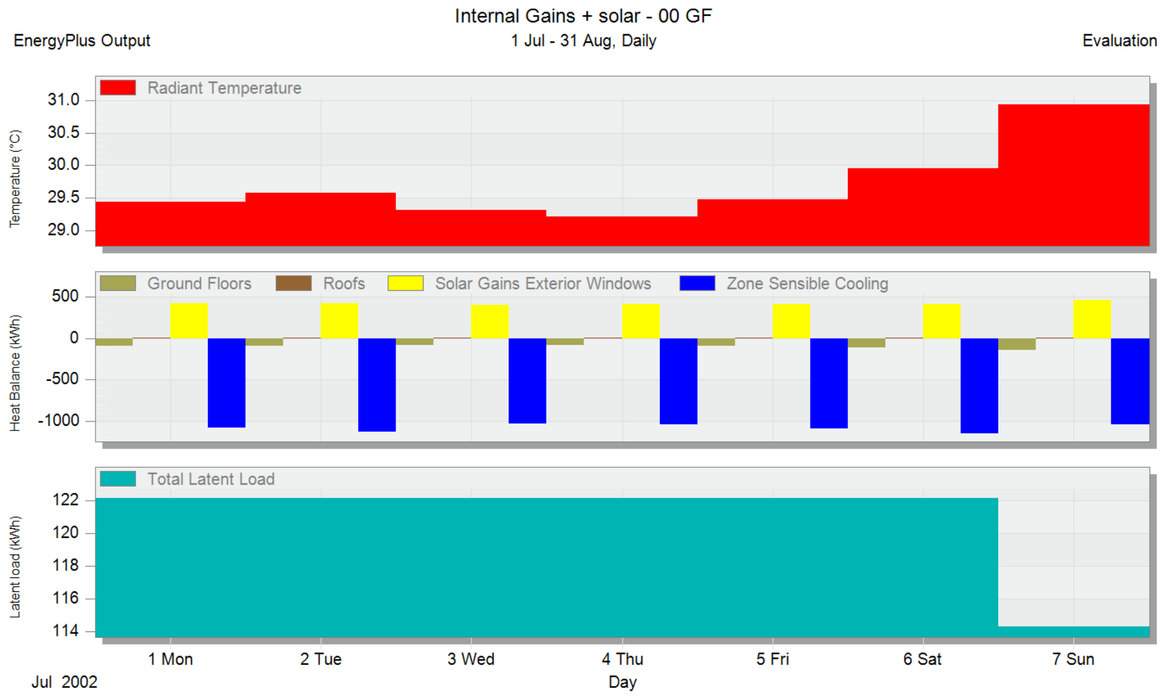


Fig. 19: Simulation Data for Pediatric Clinic, 00 GF

Table 7: Simulation Data for Pediatric Clinic, 00 GF

Internal Gains + solar - 00 GF

EnergyPlus Output | 1 Jul - 31 Aug, Daily | Evaluation

Day							
Radiant Temperature (°C)	29.44	29.58	29.31	29.21	29.47	29.96	30.94
Ground Floors (kWh)	-92.72	-95.65	-78.08	-84.96	-96.01	-110.65	-143.79
Roofs (kWh)	6.53	10.62	6.29	4.09	8.49	10.78	5.51
Solar Gains Exterior Windows (kWh)	418.58	419.49	404.69	412.94	415.40	417.05	465.58
Zone Sensible Cooling (kWh)	-1083.93	-1127.74	-1029.89	-1040.53	-1093.05	-1145.89	-1046.00
Total Latent Load (kWh)	122.18	122.19	122.20	122.18	122.18	122.20	114.27

After the alterations in the roof's green percentage, a change was seen in the roof heat balance, where the in the prior scenario we noticed a peak value of 21.57 kWh and a minimum of 9.81 kWh, whereas now we have 10.78 kWh and 5.51 kWh as peak and minimum value respectively. The temperature is maintained across scenarios and days having Sunday giving a maximum value of 30.94.

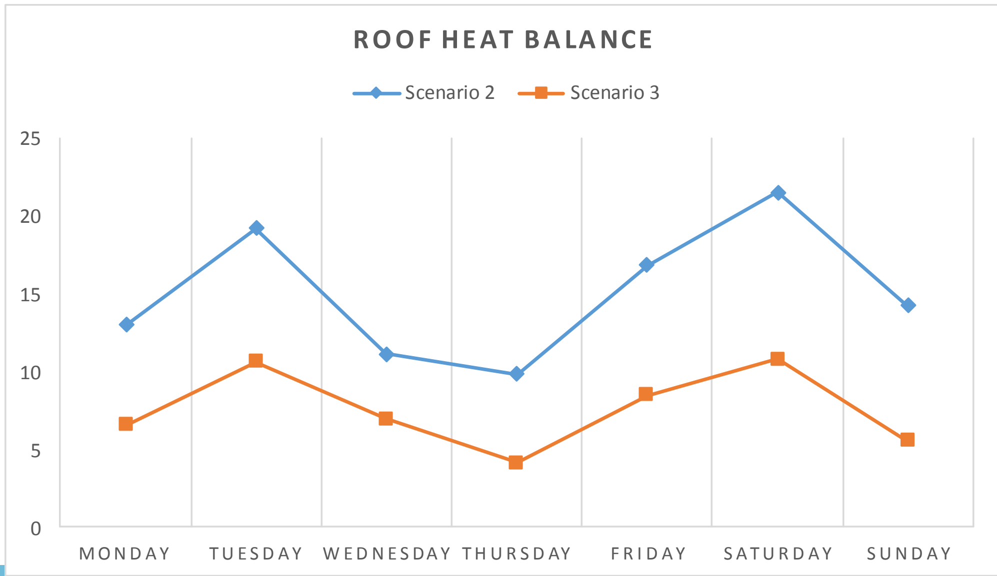


Fig.20: Roof Heat Balance (Scenarios 2 and 3)

As a result, scenario 3 where 70% of the roof is covered with green is more suitable to conduct and progress the following scenarios both 4 and 5. To better optimize the result and indicate which type of green roof is more suitable the intensive or the extensive for this prototype's case.

3.1.4. Scenario 4 | Intensive Green Roof – *70% Coverage*

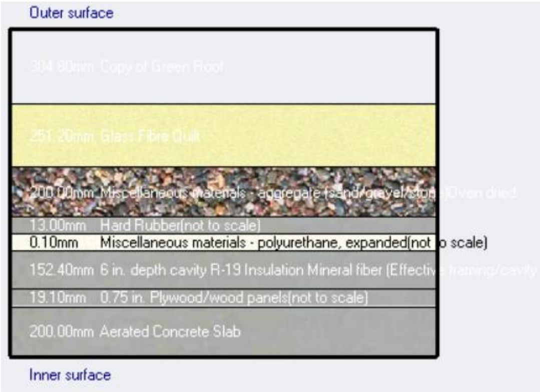


Fig.21: Exported Zone 7 Layers

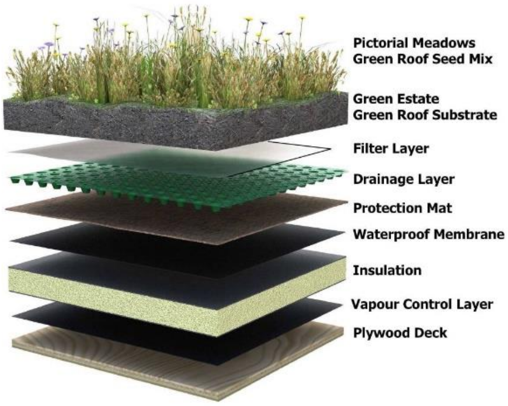


Fig.22: Intensive Green Roof Layers

In this scenario, simulations and cooling design studies will be presented according to changing the layering parameters of green roof as the following:

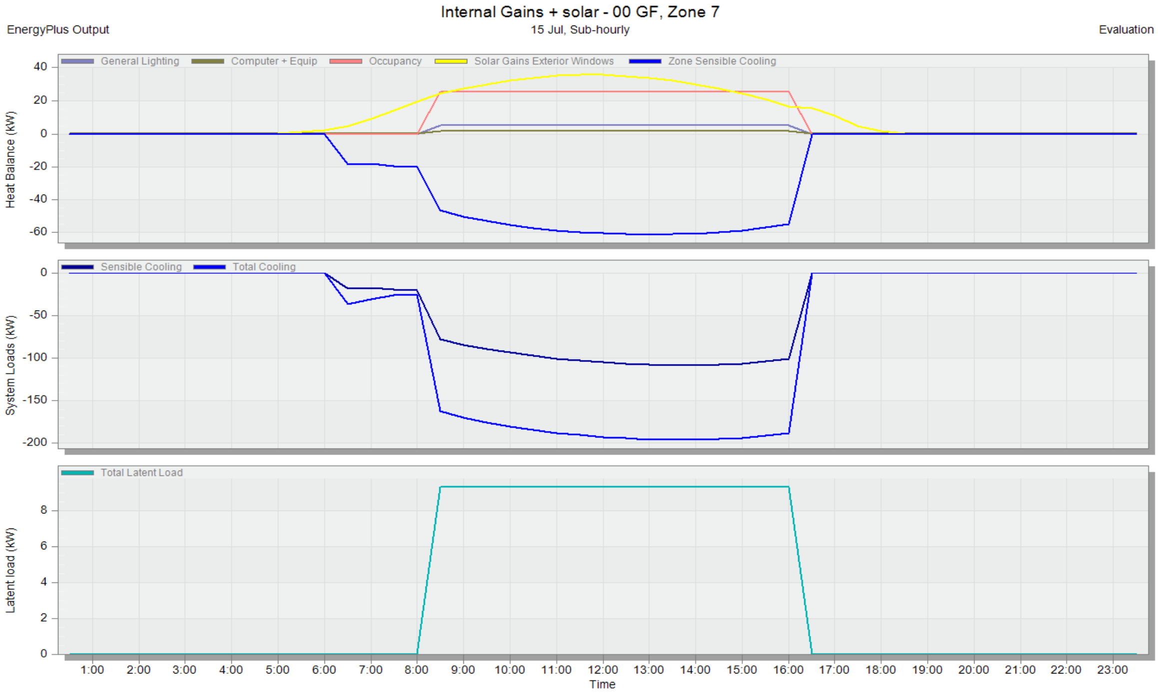
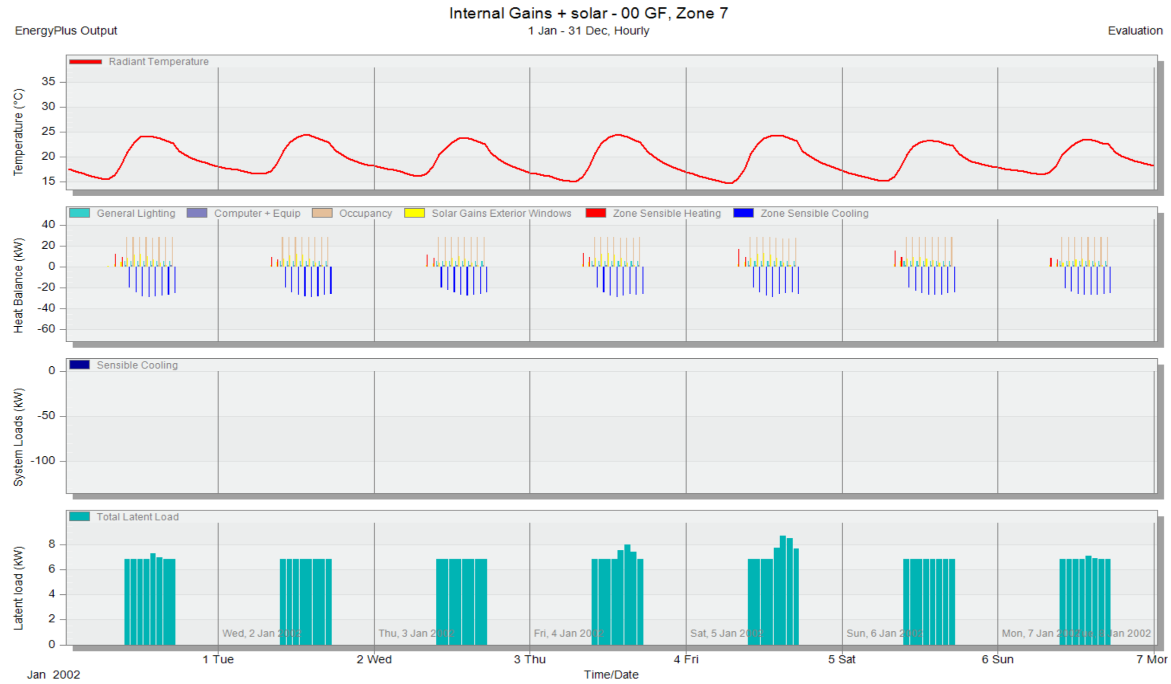


Fig. 23: Scenario 4 - Summer Design Data for Pediatric Clinic, 00 GF, Zone 7

Table 8: Scenario 4- Summer Design Data for Pediatric Clinic, 00 GF, Zone 7



Internal Gains + solar - 00 GF, Zone 7

EnergyPlus Output — 15 Jul, Sub-hourly — Evaluation

Time	2:00	4:00	6:00	8:00	10:00	12:00	14:00	16:00	18:00	20:00	22:00
General Lighting (kW)	0.00	0.00	0.00	0.00	5.08	5.08	5.08	5.08	0.00	0.00	0.00
Computer + Equip (kW)	0.08	0.08	0.08	0.08	1.69	1.69	1.69	1.69	0.08	0.08	0.08
Occupancy (kW)	0.00	0.00	0.00	0.00	25.74	25.74	25.74	25.74	0.00	0.00	0.00
Solar Gains Exterior Windows (kW)	0.00	0.00	2.28	19.89	32.63	36.07	30.46	16.91	1.67	0.00	0.00
Zone Sensible Cooling (kW)	0.00	0.00	0.00	-20.42	-55.60	-60.82	-60.93	-55.20	0.00	0.00	0.00
Sensible Cooling (kW)	0.00	0.00	0.00	-20.42	-93.60	-105.27	-108.73	-101.44	0.00	0.00	0.00
Total Cooling (kW)	0.00	0.00	0.00	-25.33	-180.34	-192.78	-196.16	-187.77	0.00	0.00	0.00
Total Latent Load (kW)	0.00	0.00	0.00	0.00	9.33	9.33	9.33	9.33	0.00	0.00	0.00

3.1.4. Scenario 5 | Extensive Green Roof – *70% Coverage*

In this scenario, simulations and cooling design studies will be presented according to changing the layering parameters of green roof as the following:

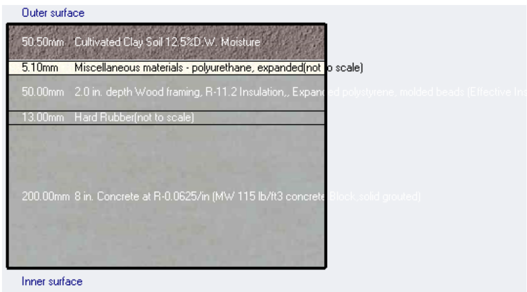


Fig. 24: Exported Zone 7 Layers

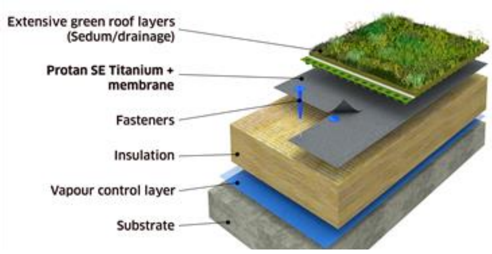


Fig. 25: Extensive Green Roof Layers

Table 9: Scenario 5 Simulation Data

Internal Gains + solar - 00 GF, Zone 7

EnergyPlus Output — 1 Jan - 31 Dec, Hourly — Evaluation

Time/Date										
Radiant Temperature (°C)	23.76	16.72	19.20	23.05	16.13	21.22	17.66	17.30	23.12	16.67
General Lighting (kW)	5.08	0.00	0.00	5.08	0.00	0.00	0.00	0.00	5.08	0.00
Computer + Equip (kW)	1.69	0.08	0.08	1.69	0.08	0.08	0.08	0.08	1.69	0.08
Occupancy (kW)	28.05	0.00	0.00	28.22	0.00	0.00	0.00	0.00	28.21	0.00
Solar Gains Exterior Windows (kW)	3.84	0.00	0.00	8.58	0.00	0.00	4.58	0.00	3.82	0.00
Zone Sensible Heating (kW)	0.00	0.00	0.00	0.00	0.00	0.00	9.05	0.00	0.00	0.00
Zone Sensible Cooling (kW)	-28.05	0.00	0.00	-24.93	0.00	0.00	0.00	0.00	-26.59	0.00
Sensible Cooling (kW)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total Latent Load (kW)	7.02	0.00	0.00	6.86	0.00	0.00	0.00	0.00	6.86	0.00

Table 10: Scenario 5 - Summer Design Data for Pediatric Clinic, 00 GF

EnergyPlus Output — 15 Jul, Sub-hourly — Evaluation

Time	2:00	4:00	6:00	8:00	10:00	12:00	14:00	16:00	18:00	20:00	22:00
Radiant Temperature (°C)	31.11	30.87	30.95	31.27	34.44	35.51	35.37	33.87	32.85	31.94	31.61
Outside Dry-Bulb Temperature (°C)	27.59	27.22	27.22	28.69	30.88	32.41	33.20	32.83	31.74	30.15	29.05
Ground Floors (kW)	0.41	0.47	-0.47	-3.08	-7.59	-7.08	-4.57	-0.25	0.40	0.46	0.33
Roofs (kW)	2.33	2.29	1.70	2.34	-2.35	-2.79	-1.84	0.40	0.81	1.97	2.22
Solar Gains Exterior Windows (kW)	0.00	0.00	2.28	19.89	32.63	36.07	30.46	16.91	1.67	0.00	0.00
Zone Sensible Cooling (kW)	0.00	0.00	0.00	-22.30	-55.49	-60.04	-60.24	-55.26	0.00	0.00	0.00
Sensible Cooling (kW)	0.00	0.00	0.00	-22.30	-93.49	-104.49	-108.04	-101.50	0.00	0.00	0.00
Total Cooling (kW)	0.00	0.00	0.00	-25.28	-180.15	-191.87	-195.37	-187.86	0.00	0.00	0.00
Total Latent Load (kW)	0.00	0.00	0.00	0.00	9.33	9.33	9.33	9.33	0.00	0.00	0.00

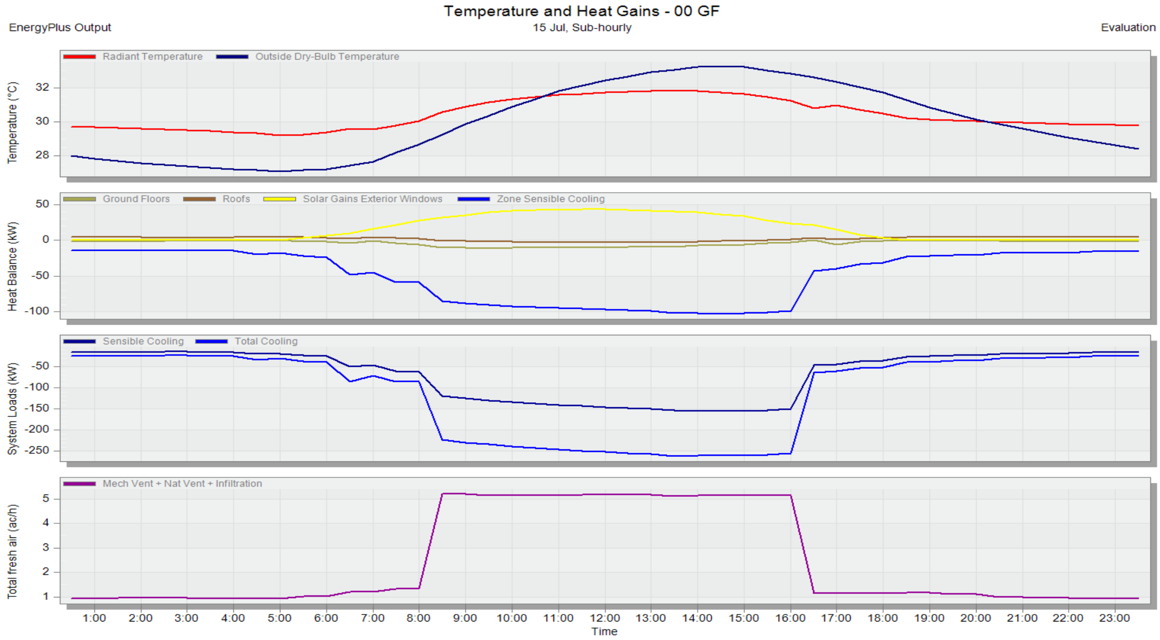
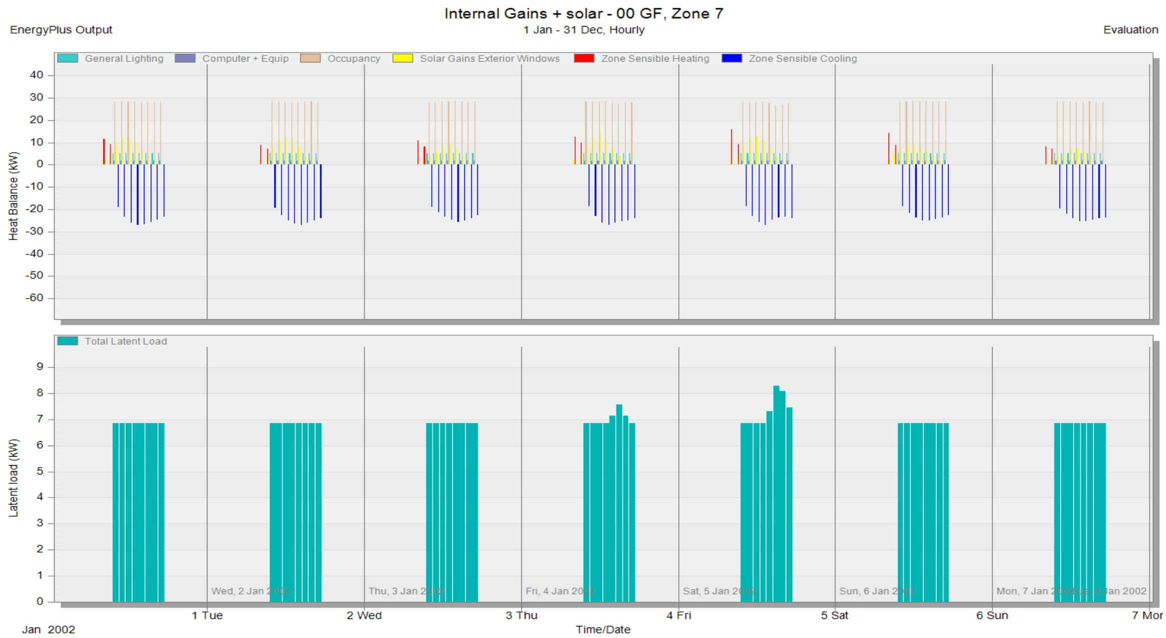


Fig.26: Simulation Data for Pediatric Clinic, 00 GF, Zone 7

Table 11: Simulation Data for Pediatric Clinic, 00 GF, Zone 7



Internal Gains + solar - 00 GF, Zone 7

EnergyPlus Output — 1 Jan - 31 Dec, Hourly — Evaluation

Time/Date										
General Lighting (kW)	5.08	0.00	0.00	5.08	0.00	0.00	0.00	0.00	5.08	0.00
Computer + Equip (kW)	1.69	0.08	0.08	1.69	0.08	0.08	0.08	0.08	1.69	0.08
Occupancy (kW)	28.21	0.00	0.00	28.22	0.00	0.00	0.00	0.00	28.22	0.00
Solar Gains Exterior Windows (kW)	3.84	0.00	0.00	8.58	0.00	0.00	4.58	0.00	3.82	0.00
Zone Sensible Heating (kW)	0.00	0.00	0.00	0.00	0.00	0.00	9.30	0.00	0.00	0.00
Zone Sensible Cooling (kW)	-25.69	0.00	0.00	-23.23	0.00	0.00	0.00	0.00	-24.51	0.00
Total Latent Load (kW)	6.86	0.00	0.00	6.86	0.00	0.00	0.00	0.00	6.86	0.00

- After observation, it is noticed that the roof's heat balance has been maintained and ranging from -2.79 and +2.33 after the introduction of an extensive green roof, after priorly reaching 10.28 kWh in previous cases.
- Additionally, we find that the increase in temperatures in present in scenario 5 where the layering of the ground floor in zone 7 is much less than the layering in scenario 4, due to using extensive and intensive green roof layering, respectively. A peak of 35.51°C in scenario 5 and 21.22 °C in scenario 4 of radiant temperature.

3.1.5. Overlapping Scenarios & Overviewing Results |

Table 12: Comparative Table summarizing all scenarios

	Parameters	Roof Gains	Radiant Temperature	Solar Gains	Total Latent Load
Scenario One	Flat Roof - Energy Code Standard – Medium Weight Concrete	*Base Case Scenario*	*Base Case Scenario*	*Base Case Scenario*	*Base Case Scenario*
Scenario Two	50% Covered Green Roof	Decreased by 30%	Decreased by 27%	Decreased by 10%	Decreased by 12%
Scenario Three	70% Covered Green Roof	Decreased by 12%	Decreased by 8%	Decreased by 16%	Decreased by 15%
Scenario Four	Intensive - Non-Vegetated Green Roof	Maintained	Maintained	Maintained	Maintained
Scenario Five	Extensive - Vegetated Green Roof	Decreased by 30%	Decreased by 25%	Maintained	Decreased by 30 to 45%

**** Scenario Three was taken as a model for both cases 4 and 5 in order to find the optimum results in both followed scenarios, also worth mentioning that this study is a progressive one.***

4. Conclusion

Various test scenarios where assessed in this study in order to find the suitable roof coverage of green, and later on to enhance the results and pick out which type of roof suits best for such project (intensive or extensive), through modeling the prototype using energy plus software such as design builder. Based on this study, the findings can be emphasized as followed:

Ground floor surface area, and mainly the main waiting hall was highly exposed to the expenditure solar rays of the sun, thus increasing the radiant temperature of the indoor space.
A suitable solution was proposed to introduce green roof as a solution to such problem allowing better incorporation of green element in the project.
After trials in the first 3 scenarios, roof coverage was best chosen to be used as green rather than 50% or having no green at all such as the base case scenario.
After choosing the percentage, 2 additional trials experimenting with two types of roofs intensive and extensive, ending up by choosing intensive green roof as a solution with 70% coverage due to having it more layered and better insulated.

Hence, this study explains that the use of simply green construction sustainable strategies allows the prototyped building to heat less in its thermal mass and thus consume less energy, fuel, and costs on the cooling of its spaces.
Therefore, this study can be used to potentially show a client, construction company, or consultants the better use of green roofs on the whole building performance on the long run, and better incorporate in the future such solutions in large urban contexts.

5. References

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