SCHOOL OF ENERGY, GEOSCIENCE, INFRASTRUCTURE AND SOCIETY

D10YD

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THE BROADWAY CINEMA

(Stage 1)

BENG/MENG ARCHITECTURAL ENGINEERING

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Abstract

Designing a multi-use building can experience some difficulties. These difficulties can occur in site analysis, design conditions, building services, accessibility, lighting, fire safety and structural components. In order to counter such problems, design projects go into immense depth in detail through many iterations of the initial design to minor tweaks in the thermal template for each wall. As design projects require architects, civil engineers, architectural engineers etc… to come together to establish the process of constructing a multiple storey structure, the planning stage can take a significant period of time trying to achieve the best possible outcome for the building or structure. The time to achieve this feat is mainly based on conflicts that can arise due to miscommunications and misunderstandings within the internal board. This planning can include the likes of plans, sheets, schedules, thermal templates etc...

In the twenty-first century, building a project entails more than just constructing a standing structure in the wide area allotted. When finalizing a project, elements such as natural preservation, environmental friendliness, user friendliness, ease of access, low site waste, and many more are carefully considered. It also explains how future developments can be built in the same area without causing any disruption to the existing building and its systems.

Introduction

The United Nations initiated a conference regarding the rapid climate change problems that can occur in the near future. The UNFCCC (United Nations Framework Convention on Climate Change) consists of all the countries that took part in signing the agreement, back in the early 90's, for the convention to take place every year to understand and visualize new initiatives on how to tackle the upcoming problem of climate change. The conference is headlined as 'Conference of the Parties', or more commonly known as COP, the most recent being the 27th edition taking place in 2021 and the next, COP 28, is to be held in November 2022 in Dubai, UAE. As climate change affects many aspects of everyday life including, ventilation requirements, energy-efficient areas, and user comfort. Hence stating that, buildings play an important role in conflicting climate change as buildings are a part of people's everyday lives.

With the context established, this design project focuses on creating a conference centre headquarters for COP 28 that meets the standards for sustainability, eco-friendliness, and energy-efficiency. The conference centre will be located near Al Jaddaf Waterfront in Dubai, according to COP 28. Because a conference centre requires various rooms with specific functions, the designated spaces in accordance with COP 28 are as follows.

Designated Area	Quantity
Courtyard Area	1
COP Auditorium	1
COP Labs	3
United Nations Workshops	3
Office Workspace	10
Meeting Rooms	3
Exhibition Main Space	1
Exhibition Secondary Spaces	2
Café / Restaurant	1
Leisure Area	1
External Farms	1

Table 1. Demonstrates the required rooms with their respective quantities

Functionality being one of the important aspects for COP 28, meanwhile, form can be creatively proposed. The building design itself should consider utilizing on-site energy generation as much as possible.

Planning of such design was taken into deep consideration to avoid unwanted misinterpretations and misunderstandings to allow COP 28 to be aware of the estimations regarding the construction of the building itself. Using sheets, iterations, thermal templates, the design will undergo many evaluations for maximum efficiency for the future references.

Using the likes of Autodesk Revit and IES-VE (Integrated Environment Solutions – Virtual Environment), near accurate readings can be obtained that simulate real world implications virtually, allowing to gain an understanding on the design, sustainability and efficiency of the building. Autodesk Revit focuses more on designing the minute details of the design to overlook any design alterations, whereas, IES-VE is a simulation software that accurately concludes the building performance by simulating post occupancy measures and thermal templates for the building.

This report will be concluded by thoroughly discussing the different aspects, including building conditions, building services, accessibility, lighting etc… that complete a building.

Site Analysis

As previously mentioned, the preferred site for this extensive building is locate in Al Jaddaf, Dubai. To be precise, Al Jaddaf Waterfront is the exact position of the site. Figure 1 illustrates the overview of Al Jaddaf Waterfront with its neighbouring surroundings.

Figure 1. Birds eye view of the location and site itself.

Visually, the overview clearly demonstartes that the site is embodied with water from the Dubai Creek. The waterfront is a man made island allows structures to be built upon it and it already houses walkways, sculpture gardens and Art Jameel. Art Jameel is an existing building on the north side of the site which are low rise buildings with different heights that bring character to the site itself. The waterfront is home to a sculpture garden positioned facing the east side overlooking the Dubai Creek. The site has an over head bridge near perpendicular to the south side with a road leading down onto the island into a parking zone for the cars to access the current Art Jameel. The over head bridge provides shade from the sunlight that is utilized in the design itself.

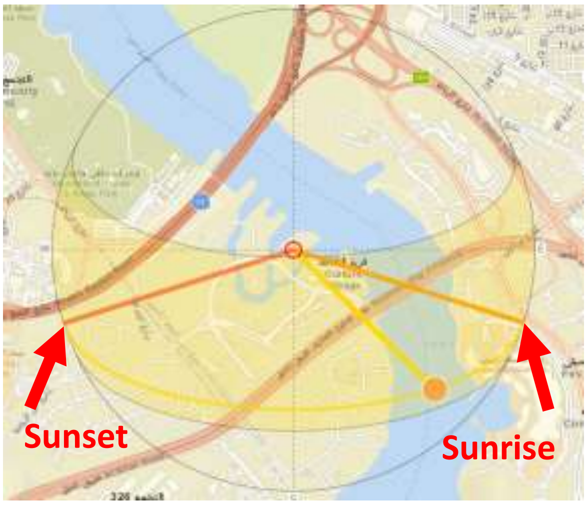

Figure 2. Illustrates the sun path as well as the sunrise and sunsetting time according to November 2022

The sun path, as seen from Al Jaddaf, is clearly visualized in *Figure 2*. Demonstrating the sun path on an overview of the site can be seemed as a deceiving element as it doesn't factor in neighbouring obstacles. Al Jaddaf, as seen is in the middle of neighbouring buildings and islands which counter the sun rays spanning across the site after a period of time. Taking this into consideration for sustainability, solar PV panels would have to be place on one side of the building at an angle to provide maximum energy-efficiency rather than having solar panels covering the roof area which would have a negative impact on the buildings energy management system by not generating nearly as much as one specific area of the building.

Figure 3 on the other hand illustrates the wind direction that the site experiences. The north west side experiences wind speeds up to 12km/h. this is due to the fact that specific viewpoint shares a much more open area in comparison to the south side which is totally covered by neighbouring buildings and obstacles.

Figure 3. Illustrates the wind direction and a simplified sun path

Building Design

The building design is deemed to be quite straightforward as the building has a curved shaped throughout with the spacing of the zones strategically as the service rooms are allocated next to each other away from the productivity spaces. This causes lesser distrubances and any maintenance requirements can be dealt with without affecting the overall circulation of the building. The total area of the building is around 2,322m^2.

The workshops and labs are accessible individually however they share walls. This planned formation allows individuals to feel more relaxed and more focused on improving productivity. Two bathrooms have been allocated within the building to accommodate every user easily by not overcrowding any area with one next to the café which houses 50 occupants providing convienancy for personal needs.

The exhibition spaces are located on the north west side of the building. these are not connected to the main building as exhibition spaces contain a lot of disturbances when fully occupied which can lead to disturbances in the building.

The Auditorium houses and inverted tinted glass dome allowing daylight to eneter the space, essentially requiring lesser use of artificial lighitng during the day.

The main concern in this climate can be the thermal transmittance if the materials arent chosen accordingly. The following table demonstrates the materials chosen and their respective U-Values:

Type	Material	U-Value (W/m^{2}K)
Walls	Lightweight Aggregate Concrete blocks	0.32
Glazing	Low-E Double Glazing Windows	1.2
Roof	Uninsulated roof	2.5

Table 2. Demonstrates the U-Values chosen

Reference Sheets
A101-104, A106

IES-VE (Building Conditions)

IES-Virtual Environment (IES-VE) was used during COP 28. This simulation software is primarily concerned with energy modelling, building and system design, and compliance. IES-VE was used to its full ability in this design to obtain a general conclusion on the building's internal and external design conditions. These factors dictate the cooling or heating loads that must be proficient to counteract external climates such as summers and winters. As a result, design conditions have been separated into two categories: indoor design conditions and outdoor design conditions.

The American Society of Heating, Refrigeration, and Air Conditioning Engineers (ASHRAE) have developed standards to ensure energy-efficiency, comfort levels, and a basic grasp of standardized variables that take control when discussing the thermal components of a future project. As satisfying ASHRAE Standards can assist a structure in gaining LEED Certification of sustainability, these standards help architects and engineers. The comfort level of HVAC systems in such a structure necessitates the use of ASHRAE Standards.

The Chartered Institution of Building Services Engineers (CIBSE), like ASHRAE, is a professional engineering society headquartered in London, United Kingdom. CIBSE is a standard-setter that provides international guidance through Building Regulations and regulations to improve the performance of building services.

Internal Design Conditions

The heating and cooling demands are determined by internal design conditions. This refers to the air conditioning or HVAC systems placed within a building that are related to the comfort level of users, particularly in such buildings. As previously stated, IES-VE was utilized to analyse the building's loads, energy, and carbon emissions.

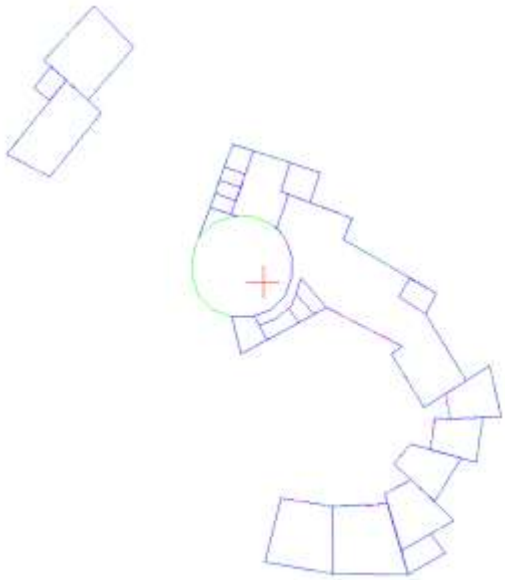

Figure 4. IES-VE model with zones

The image on the left depicts the IES-VE simulated building. The IES model was created as accurately as possible using the Revit blueprints for the building itself in order to reach the most dependable conclusions. The model is made up of numerous zones that matched the COP 28 standards. The windows and door frames were added with the proper size to achieve the greatest potential outcomes for heat gains and losses because the model was to be created as a near exact reproduction of the original design.

IES-VE, being a simulation software, allows to assign thermal templates using the Building Template Manager option within the software. Assisting in defining and simulating the indoor conditions of allocated zone depending on the function of the specified zone. The Building Template Manager designates the various aspects of indoor design conditions which include, Building Regulations, Room Conditions, System, Internal Gains and Air Exchanges.

System

To begin, the building template manager used the UK NCM Wizard to assign the Building Area Type and the Activity that will occur in the designated zone. The National Calculation Methodology (NCM) is associated with the Secretary of State's initiative to calculate and assess the energy performance of a building by developing criteria that specify the functioning of the space. It is an expressive form of knowledge and awareness of the building's energy analysis. The following figure depicts the NCM

Standards assigned to each of the building's zones:

Template Name	NCM Room Type	NCM Building Area Type	NCM Activity
Auditorium	Heated or occupied room	D2: General assembly and Leisure...	NCM D2: Auditoria
Bathrooms	Heated or occupied room	D1: Primary or Secondary school (...	NCM D1Edu: Toilet
Exhibition spaces	Heated or occupied room	D2: General assembly and Leisure...	NCM D2: Auditoria
Labs	Heated or occupied room	B1: Office or Workshop (Office)	NCM Office: Office
Main Lobby / Cafe	Heated or occupied room	D1: Primary or Secondary school (...	NCM D1Edu: Circulation area
Main Office	Heated or occupied room	B1: Office or Workshop (Office)	NCM Office: Office
Meeting Rooms	Heated or occupied room	D1: Primary or Secondary school (...	NCM D1Edu: Office (PrmSchl: Meeting)
Office Workspace	Heated or occupied room	B1: Office or Workshop (Office)	NCM Office: Office (Office: Common)
Return Air Plenum	Heated or occupied room	Not Set	-
Room (ApSys, IP)	Heated or occupied room	Not Set	-
Room (ApSys, metric)	Heated or occupied room	Not Set	-
Service Rooms	Heated or occupied room	Other: Emergency services	NCM EmgcySvc: Light plant room
Supply Air Plenum	Heated or occupied room	Not Set	-
Void	Heated or occupied room	Not Set	-
Workshops	Heated or occupied room	B1: Office or Workshop (Workshop)	NCM OfficeW: Workshop - small scale

Figure 5. NCM Standards for each zone

The zones shown above indicate that each zone has been specified according to the best interpretation of the standards.

Moving onto the specifics relating the thermal templates for each zone, the System tab entails the type of HVAC system that is being used throughout the building. For this design project, Single – Duct VAV's are being utilized to its maximum potential in order to achieve efficiency. Variable Air Volume systems or VAV's were chosen as they are very energy efficient as the system varies air flow depending on the requirements hence uses less power to operate the fan as the fan will operate conditionally. VAV's generally require less maintenance due to the fact that they don't contain chilled water coils therefore the only maintenance that is necessary for this system is filter replacement and condensate pan cleaning that can be done annually or semi-annually in the air handling unit, meaning that, when maintenance is required, it can be done without causing disturbance in working places. (Ljungquist, 2017). The System tab in IES-VE also helps in determining the outdoor air supply along with the flow rate.

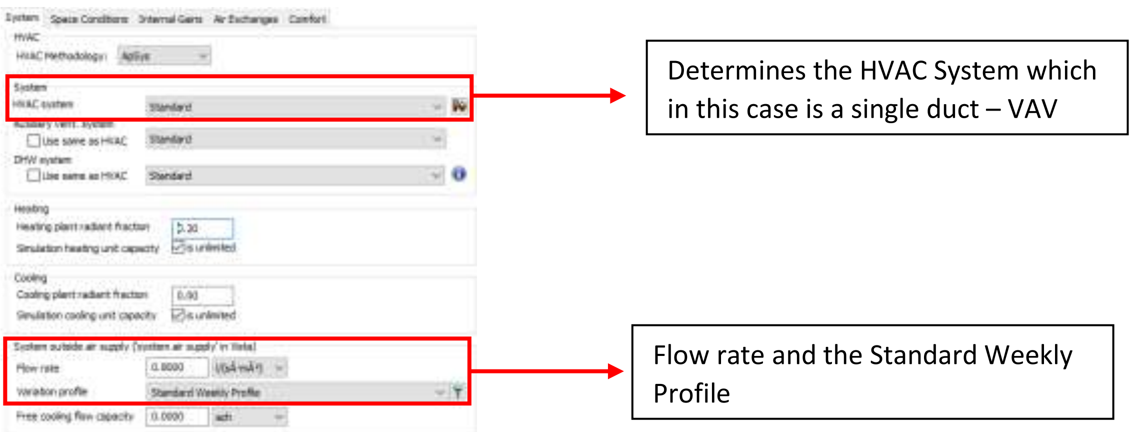

Figure 6. Illustrates the IES-VE database under the system tab

Space Conditions

Progressing forward from the System settings, Space Conditions were determined that focus on the heating and cooling profile of the zones. Each zone has its own profile regarding the occupants and the function. As mentioned before, UAE is host to a very hot and humid climate throughout the year, meaning that its desert like conditions allows building the opportunity to use no heating systems within the building as it would only increase cost, maintenance and unwanted carbon emissions. On the other hand, the same situation can be perceived differently since the climate conditions doesn't make use of heating systems, buildings are bound to be implemented with substantial cooling systems that take up most of the carbon emission readings.

As cooling profiles have to be made in correspondence to the function, standards were used to ensure the building meets legal regulations and can provide general user comfort in every zone within the building. Two standards were used in this design project for the cooling profiles to achieve the best possible outcome:

- CIBSE Guide B 2006: Heating, Ventilating, Air Conditioning and Refrigeration
- Dubai Building Codes 2021

CIBSE Guide B was chosen as it provides a clear understanding over the internal design conditions for the auditorium. As the auditorium requires the greatest number of occupants, it is crucial to provide accurate details that comply with both the standards, more so the Dubai Building codes. The following images illustrate the air temperature that is to be used in IES-VE from both the standards:

Table 2.14 Design requirements: assembly halls and auditoria

Parameter	Design requirement
Fresh air ventilation rates	To suit occupancy levels
Air change rate	3–4 air changes per hour for displacement strategy
	6–10 air changes per hour for high level mechanical strategy
Temperature and humidity:	
— heating only	20 °C; 40% RH (minimum)
— with cooling	20–24 °C; 40–70% RH

H.4.6.3 Indoor design conditions

The design criteria values shown in Table H.2 shall be used for indoor design conditions in Dubai.

Design criteria	Value to be used
Dry bulb temperature	24 °C ±1.5 °C
Relative humidity	50% ±5%

Figure 7. (left) CIBSE Guide Standards for Auditorium (right) Dubai Building Codes

A temperature of 22.5^{o}C was chosen for the auditorium. This figure was chosen because it fits both specifications; also, the auditorium has a wide glass atrium ceiling that allows direct sunlight to penetrate the area; as a result, the auditorium has higher solar heat gains than the rest of the structure. Higher solar heat uptake and direct sunlight results in more radiation absorption within the area, raising the temperature. This increase in temperature necessitates greater cooling within the area in order to make the auditorium thermally comfortable for the occupants who are seated there for extended periods of time. (Etheridge, 2010)

The rest of the zones utilize a constant temperature of 23.5^{o}C.

IES-VE employs weekly profiles to mimic how the building would function on a weekly basis in the real world, which means that the building performance may be replicated as accurately as possible using actual data that correlates with the working hours and weekdays that are standardised in the UAE. After the law changes in January 2022, the new working hours in Dubai will be 7:30 a.m. to 3:30 p.m. Maintaining an 8-hour schedule on a daily basis, with the exception of Fridays, when the cut-off time is 12:00 p.m. owing to Friday Prayer. (Anon., 2022)

The following image illustrates the standard daily profile that has been utilized throughout the software to ensure that the building performance is simulated that of the real world.

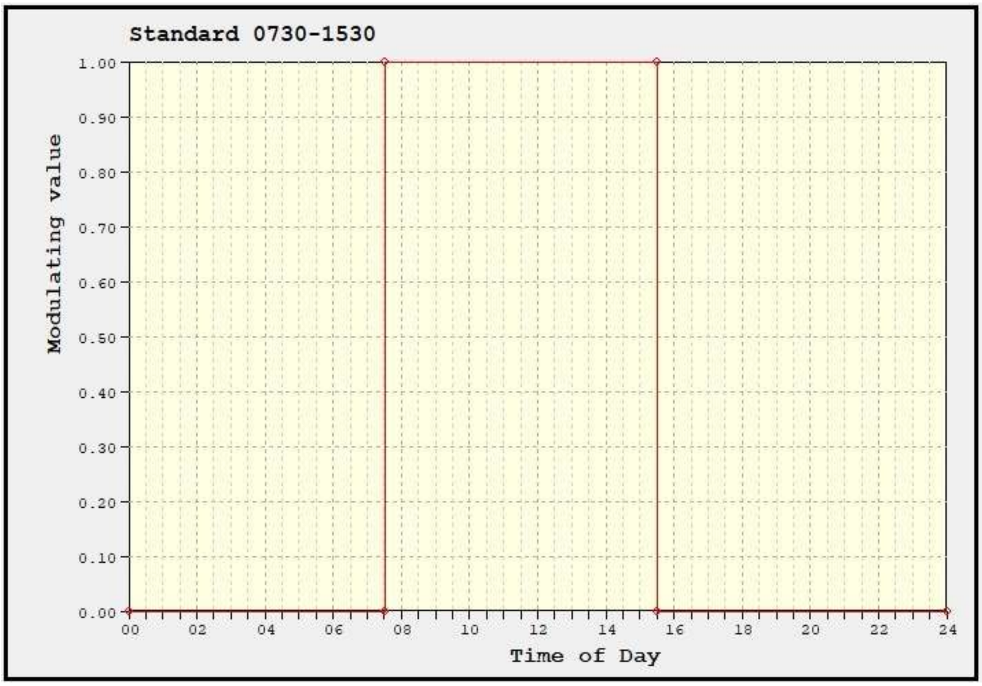

Figure 8. Illustrates the Standard Daily Profile (7:30am to 3:30pm)

The values shown in Figure 8 have been tabulated to give an overview on how the graph has been contrived. Table 3 demonstrates the values that suggest when the system is to be activated and deactivated by assigned '0' for deactivation and the number '1' for activation of the system. These profiles help to gain an understanding of where the system lacks in efficiency and where the room for improvement is, moreover, the daily profiles suggest that the system doesn't work for the whole day, yet meets the requirements for a working day in the UAE.

	Time	Value
1	00:00	0.000
2	07:30	0.000
3	07:30	1.000
4	15:30	1.000
5	15:30	0.000
6	24:00	0.000

Table 3. Daily timings for activation

Using this daily profile, the weekly profiles are generated as the software works with weekly profiles rather than just daily profiles. The weekly profile is as follows:

	Daily Profile:
Monday	Standard 0730-1530 [DAY_0028]
Tuesday	Standard 0730-1530 [DAY_0028]
Wednesday	Standard 0730-1530 [DAY_0028]
Thursday	Standard 0730-1530 [DAY_0028]
Friday	Friday [DAY_0029]
Saturday	Always Off (0%) [OFF]
Sunday	Always Off (0%) [OFF]
Holiday	Always Off (0%) [OFF]
Heating-Rm	Standard 0730-1530 [DAY_0028]
Cooling-Rm	Standard 0730-1530 [DAY_0028]
Heating-Sys	Standard 0730-1530 [DAY_0028]
Cooling-Sys	Standard 0730-1530 [DAY_0028]

Table 4. Demonstrates the Weekly profile

As the weekly profiles require the daily profiles for each day are required to establish how the building performs daily. Hence stating that, the weekdays from Monday to Thursday have the standard daily profile which was discussed above and Friday has its own profile as the time requirements differ from the rest of the days and the profile suggests that the cooling systems activate at the same time however, they deactivate at 12:00 pm rather than 3:30 pm. The weekly profile also establishes that the building systems are always turned completely off during the weekend and holidays to ensure that unnecessary equipment isn't consuming more energy indefinitely affecting the sustainability of the building.

Internal Gains

Internal gains are a very important aspect when it comes to defining and examining the energy-efficiency of the building. Both electricity consumption and heat gains give an overview on the requirements of the area in relation to the specific function of the area.

Hence stating that, the zones that the building houses have internal heat gains in regards to the equipment, occupancy and lighting within the area. The zones differ from function therefore have different requirements to meet comfort and sustainability.

To meet sustainability requirements and global regulations, CIBSE Guide A 2006: Environmental Design were used to obtain standardised internal gains for the different aspects that contribute to the total internal gains within the zone.

The following table indicates the occupancy levels of each zone:

Zone	Occupants
Auditorium	100
Exhibition Spaces	10
Office Workspace	9
Bathrooms	8
Meeting Rooms	6
Main Office	1
Main Lobby / Café	60
Workshops	1
Labs	18
Service Rooms	1

Table 5. Zones with their respective occupants.

For this specific part of the project, the zones have been inputted to have the maximum number of occupants in a single sitting. The particular reason for this circumstance entails that the projects results will be for the worst-case scenario. The worst-case scenario suggests that the building performance will still meet the benchmarks and requirements when the building is fully occupied, assisting in obtaining a better sustainability standard.

As occupants also play a role in the internal gains, CIBSE Guide A was utilized to gather information and values regarding occupant gains within an area. The following edited image is from CIBSE Guide A which demonstrates the sensible and latent gains from a mix of male and female occupants within the area. These values have been inputted into IES-VE multiplied by the number of occupants in each area.

Table 6.3 Typical rates at which heat is given off by human beings in different states of activity.

Degree of activity	Typical building	Total rate of heat emission for adult male / W	Rate of heat emission for mixture of males and females / W			Percentage of sensible heat that is radiant heat for stated air movement / %	
			Total	Sensible	Latent	High	Low
Seated, very light work	Offices, hotels, apartments	130	115	70	45	—	—

Source: ASHRAE Handbook: *Fundamentals* (2001)[6]

Figure 9. Benchmark for occupant sensible gain

Along with occupants, the equipment within the areas also affects the final internal gain readings massively as equipment can be used for most of the day, and the worst-case scenario entails that the equipment is working for the whole day whether or not it is being utilized. The following images entail the maximum sensible gains for the computers and their respective monitors. The machinery chosen from CIBSE Guide A consist of the highest sensible gains.

Table 6.7 Typical heat gains from PCs[14]

Nature of value	Value for stated mode / W	
	Continuous	Energy saving
Highly conservative	75	30

Table 6.8 Typical heat gains from PC monitors[14]

Monitor size	Value for stated mode / W	
	Continuous	Energy saving
Large (19–20 inch)	80	0

Figure 10. Benchmark for equipment heat gain

The last part affecting internal gains is lighting. Lighting that spreads throughout the building plays the most affective role as many areas require the lighting to be activated during the day as well. Hence stating that, the lighting for the various zones was also determined via CIBSE Guide A and each zone has a different lighting according to the functionality. The resulting image provides the details of which table was used from the CIBSE Guides and how it correlates to each of the zones.

Table 6.2 Benchmark allowances for internal heat gains in typical buildings

Building type	Use	Density of occupation / person·m^{-2}	Sensible heat gain / W·m^{-2}			Latent heat gain / W·m^{-2}	
			People	Lighting*	Equip't†	People	Other
Offices	General	12	6.7	8–12	15	5	—
		16	5	8–12	12	4	—
	City centre	6	13.5	8–12	25	10	—
		10	8	8–12	18	6	—
	Trading/dealing	5	16	12–15	40+	12	—
	Call centre floor	5	16	8–12	60	12	—
	Meeting/conference	3	27	10–20	5	20	—
	IT rack rooms	0	0	8–12	200	0	—
Leisure	Hotel reception	4	20	10–20	5	15	—
	Banquet/conference	1.2	67	10–20	3	50	—
	Restaurant/dining	3	27	10–20	5	20	—
	Bars/lounges	3	27	10–20	5	20	—

* The internal heat gain allowance should allow for diversity of use of electric lighting coincident with peak heat gain and maximum temperatures. Lighting should be switched off in perimeter/window areas (up to say 4.5 m) and no allowance account for any dimming or other controls.

Figure 11. Benchmark for lighting sensible gain

Using the above Figure, the following table was constructed to summarize the lighting sensible gains for each zone

Zone	Lighting Sensible Gain (W/m²)
Main Office	10
Workshops	10
Labs	10
Bathrooms	12
Auditorium	15
Exhibition Spaces	15
Meeting Rooms	15
Main Lobby / Café	15
Service Rooms	15

Table 6. Inputted values of sensible heat gain used in IES-VE

For the internal gains, the Standard Weekly Profile was utilized to simulate the worst-case scenario, in this case, is the equipment will be simulated as working nonstop for the whole of the working hours, plus, every zone is filled with its maximum number of occupants.

Building Loads

Moving on from the basic input values that need to be evaluated to determine the building loads, IES-VE using an open-source software by the name of APACHE. APACHE conducts a test within IES-VE that uses the building templates created in the previous section to run a simulation that provides conclusive results on how the building would function in the real world.

Hence, building loads, energy analysis and carbon emissions are the three main aspects that APACHE provides after running the test.

The room sensible cooling load was first examined and evaluated. From the generic visual of the cooling load values to a breakdown of the peak load down to the specifics of the day and time when it reached the predicted load during the year. This evaluation determines any room for improvements and suggests any retrofitting within the building. Moreover, by simulating the cooling load pattern, an overview can be provided of results which was obtained through the selected values within the building templates, hence, it can provoke a few changes regarding the chosen system.

As mentioned before, the building doesn't make use of a heating system consequently aiding the building in over achieving any building loads and only focuses on a cooling system.

The following graph visualises the annual overall simulated cooling load.

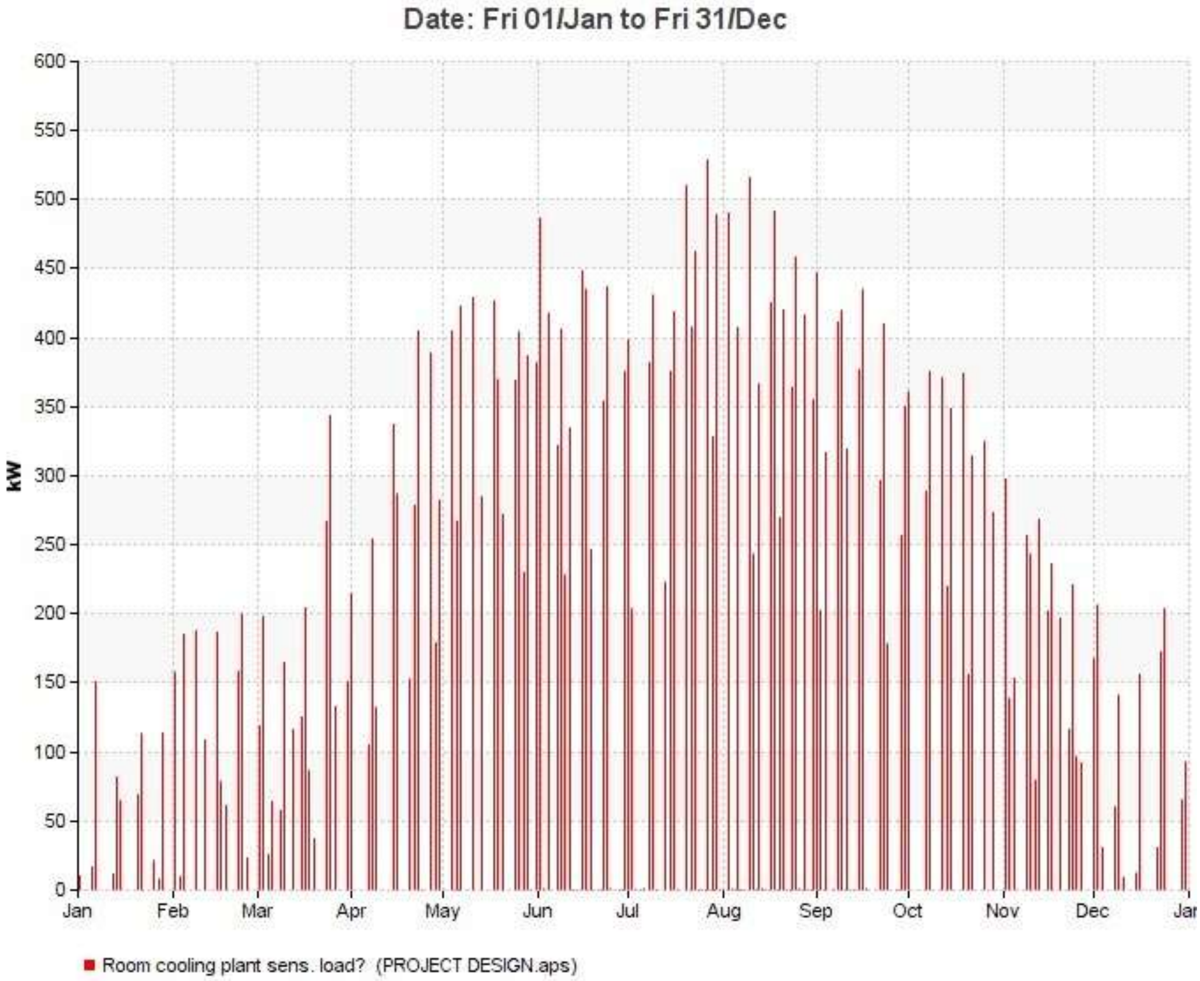

Figure 12. Illustrates the cooling load graph in kilowatts

As the cooling load is being evaluated annually, the above graph clearly demonstrates that the cooling load remains constant at around 200 kW from the start of the year till the end of March where the cooling load exponentially increases until it reaches its highest by the end of July. From then, the cooling load gradually decreases to the end of the year.

The following illustrations provide an overview on the breakdown of the peak and off-peak loads experienced within the building.

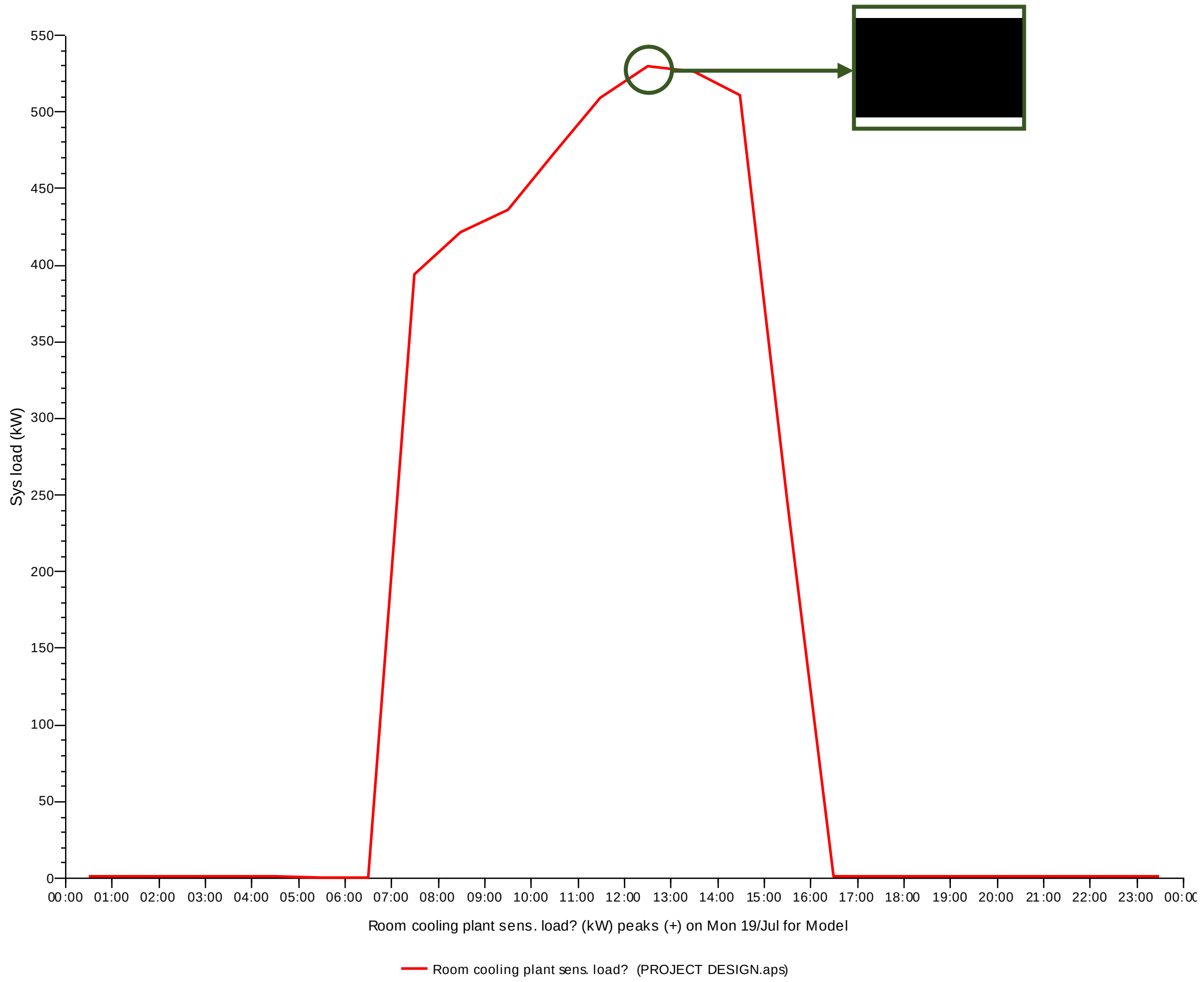

Figure 13. Illustrates the peak load on July 19th

The peak load graph shows a clear understanding of how the cooling load is spread throughout the day. Witnessing the Standard Daily Profile, the cooling load values start tabulating at 7:30 pm and reach a peak at around the 1:00 pm mark and finally ending at 3:30 pm which indefinitely indicates that the building templates have integrated into the software illustriously.

The cooling load reaches a peak of around 529.5 kW in the middle of July. Using this information, it can be stated that according to the weather conditions in July, being the hottest month in Dubai according to WeatherSpark.com, the cooling requirements therefore increase and reach that peak (Anon., 2022).

Due to the off-peak load being close to nil, visualising such a value by a specific graph isn't possible, hence, the table below summarizes the cooling load system within the building.

Type	Min. Value	Min. Time	Max. Value	Max. Time	Mean
Sys load (kW)	0	00:30,01/Jan	529.5	12:30,19/Jul	62.0

Table 7. Summary of the peak and off-peak loads obtained from IES-VE

As IES-VE analyses the cooling load annually, it also provides a monthly breakdown which clearly displays how the cooling load varies per month. The following table was obtained from IES which contains the cooling load values in MWh. In correlation to the CIBSE Guides, the benchmarks are drafted in kWh/m^2 , hence, the original values obtained from IES have to be converted in order to compare with the CIBSE Guides to ensure that the building is meeting the benchmarks. The conversion was done via steps, first by converting MWh to kWh and then dividing the calculated values by the total floor area which is designed to be at 3,033m^2 in IES-VE.

Date	Room cooling plant sens. load (MWh)	kWh
Jan 01-31	11.9	11935.7
Feb 01-28	18.2	18203.8
Mar 01-31	31.0	31045.1
Apr 01-30	45.2	45173.9
May 01-31	59.2	59205.9
Jun 01-30	69.0	69028.9
Jul 01-31	69.9	69869.9
Aug 01-31	73.3	73273.3
Sep 01-30	64.6	64618.9
Oct 01-31	47.2	47225.9
Nov 01-30	34.5	34498.2
Dec 01-31	18.7	18707
Summed total	542.8	542786.4

/ Area (3033m^2)

kWh/m^2
3.9
6.0
10.2
14.9
19.5
22.8
23.0
24.2
21.3
15.6
11.4
6.2
179.0

Table 8.Cooling Load values from IES-VE

The final cooling load value computed is around 179 kWh/m^2. in comparison to the CIBSE Guide benchmarks, this design projects cooling load estimation is just under the benchmark value which is determined to be at 180 kWh/m^2.

	Benchmark relative to floor area kWh/m^2/yr		
	New	TM46	Difference
Electricity	110	180	39%
Gas	140	420	67%

Table 9. CIBSE Benchmarks

Due to the estimated value being borderline meeting the requirements, it can raise concerns on if the design project was correctly endured. As the IES-VE design was considered to be the worst-case scenario the building can go through, the design was in fact not as accurate to that of the Revit model. First limitation arises from IES which entails that the design wasn't precise as the total floor area designed in IES was around 3033m^2 whereas the initial floor area was around 2322m^2. This limitation was approved and developed into the worst-case scenario as IES showed a few restraints when designing the building. However, the building in its worst case scenario still meets the requirements which suggests that the building in its initial design would comfortably operate in the CIBSE benchmarks.

Building Energy Performance

The building energy performance consists of the total energy and electricity consumption and for this design project, lighting is also being discussed and evaluated. By examining and evaluating the building energy performance, it can give an overview of the energy analysis of the building, meaning that it indicates where the building lacks in performing and where the building is consuming the most energy. Utilizing various forms of graphs and tables from IES-VE to understand the simulated building energy performance for this design project.

Essentially, lighting is one of, if not, the main aspect that contributes to a building's annual energy consumption. as it is the only electrical element that is wide spread across every zone within the building, lighting can also have a negative impact on the energy consumption if not taken into consideration properly. Hence, the lighting for each zone according to the Dubai Building Codes were placed to give an understanding of the various aspects of energy-efficiency that lighting can contribute to.

The following table demonstrates the chosen lighting for the various zones in the building with their respective specifications.

LEDs used from TRILUX	**Lumens/Bulb (lm)**	**Connected Load (W)**	**Luminous Efficacy (lm/W)**	**Colour Temp (K)**	**Location**
ArimoFit Sky M59 PW19 53-840 ETDD	5300	42.0	126.2	4000	Auditorium, Lobby, Offices and Exhibition Spaces
ArimoFit M84 PW16 30-840 ETDD	3000	22.0	136.4	4000	Meeting Rooms and Service Rooms
Avelia C09 OA 2600-830 ETDD 01	2550	30.0	85.0	3000	Bathrooms

For the purpose of this section, the above values weren't tabulated into IES-VE due to the fact that IES-VE limits the input values for lighting hence stating that allows the discussion for the worst-case scenario for the building.

Using the values that were inputted for lighting in the 'Internal Gain' section of the report, the tests were carried out to determine the simulated readings by APACHE. The following graph indicates the total lighting energy consumption per year.

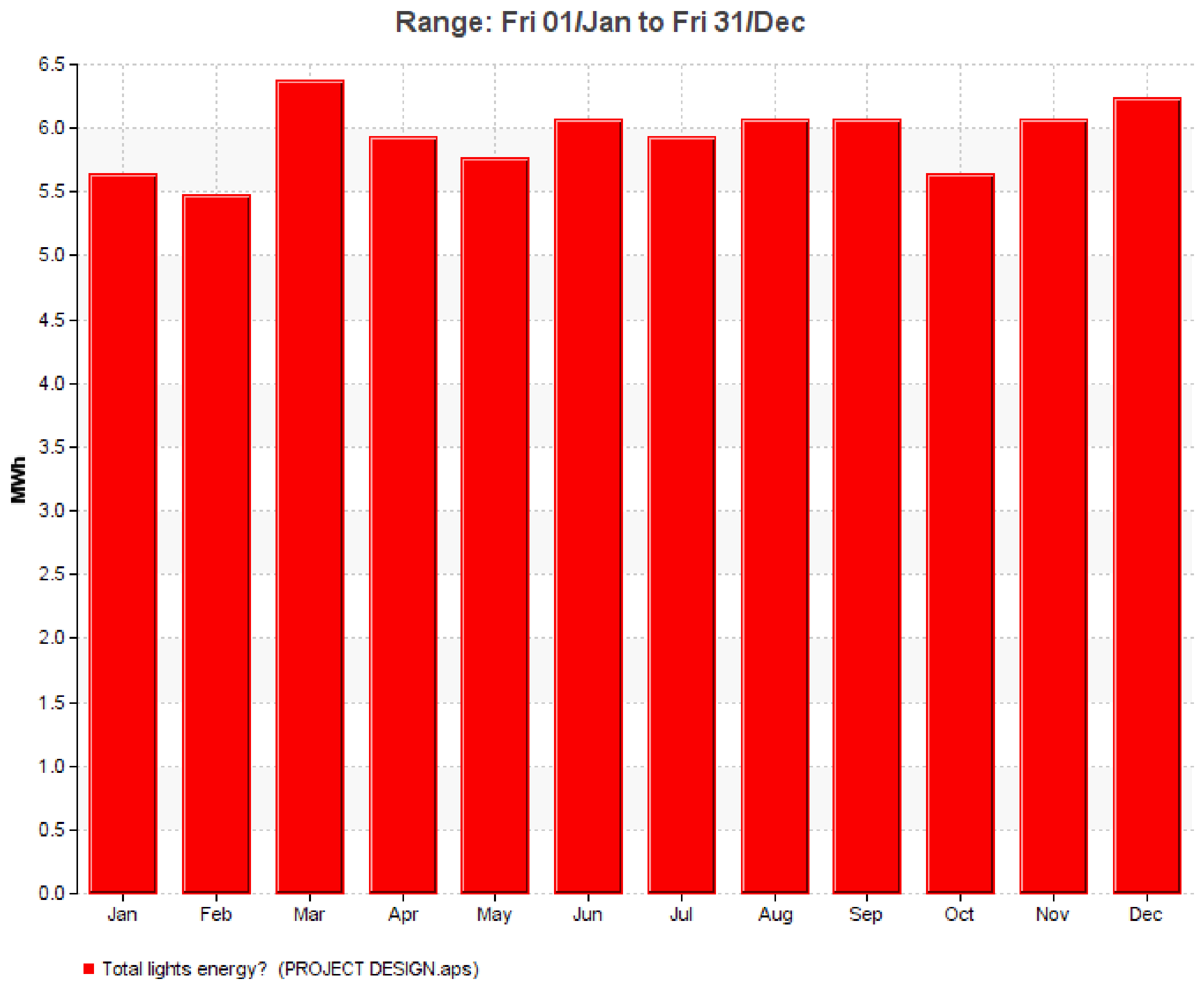

Figure 14. Total light energy consumption on a monthly basis

The above graph shows variations in the lighting energy consumption on a monthly basis which indicates that the variations are due to the full number of weeks in a month.

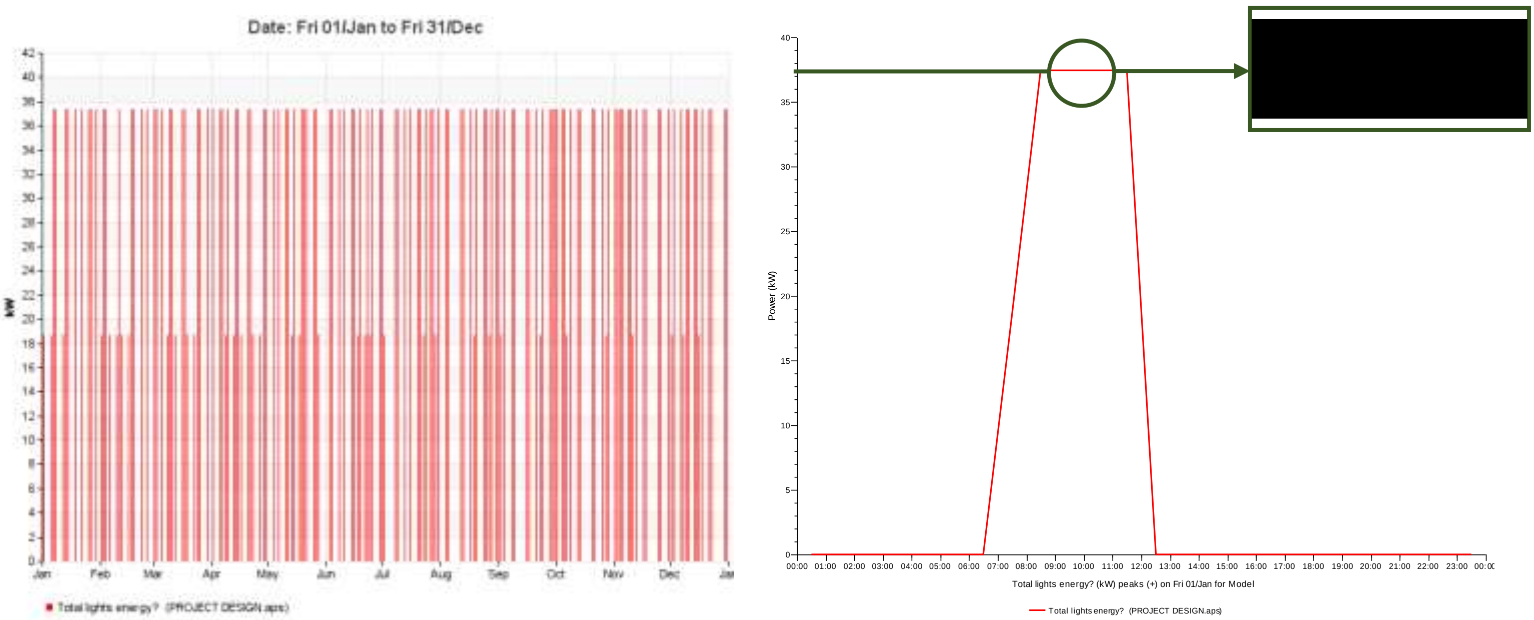

Figure 15. Lighting Energy Consumption in kW

Moving on from lighting energy, the total energy and electricity consumption was evaluated. This includes lighting, equipment, occupants and HVAC Systems.

The following graph shows the total electricity consumption of the building on a monthly basis

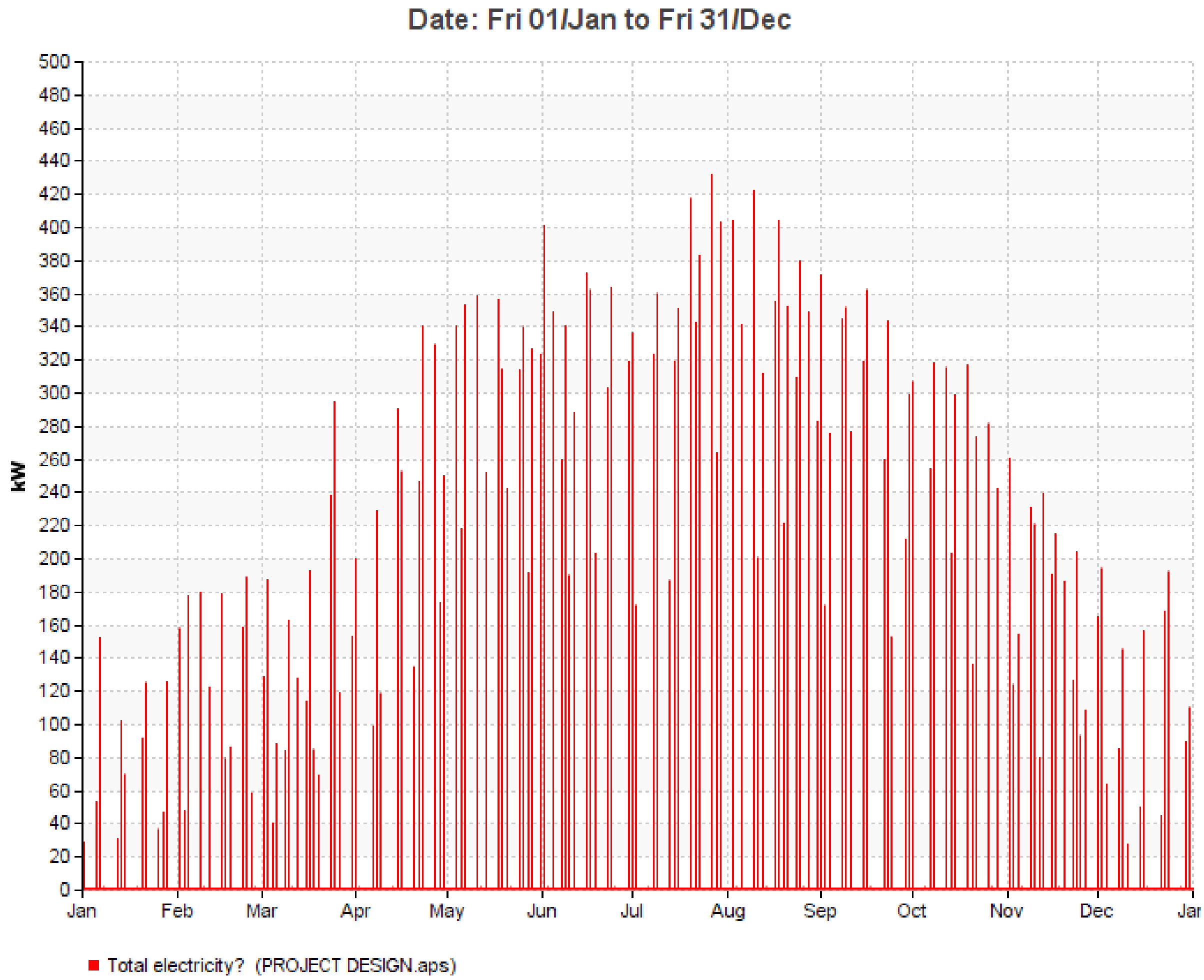

Figure 16. Total electricity graph

The graph is quite similar, visually, to that of the cooling loads evaluated in the last section. It can be stated that the cooling load simulation can deemed to be correct as it is in correlation with the total electricity consumption. the peak loads for both of the graphs are during the same period and off-peak loads are similar, if not, the same for both of the graphs. The same method was used for the total electricity consumption and total energy consumption to figure out if they meet the requirements and stand within the CIBSE benchmarks.

The peak electricity consumption was tabulated via IES-VE and the monthly average electricity consumption were utilized.

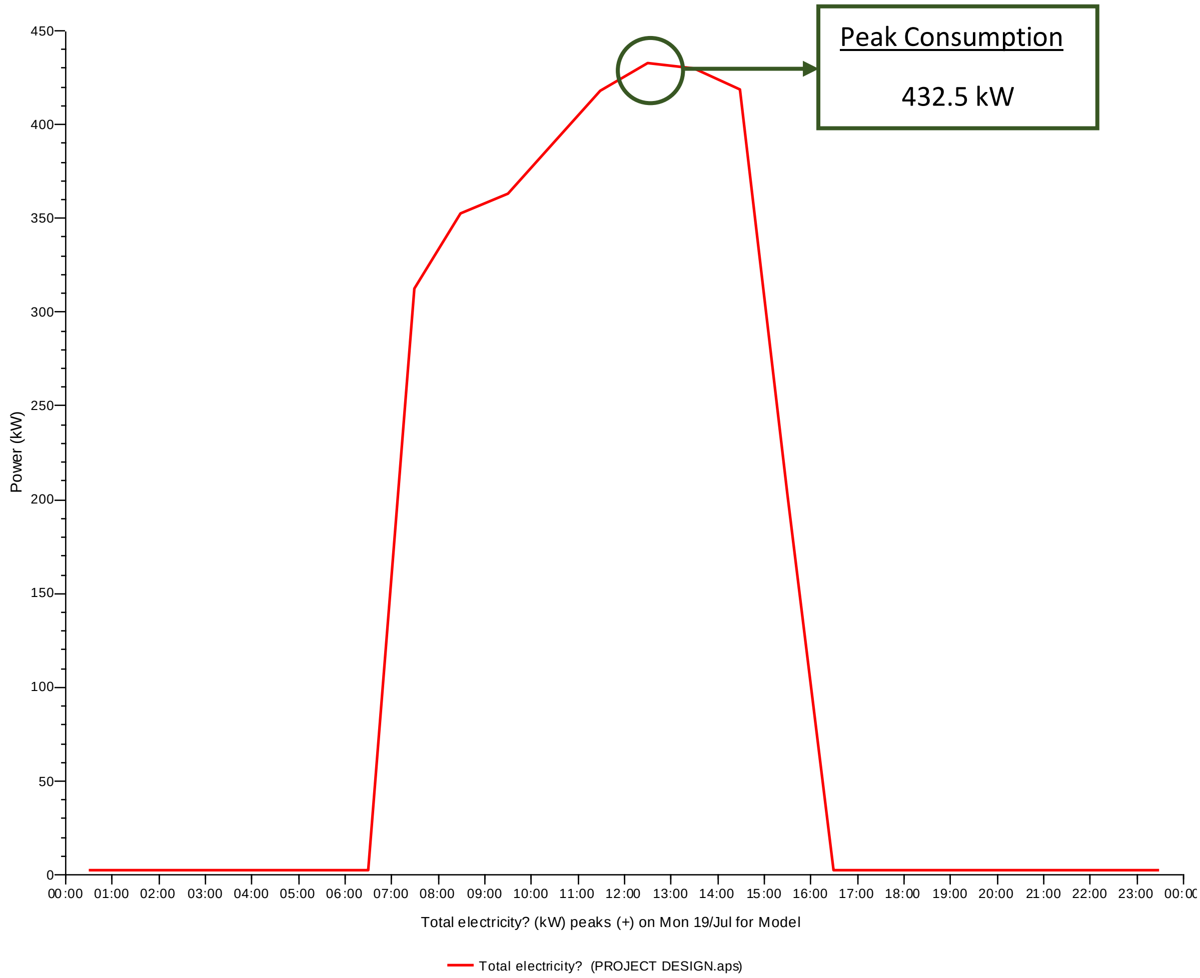

Figure 17. Graph for peak electricity consumption

Peak Date	Peak Time	Total electricity (kW)
19-Jul	12:30	432.5

Table 10. Peak Consumption Details

After evaluating the peak consumption, the monthly electricity consumption is converted from MWh to kWh/m^2 to compare with the CIBSE Guides.

Date	Total electricity (MWh)	kWh
Jan 01-31	16.127	16127
Feb 01-28	20.4478	20447.8
Mar 01-31	31.0144	31014.4
Apr 01-30	40.9541	40954.1
May 01-31	51.187	51187
Jun 01-30	58.7158	58715.8
Jul 01-31	59.243	59243
Aug 01-31	61.8955	61895.5
Sep 01-30	55.4578	55457.8
Oct 01-31	42.1984	42198.4
Nov 01-30	33.2056	33205.6
Dec 01-31	21.7613	21761.3
Summed total	492.2076	492207.6

/ Area ($3033m^2$)

kWh/m^2
5.3171777
6.7417738
10.225651
13.502835
16.87669
19.358985
19.532806
20.407352
18.284801
13.913089
10.948104
7.1748434
162.28408

Table 11. Monthly Electricity consumption

In correspondence to the CIBSE Guide, the total electricity consumption of 162.3 kWh/m^2 stands within the benchmarks comfortably as the CIBSE benchmarks, shown Table 9, denote that the TM46 value for the benchmark regarding electricity consumption is at 180 kWh/m^2.

Moving onto the energy analysis, the same procedures were taken place to analyse the total energy consumption of the building. The difference between energy and electricity consumption is that electricity can be deemed as just a part of the energy consumption. this correlates to the total energy consumption containing more sources, for example, natural gas. However, this specific project uses minimal, if not, no natural gas for energy generation, hence the graphs and values obtained from IES-VE are near identical. This indicates that the model made in IES isn't faulty and is simulating the worst-case scenario splendidly.

The first step of the energy analysis contains the overall general graph which visualizes the basic readings.

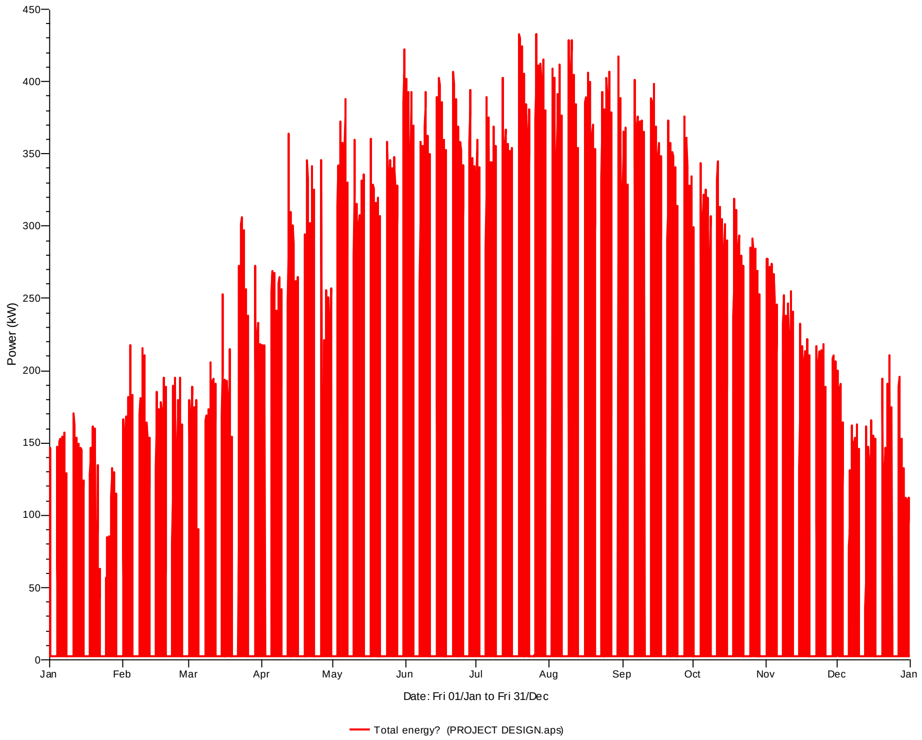

Figure 18. Total energy consumption graph

Just by visualizing the above graph, it can be positively stated that the electricity consumption and energy consumption graphs are near identical. The next procedure includes the peak consumption values and the specifics.

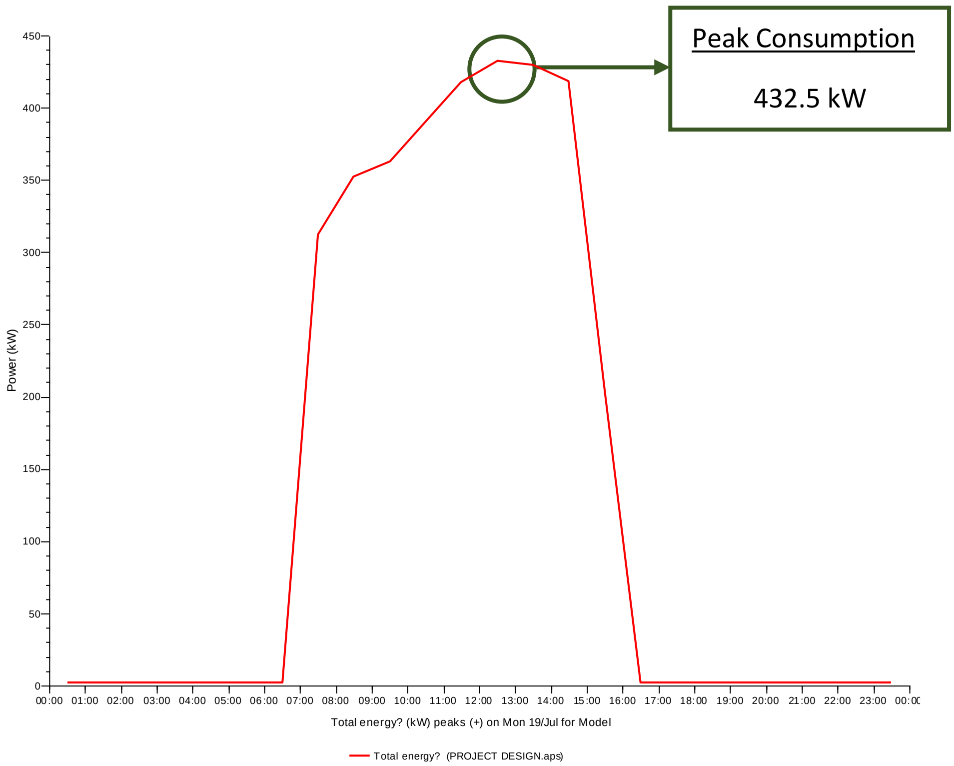

Figure 19. Peak Consumption graph

Peak Date	Peak Time	Total energy (kW)
19-Jul	12:30	432.476

Table 12. Peak Energy Consumption

After examining and comparing with the peak electricity consumption, the values are deemed to be the exact same. Moreover, the peak cooling load was determined to be on the same day, which indefinitely proves that the simulation is satisfactory.

Moving on, not changing the practice, the energy analysis is done by obtaining the various values form IES and comparing them to, this time, CIBSE Guide F.

Date	Total energy (MWh)	kWh
Jan 01-31	16.1326	16132.6
Feb 01-28	20.4478	20447.8
Mar 01-31	31.0144	31014.4
Apr 01-30	40.9541	40954.1
May 01-31	51.187	51187
Jun 01-30	58.7158	58715.8
Jul 01-31	59.243	59243
Aug 01-31	61.8955	61895.5
Sep 01-30	55.4578	55457.8
Oct 01-31	42.1984	42198.4
Nov 01-30	33.2056	33205.6
Dec 01-31	21.7613	21761.3
Summed total	**492.2132**	**492213.2**

/ Area (3033m^2)

kWh/m^2
5.3190241
6.7417738
10.225651
13.502835
16.87669
19.358985
19.532806
20.407352
18.284801
13.913089
10.948104
7.1748434
162.28592

Table 13. Monthly Energy Consumption

As mentioned before, the similarities between the both electricity and energy consumption has also been proved by the total energy consumption in kWh/m^2 which is near identical to that of which of the total electricity consumption which is 162.3 kWh/m^2. However, unlike the total electricity consumption, the energy consumption is being compared to the CIBSE Guide F.

Table 20.1 Fossil and electric building benchmarks — *continued*

Building type	Energy consumption benchmarks for existing buildings / ($kW \cdot h \cdot m^{-2}$) per year (unless stated otherwise)				Basis of benchmark
	Good practice		Typical practice		
	Fossil fuels	Electricity	Fossil fuels	Electricity	
Offices:[10][f]					
— air conditioned, standard	97	128	178	226	Treated floor area
— air conditioned, prestige	114	234	210	358	Treated floor area
— naturally ventilated, cellular	79	33	151	54	Treated floor area
— naturally ventilated, open plan	79	54	151	85	Treated floor area

Figure 20. CIBSE Guide F table for benchmarks

The figure above clearly demonstrates that the total energy consumption simulated by IES-VE adequately meets the benchmarks as the good practice for total energy consumption correlates to 234 kWh/m^2, in comparison to 162.3 kWh/m^2.

After analysing the loads and electrical and energy consumption, it can be comfortably stated that the IES simulation has proved to provide sensible readings for the worst-case scenario for the building.

Carbon Emissions

Carbon emissions are one of the main problems globally. According to architecture2030.org, the built environment contributes to at least 40% of the annual global carbon emissions, as they take up most part of an area and contribute withstand the requirements of people's everyday lives. The contribution to the global carbon emissions comes from material manufacturing, renovation, refrigerants and high energy consumption.

Hence stating that, it is crucial to evaluate and examine any extensive carbon emissions that could lead to bad ratings and an overall negative image for a project. It also allows to gain an understanding of whether or not the building would function positively with the proper total energy and electrical consumptions.

The total carbon emissions were determined from IES-VE after running the tests form APACHE. The following graph demonstrates the generic values for the carbon emissions for the current design project.

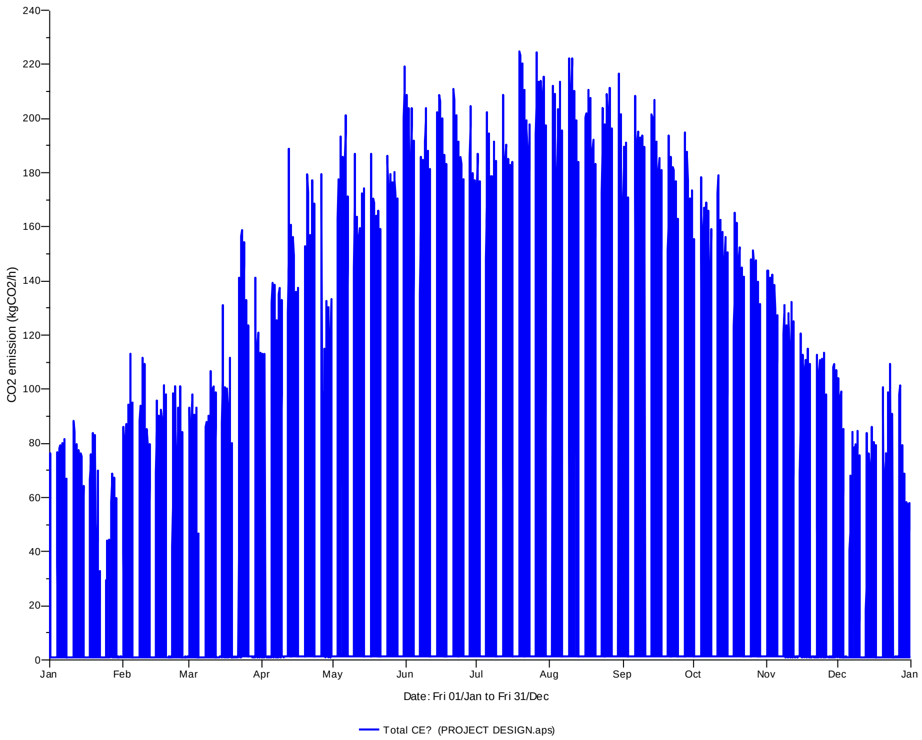

Figure 21. Total carbon emissions graph

As mentioned, many times before, each graph shows its similarity to each other, hence proving that the simulation doesn't contain any damaging faults and the buildings worst case scenario method has worked to determine whether or not the building would function positively.

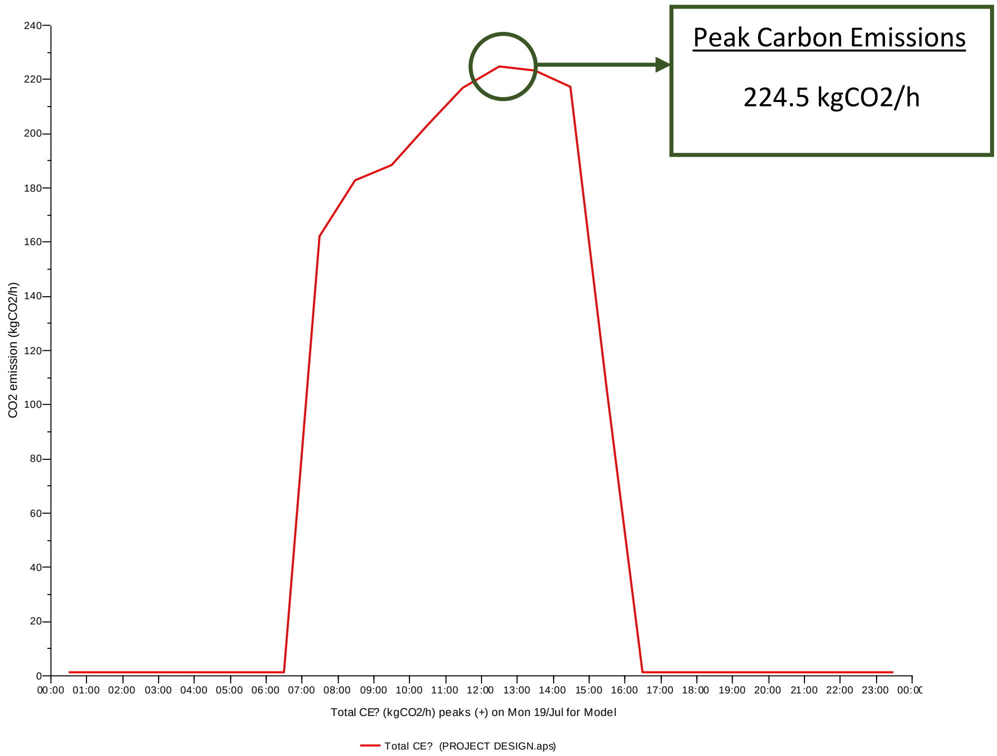

Figure 22. Illustrates the peak carbon emissions

Peak Date	Peak Time	Total CE (kgCO2/h)
19-Jul	12:30	224.5

Table 14. Peak carbon emission details

Similar to the loads and consumption, the peak carbon emissions also fall on the same day. This also correlates back to the point of July the 19th being the most consuming day in every aspect. Proving that this occurrence can be due to the fact of weather conditions, more activity, and human error.

Moving onto comparison with benchmarks, the carbon emissions also take a similar procedure in determining whether or not the building meets the requirements and fits comfortably with the benchmarks provided by CIBSE.

Date	Total CE (kgCO2)
Jan 01-31	8371
Feb 01-28	10612
Mar 01-31	16096
Apr 01-30	21255
May 01-31	26566
Jun 01-30	30473
Jul 01-31	30747
Aug 01-31	32124
Sep 01-30	28783
Oct 01-31	21901
Nov 01-30	17234
Dec 01-31	11294
Summed total	**255457**

/ Area (3033m^2)

kgCO2/m^2
2.8
3.5
5.3
7.0
8.8
10.0
10.1
10.6
9.5
7.2
5.7
3.7
84.2

By evaluating the monthly status of the carbon emissions in relation to the building and by comparing to the CIBSE Guide, it can be stated that the buildings total carbon emissions are above the mentioned in the CIBSE benchmarks in Table 15.

A number of justifications can be provided in concern for this reason. Firstly, as mentioned before, a few limitations with the software established this unsatisfactory result. Moreover, the benchmark used from CIBSE is deemed to be the closest possible function for the design project, therefore, it doesn't include some parts of the design such as the café where heavy electrical appliances are being used.

[A]	[B]	[C]	[M]	[N]	[O]
Name and Description			Illustrative CO_2 benchmarks calculated from the energy benchmarks (see Table 3)		
Category	Name	Brief Description	Illustrative electricity typical benchmark (kgCO2/m2)	Illustrative fossil-thermal typical benchmark (kgCO2/m2)	Illustrative total typical benchmark (kgCO2/m2)
1	General Office	General office and commercial working areas	52.3	22.8	75.1

Table 15. Benchmarks from CIBSE guides

External Design Condition

External design conditions or more commonly known as outdoor design conditions relate to the outdoor weather condition that typically have an impact on a buildings HVAC Systems. These design conditions generally include the various concepts of outdoor circumstances which may include variable air temperature, humidity, wind conditions and solar radiation. As the site is located in Dubai, annual readings for Dubai's climate were specifically evaluated in this section.

In 'Site Analysis', Dubai's climate was briefly explained as a hot and humid climate throughout the year. This is due to the fact that the city is built in a desert which experiences very less rainfall and rarely experiences overcast conditions. Hence, it is deemed to be extremely important to gain an understanding on how conditions like these would affect the cooling load for an upcoming project. If this isn't taken into deep consideration, the building can house an undersized system which will cause renovations essentially increasing the total carbon emitted by the project.

For this report, the outdoor design conditions were examined and evaluated from the data provided from Weatherspark.com.

Average Temperature in Dubai

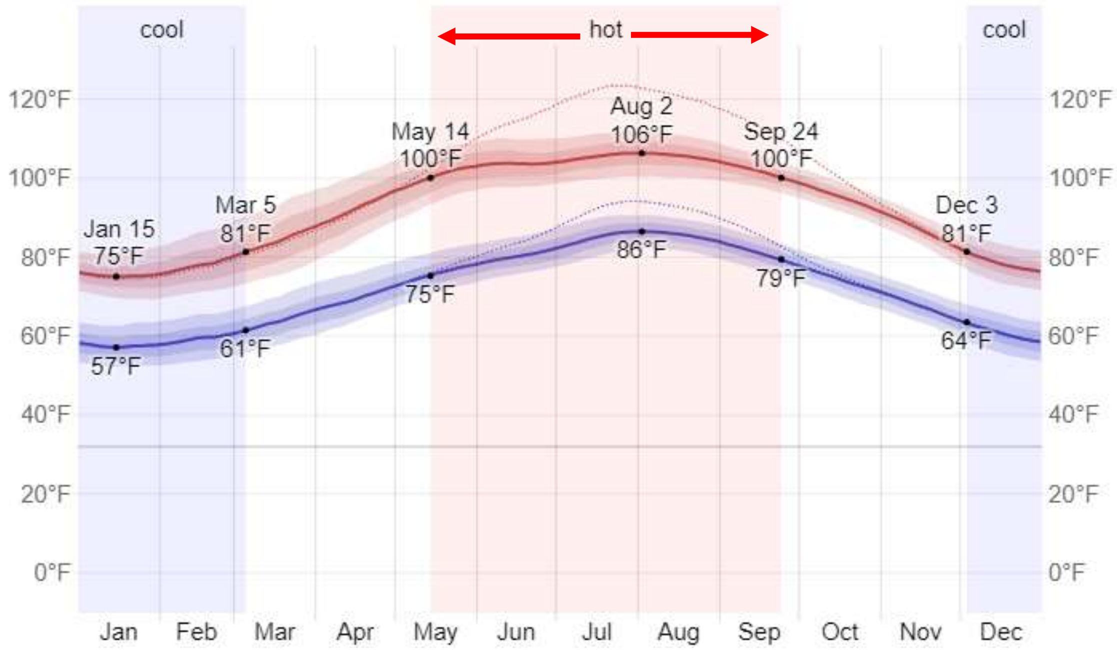

Figure 23. Average Temperatures in 2022 for Dubai

Average	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
High	75°F	78°F	84°F	93°F	101°F	104°F	106°F	106°F	101°F	95°F	87°F	78°F
Temp.	66°F	68°F	73°F	81°F	88°F	91°F	95°F	95°F	91°F	84°F	77°F	69°F
Low	58°F	59°F	64°F	70°F	76°F	80°F	86°F	86°F	81°F	74°F	67°F	61°F

Table 16. Average Monthly Temperatures

Analysing the above criteria, the data suggests that Dubai's hot runs for around 4 and a half months starting from the middle of May till the last week of September. Going back to the loads and total energy consumption of the building, the peak loads determined from IES have been justified as the hottest month in Dubai is July. With the highest temperature reaching just above 106°F (41.1°C) and hitting a low of 86°F (30°C). The month of August experiences around the same temperatures in Dubai. Meanwhile, the coolest month experienced in Dubai is January with an average low of 58°F (14.4°C) and an average high of 75°F (23.9°C).

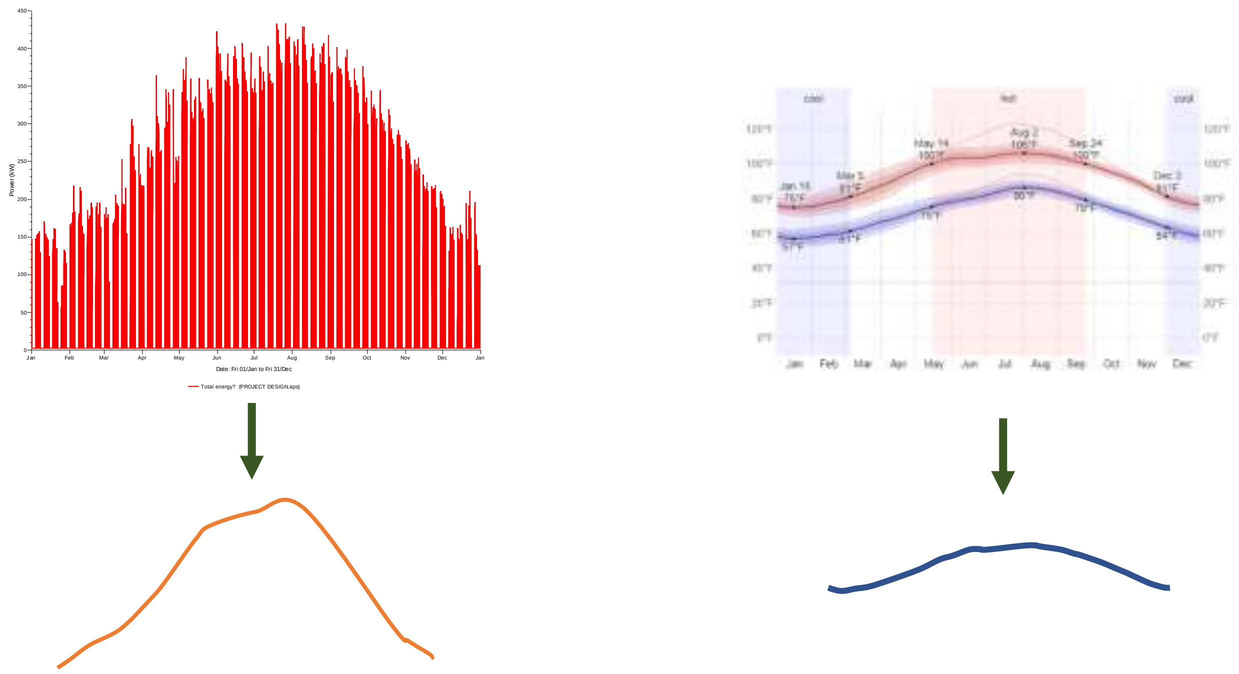

Figure 24. Comparison of the temperature and total energy lines

The lines can be visually seen from the figure above indicating that the lines aren't identical but can see a similarity between the formation of the lines, as the months progress, the values increase for the total energy consumption and the temperature until July/August where the decline starts to happen.

Humidity

The main complaints that the population admits to having is humidity in Dubai. It creates an uncomfortable environment and causes people to feel hotter than what is expected. Hence, from a thermal comfort point of view, it is essential for user comfort in the building to analyse the humidity levels of Dubai.

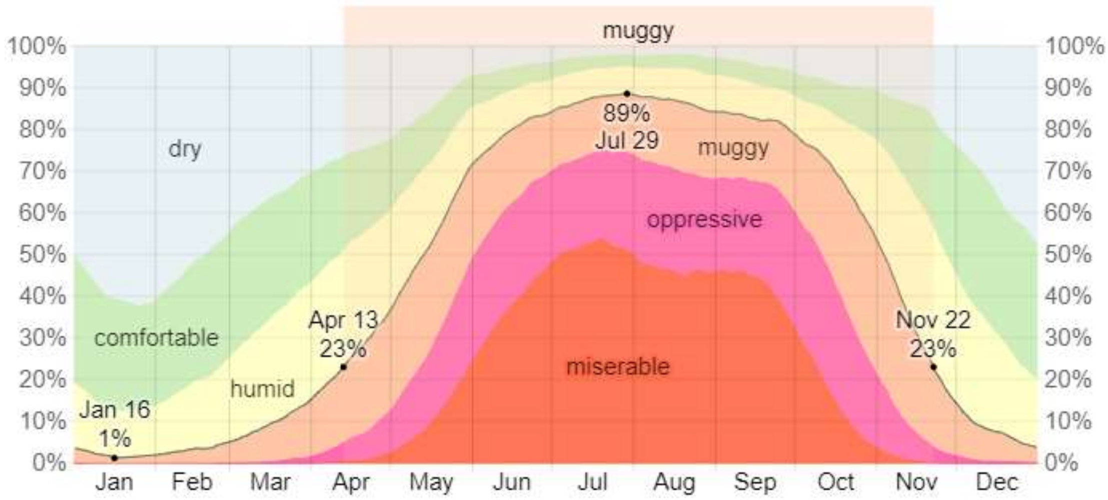

Figure 25. Humidity Levels on a monthly basis

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Muggy Days	0.6d	0.9d	3.0d	7.8d	17.0d	23.9d	27.0d	26.8d	24.7d	21.0d	9.3d	2.3d

Table 17. Average Monthly humidity levels

Weather Spark calculates humidity levels based on dewpoint, which is how rapidly perspiration evaporates. Dewpoint is directly linked to humidity, with lower dewpoint levels implying a drier atmosphere and higher dewpoint levels implying a more humid environment. Figure 25 shows that humidity levels rise until July and then progressively decline until December. The month of July has the muggiest days, implying that individuals would be subjected to a muggy climate or worse during the month.

The humid season lasts nearly 7 and a half months, from mid-April to the last week of November. In regard to the cooling loads that increase during this time, it also implies that the thermal comfort of users is being evaluated, necessitating more and more cooling within the structure, which effectively leads to an increase in the building's total energy consumption and carbon emissions.

Wind

As Dubai is home to desert like climate conditions, it is rare to experience heavy winds, hence stating that, the wind study is done 10 meters above the ground as altitude proves to experience greater wind speeds. Wind is also provisional to many factors which include, topography, geographical location and obstructions.

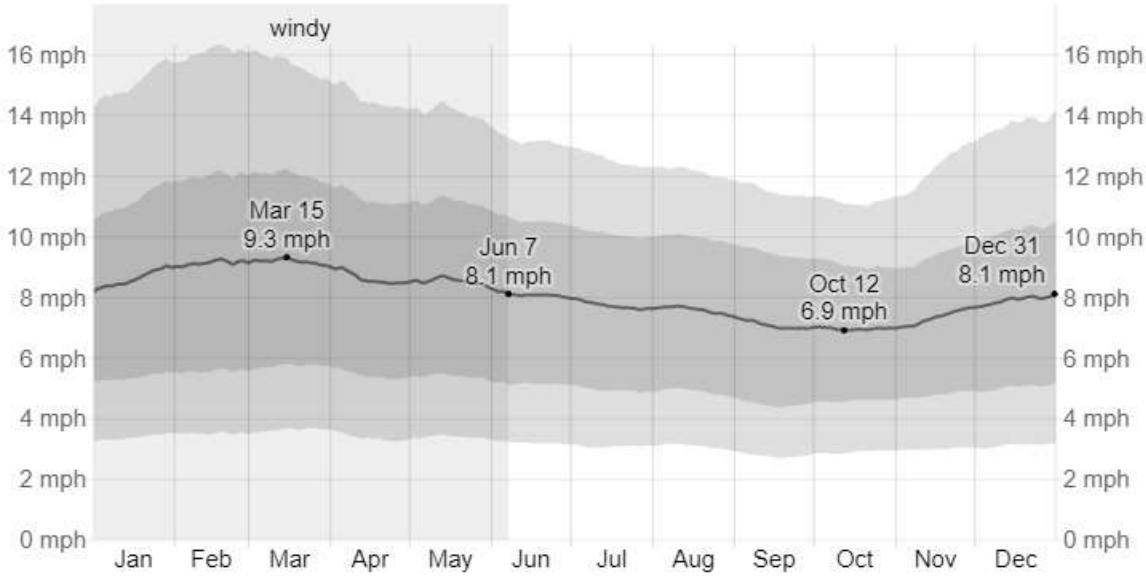

Figure 26. Average Wind Speeds

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Speed (mph)	8.6	9.1	9.2	8.6	8.5	8.1	7.7	7.6	7.1	7	7.4	7.9

Table 18. Average wind speed

The average wind speeds can be deemed as inversely proportional to the humidity as the months go by, the winds speeds decrease and towards the end of the year, the wind speeds take a steady increase. This is a seasonal change, summer experiences slow wind speed as compared to the relatively higher speeds in the winter season.

The direction of the wind is the most important factor in permitting natural ventilation to occur in a building. As a result, investigating wind direction can help in constructing the building to accomplish natural ventilation rather than relying just on mechanical ventilation. However, Dubai has a climate that generates less wind than others. According to Weather Spark, the majority of the year, 11 months to be exact, is dominated by winds from the west, with winds from the east dominating the remaining 4 and a half weeks. This gives a window of opportunities when it comes to designing and constructing a building to shape it in a way which it can provide a beneficial function to the building by helping in reducing carbon emissions and total energy consumption.

As mentioned in the 'Site Analysis' section, the site for this project also experiences wind from a similar side, North West to be exact, as obstructions deny the site form experiencing wind from the west directly. Hence, the form of the building was designed in a way so that the wind can contribute to the natural ventilation aspects of the building.

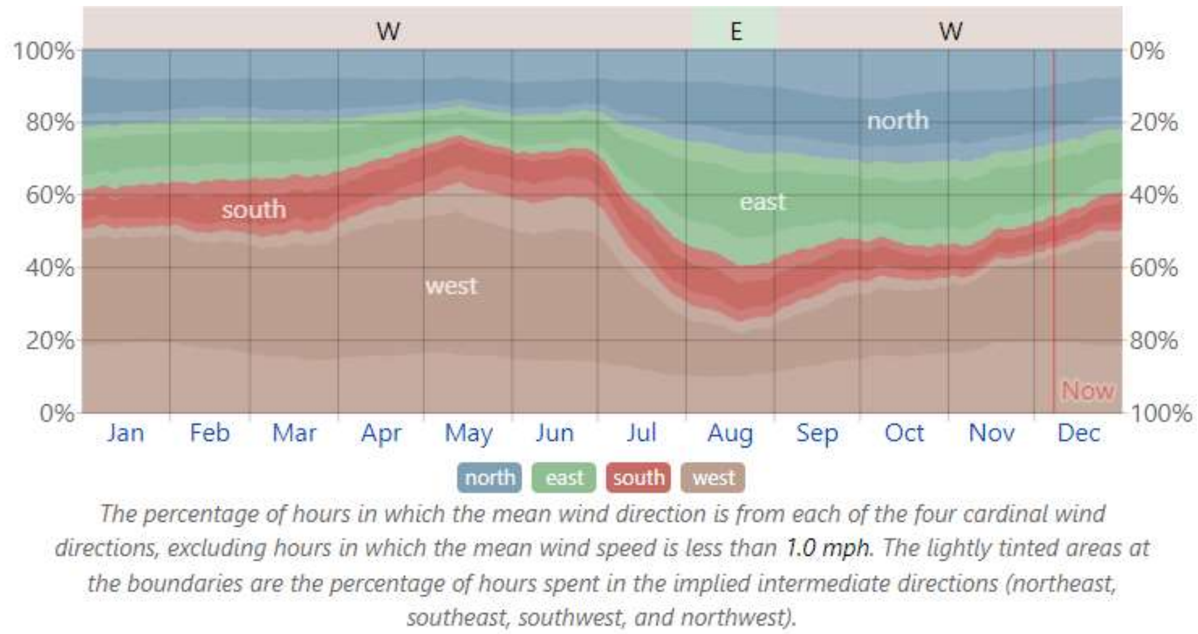

Figure 27. Image is taken directly from Weather Spark explaining the graph conclusively

Building Services

Mechanical

Mechanical services mainly include the application and implementation of the HVAC System of a building. Being on the most important aspects when it comes to the functionality of the building, HVAC systems prove to be the most crucial as they highly tailor thermal comfort for users. As an air handling unit is required for supplying air to the various zones in the building, the HVAC systems are usually housed within an AHU room. These specifically labelled rooms are needed due to being logistically applicable in a building whose main function is productivity as these rooms occupy plinths. These 125mm high plinths help in diminishing acoustic and vibration levels in the building which cause unwanted distractions.

As HVAC systems are mechanical, these systems are systemized by mechanical engineers. HVAC systems are generally very practical as the modern days prove that each zone has unique requirements depending on the function. Hence stating that, implementing a system which meets all the required demands and is energy efficient helping the building achieve great sustainability standards.

Keeping those aspects in mind, a Variable Air Volume (VAV) system was chosen for this specific project. VAV systems provide constant air temperature with varying airflow rate providing heating or cooling depending on the zone. It is the most used HVAC system in the modern days as compared to the standard Constant Air Volume (CAV) system which differs from the VAV system completely as it provides constant air flow with varying air temperature.

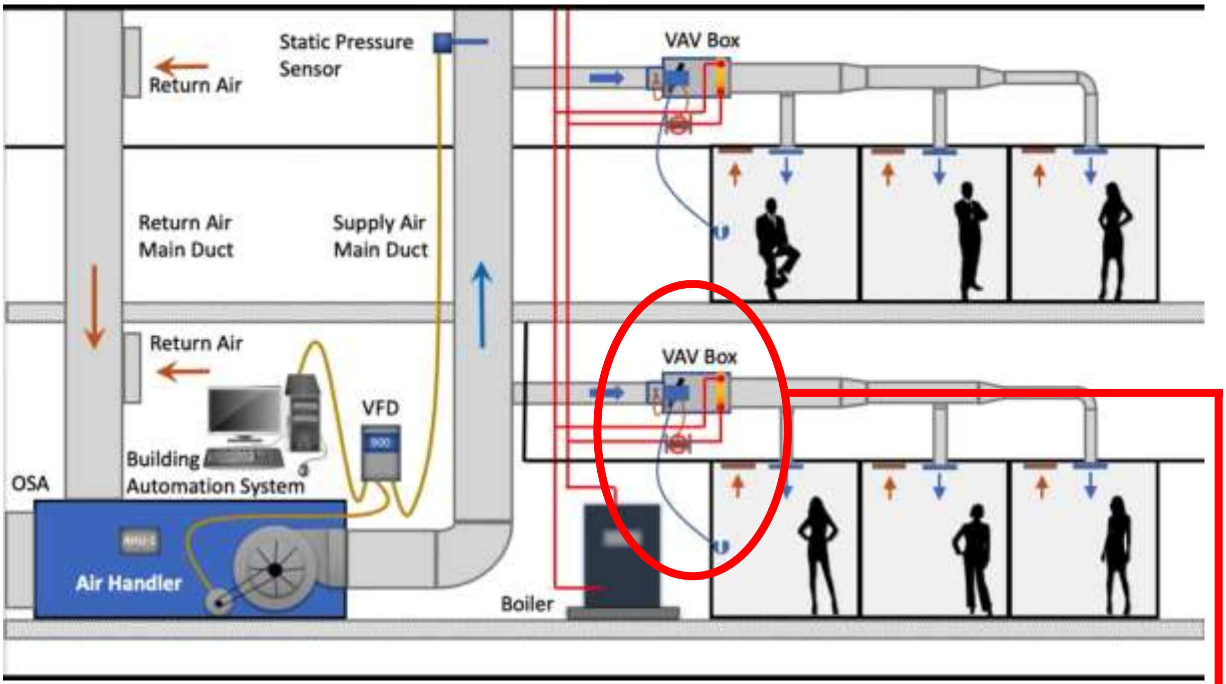

Figure 28. Standard demonstration of a VAV system in a building. Source (Instructor, 2022)

Figure 28 depicts the operation of a VAV system within a structure. The air handler adjusts the airflow to meet the needs of the various zones. As a result, VAV boxes prefer to adjust airflow based on the purpose of the defined area. The temperature sensor, as shown in Figure 29, informs the VAV box about the zone's air temperature requirements and circumstances.

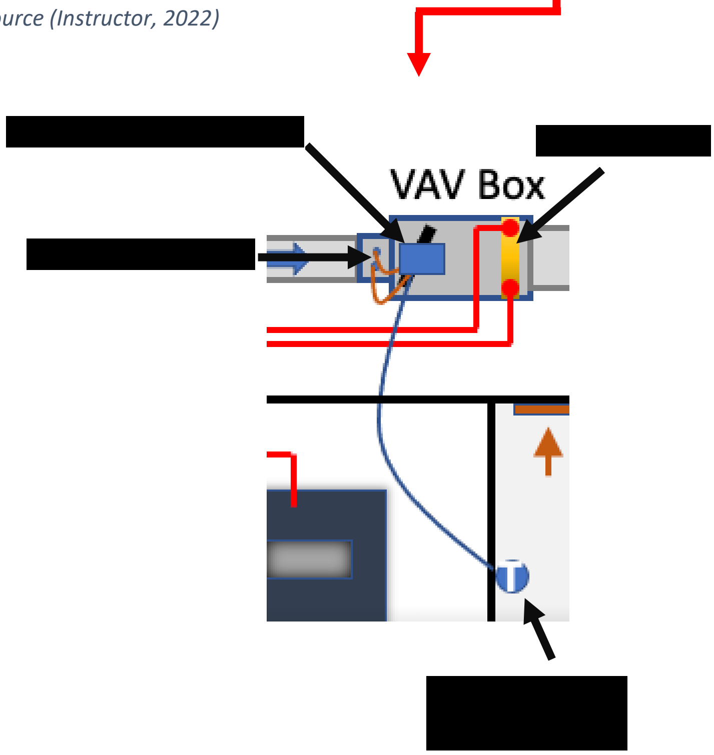

Figure 29. Labelled diagram of the VAV System

The air handling unit will supply air through the supply air main ducts which will travel to the VAV boxes connected to all the zones. The air handler unit will then adjust the volume air flow rate accordingly. As the demand is controlled by the temperature sensor located within the areas, the VAV box will open or close it dampers accordingly via the actuators situated within the box. This causes appropriate pressure changes in the supply air main duct that the static pressure sensor detects. The dampers are inversely proportional to the pressure requirements, meaning that, when the dampers are closing due to low demand in the areas the pressure in the main duct increases and vice versa. For example, if the pressure increases as the dampers are closed, the static pressure sensor will indicate the Variable Frequency Drive (VFD) will send a signal to the air handling unit to decrease the rpm of the fan. This indefinity helps the building in consuming lesser energy than expected.

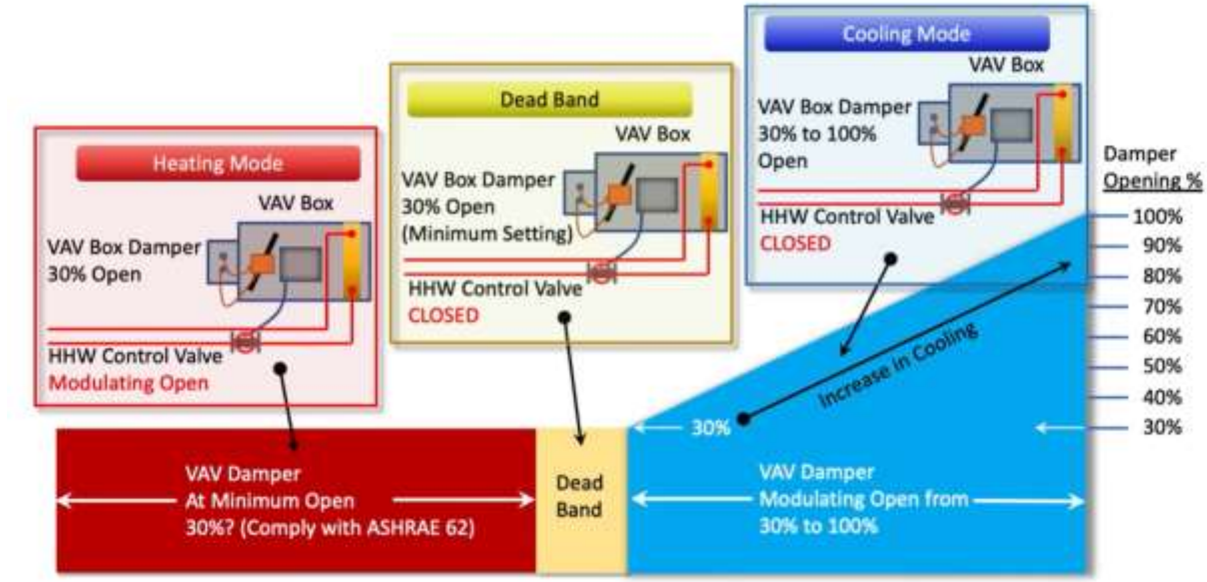

Figure 30. Visual demonstration of how the dampers function (Instructor, 2022)

VAV boxes have three systems or modes which they can function on depending on the requirements of the area.

The above demonstration suggests that the damper opens at a minimum of 30% when heating is required. The boiler in located in the AHU supply's hot water through the pipes into the VAV reheating coil essentially heating the air according to the heating hot water valve. The heating hot water valve modulates depending on the temperature requirements through the temperature sensor.

The dead band mode indicates when the area doesn't require any heating or cooling as the area maybe experiencing a comfortable temperature for the users. Hence stating that, the dead band mode remains at the minimum 30% of the dampers opened and the heating hot water valve is closed as unnecessary heating from the boiler would only increase energy consumption.

Lastly, the cooling mode is the most used and in relation to Dubai as heating is required to a bare minimum due to the climate. The dampers modulate between 30% to 100% relative to the base requirements of the users. The heating hot water valve remains closed for the same reason.

The main reason the dampers modulate are due to the fact that ASHRAE Standards 62 have to be met. The following points determine how ASHRAE Standards are being met with the above information:

- Supply air volume at 30%,

Meaning that the dampers must remain open at a minimum of 30% to ensure that the systems don't entirely turn off.

- Around 0.4 cfm/sf

Meeting the zone condition area

- VAV Systems should never be shut off when the system is operating

After discussing the details regarding VAV systems, it can be concluded that the AHU can provide a number of beneficiaries including:

- Fewer noise levels
- Reducing risk of maintenance as the system decreases the compressor wear
- Energy efficient by temperature control and varying airflow

The following discussion is in regards to how this project has implemented a VAV system.

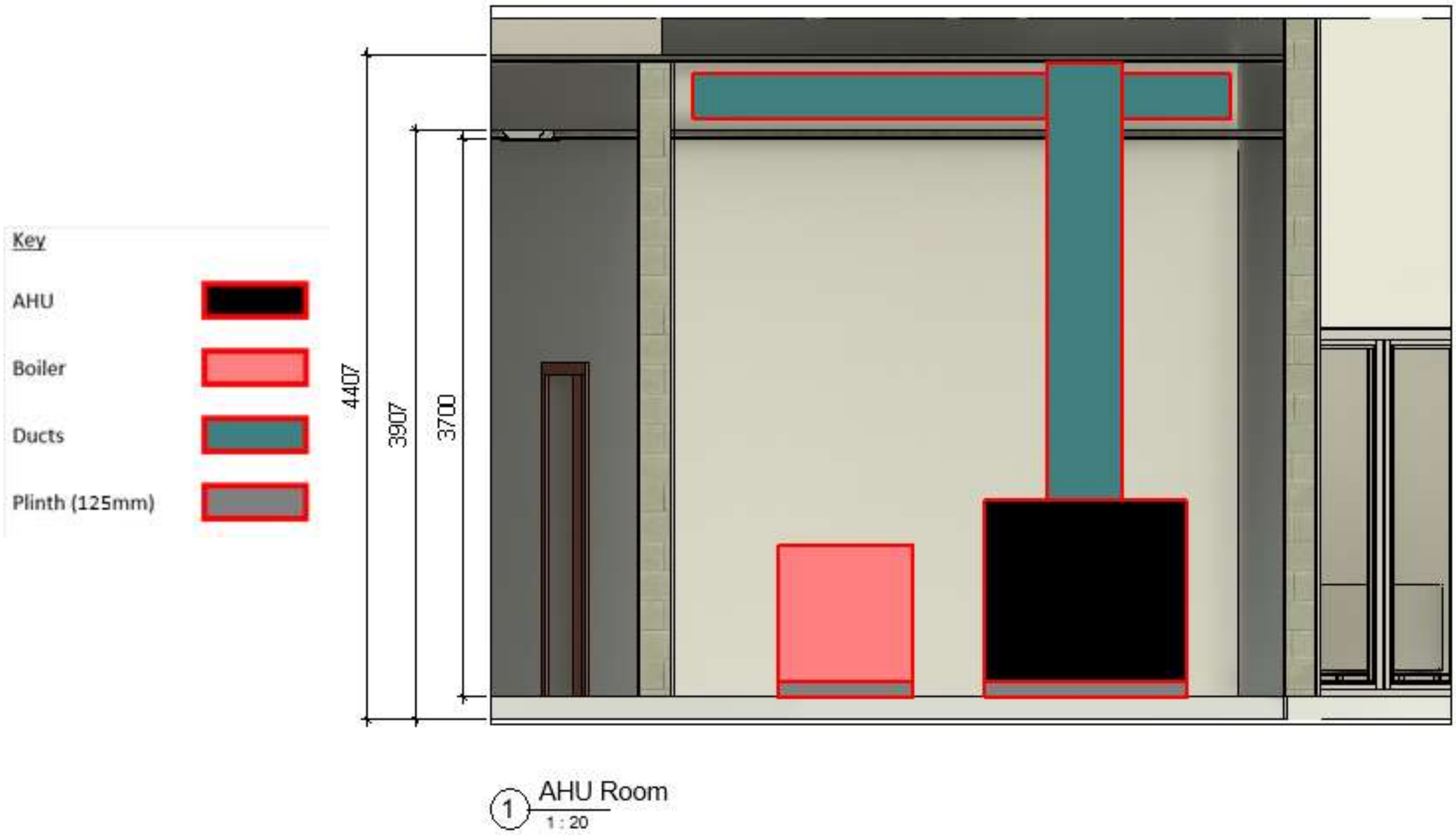

Figure 31. The AHU Room block layout

Figure 31 illustriously demonstrates the layout that can be visualized within the AHU room of the building. The main supply duct branches out in the false ceiling distributing across the main areas of the building. the building consists of three AHUs shown in Figure 32, to meet every zone requirement and they building doesn't face any problems of under-sizing the HVAC system. The filled regions highlight how the AHUs are spread across the building. The plinth height is according to DEWA specifications.

Reference Sheets
A110

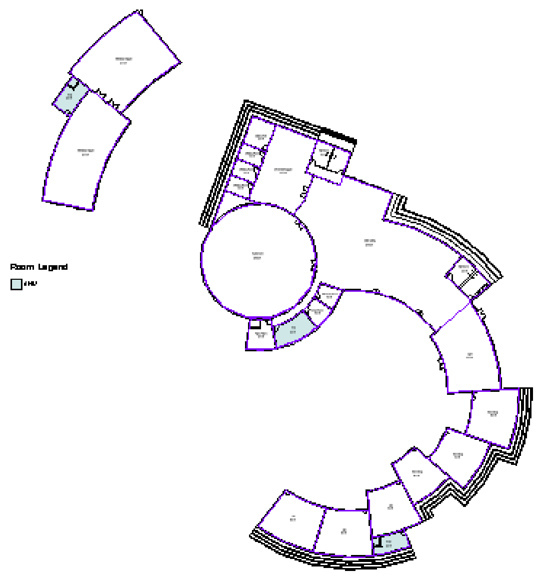

Figure 32. AHUs in the building

Electrical

Electricity shapes how a building function. Lighting components and electrical appliances, in this case, computers are the purpose of the building. From a sustainable point of view, the high consumption electrical appliances such as the mechanical systems need to be taken into account before the completion of the design. If not, the project could end up a failure and can cause an outstanding amount of loses across the construction board. Hence a professional electrical engineer provides information on how the building could function more energy efficiently. The electrical engineers also provide with better sustainability solutions in relation to the design of the building.

The Dubai Electricity and Water Authority (DEWA) are the main distributors of electricity throughout Dubai. Dubai mainly generates its electricity from natural gas power facilities and is currently in the process of completely transitioning into a 100% renewable energy generation by already taking the first step into solar generation. For this project, DEWA will provide electricity and water.

DEWA Specifications

DEWA provides detailed specifications for electrical installations for Dubai. This clears any doubts when concerns about electricity come up when designing a building. DEWA supplies details for underground cables in a handbook titled "Handbook on EHV Overhead Lines and Underground Cable Protective Regulations'.

The handbook first analyses the underground cables that provide electricity throughout the country. There are deemed to be two cables with different voltages; 400kV and 132kV depending on the requirements of the building. These power cables usually come in many different types; however, DEWA currently utilizes cross-linked polyethene cables (XLPE). This material is thermally insulated material which consists of cross-linked polymers. This makes the material more tightly bound increasing tensile strength. This strength allows the cables to stay intact for a substantial period of time requiring less maintenance. The cables DEWA uses consist of the following dimensions.

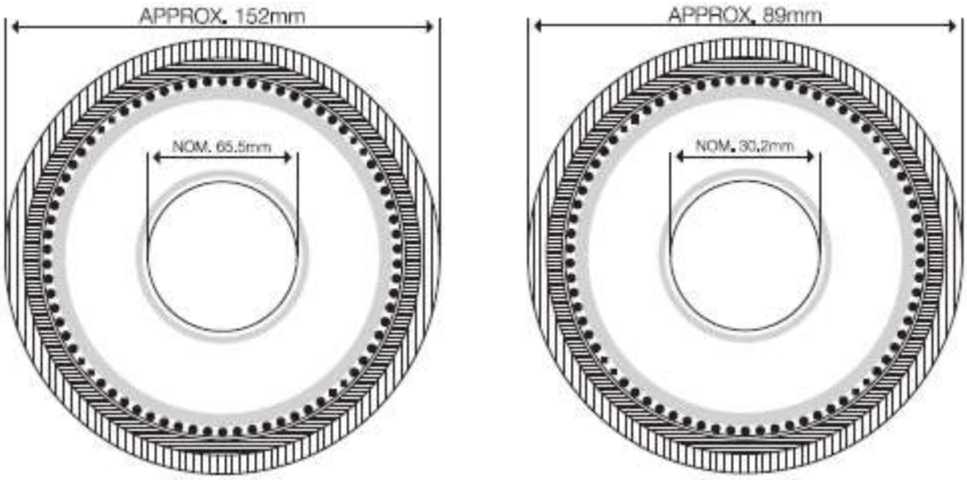

Figure 33. (left) 400kV XLPE Cable (right) 132kV XLPE Cable

The cable sizes work directly proportional to the voltage requirements, as the cable sizes increase as the voltage requirements increase and vice versa.

The purpose of evaluating this handbook provided by DEWA is to gain an understanding how these cables will approach the building.

DEWA proposes a number of ways for these underground cables to scope over to a project. The best case in this scenario is option 'd' which suggests that 'HDPE ducts by directional drilling method'. The purpose for this entails that the cables can travel underneath the asphalt roads which in this case is pathed by a bridge. Hence, it seems like the most logistical approach being the most cost efficient. The following diagram illustrates the directional drilling methods.

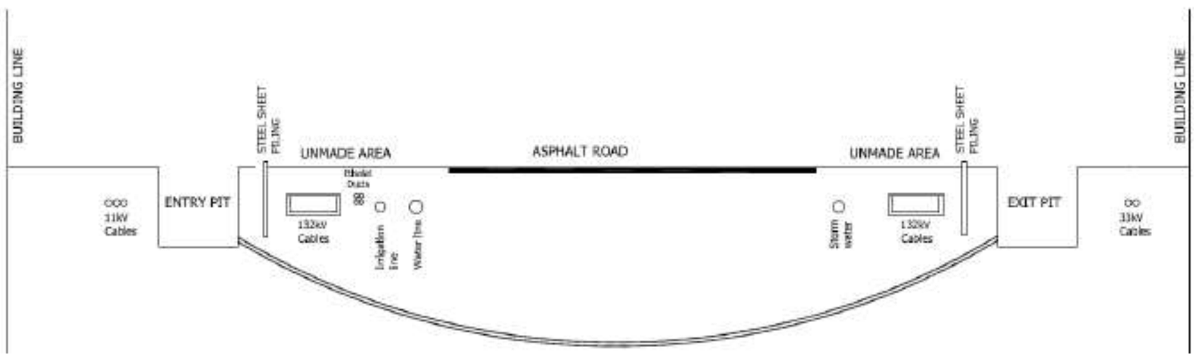

Figure 34. HDPE ducts by directional drilling method

For this project, the neighbouring road was used to supply the pipelines to the plant room of the building.

Reference Sheets
A109

Lighting

Lighting, as mentioned before, is one of the main aspects that contribute to the total energy consumption, hence, it is important to take this into deep consideration when electricity is being discussed. Luckily for lighting, it is plain simple in the modern days as to which approach to take especially for an office building. LEDs are being utilized in almost every upcoming project due to them being highly energy efficient. Table 19 clearly demonstrates how LED's compare to traditional lighting.

Reference Sheets
A107

Type of Light Bulb		
60- Watt Incandescent Bulb	14-Watt Fluorescent Bulb	12-Watt LED
		
Energy Usage – 60W	Energy Usage – 14W	Energy Usage – 12W
Lumens - 870	Lumens – 900	Lumens - 1300
Bulb Lifetime – 750hr	Bulb Lifetime – 10,000+hr	Bulb Lifetime – 50,000+hr

Table 19. Comparison between different lighting solutions

When it comes to choosing lighting for the building, the table above demonstrates a definite preference. LEDs provide more brightness with reduced energy consumption and a longer lifetime that requires little to no maintenance.

It is critical for an office workstation to have high intensity lights so that users can feel more focused and productive. Each zone has various lighting requirements, and each zone is influenced differently by lighting. The lighting for each zone is shown in the table below.

LEDs used from TRILUX	**Lumens/Bulb (lm)**	**Connected Load (W)**	**Luminous Efficacy (lm/W)**	**Colour Temp (K)**	**Location**
ArimoFit Sky M59 PW19 53-840 ETDD	5300	42.0	126.2	4000	Auditorium, Lobby, Offices and Exhibition Spaces
ArimoFit M84 PW16 30-840 ETDD	3000	22.0	136.4	4000	Meeting Rooms and Service Rooms
Avelia C09 OA 2600-830 ETDD 01	2550	30.0	85.0	3000	Bathrooms

Table 20. Chosen lighting for different zones

The first step into taking energy efficient measures, proximity sensors can be used for lighting. Proximity sensors are built into each room to enable energy-efficient lighting since they prevent the usage of lighting when a room is vacant by turning the lights off automatically. Proximity or occupancy sensors can also be used for smart HVAC systems that neutralise the HVAC systems into going into the dead band mode while the area is vacant.

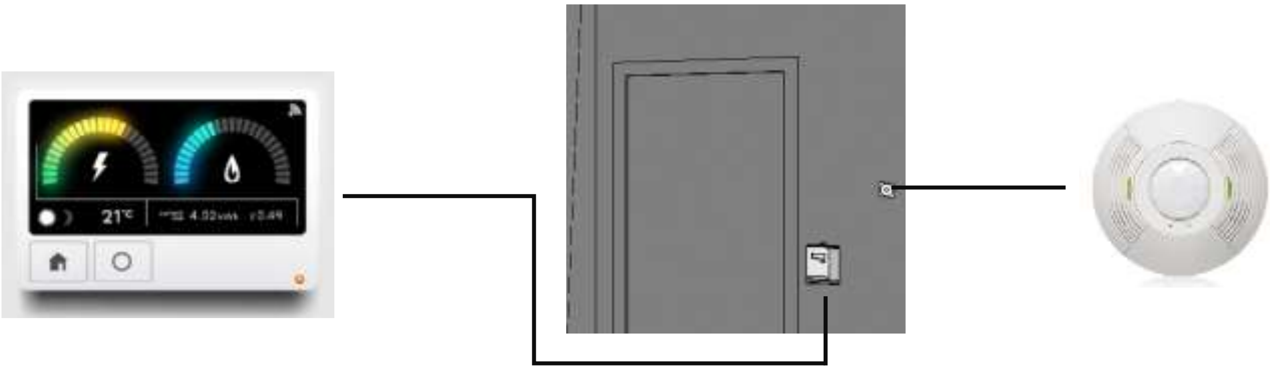

Figure 35. Visualizes the proximity sensors (right) and the smart meter (left) located in the plant room

A smart meter is installed in the building's service room to record the building's energy use on a monthly or annual basis. This would aid in determining areas for improvement or problems that may arise during the installation phase. It is strategically placed so that if maintenance is necessary, the smart meter can be repaired without disrupting the building's workflow.

Reference Sheets
A112

Energy Efficient Measures

As the proximity sensors and smart meters already play into energy efficient measures, there are a few more which are energy efficient that help the building achieve a great sustainability record. One of the main proposals for this building is the solar PV panels located on the north west side of the building strategically facing the south east which proves to experience more sunlight than others.

As it is an important factor of generating electricity for parts of the building, it is crucial in implementing a solar panel which is highly efficient for the building. hence the following are the specifications chosen for the solar panels selected.

SunPower MAXEON 6	
Power	425W
Power Tolerance	+5/0%
Panel Efficiency	22.0%
Rated Voltage	40.3 V
Rated Current	10.58 A
Temperature	-40oC to +60oC
Impact Resistance	25 mm diameter hail at 23 m/s
Solar Cells	66 Maxeon 6 Cells
Weight	21.8kg

Table 21. Solar panel specification

Frame

1872mm x 1032mm x 40mm

The above solar panel can be visualized on the building itself on the Revit model shown below:

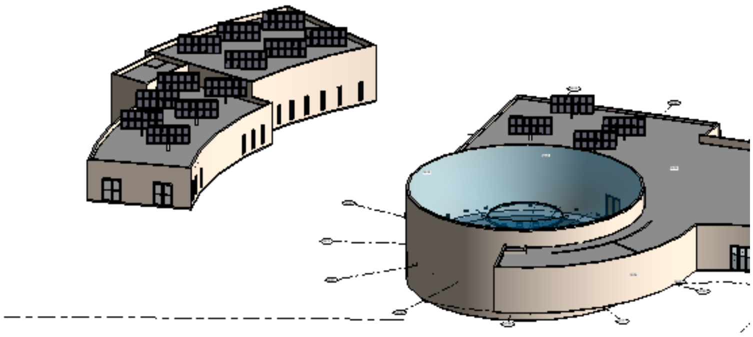

Figure 36. Revit model showing the solar panels

The building houses more energy efficient solutions which will be discussed later on in the report.

Plumbing

Plumbing is concerned with the building's water works. DEWA also has facilities for water regulation and transmission planning which is a critical factor in addressing water demands within the structure.

DEWA Water systems

As mentioned, Dubai has a desert like climate which lacks natural sources of water such as rainfall. Therefore, Dubai has to rely on desalinated seawater for meeting water demands for consumption or drinking. Seawater used form the Arabian Gulf gets treated in desalinated plants which process the water to be safe for consumption and then is set out to meet water demands accordingly. There are two main desalination plants within Dubai which account to almost 80% of water needs (Anon., 2022)

As this building covers an area of around 2300m^2, it cannot be considered as a major project that requires potable water bulk storage systems, but do require local storage systems which covers at least 24 hours of water requirements according to DEWA.

The following determine the pipeline details provided by DEWA:

Diameter	600-1200mm
Material	Glass fibre Reinforced Epoxy (GRE) PN 10
Fittings	GRE material complying with DEWA specifications

Table 22. Specifications of transmission pipelines

The water distribution pipelines provided by DEWA have a diameter range from 100 to 450mm and are constructed with the same material of the transmission pipelines (GRE). The developer is obligated to provide corridors for the water distribution pipelines.

Water Heating from Energy-efficiency

Heat pump water heaters, which provide on-site water heating, have been installed in the building. Heat pump water heaters operate on the principle of heat transfer rather than direct heat generation. As a result, energy-efficiency improves as they consume less electricity; according to energy.gov, energy-efficiency improves two to three times as a result of this. They typically reduce 3000kV in total.

Heat pump water heaters work in warm environments more commonly in temperatures ranging from 4.4°C-32.2°C by capturing surrounding air and transferring the heat at a higher temperature using electricity into the water storage essentially heating the water.

They produce low noise levels essentially causing low disturbance levels throughout the building. The ASHP is located in the pump room as locating it outside for substantial periods of time can cause damages to the heat pump itself and can require unwanted maintenance costs.

Reference Sheets
A112

Fire Safety

The most significant aspect in building design is undoubtedly fire safety. When it comes to fire evacuation procedures, most users are concerned about their personal safety. As a result, it can be stated that having a fire evacuation strategy is critical to fire safety.

The fire evacuation plan consists of the circulation necessary for evacuating the area in the lowest time possible. This specific building consists of individual zones sharing walls; hence, it can be deemed much easier for a user to act quickly when such a situation arises.

A fire hose reel is installed in the main lobby since fires spread much more easily in open spaces, and a fire extinguisher is located in every single zone, notably the café where the risk of fire is considerably larger than the rest.

The building houses a number of exit points, mainly leading to the main courtyard, allowing a meeting point to be set for people to gather to ensure everybody is safe.

Reference Sheets
A105

Conclusion

It is safe to say that the goal of this report has been accomplished after this extensive discussion of this design project.

Discussing the basics first by locating the site and analysing its features. It was found that the site is a man-made island embodied with water, also known as the Dubai Creek. An overhead road provides a bridge leading onto the site for accessing the already constructed Art Jameel in the north side of the site. The site itself experiences wind coming from the north west side and opposing that is the sun path.

The building's design incorporates a curved shape and strategic room arrangement to maximize user productivity. It contains all the components a regular user would require to carry out daily tasks. The materials picked out have a reasonably low thermal resistance U-Value, raising building standards by preventing significant heat gains.

The software IES-VE, which models how the building will work in the real environment, was used to comprehensively discuss outside and indoor design circumstances. This was accomplished by entering numerous design conditions such as weather, internal gains, air infiltration, HVAC systems, and geographical location into the software offering cooling loads, total electricity and energy consumption, and carbon emissions. Due to software constraints, the inputted numbers were compared to global norms and assessed to represent the worst-case situation for the building.

Evaluating the basics regarding the building services were thoroughly discussed using standards and local systems from DEWA. Energy efficient solutions were then provided that proved to be sustainable for this type of a building. from HVAC systems to underground transmission lines, every aspect was covered. Each building service was provided with its contributing Sheets which are located in the Appendix.

Lastly, fire safety was discussed and the importance of a fire evacuation plan in every separate location. This was also referenced by corresponding Sheets from the Appendix.

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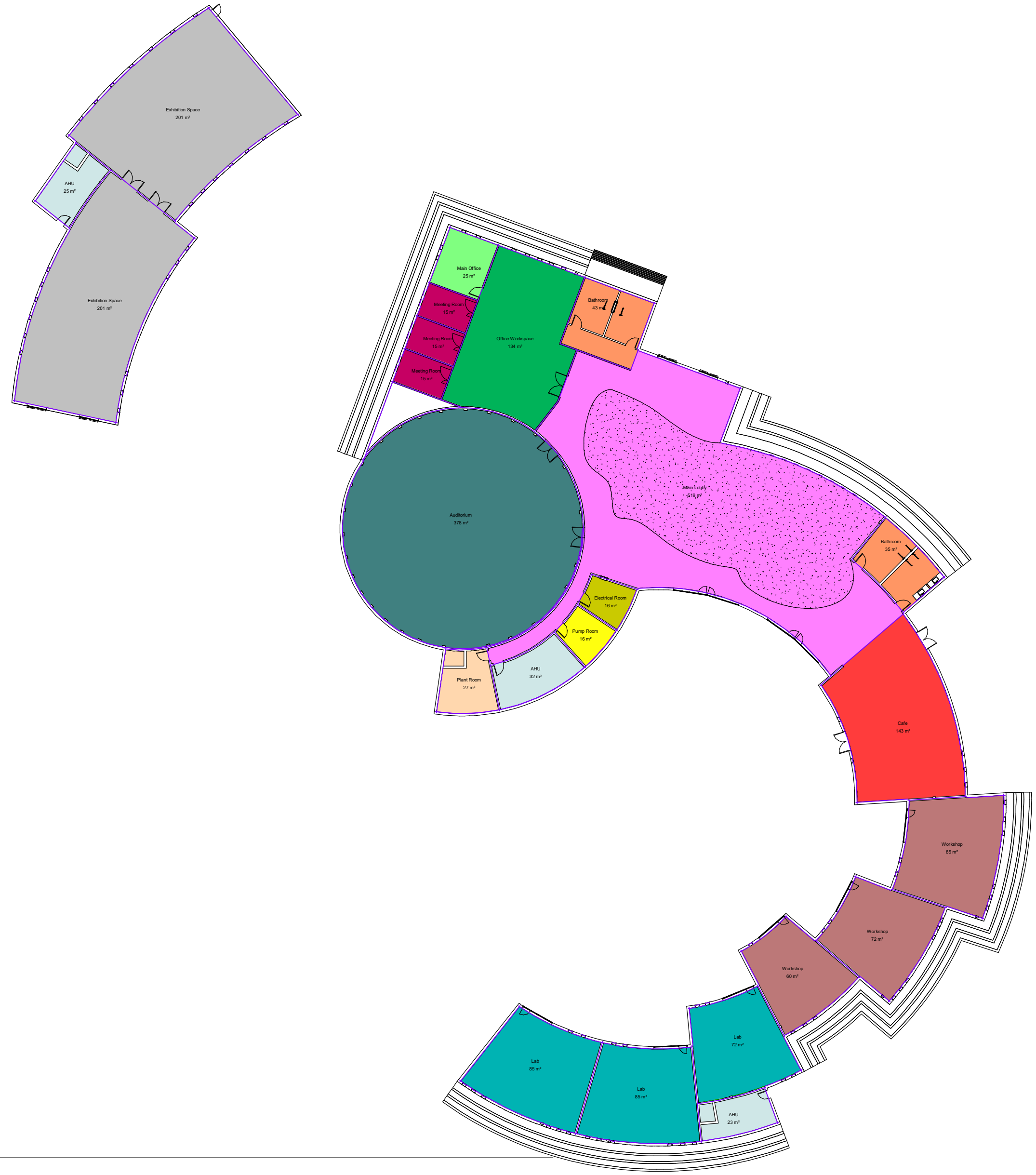
APPENDIX: ARCHITECTURAL DRAWINGS

Room Legend

- AHU
- Auditorium
- Bathroom
- Cafe
- Electrical Room
- Exhibition Space
- Lab
- Main Lobby
- Main Office
- Meeting Room
- Office Workspace
- Plant Room
- Pump Room
- Workshop



1 Ground Level
1 : 200

HERIOT WATT UNIVERSITY

www.autodesk.com/revit

No.	Description	Date

Blending Jameel

Colored Floor Plan

Project number	0001
Date	Issue Date
Drawn by	Author
Checked by	Checker

A101

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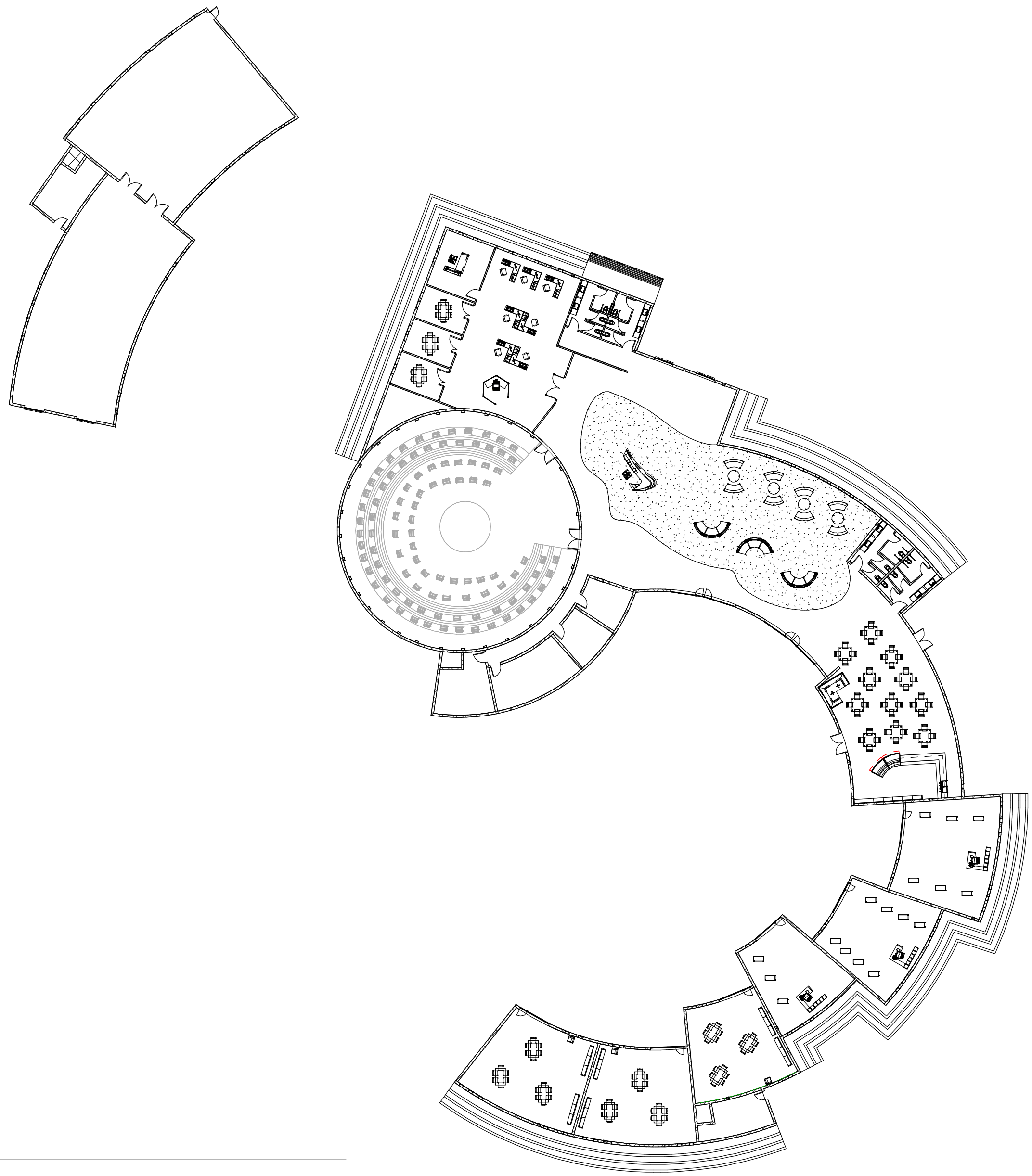

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HERIOT WATT UNIVERSITY

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No.	Description	Date

Blending Jameel

Ground Floor Plan

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Date	Issue Date
Drawn by	Author
Checked by	Checker

A102

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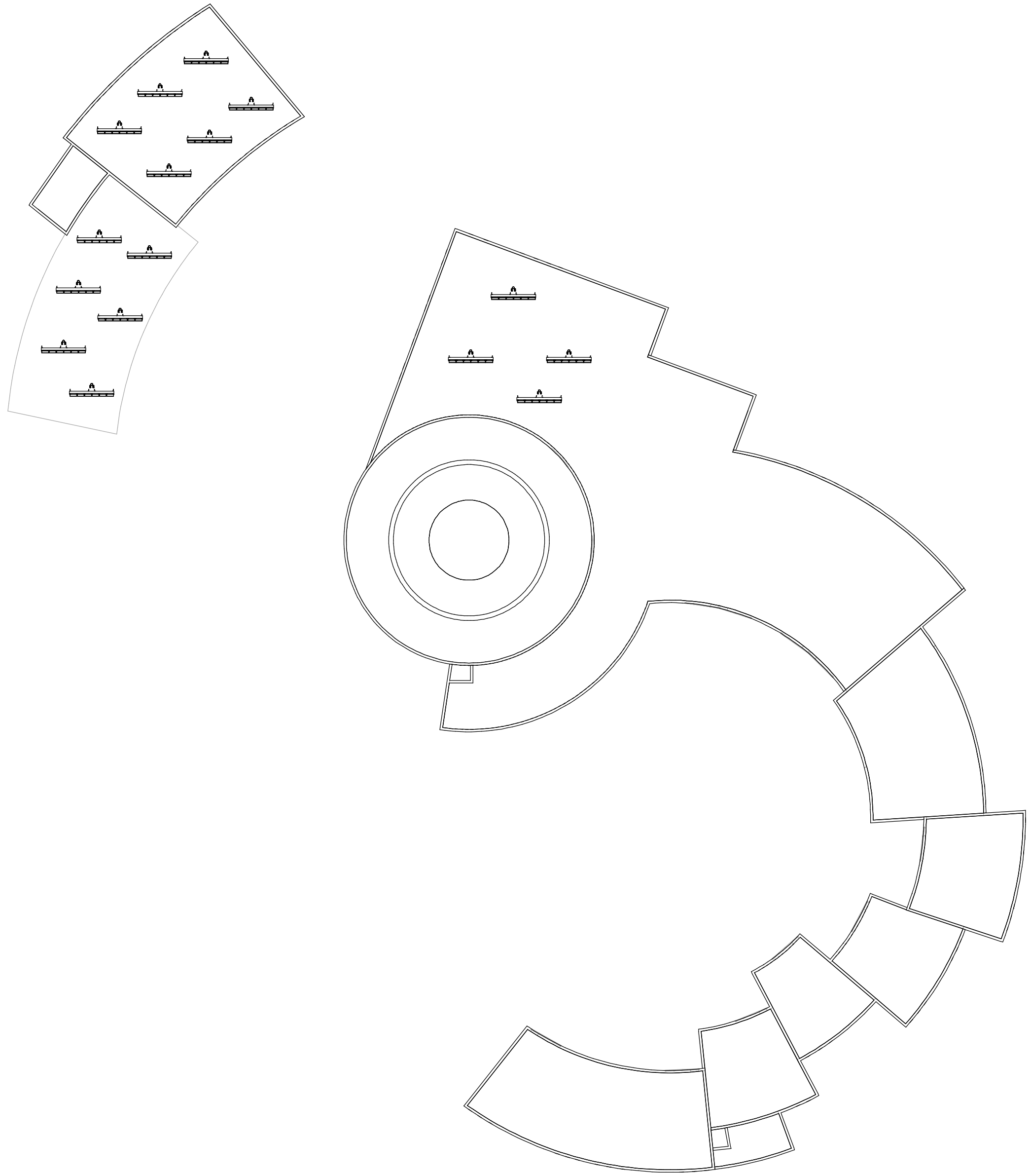

1 Roof Level
1 : 200

HERIOT WATT UNIVERSITY

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No.	Description	Date

Blending Jameel

Roof Plan

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Date	Issue Date
Drawn by	Author
Checked by	Checker

A103

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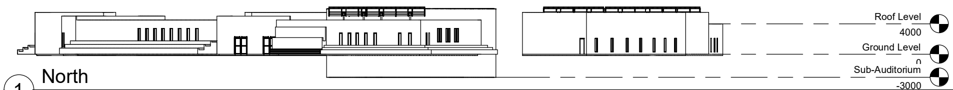
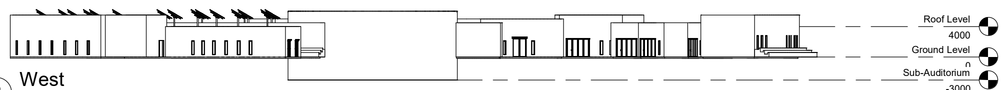
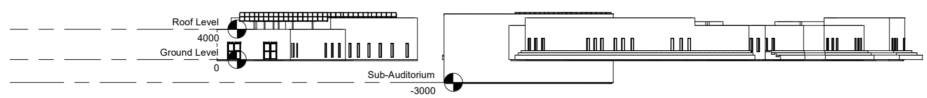


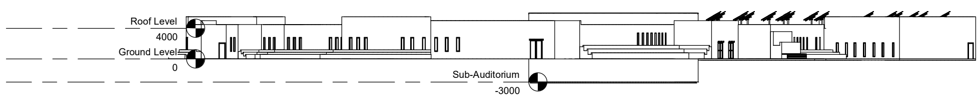
1 North
1 : 300



2 West
1 : 300



3 South
1 : 300



4 East
1 : 300

HERIOT WATT UNIVERSITY

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No.	Description	Date

Blending Jameel

Building Elevations

Project number	0001
Date	Issue Date
Drawn by	Author
Checked by	Checker

A104

Scale	1 : 300

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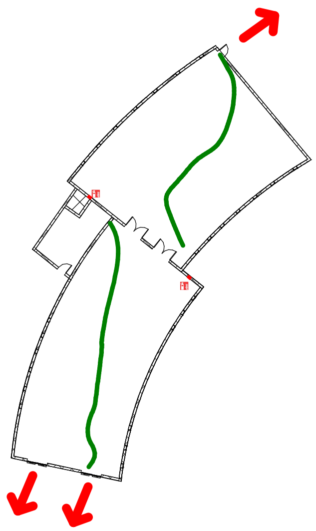
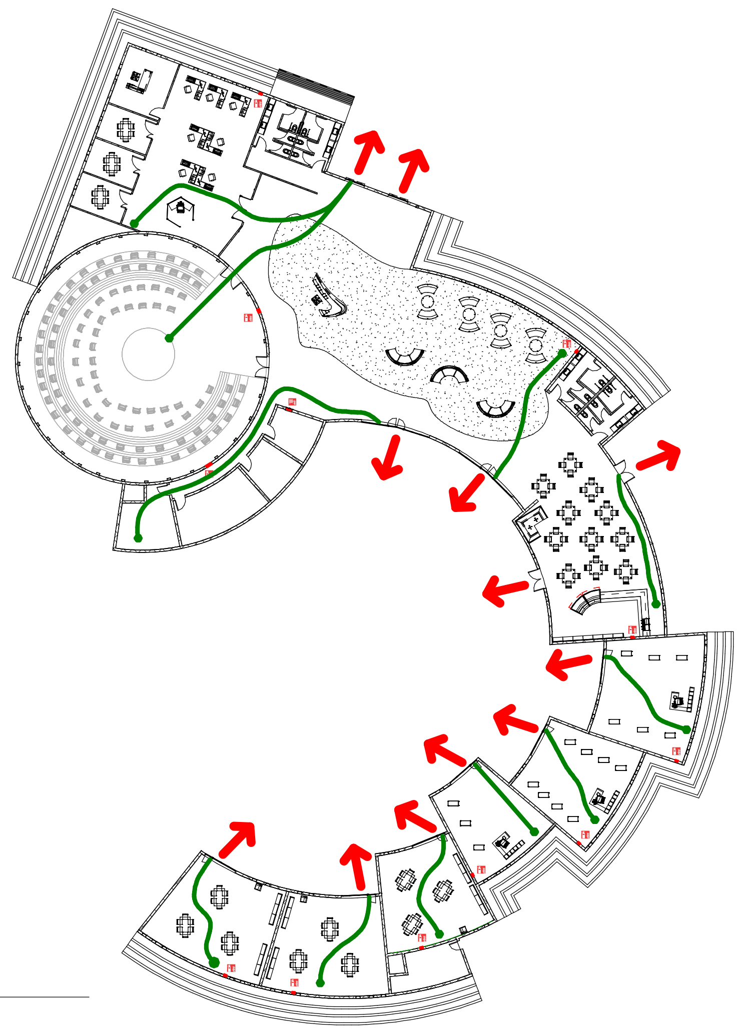
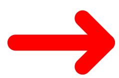




Key

Fire Extinghuisher	
Fire Hose Reel	
Primary Route	
Exits	

1 Fire Evacuation Plan
1 : 200

HERIOT WATT UNIVERSITY

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No.	Description	Date

Blending Jameel

Fire Evacuation Plan

Project number	0001
Date	Issue Date
Drawn by	Author
Checked by	Checker

A105

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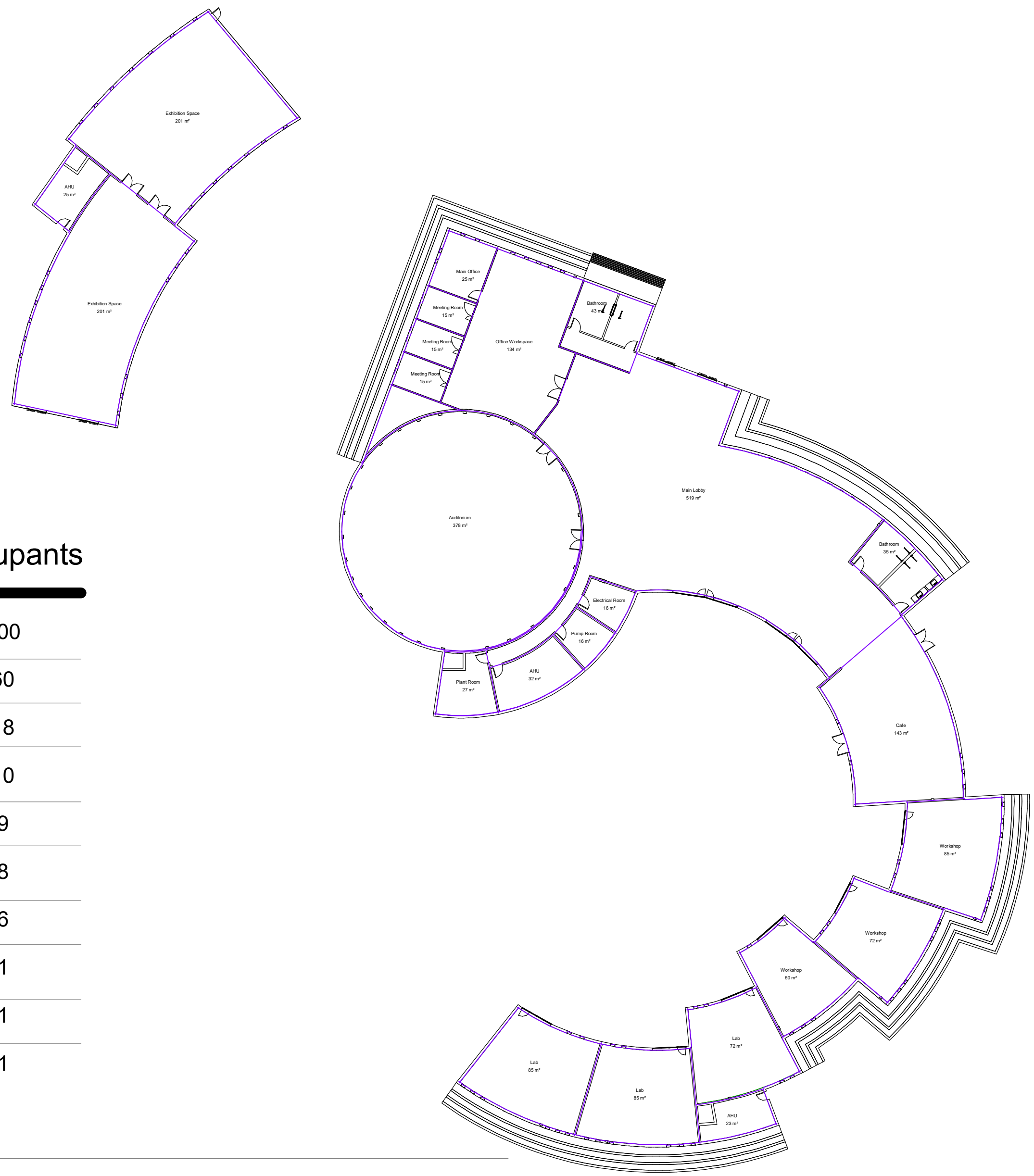

Key

Zone	Area	Occupants
Auditorium	378m^2	100
Main Lobby/Cafe	662m^2	60
Labs	242m^2	18
Exhibition Spaces	402m^2	10
Office Workspace	134m^2	9
Bathrooms	78m^2	8
Meeting Rooms	45m^2	6
Main Office	25m^2	1
Workshops	217m^2	1
Service Rooms	139m^2	1

1 Ground Level
1 : 200

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No.	Description	Date

Blending Jameel

Area and Occupancy Plan

Project number 0001

Date Issue Date

Drawn by Author

Checked by Checker

A106

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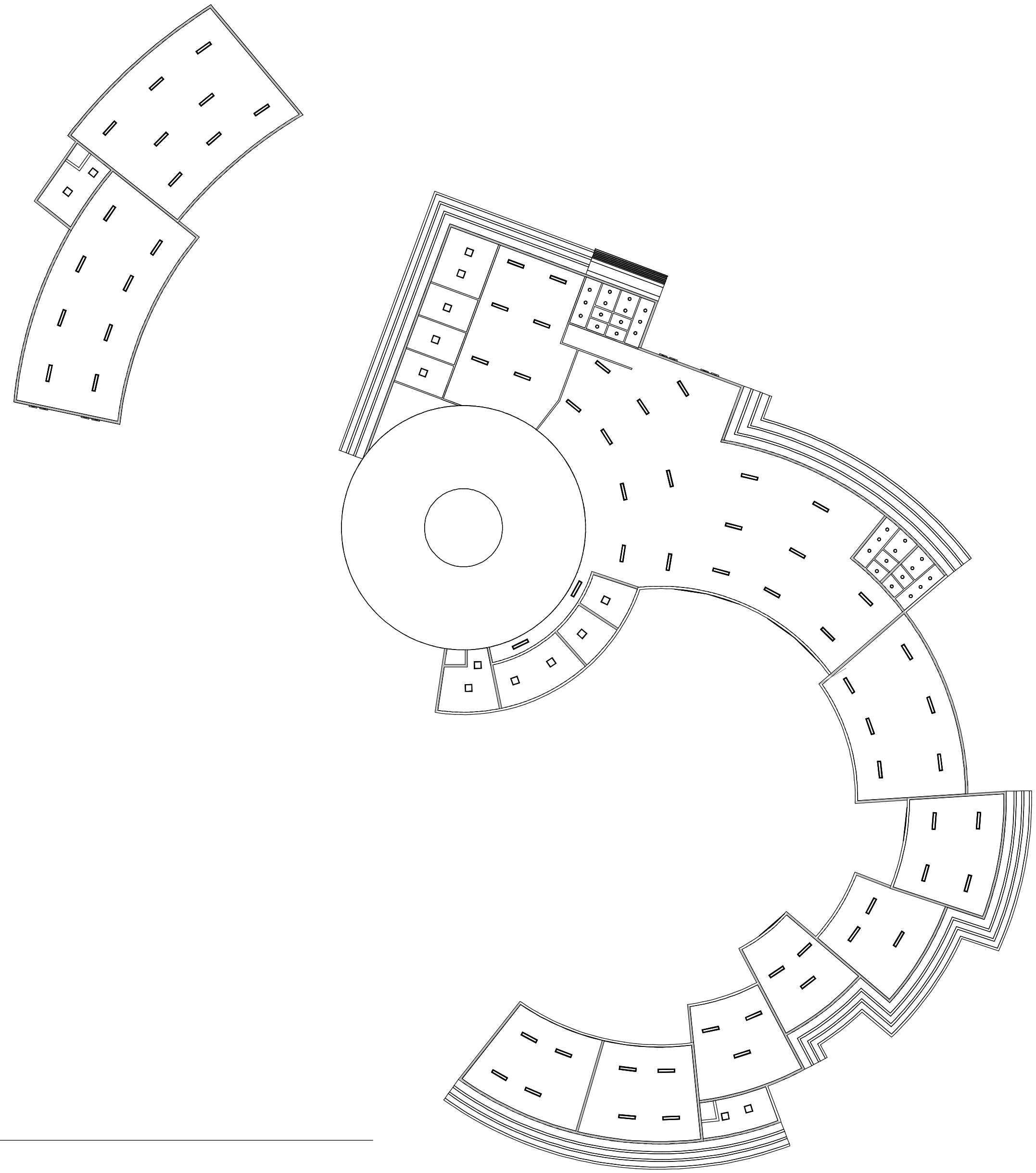

1 Lighting
1 : 200

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No.	Description	Date

Blending Jameel

Lighting

Project number	0001
Date	Issue Date
Drawn by	Author
Checked by	Checker

A107

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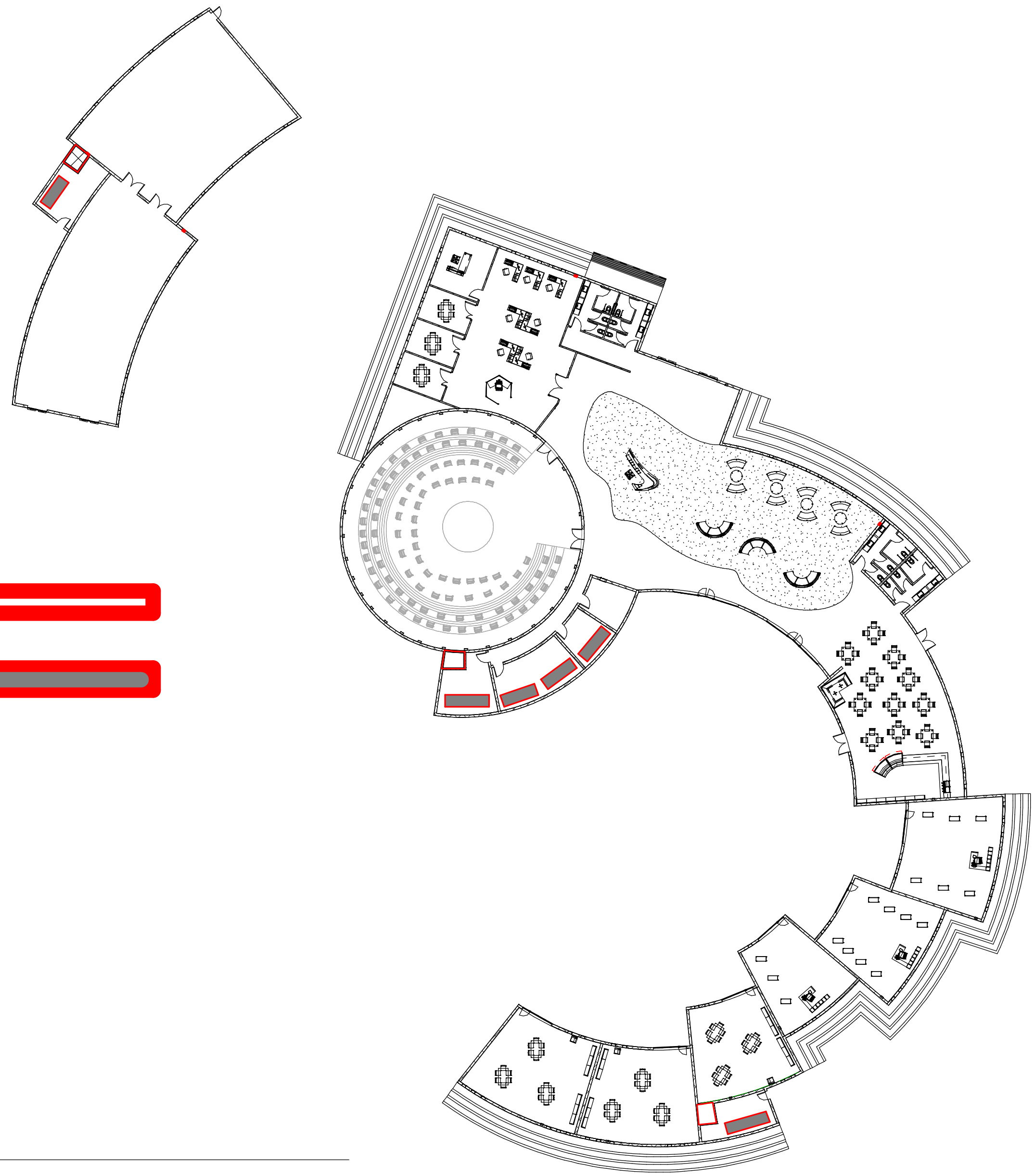

Key

Service Riser

Plinth (125mm)

1 Ground Level
1 : 200

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No.	Description	Date

Blending Jameel

Service Risers and Plinths

Project number	0001
Date	Issue Date
Drawn by	Author
Checked by	Checker

A108

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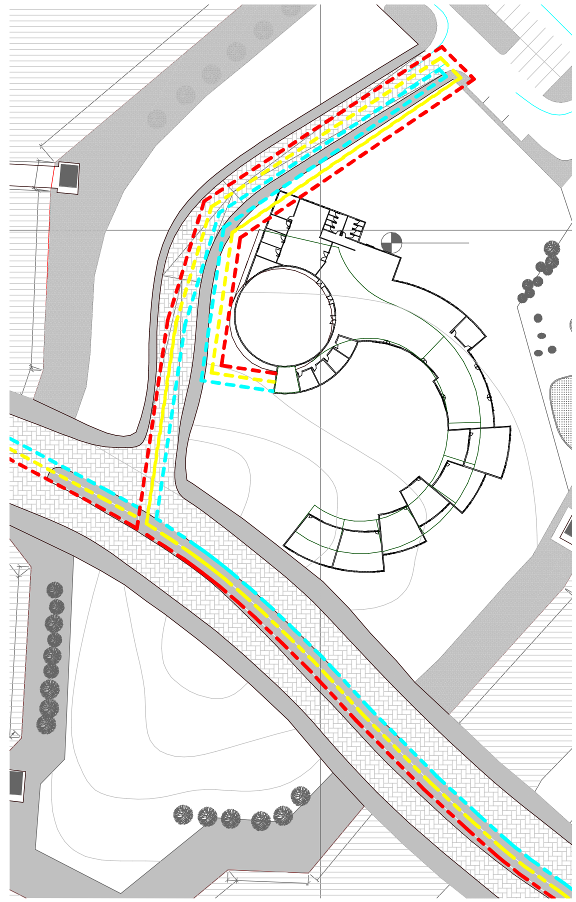
Key

Electricity Supply

Gas Supply

Water Supply

Plant Room



1 Level 1
1 : 500

HERIOT WATT UNIVERSITY

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No.	Description	Date

Blending Jameel

Utility Supply

Project number	0001
Date	Issue Date
Drawn by	Author
Checked by	Checker

A109

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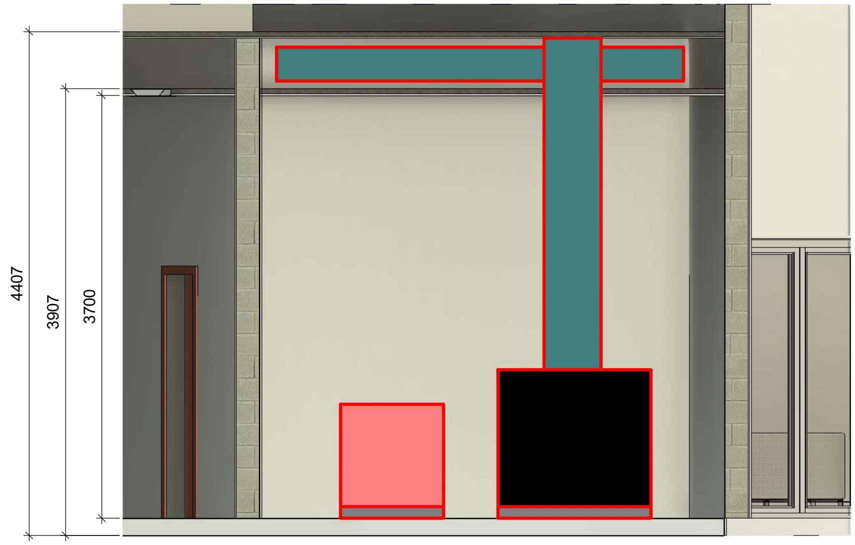


Key

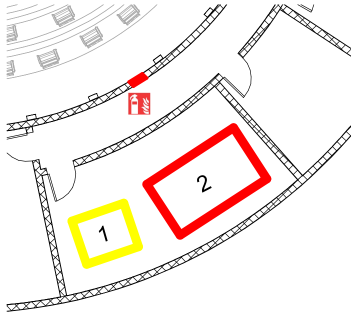
AHU

Boiler

Ducts

Plinth (125mm)

1 AHU Room Section
1 : 20



Key

1 Boiler

2 Air Handler

2 AHU Room
1 : 75

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No.	Description	Date

Blending Jameel

AHU Room Section Block Layout

Project number	0001
Date	Issue Date
Drawn by	Author
Checked by	Checker

A110

Scale	As indicated

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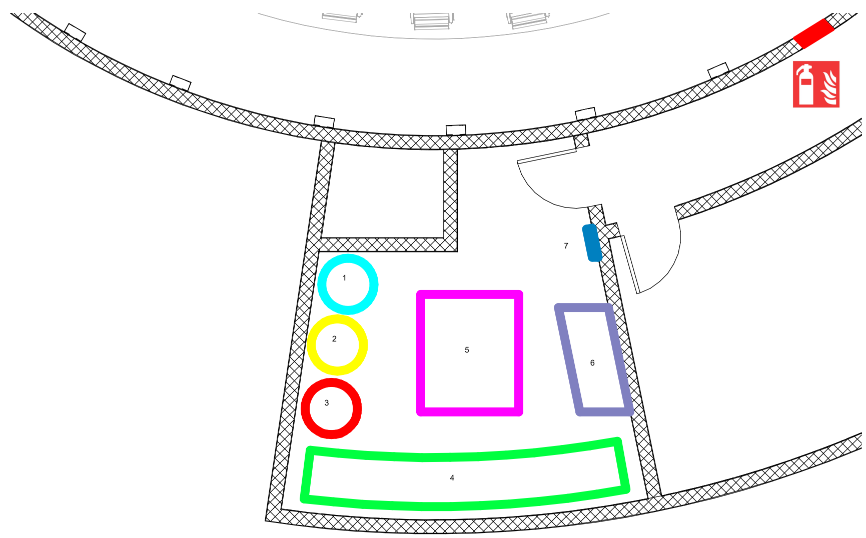
Key

- 1 Water Pipeline
- 2 Electricity Pipeline
- 3 Gas Pipeline
- 4 Back-up Electricity Generators
- 5 HVAC Equipment
- 6 Batteries
- 7 Smart Meter



1 Plant Room
1 : 35

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No.	Description	Date

Blending Jameel

Plant Room
Block Layout

Project number	0001
Date	Issue Date
Drawn by	Author
Checked by	Checker

A111

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Key (Electrical Room)

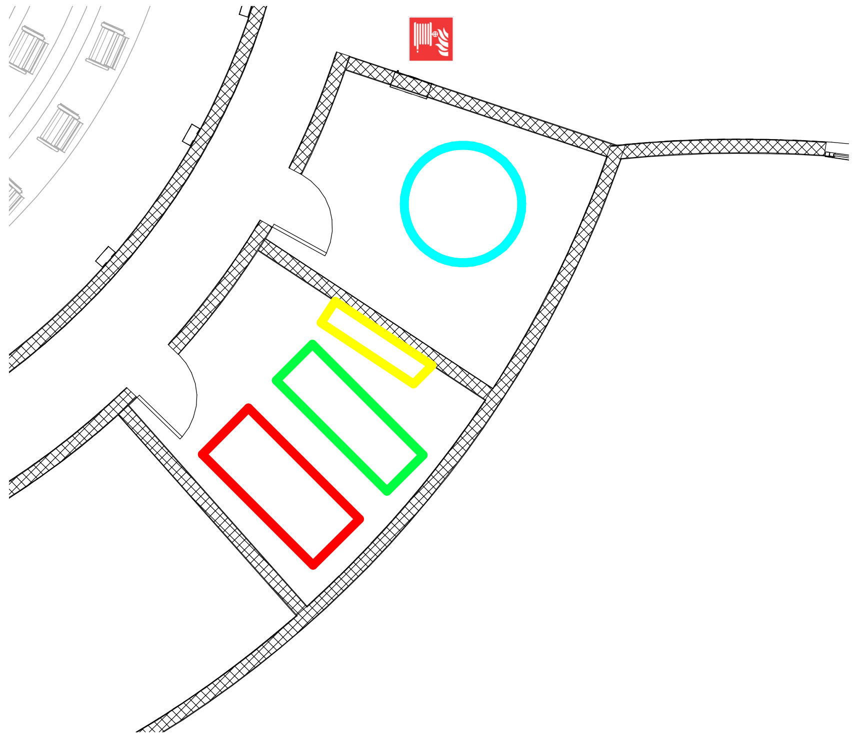
Electrical Switchboard

Distribution Board

Computer Server

Key (Pump Room)

Heat Pump Water Heater



1 Electrical and Pump room
1 : 35

HERIOT WATT UNIVERSITY

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No.	Description	Date

Blending Jameel

Electrical and Pump Room Block Layout

Project number	0001
Date	Issue Date
Drawn by	Author
Checked by	Checker

A112

Scale	1 : 35

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