UCL Bartlett Central House - Electricity Consumption Analysis

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Summary

UCL has been striving for sustainability practices for more than a decade. Central House is one of UCL's many school buildings which hosts the Bartlett School Of Planning, the Bartlett School of Environment, Energy and Resources, and the Bartlett Library. Recently, Central House has been found to be consuming more electricity than needed, especially during closure hours. Hence, this report aims to find out Central House's abnormal energy consumption levels by analysing data collected by Fabrique, and providing recommendations to improve efficiency. This report finds that Central House's electricity consumption during opening and closure hours are similar, without a notable decline when the building is vacant, which shows that there is currently a significant amount of unnecessary electricity loss and carbon emissions. To pave way for a more sustainable future for Central House, UCL should aim to find ways to switch off unused systems and appliances when the building is unoccupied, and perform regular check-ins and renewals to improve overall energy efficiency in the long term.

Electricity Consumption Analysis - Easter Holiday vs School Days

The figures below show the daily electricity consumption levels of Central House in the month of April 2023, as well as the daily electricity consumption in March for reference. The week of the Easter Holiday is highlighted in a lighter colour according to UCL closure times which start from 5:30 pm on Wednesday 5 April 2023 to 9:00 am on Thursday 13 April 2023. As seen in the figure, even though Easter holiday is a school closure period with no teaching activity and supposedly significantly less student activity, it maintains a similar consumption level to non-closure periods. The average consumption level of school days is approximately 1745kWh per day, at an average rate of 73kW per hour. The average energy consumption during Easter holiday is 66kW per hour. Assuming there is near negligible activity at Central House during Easter, the highlighted portion of the graph signifies the building's consumption base load (66kWh). Surprisingly, the base load is currently at a similar level to regular school days, whereas it should be close to zero. Compared to March, electricity consumption during Easter shows a slight decrease, however, there is also a general drop in electricity usage in April likely due to seasonal changes. Central House is physically closed during the closure period, so it should aim to have very low energy consumption throughout those times.

Figure 1: Energy Consumption In March

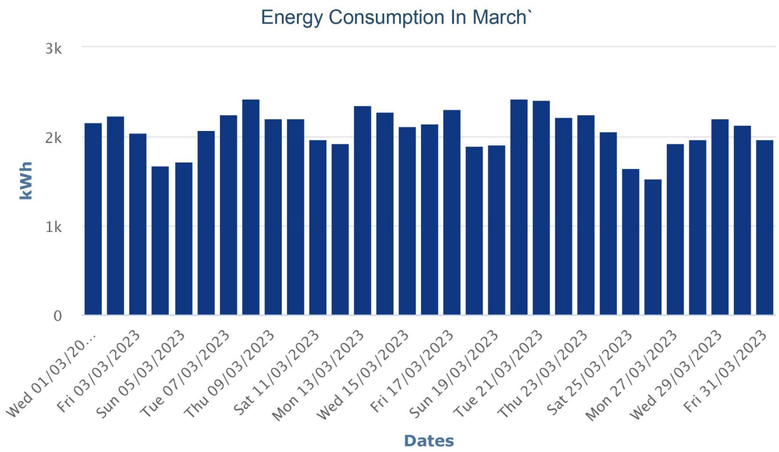
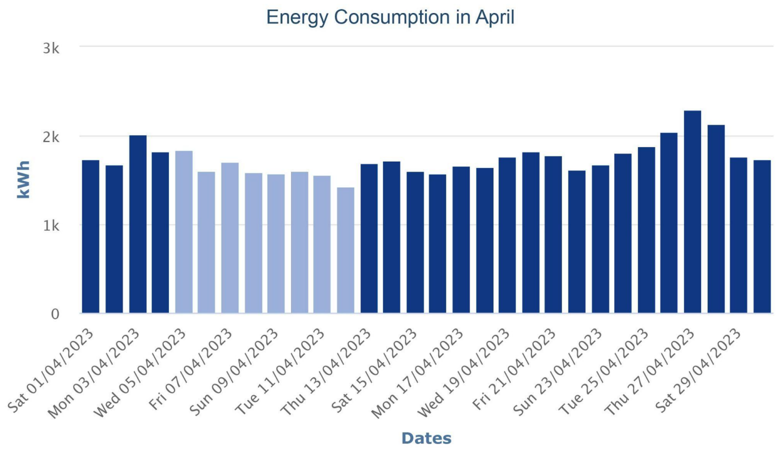


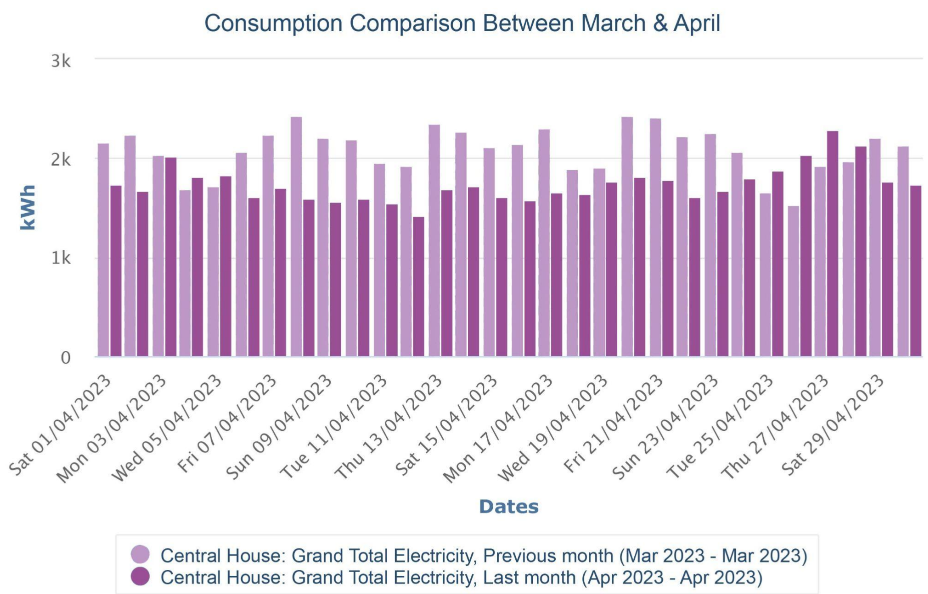
Figure 2: Energy Consumption In April (Easter highlighted)



Energy Consumption Analysis - March vs April

Interestingly, Figure 3 shows that there could be a large difference in energy consumption levels between months. The lighter purple shows the electricity consumption levels in March, while the darker purple shows data in April. The most prominent reason which could induce drastic changes in consumption is seasonal and weather changes. The average temperature in March is 12° / 6° whilst the average temperature in April is 15° / 7°, hence there is more heating needed in March which would result in more electricity used. Another explanation for fluctuating use of electricity is the exam schedule. UCL courses start to have deadlines and exams starting in April, so students may have more incentive to use the study spaces at Central House in the month of March for preparation.

Figure 3: Energy Consumption Comparison Between March & April



Energy Consumption Analysis - Day vs Night

The three figures below show an hourly analysis of typical school days which were randomly chosen. Central House opening hours are from 7am - 8:30 pm, thus 7am - 8pm are highlighted in a lighter colour. In all three figures, peak consumption load occurs from 3pm to 4pm, possibly because the building is most used in that time of day. All school days show a bell curve graph, in which the distribution is slightly curved to the right. This indicates that peak consumption is usually in the afternoon, and electricity use lowers early in the morning and late at night which are presented on both sides of the horizontal axis. However, the curve is not steep, indicating that there isn't a significant decrease in electricity consumption when the building has closed down. In all three school days, the consumption level during closing hours doesn't hit anywhere close to zero, and instead sustains around 60-70 kWh per hour throughout the night. That being the case, it could be concluded that there is excess energy waste when Central House is not in use, and it may also be useful to explore if there is additional electricity used during the day as well.

Figure 4: Energy Consumption On A Random School Day 1

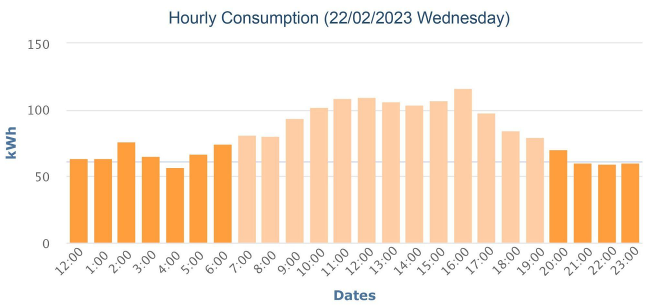


Figure 5: Energy Consumption On A Random School Day 2

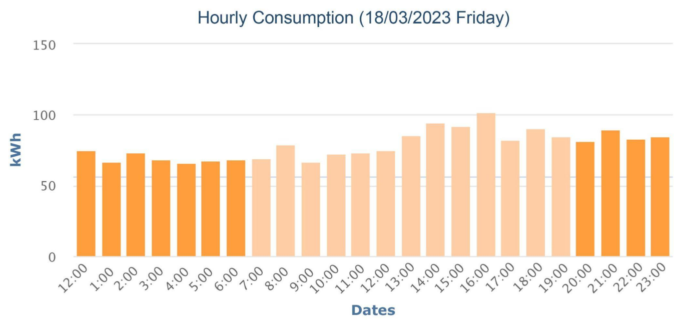
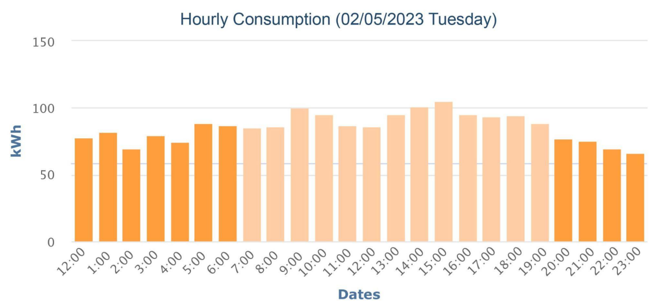


Figure 6: Energy Consumption On A Random School Day 3



Energy Consumption Analysis - Weekday vs Weekend

Below is the electricity consumption of 3 random weekdays in March, April, and May and their corresponding randomly chosen weekend on its right. A comparison between weekdays and weekends shows the typical consumption when Central House is fully in function and when it is unoccupied. The average electricity consumption on a weekday is 90.65 kWh per hour. On the other hand, the average on a weekend is 69.78 kWh per hour. It can be seen that there is a substantial decrease between weekdays and weekends, but the amount of electricity consumed is still unjustifiable considering the building is totally vacant. It should be noted that in both May and April, the electricity consumed on the weekday is lower than on the weekend. For instance, the average consumption on a May weekday is 65.43 kWh per hour while on the weekend it is 73.32 kWh per hour. This may be due to those months being the end of the spring semester and near exam times, hence regular classes are not hosted in the building like usual and most students have left for the summer holidays if they have completed their exams early. However, the reasons why consumption during the weekday is lower than at the weekend could be further scrutinized.

Figure 7: Energy Consumption On A Weekday 1

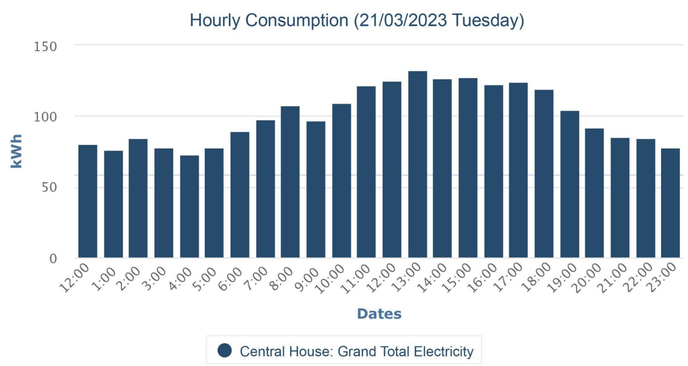


Figure 8: Energy Consumption On A Weekend 1

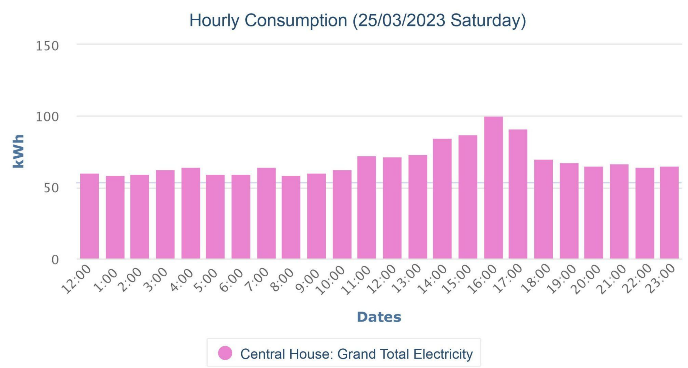


Figure 9: Energy Consumption On A Weekday 2

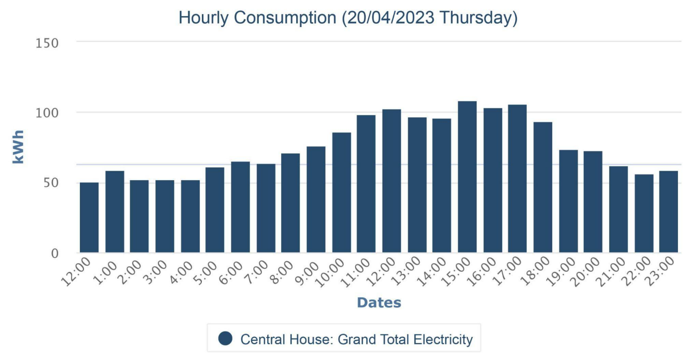


Figure 10: Energy Consumption On A Weekend 2

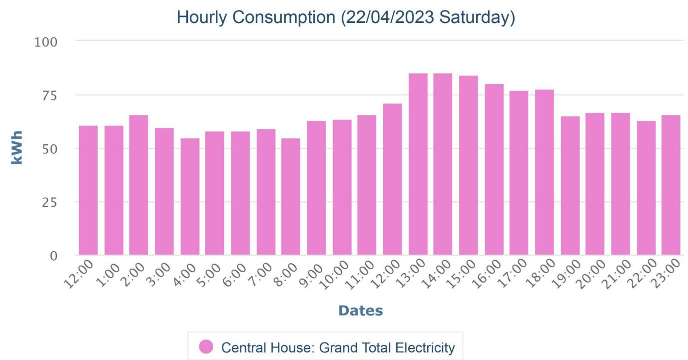


Figure 11: Energy Consumption On A Weekday 3

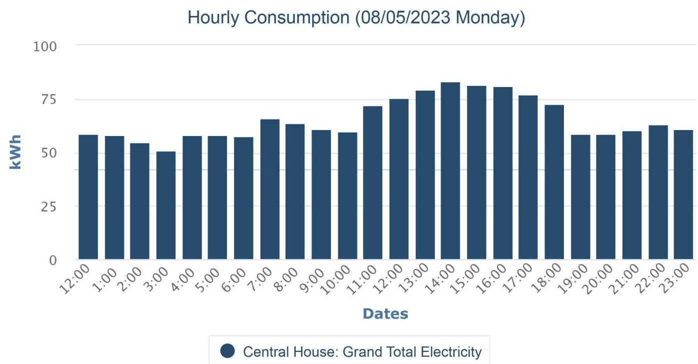
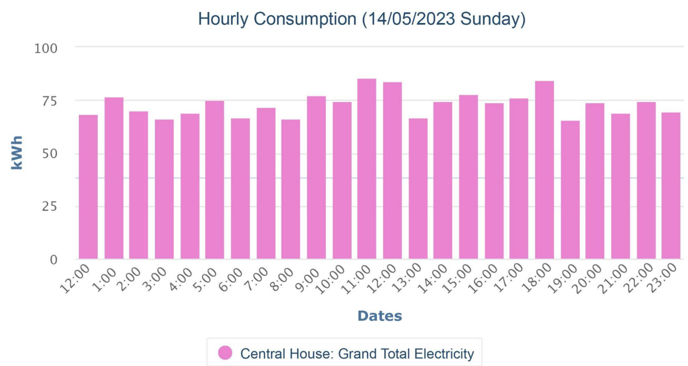


Figure 12: Energy Consumption On A Weekend 3



Energy Consumption Analysis - Estimated Daily Load Curve vs Actual Daily Load Curve

Figure 13 and Figure 15 were created by estimating the main electrical appliances used in Central House, the time of day they are typically used (see Appendix, Table 1 & 2), and the typical electrical load each appliance has. The number is then used to calculate the approximate energy consumption of a weekday and weekend respectively. The estimated load curve is illustrative to see what the ideal electricity consumption for Central House might look like, and deduce the potential reasons which may cause a difference between the estimated and the actual load curve. Nonetheless, the calculations are based on rough estimates and would need more valid data collected from Central House to increase the accuracy of the estimated load curve.

The main distinction between both Figures 13 & 15 and Figures 14 & 16, is that during closure periods, the estimated curve is always close to zero and has a steep slope when transitioning to opening times. Contrarily, the actual curve maintains a fairly flat slope with minor peaks and troughs throughout the day regardless if the building is opened or closed. This is alarming as it reveals that there is significant energy loss for a significant part of the day when the building is not in use. Hence, Central House should investigate the source of consumption and why it is unable to switch off when the building is uninhabited.

1) **Weekday**

Figure 13: Estimated Daily Load Curve For A Weekday 1

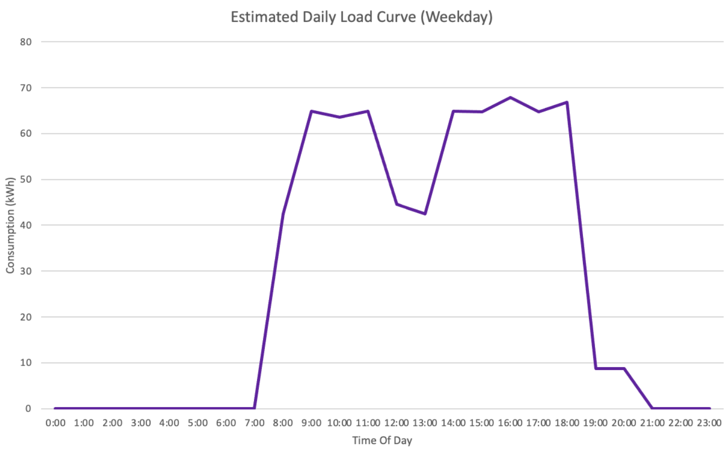
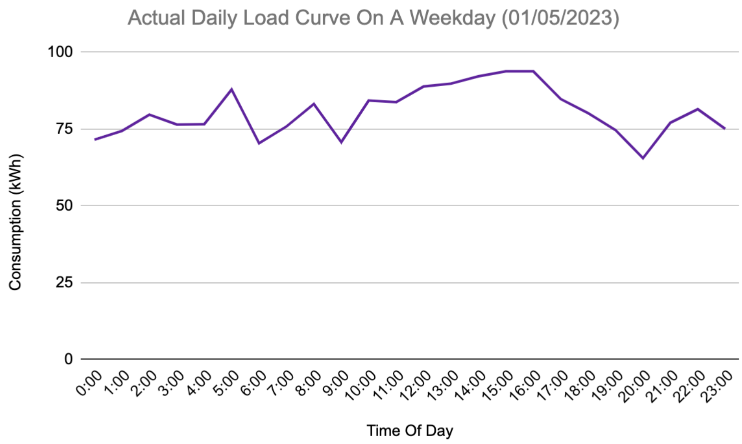


Figure 14: Actual Daily Load Curve For A Weekday 1



2) Weekend

Figure 15: Estimated Daily Load Curve For a Weekend 2

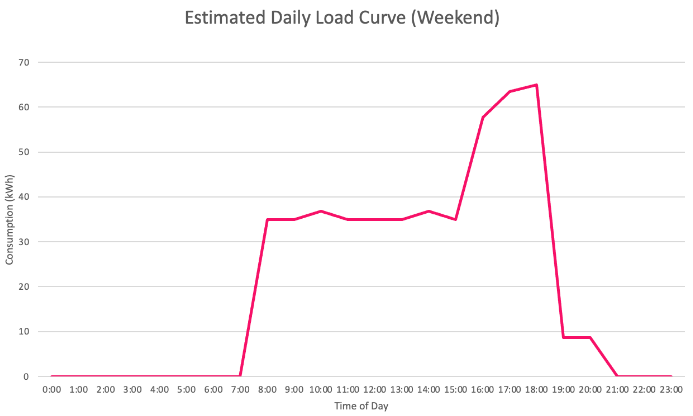
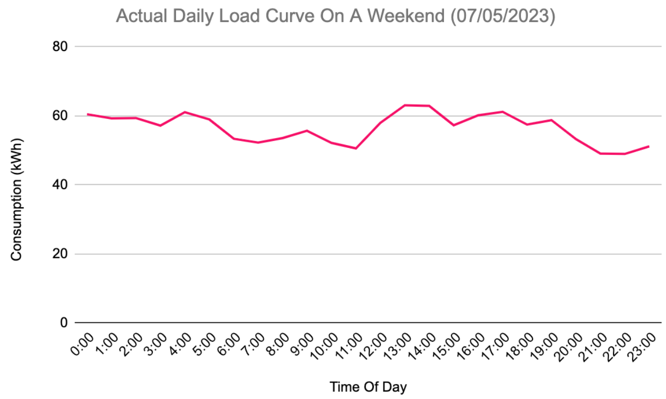


Figure 16: Actual Daily Load Curve For A Weekend 2



On the other hand, it could be inferred that the energy consumption at Central House right now during peak load is reasonable since both estimated graphs peak around similar consumption levels. When estimating the time of use for the main appliances used in Central House, the assumptions are personalized to the typical student's study habits and class schedule, therefore the estimated curve appears to be similar to the actual curve. Accordingly, the short-term goal should be to reflect on lowering energy consumption during the building's closure hours rather than lowering consumption as a whole, even though reducing general energy consumption could be set as a sustainable goal in the long term to minimise the Central House's general environmental implications.

Limitation

Figures 13 and 15 only provide a rough assumption of what the shape of a daily load curve should ideally look like, however, it is not to be used for an exact reference or representation as it is based on various broad assumptions. Firstly, the main appliances used in Central House are assumed to be lights, wall adapters, computers (PC and servers), desk lamps, air conditioning, printers, and classroom smart boards, the number of these appliances present at Central House is also estimated. Secondly, the consumption load for each appliance that is used for calculation is in accordance with general the load of general office appliances and not specific to the specific products at Central House. Finally, the time of day and how long each appliance is used is a large generalisation of student activities which may vary each day. A more accurate representation of an estimated daily load curve could be curated through site visits to collect data that is more specific to Central House.

Recommendations

The DEC and AC reports are advisory reports presented along with Display Energy Certificates and Air Conditioning Inspection Certificates respectively for public buildings. These reports are written by government inspectors to guide building managers on how to raise their building's energy performance. The recommendations suggested below are partly adapted from DEC and AC reports on Central House.

1) **Short Term Recommendations**

Energy Performance - The current energy performance rating of Central House is D (84) while the typical score for public buildings is a D (100) (Shellard, I. (2021)). If Central House is able to minimize its energy consumption when the building is not in use, it can significantly decrease consumption and emissions to reach a grade of C. Central House has been graded C in both 2022 and 2021 before but most likely due to irregular inactivity during Covid 19.

Power Saving - DEC report uncovers that "heating and cooling systems have been found to be simultaneously operating" (Shellard, I. (2021)). It may be worthwhile to find ways to ban the HVAC system from allowing both systems to run at the same time, as this is not necessary during any time of the year. Additionally, computers should also be better managed to power down when it is unused to minimize energy loss (Shellard, I. (2021)). If necessary, there is also the option to fully shut down the HVAC and computer system during closure, and reboot in the early morning.

Air conditioning management - UCL notes that "In the summer where air conditioning is provided the systems will aim to maintain a minimum internal temperature of 22°C" for cognitive performance (UCL (2020)). Research shows that the optimal temperature for studying is 20°C to 24°C during hotter months and 23°C to 26°C during colder months (IES (2018)). However, previous student research on Central House disclosed that most students found the Bartlett Library too cold. So, perhaps UCL could consider experimenting with different kinds of manual temperature control systems within a set boundary to enhance energy use and comfort. The AC report also recommends increasing efficiency by "increasing the set point to 24°C in the hotter months, as the evaporator temperature can be allowed to rise, which in turn will increase the COP for the equipment" (Hill, S. (2020)).

2) Long Term Recommendations

System Refurbishment - The AC Report notes that “There are a number of units where the condenser fins have corroded and are starting to disintegrate” (Hill, S. (2020)). Thus, UCL should consider conducting more regular evaluations of air conditioning performance and check-ins on other building systems. Refurbishing old machines could also increase efficiency so that it uses fewer units of energy to generate the same amount of power.

Building Fabric - The building structure and construction material could be enhanced to increase insulation and minimize accidental air leaks that may hinder heating and cooling efficiency (Shellard, I. (2021)). It is important to implement regular upkeeps and maintenance on buildings to ensure a safe, healthy, and user-friendly experience in the long term. Arch Daily discloses that buildings deteriorate over time and latent defects can “incur costs higher and more sudden than consistent building maintenance costs” (Cao, L. (2020)).

Renewable Energy Transition - Currently Central House’s main heating fuel is natural gas and is at 0% renewable energy. However, there are solar panels installed on the roof of the building. Under the circumstance that the solar panels are not for other use, UCL should explore the feasibility of Central House self-generating solar energy for its own consumption to curtail carbon emissions even further.

Work Cited

Cao, L. (2020). Why is Building Maintenance Important? [online] ArchDaily. Available at: https://www.archdaily.com/928044/why-is-building-maintenance-important.

Hill, S. (2020). *Air conditioning inspection report*. GOV.UK. Available at: https://find-energy-certificate.service.gov.uk/energy-certificate/9092-4200-3500-9247-2500

IES (2018). Optimal classroom temperature to support student learning - REL West. [online] Institute of Education Sciences. Available at: https://ies.ed.gov/ncee/edlabs/regions/west/Ask/Details/64#:~:text=Changing%20thermostat%20settings%20or%20opening.

Shellard, I. (2021). *Display energy certificate (DEC) recommendation report*. GOV.UK. Available at: https://find-energy-certificate.service.gov.uk/energy-certificate/8810-8720-2282-1699-4092#assessor

UCL (2020). *UCL Heating, Cooling & Ventilation Policy*. Estates. Available at: https://www.ucl.ac.uk/estates/policies/2020/sep/ucl-heating-cooling-ventilation-policy.

[All data collected from Sustainable UCL Fabrique]

Appendix

Table 1: Calculations For Estimated Daily Load Curve For A Weekday (Figure 6)

	Lights	Charger	Computer	Lamp	AC	Printer	Smart Board
0:00	0	0	0	0	0	0	0
1:00	0	0	0	0	0	0	0
2:00	0	0	0	0	0	0	0
3:00	0	0	0	0	0	0	0
4:00	0	0	0	0	0	0	0
5:00	0	0	0	0	0	0	0
6:00	0	0	0	0	0	0	0
7:00	0	0	0	0	0	0	0
8:00	1	0	0	0	1	0	0
9:00	1	0	1	0	1	0	1
10:00	1	0	1	0	1	0	0
11:00	1	0	1	0	1	0	1
12:00	1	1	0	0	1	1	0
13:00	1	0	0	0	1	0	0
14:00	1	0	1	0	1	0	1
15:00	1	0	1	1	1	0	0
16:00	1	1	1	1	1	0	1
17:00	1	0	1	1	1	0	0
18:00	1	1	1	1	1	1	0
19:00	1	0	0	1	0	0	0
20:00	1	0	0	1	0	0	0
21:00	0	0	0	0	0	0	0
22:00	0	0	0	0	0	0	0
23:00	0	0	0	0	0	0	0

	Appliance 1	Appliance 2	Appliance 3	Appliance 4	Appliance 5	Appliance 6	Appliance 7	Total	kW
0:00	0	0	0	0	0	0	0	0	0
1:00	0	0	0	0	0	0	0	0	0
2:00	0	0	0	0	0	0	0	0	0
3:00	0	0	0	0	0	0	0	0	0
4:00	0	0	0	0	0	0	0	0	0
5:00	0	0	0	0	0	0	0	0	0
6:00	0	0	0	0	0	0	0	0	0
7:00	0	0	0	0	0	0	0	0	0
8:00	7500	0	0	0	35000	0	0	42500	42.5
9:00	7500	0	21000	0	35000	0	1400	64900	64.9
10:00	7500	0	21000	0	35000	0	0	63500	63.5
11:00	7500	0	21000	0	35000	0	1400	64900	64.9
12:00	7500	1800	0	0	35000	300	0	44600	44.6
13:00	7500	0	0	0	35000	0	0	42500	42.5
14:00	7500	0	21000	0	35000	0	1400	64900	64.9
15:00	7500	0	21000	1200	35000	0	0	64700	64.7
16:00	7500	1800	21000	1200	35000	0	1400	67900	67.9
17:00	7500	0	21000	1200	35000	0	0	64700	64.7
18:00	7500	1800	21000	1200	35000	300	0	66800	66.8
19:00	7500	0	0	1200	0	0	0	8700	8.7
20:00	7500	0	0	1200	0	0	0	8700	8.7
21:00	0	0	0	0	0	0	0	0	0
22:00	0	0	0	0	0	0	0	0	0
23:00	0	0	0	0	0	0	0	0	0

Appliance 1	Lights	Appliance 2	Wall Adapter (laptop charger)	Appliance 3	Computer (PC+Server)	Appliance 4	Lamp	Appliance 5	AC	Appliance 6	Printer	Appliance 7	Smart Board
Load (W)	50	Load (W)	30	Load (W)	600	Load (W)	15	Load (W)	1000	Load (W)	50	Load (W)	175
Number	150	Number	60	Number	35	Number	80	Number	35	Number	6	Number	8
Total Load (W)	7500	Total Load (W)	1800	Total Load (W)	21000	Total Load (W)	1200	Total Load (W)	35000	Total Load (W)	300	Total Load (W)	1400

Table 2: Calculations For Estimated Daily Load Curve For A Weekday (Figure 8)

	Lights	Heater	Computer	Lamp	AC	Printer	Smart Board
0:00	0	0	0	0	0	0	0
1:00	0	0	0	0	0	0	0
2:00	0	0	0	0	0	0	0
3:00	0	0	0	0	0	0	0
4:00	0	0	0	0	0	0	0
5:00	0	0	0	0	0	0	0
6:00	0	0	0	0	0	0	0
7:00	0	0	0	0	0	0	0
8:00	0	0	0	0	1	0	0
9:00	0	0	0	0	1	0	0
10:00	0	1	0	0	1	0	0
11:00	0	0	0	0	1	0	0
12:00	0	0	0	0	1	0	0
13:00	0	0	0	0	1	0	0
14:00	0	1	0	0	1	0	0
15:00	0	0	0	0	1	0	0
16:00	0	1	1	0	1	0	0
17:00	1	0	1	0	1	0	0
18:00	1	0	1	1	1	1	0
19:00	1	0	0	1	0	0	0
20:00	1	0	0	1	0	0	0
21:00	0	0	0	0	0	0	0
22:00	0	0	0	0	0	0	0
23:00	0	0	0	0	0	0	0

	Appliance 1	Appliance 2	Appliance 3	Appliance 4	Appliance 5	Appliance 6	Appliance 7	Total	kW
0:00	0	0	0	0	0	0	0	0	0
1:00	0	0	0	0	0	0	0	0	0
2:00	0	0	0	0	0	0	0	0	0
3:00	0	0	0	0	0	0	0	0	0
4:00	0	0	0	0	0	0	0	0	0
5:00	0	0	0	0	0	0	0	0	0
6:00	0	0	0	0	0	0	0	0	0
7:00	0	0	0	0	0	0	0	0	0
8:00	0	0	0	0	35000	0	0	35000	35
9:00	0	0	0	0	35000	0	0	35000	35
10:00	0	1800	0	0	35000	0	0	36800	36.8
11:00	0	0	0	0	35000	0	0	35000	35
12:00	0	0	0	0	35000	0	0	35000	35
13:00	0	0	0	0	35000	0	0	35000	35
14:00	0	1800	0	0	35000	0	0	36800	36.8
15:00	0	0	0	0	35000	0	0	35000	35
16:00	0	1800	21000	0	35000	0	0	57800	57.8
17:00	7500	0	21000	0	35000	0	0	63500	63.5
18:00	7500	0	21000	1200	35000	300	0	65000	65
19:00	7500	0	0	1200	0	0	0	8700	8.7
20:00	7500	0	0	1200	0	0	0	8700	8.7
21:00	0	0	0	0	0	0	0	0	0
22:00	0	0	0	0	0	0	0	0	0
23:00	0	0	0	0	0	0	0	0	0

Appliance 1	Lights	Appliance 2	Wall Adapter (laptop charger)	Appliance 3	Computer (PC+Server)	Appliance 4	Lamp	Appliance 5	AC	Appliance 6	Printer	Appliance 7	Smart Board
Load (W)	50	Load (W)	30	Load (W)	600	Load (W)	15	Load (W)	1000	Load (W)	50	Load (W)	175
Number	150	Number	60	Number	35	Number	80	Number	35	Number	6	Number	8
Total Load (W)	7500	Total Load (W)	1800	Total Load (W)	21000	Total Load (W)	1200	Total Load (W)	35000	Total Load (W)	300	Total Load (W)	1400