Property Portfolio

Energy Report

This version of the decarbonisation plan has been adapted so that it is suitable for publication. Sensitive information and data have been removed from this version.

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Disclaimer

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Background to this Report

Broadland District Council and South Norfolk Council are developing a carbon reduction strategy for their respective property portfolio, Groundwork Norfolk have been contracted to independently assess and report on the energy efficiency of the individual properties. This report presents the findings of the desk-based research, on-site audit and discussions with representatives at each building.

Methodology and Scope of Reporting

The onsite audits consisted of a visual inspection of the building construction, insulation, the glazing and doors, the space and water heating systems and controls, lighting and any other equipment on site. GHG emissions are expressed as tonnes of CO_2 equivalents (tCO_2e). This is a unit of measurement used to indicate the global warming potential of a greenhouse gas, expressed in terms of the global warming potential of one unit of carbon dioxide. The relevant year's UK Government's Carbon Conversion Factors have been applied to the units of energy and fuel consumption to calculate the associated emissions savings.[1]

Buildings have been assessed against the supplied 2018/19 emissions inventory data where applicable or more recent consumption data if relevant and available.

Any cost estimates given with this report are based on the Aecom Spon's 2022 Price Books, adjusted for estimated project size and location.[2] No representation, express or implied, is made with regard to the accuracy of this information and they are provided only for illustrative purposes. The authority must seek accurate costs from professional suppliers prior to any commitment being made.

Energy Reports

The following reports concentrate on the recommended measures for each property based on ease of achievement, effectiveness and/or maximising emissions savings.

[1] Greenhouse gas reporting: conversion factors
https://www.gov.uk/government/collections/government-conversion-factors-for-company-reporting

[2] Routledge Taylor and Francis Group.
https://www.routledge.com/spon-press?utm_source=google&utm_medium=cpc&utm_term=search&utm_campaign=B027362_hr1_5ll_5ec_d769_ppc-spons-p3-conversion&gclid=Cj0KCQjw9ZGYBhCEARIsAEUXITWS1ZLazwp3GKE44mOg0oU1Cd-A4gU5enVDavZzIXGbRM2gq-huQM0aArDfEALw_wcB

Summary Emissions Savings Table

	Measure	Savings (tCO_2e)	High Priority	Medium Priority	Low Priority
Carrowbreck House	Lighting Upgrade	0.1	✓		
Carrowbreck House	Solar PV	4.9	✓		
Carrowbreck House	Upgrade outbuildings	tbc			✓
Wymondham Leisure Centre	Solar PV Generation	22.6	✓		
Wymondham Leisure Centre	Solar Battery Storage	8.7	✓		
Wymondham Leisure Centre	Monitor Waste Heat from CHP to Assess Potential for Use in Gym Complex	tbc	✓		
Wymondham Leisure Centre	Water Circulation Pump Upgrade	3.8		✓	
Diss Leisure Centre	Solar PV Generation	19.4	✓		
Diss Leisure Centre	Solar Battery Storage	7.5	✓		
Diss Leisure Centre	Investigate Insulation of Pool Hall	32.2	✓		
Diss Leisure Centre	Water Circulation Pump Upgrade	1.9		✓	
Diss Leisure Centre	Pool Cover	10-30%		✓	
Diss Leisure Centre	Investigate CHP Potential	20-30%			✓
Diss Leisure Centre	Air Handling	tbc			✓
Long Stratton Leisure Centre	Solar PV Array	8.2	✓		
Long Stratton Leisure Centre	Battery Storage	3.2	✓		
Long Stratton Leisure Centre	Solar Thermal Water Heating	2.2		✓	
Ketteringham Depot	Lighting Upgrade	0.4	✓		

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Ketteringham Depot	Solar PV	1.6	✓		
Ketteringham Depot	Heat Loss Reduction	6		✓	
Ketteringham Depot	Electric Heating	50			✓
Ketts Park	LED Lighting Upgrade to Tennis Floods and remaining interior lights	3.4	✓		
Ketts Park	Solar PV Array	4.3		✓	
Ketts Park	PV Battery Storage	2.6		✓	
Ketts Park	Common and Changing Areas Air Sourced Heat Pump Upgrade	2.1			✓
Temporary Accommodation 1	Upgrade Double Glazing	0.9	✓		
Temporary Accommodation 1	Upgrade Loft Insulation	0.7	✓		
Temporary Accommodation 1	Solar PV	2	✓		
Temporary Accommodation 1	Heat Pump Heating Upgrade	8.3			✓
Temporary Accommodation 2	Replace Poorly Fitting Double Glazing	0.3	✓		
Temporary Accommodation 2	Insulation Original Loft & Upgrade Extension Loft Insulation	1.3	✓		
Temporary Accommodation 2	Wifi Controlled Electric Heating	0.7		✓	
Temporary Accommodation 2	Solar PV	1.2			✓
Temporary Accommodation 2	Internal Wall Insulation	2.3			✓
Temporary Accommodation 3	Upgrade Double Glazing	0.3	✓		
Temporary Accommodation 3	Insulation of Original Loft & Upgrade of Extension Loft Insulation	0.9	✓		

Temporary Accommodation 3	Wifi Controlled Electric Heating	0.3		✓	
Temporary Accommodation 3	*Optional Heat Pump Heating Upgrade*	*2.6*		✓	
Temporary Accommodation 3	Solar PV	0.5		✓	
Temporary Accommodation 3	Internal Wall Insulation	0.9		✓	
The Octagon	Lighting Upgrade	0.1	✓		
The Octagon	Solar PV	0.5	✓		
The Octagon	Double Glazing	0.5		✓	
The Octagon	Roof Insulation	0.3			✓
The Octagon	Wall Insulation	0.2			✓
Crafton House	Solar PV	8.3	✓		
Crafton House	Battery Storage	3.6	✓		
Crafton House	Individual Tenant Sub-metering	2		✓	
Diss Business Centre	Lighting Upgrade	0.3	✓		
Diss Business Centre	Roof Insulation	2.5	✓		
Diss Business Centre	Solar PV	9.6	✓		
Diss Business Centre	Upgraded Glazing	3		✓	
Diss Business Centre	Internal Wall Insulation	10			✓
Diss Business Centre	Heat Pump Installation	23.8			✓
Loddon Business Centre	Investigate Unaccountable Electricity Consumption	tbc	✓		
Loddon Business Centre	Sash Upgrading and Secondary Glazing	0.3	✓		
Loddon Business Centre	Roof Insulation	1.6	✓		
Loddon Business Centre	Internal Wall Insulation	1.4		✓	
Loddon Business Centre	Solar PV Arrays	0.7		✓	

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Loddon Business Centre	Battery Storage	0.3		✓	
Loddon Business Centre	HVAC Heating Upgrade	1.6			✓
Trumpeter House	Solar PV	3.2	✓		
Trumpeter House	Battery Storage	1.2	✓		
Trumpeter House	Window Solar Control Film	0.2		✓	

Behaviour Change

Monitor – It is recommended that the energy consumption of each building is regularly monitored. By taking, recording and analysing regular meter readings, trends and patterns in energy use can be identified. For larger sites or for particularly energy intensive pieces of equipment, smart and/or sub meters might also be considered.

Compare energy against trends - It is recommended that the organisation compares its energy use to trends such as weather, production, staff numbers or turnover, depending on what is most appropriate for each building.

Identify the baseline energy use - It is recommended that a baseline energy use be set for each property that will allow for performance to be benchmarked. The consumption can be converted to represent performance in relation to productivity or other variable factor and be used to make realistic reduction targets.

Increase Environmental Awareness amongst staff - Engaging staff in regard to energy efficiency and energy reduction can improve energy efficiency (e.g. By having stickers/posters in place, sending emails, having a switch off campaign).

Measure – It is recommended that the internal temperature of each building be measured on an on-going basis to ensure that it is not heating or cooling excessively. The Carbon Trust recommends that the temperature in offices should be between 19-21^{o}C for heating. To ensure that the business is not over or under heating it is recommended;

- Staff are dressed appropriately for the temperature
- Proper controls on heating and cooling and that staff cannot change
- Staff are not opening windows whilst heating or cooling is on

Campaign – An awareness campaign around energy use and the resultant behaviour change can result in a 5% reduction in energy consumption. An effective campaign will target specific behaviours (switching off or using controls correctly for example) and be tailored to staff in regards to methods of motivation and engagement. Things to consider include;

- **Target** – people will be more likely to respond to a set target, ensure that you let staff members know of the organisations target and any progress against this.
- **Competition** – turning the campaign in to a competition could engage staff effectively
- **Comfort** – an appropriate temperature in the work environment will be more comfortable for staff
- **Recognition** – ensure staff members making progress towards a reduction target are recognised for their efforts. Any reward should be appropriate and appealing.
- **Environmental** – some members of staff will simply be driven by the fact that they can help to reduce the organisation’s environmental impact, keeping them updated with progress will therefore help to keep them motivated.

The Carbon Trust suggests that a budget of between 1% and 2% of total annual utility spend should be assigned to the implementation of a campaign.

Site Audits

Carrowbreck House

The main three-storey building contains offices, training rooms, meeting rooms and services (Figure 1). Two single-storey outbuildings offer further training and function rooms (Figures 2 and 3). It is understood that the original building formed part of the NHS estate but was taken over by the Council in 2009 and subsequently re developed in 2013/14 to a high sustainability standard and has a district ground sourced heat pump system throughout all the buildings.

Figure 1: The Main Building

Figure 2 and 3: The Two Outbuildings

The only energy supply is electricity which is supplemented by a small solar PV array estimated to be around 3.5kWp and potentially generating 3,200kWh pa.

The 2018/19 benchmark carbon emissions report for the site show an emission of 11.4tCO_2e, which is purely associated with grid-supplied electricity. It is not known how much of the solar generated electricity has been used on site or exported to the grid, however an estimated use would be approximately 2,200kWh pa, saving 0.8tCO_2e, which is only approximately 7% of the total imported electricity of 32,342kWh for that period.

The breakdown of emissions associated with electricity consumption (Figure 4) shows the ground sourced heat pump equipment accounting for 70% of the emissions, server room A/C accounts for a total of 12%, followed by office equipment, lighting and catering equipment.

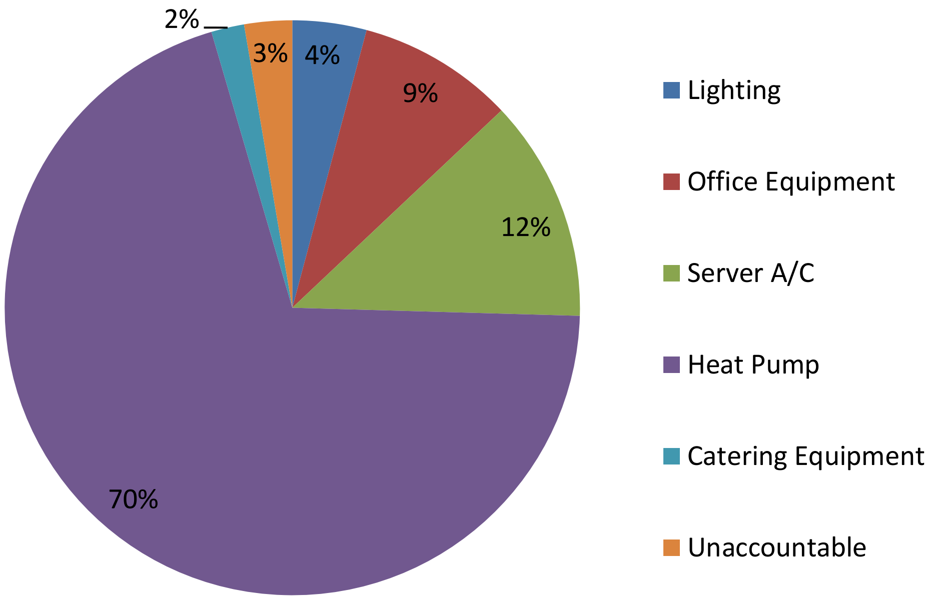

Figure 4: Breakdown of the Electricity Consumption Emissions.

Table 1: Key Recommendations for Carrowbreck House

	Measure	Savings (tCO2e)
Short Term	Lighting Upgrade	0.1
Short Term	Solar PV	4.9
Long Term	Upgrade outbuildings	tbc
Total Savings		**5.0**
2018/19 Emissions		**11.4**

Lighting

The lighting mainly consists of compact fluorescent lamps and T5 fluorescent tube lighting. While these are the most efficient of their type, upgrading to LED would reduce the energy consumed and give the opportunity to install more sensors to detect motion in less frequented areas and daylight sensors in areas with windows, to dim or extinguish lights when not required.

LED lighting can also improve the working environment for staff and visitors.

It is estimated that replacing the remaining conventional lighting with LED would save 0.1tCO_2e with further savings possible with sensors.

Construction

The main building and rendered outbuilding are presumed to have insulation specified to the regulations applicable in 2013 however it is worth ensuring the roof insulation is increased to the more recent specifications.

It has not been possible to ascertain the insulation levels in the wooden outbuilding although this is understood to be unused presently.

Glazing

The double glazing appears to be in good condition and well fitting, although replacement with more modern units could offer a slight reduction in heat loss and an improvement in functionality.

Heating

The electric ground sourced heat pump offers the most energy efficient and lowest emission option claiming a coefficient of performance of 410-440%. The system heats the main building and the outbuildings through a distribution system and underfloor heating (Figure 5).

Figure 5: Part of the Ground Sourced Heat Pump Distribution System

It appears that each room is zoned allowing a high degree of control and underfloor heating offers a high efficiency factor however it does not offer the immediate reactivity of blown-air heating.

Solar PV

The current solar PV array is estimated to generate 3,200kWh pa of which 2,200kWh is estimated to be used on site with the remainder being exported to the grid at times of low demand such as weekends. This only contributes approximately 7% of the electricity demand on site whereas an additional ground mounted array of 60 panels could generate 20,000kWh of which an estimated 14,000kWh could be used on site, contributing over 40% of the total demand and saving 4.9tCO_2e pa.

Wymondham Leisure Centre

The leisure centre underwent an extensive renovation in 2015/16 in order to overhaul the 1980's sports hall and 1990's swimming pool and add a new dry sports centre and visitor facilities.

Figure 1: The Main Entrance and Dry Sports Centre

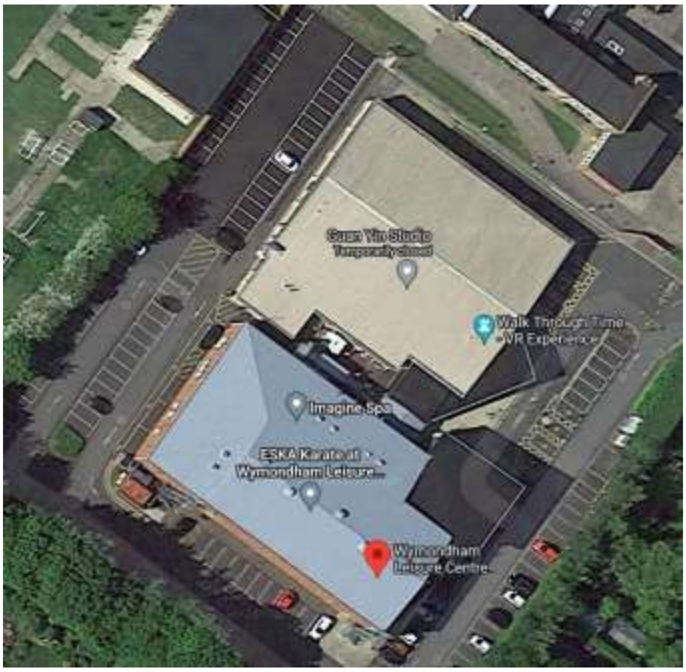

Figure 2: The Pool Complex (Top) and Dry Sports Centre (Bottom)

The site has both natural gas and electricity grid supplies, with a Combined Heat and Power (CHP) system supplying supplementary electricity to the site and heat to the pool complex.

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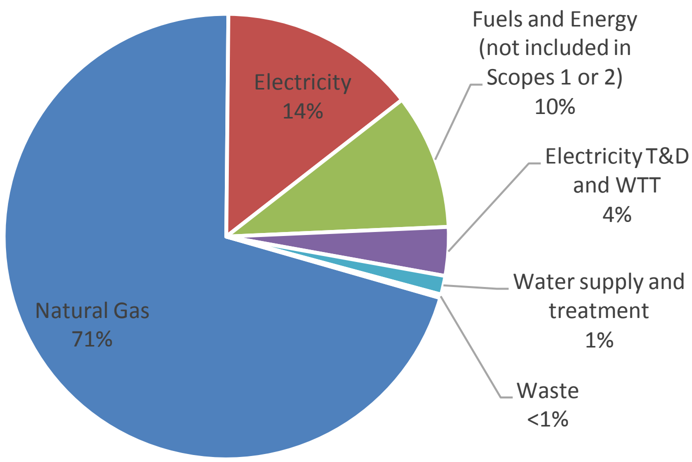

Figure 3: Breakdown of the Site Emissions from the 2018/19 Emissions Report.

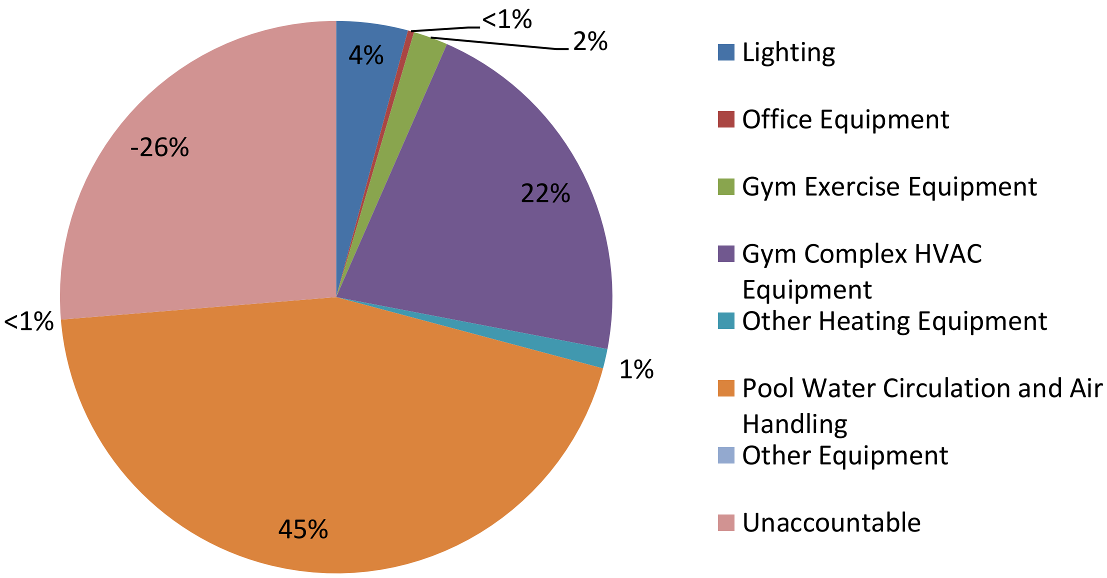

Figure 4: Breakdown of the Electricity Consumption Emissions.

It has not been possible to obtain data on the total electricity generated by the CHP plant, what has been used on site or what has been exported to the grid (unused). It is assumed the estimated missing unaccountable electricity imported (-26%) in Figure 4 has been supplied by the CHP plant.

The building has a voltage optimising system intended to increase efficiency.

Table 1: Key Recommendations

	Measure	Savings (tCO2e)
Short Term	Solar PV Generation	22.6
Short Term	Solar Battery Storage	8.7
Short Term	Monitor Waste Heat from CHP to Assess Potential for Use in Gym Complex	tbc
Mid Term	Water Circulation Pump Upgrade	3.8
Total Savings		**35.2**
2018/19 Emissions		**610.1**

Lighting

The lighting is primarily LED and although the consumption associated with the lighting is low any remaining lighting should be upgraded to LED with daylight and motion sensors where appropriate.

Construction

Having been extensively refurbished in part and with a newly built section in 2015 it is assumed the insulation levels are good with little scope for further economic intervention.

The glazing is double with sun shades to some southern faces to reduce heat gain, although it was noticed that these can inhibit the cleaning of the exterior surface somewhat.

Motors and Pumps

The major demand for motors and pumps is associated with the pool water recirculation and filtration systems. There are four 7.5kW pumps within the basement systems which are variable speed and controlled individually. The manufacturers efficiency rating for the installed F model pumps is 88.7% whereas F-PM model pumps have a manufacturers efficiency rating of 95%, and based on this report's estimated consumption of the existing pumps upgrading may save 3.8tCO_2e per year.

Specialist professional advice would be required and it is recommended to monitor the kWh consumption of each pump for a period of time to accurately assess any potential efficiency savings.

Heating and Cooling

The pool complex basement contains the CHP unit and associated water pumps, motors and water filtration. The CHP unit produces electricity 24hrs a day to offset the imported grid electricity and heat exchangers recover engine and exhaust heat for the pool water and complex. This is backed up with four natural gas boilers for occasional heat boosting and emergencies which are located within the ground floor plant room along with air handling units.

It has not been possible to obtain data on the actual kWh of electricity generated by the CHP plant or how much was used on site rather than exported to the grid and it recommended that this data be sought in order to better understand the total electricity demand of the site.

The heat demand for the pool complex will vary seasonally but the heat generated by the CHP is estimated to remain reasonably consistent leading to periods of excess heat generation within the CHP plant. In order to protect the CHP engine from overheating it is necessary to 'dump' this excess heat through a radiator and fan arrangement located in the central yard (Figure 5).

Figure 5: The CHP External Water Radiator and Fan Assembly

The dry sports building has an extensive HVAC system supplying heating and cooling on demand (Figure 6) with an air handling unit located adjacent to it.

Figure 6: The Dry Sports Centre HVAC Inverters Located in the Central Yard

The pool system and the dry sports systems are not interconnected despite being only metres apart and it is recommended that a process of monitoring be implemented to establish the yearly pattern for heat dumping from the CHP, the kWhs of heat dumped and the yearly pattern for heat demand within the dry sports building to establish whether there is any benefit to redistributing the CHP waste heat.

Air Handling

The site has two independent air handling systems, one for the dry sports centre and the other for the pool complex, requiring very different parameters.

Air handling systems control the humidity, temperature and air quality by removing contaminants. Acceptable ventilation rates for a pool and its surrounding areas is between 4 and 6 air changes per hour.

The systems dehumidify the recycled air and mix in fresh air however it is understood that the systems are currently being used on a high fresh air mix due to Covid restrictions. This should be reviewed regularly to ensure the default heat exchanger set up is recovering the maximum hot air to reduce heat demand, as space heating within a pool complex can account for 50% of a pool complex energy consumption. [3]

At the pool surface the movement of air increases unwanted evaporation rates (and energy loss) which is to be balanced with the need to remove contaminants and supplying fresh air to breathe. Dehumidifying the air in the pool sides and pool hall roof voids can reduce unwanted condensation and subsequent building fabric deterioration. Improvements in air handling such as high efficiency and variable speed motors and direct dehumidification has improved energy efficiencies and it is recommended the air handling units be surveyed professionally to accurately establish the current set up.

Figure 7: Air Handling Unit for the Dry Fitness Centre.

The pool itself has a floating cover fitted at night which substantially reduces evaporation from the water surface, thereby reducing heat demand to maintain temperature and also potentially reducing the need for high ventilation rates later at night. It is recommended that the ventilation rates and humidity be monitored to assess whether the air recirculation rates can be reduced overnight.

[3] Carbon Trust. In-depth technology guide CTG009 -Swimming Pools. A Deeper Look at Energy Efficiency

Solar PV

It is understood that a solar PV array is currently being considered for the site but it is important to consider the current CHP generation and balance any potential solar array with actual electricity demand to avoid over generating and excessive exporting of electricity which may not be financially sound although may be considered to 'offset' other Council emissions elsewhere. As previously recommended, it is important to record the imported grid electricity and the actual kWh generated by the CHP plant and the amount exported to the grid in order to properly assess the total electricity demand of the site.

It is likely that the site would benefit from a solar array, and as an indication, a solar array of 100kWp is estimated to produce 90,000kWh per year of which 65,000 is estimated could be used on site saving 22.6tCO_2e. A battery storage system would be able to provide electricity in the evening saving a further estimated 8.7tCO_2e.

Diss Leisure Centre

The leisure centre is located at the site of an open-air lido which the Council took over in 1974 and the roof was added in the 1980's. The pool is the main facility with only a small fitness suite provided.

Figure 1: The Main Entrance and Dry Sports Centre

Figure 2: The Pool Complex

The site has both natural gas and electricity grid supplies with a voltage optimising system intended to increase efficiency.

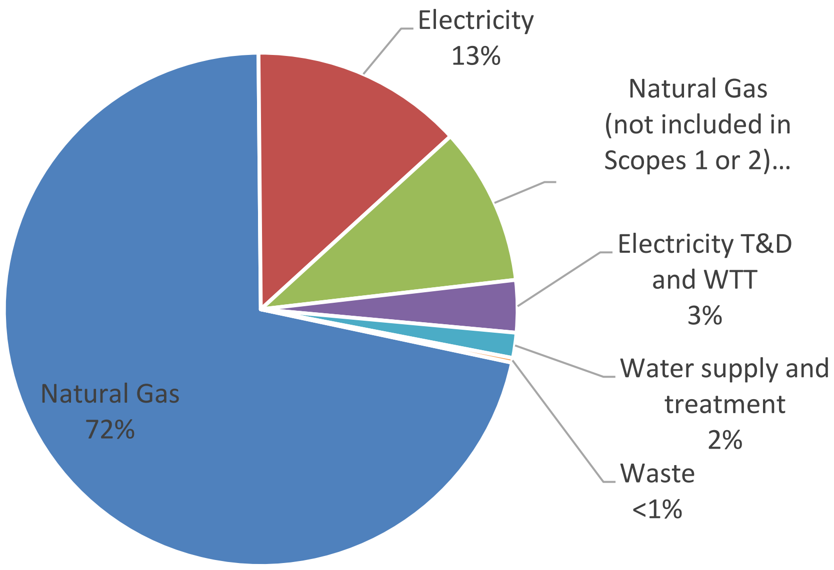

Figure 3: Breakdown of the Site Emissions from the 2018/19 Emissions Report.

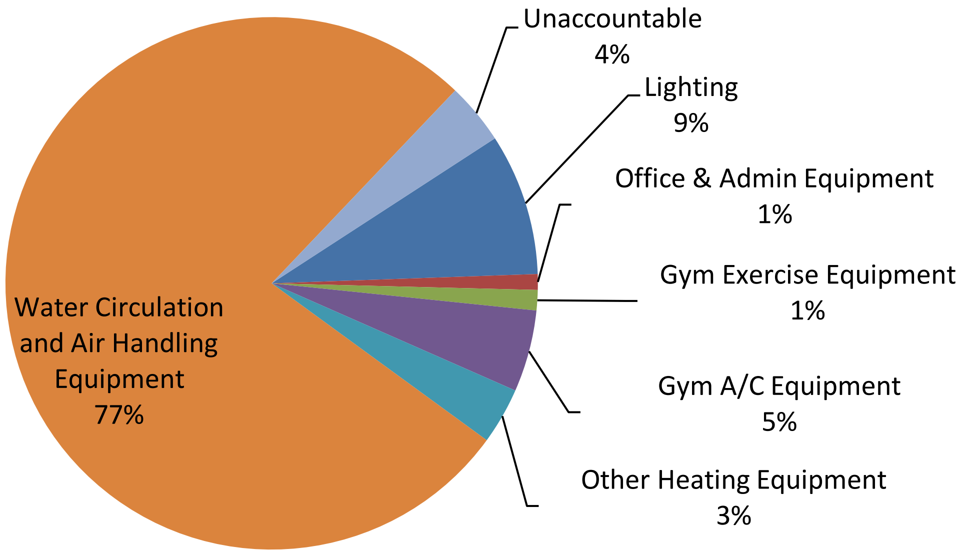

Figure 4: Breakdown of the Electricity Consumption Emissions.

Heating is primarily supplied by natural gas boilers.

Table 1: Key Recommendations

	Measure	Savings (tCO2e)
Short Term	Solar PV Generation	19.4
Short Term	Solar Battery Storage	7.5
Short Term	Investigate Insulation of Pool Hall	32.2
Mid Term	Water Circulation Pump Upgrade	1.9
Mid Term	Pool Cover	10-30%
Long Term	Investigate CHP Potential	20-30%
Long Term	Air Handling	tbc
Identified Savings		**61.0**
2018/19 Emissions		**523.8**

Lighting

The lighting within the main pool hall is fluorescent tube which it is understood is due for replacement. The remaining lighting is primarily LED, with sensors where appropriate.

Construction

The building was constructed to cover the open-air lido and is of an industrial metal frame and metal panel construction offering poor heat retention in the winter and excessive heat gain in the summer. It is understood that the pool is being considered for a refurbishment inline with Wymondham and Long Stratton and it is estimated that if the insulation were bought up to current standards the saving in heating could be 32.2tCO_2e and the reduced summer heat gain may improve the environment for staff and visitors.

Motors and Pumps

As expected the major demand for motors and pumps is associated with the pool water recirculation and filtration systems. There are two 7.5kW pumps within the water plant room which are variable speed and controlled individually. The manufacturers efficiency rating for the installed F model pumps is 88.7% whereas F-PM model pumps have a manufacturers efficiency rating of 95%, and based on this report's estimated consumption of the existing pumps upgrading may save 1.9tCO_2e per year.

Specialist professional advice would be required and it is recommended to monitor the kWh consumption of each pump for a period of time to accurately assess any potential efficiency savings.

Heating and Cooling

The fitness gym is heated and cooled by two HVAC units located to the side of the building (Figure 5) and the pool is heated by a natural gas system located within the pool plant room (Figure 6).

Figure 5: The Gym HVAC Systems

Figure 6: The Pool Natural Gas Heating System

Combined Heat and Power (CHP) plants generate electricity with a natural gas-powered engine and the subsequent recovered heat can supply the pool heat demand. They are estimated to reduce overall energy consumption by 20-30%. [4]

It is recommended that the generation and consumption data for the CHP at Wymondham Leisure Centre be recorded and analysed in order to better establish the savings being achieved there and the potential savings at Diss Leisure Centre. However, from the data available at this time, the 2018/19 consumption of gas and electric at Diss accounts for carbon emissions of 514tCO_2e, whereas at Wymondham Leisure Centre the overall emissions are 600tCO_2e despite being twice the floor area, although it should be noted that most of the additional floor area is associated with dry sports and the pools are similar sizes.

Air Handling

The air handling system is located in a separate plant room adjacent to the pump plant room and controls the humidity, temperature and air quality by removing contaminants. Acceptable ventilation rates for a pool and its surrounding areas is between 4 and 6 air changes per hour.

The system dehumidifies the recycled air and mixes in fresh air however it is understood that the systems are currently being used on a high fresh air mix due to Covid restrictions. This should be reviewed regularly to ensure the default heat exchanger set up is recovering the maximum hot air to reduce heat demand, as space heating within a pool complex can account for 50% of a pool complex energy consumption. [5]

At the pool surface the movement of air increases unwanted evaporation rates (and energy loss) which is to be balanced with the need to remove contaminants and supplying fresh air to breathe. Dehumidifying the air in the pool sides and pool hall roof voids can reduce unwanted condensation and subsequent building fabric deterioration. Improvements in air handling such as high efficiency and variable speed motors and direct dehumidification has improved energy efficiencies and it is recommended the air handling units be surveyed professionally to accurately establish the current set up.

The pool does not have an insulated pool cover. It is recommended that this be considered in any future refurbishment project as a priority as this can substantially reduce evaporation from the water surface, thereby reducing heat demand to maintain temperature and also potentially reducing the need for high ventilation rates later at night. It would be recommended that the ventilation rates and humidity be monitored to assess whether the air recirculation rates can be reduced overnight.

Solar PV

It is understood that a solar PV array is currently being considered for the site but it is not known if that is to be part of a larger refurbishment programme. Should that be the case the size of solar array should be balanced with any other planned energy generation such as CHP to avoid excessive unwanted exporting of energy to the grid.

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[4] Carbon Trust. In-depth technology guide CTG009 -Swimming Pools. A Deeper Look at Energy Efficiency
[5] Carbon Trust. In-depth technology guide CTG009 -Swimming Pools. A Deeper Look at Energy Efficiency

It is likely that the site would benefit from a solar array, and as an indication, a solar array of 100kWp is estimated to produce 78,000kWh per year of which 55,000 (22% of consumption) is estimated could be used on site saving 19.4tCO_2e. A battery storage system would be able to provide electricity in the evening saving a further estimated 7.5tCO_2e.

Long Stratton Leisure Centre

The dry sports and leisure facility was refurbished in 2019 when an extension was added to the front of the building replacing a single storey flat-roofed annexe. Heating oil space and water heating was also replaced with all electric HVAC space heating and calorifier water heating.

The facility offers a reception with café, children's soft play area, fitness suite, sports hall, changing facilities and separate school changing rooms. The site also includes a floodlit football pitch used by clubs and the neighbouring school.

Figure 1: The Refurbished Front Facade

Figure 2: The Pre-existing Sport Hall to the Rear.

Energy consumption on site is primarily electricity although there is a relatively small amount of petrol used for the ride-on mower used in the grounds which was omitted from the 2018/19 benchmark Council greenhouse gas inventory.

Figure 3 shows the estimated breakdown of the electricity consumption, with the unaccountable element possibly due to additional equipment not seen during the audit, underestimation of the frequency of use of equipment or upgrades of equipment since the last full years consumption data. The emissions associated with this electricity consumption was 67.2tCO_2e in 2021/22.

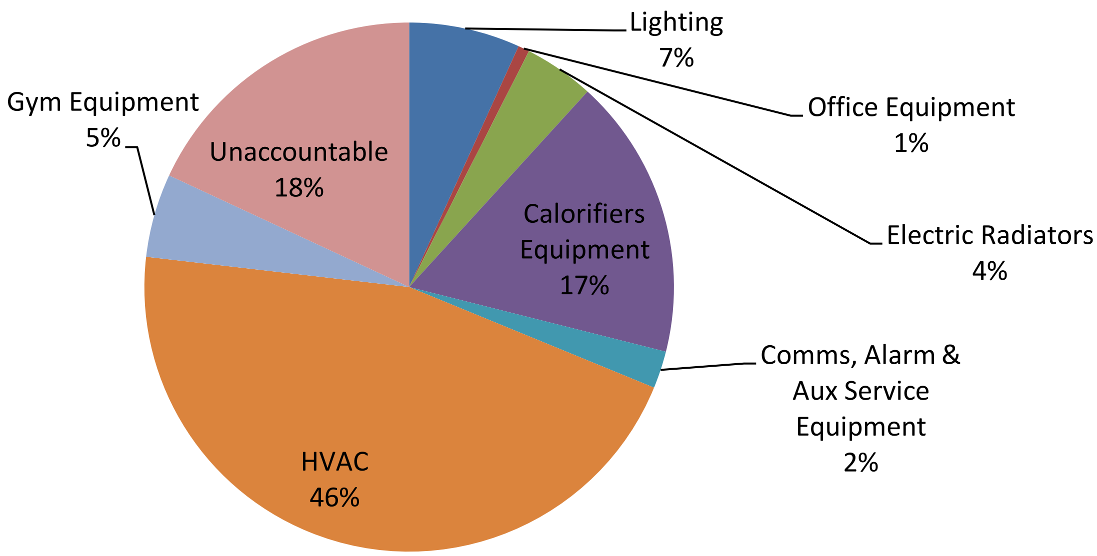

Figure 3: Breakdown of the Electricity Consumption Emissions.

Table 1: Key Recommendations

	Measure	**Savings (tCO2e)**
Short Term	Solar PV Array	8.2
Short Term	Battery Storage	3.2
Mid Term	Solar Thermal Water Heating	2.2
Identified Savings		**13.6**
2021/22 Emissions		**67.2**

Lighting

The lighting is primarily LED with sensors in the appropriate areas ensuring minimal consumption. It is understood that the external pitch flood lighting is also LED.

Construction

The front extension is assumed to have been built according to 2019 building regulations and should therefore be reasonably well insulated. Additional insulation may offer further small savings in heating and cooling however it would need to be a low cost option to be economical. The sports hall, the original building, may be the target for any future improvement however the exterior is metal clad and presumably insulated within the cavity created.

All entrance doors and windows are double glazed and it is understood that the ill-fitting wooden emergency doors are due to be replaced soon.

Heating

The space and water heating were upgraded from oil to electric in 2019 (Figures 4 and 5) and the annual electricity consumption reflects that change, rising from 112,848kWh in 2018/19 to 230,825kWh in 2021/22. It is estimated that this positive upgrade has saved over 100tCO_2e in emissions.

Figure 4: HVAC Condenser Units Supplying Space Heating

Figure 5: Twin Calorifiers and Water Storage Vessels

Located within the sports hall walls are obsolete fan assisted radiators associated with the previous oil boiler and the space is now heated with suspended radiant heaters providing sufficient heating for sports use and controlled by zoned sensors to avoid heating courts and areas not in use.

Solar PV

It is understood that solar PV is planned to be installed in 2023 on the hall roof, near the electrical supply plant room and HVAC units (Figure 6).

The size of the planned array is unknown but it is estimated that a 50kWp system could generate 40,000kWh per year of which it is estimated 70% could be used on site therefore offsetting 28,000kWh of grid electricity and saving 8.2tCO_2e.

The addition of a battery storage system could offset the evening demand, particularly relating to the internal and external lighting potential saving a further 3.2tCO_2e.

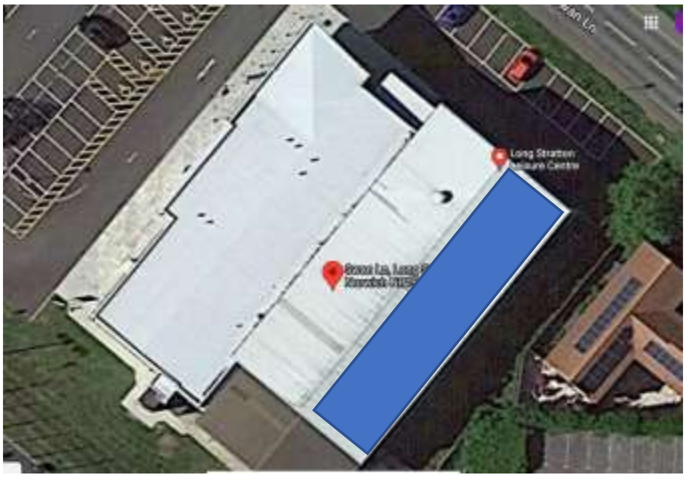

Figure 6: Potential Solar PV Array Location

Solar Thermal Water Heating

The centre has twin electric calorifiers supplying the hot water demand which may benefit from the addition of solar thermal water heating. It is estimated that an array of evacuated tube type panels, covering approximately 14m^2 above the hot water plant room, could supply 7,500kWh of water heating, or approximately 20% of the current water heating demand saving 2.2tCO_2e.

Figure 7: Potential Solar Thermal Water Heating Location

Ketteringham Depot

The property consists of single-storey building containing offices and meeting rooms (Figure 1), behind which are two portacabins. Various large workshops are located within the large refuse vehicle parking area (Figure 2).

Figure 1: The Main Office

The site has mains electricity supply, heating oil storage and diesel fuel storage for the refuse fleet.

The 2018/19 benchmark carbon emissions report for the site show total emissions of 1,700tCO_2e, the breakdown of which is shown in Figure 3, of which 36.3tCO_2e is associated with the buildings and 1,657.8tCO_2e is associated with the fleet fuel consumption.

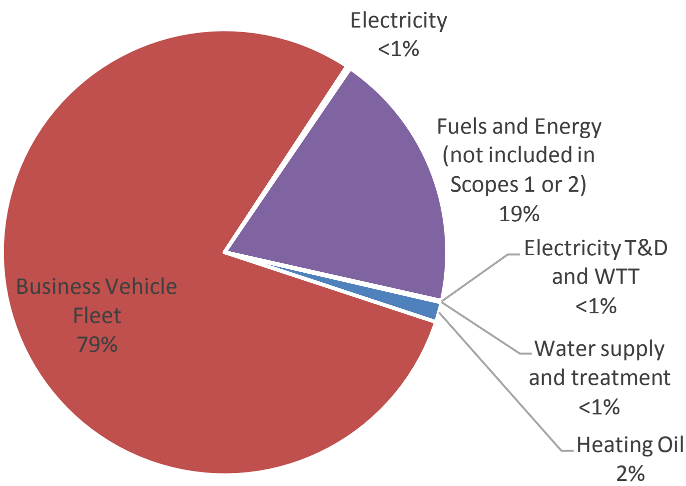

Figure 2: Breakdown of the Site Emissions from the 2018/19 Emissions Report.

It can be seen that the electricity and heating oil supplies account for less that 5% of the total emissions associated with the depot. It is estimated that the newly installed oil heater within the workshop will add another 30 to 40tCO_2e annually when commissioned, equivalent to the 2018/19 reported consumption for the existing oil heating.

The breakdown of emissions associated with electricity consumption (Figure 4) shows workshop equipment accounting for 48% of the emissions, electric heating accounts for a total of 16%, followed by lighting and catering and laundry equipment.

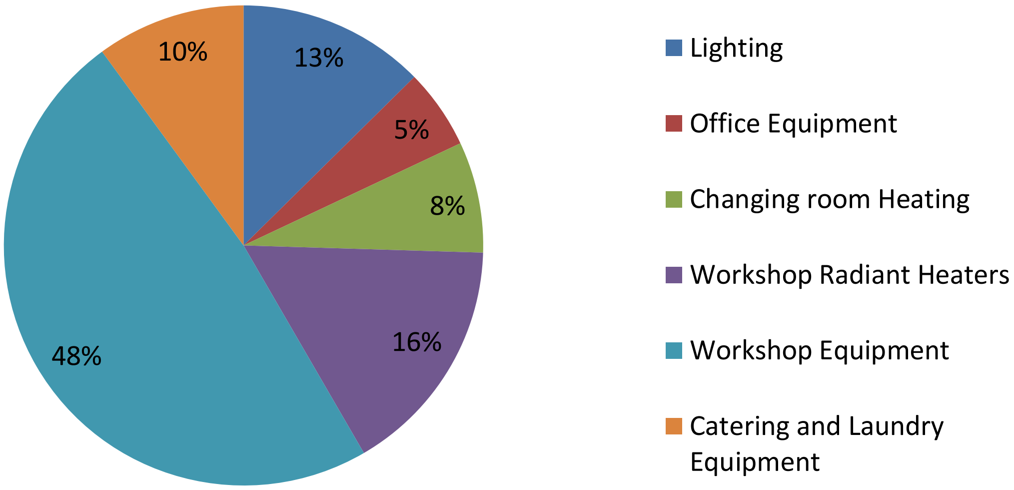

Figure 3: Breakdown of the Electricity Consumption Emissions.

Table 1: Key Recommendations for Ketteringham Depot

	Measure	Savings (tCO_2e)
Short Term	Lighting Upgrade	0.4
Short Term	Solar PV	1.6
Mid Term	Heat Loss Reduction	6.0
Long Term	Electric Heating	50.0
Identified Savings		**58.0**
2018/19 Emissions inc Refuse Fleet		**1694.1**

Lighting

Some lighting has been upgraded to LED and a programme of further upgrades with sensors would reduce the lighting demand and potentially improve the working environment. Motion sensors in areas of infrequent use, such as parts stores, would avoid inadvertent unnecessary lighting and daylight sensors in workshops can dim or extinguish lighting if the natural light levels are sufficient with skylights.

It is estimated that replacing the remaining conventional lighting with LED would save 0.4tCO_2e with further savings possible with sensors.

Construction

The office is of an old design, with poor insulation properties, with a conservatory to the rear for meetings. The portacabins, used for meetings and training also offer little insulation.

It is unlikely a programme of retrofit insulation to the office building would provide economic savings and replacement of the buildings may offer an opportunity to reduce emissions while also potentially improving the working environment.

The main workshops are constructed with solid block lower walls and uninsulated corrugated panels upper walls and roofs. Older units are brick and block.

The heat losses from such buildings is significant particularly with the large open doors.

Heating

Electric and oil heating accounts for 30tCO_2e of the 36.3tCO_2e emissions associated with the use of the buildings at the depot in the 2018/19 report. The majority of the emissions are associated with the oil heaters (Figures 6 and 7).

Figure 6: One of Two Existing Oil Heaters in the Smaller Workshops

Figure 7: New Oil Heater and Storage Tank at the Large Workshop

The new oil heater will be supplementing existing infrared radiant heaters located around the main work area.

Hot air oil heaters such as these are ineffective in large open spaces with much of the heat being lost to the roof spaces and through ventilation. Recommendations would include: improved insulation of the walls and roofs which would reduce heat loss; installation of automated, quick operating and insulated shutter doors which would reduce heat loss to ventilation; and recirculation of the rising heat from the rafters through destratification fans (Figures 8 and 9).

Figure 8: Spray Insulation

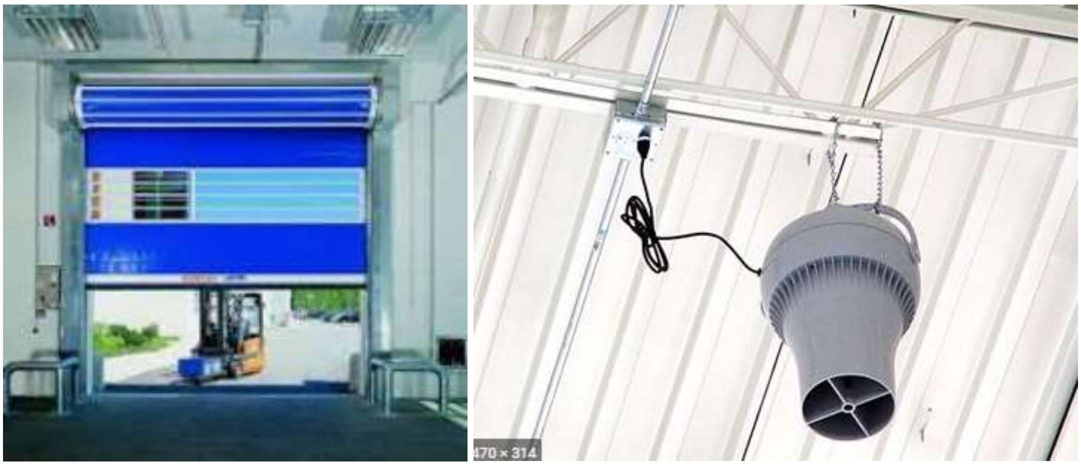

Figure 9: Fast Roller Shutter Doors and Destratification Fans

The emissions associated with heating, including the new oil heater, are estimated to be 60tCO_2e. A 10% reduction in that through reduced heat loss could save 6tCO_2e. Alternative non-fossil fuel heating could reduce those emissions by 50.0tCO_2e

Solar PV

The roofs at the site may be unsuitable for solar PV installation if they contain asbestos and the consumption of electricity at the site is low at 16,000kWh. However an 8kWp array could generate an estimated 6,500kWh, of which 4,500 could be used on site avoiding 1.6tCO_2e in imported electricity.

Ketts Park

The site is located within a large public park with the Town Council building located nearby. Energy use is attributed to the sports hall building, an adjacent hut and two floodlit playing surfaces, one containing 3 tennis courts and the other a single football pitch.

Figure 1: The Building

The site is serviced by grid electricity and water. Waste water is pumped off site to the main sewers. The greenhouse gas emission report for the benchmark year 2018/19 show electricity consumption of 74,722kWh and associated carbon emissions, including water, of 26.6tCO_2e.

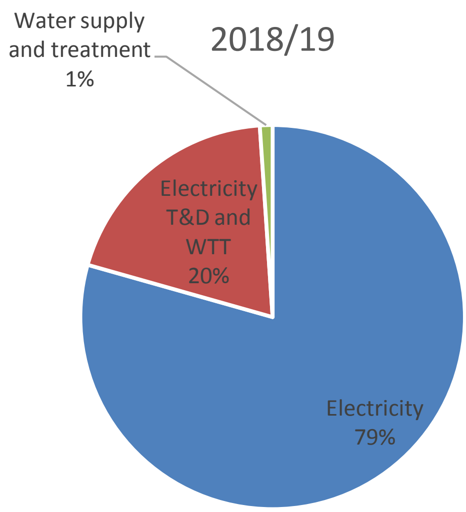

Figure 2: Breakdown of the Site Emissions from the 2018/19 Emissions Report.

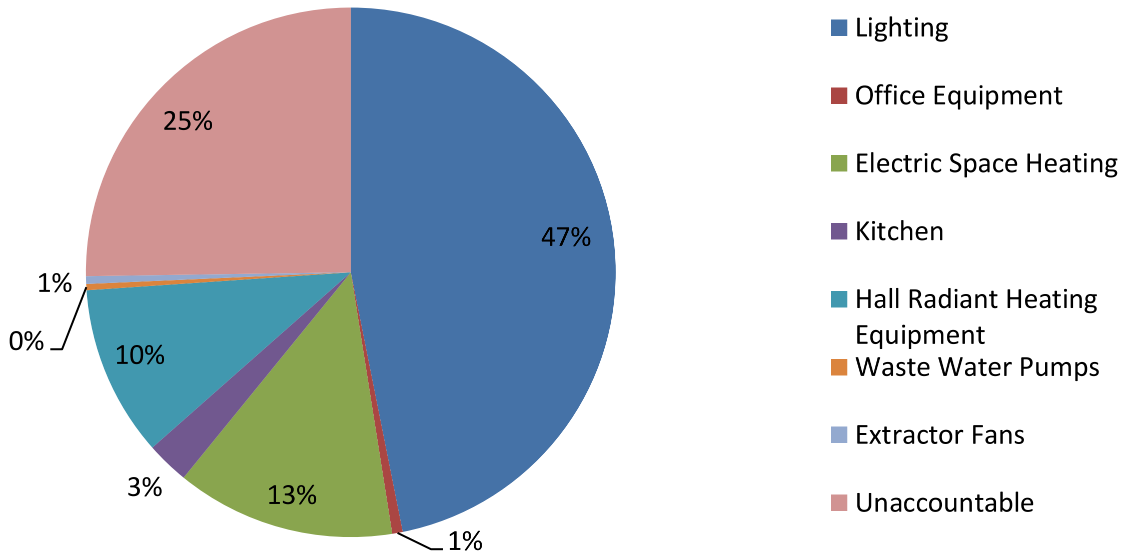

Figure 3: Breakdown of the Electricity Consumption Emissions Estimated from the Audited Equipment for this Report.

The estimated consumption of the equipment audited for this report leaves an unaccounted consumption of 25% when compared to 2018/19 consumption, this is possibly to be due to the upgrading of the football pitch flood lighting to LED in the interim period, if that is not the case the frequency of floodlighting use may have been under estimated.

Table 1: Key Recommendations

	Measure	**Savings (tCO_2e)**
Short Term	LED Lighting Upgrade to Tennis Floods and remaining interior lights	3.4
Mid Term	Solar PV Array	4.3
Mid Term	PV Battery Storage	2.6
Long Term	Common and Changing Areas Air Sourced Heat Pump Upgrade	2.1
Identified Savings		**12.4**
2018/19 Emissions		**26.6**

Lighting

Assuming the football pitch floodlighting upgrade to LED has been carried out since the 2018/19 baseline year, the energy consumption and associated emissions savings from the measure were as substantial as would be expected. The planned upgrading of the tennis court floodlighting would also be expected to offer substantial savings. If combined with the upgrading of the remaining internal lighting the expected savings would be 3.4tCO_2e.

Construction

Anecdotally the building does not seem to suffer from excessive heat gains or heat losses so is assumed to be reasonably well insulated.

Heating

The main sports hall is heated with suspended radiant heating panels which are understood to be used only occasionally as the temperature required for sports is fairly low. They are zoned allowing for partial hall heating as required. Radiant heating panels offer an efficient form of heating as they do not heat the air, but heat the people, surfaces and objects, avoiding excessive heat loss to the roof space.

The remaining areas of the building are heated with storage heaters and electric radiators. Storage heaters are particularly inefficient due to the lack of reactive control and heat loss at night. Upgrading this heat demand to air sourced heat pumps would offer an estimated saving of 2.1tCO_2e pa. They could also offer an enhanced visitor experience and increase remote control by staff to ensure minimal consumption.

Figure 4: Storage Heater

Solar PV

Subject to structural surveys, solar PV on the roof would offer a substantial emissions saving opportunity due to the high electricity consumption from the heating and floodlighting.

It may be possible to install a solar array over both sides of the hall roof, as while the north-west facing roof would generate slightly less than the south-east it would offer late evening power in the summer months for immediate use or battery charging. A battery storage system could offer electricity during the evening times when the hall and pitches are used frequently.

Figure 5: Potential Solar PV Array Sites.

It is estimated a solar array of this size could save 4.3tCO_2e and a battery storage system could save additional 2.6tCO_2e.

Temporary Accommodation 1

This temporary housing accommodation comprises 6 units.

The electricity consumption has decreased substantially since the baseline year of 2018/19 when the consumption was 25,607kWh, the most recent year's consumption data available, 2020/21, shows 10,440kWh. Gas consumption in the same periods is broadly consistent and the electricity data provided shows an exceptionally high consumption in October 2018 of 13,867kWh whereas normal monthly consumption is around 1,000kWh which perhaps indicates either an error or a correction.

The key recommendations from the on-site audit and desk research are outlined in Table 1, with further details in the relevant sections of this report.

Table 1: Key Recommendations for Temporary Accommodation 1

	Measure	Savings (tCO_2e)
Short Term	Upgrade Double Glazing	0.9
Short Term	Upgrade Loft Insulation	0.7
Short Term	Solar PV	2.0
Long Term	Heat Pump Heating Upgrade	8.3
Identified Savings		**11.9**
2020/21 Emissions		**19.1**

The Building

It has been assumed the original construction would have complied with the applicable building regulations at the time and there is no evidence of any retrofitting.

The building is heated by natural gas with the centralized boiler located in the plant room to the front of the building. This is centrally controlled by programmable timers and individual thermostatic radiator valves (TRVs) in each flat.

EPC

The current Energy Performance Certificate (EPC) for one unit gives a rating of C against an average energy rating of D and suggests a potential of C with a very slight improvement in emissions.

Windows and Doors

The windows and doors are double glazed throughout, and although they are timber framed appear in reasonable order (Figure 3). It is understood a complete replacement of the glazing is underway and newer glazing would offer improved heat loss through better fit, increased double glazing cavity and reduced thermal conductivity through the frames.

Upgrading the double glazing to modern standards is estimated to save 0.9tCO_2e per year.

Insulation

The original building is constructed of brick cavity and is assumed to contain some cavity wall insulation.

The central corridor has a suspended ceiling with insulation, above which is open to the roof rafters and each room has a plaster board ceiling which is presumed to be similarly insulated above.

Additional insulation of the roof and loft space to current standards is estimated to save 0.7tCO_2e.

Space Heating

The heating consists of a central pressurized natural gas boiler providing hot water for the radiators and the hot water tank. The heating is centrally controlled by a programmable timer and each radiator can be further controlled with the installed TRVs. This does require the manual control by the tenants. A building management system and remote TRV control would give the building manager control over the system and reduce unnecessary heating of unoccupied flats.

A 5% reduction in the space heating natural gas consumption through better control and behaviour change is estimated to save a further 0.7tCO_2e per year.

Upgrading the entire heating system to an electric heat pump system offers a large reduction in carbon emissions. It is, however, important to reduce the heat losses through the walls, roof and windows first due to the lower operational heat delivery of heat pumps. These can be most effective when used with underfloor heating arrays or large wall radiators, however, air blown distribution offers the greatest reactivity to demands.

The savings associated with switching to heat pumps, based on the already the reduced heat demand through insulation, are a significant 8.3tCO_2e. On the basis the building's space heating demand (kWh) remains broadly consistent the running costs may increase despite the increased efficiency, as, at the time of writing this report, electricity was considerably more expensive than natural gas per kWh. However it would be expected that the demand would be reduced considerably with the increased controllability of the system and the improved reactivity of heat delivery.

Water Heating

The hot water is currently supplied by the natural gas boiler. Should the heating be upgraded to heat pumps then a suitable heat pump system could provide domestic hot water.

Renewable Energy Generation

The building is understood to be in use during most days when solar PV generation could be used to best effect and the building may be suitable for solar.

An 8kWpeak system located on the roofspace could provide an estimated 60% of the current total annual electricity demand, saving an estimated 2.0tCO_2e.

Should the heating be ungraded to electric heat pumps then a larger array may offer additional savings.

Temporary Accommodation 2

The key recommendations from the on-site audit and desk research are outlined in Table 1, with further details in the relevant sections of this report.

Table 1: Key Recommendations for Temporary Accommodation 2

	Measure	Savings (tCO_2e)
Short Term	Replace Poorly Fitting Double Glazing	0.3
Short Term	Insulation Original Loft & Upgrade Extension Loft Insulation	1.3
Mid Term	Wifi Controlled Electric Heating	0.7
Long Term	Solar PV	1.2
Long Term	Internal Wall Insulation	2.3
Identified Savings		**5.7**
2018/19 Emissions		**13.1**

The Building

This unit comprises 6 units of accommodation

Windows and Doors

Replacing the current windows and doors with better fitting and lower heat loss modern double glazing will save approximately 0.3tCO_2e per year.

Insulation

The original building is constructed solid walls, with no wall insulation. The extension was built prior to 1999 and has cavity walls which are assumed to be uninsulated.

The loft space of the original house is mainly boarded and is assumed to have no, or minimal, insulation. The newer extension is assumed to have minimal 100mm glass fibre insulation.

Insulating the loft space to current levels is believed to have a significant impact based on these assumptions and is estimated to save a further 1.3tCO_2e per year.

Internal insulation of the external walls of the original building is estimated to save 2.3tCO_2e.

SUSTAINABLE BUSINESS

Space Heating

The heating consists of one electric oil filled radiator in each the six bedrooms and four storage heaters in the common areas. All heaters can be controlled by the residents manually, although the storage heaters are understood to be monitored by the staff as well.

The consumption of energy for space heating is not regularly monitored against room occupancy but the recorded consumption for 2018/19 would indicate a high consumption.

Modern electric radiators can be WIFI enabled to allow for recording of consumption, control of timings and temperatures and monitoring of use.

The needs of the residents may take precedence over any external control measures however a system such as this could help introduce behaviour change, identify misuse, enable automatic temperature reduction timings and allow for remote advanced heating prior to new arrivals for example.

Assuming the loft insulation has reduced the overall heat demand, a 10% reduction in the space heating electricity consumption is estimated to save a further 0.7tCO_2e per year.

Water Heating

The water is heated by electric immersion heaters, one working on off-peak and one peak time. During the audit it was noted that the off-peak supply was disconnected and the system was running 24hrs a day. Off-peak water heating provides a full hot tank at the beginning of the day using cheaper electricity, however the requirements of the residents may mean it is not possible to supply enough hot water during the day without additional day time heating.

Timers would enable the maximization of the off-peak heating, with periodic top-up heating for the evening if demand can be met.

Renewable Energy Generation

The building is understood to be in use during most days when solar PV generation could be used to best effect. it could be possible to install a 3kWpeak system which could provide an estimated 10% of the current total annual demand, saving 1.2tCO_2e.

Temporary Accommodation 3

The electricity consumption has increased substantially since the baseline year of 2018/19 when the consumption was 10,684kWh (3.3tCO_2e), the most recent year's consumption used for this report is 24,553kWh giving a carbon footprint of 7.2tCO_2e.

The key recommendations from the on-site audit and desk research are outlined in Table 1, with further details in the relevant sections of this report.

Table 1: Key Recommendations for Temporary Accommodation 3

	Measure	**Savings (tCO_2e)**
Short Term	Upgrade Double Glazing	0.3
Short Term	Insulation of Original Loft & Upgrade of Extension Loft Insulation	0.9
Mid Term	Wifi Controlled Electric Heating	0.3
Mid Term	*Optional Heat Pump Heating Upgrade*	*2.6*
Mid Term	Solar PV	0.5
Mid Term	Internal Wall Insulation	0.9
Identified Savings Based on WIFI Heating Option		**2.9**
2021/22 Emissions		**7.2**

SUSTAINABLE BUSINESS

The Building

The original semi-detached building construction appears be cavity external walls and contains a vent to the end gable wall (Figure 2).

It has been assumed the original construction would not have incorporated wall insulation and there is no evidence of any retrofitting.

Figure 2: Cavity Air Vent Located at the Foot of the Staircase in the Hall

EPC

The current Energy Performance Certificate (EPC), gives a rating of E against an average energy rating of D and suggests a potential of C.

Windows and Doors

The windows and doors are double glazed throughout, some have been recently replaced. All appear to be well fitting and in good order. Newer windows offer incrementally improved heat loss standards but replacing would, perhaps, offer little financial or energy savings at this time.

Upgrading the double glazing to modern standards is estimated to save 0.3tCO_2e per year.

Insulation

The original building is constructed of brick cavity with no wall insulation.

The extension is estimated to have been built prior to 1990, the wall thickness indicates a simple construction with little or no cavity.

The loft is understood to be insulated to 100mm.

Insulating the main house loft space and the extension roof to current levels is estimated to save a further 0.9tCO_2e per year.

Internal wall insulation, or cavity wall insulation if appropriate, applied to all external walls is estimated to offer a further saving of 0.9tCO_2e.

Space Heating

The heating consists of electric storage heaters throughout. These appear to be connected to an 'off-peak' electricity circuit within the house however the billing summary supplied for this report does not show a separate night consumption figure. This should be checked, along with the timers and switches to ensure any potential night rate cost is being used efficiently.

A portable electric radiator is provided for occasional use when required.

As previously stated, the latest years consumption of electricity appears to be over twice that reported for the year 2018/19 which is presumed to be due to changes in use or occupancy. It was noted during the day time audit that the heating was on and that the internal temperature was very high. This is understood to be due to the specific requirements of the occupant.

The consumption of energy for space heating is not regularly monitored against room occupancy.

Modern electric radiators can be WIFI enabled to allow for recording of consumption, control of timings and temperatures and monitoring of use. Although the needs of the residents may take precedence over any external control measures, a system such as this could help introduce behaviour change, identify misuse, enable automatic temperature reduction timings and allow for remote advanced heating prior to new arrivals for example.

Assuming the loft insulation has reduced the overall heat demand, a 10% reduction in the space heating electricity consumption through better control and behaviour change is estimated to save a further 0.3tCO_2e per year.

Upgrading the entire heating system to a heat pump system offers a large increase in electrical efficiency. It is, however, important to reduce the heat losses through the walls, roof and windows first due to the lower operating heat delivery of heat pumps which are most effective when used with underfloor heating arrays or large wall radiators. Due to the fundamental different requirements of the heat pump system, the installation costs can be high.

The savings associated with switching to heat pumps, based on the already reduced heat demand through insulation, are a significant 2.6tCO_2e.

Water Heating

The hot water is provided by an electric immersion heater, it was not possible to ascertain whether the off-peak electricity supply is being utilized and it appeared the immersion may be on continually to supply hot water at all times.

A check of the off-peak timers would enable the maximization of the off-peak water heating even if the resident's needs would require hot water at all times of the day.

Renewable Energy Generation

The building is understood to be in use during most days when solar PV generation could be used to best effect and the original building may be suitable for solar.

A 2kWpeak system could provide an estimated 7% of the current total annual demand, saving 0.5tCO_2e.

The Octagon, Diss

The Octagon is an extension to a public toilet block located on Mere Street in Diss (Figure 1). The Octagon room and the connected rear office (Figure 2) are leased from the Town Council who manage the public toilets to the rear.

Previously used as the Tourist Information Office, the Octagon has been vacant for some time and is now being prepared for use as a public facing South Norfolk Council office. Due to the short lease remaining and the experimental nature of the planned use it is understood that no major redevelopment is planned at this time.

Figure 1: The Octagon and Attached Public Toilet Block to the Rear

Figure 2: Office Space Leased from the Town Council and Included in this Report

There is no consumption data available that reflects the planned use so this report has been based on estimated normal business hours of use, the equipment recorded during the audit and other equipment expected to be installed for office use (Figure 3).

The Octagon has a separate electricity supply to the toilet block although water is on a single meter and is sub-metered to the toilet block for billing to the Town Council.

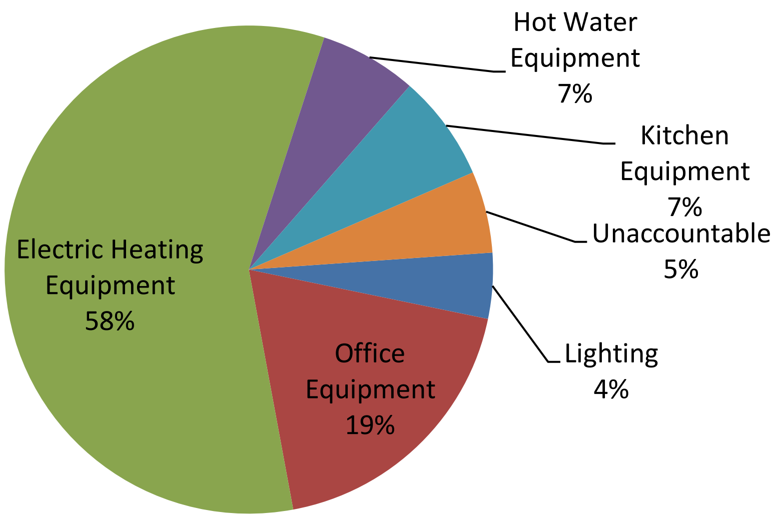

Figure 3: Breakdown of the Estimated Electricity Consumption Emissions for the Leased Building.

Table 1: Key Recommendations

	Measure	Savings (tCO2e)
Short Term	Lighting Upgrade	0.1
Short Term	Solar PV	0.5
Mid Term	Double Glazing	0.5
Long Term	Roof Insulation	0.3
Long Term	Wall Insulation	0.2
Identified Savings		**1.6**
2019/20 Emissions		**2.8**

Lighting

The lighting within the Octagon is primarily 16 no. spot lights with GU10 type LED bulbs, other lighting within the back office and toilet is fluorescent tubes and GLS bulbs. Upgrading the remaining lighting to LED is estimated to save 0.1tCO_2e, however the spot lighting may be found to be inappropriate for office use so the entire scheme may require redesigning.

Construction

It is not known when the original public toilet block was constructed however it is understood to have been extended prior to the Octagon, being added around the 1980s when part of the toilet block was annexed to the new Octagon.

The original building is rendered to the exterior but is assumed to be solid brick with no cavity and the Octagon is constructed with a low brick wall topped with windows and an entrance door to six of the eight sides. The other sides give access to the rear office and toilet.

Glazing

The Octagon room has a large expanse of single-glazed wooden windows and main door (Figure 4). Upgrading the windows and doors to modern double glazing is estimated to save 0.5tCO_2e of emissions while also substantially improving the working environment by reducing draughts, heat loss, heat gain and street noise. The main door can be electronically operated however a secondary entrance door and intermediate lobby would reduce heat demand further and avoid sudden ventilation of the working environment.

Figure 4: The Windows within the Octagonal Room

Roof Insulation

It is assumed that the level of insulation in both the Octagon and the original building is limited, with the original building having a roof void below a pitched roof and the octagonal roof having a minimum fibre insulation between the inner shiplap timber and the exterior plywood and bitumen (Figure 5).

Assuming these standard insulation levels, upgrading to modern levels is estimated to give an emission saving of a further 0.3tCO_2e.

Figure 5: Timber Clad roof within the Octagon and Bitumen Type Exterior

Wall Insulation

In the longer term insulating the walls internally is estimated to potentially save a further 0.2tCO_2e.

Heating

The main Octagon is heated by two basic storage heaters (Figure 6) and one HVAC unit (Figure 7). It is assumed the HVAC will provide the primary heat source to this room and therefore consideration should be given to decommissioning the storage heaters within this area to avoid inefficient and unnecessary use.

The third storage heater in the rear office requires setting and monitoring of the timers to ensure it is used effectively for the use of the room. Alternatively the installation of a further HVAC unit would provide more efficient heating with much increased controllability.

It is recommended to monitor the electricity consumption monthly and, if possible, submeter the HVAC units in order to establish an accurate summer demand for cooling as the building may suffer from excessive heat gain due to the windows.

Figure 6: One of Two Storage Heaters Located in the Octagonal Room

Figure 7: Internal and External Elements of the HVAC Supplying the Octagonal room

Hot water for the handwash basin is supplied by a wall mounted heater (Figure 8). This heats and stores 7 litres of water and it is recommended to ensure this is operated on a timer to avoid unnecessary heating when the building is unoccupied. Alternatively, an instant over sink point-of-use water heater would eliminate the storage of unused hot water.

Figure 8: Over-basin 7 litre Water Store

Solar PV

Subject to permissions and structural surveys it may be possible to install a small solar PV system over the toilet block (Figure 9). It is estimated that a 2.7kWp system could reduce the imported electricity by 1,800kWh per year, 18% of the consumption, saving 0.5tCO_2e.

This may be particularly useful if the demand for cooling is high.

Figure 9: Potential Solar PV Location Subject to Permissions and Survey.

Crafton House

The building was constructed in 2016 and provides a range of different sized office suites over two floors with a large car park to the rear where the main entrance is located (Figure 1). The road facing elevation overlooks what appears to be a SUDS drainage field.

The heating is provided by two large HVAC units for each of the two wings, this is supplemented by electric radiators in the toilets and common areas. An additional ventilation system provides fresh air to each room through a heat exchanger.

All windows are metal framed double-glazed units and the third level of north facing windows provides light to the 1st floor corridor which has a 'vaulted' ceiling.

Figure 1: Crafton House

Figure 2: Side Elevation showing vented HVAC plant room

The only energy supply to the building is electricity and the reported 2018/19 benchmark year consumption for the building was 125,622kWh, with emissions of 44.3tCO_2e. This has been consistent in the following years except for a slight drop in 2020/21.

There is a single electricity supply meter to the building but each office unit was originally intended to be individually sub-metered and electricity consumption recharged to the tenants through the service charge. However, the building management system is not performing as intended so the total electricity supply is divided between the tenants on what has been established to be an equitable basis.

Emissions for leased buildings is included in the scope 3 emissions (according to the Greenhouse Gas Protocol) and would incorporate the tenants' scope 1 and scope 2 emissions. However this is not included in the Council's greenhouse gas inventory presently.

The consumption within the communal areas is limited to lighting and welfare facilities and the additional electric wall heaters located in reception and toilets are understood to be unused, although these would also be considered part of the tenant's liability.

The estimated breakdown of the electricity consumption is shown in Figure 3.

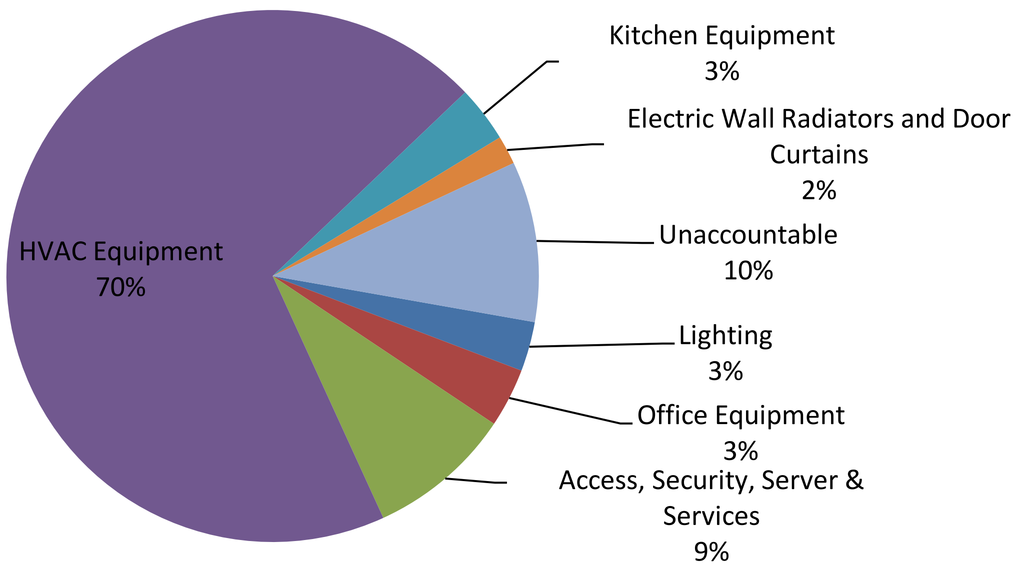

Figure 3: Estimated Breakdown of Electricity Consumption

Table 1: Key Recommendations

	Measure	Savings (tCO2e)
Short Term	Solar PV	8.3
Short Term	Battery Storage	3.6
Mid Term	Individual Tenant Sub- metering	2.0
Identified Savings		**13.9**

2021/22 Emissions	37.2

Lighting

All lighting is LED type with sensors and the rear carpark is floodlit, this is well supported by the natural daylight provided by the roof lights.

Construction

Having been built in 2016 it is assumed the general floor, roof and wall insulation conforms to the current standards with limited scope for economic improvement.

Glazing

The windows are metal framed double-glazed units most of which can be opened. They benefit from solar shades to the ground floor windows and overhanging roof to the 1st floor which cuts down solar gain and therefore cooling demand (Figure 4).

Figure 4: Solar Shades and Over Hanging Roof Reduces Solar Gain.

Heating

HVAC offers low carbon emission heating and air conditioning. The monthly consumption data shows the 6-month period from 1st May to 31st October to account for approximately 30% of the annual consumption with the same period from 1st Nov to 30th April for 70%. Assuming a consistent use of office equipment over the year and a reduced requirement for lighting during the summer this could indicate a reasonably high demand for cooling during the summer period. This is consistent for all years from financial year commencing 2017 to year ending 2022.

As the individual office use of heating and cooling systems are not sub-metered for charging purposes there is little incentive for individual office occupants to be efficient.

Solar PV electricity generation on site would reduce the imported electricity and its associated emissions while offering the opportunity to increase revenue when recharging consumption to tenants.

Installation of a new building management system (BMS), or repairing of the existing system, would enable individual tenants to be charged for their actual use of the plug electricity and their individual heating and cooling distributors which may lead to a behaviour change which Carbon Trust estimate can lead to a 5% reduction in consumption.

The main consumption on site is estimated to be associated with the HVAC systems which are not metered by tenant. However it may be possible to log actual demand of heating and cooling through a BMS linked to the individual thermostats from which consumption could be apportioned, again potentially inducing behaviour change. Overall consumption can be reduced through measures such as linking the system to interlocks on windows to avoid heating or cooling while windows are open.

Solar PV

There is currently no solar PV array on Crafton House however the adjacent similar building, Roxburgh House, has an array estimated to be around 33kWp, expected to be generating around 30,000kWh per year. A similar array at Crafton House could reduce the imported electricity by around 23,000kWh per year, 8.3tCO_2e, assuming a usage of 70% with a battery storage system offering a further estimated 10,000kWh, saving a further 3.6tCO_2e.

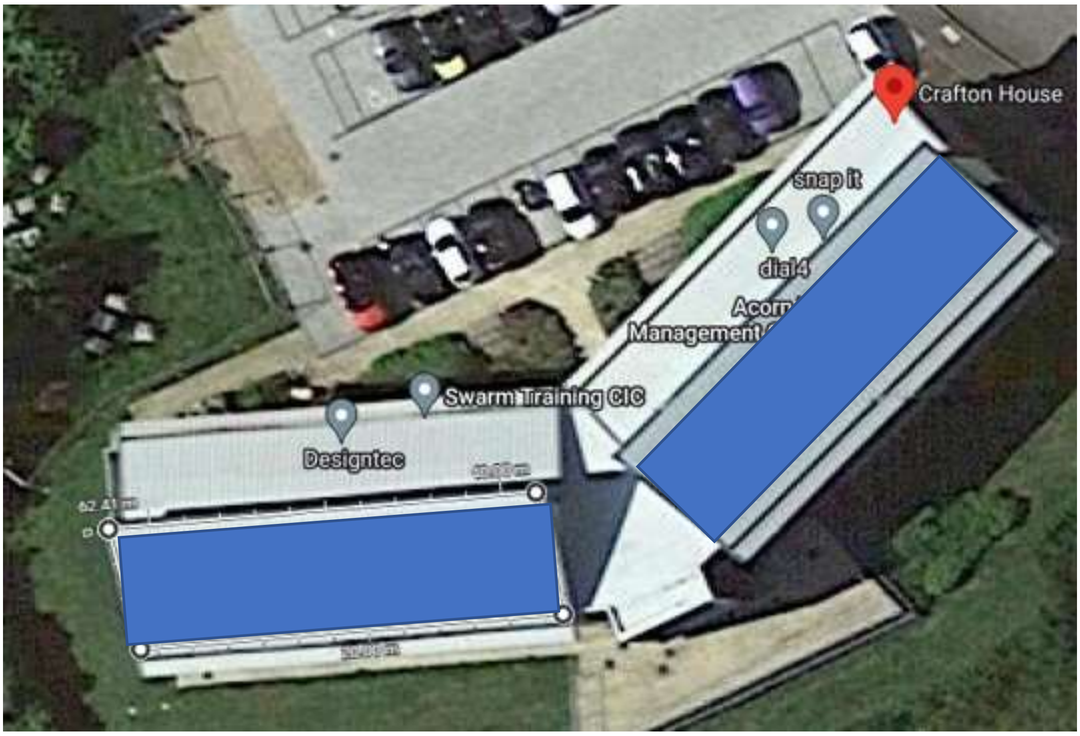

Figure 4: Potential Roof Space for Solar Arrays.

Diss Business Centre

The main property (Figure 1) is an historic barn converted in the 1990s to offer 27 self-contained business units over two floors, with reception and switchboard services. The building is solid brick construction with a metal roof. A further single-storey barn to the rear offers 7 business units (Figure 2). The building is not listed but may be subject to other restrictions.

Figure 1: Diss Business Centre Frontage

Figure 2: Old Barn Annexe

Services are limited to electricity and water, with a waste water treatment plant on site.

Each unit has a separate electricity supply meter and the tenants are responsible for their own supply contracts. The Council is only responsible for the electricity supply to the reception and common areas of the buildings with the 2018/19 consumption figure being 7,765kWh (2.7tCO_2e). Based on the audited sample of business units it is estimated that at full occupancy the total consumption for both buildings would be an additional 172,448kWh (50.2tCO_2e) (Figure 3).

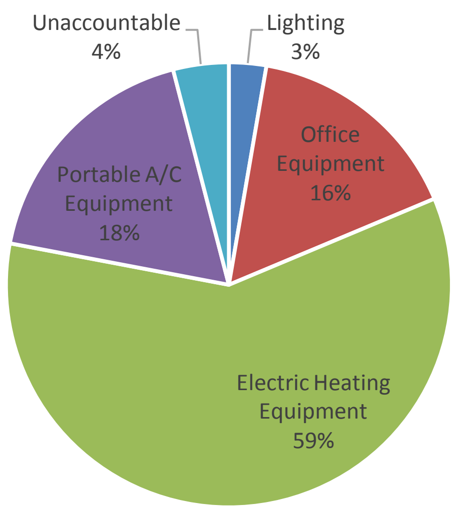

Figure 3: Estimated Electricity Consumption Breakdown for Units and Services.

Table 1: Key Recommendations for Diss Business Centre

	Measure	**Savings (tCO_2e)**
Short Term	Lighting Upgrade	0.3
Short Term	Roof Insulation	2.5
Short Term	Solar PV	9.6
Mid Term	Upgraded Glazing	3.0
Long Term	Internal Wall Insulation	10.0
Long Term	Heat Pump Installation	23.8
Identified Savings for Entire Building		**49.3**

Actual emissions data only available for common spaces within the building as each tenant has own supply meter which is not monitored by the authority
2018/19 Emissions 2.7tCO_2e

Construction

The main building is constructed with a solid, triple brick wall (Figure 4) which remains exposed as a feature in several of the business units. The Old Barn Annexe is believed to be block construction (Figure 5) and is presumed to have a cavity but no insulation.

Figure 4: Main Building Solid Brick Construction

Figure 5: Rendering to the Exterior of The Annexe Triple

The estimated total electric heat demand for both buildings is 106,500kWh (31.1tCO_2e) based on the heating equipment audited on site and subsequent heat loss calculations for the construction. An additional 32,000kWh is estimated to be required for the portable air conditioning equipment recorded during the audit.

Solid walls offer poor thermal insulation qualities and corner rooms are particularly vulnerable to excessive heat loss. Several units were also seen to be experiencing excessive heat gain during the summer audit.

Based on the estimated year of redevelopment, it is presumed the main building and annexe roof spaces are insulated with glass fibre to a minimum depth of 100mm. Ceilings are generally plasterboard; however some areas have suspended ceiling potentially offering additional insulation.

The installation of additional roof insulation to 250mm is estimated to reduce the annual heating demand by 8,500kWh, saving 2.5tCO_2e.

The additional of internal wall insulation, if feasible, could save an estimated additional 34,000kWh, (10.0tCO_2e), combined this could reduce the overall heat demand from 31.1tCO_2e to 18.6tCO_2e.

Additional insulation may also reduce the heat gain in summer and the associated air conditioning demand.

Glazing

With the exception of one barn door, the windows and doors are all double glazed in the main building.

The barn door to the front left side of the main building is poorly fitting and daylight is visible from within the associated business unit (Figure 6). Single wooden doors offer very little in the way of thermal insulation from heat loss or heat gain and the visible gaps allow uncontrollable ventilation.

The double-glazing framework appears to be in generally good order, sealed and well-fitting however several glazing units have broken down, losing the convection insulation, as shown by misting (Figure 7).

The Old Barn Annexe has newer double-glazed doors but wooden framed windows which are in very poor condition and ill fitting (Figure 8).

Figure 6: Poorly Fitting Wood Barn Doors Leading Directly into Unit 27.

Figure 7: An Example of the Broken-Down Double-Glazing Units in the Main Building.

Figure 8: Poorly Fitting Wooden Windows in The Annexe.

Upgrading all the glazing to current standards is estimated to save a further 10,000kWh annually, 3.0tCO_2e.

Heating

The space heating is currently supplied by an array of electric storage heaters, oil-filled radiators and occasional additional portable heaters as required by tenants (Figure 9).

Heat pumps offer a higher level of efficiency in heat delivered per kWh of electricity by extracting heat from the ambient air externally. In broad terms electric radiators are generally considered to be 100% efficient as they delivery 1kWh of heat for 1kWh of electricity consumed. Storage heaters can lose heat overnight, deliver heat when not required and require boosting to deliver heat later in the day so are considered to deliver less that 1kWh of heat for the same input. By comparison, heat pumps can offer average seasonal coefficients of performance of 250-300% when installed in well insulated buildings and building management system controlled, and zoned, reactive heating can offer additional savings.

Figure 9: Storage Heater in the Reception Office.

Following the insulation recommendations above. installing heat pumps is estimated to potentially save a further 36,000kWh (23.8tCO_2e).

Solar PV

The reduced total electricity demand following the measured outlined above is estimated to be 110,000kWh (32.0tCO_2e), down from 180,000kWh (52.4tCO_2e).

Professional surveys will be required to assess if the roof is suitable for solar PV installation but it may be possible to install a sub 50kWp solar PV array on the roofs indicated in Figure 10.

Figure 10: Potential Solar PV installation Sites

Such an array would generate an estimated 45,000kWh per year, and assuming 70% would be used on site this could reduce the imported electricity by 33,000kWh (30%) saving 9.6tCO_2e.

Loddon Business Centre – 1st Floor

Loddon Business Centre is a Grade II listed building with two leased retail units on the ground floor and a suite of Council managed offices on the 1st floor, accessed through a front door and small lobby.

The two ground floor units have separate natural gas boilers with their own gas and electricity supply meters. The 1st floor has a third natural gas combi boiler and has a separate electricity and gas supply for which the Council is responsible.

This report focusses on the Council managed 1st floor office's energy consumption only, as the two ground floor units are leased separately and responsible for their own utilities. At the time of the audit the second ground floor unit had been vacant for some time.

Figure 1: The Front of the Grade II listed Building

The breakdown of the 1st floor office's entire emissions shows the majority being attributed to the natural gas consumption of 29,353kWh in 2021/22 (Figure 2).

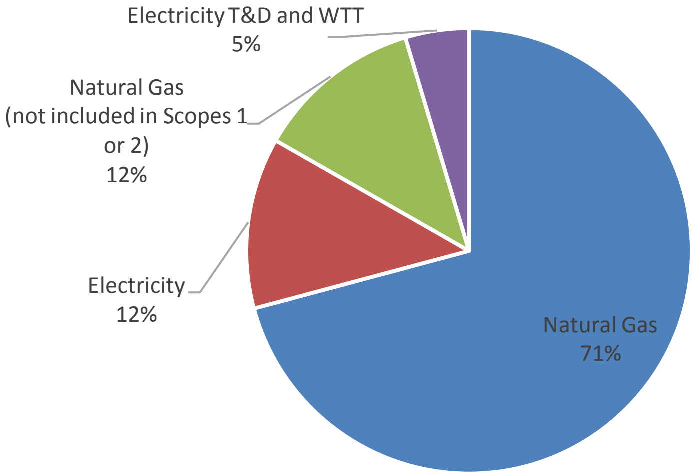

Figure 2: Breakdown of the Site Emissions from the 2021/22 Consumption Data.

The electricity consumption breakdown (Figure 3) shows a very large portion that could not be attributed to the electric equipment recorded during the audit.

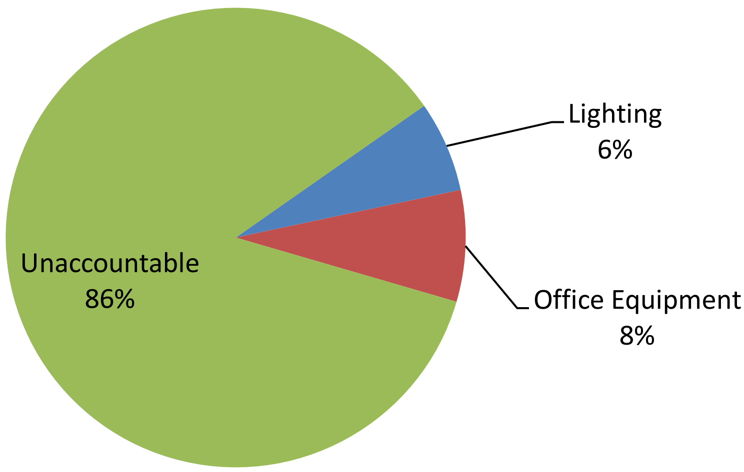

Figure 3: Breakdown of the Estimated Electricity Consumption Emissions.

Table 1: Key Recommendations

	Measure	Savings (tCO2e)
Short Term	Investigate Unaccountable Electricity Consumption	
Short Term	Sash Upgrading and Secondary Glazing	0.3
Short Term	Roof Insulation	1.6
Mid Term	Internal Wall Insulation	1.4
Mid Term	Solar PV Arrays	0.7
Mid Term	Battery Storage	0.3
Long Term	HVAC Heating Upgrade	1.6
Identified Savings		**5.8**
2021/22 Emissions		**7.6**

Energy Consumption

The consumption of both natural gas and electricity seem high for the size and occupancy of the 1st floor offices, the electricity being particularly high. It is advised that this is investigated further to identify the source of the consumption and address any issue found.

Lighting

The lighting is a mix of fluorescent and LED with some sensors. Upgrading the remaining lighting should be a priority even though the potential emissions savings will be negligible, the process would, additionally, improve the working environment for staff and visitors.

The building is Grade II listed so will be subject to restrictions externally, and potentially internally, so permission will need to be sought in order to carry out any major works. However, as the heat demand is relatively high for a building with apparently low daily occupancy rates insulation should be investigated.

Glazing

The windows on the front of the building are wood, single glazed sash windows, several of which are painted shut. However they do have aging secondary glazing panels which would be expected to reduce the heat loss and reduce traffic noise. The windows to the rear are wood framed single glazed without secondary glazing.

Figure 4: Single Glazed Wood Sash Windows to the Front of the Building

The replacing of the front windows is presumed to be out of the question (due to the listing) but Historic England have carried out extensive research in to the repairing old wood sash windows and retrofitting draft excluders which has proved to be very effective and this evidence of energy savings has satisfied a recent ERDF grant funding programme. [6]

Improving all the windows to modern heat loss regulations would save an estimated 0.3tCO_2e. This would also have the added benefit of improving the working environment, particularly in respect to the repair of the sash windows to allow them to be opened.

Insulation

It has been assumed the loft insulation consists of standard 100-150mm glass fibre and bringing that up to modern recommendations is estimated to save an additional 1.6tCO_2e.

The external walls are of solid brick construction with no cavities. Due to the Grade II listing, external wall insulation is presumed to be excluded however internal wall insulation may be possible. The process is intrusive and requires refinishing of the wall surfaces, window returns and electric outlets, and does reduce the internal space, however it offers a substantial carbon saving of an additional estimated 1.4tCO_2e.

Heating

All the 1st floor offices are heated with natural gas from a single combi boiler, each radiator has a TRV for control. The natural gas (heat) demand for the period 2021/22 was 29,353kWh, which is inline with

[6] https://historicengland.org.uk/images-books/publications/traditional-windows-care-repair-upgrading/heag039-traditional-windows-revfeb17/

the previous year however in the year 2019/20 it was 51,587kWh which is presumed to be due to weather patterns.

TRVs allow individual setting but are prone be being left on/high, even when a room is unoccupied for long periods so, as it is understood that the pattern of use of the offices is sporadic at times, it could mean rooms are being heated unnecessarily and excessively.

The 2021/22 consumption of natural gas of 29,353kWh accounts for 6.3tCO_2e, but with the glazing and insulation measures already recommended this is estimated to be reduced to 12,380kWh, 2.7tCO_2e.

One option would be a building management system (BMS) to allow more zoning of the heating by room, with timers and remote control to reduce the consumption and reflect occupancy more accurately. Alternatively, the installation of multiple HVAC units would replace the demand for fossil fuels and offer a greater degree of controllability and zoning by room. Due to the greater efficiency of HVAC the estimated heat demand would be reduced to 8,900kWh with emissions of 1.6tCO_2e and purchasing 100% certified electricity could offset these emissions.

It is important to remember that electricity costs considerably more that natural gas per kWh and switching to electricity for heating could cost more than natural gas for the same heat delivery however the additional controllability of zoned HVAC could balance that out with the additional benefit of the emissions reduction.

All calculations in this report have been based on 40p per kWh for electricity and 15p per kWh for natural gas, excluding taxes.

Figure 5: Natural Gas Combi Boiler Located in 1st Floor Cupboard

Solar PV

The restrictions on the property may mean Solar PV on the roof is disallowed. However, should it be possible, and subject to structural surveys, it may be possible to install a small 3-4kWp array on two or three of the south and southwest facing rear roofs (Figure 6).

A system of that size is estimated to generate 3,000-3,500kWh, saving around 0.7tCO_2e and a battery storage system is estimated to potentially save a further 0.3tCO_2e if the evening demand is sufficient to warrant the capital costs.

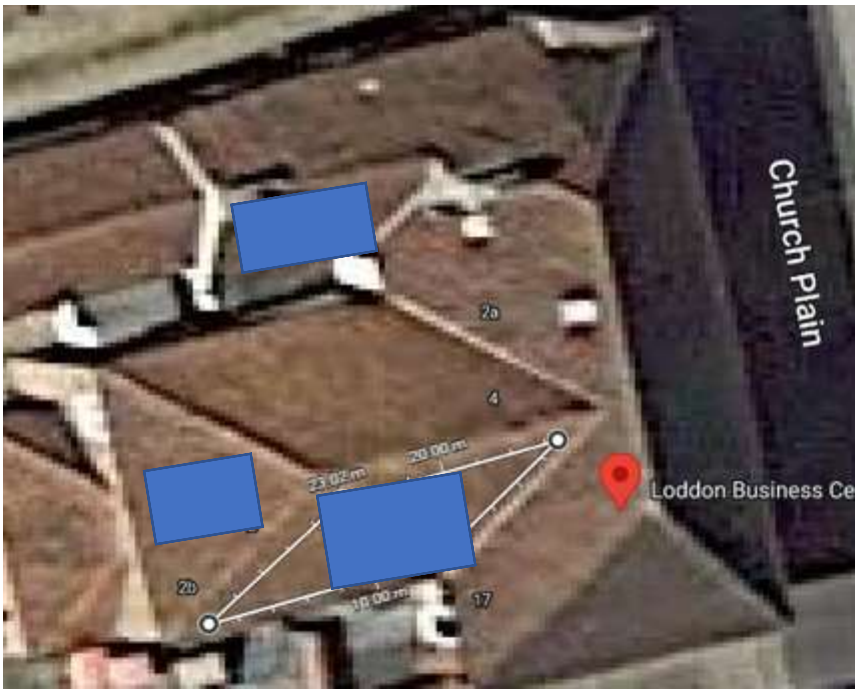

Figure 6: Potential Solar Array Locations.

Trumpeter House

Built in 2019 the building has an internal floor area of approximately 780m^2 over two floors, offering tenanted office units with communal facilities. The building is primarily heated by two external HVAC systems, with the addition of one extra small HVAC unit and electric radiators in toilets and reception.

The windows are uPVC double-glazed with a large number of skylights for the 1st floor spaces offering natural light. Most include blinds for shade.

Figure 1: Trumpeter House

Figure 2: The Rear Car Park

The only energy supply to the building is electricity and the reported 2018/19 benchmark year consumption for the entire building is 33,190kWh, with emissions of 11.7tCO_2e.

The estimated breakdown of the electricity consumption is shown in Figure 3.

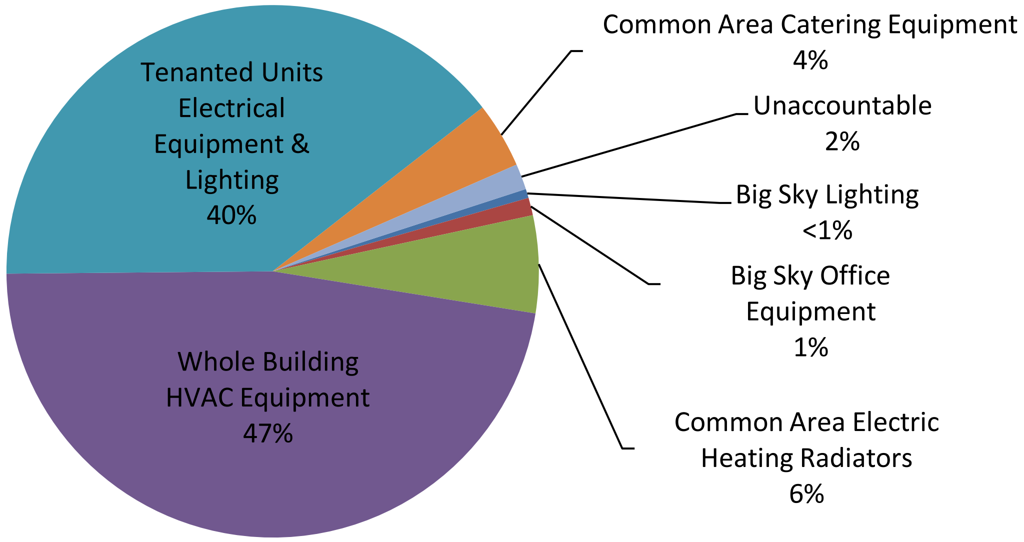

Figure 3: Breakdown of the Electricity Consumption Emissions.

Table 1: Key Recommendations

	Measure	Savings (tCO2e)
Short Term	Solar PV	3.2
Short Term	Battery Storage	1.2
Mid Term	Window Solar Control Film	0.2
Identified Savings		**4.7**
2018/19 Emissions		**11.7**

Lighting
All lighting is LED type with motion sensors and manual override option and the rear carpark is floodlit. Internally electric lighting is well supported by the natural daylight provided by the roof lights.

Construction
Having been built in 2019 it is assumed the general floor, roof and wall insulation conforms to the current standards.

Glazing
Solar control film applied to the windows can reduce heat gain during the summer and heat loss during the winter. Metal free and comprising of multiple layers of acrylic and polyester films can reduce

transmitted solar energy from 87% with typical unprotected glass to 12% without reducing the light transmission significantly. This can lead to much improved working environment and reduce the demand for cooling and heating saving an estimated 0.2tCO_2e

Heating

HVAC offers low-carbon heating when associated with an electricity supply that is certified 100% renewable. It is understood the Council is pursuing this as and when supply contracts are renewed. Solar PV electricity generation on site would further reduce this.

Solar PV

The available roof space is reduced by the skylights however it may, subject to structural surveys, be possible to install solar PV on all spaces in order to offer an array of orientations to maximise generation through the entire day. An 8kWp array would reduce the imported electricity by an estimated 9,000kWh, saving 3.2tCO_2e and a battery storage system would offer the opportunity to maximise the consumption on site during late afternoon and early evening periods, saving a furthe estimated 3,500kWh, 1.2tCO_2e.

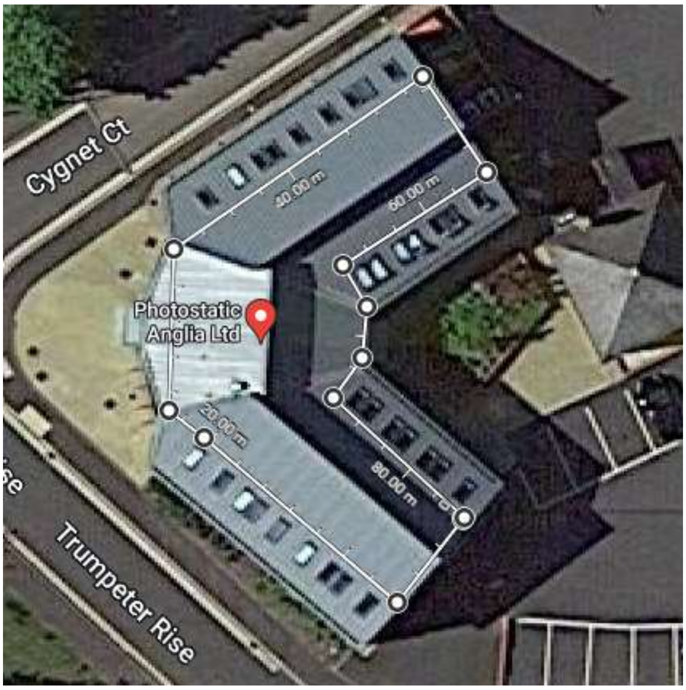

Figure 4: Potential Roof Space for Solar Arrays offering Day-long Generation Potential

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