

Introduction

Manchester City Council Capital Programmes & Procurement have commissioned Conlon Construction Limited and in turn Walmsley Associates to implement proposals working towards the Decarbonisation of the National Football Museum, by the replacement of existing Air Handling Units providing fresh air ventilation, tempering and summertime cooling.

Scope of Plant Replacement

The scope of plant replacement currently includes: -

1. Replacement of the 8No. Air Handling units
2. BMS upgrades to AHU plant and LTHW Heating.
3. Metering and Monitoring.

By changing the 8No. Air handling units, , a Carbon saving of **24,299.89 CO₂ kg per annum** is currently estimated.

Building Operation and Usage

The building under normal operating parameters (prior to the pandemic) is open approximately 11 hours/day; 5 1/2 days a week; 50 weeks a year.

2,754 hours/year for the kWh/year calculation.

Fuel	Cost of Energy	CO ₂ Emission Rate
Electricity	£0.14.37/kWh _e (14.37p/kWh)	0.275 CO ₂ /kWh _e
Gas	£0.0380/kWh _g (3.80p/kWh)	0.202 CO ₂ /kWh _g

AHU Replacements

The building contains the following AHUs to be replaced:

Unit	Location	Menerga Unit type	Existing Duty (m3/s)
AHU/GF1	AHU GF1 West Mall & Retail Areas	581901	4.450
AHU GF2	AHU GF2 Foyer & Offices	581601	3.600
AHU EX3	AHUEX3 Exhibition Level 1	581301	3.100
AHU EX4	AHUEX4 Exhibition Level 1	581301	3.100
AHU EX5	AHUEX5 Exhibition Level 2	581301	3.100
AHU EX6	AHUEX6 Exhibition Level 2	581301	3.100
AHU EX7	AHUEX7 Exhibition Level 3	581301	3.100
AHU EX8	AHUEX8 Exhibition Level 4	581301	3.100

The existing units were supplied by Menerga and contain plate heat exchangers, and double recuperative air conditioning and Low temperature hot water (LTHW) heating coil to temper the fresh air drawn into the building. They were sized to cover the occupancy requirement of the building, when it was originally constructed as “Urbis” the City museum, but were retained and re-tasked to support the occupancy fresh air requirements of the National Football Museum.

Replacement of AHU's

The replacement of the Air Handling Units with new replacement models with efficient motors and thermal wheels for energy recovery, linked to the existing LTHW Heating system, and complete with a new chilled water central cooling system, should provide a substantial energy and carbon savings.

Method of Calculation

In the absence of any recent energy consumption data (due to the Covid-19 pandemic) a comparison of energy consumption has been undertaken for both heating and cooling using the equivalent hours calculation methods from CIBSE B Guide on owning and operating costs.

This involves the calculation of Equivalent Hours for heating and cooling plant using their design-day duty (without margins) and then using a degree day formula, in addition to some knowledge of the built form and the occupancy time and building usage

The calculation also involves the use of degree-days, and these are a means of comparison over different periods, the variations in load sustained by heating and cooling plants in different parts of the country.

An “equivalent hour of operation”, can be defined where the plant operates at full load but the fuel consumption is the same.

Example of heating and cooling calculation using degree day methodology using AHU GF1

Assessment of the equivalent hours of operation		Heating	Cooling	Comment
Degree Days	D	2282.5	219.6	taken for Manchester Weather data (heating at 15.5°C, cooling at 16°C)
Heat Loss/Heat Gain (kW)		68kW	113.98kW	Example taken from AHU GF1
Design temperature difference (K)	td	26	12	Temperature difference between indoor and outdoor on peak day
Equivalent full-load annual operation (hours) uncorrected	E	2106.92	439.20	$E = [24 \times D] / [td]$
Correction Factors for Building & Plant response				
Intermittent Responsive Plant	(a)	0.85	0.85	
Length of working week (6 days)	(b)	0.93	0.93	
Length of Working Day (8 hours)	(c)	1.00	1.00	
Calculation				
Equivalent full-load annual operation (hours) Corrected	Eq	1656.57	345.32	
Net Annual Heat Requirement (GJ/annum)	Qr	405.53	141.69	$E_q = E \times (a) \times (b) \times (c)$
Net Annual Heat Requirement (kWhrs/annum)		112,646.6	39,359.7	

Estimate of Carbon Emission from Existing Air Handling Units

Existing LTHW Heating Estimates

Unit	Location	Menerga Unit type	Existing Duty (m3/s)	Heating Load (kW)	Total Heating Load (kW)	Boiler Efficiency	Gas Power Input (kW)	Equivalent Full Load Operation (hours/annum)	CO2/kW	Total CO2 Emission kg
AHU/GF1	AHU GF1 West Mall & Retail Areas	581901	4.450	82.000	82.000	87.0%	94.253	1656.570	0.202	31,539.6
AHU GF2	AHU GF2 Foyer & Offices	581601	3.600	48.000	48.000	87.0%	55.172	1656.570	0.202	18,462.2
AHU EX3	AHU EX3 Exhibition Level 1	581301	3.100	34.000	34.000	87.0%	39.080	1656.570	0.202	13,077.4
AHU EX4	AHU EX4 Exhibition Level 1	581301	3.100	34.000	34.000	87.0%	39.080	1656.570	0.202	13,077.4
AHU EX5	AHU EX5 Exhibition Level 2	581301	3.100	34.000	34.000	87.0%	39.080	1656.570	0.202	13,077.4
AHU EX6	AHU EX6 Exhibition Level 2	581301	3.100	34.000	34.000	87.0%	39.080	1656.570	0.202	13,077.4
AHU EX7	AHU EX7 Exhibition Level 3	581301	3.100	34.000	34.000	87.0%	39.080	1656.570	0.202	13,077.4
AHU EX8	AHU EX8 Exhibition Level 4	581301	3.100	34.000	34.000	87.0%	39.080	1656.570	0.202	13,077.4
	Total			334.000	334.000	87.0%	383.908		0.202	128,466.1

Existing Fan Estimates

Unit	Location		Existing Duty (m3/s)	Supply Fan Power (kW)	Extract Fan Power (kW)	Controls Power (kW)	Electrical Power (kW)	Hours of Operation per Annum	CO2/kW from VRF/Electrical heating	Total CO2 Emission kg
AHU/GF1	AHU GF1 West Mall & Retail Areas	581901	4.450	5.700	5.900	13.300	24.900	2,754.00	0.275	18,858.0
AHU GF2	AHU GF2 Foyer & Offices	581601	3.600	4.600	4.900	9.800	19.300	2,754.00	0.275	14,616.9
AHU EX3	AHU EX3 Exhibition Level 1	581301	3.100	3.800	4.000	5.700	13.500	2,754.00	0.275	10,224.2
AHU EX4	AHU EX4 Exhibition Level 1	581301	3.100	3.800	4.000	5.700	13.500	2,754.00	0.275	10,224.2
AHU EX5	AHU EX5 Exhibition Level 2	581301	3.100	3.800	4.000	5.700	13.500	2,754.00	0.275	10,224.2

AHU EX6	AHU EX6 Exhibition Level 2	581301	3.100	3.800	4.000	5.700	13.500	2,754.00	0.275	10,224.2
AHU EX7	AHU EX7 Exhibition Level 3	581301	3.100	3.800	4.000	5.700	13.500	2,754.00	0.275	10,224.2
AHU EX8	AHU EX8 Exhibition Level 4	581301	3.100	3.800	4.000	5.700	13.500	2,754.00	0.275	10,224.2
	Total						125.200			94,820.2

Existing Cooling Estimates – DX cooling coil taking into account adiabatic element

Unit	Location	Menerga Unit type	Existing Duty (m3/s)	Heating/ Cooling (kWe)	Total Power Clg (kWe)	Electrical Power (kW)	Equivalent Full Load Operation (hours/annum)	CO2/kW from VRF/Electrical heating	Total CO2 Emission kg
AHU/GF1	AHU GF1 West Mall & Retail Areas	581901	4.450	17.200	17.200	17.200	345.320	0.275	1,633.4
AHU GF2	AHU GF2 Foyer & Offices	581601	3.600	14.300	14.300	14.300	345.320	0.275	1,358.0
AHU EX3	AHU EX3 Exhibition Level 1	581301	3.100	11.500	11.500	11.500	345.320	0.275	1,092.1
AHU EX4	AHU EX4 Exhibition Level 1	581301	3.100	11.500	11.500	11.500	345.320	0.275	1,092.1
AHU EX5	AHU EX5 Exhibition Level 2	581301	3.100	11.500	11.500	11.500	345.320	0.275	1,092.1
AHU EX6	AHU EX6 Exhibition Level 2	581301	3.100	11.500	11.500	11.500	345.320	0.275	1,092.1
AHU EX7	AHU EX7 Exhibition Level 3	581301	3.100	11.500	11.500	11.500	345.320	0.275	1,092.1
AHU EX8	AHU EX8 Exhibition Level 4	581301	3.100	11.500	11.500	11.500	345.320	0.275	1,092.1
	Total			100.500	100.500	100.500			9,543.8

The air handling units due to be replaced, are estimated to emit **232,830.05 kg CO₂ /annum** from their heating, cooling and fan and control energy provision

Estimate of Carbon Emission from New Air Handling Units

LTHW Heating Estimates

Unit	Location	Proposed Duty (m3/s)	Total Heating Load (kW)	Boiler Efficiency	Gas Power Input (kW)	Equivalent Full Load Operation (hours/annum)	CO2/kW	Total CO2 Emission kg
AHU/GF1	AHU GF1 West Mall & Retail Areas	4.450	68.630	87.0%	78.885	1656.570	0.202	26,397.0
AHU GF2	AHU GF2 Foyer & Offices	3.600	35.692	87.0%	41.025	1656.570	0.202	13,728.1
AHU EX3	AHU EX3 Exhibition Level 1	3.100	15.557	87.0%	17.882	1656.570	0.202	5,983.7
AHU EX4	AHU EX4 Exhibition Level 1	3.100	15.557	87.0%	17.882	1656.570	0.202	5,983.7
AHU EX5	AHU EX5 Exhibition Level 2	3.100	15.557	87.0%	17.882	1656.570	0.202	5,983.7
AHU EX6	AHU EX6 Exhibition Level 2	3.100	15.557	87.0%	17.882	1656.570	0.202	5,983.7
AHU EX7	AHU EX7 Exhibition Level 3	3.100	15.557	87.0%	17.882	1656.570	0.202	5,983.7
AHU EX8	AHU EX8 Exhibition Level 4	3.100	15.557	87.0%	17.882	1656.570	0.202	5,983.7
	Total		197.664	87.0%	227.200		0.202	76,027.2

Fan Estimates

Unit	Location	Proposed Duty (m3/s)	Supply Fan Power (kW)	Thermal Wheel Power (kW)	Extract Fan Power (kW)	Electrical Power (kW)	Hours of Operation per Annum	CO2/kW from VRF/Electrical heating	Total CO2 Emission kg
AHU/GF1	AHU GF1 West Mall & Retail Areas	4.450	16.200	0.800	10.350	27.350	2754.000	0.275	20,713.5
AHU GF2	AHU GF2 Foyer & Offices	3.600	16.200	0.800	10.350	27.350	2754.000	0.275	20,713.5
AHU EX3	AHU EX3 Exhibition Level 1	3.100	6.900	0.800	7.400	15.100	2754.000	0.275	11,436.0
AHU EX4	AHU EX4 Exhibition Level 1	3.100	6.900	0.800	7.400	15.100	2754.000	0.275	11,436.0
AHU EX5	AHU EX5 Exhibition Level 2	3.100	6.900	0.800	7.400	15.100	2754.000	0.275	11,436.0
AHU EX6	AHU EX6 Exhibition Level 2	3.100	6.900	0.800	7.400	15.100	2754.000	0.275	11,436.0
AHU EX7	AHU EX7 Exhibition Level 3	3.100	6.900	0.800	7.400	15.100	2754.000	0.275	11,436.0

AHU EX8	AHU EX8 Exhibition Level 4	3.100	6.900	0.800	7.400	15.100	2754.000	0.275	11,436.0
	Total					145.300			110,043.0

Cooling Estimates – Chilled Water Cooling provision

Unit	Location	Proposed Duty (m3/s)	Cooling (kW)	Cooling (kWe)	Chilled Water Distribution Efficiency (%)	Electrical Power (kWe)	Equivalent Full Load Operation (hours/annum)	CO2/kW from VRF/Electrical heating	Total CO2 Emission kg
AHU/GF1	AHU GF1 West Mall & Retail Areas	4.450	113.980	34.963	90.0%	38.848	345.320	0.275	3,689.1
AHU GF2	AHU GF2 Foyer & Offices	3.600	92.210	28.285	90.0%	31.428	345.320	0.275	2,984.5
AHU EX3	AHU EX3 Exhibition Level 1	3.100	81.290	24.936	90.0%	27.706	345.320	0.275	2,631.1
AHU EX4	AHU EX4 Exhibition Level 1	3.100	81.290	24.936	90.0%	27.706	345.320	0.275	2,631.1
AHU EX5	AHU EX5 Exhibition Level 2	3.100	81.290	24.936	90.0%	27.706	345.320	0.275	2,631.1
AHU EX6	AHU EX6 Exhibition Level 2	3.100	81.290	24.936	90.0%	27.706	345.320	0.275	2,631.1
AHU EX7	AHU EX7 Exhibition Level 3	3.100	81.290	24.936	90.0%	27.706	345.320	0.275	2,631.1
AHU EX8	AHU EX8 Exhibition Level 4	3.100	81.290	24.936	90.0%	27.706	345.320	0.275	2,631.1
	Total		693.930	212.862		236.513			22,460.0

The new air handling units are estimated to emit **208,530.16 kg CO₂ /annum** from their heating, cooling and fan and control energy provision

Summary of Existing & Proposed Carbon Dioxide Estimates

		Existing			Proposed		
		Heating Energy CO ₂ Emission	Cooling Energy CO ₂ Emission	Fan Energy CO ₂ Emission	Heating Energy CO ₂ Emission	Cooling Energy CO ₂ Emission	Fan Energy CO ₂ Emission
AHU/GF1	West Mall & Retail Areas	31,539.57	1,633.36	18,858.02	26,396.96	3,689.12	20,713.52
AHU GF2	Foyer & Offices	18,462.19	1,357.97	14,616.86	13,728.11	2,984.51	20,713.52
AHU EX3	Exhibition Level 1	13,077.38	1,092.07	10,224.23	5,983.69	2,631.06	11,435.99
AHU EX4	Exhibition Level 1	13,077.38	1,092.07	10,224.23	5,983.69	2,631.06	11,435.99
AHU EX5	Exhibition Level 2	13,077.38	1,092.07	10,224.23	5,983.69	2,631.06	11,435.99
AHU EX6	Exhibition Level 2	13,077.38	1,092.07	10,224.23	5,983.69	2,631.06	11,435.99
AHU EX7	Exhibition Level 3	13,077.38	1,092.07	10,224.23	5,983.69	2,631.06	11,435.99
AHU EX8	Exhibition Level 4	13,077.38	1,092.07	10,224.23	5,983.69	2,631.06	11,435.99
Total (kg CO ₂ /annum)		128,466.05	9,543.78	94,820.22	76,027.19	22,460.01	110,042.96
Total Per Annum (kg CO ₂ /annum)		232,830.05			208,530.16		

The annual reduction in carbon emissions with the replacement of the AHU's is estimated to be
24,299.89 kg CO₂ /annum

Presenting the carbon/energy/costs know to date

Existing							
		Heating Duty	Cooling Duty	Fan Power	Heating Energy	Cooling Energy	Fan Energy
AHU/GF1	AHU GF1 West Mall & Retail Areas	82.00	17.20	24.90	135,838.74	5,939.50	68,574.60
AHU GF2	AHU GF2 Foyer & Offices	48.00	14.30	19.30	79,515.36	4,938.08	53,152.20
AHU EX3	AHU EX3 Exhibition Level 1	34.00	11.50	13.50	56,323.38	3,971.18	37,179.00
AHU EX4	AHU EX4 Exhibition Level 1	34.00	11.50	13.50	56,323.38	3,971.18	37,179.00
AHU EX5	AHU EX5 Exhibition Level 2	34.00	11.50	13.50	56,323.38	3,971.18	37,179.00
AHU EX6	AHU EX6 Exhibition Level 2	34.00	11.50	13.50	56,323.38	3,971.18	37,179.00
AHU EX7	AHU EX7 Exhibition Level 3	34.00	11.50	13.50	56,323.38	3,971.18	37,179.00
AHU EX8	AHU EX8 Exhibition Level 4	34.00	11.50	13.50	56,323.38	3,971.18	37,179.00
	Total (kWhrs/annum)	334.00	100.50	125.20	553,294.38	34,704.66	344,800.80

Proposed							
		Heating Duty	Cooling Duty	Fan Power	Heating Energy	Cooling Energy	Fan Energy
AHU/GF1	AHU GF1 West Mall & Retail Areas	68.63	34.96	27.35	113,689.87	12,073.49	75,321.90
AHU GF2	AHU GF2 Foyer & Offices	35.69	28.29	27.35	59,126.03	9,767.47	75,321.90
AHU EX3	AHU EX3 Exhibition Level 1	15.56	24.94	15.10	25,771.33	8,610.76	41,585.40
AHU EX4	AHU EX4 Exhibition Level 1	15.56	24.94	15.10	25,771.33	8,610.76	41,585.40
AHU EX5	AHU EX5 Exhibition Level 2	15.56	24.94	15.10	25,771.33	8,610.76	41,585.40
AHU EX6	AHU EX6 Exhibition Level 2	15.56	24.94	15.10	25,771.33	8,610.76	41,585.40
AHU EX7	AHU EX7 Exhibition Level 3	15.56	24.94	15.10	25,771.33	8,610.76	41,585.40
AHU EX8	AHU EX8 Exhibition Level 4	15.56	24.94	15.10	25,771.33	8,610.76	41,585.40
	Total (kWhrs/annum)	197.66	212.86		327,443.85	73,505.49	400,156.20
<i>Comparison (existing and proposed) kWhrs/annum</i>					225,850.53	-38,800.83	-55,355.40

Note that improvements in heat recovery from the use of a thermal wheel lead to good energy savings, but provision of more effective cooling system expend additional energy. Also note that fan energy is expected to increase – but that would be subject to commissioning data and may well reduce.