Energy Statement

Development of Site (A21-021) at Rover Way, Cardiff

Parc Calon Gwyrdd

Project number:

11th June 2021

Quality information

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1. Introduction

AECOM have been commissioned by Parc Calon Gwyrdd (PCG) to produce an energy statement for the proposed site (A21-021) at Rover Way in Cardiff. The Proposed Development will consist of distribution / storage space (B8), likely to be utilised as distribution centres.

The statement forms part of the outline planning application and presents potential options to reduce overall energy use and maximise the use of renewable energy technologies.

The following sections specify the project's proposed approach to Cardiff Council's Planning Policies and are structured as follows:

- Section 2 presents an interpretation of planning requirements and the scope and limitations of the assessment
- Section 3 presents an overview of the proposed development
- Section 4 presents the baseline energy demand and emissions of the proposed development
- Section 5 discusses demand reduction and energy efficiency options
- Section 6 presents the conclusion and results of savings calculations for the proposed option.

This energy statement has been produced by AECOM for the proposed development of the Site of 50,000m^2 of B8 distribution / storage space.

Key background information on the site is based on early concept design information provided by the Architect. The recommended Low and Zero Carbon (LZC) technologies indicated in this report will likely change as the design evolves, however any changes in the reduction in carbon dioxide equivalent (CO_{2e}) emissions will be notified.

This Statement is based on the estimated load requirements of the building (baseline energy demand) and engineering calculations for relevant LZCs. The study was conducted by individuals who have acquired substantial expertise or a recognised qualification for undertaking assessments, designs and installations of low or zero carbon solutions in the commercial buildings sector and who are not professionally connected to a single low or zero carbon technology or manufacturer.

This report contains rounded numbers for ease of reading and in line with limitations of accuracy. Sometimes the rounding produces small (negligible) differences between different tables, which should be ignored.

2. Interpretation of Planning Requirements

As set out in the Cardiff Local Development Plan (LDP) 2006-2026 Policy EN12 – Renewable Energy and Low Carbon Technologies.

> *"EN1 sets out the planning authority's expectations of developers at application stage in relation to 'major' (>1,000m^2 commercial space) proposals. The potential for renewable energy is to be maximised, supported by an independent energy assessment".*

Cardiff Planning Obligations SPG (Supplementary Planning Guidance) Edition 1, 26 January 2017 expands on EN12. 14. Renewable Energy and Low Carbon Technologies, 14.1. Planning Policy Wales. (paragraph 4.12.2) states that

> *"The overall aspiration is to secure zero carbon buildings while continuing to promote a range of Low and Zero Carbon (LZC) technologies as a means to achieve this".*

Paragraph 14.5 – 14.7 sets out expectations for an energy statement as follows:

> *"Developers will be expected to prepare an Independent Energy Assessment, which investigates the technical feasibility and financial viability of incorporating LZC technologies and opportunities to minimise carbon emissions associated with heating, cooling and power systems beyond the minimum standards set out in Building Regulations Part L (conservation of fuel and power). Consistent with TAN 12 and Welsh*

Government's 'Energy Efficiency in Wales' Strategy, developers will be expected to follow the principles of the energy hierarchy, which advocates a sequential approach to minimising energy demand and carbon emissions:

> *1. Energy Reduction – Reduce the amount of energy used ('smart' heating and lighting, behavioural changes), use of passive design measures,*
>
> *2. Energy Efficiency – Using energy efficient systems (better insulation, efficient appliances and lighting),*
>
> *3. Renewable Energy – Generate heat and electricity from renewable sources (solar PV and thermal, wind, biomass, hydro, geothermal),*
>
> *4. Minimise carbon impact of other energy generation – Using low carbon technologies to reduce residual CO2 emissions (heat pumps, CHP and CCHP systems, district heat networks).*

As a minimum, assessments will be expected to include a non-technical executive summary and the following details:

- *Carbon footprint: Anticipated total energy demand / carbon dioxide emissions associated with the development (both regulated and unregulated loads should be identified),*
- *Assessment of options to reduce energy demand and emissions at each stage of the energy hierarchy,*
- *Measures of mitigation and proposed CO2 reductions at each stage of the energy hierarchy, expressed in relation to compliance with Part L of the Building Regulations as the benchmark.*

Following review of the Cardiff Council planning policies, the requirements are interpreted as follows:

- They relate to both regulated and non-regulated emissions.
- The baseline against which the reduction should be measured is the residual emissions remaining after any savings from energy efficiency.

The following should be noted:

- This Statement is produced for the submission of an Outline Application and excludes any work in support of a detailed planning application e.g. Part L model. Detailed design will be developed further post-consent.
- Data on building types, floor areas, massing/ storeys, orientation, etc is provided by the client / design team and from data from previous AECOM projects
- No building overheating analysis has yet been undertaken.
- The Energy Statement outlines the likely practical options for low carbon renewable energy supply and provides details on the suitable placement of these systems.
- This study was 100% desk based.
- The DEFRA Carbon Factors were used in the preparation of this Statement.
- The technologies proposed have been sized based on the projected whole building baseline regulated loads.
- It is assumed 24hr, 365day operation of the site.
- This study is to be taken as an Energy Statement only and does not contribute towards BREEAM credit Ene04.

3. Overview of Proposed Site

3.1. Site location and layout

The site for the proposed Rover Way (A21-021) development is located approximately 3.5km south-east to east from the City Centre. The proposal sees the development of previously unoccupied land to provide commercial distribution and storage space. Figure 1 shows the proposed Rover Way site for the development.

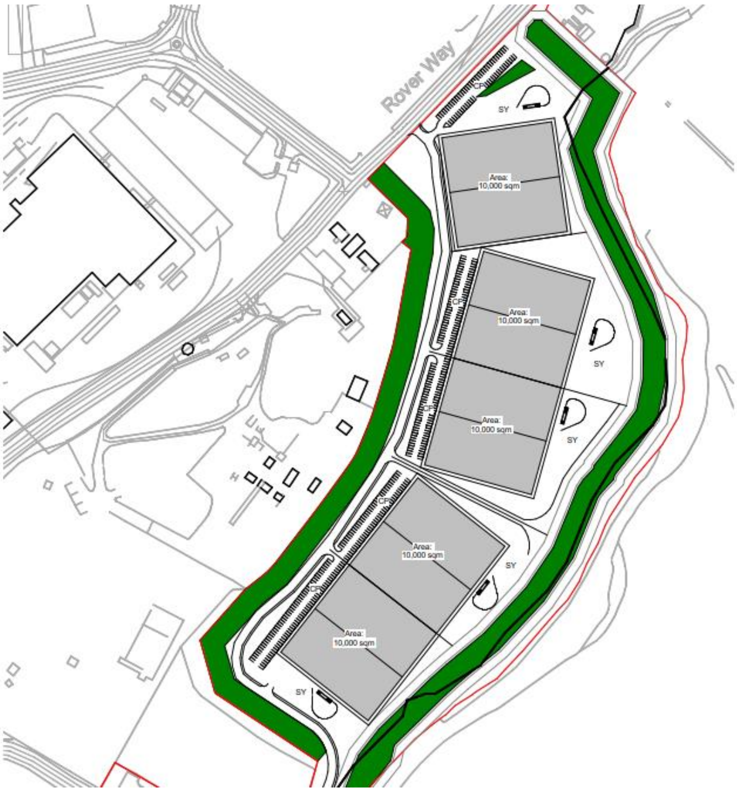

Figure 1: Proposed development of B8 (A21-021) Site at Rover Way, Cardiff [1]

We have utilised an indicative layout of 5 individual units forming the 50,000 sq.m of B8 development.

3.2. Constraints

The site is enclosed by Rover Way to the West and the Bristol Channel / Severn Estuary to the East. Although Water Source Heat Pumps (WSHPs) offer better efficiency than Air Source Heat Pumps (ASHPs), assessment is excluded of WSHPs due to the need for specialist titanium heat exchangers or an intermediate water processing step would be required due to sea water's corrosive properties. The saline water from the Estuary is also likely to make maintenance of the heat exchanger more costly due to increased corrosion rates. Additionally, further permits such as a water extraction licences will be needed.

The buildings are proposed to run off renewable electricity-based technologies and therefore we have not assessed Combined Heat & Power (CHP) engines. The size and anticipated heat requirements of the site have ruled out the use of a Ground Source Heat Pump (GSHP) system, as there is insufficient surrounding land to accommodate boreholes. Assessment of solar thermal systems has also been excluded since the panels compete with the Solar PV in terms of roof space and potentially higher efficiencies are achieved by utilsing an ASHP system.

There do not appear to be any further environmental issues on the site that could significantly constrain the use of other low carbon and renewable energy systems, such as air source heat pumps (ASHPs).

[1] A21 021 Rover Way Site Plan – Southgate and Sarabia Architects – Proposed Masterplan – Scheme 2

4. Baseline Energy Demand and Emissions

4.1. Floor areas and building types

Table 1 summarises the floor areas used to calculate the baseline energy demand and emissions, along with the energy and emissions data. The regulated emissions baseline is based on the estimated CO_{2e} emissions associated with a building of this type that is compliant with Part L of the Building Regulations.

For the baseline, natural gas-fired heating is assumed for the units. Two scenarios for the heated area of the building are considered. Scenario one assumes 10% of the area of units is heated (as is usually the case with a distribution activity); and scenario 2 assumes the total area of buildings is heated (for comparison purposes). Additional data is provided in Appendix A: Baseline Energy Demand and Emissions, including how modelling results were employed for this Statement.

Table 1: Rover Way Development Baseline Model Energy Demand and Emissions

	Scenario 1	Scenario 2
Building Type	Distribution & Storage	Distribution & Storage
Total Floor Area (m^2)	50,000	50,000
The proportion of the conditioned area of the building (heated)	**10%**	**100%**
Annual Regulated Electricity Demand for the Baseline Model (kWh)	1,874,675	1,874,675
Annual Regulated Gas Demand for the Baseline Model (Natural Gas for Heating and Domestic Hot Water) (kWh)	179,306	487,563
Total Regulated Demand for the Baseline Model (kWh)	2,053,981	2,362,238
Annual Unregulated Electricity Demand (for Equipment) for the Baseline Model (kWh)	2,337,000	2,337,000
Total Annual Demand (kWh)	4,390,981	4,699,238
Total Regulated Emissions for Baseline Model (tonnes of CO_{2e} Per Annum)	472	539
Total Unregulated Emissions for the Baseline Model (tonnes of CO_{2e} Per Annum)	540	540
Projected Total Emissions (tonnes of CO_{2e} Per Annum)	1,012	1,079

5. Demand Reduction and Energy Efficiency

TAN 12 and the Welsh Government's 'Energy Efficiency in Wales' Strategy expect developers to follow the principles of the energy hierarchy, which advocates a sequential approach to minimising energy demand and carbon emissions. Requirements one and two are to reduce the amount of energy used (better insulation and airtightness) and to employ energy-efficient systems (more efficient appliances and lighting).

Table 2 shows the construction details and fabric u-values taken from the notional building of the existing Part L Wales Building Regulations. The second column shows the same figures for a building from which modelling data is employed for this Statement. The third column shows the projected specification for the Rover Way development.

It can be seen from Column 2 that the base specification underpinning the energy figures utilised for this Statement are considerably better than Part L and so much so that lighting standards are relaxed considerably whilst still achieving much-improved energy performance. The projected Rover Way specification (column 3) will achieve the best fabric and services standards, significantly reduced demand for energy whilst maintaining the highest levels of efficiency.

Table 2: Building Specification

	U Value/ Service Detail		
	Notional Building of Current Part L of the Building Regulations in Wales (2014)	**Base Specification for the Assumed Energy Demand Data**	**Projected Specification for the Rover Way Development**
External Walls U Value (W/m^2K)	0.26	0.20	0.20
Roof U Value (W/m^2K)	0.18	0.18	0.18
Windows U Value (W/m^2K)	1.8	1.6	1.6
Heat-Loss Floor U Value (W/m^2K)	0.22	0.08[2]	0.08[3]
Air Permeability ($m^3/m^2/hour$)	5	3	3
Low Energy Lighting (llm/cW)	65	100	65
Ventilation	Terminal Unit SFP: 0.3W/l/s Heat recovery efficiency (HR) (%): 70%	MVHR, SFP: 0.3w/l/s with 80% HR in offices	MVHR, SFP: 0.3w/l/s with 80% HR in offices
Heating Plant and Domestic Hot Water Provision	When mains gas is available on site, mains gas is assumed to be used to supply both space and water heating. Where no mains gas on site, use of oil is assumed.	Mains gas is assumed to be used to supply both space and water heating.	ASHP for space heating and domestic hot water demand

5.1. Heating systems and combined heat & power (CHP)

TAN 12 and the Welsh Government's 'Energy Efficiency in Wales' Strategy expect developers to follow the principles of the energy hierarchy, which advocates a sequential approach to minimising energy demand and carbon emissions. The final step in the hierarchy is to minimise carbon impact through low and zero heating and cooling technologies and decentralised networks.

[2] including ground floor contact adjustment.
[3] including ground floor contact adjustment.

Table 3 shows a review of such opportunities, with associated comments for this development.

Table 3: Comments on the heat hierarchy

No.	Detail	Comments
1	Connection to existing CHP/CCHP distribution networks	Following desk top analysis, it is understood that there are currently no local CHP / CCHP distribution networks currently available or planned for installation in the immediate area (see figure 2).
2	Site-wide renewable CHP/CCHP	The only option for a renewable CHP / CCHP system would be biomass which has been discounted for air quality reasons.
3	Site-wide gas-fired CHP/CCHP	Given the Government's policy announcement regarding no gas in housing by 2025, the applicant has made the decision to not include gas on this site.
4	Site-wide renewable community heating/cooling	A site-wide approach to space heating and Domestic Hot Water via air source heat pumps is proposed for the development.
5	Site-wide gas-fired community heating/cooling	Given the government's policy announcement regarding no gas in housing by 2025, the applicant has made the decision to not include gas on this site.
6	Individual building renewable heating	N/A

5.2. Heat Network

A connection to the proposed Cardiff heat network has been considered. The Heat Network is envisaged to begin at the Trident Park Energy Recovery Facility (ERF) plant in Cardiff Bay and run through large parts of the Bay area before crossing the main Cardiff to London railway line. It will then skirt the southern edge of the city centre and finally end in the western parts of Newport Road[4]. Viridor EC is the closest part of the network to the Rover Way Development, and a connection to the site will require about $2km^2$ of a hard dig heat pipe. Therefore, this option has not been investigated further.

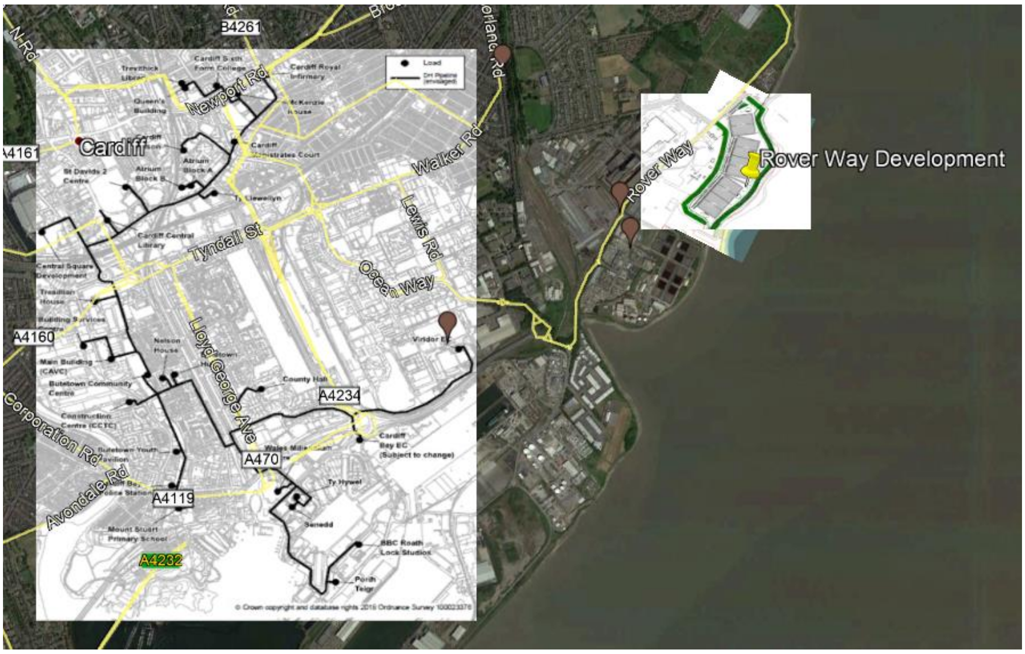

Figure 2: The Cardiff Heat Network and the Rover Way Development Location[5]

[4]https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/885342/Heat_Networks_Project_Pipeline_January_to_March_2020.pdf
[5] Source: Google Earth and https://cardiff.moderngov.co.uk/documents/s21305/Cabinet%2019%20April%202018%20District%20heat.pdf?LLL=0

6. Proposed Renewable Energy Solution

6.1. Overview

TAN 12 and the Welsh Government's 'Energy Efficiency in Wales' Strategy expect developers to follow the principles of the energy hierarchy, which advocates a sequential approach to minimising energy demand and carbon emissions. Requirement three is for developers to generate heat and electricity from renewable sources. The remainder of this Statement is considered with identifying the strategy for renewables.

The Rover Way development is speculative. The occupancy, nature of process equipment and the associated changes in non-regulated loads may well vary widely. For this reason, the assessment of renewables is based on projected regulated loads only.

6.2. Air Source Heat Pumps (ASHPs)

Air source heat pumps (ASHPs) employ the refrigeration cycle to move heat from external ambient air to the inside of a building. There are two types of commonly available ASHPs, depending on the heat distribution system in the building:

- Air-to-air – This is the most common, for example in 'split' and variable refrigerant flow (VRF) air conditioning systems. Heat is transferred from ambient air to the building (or vice-versa) via direct expansion coils into a moving airstream.
- Air-to-water – Heat is transferred from ambient air to the building (or vice-versa) via heat exchangers with a 'wet' piped system, such as low-pressure hot water (LPHW).

ASHP systems can also be used to generate hot water, albeit causing the system to operate at reduced efficiency due to the higher flow temperatures required. When used as space heating devices, ASHPs achieve their best seasonal performance factors (SPFs) when they operate on low flow and return temperatures. This makes them particularly suitable for use with underfloor heating systems, large sized radiators on weather compensated circuits, or all-air heating systems.

For this development, we are proposing a VRF ASHP system for space heating via mechanical ventilation and a dedicated ASHP system providing Domestic Hot Water. Savings calculations are based on the entire space heating (Scenario 2, 100% of the area) and domestic hot water demand being met by ASHPs. The heating is therefore entirely met by electricity, removing any gas demand. We have used recent modelling for similar projects as a guide for the expected demands and plant requirements of this development.

Table 4: ASHP System

Baseload Energy			
No.	**Item**	**Value**	**Units**
1	Total Heat Demand	487,563	kWh
2	Size of ASHP	561	kW
3	Demand met by ASHP	487,563	kWh
Annual Energy Generated - ASHP			
4	CoP	2.5	
5	Electricity Consumed	195,025	kWh
Emissions Generated by ASHP System			
ASHP			
6	Energy Used	195,025	kWh
7	Carbon Factor	0.23	$kgCO_2/kWh$
8	Carbon Emitted	45	tCO_{2e}
Total			
9	Carbon Emitted	45	tCO_{2e}
Emissions Saved by ASHP			
10	Base Scenario Gas Emissions	105	tCO_{2e}
11	ASHP Emissions	45	tCO_{2e}
12	Emissions Saved	60	tCO_{2e}
13	Total Regulated Emissions	539	tCO_{2e}
14	Percentage Reduction	11.2%	%

From Table 4, the total heat demand can be seen as 487,563 kWh whilst the size of the ASHP system is given as 561 kW. The demand met by the ASHP is equivalent to the total heat demand. The Coefficient of Performance (CoP) is assumed to be 2.5 - which is a typical CoP for ASHP systems of this size. The total carbon emitted by the ASHP system is 45 tCO_{2e}. Finally, the emissions saved by the ASHP system has been calculated as 60 tCO_2, this gives the system a percentage emissions reduction of 11.2%.[6].

6.3. Solar Photovoltaics (PV)

Solar photovoltaic (PV) systems convert energy from the sun into direct current (DC) electricity through the use of semi-conductor cells connected together and mounted into modules. Modules are connected to an inverter that converts DC into alternating current (AC), enabling integration with the normal grid supply. If the output of a PV system exceeds the building demand at any time, the surplus electricity can then be exported to the grid. However, the modelling that was conducted for this study showed that there will be no surplus of generated electricity that may then be exported to the grid.

PV technologies can be categorised into monocrystalline, polycrystalline and amorphous silicon (thin film) systems. Monocrystalline cells are the most efficient, with a conversion efficiency of 15-20% (the fraction of incident solar energy that is converted into electricity). Amorphous silicon is the least efficient (6-8%). Installed costs of these technologies are commensurate with their performance, and monocrystalline is the most expensive of the three. A fourth variety, hybrid, utilises both thin film and polycrystalline silicon to improve performance.

Various options exist, most normally being fixed to sloping or flat roofs; but they can also be incorporated into building facades, glass roof structures and solar shading devices (often at much greater cost). Careful consideration of the building’s design features, and the budgetary concerns of the development are required when deciding which type of installation might be the most appropriate. PV modules can also be equipped with tracking systems, which allow the modules to follow the course of the sun. This can potentially increase electricity production compared with modules at a fixed inclination but can be an expensive addition, usually reserved for larger-scale installations.

Appendix B. shows the estimated available roof area of each unit for solar PV installation; however, in this study, the roof pitch for each solar PV unit is assumed to be 35°, and the roofs are assumed to be oriented towards the south.

As mentioned in section 4, two scenarios for the amount of heated area of the buildings are considered. Therefore, two PV systems are provided based on the two scenarios and systems are sized based on electricity demand in each option.

Additionally, the daily PV generated across the year is averaged and used to include a battery to reduce the development reliance on the grid and compensate for the intermittent nature of renewable energy.

6.3.1. Solar PV Scenario 1

Scenario 1 assumes 10% of the area of units is heated via ASHP. Additionally, two options in this scenario are considered to calculate the amount of PV required to meet the total annual electricity demand or regulated electricity demand only. Table 5 shows the result of the assessment.

[6] The ASHP system GHG savings are in comparison to a gas heating system when 100% of the space is heated.

Table 5: Scenario 1 Solar PV- Energy & System Parameters

No.	Item	Scenario 1 PV Option 1	Scenario 1 PV Option 2	Units
	Energy & system parameters			
1	Note	**PV System to meet the regulated demand only**	**PV System to meet total the (regulated and unregulated) demand**	m^2
2	Total available roof area	50,000	50,000	m^2
3	PV panels coverage factor	22%	50%	%
4	Area of active PV	11,000	25,000	m^2
5	PV active area per unit output	6.6	6.6	m^2/kW_p
6	PV Panel Orientation	0	0	°
7	PV Panel Inclination	35	35	°
8	% of optimum iradiance	100%	100%	%
9	PV system peak output	1,667	3,788	kW_p
10	Solar PV annual electricity generation	1,958,333	4,450,758	kWh p.a.
11	Total regulated electricity demand assuming ASHP is used for heating	1,946,397	1,946,397	kWh p.a.
12	Total regulated and unregulated electricity demand assuming ASHP is used for heating	4,283,397	4,283,397	kWh p.a.
13	Battery Capacity	5,365	12,194	kWh
	GHG emissions impact			
14	Electricity GHG emission factor	0.231	0.231	$kgCO_2e/kWh$
15	Annual GHG emissions saving	452.6	1,028.7	tCO_2e p.a.

The results for the solar PV system from Table 5 indicates a total annual electricity generation of 1,958,333 kWh p.a when 22% of the roof area is utilised for PV panels (option 1) and 4,450,758kWh p.a. when 50% of the roof area is utilised (option 2). The data shows the PV system can supply the total annual electricity demand (regulated and unregulated) of the development resulting in annual GHG emissions saving of 1,028.7 tCO_{2e} p.a.

6.3.2. Solar PV Scenario 2

Scenario 2 assumes 100% of the area of units is heated via ASHP, and the PV system is sized accordingly. Two options in this scenario are also considered to calculate the amount of PV required to meet the total annual electricity demand or regulated electricity demand only. Table 6 shows the result of the assessment.

Table 6: Scenario 2 Solar PV Energy & System Parameters

No.	Item	Scenario 2 PV Option 1	Scenario 2 PV Option 2	Units
	Energy & system parameters			
1	Note	**PV System to meet the regulated demand only**	**PV System to meet total the (regulated and unregulated) demand**	m^2
2	Total available roof area	50,000	50,000	m^2
3	PV panels coverage factor	24%	51%	%
4	Area of active PV	12,000	25,500	m^2
5	PV active area per unit output	6.6	6.6	m^2/kW_p
6	PV Panel Orientation	0	0	°
7	PV Panel Inclination	35	35	°
8	% of optimum iradiance	100%	100%	%
9	PV system peak output	1,818	3,864	kW_p
10	Solar PV annual electricity generation	2,136,364	4,539,773	kWh p.a.
11	Total regulated electricity demand assuming ASHP is used for heating	2,069,700	2,069,700	kWh p.a.
12	Total regulated and unregulated electricity demand assuming ASHP is used for heating	4,406,700	4,406,700	kWh p.a.
13	Battery Capacity	5,853	12,438	kWh
	GHG emissions impact			
14	Electricity GHG emission factor	0.231	0.231	$kgCO_2e/kWh$
15	Annual GHG emissions saving	493.8	1,049.2	tCO_2e p.a.

Table 8 shows a total annual electricity generation of 2,136,364 kWh p.a when 24% of the roof area is covered in PV (option 1) and 4,539,773kWh p.a. kWh when 51% of the roof area is utilised (option 2). The data shows the PV system can supply the total annual electricity demand (regulated and unregulated) of the development resulting in annual GHG emissions saving of 1,049.2 tCO_{2e} p.a.

6.4. Wind Turbines

Wind energy can be one of the most cost-effective methods of renewable power generation. Turbines can produce electricity without carbon dioxide emissions, ranging from watts to megawatt outputs. The most common design is for three blades mounted on a horizontal axis, which is free to rotate into the wind on a tall tower; however, the blades can be mounted on a vertical axis for a less noisy system and a system that isn't dependent on wind direction. The blades drive a generator either directly or via a gearbox [generally for larger machines] to produce electricity. The electricity can either link to the grid or charge batteries. An inverter is required to convert the electricity from direct current [DC] to alternating current [AC] for feeding into the grid.

There are a variety of wind turbines on the market ranging from smaller turbines that can be attached directly to a buildings structure to larger stand-alone turbines. However, small scale wind turbines, i.e. building integrated turbines [<20 kW] are typically disturbed by wind turbulence and do not operate as effectively.

Having reviewed the planning application documents made to Cardiff Council; a previously submitted application has been identified for a single wind turbine at Rover Way, Cardiff. This relates to the installation of a high yield 500Kw wind turbine generator. The proposed development consisting of a single wind turbine with a hub height of up to 50m and a rotor of up to 54m diameter (giving a maximum height to blade tip of 77m), electrical infrastructure and an associated access track and hard crane standing has been approved.

Furthermore, Cardiff Council previously granted permission for the erection of one 10.6m High Micro Wind Turbine and Associated Works opposite Rover Way at Ffordd Pengam, Cardiff (Decision: Granted 07 Jan 2010); which is opposite the current proposed site for this study. The two aforementioned planning applications have been cited to show precedent for planning permissions in and around the site.

For the purpose of this study, a high-level assessment of the available space at the proposed site based on the site layout was conducted. For each of the individual turbines, a value of 10% of the max height of the respective turbines was added in order to calculate turbine topple distance.

Therefore, the indicative installed capacities of the wind turbine solutions assessed for the purposes of this study are 500kW and 250kW. The wind turbines can be used as alternatives to or in conjunction with the proposed solar PV system and the proposed heating solutions (ASHP) at Rover Way, Cardiff.

For the purpose of this study, we have averaged the daily electricity generated across the year and included a battery to cover a one average day of generated electricity by the turbines with the view of reducing the development reliance on the grid as well as compensating for the intermittent nature of the renewable energy.

Total Battery Capacity for Wind Turbines = 4.97 MWh

Table 7: Wind Energy (Turbines)

Ground Mounted

No.	Item	Value	Units
1	Turbines Generation Power	750	kW
2	Battery Capacity	4968 .	kWh
3	Total Annual Electricity Generation	1,813,320	kWh p.a
4	Generation Power	750	kW
CO2 Reduction			
5	Consumed Electricity Generation	1,813,320	kWh p.a.
6	Carbon Factor	0.231	$kgCO_2/kWh$
7	GHG Emissions Saving	419.09	tCO_2 p.a.

The results for the wind turbines from Table 7 indicates a total annual electricity generation of 1,813,320 kWh p.a. This is based on the installation of two wind turbines (500 kW and 250 kW). Furthermore, the carbon factors used within this study have been sourced from the latest available data from DEFRA. The total unregulated annual electricity demand for the site at Rover Way, Cardiff is 1,946,397 kWh p.a., assuming ASHP is used for heating, and only 10% of the total area is heated. As is evident from Table 7 the two wind turbines do not meet the required demand. The annual GHG emissions savings made by installing the wind turbines are given as 419.09tCO_2.

6.5. Summary of Results

The solar PV system is capable of generating enough electricity to meet the total regulated and unregulated electricity demand utilising 51% of the roof space. It is considered that this enables the project to move ahead utilising a traditional gable roof as opposed to mono-pitch or saw-tooth arrangement. Wind turbines can also be used as an alternative solution to meet the demand partially or in conjunction with the PV system.

- The Total Annual Regulated Electricity Demand assuming 100% Conditioned Space and that an ASHP is used for Space Heating and Domestic Hot Water is: **2,069,700kWh p.a.**
- The Total Annual Electricity Demand assuming 100% Conditioned Space and that an ASHP is used for Space Heating and Domestic Hot Water is: **4,406,700kWh p.a.**

The energy requirement of the ASHP heating system and the unregulated demand in the buildings can therefore entirely be met by electricity generated by solar PV, resulting in annual GHG emissions savings of 1,049.2 tCO_{2e}. Table 8 shows a summary of the results from each system.

Table 8: % of Demand Met by Each System for Different Scenarios

Options	Battery Size for 1 day Demand (kWh)	% of Demand Met by Solar PV on 24% of South Facing Roof	% of Demand Met by Solar PV on 51% of South Facing Roof	% of Demand that Could be Met by Two Wind Turbines 1x 500kW 1x250kW
10% Conditioned Space Regulated Demand	5,365	100	100	93
10% Conditioned Space Total Demand	12,194	50	100	42
100% Conditioned Space Regulated Demand	5,853	100	100	88
100% Conditioned Space Total Demand	12,438	49	100	41

The condensed Table 9 below shows a summary of the proposed renewable technologies. Table 9 demonstrates the technologies, which consist of solar PV and an ASHP system, generate sufficient renewable electricity to meet the required annual demands of the site. The total regulated and unregulated electricity demand for the site is 4,406,700 kWh p.a. Wind turbines are not included in the proposed system however a combination of a small wind turbine (250kW) and solar PV can also be utilised to compensate for the intermittent nature of solar PV system and reduce the PV panels size.

Table 9: Energy and Emissions from Solar PV and ASHP System

Renewable Energy Technology	Renewable Electricity Generation (kWh p.a.)	GHG Savings (tCO_{2e} p.a.)
Solar PV Scenario 2 Option 2 Battery Capacity: 4,968kW	4,539,773	1,049.2 [7]
ASHP System	-	60 [8]
Total:	**4,539,773**	**1,109.2**
Total Regulated and Unregulated Electricity Demand	**4,406,700**	

[7] Assuming the electricity generated by the system replaces the grid electricity demand for the proposed solutions which uses ASHP for heating and Domestic Hot Water

[8] The ASHP system GHG savings are in comparison to a gas heating system.

Appendix A - Assumptions of the Energy Model

No Part L model has yet been produced specifically for Rover Way.

However, construction details have been selected to ensure that all fabric U-values exceed or match the requirements of the current Part L of the Building Regulations in Wales. The following assumptions have been made in relation to the model used to derive energy loads.

The calculation is based on the Part L of the Building Regulations for regulated and nonregulated energy demand.

It is assumed that the building will have good daylight levels, benefitting from wide windows to the office elements.

The building services are assumed to be have high efficiency to minimise distribution loss.

Office accommodation is generally glazed on the North West façade, rather than a South facing façade.

Windows have a G value of 0.4.

It is assumed 24hr, 365day operation of the site.

In relation to Part L regulation, the building is assumed to be a B8 Storage or Distribution Development

The natural gas heating system in the baseline model is assumed to have a heating efficiency of 91%

AECOM's previous project data is used to size the proposed solution ASHP sized without any detailed design work. The figure includes 32% redundancy (assuming 2 boilers, each at 66% of the load).

Appendix B - Roof: Solar PV Assumptions

The area for the PV panels were provided by the Architect. Additionally, the following assumptions are made in relation to the solar PV assessment.

- The roof pitch for each of the solar PV units is assumed to be 35º.
- It is assumed that each unit will orientation of up to 0º from south and all of the roof area can be utilised for solar PV installation.

Figure 3 and Table 10, shows details of the assumed roof sections for solar PV installation.

Figure 3: Proposed Location of the Solar PV System

Table 10: Roof Area for PV

Reference	Section Area (m^2)	Orientation from South	Assumed Roof Pitch
A	5,000	0^{o}	35^{o}
B	5,000	0^{o}	35^{o}
C	5,000	0^{o}	35^{o}
D	5,000	0^{o}	35^{o}
E	5,000	0^{o}	35^{o}

Appendix C – Wind Turbine Location: Assumptions

Figure 4 shows possible locations of the wind turbines and their distances to the closed by roads. The selected turbines (250kW-500kW) in this study can have a tip height of no more than 77m.

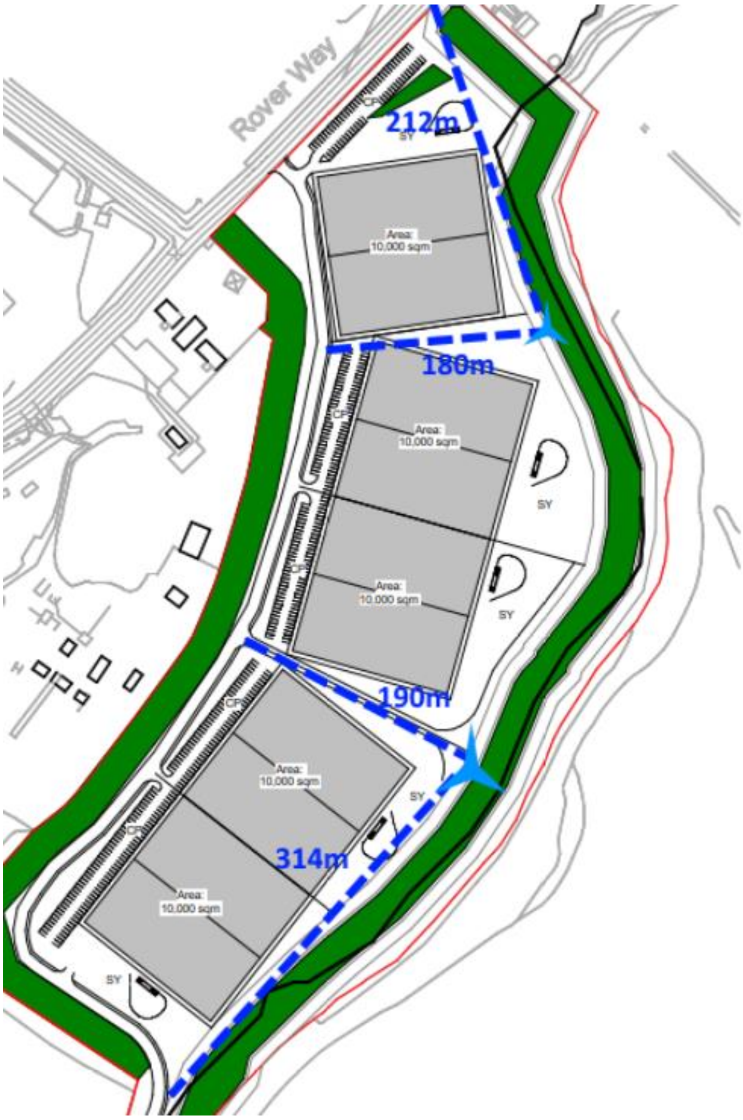

Figure 4: Proposed Location of the Wind Turbines and Their Distance to Roads