

St. Modwen Developments Limited

Coed Darcy

Energy Strategy

COED-ARUP-ZZ-XX-PP-N-0002

P02 | 11th October 2021

This report takes into account the particular instructions and requirements of our client.

It is not intended for and should not be relied upon by any third party and no responsibility is undertaken to any third party.

Job number 281667-00

Ove Arup & Partners Ltd
63 St Thomas Street
Bristol
BS1 6JZ
United Kingdom
www.arup.com

ARUP

Document Verification



Job title		Coed Darcy		Job number	
				281667-00	
Document title		Energy Strategy		File reference	
Document ref		COED-ARUP-ZZ-XX-PP-N-0002			
Revision	Date	Filename	COED-ARUP-ZZ-XX-PP-N-0002.docx		
Draft	04/10/2021	Description	Draft issue for PAC input and comment.		
			Prepared by	Checked by	Approved by
		Name	Stuart Cannon	Helen Charlick	David Littler
		Signature			
P01	08/10/2021	Filename	COED-ARUP-ZZ-XX-PP-N-0001 P01.docx		
		Description	Formal issue with client comments incorporated.		
			Prepared by	Checked by	Approved by
		Name	Stuart Cannon	Helen Charlick	David Littler
		Signature			
P02	11/10/2021	Filename	COED-ARUP-ZZ-XX-PP-N-0001 P01.docx		
		Description	Formal issue with client comments incorporated.		
			Prepared by	Checked by	Approved by
		Name	Helen Charlick	Helen Charlick	David Littler
		Signature			
		Filename			
		Description			
			Prepared by	Checked by	Approved by
		Name			
		Signature			
Issue Document Verification with Document ☒					

Contents

	Page
Executive summary	3
1 Context & purpose	4
1.1 Overview	4
1.2 Drivers for sustainable energy – policy	5
2 Site overview	7
3 Methodology	9
4 Demand assessment	10
5 Low and zero carbon technologies	11
5.1 Our approach	11
5.2 Primary screening	11
5.3 Energy delivery	13
6 Techno-economic assessment of technologies	14
6.1 Sizing constraints	14
6.2 Modelling scenarios	14
6.3 Results	15
7 Recommendations and next steps	17
7.1 Recommendations	17
7.2 Next steps	17

This report has been prepared specifically for and under the instructions of St. Modwen Developments Limited.

This report may be provided to third parties solely to inform any such person that our report has been prepared and to make them aware of its substance but not for the purposes of reliance. No third party is entitled to rely on this report unless and until they and we sign a reliance letter in the form attached to our appointment. We do not in any circumstances accept any responsibility or liability to retail investors whether via bond issue or otherwise and no such party is entitled to relay on this report.

In preparing this report we have relied on information provided by others and we do not accept responsibility for the accuracy of such information.

We emphasise that the forward-looking projections, forecasts, or estimates are based upon interpretations or assessments of available information at the time of writing. The realisation of the prospective financial information is dependent upon the continued validity of the assumptions on which it is based. Actual events frequently do not occur as expected, and the differences may be material. For this reason, we accept no responsibility for the realisation of any projection, forecast, opinion or estimate.

Findings are time-sensitive and relevant only to current conditions at the time of writing. We will not be under any obligation to update the report to address changes in facts or circumstances that occur after the date of our report that might materially affect the contents of the report or any of the conclusions set forth therein.

In preparing this report we have relied on information supplied by others. We have relied in particular on the accuracy and completeness of such information and accept no liability for any error or omission in this report to extent the same results from errors or omissions in the information supplied by others.

Glossary of terms	
Abbreviation	Full name
AC	Air change
ASHP	Air source heat pump
BAU	Business as usual
BEIS	Department for Business, Energy & Industrial Strategy
CAPEX	Capital expenditure
CCC	Committee on Climate Change
CHP	Combined heat and power
COP	Co-efficient of performance
DC	Direct current
DHW	Domestic hot water
EV	Electric vehicle
GHG	Green house gases
GIA	Gross internal area
GSHP	Ground source heat pump
kgCO ₂	Kilograms of carbon dioxide
KPI	Key performance indicator
LCOE	Levelised costs of energy
LZC	Low and zero carbon
MW, kW	Megawatt, kilowatt (units of electrical or thermal power)

MWh, kWh

Megawatt-hour, kilowatt-hour (units of electrical or thermal energy)

NDC

Nationally Determined Contribution

NZC

Net zero carbon

OPEX

Operational expenditure

PRI

Pressure regulating installation

PV

Photovoltaic

SDGs

Sustainable Development Goals

STHW

Solar thermal hot water

WSHP

Water source heat pump

Executive summary

Arup has undertaken an energy strategy using the energy hierarchy for Coed Darcy – a proposed mixed-use development located in South Wales consisting of circa 1,800 homes, a new school and a number of commercial properties. We used the energy hierarchy to perform our analysis, as shown in Figure 1.

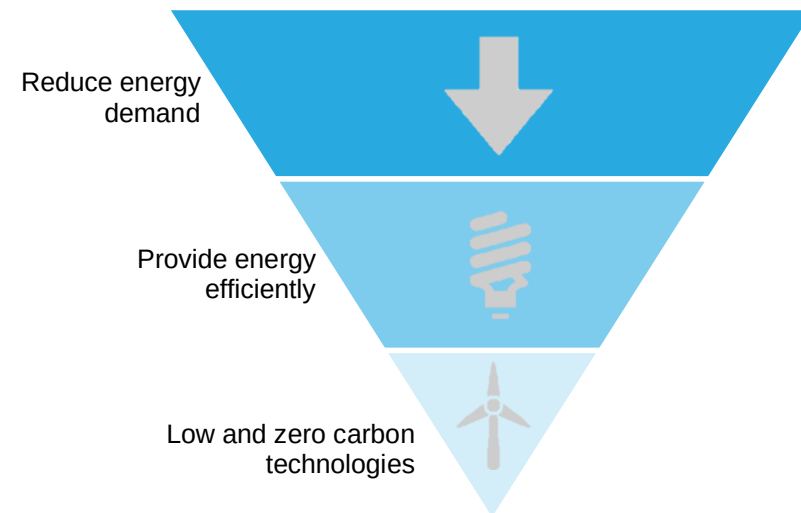


Figure 1: Energy hierarchy – the basis of Coed Darcy’s energy strategy

Once we had determined the demands for the development and considered the improvements that could be made to building fabric, we took a two stage approach, firstly we sifted a long list of technologies for relevance to the development, and then we undertook optimisation modelling using Arup’s suite of whole systems energy modelling tools to determine the energy strategy for Coed Darcy.

Results

We undertook optimisation modelling to assess which of the shortlisted technologies gave the lowest carbon, lowest cost solution for two scenarios:

- 2025 – excluded hydrogen-based technologies, included photovoltaics (PV), air source heat pumps (ASHPs), ground source heat pumps (GSHPs), hydrogen ready gas boilers, batteries, grid connected electricity and gas, resistance heating.
- Hydrogen feasibility 2050 – included all technologies and a reduced grid carbon intensity to reflect a 2050 decarbonisation prediction.

We also included two baseline scenarios for comparison, which use conventional gas boilers for heating, conventional high demand assumes the buildings are built to current standards, whereas conventional low demand assumes the buildings are built to 2025 standards.

The results of the modelling can be seen in Figure 2, the baseline scenarios have high carbon intensity because they include gas boilers, whereas the optimised scenarios, which use a combination of PV, GSHPs, ASHPs and batteries to supply the required energy demands, have reduced carbon emissions and levelised costs of energy (LCOE).

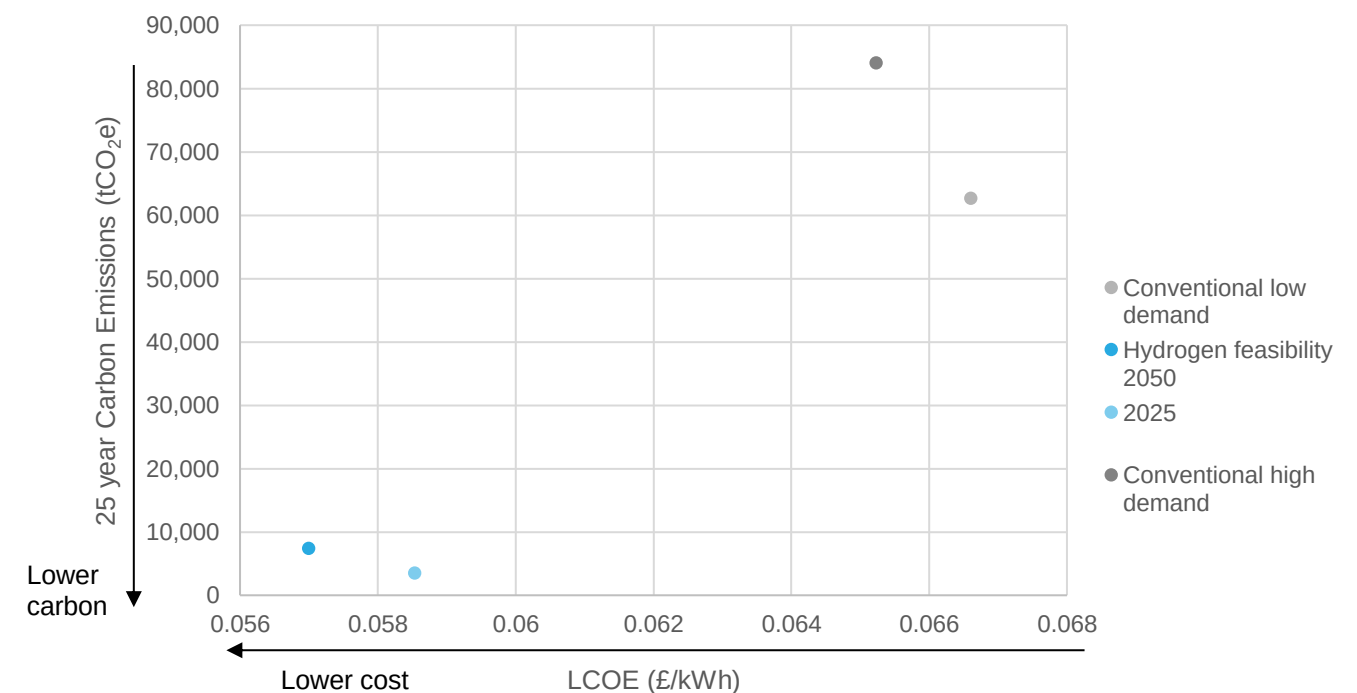


Figure 2: Comparison of LCOE and 25 year carbon emissions for the different scenarios

Conclusion

We recommend that the energy strategy for Coed Darcy prioritises the following:

1. **Set targets on building carbon emissions and energy demands** – Set the development aspirations for energy demand and carbon emissions for each building typology. This should include carbon targets for 2025 and 2050 which align to Welsh Government and local council policy.
2. **Maximise passive design measures** – Maximise the impact of passive design measures such as building layout and orientation, as detailed in Appendix B.
3. **Take a fabric first approach** - The development should have high performing building fabric and align to 2025 standards as detailed in Table 5.
4. **Maximise GSHPs** – Incorporate the use of GSHPs wherever feasible, using ASHPs where this is not possible.
5. **Maximise roof mounted PV** – Incorporate PV on viable south facing roofs.
6. **Encourage use of EVs** - consider in home battery storage.

1 Context & purpose

1.1 Overview

Summary of proposed development

The Coed Darcy site is located to the west of Neath in Neath Port Talbot. The mixed-use development will be delivered over a number of phases and will consist of circa 1,800 homes, a new school and a number of commercial properties (935 m² gross internal area (GIA)). The site benefits from previous outline planning permission and includes approximately 300 homes to the south of the site delivered by a previous housing developer. St Modwen are applying for outline planning permission for the site. The outline planning application will cover the following:

“The outline planning application, with all matters reserved except for strategic access, for residential uses (C2 & C3 use class), including land for education (D1 use class) with associated public open space, commercial uses (A1, A2, A3, B1, D1 & D2), commercial / employment (B2 & B8) uses, public open space, highway works, sustainable drainage, ecological mitigation and enhancement, landscaping, ground remediation, and associated engineering and infrastructure works.”

The buildings and facilities associated with the proposed Coed Darcy development will have energy requirements for heating and power, supplying a variety of end uses. It is therefore important that the site energy strategy provides clean, efficient and cost-effective energy, in line with St Modwen’s vision as well as national policy.

This energy strategy explores these aims taking a holistic view of the site’s energy requirements and includes:

- An overview of the site, covering previous uses, proposed new buildings, phasing plans and geological features including topography, ground conditions and ground contamination.
- A review of the existing utilities capacities to inform the feasibility of different technology options.
- A summary of the approach taken for the appraisal methodology.
- A detailed demand assessment with an indication of the building design measures to meet certain performance criteria.
- Low and zero carbon (LZC) technology appraisal with an integrated risk matrix to provide a summary of the assessment.
- A techno-economic analysis of the short-listed technologies which includes an optimised solution for cost and carbon.
- The strategy is summarised with recommendations and next steps.

Autonomy and resilience

Assessing options for improved energy sustainability will enable the scheme to take advantage of the most appropriate means of energy provision. LZC technologies could offer several benefits to the development including a reduction to carbon emissions, improving the sustainability

credentials of the scheme and a reduced reliance on grid energy which can reduce exposure to fluctuation in fossil fuel-based energy prices. The inclusion of passive building design measures will reduce heating and cooling loads of buildings reducing the amount of energy required and thus also operational costs.

Impacts of climate change

It is important to plan for climate changes to ensure that new developments remain resilient to the climate throughout their service life and that buildings remain comfortable for users under possible future climate scenarios.

Planning Policy Wales and Future Wales 2040 sets out the Welsh Government’s land use planning policies and encourages projects which incorporate sustainable design measures. The document also highlights some of the climate change impacts that Wales can expect over the following decades:

- Increase in winter rainfall and in the frequency of intense rainfall.
- Increase in the length of the growing season.
- Rising sea levels.
- More extreme weather, such as severe storms.
- Hotter average temperatures.
- An increase in the number of hot and dry summers and an increase in the number of extremely hot days.
- Milder winters and a reduction of snowfall.

This will have a range of impacts, including:

- An increase in flash flooding due to heavy rain and an increase in river and coastal flooding and erosion.
- Increase in winter storm damage.
- Increased risk of subsidence in subsidence prone areas.
- Increased thermal discomfort in buildings.

1.2 Drivers for sustainable energy – policy

The following section draws on policy for sustainable energy provision from the global scale to the local scale.

UN Sustainable Development Goals (SDGs)

The UN SDGs lead in guiding sustainable development on a global scale. The SDGs are an important part of the *2030 Agenda for Sustainable Development*, which was adopted by all UN Member States in 2015.



Figure 3: UN Sustainable Development Goals

The 17 SDGs, and 169 subsequent targets, set out the overarching goals that the global community should aim to achieve to move toward sustainable development. The following SDGs are the most relevant to the energy strategy for Coed Darcy:

- 3 – Good Health and Well-being
- 7 – Affordable and Clean Energy
- 11 – Sustainable Cities and Communities
- 13 – Climate Action

If efforts are made to maximise Coed Darcy's impact against these SDGs, the development will ensure alignment to the wider global direction of movement towards addressing global challenges and driving sustainable development.

UK planning policy and sustainable development

The UK has some of the world's strongest climate change mitigation policy and legislation. In 2008, parliament passed the Climate Change Act¹, which mandated a reduction in Greenhouse Gas (GHG) emissions of 80% on 1990 levels by 2050². In 2019, the Climate Change Act was strengthened and committed the UK to reaching Net Zero carbon emissions by 2050, with interim carbon budgets every 5 years. The Climate Change Act also created the UK Committee on Climate Change (UKCCC). This is an independent advisory body that advises the government on decarbonisation pathways, and reviews progress towards these targets.

¹ Climate Change Act 2008 (legislation.gov.uk)

² All reductions quoted in this piece are from a 1990 baseline. A very small minority of GHG gases, (such as hydrofluorocarbons, perfluorocarbons, sulphur hexafluoride and nitrogen trifluoride) are measured from 1995 levels. Carbon Dioxide, Methane and Nitrous Oxides are measured from a 1990 baseline

In late 2020, despite the impacts of the ongoing coronavirus pandemic, and acting on the advice provided by the UKCCC, the UK submitted an ambitious Nationally Determined Contribution (NDC) to the parties signatory to the Paris Agreement and the United Nations Framework Convention on Climate Change. This NDC committed the UK to reducing economy wide greenhouse gas emissions by at least 68% by 2030, compared to 1990 levels.³ This ambition is commensurate with their 2050 target.

Well-being of Future Generations (Wales) Act 2015

The Well-being of Future Generations (Wales) Act further embeds sustainable development into the Welsh planning system. Welsh planning policy seeks to improve sustainability through several measures including promoting a move towards a low carbon economy and encouraging sustainable building standards such as incorporation of renewable and low carbon energy sources.

Future Wales, The National Plan 2040

The Welsh national development framework is a plan for promoting development and change over the next two decades that enhances wellbeing and quality of life in Wales, by shaping places of work, travel, the environment and housing. The plan aims to support:

- A low carbon economy and decarbonisation of industry and the growth of renewable and sustainable energy.
- Growth in innovation.
- Infrastructure development around energy, transport and digital comms.

UKCCC Advice to Welsh Government

In late 2020, the UKCCC presented to Welsh ministers their recommendations on targets and carbon budgets based on the latest evidence and analysis. The latest analysis and evidence supported a recommendation to reduce all GHG emissions to Net Zero by 2050. Further recommendations on targets on the pathway to net zero included interim targets for 2030 and 2040, which were reductions of 63% and 89% respectively. Finally, the committee recommended that the second carbon budget (2021-2025) should be tightened to a minimum reduction of 37%.

The advice stressed, that although good progress had been made in reducing emissions and meeting the first carbon budget, this was almost entirely due to reductions in fossil fuel fired electricity generation. Gaps remain in a cohesive economy wide strategy for 2050, and significant policy progress needs to be made, utilising the full range of devolved and reserved policy levers to deliver emissions reductions other sectors, particularly buildings, industry (manufacturing and construction), transport and agriculture.

Welsh Government policy context

The Environment (Wales) Act 2016⁴ requires the Welsh Government to set targets for reducing emissions of GHGs. When setting emissions targets, the Welsh Senedd (Parliament) considers the

³ The United Kingdom's Nationally Determined Contributions (publishing.service.gov.uk)

⁴ Environment (Wales) Act 2016 (legislation.gov.uk)

UKCCC recommendations, as well as a range of other factors and reports, including the future trends report prepared under provision of the Well Being of Future Generations Act 2015⁵.

The first carbon budget approved by the Senedd was a reduction in GHG emissions of an average of 23% in the period 2016-2020. Although there are no published emissions data from 2019 to 2020, Wales is likely to have met the first carbon budget.

Under the Environment (Wales) Act 2016, the Welsh Government must publish a report for each budgetary period which sets out proposals and policies for meeting that period’s carbon budget. The first of these was delayed, and only published in March 2019. The second, corresponding to the second carbon budget, is due to be published in November 2021.

Net Zero Wales

In March 2021, the Senedd approved a Net Zero target for Wales by 2050, going beyond the previous target of an 80% reduction, set in 2016. In addition, the Senedd approved the second and third carbon budgets, as well as targets for 2030 and 2040. The Senedd also confirmed their ambition in delivering the 2nd carbon budget through action taken within Wales, without relying on international offsets. These developments are summarised in the table below.

Table 1: Targets and Carbon Budgets approved by Senedd Cymru in March 2021⁶

Budget / target date	Target
Carbon budget 2 (2021-2025)	Average 37% reduction
Carbon budget 2 offset limit	0%
Carbon budget 3 (2026-2030)	Average 58% reduction
2030 target	63% reduction
2040 target	89% reduction
2050 target	At least 100% reduction (net zero)

The Senedd has accepted the UKCCC advice and support their conclusions that this ambitious decarbonisation can be delivered at minimal negative cost to the economy, as well as offering co-benefits to societal health through improved air quality, healthier modes of travel and diets, sustainable employment models that promote wellbeing, and more comfortable homes. However, the largest driver of health outcomes in the UK remains economic inequality. Therefore, the Senedd recognises that a just transition is an essential part to any climate policy⁷.

Other government strategies for decarbonisation include securing complete coverage of Wales by electric vehicle and hydrogen refuelling facilities as well as establishing the comparative advantage of hydrogen and marine energy as niche Welsh services in the wider UK and global economies.

Local Government policy context

The Energy Generation in Wales report⁸, published in 2018 outlines the total existing capacity of renewable, nuclear, and fossil fuel electricity generation in Wales. It estimated that at the time of

writing, 50% of electricity consumption came from renewable sources and 778 MW of installed renewable energy capacity was locally owned. The Welsh government has a target of meeting 70% of Wales’ electricity demand from Welsh renewable electricity sources by 2030. In 2017, the principal area of Neath Port Talbot was meeting 75% of its electricity consumption through local renewable generation. It is also the principal area with the highest renewable energy generation in Wales, producing approximately 1,100GWh in that same year. The following local policies are outlined in the Neath Port Talbot County Borough Council Local Development Plan (2011-2026):⁹

- A proportionate contribution to meeting national renewable energy targets and energy efficiency targets will be made while balancing the impact of development on the environment and communities. This will be achieved by:
 - Encouraging where appropriate, all forms of renewable energy and low carbon technology development;
 - Encouraging energy conservation and efficiency measures in all new major development proposals;
 - Ensuring that development will not have an unacceptable impact on the environment and amenity of local residents.
- Schemes that connect to existing sources of renewable energy, district heating networks and incorporate on-site zero / low carbon technology (including microgeneration technologies) will be encouraged.
- According to the Wales Development Plans Update, released in 2019, Neath Port Talbot Council has not yet begun a review for a future local development plan. This is anticipated to commence in 2022.

Policy summary Wales Spatial Plan

Welsh decarbonisation targets and interim carbon budgets are broadly in line with wider UK commitments. Both the UK Government and the Welsh Government have accepted the advice of the UKCCC on the critical need to reach Net Zero by 2050, along with commensurate interim commitments. The route by which this is to be achieved, and across which sectors, has not yet been agreed. Progress so far has been good, due largely on the decarbonisation of the power sector. Policies that enable emissions cuts in buildings, industry, transport, and agriculture will need to be leveraged if interim carbon budgets and the target for 2050 are to be reached. Conditions are geared well for action. There is a clear policy signal from both the UK and Welsh Government, a facilitating energy regulator, committed utilities companies and high public support¹⁰.

The development should align decarbonisation efforts to the carbon budgets approved by the Senedd Cymru which requires a 63% reduction by 2030, 89% by 2040 and 100% by 2050 from 1990 levels. In practical terms this will require the development to prioritise high performance building fabric (see section 4), a high provision of electrified technologies (see section 0) and a maximized provision of renewables.

⁵ Well-being of Future Generations (Wales) Act 2015 (legislation.gov.uk)

⁶ Climate change targets and carbon budgets | GOV.WALES

⁷ The Climate Change (Wales) Regulations 2021: integrated impact assessment | GOV.WALES

⁸ Energy Generation in Wales

⁹ Local Development Plan – Neath and Port Talbot

¹⁰ Net Zero Public Dialogue (publishing.service.gov.uk)

2 Site overview

The geographic location, layout and accessibility of the site are important considerations in developing an energy strategy. This is due to requirements and parameters which can be necessary for certain technologies or make one strategy particularly more effective than another.

Overview

A masterplan of the proposed site is shown in Figure 4. The site comprises of circa 1,800 residential dwellings, a school, a small number of commercial buildings and a potential future metro station which is outside of the site application area. This land is reserved to be delivered by the Welsh Government. The site itself was previously used as an oil refinery and is predominately brown field land with some areas of ecological interest (on the site borders), which may be expanded as part of the development.

The layout shown in Figure 4 shows the northern aspect of the site; another parcel of land exists to the south which is currently undeveloped without any master planning proposals at present beyond the Local Development Plan (LDP) allocation. This assessment has excluded the ‘south site’ at present. This assessment has also excluded any energy consumption associated with the potential metro station, as it is assumed to be a small local station with only a simple shelter, lighting and potential ticket machine.



Figure 4: Illustrative site masterplan (source: Powell Dobson 17/09/2021)

New buildings

The site will include a mix of different building typologies which are predominately residential units. Table 2 lists the different typologies and the indicative quantity of each type, their assumed gross internal area (GIA) and total area across the site.

Table 2: Breakdown of new buildings

Building typology	Quantity	Area per unit (GIA) (m²)	Total area (GIA) (m²)
1b flat	130	39	5,070
2b flat	120	70	8,400
2 bed	420	79	33,180
3 bed	724	93	67,332
4 bed	390	121	47,190
School	1	1938	1,938
Commercial units	1	935	935

Phasing

The development is anticipated to be delivered over 13 years from 2024 to 2036 with an increasing rate of delivery over the first three years before a consistent 150 units are delivery each year (see Table 3).

Table 3: Phasing proposal

Year	Residential units per year*
2024	35
2025	124
2026	124
2027	150
2028	150
2029	150
2030	150
2031	150
2032	150
2033	150
2034	150
2035	150
2036	150

*The phasing proposal is based on the housing trajectory that was presented to the local authority prorated to reflect the updated number of total dwellings.

Infrastructure capacities

The new development will join onto an existing development of dwellings delivered as part of the previous outline planning application. The previous outline planning permission allowed for a total

of 728 flats, 2970 houses and 18 commercial units and the original utilities application¹¹ was based on this completed scale.

The original application stated that the gas supply will be capable of feeding 4000 domestic plots and 18 commercial units with the pressure regulating installation (PRI) having the capacity to supply 900 plots. The electrical supply will have a capacity for 4000 domestic units and an additional 11kV and substations will be installed in next phases.

This assessment has assumed that the referenced application was delivered as part of the first phase of dwellings and no further searches have been completed. On this basis, Table 4 provides the capacity used by the existing dwellings and the remaining capacity for the proposed development.

Table 4: Utility capacity

Scale	Peak gas capacity	Peak electricity capacity	Gas annual consumption	Electricity annual consumption
	kW	kVA	kWh	
Phase 1 - 302 dwellings	13,505	473	5,267,211	1,100,800
Total development	45,543,578	7,642	45,543,578	17,371,180
Capacity remaining	45,530,073	7,169	40,276,367	16,270,380

Topography

The site is generally uneven and significant earthworks will be required as part of the development enabling works. The finished site will have a slope from the north to the south, which will increase the risk of overshadowing and could increase the amount of pumping power if a heat network was considered. Other features, such as the retaining wall, will also present a risk of overshadowing and further detail on this can be found in the Coed Darcy Passive Design Guiding Principles report (see Appendix B).

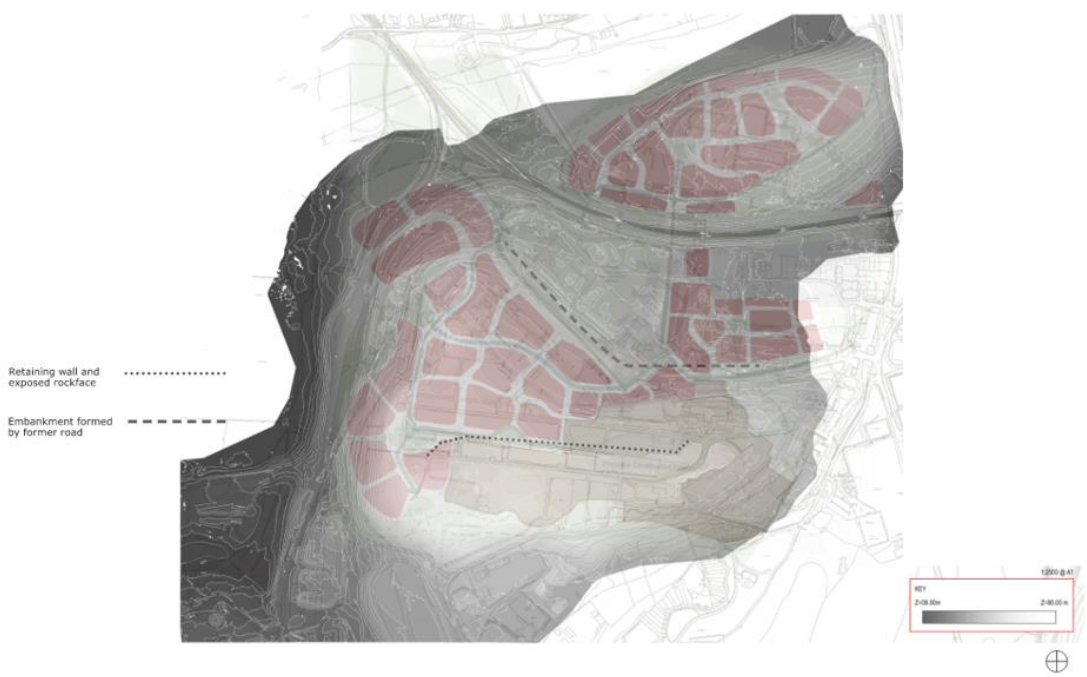


Figure 5: Site layout over laid on a site levels map

Ground conditions

Ground conditions across the site are highly variable due to the site’s topography and because of its historical uses which required demolition, remediation and earthworks. The presence and thickness of made ground and depth to bedrock can vary significantly within short distances due to the quarrying and rock break out during construction of the refinery (see Figure 6). Understanding the composition of the ground will inform how the energy strategy is developed and highlight any issues for certain technologies e.g. shallow bed rock will increase the difficulty of excavating ground to lay pipe networks and any other technologies that require underground works.

Made Ground and natural soils at the site are variable in composition, including both granular and cohesive material. Instances of instability have been observed during previous ground investigations and is normally associated with groundwater strikes (granular material that becomes saturated with water and will be unstable and can result in the collapse of exploratory holes).

¹¹ SSE Utility Solutions Coed Darcy phase 1a-1b-1c & remaining phases Ref:807/322281Rev10

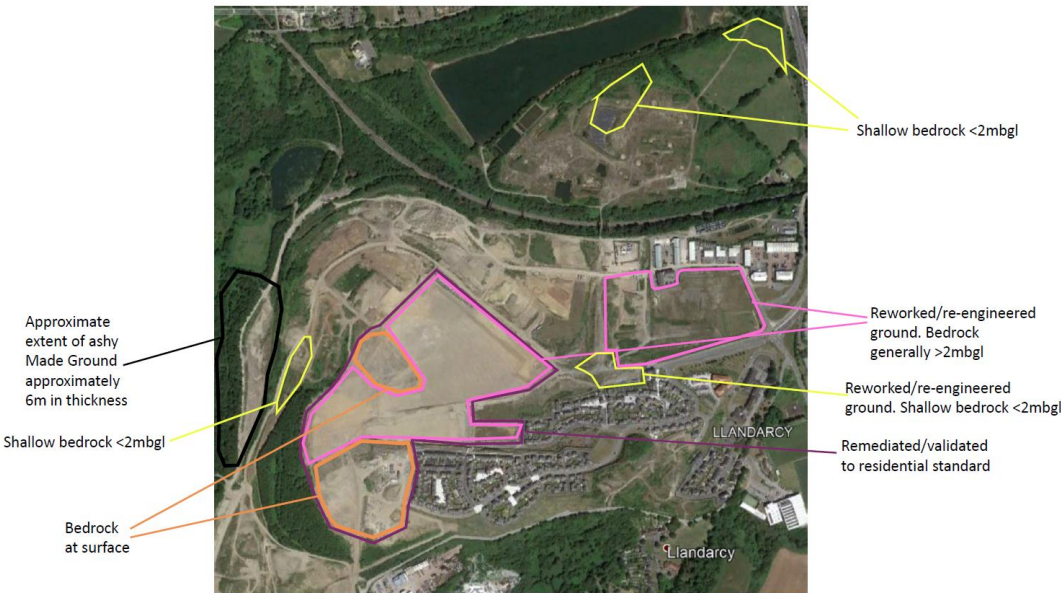


Figure 6: Site plan with ground conditions detailed (source: PJA)

Contamination

The use as a former oil refinery has resulted in residual contamination in shallow soils, bedrock and groundwater with varying amounts of remediation already completed. In some areas the remediation involved removal of gross contamination only, such as oil-saturated soils and free-phase hydrocarbons, whilst in other areas remediation was completed to a base standard.

The site will require further remediation as part of the proposed development which is likely to include some source removal (excavation and capping of contaminated soils). Contaminants in Made Ground soils and natural soils are likely to include asbestos, metals, and organic compounds such as polycyclic aromatic hydrocarbons, petroleum hydrocarbons and chlorinated solvents. The nature of the sandstone bedrock underlying the site means that residual free-phase hydrocarbons are present in fractures, but in insufficient volumes to enable recovery. As noted above, certain technologies will require excavation of ground to install and where these technologies are recommended as part of the energy strategy, future consideration should be made around the issues highlighted on contamination.

3 Methodology

The study

We have taken a whole systems approach to modelling the energy use at Coed Darcy. This includes looking at future changes including: the decarbonisation of the electricity grid, the potential of using hydrogen and the impact of electric vehicle demand.

An overview of the approach used in this study is presented in Figure 7. The study aims to review several relevant technologies against the development and its energy needs. A shortlist of technologies will then undergo whole systems techno-economic modelling. This informs the development of an energy strategy to meet the demands of the development in a cost efficient, secure, and sustainable way.

The energy hierarchy

The ‘Energy Hierarchy’, presented in Figure 8, typically prioritises minimising energy demand as the most cost-effective solution to improving energy sustainability. The next step is to meet energy demands efficiently through effective design and specification of building services and system controls to facilitate efficient operation. To ensure sustainability, the energy which it is not possible to save using the solutions should be provided using renewable energy.

Opportunities for the design team to explore to minimise energy demand have been outlined in the ‘Energy reduction’ section.

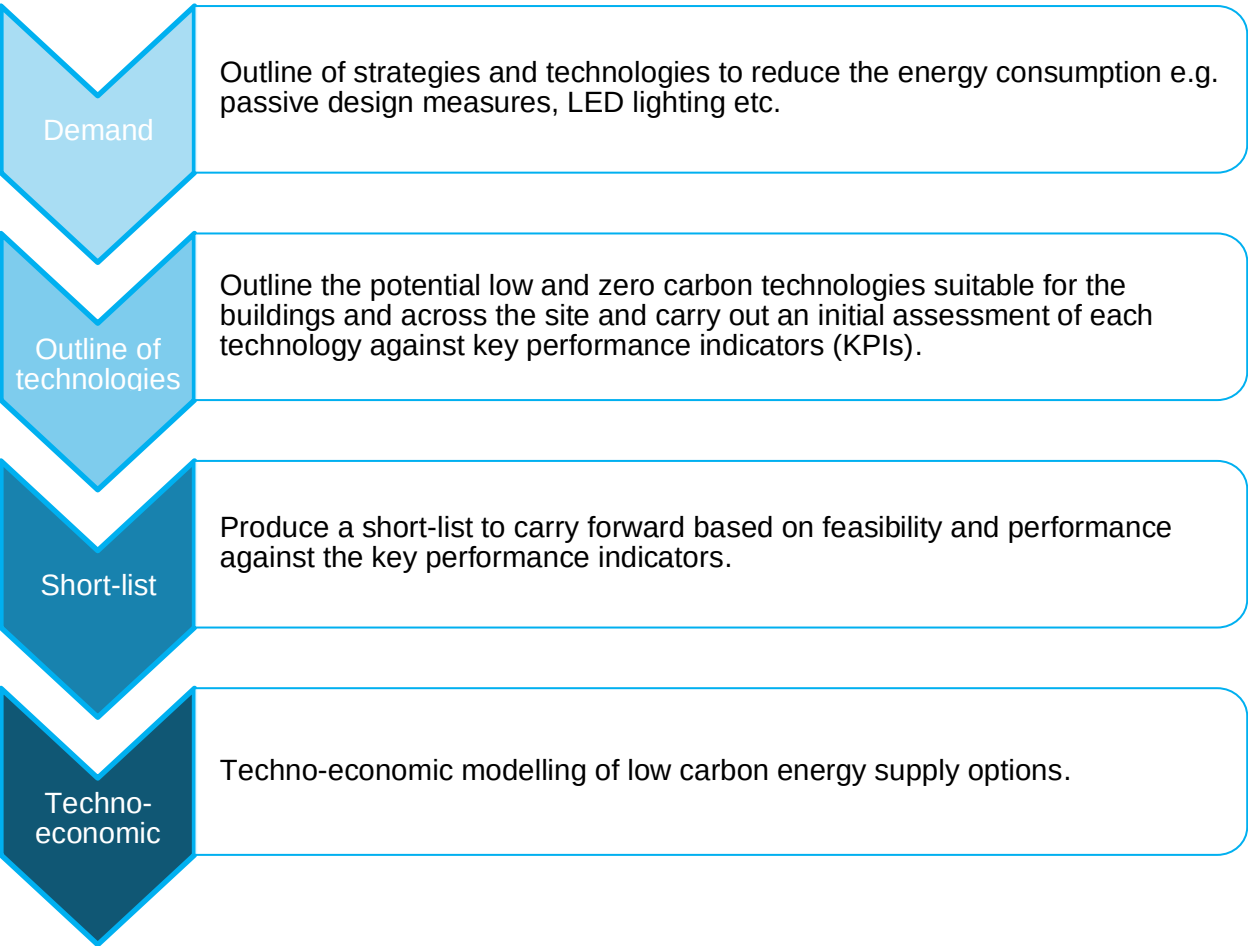


Figure 7: Overview of methodology

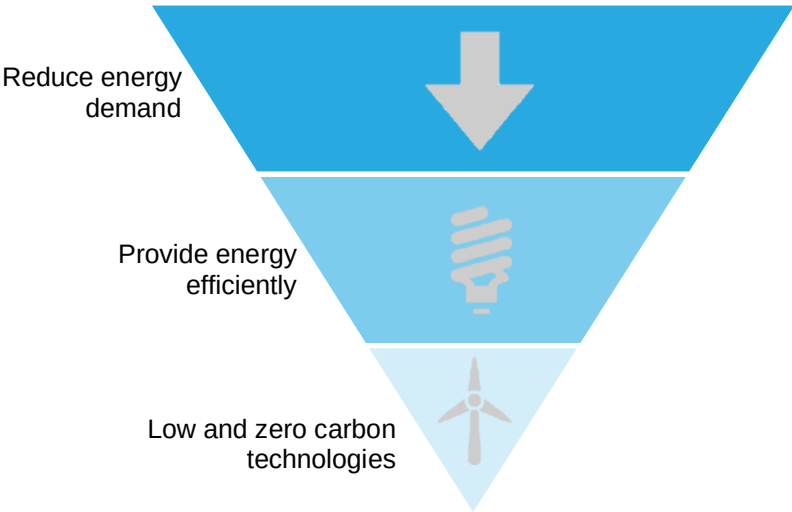


Figure 8: Energy hierarchy

4 Demand assessment

The following section provides an overview of the different energy demands anticipated across the site. This will inform the different technology options required to meet the estimated demands. The main energy demands for the Coed Darcy development can be grouped as building heating (space and DHW), other building energy consumption (electrical) and electric vehicle charging demands.

Reducing building demand

The aim is to deliver a low carbon development with buildings and residential properties that have low energy demands. Reducing demand is largely driven by passive design measures which are heavily influenced by master plan layout, site topography and plot orientation and form. As part of the master plan development, a ‘passive design guiding principles’ document was fed into the design process to maximise any potential passive design (see Appendix B).

Once layouts and plot orientations are fixed, demand can be reduced through a ‘fabric first’ approach, where insulation and air tightness are maximised to reduce heat loss from the building and ultimately reduce heating demand. Part L1A sets standard for the conservation of fuel and power in dwellings. The standard is currently under consultation for an imminent update this year and a further update in 2025. The proposed changes will require a regulated carbon emission saving of approximately 30% and 75% on the current standard. Table 5 provides an example of what the typical U-values and air permeability standards are for a compliant building today, and compares this to a set of standards which would achieve an approximate carbon saving of 75%. The proposed standards are the upper limit of current best practice and align to the requirements set by the passivhaus standard.

Table 5: Impact of high performing fabric (based on a two bed house)

Building element	Units	Part L1A 2014 ¹² performance values	Proposed performance values to meet Part L 2025	Passivhaus limiting criteria
------------------	-------	--	---	------------------------------

¹² Building Regulations Part L and F Review - Changes to Part L (conservation of fuel and power)

U-values	Roof	W/m²K	0.13	0.1	0.15
	External walls		0.18	0.13	0.15
	Floor		0.13	0.08	0.15
	Windows		1.4	0.8 (triple glazing)	0.8
	Door		1	1	-
Air permeability		m³/hm² @ 50pa	5 (0.4 ac/h)	0.6 (0.07 ac/h)	0.6 (0.07 ac/h)
Heating source		-	Gas fired boiler (90% efficient)	Air source heat pump (COP 2.5)	-
Regulated carbon saving from 2014 standard		%	-	75	
Annual heating load		kWh/m²	-	-	15

With construction planned for 2024 the development should aspire to meet the 2025 target (as outlined in Table 5). This table also demonstrates how these target values are within the limiting criteria for Passivhaus standard, meaning this standard could be used as a reliable framework for creating an energy efficient development. The following demand assessment and subsequent analysis is based on the proposed 2025 performance requirements.

Electric vehicle (EV) demand

To future proof the energy strategy, we have assumed that all homes will have one EV. This allows us to consider the electricity load, and whether it meets the infrastructure capacities provided by SSE Utility Solutions.

Demand summary

Table 6 provides a summary of the different estimated energy demands of the development. The heat and electricity demand of the development will vary over the course of the day, month and year. Figure 9 provides comparison between a typical day for summer and winter. As expected, the heating demand in winter is greater than summer with the electricity and EV demands relatively unaffected by seasonality. Energy demand is assumed to be the same under the 2025, 2050 and BAU – low scenarios with an increase under the BAU – high scenario associated with a drop in fabric performance (2014 values in Table 5).

Table 6: Summary of development demands

Total annual demands		Scenarios	
		2025, hydrogen feasibility 2050 and conventional low demand	Conventional high demand
Annual electricity consumption	kWh	4,830,000	4,830,000
Annual heating consumption		8,961,000	12,730,000
Annual EV consumption		2,356,000	2,356,000

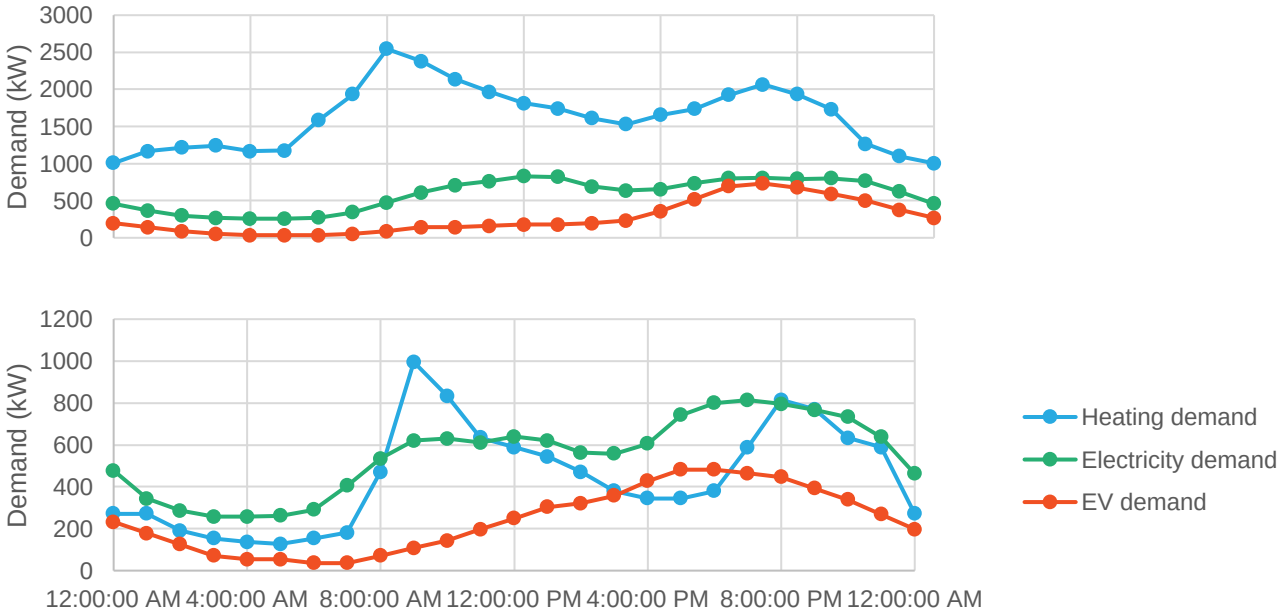


Figure 9: Typical daily profiles for winter (top) and summer (below)

5 Low and zero carbon technologies

To explore the different low and zero carbon energy solutions for the site, a wide range of different technologies have been considered. These technologies can be grouped by means of their energy delivery; electricity, heat or both and are listed in Table 7 below:

Table 7: Long list of technologies considered for the site

Technology	Energy delivery
Solar PV - ground	Electricity
Solar PV - building integrated	Electricity
Solar PV - floating	Electricity
Wind - onshore	Electricity
Hydro	Electricity
Biomass boilers	Heat
Heat pumps – ground source heat pump (GSHP), water source heat pump (WSHP) and air source heat pump (ASHP)	Heat
Energy from mine water / sewer (utilising heat pump)	Heat
Hydrogen ready boiler	Heat
Resistance heating (electric radiators)	Heat
Solar thermal	Heat
Combined heat and power (CHP) gas, hydrogen and biomass	Both
Deep geothermal	Heat or electricity

5.1 Our approach

Our approach to carrying out the comparison consisted of a primary screening process using a pass / fail criteria on key performance indicators (KPIs), to sift any technologies not suitable for the site

and a techno-economic modelling analysis using a python based linear optimisation tool on all the technologies that passed the initial sifting process.

Key performance indicators

The KPI assessment allows unsuitable technologies to be excluded from any further analysis and the KPIs developed for Coed Darcy are:

1. Spatial and access requirements – Is there sufficient space and access to implement the solution including any ancillaries and storage?
2. Fuel / power source – Is the fuel / power source required for operation in the study area or its vicinity?
3. Carbon emissions – Does the technology facilitate (or contribute towards) a low or zero emissions development now or in the future?

5.2 Primary screening

1. Spatial and access requirements – Is there sufficient space and access to implement the solution including any ancillaries and storage?

Technologies that failed KPI 1	Explanation
Solar PV - ground	A ground mounted PV array requires a large area of land and this is not available within the red line boundary.
Solar PV - floating	A floating PV array requires a body of water. Options were explored to use the ponds / lakes to the north west of the site but these are of ecological interest and no other suitable locations were present on the site.
Wind - onshore	There is insufficient free space to locate wind turbines on the site and the proximity of houses would mean any potential location would be unsuitable.
Hydro	There is no hydro source in the vicinity of the site.
Biomass boilers	Biomass boilers require substantial storage space and access routes, neither of which are available on the site.
Solar thermal	Solar thermal is a competing technology with solar PV and solar PV is the preferred option on cost and carbon saving potential.
CHP biomass	See explanation for biomass boilers.
Deep geothermal	A large site, away from residential development is required for deep geothermal. Hence, the Coed Darcy development is not suitable.

2. Fuel / power source – Is the fuel / power source required for operation in the study area or its vicinity?

Technologies that failed KPI 2	Explanation
WSHP	The site does not have a suitable body of water within close enough proximity to enable a WSHP to be a feasible solution.

Energy from mine water / sewer (utilising heat pump)	No known locations of suitable sewers or mines are in close vicinity to the site - this technology is discounted.
--	---

3. Carbon emissions – Does the technology facilitate (or contribute towards) a low or zero emissions development now or in the future?

Technologies that failed KPI 3	Explanation
Gas CHP	The use of a gas CHP ties the development to the use of fossil fuels with no ability to decarbonise hence, this does not align to the net zero aspiration of the development.

Following the primary screening process the following technologies have passed the three KPIs and will be analysed further:

- Building integrated PV
- GSHP
- ASHP
- Hydrogen ready boiler
- Resistance heating
- Hydrogen fuel cell CHP

5.3 Energy delivery

Energy delivery method is relatively independent of which energy generation technologies are deployed as part of the energy strategy. The delivery method defines how energy is distributed across the site. For example, energy could be generated at a central energy centre and distributed across the site, alternatively more ‘local’, building-specific, technologies may be deployed to supply solely the building that it is associated with, or it could be connect to a form of site wide network/grid.

District heat network

A district heat network works by distributing heat to many different buildings or processes from a centralised source. The heat can be supplied by several on-site sources including boilers, CHP units, heat pumps and off-site sources such as waste heat from industrial processes or mine water.

At an early stage the feasibility of a site for the application of a heat network can be assessed on the density of dwellings. As a guide, the number of dwellings per hectare should be 50 to make a heat network financially viable. This is based on the likely energy demand and cost of installing the network. The Coed Darcy development has on average 44 dwellings per hectare and is targeting a lower heating demand than standard practice. Both these factors reduce the viability of a heat network and hence, the application of a heat network has not being explored any further in this strategy.

6 Techno-economic assessment of technologies

We used our suite of whole energy systems modelling tools to model the energy system for Coed Darcy. We used linear optimisation to assess the solution that had the lowest cost and carbon objectives in 2025 and 2050. The tool inputs include:

- Demand files – heat (space and DHW), electricity and EV charging
- Solar irradiation files
- Capital costs (capex)
- Operating (or maintenance / management) costs (opex)
- Operational carbon
- Other technical inputs for each technology, or storage component such as:
 - Efficiency
 - Life expectancy

We modelled the supply and storage of heat, power and electricity on an hourly basis in order to optimise the system for lowest cost and carbon. The ratio of optimisation for cost vs carbon can be weighted i.e. you can create bias in the model to create a lower carbon solution with higher costs. The model then outputs how and when each technology should operate in the optimised system.

6.1 Sizing constraints

To account for technical, site and project specific constraints, caps can be placed on certain parameters for different technologies within the model. Table 8 shows the different caps placed on technologies for the Coed Darcy energy model.

Table 8: Model constraints

Technology	Constraint	Units
Roof mounted PV*	40,000	m ²
Electricity grid connection	7,100	kVA
Gas network connection	45,530,000	kW

*The total roof space for the development, based on houses being two storeys and flats being four storeys is 80,000m². A spacing factor of 50% has been applied to account for PV spacing and unsuitable roof space hence, a limit of 40,000m² has been applied to the model for available area of roof mounted PV. The model assumes that all roofs face south, have no over shading and can support PV.

6.2 Modelling scenarios

We wanted to understand the impact of grid decarbonisation and the future potential of using hydrogen to heat the homes at Coed Darcy. To do this, two scenarios were created: ‘2025’ and a ‘hydrogen feasibility 2050’.

The hydrogen feasibility 2050 scenario aimed to assess the future potential of using hydrogen to heat the homes on the development by modelling the same development but in a 2050 setting, where natural gas had been switched to hydrogen and the grid had significantly decarbonised.

The hydrogen feasibility 2050 scenario is not a projection of the 2025 model or a proposal to retrofit certain technologies in the future, but an exploration of how the development could be delivered in 2025 with the option of using hydrogen in the future. For example, if the optimised solution for heating the development in 2050 is boilers using hydrogen, a potential solution may be the use of hydrogen ready boilers that use natural gas till the network is switched to hydrogen at some date in the future.

2025

For the 2025 scenario the hydrogen fuel cell CHP was excluded and the hydrogen ready boilers were fuelled using natural gas. The technologies analysed were photovoltaics (PV), air source heat pumps (ASHPs), ground source heat pumps (GSHPs), hydrogen ready gas boilers, batteries, grid connected electricity and gas, resistance heating.

Hydrogen feasibility 2050

For the 2050 scenario all technologies were included and the hydrogen ready boilers were fuelled by hydrogen. This scenario also accounted for an electricity grid that had significantly decarbonised.

Table 9: Analysed technologies

Technology	2025	Hydrogen feasibility 2050
Solar PV - building integrated	✓	✓
Heat pumps – GSHP and ASHP	✓	✓
Hydrogen ready boiler	✓ (gas)	✓ (hydrogen)
Resistance heating (electric radiators)	✓	✓
Hydrogen fuel cell CHP	✗	✓

To compare the cost and carbon emissions of both optimised solutions to a more conventional solution, a baseline scenario was developed. This used gas fired boilers for heating with no LZC technologies. To provide an upper and lower boundary on the baseline scenario two options were developed:

- Conventional low demand – which uses the 2025 building standards (see Table 5)
- Conventional high demand – which uses the current building standards for building regulation compliance (see Table 5)

6.3 Results

Figure 10 details the technology mix for each scenario which highlights the following:

- That the use of hydrogen does not factor into the optimised (for cost and carbon) technology mix when assessed under a 2050 scenario.
- A decarbonised grid favours a greater capacity of ASHPs and resistance heating over GSHPs.
- The capacity of PV (and supplementary batteries) also reduces under a decarbonised grid.

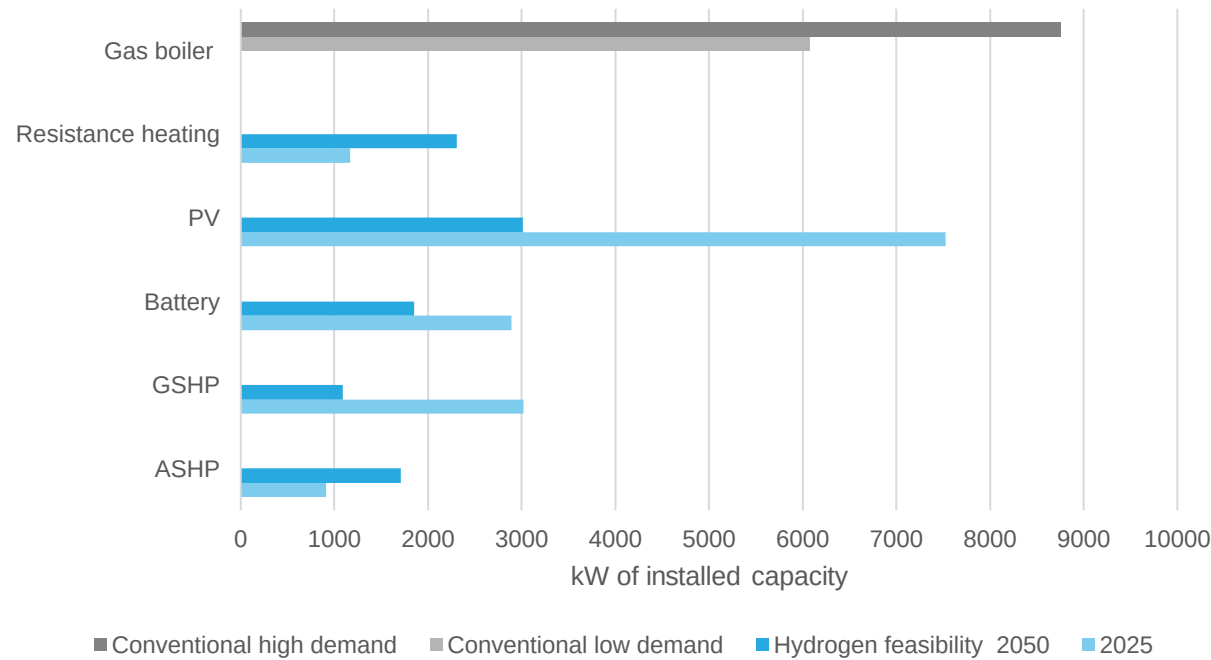


Figure 10: Installed capacity of different technologies under the four scenarios

The two optimised solutions demonstrate a significant 25 year reduction in carbon emissions compared to both options of the baseline scenario with the 2025 solution providing the lowest emissions over a 25 year period (see Figure 11).

In the context of the Welsh Government 2050 net zero target, a key factor is the annual emissions in 2050. Table 10 shows that the annual emissions for each scenario. The annual emissions for both optimised solutions are significantly lower than the baseline with the annual emissions for the 2025 and hydrogen feasibility 2050 scenarios being 15 and 31 tCO₂e respectively.

The 2050 annual emissions are based on a conservative grid decarbonisation scenario and should the grid decarbonise further or to fully net zero (as predicted in some forecasts) the development will fully decarbonise owing to it being fully electric in both optimised solutions. This would not be the case is gas boilers were used.

Table 10: Annual emissions comparison

Date		2025	Hydrogen feasibility 2050	Conventional low demand	Conventional high demand
2025 annual emissions	tCO ₂ e	470	1,000	3,600	4,400
2050 annual emissions		15	31	2,000	2,800

To understand the cost of the different options the levelised cost of energy (LCOE) of each scenario is calculated. The LCOE provides a measure of the net present cost of energy generation for a technology over its lifetime (capital, operational and replacement costs) and normalises for the required energy demand. This allows different technologies and systems to be compared on a consistent basis.

$$LCOE \text{ (£/kWh)} = \frac{\text{Net present value (£)}}{\text{Total enrgy demand (kWh)}}$$

For the two optimised solutions, the 2050 solution provides a marginally lower LCOE which is due to a switch from GSHPs to ASHPs and resistance heating, and a lower capacity of batteries and PV. The LCOE is higher for both baseline options. Hence, both optimised scenarios provide a cost and carbon saving over a conventional solution.

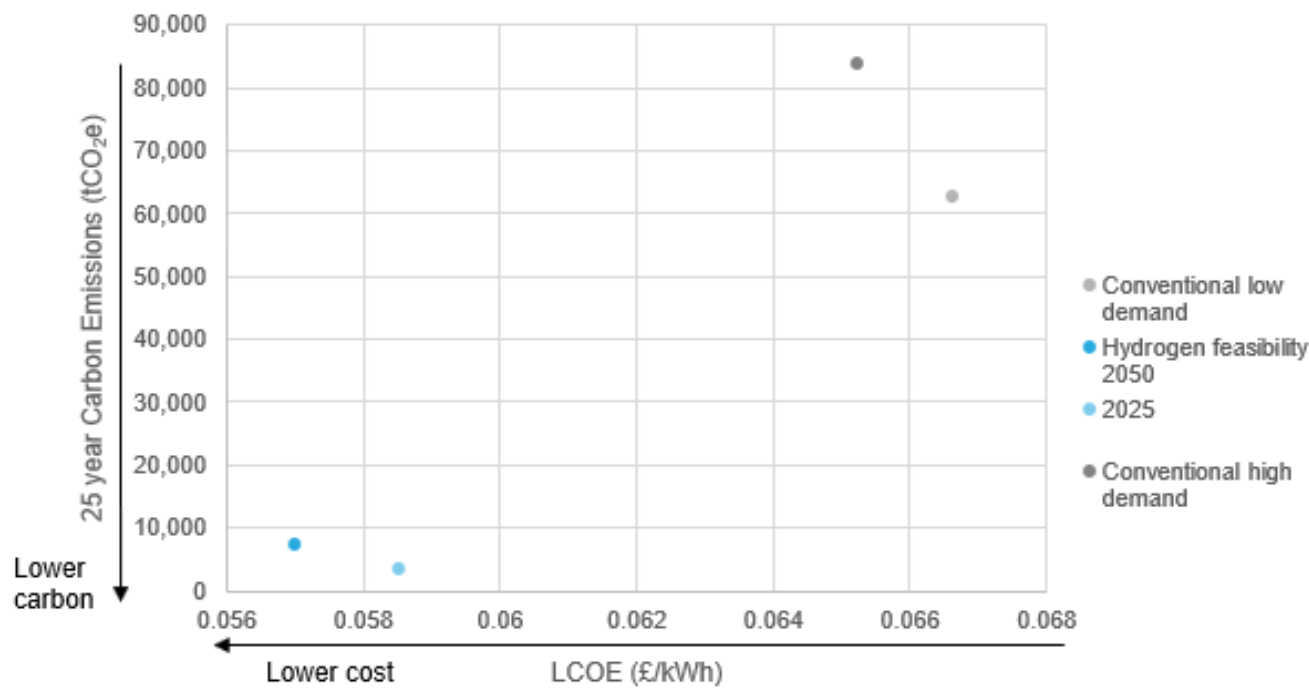


Figure 11: Comparison of LCOE and 25 year carbon emissions for the different scenarios

The following Sankey diagrams show the annual energy flows for the 2025 and 2050 scenarios. A large proportion of the energy comes from PV (with battery storage (the battery out is charging the battery and the battery in is using the battery at other times of day)), and a smaller proportion coming from the grid. The electricity is either used for EVs, electricity demand or to provide heat via GSHPs or ASHPs with a small amount of top up resistance heating (likely to be within the heat pump / immersion tank).

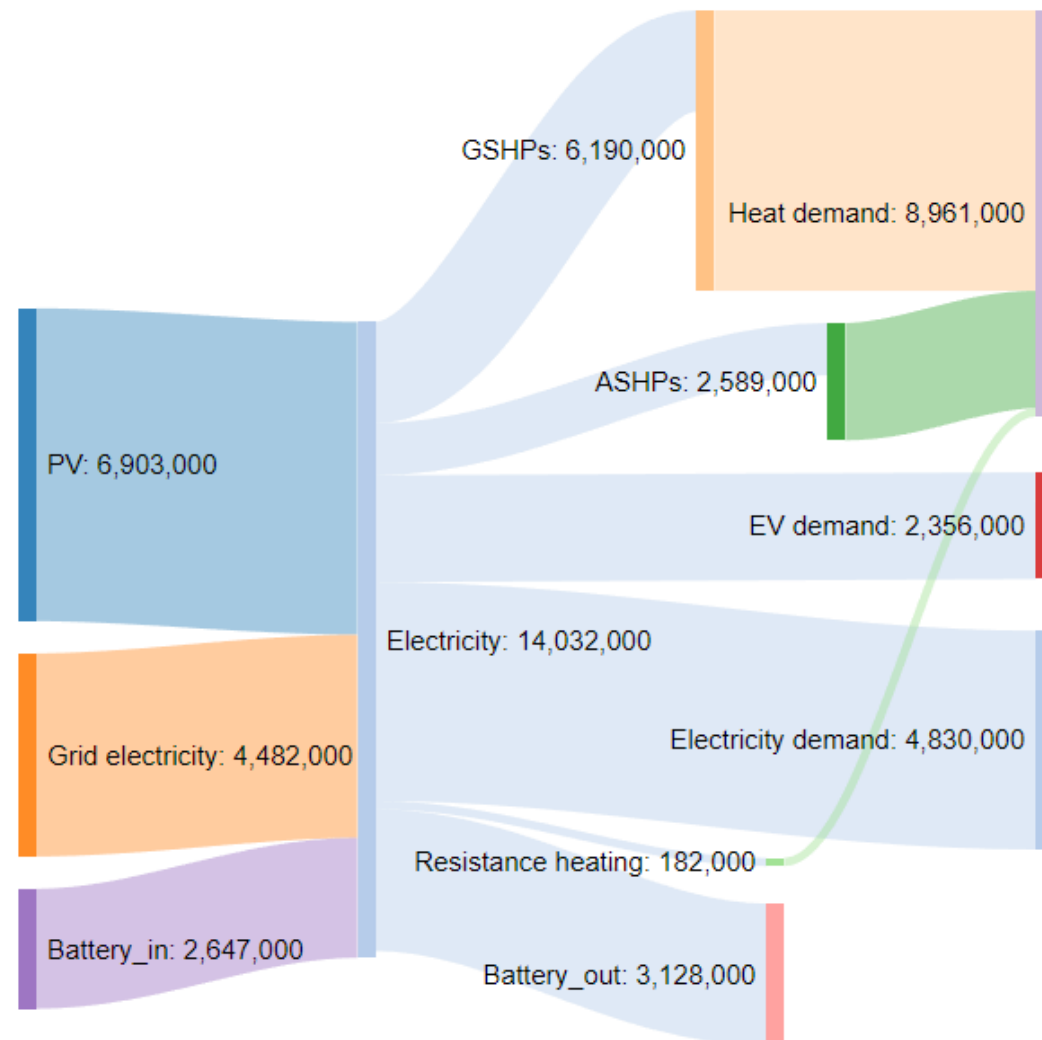


Figure 12: Sankey diagram to show energy flows in the 2025 optimised system (kWh/year)

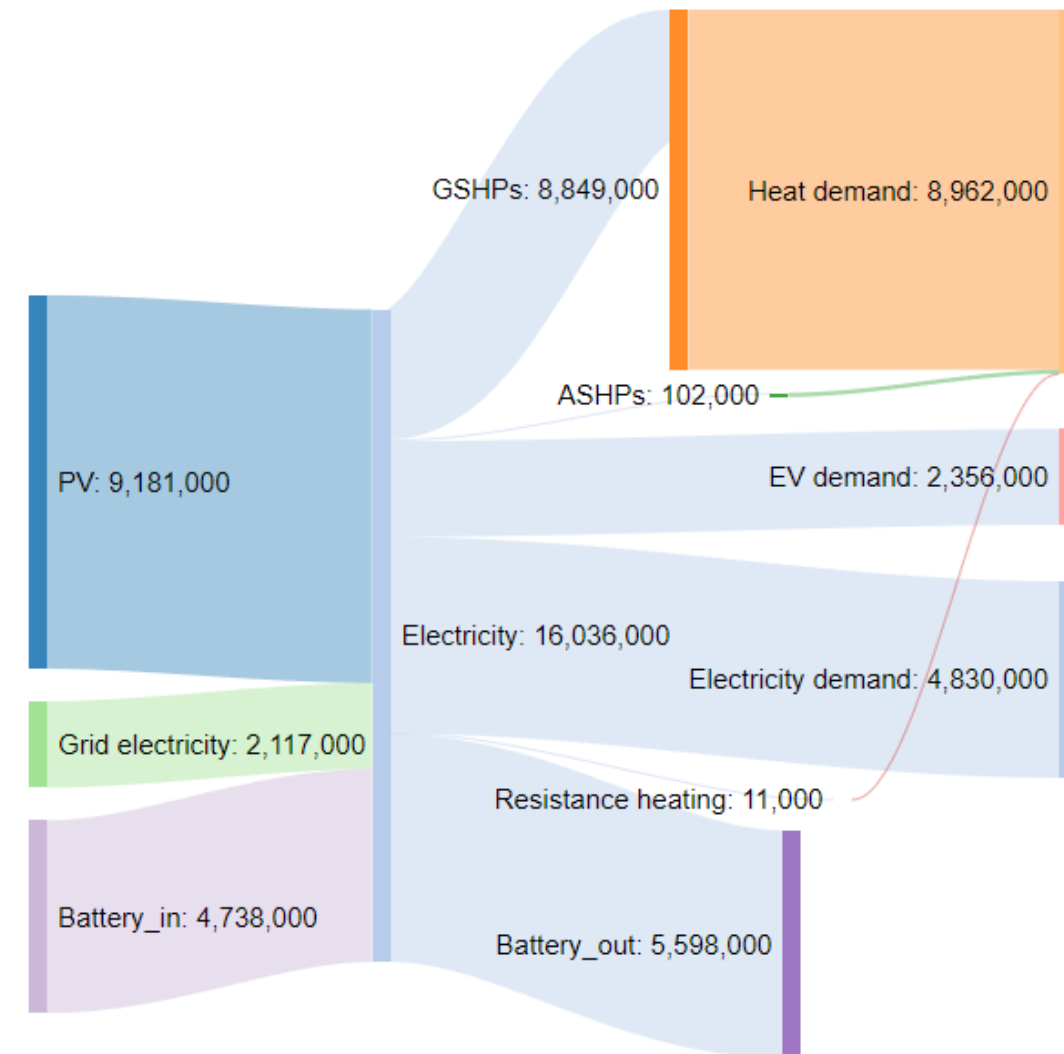


Figure 13: Sankey diagram to show energy flows in the hydrogen feasibility 2050 optimised system (kWh/year)

7 Recommendations and next steps

7.1 Recommendations

We recommend that the energy strategy for Coed Darcy prioritises the following:

- Set targets on building carbon emissions and energy demands** – Set the development aspirations for energy demand and carbon emissions for each building typology. This should include carbon targets for 2025 and 2050 which align to Welsh Government and local council policy.
- Maximise passive design measures** – Maximise the impact of passive design measures such as building layout and orientation, as detailed in Appendix B.
- High performance fabric** - The development should align performance standards to the 2025 values detailed below.

Table 11: Fabric performance targets

Building element		Units	Proposed performance values to meet Part L 2025
U-values	Roof	W/m²K	0.1
	External walls		0.13
	Floor		0.08
	Windows		0.8 (triple glazing)
	Door		1
Air permeability		m³/hm² @ 50pa	0.6 (0.07 ac/h)

- Maximise GSHPs** – Maximise the use of GSHPs wherever feasible, using ASHPs where this is not possible.
- Maximise roof mounted PV** – Incorporate PV on viable south facing roofs.
- Encourage use of EVs** - consider in home battery storage.

7.2 Next steps

To enable further assessment into the viability of this strategy, we recommend that the following steps are taken forward in the detailed design stages of the development:

- Use the passive design guiding principles and 2025 standards to design the building fabric and orientations of buildings within plots.
- Undertake PV assessments on the building types across the development.
- Undertake a detailed feasibility study into the use of GSHPs across the site to understand if any areas of the site are unsuitable due to issues with shallow bedrock and / or and ground contamination. Consider options such as shared ground loop arrays.
- Consider batteries storage to store electricity generated from the building’s renewable energy supply or to export energy from the grid during low peak times.
- Further investigation should be done on the existing utilities capacities, including a review of any utility mark ups to develop connection plans.
- Updating the overall programme with the phasing of technologies for instance GSHP boreholes/arrays would need to be undertaken before landscaping depending on suitable locations for boreholes/arrays to be laid.

Appendix A

Assumptions Log

Table 12: Assumptions log

Technology	Factor	Assumption	Units	Reference
Grid power	Lifespan	99	Years	Assumed no limit grid connection life.
Grid power	Capacity	7,169	kW installed	Cap on capacity based on the existing utilities infrastructure (see section 7).
Grid power	Opex	0.1128	£ / kWh	BEIS 2019 Updated Energy and Emissions Projections. Annex M. https://www.gov.uk/government/publications/updated-energy-and-emissions-projections-2019 - 2020 industrial price.
Grid power	Capex	7.05	£ / kW	Based on SSE Utility Solutions quote.
Grid power	Operational carbon factor	0.1482	kgCO ₂ e / kWh	FES 2020 Data workbook SV.27: Power sector carbon intensity https://www.nationalgrideso.com/future-energy/future-energy-scenarios/fes-2020-documents . Note that this is very different to BEIS - which puts the number at 0.23314 kgCO ₂ e/kWh.
Natural gas supply	Lifespan	99	Years	Assumed no limit gas connection life.
Natural gas supply	Capacity	45,530,073	kW installed	Cap on capacity based on the existing utilities infrastructure (see section 7).
Natural gas supply	Opex	0.021	£ / kWh	BEIS 2019 Updated Energy and Emissions Projections. Annex M. https://www.gov.uk/government/publications/updated-energy-and-emissions-projections-2019 .
Natural gas supply	Capex	7.6	£ / kW	Based on SSE quote.
Natural gas supply	Operational carbon factor	0.18316	kgCO ₂ e / kWh	Gross CV 2021 - UK Government GHG Conversion Factors for Company Reporting.
Hydrogen supply	Lifespan	99	Years	Assumed no limit hydrogen connection life.
Hydrogen supply	Opex	0.18	£ / kWh	£6/kg is a standard price from suppliers including Ryse Hydrogen, converted to £/kWh.
Hydrogen supply	Capex	7.6	£ / kW	Based on gas capex.
Hydrogen supply	Operational carbon factor	0.0072	kgCO ₂ e / kWh	Shipping costs for hydrogen import.
Rooftop PV	Lifespan	25	years	BEIS Electricity Generation Costs (2020) - GOV.UK (www.gov.uk)
Rooftop PV	Capacity	40000	m2	Based on available roof area see section 6.
Rooftop PV	Efficiency	0.209	(fraction)	Solarsense quote
Rooftop PV	Capex	955.5	£ / kW	BEIS Electricity Generation Costs (2020) - GOV.UK (www.gov.uk)
Rooftop PV	Opex	0.008	£ / kWh generated	BEIS Electricity Generation Costs (2020) - GOV.UK (www.gov.uk)
Resistance heating	Lifespan	15	years	https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/831079/Electric_heating_options_in_off-gas_grid_homes.pdf
Resistance heating	Efficiency	1	(fraction)	Direct electric heating is 100% efficient.
Resistance heating	Capex	60	£ / kW	From Gleeds.
Resistance heating	Opex	0	£ / kWh generated	https://www.climateexchange.org.uk/media/1897/electrification_of_heat_and_impact_on_scottish_electricity_system_-_final_report1.pdf
ASHP	Lifespan	15	years	Danish Energy Agency (2018) Technology Data for Individual Heating Plants. https://ens.dk/en/our-services/projections-and-models/technology-data/technology-data-individual-heating-plants
ASHP	Efficiency	2.25	(fraction) (COP)	ASHP COP based on 52/45oC LTHW circuit
ASHP	Capex	350	£ / kW	From Gleeds
ASHP	Opex	0.00052	£ / kWh generated	From Gleeds.
GSHP	Lifespan	20	years	Danish Energy Agency (2018) Technology Data for Individual Heating Plants. https://ens.dk/en/our-services/projections-and-models/technology-data/technology-data-individual-heating-plants
GSHP	Efficiency	2.77	(fraction)	https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/606818/DECC_RHPP_161214_Final_Report_v1-13.pdf

Technology	Factor	Assumption	Units	Reference
GSHP	Capex	800	£ / kW	From Gleeds.
GSHP	Opex	0.00108	£ / kWh generated	From Gleeds.
Hydrogen boiler	Lifespan	15	years	Currie & Brown and AECOM for CCC (2019) The costs and benefits of tighter standards for new buildings. https://www.theccc.org.uk/publication/the-costs-and-benefits-of-tighter-standards-for-new-buildings-currie-brown-and-aecom/
Hydrogen boiler	Efficiency	0.84	(fraction)	As gas boilers.
Hydrogen boiler	Capex	90	£ / kW	Imperial College London for CCC (2018) Analysis of alternative UK heat decarbonisation pathways. https://www.theccc.org.uk/publication/analysis-of-alternative-uk-heat-decarbonisation-pathways.
Hydrogen boiler	Opex	3.6	£/kW/year	Imperial College London for CCC (2018) Analysis of alternative UK heat decarbonisation pathways. https://www.theccc.org.uk/publication/analysis-of-alternative-uk-heat-decarbonisation-pathways.
CHP hydrogen fuel cell	Capex	2094	£ / kW	https://www.energy.gov/sites/prod/files/2016/07/f33/fcto_battelle_mfg_cost_
CHP hydrogen fuel cell	Opex	14.2	£/kW/year	https://www.energy.gov/sites/prod/files/2016/07/f33/fcto_battelle_mfg_cost_
CHP hydrogen fuel cell	Lifespan	15	years	https://www.2-g.com/en/hydrogen-chp/
CHP hydrogen fuel cell	Heat efficiency	0.42	(fraction)	https://www.2-g.com/en/hydrogen-chp/
CHP hydrogen fuel cell	Electricity ratio	0.95	(fraction)	https://www.2-g.com/en/hydrogen-chp/
Battery	Efficiency	0.92	(fraction)	https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/910261/storage-costs-technical-assumptions-2018.pdf
Battery	Lifespan	15	years	Mott MacDonald for BEIS (2018) Storage cost and technical assumptions for BEIS. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/910261/storage-costs-technical-assumptions-2018.pdf
Battery	Capex	480.3	£ / kW	Mott MacDonald for BEIS (2018) Storage cost and technical assumptions for BEIS. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/910261/storage-costs-technical-assumptions-2018.pdf 50MW Frequency Management batter
Battery	Opex	7.3	£ / kW / year	Mott MacDonald for BEIS (2018) Storage cost and technical assumptions for BEIS. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/910261/storage-costs-technical-assumptions-2018.pdf 50MW Frequency Management batter
Hydrogen boiler in gas mode	Lifespan	15	years	Currie & Brown and AECOM for CCC (2019) The costs and benefits of tighter standards for new buildings. https://www.theccc.org.uk/publication/the-costs-and-benefits-of-tighter-standards-for-new-buildings-currie-brown-and-aecom/
Hydrogen boiler in gas mode	Efficiency	0.84	(fraction)	HM Government (2013) Part L Domestic Building Services Compliance Guide. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/697525/DBSCG_secure.pdf
Hydrogen boiler in gas mode	Capex	90	£ / kW	From Gleeds.
Hydrogen boiler in gas mode	Opex	3.6	£ / kW / year	From Gleeds.

Appendix B

Passive design guiding principles

Coed Darcy | Passive Design Guiding Principles

Project note P01.1

8th October 2021

ARUP

Introduction

ARUP

The Coed Darcy site is located to the west of Neath in Neath Port Talbot. The mixed-use development will be delivered over a number of phases and will consist of circa 1,800 homes, a new school and a number of commercial properties (935 m² gross internal area (GIA)). The site benefits from previous outline planning permission and includes approximately 300 homes to the south of the site delivered by a previous housing developer. St Modwen Development Limited is applying for outline planning permission for the site.

The aim is to deliver a low carbon development with buildings and residential properties that have low energy demands. Reducing demand is largely driven by passive design measures which are heavily influenced by master plan layout, site topography and plot orientation and form. Once energy requirements have been minimised through passive measures, active measures can be implemented, and renewable generation can be considered.

This design note aims to provide a set of guiding principles relating to passive design measures which should be considered at an early design / planning stage as well as some precedent studies. The passive design measures detailed within this note have been informed by the current WIP master planning layouts (21009(05) 103) produced by Powell Dobson architects. This note is intended to inform any refinement of the current masterplan as well as future development of layout, massing, building heights and housing typology mix. This is presented with a view to minimise energy demand through passive design measures which in turn should reduce overall costs of improvements to fabric and other active measures such as integrated or offsite renewables. The layouts are part of a strategic masterplan to accompany an outline planning application, hence, the high level assessment of the current proposal is based on a number of assumptions which are noted in the following sections of this note.



Figure 1: Coed Darcy

Passive design measures

Figure 2: Building typology and form factor (source :LETI Climate Emergency Design Guide)



4

Passive design measures: overshadowing

Overshadowing from one building to the next can limit the positive impact of solar heat gain in winter, when the sun is at its lowest zenith angle (see figure 4). To avoid overshadowing adequate spacing should be provided between dwellings, as a rule of thumb 1.5m should be allowed for every 1m of height. South facing glazing should also be maximized to increase the benefit of winter solar heating. However, care should be taken to limit the risk of summer overheating which can be achieved through horizontal shading on southern glazing and vertical shading on west / east facing glazing. The optimal location for roof mounted photovoltaics can conflict with maximising low winter sun, so a balanced holistic approach to building design should be employed where PV is desired.

Figure 5 and 6 identify some areas on the current master plan where overshadowing may be an issue, in particular the high density plots where it is likely that a greater number of storeys will be provided.

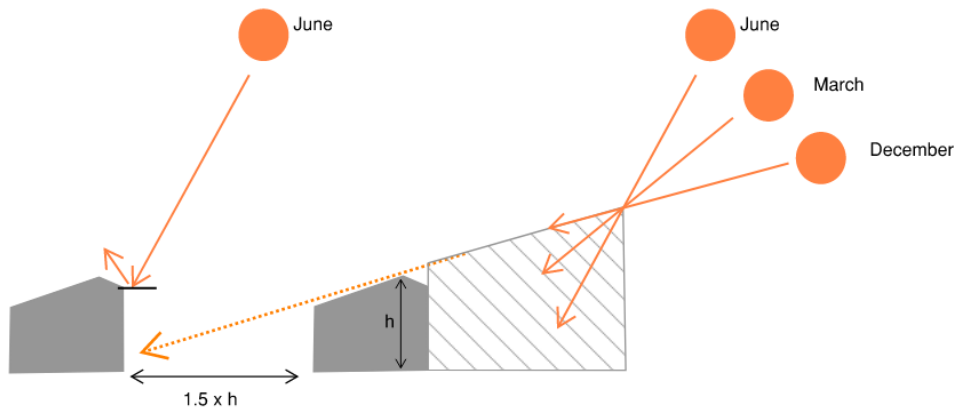


Figure 4: Impact of building height and spacing



Figure 5: Potential issue associated with high density housing and street widths

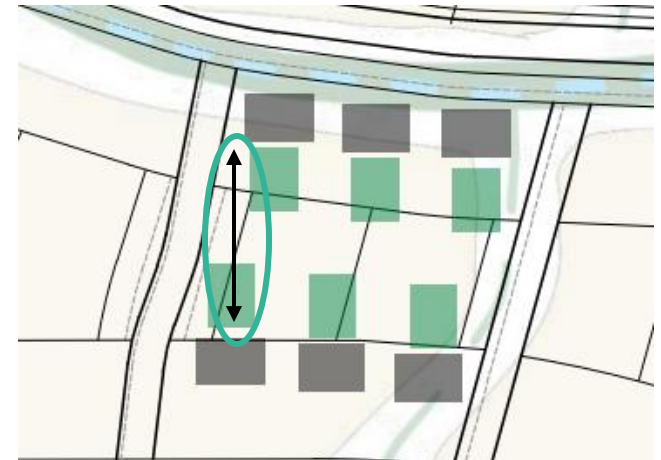


Figure 6: The distance between back to back plots should be large enough to prevent overshadowing

Passive design measures: orientation

A large proportion of any residential building's mechanical building load will be dedicated to maintaining a comfortable internal temperature. In passive house buildings, it is recommended that the building's façade is oriented 30 degrees of due south. If the longer façade faces a more easterly direction, then the building will benefit from morning solar gain. If it faces a westerly direction, then it will benefit from evening solar gains. These gains are useful during winter months to counteract heat loss from the building. In summer, this 30-degree orientation will allow less solar gain than a façade that faces directly south. This coupled with shading and low emissivity glazing can help to reduce the risk of overheating. It's also important to consider the topography of the site and proximity of buildings to one another, which can influence the building's interaction with solar gains.

Another factor worth considering with regards to building form is the available roof area that could be used for onsite energy generation via solar photovoltaic panels.

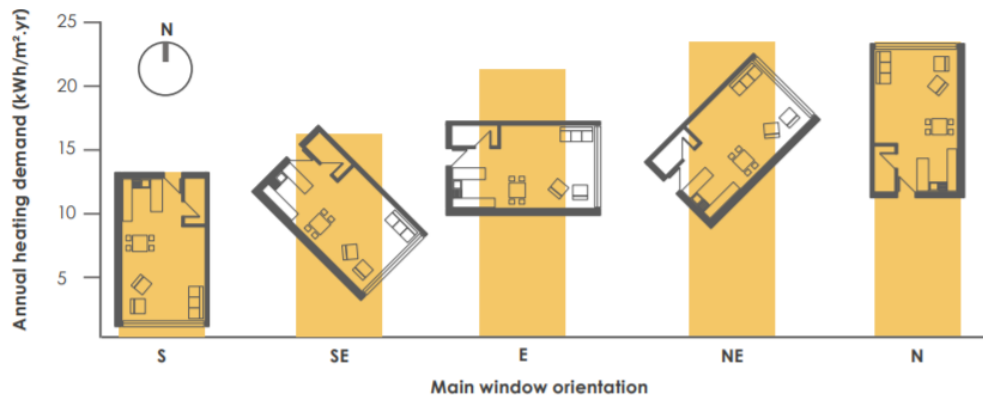


Figure 7: Impact of building orientation on heating demand

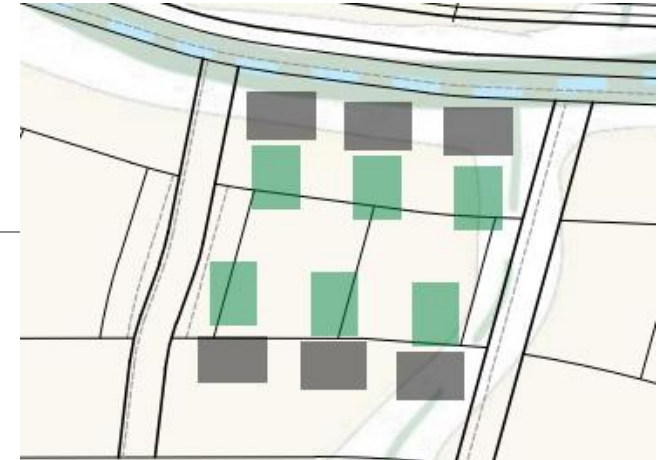


Figure 8: Potential layout implications

The current master plan proposals do not propose any detailed design at this stage, rather, this will follow as part of reserved matters applications which will then detail orientation of buildings. However, the layout of spaces should prioritise occupied spaces (living rooms, kitchens and dining rooms) being southerly facing and lower occupancy spaces (WCs, utility and plant rooms) on the north. Where houses are orientated back to back this will mean that layouts should be reversed.

Existing site topography

ARUP

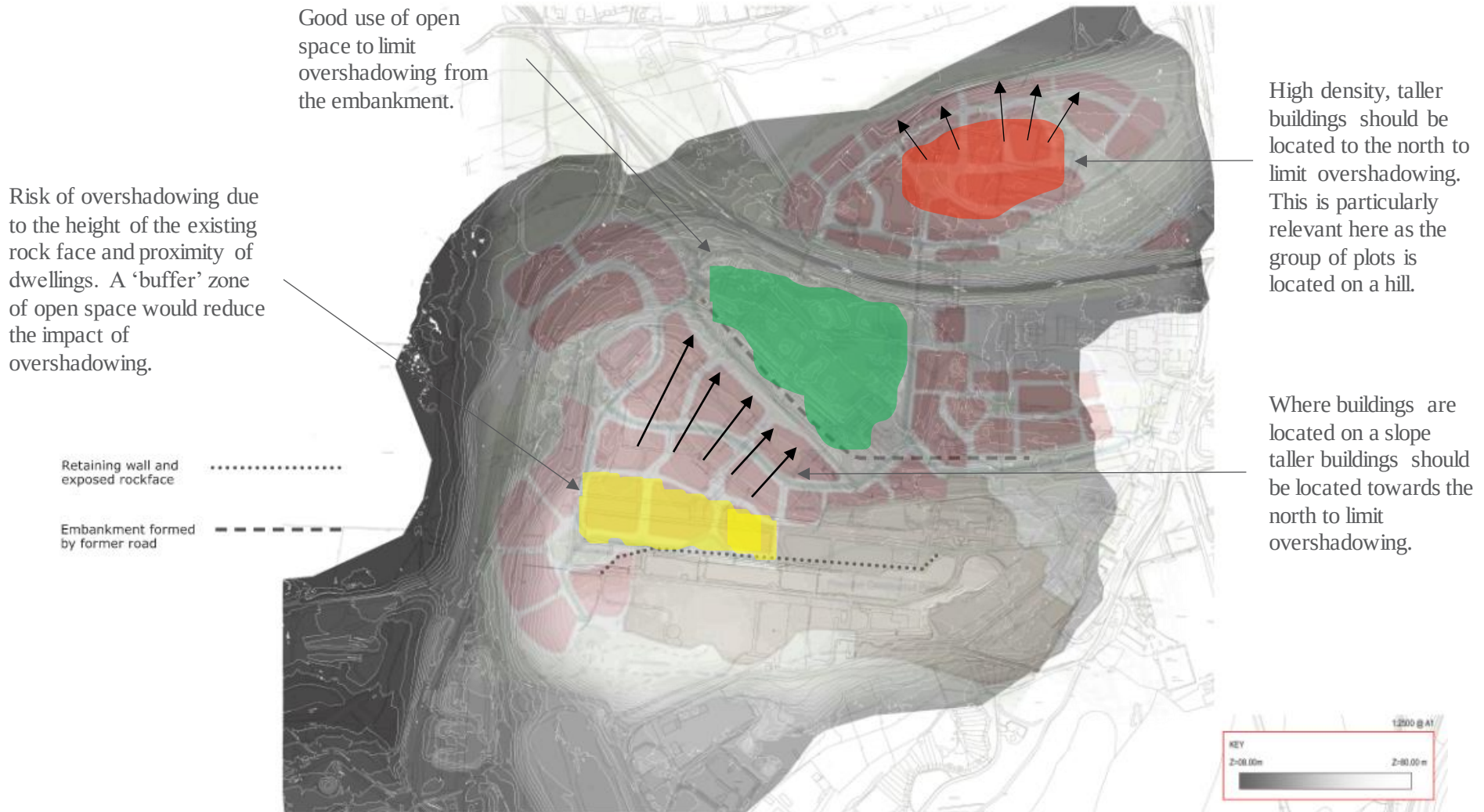


Figure 9: Stie topography overlaid with density layout

Additional master plan observations



Consider locating taller high density properties to the north preventing overshadowing.

Maximise south facing glazing for useful winter solar heating occupied spaces to the rear of the property. With a rectangular shape and a long east – west axis.

Spacing between rows for solar access (15-degree winter sun).

Figure 10: Potential layout implications

Passive design measures: additional considerations



The measures discussed so far within in this design note have been focused on master planning decisions and how they can limit or facilitate good passive design. Once orientation, building typology mix and layouts have been established, there are a number of additional passive design measures which are critical to the delivery of a operationally efficient building.

FABRIC

The fabric performance of a building will have a significant impact on its ability to retain heat and operational energy consumption. Passivhaus is a standard that optimises operational building performance and provides a good benchmark to target. Table 1, provides the Passivhaus standards for fabric and compares these to the limiting values as defined Part L1A for new dwellings.

THERMAL BRIDGING

Junctions and structural connections create paths for heat to transfer out of a building. These areas are known as thermal bridges, this is a good guiding principle for all low operational carbon designs. It is a requirement for any Passivhaus development that thermal bridges are eliminated.

The metric for ensuring this is to have a psi value of 0.01W/m.K or less. Once a building is completed, it is very difficult to counteract any thermal bridging that may be occurring. It is therefore recommended that these construction details are carefully considered at design stage.

Table1: Passivhaus and Part L1A fabric parameters

Requirement	Part L1A (2013)	Passivehaus recommended values	Units
External wall U-value	< 0.18	0.13 - 0.15	W/m ² .K
Floors U-value	< 0.13	0.08 - 0.01	W/m ² .K
Roof U-value	< 0.13	0.1-0.12	W/m ² .K
Windows U-value	< 1.4	0.8 - 1	W/m ² .K
Doors U-value	< 1.4	1	W/m ² .K
Heating energy demand	45	<15	kWh/m ² .yr
Primary energy load	190	120	kWh/m ² .yr

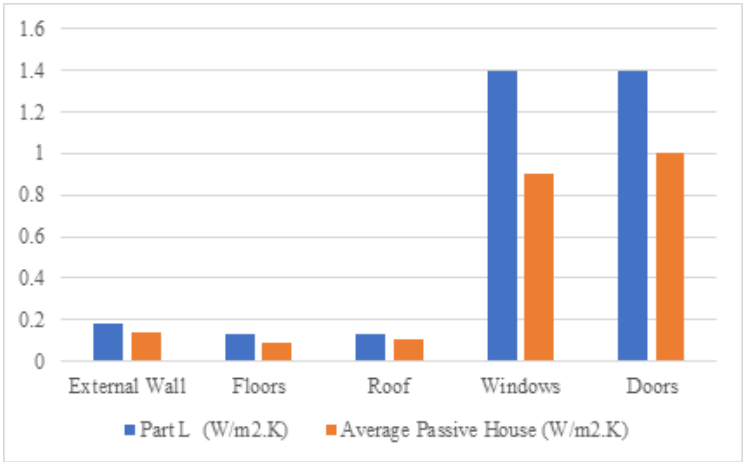


Figure 11: Passivhaus and Part L1A fabric parameter comparison

Passive design measures: additional considerations

VENTILATION AND HEAT RECOVERY

Mechanical ventilation and heat recovery units are often used for winter energy heat recovery. It also allows for control of the air change rate throughout the building and when implemented, can reduce the risk of condensation.

Openable windows increase the available ventilation in the summer months and can reduce the risk of overheating. A building's form will influence its potential for natural ventilation. For single sided ventilation to be achieved, the depth of a space's floorplan must be no greater than twice the floor to ceiling height and for cross ventilation, the depth of a space's floorplan must be no greater than five times the floor to ceiling height. The rules of thumb are taken from BSRIA Rules of Thumb (5th Edition). Other methods include passive stack ventilation or wind driven ventilation. These would both require careful consideration and would impact the form and orientation of the building.

AIR TIGHTNESS

Rigorous air tightness prevents heat leaking from the dwelling and being wasted. Testing the dwelling throughout the construction process helps to identify any issues. One of the fundamental characteristics of a passive house is a rigorous air tightness standard which must not exceed 0.6 air changes per hour (ACH) at 50Pa.

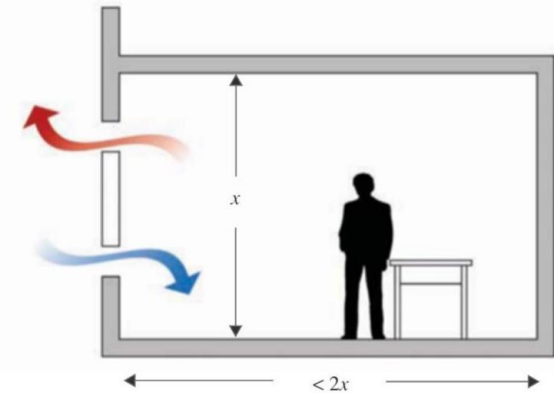


Figure 12: Single sided natural ventilation

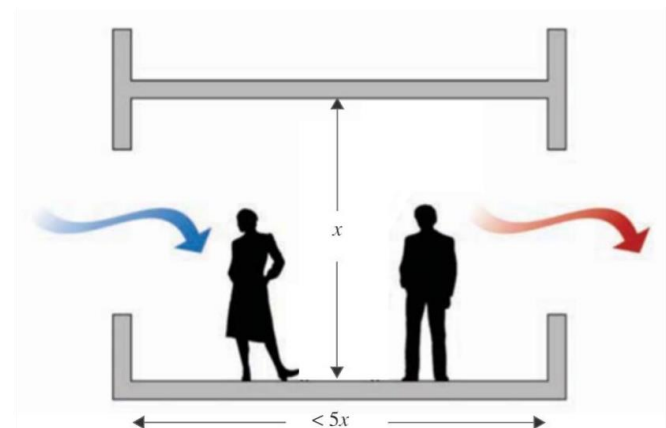


Figure 13: Cross flow natural ventilation

Precedent studies

Precedent studies: Milford Way, Swansea, 2018

ARUP



BUILDING

Milford Way is a social housing scheme in Swansea and the first council houses built in the area in over 40 years. The development consists of 30 new homes which provide 1 and 2 bed houses to council tenants. All of the homes are built to Passivhaus standards with estimated energy bills totalling no more than £70 per year (helping alleviate fuel poverty). The homes were delivered to a low cost budget on a tight programme with planning achieved in 8 weeks.

SYSTEMS

Ventilation is provided by mechanical ventilation heat recovery (MVHR) units which minimises heat loss through the winter.

Figure 14: Milford Way, Swansea, 2018 Photography ©Phil Boorman

Precedent studies: Goldsmith Street, Norwich 2019

ARUP



BUILDING

Goldsmith Street is a Passivhaus certified high-density social housing scheme in the North of England. The terraced housing provides increased thermal efficiency due to its high form factor. To align with the Passivhaus standards the windows had to be smaller than Georgian or Victorian style housing, so the architects have used a set-back panel around the windows to give an enlarged feel. The dwellings come pre-wired for a number of different services to prevent service providers' drilling through vapour barrier lines and creating thermal bridging issues at a later date.

SYSTEMS

Ventilation is provided by mechanical ventilation heat recovery (MVHR) units which minimises heat loss through the winter.

Figure 15: Goldsmith Street, Norwich. 2019, Stirling Prize winner Norwich City Council, Mikhail Riches architects

Precedent studies: Hanham Hall, Bristol 2015

ARUP



BUILDING

Hanham Hall was one of the first large scale housing developments in England to achieve the 2016 zero-carbon standard (Code for Sustainable Homes L5). The development consists of 186 homes built to the highest standards in terms of fabric and acoustic performance which includes the application of Structural insulated panels (SIPs). The orientation and glazing proportions have been carefully designed to minimise heat loss and to increase winter solar heat gain. The ventilation is provided naturally via stack and cross flow systems.

SYSTEMS

Heat is provided by an onsite biomass CHP and roof mounted PV contributes to the home's electricity demand.

Figure 16: Hanham Hall, Bristol, 2015. Multi-award winning, Barratt Developments, HTA Architects

Precedent studies: BedZED, London 2002

ARUP



BUILDING

The BedZED development located in South London was the UK's first major zero-carbon development. The homes are thermally efficient owing to their compact design and high form factor. Winter solar gain is maximised through a largely glazed south facing façade and the roof shape and plot layout reduces the first row of houses overshadowing the row behind. These design measures result some houses having minimal to no heating demand.

SYSTEMS

The homes benefit from PV and solar thermal heating which reduces carbon emissions. This and the passive design measures noted above result in the development achieving an EPC 'A'.

Figure 17: BedZED, London 2002 Bill Dunster, The Peabody Trust, Arup

Precedent studies: Pobl Active Homes, Neath Port Talbot, 2018 **ARUP**



BUILDING

The Active Homes social housing development aims to harness integrated renewables as much as possible through four channels: consuming, generating, storing and releasing energy. The project aims to reduce both carbon emissions and fuel poverty. The buildings are made from pre-assembled Structurally Insulated Panels to minimise heat loss and are covered in solar walls which provide solar thermal energy to supplement the heat pumps. They are fitted with solar integrated roofs to provide 65% of the home's electricity.

SYSTEMS

The buildings are each fitted with a 13.5 kWh Tesla Powerwall battery, to store excess electricity generated by the PV solar roof and are recharged overnight. The homes are heated with an Ariston air pump, supplemented by the solar walls, and employ Mechanical Ventilation and Heat Recovery to remove the need for a gas boiler.

Figure 18: Neath Port Talbot Active Homes Development, SPECIFIC
<https://www.specific.eu.com/active-homes-neath/>