ncl.ac.uk/research/energy/
energy@ncl.ac.uk
Prof Sara Walker, Centre Director

Hebburn Minewater Energy Scheme Summative Assessment Report

(Final)

October 2023

Contents

1. Introduction

This report sets out the Summative Assessment of the Hebburn Minewater Energy Scheme. This £11.6m ERDF project is close to completion, having originally secured funding in 2020. The following sections relate to the ERDF Summative Assessment guidelines. In relation to the Summative Assessment, Prof Walker as the independent evaluator has applied the following questions:

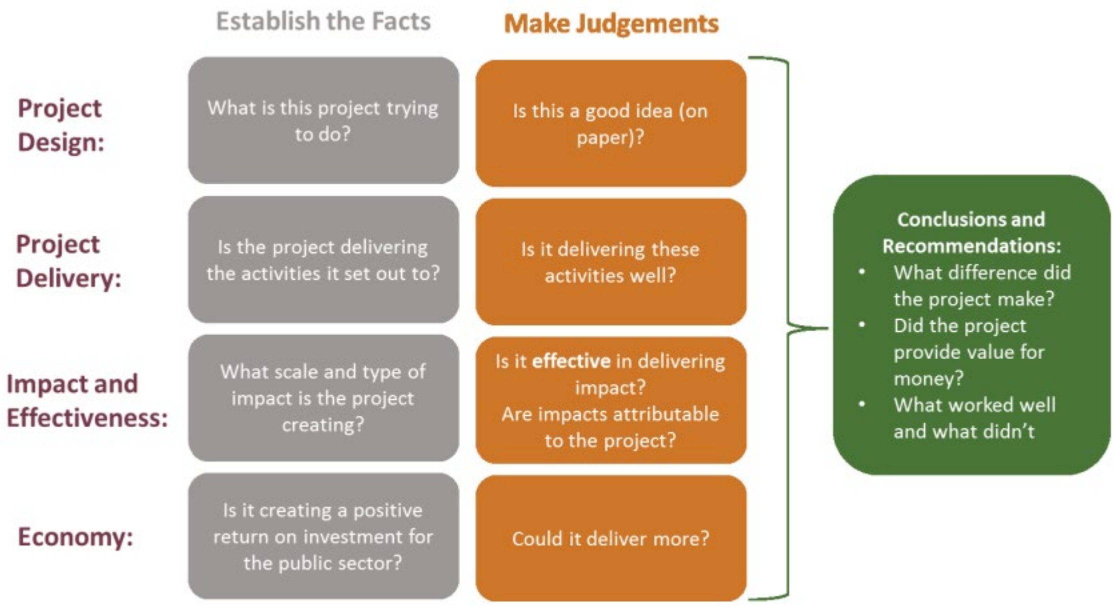


Figure 1. Key summative assessment questions

Source: European Regional Development Fund Summative Assessment Guidance – Appendices ESIF-GN-1-034.

This Summative Assessment is based on evidence gathered through:

- A review of project documents, including contractor drawings, minutes of progress meetings, and ERDF documentation (covering the period to June 2023);
- Consideration of the changing context within which the project has been delivered;
- Consultations with the key project officer: Stephen Kelleher, Senior Project Manager, Driver Project Services;
- The submitted Summative Assessment Plan, prepared by Prof Walker;
- A site visit on 11th October 2023.

An interim report was prepared between May and July 2023. This is the final report, which was completed after a site visit (early October).

2. Project context

The project intended the installation of a small heat network and water source heat pump, using minewater as the primary heat source. The scheme's feasibility study showed significant potential to source minewater from the High Main Seam and Bensham Seams at Hebburn Colliery, which is the proposed project site. This is the basis of Hebburn Minewater Energy Scheme.

The overall project cost, at the time of applying for ERDF funding, was £7,745,632. The ERDF contribution was £3,872,816.

The original design intent (Stage 3 design) was a heat pump of $450kW_{th}$, a $20m^3$ thermal store, combined with the retained gas boilers (3 x $605kW_{th}$) and Combined Heat and Power (CHP) unit ($230kW_{th}$) at the Hebburn Central plant room. The new Energy Centre and existing Hebburn Central plant room would be connected via a low temperature heat network, with additional connections to Durham Court and Lincoln Court. The age and static pressure requirements of the Durham Court building was such that a heat substation was included in the design, to enable Durham Court to be hydraulically separated from the rest of the district heat network. The initial design intent also included a low voltage (LV) connection between Hebburn Central and the new Energy Centre, which would enable electricity generated by the CHP unit to be used for the operation of the heat pump.

At the time of the initial proposal, the Durham Court and Lincoln Court heat loads were served by individual gas boilers. Lincoln Court was to be demolished, and the design of the heat network made assumptions about the load of the building which was planned to replace this. Hebburn Central heat loads were served by three gas boilers and a Combined Heat and Power Unit. Gas was supplied via Northern Gas Networks distribution system, and electrical loads were met through Northern Powergrid electricity distribution network (some Hebburn Central electrical load was served by the CHP). Durham court's boiler plant is really dated (over 17 years old) and was due for a significant plant room refurbishment (replacing boiler like for like). Hebburn central's gas boiler plants are significantly over sized, and the installed CHP plant hardly turned on during the first 2 years of operation. The CHP plant output has been moderated down to improve the CHP plant utilisation. Spare heat from Hebburn Central boilers and CHP could have been easily shared with council buildings nearby (Durham and Lincoln) with a district heat network infrastructure.

The project was seeking to contribute to South Tyneside Council's net zero commitment, by decarbonising heating load and demonstrating a relatively under-utilised innovative technology (for the UK) of a water-source heat pump using minewater as the primary heat source. The project was trying to address energy cost for end users of the buildings, and greenhouse gas emissions reduction. The choice of technologies makes this low carbon heating scheme more expensive than the business as usual, which results in a need for capital investment to support the project investment. The rationale was therefore strong.

The design has incorporated flexibility to enable extension of the heat network at a later date. The stage 3 design report refers to an additional 3MW peak heat load, and whilst the peak electrical demand at the Energy Centre is predicted to be a little over 0.5MW, a 1MW transformer was sized, which would enable further heat pump installation at the Energy Centre.

However, in late 2021 it was clear from minewater testing results, and understanding of the flow rates at the test boreholes, that the scheme could not be operated as a minewater-only district heat network. The water-source heat pump (with minewater) design was therefore adjusted to an air-source heat pump. This was a risk which the project team were aware of, and had planned for, with an air-source heatpump always included as an alternative should the minewater heat source prove infeasible. The thermal storage, gas-fired co-generation and heat network are unchanged in the final design.

On completion of the project, it is South Tyneside Council's intention to review the well options to achieve connectivity between the coal seams, and mine water, and have a hybrid system, of mine water/air source to feed the heat pump.

One further change to the project scope was that the Lincoln Court redevelopment was removed from the scheme, since this redevelopment was taken over by Carbon Homes and as a result South Tyneside Council do not have influence over the connection of this redevelopment to the district heat network.

There is excellent strategic alignment of the design concept to central and local government priorities. Since the project was initiated in 2020, the strategic alignment remains excellent, with a continued drive to support low carbon energy systems at the local, regional and national level.

At the time of the original proposal, the concept design of the scheme was already aligned to policy priorities. More recently, the cost-of-living crisis, rising energy prices, and uncertainty of supply linked to the war in Ukraine, have resulted in greater public awareness of, and concern for, their energy costs. This has emphasised the importance to the local community of a transition to clean and affordable heat. It is also highly relevant to the council, as the energy bill payer for the public sector buildings that will be connected to the heat network.

Key policy announcements made since project initiation, which demonstrate the continued strategic alignment, include:

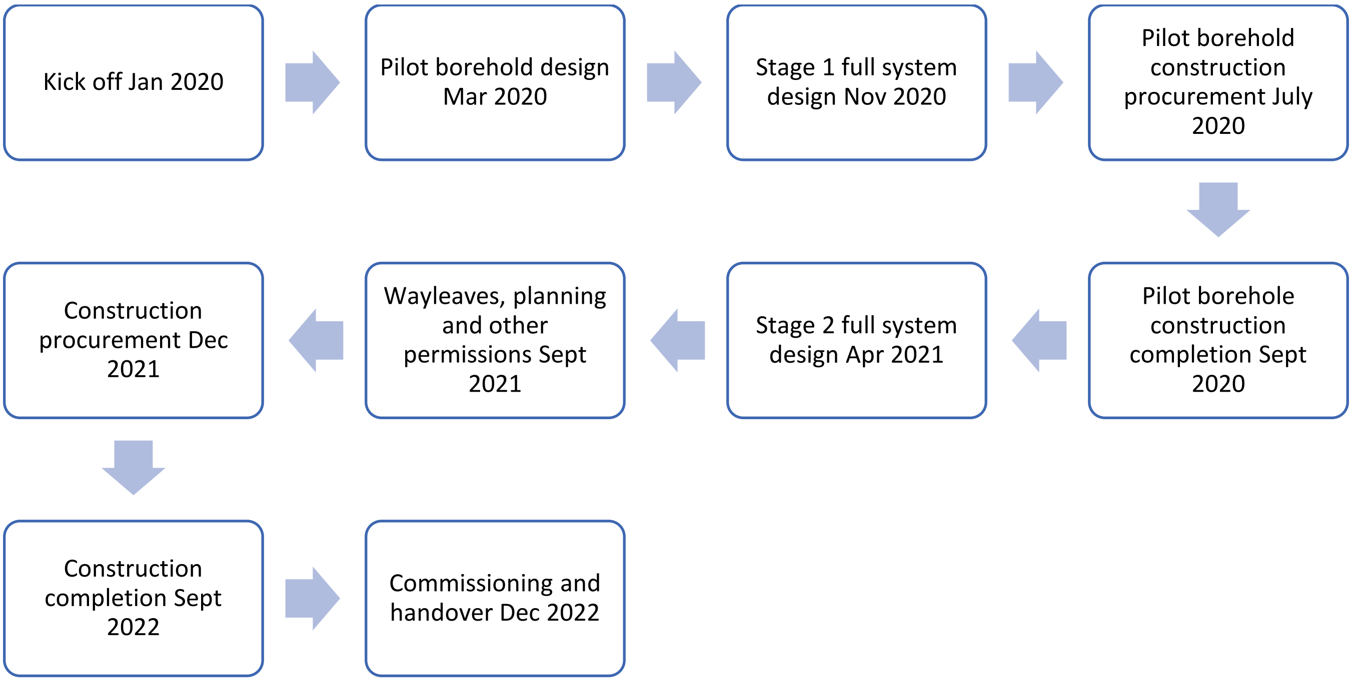
Policy	Relevance to project
HM Government Heat and Buildings Strategy, October 2021 Heat and building strategy (accessible webpage) - GOV.UK (www.gov.uk)	Addresses the key issues of carbon emissions associated with heating and powering buildings. The ambition to phase out installation of natural gas boilers clearly raises the issue that business as usual boiler replacement for buildings connected to the Hebburn scheme would not be consistent with Government priorities.
Net Zero Strategy: Build Back Greener, October 2021 Net Zero Strategy: Build Back Greener - GOV.UK (www.gov.uk)	Proposes improvements in energy efficiency of buildings, a move to low-carbon heating technologies, and moving energy levies onto gas to reduce the cost. Furthermore, this outlines wider benefits of levelling up, reducing bills, tackling fuel poverty, increasing property value and improving health. The policy also identifies the need for heat network development. Hebburn Minewater Energy Scheme delivers on low carbon heating and heat networks, and the financial viability of the project would be further improved if electricity prices were to reduce.
Heat pump net zero investment roadmap, April 2023 Heat pump net zero investment roadmap - GOV.UK (www.gov.uk)	Describes a range of policy measures to support growth in the heat pump market, with an aspiration to reach 600,000 heat pump installations per year by 2028 and stimulate heat pump manufacture in the UK. The Hebburn scheme continues to be a valuable demonstrator for heat pump application.
Sustainable South Tyneside 2020-2025, May 2020 South Tyneside Council | Sustainable South Tyneside 2020-2025	Outlines the Council commitment to combating climate change. Refers to the Hebburn scheme, as part of the theme on reducing emissions from council buildings.
North East Devolution Deal (undated) North East devolution deal (northeastca.gov.uk)	Describes planned activity around energy infrastructure in order to deliver regional green growth, including green heat. The deal makes reference to pilots in minewater at South Tyneside (the Hebburn scheme), and hence there is clear recognition of the value of pilots and of the work of the Council. This devolution deal is at early stages, but the relevant parties are "minded to

	agree" on the deal. The deal prioritises green growth and therefore the Hebburn scheme is well aligned to that, and to aspirations in the deal around green heat.
Minewater heat (May 2023) Mine water heat - GOV.UK (www.gov.uk)	This Coal Authority statement on minewater heat refers to the Hebburn scheme. It also highlights the potential contribution which minewater schemes can make to sustainability, and the transition to net zero.
The case for deep geothermal energy – unlocking investment at scale in the UK (July 2023) The-case-for-deep-geothermal-energy-–-unlocking-investment-at-scale-in-the-UK.pdf (northeastlep.co.uk)	This report highlights the potential for heat networks and deep geothermal (including minewater) to contribute to social renewal and "levelling-up", due to the coincidence of location of deep geothermal with areas of deprivation.
The Case for Mine Energy – unlocking deployment at scale in the UK (May 20212) Mine-Energy-White-Paper_FINAL.pdf (northeastlep.co.uk)	Further supports the above point on social renewal: *"Many parts of the coalfields have still not fully recovered from the decline of mining, and such recovery has been experienced is now at risk as a result of the coronavirus pandemic. The development of mine water heat networks would bring immediate and direct economic benefits to coalfield communities and businesses and contribute to the government's 'levelling up' agenda."*

At present it is expected that the changes in context shall lead to a stronger economic case for the project, but this can be confirmed following full commissioning of the scheme and associated performance data.

3. Project progress

In the original ERDF proposal, the project milestones were:



In May 2022, an extension was agreed with the funder, for the final two milestones:

As of July 2023, the Energy Centre building was not completed, and internal mechanical and electrical fit-out were yet to be completed.

The key reasons for the delays to project milestones (and subsequent extension agreed with the funder) have been:

- Delays to the appointment of the borehole construction contractor, due to initial failure to appoint and a second tender exercise being required. Planning Approval received 30/04/2021. Coal Authority Permit to Drill issued 27/05/2021. Borehole drilling actually started June 2021 with original forecast completion of drilling scheduled for 06/10/2022. The actual completion was 24/10/2022, delayed due to a number of geological and technical challenges risks that were known, and realised.
- Minutes of meetings show high standard of reporting, for example H&S reporting, monitoring of noise, monitoring of dust. Minutes also report some minor disruption to site following Storm Arwen (26 / 27th November 2021).
- Planning permission for the Energy Centre was received February 2022.

- Construction of the Energy Centre was due to begin December 2021, following successful procurement. A letter of intent to appoint Vital Energi was issued March 2022, with a revised start of the Energy Centre construction of June 2022. Access to site for the Energy Centre contractor was delayed, due to the later start to the borehole drilling, and extended drilling contract, with access to the site being delayed 5 months from May 2022 to October 2022.

3.1. Update October 2023

The independent evaluator Prof Sara Walker visited the scheme on 11th October 2023. The Energy Centre internal fit out had been completed, and final commissioning tests were being undertaken.

As built drawings were provided post-site visit. These are consistent with previous system drawings which had been provided at the interim report stage.

3.1.1. Paul Younger Energy Centre

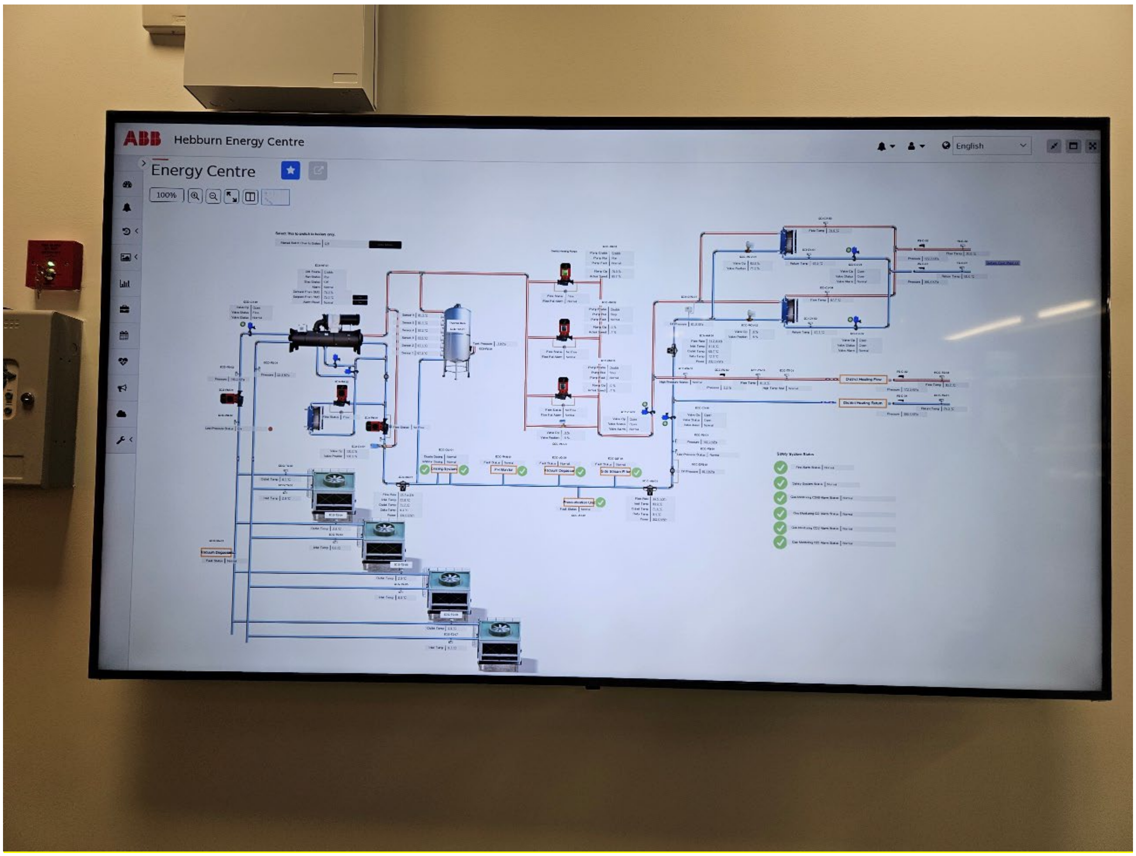
Professor Paul Younger (above-left image) was regarded as one of the world's foremost experts in the remediation of pollution associated with mining, and strong advocate for heat recovery from mine water.

Born in Hebburn, he was a passionate ambassador for the Northeast and invested substantial personal effort to support local communities and issues, which was recognised by his appointment as a Deputy Lieutenant of Tyne and Wear.

And in 2011, he was conferred with the honour of Freeman of the Borough of Gateshead, joining other luminaries such as football legend Bob Moncur, Olympic triple jumper Jonathan Edwards and former athlete and cousin, Brendan Foster.

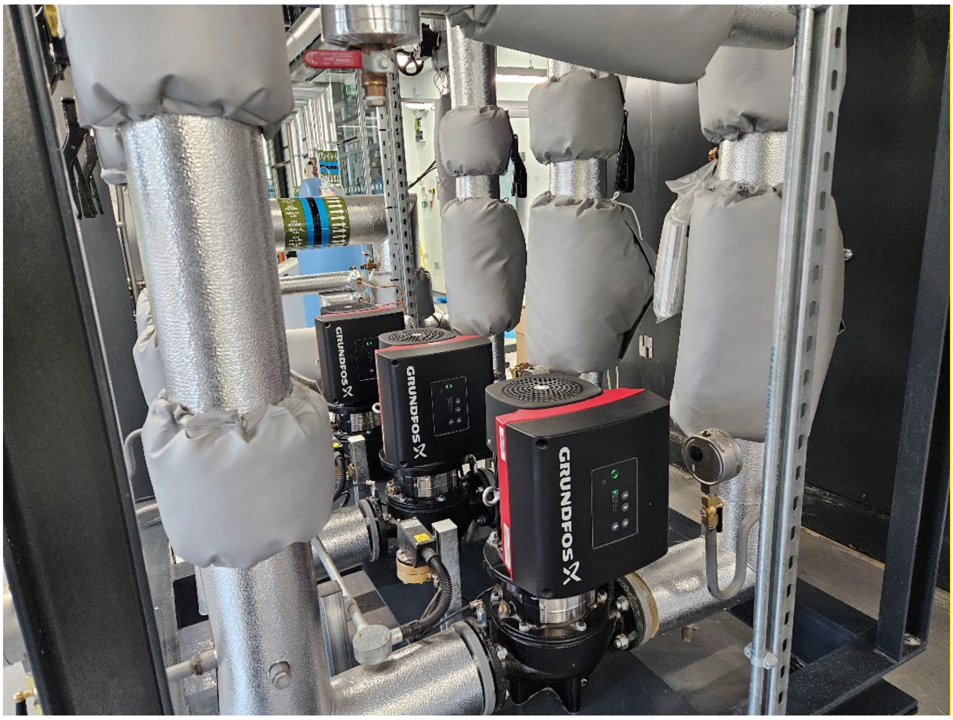
The naming of the Energy Centre (above left image) is a fitting tribute to Paul Younger, who passed away in 2018.

ncl.ac.uk/research/energy/
energy@ncl.ac.uk
Prof Sara Walker, Centre Director



At the entrance to the Energy Centre is an interactive display which is a mirror of the Building Energy Management System display.

The thermal store and Durham Court heat exchangers are shown in the above image.



There are three distribution pumps for the heat network. Two are duty pumps and one is standby. The flow meters adjacent to the distribution pumps were showing a flow rate of 8 litres/s at the time of the site visit, which is very close to the design flow rate of 8.9 litres/s. Hydraulic test results at commissioning show the heat network was maintained at 13 bar.

This is the heat pump housing. Heat pump commissioning documentation was provided post-visit, and this showed commissioning had been completed on 29th September 2023. The NICEIC was also provided, demonstrating compliance of the electrical systems within the Energy Centre.

There is flexibility in the design at the Energy Centre, with headroom on the electrical connection and internal space to facilitate a second heat pump in the future.

3.1.2. Durham Court

We then moved to Durham Court, to see the internal plant room.

Durham Court (left image) is immediately adjacent to the Energy Centre. Above, the right image shows the distribution pumps at Durham Court.

The existing gas boilers remain in situ at Durham Court, but only three of the six were working prior to the commissioning of the heat network, and these were beyond end of life.

3.1.3. Hebburn Central

We then visited the plant room at Hebburn Central.

ncl.ac.uk/research/energy/
energy@ncl.ac.uk
Prof Sara Walker, Centre Director

Hebburn Central (in the above image) comprises leisure facilities and library. The electrical connection to the Energy Centre is fed from Hebburn Central. The heat network is supplied heat firstly from the heat pump, then the Combined Heat and Power unit at Hebburn Central can top up, and a final top up is possible from the Hebburn Central gas boilers. The image below is of the existing gas-fired CHP (150kW) unit at Hebburn Central. When the CHP is operating to provide heat to the network, it is also generating electricity which can supply Hebburn Central and the Energy Centre. Furthermore, Hebburn Central has 200kW of photovoltaics on the roof, providing electricity to the building and the Energy Centre. South Tyneside Council is on a 100% renewable energy tariff from EDF. Therefore, the vast majority of supplied electricity to the heat pump is from renewable energy sources.

Transition to clean affordable energy | Justice and Ethics | Energy | Security and Resilience

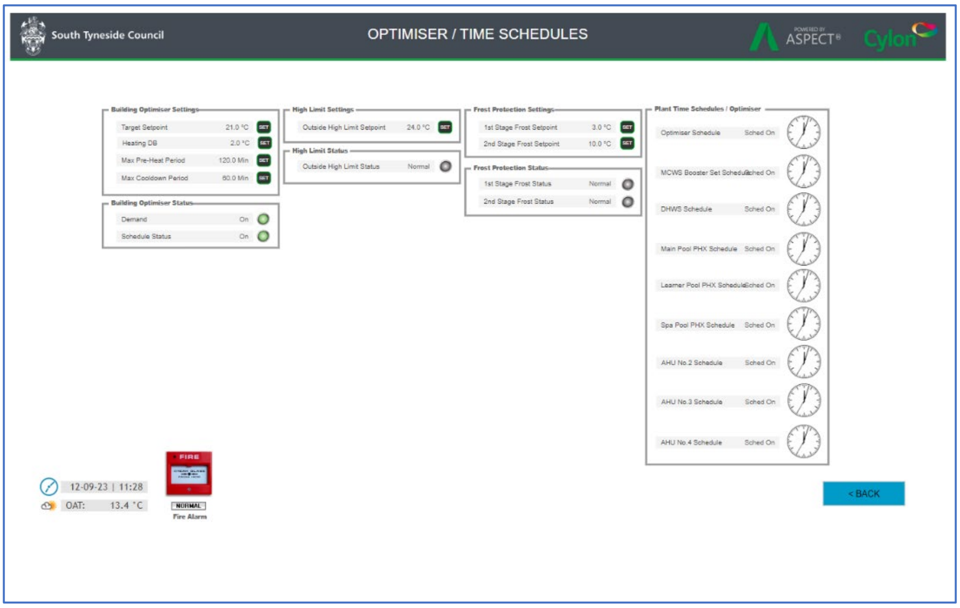
Demonstration | Sustainability | Policy and Regulation | Materials | Digital Innovation | Behaviour | Technology | Systems Infrastructure | Business Models | Design

3.2. Planned user displays

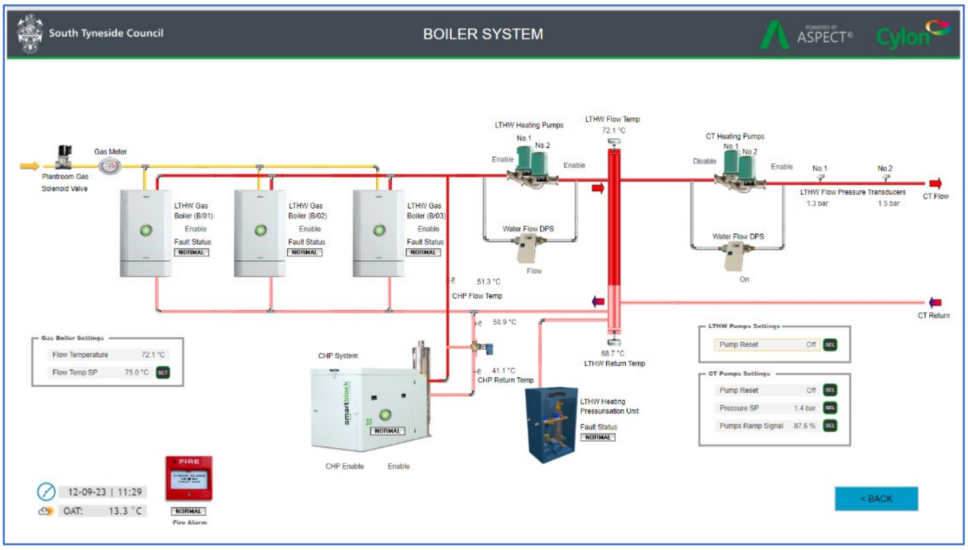
The Energy Management System menu is shown below. This enables the user to call up data for specific system elements.

From the menu, the user can navigate to layout images, such as the example below.

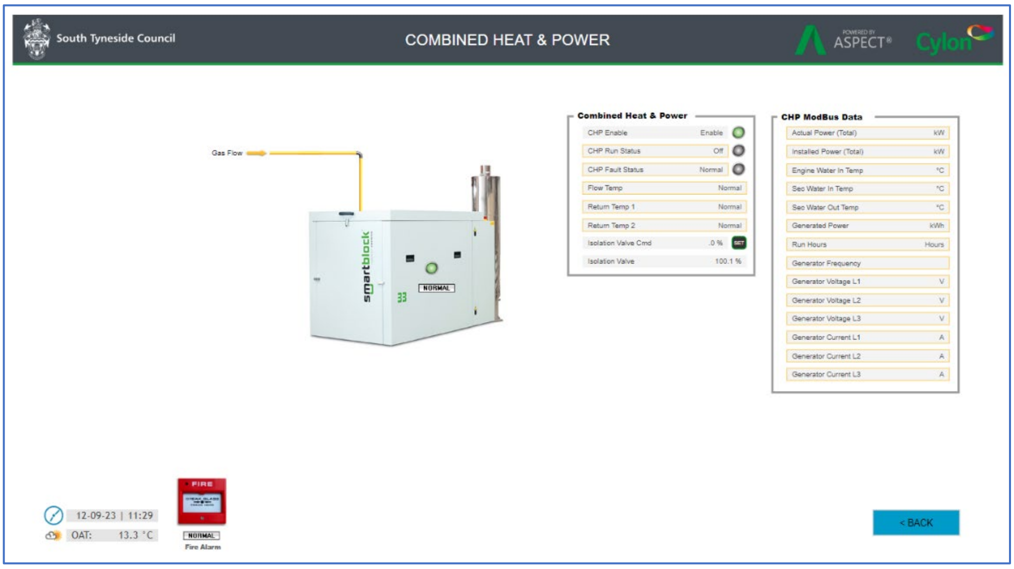
The optimiser and time schedule interface looks like the below image.



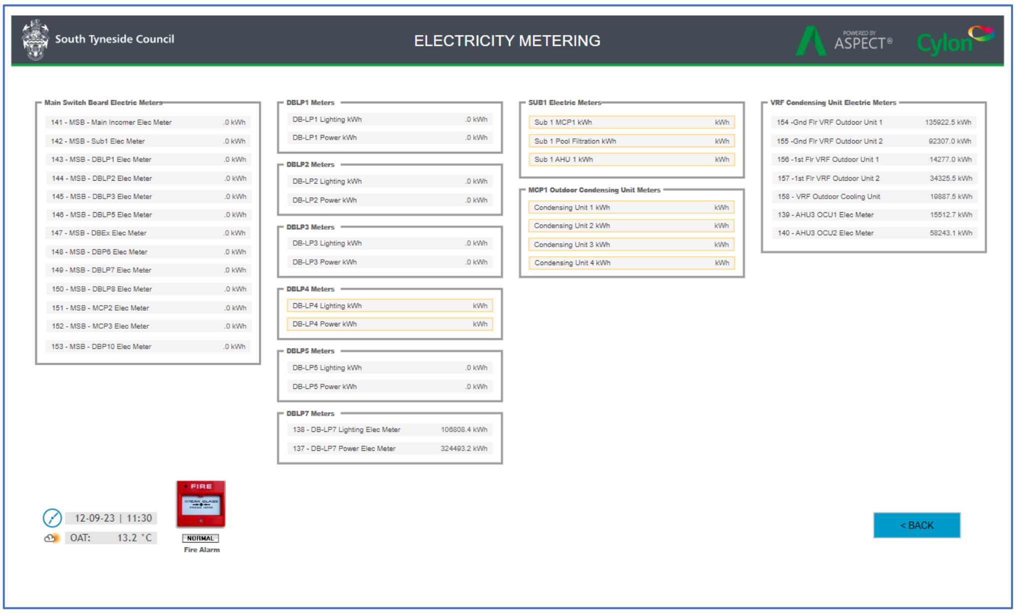
The Low Temperature Hot Water system for Hebburn Central is visualised in the below image, showing the CHP and three back-up boilers.



The Combined Heat and Power plant can also be displayed using the menu option, see below image.



The metering menu option leads to a display like the below image, which for this example shows the electricity metering.



This demonstrates that the installation has an appropriate graphical user interface to enable the client, South Tyneside Council, to interrogate the performance of the system.

4. Progress against targets

Energy and carbon targets

The targets considered here are those in the grant agreement.

ER/C/O/30 Additional capacity of renewable energy production: 200kW

Capacity of **$450kW_{th}$** (50658-VE-EC-XX-SC-M-5601_C3_New Energy Centre P&ID.pdf), compared with an original estimated $200kW_{th}$ (200501 Hebburn MW GFA final.pdf). This revised capacity was introduced at the stage 4 design.

225% of target achieved.

ER/C/O/31 Number of household with improved energy consumption classification: 111

Actual households **107**. This relates to the number of social housing units in Durham Court which have received internal upgrade works to connect to the heat network. At the time of this report, 4 units still required internal works. The project team has been informed, that South Tyneside Homes are working to gain access the 4 remaining units, and it is hoped that the work will be carried out within the next nine months.

96% of target achieved.

ER/C/O/32 Decrease of annual primary energy consumption of public buildings: 1,578MWh

- The business as usual (BAU) thermal demand is estimated in the Stage 2 design report as 3,040 MWh/yr (for Hebburn Central and Durham Court only).
- If the heat output was met by the existing gas boilers and the CHP system then this would require 4,264MWh/yr of gas, which equates to 4,742MWh/yr of primary energy.
- The associated electricity generation by the CHP would be 454MWh/yr in this BAU scenario.
- For the new scheme, assuming the heat pump serves 73% of heat demand, the gas CHP serves 9.4% of heat demand, and the gas boilers serve 17.7% of heat demand (stage 3 report), then the new scheme would require 1,226MWh/yr of gas for the CHP and boilers and 760MWh/yr of electricity for the heat pump.
- The net reduction in gas demand comparing BAU and the new scheme is **3,039MWh/yr**.
- The CHP is used less often to the BAU scenario, and so electricity generation is reduced to 184MWh/yr with the heat pump scheme.
- The net electricity demand for the new scheme is **576MWh/yr**.
- The primary energy equivalent of the gas demand is 1,363MWh/yr, and of the electricity demand is 1,487MWh/yr.

The overall decrease of annual primary energy consumption, is estimated as **1,895MWh/yr**. This estimate can be confirmed at a later date based on amended Energy Performance Certificates, and metered consumption.

120% of target achieved.

ER/C/O/34 Annual decrease in GHG emissions: 280.67 tCO_2e

- The business as usual gas consumption would lead to annual emissions of 873 tCO_2e and the electricity generation by the CHP would avoid 174 tCO_2e, a net emissions of **698 tCO_2e**.
- Reduced gas usage results in a new annual emissions from gas use of 251 tCO_2e.
- Increased electricity usage leads to a net emissions increase of 222 tCO_2/yr.
- Net emissions for the new scheme are estimated as **472.38 tCO_2e**.

The net emissions saving for the scheme is **226 tCO_2e/yr**.

81% of target achieved.

It should be noted that the consultant's carbon modelling is based on a daily time resolution, whereas this summative assessment assumes broad annual averages. The Coefficient of Performance of the heat pump (assumed as 2.92), and contribution of the heat pump (assumed as 73%) and CHP (assumed as 9.4%) to heat demand, are influential in the estimate of GHG emissions reduction. At present, it is estimated that 81% of the C34 target will be achieved. However, if a COP of 3.2 is assumed the emissions savings increase to 253tCO_2e, around **90%** of the target. Alternative scenarios are detailed in Section 10 SUPPLEMENTARY CALCULATIONS and summarised below.

COP	% contribution to heat demand from:			Primary energy saving (MWh/yr)	GHG emissions saving (tCO_2e/yr)
	HP	CHP	Boiler		
2.92	73	9.35	17.45	1,894.94	226.39
3.2	73	9.35	17.45	2,074.65	253.45
2.92	73	17	10	1,069.53	245.02
2.92	65.2	12.8	22	1,865.50	207.55

5. PROJECT MANAGEMENT

Project leadership

Project management has been provided to South Tyneside Council by Driver Project Services from 1st June 2020, specifically, Stephen Kelleher as the Senior Project Manager. Leadership across the contracted parties is evidenced through engagement in progress meetings by South Tyneside Council, South Tyneside Homes, Buro Happold, Vital Energi, Faulkner Browns, Gardiner & Theobald, and Driver Project Services, for example.

Wider Council involvement

Various members of South Tyneside Council (from energy, legal, highways, street lighting, leisure, for example) have supported the project as evidenced by the Project Directory of contacts. Progress meetings also refer to site visits by Councillors, who have engaged with the project. The project also engaged with the North East Local Enterprise Partnership (NELEP) Minewater Task Force, and had a visit from a local MP.

Meetings, and project governance

The evidence shows the project has been very well managed. At the design stage (to RIBA Stage 4) there are fortnightly meeting minutes which clearly identify design choices, and appropriate consultation on these between the design team and client. Monthly progress reports during the construction phase include reporting on health & safety, and the project risks. There is a comprehensive risk register which has been updated (the team have now issued version 10). Safety, Health, Environment and Quality reports demonstrate very good practices for site health and safety. There is also a very good report and score from the Considerate Constructors Scheme site visit. Monthly progress meetings show a detailed record of any delays and changes to expenditure.

The standard of documentation is very good. For example, there are fortnightly meetings, with minutes, for the design stages in 2020-2021, and clear documentation from the contractor for the stage 5 design drawings. There is a comprehensive document issue sheet and register.

Whilst building work is not quite complete, appropriate inspection and sign off of components of the work is in evidence, some commissioning documentation has been completed, and final commissioning and handover is expected w/c 30th October.

Appropriate beneficiaries were engaged with, and this is also reported on as a regular communications item in the monthly progress meetings.

Potential areas for improvement

Driver Project Services carried out a Lessons Learned exercise, consulting with all parties, stakeholders and South Tyneside council staff, and issued its report at the end of August 2023. This report identified the following areas for improvement:

- It is not appropriate to limit feasibility studies to a pre-selected preferred choice (e.g. mine water) without conducting a full evaluation of all options. If the Lead Designer had been appointed sooner and asked to evaluate the heat network and use of all renewable technologies with regards to carbon savings, the mine water option may not have been the preference. This may have resulted in savings in drilling costs and program duration.
- A Project Board should be established at the inception of the project, with key senior officers appointed to develop and agree on the project strategy, budget, program, procurement, communications, and appointment of consultants, and to steer the project as it progresses. For this project, the Project Board was appointed after funding was secured, and this delayed some key decision making.
- As a Well Operator, STC has a duty to manage the mine water extraction wells. While the wells are currently not in use and are in a state of suspension, the well assets should be assessed, to evaluate

the work that has been done on the wells and consider what options are available to develop the wells in support of the planned Hebburn 2 Heat Network Extension.

Contribution to ERDF Horizontal Principles

The nature of the project, in terms of increasing renewable energy capacity and reducing greenhouse gas emissions, directly contributes to the horizonal principle of sustainable development. As a demonstrator project and learning experience for South Tyneside Council and supply chain, it can cascade learning to future projects and thereby have a broader contribution to sustainable development targets.

6. PROJECT OUTCOMES AND IMPACT

Expected outcomes

Outcomes are yet to be confirmed, post commissioning of the overall scheme.

The appropriate evaluation in this case would be an interrupted time series analysis and difference-in-difference analysis, as described in the Magenta Book (p48). The approach would be to take time-series data, to test for a causal change in the data trend. This requires time-series data for gas and electricity consumption prior to the project.

At this stage, it is only possible to comment on progress towards the outcomes.

With regards the number of properties (C31), all but 4 of the 111 properties in Durham Court have had dwelling modification work, with plans to complete the remaining works within nine months, when access sis arranged.

With regards the installed renewable energy capacity (C30), decrease of annual primary energy consumption (C32) and estimated GHG reductions (C34), this is delivered as a result of the heat network (installed), air source heat pump (installed), CHP unit (existing), back up gas boilers (existing), upgrade of the Northern Power Grid transformer (installed), and private wire connection between Hebburn Central and the Energy Centre (installed). Performance data should confirm the expected outcomes, with C30 exceeded, C32 expected to be exceeded, and C34 expected to be around 81% of the target.

Wider benefits

The experience of South Tyneside Council in delivery of this project can benefit the wider civic partners across the north east, particularly beyond the three Council members of the North East Combined Authority given that the new Devolution Deal for the North East will see seven local authorities joining forces.

It is recommended that the project team collate evidence of sharing of project experience, so that evidence is built up over time of the wider benefits of the project.

Given the recent energy price crisis across the UK, there is potential for the buildings connected to the Hebburn scheme to be shielded somewhat from volatility in gas and electricity prices. This may lead to a better financial performance of the project over the lifetime, although predicting future energy prices is very difficult to do with accuracy. It is recommended that the project team also collate evidence of this potential financial benefit.

Scheme expansion

South Tyneside Council has commissioned Buro Happold to carry out a Techno-Economic Feasibility Study (TEFS) to investigate expansion of the Hebburn Heat Network. The study highlighted several Council-owned schools, community buildings and nursing care facilities which could be connected to an extension of the heat network. The study was concluded in August 2022, with a recommendation to investigate four potential scenarios that would enable extension of the network, and to carry out a Detailed Project Development (DPD) Study that provides an Outline Business Case (OBC) that would support and achieve the metrics to apply for Green Heat Network Funding (GHNF).

The four scenarios are:

- Scenario A: Expansion of the Hebburn Minewater DHN scheme to incorporate council owned school properties and a community hub (School Cluster)

- Scenario B: Expansion of the Hebburn Minewater DHN scheme to incorporate council owned school properties, a community hub (School Cluster) and additional private care units (Private Care Cluster)
- Scenario C: A new energy centre utilising alternative low carbon technology. This network would connect to the School Cluster.
- Scenario D: A new energy centre utilising alternative low carbon technology. This network would connect to the School Cluster and Private Care Cluster

Buildings identified for the Hebburn Minewater Network expansion (Buro Happold TEFS report)

The DPD Study commenced in May 2023, and will include a review of the wells drilled and how the Council can achieve connectivity, to utilise the mine water with the air source heat pump, and other technologies.

7. PROJECT VALUE FOR MONEY

Carbon savings

By project closure, there is an estimated reduction in GHG emissions of 226 tons CO_2e.

The lifetime value of saved carbon emissions can be compared with the investment cost of the scheme. Assuming the central traded carbon values from 2023 onwards, with a flat rate from 2050 onwards (BEIS published values only go to 2050) then the value of the saved carbon from the scheme is **£2.1m**.

"Greenhouse gas emissions values ("carbon values") are used across government for valuing impacts on GHG emissions resulting from policy interventions. They represent a monetary value that society places on one tonne of carbon dioxide equivalent (£/tCO2e). They differ from carbon prices, which represent the observed price of carbon in a relevant market (such as the UK Emissions Trading Scheme)."[1]

Whilst this £2.1m amount is not discounted, it compares favourably with the project ERDF 2020 value of £7.746m (the carbon saving value is more than ¼ of the total investment).

[1] Valuation of greenhouse gas emissions: for policy appraisal and evaluation - GOV.UK (https://www.gov.uk/government/publications/valuing-greenhouse-gas-emissions-in-policy-appraisal/valuation-of-greenhouse-gas-emissions-for-policy-appraisal-and-evaluation#annex-1-carbon-values-in-2020-prices-per-tonne-of-co2) Annex 1: Carbon values in £2020 prices per tonne of CO2

8. CONCLUSIONS AND LESSONS LEARNT

A high value demonstration project, delivering very good carbon savings

Hebburn Minewater Energy Scheme was well aligned with the priorities of South Tyneside Council, and UK Government objectives, at the time of ERDF grant award. It was an ambitious project, given minewater heat recovery was relatively unproven at the inception of the project.

Since that time, changes in the energy landscape have further strengthened the case for the Hebburn Energy Scheme. Concerns about cost and security of supply, and climate change, have increased since the project began. New policies from UK Government have highlighted the strategic value of heat networks and heat pumps in the transitions to net zero, and as such the project has high value as a demonstration of the two technologies. The experience of South Tyneside Council in delivery of this project can benefit other civic partners, and so it is recommended that the project team collate evidence of sharing of project experience, so that evidence is built up over time of the wider benefits of the project.

South Tyneside Council has commissioned Buro Happold to carry out a Techno-Economic Feasibility Study (TEFS) to investigate expansion of the Hebburn Heat Network. The study highlighted several Council-owned schools, community buildings and nursing care facilities which could be connected to an extension of the heat network. The study was concluded in August 2022, with a recommendation to investigate four potential scenarios that would enable extension of the network. The learning from the initial demonstration project is, therefore, being put into immediate use on the potential extension.

The DPD Study is looking into the options for gaining connectivity to the coal seams, and using the wells to deliver a hybrid of mine water and air source to feed the second heat pump, but also carrying out a techno economic risk assessment of using the mine water against other renewable energy sources, and comparing both Capex/Opex analysis.

A flexible delivery model

The project team have encountered a number of unexpected difficulties related to the project delivery at the Paul Younger Energy Centre, given that in late 2021 it was clear from minewater testing results, and understanding of the flow rates at the test boreholes, that the scheme could not be operated as a minewater-only district heat network. The water-source heat pump (with minewater) design was therefore adjusted to an air-source heat pump. This was a risk which the project team were aware of and had planned for.

The Energy Centre Heat Network is expected to be completed and operational in October 2023, a delay of 10 months from the original schedule and 5 months from the revised program agreed upon with the contractor and the ERDF, owing to the drilling setbacks.

Regular, structured communications with the different contractors has been a key element to managing the project. Robust reporting, including a clear risk register, have been very useful tools for the project team as part of that communication process.

Overall

In summary, the project has exceeded the expected target outcome for C30, and is expected to exceed target outcome for C32. Difficulties in property access mean that C31 is not quite met (96% complete) but efforts are still ongoing to retrofit the final 4 properties. C34 is predicted to not quite be met (81%) but the actual

CO2 saving is somewhat dependent on the extent to which heat is provided by the heat pump, CHP and back up boilers.

The delivery of the project was somewhat delayed. This was due to a number of factors, around borehole drilling and amendments to design following poor borehole performance.
The delivery has been flexible, to respond to challenges of poor borehole performance. The value of the project learning could be significant for future civic partner energy projects, particularly given the plans to extend the heat network under Hebburn 2.

9. Additional information for the ERDF template

Project context 500 word version:

The project intended the installation of a small heat network and water source heat pump, using minewater as the primary heat source. The scheme's feasibility study showed significant potential to source minewater from the High Main Seam and Bensham Seams at Hebburn Colliery, which is the proposed project site. This is the basis of Hebburn Minewater Energy Scheme.

The original design intent was a heat pump of 450kW$_{th}$, a 20m^3 thermal store, combined with the retained gas boilers (3 x 605kW$_{th}$) and Combined Heat and Power (CHP) unit (230kW$_{th}$) at the Hebburn Central plant room. The new Energy Centre and existing Hebburn Central plant room would be connected via a low temperature heat network, with additional connections to Durham Court and Lincoln Court. The design also included a low voltage (LV) connection between Hebburn Central and the new Energy Centre, which would enable electricity generated by the CHP unit to be used for the operation of the heat pump.

At the time of the initial proposal, the Durham Court and Lincoln Court heat loads were served by individual gas boilers. Hebburn Central heat loads were served by three gas boilers and a Combined Heat and Power Unit.

The project was seeking to contribute to South Tyneside Council's net zero commitment, by decarbonising heating load and demonstrating a relatively under-utilised technology (for the UK) of a water-source heat pump using minewater as the primary heat source. The project was trying to address energy cost for end users of the buildings, and greenhouse gas emissions reduction. The choice of technologies makes this low carbon heating scheme more expensive than the business as usual, which results in a need for capital investment to support the project investment. The rationale was therefore strong.

In late 2021 it was clear from minewater testing results, and understanding of the flow rates at the test boreholes, that the scheme could not be operated as a minewater-only district heat network. The design was therefore adjusted to an air-source heat pump. This was a risk which the project team were aware of, and had planned for. The thermal storage, gas-fired co-generation and heat network are unchanged in the final design.

One further change to the project scope was that the Lincoln Court redevelopment was removed from the scheme.

The design has incorporated flexibility to enable extension of the heat network at a later date. The stage 3 design report refers to an additional 3MW peak heat load, and the electrical design will enable a further heat pump installation at the Energy Centre.

There is excellent strategic alignment of the design concept to central and local government priorities. Since the project was initiated in 2020, the strategic alignment remains excellent, with a continued drive to support low carbon energy systems at the local, regional and national level.

Project progress 500 word version:

Energy and carbon targets
The targets considered here are those in the grant agreement.

ER/C/O/30 Additional capacity of renewable energy production: 200kW
Capacity of 450kWth (50658-VE-EC-XX-SC-M-5601_C3_New Energy Centre P&ID.pdf), compared with an original estimated 200kWth (200501 Hebburn MW GFA final.pdf). This revised capacity was introduced at the stage 4 design.
225% of target achieved.

ER/C/O/31 Number of household with improved energy consumption classification: 111
Actual households 107. This relates to the number of social housing units in Durham Court which have undergone internal works to connect to the heat network.
96% of target achieved.

ER/C/O/32 Decrease of annual primary energy consumption of public buildings: 1,578MWh

- The business as usual (BAU) thermal demand is estimated in the Stage 2 design report as 3,040 MWh/yr (for Hebburn Central and Durham Court only).
- If the heat output was met by the existing gas boilers and the CHP system then this would require 4,264MWh/yr of gas, which equates to 4,742MWh/yr of primary energy.
- The associated electricity generation by the CHP would be 454MWh/yr in this BAU scenario.
- For the new scheme, assuming the heat pump serves 73% of heat demand, the gas CHP serves 9.4% of heat demand, and the gas boilers serve 17.7% of heat demand (stage 3 report), then the new scheme would require 1,226MWh/yr of gas for the CHP and boilers and 760MWh/yr of electricity for the heat pump.
- The net reduction in gas demand comparing BAU and the new scheme is 3,039MWh/yr.
- The CHP is used less often to the BAU scenario, and so electricity generation is reduced to 184MWh/yr with the heat pump scheme.
- The net electricity demand for the new scheme is 576MWh/yr.
- The primary energy equivalent of the gas demand is 1,363MWh/yr, and of the electricity demand is 1,487MWh/yr.

The overall decrease of annual primary energy consumption, is estimated as 1,895MWh/yr.
120% of target achieved.

ER/C/O/34 Annual decrease in GHG emissions: 280.67 tCO2e

- The business as usual gas consumption would lead to annual emissions of 873 tCO2e and the electricity generation by the CHP would avoid 174 tCO2e, a net emissions of 698 tCO2e.
- Reduced gas usage results in a new annual emissions from gas use of 251 tCO2e.
- Increased electricity usage leads to a net emissions increase of 222 tCO2/yr.
- Net emissions for the new scheme are estimated as 472.38 tCO2e.

The net emissions saving for the scheme is 226 tCO2e/yr.
81% of target achieved.

It should be noted that the consultant's carbon modelling is based on a daily time resolution, whereas this summative assessment assumes broad annual averages. The Coefficient of Performance of the heat pump (assumed as 2.92), and contribution of the heat pump (assumed as 73%) and CHP (assumed as 9.4%) to heat demand, are influential in the estimate of GHG emissions reduction. At present, it is estimated that 81% of the C34 target will be achieved. However, if a COP of 3.2 is assumed, the emissions savings increase to 253tCO2e, around 90% of the target.

Project progress 500 word version:

Project leadership
Project management has been provided to South Tyneside Council by Driver Project Services from 1st June 2020, specifically, Stephen Kelleher as the Senior Project Manager. Leadership across the contracted parties is evidenced through engagement in progress meetings by South Tyneside Council, South Tyneside Homes, Buro Happold, Vital Energi, Faulkner Browns, Gardiner & Theobald, and Driver Project Services, for example.

Wider Council involvement
Various members of South Tyneside Council (from energy, legal, highways, street lighting, leisure, for example) have supported the project as evidenced by the Project Directory of contacts. Progress meetings

also refer to site visits by Councillors, who have engaged with the project. The project also engaged with the North East Local Enterprise Partnership (NELEP) Minewater Task Force, and had a visit from a local MP.

Meetings, and project governance
The evidence shows the project has been very well managed. At the design stage (to RIBA Stage 4) there are fortnightly meeting minutes which clearly identify design choices, and appropriate consultation on these between the design team and client. Monthly progress reports during the construction phase include reporting on health & safety, and the project risks. There is a comprehensive risk register which has been updated (the team have now issued version 10). Safety, Health, Environment and Quality reports demonstrate very good practices for site health and safety. There is also a very good report and score from the Considerate Constructors Scheme site visit. Monthly progress meetings show a detailed record of any delays and changes to expenditure.

The standard of documentation is very good. For example, there are fortnightly meetings, with minutes, for the design stages in 2020-2021, and clear documentation from the contractor for the stage 5 design drawings. There is a comprehensive document issue sheet and register.

Whilst building work is not quite complete, appropriate inspection and sign off of components of the work is in evidence, some commissioning documentation has been completed, and final commissioning and handover is expected in October/November.

Appropriate beneficiaries were engaged with, and this is also reported on as a regular communications item in the monthly progress meetings.

Potential areas for improvement
Driver Project Services carried out a Lessons Learned exercise, consulting with all parties, stakeholders and South Tyneside council staff, and issued its report at the end of August 2023. This report identified the following areas for improvement:
- It is not appropriate to limit feasibility studies to a pre-selected preferred choice (e.g. mine water) without conducting a full evaluation of all options.
- A Project Board should be established at the inception of the project, with key senior officers appointed to develop and agree on the project strategy, budget, program, procurement, communications, and appointment of consultants, and to steer the project as it progresses.
- As a Well Operator, STC has a duty to manage the mine water extraction wells. While the wells are currently not in use and are in a state of suspension, the well assets should be assessed, to evaluate the work that has been done on the wells and consider what options are available to develop the wells in support of the planned Hebburn 2 Heat Network Extension.

Contribution to ERDF Horizontal Principles
The nature of the project, in terms of increasing renewable energy capacity and reducing greenhouse gas emissions, directly contributes to the horizonal principle of sustainable development. As a demonstrator project and learning experience for South Tyneside Council and supply chain, it can cascade learning to future projects and thereby have a broader contribution to sustainable development targets.

Project outcomes and impact

Expected outcomes
Outcomes are yet to be confirmed, post commissioning of the overall scheme.

The appropriate evaluation in this case would be an interrupted time series analysis and difference-in-difference analysis, as described in the Magenta Book (p48). The approach would be to take time-series data, to test for a causal change in the data trend. This requires time-series data for gas and electricity consumption prior to the project.

At this stage, it is only possible to comment on progress towards the outcomes.

With regards the number of properties (C31), all but 4 of the 111 properties in Durham Court have had dwelling modification work.

With regards the installed renewable energy capacity (C30), decrease of annual primary energy consumption (C32) and estimated GHG reductions (C34), this is delivered as a result of the heat network (installed), air source heat pump (installed), CHP unit (existing), back up gas boilers (existing), upgrade of the Northern Power Grid transformer (installed), and private wire connection between Hebburn Central and the Energy Centre (installed). Performance data should confirm the expected outcomes, with C30 exceeded, C32 expected to be exceeded, and C34 expected to be around 81% of the target.

Wider benefits

The experience of South Tyneside Council in delivery of this project can benefit the wider civic partners across the north east, particularly beyond the three Council members of the North East Combined Authority given that the new Devolution Deal for the North East will see seven local authorities joining forces.

It is recommended that the project team collate evidence of sharing of project experience, so that evidence is built up over time of the wider benefits of the project.

Given the recent energy price crisis across the UK, there is potential for the buildings connected to the Hebburn scheme to be shielded somewhat from volatility in gas and electricity prices. This may lead to a better financial performance of the project over the lifetime, although predicting future energy prices is very difficult to do with accuracy. It is recommended that the project team also collate evidence of this potential financial benefit.

Project value for money

Carbon savings

By project closure, there is an estimated reduction in GHG emissions of 226 tons CO_2e.

The lifetime value of saved carbon emissions can be compared with the investment cost of the scheme. Assuming the central traded carbon values from 2023 onwards, with a flat rate from 2050 onwards (BEIS published values only go to 2050) then the value of the saved carbon from the scheme is £2.1m.

“Greenhouse gas emissions values (“carbon values”) are used across government for valuing impacts on GHG emissions resulting from policy interventions. They represent a monetary value that society places on one tonne of carbon dioxide equivalent (£/tCO_2e). They differ from carbon prices, which represent the observed price of carbon in a relevant market (such as the UK Emissions Trading Scheme).”

Whilst this £2.1m amount is not discounted, it compares favourably with the project ERDF 2020 value of £7.746m (the carbon saving value is more than ¼ of the total investment).

10. SUPPLEMENTARY CALCULATIONS

Business as usual scenario – existing scheme of CHP and gas boilers.

BAU with existing scheme:		
Heat Demand for Hebburn Central (adjusted for Climate Change)	1570	MWh
Gas boiler efficiency	81%	existing
55% of demand is met by gas boiler	55%	
CHP thermal efficiency	49.50%	existing
45% of thermal demand met by CHP	45%	
Gas demand for HC boiler	1,066	MWh
Gas demand for HC CHP	1,427	MWh
Total gas demand HC	2,493	MWh
Heat Demand for Durham Court (adjusted for Climate Change)	1,470	MWh
Gas boiler efficiency	83.00%	
Gas demand for DC	1,771	MWh
TOTAL gas demand HC + DC	**4,264**	**MWh**
Gas emissions kg/kWh	**0.20463**	
Annual gas emissions BAU	**872.63**	**t/yr**
Primary equivalent of gas demand	**4,742**	**MWh**
CHP electrical efficiency	31.80%	
Electricity generated by CHP	453.87	MWh
Electricity emissions kg/kWh	0.38	
Annual electricity emissions saving via CHP generation	174.48	t/yr

ncl.ac.uk/research/energy/
energy@ncl.ac.uk
Prof Sara Walker, Centre Director

Newcastle University / Centre for Energy

Heat network scheme: COP 2.92, heat pump contribution 73%, CHP contribution 9.4%, gas boiler contribution 17.7%

New scheme: Stage 3 design report assumptions					
Heat pump					
Capacity	450	kW			
COP	2.92				
Availability	95%				
Fraction of thermal demand met	73%				
HP Electrical demand	760.00	MWh			
HP Heat output	2,219.20	MWh			
CHP					
Fraction of thermal demand met	9.35%				
CHP heat output	284.24	MWh			
CHP gas input	574.22	MWh			
CHP electrical output	182.60	MWh			
Gas boiler					
Fraction of thermal demand met	17.65%				
Boiler heat output	536.56	MWh			
Boiler gas input	646.46	MWh			
BAU gas demand	4,264	MWh	BAU gas emissions	872.63	tCO2
BAU electricity generation	453.87	MWh	BAU elec emissions	- 174.48	tCO2
			BAU TOTAL EMISSIONS	698.14	tCO2
HP scheme gas demand	1,220.68	MWh	HP scheme gas emissio	249.79	tCO2
HP SCHEME NET ELECTRICITY DEMAND (HP DEMAND - CHP	577.40	MWh	HP scheme elec emissi	221.97	tCO2
			HP scheme TOTAL EMI	471.76	tCO2
NET REDUCTION IN GAS DEMAND	3,043.73	MWh			
NET REDUCTION IN GHG EMISSION	226.39	tCO2			
Primary equivalent of electricity demand	1,489.69	MWh			
Primary equivalent of gas demand	1,357.40	MWh			
Reduction in net primary energy demand	1,894.94	MWh			

TRANSITION TO CLEAN AFFORDABLE ENERGY | Justice and Ethics | Energy | Security and Resilience

Demonstration | Sustainability | Policy and Regulation | Materials | Digital Innovation | Behaviour | Technology | Systems Infrastructure | Business Models | Design

ncl.ac.uk/research/energy/
energy@ncl.ac.uk
Prof Sara Walker, Centre Director

Newcastle University / Centre for Energy

Alternative new scheme with higher COP (3.2, as per stage 3 report): **253**tCO_2e GHG emissions saving with a higher COP for the heat pump.

New scheme: COP 3.2					
Heat pump					
Capacity	450	kW			
COP	3.2				
Availability	95%				
Fraction of thermal demand met	73%				
HP Electrical demand	693.50	MWh			
HP Heat output	2,219.20	MWh			
CHP					
Fraction of thermal demand met	9.35%				
CHP heat output	284.24	MWh			
CHP gas input	574.22	MWh			
CHP electrical output	182.60	MWh			
Gas boiler					
Fraction of thermal demand met	17.45%				
Boiler heat output	530.48	MWh			
Boiler gas input	639.13	MWh			
BAU gas demand	4,264	MWh	BAU gas emissions	872.63	tCO2
BAU electricity generation	453.87	MWh	BAU elec emissions	- 174.48	tCO2
			BAU TOTAL EMISSIONS	698.14	tCO2
HP scheme gas demand	1,213.35	MWh	HP scheme gas emissic	248.29	tCO2
HP SCHEME NET ELECTRICITY DEMAND (HP DEMAND - CHP	510.90	MWh	HP scheme elec emissi	196.40	tCO2
			HP scheme TOTAL EMI	444.69	tCO2
NET REDUCTION IN GAS DEMAND	3,051.05	MWh			
NET REDUCTION IN GHG EMISSION	253.45	tCO2			
Primary equivalent of electricity demand	1,318.12	MWh			
Primary equivalent of gas demand	1,349.25	MWh			
Reduction in net primary energy demand	2,074.65	MWh			

ncl.ac.uk/research/energy/
energy@ncl.ac.uk
Prof Sara Walker, Centre Director

Newcastle University / Centre for Energy

Alternative new scheme with CHP providing 17% and gas boilers 10% of heat load: **245**tCO_2e GHG emissions saving.

New scheme: Higher CHP contribution						
Heat pump						
Capacity	450	kW				
COP	2.92					
Availability	95%					
Fraction of thermal demand met	73%					
HP Electrical demand	760.00	MWh				
HP Heat output	2,219.20	MWh				
CHP						
Fraction of thermal demand met	17.00%					
CHP heat output	516.80	MWh				
CHP gas input	1,044.04	MWh				
CHP electrical output	332.00	MWh				
Gas boiler						
Fraction of thermal demand met	10.00%					
Boiler heat output	304.00	MWh				
Boiler gas input	366.27	MWh				
BAU gas demand	4,264	MWh	BAU gas emissions		872.63	tCO2
BAU electricity generation	453.87	MWh	BAU elec emissions	-	174.48	tCO2
			BAU TOTAL EMISSIONS		698.14	tCO2
HP scheme gas demand	1,410.31	MWh	HP scheme gas emissic		288.59	tCO2
HP SCHEME NET ELECTRICITY DEMAND (HP DEMAND - CHP	428.00	MWh	HP scheme elec emissi		164.53	tCO2
			HP scheme TOTAL EMI		453.12	tCO2
NET REDUCTION IN GAS DEMAND	2,854.10	MWh				
NET REDUCTION IN GHG EMISSION	245.02	tCO2				
Primary equivalent of electricity demand	1,104.23	MWh				
Primary equivalent of gas demand	1,568.26	MWh				
Reduction in net primary energy demand	2,069.53	MWh				

Transition to clean affordable energy | Justice and Ethics | Energy | Security and Resilience

Demonstration | Sustainability | Policy and Regulation | Materials | Digital Innovation | Behaviour | Technology | Systems Infrastructure | Business Models | Design

ncl.ac.uk/research/energy/
energy@ncl.ac.uk
Prof Sara Walker, Centre Director

Newcastle University / Centre for Energy

Alternative new scheme with lower heat pump contribution – consistent with Nov 22 Updated Carbon Analysis :**208**tCO_2e GHG emissions saving.

New scheme - lower heat pump contribution					
Heat pump					
Capacity	450	kW			
COP	2.92				
Availability	95%				
Fraction of thermal demand met	65.20%				
HP Electrical demand	678.79	MWh			
HP Heat output	1,982.08	MWh			
CHP					
Fraction of thermal demand met	12.80%				
CHP heat output	389.12	MWh			
CHP gas input	786.10	MWh			
CHP electrical output	249.98	MWh			
Gas boiler					
Fraction of thermal demand met	22.00%				
Boiler heat output	668.80	MWh			
Boiler gas input	805.78	MWh			
BAU gas demand	4,264	MWh	BAU gas emissions	872.63	tCO2
BAU electricity generation	453.87	MWh	BAU elec emissions	- 174.48	tCO2
			BAU TOTAL EMISSIONS	698.14	tCO2
HP scheme gas demand	1,591.88	MWh	HP scheme gas emission	325.75	tCO2
HP SCHEME NET ELECTRICITY DEMAND (HP DEMAND - CHP	428.81	MWh	HP scheme elec emissior	164.85	tCO2
			HP scheme TOTAL EMISS	490.60	tCO2
NET REDUCTION IN GAS DEMAND	2,672.52	MWh			
NET REDUCTION IN GHG EMISSION	207.55	tCO2			
Primary equivalent of electricity demand	1,106.34	MWh			
Primary equivalent of gas demand	1,770.18	MWh			
Reduction in net primary energy demand	1,865.50	MWh			

TRANSITION TO CLEAN AFFORDABLE ENERGY | Justice and Ethics | Energy | Security and Resilience

Demonstration | Sustainability | Policy and Regulation | Materials | Digital Innovation | Behaviour | Technology | Systems Infrastructure | Business Models | Design

LIFETIME VALUE FOR MONEY

The lifetime value for money is estimated based on the value of saved carbon emissions, compared with the investment cost of the scheme. Assuming the central traded carbon values from 2023 onwards, with a flat rate from 2050 onwards (BEIS published values only go to 2050) then the value of the saved carbon from the scheme is £2.1m.

Year	Carbon value (central) £/tCO2e	Scheme tCO2e	Value of saved CO2e
TOTAL VALUE OF SAVED CO2e			**2,138,839.53**
2023	252	225.76	56,891.24
2024	256	225.76	57,794.27
2025	260	225.76	58,697.31
2026	264	225.76	59,600.34
2027	268	225.76	60,503.38
2028	272	225.76	61,406.41
2029	276	225.76	62,309.45
2030	280	225.76	63,212.48
2031	285	225.76	64,341.28
2032	289	225.76	65,244.31
2033	293	225.76	66,147.35
2034	298	225.76	67,276.14
2035	302	225.76	68,179.18
2036	307	225.76	69,307.97
2037	312	225.76	70,436.77
2038	316	225.76	71,339.80
2039	321	225.76	72,468.60
2040	326	225.76	73,597.39
2041	331	225.76	74,726.19
2042	336	225.76	75,854.98
2043	341	225.76	76,983.77
2044	346	225.76	78,112.57
2045	351	225.76	79,241.36
2046	356	225.76	80,370.16
2047	362	225.76	81,724.71
2048	367	225.76	82,853.51
2049	373	225.76	84,208.06
2050	378	225.76	85,336.85
2051	378	225.76	85,336.85
2052	378	225.76	85,336.85

If the same process was applied, using the low and high scenarios, then the total value of the saved carbon would instead be £1.1m or £3.2m.

Year	Carbon value (low) £/tCO2e	Value of saved CO2e	Carbon value (high) £/tCO2e	Value of saved CO2e
		1,073,934.94		3,208,710.82
2023	126	28,445.62	378	85,336.85
2024	128	28,897.14	384	86,691.41
2025	130	29,348.65	390	88,045.96
2026	132	29,800.17	396	89,400.51
2027	134	30,251.69	402	90,755.07
2028	136	30,703.21	408	92,109.62
2029	138	31,154.72	414	93,464.17
2030	140	31,606.24	420	94,818.73
2031	142	32,057.76	427	96,399.04
2032	144	32,509.28	433	97,753.59
2033	147	33,186.55	440	99,333.90
2034	149	33,638.07	447	100,914.21
2035	151	34,089.59	453	102,268.77
2036	153	34,541.11	460	103,849.08
2037	156	35,218.38	467	105,429.39
2038	158	35,669.90	474	107,009.70
2039	161	36,347.18	482	108,815.78
2040	163	36,798.70	489	110,396.09
2041	165	37,250.21	496	111,976.40
2042	168	37,927.49	504	113,782.47
2043	180	40,636.60	511	115,362.78
2044	173	39,056.28	519	117,168.85
2045	176	39,733.56	527	118,974.92
2046	181	40,862.36	535	120,781.00
2047	184	41,539.63	543	122,587.07
2048	186	41,991.15	551	124,393.14
2049	189	42,668.43	559	126,199.21
2050	189	42,668.43	568	128,231.04
2051	189	42,668.43	568	128,231.04
2052	189	42,668.43	568	128,231.04