East London Energy

Decarbonisation Opportunities

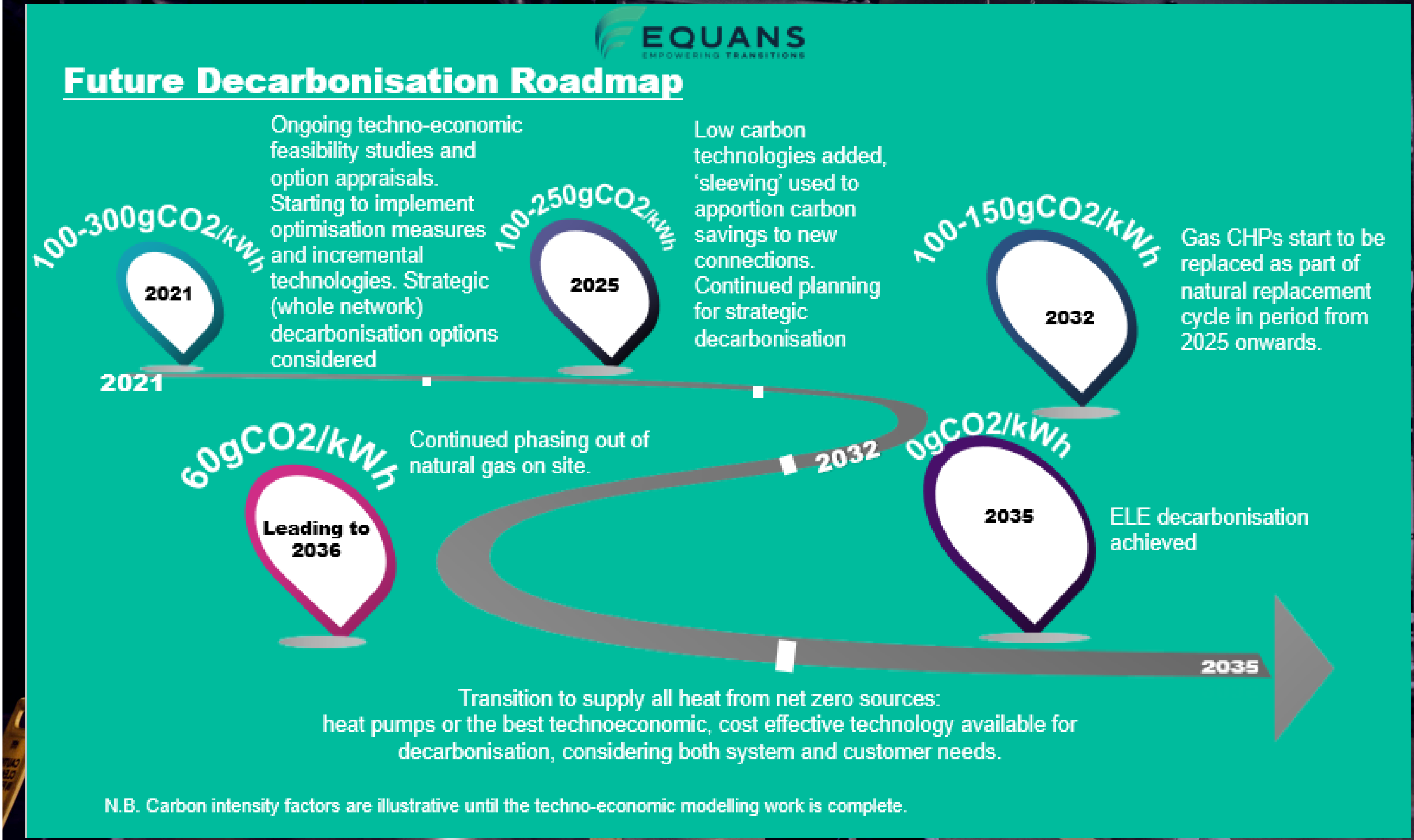


Figure1: Proposed roadmap of declining scheme carbon factors as low-carbon technologies are introduced

Executive summary

**EQUANS is a global energy and services business.
EQUANS' ambition is to become the world leader in zero-carbon transition working with companies and local authorities to deliver zero carbon and 'Make net zero-carbon happen'**

EQUANS own and operate multiple heating and cooling networks across the UK. Decarbonising these existing networks and delivering more low and zero-carbon heat through heating and cooling networks is key to our work to help companies and local authorities decarbonise.

We are a founding member of the UK Heat Networks Industry Council, which is working with the UK Government to develop zero-carbon heat networks via the development of appropriate policy and regulatory frameworks. The Council's members are committed to developing decarbonisation plans for all schemes and to only operate net zero schemes by 2035. We are committed to working with partners, customers and developers who share our ambition to lead this transition of the sector and to support the efforts of those with their own net zero targets. By decarbonising the network, we will allow all 71 currently connected buildings, and imminent upcoming connections, to be decarbonised to help transition the whole neighbourhood to net-zero.

Decarbonising our existing networks will require phasing out of local fossil fuel use for heating and investment in new lower carbon heat generating plant, networks and controls.

At the Queen Elizabeth Olympic Park, we are already looking to decarbonise the network and undertaking feasibility studies, to start integrating heat pumps within the next two years. Using locally available resources of water source or waste heat, and scope for using green gas and/or additional biofuels will support a transition away from natural gas in our CHP plants.

Our proposed carbon reduction goals, as set out in our roadmap (Fig.1), signal the intended carbon intensity of the scheme at key milestones.

Executive Summary

We will continue to develop and evolve our decarbonisation road map for the East London Energy (ELE) network and EQUANS networks across the UK. Our roadmaps will be agile to reflect an evolving policy and regulatory environment. The precise timing and scale of investments will be informed by robust techno-economic feasibility work to determine the most cost-effective approach, potential impact on customers and the business case for investment.

We are currently undertaking techno-economic feasibility work to assess the most appropriate and viable options for our next steps on the ELE decarbonisation roadmap as shown in our 12 month action plan below. We are also working with BEIS on their Greening Existing Networks (GEN) project to explore the opportunities and barriers to decarbonising existing heat networks.

Broadly our decarbonisation strategy is a 3-tier approach focusing on near term action to decarbonise alongside plans for longer term, wholesale decarbonisation, with actions and investigations undertaken in parallel:

1. **System optimisation and efficiency improvements –** Adapting and getting the most out of existing on-park assets and benefiting from wider energy system carbon and price signalling:
   - Optimising operational efficiency using 24/7 monitoring though software with the potential to operate CHP engines for optimal carbon savings.
   - Upgrades to existing equipment. For example:
     - Changing cooling generation technology to match cooling demands most appropriately - moving from larger more traditional chillers to smaller two-way heat pumps for lower night-time loads.
     - Modifying existing boilers to utilise biofuels
   - Green gas supply to the CHP engines (produced off-site and transacted via RGGOs/certificates)
   - Maximising the flexibility benefits of existing equipment and introducing additional controls and storage.
   - Improving return temperature / dT, which could have significant benefit to cooling and potential future benefit to heating in the future

2. **Incremental installation of low carbon technology.** Investigating local lower carbon generation and heat source opportunities and determining their feasibility. At ELE we are looking at heat pumps utilising heat from water, sewage, air, chiller recovery and the scope for heat from solar thermal.

3. **Strategic Decarbonisation –** asset replacement strategies, developing strategic roadmaps and plans for full reduction scheme carbon factors. EQUANS are considering:
   - Emerging technology options and innovation
   - The policy and regulatory environment
   - Existing asset replacement cycles over the next 15 years
   - Build out opportunities, master planning and zoning across the wider area to factor in scope for connection to large waste heat sources e.g. Edmonton EfW
   - Role (if any) of hydrogen for heating in UK.

This document presents the options for decarbonisation for ELE. The content of this report was written and agreed in September 2021. EQUANS and our partners (LLDC and Unibail-Rodamco-Westfield(URW)) are working to refine the decarbonisation options and develop a planned roadmap. Progress and updates on this work will be included as addendum's to the main body of this report.

The next stage of work is to complete the options appraisal, detailed design, financial models and investment case. We are working with partners to progress the investment case and grant funding applications for the new technologies to be installed and operating as soon as possible.

The work will be to fully evaluate and design the integration of these technologies into the scheme in technically and commercially viable ways. The following table shows our current 12- month action plan*:

*To be updated following outcome of ongoing techno-economic study

12 month action plan

		Q4 2020	Q1 2021	Q2 2021	Q3 2021	Q4 2021	2022
Strategic decarbonisation	Overarching Roadmap & TEF studies. Joint with LLDC and Westfield	Funding secured		High Level review	Technical and financial reviews followed by Report Finalisation & Roadmap review. Exploring opportunities for GHNF		
	Low carbon CHPs and carbon accounting	Addressing govt policy & accounting rules			Monitoring and reporting of operation vs marginal plant plus offsetting of any excess emissions (e.g. via green gas certificates		
	EfW Connection	Monitor and join up local area HN projects, mapping and master planning Work with GLA to develop cross borough discussions. Awaiting outputs of BEIS GEN project. Continue dialogue with Energetik.				Potentially secure feasibility funding (HNDU) & develop potential business case	
	New development connection opportunities	8 development plots/~27MW of heat demand for planning approval (5 plots/13MW off-park) providing opportunity for funding contributions from connection fees or offset payments. Strategic review of connection opportunities to support decarbonisation.					
	Connection to EDEC and Docks	Explore integration of the EDEC and ELE decarbonisation roadmaps from a strategic perspective. Working with GLA to explore possibility and options, including possibility of developing strategic decarbonisation options form the river and other large-scale sources of waste heat e.g. sewage and industry.					
	Role for hydrogen	Explorations of the potential role of hydrogen in heat networks					
Sytem Optimisation	Biomass & Biofuels	If selected for further consideration - Improve future cost assumptions for biofuel conversion, consider EA and air quality assumptions, consider feasibility of getting a tanker delivery). Monitor stakeholder positions on biomass and air quality.					
	Green Gas	Ongoing dialogue with BEIS around the use and carbon accounting for biogas and green gas certification integration into existing networks.					
	2 way heat pumps for lower night-time chill loads	-x-	-x-	-x-	High-level Scoping	Investigating funding opportunities and undertaking further concept design.work	Outline Investment Case. If go - Detail Design and Procurement.
	Improving return temperature / dT	Continued exploration of opportunities to improve efficiencies. Identifying funding opportunities to implement solution e.g. HNES					
	Battery Integration	-x-	-x-	Installation of on-site battery at Kings Yard	Exploring opportunities for flexibility and DSR alongside integration of low carbon technologies		
Incremental Decarbonisation	Kings Yard heat pump integration	-x-	High-level Scoping	Concept Design	Securing LEA feasibility Funding Detailed Feasibility & Plume Modelling		Permitting and Investment Case. (start on site Q1 23)
	Waste heat recovery - cooling towers	-x-	-x-	-x-	High-level Scoping	Investigating funding opportunities and undertaking further concept design work	Outline Investment Case. If go - Detail Design and Procurement.
	Solar thermal	-x-	High level Scoping	Concept Design & Optioneering (TEF)	Business Case Review	Investment Case. If go - Detail Design and Procurement	
	Waste heat recovery - Sewage	-x-	Thames Water dialogue & design review	Due to ongoing existing works on the Abby Mills pumping station, water waste recovery site this project is unlikely to be able to be developed in the short term. There is however scope to further explore Greenway and ongoing engagement with Thames Water is required to ensure we can act on any opportunities as they arise.			
	Waste heat recovery - TfL Pudding Mill lane vent shaft scale	TfL dialogue	Concept Design & Optioneering (Techno Economic Feasibility)	Outline Investment Case. If go - Detail Design and Procurement. (would be integrated into the DH connection of Pudding Mill Lane redevelopment - heat on subject to developer's programme			

Background

About EQUANS - Urban Energy

EQUANS is a global energy and services business. We are a global market leader in city centre district heating schemes with an established and long track record of delivering energy and carbon savings consistent with government aspirations and client needs.

EQUANS' approach to the management and development of heating and chilled water networks is that they provide a technology agnostic form of transmission, selecting the source(s) of generation which best optimise benefits to the system, so that they remain flexible and responsive with time. To transition to net zero, our approach in the near term is to seize opportunities to integrate low-carbon technology into our schemes. This would provide near term carbon savings and progressively change the technology mix of the scheme and marginally improve the carbon intensity (against BAU) over time. For the longer-term achievement of net zero, we are exploring how best to either substitute natural gas with major net zero heat sources EfW, bioenergy, and replace the existing fossil based generating assets at the end of their natural operating lives with lower-carbon plant.

We have dedicated resource to work with the technical and engineering specialists within the business to develop a programme of work to assess the opportunities, secure funding and develop & install commercially viable solutions, with a commitment to collaborating widely to find the best way forward for each of our schemes and the places in which they operate.

Background

About East London Energy (ELE)

The concept of the ELE district energy system was developed by the Olympic Delivery Authority (ODA now the London Legacy Development Corporation (LLDC)) to supply low cost, low carbon heating and chilled water (CHW) to buildings across the Queen Elizabeth Olympic Park (QEOP) and surrounding areas. EQUANS (formerly Cofely) was awarded a 40-year contract by the ODA to develop the system, with EQUANS providing funding to design and build the scheme and then provide operation, maintenance and associated metering and billing services for the term. As part of the form of agreement with the ODA, new developments "on-park" are obligated to connect to the district energy system.

The ELE network currently operates with baseload heat provided by CHP and biomass boiler, with back-up and top-up provided by the gas fired boilers. The chilled water on the cooling network is generated from a combination of absorption chillers, supplied with heat by the CHPs, and electric vapour compression chillers, supplied with electricity from CHP generation and grid import. Carbon emissions are 72% lower than equivalent services, with biomass boilers offering over 1000 tonnes/year reduction in carbon emissions than if heating services were provided via gas boilers. To date, the East London Energy scheme has exceeded the carbon targets set out in the concession agreement and will continue to do so in the future based on the current operating regime

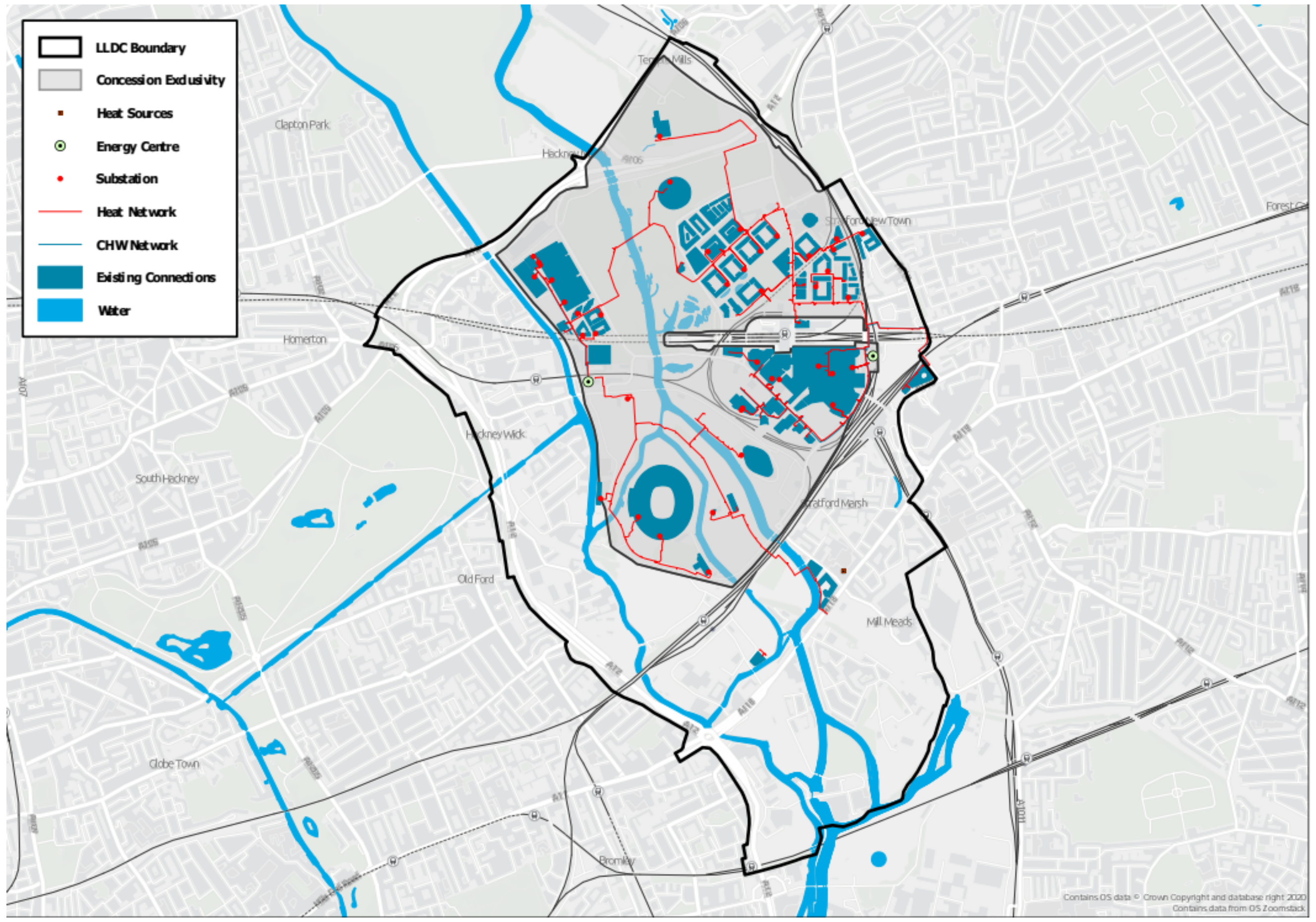


Figure 2. Overview of ELE and incremental decarbonisation opportunities

	Target	Delivered*	Target Met
Carbon emissions 20% lower than equivalent services	20%	72%	✓
Biomass carbon emissions are at least 1000 tonnes per annum less than heating services were provided via gas boilers, increasing in correlation with demand's growth	1,188	1,796	✓
Use all reasonable endeavours to procure a 15% reduction in carbon emissions	15%	73%	✓

*Based on 2006 Building regulations

Current challenges

The original £100m+ investment case was based upon the 9MW gas CHPe, 80MW gas boilers, 3.5MW biomass boiler and 57MW chillers installed in 2008-2010 being operated through to 2052, with additional CHPs being introduced in the 2020s and 2030s to provide additional baseload capacity. Departing from this technology mix changes the economics of the scheme, requiring detailed techno-economic appraisals to protect the original investment and future investment; and to ensure energy tariffs for consumers and connection fees to developers remain competitive in the wider market.

Grid data confirms the electricity generated by the CHP engines is currently displacing less efficient generation plant that is operating at the margin on the power grid - coal, gas turbines or imports. It is expected that the 'marginal plant' will gradually start to become cleaner sources of generation than the ELE CHPs, reducing the available periods in which operating the CHPs with natural gas provides carbon savings. The frequency and duration of these future periods of low-carbon marginal plant are difficult to predict, being dependent upon build rates for new renewable capacity, demand peaks coinciding with favourable weather for renewables and market signals for fossil-based assets.

We are working with the UK Government to better understand how we can transition away from gas dependency and optimise CHP operational hours in the future (to always provide carbon savings that benefit our connected customers in their journey to net zero) and what that means for when new baseload heat generating capacity will be required.

For new developments seeking to connect to the scheme, there remains significant uncertainty as to whether the ongoing but diminishing benefits of CHP will be recognised in the forthcoming updates to the building regulations and therefore whether CHP based schemes can offer compliant solutions. However, we are working closely with the GLA, ADE and UKDEA to engage with the government, manage the outcome and impacts in any changes to policy, and where necessary propose solutions (such as Sleeving see section 5.1) which enables new connections to be supplied with lower carbon heat and enables the transition away from gas for existing customers.

By decarbonising the network, we will allow all 71 currently connected buildings, and imminent upcoming connections, to be decarbonised to help transition the whole neighbourhood to net-zero.

Overarching Roadmap & TEF studies

EQUANS are undertaking a programme of activities for the decarbonisation of ELE which considered opportunities for:

- **System optimisation and efficiency improvements**
- **Incremental installation of low carbon technology**
- **Strategic decarbonisation (strategic roadmap for decarbonisation over the next 15 years).**

EQUANS are undertaking decarbonisation work jointly with LLDC and URW. We are currently undertaking a techno-economic feasibility study of the options available for introducing low-carbon sources of heat generation which both decarbonise the system and protect the needs of LLDC and URW.

- Identification of potential solutions available and operational characteristics and requirements
- Assessment of compatibility with scheme operating parameters and characteristics
- Definition of key constraints affecting their integration into the existing scheme and how they can be overcome (e.g. operating temperatures)
- Opportunity assessment for incremental decarbonisation presented by growth and new development connections within and outside the concession area
- Opportunity assessment presented by asset replacement cycles and commercial impact of accelerated asset replacements
- Concept designs for integration of low carbon solutions and associated energy model
- assessment of potential impacts on tariffs and/or commerciality
- Carbon performance under various scenarios of emissions factors (and SAP assumptions)
- Indicative delivery programme

We continue to work with the GLA and plan to further explore strategic growth opportunities and potential connections to major sources of heat, e.g. Edmonton EfW with the surrounding boroughs.

We are also working with BEIS on their GEN project to explore the opportunities and barriers to decarbonising existing heat networks. This work includes ELE as one of the focus projects. The outcome of the study will conclude in summer 2021 and we will incorporate the finding of the study into our wider techno-economic feasibility and decarbonisation studies.

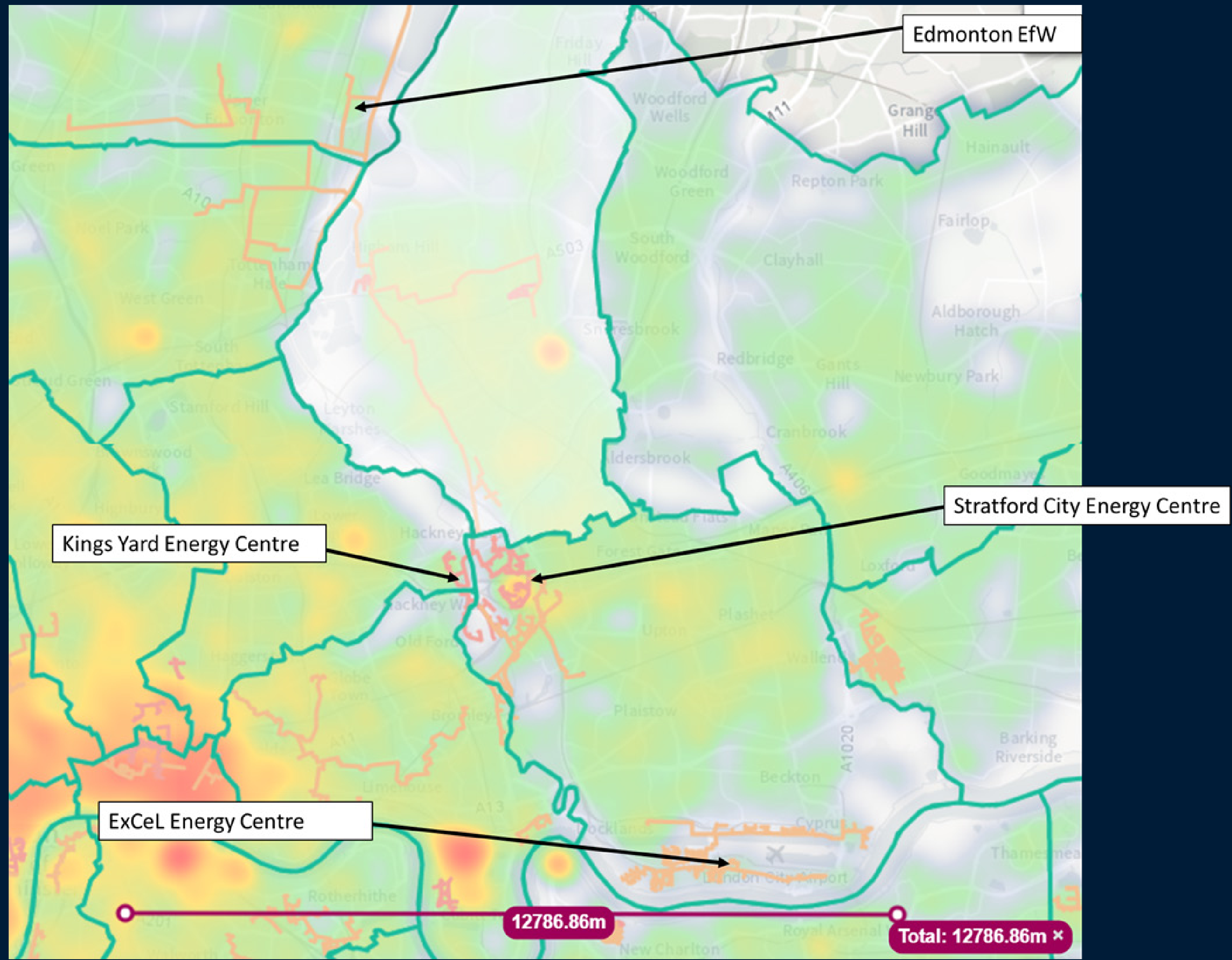


Figure 3. The London Heat Map showing existing (red lines) and potential (orange lines) heat networks in the vicinity of ELE.

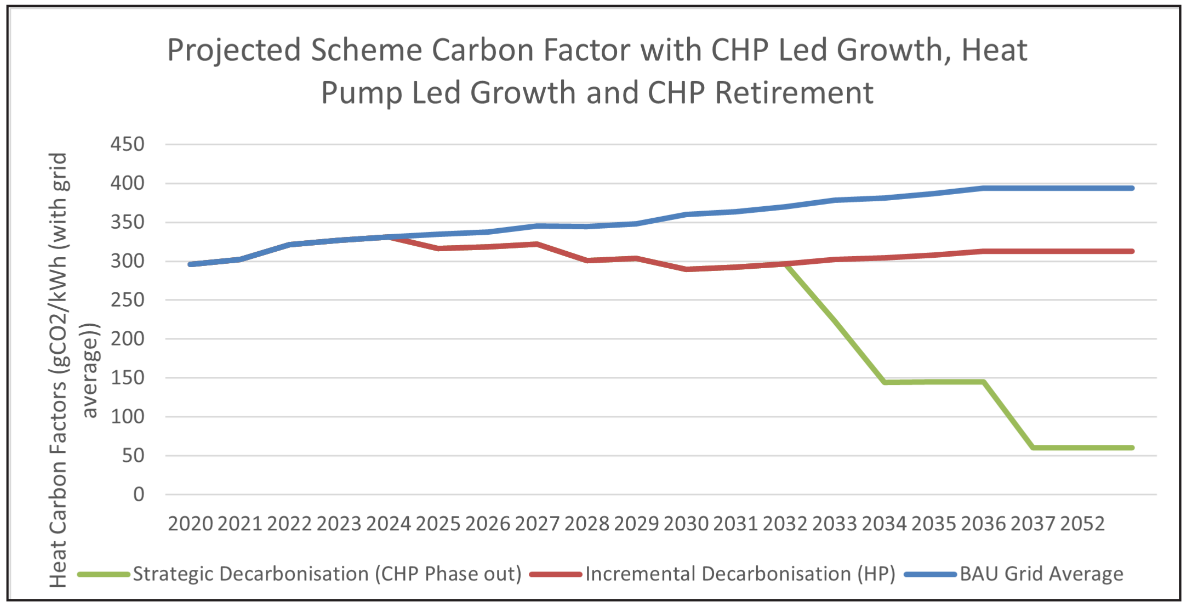
Illustrative decarbonisation scenarios

Although plant operation varies from year to year, the heat output typically currently comprises approximately:

- **47% CHP (natural gas)**
- **28% biomass**
- **25% gas boilers**

Stack emissions from this plant mix would be ~370g CO2/kWh, but this is offset by the carbon saved by the CHP electricity displacing the emissions from the marginal plant in operation on the national grid.

Assuming gas turbine marginal grid plant, with associated transmission and distribution losses, the avoided emissions could be ~240 g CO2/kWh, giving a scheme net heat carbon factor of ~110g CO2/kWh today.



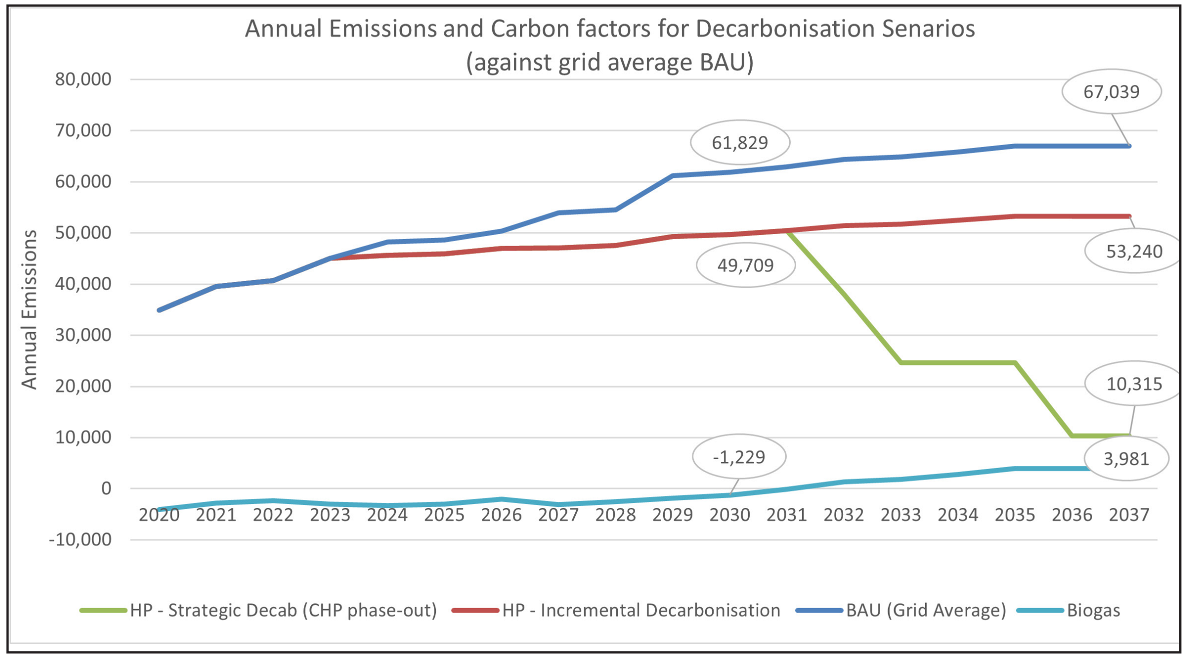


Figure 3. Graphs showing impact on carbon & emissions with introduction of low carbon technologies

The benefits of CHP will diminish when the marginal plant starts to become renewable sources of generation.

As an illustration we have completed some high-level assessments of how changes to the ELE technology-mix could help to reduce carbon emissions and change the scheme factor to meet the needs of customers:

- Maintaining CHP (discounting any carbon saved by the CHP electricity) whilst substituting gas boiler heat with waste heat, heat pump or bioenergy achieves ~240-255gCO2/kWh, similar to that from a typical gas boiler system;
- Using green gas in the CHP or replacing the CHP heat with heat pumps, could achieve ~110-120gCO2/kWh; This could be further reduced by introducing electric peaking boilers.
- Replacing existing plant with an energy from waste connection could result in ~132gCO2/kWh. This could be further reduced by increasing the base load form the EfW, offset z factor emissions and or introducing electric peaking boilers.
- Using only green gas in the existing scheme plant could achieve ~20gCO2/kWh (depending on the carbon content of the gas)

As indicated on the illustrative chart below, the gradual introduction of heat pump (HP) technology to displace CHP can reduce annual emissions (when measured against "grid average" emissions as utilised in the building regulations, and against the marginal plant reflected the day-day reality) helping to decarbonise the network. However, major strategic decarbonisation options will need to be considered to transition to net zero and phase out natural gas.

The planned techno-economic feasibility work will ensure we fully understand the technical constraints and commercial implications of such options. It will allow us to optimise their introduction (in the most appropriate sequence, timeframes and mix) to align with customer need.

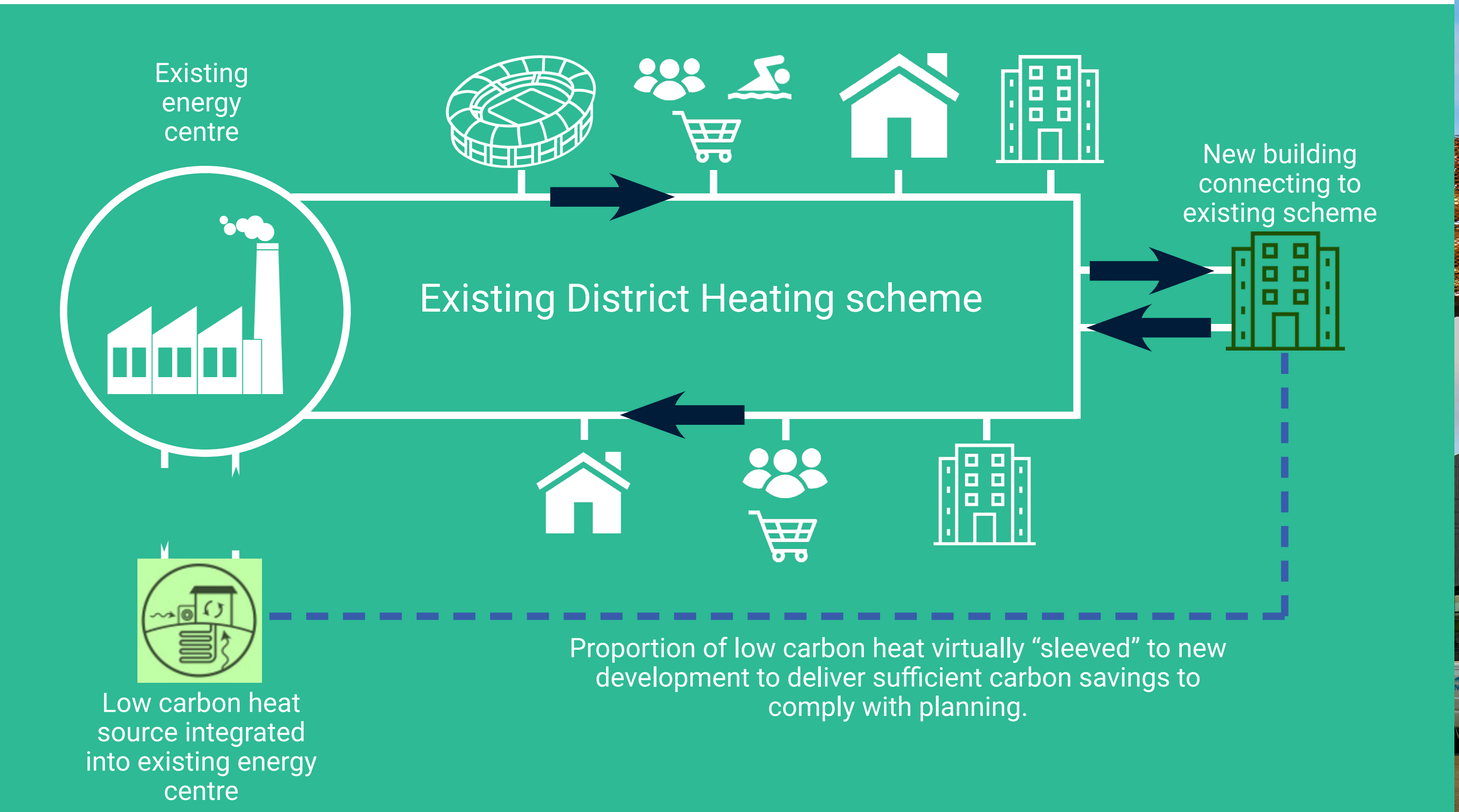
Sleeving 'Low-Carbon Heat'

The principal of 'sleeving' renewable electricity through the electricity network to end users via power purchase agreements is a well-established mechanism for connecting customers to renewable energy production at least cost. It enables end users to report carbon savings associated with the use of renewable electricity and meet carbon reduction targets (see also above for green gas supply). Adopting a similar approach to 'sleeving' low-carbon heat through a heat network would maximise the potential of new low or zero carbon technology added into an existing network and reduce the cost of transition.

For example, a single large heat pump could be installed in an existing energy centre instead of new individual building-level heat pumps, at lower capital cost and improved operational efficiency (i.e. increased running hours). The low-carbon heat would be "sleeved" through the network to the new development in perpetuity to safeguard compliance with building regulations and planning policy. This is easily achieved through the incorporation of appropriate obligations/penalties in the Master Supply and/or Energy Services agreements. This approach would need to be recognised by Planning Authorities and Building Control, as a compliant approach to Part L and planning policy.

This approach will ensure that new developments connecting to existing networks can continue to be compliant with future planning and Part L of the Building Regulations, BEIS have made early indications that Sleeving may be treated as an acceptable means of carbon accounting in the next edition of Building Regulations due to be updated in 2022. Additionally, with spare plant capacity, existing customers on the network could also choose a "lower-carbon heat supply tariff". This provides opportunity to increase consumer choice and potentially to crowd-fund network transition investment. Without the introduction of sleeving, existing networks may be unable to connect new developments and quickly become stranded assets, with no incentive for ESCO operators to invest in decarbonisation initiatives (until the introduction of regulation).

Figure 5. Diagram outlining principle of Sleeving



Technologies

The following provides an outline of technologies considered, the benefits they could bring and assessment of the challenges for deploying them.

The joint EQUANS, LLDC and URW decarbonisation studies will review the options available for introducing low-carbon sources of heat generation and the outputs of the first study will select up to 3 technologies to take forward to more detailed feasibility and design.

6.1 Cogeneration/Combined Heat and Power

Good quality CHP producing both power and heat is a well-established technology enabling the efficient use of primary energy and a cost-effective way of reducing carbon emissions. The ongoing growth of wind and solar power generation will eventually reduce the operational hours of inefficient thermal assets, such as coal and gas turbines (without heat recovery), and thereby reduce the frequency with which the operation of good quality CHP saves carbon. Due to the intermittency of wind and solar generation, there will still be many occasions across the year when 'flexible' thermal generation is required and from an energy efficiency and carbon perspective, is best met by good quality CHP. Therefore, there will continue to be an important role for good quality CHP in district heating particularly when integrated alongside electrical heating and thermal stores to balance supply and demand using digital technology to optimise operation/energy efficiency/carbon savings. In addition, as work accelerates to scale green gas production to decarbonise the gas grid, the substitution of natural gas with lower-carbon gases in CHP is likely to become increasingly cost competitive providing additional optionality for achieving heat decarbonisation at scale. EQUANS recognises a market framework which properly values these benefits and incentivises efficiency system operation will be required and continues to work with a wide-range of stakeholders to achieve this transition.

6.2 Heat pumps / Low grade heat recovery

Heat pumps use a refrigeration cycle to raise lower grade heat to levels required for the end use. The heat pump itself is a mature technology readily available throughout the UK. The key challenges around heat-pumps are primarily around the source of heat and corresponding availability (initial deployment as well as year-round availability of heat) and associated influence on quantum of low carbon heat that can be provided, efficiency of heat generated and cost impact. Even with higher levels of efficiency than combustion plant, the cost of generating heat will be higher compared to gas CHP.

Large commercial scale heat pumps have the ability to raise flow temperatures above that of domestic scale heat pumps whilst maintaining good efficiencies. Lower temperatures on the network will improve heat pump efficiencies and enable them to supply a higher proportion of heat into the network. Ensuring connecting building are designed and built to maintain appropriate low flow temperatures is key to enabling efficient operation of the wider network. EQUANS' technical standards ask that secondary network are designed to meet the following parameters and minimise loses:

- The nominal secondary system flow temperature is to be 70°C
- The nominal return temperature from the Secondary Network at the Substation is to be 40°C.
- (An alternative temperature may be used at the discretion of the Developer, but the maximum volume weighted average return shall be no higher than 45°C)
- Secondary networks are designed, installed and commissioned in line with best practice, including the recently updated CP1 2020 Heat Networks: Code of Practice for the UK.

There are several sources of heat that could be connected to a heat pump on or around the Queen Elizabeth Olympic Park. The following considers various sources of heat that could be connected to a heat-pump to supply the ELE network:

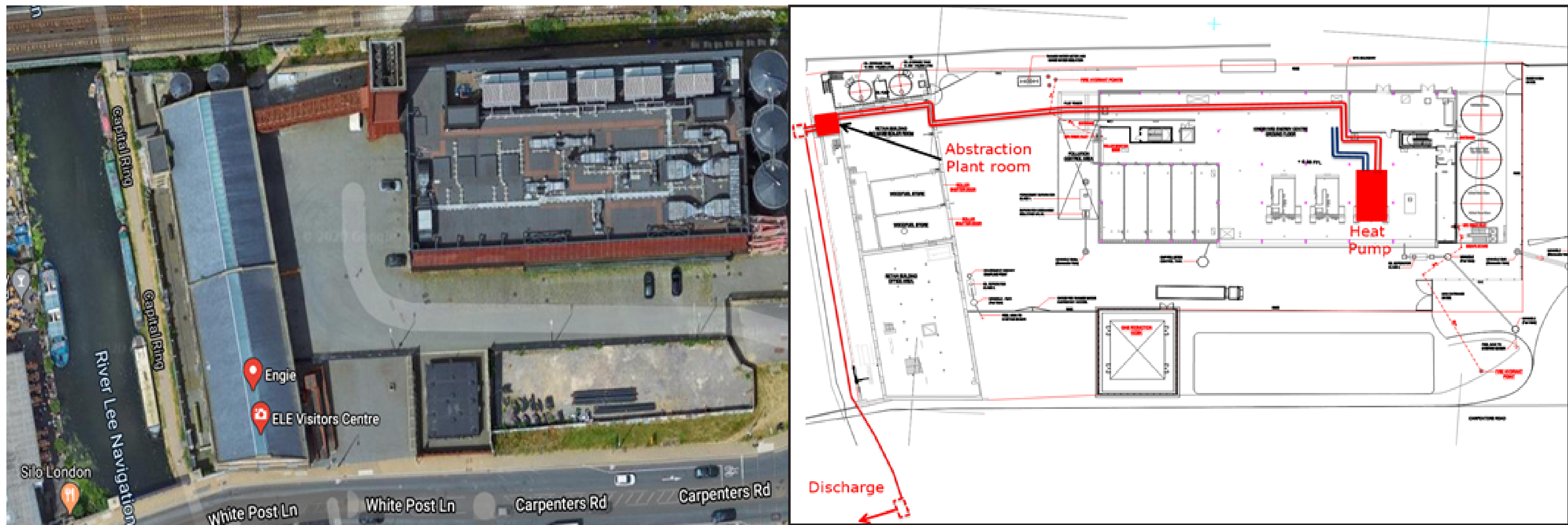
6.2.1 Water source – river

The Kings Yard Energy Centre is immediately adjacent to the River Lea Navigation, so provides potential for deployment of this solution. To date a feasibility study has been commissioned and completed to investigate this solution, which is now being taken into the next stages of concept design development to determine the deliverability and further refine the solution outlined so far.

The feasibility study to date suggests a circa 3MW heat pump to be located in the Kings Yard Energy Centre, with abstraction point adjacent to the Energy Centre and discharge point circa 150m downstream. The system may also provide opportunities for 'free cooling', through rejection of low-grade heat to the river rather than through cooling towers so reducing the electricity consumption needed to generate CHW for the scheme providing further carbon savings.

- **Environmental** - considering a 3MW heat pump, carbon content of heat from this technology could be in the order 0.034 kgCO2/kWh to 0.045 kgCO2/kWh based on SAP 10.1 figure. Other key environmental considerations around the viability of a river source heat pump include Environmental Agency requirements around extract and discharge and associated impact on temperature on the river, which may impact viability and/or scale.
- **Availability & compatibility with heat network** – deployment availability due to proximity of the river and interconnection with the ELE network is good. Year-round availability of heat will however not be as consistent as river temperatures reduce during winter, so viability of heat extraction at reasonable CoPs will decrease. Form of refrigeration within the heat pump will be a consideration, cost and environmental consideration, to raise to a temperature appropriate for interconnection with the ELE network.
- **Space** – the Kings Yard energy centre has potential space available for the heat pump itself. Location of the network within the canal towpath and also equipment within the River itself may be the challenging aspects in this regard. This would need coordination with the Canals and Rivers Trust as well as the LLDC.
- **Cost considerations** – capital cost circa £1000-2000/kW installed, with OPEX at approximately 5% of the capital installation costs. Use of river water charge from the Canals and Rivers Trust would also be a consideration.
- **Market Maturity** – heat pump itself is a mature readily available technology. However, as with many of the heat pump solutions considered here the application of the heat pump and source of heat is the more novel element and comes with greater risk around deliverability, efficiencies and proportion of heat that can be achieved.

Figure 6: Heat pump solution within Kings Yard Energy Centre with abstraction and discharge points on the River Lea Navigation



6.2.2 Ground source – borehole

The ground stores thermal energy from the sun, maintaining fairly constant temperatures all year round in the order of 10-12degC at only tens of meters below surface level. Ground source heat pumps can come in the form of either open loop or closed loop. Closed loop can be horizontal or vertical, with commercial applications typically being in the form of vertical boreholes, circulating heat from the ground into a fluid contained within a pipework system. Open loop systems extract and discharge aquifer water.

With the ELE system having both heating and cooling requirements, there may also be opportunities to optimise the use of the boreholes utilising it as both source of heat and a source of heat rejection. Depending on form and depth of borehole there may also be seasonal heat and cooling storage potential, to optimise year-round balancing of the system.

A possible location of the heat-pump itself could be either the Kings Yard or Stratford Energy Centres. Initial discussions with a borehole provider suggest for a circa 1MW a closed loop system would require in the order of 60-65No boreholes at 200m depth and 8m separation between each of the boreholes. This would require an area in the order of 3000m2 (56m x 56m). Integration into foundations of new developments could be an option, but this tends to increase cost and would have limited output.

For an open loop 1MW system 1-2 doublets may be needed (so 2-4 boreholes in total) at a depth of 120m each with a separation distance of circa 100m.

A key challenge around both options is space, the closed loop being the most constrained in terms of area and therefore appears the most limited in the capacity that it could deliver. Similarly, the open loop location of the boreholes and interconnecting network infrastructure is a challenge.

- **Environmental** - considering a 1MW heat pump, carbon content of heat from this technology could be in the order 0.034 kgCO2/kWh to 0.045 kgCO2/kWh based on SAP 10.1 figure. Other environmental considerations will include for the open loop system extract and discharge considerations with the Environment Agency, which is influenced by the volume of water extracted from the aquifer each day.
- **Availability & compatibility with heat network** – availability of the scale of a borehole system that could be deployed appears limited but has potential to form part of the technology mix on the site. Year round availability of heat is good. As with all heat pump systems the form of refrigeration selected will be influenced by the temperatures required to be compatible with integration into the ELE network.
- **Space** – As above, this is a key constraint to the system.
- **Cost considerations** - capital cost circa £1500-2500/kW installed, with OPEX at approximately 5% of the capital installation costs.
- **Market Maturity** – heat pump itself is a mature readily available technology. However, as with many of the heat pump solutions considered here the application of the heat pump and source of heat is the more novel element and comes with greater risk around deliverability, efficiencies and proportion of heat that can be achieved. Existing commercial systems in the UK tend to be less than 1MW at present.

6.2.3 Sewage heat recovery – Thames Water Recycling plant, Old ford site.

Domestic hot water is used then flushed down drains, injecting heated water into the sewage system. The average temperature of sewer networks in the UK is in the order of 10-20degC, providing a stable source of low-grade heat year-round.

To date EQUANS has worked with SHARC Energy Systems to develop an outline feasibility study to identify the potential sources and capacity of sewage heat recovery system. The sewer system under the Greenway, in close proximity to the Fish Island and Pudding Mill Lane developments, as well as the existing heat network just to the south of the Stadium has been identified. Thames water have provided flow rates for this network, which in combination with the SHARC technology would suggest there may be in the order of 7MW capacity available. This could provide in the order of 35GWh of heat generation a year. These figures are dependent on further monitoring of the sewer system to establish the flow and return temperatures as well as year-round flow rates and further development of technical viability of deployment.

One of the challenges to the system in this location would be establishing appropriate space for heat recovery and heat pump kit on this site. This would need further discussion with stakeholders including Thames Water, LLDC and developers in the area.

- **Environmental** - considering a 1MW heat pump, carbon content of heat from this technology could be in the order 0.034 kgCO2/kWh to 0.045 kgCO2/kWh based on SAP 10.1 figure
- **Availability & compatibility with heat network** – availability of a source of heat and potential year-round access to heat appear good at present. As with all heat pump systems the form of refrigeration selected will be influenced by the temperatures required to be compatible with integration into the ELE network.

Figure 7. Location of sewer in relation to existing DH Network

- **Space** – As above, discussions LLDC highways and Thames Water will be key to the viability
- **Cost considerations** - capital cost circa £1000-2000/kW installed, with OPEX at approximately 5% of the capital installation costs.
- **Market Maturity** – heat pump itself is a mature readily available technology. However, as with many of the heat pump solutions considered here the application of the heat pump and source of heat is the more novel element and comes with greater risk around deliverability, efficiencies and proportion of heat that can be achieved. There have only been a handful of sewer heat recover systems delivered in the UK to date, these have so far been less than 1MW.

There may be further opportunities for waste heat recovery from other Thames Water sites, including the Abbey Mill pumping station, which is currently undergoing major works by Thames Water as part of the super sewer works. The current work is likely to restrict opportunities for heat recovery for the next few years, but once built will be one of the larges sewers in the UK. We will explore future opportunities at Abbey Mill through further discussion with Thames Water representatives.

6.2.4 Low-Grade Heat Recovery

Recovery of heat from industrial processes can provide a stable, clean (in terms of complexities around filtration being removed) form of low-grade heat. Examples of these applications include the Bunhill scheme in Islington recently connecting a 1MW heat-pump into the existing CHP led heat network system recovering heat from a London tube system. The GreenScies project, which EQUANS worked on the first phase of in collaboration with Southbank University, Islington Council and a number of other bodies, is also considering as part of the feasibility stages of the project the potential of heat recovery from data centres for integration into a heat network.

- **Data centre heat recovery** – no data centres with cooling heat rejection within close proximity of the site have been identified at this stage. However, this is a significant re-development area so we would suggest this could be a potential at some point in the future.
- **Heat from London Underground ventilation shaft** – ARUP are in the process of developing a study to identify potential locations that would enable heat recovery from ventilation shafts supplying tube lines. To date we understand a location near the Pudding Mill Lane development has been identified, which ARUP are currently in the process of exploring further.
- **Cooling tower heat recovery** – Similar to data centre heat recovery this would use the heat rejected to atmosphere. However, in this instance generation is associated with chilled water demand for space cooling, the availability of heat is therefore far more seasonal (unlike data centres which is relatively stable throughout the year), with greatest generation during summer when heat loads are at their lowest.

Figure 2. Overview of ELE and incremental decarbonisation opportunities

6.2.4.1 Low-Grade Heat Recovery – TfL Tube Vent Shaft

The Pudding Mill Lane site is one of seven sites examined for the potential to recover heat for injection into heat networks. EQUANS met with the consultant engineers mid-February 2020, and later in October 2020, to understand the initial work undertaken. The current study suggests using circa 645kW heat pump which would recover in the order of 2.96GWh of heat a year from a vent shaft of this scale (using the existing fan coil), depending on the temperatures received. EQUANS has responded to the TfL Market Sounding Question to further evaluate the opportunity, and met with the TfL team in March 2021 where they advised that further details on the process would be released in July 2021.

- **Environmental** - considering a 1MW heat pump , carbon content of heat from this technology could be in the order 0.034 kgCO2/kWh to 0.045 kgCO2/kWh based on SAP 10.1 figure
- **Availability & compatibility with heat network** - - availability for deployment as a source of heat appears good however dependability and availability of heat when it is most required all year-round is a challenge. As with all heat pump systems the form of refrigeration selected will be influenced by the temperatures required to be compatible with integration into the ELE network.
- **Space** – space for a heat pump may be available adjacent to the vent shaft, on TfL land. Further discussion with TfL would be required, viability of this will be informed by the ARUP study.
- **Cost considerations** – capital cost may be in the region of £500-1500 kW installed, however highly dependent on location. OPEX circa 5% annually of installed heat pump costs.
- **Market Maturity** – heat pump itself is a mature readily available technology. However, as with many of the heat pump solutions considered here the application of the heat pump and source of heat is the more novel element and comes with greater risk around deliverability, efficiencies and proportion of heat that can be achieved. Heat recovery from chilling systems is not a common system in place at present.

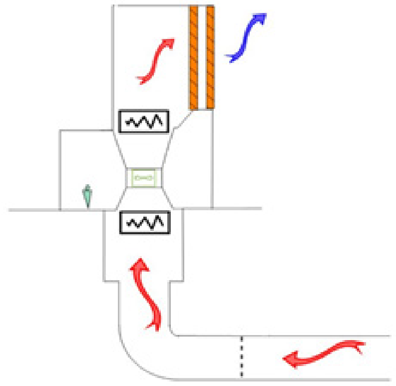


Figure 8. Schematic of Heat Pump

6.2.4.2 Low-Grade Heat Recovery – Cooling Towers

Heat recovery from the cooling towers on the Energy Centres appears to have good potential at this stage, with circa 60MW of heat rejection capacity that could be utilised.

- **Environmental** - considering a 1MW heat pump, carbon content of heat from this technology could be in the order 0.034 kgCO2/kWh to 0.045 kgCO2/kWh based on SAP 10.1 figure
- **Availability & compatibility with heat network** - availability for deployment as a source of heat appears good however dependability and availability of heat when it is most required all year-round is a challenge. As with all heat pump systems the form of refrigeration selected will be influenced by the temperatures required to be compatible with integration into the ELE network.
- **Space** – space within the Kings Yard and Stratford energy centres may be a possibility.
- **Cost considerations** – capital cost may be in the region of £500-1500 kW installed, however highly dependent on location. OPEX circa 5% annually of installed heat pump costs.
- **Market Maturity** – heat pump itself is a mature readily available technology. However, as with many of the heat pump solutions considered here the application of the heat pump and source of heat is the more novel element and comes with greater risk around deliverability, efficiencies and proportion of heat that can be achieved. Heat recovery from chilling systems is not a common system in place at present.

6.3 Biomass/Biofuel

The Kings Yard Energy Centre currently hosts 3MW of biomass boilers (woodchip) and has capacity for space in the energy centre and fuel capacity also for additional biomass boiler. The existing biomass boilers provides element of base load, but as the scheme grows additional biomass boilers can be run most of the year towards base load contribution. In addition, one of the gas boilers at Stratford Energy Centre is equipped with duel fuel burner and set up with an oil tank, which will take biofuel as a source to generate heat. Further investigation is underway on the technical modifications that might require to run alternative low carbon fuels with the manufacturers of these boilers. If feasible this might be the lowest cost option to contribute towards decarbonisation of the heat network.

Further stakeholder engagement will be required with environment department of the local council and Environment Agency.

- **Environmental -** considering additional 1MW biomass boiler, carbon content of heat from this technology could be in the order 0.027 kgCO2/kWh based on SAP 10.1 figure.
- **Availability & compatibility with heat network** – availability of a source of heat and potential year-round access to heat appear good at present. One of the biggest advantages is the operating temperatures required are compatible with integration into the ELE network.
- **Space** – as above, space available for additional capacity in the energy centre.
- **Cost considerations -** capital cost circa £500-1000/kW installed, however emissions scrubbing technology to ensure air quality may add significant additional costs.
- **Market Maturity** – biomass boiler itself is a mature readily available technology.
- **Cost of heat generation** – fuel costs are currently higher than natural gas. Without stronger policy support for a stable and appropriate carbon price, fuel switching would put upwards pressure on tariffs compared to those currently receiving heat via gas combustion technologies.

6.4 Green Gas

The combustion of natural gas produces ~210 gCO2/kWh depending upon the mixture of gases imported into the distribution network at any time (e.g. increasing proportions of Qatari LNG increase emissions, whilst increasing proportion of North Sea gas, reduce it). Substituting natural gas (either in total or in blended proportions) with biogas or hydrogen reduces these emissions by 60-100% (Depending on feedstock). Existing combustion plant can readily accept biomethane (upgraded biogas with properties equivalent to natural gas) without adjustment whereas other green gas blends (Including hydrogen) will need plant adjustments or investment.

Local production of biogas for direct combustion at the volumes needed is not viable for ELE (see below). The biogas would need to be transported by road as CNG or shipped via the existing natural gas grid using certificates as proof of origin and ownership (RGGOs - "Renewable Gas of Guaranteed Origin"). There is an established and growing market for green gas supply via the gas network, allowing purchasers to report carbon savings in accordance with Government's greenhouse gas reporting guidelines.

We will consider green gas as a short-term measure to optimise the current systems operational carbon emissions and well as following national and local research and development defining scope and role that hydrogen may play in heating.

6.5 Energy from waste

The site in closest proximity to the ELE Heat network is the North London Waste Authority's Energy from Waste plant in Edmonton, which is currently supplying heat to Enfield council's Lea Valley Heat Network.

This is approximately 10km from the ELE site via highways as the crow flies with major river, rail and road crossings required, with cost of connection likely being greater than £30m. We have had initial discussions with Energetik, operators of Lea Valley Heat Network, to explore the potential of this connection and intend to work further with them to assess and develop the business case and potential for a feasibility study (by end 2022). These investigations will form part of the strategic master planning work we hope to do with surrounding local boroughs.

6.6 Solar

Solar deployment in the UK to date has been focused on generating electricity for local use (e.g. to heat and store water) or for export to the grid. Opportunities have been influenced by the availability of a "feed-in-tariff" which has offered an attractive return on investment. Across the park we have previously examined opportunities for solar PV deployment on the roof spaces of the Copper Box Arena and the London Stadium to sell electric directly via a private wire. However, investigations into the opportunities concluded that fitting solar PV would not be feasible due to the limited load bearing capabilities of either roof.

More recently we have been introduced by EQUANS Group to a Swiss based solar-thermal company, who have developed a high-temperature/high efficiency panel suitable for district heating. We have identified an available footprint on Westfield's car park that could provide 2MW to 3MW of solar thermal capacity which could be fed into the DH network or supplied directly to prospect developments near the proposed roof space. We are in the process of assessing the project's commercial and technical viability and once concluded, will present our findings to the LLDC and Westfield to agree next steps

6.7 Other Technologies

The following technologies were also considered but not looked into in any further detail for the following reasons:

- **Deep geothermal -** We will continue to review the potential for geothermal as new technologies emerge.
- **Air source heat pump –** Air source heat pumps have not been considered further at this stage due to limited availability of roof space, which already has a significant allocation cooling towers on the energy centres and developments around the site to PV, as well as relatively low CoPs that can be achieved when raising the temperature to a suitable level for compatibility with the existing network
- **Fuel cells –** this has been discounted at this stage due to the maturity and potential scale of heat this technology could provide. High capital costs due to material selection and source of base fuel for generation continue to be challenges to fuel cells at this time
- **Biogas from small scale Anaerobic Digestion –** A feasibility study was undertaken by EQUANS in 2017, in collaboration with Westfield Stratford, around the installation of a small-scale anaerobic digester at Kings Yard energy centre. The proposal was to divert organic food waste leaving the shopping centre, transporting it a short distance to the energy centre. A technical solution was reached; however, the project was not developed further due to a number of constraints, including:
  - Space constraints meant that only a small digester could be installed, eroding any economies of scale.
  - Quality of organic waste was low, and additional resource would have been required to inspect the waste being fed into the digester.
  - Business case would have required a large proportion of upfront capital to be grant funded to reach required investment criteria.
  - Finding a guaranteed, long term off taker for the substrate / fertilizer in the urban area was challenging, without paying to divert it.
  - The area around the energy centre is earmarked for residential housing and future developers would have objected to daily odorous deliveries of food waste.

Technology summary

The following summarises the viability of the different options considered and the solutions and/or mix of solutions that will be taken forward for further consideration.

Cogeneration/Combined Heat and Power

Good quality CHP producing both power and heat is a well-established technology enabling

Tech*	Technical Barriers / opportunities				Commercial Barriers / opportunities				Commentary
	Compatibility Network	Availability	Environmental	Space	Capital Cost	Operational Cost	Market maturity	Priority	Key opportunities or barriers
Gas CHP								1	**Action: Pursue robust accounting for carbon emissions savings and optimised operation (Q1 2022)** Gas CHP has been catalyst to the development of DH networks in the UK and even in the electrification of heat, gas CHP has an important role to play, both to plug the gap between in the intermittent nature of renewable energy generation (wind and solar) but also when integrated alongside electrical heating (heat pump) and thermal stores to balance supply and demand using digital technology to optimise operation/energy efficiency/carbon savings. Opportunity to further decarbonise with green gas with appropriate methodologies and policies for reporting carbon emissions savings.
Heat pumps - water, river source								1	**Action: Develop concept design, progress to investment case and installation (Q3 2022)** Water source application not yet fully commercialised in DH application, environmental concerns around impact on water conditions a constraint, as well as availability of appropriate water sources and relatively high capital cost. Space to output a consideration as a well as compatibility of temperature regime. Potential deployment of this solution on the Kings Yard site has been explored through a study to date, demonstrating this solution may have some potential to contribute to the energy mix of the site
Heat recovery								1	**Action: Develop concept design progress to investment case and installation for ENGIE cooling towers (Q2 2022)** Recovery of low-grade heat from industrial processes, through the use of heat pumps. Availability of appropriate sources in proximity is typically the major constraint as well as compatibility of temperature regimes. Recovery of heat from the Kings Yard cooling towers and has been found to have the greatest potential at this time, however availability of heat when most needed is the greatest challenge
Vent shaft heat recovery (ASHP								1	**Action: Develop concept design, progress to investment case and installation** Heat recovery from underground ventilation application not yet fully commercialised in DH application, operation concerns around particulate cleaning, space availability, canal crossing as well relatively high capital cost. TfL tube vent shaft near the Pudding Mill Lane development offers potential for demonstrator.
Biomass / biofuel								2	**Action: improve future cost assumptions and ascertain stakeholder support** Biomass and biofuels can include a wide range of technologies from burning of woodchips and pellets to use of biomethane or biodiesel and potentially pyrolysis technologies. Space (for fuel storage as well as delivery routes), air quality and fuel security are critical considerations for these technologies and put constraints on application. ELE's original strategy for future expansion of the site included space provision for a further biomass installation to the existing biomass boiler. However, the ELE area is part of an Air Quality Management Zone, so further deployment of biomass on the ELE site though it could potentially reduce CO2 emissions may have a detrimental impact on other environmental considerations such as air quality. Green Gas Certificates, as a form of off-site injection into the system, has been considered and their application.

Tech*	Technical Barriers / opportunities				Commercial Barriers / opportunities				Commentary
	Compatibility Network	Availability	Environmental	Space	Capital Cost	Operational Cost	Market maturity	Priority	Key opportunities or barriers
Energy from Waste								2	**Action: work with stakeholders to develop business case for Edmonton EfW and secure funded needed for feasibility work (Q4 2022)** Can include a wide range of heat sources including heat from waste incineration to syngas generation through anaerobic digestion or pyrolysis processes. Availability of appropriate sources in close proximity to a site are typically a major barrier. Distance from the closest site has been identified as the key barrier to deployment, which needs to be tackled in collaboration with others including the GLA and neighbouring local authorities.
Green Gas								2	**Action: collaborate widely to develop business case and safeguards needed to assure additionality (Q2 2022)** This has been identified has having a high potential for reduction in carbon content of the heat network. Cost and impact on end consumer heat charges being the greatest challenge.
Heat pumps – sewage source								3	**Action: Keep under review.** Appears to be some potential for deployment of this solution. The technology is however relatively immature particularly at scale.
Solar thermal								3	**Action: Develop concept design, progress to investment case and installation** Mature readily available technology. Availability of appropriate roof space, output to space a consideration, as a well as compatibility of network temperature regime. Traditional solar thermal typically generates heat at < 60degC. High temperature solar thermal systems are starting to enter the market but are still relatively immature at this stage. For the ELE site competition for roof space with PV cells is the most significant influence on deployment and potential scale of heat input that could be provided.
Deep geo'								3	**Action: Keep under review** Availability and high capital cost are the most significant barriers. Highly dependent on location. We will continue to review as new technologies emerge.
Fuel cells								x	Current high capital and operational costs tend to be prohibitive at present. Not yet at fully commercialised technology, but interesting developments in static plants.
Heat pumps - air source								x	**Action: Keep under review** Mature readily available technology. Space to output a consideration as a well as compatibility of network temperature regime. Limited availability of roof space, due to allocation to PVs and also compatibility of temperature regimes, this has not been taken forward as an option at this stage. Not suitable for deployment on ELE.

Priorities

With a view to integrating additional low-carbon heat into the scheme before the end of 2022, the high-level assessment completed to date suggests the following priorities:

Priority 1: secure funding for concept design and investment cases in the next 3-12 months:

1. Valuing the benefits of CHP in compliance and policy.
2. Deployment of heat pumps to utilise ambient heat in the ground and open water.
3. Deployment of heat pumps to utilise heat rejected from chillers at Stratford Energy Centre and the TfL vent shaft at Pudding Mill Lane (for demonstration purposes).
4. Progress development of business case for EfW connection as the potential long-term solution.

Priority 2: engage with stakeholders to develop understanding of the risk and opportunities and build consensus on timetable for solutioning and implementation (3-6 months).

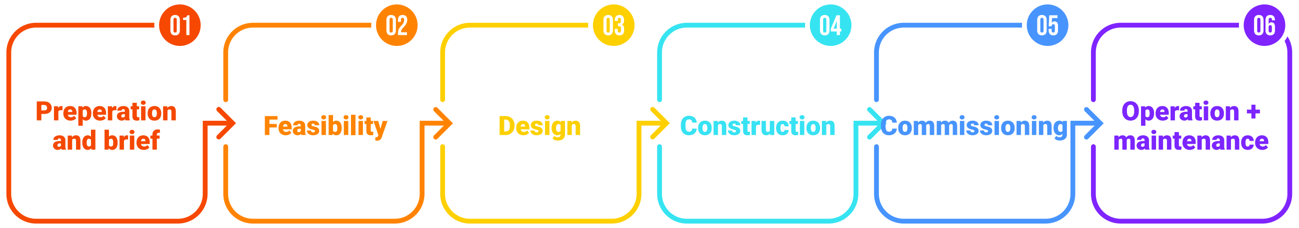
5. Additional biomass capacity and replacement of natural gas with biofuel
6. Costs and feasibility of other sources of waste heat identified (e.g. Abbey Mills pumping station).
7. Cost and availability of green gas and systems needed to provide assurance of enduring carbon savings/additionality.

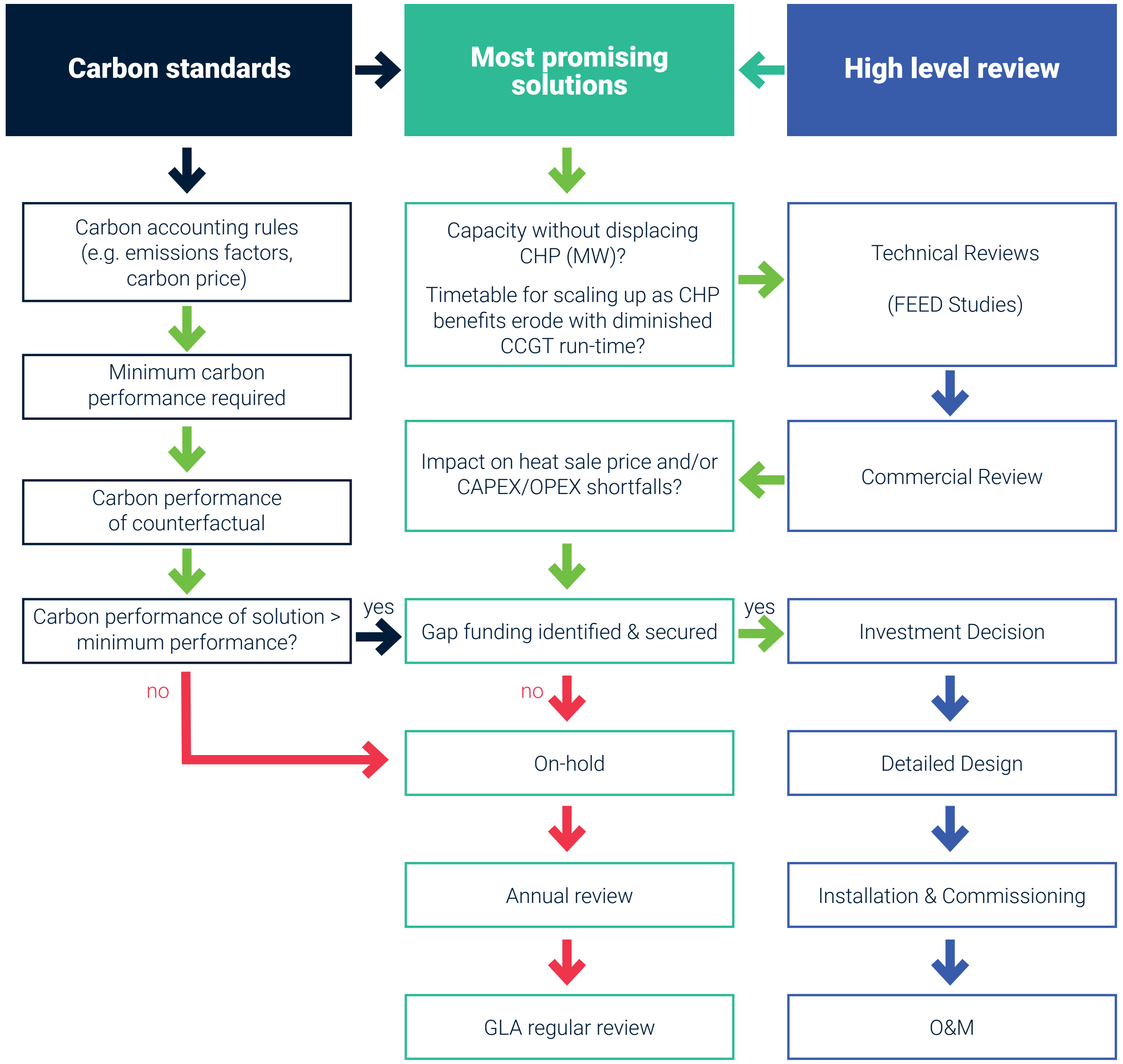
Priority 3: keep under review the case for pursuing opportunities to install:

8. Heat pumps for the recovery of waste heat from sewage
9. Solar thermal across the Olympic Park buildings

Programme

Our programme through to installation will follow that as identified by Code of Practise for Heat Networks, wherein we are stage 2 i.e., Feasibility phase for each of these technology options.





Our high-level plan for the next 12 months is shown in the executive summary. Once funding is secured to develop the roadmap and techno-economic feasibility studies, more detailed project plans can be developed.

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Addendum: Techno-Economic Feasibility Study of Decarbonisation Options for East London Energy – Report 1 Update

March 2022

EQUANS are undertaking a techno-economic feasibility study to assess the options available for introducing additional low-carbon sources of heat generation to the East London Energy (ELE) scheme and developing detailed plans and roadmap for strategically decarbonising the heat network. The energy network distributes heat across 20km of network to 7,000 existing homes and 100 commercial premises, alongside cooling to 11 sites.

The key objectives of the overarching decarbonisation study are to:

- Identify the preferred option(s) to decarbonise the whole network by 2035. Allowing connected customers to meet corporate objectives and EQUANS to comply with policy.
- To enable compliance with building regulations. This will require decarbonisation of the network and identification of options that enable continued connection of new developments.
- Ensure a fair net zero transition to existing customers and identify ways to minimise any cost associated with introduction of low carbon technology

To keep pace with the transition of the electricity network to lower-carbon forms of generation, the Queen Elizabeth Olympic Park (QEOP) energy network will need to reduce natural (fossil fuel) gas consumption and utilise other lower-carbon forms of energy. This will require capital investment, impact operation and maintenance regimes and costs, and could put upwards pressure on customer bills. The overarching study appraises the technology options, investment requirements and cost impacts to identify the optimal roadmap to net zero emissions from the QEOP energy network, consistent with the ambitions of the London Legacy Development Corporation (LLDC), Westfield Stratford City (Westfield) and many of the developers active in the local area. With an agreed roadmap built through collaboration and consensus, funding will potentially be sought (e.g. via the Green Heat Networks Fund, and other sources) to make the investments needed and to sustain growth of the network as regeneration of the surrounding areas continues.

Since commissioning in 2011, the scheme is estimated to have saved ~97,000 TCO_2. Increased decarbonisation of the national electricity grid means that without new investment in alternatives to natural gas, annual CO2e emissions from the scheme will increase from their baseline of 36,548T today, to 60,980T in 2035. Acting now will help existing and new buildings connected to the network transition to Net Zero and will result in substantial carbon savings in the 2020s and beyond.

To date, the potential decarbonisation technologies available have been explored in the context of their local availability, the policy environment, timing, barriers, and opportunities to expedite decarbonisation. A three-tiered approach to decarbonisation has been taken:

- **System optimisation and efficiency improvements** – Adapting and getting the most out of existing assets, reducing temperatures and losses, and benefiting from wider energy system carbon and price signalling.
- **Incremental installation of low carbon technology** – Investigating local lower carbon generation and heat source opportunities for part of the scheme demand, or as incremental steps. e.g. Heat Pumps meeting a percentage of the network total heating or cooling demand.
- **Strategic decarbonisation** – Wholesale decarbonisation options for the entire scheme and growth opportunities e.g. Energy from Waste connection.

The first stage of the work was undertaken in late 2021 and included options appraisal of a long list of technology options. The table below gives a high-level overview of carbon reduction which could be achieved by each technology evaluated.

Technology	Capacity Assumed (MW)*	Carbon Reduction (%) **
Green Gas	N/A	92
Additional Biomass	1	8
Water Source Heat Pump	3	23
Chiller Heat Pump	3	15
Sewer Source Heat Pump	3	18
Ground Source Heat Pump	3	12
Solar Thermal	2.4	3
TfL Vent Shaft	0.7	3
EfW	10	62
Major Air Source Heat Pumps	10	71
Biofuel CHP	20	75
Geothermal	20	~75
**Assumed MW available is to give indicative number e.g. EfW potential for greater capacity*		
***Based on SAP 10.1 carbon factors. Carbon reduction compared to current operation.*		

The first stage of work concluded that incremental technologies could decarbonise ELE but could limit growth, and constraints may mean that they could struggle to meet the scale required. As a result, a combined strategic focus on the long-term site wide options as well as immediate smaller scale technologies is being taken to decarbonise ELE.

Three strategic technologies have been short listed from a long-list of 20 potential low-carbon heat sources, for further detailed assessment:

- Energy from Waste
- Geothermal
- Heat Pumps

In addition, EQUANS will continue to pursue opportunities for project level incremental decarbonisation and system optimisation activities. We are pursuing two heat pump projects, ~3MW each, at Stratford City and Kings Yard energy centres and have been successful in securing funding from the Heat Network Efficiency Scheme for an optimisation study for a number of blocks connected to the ELE network. We will work with connected partners to continue to identify optimisation opportunities for the existing assets and seek funding where possible to achieve this.

The next stage of the study is to complete the options appraisal of the 3 preferred strategic technology options to refine a timeline to implement the technologies. EQUANS will continue to work with key stakeholders to achieve the carbon milestones set out in our roadmap.