Our reference: MGLA140426-8097

8 June 2026

Dear

Thank you for your request for information which the Greater London Authority (GLA) received on 14 April 2026. Your request has been considered under the Environmental Information Regulations (EIR) 2004.

You requested:

I have obtained GLA case studies showing that Citigen (E.ON), London Borough of Barking & Dagenham, and Royal Borough of Greenwich successfully accessed LEA support for heat network decarbonisation during this period. These organisations received free technical support, feasibility studies, and assistance securing HNIP capital grants - the exact support PDHU needed but apparently never accessed.

I am seeking to understand:

1. Whether Westminster applied for LEA support and, if so, what happened
2. What contact occurred between GLA and Westminster regarding PDHU CHP decommissioning

Our response to the specific elements of your request is as follows:

1. **Westminster City Council and PDHU - LEA/DEEP Applications and Contact**
    a) *Did Westminster City Council, any entity managing PDHU, or any contractor operating PDHU (including Fair Heat, AECOM, or others) apply for LEA or DEEP support during 2015-2025?*

Response: WCC did apply for LEA support for PDHU during 2015-2025 (March/April 2022).

b) *If yes:*

- *Dates of applications or expressions of interest*
- *What support was requested*
- *Assessment of the application*
- *Outcome (successful/unsuccessful) and reasons*
- *Any support provided and project outcomes*
- *Technical reports or feasibility studies produced*

Response: Yes, WCC did apply for LEA support for PDHU. Please see details below.

- Dates of applications or expressions of interest: 17 March 2022 WCC's application was received.

- What support was requested: For commercialisation and project delivery of a river source heat pump scheme to be integrated into the existing PDHU heat network.

- Assessment of the application: The application was evaluated and a decision was taken to interview WCC for support (as part of the application process) before a final support decision was made.

- Outcome (successful/unsuccessful) and reasons: Following the interview it was decided by GLA that the support funding amount was too great. WCC were then asked to reduce their funding support request.

- Any support provided and project outcomes: WCC did not resubmit a reduced funding request, and so no support was provided by LEA for PDHU.

- Technical reports or feasibility studies produced: N/A

c) If no applications were received:
- *Any records of informal inquiries or discussions with Westminster about LEA eligibility for PDHU*
- *Any outreach undertaken by GLA/LEA to Westminster regarding heat network support programmes during 2018-2023*

Response: N/A as an application was received as above.

d) All correspondence, emails, meeting notes, or records of contact between GLA/LEA programme staff and Westminster City Council regarding:
- *PDHU decarbonisation*
- *LEA/DEEP eligibility*
- *Heat network support programmes*
- *Low-carbon technology options*
- *Funding opportunities for district heating*
- *Any contact during 2018-2025*

Response: Please find attached the correspondence that we hold within the scope of your request.

Please note that some names of members of staff are exempt from disclosure under Regulation 13 (Personal information) of the EIR. Information that identifies specific employees constitutes as personal data which is defined by Article 4(1) of the General Data Protection Regulation (GDPR) to mean any information relating to an identified or identifiable living individual. It is considered that disclosure of this information would contravene the first data protection principle under Article 5(1) of GDPR which states that Personal data must be processed lawfully, fairly and in a transparent manner in relation to the data subject.

2. PDHU Eligibility Assessment

e) What support could LEA have provided for a heat network of PDHU's scale and characteristics, including:

- *CHP viability assessment during energy crisis*
- *Heat pump integration feasibility*
- *Technology transition planning*
- *Business case development*
- *Assistance securing HNIP or other capital grants*

Response: LEA support could have supported with the last four bullet points above. CHP viability assessment would not have been eligible since this is about financial viability, rather than decarbonisation.

f) LEA programme eligibility criteria during 2018-2025, and how these applied to municipal heat networks serving existing residential estates

Response: LEA eligibility criteria for support were both quantitative and qualitative. Supporting low carbon heat networks serving residential estates were eligible for LEA support, if qualitative and quantitative evaluation scores were above the 40 per cent threshold.

3. LEA Programme Performance and Outputs

g) How many applications were from Westminster City Council or Westminster-based organisations (any projects, not just PDHU)

Response: As well as the application for LEA support with PDHU, two applications to LEA from WCC were received (not related to PDHU) which brings the total to three LEA applications received from WCC.

h) List of all successful LEA/DEEP supported projects in Westminster during 2015-2025, including project names, organisations, and brief descriptions

Response: The two WCC decarbonisation projects supported by LEA during 2015-2025 are as follows:

I. Eight communal heating feasibility studies

This work looked at eight communally-heated blocks with the intention to consider interconnection to a heat network.

II. NW8 heat network interconnection and utilisation of waste heat

This LEA support was for heat decarbonisation of blocks of flats in NW8, where gas supplies needed to be removed. This study included looking at available waste heat and a heat pump-led solution to the supply of heat.

4. Citigen, Barking & Dagenham, and Greenwich Projects

i) Technical reports, feasibility studies, or assessments produced for these projects that are suitable for public release, particularly:

- *Citigen: CHP viability assessment, heat pump integration methodology, hybrid system design*
- *Greenwich: Heat pump technology selection and integration with existing systems*
- *Any comparative analyses of CHP operation vs decommissioning during 2021-2023 energy crisis*

Response: The GLA LEA team requested the reports from all LEA-supported projects to be published. Only those available on the Zero Carbon Accelerator webpage here: Local Energy Accelerator (LEA) project outputs — Knowledge Hub — Zero Carbon Accelerator agreed to have their reports published. No such analysis of CHP operation vs decommissioning was carried out by the GLA.

Citigen

Please find attached a copy of Citigen's Hydraulic Analysis of DH & DC Networks. They have asked for the following context to accompany disclosure:

> *This report was commissioned and completed in 2023, using assumptions based on the available data at that time.*
>
> *It was up to a RIBA Stage 2 level of design, so it needs to be viewed as a high-level view into the future rather than a depiction of actual operation at present when this information is published.*
>
> *Citigen cannot be held responsible for any difference between the report and current position.*

RB Greenwich

The Greenwich Ernest Dence project was specifically: early-stage feasibility, concept design, and tendering for the low carbon communal heating scheme for the Ernest Dence estate, rather than *"Heat pump technology selection and integration with existing systems"*.

Please find attached a copy of:

- Bill Walden House - Low carbon technology feasibility
- Jervis and Woodville Courts - Low carbon technology feasibility
- Strand Court - Low carbon technology feasibility

LB Barking & Dagenham

I can confirm that we hold two reports in relation to the two projects: Barking Town Centre and Becontree Heath Heat Networks. Following consultation with LBBD, we believe that this information falls under the exception to disclose in Regulation 12(5)(f) (Disclosure would adversely affect the interests of the person who provided the Information).

Regulation 12(5)(f) applies where disclosure would adversely affect the interests of the person who voluntarily supplied the information. In this case, LBBD has confirmed that the information, including customer data within the requested documents, was obtained from

Thames Water under a Non-Disclosure Agreement (NDA). LBBD was in turn under no legal obligation to provide this information to the GLA, and it was supplied on a strictly voluntary and confidential basis.

The exception is therefore engaged because disclosure would undermine the reasonable expectations of confidentiality held by Thames Water at the time the information was provided. Releasing the information would constitute a breach of the agreed contractual terms and would prejudice Thames Water's commercial and operational interests. It would also be likely to damage the relationship of trust between the GLA and third parties, discouraging organisations from voluntarily sharing information in the future. This would have a wider adverse impact on the GLA's ability to carry out its functions effectively, particularly where cooperation and information-sharing are essential.

While it is not necessary to evidence specific harm for the exception to be engaged, the likelihood of legal action arising from a breach of the NDA, alongside the broader chilling effect on future information-sharing, demonstrates clear and tangible adverse impacts.

As Regulation 12(5)(f) is a qualified exception, the GLA has considered the public interest test. There is a recognised public interest in transparency, particularly in relation to environmental and energy efficiency initiatives, and disclosure would contribute to public understanding of the data underpinning this programme.

However, this must be balanced against the strong public interest in maintaining trust and confidence in agreements between public authorities and third parties. There is a significant public interest in ensuring that organisations can safely share information without fear that it will be disclosed in breach of confidence. Undermining such arrangements would not only expose the LBBD to potential legal liability but would also impair the ability of the GLA to obtain similar information in the future, thereby reducing the quality and effectiveness of environmental policy development and delivery.

On balance, the public interest favours maintaining the exception. Disclosure would cause unjustified harm to the interests of the information provider, weaken established information-sharing frameworks, and ultimately hinder the GLA's ability to serve the public interest effectively.

j) *Carbon savings achieved or projected for these projects*

Citigen: 1,158tCO2e/yr was estimated to be saved by 2030.

The Greenwich Ernest Dence project was specifically: early-stage feasibility, concept design, and tendering for the low carbon communal heating scheme for the Ernest Dence estate, rather than *"Heat pump technology selection and integration with existing systems"*.

The case study for the Ernest Dence (Royal Borough of Greenwich) project is here: Local Energy Accelerator | London City Hall and states that around 4,000 tonnes CO_2e should be saved over the lifetime of the ground source heat pump.

London Borough of Barking and Dagenham: 526,611 tCO2e/yr was estimated to be saved over 40 years from two projects: Barking Town Centre and Becontree Heath Heat Networks.

5. Heat Network Policy and Guidance

k) *Any guidance, briefing papers, or policy documents issued by GLA to London boroughs during 2018-2023 regarding:*

- *Management of existing gas CHP systems during the energy transition*
- *Interpretation of London Plan (2021) policies on gas CHP phase-out*
- *Technology transition strategies (heat pumps, hydrogen-ready, etc.)*
- *Revenue generation from CHP electricity sales during transition periods*
- *Use of carbon offsets as bridge strategy during technology transitions*

Response: See response directly below (question m)

l) *Whether GLA issued any specific guidance on heat network CHP operations during the 2021-2023 energy crisis*

Response: No, the GLA did not issue guidance on heat network CHP operations during the 2021-2023 energy crisis.

m) *Whether GLA recommended immediate CHP decommissioning vs. gradual transition for existing heat networks during 2020-2023*

Response: The London Plan policy SI 3 applies to major, referable developments required to submit a planning application. Generally, these are for new-build developments.

In the period of 2018-2023, the GLA did not publish any specific guidance on managing existing heat networks. But the GLA did release informal guidance to local authorities on the expansion of existing heat networks with additional low carbon heat to serve new developments. This guidance was released following a national government statement, which set out their commitment to support the expansion of heat networks. Their intent and aim was for any additional homes connecting to the existing heat network that require additional capacity to be added to the heat network using a low carbon source.

> *"The FHS and FBS should not prevent new buildings connecting to existing heat networks. However, homes and buildings constructed to the FHS and FBS should have low carbon emissions, regardless of their heat source. We therefore plan to link dispensation for new buildings connecting to existing heat networks to the nature and quantity of additional low carbon heat generation that has been added to the network i.e. at a minimum, the heat required by any additional homes connected to an existing heat network should match the low carbon heat generation capacity that has been added to the network. As part of the upcoming 2023 consultation, we are looking at a series of options for how this principle can be implemented."*

In response to this, the GLA did create guidance for local authorities (released in 2022 Date) to support the expansion of heat networks, called 'sleeving'. Where new developments connecting to the heat network would require a low carbon heat source added to the network. This is not a removal and replacement of existing heat systems – it is increasing the capacity of the heat network with new additional heat sources.

Planning policy and guidance cannot be used to inform decisions made by heat network operators on the existing heat sources, as would have been the case for the replacement of plant for the PDHN. However, GLA guidance did advise that district heat network operators for existing heat networks should create a decarbonisation strategy for their network to support the gradual replacement of the network's high carbon sources.

The aim of the decarbonisation strategy was for district network operators to create a long-term strategy for the gradual replacement of high-carbon heat sources. The GLA recognises the need to manage upfront replacement costs, disruption and affordability on customers connected to the existing network. For these reasons, the GLA recognise this would be a phased transition to decarbonise heat sources.

Given that the London Plan policy SI3 applies to new development, new heat networks and expansions of heat networks, the decision to replace heating systems in existing networks, would be a decision for the district heat network operator. The GLA expects heat network operators to consider the replacement of high-carbon heat sources in an economically viable, affordable, and fair way for customers. In terms of revenue generation, the GLA do not provide guidance on this, it would expect the heat network operator to review and assess this.

In terms of specific guidance on carbon-offset, the GLA explores opportunities for varying carbon-offset or using it to decarbonise heat sources. This again, is something that would be reviewed on a case-by-case basis upon review of a referrable planning application. Without a planning application, the GLA cannot use or enforce carbon-offsets on heat networks.

6. Policy Context - London Plan and CHP Guidance

n) *The GLA's official interpretation during 2020-2023 of the January 2018 London Plan statement that gas CHP would be "more limited over time" - specifically:*

- *Whether this meant immediate decommissioning or gradual phase-out*
- *Recommended transition timelines*
- *Whether existing CHP systems should maintain operations during transition*
- *Whether carbon offsets were considered acceptable bridge strategies*

Response: see below response following question o)

o) *Any analysis or modelling conducted by GLA on the financial impact of CHP decommissioning vs. gradual transition during the 2021-2023 electricity price surge*

Response: The statement that gas CHP would be "more limited over time" is correct; the GLA aims to phase out CHP gradually and replace them with low carbon heat sources including heat pumps and waste heat. The GLA has not released any recommended timelines, or views on immediate decommissioning because this is very much dependent on the heat network on a case-by-case basis. It will be dependent on the heat network operators, when the heat network was installed, the lifetime of the CHP / gas boilers, affordability and cost to residents / non-domestic consumers, timelines for replacement and new development.

The London Plan (currently, and in the period 2020-2023) can only review applications of new developments connecting to an existing heat network, or changes to existing heat networks if they are a referable planning application. Therefore, the London Plan cannot be used to require immediate or gradual changes to existing heat networks and how they operate. That would be a decision for the heat network operators. As mentioned previously, the GLA expects heat network operators to consider the replacement of high-carbon heat sources in an affordable and cost-effective way.

In terms of financial modelling, the GLA would have done its viability assessment for the London Plan draft release in 2020-2021. This would have considered risks to pricing but would not have considered decommissioning of CHP decommissioning during 2021-2023, or replacement to heat sources for existing heat networks. The modelling would have only been undertaken for new upcoming heat networks and expansion to existing heat networks.

7. Comparative Heat Network Data

p) Any GLA-held data on London heat networks' operational performance during 2019-2024, including:

- *Which London networks maintained CHP operations during 2021-2024 energy crisis*
- *Revenue generation from electricity sales*
- *Use of electricity revenue to offset consumer costs*
- *Technology transitions implemented (heat pump additions, etc.)*

Response: The GLA does not hold this data.

q) Any GLA assessments comparing PDHU's performance or management decisions to other London municipal heat networks

Response: The GLA has not completed such assessments.

If you have any further questions relating to this matter, please contact me, quoting the reference MGLA140426-8097.

Yours sincerely

Information Governance Officer

If you are unhappy with the way the GLA has handled your request, you may complain using the GLA's FOI complaints and internal review procedure, available at: https://www.london.gov.uk/about-us/governance-and-spending/sharing-our-information/freedom-information

From: Local Energy Accelerator
To: [redacted]
Cc: EMS244 PDHU Heat Pump Opportunity; [redacted] WCC; [redacted]
Subject: RE: LEA updated application document
Date: 21 March 2022 09:21:00
Attachments: image002.jpg
image003.jpg

Dear [redacted]

Many thanks for your application. We will score and get back to you soon about a short remote interview.

Many thanks

[redacted] **Energy Systems**

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london.gov.uk

[redacted]london.gov.uk

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From: [redacted]

Sent: 17 March 2022 09:00

To: Local Energy Accelerator

Cc: EMS244 PDHU Heat Pump Opportunity ; [redacted] WCC ; [redacted]

Subject: FW: LEA updated application document

Dear GLA LEA

Please find enclosed an application on behalf of WCC for funding under the GLA LEA in relation to decarbonisation of the energy supply at Pimlico District Heating Undertaking.

Kind regards

[redacted]

Silver EMS Ltd

A St Clare House, 30/33 Minories, London, EC3N 1DD

P 020[redacted] | M [redacted] |

From: [redacted]
To: [redacted]
Cc: [redacted] WCC; EMS244 PDHU Heat Pump Opportunity; [redacted] susesco.co.uk; [redacted]
Subject: RE: LEA application WCC/PDHU
Date: 08 June 2022 10:25:00
Attachments: image001.jpg
image002.png

Once you have resubmitted your application we can get an answer to you within a few days about funding your project I would hope. Yes I would allow about 3-4 weeks for procuring from the Fwk for this.

[redacted] **Energy Systems**
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[redacted] london.gov.uk
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From: [redacted]
Sent: 08 June 2022 10:20
To: [redacted]
Cc: [redacted] ; [redacted] ; [redacted] WCC ; EMS244 PDHU Heat Pump Opportunity ; [redacted] susesco.co.uk; [redacted]
Subject: RE: LEA application WCC/PDHU

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Hi [redacted]
Thanks, much appreciated.
Please can you remind me of timescales for notification once we have resubmitted? We also need to consider procurement timescales through the framework, Perhaps we should allow 3 to 4 weeks for the type of support we are seeking?
Kind regards
[redacted]
Silver EMS Ltd
A St Clare House, 30/33 Minories, London, EC3N 1DD
P 020 [redacted] | M [redacted] |

From: [redacted] <[redacted] london.gov.uk>
Sent: 08 June 2022 10:15
To: [redacted] <[redacted] silverems.com>

Cc: [redacted] <[redacted]london.gov.uk>; [redacted] <[redacted]BuroHappold.com>; [redacted] WCC <[redacted]westminster.gov.uk>; EMS244 PDHU Heat Pump Opportunity <[redacted]silverems.com>; [redacted]susesco.co.uk; [redacted] <[redacted]silverems.com>
Subject: RE: LEA application WCC/PDHU

Hi [redacted]

Ok thanks for letting me know. Not a hard deadline, just don't want to delay your project.

Thanks

[redacted] **Energy Systems**
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[redacted]london.gov.uk
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From: [redacted] <[redacted]silverems.com>
Sent: 08 June 2022 10:06
To: [redacted] <[redacted]london.gov.uk>; [redacted] WCC <[redacted]westminster.gov.uk>
Cc: [redacted] <[redacted]london.gov.uk>; [redacted] <[redacted]BuroHappold.com>; EMS244 PDHU Heat Pump Opportunity <[redacted]silverems.com>; [redacted]susesco.co.uk; [redacted] <[redacted]silverems.com>
Subject: RE: LEA application WCC/PDHU

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Hi [redacted]

Apologies for the delay, we are awaiting confirmation on additional consultancy costs to input to the revised breakdowns.

The relevant person who can help (from another organisation) is on leave, returning 14th June. Is there a hard deadline we need to be aware of? I will establish through an alternative contact if so?

Kind regards

[redacted]

Silver EMS Ltd
A St Clare House, 30/33 Minories, London, EC3N 1DD
P 020[redacted] | M [redacted] |

From: [redacted] <[redacted]london.gov.uk>
Sent: 07 June 2022 17:07
To: [redacted] <[redacted]silverems.com>; [redacted] WCC <[redacted]westminster.gov.uk>
Cc: [redacted] <[redacted]london.gov.uk>; [redacted] <[redacted]BuroHappold.com>
Subject: RE: LEA application WCC/PDHU

Hi both

Any response to my email below? I'm not sure I have seen a reply

Many thanks

[redacted] **Energy Systems**
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[redacted]london.gov.uk
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From: [redacted]
Sent: 19 May 2022 08:00
To: [redacted] <[redacted]silverems.com>; [redacted] WCC <[redacted]westminster.gov.uk>
Cc: [redacted] <[redacted]london.gov.uk>; [redacted] <[redacted]BuroHappold.com>
Subject: LEA application WCC/PDHU

Hi both

We would like to support this project but are concerned regarding the reliance on achieving GHNF success and note that a number of the commercialisation activities would be contingent on this success.

We would like to focus the application on supporting you to a successful board decision and GHNF application which would then set the commercialisation and delivery timelines.

Therefore please revise the costs requested within your proposal to get you to this point (with a revised breakdown) and send back to us.

For the avoidance of doubt the LEA programme cannot fund physical works in case any of the surveys were intrusive or pay for licencing fees but can pay for the professional services delivered by our framework of consultants.

In review of the project proposal would it be your intention for EMS to retain the design lead role, including Techno-economic modelling and Financial modelling (needed for GHNF application)? If so – have you had any thoughts about which lots might be used from the framework - this will need to be a coherent package of works for ease of procurement.

Best regards

[redacted] **Energy Systems**
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[redacted]
london.gov.uk
[redacted]london.gov.uk
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From: [redacted]
To: [redacted] WCC
Cc: [redacted] WCC; [redacted]
Subject: RE: LEA - Support to WCC OBC
Date: 07 December 2022 15:03:00
Attachments: image001.jpg

Hi [redacted]

Sincere apologies, I was going through an extremely busy period when you sent this email and it has slipped through my net. I recall that originally you were asking for more funding than we had and too much funding for one project. We are low on funding remaining, though if you can let me know what level of support is needed and the outcome of your board meeting.

Kind regards

[redacted] **Energy Systems**
GREATER**LONDON**AUTHORITY
City Hall, Kamal Chunchie Way, London E16 1ZE
[redacted]
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[redacted]london.gov.uk

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From: [redacted] WCC
Sent: 16 November 2022 11:01
To: [redacted]
Cc: [redacted] WCC
Subject: LEA - Support to WCC OBC

Hi [redacted]

You may recall that WCC made an enquiry with the LEA regarding providing support to the PDHU Decarbonisation project back in the summer. The project is now progressing and we are in the final stage of developing the Strategic Outline Case, with the paper going to the Board in December. If approved, the OBC will commence soon afterwards and I wanted to understand whether this is something LEA can support and to what level.

Would it be possible to arrange a call to run through where it was left and the steps we need to take?

Thanks

[redacted] - PDHU
[redacted]

From: Local Energy Accelerator
To: [redacted] [redacted] WCC
Cc: [redacted] [redacted] WCC; [redacted] [redacted] WCC; Local Energy Accelerator
Subject: RE: WCC Communal Heat Network - Feasibility
Date: 12 July 2023 19:51:00
Attachments: image001.jpg

Hi [redacted]
We can have a conversation about what support is needed?
Let me know some times and days you're available in next few weeks to discuss.
Thanks

[redacted] **Energy Systems**
GREATER**LONDON**AUTHORITY
City Hall, Kamal Chunchie Way, London E16 1ZE
[redacted]
london.gov.uk/lea
[redacted]london.gov.uk

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From: [redacted] [redacted] WCC
Sent: 12 July 2023 11:47
To: Local Energy Accelerator
Cc: [redacted] [redacted] WCC ; [redacted] [redacted] WCC
Subject: WCC Communal Heat Network - Feasibility

Hi

It is great to hear the LEA have been awarded funding by the GLA to support Local Authority carbon reduction projects.

WCC have already accessed the LEA Framework to procure a specialist provider for the PDHU decarbonisation programme – which has run quite smoothly. However, PDHU only accounts for 50% of the properties fed by heat networks/communal systems in the Borough. WCC would like to start looking at these other systems to identify how they can be decarbonised – with the current plan to start with those systems which are due a replacement heating system before 2030.

Would it be possible to access the funded support of the PDU to undertake feasibility studies across these networks?

It would be good to arrange a call to discuss the project in more detail.

Thanks in advance

[redacted]

****

FREE EARLY EDUCATION AND CHILDCARE

From: Local Energy Accelerator
To: [redacted] WCC
Cc: [redacted] WCC; [redacted] WCC; Local Energy Accelerator
Subject: RE: Westminster LEA Application
Date: 21 August 2023 17:12:00
Attachments: image002.jpg
image003.jpg

Hi [redacted]
Received, thank you. We will review and aim to get back to you by the end of the week with any clarification questions.
Kind regards

[redacted] **Energy Systems**
GREATER**LONDON**AUTHORITY
City Hall, Kamal Chunchie Way, London E16 1ZE
[redacted]
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From: [redacted] WCC
Sent: 20 August 2023 21:05
To: Local Energy Accelerator
Cc: [redacted] WCC ; [redacted] WCC
Subject: Westminster LEA Application
Hello,
I am writing to submit an application for LEA funding on behalf of Westminster City Council. I have attached the application form, as well supplementary information on the communal systems we are seeking funding for. Please let me know if you have any follow up questions or concerns.
Thank you very much for your consideration and we look forward to the next steps.
Best regards,

[redacted] Housing Sustainability
Housing & Commercial Partnerships
Westminster City Council
64 Victoria Street, SW1E 6QP (12th floor)
Email: smatson@westminster.gov.uk

EON Citigen

Hydraulic Analysis of DH & DC Networks

Meeting: 2023-06-23

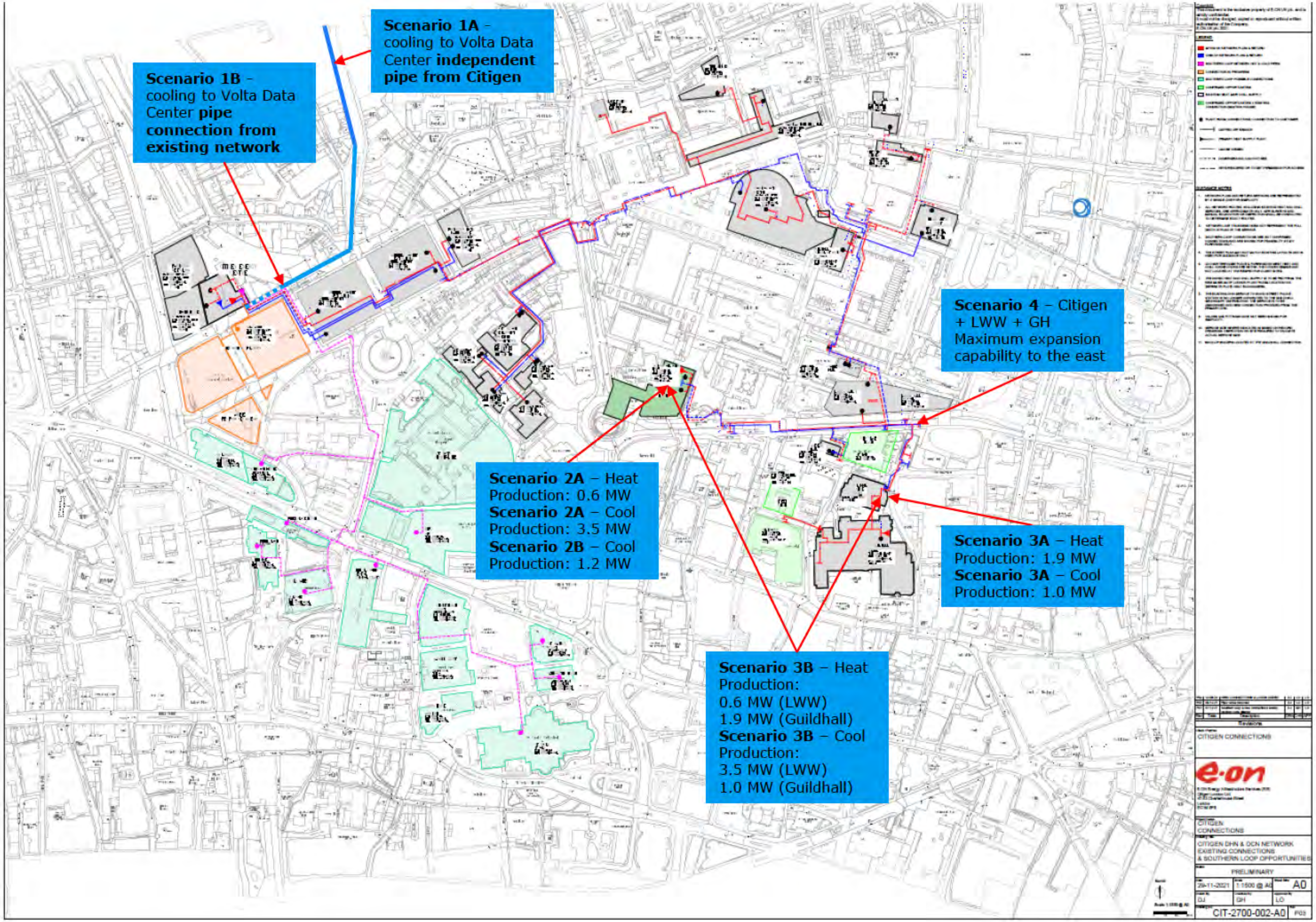
Bright ideas.
Sustainable change.

New scenarios

New scenarios

Simulation	DHN	DCN
Baseline: Simulation of future load (pre-contracted)	**COWI-H3** Tsup/Tret = **89/72** °C Peak demand: 12.4 MW	**COWI-C3** Tsup/Tret = 6.0/13 °C Peak demand: 6.0 MW
Scenario 1A - cooling to Volta Data Center **independent pipe from Citigen**	-	Additional load = 6 MW-c (min dP 0.5) Tsup/Tret to Volta = 6/18 degC DN300 (9.1 MW theor. capacity) Peak demand: 12 MW
Scenario 1B - cooling to Volta Data Center **pipe connection from existing network (see map)**	-	Same as 1a
Scenario 2A – LWW	New production: 0.6 MW-h @80 °C to offset production from EC Peak: 11.5 MW (Bastion House and MoL are removed)	MAX: New production: 3.5 MW-c to offset production from Citigen Peak demand= 12 MW
Scenario 2B – LWW	-	MIN: New production: 1.2 MW-c to offset production from Citigen Peak demand= 12 MW
Scenario 3A – Guildhall (only)	New production: 1.9 MW-h @80 °C to offset production from EC Peak demand: 13 MW (Bastion House and MoL replaced by 2.6 MW load at LWW)	New production: 1.0 MW-c to offset production from Citigen Peak demand: 12 MW
Scenario 3B – Guildhall + LWW	New production= 1.9 + 0.6 MW-h to offset production from EC Peak: 11.5 MW (Bastion House and MoL are removed)	New production = 1.0 + 3.5 MW-c to offset production from EC Peak demand= 12 MW
Scenario 4 – Citigen + LWW + GH Maximum expansion capability to the east	Total production= 1.9 + 0.6 + 12.4 MW-h Peak demand to be evaluted (min dP 0.5 / existing pump limits)	Total production = 1.0 + 3.5 + 6 MW-c Peak demand to be evaluted (min dP 0.5 / existing pump limits)

Rar Scenarios 2, 3 will be based on 1B. Sc. 4 we start on 1B, then discuss based on results


Scenario 1A – cooling to Volta Data Center **independent pipe from Citigen**
Scenario 1B – cooling to Volta Data Center **pipe connection from existing network**
Scenario 4 – Citigen + LWW + GH Maximum expansion capability to the east
Scenario 2A – Heat Production: 0.6 MW
Scenario 2A – Cool Production: 3.5 MW
Scenario 2B – Cool Production: 1.2 MW
Scenario 3A – Heat Production: 1.9 MW
Scenario 3A – Cool Production: 1.0 MW
Scenario 3B – Heat Production:
0.6 MW (LWW)
1.9 MW (Guildhall)
Scenario 3B – Cool Production:
3.5 MW (LWW)
1.0 MW (Guildhall)
CITIGEN CONNECTIONS
e·on
CITIGEN DHN & DCN NETWORK EXISTING CONNECTIONS & SOUTHERN LOOP OPPORTUNITIES
PRELIMINARY
A0
CIT-2700-002-A0

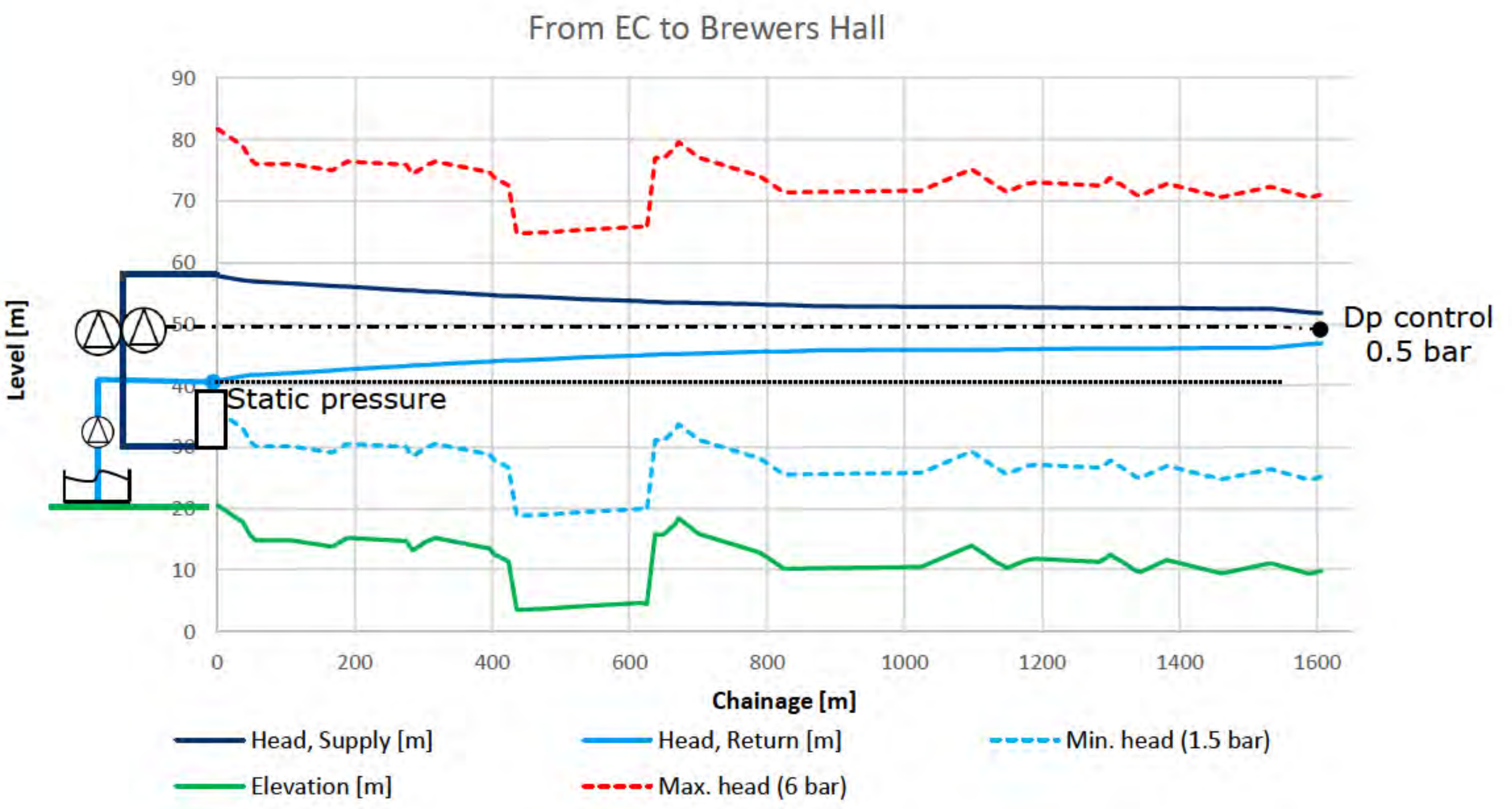
General updates in C3 model

- Pressure drop correction factor changed from 1.0 to 1.1 (both supply and return pipe)
- Soil temperature increased from 10 degC to 15 degC (summer peak load conditions)
- Insulation class of pipes changed from Series 1 to Series 2
- Added path to Volta Data Center and corresponding elevations
- Changed control strategy in central plant: fixing return pressure and min Dp at critical consumer

Scenario 1A-DCN
Direct connection from Citigen EC to Volta DC (Independent Pumps)

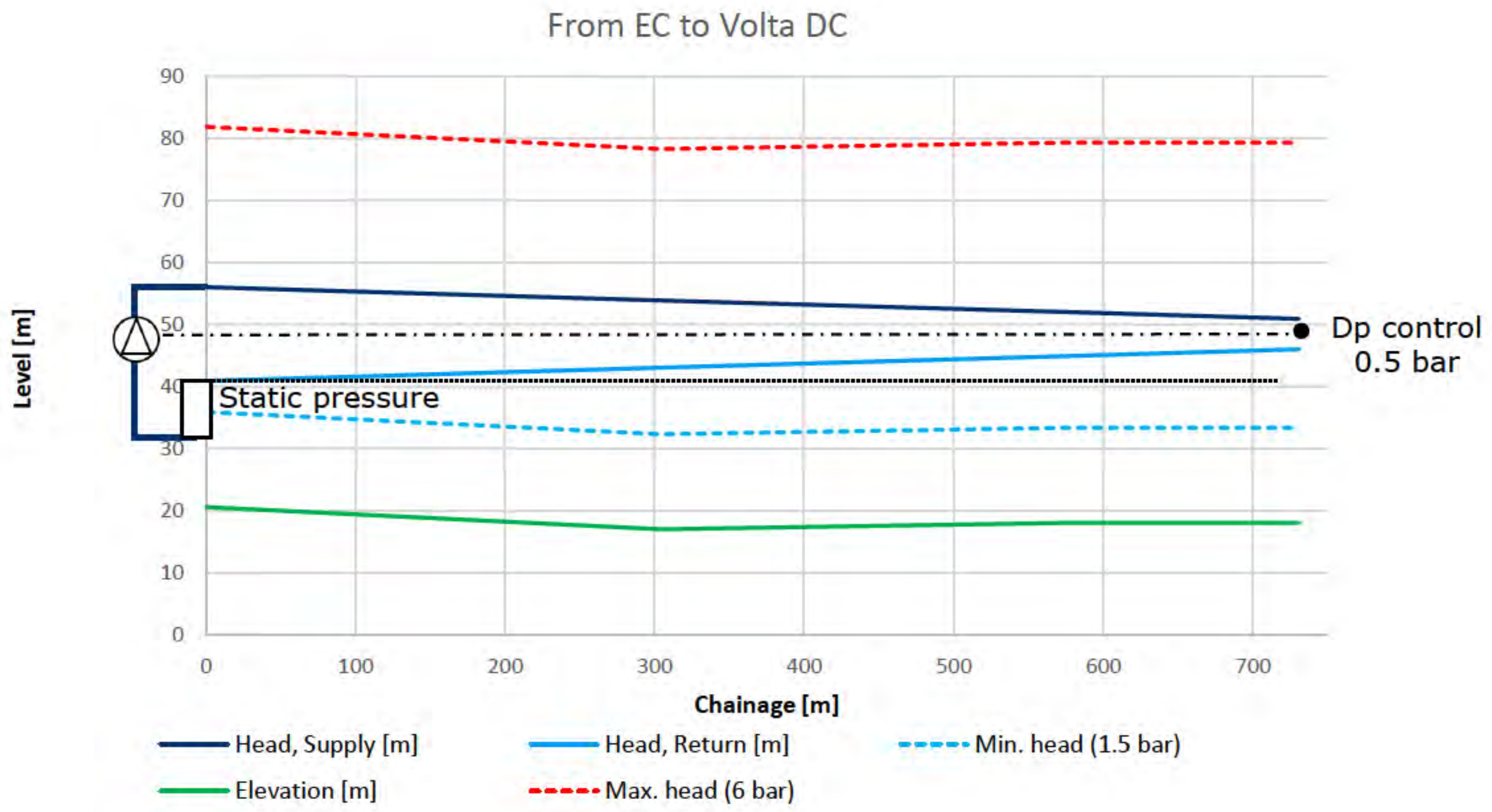
- Assumed pressure drop within EC: 1.5 bar

Scenario 1A – Head Profile: Citigen EC to Brewers Hall (critical node)



- Assumed pressure drop within EC: 1.5 bar

Scenario 1A – Head Profile: Citigen EC to Volta DC



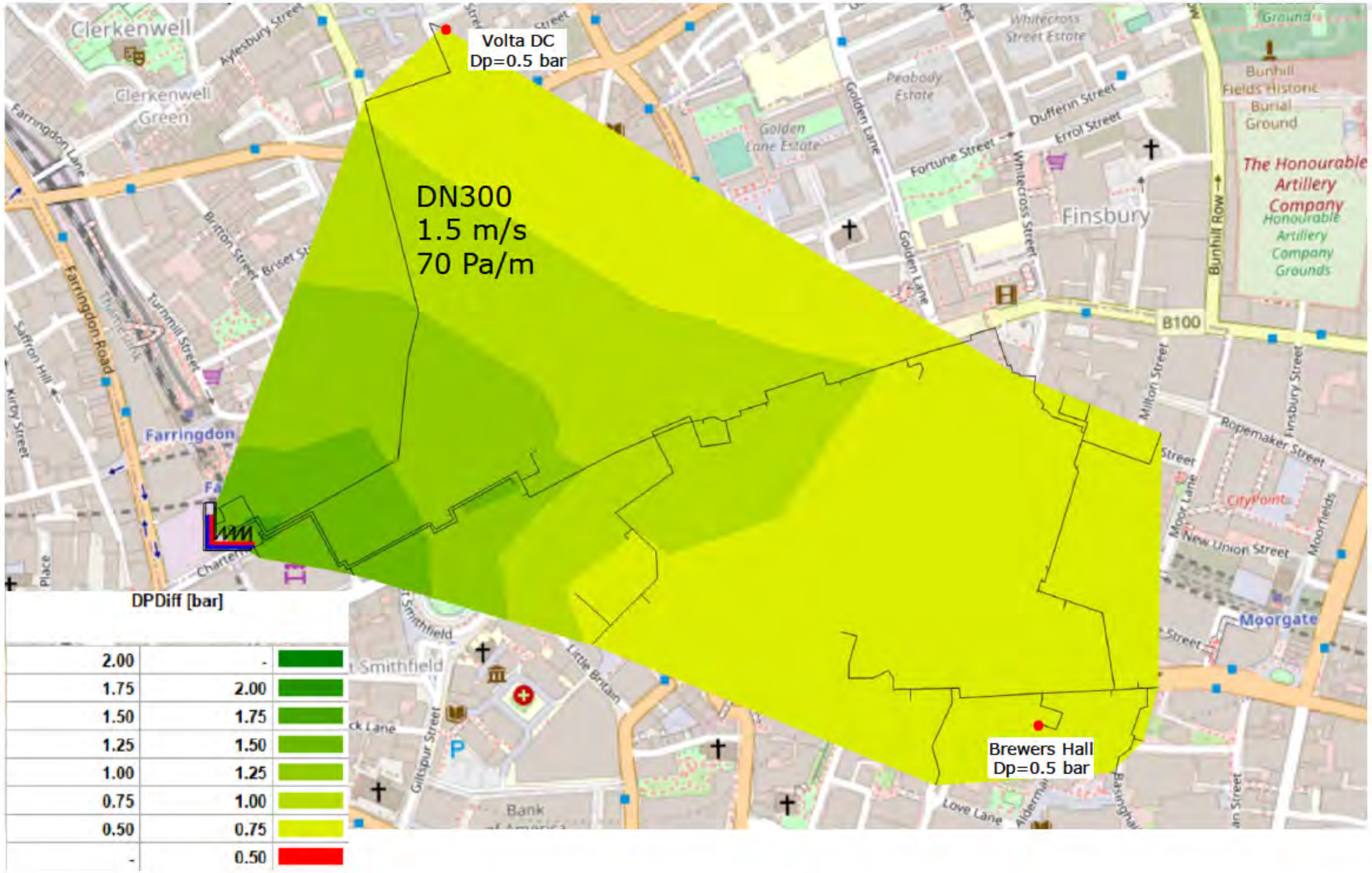
Scenario 1A – Pressure Difference

Results:

- Critical node for DCN (control node) is Brewers Hall (0.5 bar)
- Critical node for Volta is Volta DC (0.5 bar)

PRODUCTION		Supply to DCN	Supply to Volta
Power	[kW]	5,975	6,003
Flow	[kg/s]	204	119
Temp. Supply	[°C]	6.0	6.0
Temp. Return	[°C]	13.0	18.0
Press. Supply	[barg]	3.7	3.5
Press. Return	[barg]	2.0	2.0
Press. Diff.	[bar]	1.7	1.5

NETWORK		Supply to DCN	Supply to Volta
Highest pressure	[barg]	5.1	3.7
Lowest pressure	[barg]	2.0	2.0
Lowest press. diff.	[bar]	0.5	0.5
Highest velocity	[m/s]	2.6	1.5
Highest press. gradient	[Pa/m]	197	70



Scenario 1A - Pumping Capacity

PRODUCTION		Supply to DCN	Supply to Volta
Power	[kW]	5,975	6,003
Flow	**[kg/s]**	**204**	**119**
Temp. Supply	[°C]	6.0	6.0
Temp. Return	[°C]	13.0	18.0
Press. Supply	[barg]	3.7	3.5
Press. Return	[barg]	2.0	2.0
Press. Diff. (DCN only)	[bar]	1.7	1.5
Press. Diff. (EC+DCN)	**[bar]**	**3.2***	**3.0***

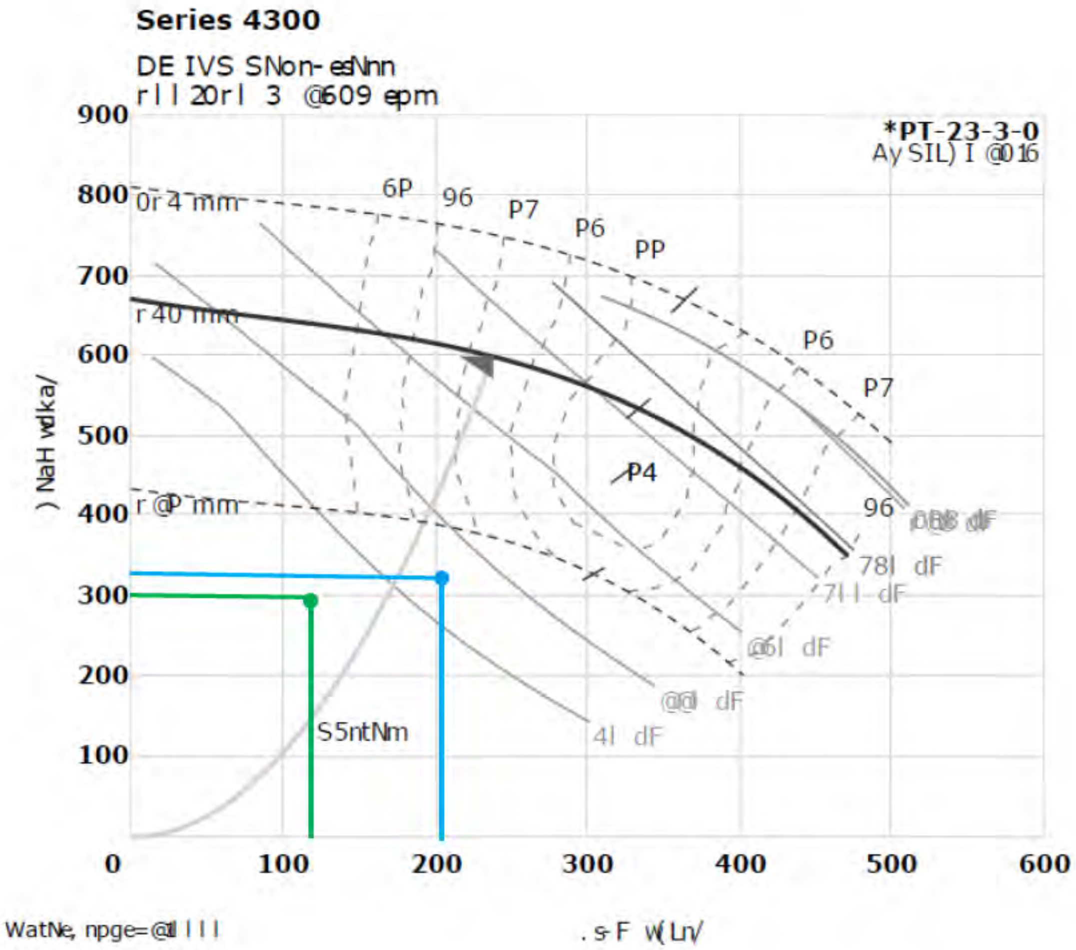
* 1.5 bar pressure drop is assumed inside the EC (production, valves, etc.)

Model: Series Design Envelope Sensorless 4300 3043-250.0

Project name:		**Representative:**	
Location:		**Phone number:**	
Date submitted:	10/7/2022 6:46 AM	**e-mail:**	
Engineer:		**Submitted by:**	

Application design data

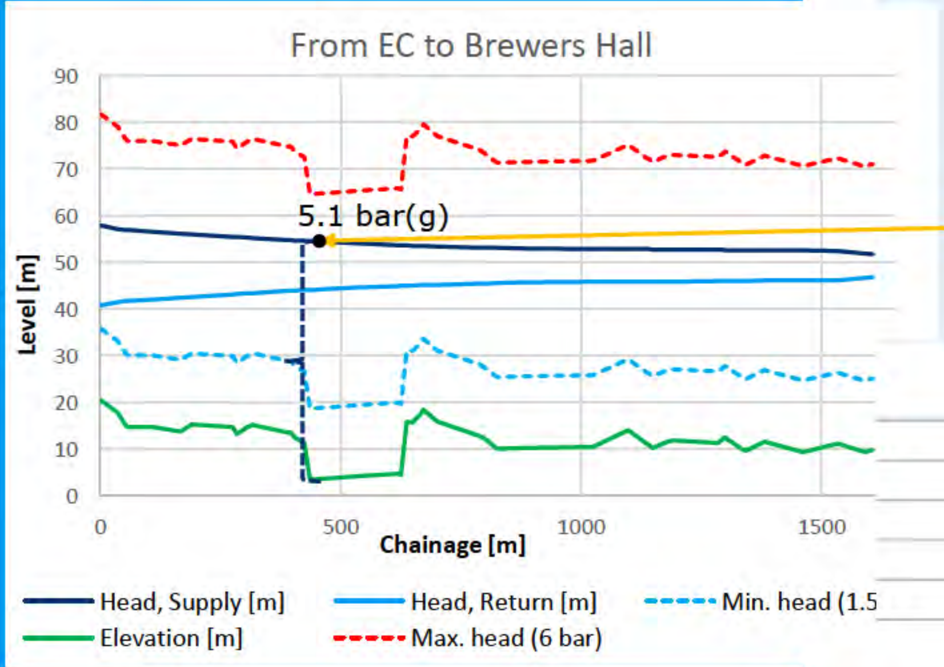
Tag number:	43649	Configuration:	Single
Service:		Suction pressure:	0 ft
Location:		Fluid:	Non-Potable
Qty:	1	Operating temperature:	16 °C
Total system flow:	238 L/s	Duty flow per pump:	238 L/s
System head:	600 kPa	Viscosity:	31 SSU
Environment:	Indoors	Specific gravity:	1.0000
Total dissolved solids:	0 ppm	Safety factor % flow:	0 %
Efficiency at Design:	83.34 %	Safety factor % head:	0 %
NPSHR:	13.83 kPa	Absorbed Power/BHP:	171.17 kW
Min. maintained system pressure*:	240 kPa	Impeller diameter:	394 mm

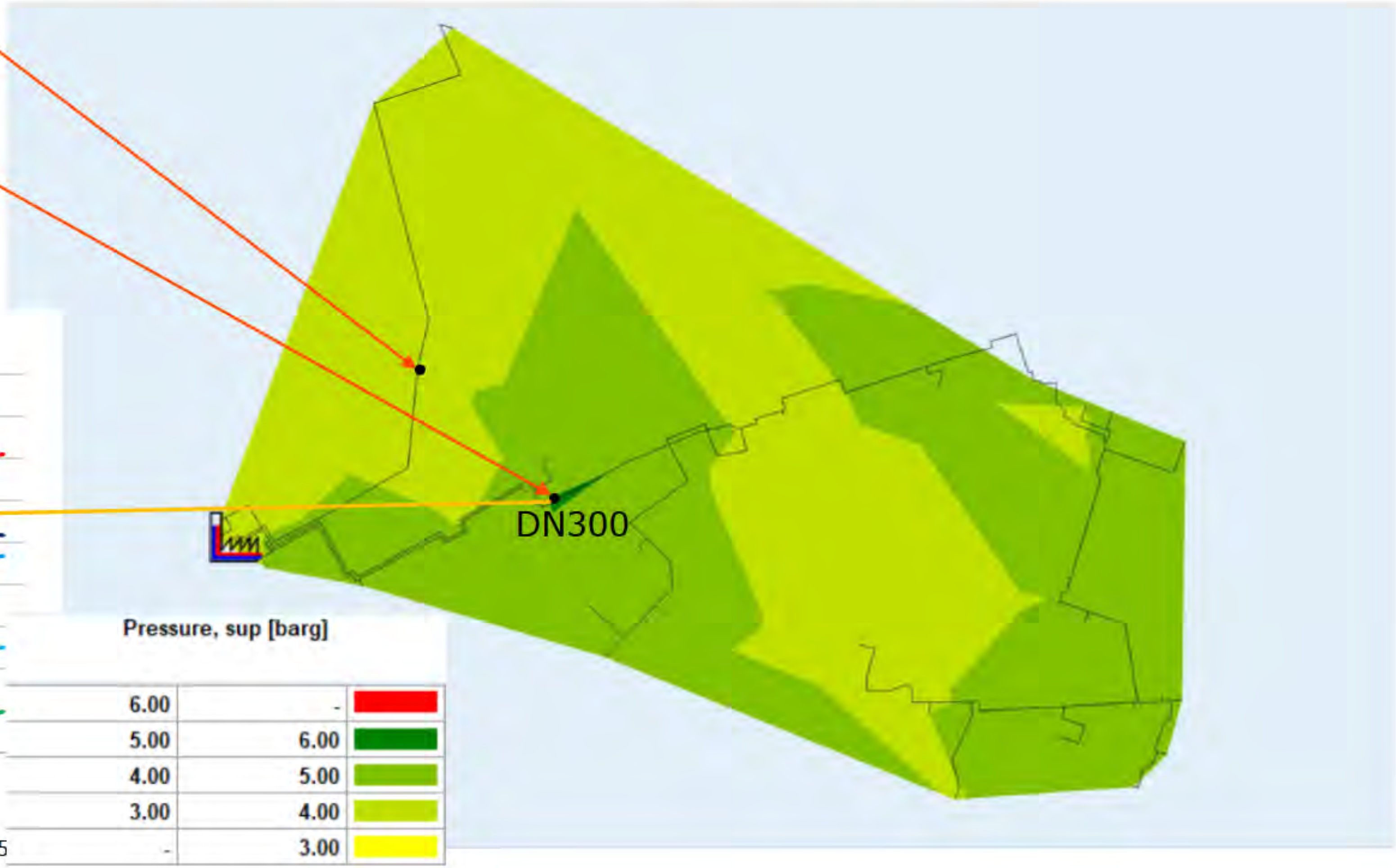


Scenario 1A – Supply Pressure

Results:

- Highest supply pressure in pipe to Volta: 3.7 barg
- Highest supply pressure in DCN: 5.1 barg (close to Smithfield Market East builiding), corresponding to a low elevation area

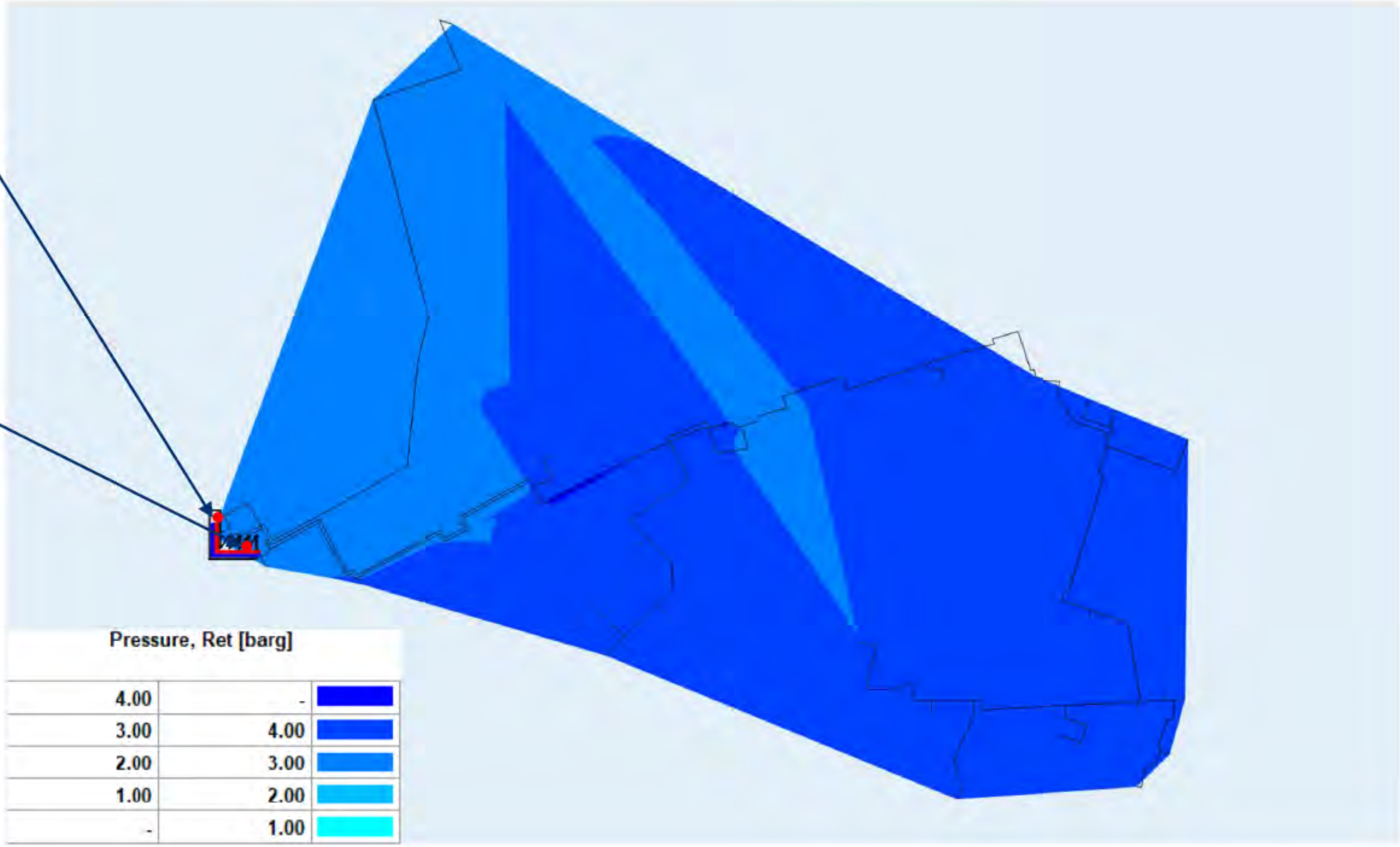




Results:

- Lowest return pressure: 2.0 barg (Farringdon West Bloom)
- Lowest return pressure: 2.0 barg (at EC)

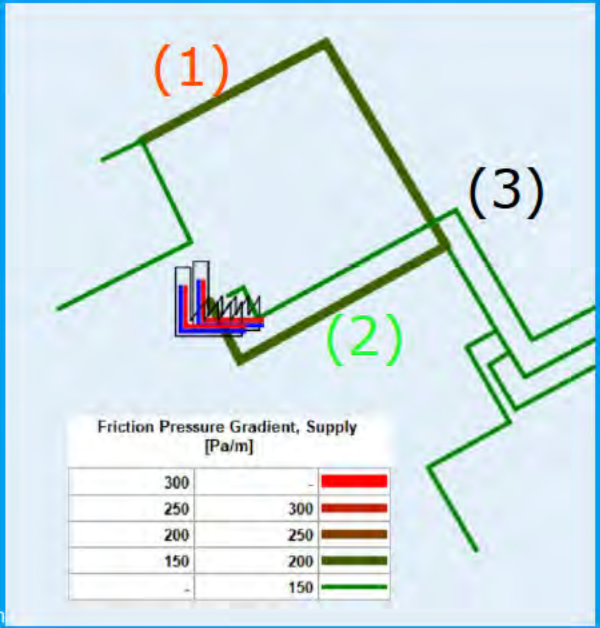
Scenario 1A – Return Pressure

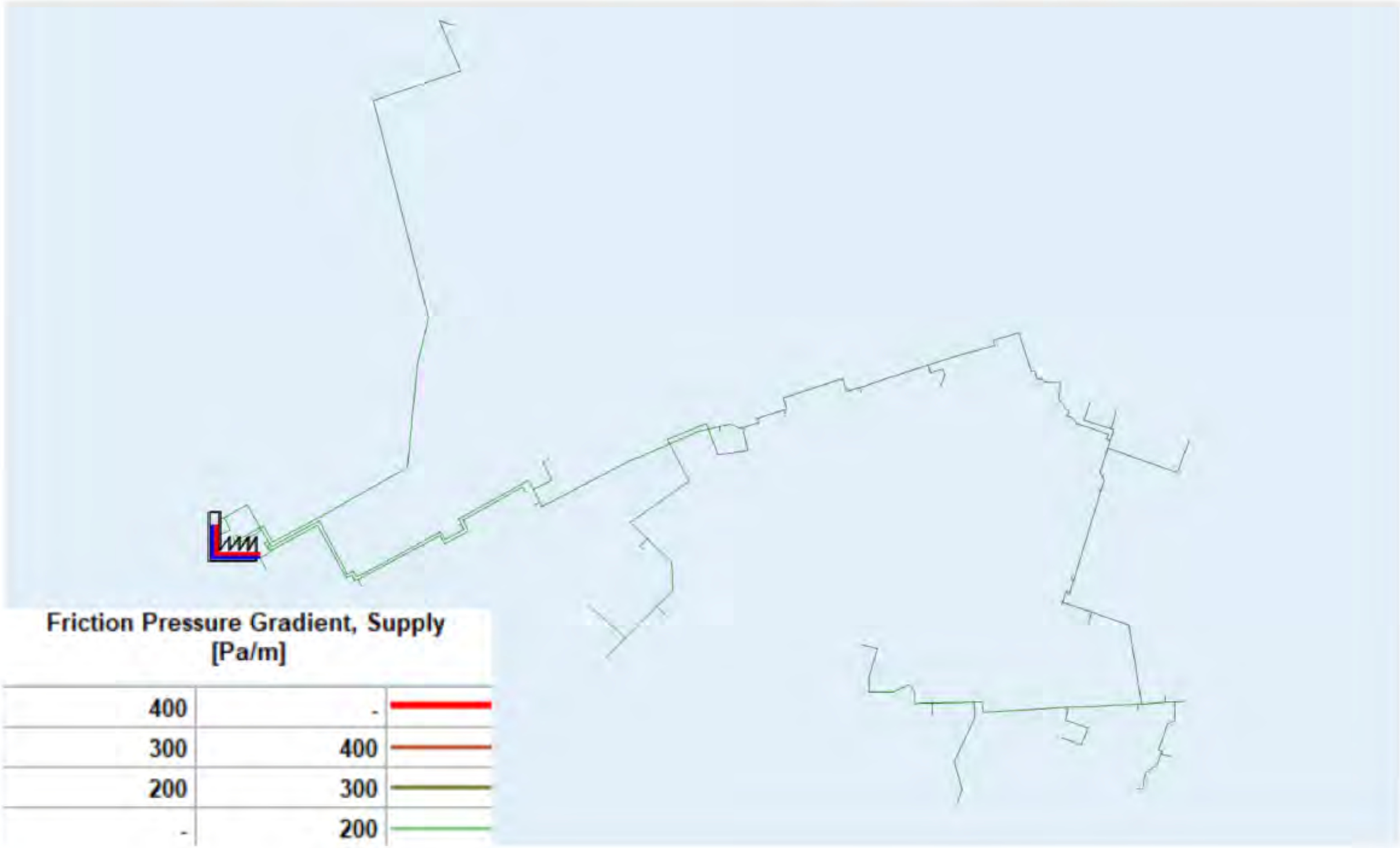


Scenario 1A – Pressure Drop Gradient

Results:

- The highest pressure gradients are
  - DN150 to Farringdon West Bloom and 33 Charterhouse (197 Pa/m; 1.7 m/s); **(1)**
  - DN300 internal to the EC and supplying DCN (196 Pa/m; 2.6 m/s) **(2)**
- The DN300 to Volta DC has a gradient of 70 Pa/m (1.5 m/s) **(3)**
- <300 Pa/m criterion for cooling

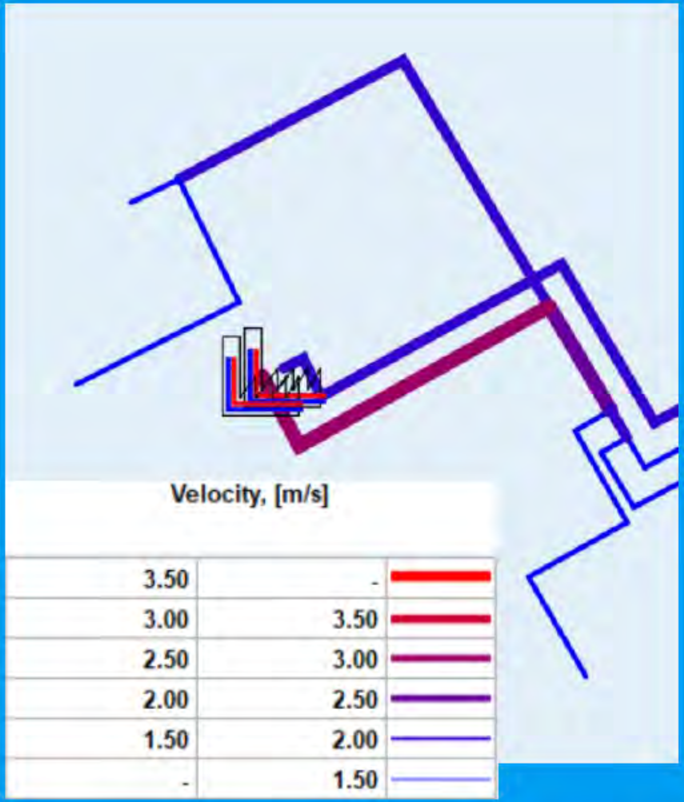


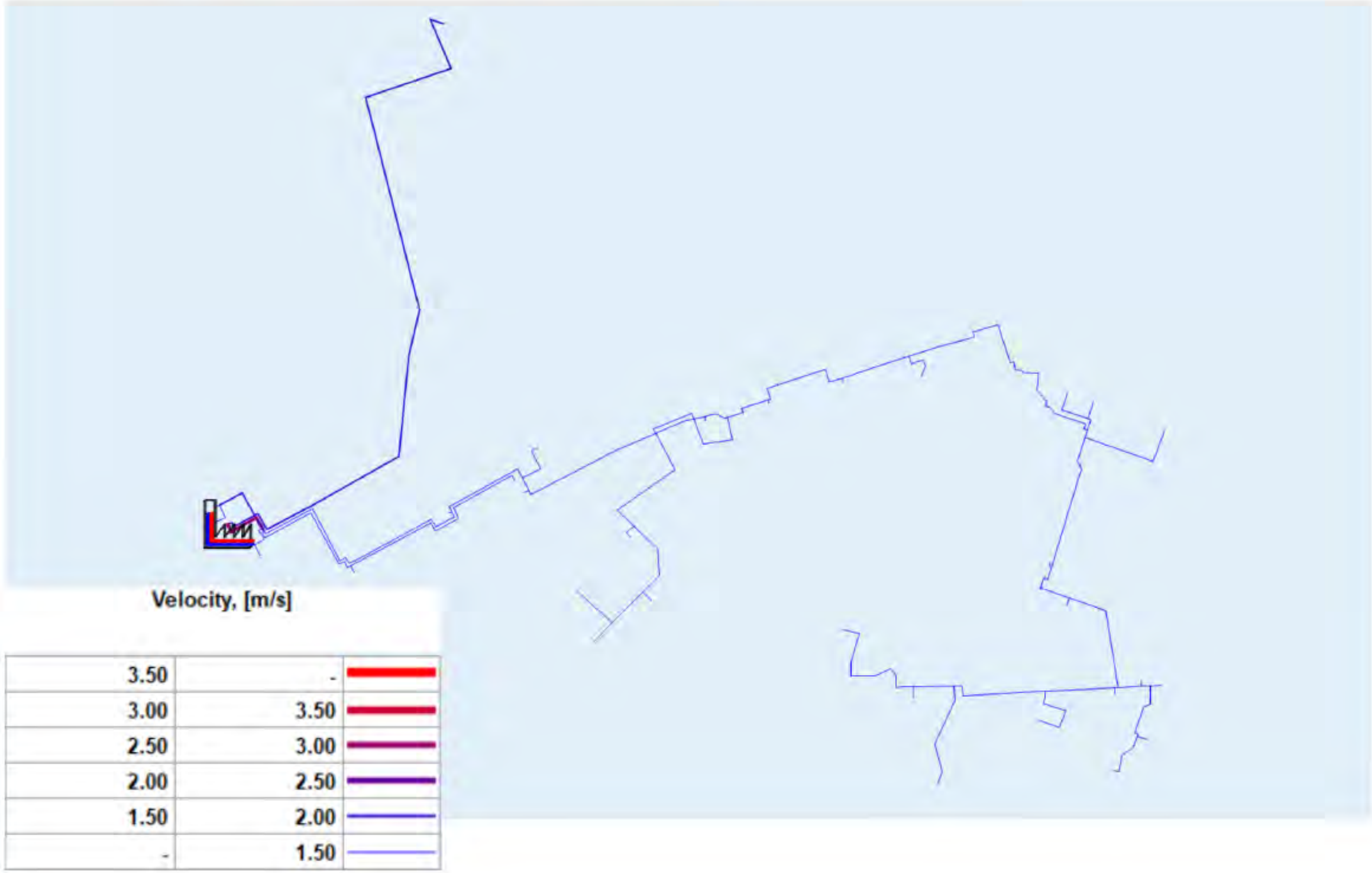


Scenario 1A – Velocity

Results:

- The highest velocity is at the DN300 internal to the plant (2.6 m/s)
- The DN300 to Volta DC has a velocity of 1.5 m/s

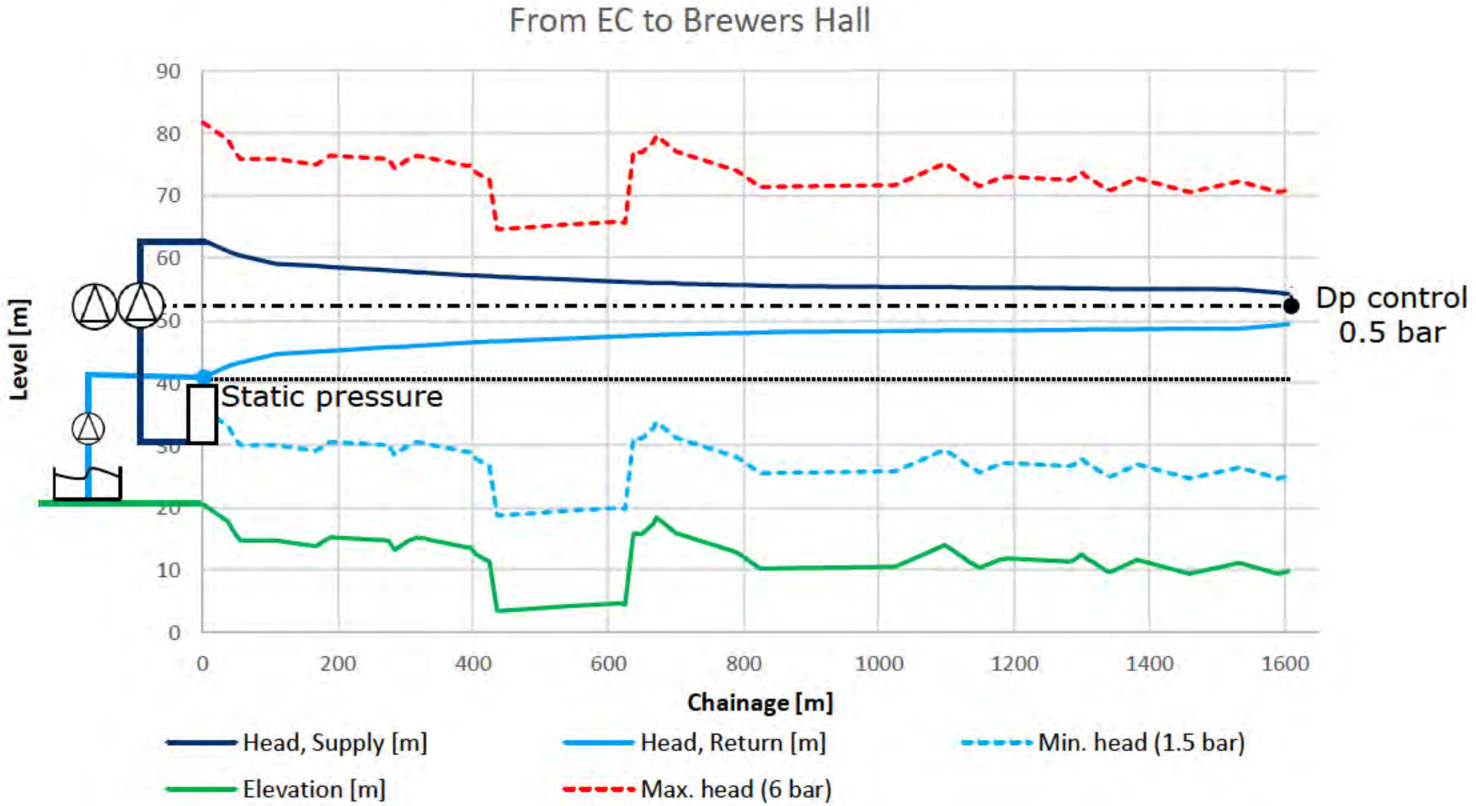




Scenario 1B-DCN Connection to Volta via existing Network

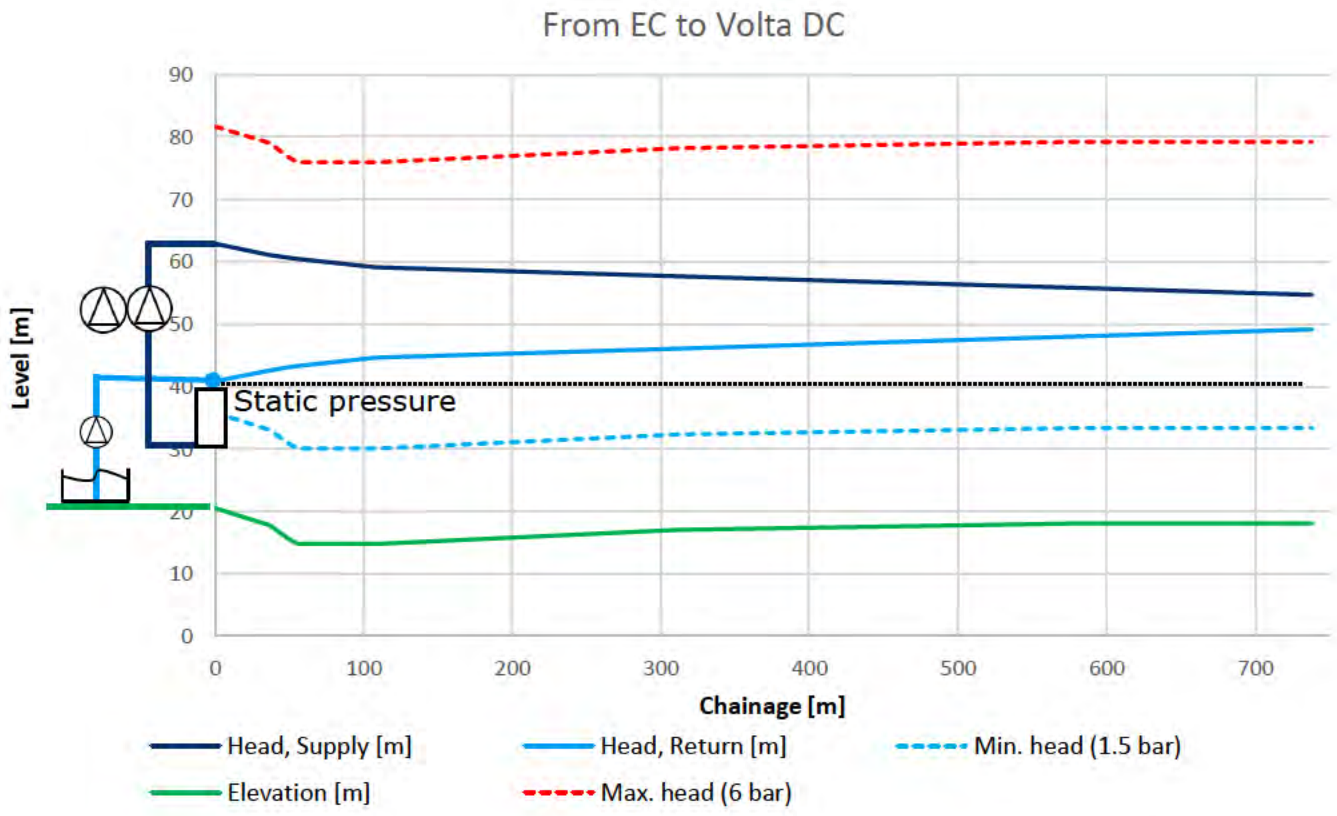
Scenario 1B – Head Profile: Citigen EC to Brewers Hall (critical node)

- Assumed pressure drop within EC: 1.5 bar



Scenario 1B – Head Profile: Citigen EC to Volta DC

- Assumed pressure drop within EC: 1.5 bar
- DP control at Brewers Hall



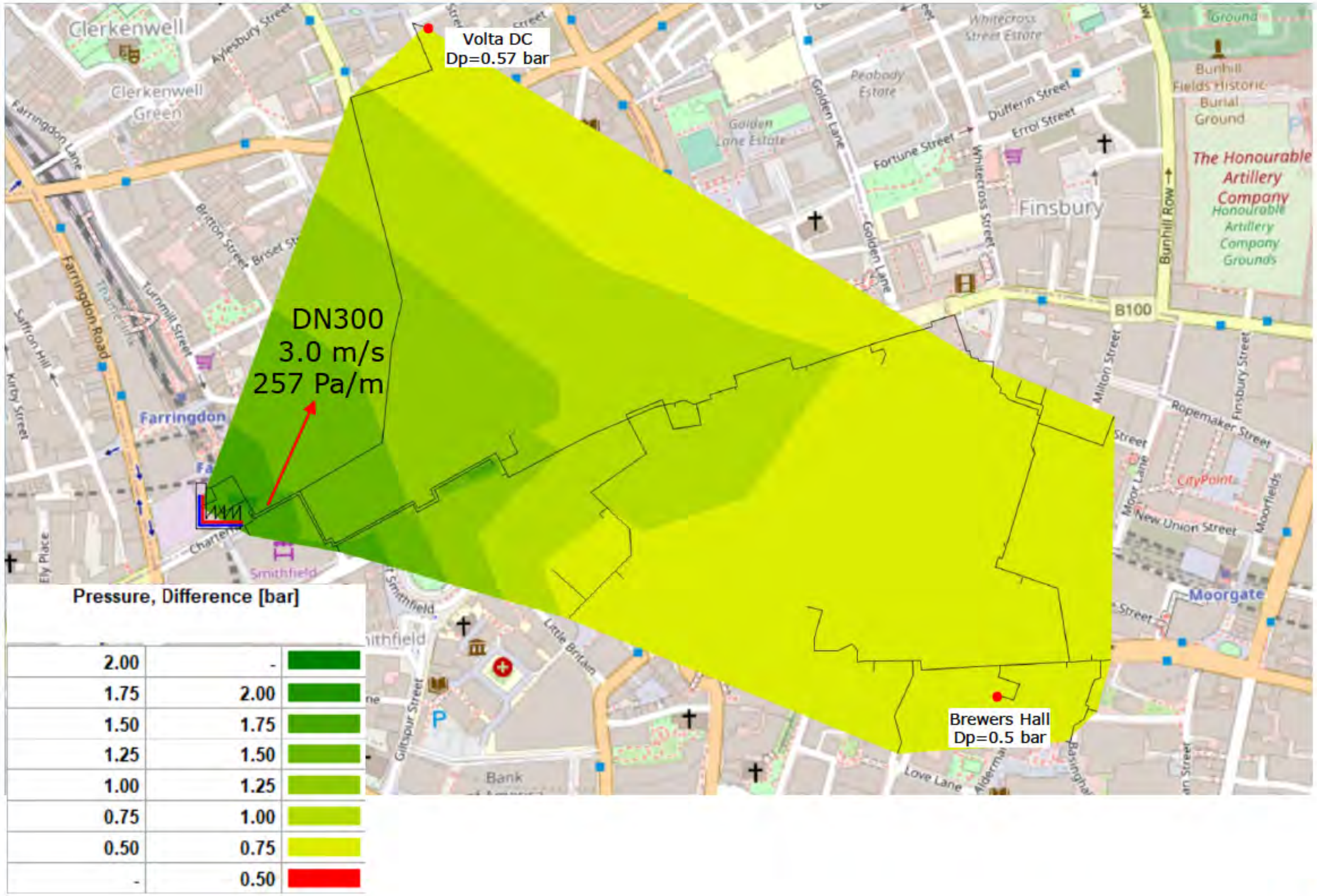
Results:

- Critical node (control node) is Brewers Hall (0.5 bar)
- Pressure difference at Volta is 0.57 bar (consumer with 2nd lowest Dp)

PRODUCTION		
Power	[kW]	11,978
Flow	[kg/s]	323
Temp. Supply	[°C]	6.0
Temp. Return	[°C]	14.8
Press. Supply	[barg]	4.2
Press. Return	[barg]	2.0
Press. Diff.	[bar]	2.2

NETWORK		
Highest pressure	[barg]	5.3
Lowest pressure	[barg]	2.1
Lowest press. diff.	[bar]	0.5
Highest velocity	[m/s]	4.1
Highest press. gradient	[Pa/m]	484

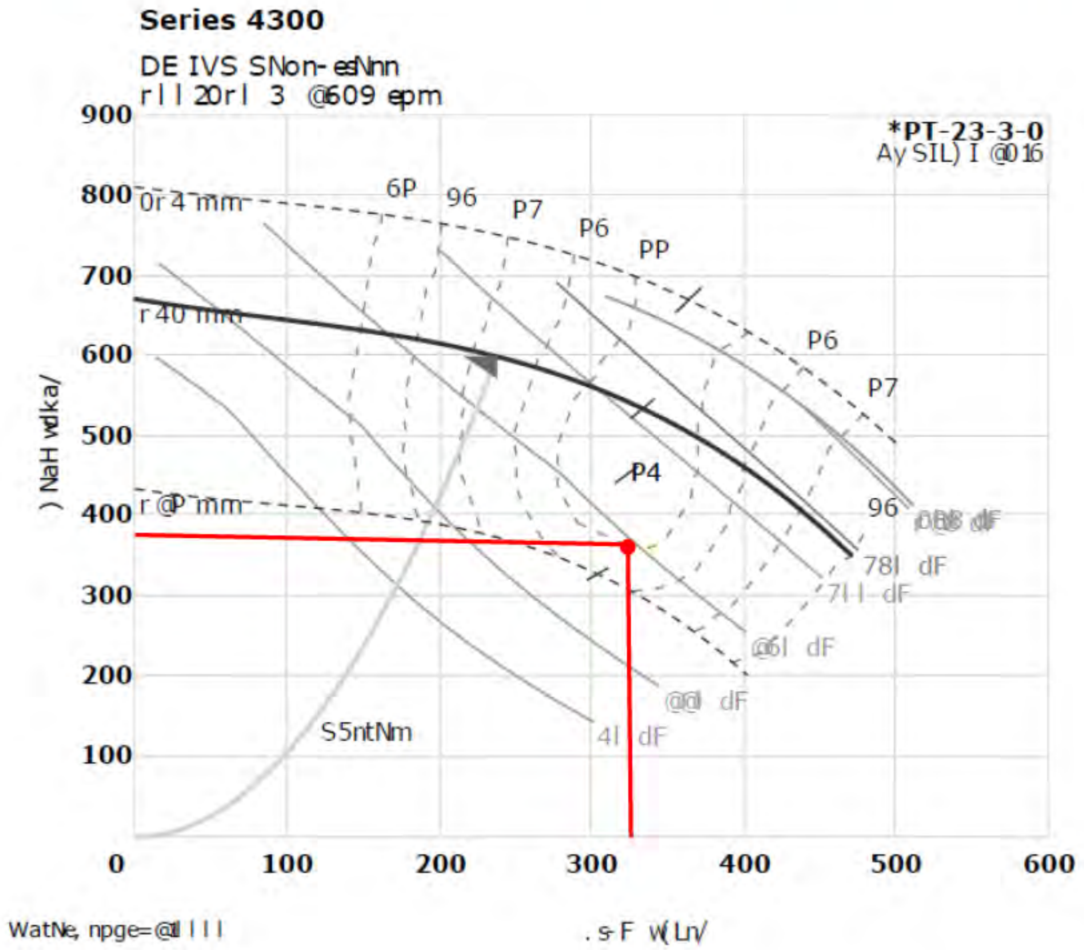
Scenario 1B – pressure difference



PRODUCTION		
Power	[kW]	11,978
Flow	**[kg/s]**	**323**
Temp. Supply	[°C]	6.0
Temp. Return	[°C]	14.8
Press. Supply	[barg]	4.2
Press. Return	[barg]	2.0
Press. Diff. (DCN only)	[bar]	2.2
Press. Diff. (EC+DCN)	**[bar]**	**3.7***

* 1.5 bar pressure drop is assumed inside the EC (production, valves, etc.)

Scenario 1B - Pumping Capacity



Model: Series Design Envelope Sensorless 4300 3043-250.0

Project name:		**Representative:**	
Location:		**Phone number:**	
Date submitted:	10/7/2022 6:46 AM	**e-mail:**	
Engineer:		**Submitted by:**	

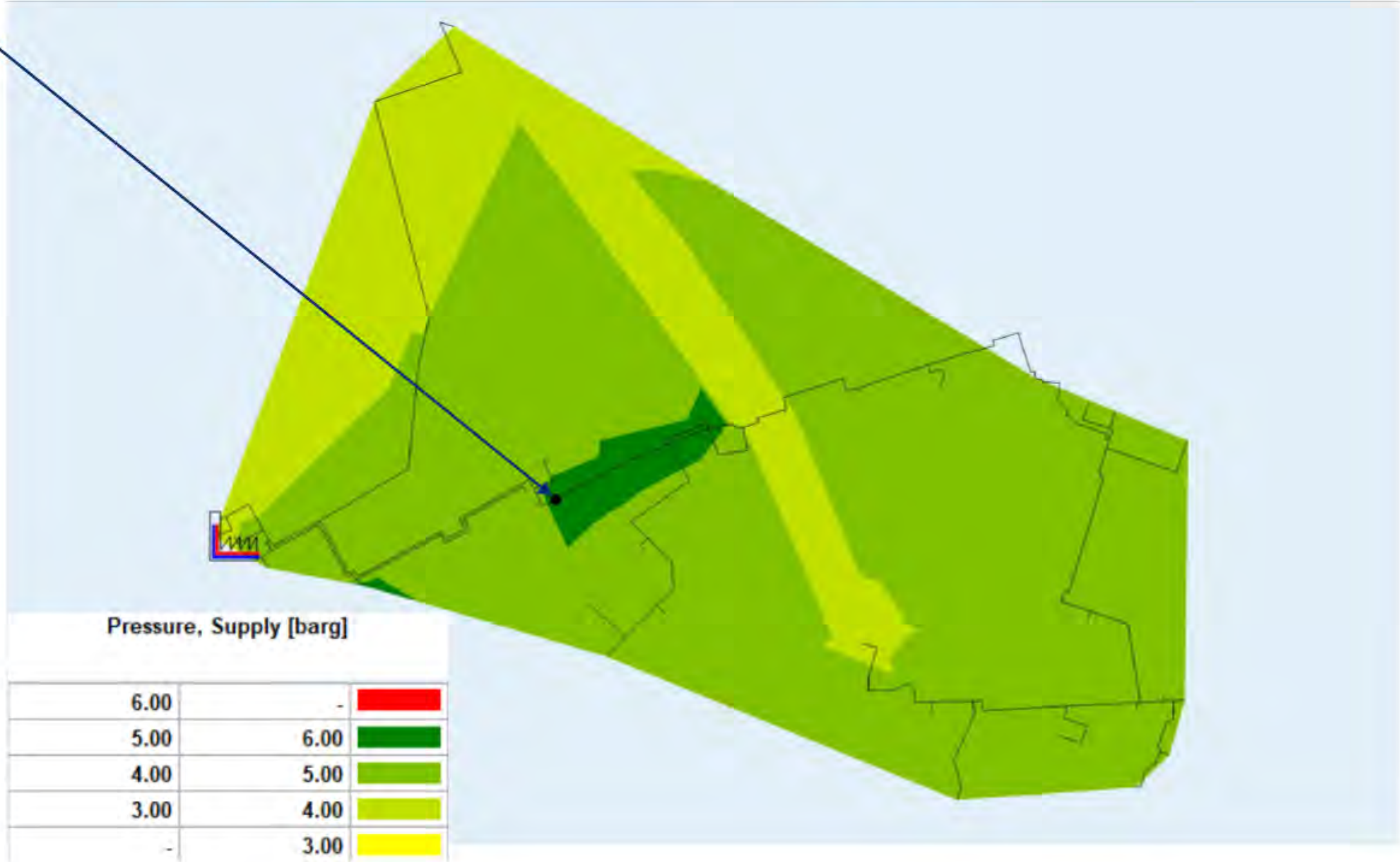
Application design data

Tag number:	43649	Configuration:	Single
Service:		Suction pressure:	0 ft
Location:		Fluid:	Non-Potable
Qty:	1	Operating temperature:	16 °C
Total system flow:	238 L/s	Duty flow per pump:	238 L/s
System head:	600 kPa	Viscosity:	31 SSU
Environment:	Indoors	Specific gravity:	1.0000
Total dissolved solids:	0 ppm	Safety factor % flow:	0 %
Efficiency at Design:	83.34 %	Safety factor % head:	0 %
NPSHR:	13.83 kPa	Absorbed Power/BHP:	171.17 kW
Min. maintained system pressure*:	240 kPa	Impeller diameter:	394 mm

Results:

- Highest supply pressure: 5.3 barg (close to Smithfield Market East builiding), corresponding to a low elevation area

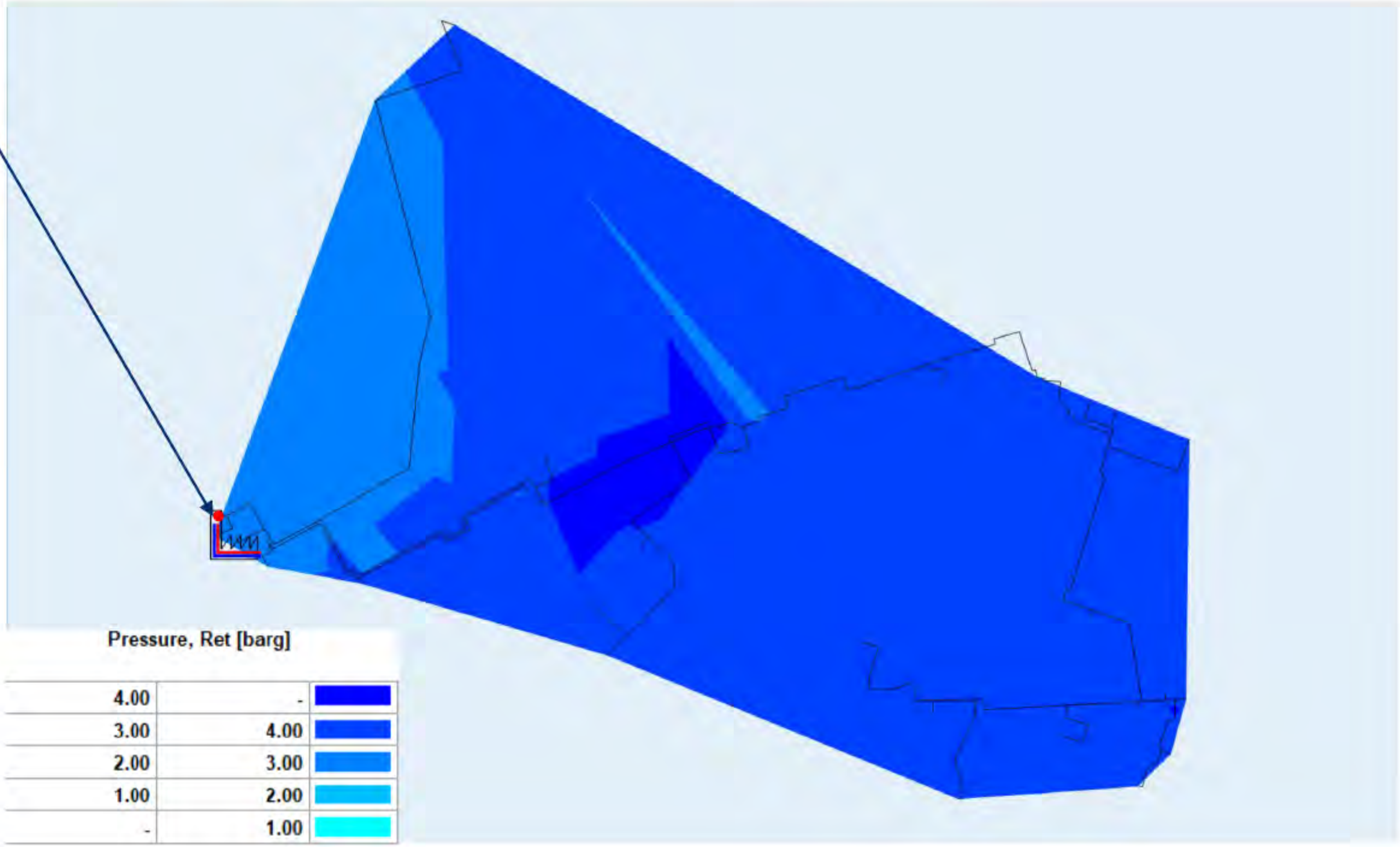
Scenario 1B – Supply Pressure



Results:

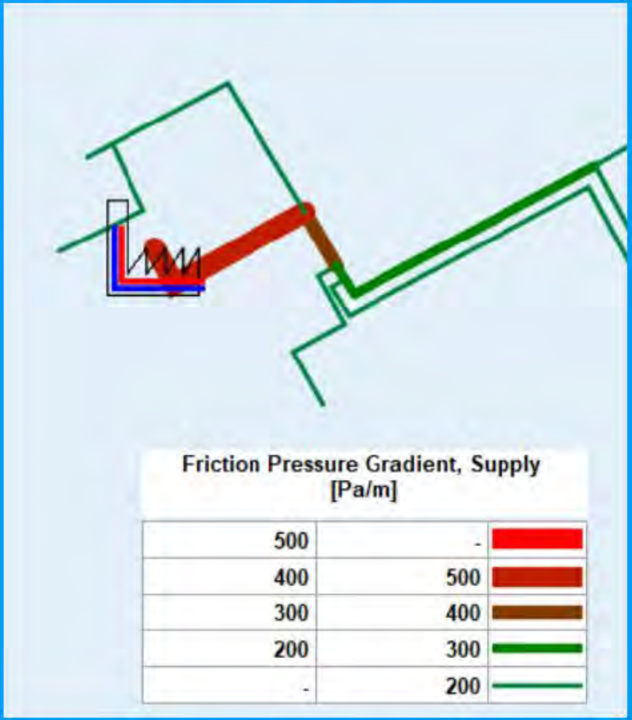
- Lowest return pressure outside the EC: 2.1 barg (Farringdon West Bloom)

Scenario 1B – Return Pressure

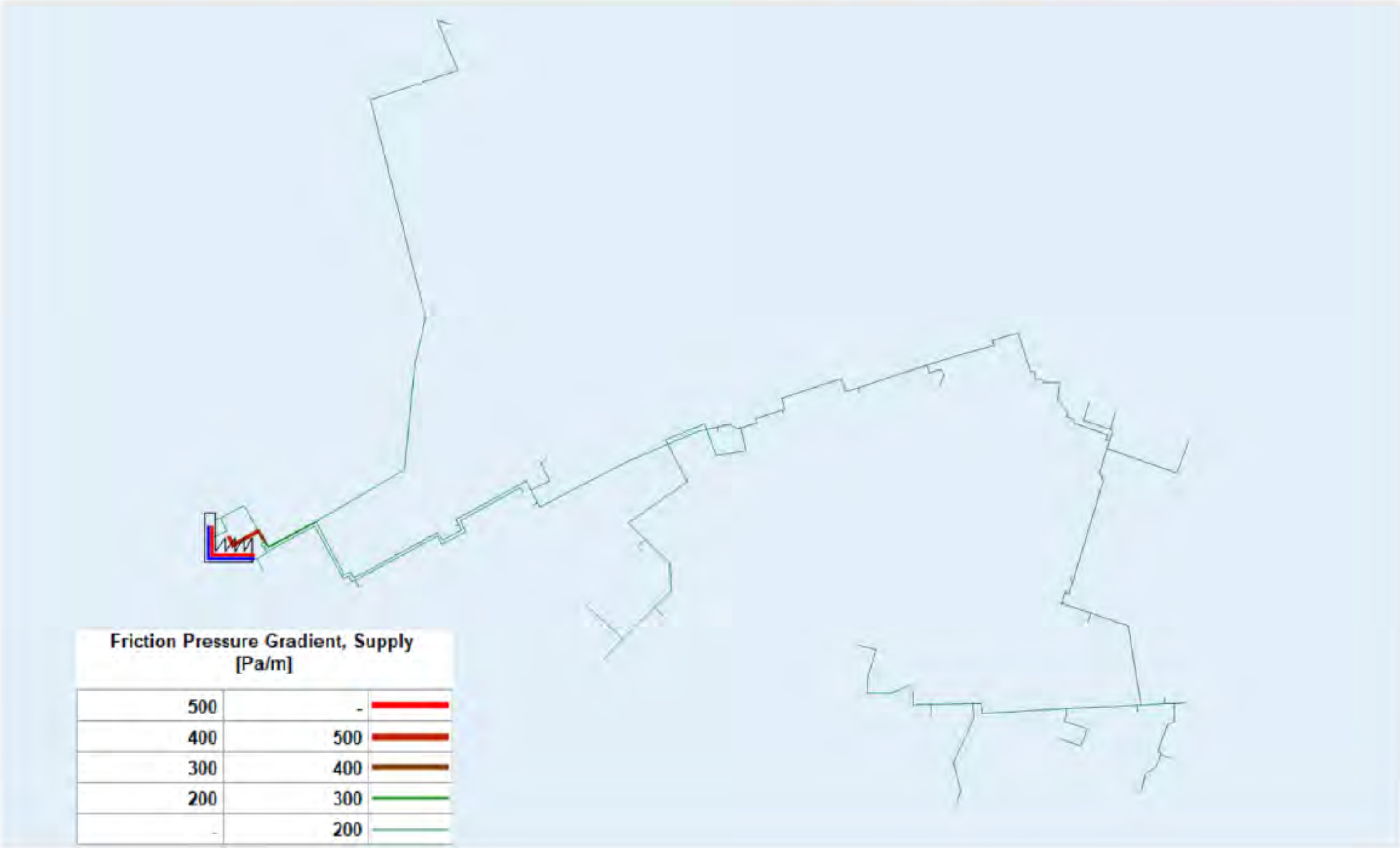


Results:

- The highest pressure gradient is at the DN300 internal to the plant (**484 Pa/m; 4.2 m/s**)
- The common DN300 supplying both Volta DC and the rest of DCN has a pressure drop gradient of 257 Pa/m (3.0 m/s)
- The DN300 to Volta DC has a gradient of 70 Pa/m



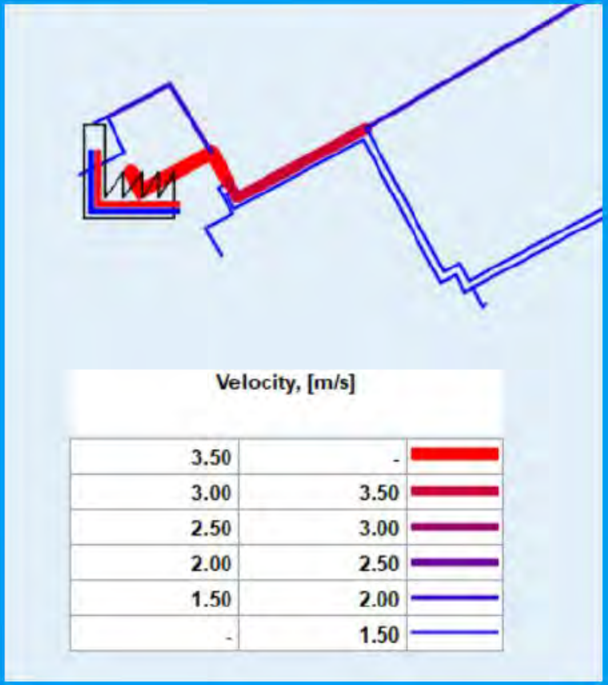
Scenario 1B – Pressure Drop Gradient

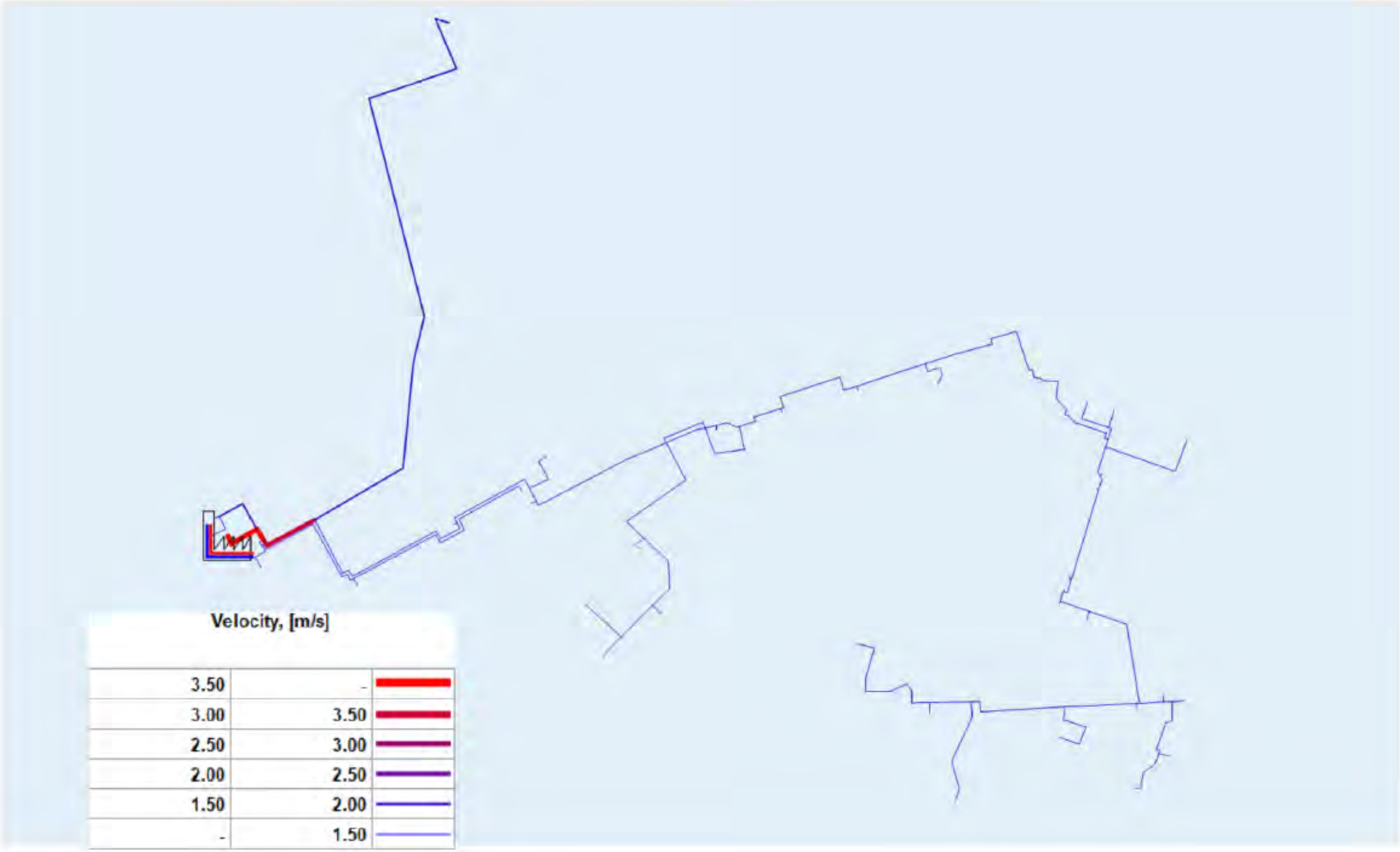


Scenario 1B – Velocity

Results:

- The highest velocity is at the DN300 internal to the plant (4.15 m/s)
- The common DN300 supplying both Volta DC and the rest of DCN has a velocity of 3.0 m/s
- The DN300 to Volta DC has a velocity of 1.54 m/s





Comparison between 1A and 1B

	Parameter	Unit	Scenario 1A		Scenario 1B
			DCN	Volta	
Production	Flow	[kg/s]	204	119	323
	Head excl. Internal loss	[bar]	1.7	1.5	2.2
	Head inl. Intermal loss	[bar]	3.2	3.0	3.7
	Estimated electric power (*)	[kW-el]	87	48	159
	Estimated yearly electricity for pumping (*)	[MWh-el]	45	417	537
Distribution System	Highest pressure	[barg]	5.1	3.7	5.3
	Highest velocity	[m/s]	2.6	1.5	4.1
	Highest pressure gradient	[Pa/m]	197	70	484
	Lowest pressure difference	[bar]	0.5	0.5	0.5
	Additional trench length to Volta	[m]		731	630

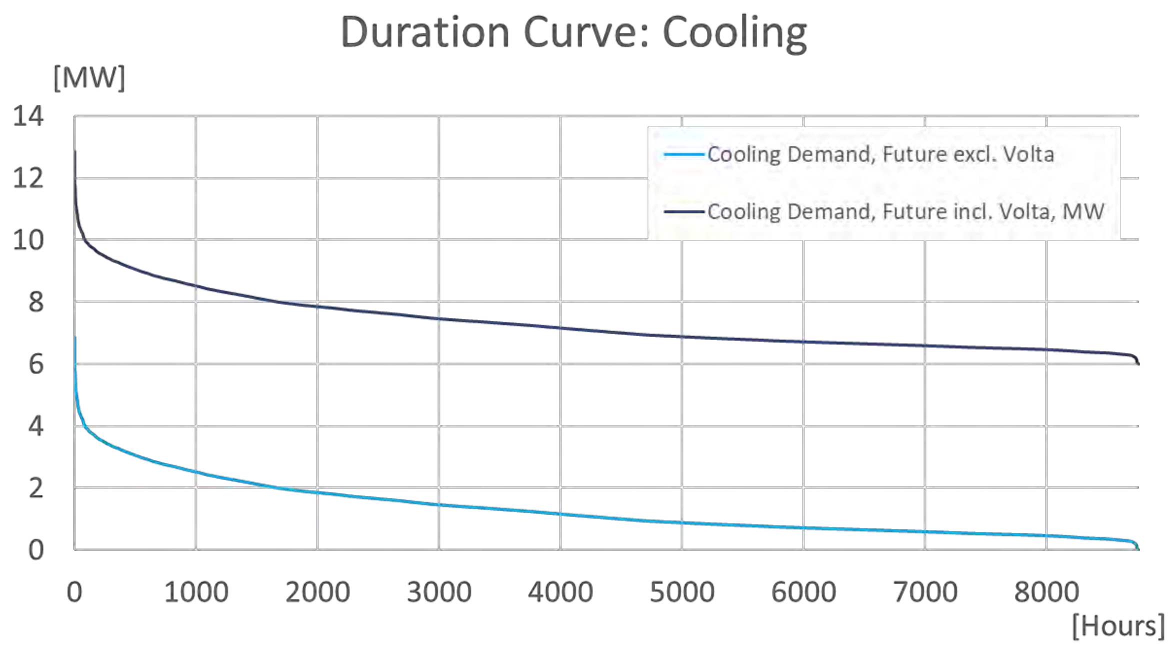
→ (537-462)/462 = +16%

For scenario 1B yearly electricity estimated **16%** higher than in scenario 1A

* Assuming an overall pump+motor efficiency of 75%
Cooling pumps 300-430 have 238 l/s @600 kPa; electric motor: 250 kW-el

Assumptions for yearly pumping energy calculation

- Hydraulic power to overcome network losses calculated in TERMIS at hour 1, 500, 1000, 2000, 5000, 8000 of the load duration curve
- Other points on load curve are polynomially (x^3) interpolated
- Pressure drop within EC: 1.5 bar at peak flow for each of the cooling lines:
  1. production to current DCN
  2. production to Volta
- Pressure drop along EC lines changes proportionally to the square of the flow
- Constant overall pump+motor efficiency of 75%

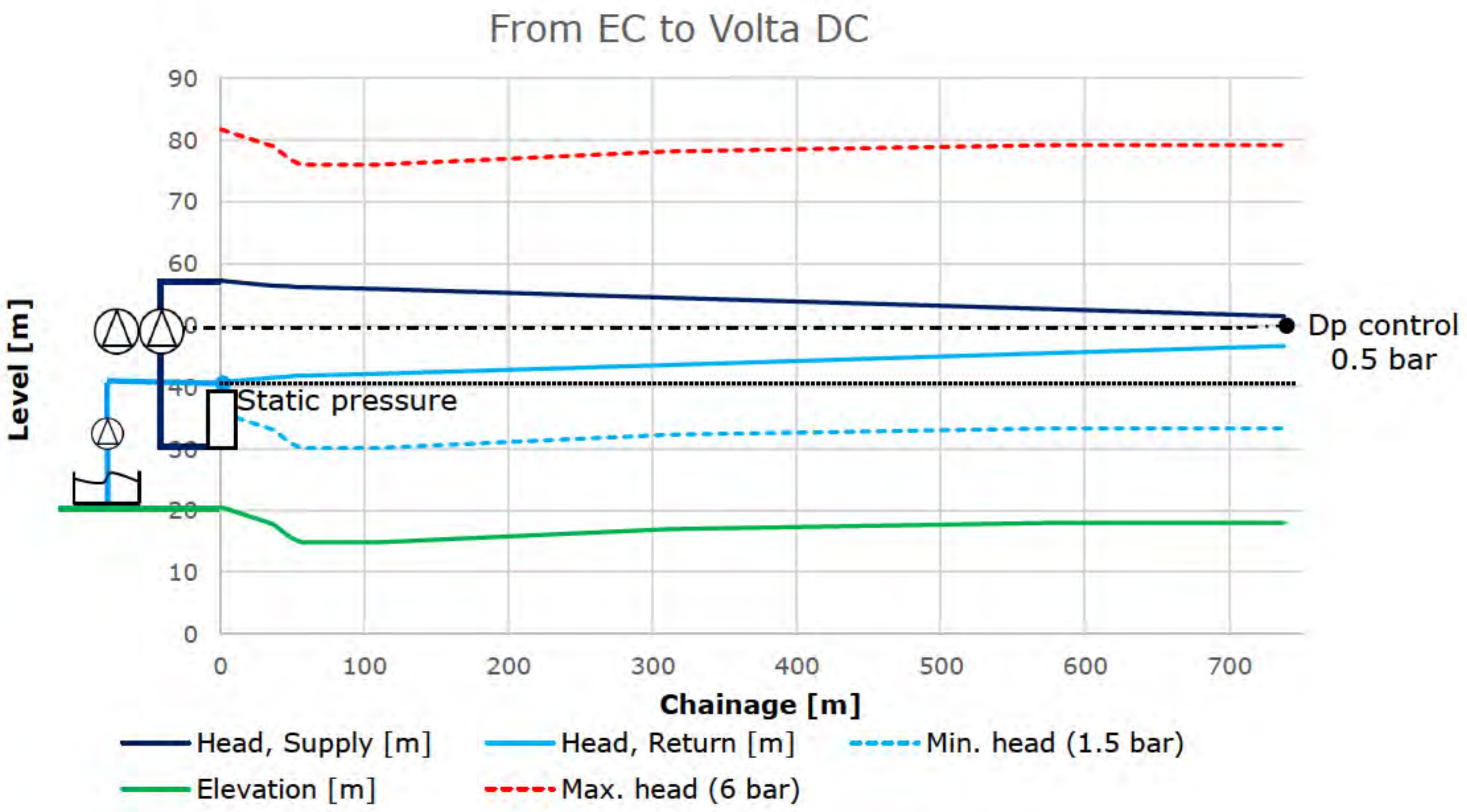


Scenario 2A-DCN
3.5 MW-c production at LWW

(common Volta connection)

- Assumed pressure drop within EC: 1.5 bar

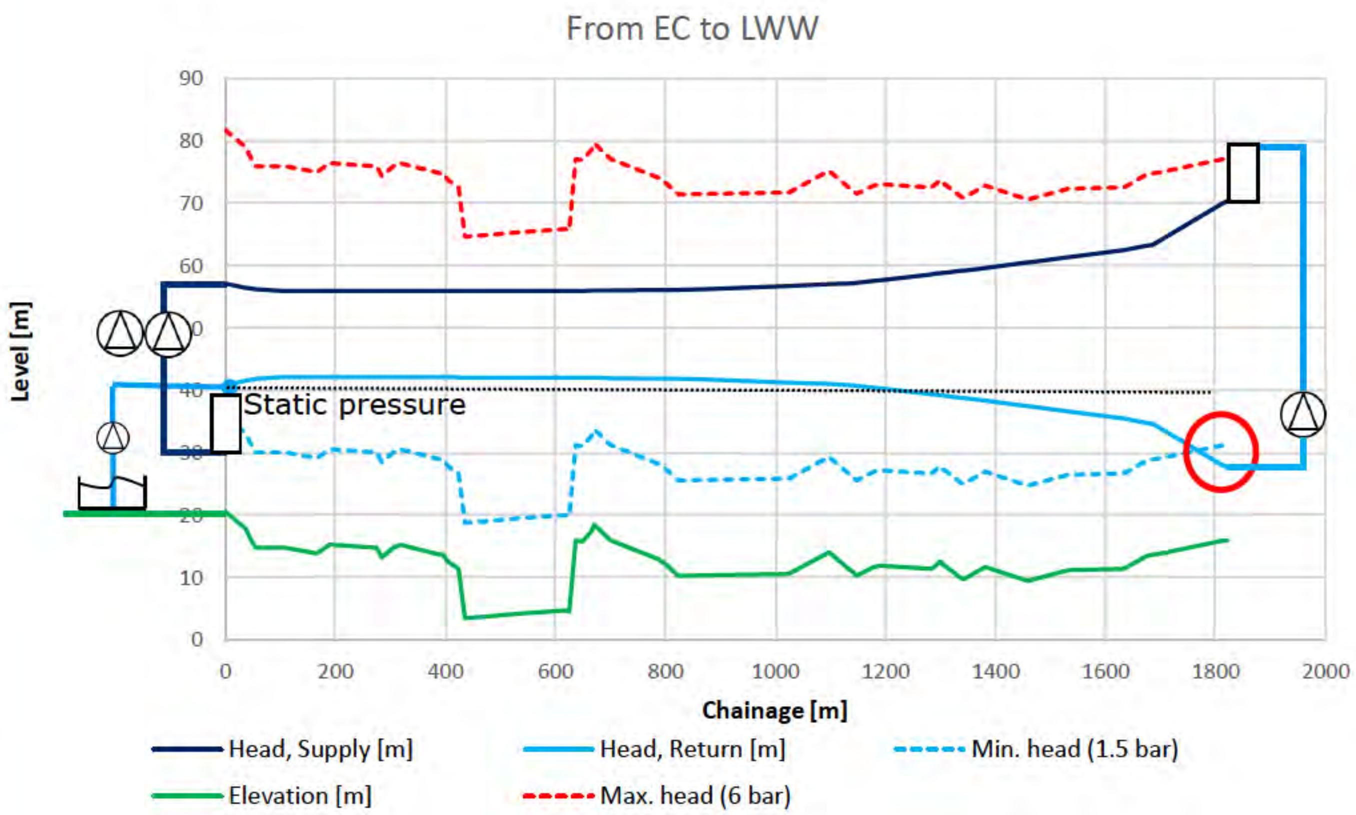
Scenario 2A-DCN – Head Profile: Citigen EC to Volta DC (critical node)



Scenario 2A-DCN – Head Profile: Citigen EC to LWW

- Assumed pressure drop within EC: 1.5 bar
- DP control at Volta DC

Note:
LWW pumps are placed upstream the chillers.
The conceptual layout of LWW will impact the internal pressures at LWW



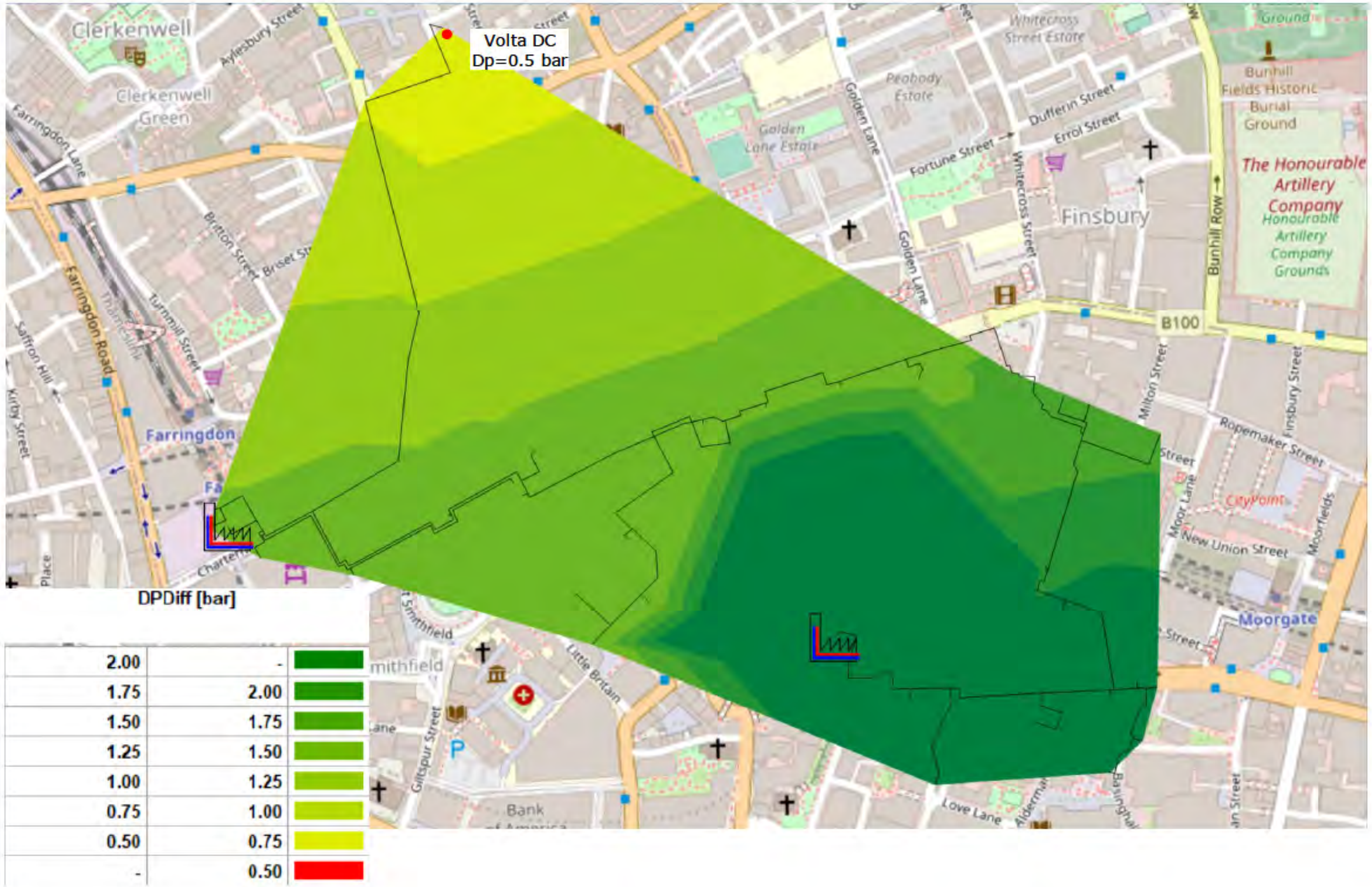
Scenario 2A-DCN – Pressure Difference

Results:

- Critical node (control node) is Volta DC (0.5 bar)

PRODUCTION		Citigen EC	LWW
Power	[kW]	**8,475**	**3,500**
Flow	[kg/s]	206	117
Temp. Supply	[°C]	6	6
Temp. Return	[°C]	15.8	13.1
Press. Supply	[barg]	3.6	5.4
Press. Return	[barg]	2.0	1.2
Press. Diff.	[bar]	1.6	4.2

NETWORK		
Highest pressure	[barg]	5.4
Lowest pressure	[barg]	1.2
Lowest press. diff.	[bar]	0.5
Highest velocity	[m/s]	3.3
Highest press. gradient	[Pa/m]	512



Scenario 2A-DCN - Pumping Capacity

PRODUCTION		Citigen EC	LWW
Power	[kW]	8,475	3,500
Flow	**[kg/s]**	**206**	**117**
Temp. Supply	[°C]	6	6
Temp. Return	[°C]	15.8	13.1
Press. Supply	[barg]	3.6	5.4
Press. Return	[barg]	2.0	1.2
Press. Diff. (DCN only)	[bar]	1.6	4.2
Press. Diff. (EC+DCN)	**[bar]**	**3.1***	**5.7***

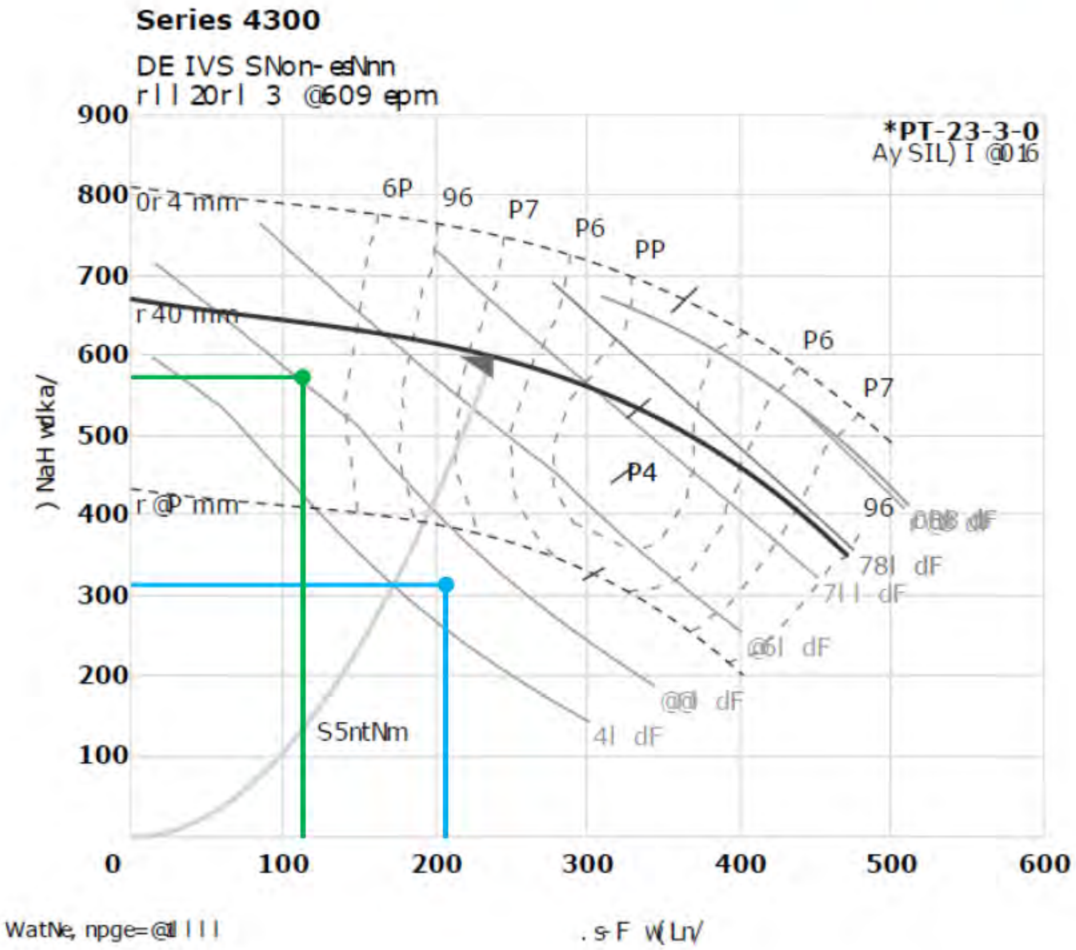
* 1.5 bar pressure drop is assumed inside the EC (production, valves, etc.)

Model: Series Design Envelope Sensorless 4300 3043-250.0

Project name:		**Representative:**	
Location:		**Phone number:**	
Date submitted:	10/7/2022 6:46 AM	**e-mail:**	
Engineer:		**Submitted by:**	

Application design data

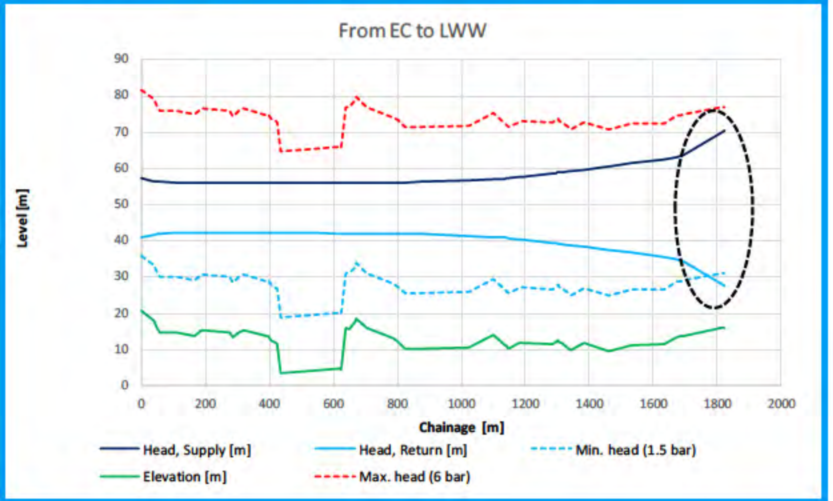
Tag number:	43649	Configuration:	Single
Service:		Suction pressure:	0 ft
Location:		Fluid:	Non-Potable
Qty:	1	Operating temperature:	16 °C
Total system flow:	238 L/s	Duty flow per pump:	238 L/s
System head:	600 kPa	Viscosity:	31 SSU
Environment:	Indoors	Specific gravity:	1.0000
Total dissolved solids:	0 ppm	Safety factor % flow:	0 %
Efficiency at Design:	83.34 %	Safety factor % head:	0 %
NPSHR:	13.83 kPa	Absorbed Power/BHP:	171.17 kW
Min. maintained system pressure*:	240 kPa	Impeller diameter:	394 mm



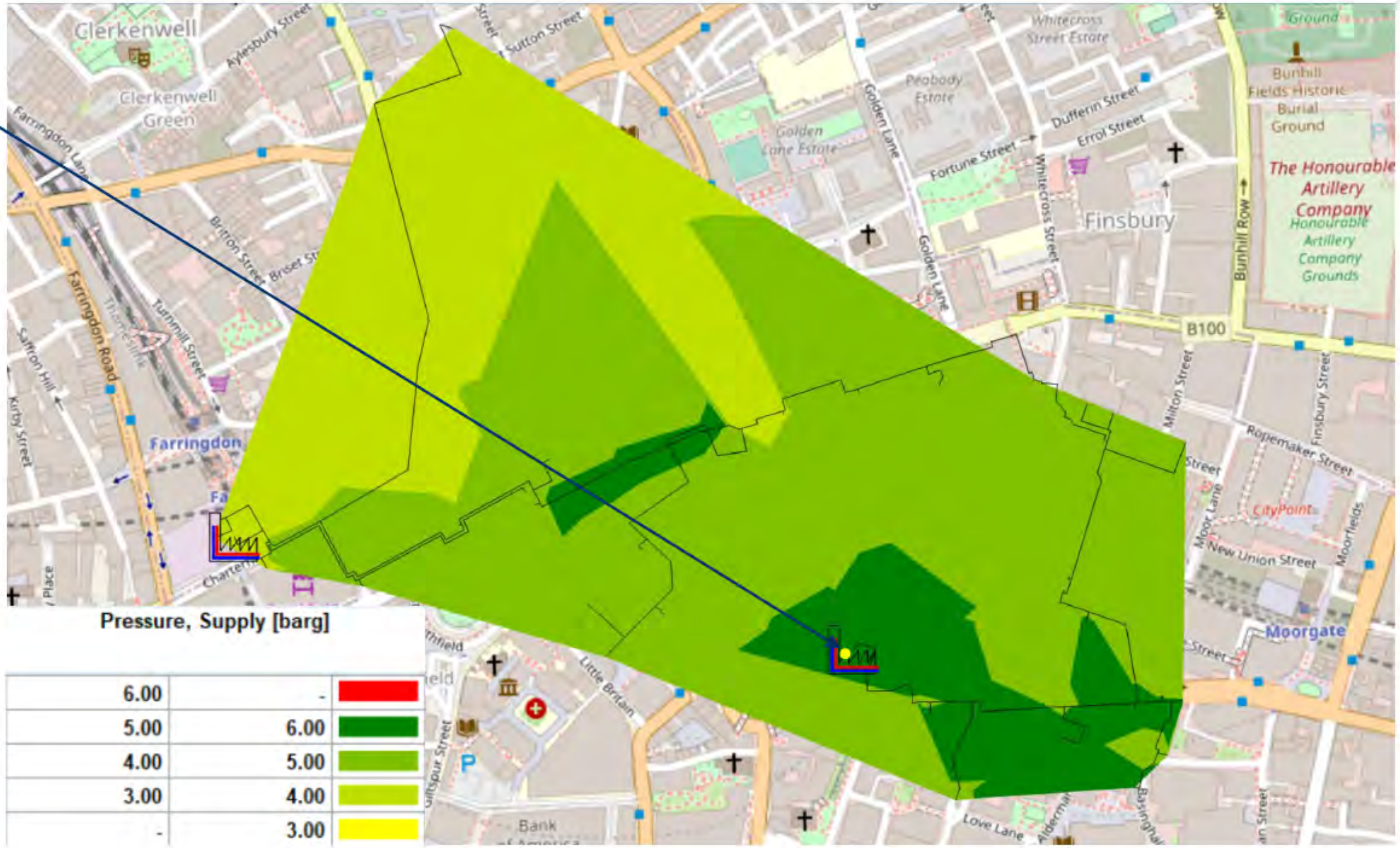
Results:

- Highest supply pressure: 5.4 barg at LWW

High pressure loss in DN200 from LWW (512 Pa/m; 3.3 m/s) impacts the pressure profile of the network



Scenario 2A-DCN – Supply Pressure

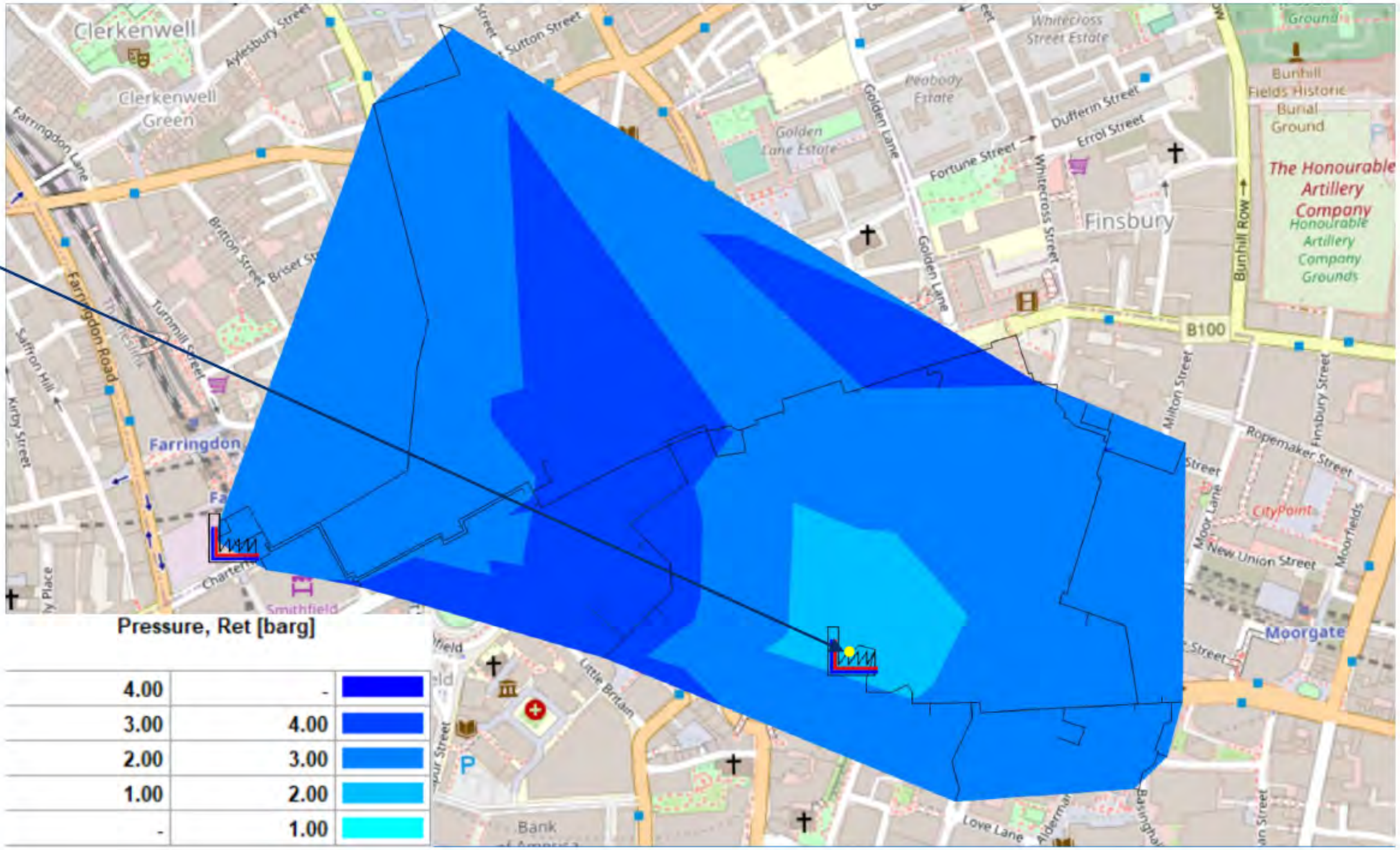


Results:

- Lowest return pressure: 1.2 barg at LWW

The minimum acceptable pressure as communicated by EON is 1.5 barg

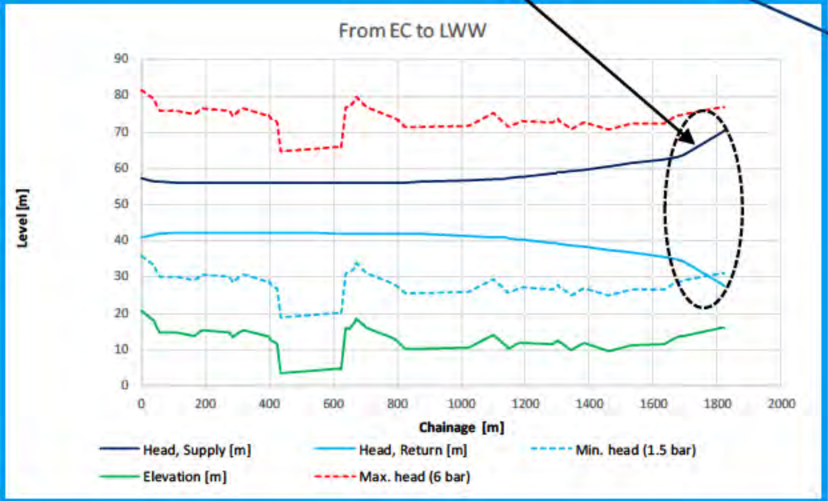
Scenario 2A-DCN – Return Pressure

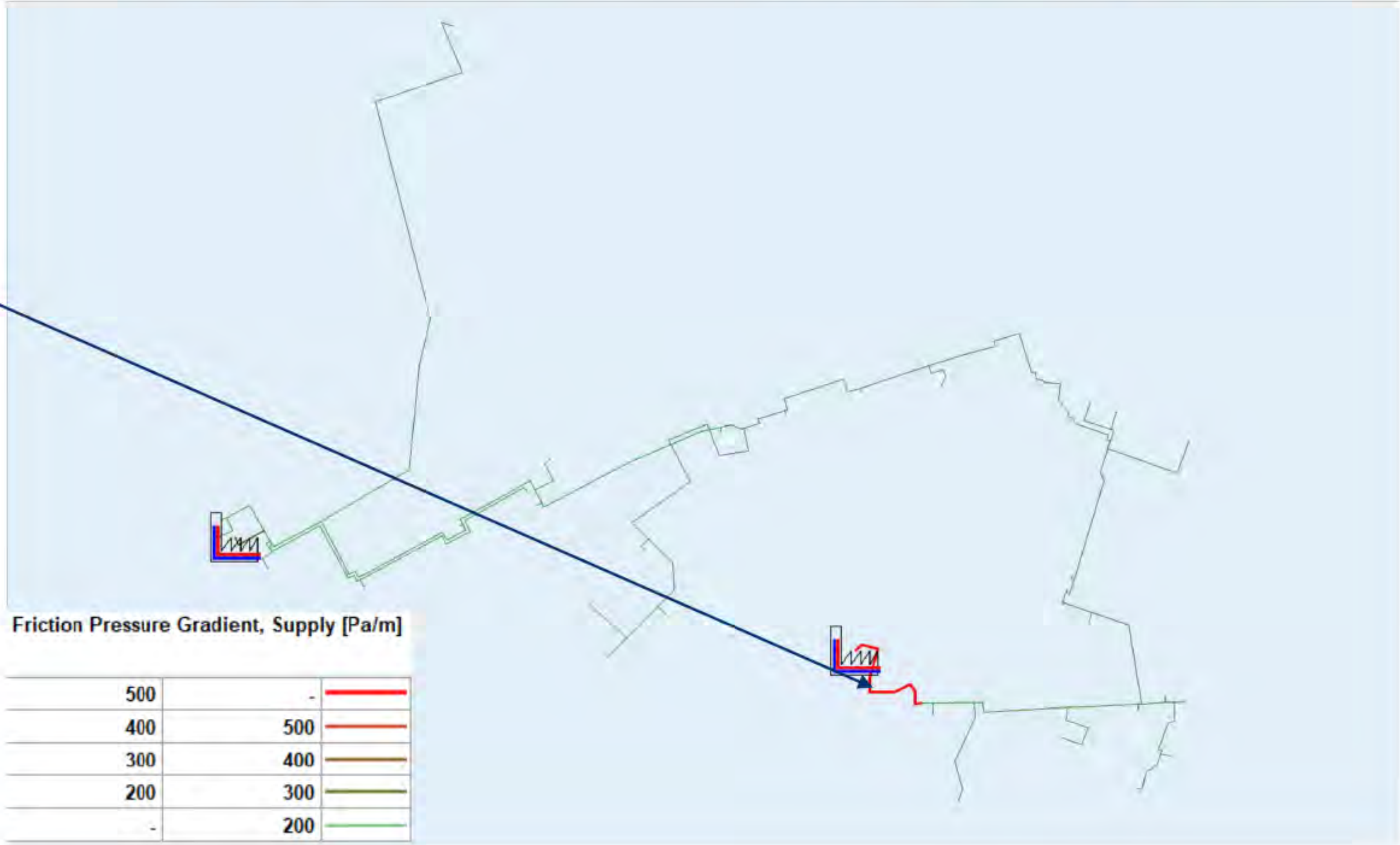


Scenario 2A-DCN – Pressure Drop Gradient

Results:

- The highest pressure drop gradient is at the DN200 from LWW (**512 Pa/m;** 3.3 m/s)

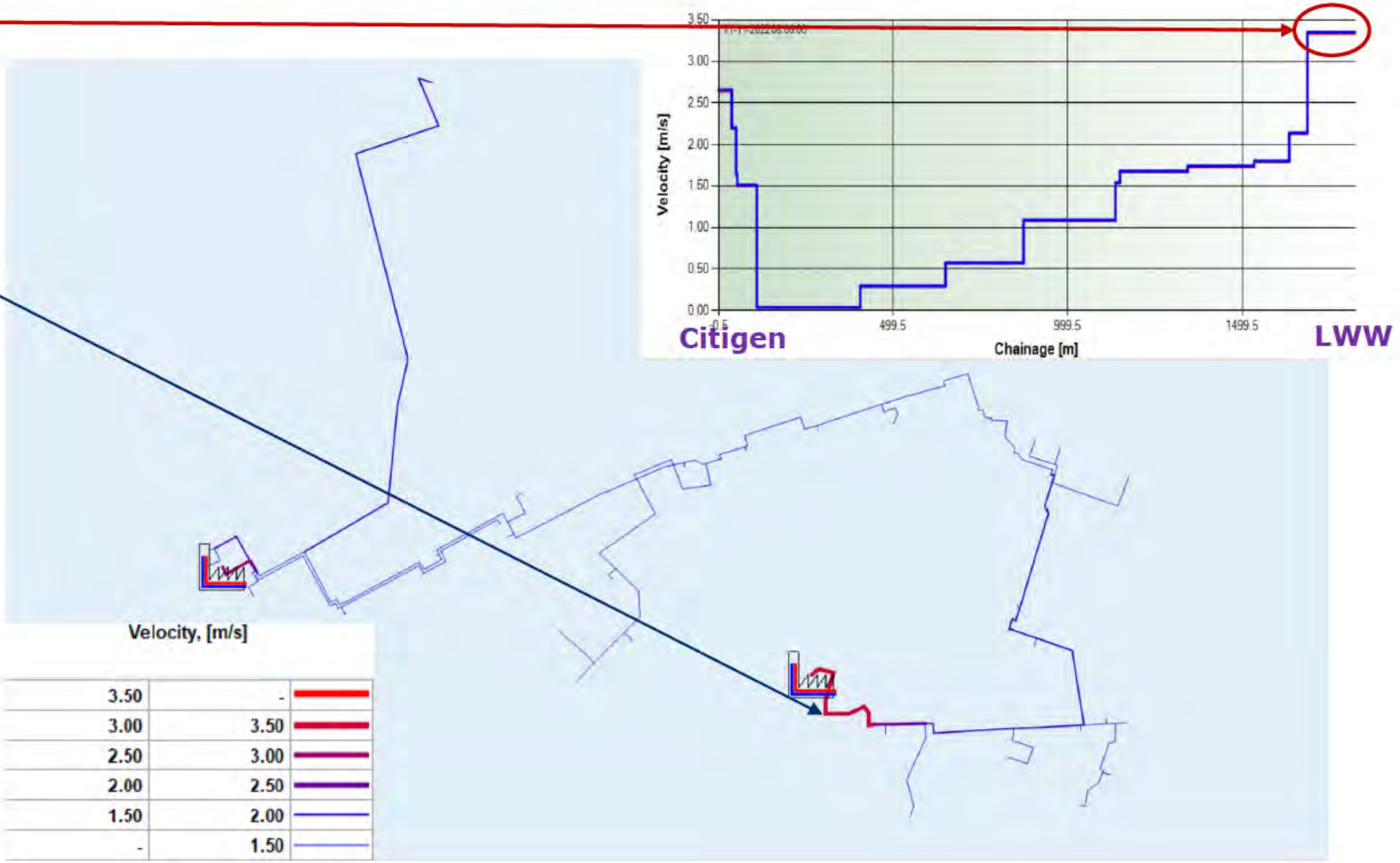




Results:

- The highest velocity is at the DN200 from LWW (3.3 m/s)

Scenario 2A-DCN – Velocity



Scenario 2A-DCN - Summary

Producing 3.5 MW-c from LWW impacts the existing DN200 to LWW.

This results in supply and return pressures at LWW at the limits of 1.5 barg (min) and 6 barg (max)

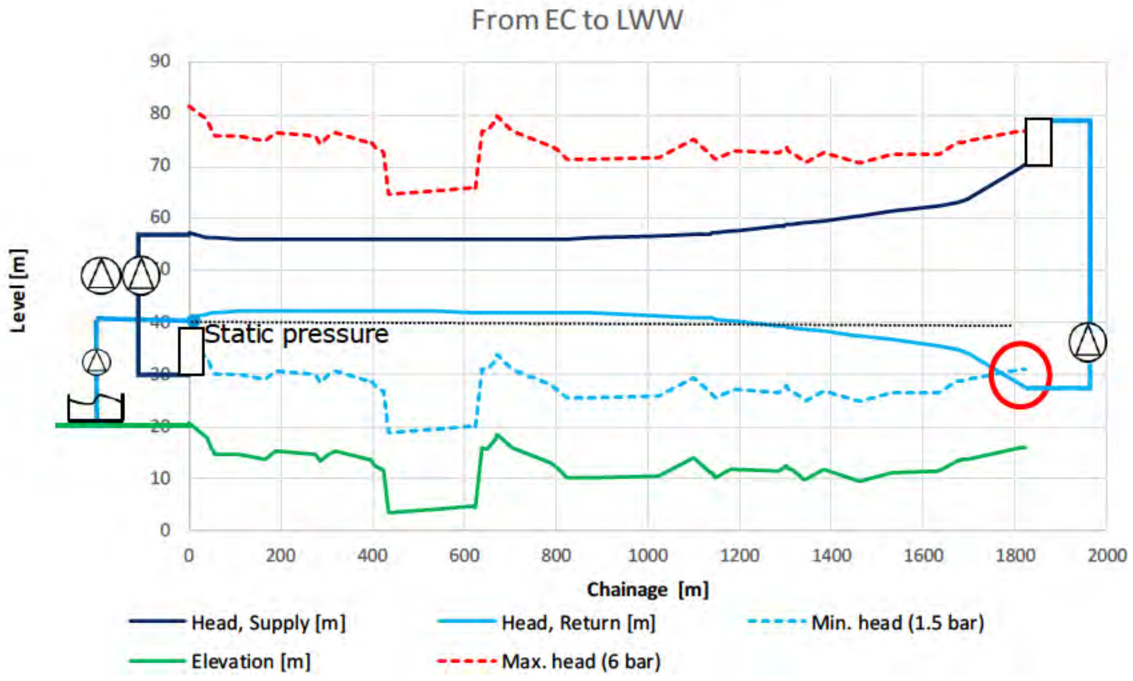
The DN200 has a quite high pressure gradient (512 Pa/m) and velocity (3.3 m/s).

It is recommended to:

- reduce the LWW output (~2.4 MW)

or

- upgrade the existing DN200 at LWW (150 m of trench-length)

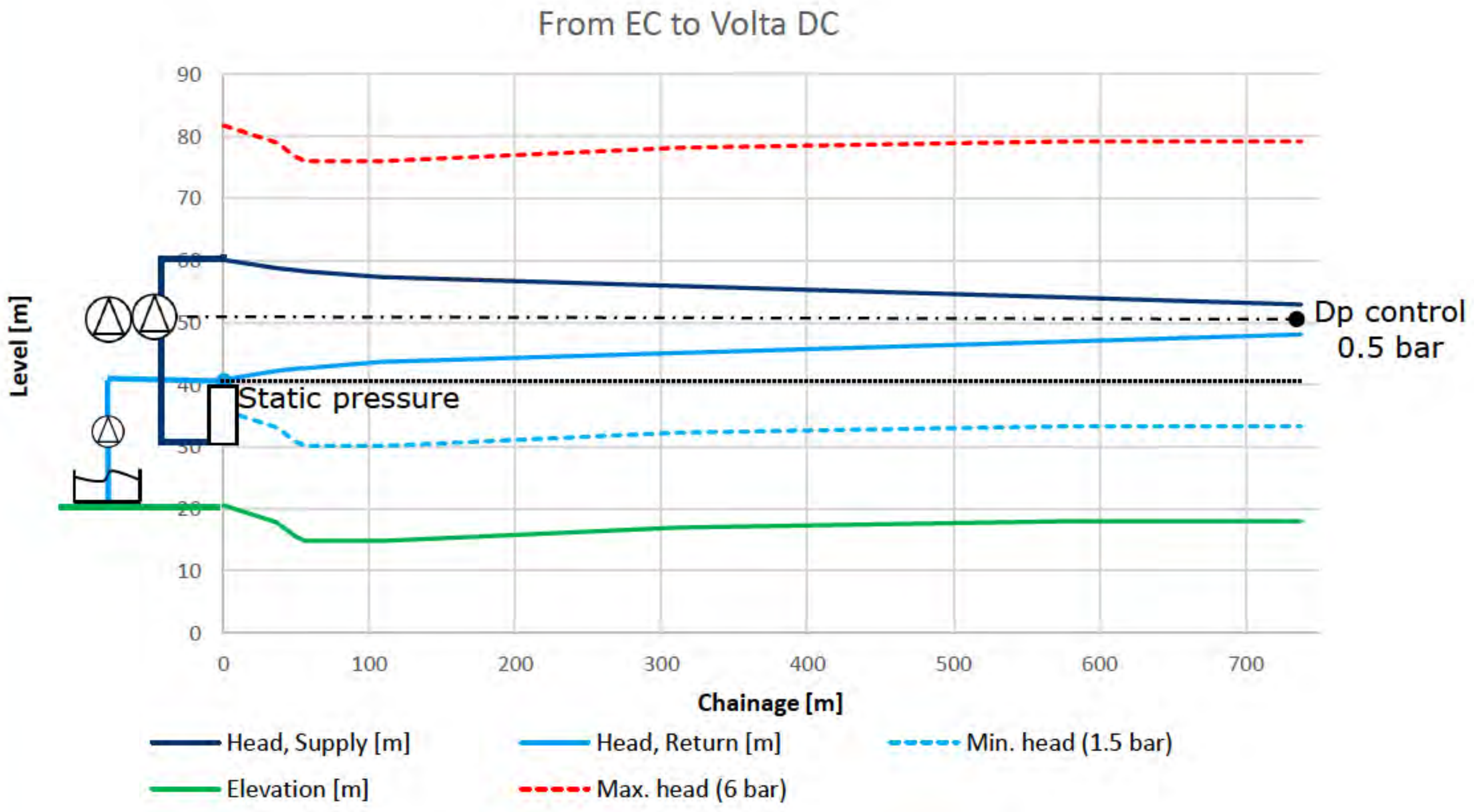


Scenario 2B-DCN
1.2 MW-c production at LWW

(Common Volta Connection)

- Assumed pressure drop within EC: 1.5 bar

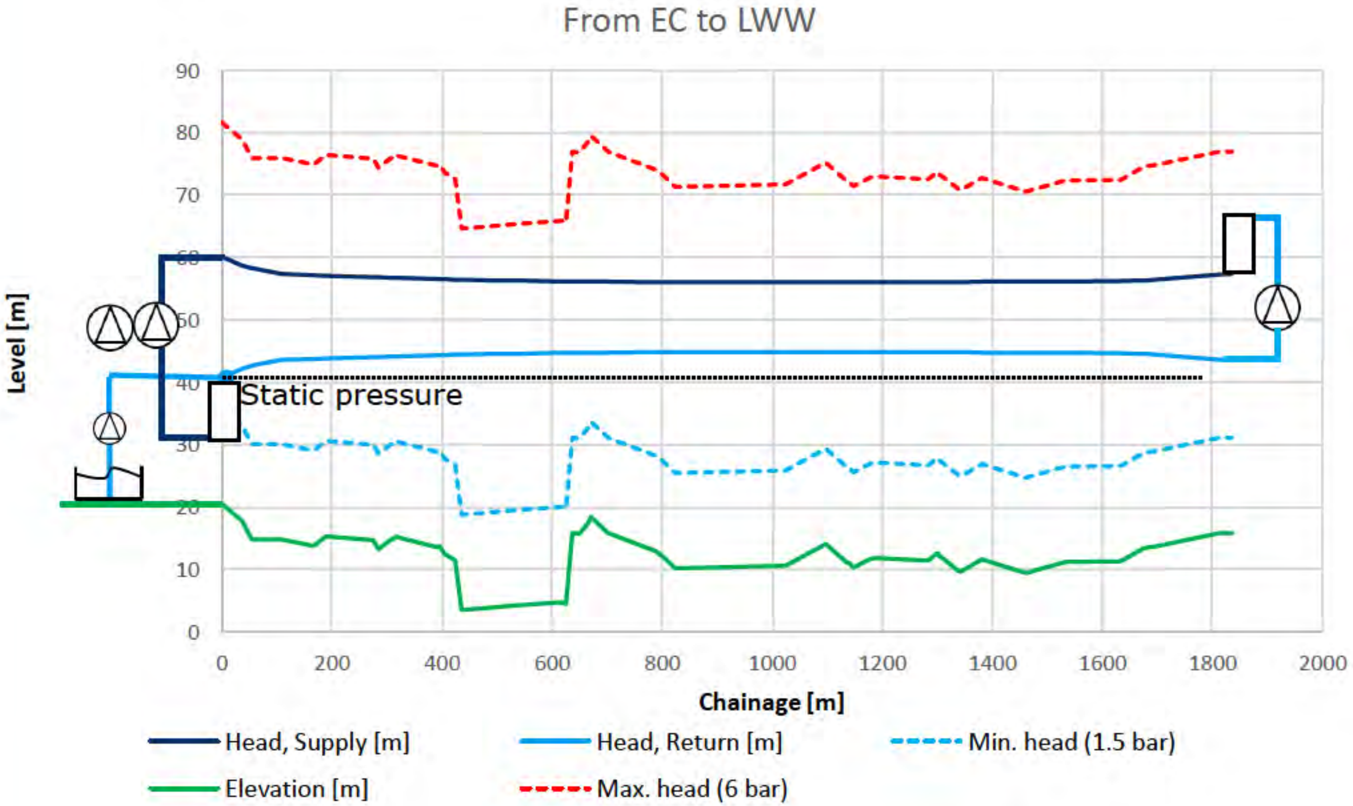
Scenario 2B-DCN – Head Profile: Citigen EC to Volta DC (critical node)



Scenario 2B-DCN – Head Profile: Citigen EC to LWW

- Assumed pressure drop within EC: 1.5 bar
- DP control at Volta DC

Note:
LWW pumps are placed upstream the chillers.
The conceptual layout of LWW will impact the internal pressures at LWW



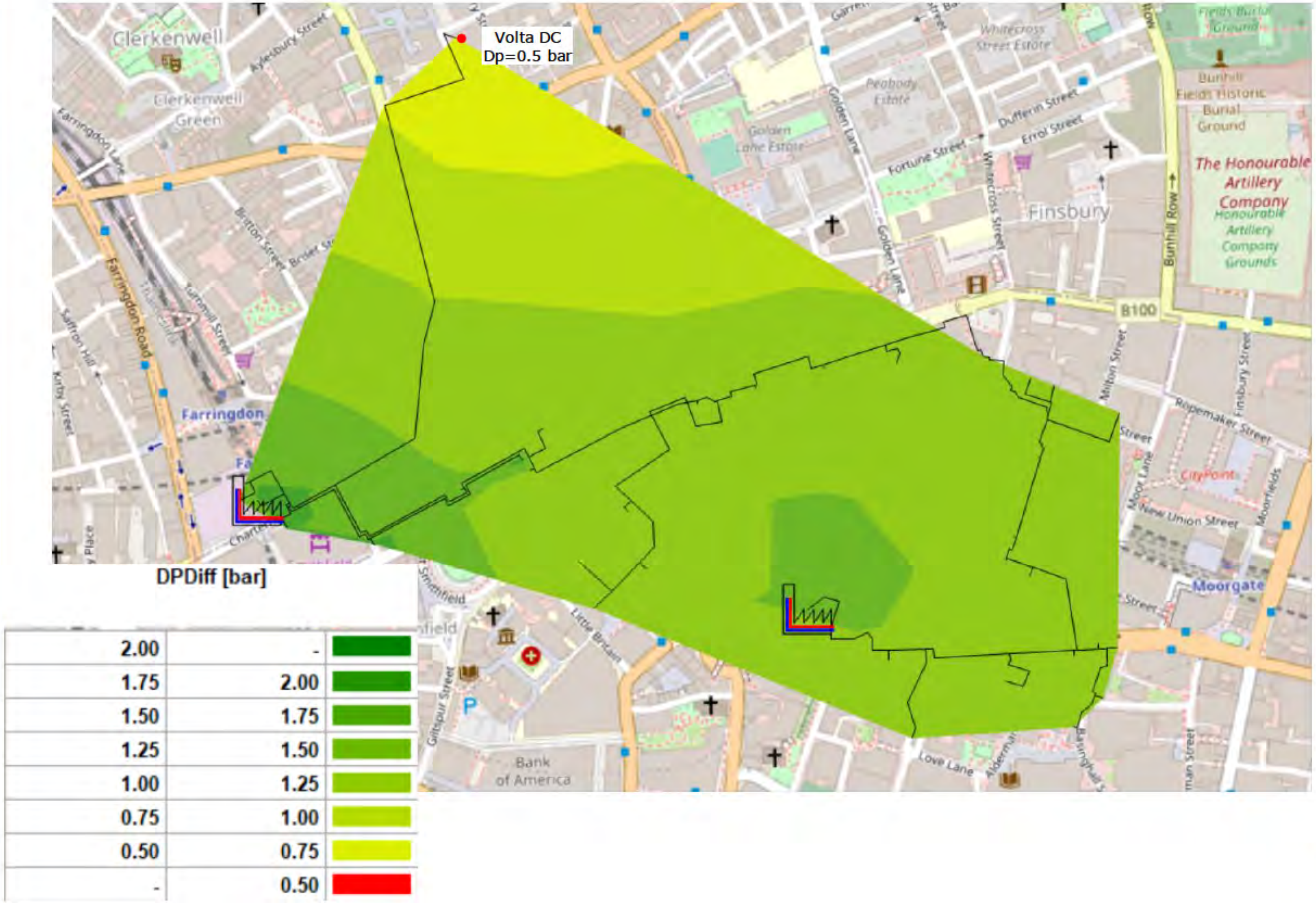
Scenario 2B-DCN – Pressure Difference

Results:

- Critical node (control node) is Volta DC (0.5 bar)

PRODUCTION		Citigen EC	LWW
Power	[kW]	**10,778**	**1,200**
Flow	[kg/s]	282	41
Temp. Supply	[°C]	6	6
Temp. Return	[°C]	15	13
Press. Supply	[barg]	3.9	4.1
Press. Return	[barg]	2.0	2.7
Press. Diff.	[bar]	1.9	1.4

NETWORK		
Highest pressure	[barg]	5.3
Lowest pressure	[barg]	2.0
Lowest press. diff.	[bar]	0.5
Highest velocity	[m/s]	3.6
Highest press. gradient	[Pa/m]	371



Scenario 2B-DCN - Pumping Capacity

PRODUCTION		Citigen EC	LWW
Power	[kW]	10,778	1,200
Flow	**[kg/s]**	**282**	**41**
Temp. Supply	[°C]	6	6
Temp. Return	[°C]	15	13
Press. Supply	[barg]	3.9	4.1
Press. Return	[barg]	2.0	2.7
Press. Diff. (DCN only)	[bar]	1.9	1.4
Press. Diff. (EC+DCN)	**[bar]**	**3.4***	**2.9***

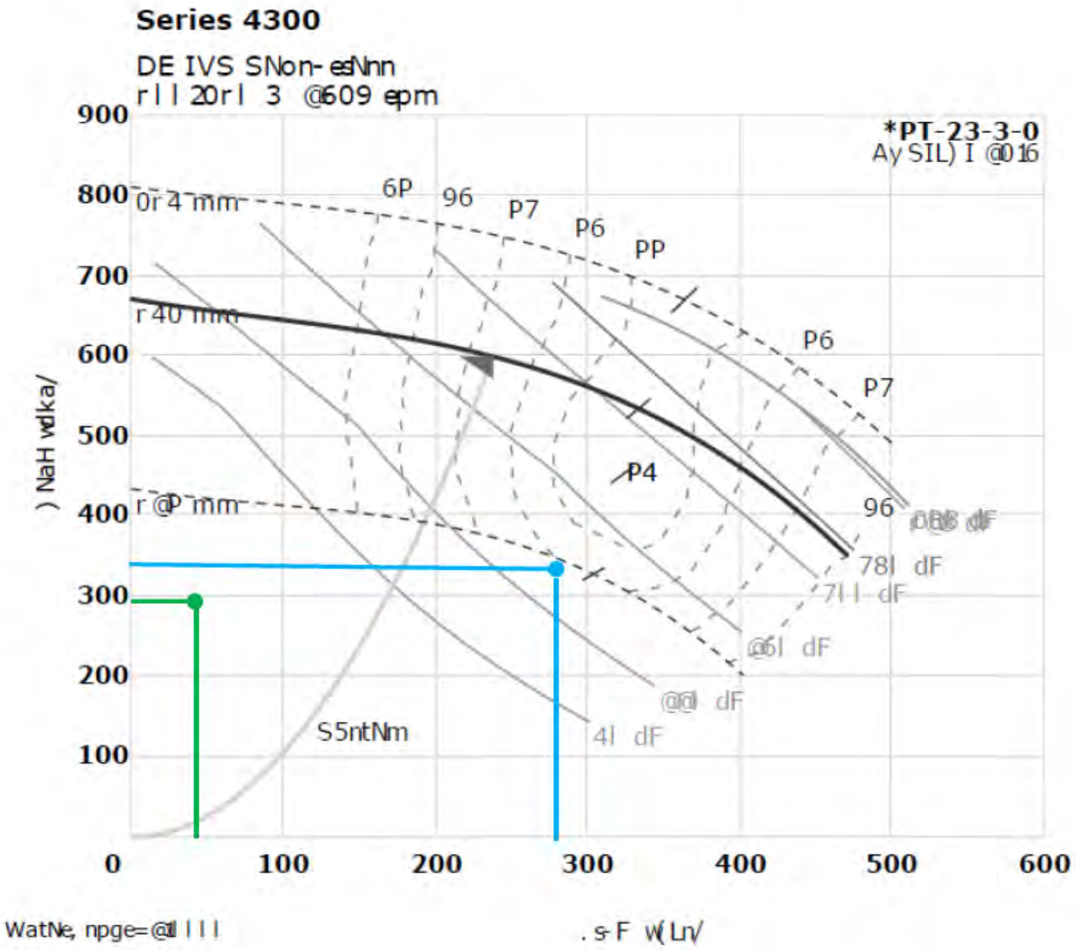
* 1.5 bar pressure drop is assumed inside the EC (production, valves, etc.)

Model: Series Design Envelope Sensorless 4300 3043-250.0

Project name:		**Representative:**	
Location:		**Phone number:**	
Date submitted:	10/7/2022 6:46 AM	**e-mail:**	
Engineer:		**Submitted by:**	

Application design data

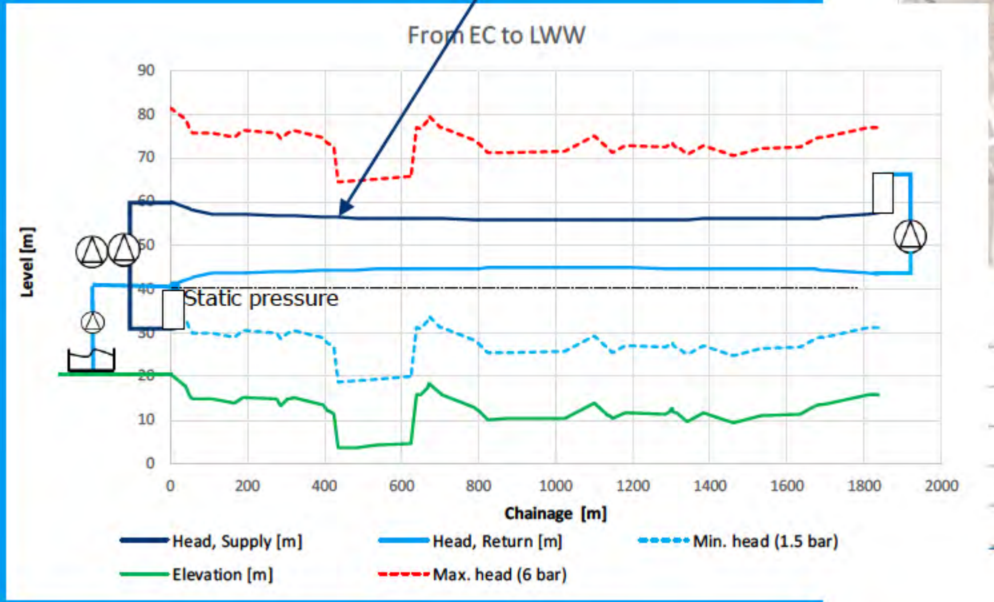
Tag number:	43649	Configuration:	Single
Service:		Suction pressure:	0 ft
Location:		Fluid:	Non-Potable
Qty:	1	Operating temperature:	16 °C
Total system flow:	238 L/s	Duty flow per pump:	238 L/s
System head:	600 kPa	Viscosity:	31 SSU
Environment:	Indoors	Specific gravity:	1.0000
Total dissolved solids:	0 ppm	Safety factor % flow:	0 %
Efficiency at Design:	83.34 %	Safety factor % head:	0 %
NPSHR:	13.83 kPa	Absorbed Power/BHP:	171.17 kW
Min. maintained system pressure*:	240 kPa	Impeller diameter:	394 mm

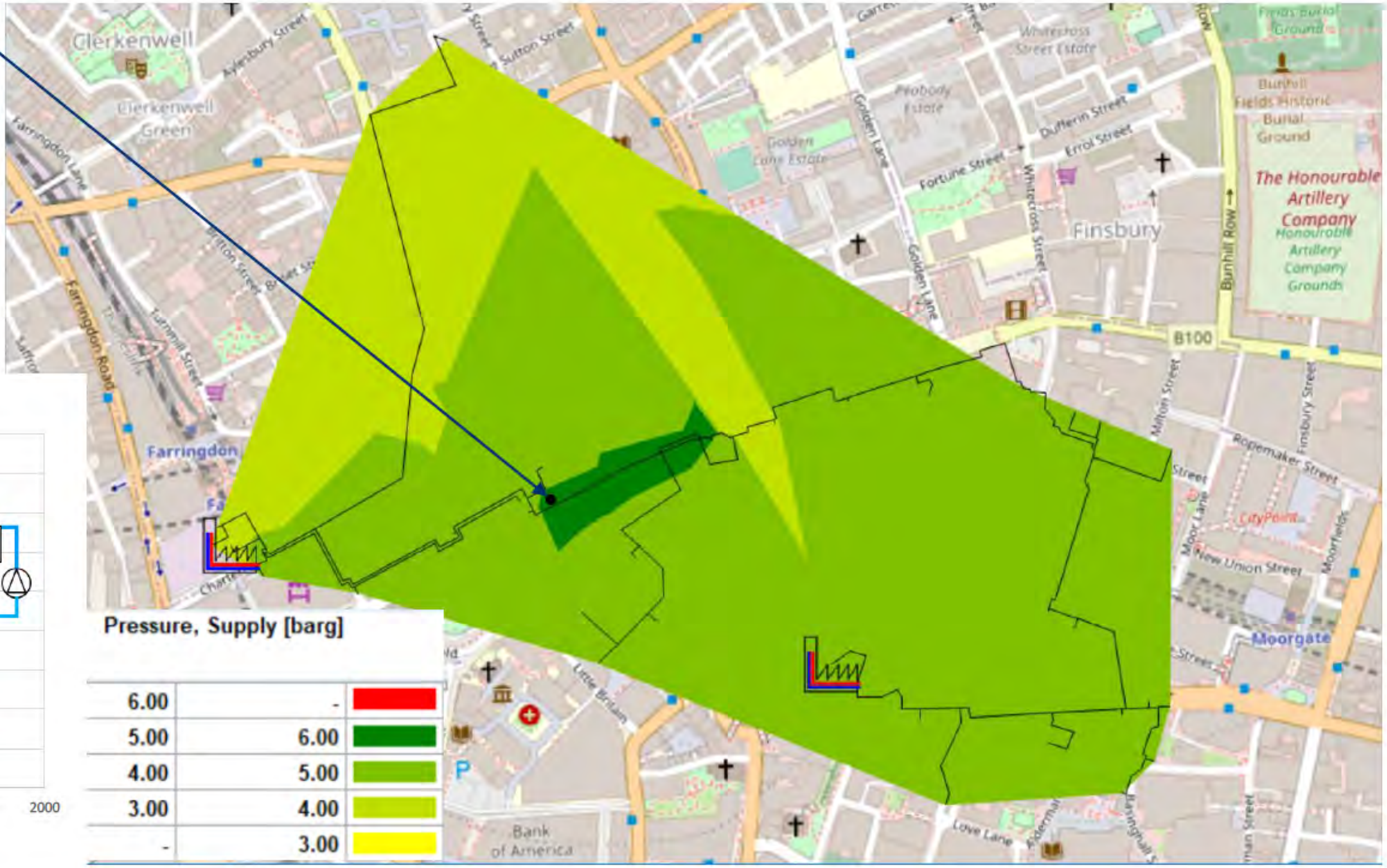


Scenario 2B-DCN – Supply Pressure

Results:

- Highest supply pressure: 5.3 barg (close to Smithfield Market East builiding), corresponding to a low elevation area

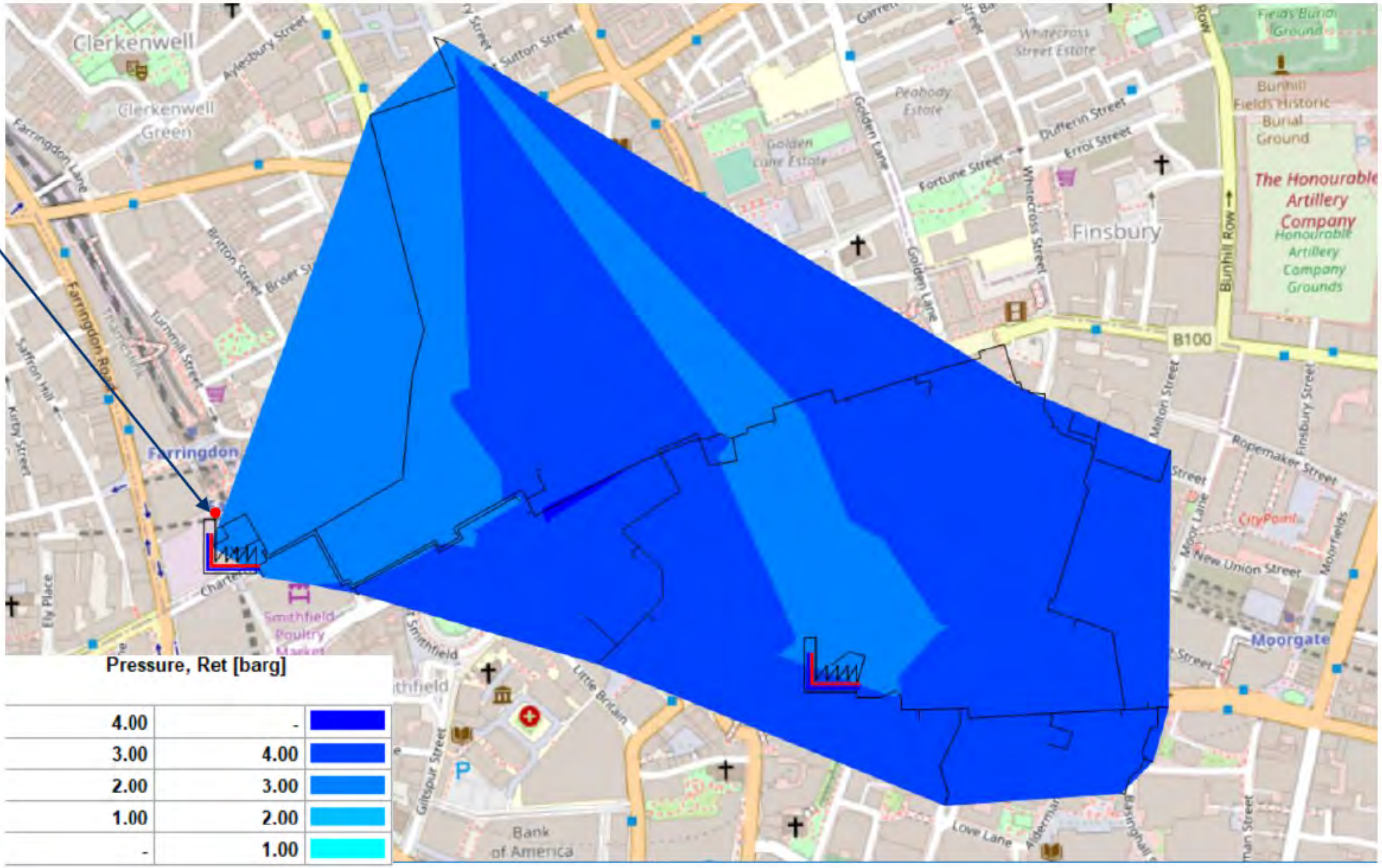




Results:

- Lowest return pressure outside the EC: 2.0 barg (Farringdon West Bloom and 33 Charterhouse)

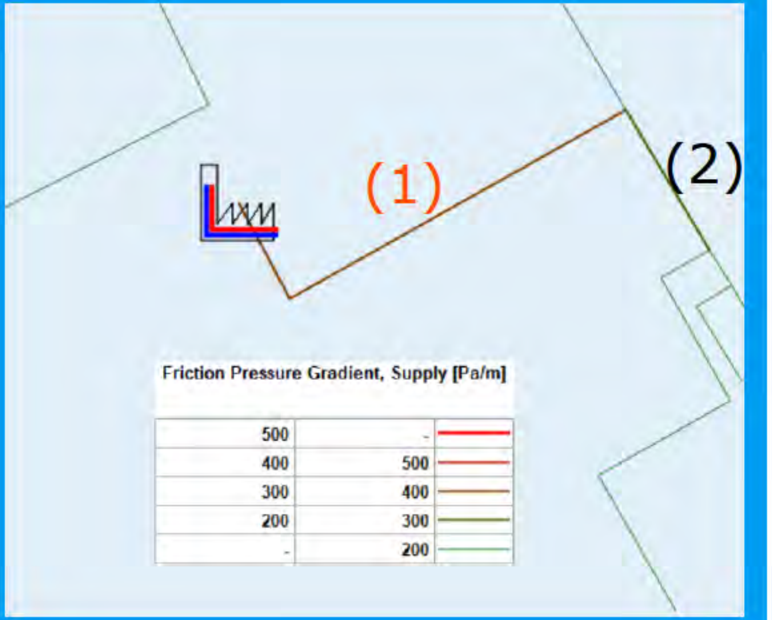
Scenario 2B-DCN – Return Pressure

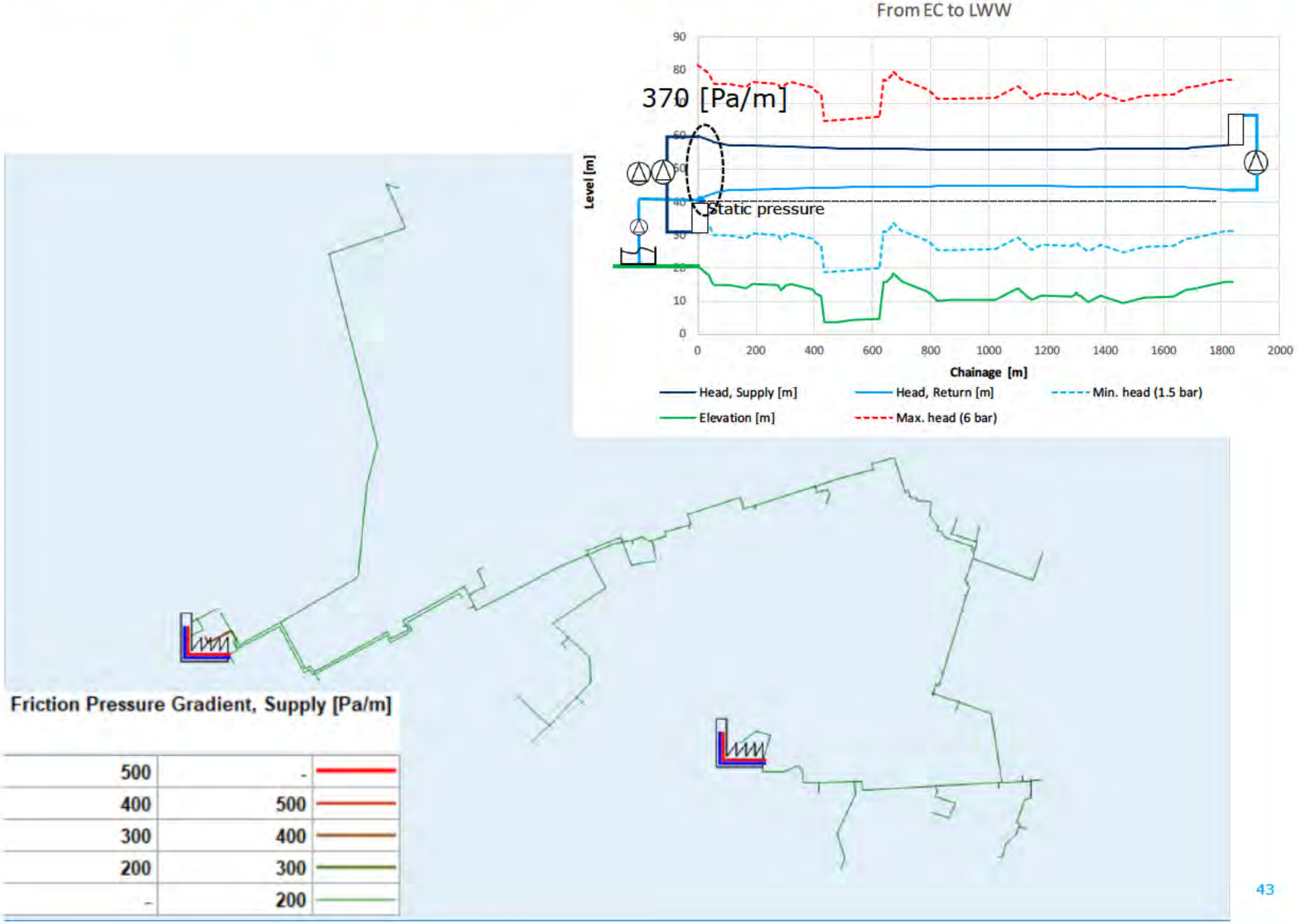


Scenario 2B-DCN – Pressure Drop Gradient

Results:

- The highest pressure gradient are:
  - at the DN300 internal to Citigen EC (**370 Pa/m; 3.6 m/s**) **(1)**
  - DN300 from Citigen to rest of DCN (286 Pa/m; 3.2 m/s) **(2)**

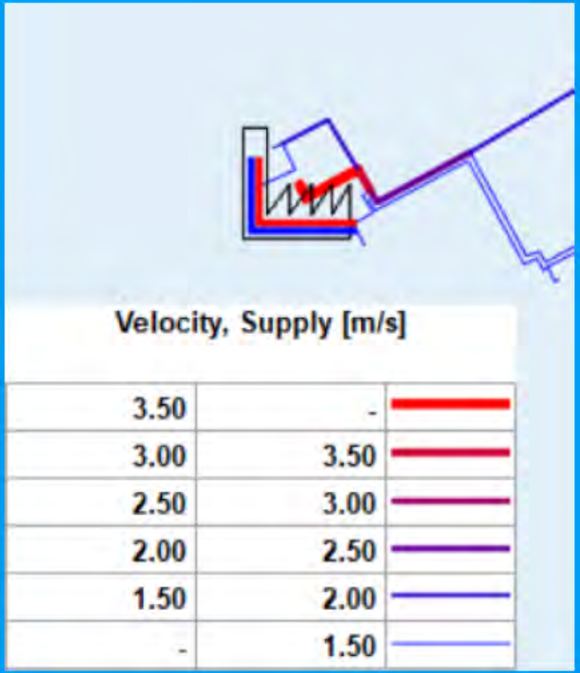




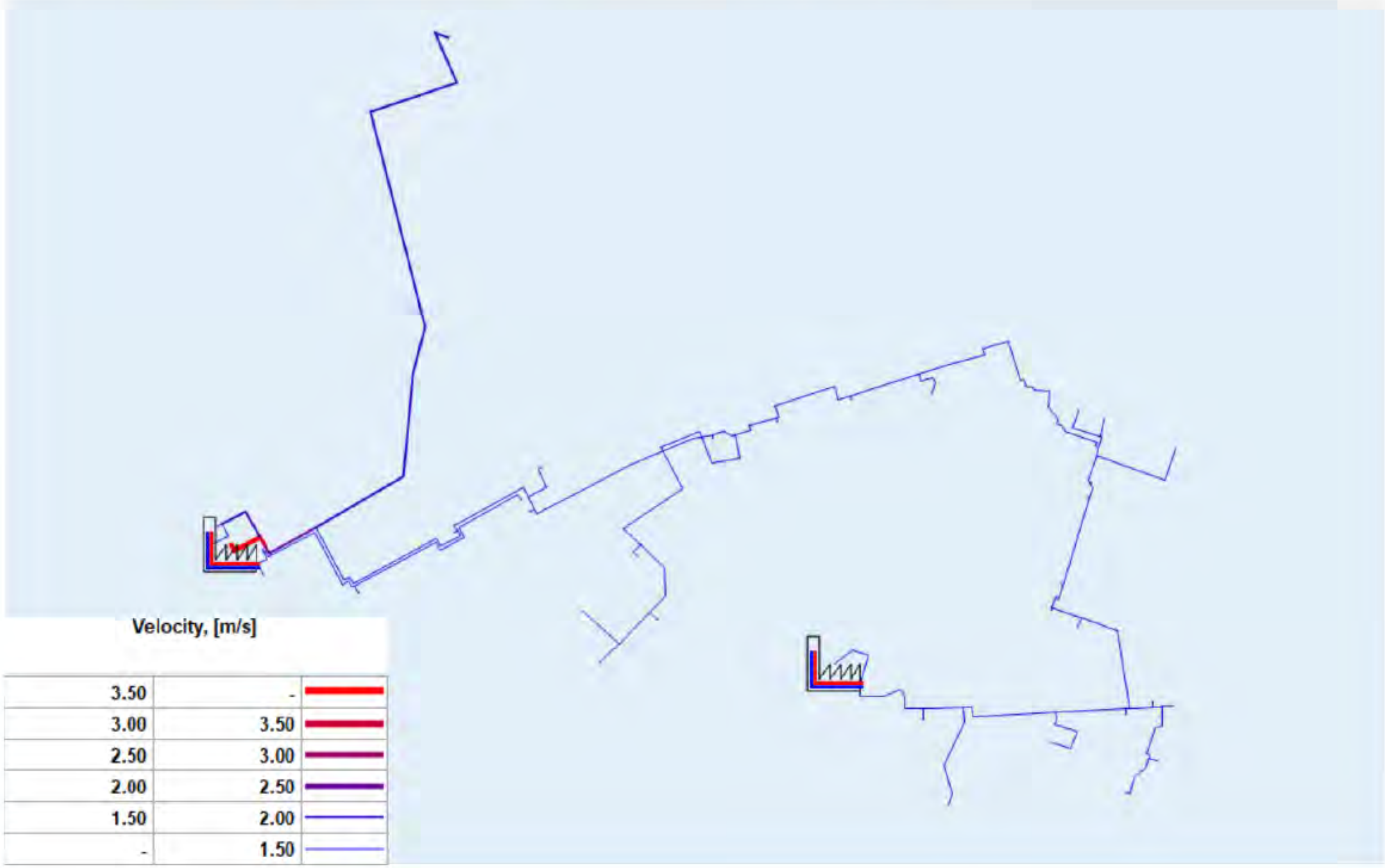
Scenario 2B-DCN – Velocity

Results:

- The highest velocity is at the DN300 internal to Citigen EC (3.6 m/s)



3.50	-	
3.00	3.50	
2.50	3.00	
2.00	2.50	
1.50	2.00	
-	1.50	

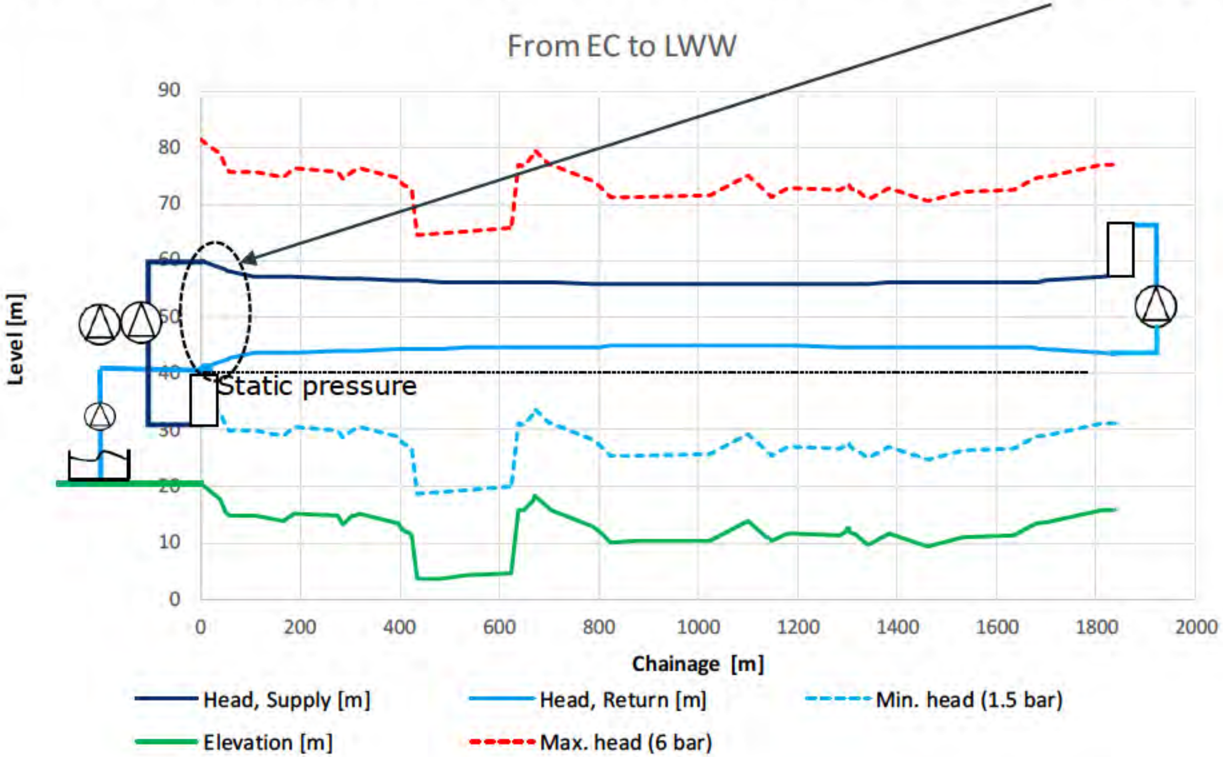


3.50	-	
3.00	3.50	
2.50	3.00	
2.00	2.50	
1.50	2.00	
-	1.50	

Scenario 2B-DCN - Summary

No major criticalities are observed in this scenario

The DN300 inside Citigen EC has a relatively high pressure gradient (370 Pa/m), velocity (3.6 m/s).

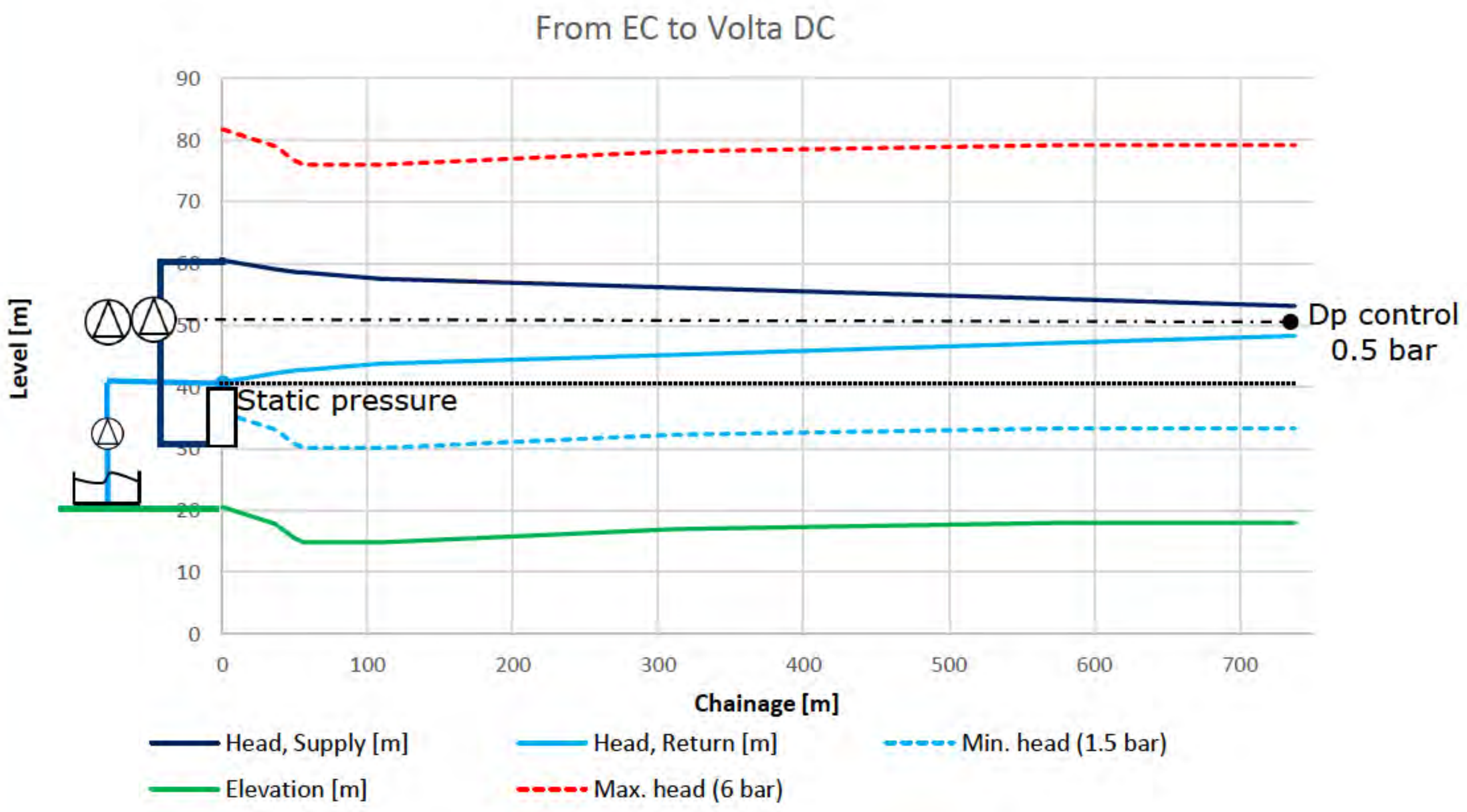


Scenario 3A-DCN
1.0 MW-c production at Guildhall

(Common Volta Connection)

- Assumed pressure drop within EC: 1.5 bar

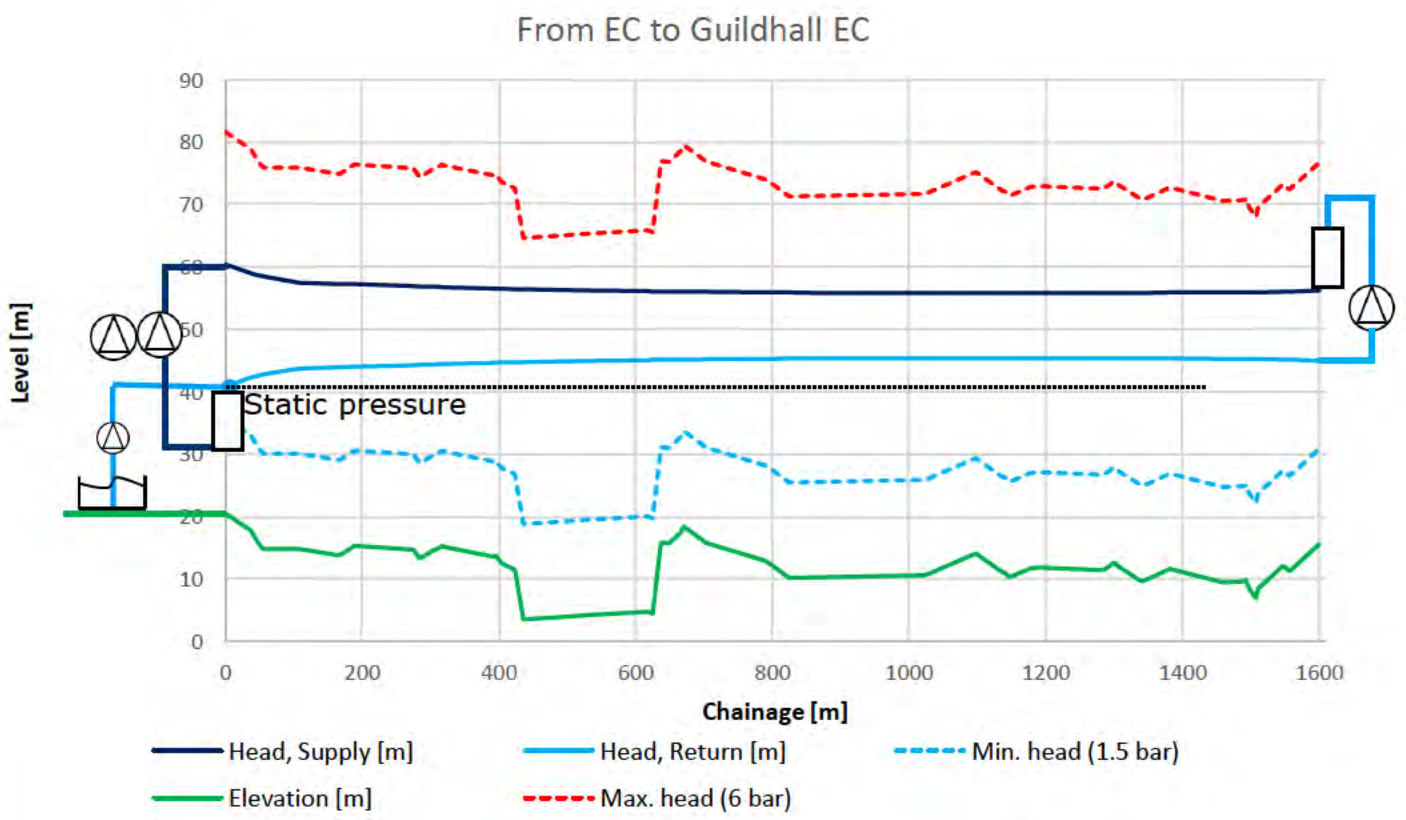
Scenario 3A-DCN – Head Profile: Citigen EC to Volta DC (critical node)



- Assumed pressure drop within EC: 1.5 bar
- DP control at Volta DC

Note:
Guildhall pumps are placed upstream the chillers.
The conceptual layout of Guildhall will impact the internal pressures

Scenario 3A-DCN – Head Profile: Citigen EC to Guildhall EC



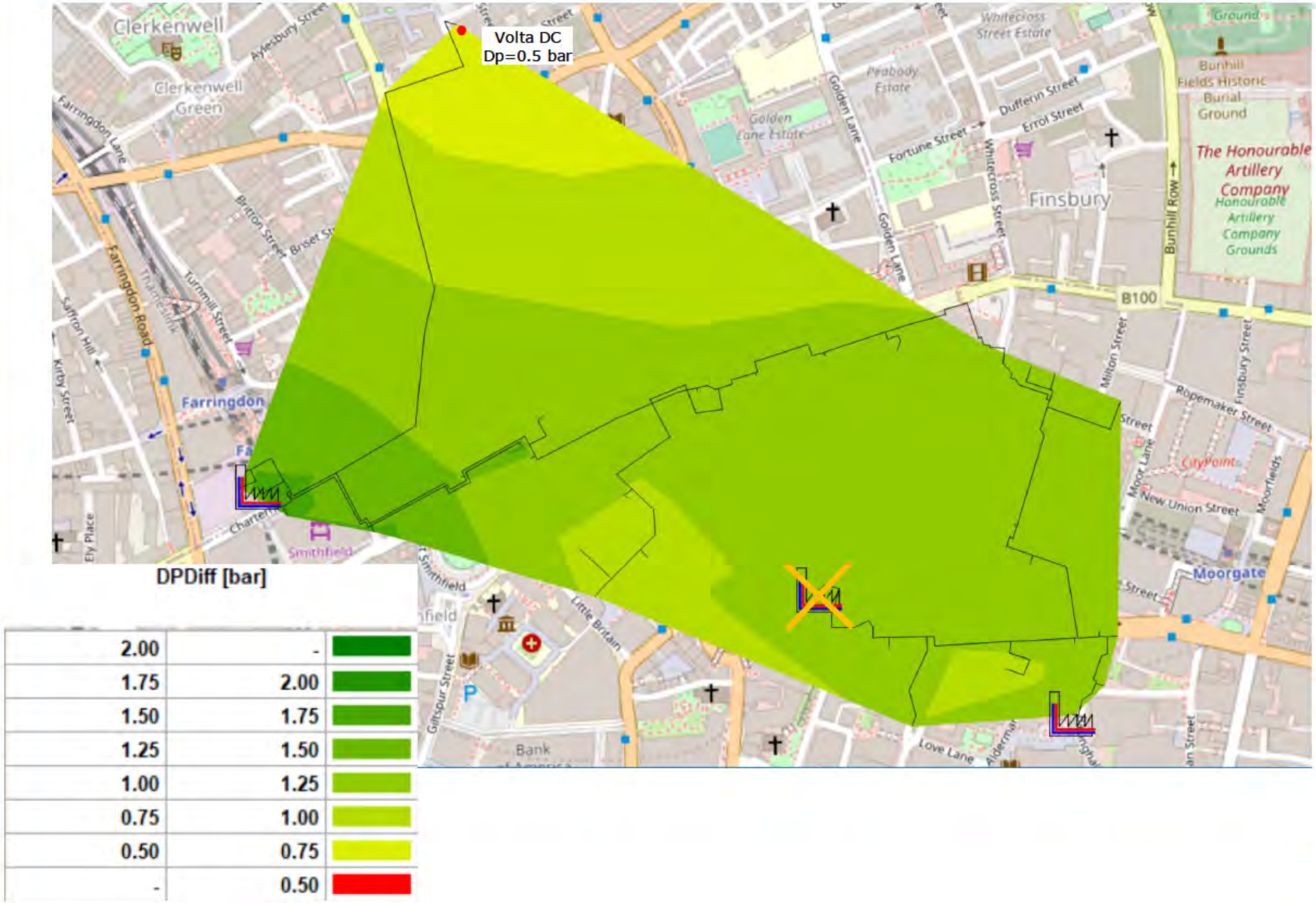
Scenario 3A-DCN – Pressure Difference

Results:

- Critical node (control node) is Volta DC (0.5 bar)

PRODUCTION		Citigen EC	Guildhall
Power	[kW]	**10,978**	**1,000**
Flow	[kg/s]	289	34
Temp. Supply	[°C]	6	6
Temp. Return	[°C]	15	13
Press. Supply	[barg]	4.0	4.0
Press. Return	[barg]	2.0	2.9
Press. Diff.	[bar]	2.0	1.1

NETWORK		
Highest pressure	[barg]	5.3
Lowest pressure	[barg]	2.0
Lowest press. diff.	[bar]	0.5
Highest velocity	[m/s]	3.7
Highest press. gradient	[Pa/m]	389



Scenario 3A-DCN - Pumping Capacity

PRODUCTION		Citigen EC	LWW
Power	[kW]	10,978	1,000
Flow	**[kg/s]**	**289**	**34**
Temp. Supply	[°C]	6	6
Temp. Return	[°C]	15	13
Press. Supply	[barg]	4.0	4.0
Press. Return	[barg]	2.0	2.9
Press. Diff. (DCN only)	[bar]	2.0	1.1
Press. Diff. (EC+DCN)	**[bar]**	**3.5***	**2.6***

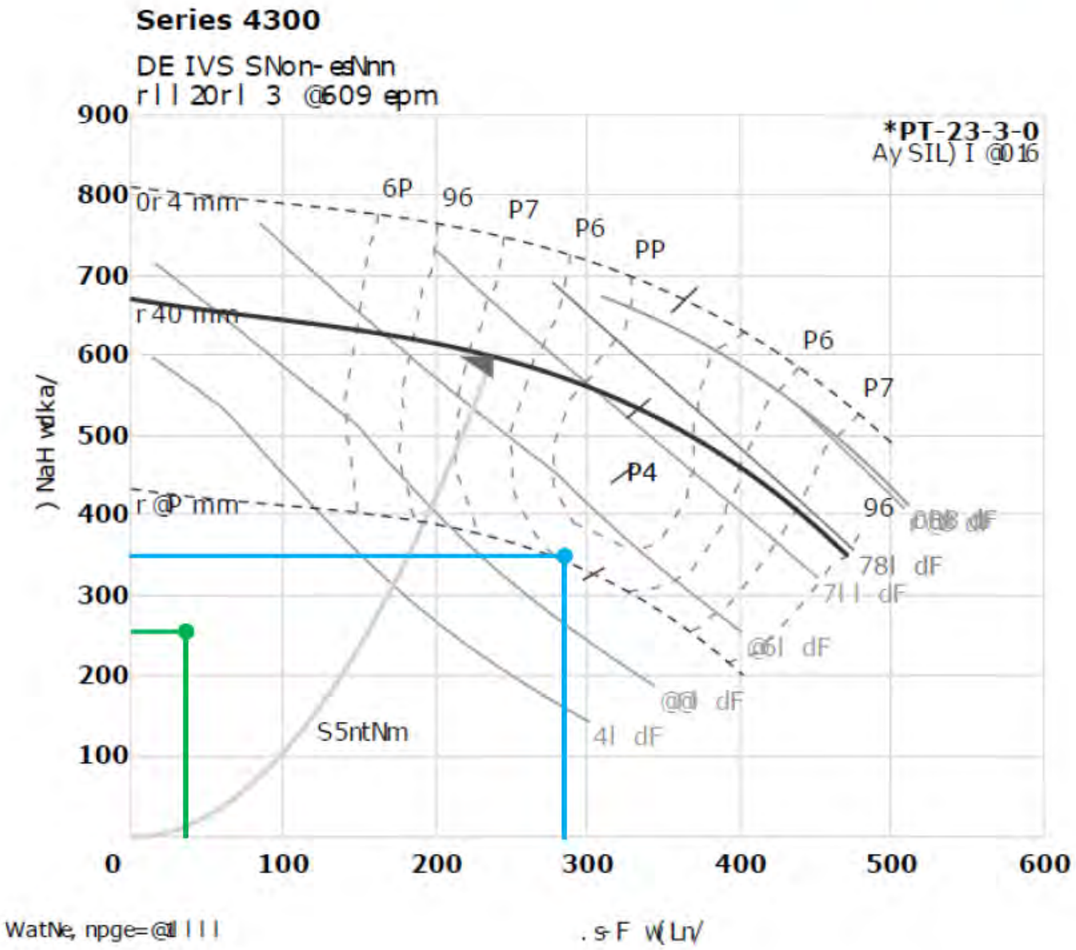
* 1.5 bar pressure drop is assumed inside the EC (production, valves, etc.)

Model: Series Design Envelope Sensorless 4300 3043-250.0

Project name:		**Representative:**	
Location:		**Phone number:**	
Date submitted:	10/7/2022 6:46 AM	**e-mail:**	
Engineer:		**Submitted by:**	

Application design data

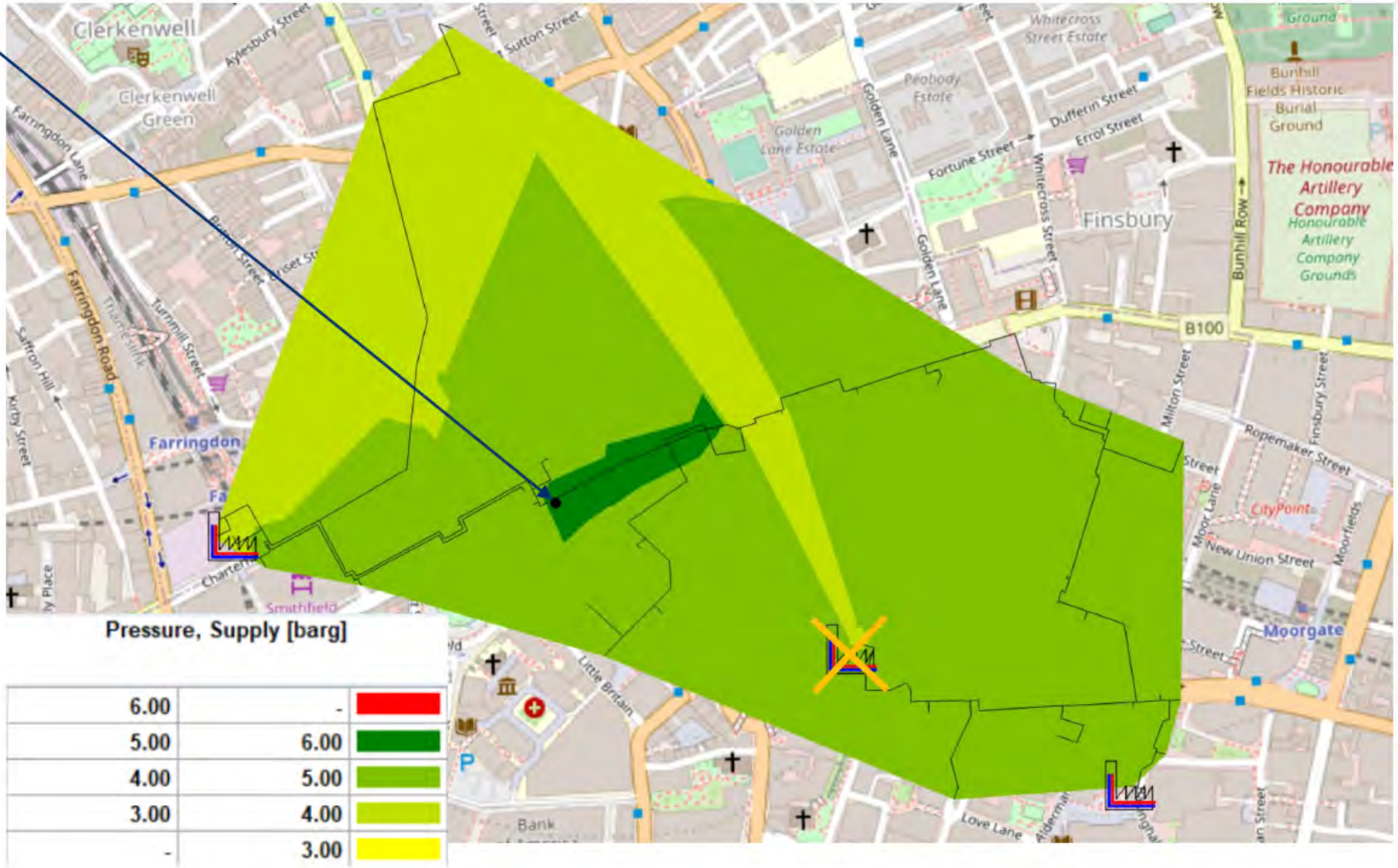
Tag number:	43649	Configuration:	Single
Service:		Suction pressure:	0 ft
Location:		Fluid:	Non-Potable
Qty:	1	Operating temperature:	16 °C
Total system flow:	238 L/s	Duty flow per pump:	238 L/s
System head:	600 kPa	Viscosity:	31 SSU
Environment:	Indoors	Specific gravity:	1.0000
Total dissolved solids:	0 ppm	Safety factor % flow:	0 %
Efficiency at Design:	83.34 %	Safety factor % head:	0 %
NPSHR:	13.83 kPa	Absorbed Power/BHP:	171.17 kW
Min. maintained system pressure*:	240 kPa	Impeller diameter:	394 mm



Results:

- Highest supply pressure: 5.3 barg (close to Smithfield Market East builiding), corresponding to a low elevation area

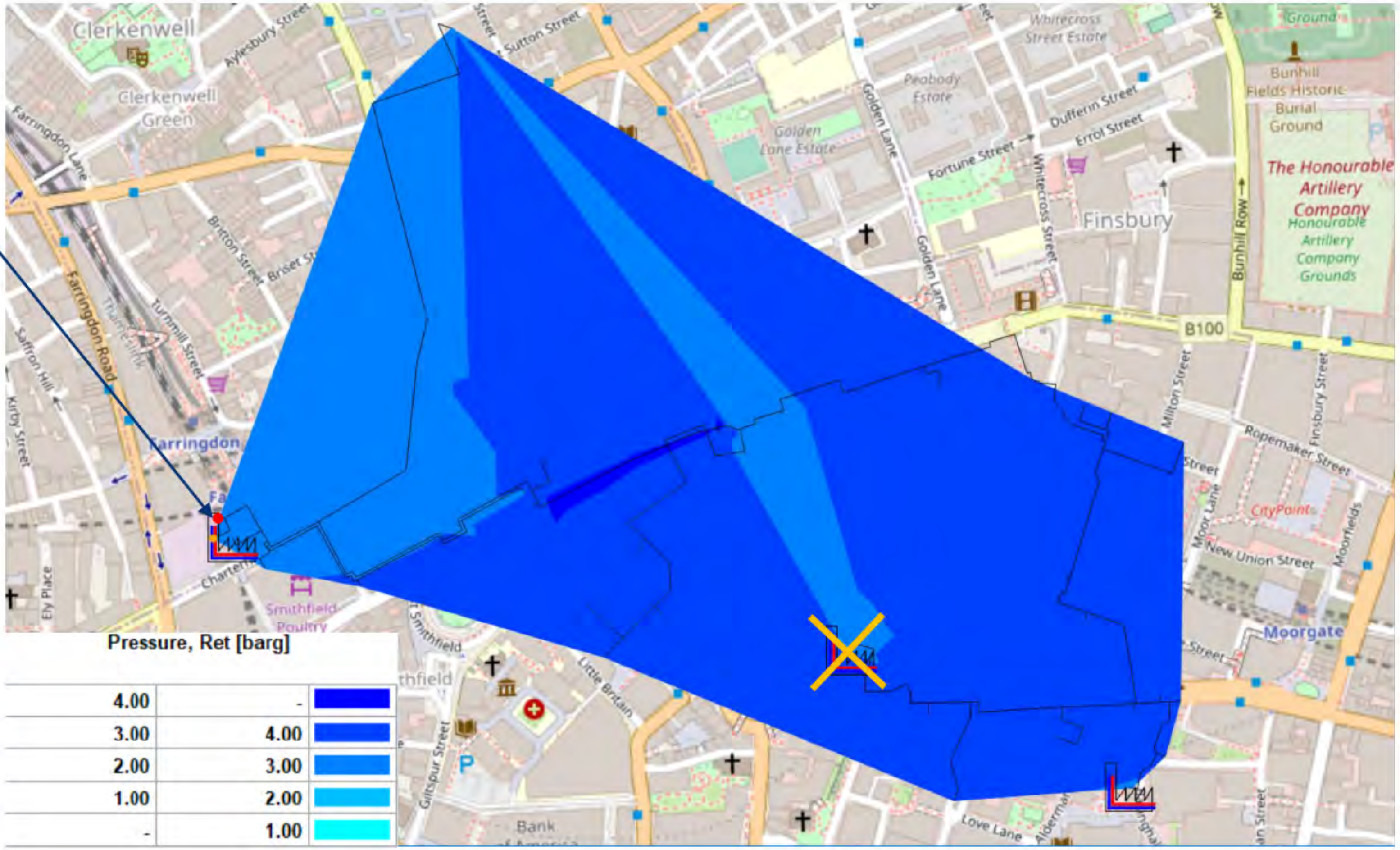
Scenario 3A-DCN – Supply Pressure



Results:

- Lowest return pressure outside the EC: 2.0 barg (Farringdon West Bloom and 33 Charterhouse)

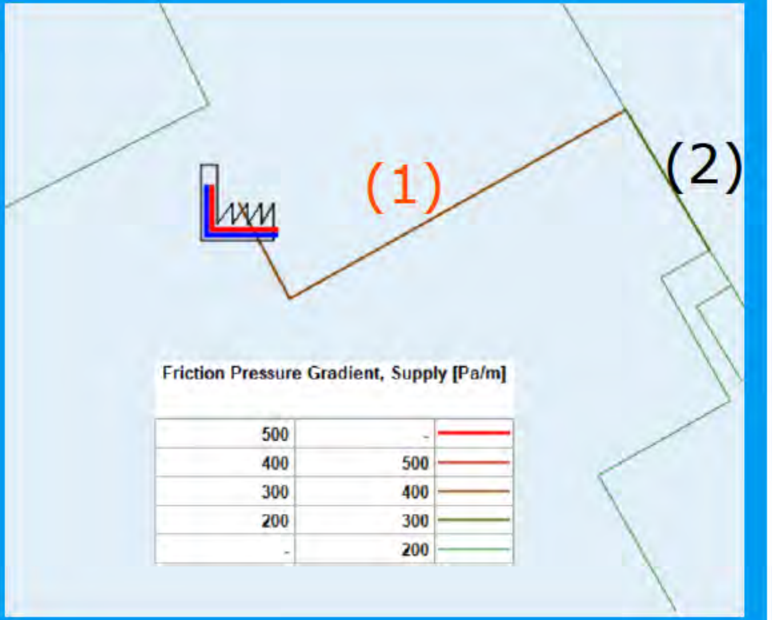
Scenario 3A-DCN – Return Pressure



Scenario 3A-DCN – Pressure Drop Gradient

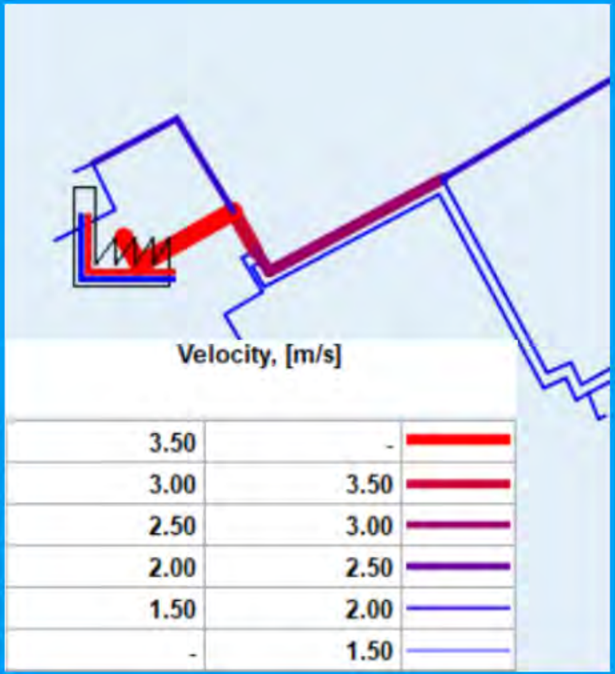
Results:

- The highest pressure gradient are:
  - at the DN300 internal to Citigen (**389 Pa/m; 3.7 m/s**) **(1)**
  - DN300 from Citigen to rest of DCN (301 Pa/m; 3.3 m/s) **(2)**

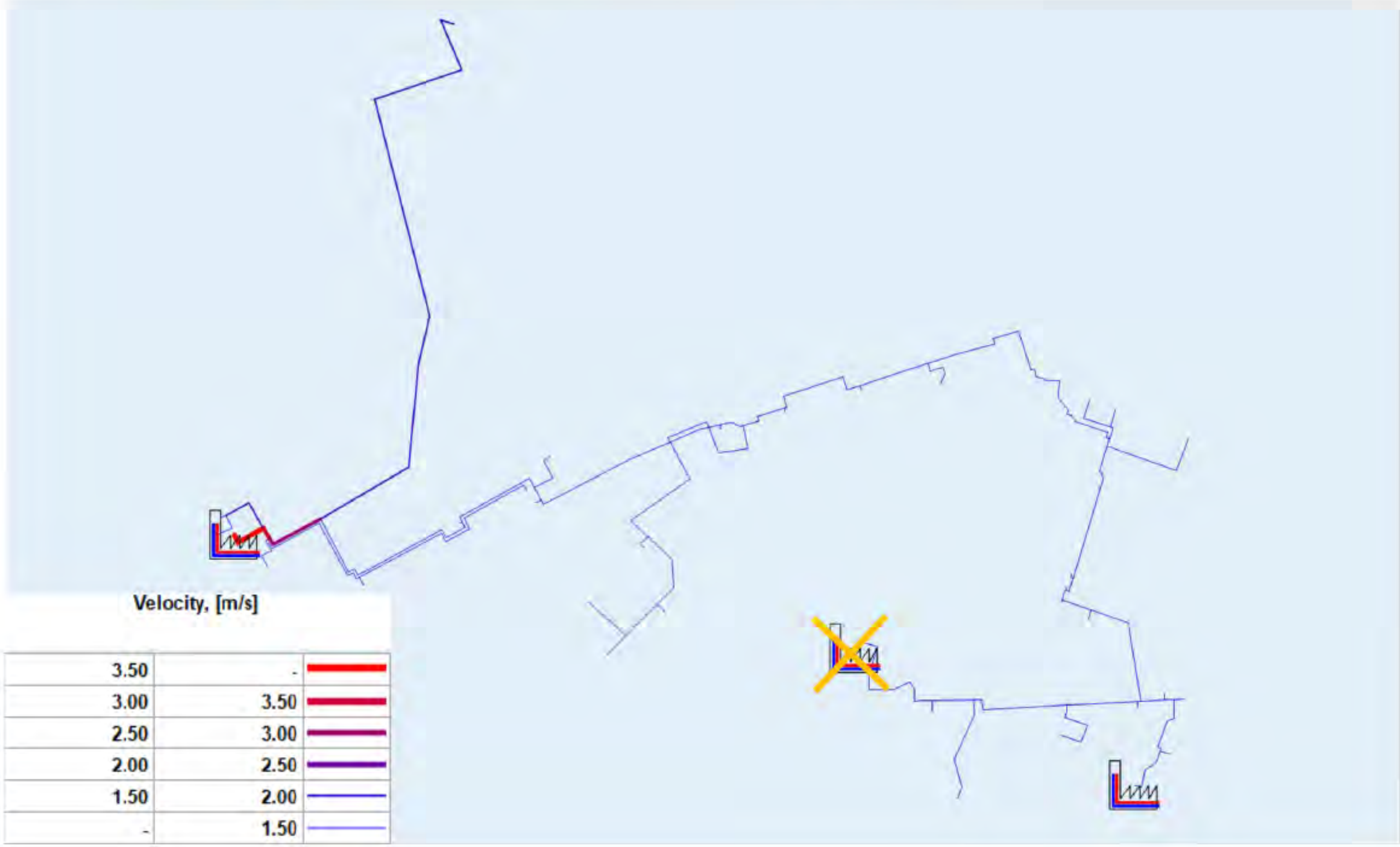


Results:

- The highest velocity is at the DN300 internal to the Citigen EC (3.7 m/s)



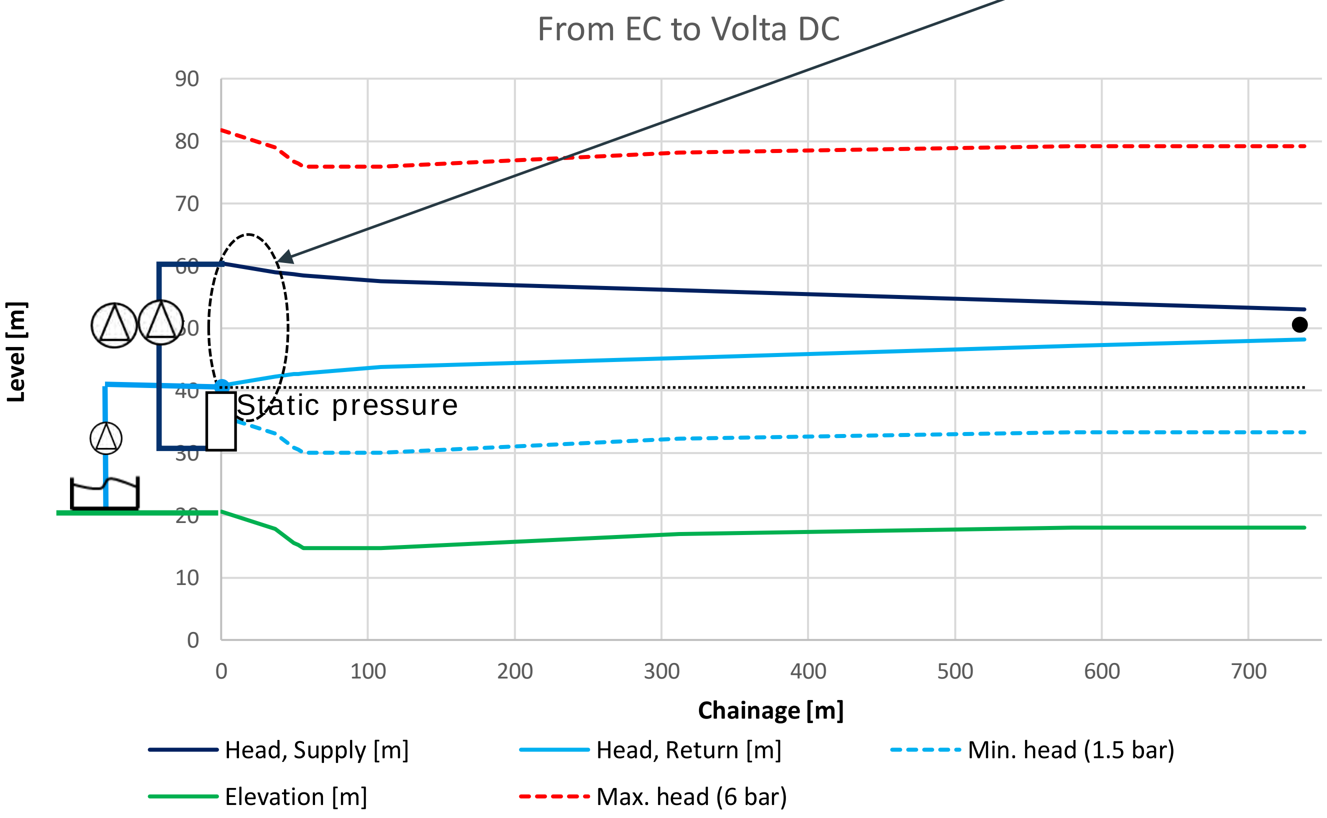
Scenario 3A-DCN – Velocity



Scenario 3A-DCN - Summary

No major criticalities are observed in this scenario

The DN300 inside Citigen EC has a relatively high pressure gradient (389 Pa/m), velocity (3.7 m/s).

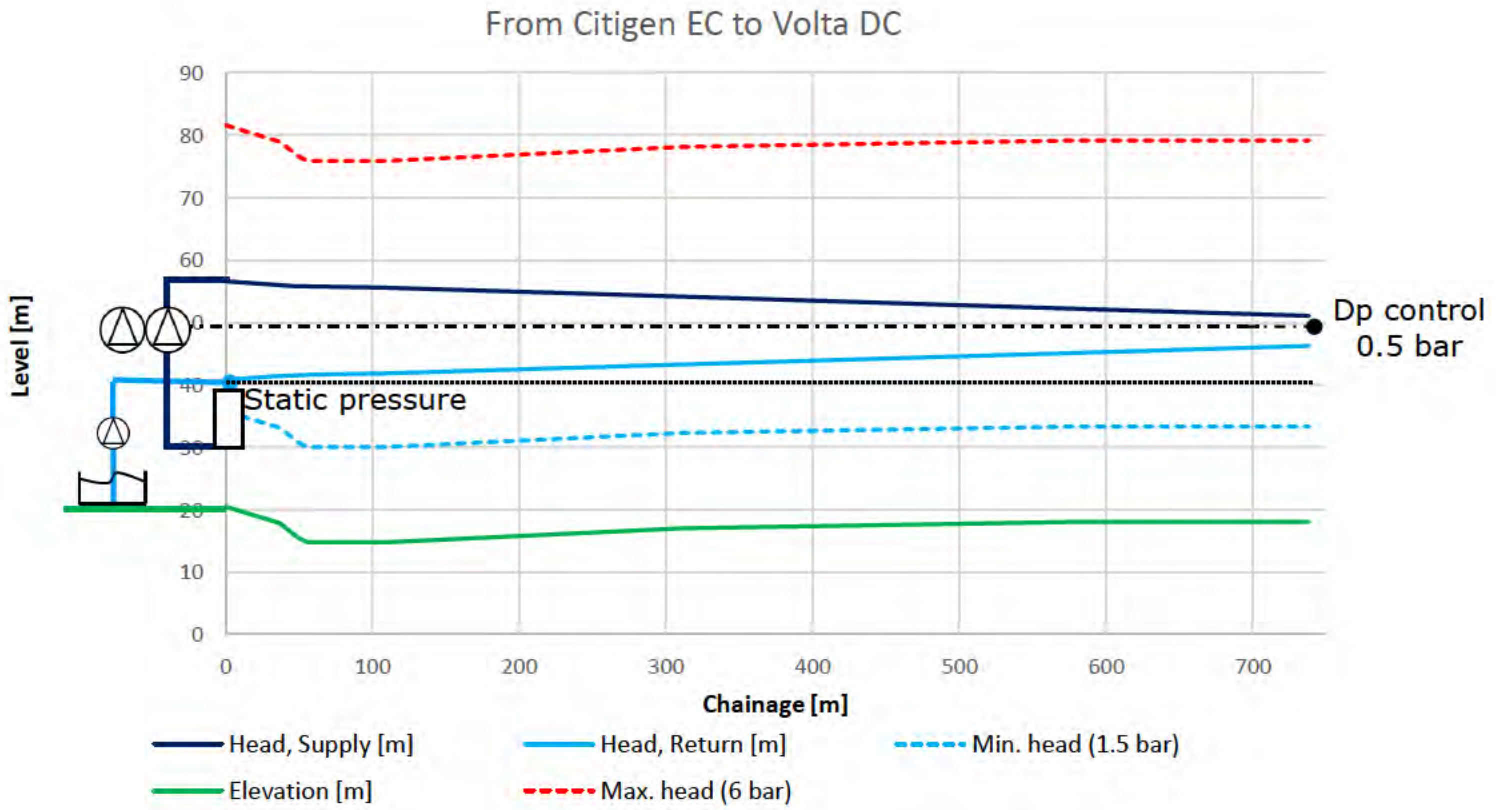


Scenario 3B-DCN
3.5 MW from LWW +
1.0 MW from Guildhall

(common Volta connection)

Scenario 3B-DCN – Head Profile: Citigen EC to Volta DC (critical node)

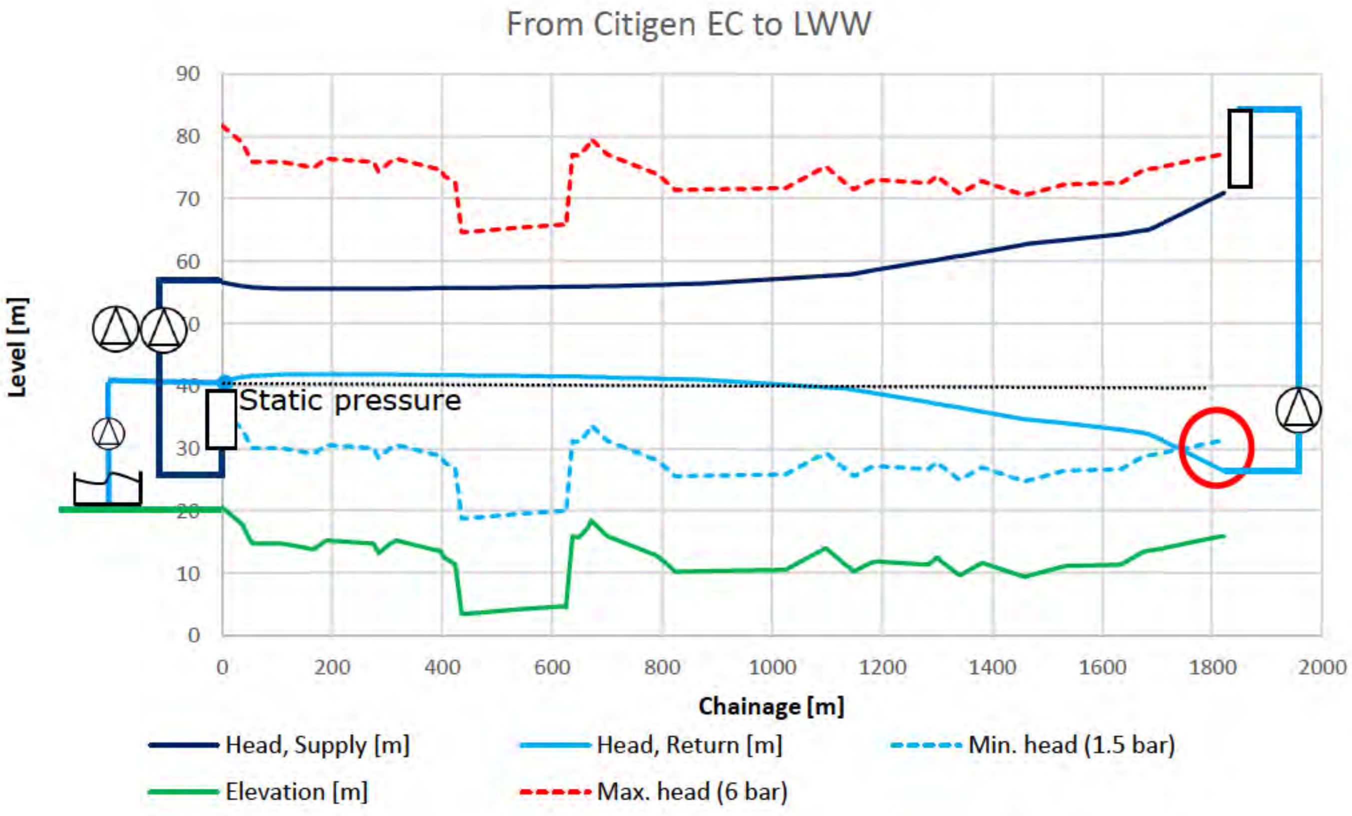
- Assumed pressure drop within EC: 1.5 bar



- Assumed pressure drop within EC: 1.5 bar
- DP control at Volta DC (0.5 bar)

Note:
LWW pumps are placed upstream the chillers.
The conceptual layout of LWW will impact the internal pressures at LWW

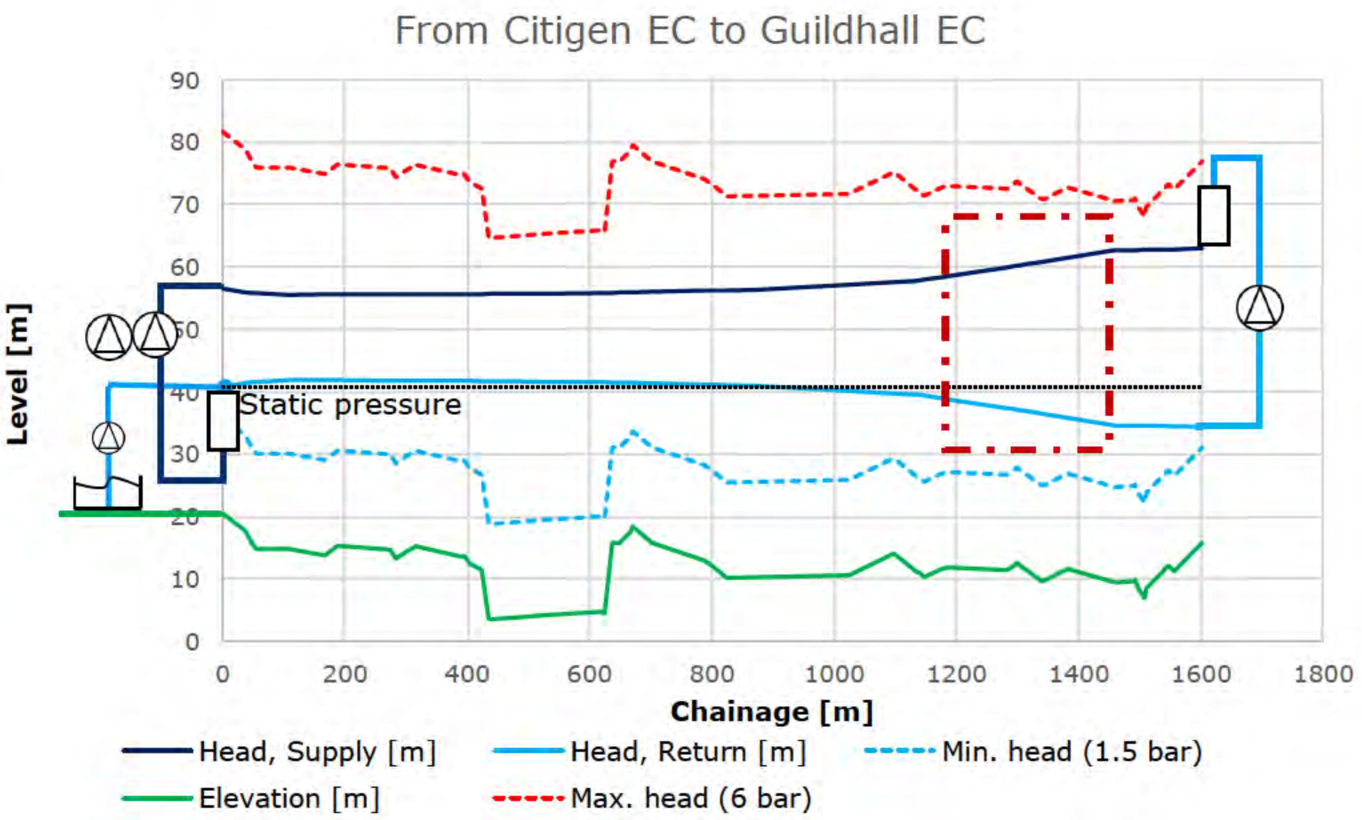
Scenario 3B-DCN – Head Profile: Citigen EC to LWW



Scenario 3B-DCN – Head Profile: Citigen EC to Guildhall EC

- Assumed pressure drop within EC: 1.5 bar
- DP control at Volta DC (0.5 bar)

Note:
Guildhall pumps are placed upstream the chillers.
The conceptual layout of Guildhall will impact the internal pressures



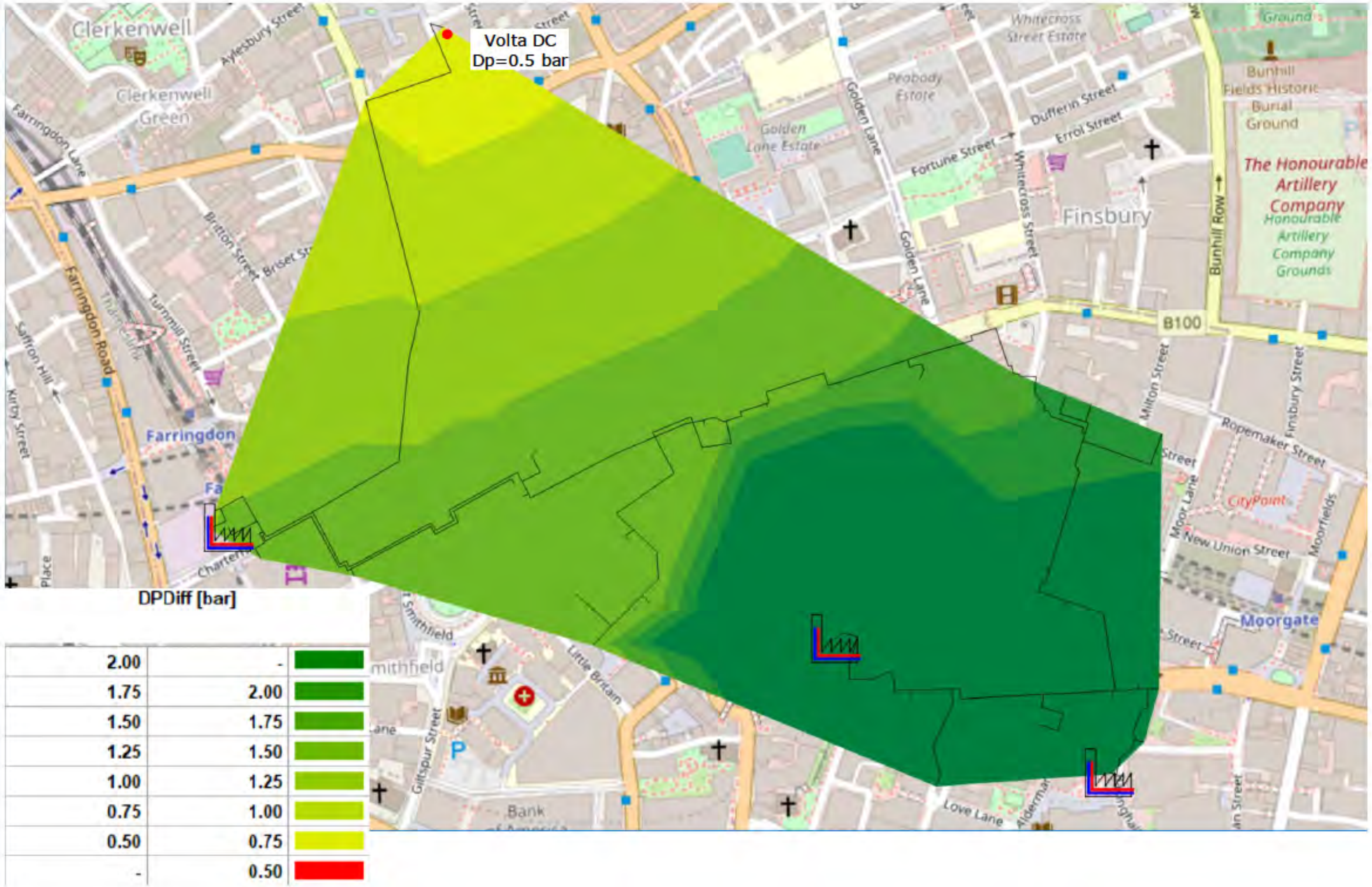
Results:

- Critical node (control node) is Volta DC (0.5 bar)

Scenario 3B-DCN – Pressure Difference

PRODUCTION		Citigen EC	LWW	Guildhall
Power	[kW]	**7475**	**3500**	**1000**
Flow	[kg/s]	185	107	30
Temp. Supply	[°C]	6	6	6
Temp. Return	[°C]	15.6	13.8	14.0
Press. Supply	[barg]	3.6	5.5	4.7
Press. Return	[barg]	2.0	1.0	1.8
Press. Diff.	[bar]	1.6	4.4	2.9

NETWORK		
Highest pressure	[barg]	5.6
Lowest pressure	[barg]	1.1
Lowest press. diff.	[bar]	0.5
Highest velocity	[m/s]	3.1
Highest press. gradient	[Pa/m]	430



Scenario 3B-DCN - Pumping Capacity

PRODUCTION		Citigen EC	LWW	Guildhall
Power	[kW]	7475	3500	1000
Flow	[kg/s]	185	107	30
Temp. Supply	[°C]	6	6	6
Temp. Return	[°C]	15.6	13.8	14.0
Press. Supply	[barg]	3.6	5.5	4.7
Press. Return	[barg]	2.0	1.0	1.8
Press. Diff.	[bar]	1.6	4.4	2.9
Press. Diff. (EC+DCN)	**[bar]**	**3.1***	**5.9***	**4.4***

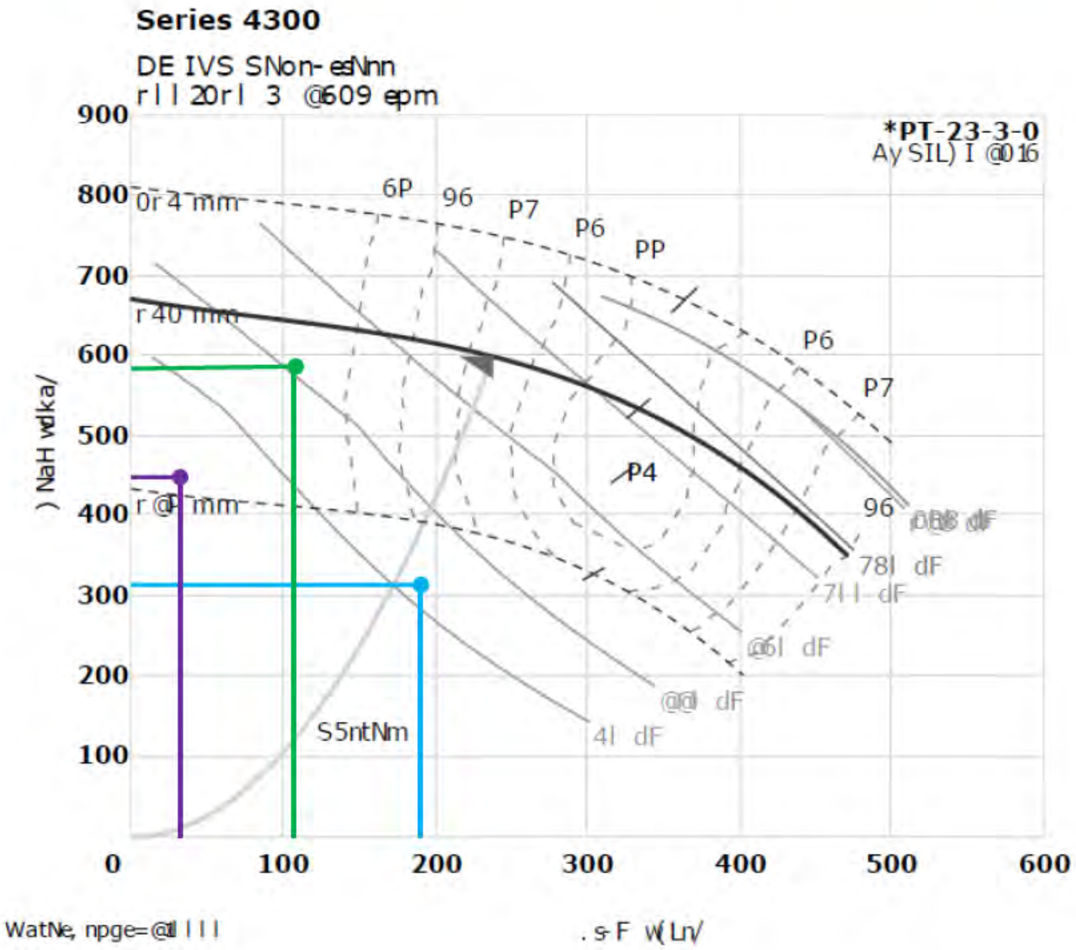
* 1.5 bar pressure drop is assumed inside the EC (production, valves, etc.)

Model: Series Design Envelope Sensorless 4300 3043-250.0

Project name:		**Representative:**	
Location:		**Phone number:**	
Date submitted:	10/7/2022 6:46 AM	**e-mail:**	
Engineer:		**Submitted by:**	

Application design data

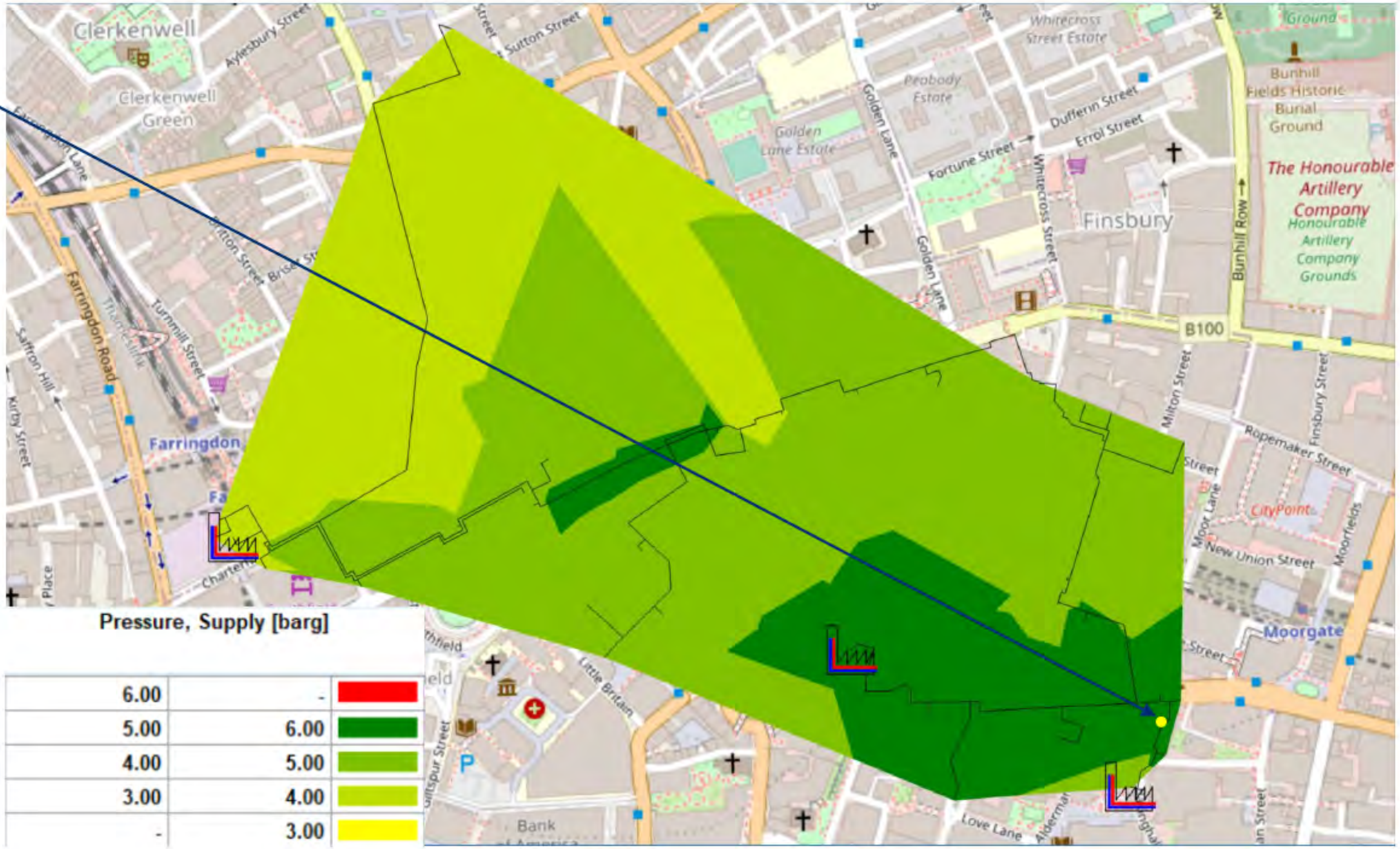
Tag number:	43649	Configuration:	Single
Service:		Suction pressure:	0 ft
Location:		Fluid:	Non-Potable
Qty:	1	Operating temperature:	16 °C
Total system flow:	238 L/s	Duty flow per pump:	238 L/s
System head:	600 kPa	Viscosity:	31 SSU
Environment:	Indoors	Specific gravity:	1.0000
Total dissolved solids:	0 ppm	Safety factor % flow:	0 %
Efficiency at Design:	83.34 %	Safety factor % head:	0 %
NPSHR:	13.83 kPa	Absorbed Power/BHP:	171.17 kW
Min. maintained system pressure*:	240 kPa	Impeller diameter:	394 mm



Results:

- Highest supply pressure: 5.6 barg close to Guildhall

Scenario 3B-DCN – Supply Pressure

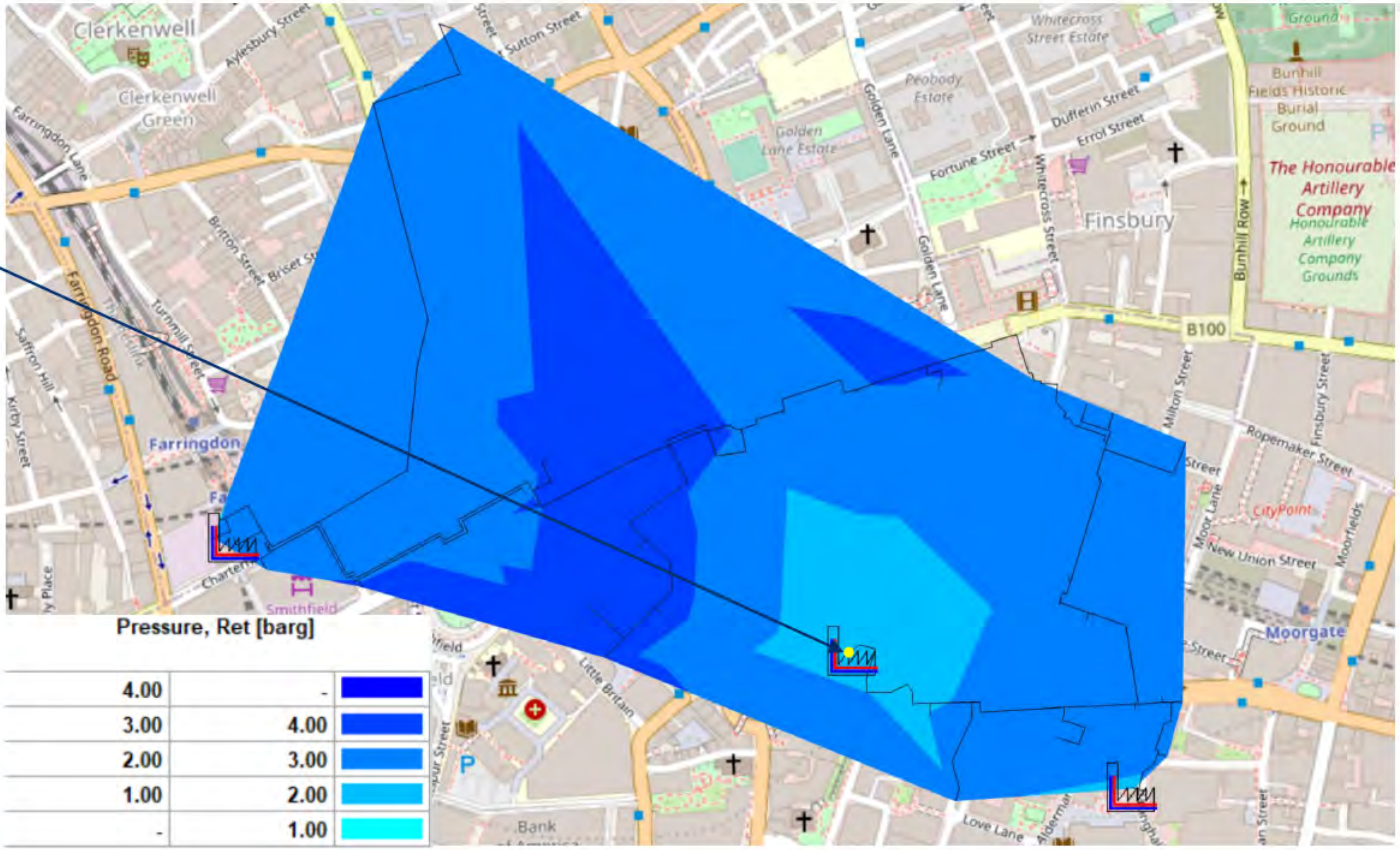


Results:

- Lowest return pressure: 1.1 barg at LWW

The minimum acceptable pressure as communicated by EON is 1.5 barg

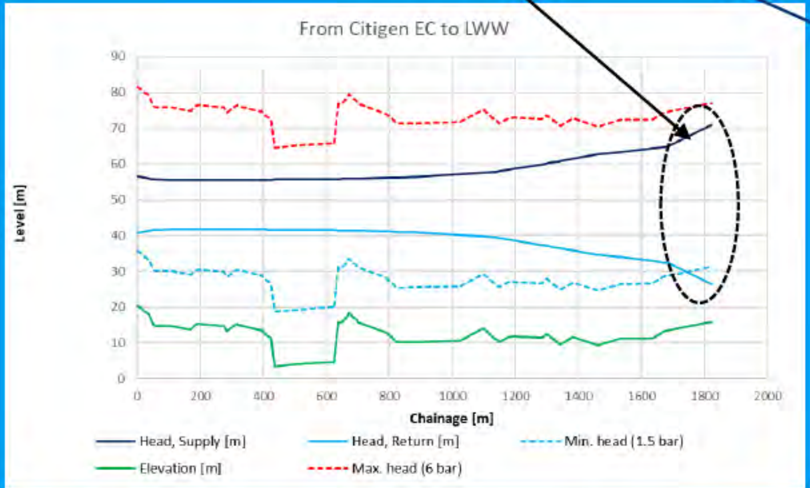
Scenario 3B-DCN – Return Pressure

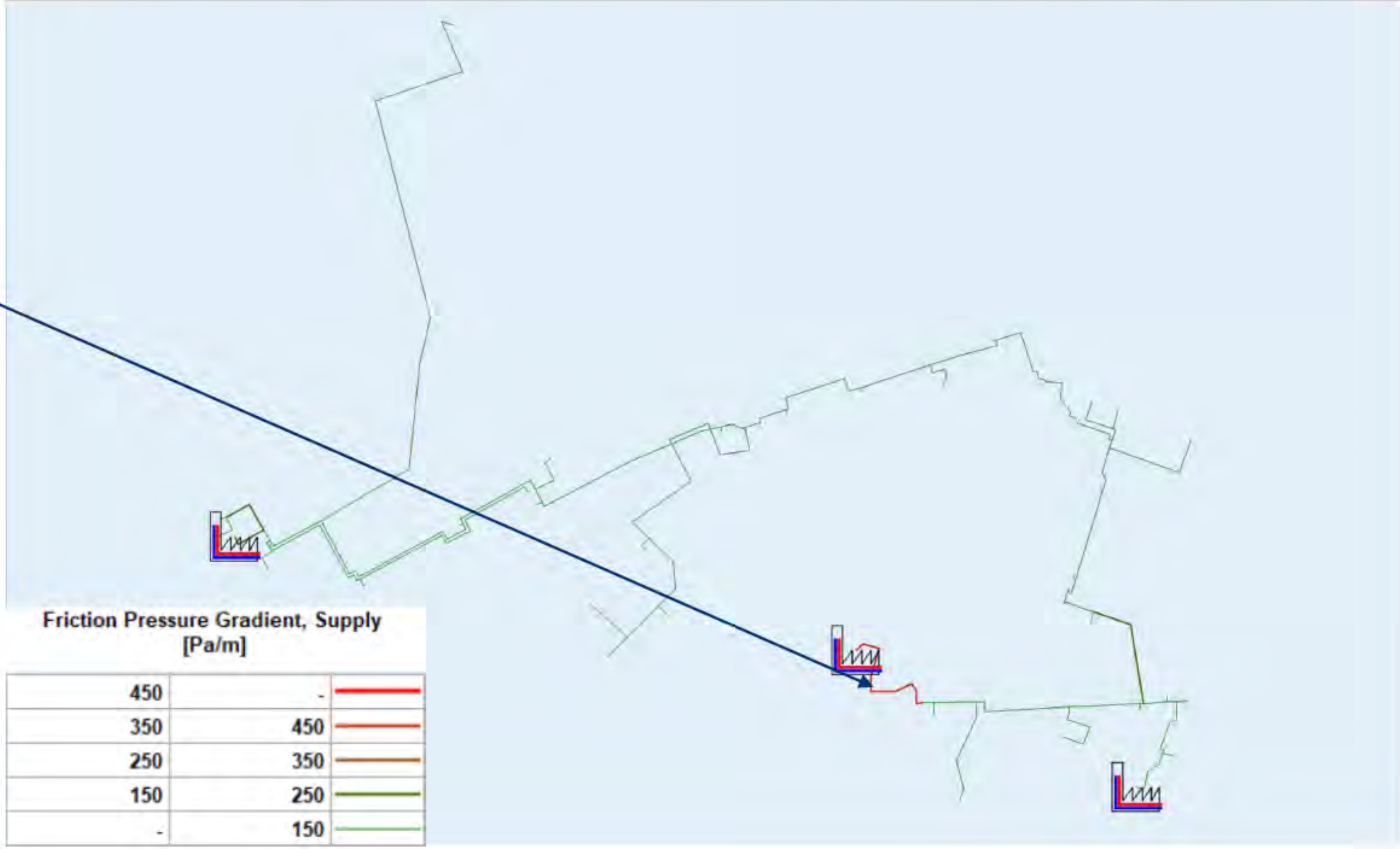


Results:

- The highest pressure drop gradient is at the DN200 from LWW (**430 Pa/m;** 3.1 m/s)

Scenario 3B-DCN – Pressure Drop Gradient





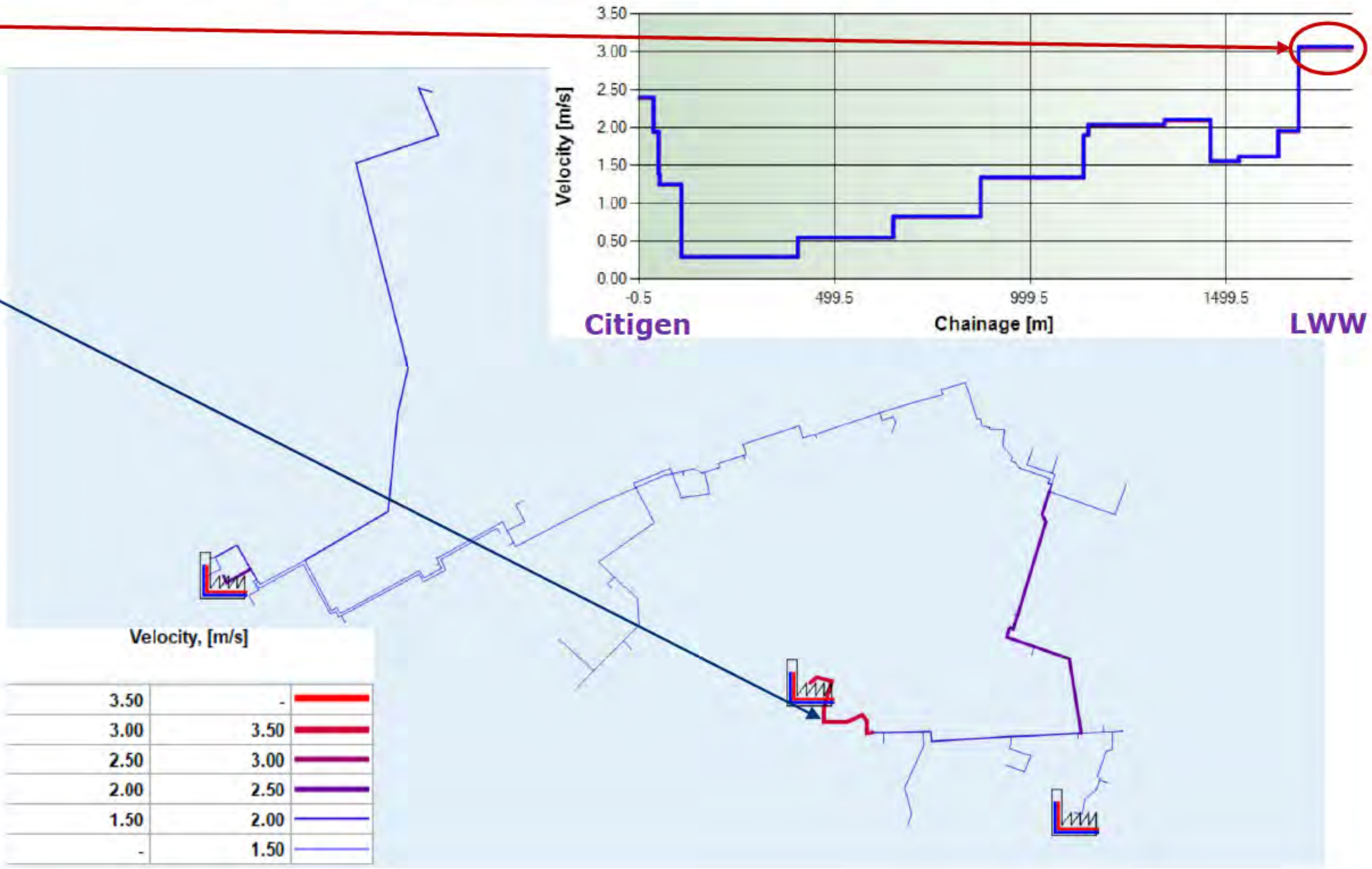
Friction Pressure Gradient, Supply [Pa/m]

450	-	
350	450	
250	350	
150	250	
-	150	

Results:

- The highest velocity is at the DN200 from LWW (3.1 m/s)

Scenario 3B-DCN – Velocity



Scenario 3B-DCN - Summary

Producing 3.5 MW-c from LWW impacts the existing DN200 to LWW.

This results in supply and return pressures at LWW at the limits of 1.5 barg (min) and 6 barg (max)

The DN200 has a quite high pressure gradient (430 Pa/m) and velocity (3.1 m/s). Pipe is under slightly lower pressure compared to scenario 2A-DCN (3.5 MW from LWW; no production from Guildhall) due to the slightly higher return temperature to LWW (contribution from Volta DC).

General updates in H3 model

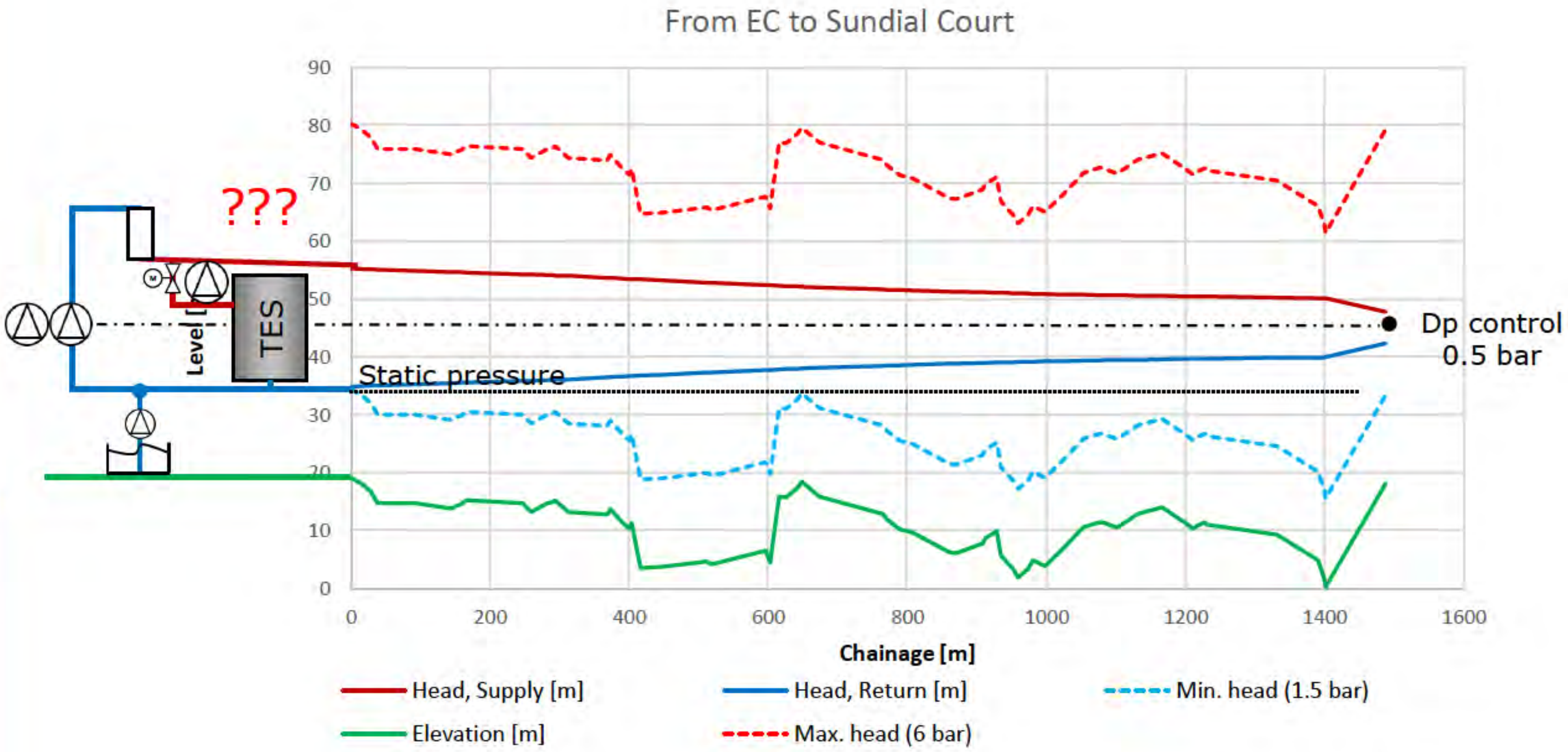
- Pressure drop correction factor changed from 1.15 to 1.1 (both supply and return pipe)
- Soil temperature increased from 0 degC to 5 degC (winter peak load conditions)
- Insulation class of pipes changed from Series 1 to Series 2
- Changed control strategy in central plant: fixing return pressure (1.5 barg) and min Dp at critical consumer
- Supply temperature for new production units (LWW & Guildhall): 80 °C (agreed at meeting on June 1st)
- Supply temperature from Citigen EC: 89 °C; Return temperature from consumers 72 °C (agreed at meeting on June 1st)

Scenario 2A-DHN
0.6 MW production at LWW

(updated after removal of Bastion House and Museum of London)

- Assumed pressure drop within EC: 1.5 bar

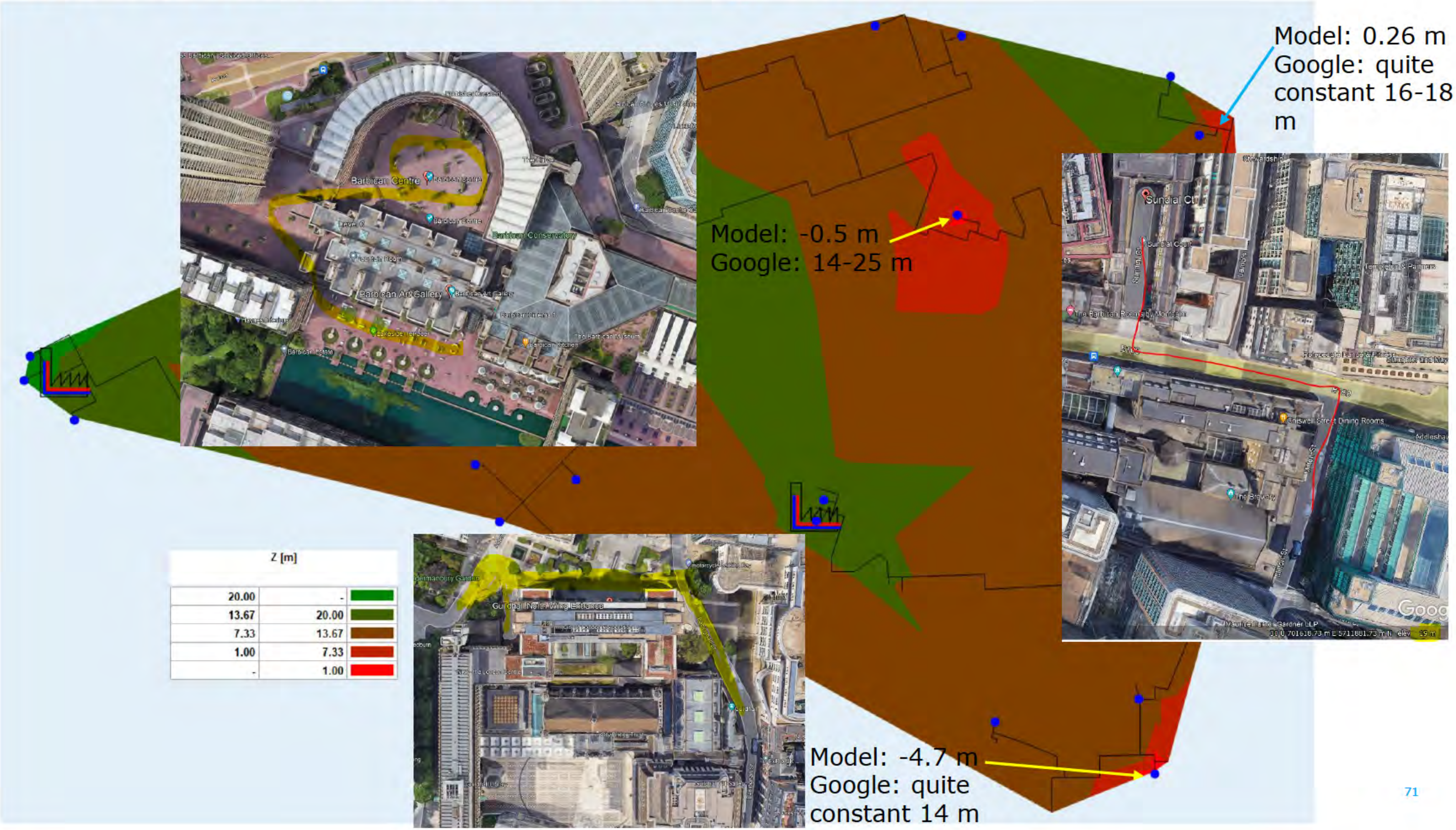
Scenario 2A-DHN – Head Profile: Citigen EC to Sundial Court (critical node)



Check on elevation: COWI report vs TERMIS model

from COWI report		TERMIS model	
Substation Level ASL [m]	m	closest node	2nd closest node
Guildhall Substation -4.7	-4.7	-1.2	-4.7
Smithfield East 9.0	9.0	9.0	
Smithfield West 9.0	9.0	9.0	
Farringdon East 9.0	9.0	9.0	
2 Fann Street 8.0	8.0	8.0	
ST. Barts Blocks F & G 9.0	9.0	9.0	
ST. Barts Blocks B & C 9.0	9.0	9.0	
ST. Barts Blocks A & E 9.0	9.0	9.0	
ST. Barts Office A B C 9.0	9.0	9.0	
Barbican Exhibition Halls 12.5	12.5	12.5	
Bernard Morgan House 12.5	12.5	not in project area	
Sundial 18.1	18.1	18.1	
Whitbread Brewery 12.1	12.1	12.1	
Barbican -0.5	-0.5	-0.5	
Heron Court 11.5	11.5	11.5	
Salters Hall 8.3	8.3	8.3	
London Wall Place 1 6.3	6.3	6.3	
London Wall Place 2 6.3	6.3	6.3	
Bastion House 15.8	15.8	15.8	
Brewers Hall 12.5	12.5	12.5	
Farringdon West 22.7	22.7	22.7	
33 Charterhouse 22.7	22.7	22.7	
Citigen LTHW Pumps Location 22.7	22.7	19.4	

Check on elevation: TERMIS vs Google Earth



Z [m]		
20.00	-	dark green
13.67	20.00	olive green
7.33	13.67	brown
1.00	7.33	dark red
-	1.00	red

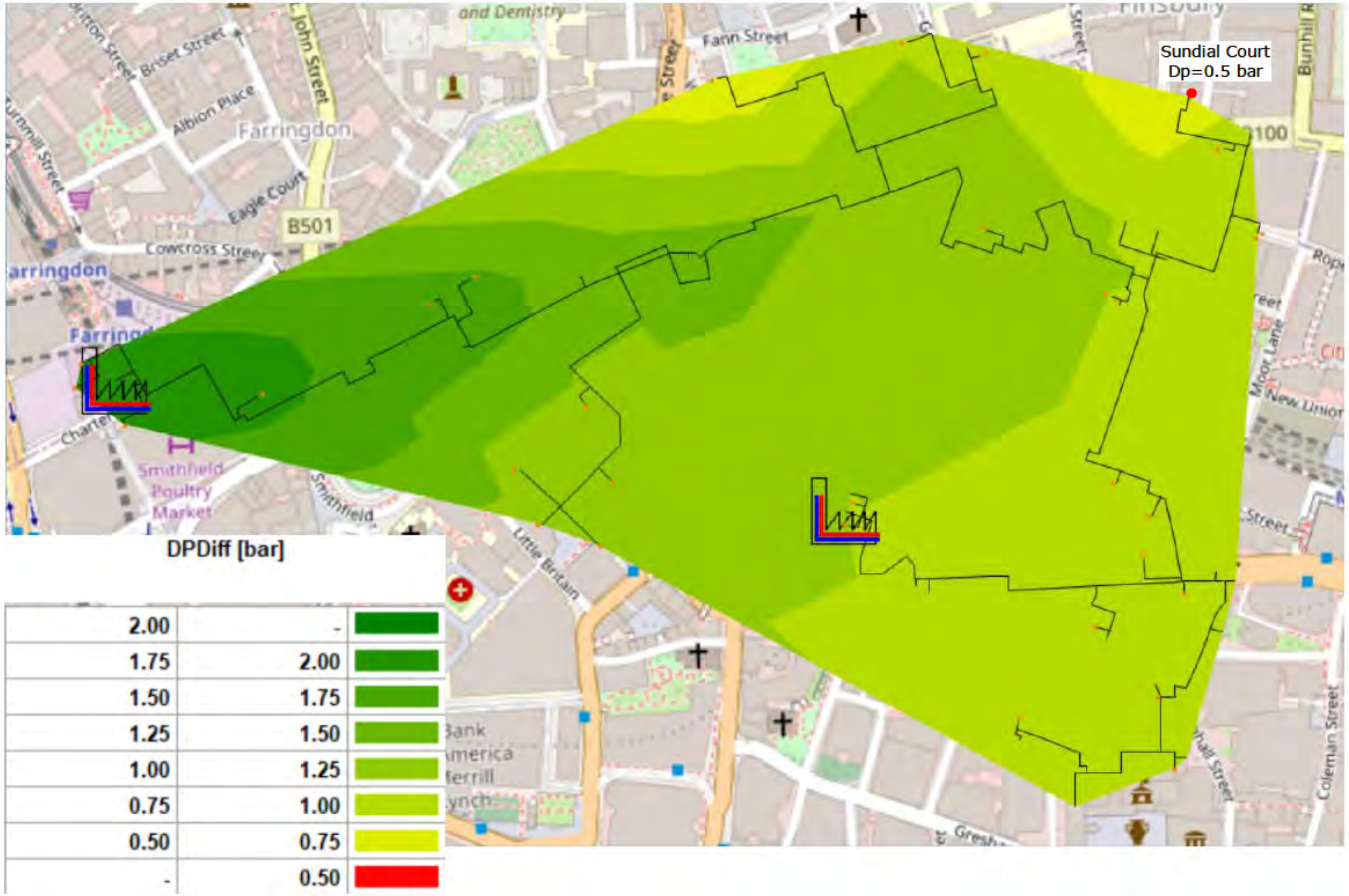
Results:

- Critical node (control node) is Sundial Court (0.5 bar)

Scenario 2A-DHN – Pressure Difference

PRODUCTION		Citigen EC	LWW
Power	[kW]	**10,897**	**600**
Flow	[kg/s]	152	18
Temp. Supply	[°C]	89	80
Temp. Return	[°C]	72	72
Press. Supply	[barg]	3.4	3.4
Press. Return	[barg]	1.5	2.4
Press. Diff.	[bar]	1.93	1.01

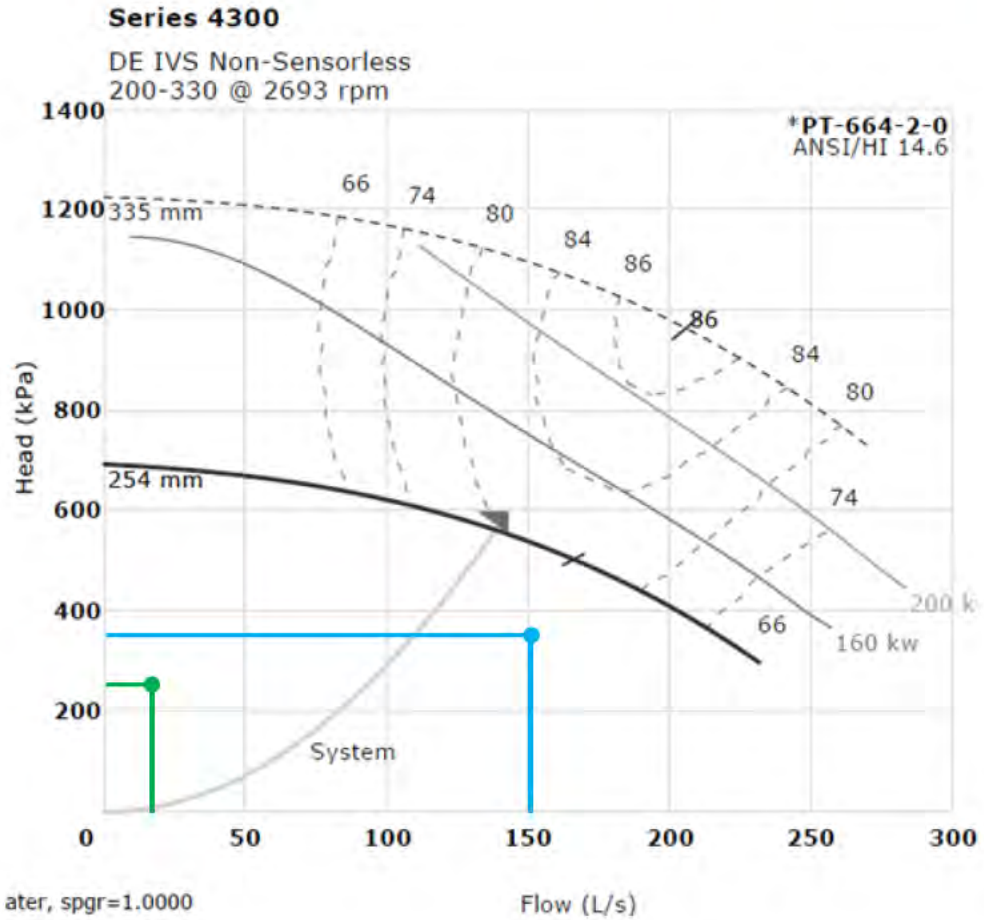
NETWORK		
Highest pressure	[barg]	5.2
Lowest pressure	[barg]	1.2
Lowest press. diff.	[bar]	0.5
Highest velocity	[m/s]	1.7
Highest press. gradient	[Pa/m]	262



Scenario 2A-DHN - Pumping Capacity

PRODUCTION		Citigen EC	LWW
Power	[kW]	10,897	600
Flow	**[kg/s]**	**152**	**18**
Temp. Supply	[°C]	89	80
Temp. Return	[°C]	72	72
Press. Supply	[barg]	3.4	3.4
Press. Return	[barg]	1.5	2.4
Press. Diff. (DCN only)	[bar]	1.93	1.01
Press. Diff. (EC+DCN)	**[bar]**	**3.4***	**2.5***

* 1.5 bar pressure drop is assumed inside the EC (production, valves, etc.)



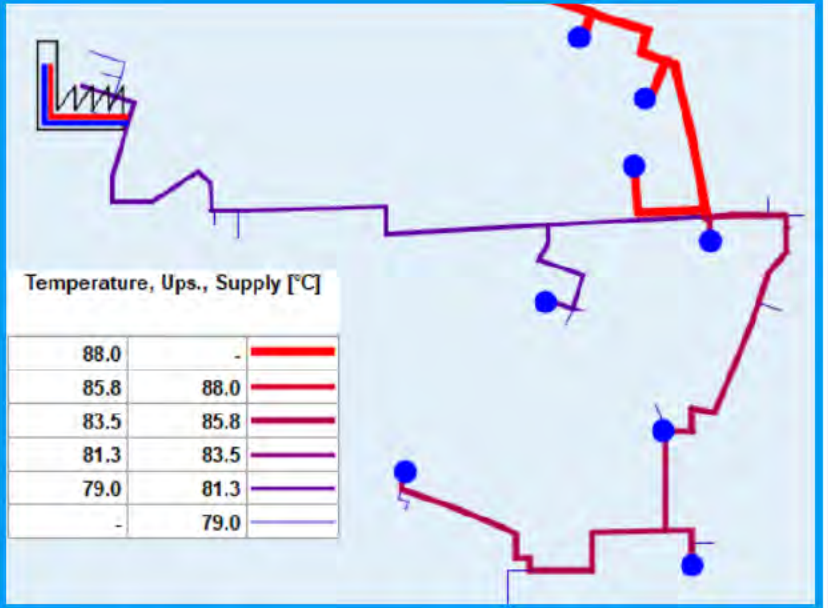
Model: Series Design Envelope 4300 2033-160.0

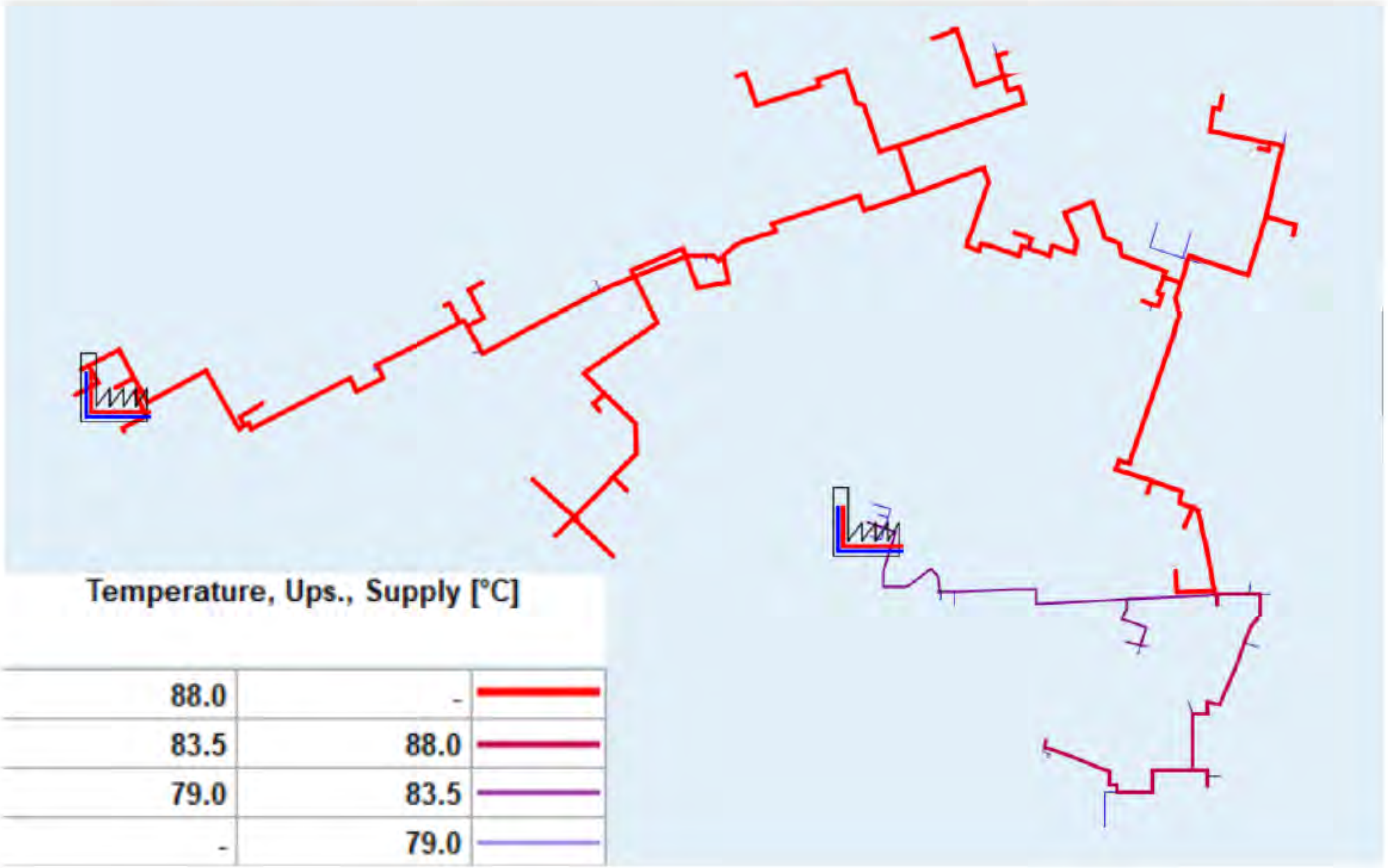
Project name:		**Representative:**	
Location:		**Phone number:**	
Date submitted:	10/7/2022 6:46 AM	**e-mail:**	
Engineer:		**Submitted by:**	

Application design data

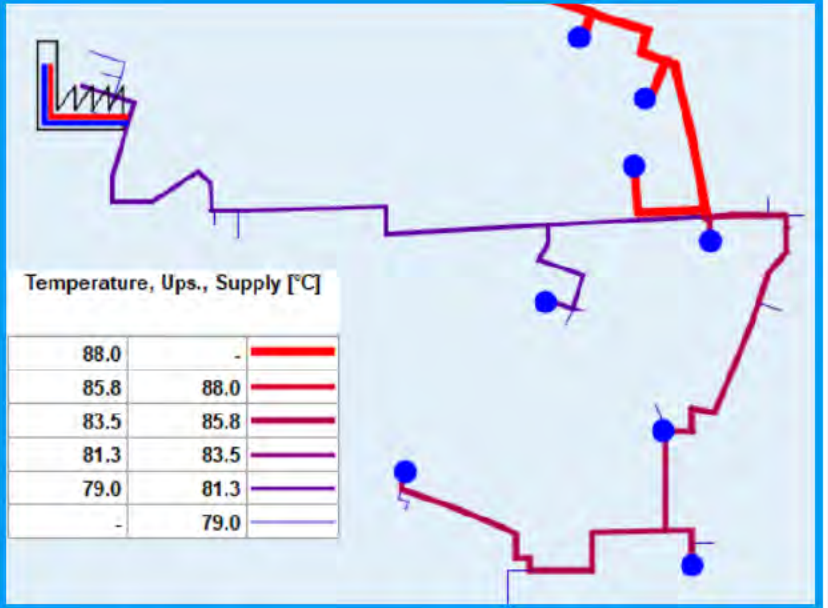
Tag number:	44402	Configuration:	Single
Service:		Suction pressure:	0 ft
Location:		Fluid:	Non-Potab
Qty:	1	Operating temperature:	16 °C
Total system flow:	143 L/s	Duty flow per pump:	143 L/s
System head:	600 kPa	Viscosity:	31 SSU
Environment:	Indoors	Specific gravity:	1.0000
Total dissolved solids:	0 ppm	Safety factor % flow:	0 %
Efficiency at Design:	84.28 %	Safety factor % head:	0 %
NPSHR:	121.02 kPa	Absorbed Power/BHP:	101.7 kW
Min. maintained system pressure*:	240 kPa	Impeller diameter:	254 mm

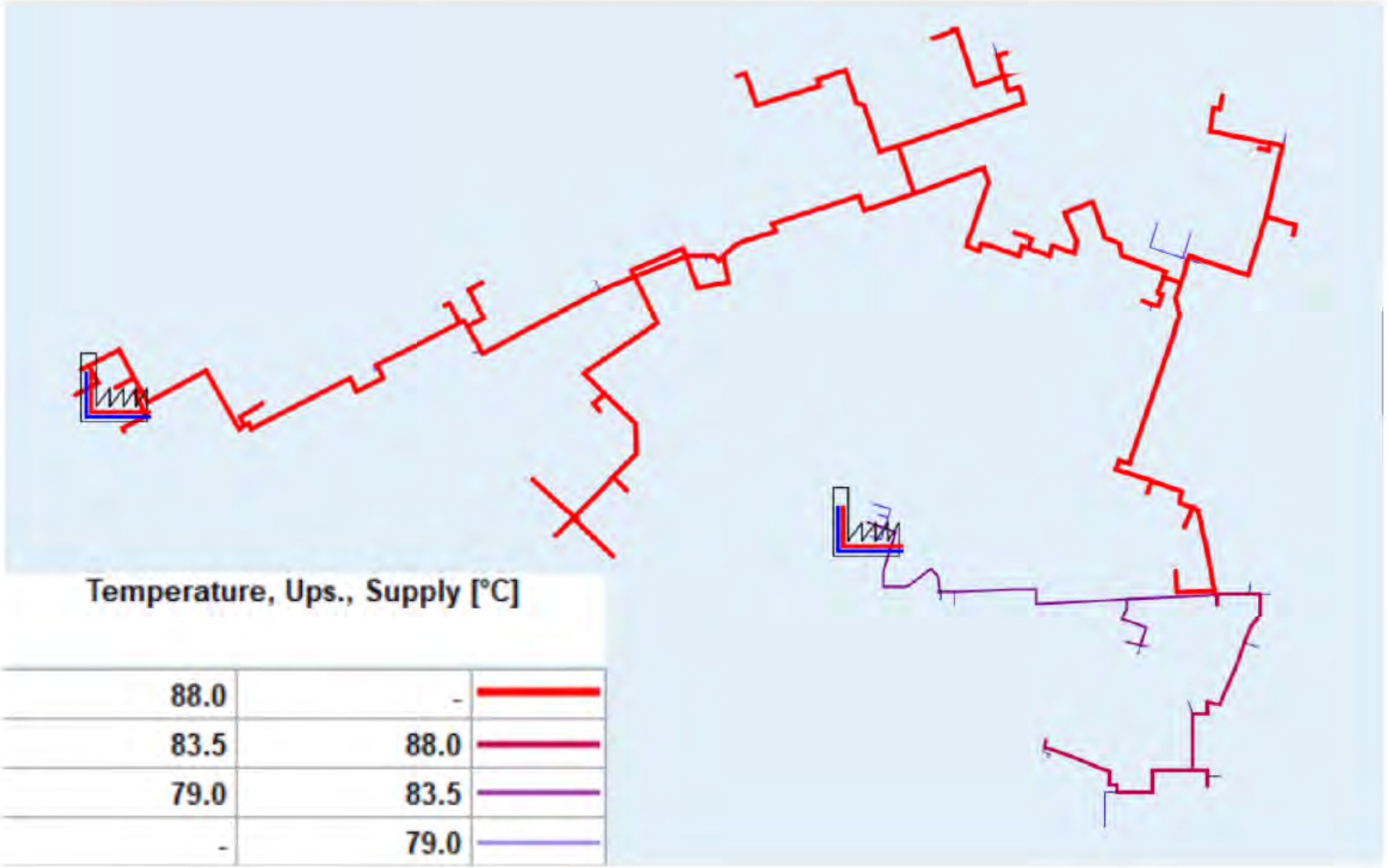
Scenario 2A-DHN – Supply temperature



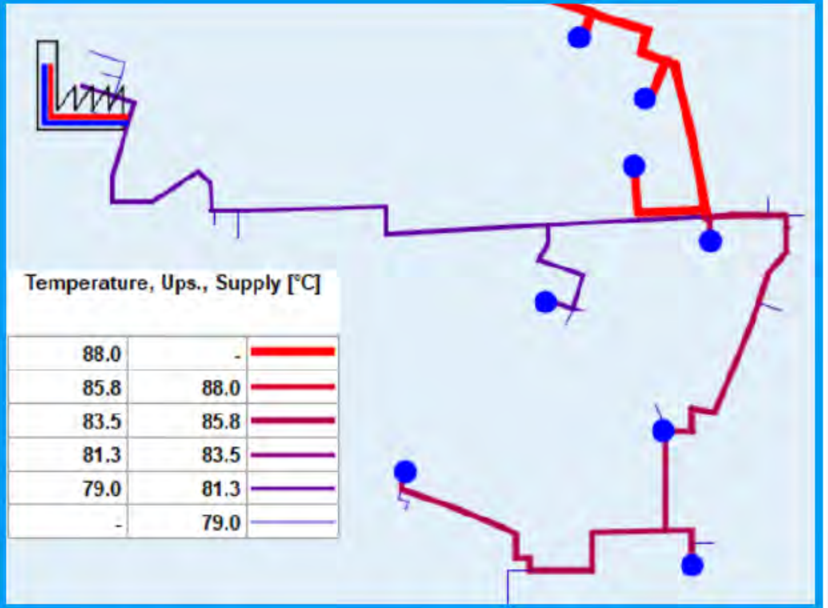


Scenario 2A-DHN – Supply temperature





Scenario 2A-DHN – Supply temperature

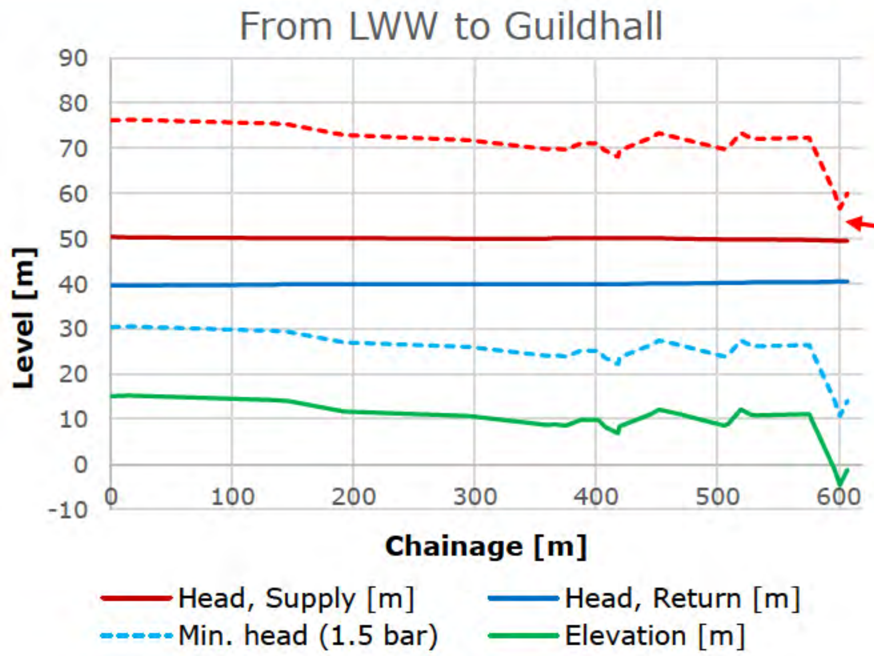


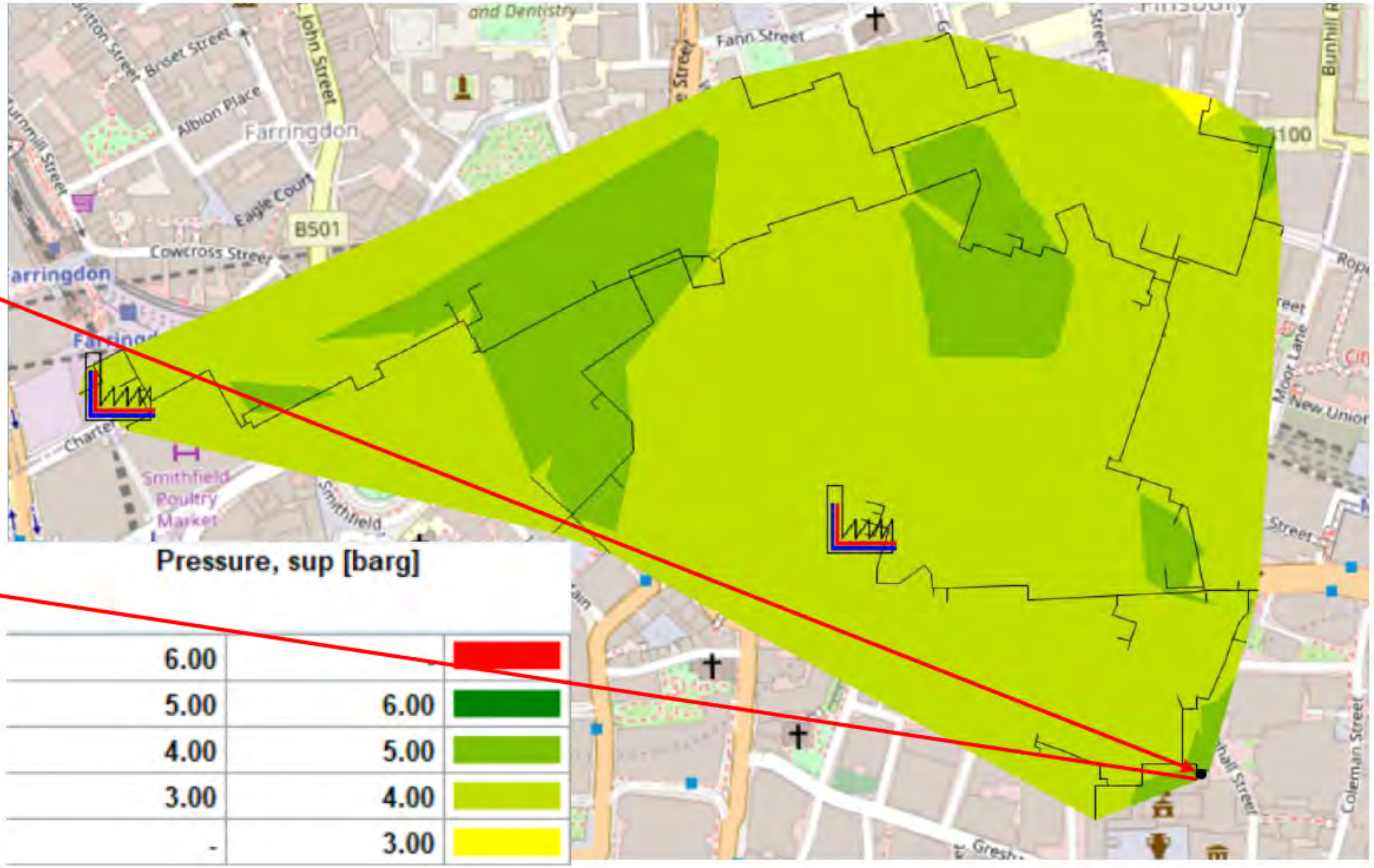
Consumer	Supply temp. °C
Guildhall	85.6
Wood Street	85.5
Guildhall Yard East	85.6
Brewers Hall	79.8
City Place House	85.6
London Wall 2	88.6
Barts Square Office A	88.6
Barts Square F-G	88.7

Scenario 2A-DHN – Supply Pressure

Results:

- Highest supply pressure:
  5.2 barg (right before Guildhall, corresponds to a low elevation point (-4.7 m)

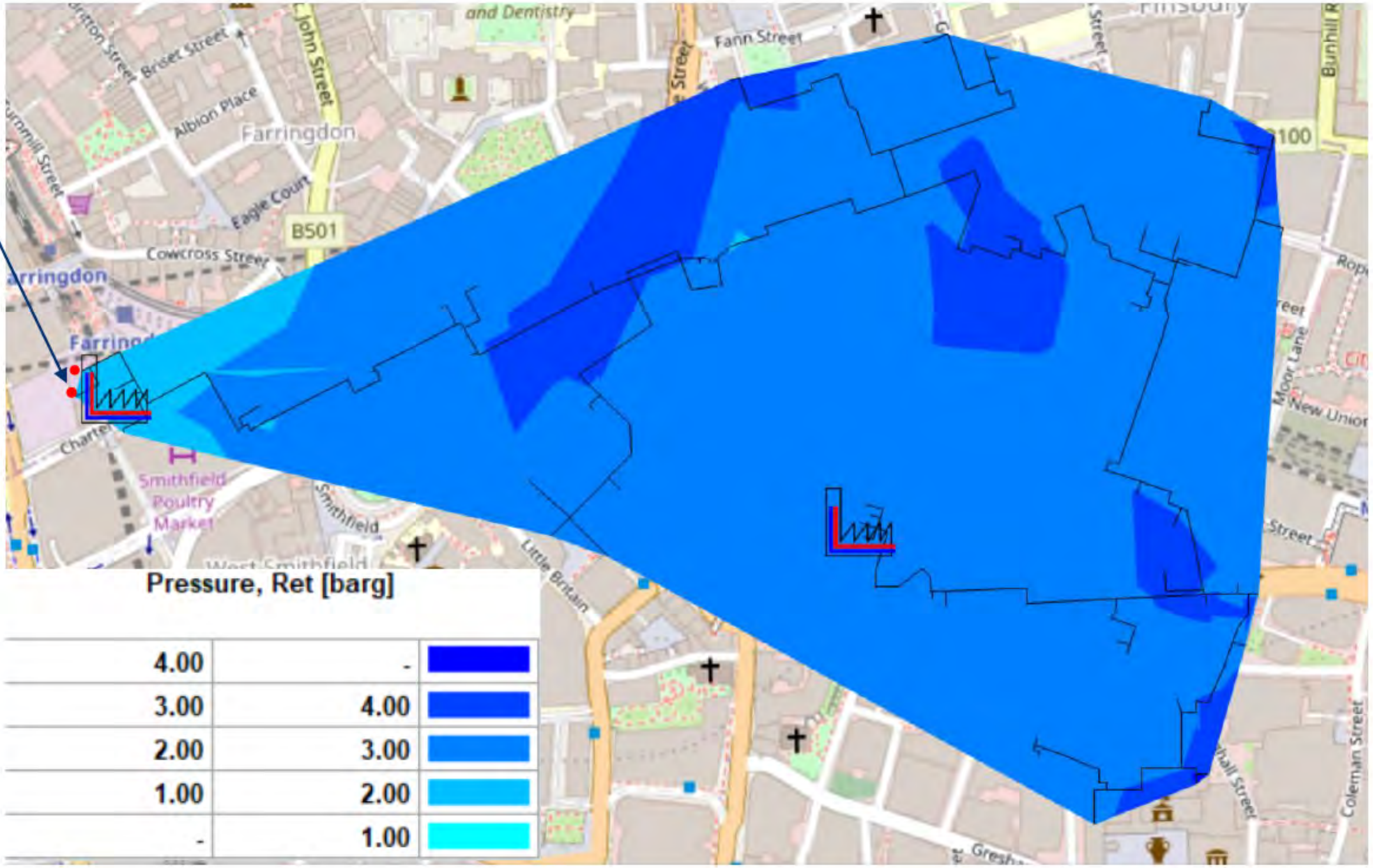




Results:

- Lowest return pressure: 1.2 barg (Farringdon West Bloom and 33 Charterhouse)

Scenario 2A-DHN – Return Pressure



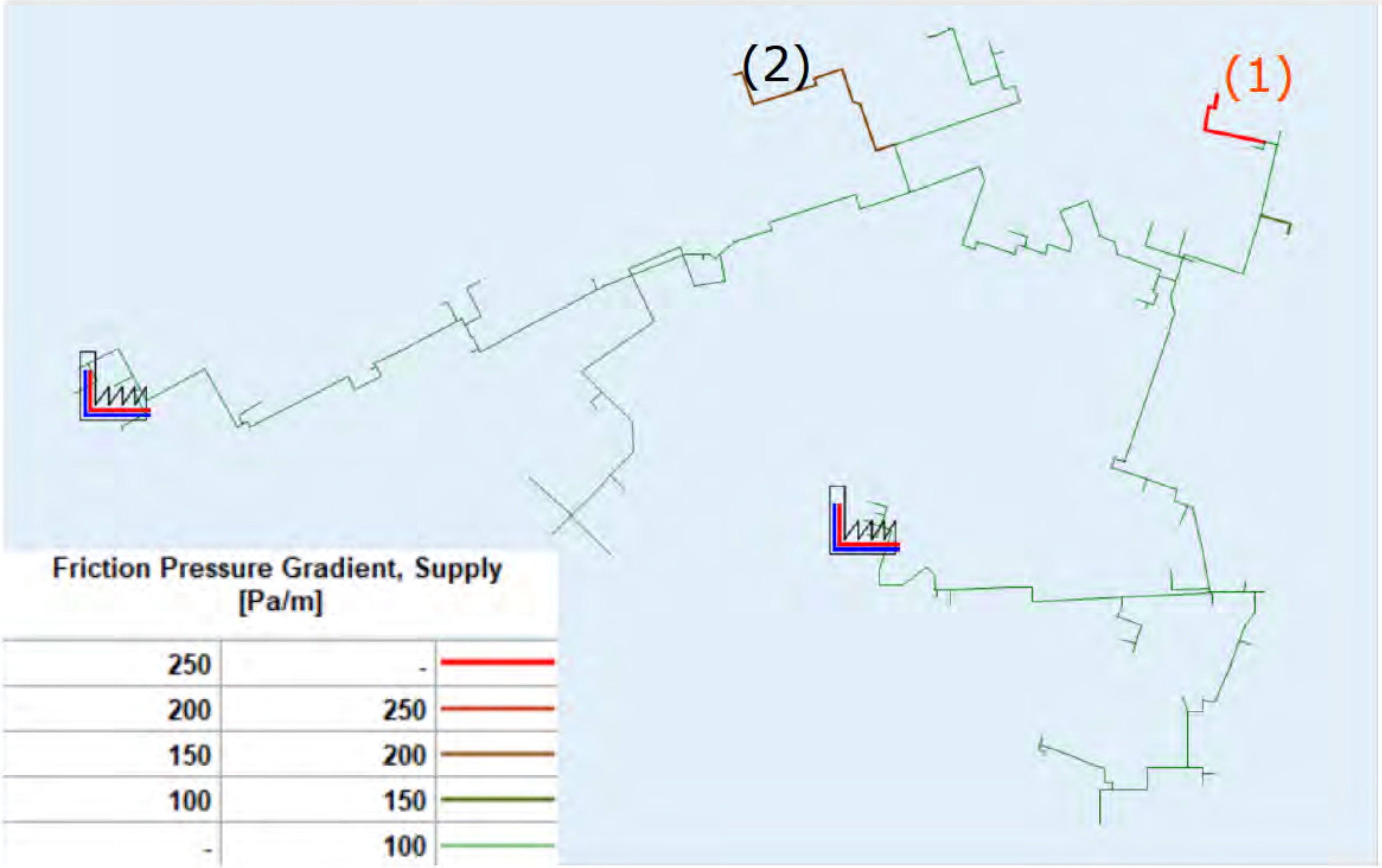
Scenario 2A-DHN – Pressure Drop Gradient

Results:

- The highest pressure gradients are found in
  - DN65 to Sundial Court (261 Pa/m; 1.3 m/s); **(1)**
  - DN80 to 2 Fann Street (Blake Tower) (152 Pa/m; 1.0 m/s) **(2)**

- DN65 (@200 Pa/m) carries
  - 403 kW (load factor=0.63), if DT=30 K (Tret=59 °C)
  - 640 kW (load factor=1), if DT=48 K (Tret=41 °C)

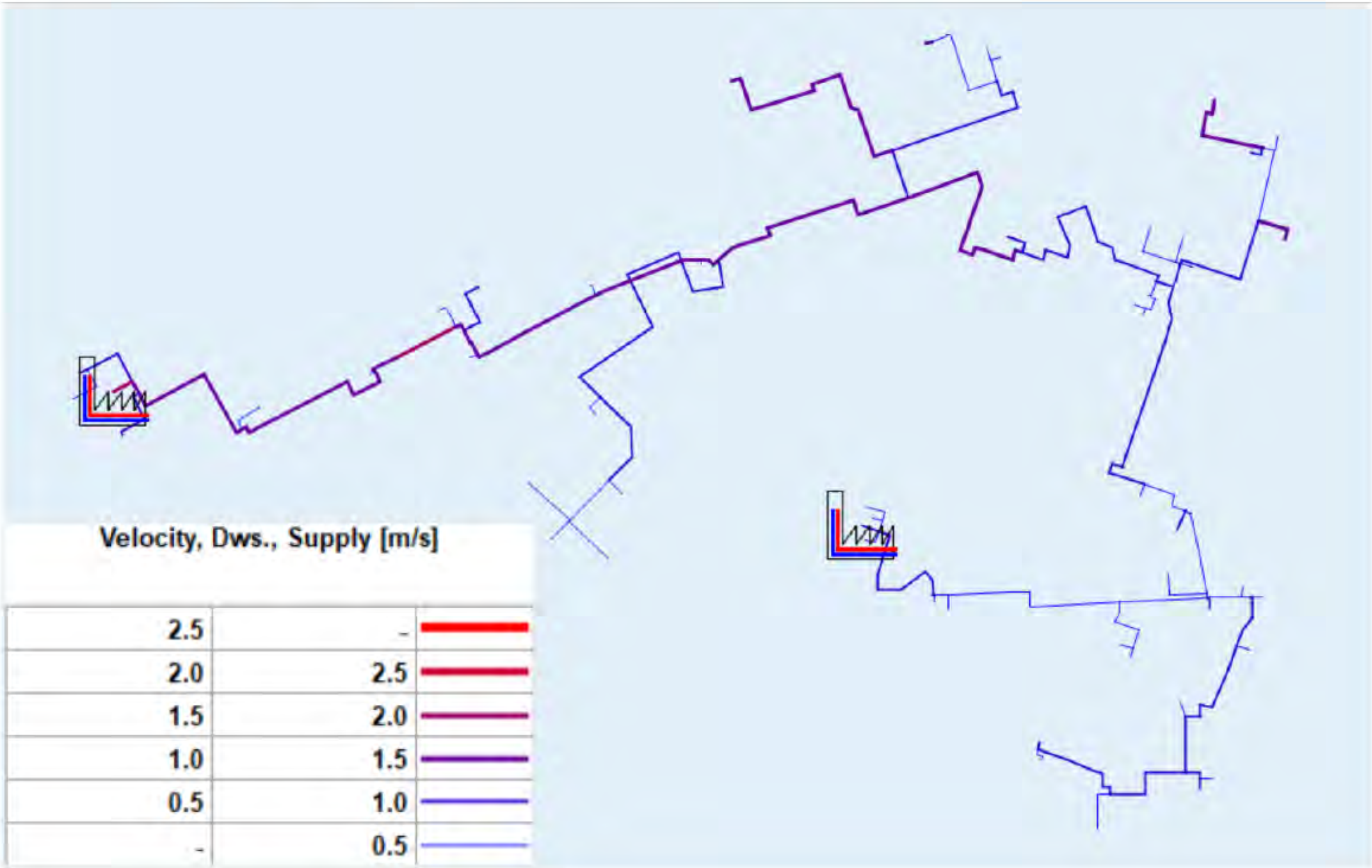
- Supply from Citigen: 89 °C
- Supply from LWW: 80 °C
- Return from buildings: 72 °C



Results:

- The highest velocity is at the DN350 internal to the Citigen EC (1.7 m/s)

Scenario 2A-DHN – Velocity



Scenario 2A-DHN - Summary

No major criticalities are observed in this scenario

The DN65 to Sundial Court has a relatively high pressure gradient (261 Pa/m).

Sundial Court is the critical point in the model.

The flow is impacted by the performance of the building. If the performance can be improved the flowrate can drop resulting in a lower pressure drop gradient and lower supply pressure required at the central plant.

Parametric analysis on 2A-DHN baseload:

- Load 5.1 MW
- 0.6 MW production at LWW
- different LWW supply temperature

Results: supply temperature at the consumers

Consumer	LWW @80C	LWW @77.5C	LWW @75C
Brewers Hall	79.6	77.3	74.9
Wood Street	82.4	80.0	76.9
Guildhall	82.6	80.1	77.0
Guildhall Yard East	82.6	80.1	77.0
City Place House	82.7	80.2	77.0
Barts Square Office A	88.1	88.1	88.1
London Wall 2	88.1	88.1	88.1
Barts Square F-G	88.2	88.2	88.2
Barts Sqaure A-E	88.3	88.3	88.3
The Denizen	88.3	88.3	88.3
Barbican Exhibition Halls	88.4	88.4	88.4
Sundial Court	88.4	88.4	88.4
2 Fann Street (Blake Tower)	88.4	88.4	88.4
Barts Square Phase 3	88.4	88.4	88.4
Whitbread Brewery	88.5	88.5	88.5
Barts Office B (90BC)	88.5	88.5	88.5
Guildhall School of Music & Drama	88.5	88.5	88.5
London Wall 1	88.6	88.6	88.6
Salters Hall	88.6	88.6	88.6
Heron GSMD (Heron Milton Court)	88.6	88.6	88.6
Heron Residential	88.6	88.6	88.6
Barbican Arts Centre	88.8	88.8	88.8
Smithfield Market East builiding	88.8	88.8	88.8
Farringdon East/Kaleidoscope	88.8	88.8	88.8
Smithfield Market West builiding	88.9	88.9	88.9
33 Charterhouse	88.9	88.9	88.9
Farringdon West Bloom	88.9	88.9	88.9
New Museum of London	89.0	89.0	89.0

Supply temp. < 88 C

Critical node, 0.5 bar Dp

With 600 kW from LWW, the affected consumers are:

- Brewers Hall
- Wood Street
- Guildhall
- Guildhall Yard East
- City Place House

(same as in the peak load scenario 2A-DHN)

Brewers Hall is the more affected consumer, as its supply comes only from LWW. The other consumers receive a mixed temperature between LWW and Citigen EC

Comments on supply temperature from HP

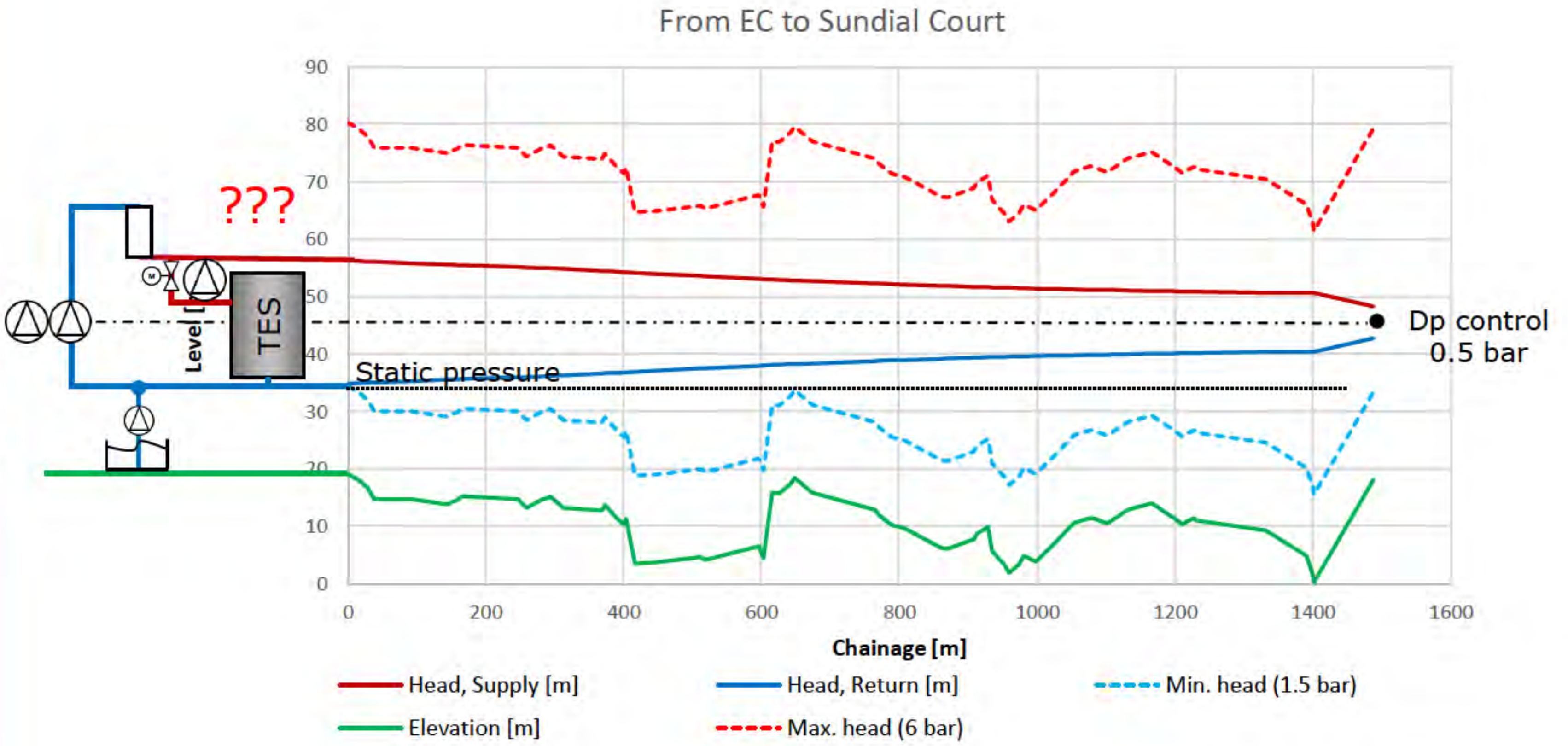
- Currently a return temperature of 72 °C from all buildings is assumed
- A 72.5 °C supply from LWW is not realistic. With just 0.5 K of temperature difference, the pressure gradients and velocities in the DN200 from LWW at 600 kW output would be extremely high. This scenario is only possible if the return temperature from buildings is decreased, or if major pipes upgrades are assumed.

Scenario 3A-DHN
1.9 MW production at Guildhall

(Bastion House and MoL replaced by new 2.6 MW load at LWW)

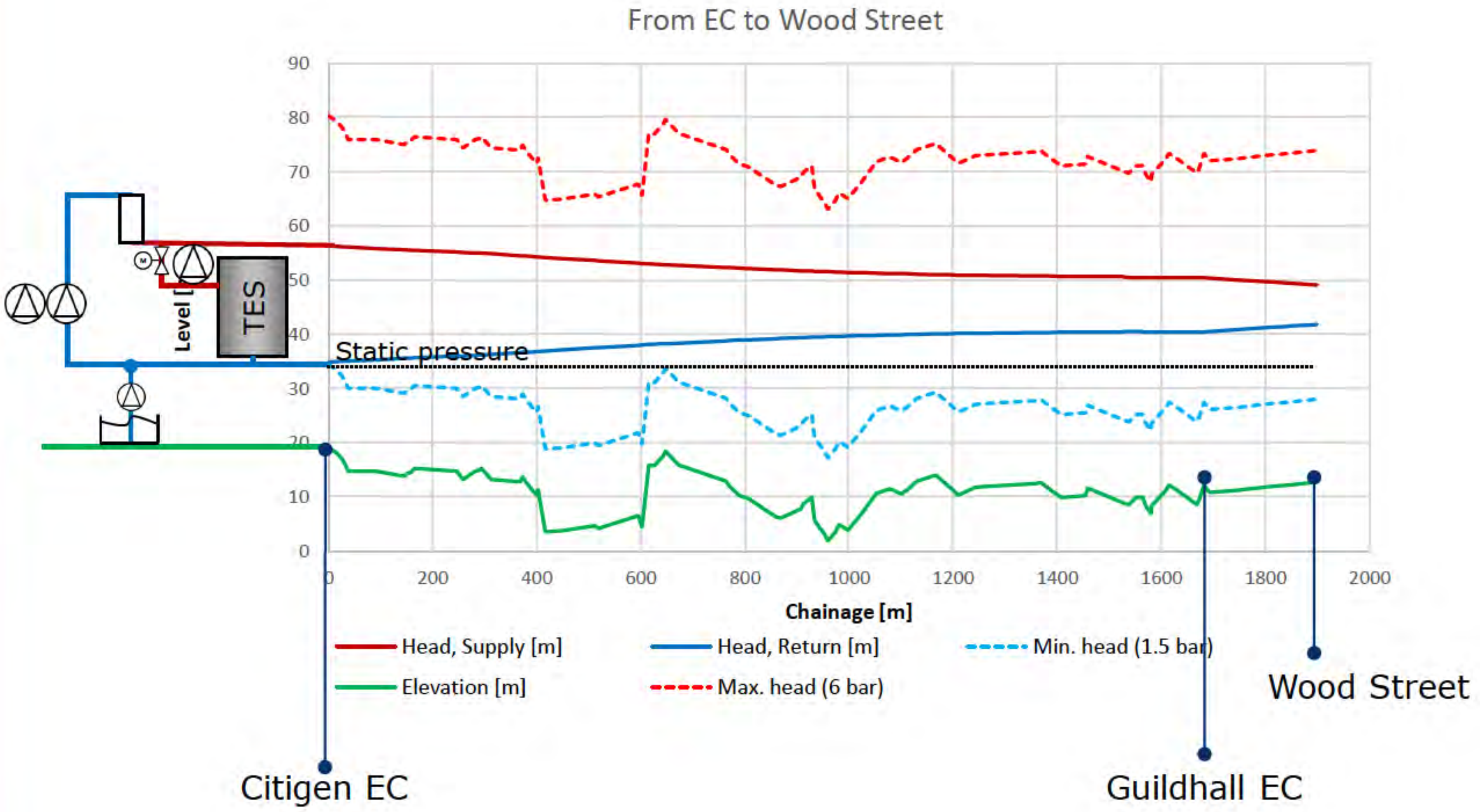
- Assumed pressure drop within EC: 1.5 bar

Scenario 3A-DHN – Head Profile: Citigen EC to Sundial Court (critical node)

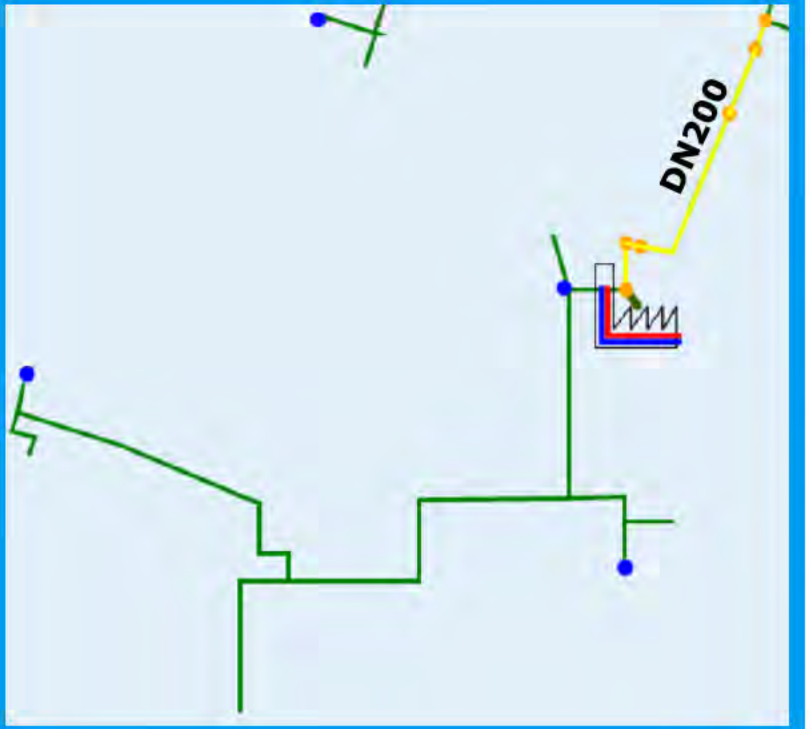


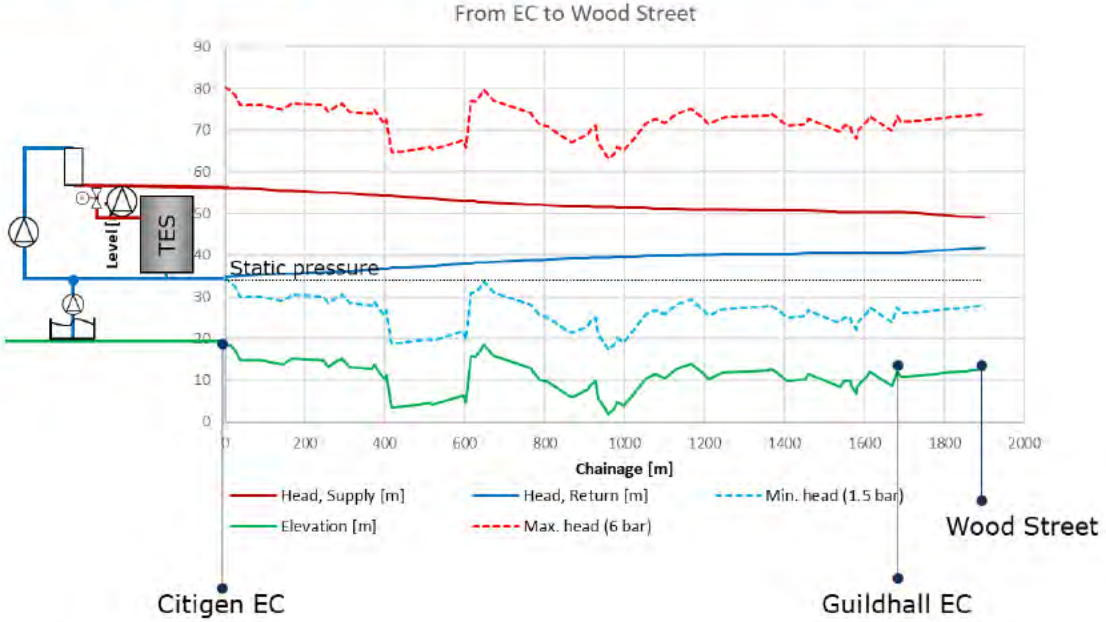
- Assumed pressure drop within EC: 1.5 bar
- Critical node: Sundial Court (0.5 bar Dp)

Scenario 3A-DHN – Head Profile: Citigen EC to Wood Street



Pressures around Guildhall EC





Consumers downstream of Guildhall EC

Consumer	Power Demand [kW]
Guildhall Yard East	527
Wood Street	1000
Guildhall	1101
Total	**2628**

Production from Guildhall EC: 1.9 MW

→ 2.6 MW × 0.63 = 1.7 MW

Flow upstream from Guildhall: 0.2 MW -> 7 kg/s in DN200

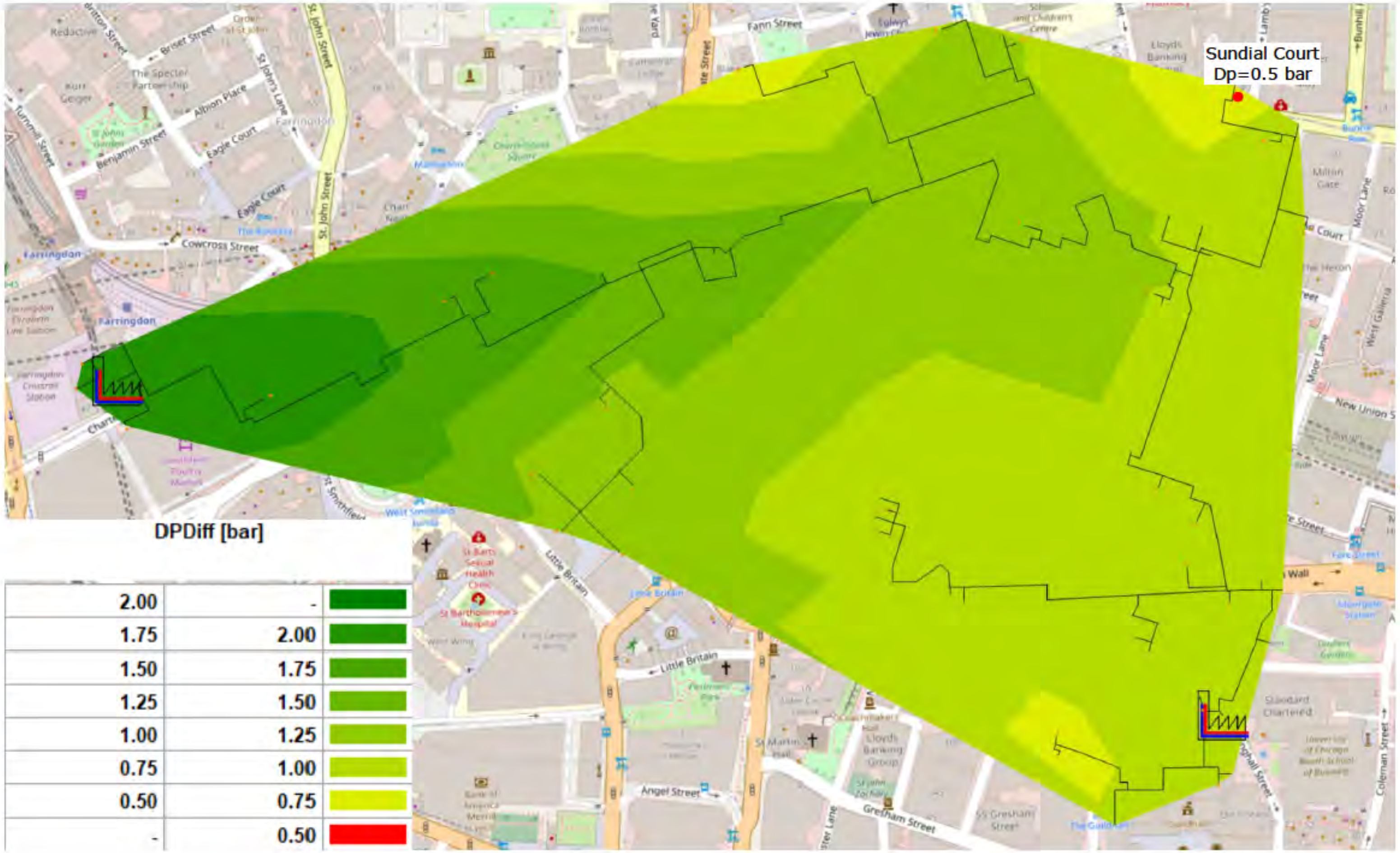
Results:

- Critical node (control node) is Sundial Court (0.5 bar)

PRODUCTION		Citigen EC	Guildhall
Power	[kW]	**11,234**	**1900**
Flow	[kg/s]	156	56
Temp. Supply	[°C]	89	80
Temp. Return	[°C]	72	72
Press. Supply	[barg]	3.5	4.8
Press. Return	[barg]	1.5	3.9
Press. Diff.	[bar]	2.0	1.0

NETWORK		
Highest pressure	[barg]	5.2
Lowest pressure	[barg]	1.2
Lowest press. diff.	[bar]	0.5
Highest velocity	[m/s]	1.7
Highest press. gradient	[Pa/m]	262

Scenario 3A-DHN – Pressure Difference



Scenario 3A-DHN - Pumping Capacity

PRODUCTION		Citigen EC	Guildhall
Power	[kW]	11,234	1900
Flow	**[kg/s]**	**156**	**56**
Temp. Supply	[°C]	89	80
Temp. Return	[°C]	72	72
Press. Supply	[barg]	3.5	4.8
Press. Return	[barg]	1.5	3.9
Press. Diff. (DCN only)	[bar]	2.0	1.0
Press. Diff. (EC+DCN)	**[bar]**	**3.5***	**2.5***

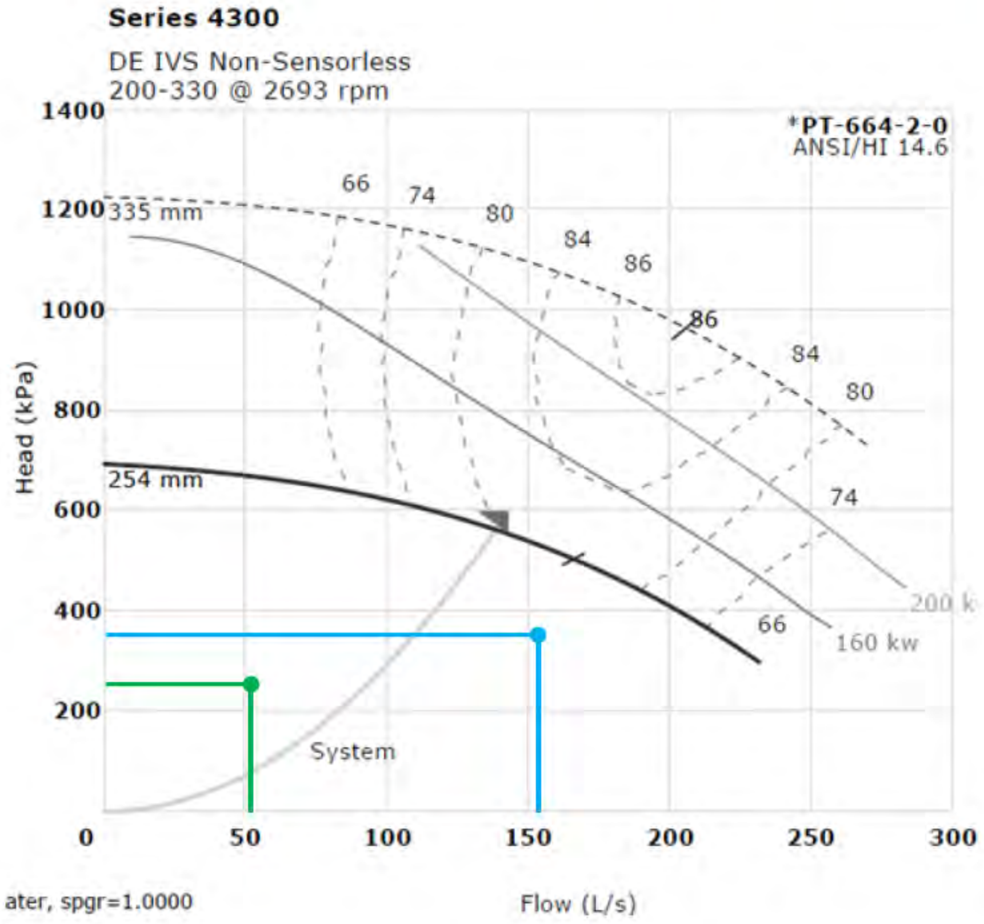
* 1.5 bar pressure drop is assumed inside the EC (production, valves, etc.)

Model: Series Design Envelope 4300 2033-160.0

Project name:		**Representative:**	
Location:		**Phone number:**	
Date submitted:	10/7/2022 6:46 AM	**e-mail:**	
Engineer:		**Submitted by:**	

Application design data

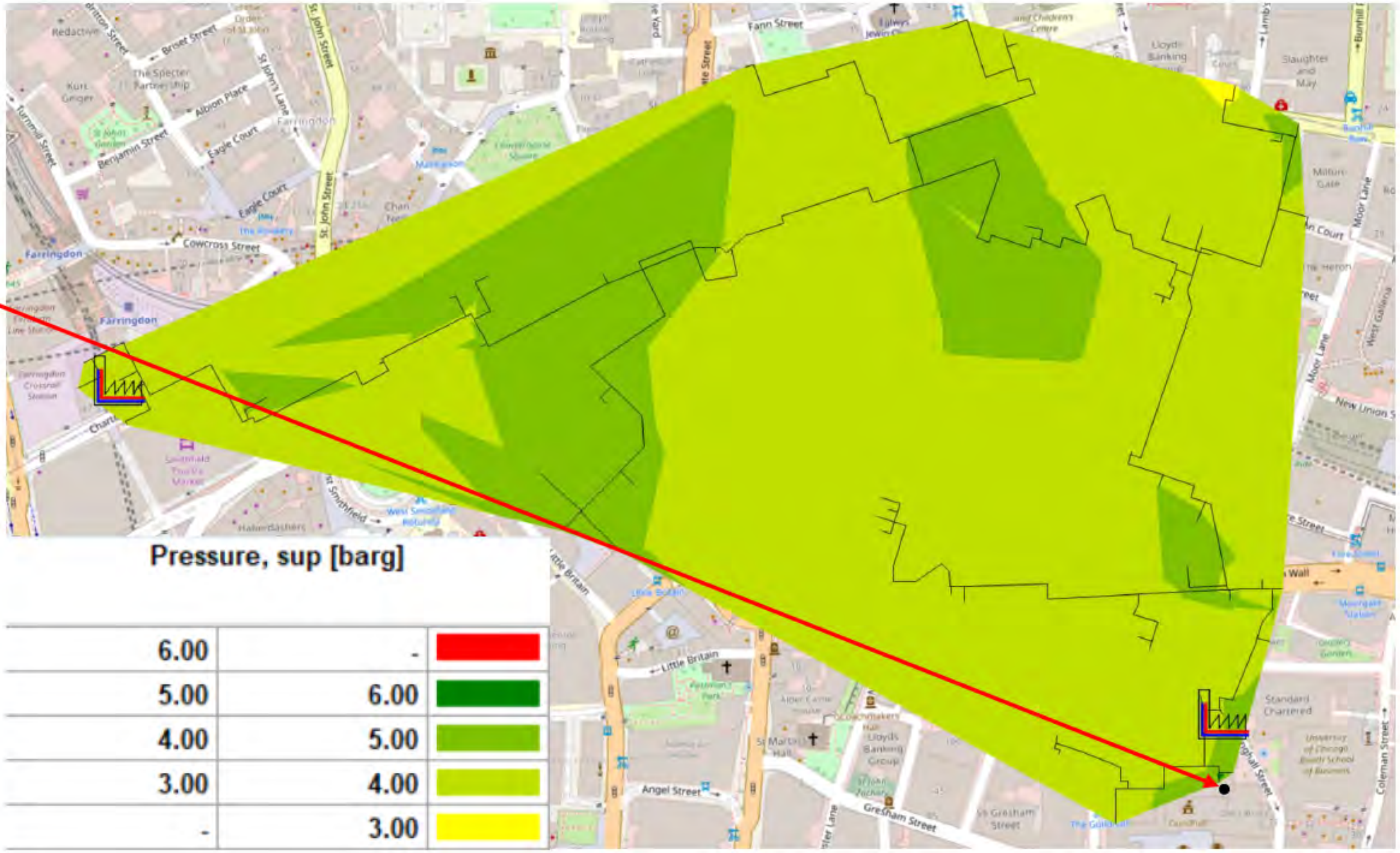
Tag number:	44402	Configuration:	Single
Service:		Suction pressure:	0 ft
Location:		Fluid:	Non-Potab
Qty:	1	Operating temperature:	16 °C
Total system flow:	143 L/s	Duty flow per pump:	143 L/s
System head:	600 kPa	Viscosity:	31 SSU
Environment:	Indoors	Specific gravity:	1.0000
Total dissolved solids:	0 ppm	Safety factor % flow:	0 %
Efficiency at Design:	84.28 %	Safety factor % head:	0 %
NPSHR:	121.02 kPa	Absorbed Power/BHP:	101.7 kW
Min. maintained system pressure*:	240 kPa	Impeller diameter:	254 mm



Results:

- Highest supply pressure:
  5.2 barg (right before Guildhall, corresponds to a low elevation point (-4.7 m)

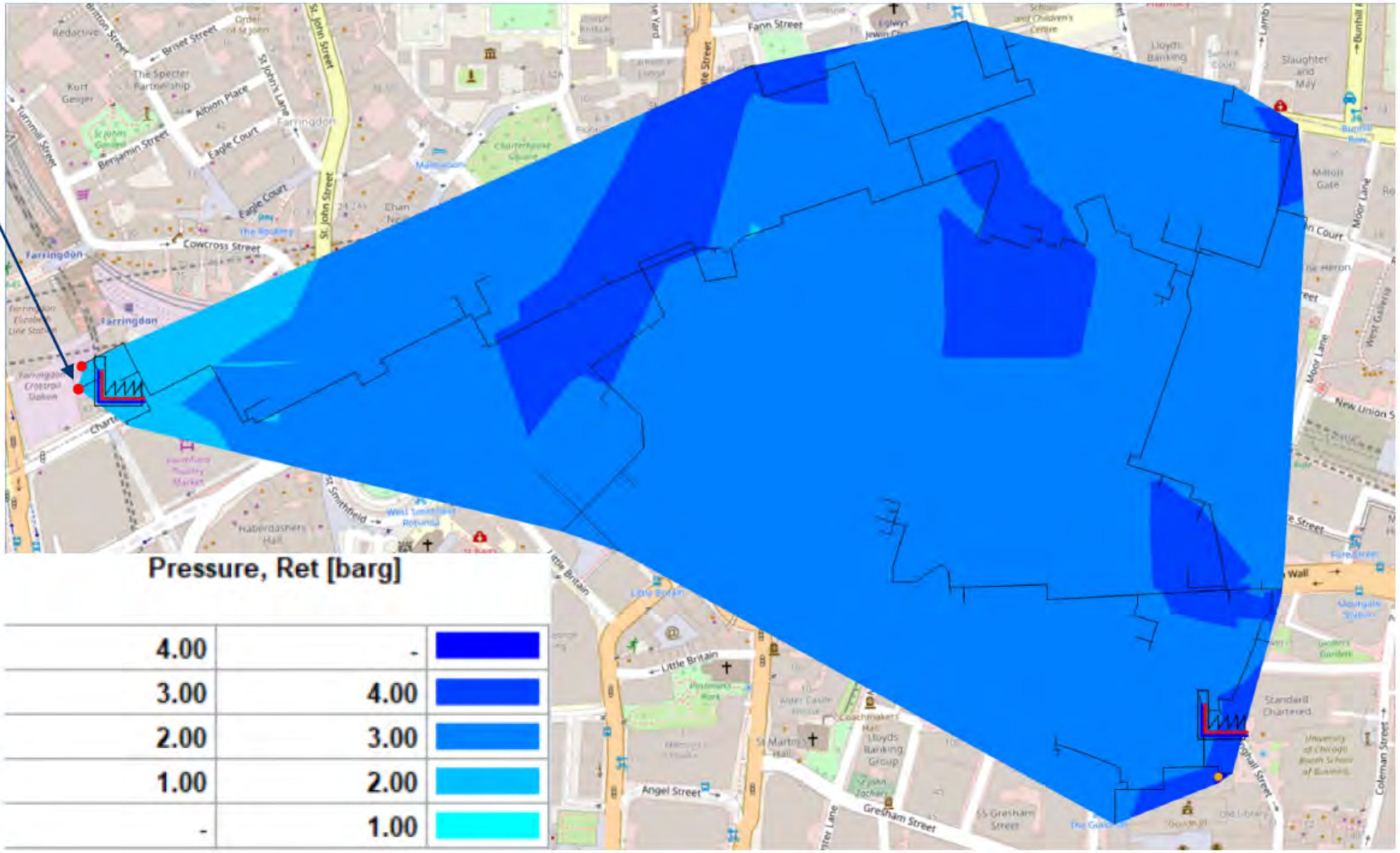
Scenario 3A-DHN – Supply Pressure



Results:

- Lowest return pressure: 1.2 barg (Farringdon West Bloom and 33 Charterhouse)

Scenario 3A-DHN – Return Pressure



Pressure, Ret [barg]

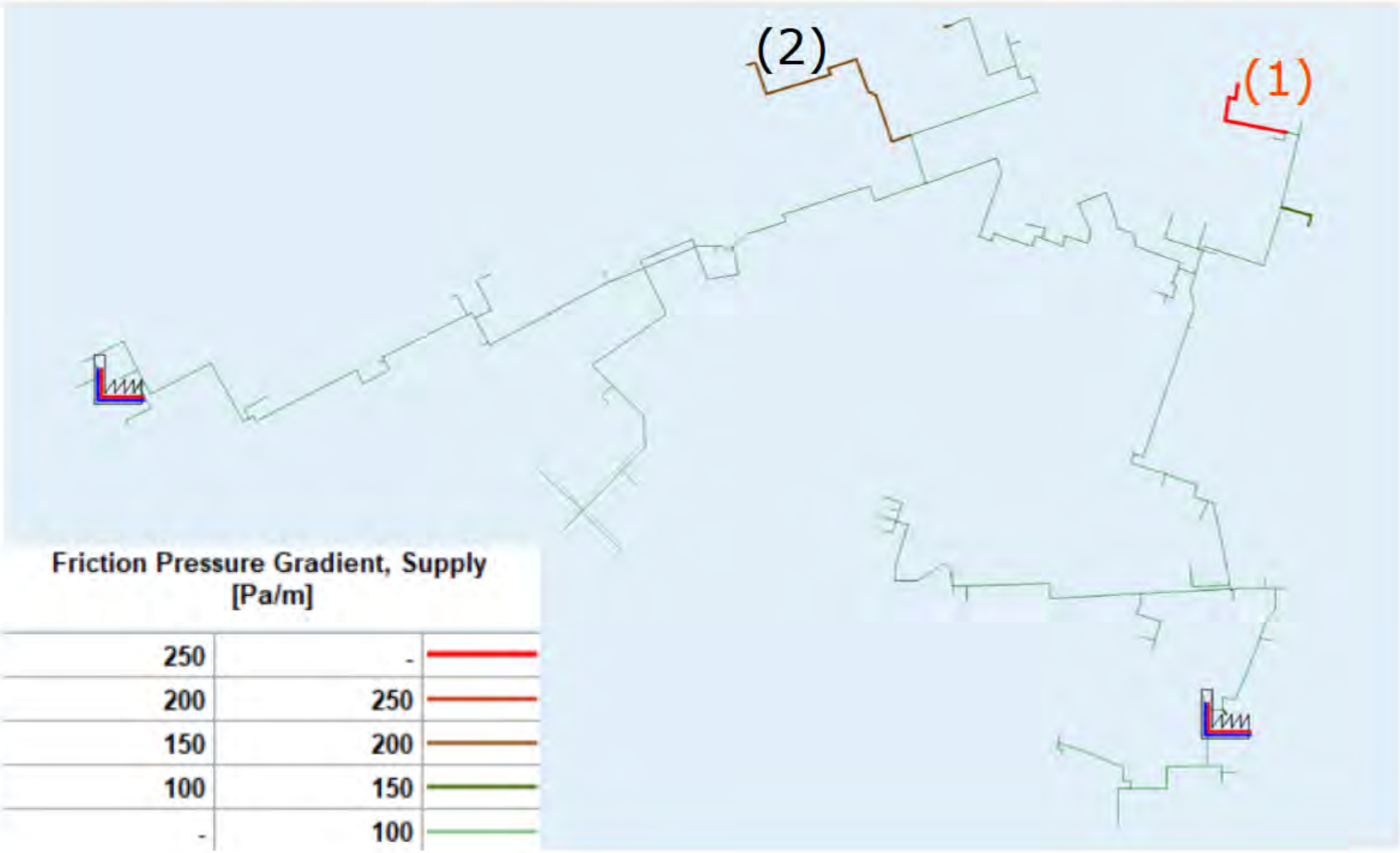
4.00	-	
3.00	4.00	
2.00	3.00	
1.00	2.00	
-	1.00	

Scenario 3A-DHN – Pressure Drop Gradient

Results (same as in 2A-DHN)

- The highest pressure gradients are found in
  - DN65 to Sundial Court (261 Pa/m; 1.3 m/s); **(1)**
  - DN80 to 2 Fann Street (Blake Tower) (152 Pa/m; 1.0 m/s) **(2)**

(same as in 2A-DHN)

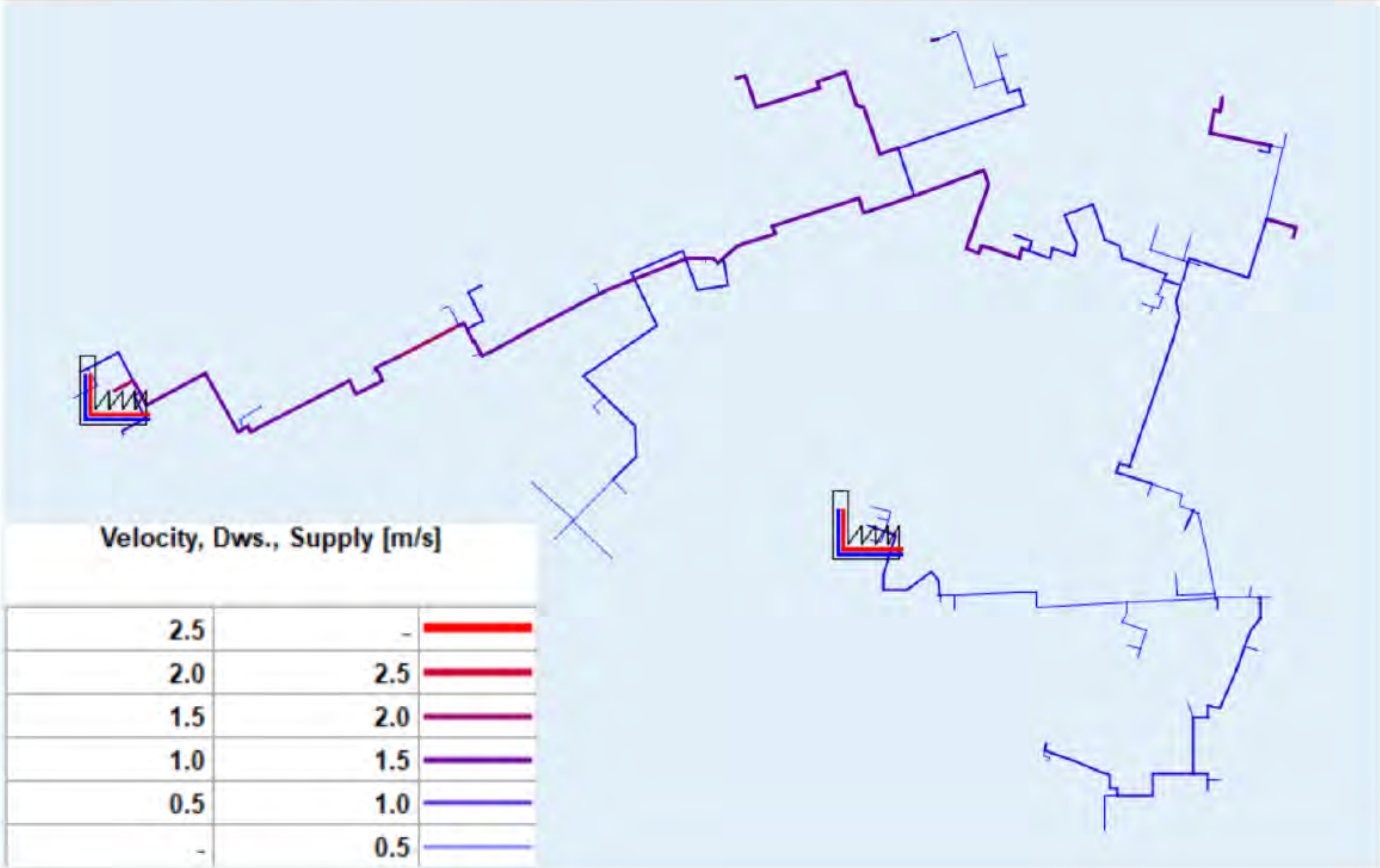


Results: (same as in 2A-DHN)

- The highest velocity is at the DN350 internal to the Citigen EC (1.7 m/s)

(same as in 2A-DHN)

Scenario 3A-DHN – Velocity



Scenario 3A-DHN - Summary

No major criticalities are observed in this scenario

The DN65 to Sundial Court has a relatively high pressure gradient (261 Pa/m).

Sundial Court is the critical point in the model.

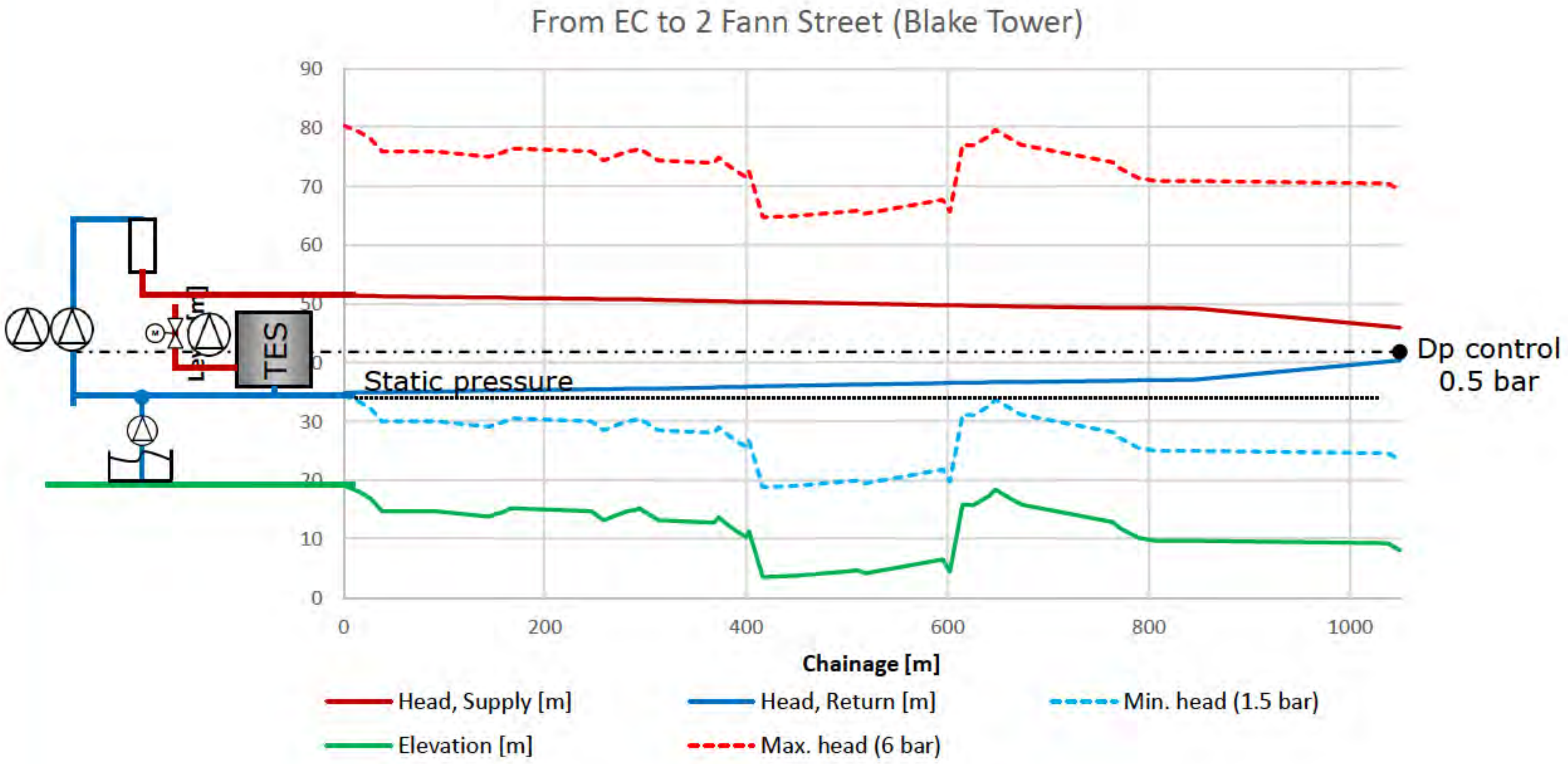
The flow is impacted by the performance of the building. If the performance can be improved the flowrate can drop resulting in a lower pressure drop gradient and lower supply pressure required at the central plant.

Scenario 3B-DHN
1.9 MW from Guildhall +
0.6 MW from LWW

(Bastion House and MoL are removed)

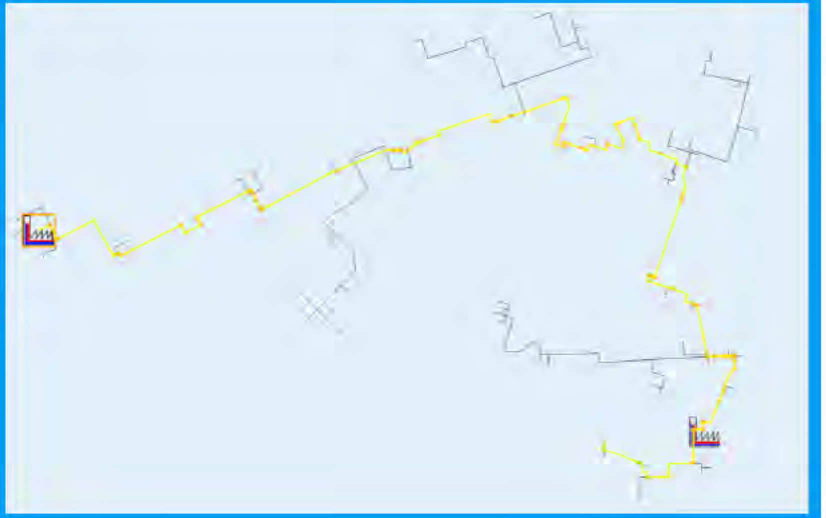
- Assumed pressure drop within EC: 1.5 bar

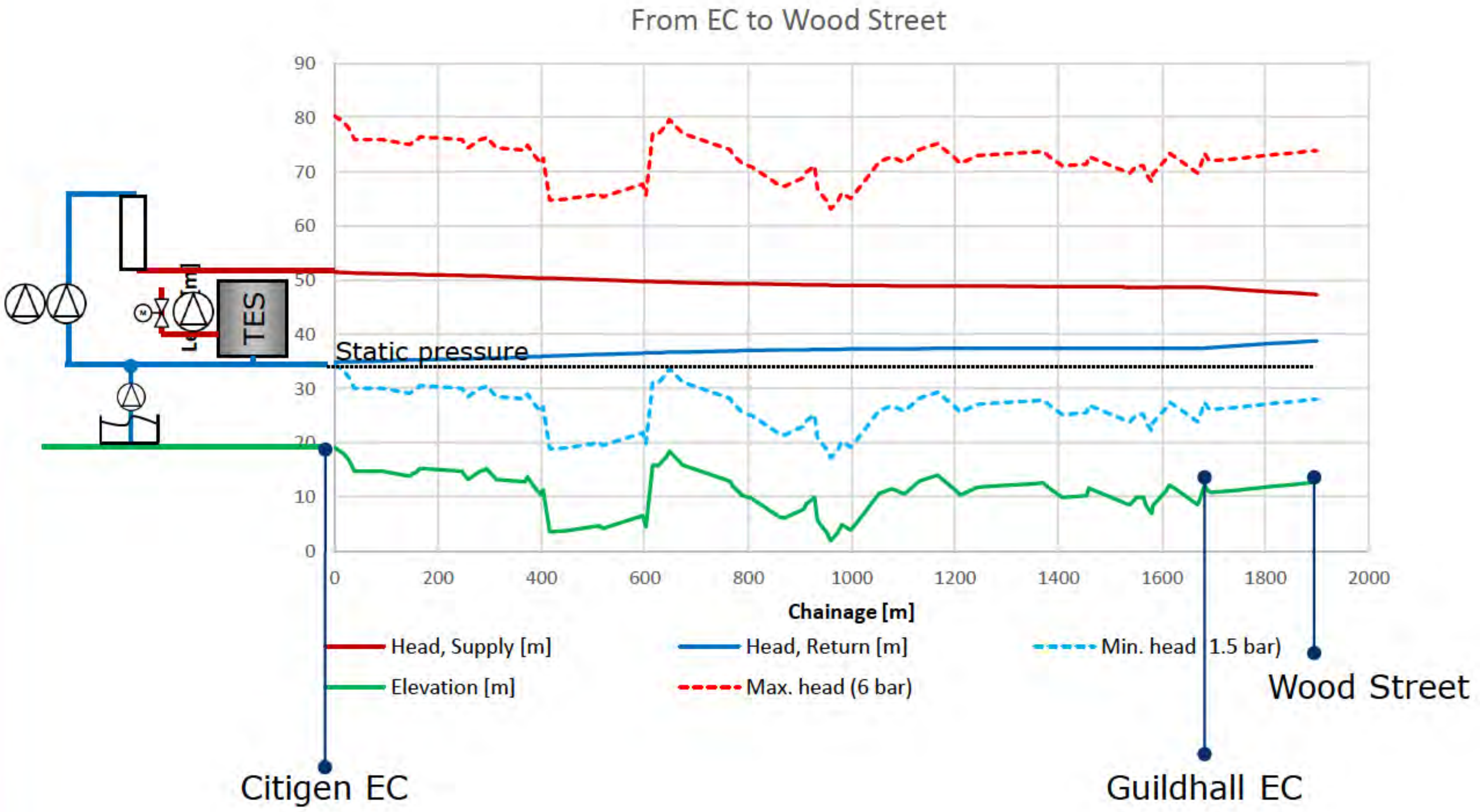
Scenario 3B-DHN – Head Profile: Citigen EC to 2 Fann Street (critical node)



Scenario 3B-DHN – Head Profile: Citigen EC to Wood Street

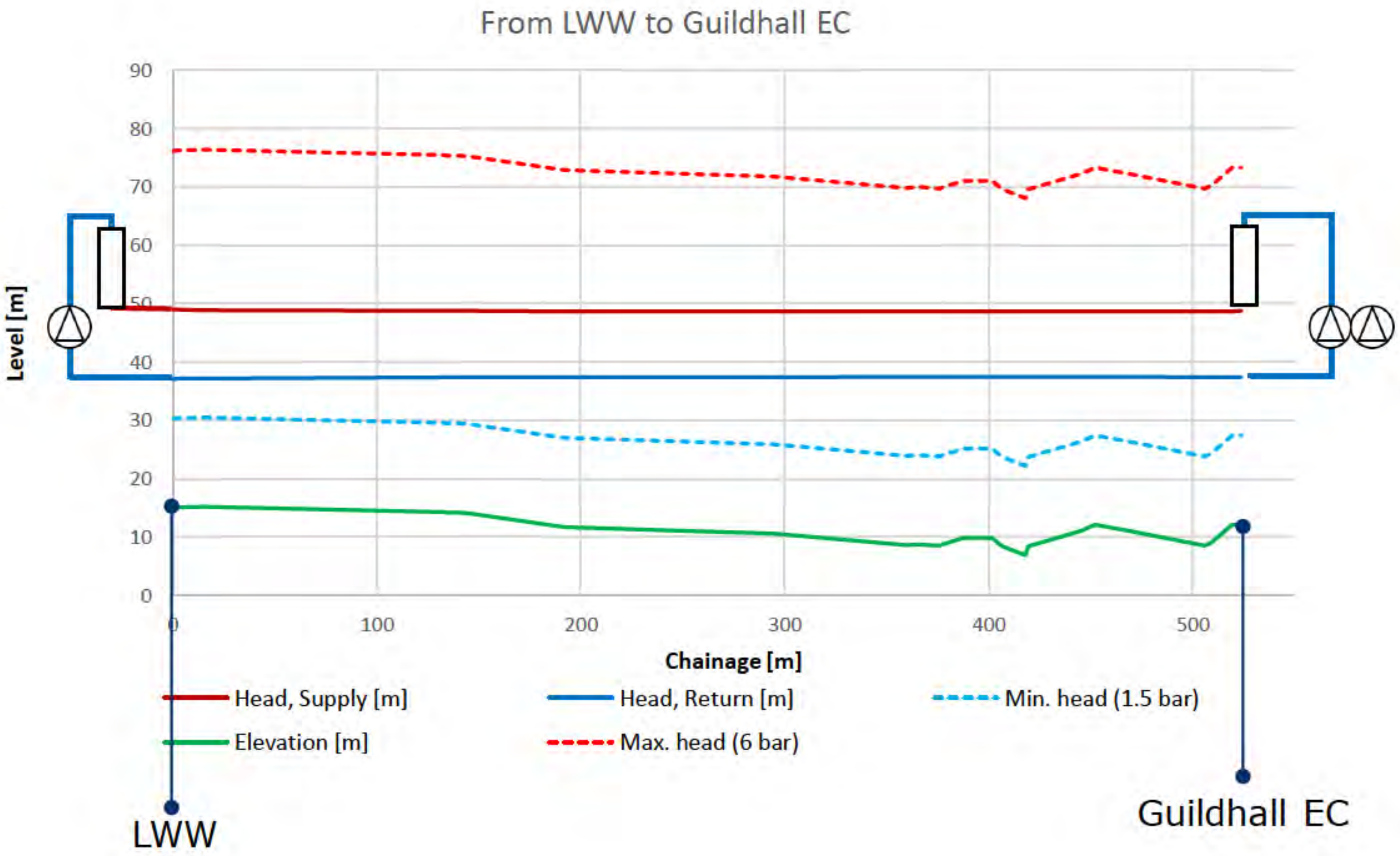
- Assumed pressure drop within EC: 1.5 bar
- Critical node: 2 Fann Street (0.5 bar Dp)





Scenario 3B-DHN – Head Profile: LWW to Guildhall EC

- Assumed pressure drop within EC: 1.5 bar
- Critical node: 2 Fann Street (0.5 bar Dp)



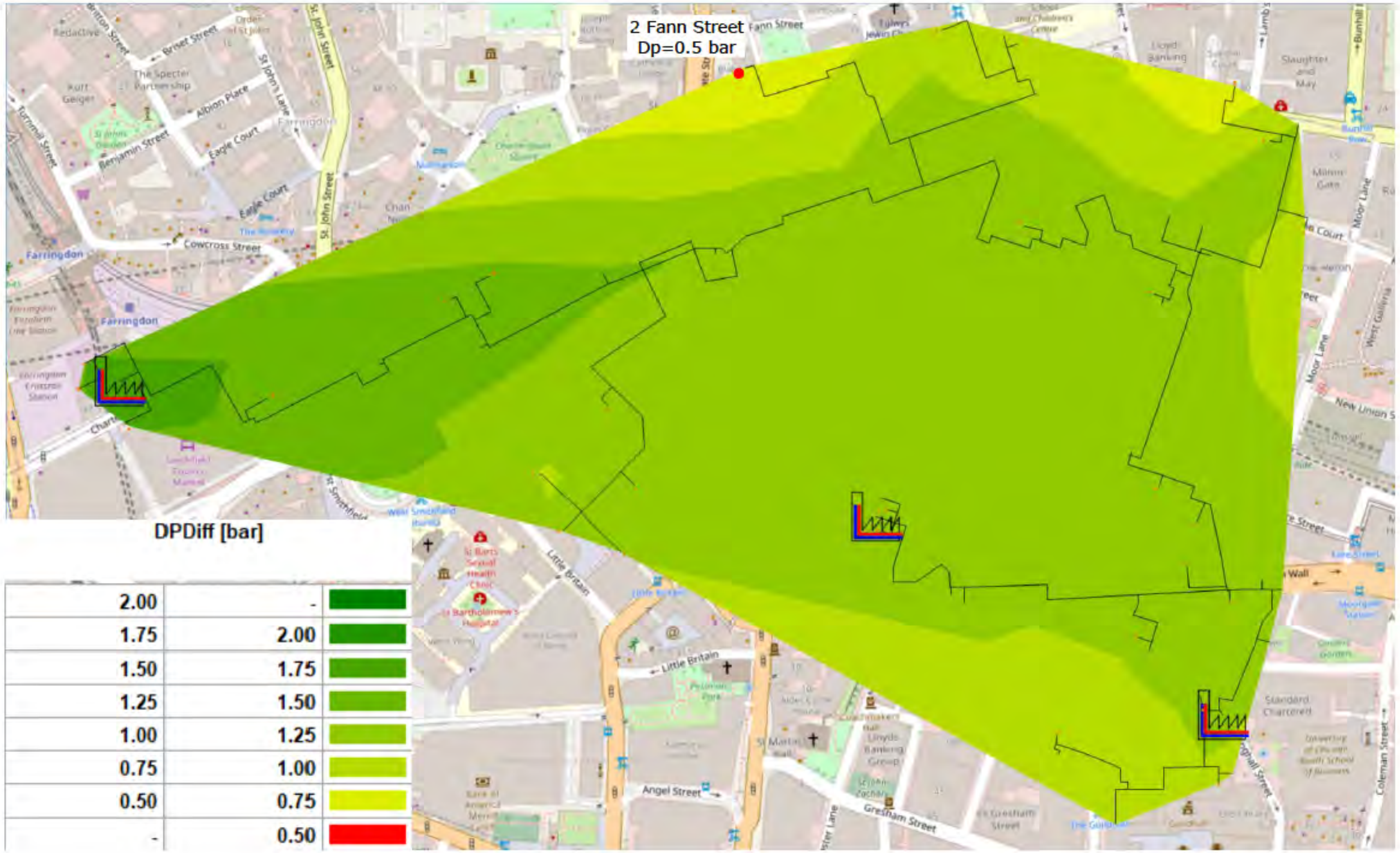
Scenario 3B-DHN – Pressure Difference

Results:

- Critical node (control node) is 2 Fann Street (Blake Tower): 0.5 bar

PRODUCTION		Citigen EC	Guildhall	LWW
Power	[kW]	**8998**	**1900**	**600**
Flow	[kg/s]	125	56	18
Temp. Supply	[°C]	89	80	80
Temp. Return	[°C]	72	72	72
Press. Supply	[barg]	3.1	4.7	3.2
Press. Return	[barg]	1.5	3.6	2.1
Press. Diff.	[bar]	1.6	1.1	1.1

NETWORK		
Highest pressure	[barg]	5.0
Lowest pressure	[barg]	1.2
Lowest press. diff.	[bar]	0.5
Highest velocity	[m/s]	1.7
Highest press. gradient	[Pa/m]	263



Scenario 3B-DHN - Pumping Capacity

PRODUCTION		Citigen EC	Guildhall	LWW
Power	[kW]	8998	1900	600
Flow	**[kg/s]**	125	56	18
Temp. Supply	[°C]	89	80	80
Temp. Return	[°C]	72	72	72
Press. Supply	[barg]	3.1	4.7	3.2
Press. Return	[barg]	1.5	3.6	2.1
Press. Diff. (DCN only)	[bar]	1.6	1.1	1.1
Press. Diff. (EC+DCN)	**[bar]**	3.1*	2.6*	2.6*

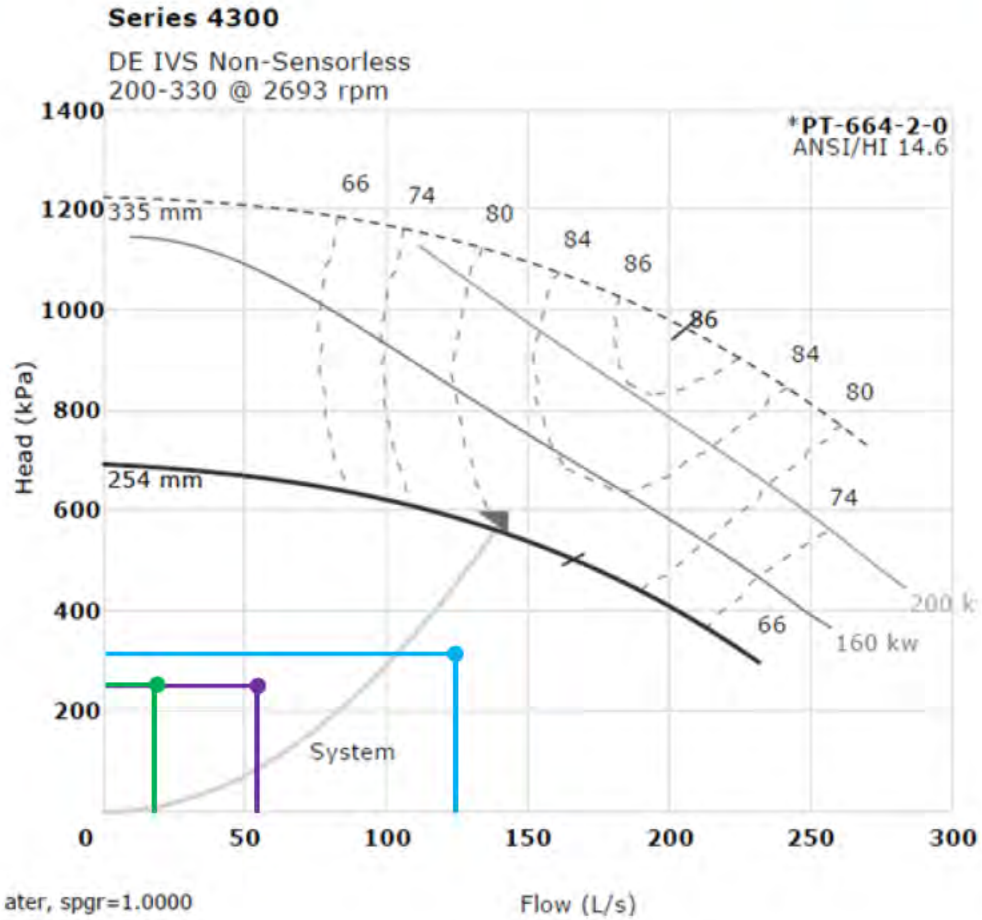
* 1.5 bar pressure drop is assumed inside the EC (production, valves, etc.)

Model: Series Design Envelope 4300 2033-160.0

Project name:		**Representative:**	
Location:		**Phone number:**	
Date submitted:	10/7/2022 6:46 AM	**e-mail:**	
Engineer:		**Submitted by:**	

Application design data

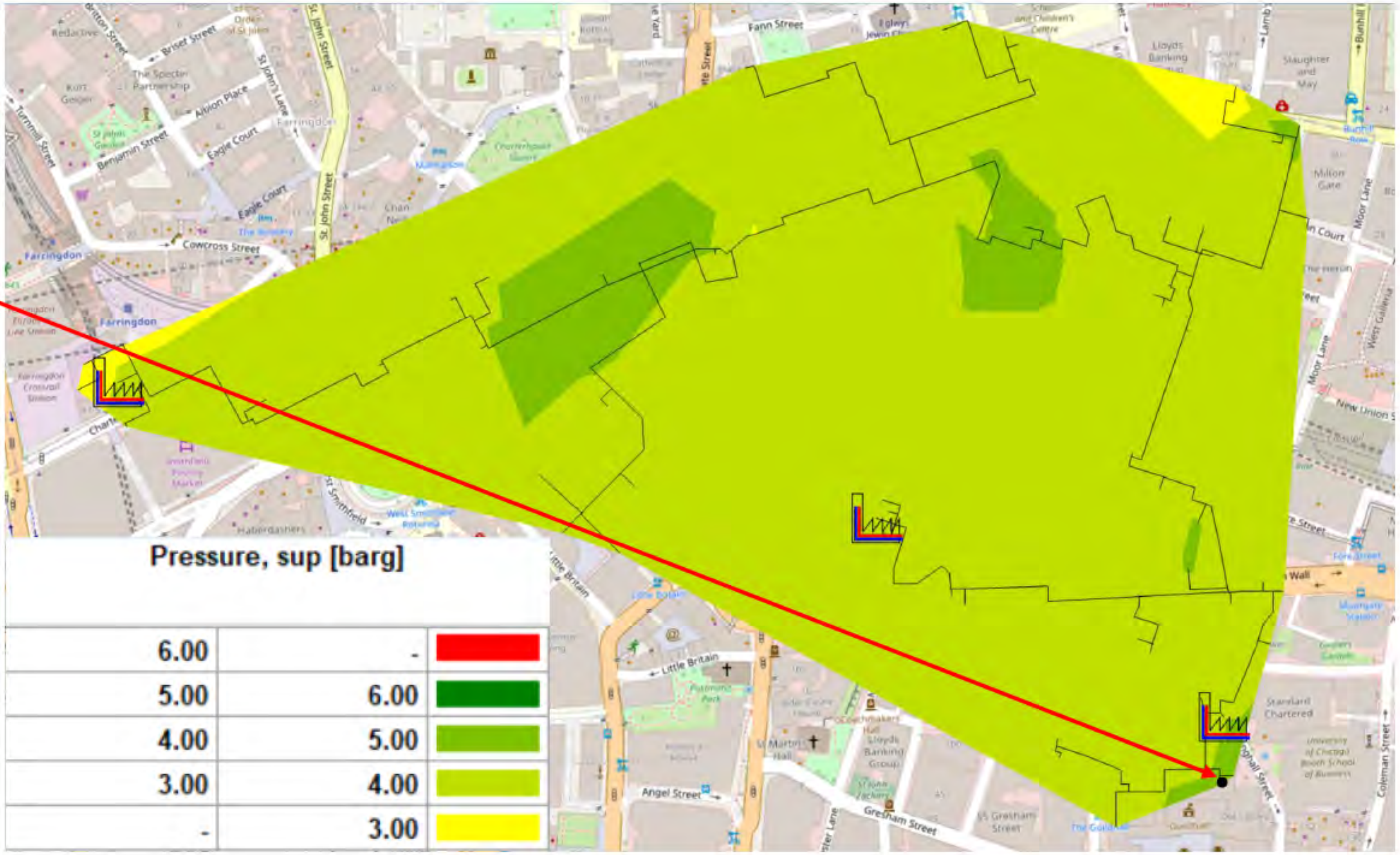
Tag number:	44402	Configuration:	Single
Service:		Suction pressure:	0 ft
Location:		Fluid:	Non-Potab
Qty:	1	Operating temperature:	16 °C
Total system flow:	143 L/s	Duty flow per pump:	143 L/s
System head:	600 kPa	Viscosity:	31 SSU
Environment:	Indoors	Specific gravity:	1.0000
Total dissolved solids:	0 ppm	Safety factor % flow:	0 %
Efficiency at Design:	84.28 %	Safety factor % head:	0 %
NPSHR:	121.02 kPa	Absorbed Power/BHP:	101.7 kW
Min. maintained system pressure*:	240 kPa	Impeller diameter:	254 mm



Results:

- Highest supply pressure:
  5.0 barg (right before Guildhall, corresponds to a low elevation point (-4.7 m)

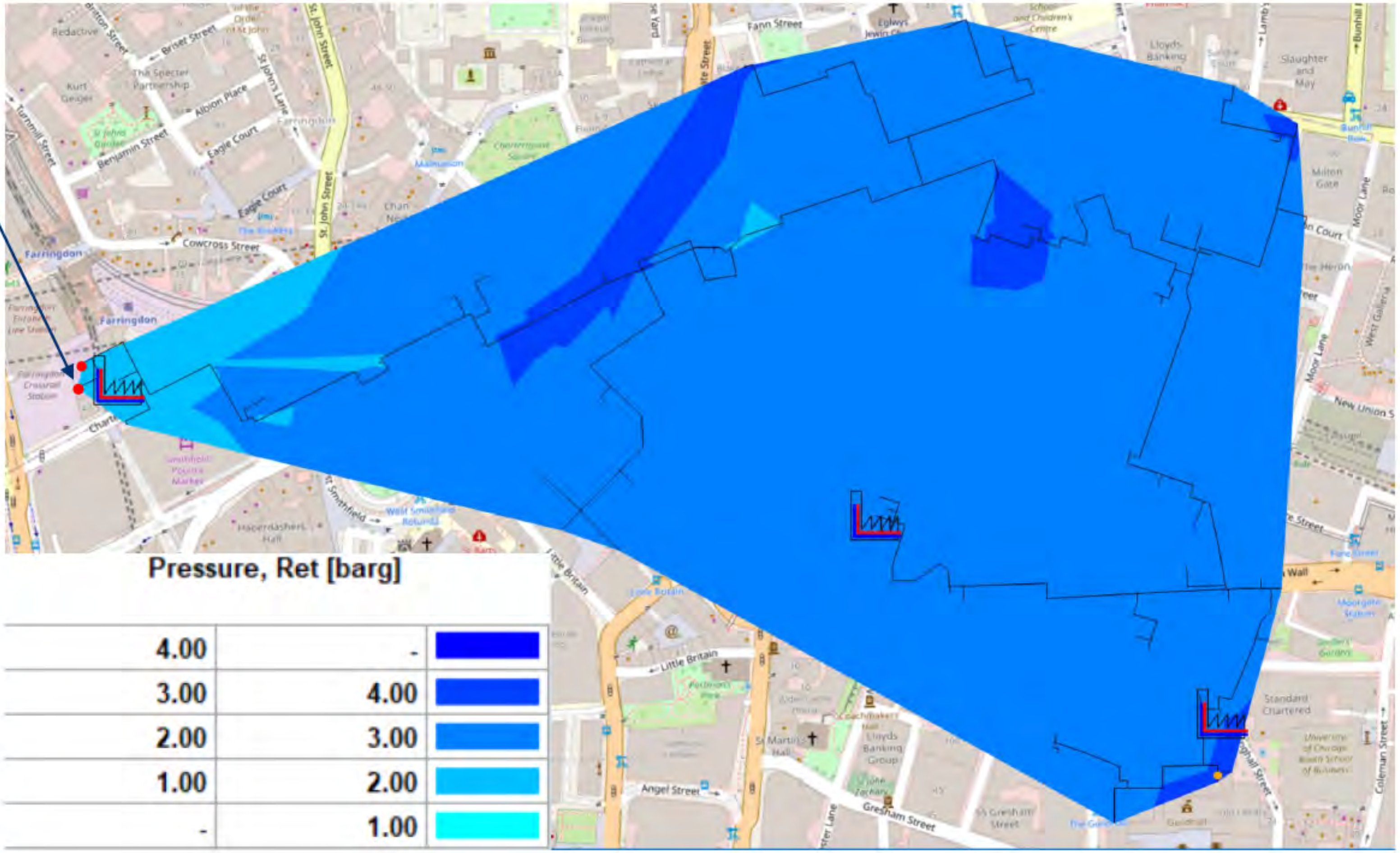
Scenario 3B-DHN – Supply Pressure



Results:

- Lowest return pressure: 1.2 barg (Farringdon West Bloom and 33 Charterhouse)

Scenario 3B-DHN – Return Pressure

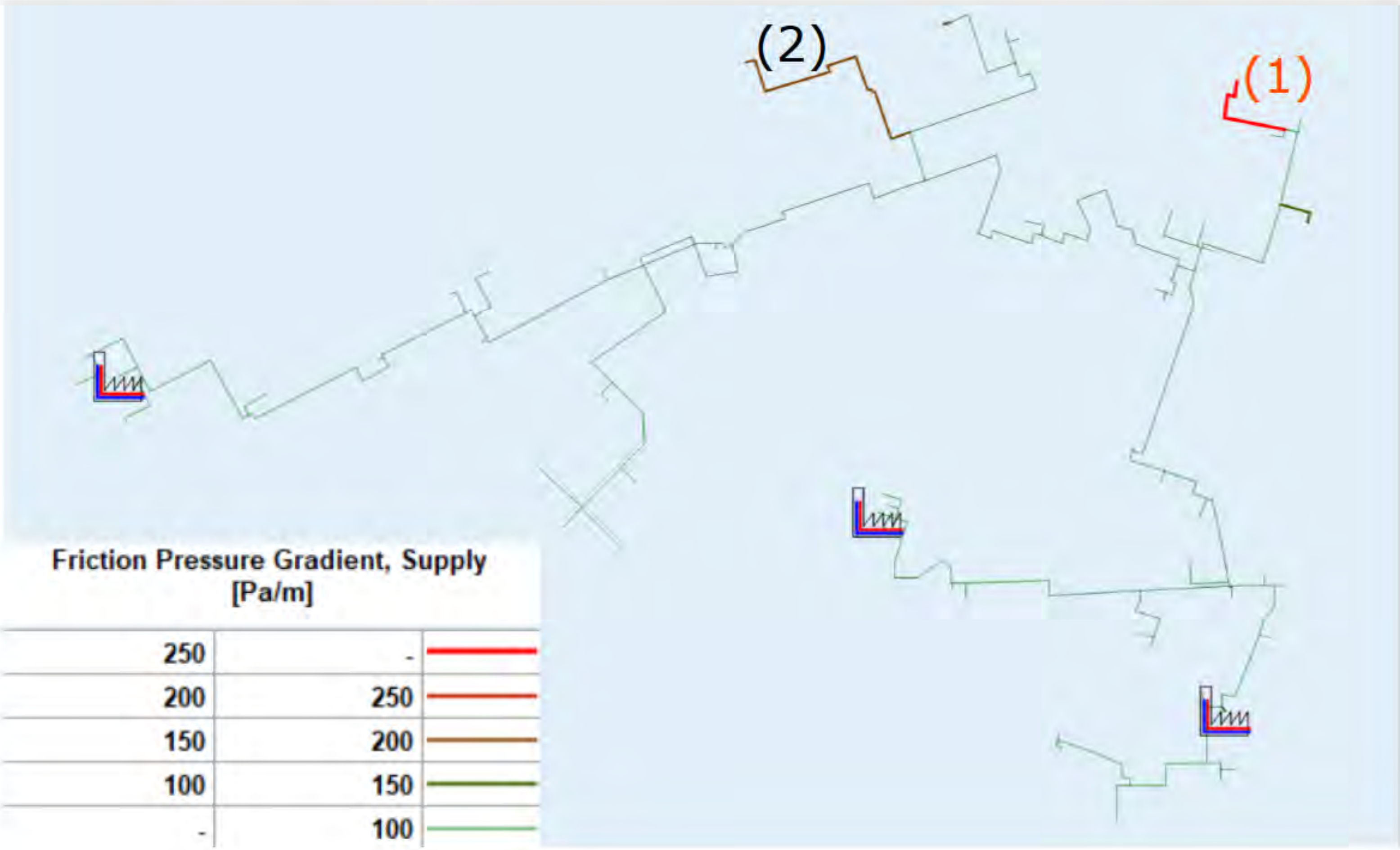


Results

- The highest pressure gradients are found in
  - DN65 to Sundial Court (263 Pa/m; 1.3 m/s); **(1)**
  - DN80 to 2 Fann Street (Blake Tower) (153 Pa/m; 1.0 m/s) **(2)**

(same as in 2A-DHN)

Scenario 3B-DHN – Pressure Drop Gradient

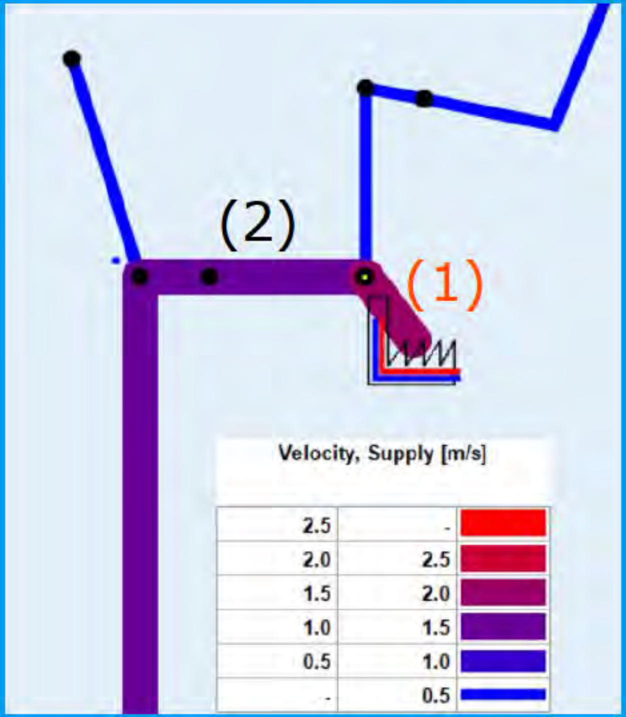


Friction Pressure Gradient, Supply [Pa/m]

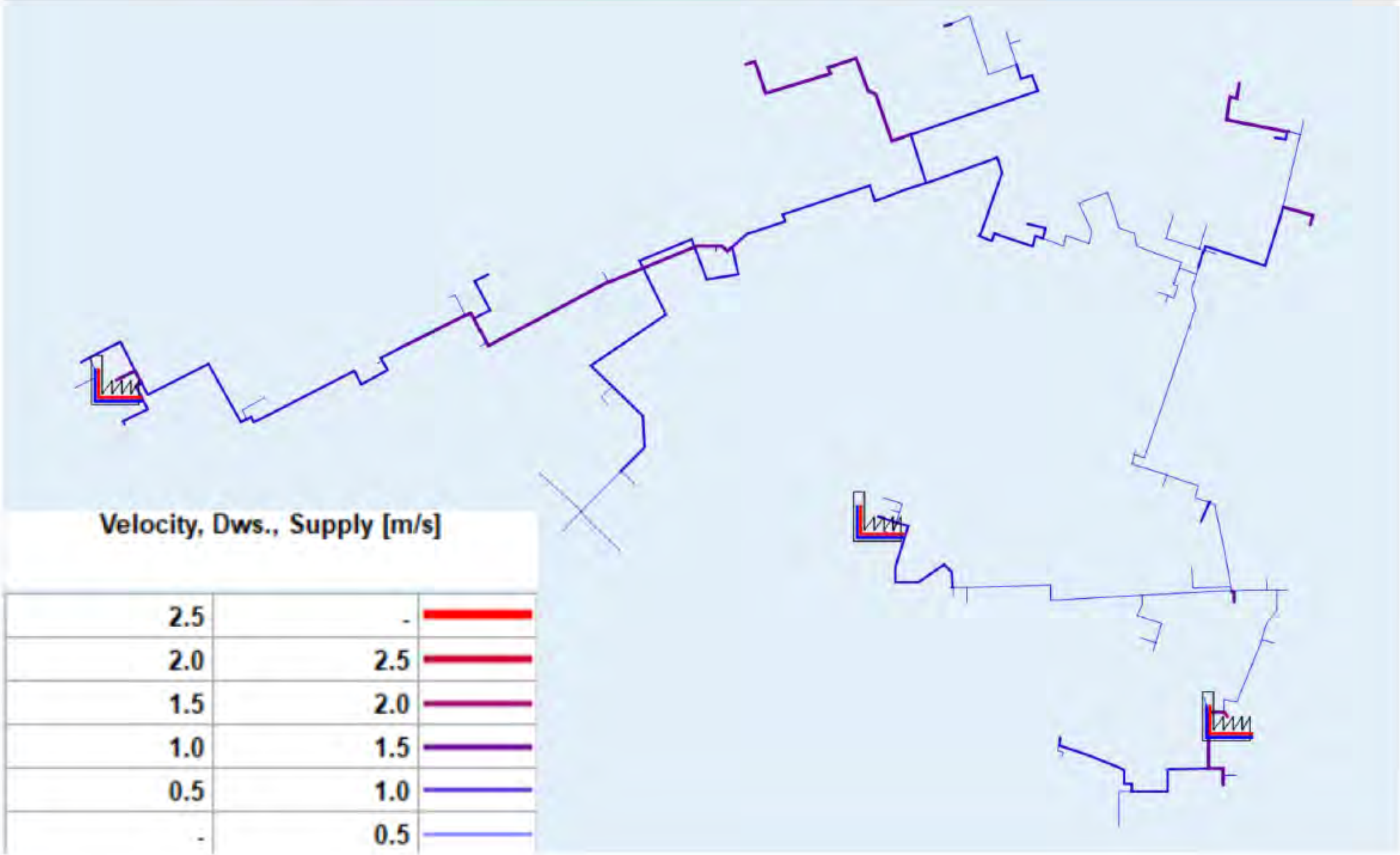
250	-	red
200	250	orange-red
150	200	brown
100	150	dark green
-	100	light green

Results:

- The highest velocity is at the <u>assumed</u> DN200 connecting Guildhall EC to the existing network (1.7 m/s) (1)
- Else, it is 1.5 m/s at the DN200 downstream of Guildhall EC toward Guildhall Yard East (2)



Scenario 3B-DHN – Velocity



Scenario 3B-DHN - Summary

No major criticalities are observed in this scenario

The DN65 to Sundial Court has a relatively high pressure gradient (261 Pa/m).

Sundial Court is no longer the critical point (2 Fann Street) in the model, so it does not impact the pressure level in the system

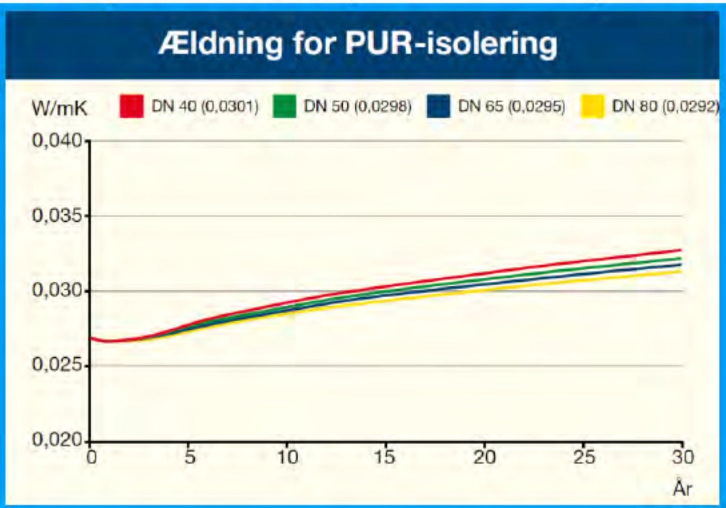
Carbon reduction potential – heat losses

Thermal losses DHN

Heat losses from DHN:

- cylindrical conduction
  -> no thermal bridges
- nominal heat loss coefficient
  -> no age effect

DN	Trench length, m	Heat loss coef. W/K/m_pipe	Heat loss, W/K
DN 65	114	0.231	53
DN 80	208	0.243	101
DN 100	716	0.252	361
DN 125	131	0.295	77
DN 150	880	0.339	596
DN 200	536	0.356	381
DN 250	289	0.342	198
DN 300	1264	0.396	1001
DN 350	313	0.377	236
Sum	**4451**	**-**	**3005**



High temperature scenario (H3)	
Overall heat transfer coeff (supply+return), kW/K	3.0
Correction factor on heat losses (age, single losses, etc.)	1.5
Supply temperature, degC (yearly)	**96**
Return temperature, degC (yearly)	**78**
Average soil temperature, degC (yearly)	**8**
Thermal losses, kW	356
Yearly thermal losses, MWh	**3119**

Scenario 3B-DH (but with 8 degC soil)	
Overall heat transfer coeff (supply+return), kW/K	3.0
Correction factor on heat losses (age, single losses, etc.)	1.5
Supply temp (Citigen; LWW/Guildhall), degC (yearly)	**89; 80**
Return temperature, degC (yearly)	**72**
Average soil temperature, degC (yearly)	**8**
Thermal losses, kW	301
Yearly thermal losses, MWh	**2638**

15% reduction in heat losses

100 tonCO_2/year saved

Assume constant temperature ”mapping” over the year

Carbon Savings

- Heat Losses:
  - Annual heat losses with the original temperatures are estimated to be: 3.2 GWh
  - Annual heat losses with the reduced temperatures are estimated to be: 2.6 GWh
  - This is roughly 600 MWh of heat saved, which is circa. 15%
  - This is equivalent of 100 tonCO2/yr*

- GSHP COP improvement:
  - It is anticipated the temperatures can be reduced to 80 degC supply (from 90 degC) and 72 degC return
  - The anticipated HP COP improvement is 8% (the COP will roughly increase from 2.6 to 2.8)
  - This is circa. 220 MWh/yr of electricity saved, which is equivalent to 30 tonCO2/yr

- Volta Data Centre:
  - From Volta waste heat roughly 50 GWh of heat can be supplied to Citigen
  - To generate 50 GWh of heat from the Volta, roughly 13 GWh of electricity is required (COP of 4)
  - 13 GWh of electricity is equivalent to 1,800 tonCO2;
  - To generate 50 GWh of heat Citigen would emit 10,500 tonCO2
  - The carbon savings are estimated to be 8,700 tonCO2/yr*

*Current Citigen Carbon Factor is 210 kgCO2/MWh

Royal Borough of Greenwich
Bill Walden House
Low carbon technology feasibility

Dr Gabriel Gallagher
Omied Khakshour
June 2020

Sustainable ENERGY

Scope of work

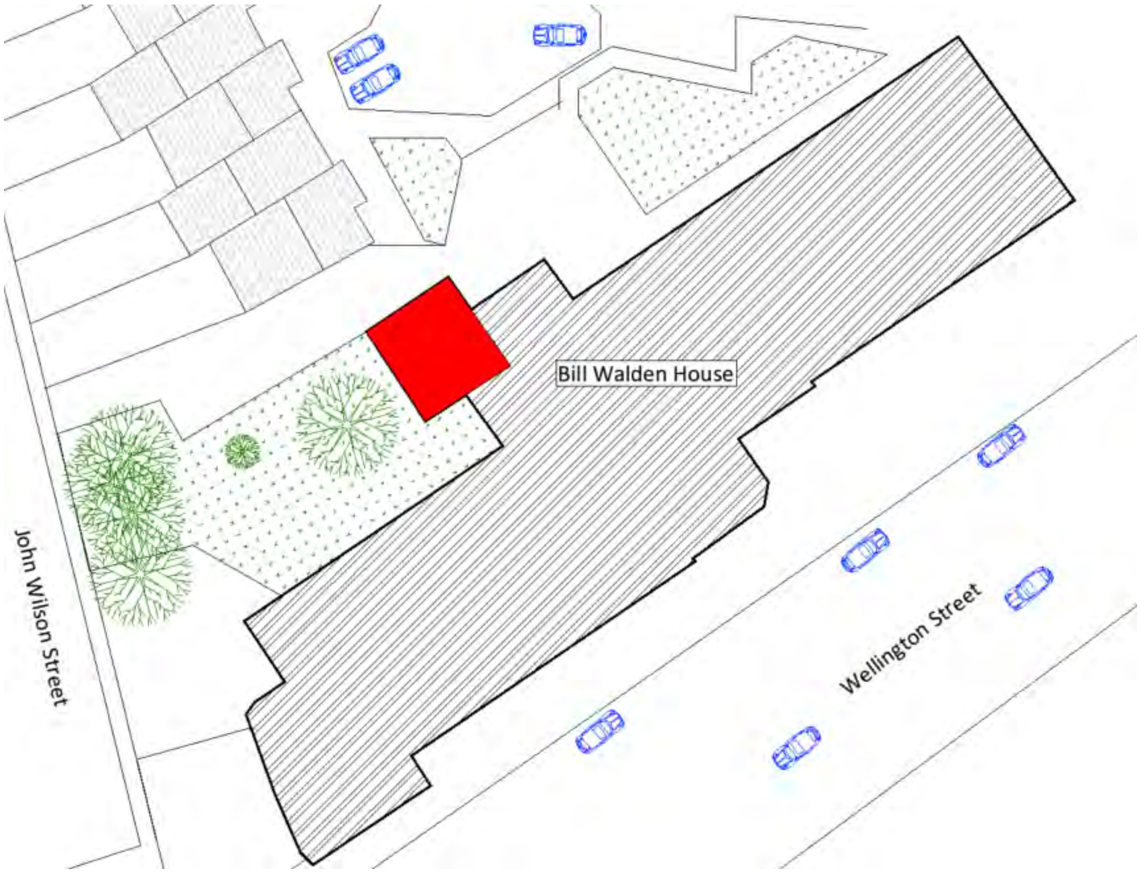
- To assess low carbon / renewable heating options for social housing
- Model heat and hot water demands for different levels of fabric improvements to inform sizing of new system
- Review and propose solutions for secondary heating and hot water systems
- Develop concept designs for refurbishment of energy centre with low carbon heating

ROYAL borough of GREENWICH

Sustainable ENERGY

Summary of Bill Walden House

- 42 dwellings in sheltered accommodation
- Central heating system plant in ground floor plant room
- Existing LTHW (82°C flow / 71°C return) communal heating system supplies radiators and communal hot water cylinder provides DHW



Design considerations

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- To ensure correct specification of low carbon heating systems – flow and return temperatures must be reduced we must:
  - Reduce radiator temperatures*
  - Increase temperature differential to reduce pipe sizes
  - Ensure peak loads are correctly estimated to prevent oversizing
  - Install heat interface units in dwellings to replace hot water cylinders
  - Maintain existing network and supply of heat to continue to provide service whilst new system is installed

* This does not mean a reduction in the potential energy supplied to each space; although, the operating temperatures are lower than existing, the new emitters will be compatible with the operating conditions and the required set points will be achieved

Heat demand profiling

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Current heat demand

- Existing gas consumption data – 748,467kWh per annum
- Existing heat demand modelled based on following assumptions:
  - Fabric to ~30 year old building regs
  - Unmetered heating controls with 23°C setpoint and 19°C set back
  - Communal DHW hot water storage tank
  - 1.5 occupants per apartment
- Heat losses from existing DHW cylinder and DHW pipework

Current heat demand

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- Fabric and ventilation loss inputs:

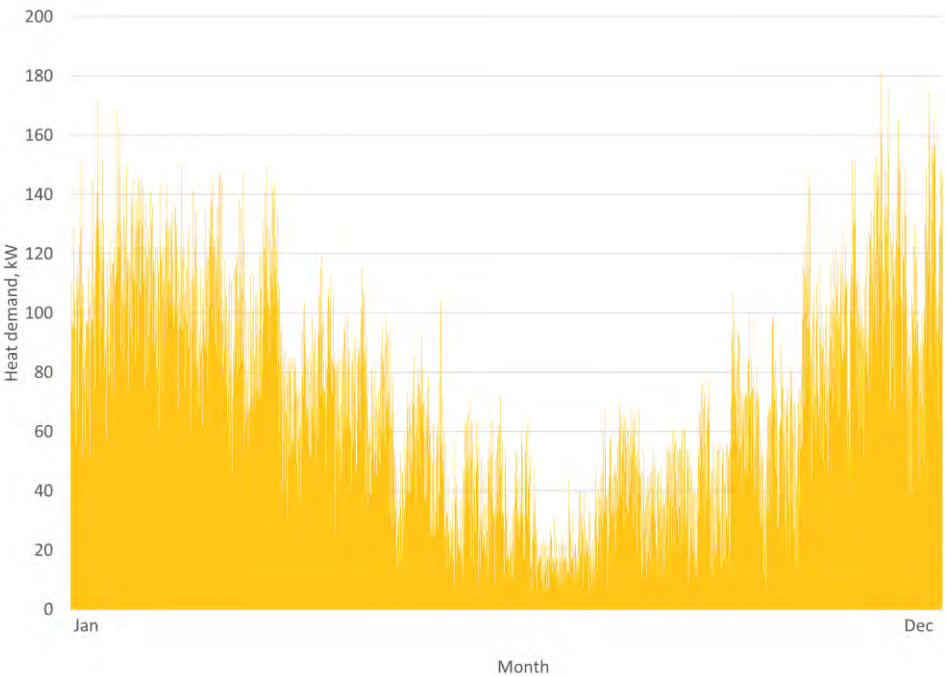
Fabric type - U-Values		
Floor	W/m^2K	0.45
Walls	W/m^2K	0.45
Glazing	W/m^2K	2.00
Roof	W/m^2K	0.25
Ventilation		
Air permeability	$m^3/h.m^2$	8

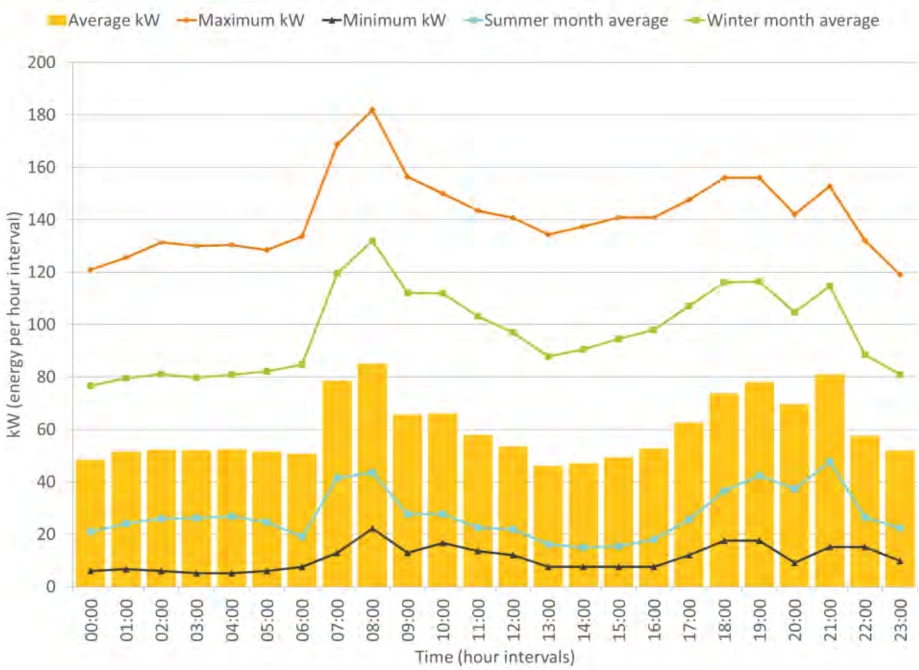
Current heat demand

- Summary of existing heat demand

Scenario	Annual Modelled Demand kWh	Peak heat kW	kWh per flat	Total kW per flat
Existing	523,968	182	12,475	4.3

- Modelled boiler efficiency of existing system – 70%





Scenario 1
Upgraded heating system demand

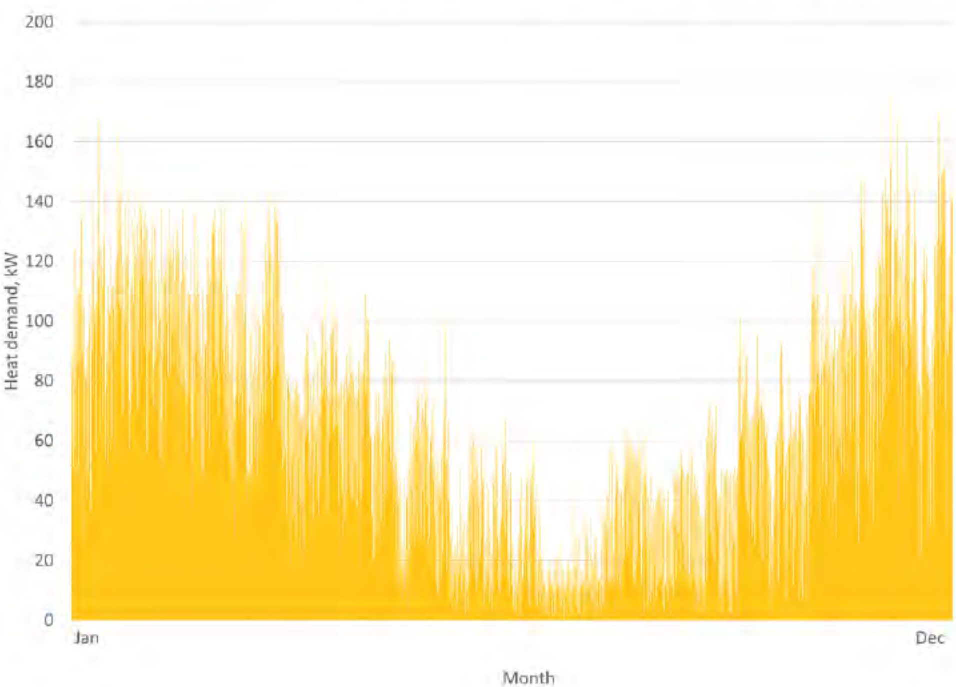
- Scenario 1 assumes:
  - No fabric changes
  - Flat fit outs for low temperature network conditions
  - Heat interface units for local heating control, metering and instantaneous hot water
  - Upgraded pipe work for the risers and laterals in each building
- The model also considers the impact of the following factors on the heat demand for the new system:
  - Assumed change in heat setting behaviour and energy usage due to the introduction of individual metering of each apartment
  - Ambient temperature controls in energy centre
  - Heating controls with a 23°C heating setpoint and 17°C set back
  - Reduction in heat losses due to the replacement of communal DHW storage tank and 4-pipe system with instantaneous plates in HIUs

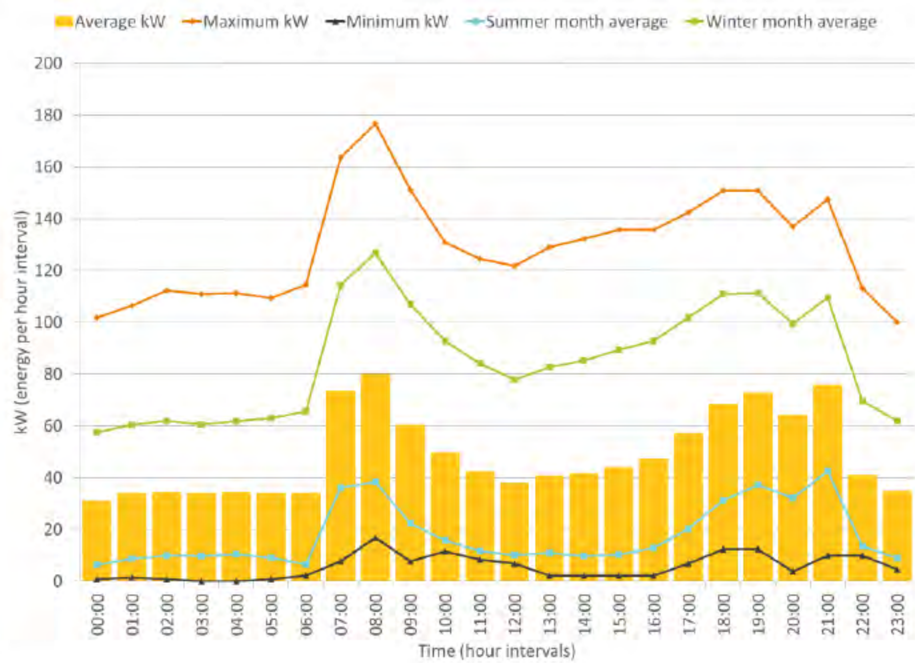
Scenario 1
Upgraded heating system demand

- Scenario 1 heat demand summary

Scenario	Annual Modelled Demand kWh	Peak heat kW	kWh per flat	Total kW per flat
1	427,320	177	10,174	4.2

- The heat demand for the site after all the above conditions are adjusted is 427,320kWh
  - 18% reduction in current heat demand





Scenarios 2,3 and 4
Fabric improvements

- As with scenario 1, scenarios 2, 3 and 4 all assume:
  - Flat fit outs for low temperature network conditions
  - Heat interface units for local heating control, metering and instantaneous hot water
  - Upgraded pipe work for the risers and laterals in each building

- With the addition of varying levels of fabric improvements as follows:
  - Scenario 2 – roof insulation improvements
  - Scenario 3 – roof insulation improvements and glazing upgrades
  - Scenario 4 – roof insulation improvements, glazing upgrades and external wall cladding

Scenarios 2,3 and 4
Fabric improvements

- Fabric improvements are to bring each element up to current retrofit/refurbishment Part L levels as below:

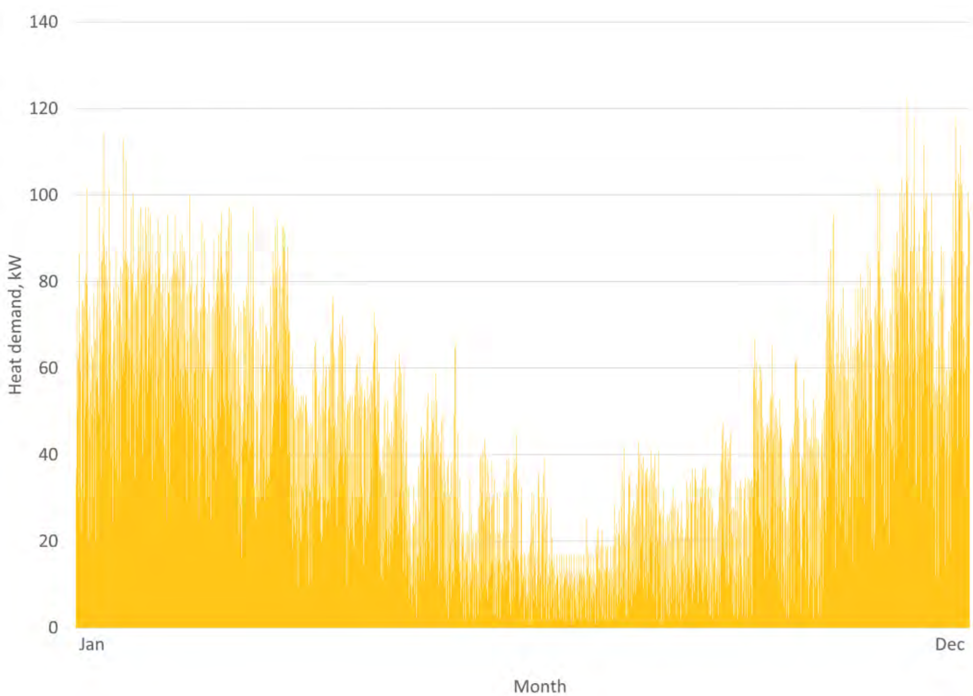
Fabric type - U-Values	Units	Scenario 1 – Existing fabric	Scenario 2 -Roof upgrade	Scenario 3 - Roof and glazing	Scenario 4 - Roof, glazing and EWI
Floor	W/m^2K	0.45	0.45	0.45	0.45
Walls	W/m^2K	0.45	0.45	0.45	0.30
Glazing	W/m^2K	2.00	2.00	1.60	1.60
Roof	W/m^2K	0.25	0.16	0.16	0.16
Ventilation					
Air permeability	$m^3/h.m^2$	8.0	7.5	6.0	5.0

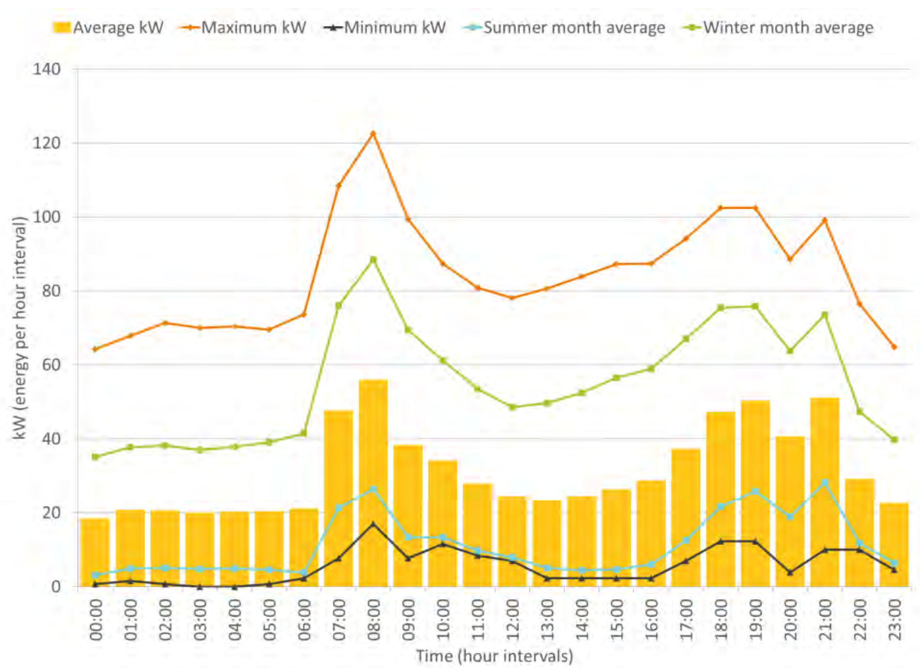
Scenario 2,3 and 4
Fabric improvements

- Summary of heat demands

Scenario	Annual Modelled Demand kWh	Peak heat kW	kWh per flat	Total kW per flat
2	399,528	167	9,513	4.0
3	354,109	151	8,431	3.6
4	274,423	123	6,534	2.9

- Annual heat demand profile and average, max, min daily profile for scenario 4





Supply options appraisal and feasibility

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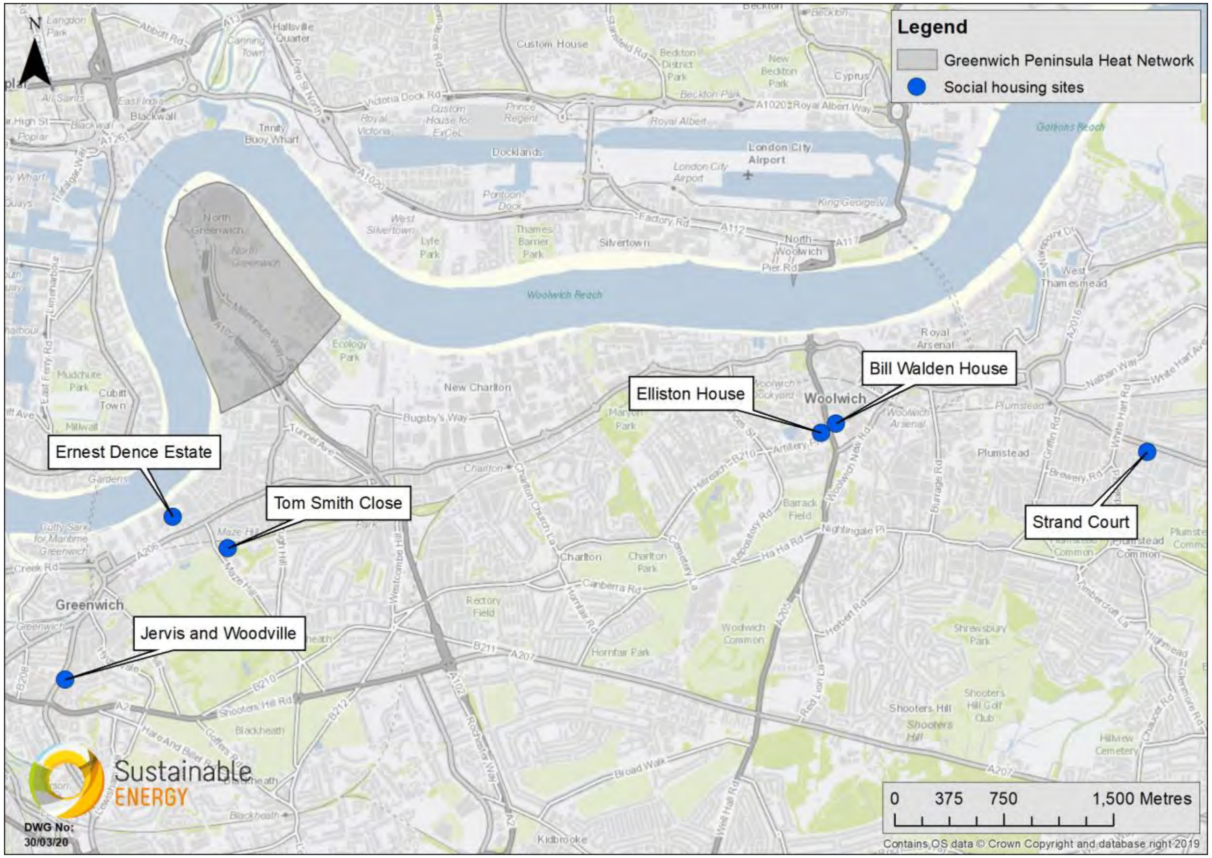
Supply options appraisal

A number of different supply options were considered for the supply of heat and electricity to Bill Walden House:

- Connection to local district heat networks
- Heat pump technologies
  - Ground source – closed loop
  - Ground source – bore hole
  - Air source
- Solar PV
- Energy storage
  - Thermal
  - Electrical

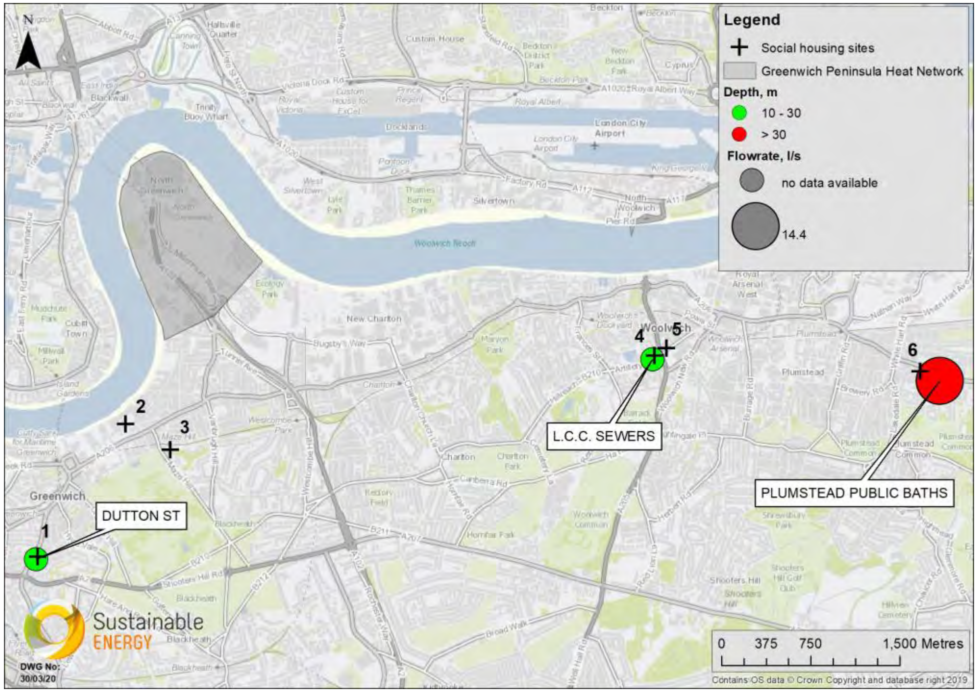
Local heat networks

- The image below shows the position of the RBG low carbon assessment sites and the location of the Greenwich Peninsula heat network
- At present there are no suitable connection points for heat supply from the existing network
- The design of the new heating systems will be compatible with connection to a large heat network if a suitable one was to become viable in the future



Ground source

- Borehole data from the national BGS resource is summarised in the GIS and table below
- Positions of gathered data is shown in the GIS
  - Colour indicated depth of bore holes
  - Width indicates flowrates measured in the bore holes
  - The assessment sites are numbered. Bill Walden House is shown at position 5



- Table with results of bore hole data

Location	Borehole name	Depth, m	Water depth, m	Flowrate, l/s	Strata details	Notes
Bill Waldon House / Elliston House 543240,178590	TQ47NW24 — L.C.C. SEWERS (M81) WOOLWICH	32.8	8.4	NA	0 - 0.91 m: Road surface and hardcore 0.91 - 5.3 m: Loam and sand 5.3 – 8.4 m: Broken shell and black silt 8.4 - 13 m: Loam 13 – 14.5 m: Yellow sand 14.5 – 15.1 m: Ballast 15.1 – 30.3 m: Fine sand 30.3 – 30.6 m: sand and flints 30.6 – 32.8 m: Chalk	Last examined in 1905

Ground source – open loop

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- There is significant risk around the open loop solution.
- No flowrate data is available for L.C.C Sewers located near Bill Walden House (site marked 5 on the image)
- A detailed hydro-geological modelling assessment would be required. This may cost in the region of £20,000.
- A trial well could be drilled into chalk aquifer but this will require significant CAPEX (upto £120,000) and there is no guarantee of a positive result.
- There is limited space for abstraction and discharge wells that are significantly separated to minimise thermal interaction. If land area cannot be found to significantly separate the wells, it is unlikely abstraction and discharge wells will be viable and so it may be possible to drill a single well where water is abstracted from one aquifer horizon and injected back to another. However, this approach is not tried and tested and detailed hydro geological modelling will be required to further assess viability as will the drilling of a test well.
- If a sufficient flowrate was found to supply the scheme then the installation would need to be ready to apply for the RHI subsidy before March 2021.
- A high level economic case for this option is shown on the next slide.

Ground source – open loop

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- A 95kW GSHP with 5,000litres thermal storage could supply 94% of the annual demand (allowing for 50weeks availability)
- A high level economic assessment is shown below:

		Current system	GSHP with Gas condensing boilers with RHI	GSHP with Gas condensing boilers without RHI
			Scenario 1	Scenario 1
Energy and carbon	**Units**			
Heat demand - Peak	kW	182	177	177
Heat annual demand	kWh	478,384	427,320	427,320
Heat annual demand - losses	kWh	45,552	-	-
Heat annual demand - Total	kWh	523,936	427,320	427,320
% heat demand low carbon	%	0%	94%	94%
25 year CO2e savings	tCO2e		1,914	1,914
First year CO2e savings, tCO2e	tCO2e		56	56
First year CO2e intensity of delivered heat	gCO2e/kWh		99	99
Build and run costs				
Capex of scheme + contingency	£		£552,564	£552,564
Fixed heat sales	£/day		1.30	1.30
Variable heat sales	p/kWh		7.50	7.50
Cost of heat to residence - annual	£		£1,238	£1,238
Payback period	Years		17	0
NPV	£		-£30,510	-£312,843
IRR	%		2.9%	-2.8%

Ground source – closed loop

- The available green space for the installation of ground loops is limited
  - Circa 473m² total shown below
- Potential issues with positioning of trees and tree roots
  - Red circles show x1.5 canopy ranges for each tree

Ground source – closed loop

- Vertical bore positions

- Potential yield*

Array type	Heat extraction rate – figures from BS EN 15450	Installation details	Potential Capacity
Horizontal –slinky pipe	• 16 - 24W/m² • Figure for moist cohesive soil • 2400h p.a operation	• 473m² green space	7.6 - 11.4kW
Vertical	• 50W/m • Figure for normal underground and water saturated sediment • 2400h p.a operation	• 7 boreholes • 0.6m diameter with 10metre spacing • 100m depth	35kW

*Numbers shown assume all existing trees are removed and all available green space could be utilised

Air source

Sustainable ENERGY

- Available resource with lower installation requirements
- Potential risks of noise to residents and cold plumes can be mitigated with suitable attenuation

Technology assessment summary

Heat source	Comments	Considered further?
Heat network connection	• No suitable networks local to the assessment site	No
Closed Loop GSHP	• Low yield potential from available land • Not viable due to land requirement for ground loops (horizontal and vertical)	No
Open Loop GSHP	• Water source unknown • High CAPEX associated with drilling boreholes into chalk aquifer (in relation to small scheme) • No guarantee of adequate resource • RHI accreditation is time sensitive and installation of bore is time intensive	No
ASHP	• Lower initial CAPEX than GSHP options • Potential noise restrictions close to residential developments	Yes

Solar PV assessment

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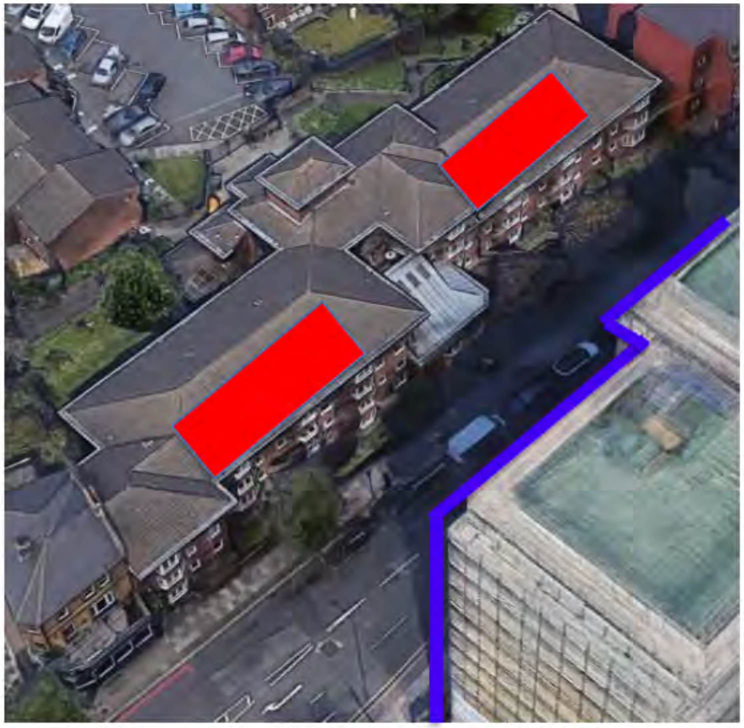
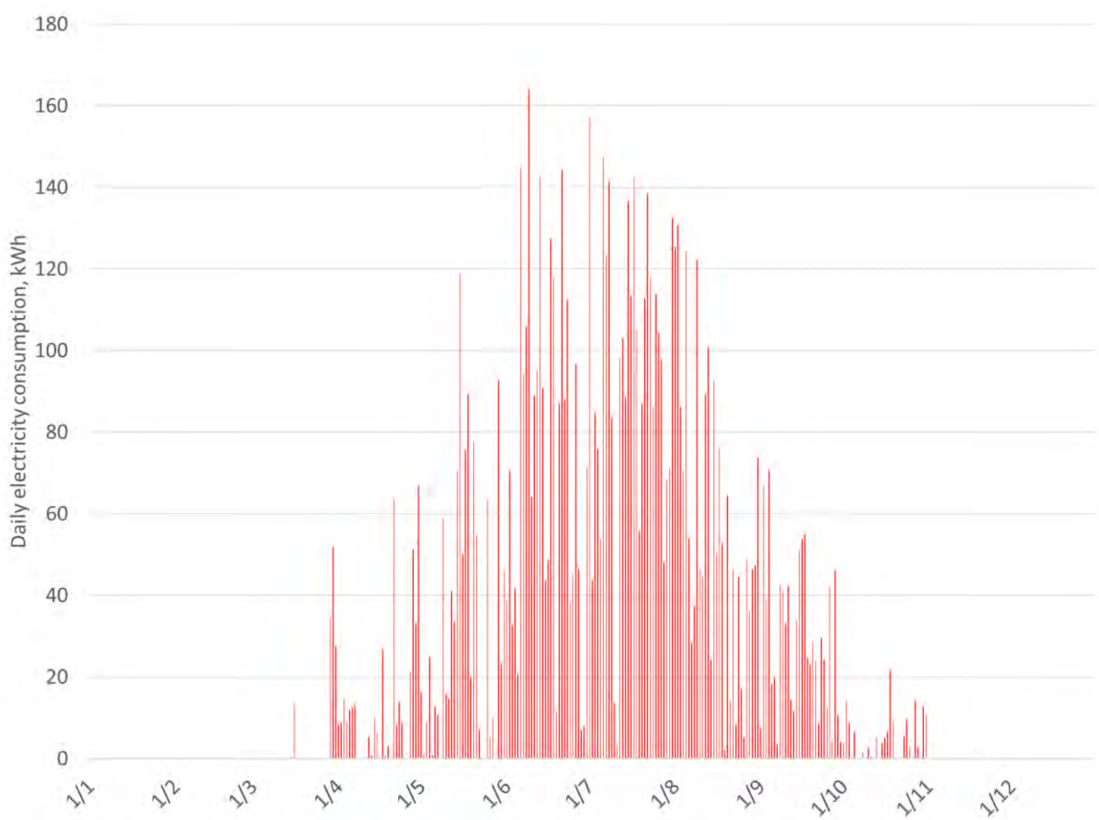
Roof top PV installation

- Circa 144m² of available roof space for installation (red)
  - South facing on pitched roof
  - Mounted flush to pitched roof
  - 30° inclination (assumed pitch of roof)
- Potential peak load circa 30kW
  - 90no. 330W panels
- Adjacent building to the South is 40m in height (blue)
  - Performance ratio due to the shading from this building is 64%
- Potential generation 21,324kWh per annum
- Installation cost including cost of PV panels, inverters, roof mounts, cabling and installation - £30,000



Roof top PV – Battery Storage

- To recoup/store excess electricity generation on the peak day would require a discharge capacity of 164kWh
- Based on round-trip efficiency of 90% a circa 180kWh battery is required
- The income gain from storing electricity over exporting is £728
  - Excess kWh at high tariff minus kWh at export tariff = £1,259 - £531= £728



- The typical lifespan of a solar battery is between 5-15years; best case scenario the battery would need to be £10,922 to pay back during its lifespan (cost of a suitable battery for this site would be in the £60,000 - £80,000 range)
- Battery storage option not currently viable

Concept design

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Design considerations

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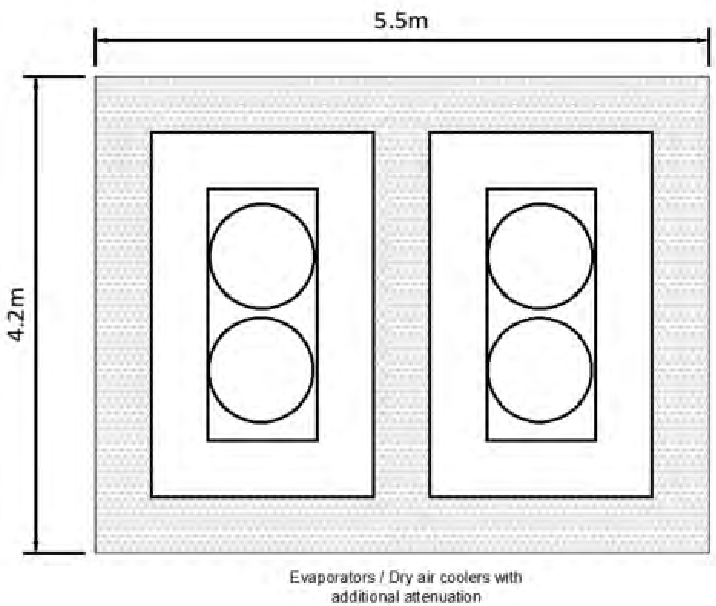
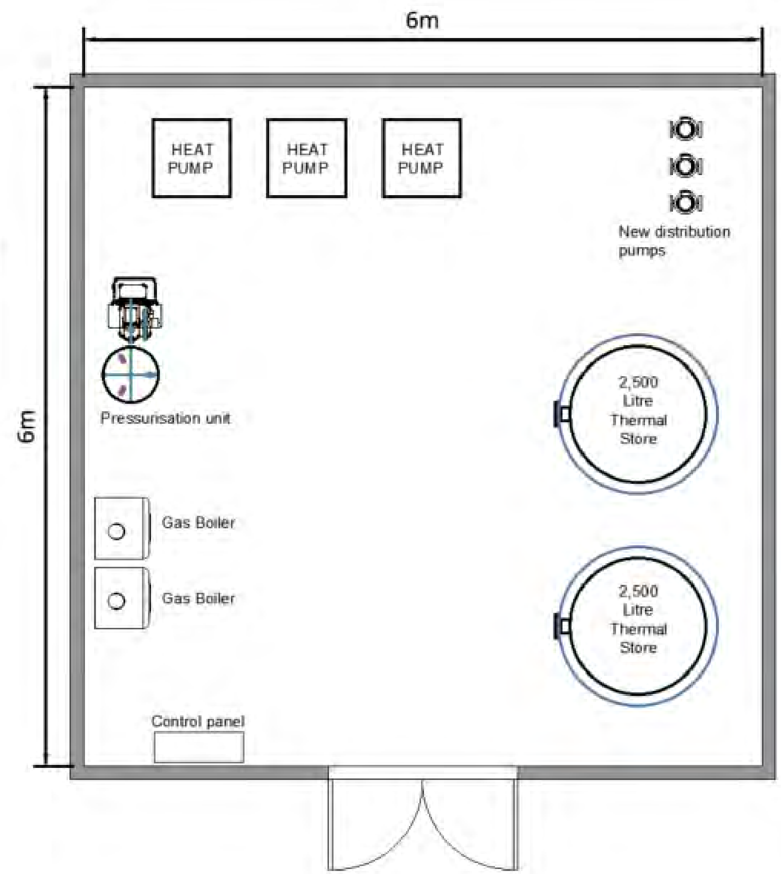
- Existing available plant room space = 6 x 6metres
- Dry air coolers can be placed on the green outside the existing plant room. Additional attenuation required to mitigate any sound issues
- The existing plant room is positioned on the ground floor (red)
- Potential position for dry air coolers (blue)
- Condensing gas boilers to supply full back up

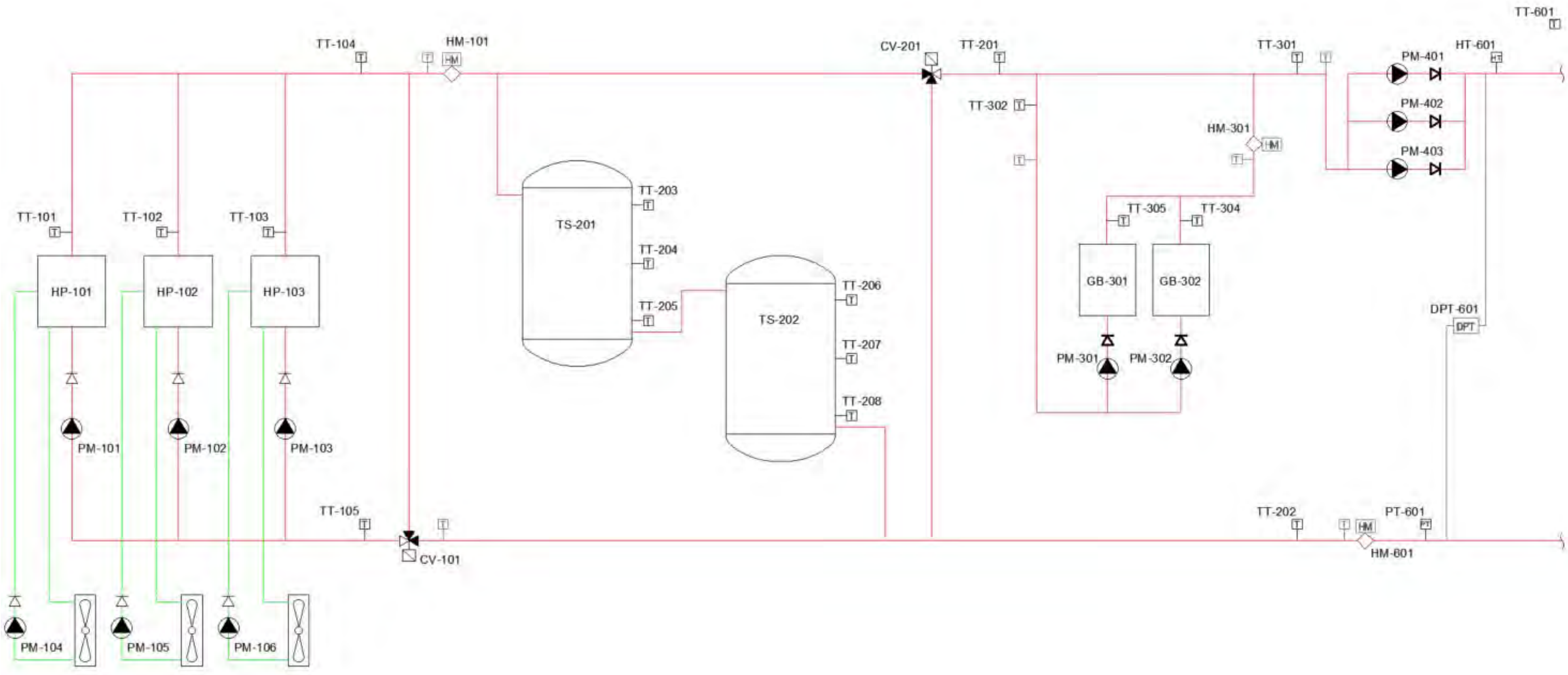
Energy Centre

- New heating plant consists of:
  - 2no. 80kW plus 1no. 20kW Air source heat pumps
  - 2no. 90kW condensing gas boilers
  - 2no. 2,500litre thermal store





PFD Schematic



Economic Assessment

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Condensing gas boiler - full scheme CAPEX

	CAPEX	CAPEX inc. contingency
Preliminary		
Contractor prelims including welfare and storage	£45,000	£54,000
Energy Centre works		
Peak and reserve gas boilers	£10,500	£11,025
Peak and reserve gas boiler flues	£4,000	£4,600
Pressurisation	£4,000	£4,200
Water treatment, flushing and testing	£5,000	£5,750
Electrical connection upgrade	£19,000	£23,750
Plantroom controls	£40,000	£48,000
Cabling and electrical housing blocks	£25,000	£30,000
Other energy centre M&E (pipework, pumps, temporary PHE)	£69,449	£83,339
Builders works	£10,000	£11,500
Network - Usual		
Customer HIUs and flat fit out	£168,000	£193,200
Risers and laterals	£150,000	£187,500
Planning, design and management		
Resident liaison officer	£10,000	£11,000
Professional, design and contracting fees	£50,000	£52,500
Clients Engineer - technical support for construction and commissioning	£30,000	£33,000
Total	£639,949	£753,364

Condensing gas boiler - gas boiler only CAPEX

	CAPEX	CAPEX inc. contingency
Energy Centre works		
Peak and reserve gas boilers	£10,500	£11,025
Peak and reserve gas boiler flues	£4,000	£4,600
Electrical connection upgrade	£19,000	£23,750
Plantroom controls	£40,000	£48,000
Cabling and electrical housing blocks	£25,000	£30,000
Other energy centre M&E (pipework, pumps, temporary PHE)	£69,449	£83,339
Planning, design and management		
Professional, design and contracting fees	£50,000	£52,500
Clients Engineer - technical support for construction and commissioning	£30,000	£33,000
Total	£247,949	£286,214

ASHP and condensing gas boiler scheme – full scheme CAPEX

Sustainable ENERGY

	Total	Total inc. cingency
Preliminary		
Contractor prelims including welfare and storage	£55,000	£66,000
Energy Centre works – common to ASHP and gas options		
Peak and reserve gas boilers	£10,500	£11,025
Peak and reserve gas boiler flues	£4,000	£4,600
Pressurisation	£4,000	£4,200
Water treatment, flushing and testing	£5,000	£5,750
Electrical connection upgrade	£19,000	£23,750
Plantroom controls	£60,000	£72,000
Cabling and electrical housing blocks	£25,000	£30,000
Other energy centre M&E (pipework, pumps, temporary PHE)	£69,449	£83,339
Builders works	£10,000	£11,500
Network – common to ASHP and gas options		
Customer HIUs and flat fit out	£168,000	£193,200
Risers and laterals	£150,000	£187,500
Energy Centre works – ASHP only		
Heat pump	£90,000	£99,000
ASHP attenuation	£10,000	£11,000
Heat pump M&E works	£30,000	£33,000
Thermal store	£6,000	£6,600
Energy centre civils works	£20,000	£23,000
Planning, design and management – common to ASHP and gas options		
Planning application and fees	£6,000	£7,500
Resident liaison officer	£10,000	£11,000
Professional, design and contracting fees	£65,000	£68,250
Clients Engineer - technical support for construction and commissioning	£40,000	£44,000
RHI Application	£4,500	£4,725
Total	£861,449	£1,000,939

ASHP and condensing gas boiler scheme – ASHP and condensing gas boiler only CAPEX

Sustainable ENERGY

	Total	Total inc. contingency
Energy Centre works – common to ASHP and gas options		
Peak and reserve gas boilers	£10,500	£11,025
Peak and reserve gas boiler flues	£4,000	£4,600
Electrical connection upgrade	£19,000	£23,750
Plantroom controls	£60,000	£72,000
Cabling and electrical housing blocks	£25,000	£30,000
Other energy centre M&E (pipework, pumps, temporary PHE)	£69,449	£83,339
Energy Centre works – ASHP only		
Heat pump	£90,000	£99,000
ASHP attenuation	£10,000	£11,000
Heat pump M&E works	£30,000	£33,000
Thermal store	£6,000	£6,600
Planning, design and management – common to ASHP and gas options		
Professional, design and contracting fees	£65,000	£68,250
Clients Engineer - technical support for construction and commissioning	£40,000	£44,000
Total	£428,949	£486,564

Fuel Tariffs

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- Tariff inputs

Gas tariff (excl. CCL)	2.171	p/kWh
Gas standing charge	9.67	£/day
CCL - natural gas (2021)	0.406	p/kWh
CCL - natural gas (2022)	0.568	p/kWh
CCL - natural gas (2023 onwards)	0.672	p/kWh
CCL - electricity	0.775	p/kWh
Energy centre electricity tariff - day	13.04	p/kWh
Energy centre electricity tariff - night	8.8	p/kWh
Electricity standing charge	0.18	£/day

OPEX and REPEX assumptions

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OPEX

- Annual cost for O&M of £2,096 used, which covers the following:
  - Annual servicing for communal heating and hot water (gas only, current maintenance contract only covers gas based systems)
  - HIUs (presumed HIUs for all below estates based on rate receiving for some estates which already have HIUs)
  - Service of BMS with annual servicing of heating and hot water
  - Pressurisation units and expansion vessels
  - Quarterly water treatment
- Annual spares and repair costs £4,890
  - Using estimated of 70% of total costs for maintenance contract from spares and repairs
- Metering and billing cost - £3,780 per annum

REPEX

- Pro-rata cost added per year based on the cost of the asset and its economic life
- Economic lifetime of the technologies used:

Technology	Useful economic lifetime (years)
Heat pump	20
Gas boilers	20
Heat network connections	25

Assessment scenarios

- ASHP sized to provide 100% of the heat demand
- For the assessment cases it is assumed that the availability of the ASHP to supply the heat demand is 96% (2 weeks for maintenance and repairs)
  - The techno economic model has a function to compare 100% (52 weeks), 96% (50 weeks) and 92% (48 weeks) availability
- Table below shows the contribution of the ASHP against the different heat demand scenarios

	Scenario 1	Scenario 2	Scenario 3	Scenario 4
Total heat demand	427,320kWh	399,528kWh	354,109kWh	274,423kWh
Peak heat demand	177kW	167kW	151kW	123kW
Heat pump capacity	180kW	180kW	180kW	180kW
Thermal store capacity	5,000litres	5,000litres	5,000litres	5,000litres
% heat demand potentially met by low carbon / renewable technology				
52 weeks availability	100%	100%	100%	100%
50 weeks availability	99%	99%	99%	99%
48 weeks availability	99%	99%	99%	98%

Assessment scenarios

- Two CAPEX scenarios are presented:
  - **CASE 1** – installation of condensing gas boiler and energy centre upgrades
  - **CASE 2** – installation of condensing gas boiler, installation of ASHP and energy centre upgrades
  - These cases include the CAPEX associated with installation of the heat generation technology systems only
- Two heat demand scenarios are presented:
  - Scenario 1 – existing fabric with upgraded heating system
  - Scenario 4 – upgraded fabric (roof, glazing and EWI) with upgraded heating system
- Additional economic assumptions:
  - ASHP cases will include income from RHI
  - Impact of PV array installation will also be presented
    - Electricity generation to offset the energy centre requirements at electricity day rate
    - Excess generation exported at 5.5p/kWh

Economic assessment (heat demand scenario 1)

		Current system	Option 1: Gas condensing boilers	Option 2: Gas condensing boilers and ASHP	Option 3: Gas condensing boilers, ASHP and PV
Energy and carbon	**Units**				
Heat demand - Peak	kW	182	177	177	177
Heat annual demand	kWh	478,384	427,320	427,320	427,320
Heat annual demand - losses	kWh	45,552	-	-	-
Heat annual demand - Total	kWh	523,936	427,320	427,320	427,320
% heat demand low carbon	%	0%	0%	99%	99%
25 year CO2e savings	tCO2e		246	1,949	1,985
First year CO2e savings, tCO2e	tCO2e		9	54	57
First year CO2e intensity of delivered heat	gCO2e /kWh		210	104	96
Build and run costs					
Capex of scheme	£		£247,949	£428,949	£458,949
Capex of scheme + contingency	£		£286,214	£486,564	£519,564
OPEX – Fuel costs	£		£16,939	£23,988	£22,421
OPEX – (O&M + fuel/elec costs)	£		£27,705	£37,954	£36,387
Fixed heat sales	£		£19,929	£19,929	£19,929
Variable heat sales	£		£32,049	£32,049	£32,049
Potential annual Income - RHI	£		-	£11,656	£11,656
Potential annual Income – PV export	£		-		£543
Economic indicators – 25 year case					
Fixed heat sales	£/day		1.30	1.30	1.30
Variable heat sales	p/kWh		7.50	7.50	7.50
Cost of heat to residence - annual	£		£1,238	£1,238	£1,238
Payback period	Years		15	0	24
NPV	£		£37,121	-£161,825	-£158,243
IRR	%		4.7%	-0.1%	0.3%
Assumptions	Capital costs excludes heating systems, water treatment and ancillaries Fixed tariff of £1.30/day Variable tariff of 7.5p/kWh (in line with Heat Trust costing)				

Economic assessment (heat demand scenario 1)

	Units	Current system	Option 1: Gas condensing boilers	Option 2: Gas condensing boilers and ASHP	Option 3: Gas condensing boilers, ASHP and PV
Resident costs – Fuel only					
Cost of heat to residence – Fuel (variable)	p/kWh	5.34	3.96	5.61	5.25
Cost of heat to residence - annual	£	£543	£403	£571	£534
Resident costs – Fuel + O&M					
Cost of heat to residence – O&M (fixed)	£/day	0.70	0.70	0.91	0.91
Cost of heat to residence – Fuel (variable)	p/kWh	5.34	3.96	5.61	5.25
Cost of heat to residence - annual	£	£800	£660	£904	£866
Subsidy requirement per apartment					
Cost of heat, savings per apartment (fuel only)	£/year			-£28	£9
Cost of heat, savings per apartment (fuel + O&M)	£/year			-£104	-£66
Remaining RHI income (whole scheme - fuel + O&M)	£/year			£7,288	£8,884
Assumptions	No accounting has been made for initial capital costs or replacement costs over lifetime. Capital for energy centre and network are part of the building and therefore will be part of the rent rather than in the energy bills.				
Social Economics – 25 year case					
Social IRR			5.2%	3.1%	3.2%
Social NPV			£56,160	-£21,948	-£14,883
Assumptions	Fixed tariff of £1.30/day Variable tariff of 7.5p/kWh (in line with Heat Trust costing)				

Economic assessment (heat demand scenario 4)

		Current system	Option 1: Gas condensing boilers	Option 2: Gas condensing boilers and ASHP	Option 3: Gas condensing boilers, ASHP and PV
Energy and carbon	**Units**				
Heat demand - Peak	kW	182	123	123	123
Heat annual demand	kWh	478,384	274,423	274,423	274,423
Heat annual demand - losses	kWh	45,552	-	-	-
Heat annual demand - Total	kWh	523,936	274,423	274,423	274,423
% heat demand low carbon	%	0	0	99%	99%
25 year CO2e savings	tCO2e		158	1,250	1,279
First year CO2e savings, tCO2e	tCO2e		5	35	37
First year CO2e intensity of delivered heat	gCO2e /kWh		210	104	94
Build and run costs					
Capex of scheme	£		£247,949	£428,949	£458,949
Capex of scheme + contingency	£		£286,214	£486,564	£519,564
OPEX – Fuel costs	£		£12,168	£16,766	£15,502
OPEX – (O&M + fuel/elec costs)	£		£22,934	£30,733	£29,468
Fixed heat sales	£		£19,929	£19,929	£19,929
Variable heat sales	£		£20,582	£20,582	£20,582
Potential annual Income - RHI	£		-	£7,476	£7,476
Potential annual Income – PV export	£		-	-	£666
Economic indicators – 25 year case					
Fixed heat sales	£/day		1.30	1.30	1.30
Variable heat sales	p/kWh		7.50	7.50	7.50
Cost of heat to residence - annual	£		£965	£965	£965
Payback period	Years		20	0	0
NPV	£		-£46,729	-£281,104	-£280,642
IRR	%		1.9%	-3.6%	-2.9%
Assumptions	Capital costs excludes heating systems, water treatment and ancillaries Fixed tariff of £1.30/day				

Economic assessment (heat demand scenario 4)

	Units	Current system	Option 1: Gas condensing boilers	Option 2: Gas condensing boilers and ASHP	Option 3: Gas condensing boilers, ASHP and PV
Resident costs – Fuel only					
Cost of heat to residence – Fuel (variable)	p/kWh	5.34	4.43	6.11	5.65
Cost of heat to residence - annual	£	£543	£290	£399	£369
Resident costs – Fuel + O&M					
Cost of heat to residence – O&M (fixed)	£/day	0.70	0.70	0.91	0.91
Cost of heat to residence – Fuel (variable)	p/kWh	5.34	4.43	6.11	5.65
Cost of heat to residence - annual	£	£800	£546	£732	£702
Subsidy requirement per apartment					
Cost of heat, savings per apartment (fuel only)	£/year			£144	£174
Cost of heat, savings per apartment (fuel + O&M)	£/year			£68	£98
Remaining RHI income (whole scheme - fuel + O&M)	£/year			£7,476	£7,476
Assumptions	No accounting has been made for initial capital costs or replacement costs over lifetime. Capital for energy centre and network are part of the building and therefore will be part of the rent rather than in the energy bills.				
Social Economics – 25 year case					
Social IRR			2.4%	-0.5%	-0.1%
Social NPV			-£34,502	-£191,386	-£188,119
Assumptions	Fixed tariff of £1.30/day Variable tariff of 7.5p/kWh (in line with Heat Trust costing)				

Increased gas tariff

- The gas tariff for Bill Walden House at the time of this assessment is 2.171p/kWh
- This figure is relatively low and an increase in this tariff has a significant affect on economic case for the condensing gas boiler only solution
- The following table presents the cases with the gas tariff increased to 3.47p/kWh (the point at which the economics are similar for the gas condensing case and the ASHP with condensing gas boiler and PV case)

Economic assessment (Increased gas tariff scenario 1)

		Current system	Option 1: Gas condensing boilers	Option 2: Gas condensing boilers and ASHP	Option 3: Gas condensing boilers, ASHP and PV
Energy and carbon	**Units**				
Heat demand - Peak	kW	182	177	177	177
Heat annual demand	kWh	478,384	427,320	427,320	427,320
Heat annual demand - losses	kWh	45,552	-	-	-
Heat annual demand - Total	kWh	523,936	427,320	427,320	427,320
% heat demand low carbon	%		0%	99%	99%
25 year CO2e savings	tCO2e		246	1,949	1,985
First year CO2e savings, tCO2e	tCO2e		9	54	57
First year CO2e intensity of delivered heat	gCO2e /kWh		210	104	96
Build and run costs					
Capex of scheme	£		£247,949	£428,949	£458,949
Capex of scheme + contingency	£		£286,214	£486,564	£519,564
OPEX – Fuel costs	£		£23,107	£24,038	£22,470
OPEX – (O&M + fuel/elec costs)	£		£33,873	£38,004	£36,437
Fixed heat sales	£		£19,929	£19,929	£19,929
Variable heat sales	£		£32,049	£32,049	£32,049
Potential annual Income - RHI	£		-	£11,656	£11,656
Potential annual Income – PV export	£		-	-	£543
Economic indicators – 25 year case					
Fixed heat sales	£/day		1.30	1.30	1.30
Variable heat sales	p/kWh		7.50	7.50	7.50
Cost of heat to residence - annual	£		£1,238	£1,238	£1,238
Payback period	Years		25	0	24
NPV	£		-£90,256	-£162,852	-£159,271
IRR	%		0.2%	-0.1%	0.2%
Assumptions	Capital costs excludes heating systems, water treatment and ancillaries Fixed tariff of £1.30/day				

Economic assessment (Increased gas tariff scenario 1)

	Units	Current system	Option 1: Gas condensing boilers	Option 2: Gas condensing boilers and ASHP	Option 3: Gas condensing boilers, ASHP and PV
Resident costs – Fuel only					
Cost of heat to residence – Fuel (variable)	p/kWh	5.34	5.41	5.63	5.26
Cost of heat to residence - annual	£	£543	£550	£572	£535
Resident costs – Fuel + O&M					
Cost of heat to residence – O&M (fixed)	£/day	0.70	0.70	0.91	0.91
Cost of heat to residence – Fuel (variable)	p/kWh	5.34	5.41	5.63	5.26
Cost of heat to residence - annual	£	£800	£806	£905	£868
Subsidy requirement per apartment					
Cost of heat, savings per apartment (fuel only)	£/year			-£29	£8
Cost of heat, savings per apartment (fuel + O&M)	£/year			-£105	-£68
Remaining RHI income (whole scheme - fuel + O&M)	£/year			£7,246	£8,800
Assumptions	No accounting has been made for initial capital costs or replacement costs over lifetime. Capital for energy centre and network are part of the building and therefore will be part of the rent rather than in the energy bills.				
Social Economics – 25 year case					
Social IRR			1.0%	3.1%	3.2%
Social NPV			-£71,217	-£22,975	-£15,910
Assumptions	Fixed tariff of £1.30/day Variable tariff of 7.5p/kWh (in line with Heat Trust costing)				

Summary and next steps

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Summary

- Under current assumptions, the economics of the gas condensing boiler are more favourable than the heat pump options but offer far lower CO_2e savings
- ASHPs are the only technically viable renewable heating option with an acceptable level of risk
- Solar PV slightly improves economics and increases CO_2e savings
- Low gas prices support the economics of the gas boiler option, when gas prices reach 3.47p/kWh then economics reach parity with the ASHP with condensing gas boiler and PV case option and the social IRR of the ASHP is higher in each case

Next Steps

- Detail dimensions for full energy system and network
- Draft tender specification for energy centre and phased works

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Royal Borough of Greenwich

Jervis and Woodville Courts
Low carbon technology feasibility

Dr Gabriel Gallagher
Omied Khakshour

May 2020

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Scope of work

- Assess low carbon / renewable heating options for social housing
- Model heat and hot water demands for different levels of fabric improvements to inform sizing of new system
- Review and propose solutions for secondary heating and hot water systems
- Develop concept designs for refurbishment of energy centre with low carbon heating and back up gas boilers

ROYAL borough of GREENWICH

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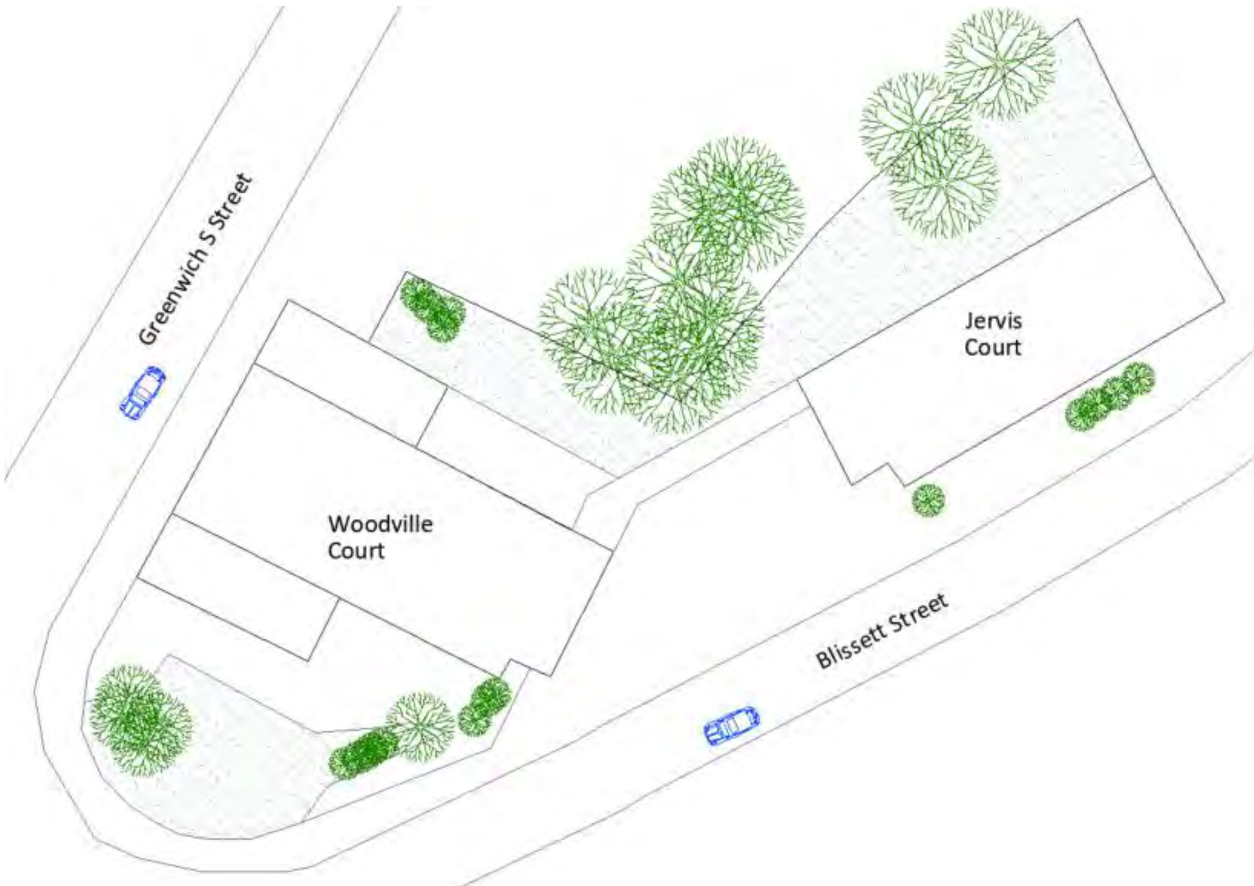
Summary of Jervis and Woodville Court

- 26 dwellings in two blocks
- Central heating system plant in Woodville Court
- Existing LTHW (82ºC flow / 71ºC return) communal heating system supplies radiators and hot water cylinders



Design considerations

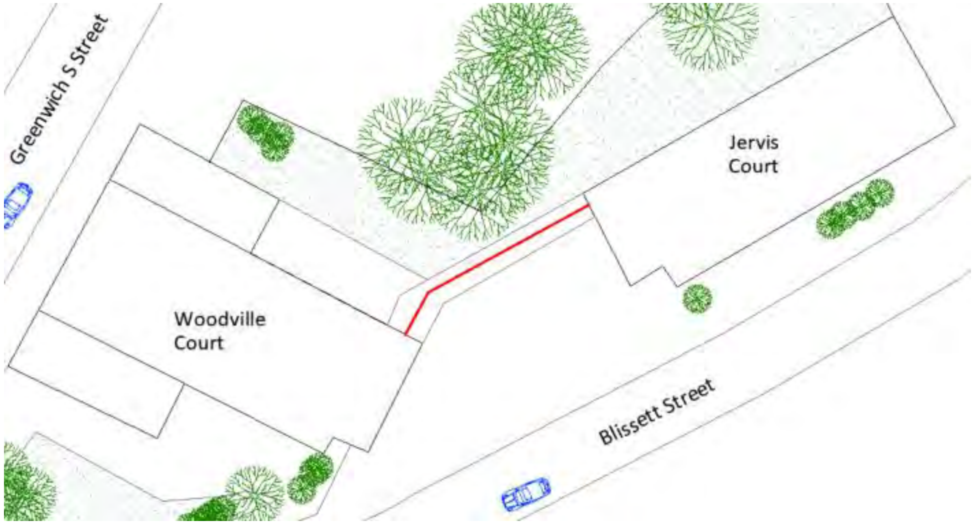
- To ensure correct specification of low carbon heating systems – flow and return temperatures must be reduced we must:
  - Reduce radiator temperatures*
  - Increase temperature differential to reduce pipe sizes
  - Ensure peak loads are correctly estimated to prevent oversizing
  - Install heat interface units in dwellings to replace hot water cylinders
  - Maintain existing network and supply of heat to continue to provide service whilst new system is installed

* This does not mean a reduction in the potential energy supplied to each space; although, the operating temperatures are lower than existing, the new emitters will be compatible with the operating conditions and the required set points will be achieved

Heat demand profiling

Current heat demand

- Existing gas consumption data - 417,046kWh per annum
- Existing heat demand modelled based on following assumptions:
  - Fabric to ~30 year old building regs
  - Unmetered heating controls with 21°C setpoint and 16°C set back
  - Individual DHW hot water storage tank per flat
  - 1.5 occupants per apartment
- External pipe losses from existing underground pipework
  - Red line shows assumed pipework layout
  - Calculated hourly heat loss – 0.44kW
  - Calculated annual heat loss – 3,854kWh/yr



Current heat demand

- Fabric and ventilation loss inputs:

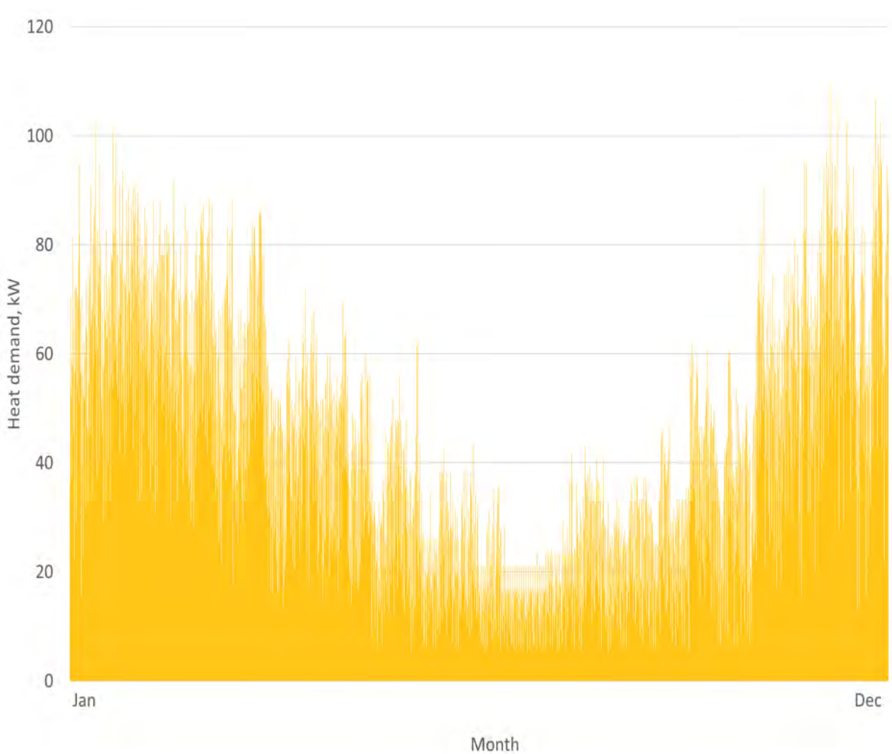
Fabric type - U-Values		
Floor	W/m^2K	0.45
Walls	W/m^2K	0.45
Glazing	W/m^2K	2.00
Roof	W/m^2K	0.25
Ventilation		
Air permeability	$m^3/h.m^2$	10

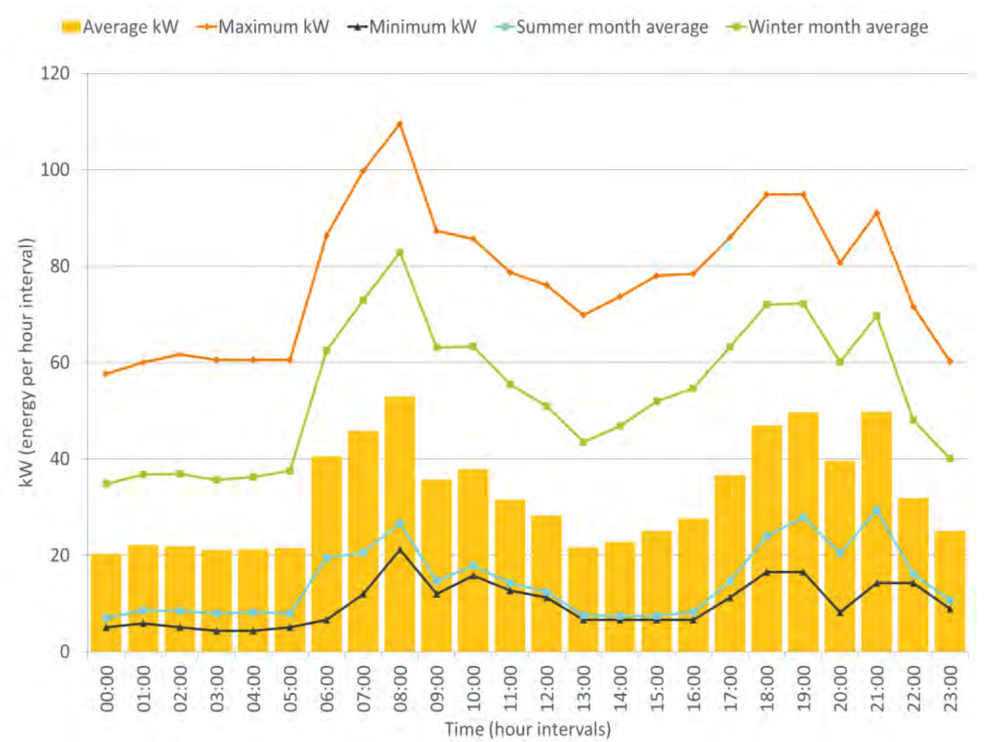
Current heat demand

- Summary of existing heat demand

Scenario	Annual Modelled Demand kWh	Peak heat kW	kWh per flat	Total kW per flat
Existing	283,869	110	10,918	4.2

- Modelled boiler efficiency of existing system – 68%
- Heat losses – 3,854kWh





Scenario 1
Upgraded heating system demand

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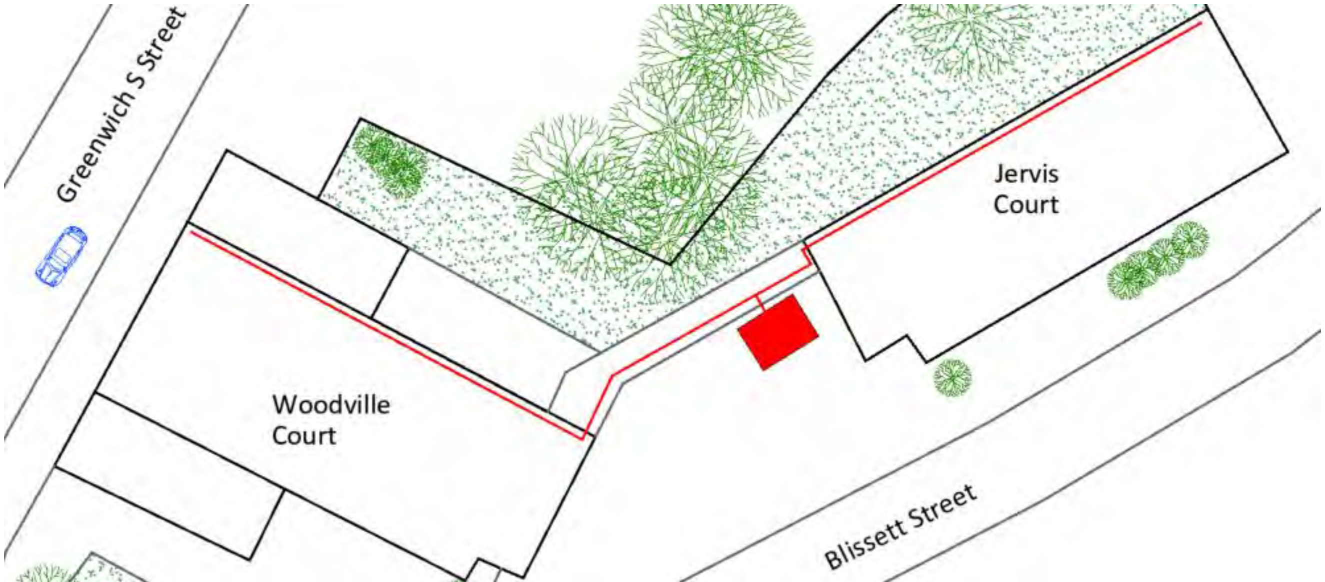
- Scenario 1 assumes:
  - No fabric changes
  - Flat fit outs for low temperature network conditions
  - Heat interface units for local heating control, metering and instantaneous hot water
  - Upgraded pipe work for the risers and laterals in each building
- The model also considers the impact of the following factors on the heat demand for the new system:
  - Assumed change in heat setting behaviour and energy usage due to the introduction of individual metering of each apartment
  - Ambient temperature controls in energy centre
  - Heating controls with a 21°C heating setpoint and 16°C set back
  - Reduction in heat losses due to the replacement of DHW storage tanks with instantaneous plates in HIUs

Scenario 1
Upgraded heating system demand

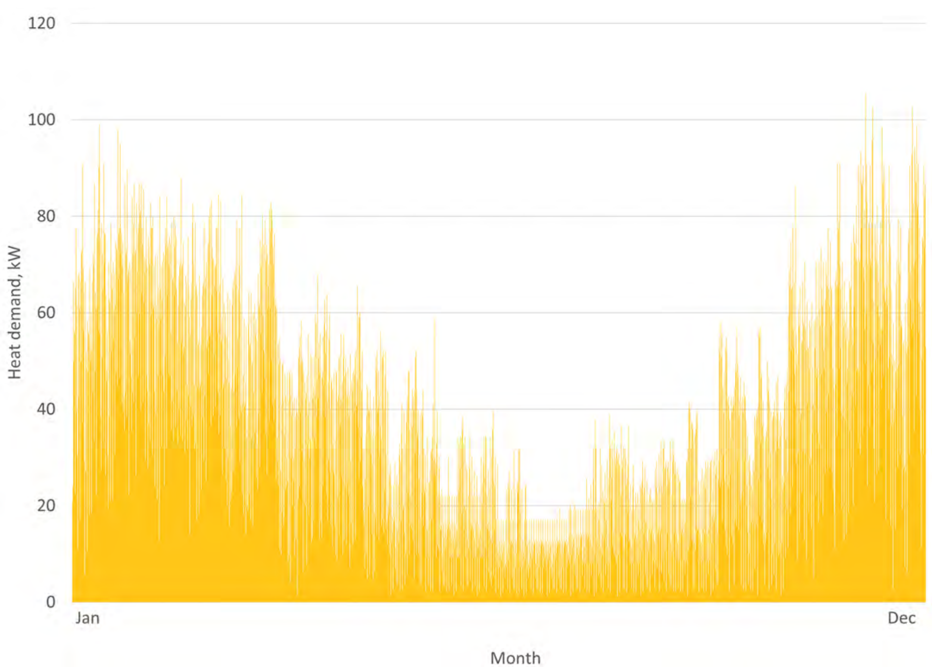
- The heat demand for the site after all the above conditions are adjusted is 221,087kWh
  - 22% reduction in current heat demand
- Pipe heat losses
  - Red square shows proposed Energy Centre location
  - Red line shows assumed pipework layout – all external to building
  - Calculated hourly heat loss – 0.3kW
  - Calculated annual heat loss – 2,628kWh/yr
    - Best practice installation assumed.
    - Total losses is circa 1% of total heat load, this is within best practice CIBSE Heat Network Code of Practise requirements.

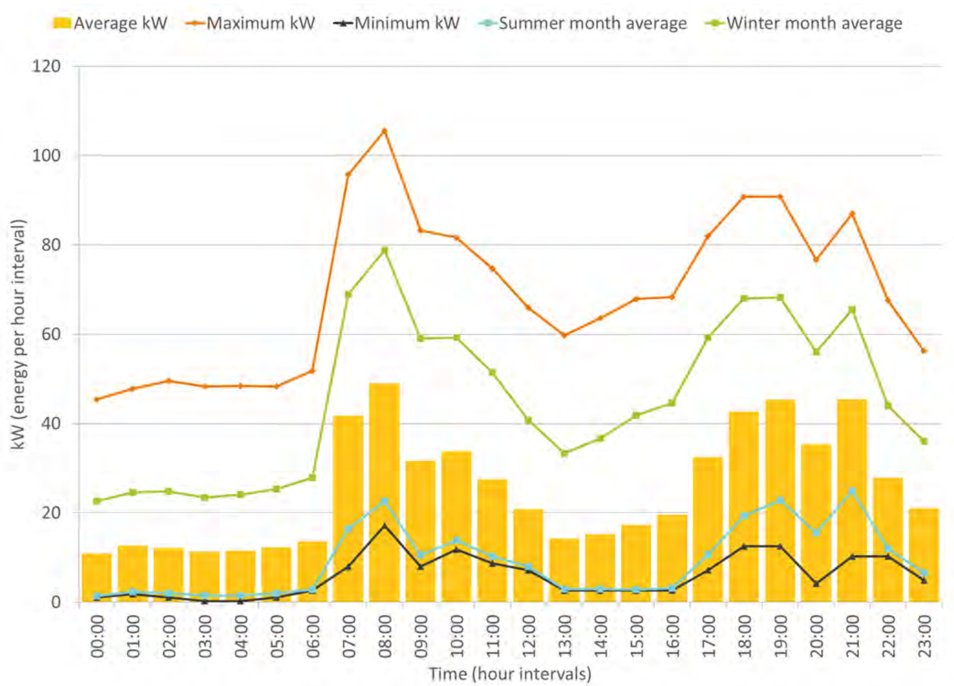


Scenario 1
Upgraded heating system demand

- Scenario 1 heat demand summary

Scenario	Annual Modelled Demand kWh	Peak heat kW	kWh per flat	Total kW per flat
1	221,087	105	8,503	4.1





Scenarios 2,3 and 4
Fabric improvements

- As with scenario 1, scenarios 2, 3 and 4 all assume:
  - Flat fit outs for low temperature network conditions
  - Heat interface units for local heating control, metering and instantaneous hot water
  - Upgraded pipe work for the risers and laterals in each building

- With the addition of varying levels of fabric improvements as follows:
  - Scenario 2 – roof insulation improvements
  - Scenario 3 – roof insulation improvements and glazing upgrades
  - Scenario 4 – roof insulation improvements, glazing upgrades and external wall cladding

Scenarios 2,3 and 4
Fabric improvements

- Fabric improvements are to bring each element up to current retrofit/refurbishment Part L levels as below:

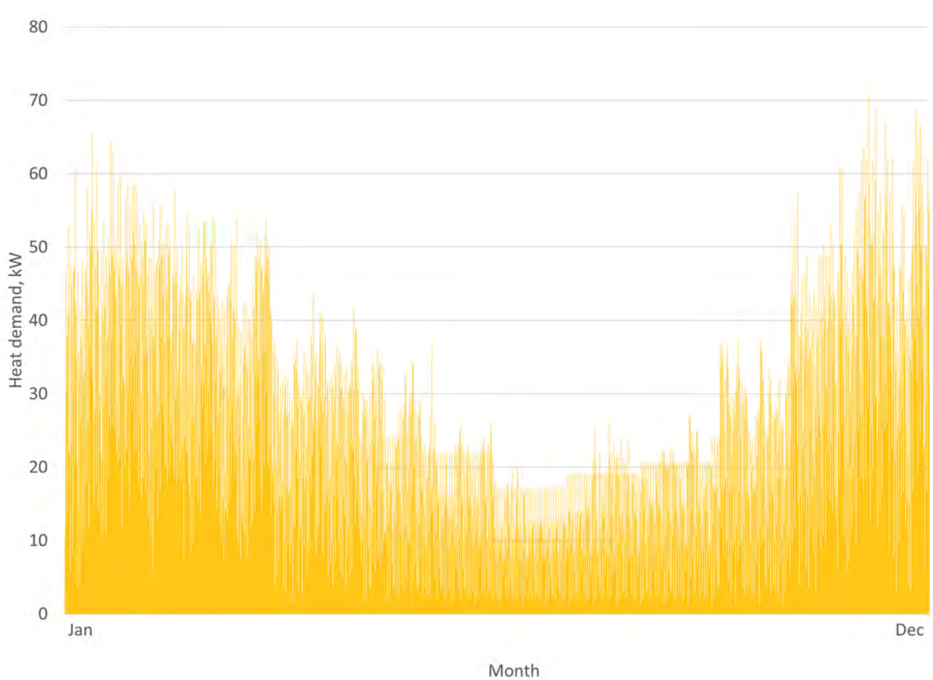
Fabric type - U-Values	Units	Scenario 1 – Existing fabric	Scenario 2 -Roof upgrade	Scenario 3 - Roof and glazing	Scenario 4 - Roof, glazing and EWI
Floor	W/m^2K	0.45	0.45	0.45	0.45
Walls	W/m^2K	0.45	0.45	0.45	0.30
Glazing	W/m^2K	2.00	2.00	1.60	1.60
Roof	W/m^2K	0.25	0.16	0.16	0.16
Ventilation					
Air permeability	$m^3/h.m^2$	10	8	7	5

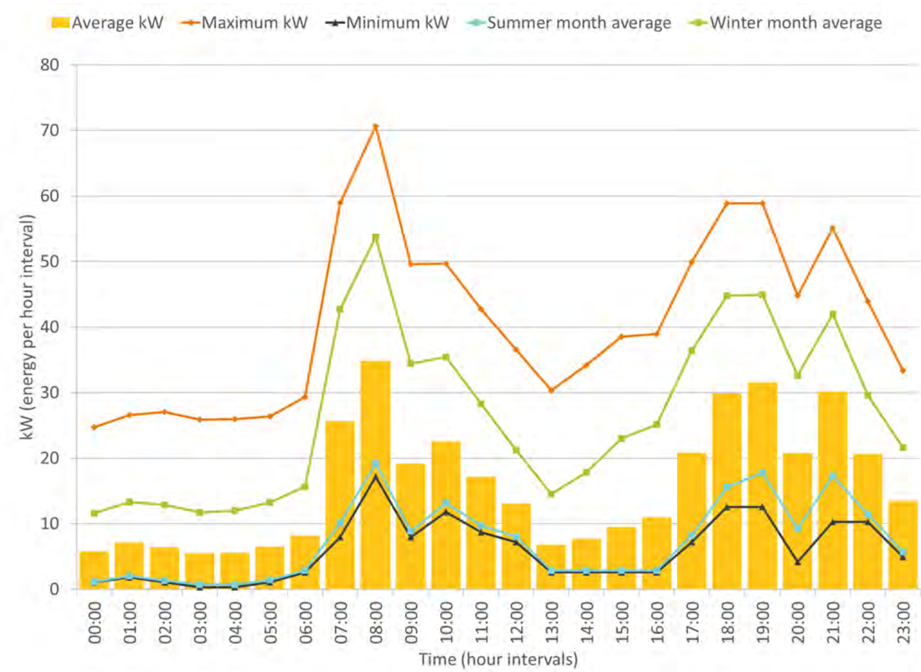
Scenario 2,3 and 4
Fabric improvements

- Summary of heat demands

Scenario	Annual Modelled Demand kWh	Peak heat kW	kWh per flat	Total kW per flat
2	190,764	93	7,337	3.6
3	173,965	86	6,691	3.3
4	138,559	71	5,329	2.7

- Annual heat demand profile and average, max, min daily profile for scenario 4





Supply options appraisal and feasibility

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Supply options appraisal

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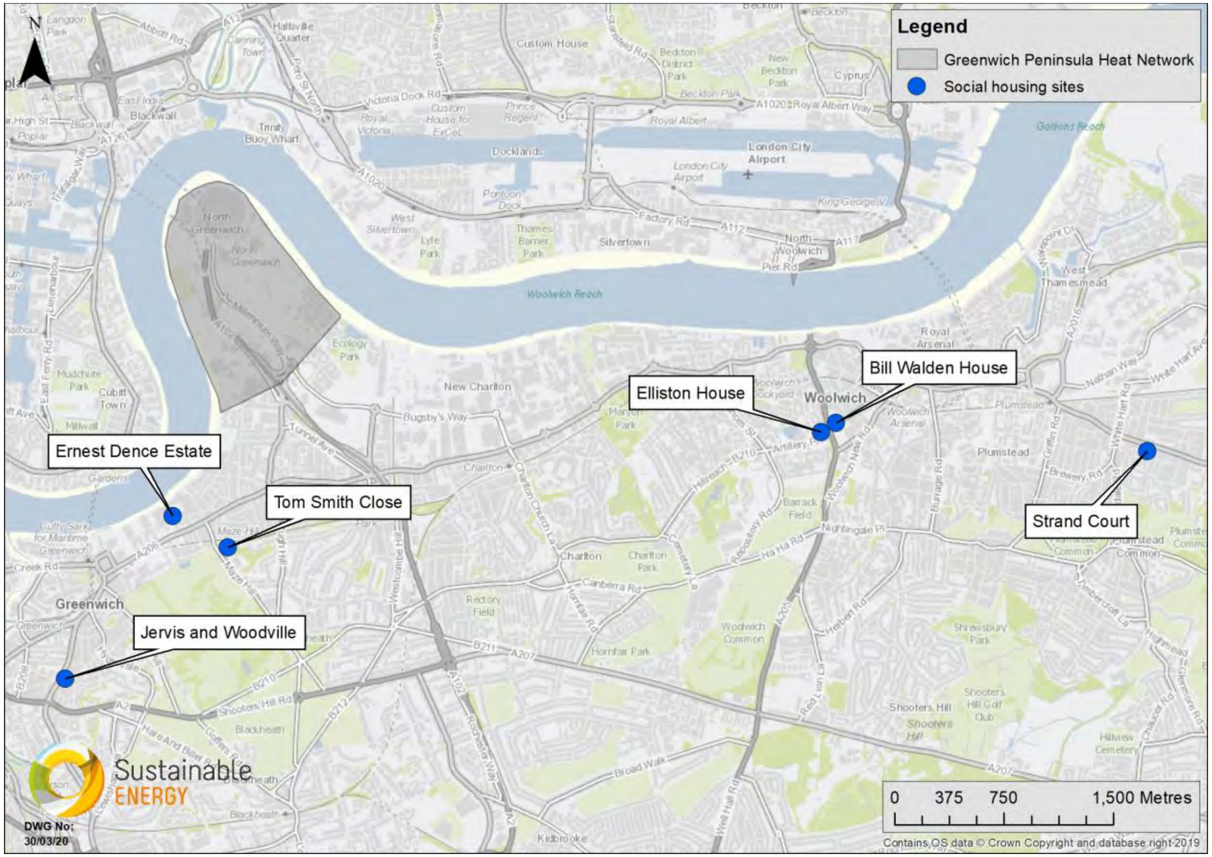
A number of different supply options were considered for the supply of heat and electricity to Jervis and Woodville Court:

- Connection to local district heat networks
- Heat pump technologies
  - Ground source – closed loop
  - Ground source – bore hole
  - Air source
- Solar PV
- Energy storage
  - Thermal
  - Electrical

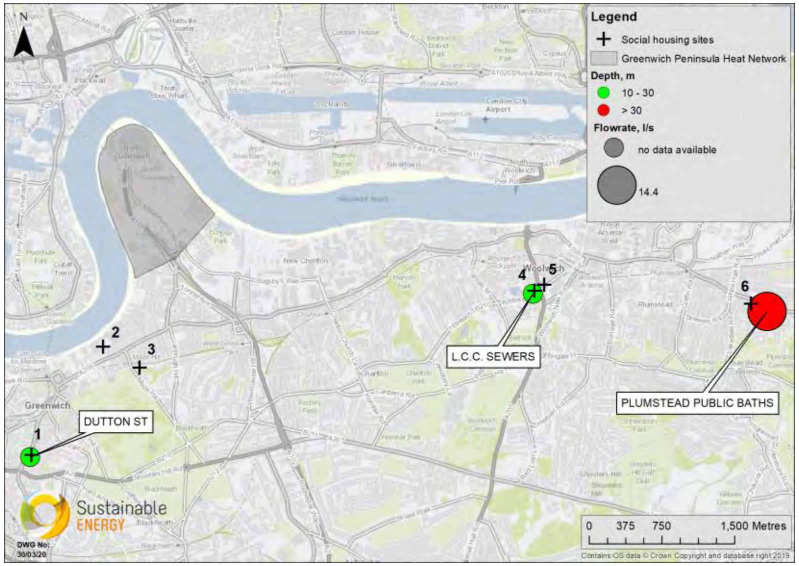
Local heat networks

- The image below shows the position of the RBG low carbon assessment sites and the location of the Greenwich Peninsula heat network
- At present there are no suitable connection points for heat supply from the existing network
- The design of the new heating systems will be compatible with connection to a large heat network if a suitable one was to become viable in the future



Ground source

- Borehole data from the national BGS resource is summarised in the GIS and table below
- Positions of gathered data is shown in the GIS
  - Colour indicated depth of bore holes
  - Width indicates flowrates measured in the bore holes
  - The assessment sites are numbered. Jervis and Woodville Court is shown at position 1



- Table with results of bore hole data

Location	Borehole name	Depth, m	Water depth, m	Flowrate, l/s	Strata details	Notes
Jervis and Woodville 538050,176910	TQ37NE493 — DUTTON ST GREENWICH BH1	18.29	15.85	NA	0-2.74 m: Fill, sand, bricks and stone 2.74-3.66 m: Brown sand, clay and stone 3.66 – 4.88 m: Sand and gravel 4.88 – 6.71 m: Sand and gravel with pockets of brown sandy clay 6.71 – 7.93 m: Brown clay, grey sand and stone 7.93 – 9.75 m: Brown grey sand 9.75 – 10.06 m: Brown silty clay and stone 10.06 – 10.97 m: Sand and gravel 10.97 – 11.89 m: Soft brown silty clay and stones 11.89 – 13.26 m: Dark grey silty clay 13.26 – 15.85 m: Greyish blue silty sand and thin layers of blue silty clay and chalk 15.85 – 17.07 m: Brown clayey sand and pebbles 17.07 – 18.29 m: Rock and putty chalk	Last examined in 1970

Ground source – open loop

- There is significant risk around the open loop solution.
- No flowrate data is available for Dutton Street located near Jervis and Woodville Court (site marked 1 on the image).
- A detailed hydro-geological modelling assessment would be required. This may cost in the region of £20,000.
- A trial well could be drilled into chalk aquifer but this will require significant CAPEX (upto £120,000) and there is no guarantee of a positive result.
- There is limited space for abstraction and discharge wells that are significantly separated to minimise thermal interaction. If land area cannot be found to significantly separate the wells, it is unlikely abstraction and discharge wells will be viable and so it may be possible to drill a single well where water is abstracted from one aquifer horizon and injected back to another. However, this approach is not tried and tested and detailed hydro geological modelling will be required to further assess viability as will the drilling of a test well.
- If a sufficient flowrate was found to supply the scheme then the installation would need to be ready to apply for the RHI subsidy before March 2021.
- A high level economic case for this option is shown on the next slide.

Ground source – open loop

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- A 45kW GSHP with 1,500litres thermal storage could supply 88% of the annual demand (allowing for 50weeks availability)
- A high level economic assessment is shown below:

		Current system	GSHP with Gas condensing boilers with RHI	GSHP with Gas condensing boilers without RHI
			Scenario 1	Scenario 1
Energy and carbon	**Units**			
Heat demand - Peak	kW	110	105	105
Heat annual demand	kWh	280,015	218,459	218,459
Heat annual demand - losses	kWh	3,854	2,628	2,628
Heat annual demand - Total	kWh	283,869	221,087	221,087
% heat demand low carbon	%	0%	88%	88%
25 year CO2e savings	tCO2e		930	930
First year CO2e savings, tCO2e	tCO2e		28	28
First year CO2e intensity of delivered heat	gCO2e/kWh		108	108
Build and run costs				
Capex of scheme + contingency	£		£333,715	£333,715
Fixed heat sales	£/day		1.31	1.31
Variable heat sales	p/kWh		7.5	7.5
Cost of heat to residence - annual	£		£1,108	£1,108
Payback period	Years		23	0
NPV	£		-£94,450	-£228,668
IRR	%		0.4%	-4.8%

Ground source – closed loop

- The available green space for the installation of ground loops is limited
  - Circa 530m² total shown below
- Potential issues with positioning of trees and tree roots
  - Red circles show x1.5 canopy ranges for each tree

Ground source – open loop

- Borehole data from the national BGS resource is summarised below
- No flowrate data is available for Dutton Street wells located at Jervis and Woodville Court (site marked 1 on the image)
- A trial well could be drilled into chalk aquifer but this will require significant CAPEX and there is no guarantee of a positive result

Air source

- Available resource with lower installation requirements
- Potential risks of noise to residents and cold plumes can be mitigated with suitable attenuation

Technology assessment summary

Heat source	Comments	Considered further?
Heat network connection	• No suitable networks local to the assessment site	No
Closed Loop GSHP	• Not viable due to land requirement for ground loops (horizontal and vertical)	No
Open Loop GSHP	• Water source unknown • High CAPEX associated with drilling boreholes into chalk aquifer (in relation to small scheme) • No guarantee of adequate resource • RHI accreditation is time sensitive and installation of bore is time intensive	No
ASHP	• Lower initial CAPEX than GSHP options • Potential noise restrictions close to residential developments	Yes

Solar PV assessment

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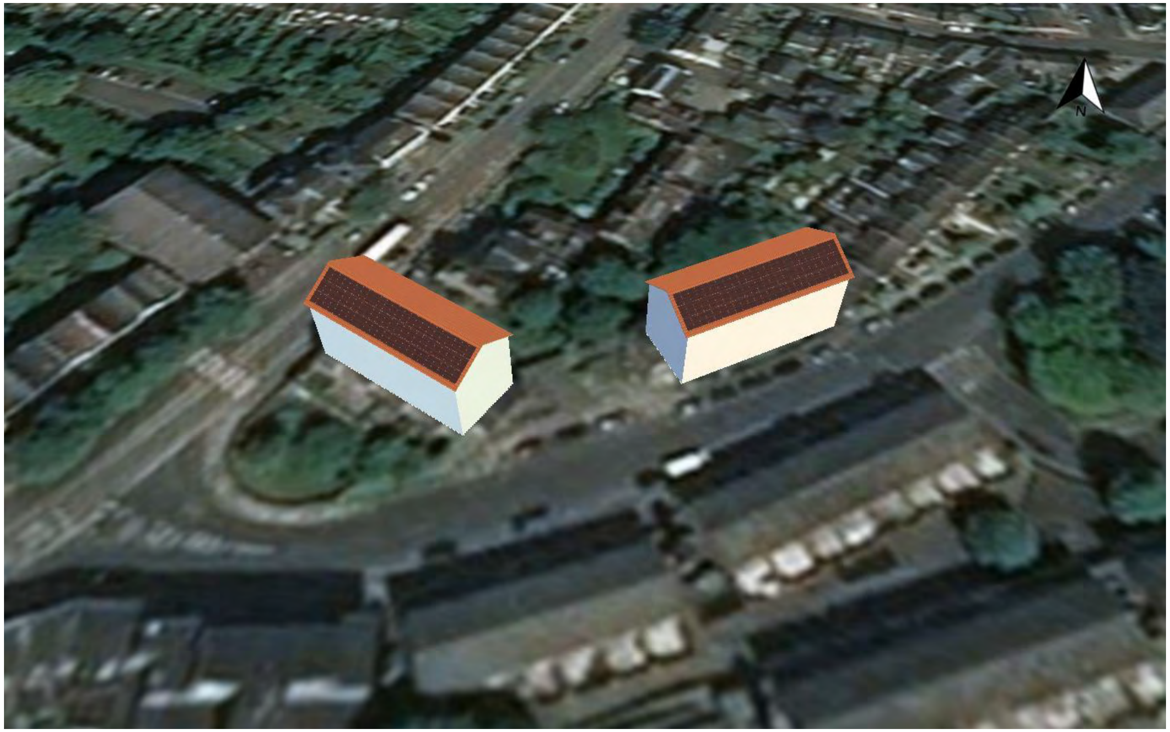
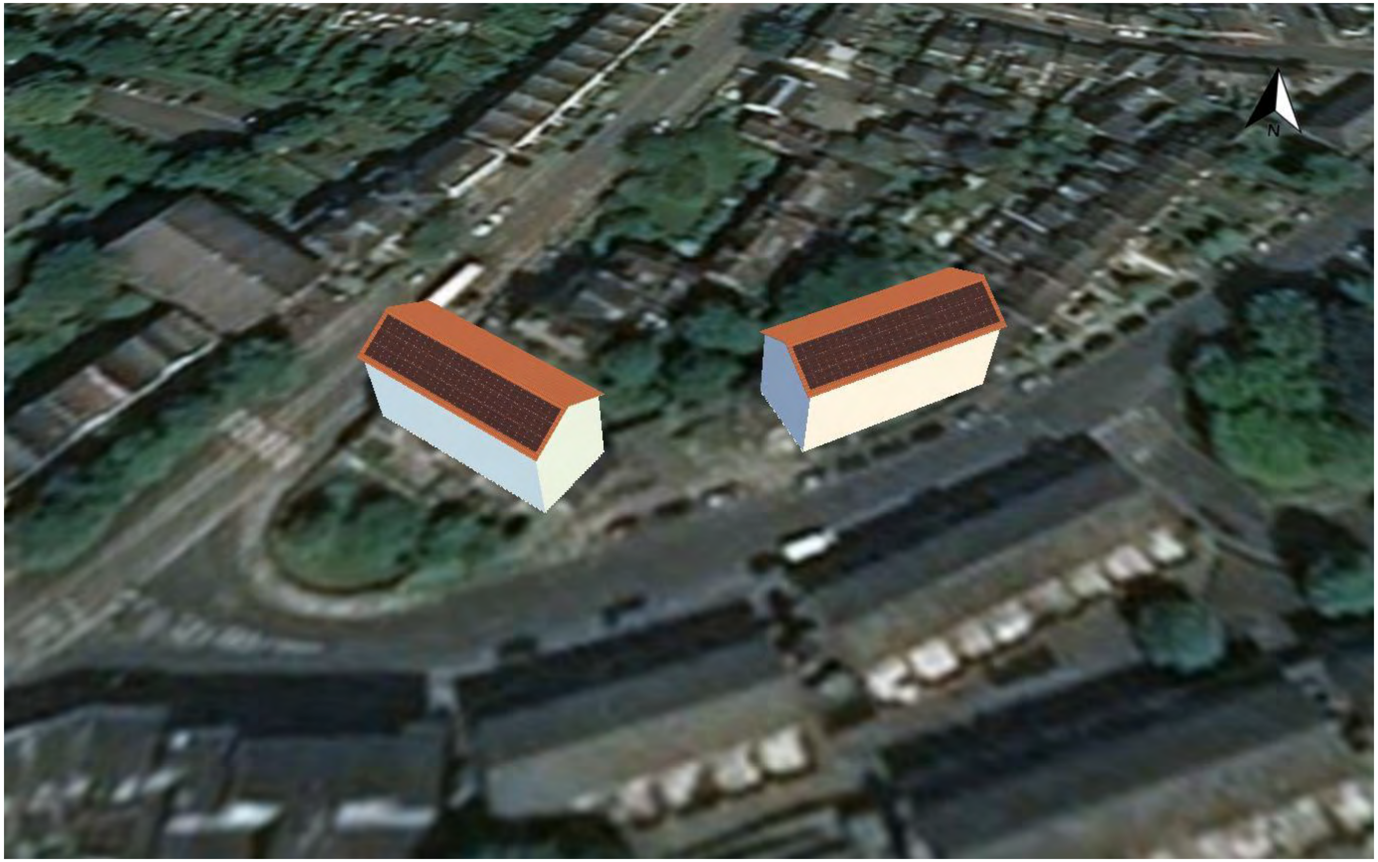
Roof top PV installation

- Circa 230m^2 of available roof space for installation
  - South facing on pitched roof
  - Mounted flush to pitched roof
  - 30° inclination (assumed pitch of roof)
- Potential peak load circa 40kW
  - 144no. 330W panels



Roof top PV installation

- Potential generation 47,078kWh per annum
- Installation cost including cost of PV panels, inverters, roof mounts, cabling and installation - £42,000



Roof top PV – Battery Storage

- To recoup/store excess electricity generation on the peak day would require a discharge capacity of 311kWh
- Based on round-trip efficiency of 90% a circa 345kWh battery is required
- The income gain from storing electricity over exporting is £2,359
  - Excess kWh at high tariff minus kWh at export tariff = £4,061 - £1,702= £2,359

- The typical lifespan of a solar battery is between 5-15years; best case scenario the battery would need to be £35,379 to pay back during its lifespan (cost of a suitable battery for this site would be in the £120,000 - £160,000 range)
- Battery storage option not currently viable

Concept design

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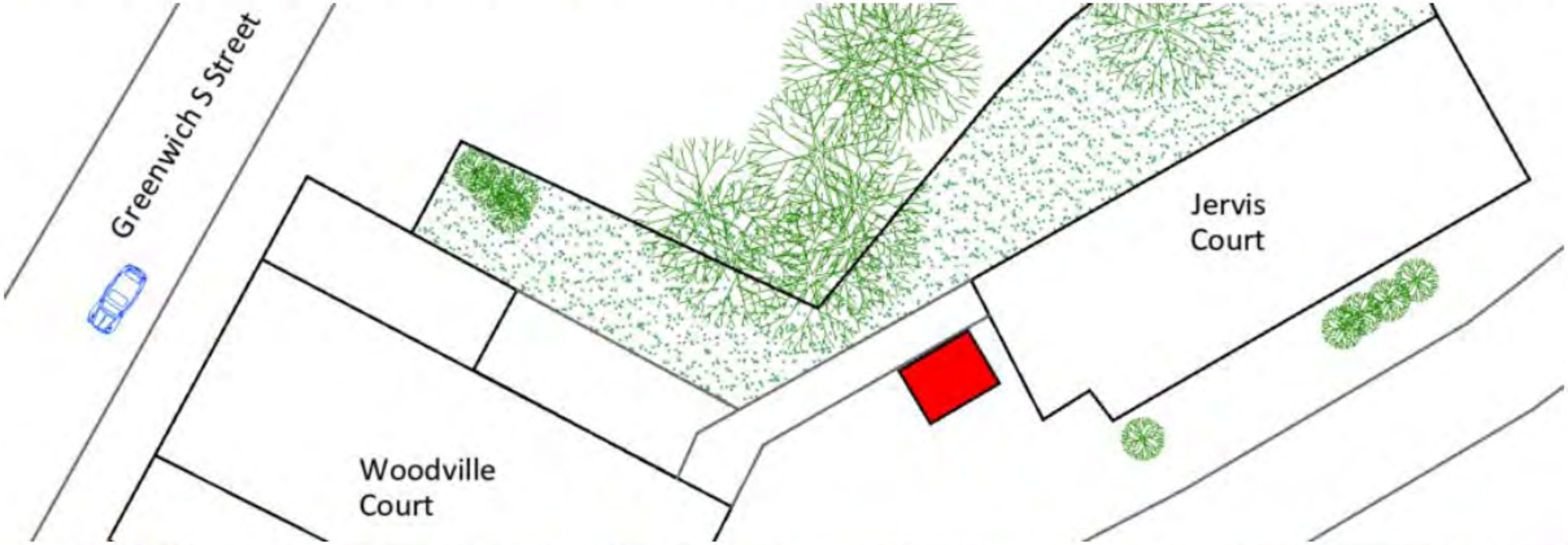
Design considerations

- The existing plant room has been deemed unsuitable by RBG for the installation of new plant due to concerns over the phasing of works
  - Plans have been made for a New Energy Centre for the condensing gas boiler option with a footprint of 4 x 3m
- The low carbon solutions will also include gas boilers sized to provide 100% back up
- New Energy Centre for low carbon solution using ASHP with separate dry air coolers requires a footprint of 5 x 3.5metres plus some additional space for the dry air coolers and attenuation (an extra 5 x 4m)
  - Requires more space and more CAPEX than the 4 x 3m energy centre
- New Energy Centre for low carbon using Monobloc ASHP requires a footprint of 4 x 3m with the ASHP positioned externally. Monobloc solution can be installed external to plant room (example of unit shown below)
  - Slight reduction in COP compared to ASHP with separate dry air cooler
- The Monobloc ASHP with the smaller Energy Centre footprint will be used in the following economic cases

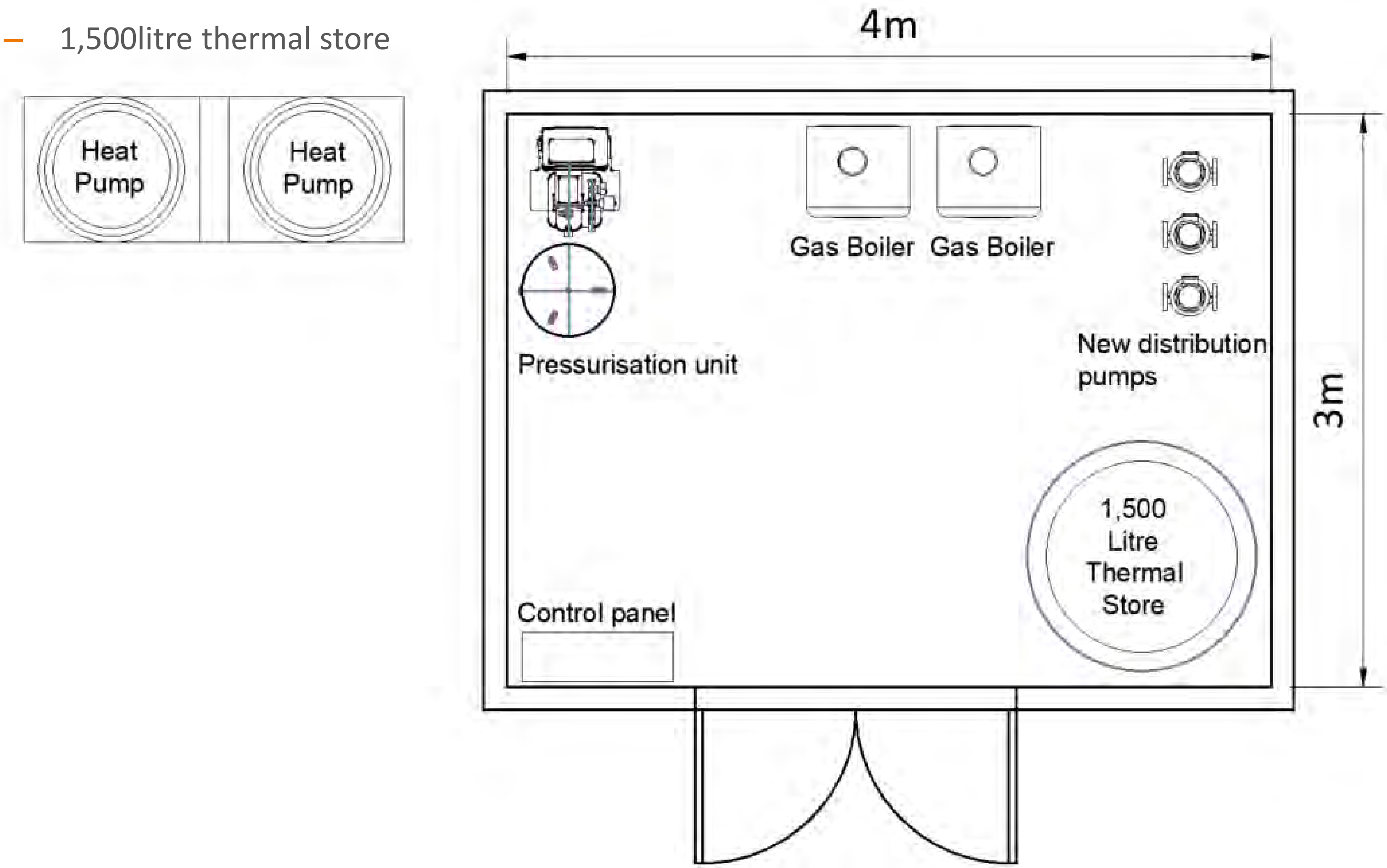
Energy Centre – Location

- The new energy centre is positioned between Jervis and Woodville Court (red)

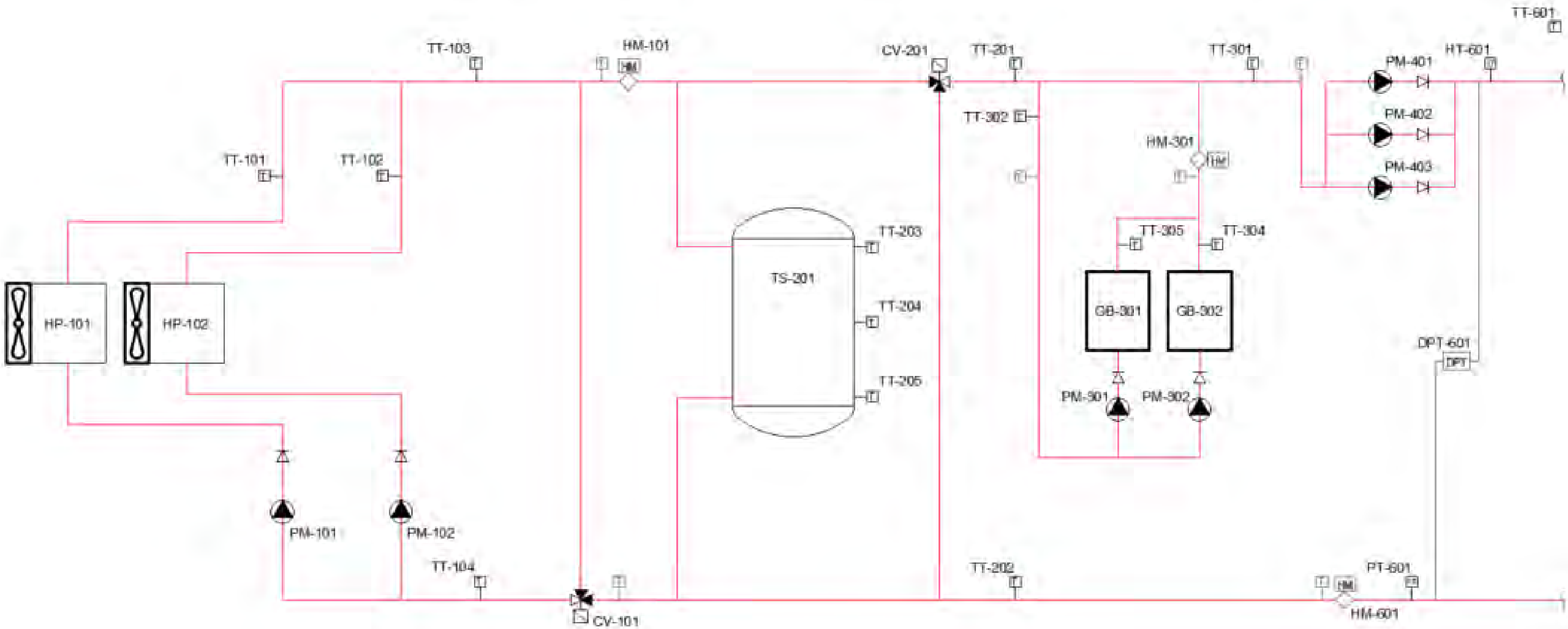


Energy Centre

- New heating plant consists of:
  - 2 x 45kW Air source heat pumps,
  - 2 x 50kW gas boilers,
  - 1,500litre thermal store



PFD Schematic



Economic Assessment

Condensing gas boiler - full scheme CAPEX

	CAPEX	CAPEX inc. contingency
Preliminary		
Contractor prelims including welfare and storage	£30,000	£36,000
Energy Centre works		
Energy Centre Construction	£17,000	19,550
Peak and reserve gas boilers	£6,400	£6,720
Peak and reserve gas boiler flues	£1,000	£1,150
Pressurisation	£2,000	£2,100
Water treatment, flushing and testing	£3,000	£3,450
Electrical connection upgrade	£11,500	£14,375
Plantroom controls	£20,000	£24,000
Cabling and electrical housing blocks	£12,500	£15,000
Other energy centre M&E (pipework, pumps, temporary PHE)	£38,725	£46,470
Builders works	£5,000	£5,750
Network - Usual		
Customer HIUs and flat fit out	£104,000	£119,600
Risers and laterals	£150,000	£187,500
Planning, design and management		
Planning application and fees	£7,500	£9,375
Resident liaison officer	£7,500	£8,250
Professional, design and contracting fees	£30,000	£31,500
Clients Engineer - technical support for construction and commissioning	£20,000	£22,000
Total	£466,125	£552,790

Condensing gas boiler - gas boiler only CAPEX

	CAPEX	CAPEX inc. contingency
Energy Centre works		
Peak and reserve gas boilers	£6,400	£6,720
Peak and reserve gas boiler flues	£1,000	£1,150
Electrical connection upgrade	£11,500	£14,375
Plantroom controls	£20,000	£24,000
Cabling and electrical housing blocks	£12,500	£15,000
Other energy centre M&E (pipework, pumps, temporary PHE)	£38,725	£46,470
Planning, design and management		
Professional, design and contracting fees	£30,000	£31,500
Clients Engineer - technical support for construction and commissioning	£20,000	£22,000
Total	£140,125	£161,215

ASHP plus condensing gas scheme – full scheme CAPEX

	Total	Total inc. contingency
Preliminary		
Contractor prelims including welfare and storage	£40,000	£48,000
Energy Centre works – common to ASHP and gas options		
Energy Centre Construction	£17,000	19,550
Peak and reserve gas boilers	£6,400	£6,720
Peak and reserve gas boiler flues	£1,000	£1,150
Pressurisation	£2,000	£2,100
Water treatment, flushing and testing	£3,000	£3,450
Electrical connection upgrade	£11,500	£14,375
Plantroom controls	£30,000	£36,000
Cabling and electrical housing blocks	£12,500	£15,000
Other energy centre M&E (pipework, pumps, temporary PHE)	£38,725	£46,470
Builders works	£5,000	£5,750
Network – common to ASHP and gas options		
Customer HIUs and flat fit out	£104,000	£119,600
Risers and laterals	£150,000	£187,500
Energy Centre works – ASHP only		
Heat pump	£38,000	£41,800
Heat pump M&E works	£15,000	£16,500
Thermal store	£2,000	£2,200
Energy centre civils works	£15,000	£17,250
Planning, design and management – common to ASHP and gas options		
Planning application and fees	£12,500	£15,625
Resident liaison officer	£7,500	£8,250
Professional, design and contracting fees	£40,000	£42,000
Clients Engineer - technical support for construction and commissioning	£30,000	£33,000
RHI Application	£4,500	£4,725
Total	£585,625	£687,015

ASHP plus condensing gas scheme – ASHP only CAPEX

	Total	Total inc. contingency
Energy Centre works – common to ASHP and gas options		
Peak and reserve gas boilers	£6,400	£6,720
Peak and reserve gas boiler flues	£1,000	£1,150
Electrical connection upgrade	£11,500	£14,375
Plantroom controls	£30,000	£36,000
Cabling and electrical housing blocks	£12,500	£15,000
Other energy centre M&E (pipework, pumps, temporary PHE)	£38,725	£46,470
Energy Centre works – ASHP only		
Heat pump	£38,000	£41,800
Heat pump M&E works	£15,000	£16,500
Thermal store	£2,000	£2,200
Planning, design and management – common to ASHP and gas options		
Professional, design and contracting fees	£10,000	£10,500
Clients Engineer - technical support for construction and commissioning	£10,000	£11,000
Total	£175,125	£201,715

Parasitic electricity BAU and saving assumptions

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- Annual kWh for Jervis and Woodville – 14,492kWh
- Calculated/estimated usage split:
  - Residential usage – 7,786kWh
  - Lift and circulation ancillaries – 2,651kWh
  - Energy centre usage – 4,054kWh
- Existing energy centre usage equates to circa hourly 0.5kW base load
- Installation of new inverter driven pumps for variable speed and additional modern modulating equipment results in an annual 4,422kWh of parasitic electricity usage

Fuel Tariffs

- Tariff inputs

Gas tariff (excl. CCL)	2.166	p/kWh
Gas standing charge	6.41	£/day
CCL - natural gas (2021)	0.406	p/kWh
CCL - natural gas (2022)	0.568	p/kWh
CCL - natural gas (2023 onwards)	0.672	p/kWh
CCL - electricity	0.775	p/kWh
Energy centre electricity tariff - day	13.12	p/kWh
Energy centre electricity tariff - night	9.01	p/kWh
Electricity standing charge	0.36	£/day

OPEX and REPEX assumptions

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OPEX

- Annual cost for O&M of £1225.84 used, which covers the following:
  - Annual servicing for communal heating and hot water (gas only, current maintenance contract only covers gas based systems)
  - HIUs (presumed HIUs for all below estates based on rate receiving for some estates which already have HIUs)
  - Service of BMS with annual servicing of heating and hot water
  - Pressurisation units and expansion vessels
  - Quarterly water treatment
- Annual spares and repair costs £2,860
  - Using estimated of 70% of total costs for maintenance contract from spares and repairs
- Metering and billing cost - £2,340 per annum

REPEX

- Pro-rata cost added per year based on the cost of the asset and its economic life
- Economic lifetime of the technologies used:

Technology	Useful economic lifetime (years)
Heat pump	20
Gas boilers	20
Heat network connections	25

Assessment scenarios

- ASHP sized to provide 100% of the heat demand
- For the assessment cases it is assumed that the availability of the ASHP to supply the heat demand is 96% (2 weeks for maintenance and repairs)
  - The techno economic model has a function to compare 100% (52 weeks), 96% (50 weeks) and 92% (48 weeks) availability
- Table below shows the contribution of the ASHP against the different heat demand scenarios

	Scenario 1	Scenario 2	Scenario 3	Scenario 4
Total heat demand	221,087kWh	190,764kWh	173,965kWh	138,559kWh
Peak heat demand	105kW	93kW	86kW	71kW
Heat pump capacity	90kW	90kW	90kW	90kW
Thermal store capacity	1,500litres	1,500litres	1,500litres	1,500litres
% heat demand potentially met by low carbon / renewable technology				
52 weeks availability	100%	100%	100%	100%
50 weeks availability	98.9%	98.8%	98.7%	98.4%
48 weeks availability	98%	97.7%	97.5%	96.9%

Assessment scenarios

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- Two CAPEX scenarios are presented:
  - **CASE 1** – installation of condensing gas boiler and energy centre upgrades
  - **CASE 2** – installation of condensing gas boiler, installation of ASHP and energy centre upgrades
  - These cases include the CAPEX associated with installation of the heat generation technology systems only
- Two heat demand scenarios are presented:
  - Scenario 1 – existing fabric with upgraded heating system
  - Scenario 4 – upgraded fabric (roof, glazing and EWI) with upgraded heating system
- Additional economic assumptions:
  - ASHP cases will include income from RHI
  - Impact of PV array installation will also be presented
    - Electricity generation to offset the energy centre requirements at electricity day rate
    - Excess generation exported at 5.5p/kWh

Economic assessment (heat demand scenario 1)

		Current system	Option 1: Gas condensing boilers	Option 2: Gas condensing boilers and ASHP	Option 3: Gas condensing boilers, ASHP and PV
Energy and carbon	**Units**				
Heat demand - Peak	kW	110	105	105	105
Heat annual demand	kWh	280,015	218,459	218,459	218,459
Heat annual demand - losses	kWh	3,854	2,628	2,628	2,628
Heat annual demand - Total	kWh	283,869	221,087	221,087	221,087
% heat demand low carbon	%	0%	0%	98.9%	98.9%
25 year CO2e savings	tCO2e		125	983	1,032
First year CO2e savings, tCO2e	tCO2e		5	27	31
First year CO2e intensity of delivered heat	gCO2e /kWh		212	113	93
Build and run costs					
Capex of scheme	£		£140,125	£175,125	£217,125
Capex of scheme + contingency	£		£161,215	£201,715	£247,915
OPEX – Fuel costs	£		£9,378	£14,169	£11,983
OPEX – (O&M + fuel/elec costs)	£		£15,804	£22,596	£20,409
Fixed heat sales	£		£12,432	£12,432	£12,432
Variable heat sales	£		£16,384	£16,384	£16,384
Potential annual Income - RHI	£		-	£5,942	£5,942
Potential annual Income – PV export	£		-	-	£1,721
Economic indicators – 25 year case					
Fixed heat sales	£/day		1.31	1.31	1.31
Variable heat sales	p/kWh		7.50	7.50	7.50
Cost of heat to residence - annual	£		£1,108	£1,108	£1,108
Payback period	Years		16	21	18
NPV	£		£13,692	-£49,710	-£28,137
IRR	%		4.3%	0.9%	2.4%
Assumptions	Capital costs excludes heating systems, water treatment and ancillaries Fixed tariff of £1.31/day Variable tariff of 7.5p/kWh (in line with Heat Trust costing)				

Economic assessment (heat demand scenario 1)

	Units	Current system	Option 1: Gas condensing boilers	Option 2: Gas condensing boilers and ASHP	Option 3: Gas condensing boilers, ASHP and PV
Resident costs – Fuel only					
Cost of heat to residence – Fuel (variable)	p/kWh	5.98	4.29	6.49	5.49
Cost of heat to residence - annual	£	£503	£361	£545	£461
Resident costs – Fuel + O&M					
Cost of heat to residence – O&M (fixed)	£/day	0.68	0.68	0.89	0.89
Cost of heat to residence – Fuel (variable)	p/kWh	5.98	4.29	6.49	5.49
Cost of heat to residence - annual	£	£750	£608	£869	£785
Subsidy requirement per apartment					
Cost of heat, savings per apartment (fuel only)	£/year			-£42	£42
Cost of heat, savings per apartment (fuel + O&M)	£/year			-£119	-£35
Remaining RHI income (whole scheme - fuel + O&M)	£/year			£2,848	£5,032
Assumptions	No accounting has been made for initial capital costs or replacement costs over lifetime. Capital for energy centre and network are part of the building and therefore will be part of the rent rather than in the energy bills.				
Social Economics – 25 year case					
Social IRR			4.8%	4.3%	5.1%
Social NPV			£23,214	£20,171	£46,546
Assumptions	Fixed tariff of £1.31/day Variable tariff of 7.5p/kWh (in line with Heat Trust costing)				

Economic assessment (heat demand scenario 4)

		Current system	Option 1: Gas condensing boilers	Option 2: Gas condensing boilers and ASHP	Option 3: Gas condensing boilers, ASHP and PV
Energy and carbon	**Units**				
Heat demand - Peak	kW	110	71	71	71
Heat annual demand	kWh	280,015	135,931	135,931	135,931
Heat annual demand - losses	kWh	3,854	2,628	2,628	2,628
Heat annual demand - Total	kWh	283,869	138,559	138,559	138,559
% heat demand low carbon	%	0	0	98.4%	98.4%
25 year CO2e savings	tCO2e		77	614	648
First year CO2e savings, tCO2e	tCO2e		3	17	20
First year CO2e intensity of delivered heat	gCO2e /kWh		214	114	91
Build and run costs					
Capex of scheme	£		£140,125	£175,125	£217,125
Capex of scheme + contingency	£		£161,215	£201,715	£247,915
OPEX – Fuel costs	£		£6,802	£9,770	£8,229
OPEX – (O&M + fuel/elec costs)	£		£13,228	£18,196	£16,655
Fixed heat sales	£		£12,432	£12,432	£12,432
Variable heat sales	£		£10,195	£10,195	£10,195
Potential annual Income - RHI	£		-	£3,677	£3,677
Potential annual Income – PV export	£		-	-	£1,978
Economic indicators – 25 year case					
Fixed heat sales	£/day		1.31	1.31	1.31
Variable heat sales	p/kWh		7.50	7.50	7.50
Cost of heat to residence - annual	£		£870	£870	£870
Payback period	Years		21	0	0
NPV	£		-£31,567	-£105,559	-£90,719
IRR	%		1.6%	-2.7%	-0.4%
Assumptions	Capital costs excludes heating systems, water treatment and ancillaries Fixed tariff of £1.31/day Variable tariff of 7.5p/kWh (in line with Heat Trust costing)				

Economic assessment (heat demand scenario 4)

	Units	Current system	Option 1: Gas condensing boilers	Option 2: Gas condensing boilers and ASHP	Option 3: Gas condensing boilers, ASHP and PV
Resident costs – Fuel only					
Cost of heat to residence – Fuel (variable)	p/kWh	5.98	5.00	7.19	6.05
Cost of heat to residence - annual	£	£503	£262	£376	£317
Resident costs – Fuel + O&M					
Cost of heat to residence – O&M (fixed)	£/day	0.68	0.68	0.89	0.89
Cost of heat to residence – Fuel (variable)	p/kWh	5.98	5.00	7.19	6.05
Cost of heat to residence - annual	£	£750	£509	£700	£641
Subsidy requirement per apartment					
Cost of heat, savings per apartment (fuel only)	£/year		-	£127	£186
Cost of heat, savings per apartment (fuel + O&M)	£/year		-	£50	£109
Remaining RHI income (whole scheme - fuel + O&M)	£/year		-	£3,677	£3,677
Assumptions	No accounting has been made for initial capital costs or replacement costs over lifetime. Capital for energy centre and network are part of the building and therefore will be part of the rent rather than in the energy bills.				
Social Economics – 25 year case					
Social IRR			2.0%	0.5%	1.8%
Social NPV			-£25,723	-£61,935	-£43,712
Assumptions	Fixed tariff of £1.31/day Variable tariff of 7.5p/kWh (in line with Heat Trust costing)				

Increased gas tariff

- The gas tariff for Jervis and Woodville Court at the time of this assessment is 2.166p/kWh
- This figure is relatively low and an increase in this tariff has a significant affect on economic case for the condensing gas boiler only solution
- The following table presents the cases with the gas tariff increased to 2.79p/kWh (the point at which the economics are similar for the gas condensing case and the ASHP case)

Economic assessment (heat demand scenario 1)

		Current system	Option 1: Gas condensing boilers	Option 2: Gas condensing boilers and ASHP	Option 3: Gas condensing boilers, ASHP and PV
Energy and carbon	**Units**				
Heat demand - Peak	kW	110	105	105	105
Heat annual demand	kWh	280,015	218,459	218,459	218,459
Heat annual demand - losses	kWh	3,854	2,628	2,628	2,628
Heat annual demand - Total	kWh	283,869	221,087	221,087	221,087
% heat demand low carbon	%		0%	98.9%	98.9%
25 year CO2e savings	tCO2e		125	983	1,032
First year CO2e savings, tCO2e	tCO2e		5	27	31
First year CO2e intensity of delivered heat	gCO2e /kWh		212	113	93
Build and run costs					
Capex of scheme	£		£140,125	£175,125	£217,125
Capex of scheme + contingency	£		£161,215	£201,715	£247,915
OPEX – Fuel costs	£		£10,911	£14,186	£11,999
OPEX – (O&M + fuel/elec costs)	£		£17,337	£22,612	£20,426
Fixed heat sales	£		£12,432	£12,432	£12,432
Variable heat sales	£		£16,384	£16,384	£16,384
Potential annual Income - RHI	£		-	£5,942	£5,942
Potential annual Income – PV export	£		-	-	£1,721
Economic indicators – 25 year case					
Fixed heat sales	£/day		1.31	1.31	1.31
Variable heat sales	p/kWh		7.50	7.50	7.50
Cost of heat to residence - annual	£		£1,108	£1,108	£1,108
Payback period	Years		19	21	18
NPV	£		-£17,966	-£50,055	-£28,483
IRR	%		2.4%	0.9%	2.4%
Assumptions	Capital costs excludes heating systems, water treatment and ancillaries Fixed tariff of £1.31/day Variable tariff of 7.5p/kWh (in line with Heat Trust costing)				

Economic assessment (heat demand scenario 1)

	Units	Current system	Option 1: Gas condensing boilers	Option 2: Gas condensing boilers and ASHP	Option 3: Gas condensing boilers, ASHP and PV
	Units				
Resident costs – Fuel only					
Cost of heat to residence – Fuel (variable)	p/kWh	5.98	4.99	6.49	5.49
Cost of heat to residence - annual	£	£503	£420	£546	£462
Resident costs – Fuel + O&M					
Cost of heat to residence – O&M (fixed)	£/day	0.68	0.68	0.89	0.89
Cost of heat to residence – Fuel (variable)	p/kWh	5.98	4.99	6.49	5.49
Cost of heat to residence - annual	£	£750	£667	£870	£786
Subsidy requirement per apartment					
Cost of heat, savings per apartment (fuel only)	£/year			-£43	£41
Cost of heat, savings per apartment (fuel + O&M)	£/year			-£120	-£36
Remaining RHI income (whole scheme - fuel + O&M)	£/year			£2,822	£5,006
Assumptions	No accounting has been made for initial capital costs or replacement costs over lifetime. Capital for energy centre and network are part of the building and therefore will be part of the rent rather than in the energy bills.				
Social Economics – 25 year case					
Social IRR			3.0%	4.3%	5.1%
Social NPV			-£8,444	£19,825	£46,200
Assumptions	Fixed tariff of £1.31/day Variable tariff of 7.5p/kWh (in line with Heat Trust costing)				

Summary and next steps

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Summary

- Under current assumptions, the economics of the gas condensing boiler are more favourable than the heat pump options but offer far lower CO_2e savings
- ASHPs are the only technically viable renewable heating option with an acceptable level of risk
- Solar PV improves economics and increases CO_2e savings
- Low gas prices support the economics of the gas boiler option, when gas prices reach 2.79p/kWh then economics reach parity with the ASHP option and the social IRR of the ASHP is higher in each case

Next Steps

- Detail dimensions for full energy system and network
- Draft tender specification for energy centre and phased works

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Sustainable
ENERGY

Sustainable ENERGY

Royal Borough of Greenwich

Strand Court
Low carbon technology feasibility

Dr Gabriel Gallagher
Omied Khakshour

June 2020

Sustainable ENERGY

Scope of work

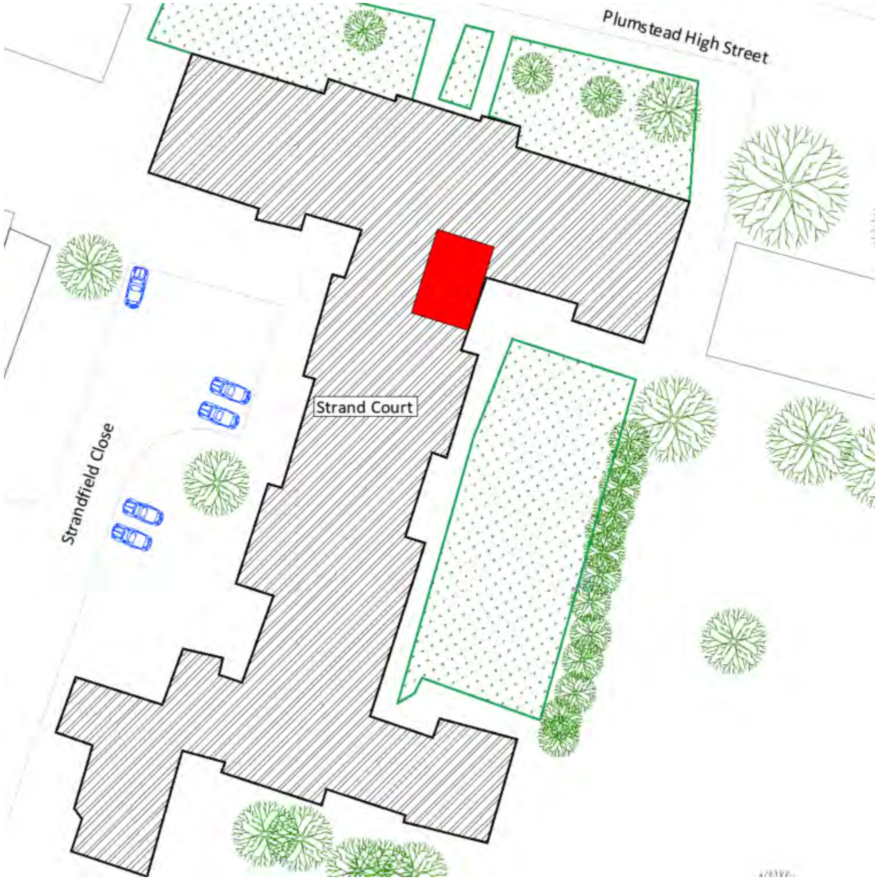
- To assess low carbon / renewable heating options for social housing
- Model heat and hot water demands for different levels of fabric improvements to inform sizing of new system
- Review and propose solutions for secondary heating and hot water systems
- Develop concept designs for refurbishment of energy centre with low carbon heating

ROYAL borough of GREENWICH

Sustainable ENERGY

Summary of Strand Court

- 60 dwellings in sheltered accommodation
- Central heating system plant in ground floor plant room (red)
- Existing LTHW (82^{o}C flow / 71^{o}C return) communal heating system supplies radiators and communal hot water cylinder provides DHW



Design considerations

Sustainable ENERGY

- To ensure correct specification of low carbon heating systems – flow and return temperatures must be reduced we must:
  - Reduce radiator temperatures*
  - Increase temperature differential to reduce pipe sizes
  - Ensure peak loads are correctly estimated to prevent oversizing
  - Install heat interface units in dwellings to replace hot water cylinders
  - Maintain existing network and supply of heat to continue to provide service whilst new system is installed

* This does not mean a reduction in the potential energy supplied to each space; although, the operating temperatures are lower than existing, the new emitters will be compatible with the operating conditions and the required set points will be achieved

Heat demand profiling

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Current heat demand

- Existing gas consumption data – 986,978kWh per annum
- Existing heat demand modelled based on following assumptions:
  - Fabric to ~30 year old building regs
  - Unmetered heating controls with 23°C setpoint and 19°C set back
  - Communal DHW hot water storage tank
  - 1.5 occupants per apartment
- Heat losses from existing DHW cylinders and DHW pipework

Current heat demand

- Fabric and ventilation loss inputs:

Fabric type - U-Values		
Floor	W/m^2K	0.45
Walls	W/m^2K	0.45
Glazing	W/m^2K	2.00
Roof	W/m^2K	0.25
Ventilation		
Air permeability	$m^3/h.m^2$	8

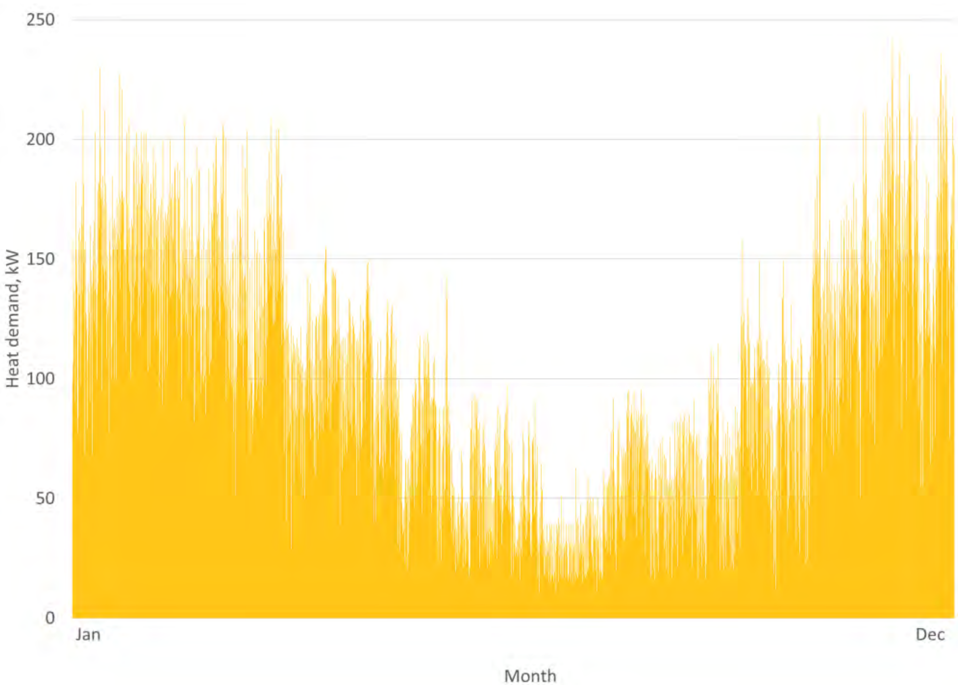
Current heat demand

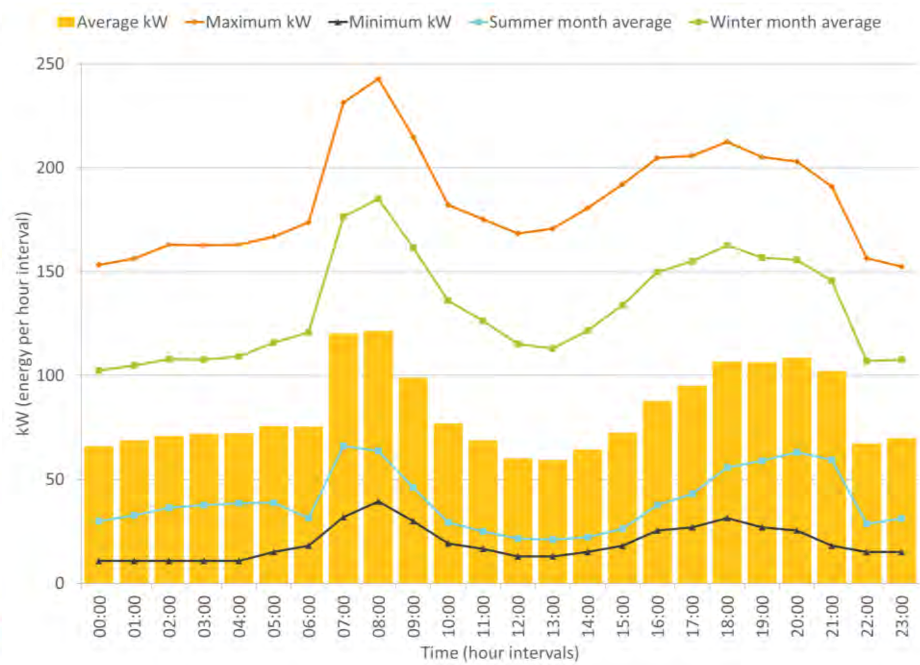
Sustainable ENERGY

- Summary of existing heat demand

Scenario	Annual Modelled Demand kWh	Peak heat kW	kWh per flat	Total kW per flat
Existing	725,250	243	12,088	4.0

- Modelled boiler efficiency of existing system – 73%





Scenario 1
Upgraded heating system demand

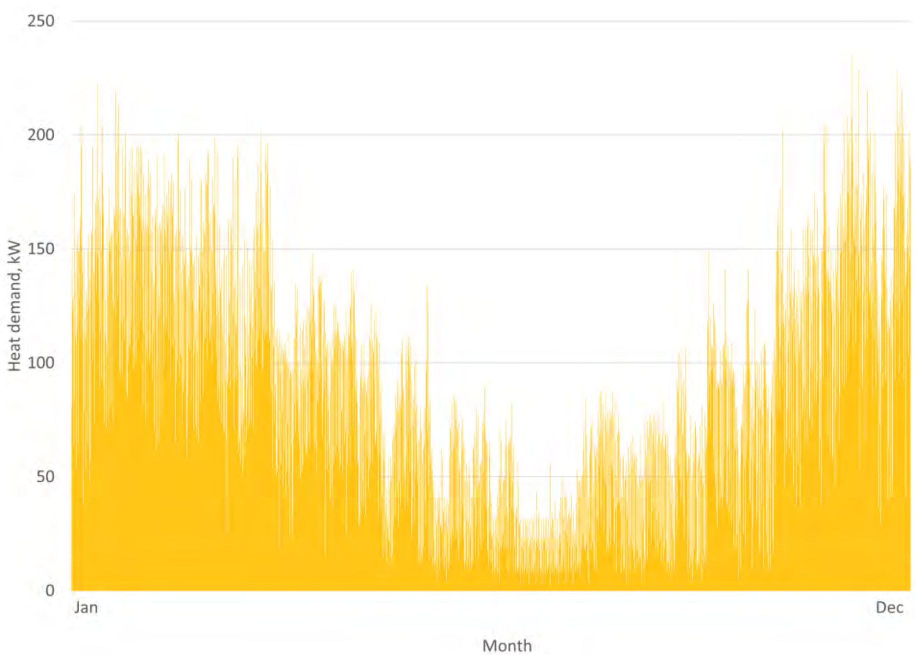
- Scenario 1 assumes:
  - No fabric changes
  - Flat fit outs for low temperature network conditions
  - Heat interface units for local heating control, metering and instantaneous hot water
  - Upgraded pipe work for the risers and laterals in each building
- Factors that have an impact on heat demand once the new system is installed:
  - Change in behaviour and housekeeping due to individual metering of each apartment
  - Ambient temperature controls in energy centre
  - Heating controls with 23°C setpoint and 17°C set back
  - Replacement communal DHW storage tanks and 4-pipe system with instantaneous plates in HIUs

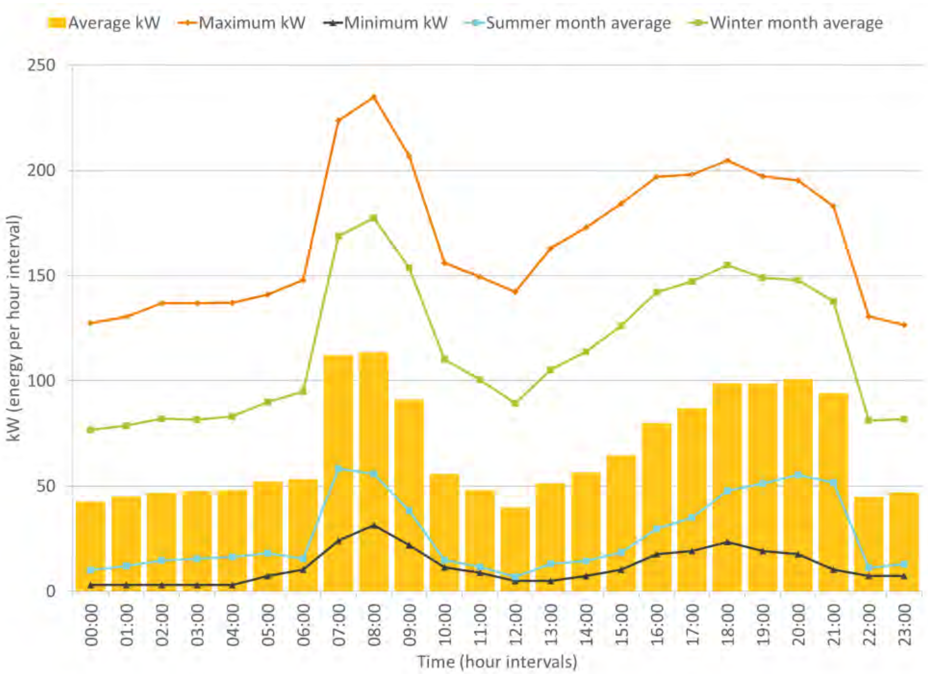
Scenario 1
Upgraded heating system demand

- Scenario 1 heat demand summary

Scenario	Annual Modelled Demand kWh	Peak heat kW	kWh per flat	Total kW per flat
1	591,639	235	9,861	3.9

- The heat demand for the site after all the above conditions are adjusted is 427,320kWh
    - 18% reduction in current heat demand





Scenarios 2,3 and 4
Fabric improvements

- As with scenario 1, scenarios 2, 3 and 4 all assume:
  - Flat fit outs for low temperature network conditions
  - Heat interface units for local heating control, metering and instantaneous hot water
  - Upgraded pipe work for the risers and laterals in each building

- With the addition of varying levels of fabric improvements as follows:
  - Scenario 2 – roof insulation improvements
  - Scenario 3 – roof insulation improvements and glazing upgrades
  - Scenario 4 – roof insulation improvements, glazing upgrades and external wall cladding

Scenarios 2,3 and 4
Fabric improvements

- Fabric improvements are to bring each element up to current retrofit/refurbishment Part L levels as below:

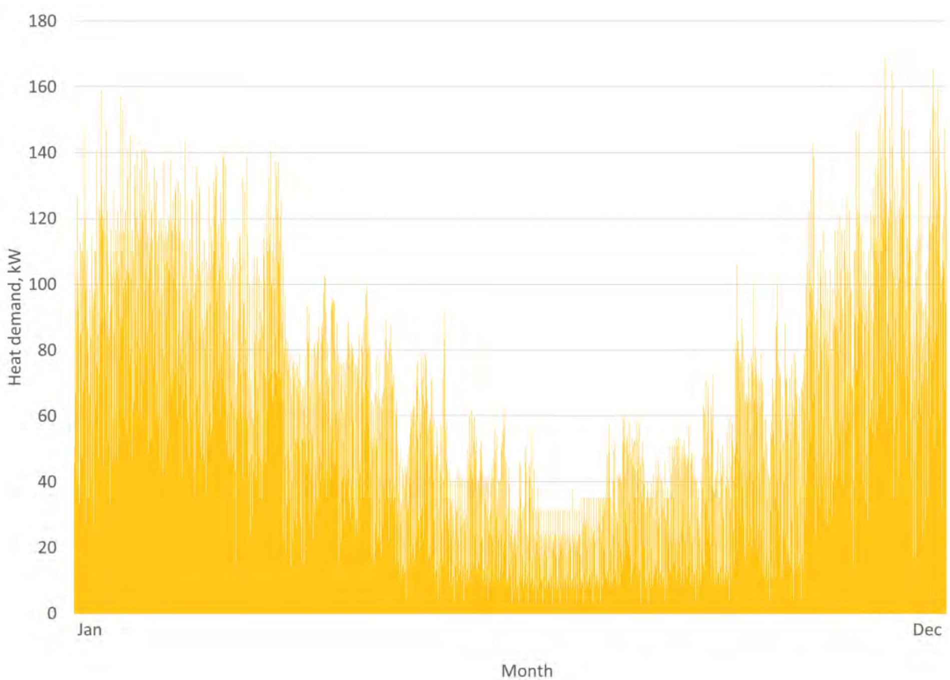
Fabric type - U-Values	Units	Scenario 1 – Existing fabric	Scenario 2 -Roof upgrade	Scenario 3 - Roof and glazing	Scenario 4 - Roof, glazing and EWI
Floor	W/m^2K	0.45	0.45	0.45	0.45
Walls	W/m^2K	0.45	0.45	0.45	0.30
Glazing	W/m^2K	2.00	2.00	1.60	1.60
Roof	W/m^2K	0.25	0.16	0.16	0.16
Ventilation					
Air permeability	$m^3/h.m^2$	8.0	7.5	7.0	5.0

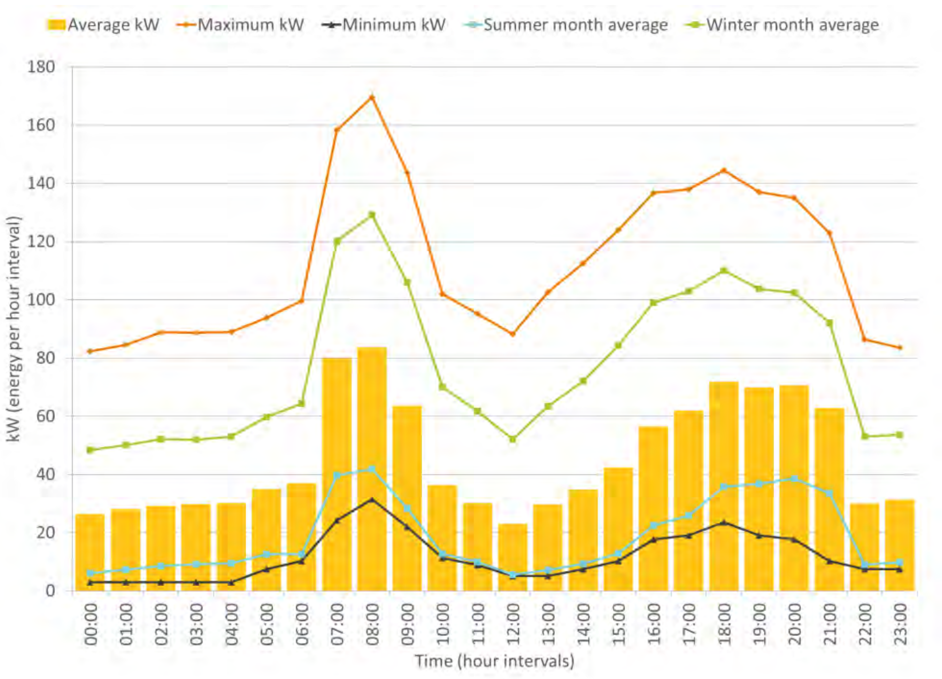
Scenario 2,3 and 4
Fabric improvements

- Summary of heat demands

Scenario	Annual Modelled Demand kWh	Peak heat kW	kWh per flat	Total kW per flat
2	556,982	223	9,283	3.7
3	525,994	213	8,767	3.5
4	399,302	170	6,655	2.8

- Annual heat demand profile and average, max, min daily profile for scenario 4





Supply options appraisal and feasibility

Sustainable ENERGY

Supply options appraisal

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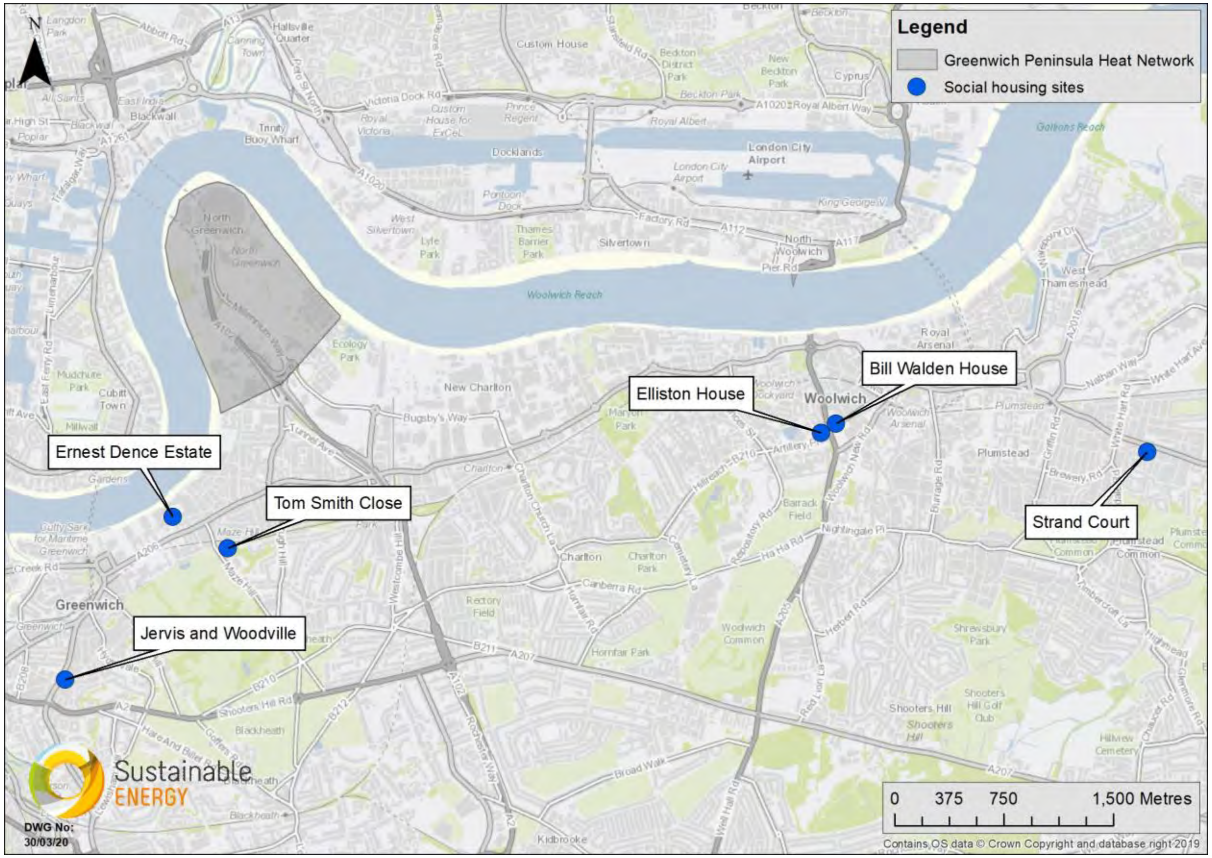
A number of different supply options were considered for the supply of heat and electricity to Strand Court:

- Connection to local district heat networks
- Heat pump technologies
  - Ground source – closed loop
  - Ground source – bore hole
  - Air source
- Solar PV
- Energy storage
  - Thermal
  - Electrical

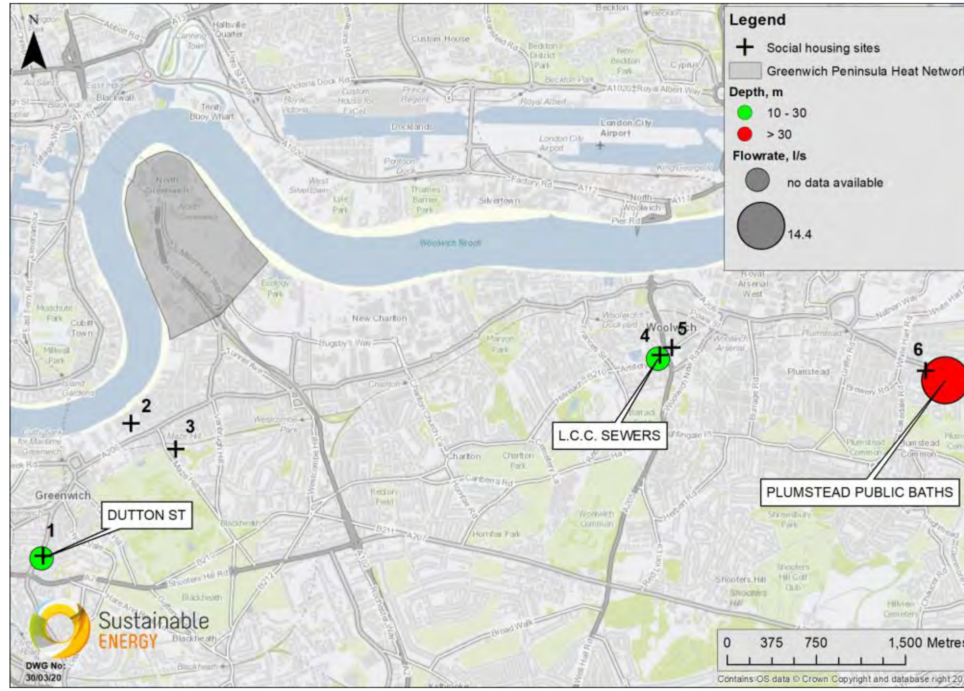
Local heat networks

- The image below shows the position of the RBG low carbon assessment sites and the location of the Greenwich Peninsula heat network
- At present there are no suitable connection points for heat supply from the existing network
- The design of the new heating systems will be compatible with connection to a large heat network if a suitable one was to become viable in the future



Ground source

- Borehole data from the national BGS resource is summarised in the GIS and table below
- Positions of gathered data is shown in the GIS
  - Colour indicated depth of bore holes
  - Width indicates flowrates measured in the bore holes
  - The assessment sites are numbered. Strand Court is shown at position 6

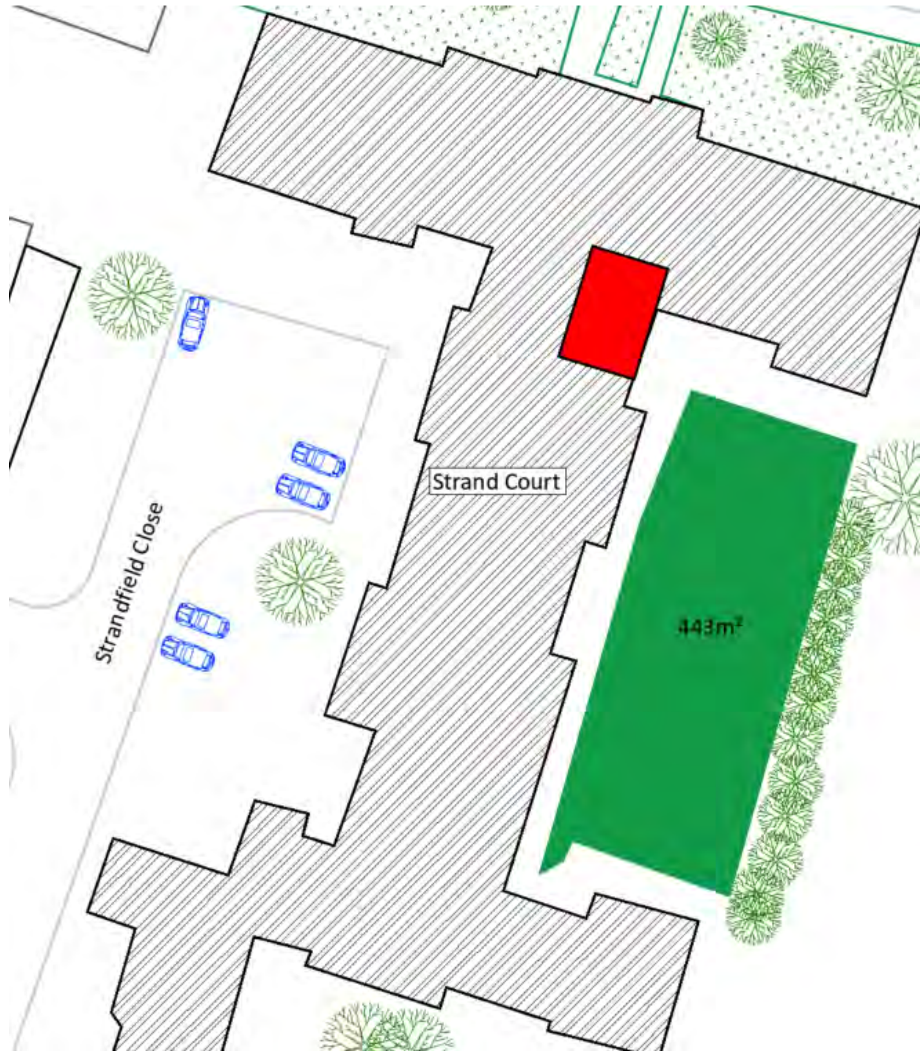


- Table with results of bore hole data

Location	Borehole name	Depth, m	Water depth, m	Flowrate, l/s	Strata details	Notes
Strand Court 545660,178410	TQ47NE5 — PLUMSTEAD PUBLIC BATHS WOOLWICH	128		14.4	0 – 3.05 m: Sand 3 – 5.2 m: Hard sand 5.2 – 32 m: Chalk and flints 32 – 37.5 m: Hard chalk and flints 37.5 – 79.3 m: Chalk and flints 79.3 – 81.7 m: Grey chalk and flints 81.7 – 83.2 m: Chalk and flints 83.2 – 95.7 m: Hard chalk and flints 95.7 – 109.2 m: Chalk and flints 109.2 – 111.9 m: Very hard chalk 111.9 – 114.3 m: Chalk and flints 114.3 – 116.1 m: Hard chalk 116.1 – 122.8 m: Chalk and flints	Last examined in 1961

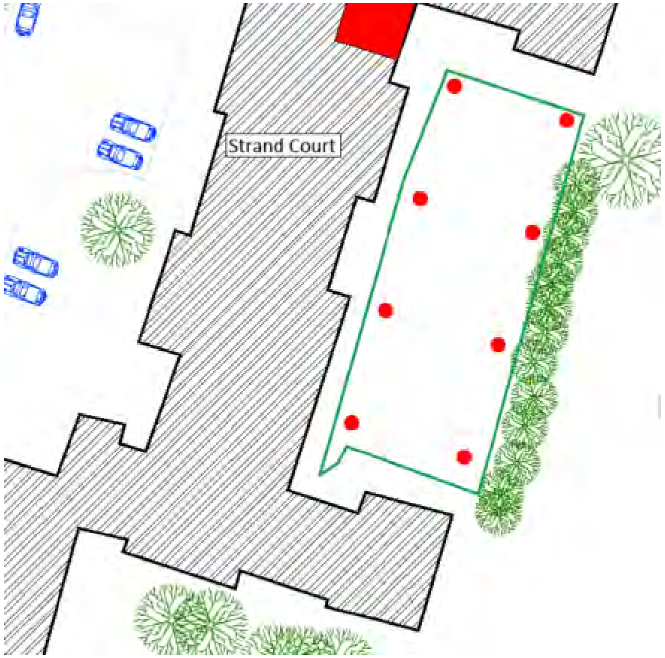
Ground source – closed loop

- The available green space for the installation of ground loops is limited
  - Circa 443m² total shown below
- Potential issues with loss of recreation space for the sheltered accommodation



Ground source – closed loop

- Vertical bore positions



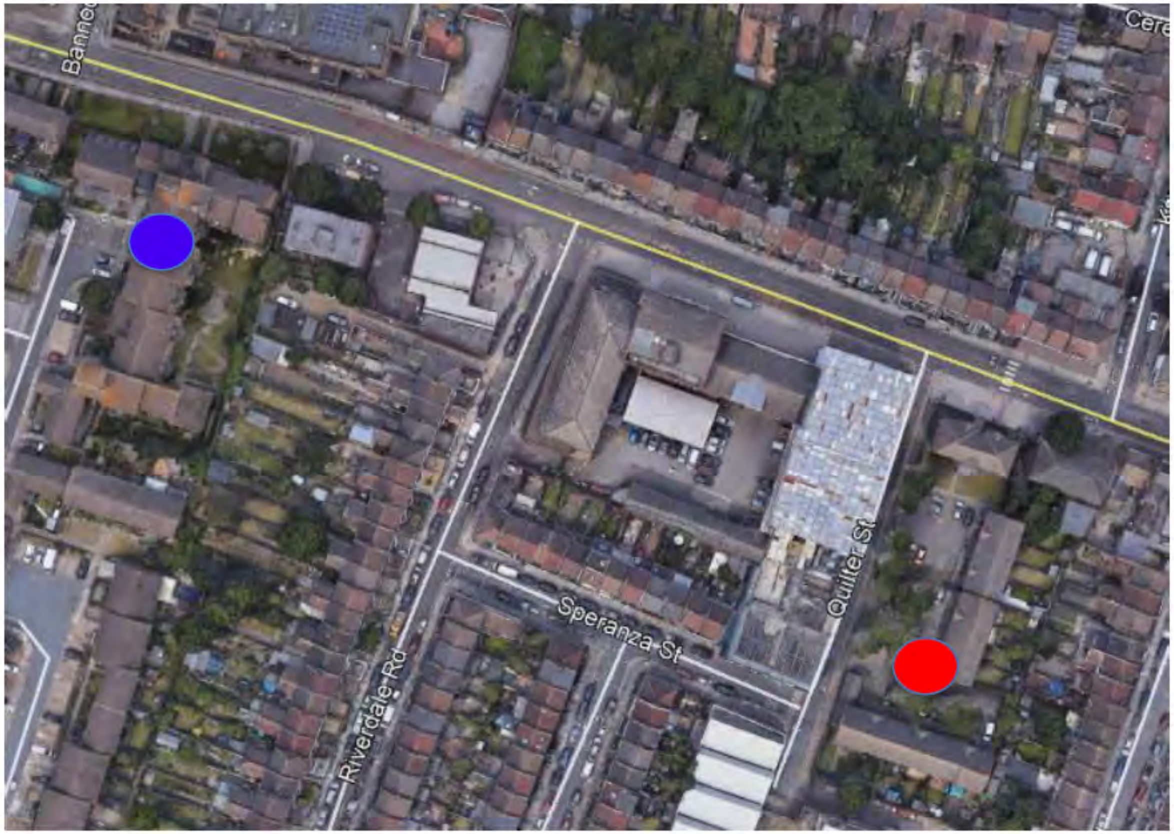
- Potential yield*

Array type	Heat extraction rate – figures from BS EN 15450	Installation details	Potential Capacity
Horizontal –slinky pipe	• 16 - 24W/m² • Figure for moist cohesive soil • 2400h p.a operation	• 443m² green space	7 – 10.6kW
Vertical	• 50W/m • Figure for normal underground and water saturated sediment • 2400h p.a operation	• 8 boreholes • 0.6m diameter with 10metre spacing • 100m depth	40kW

*Numbers shown assume all existing trees are removed and all available green space could be utilised

Ground Source– open loop

- Borehole data is taken from a source (red) which is approximately 190m from Strand Court (blue)
- Flowrate from bore of 14.4l/s
  - Heat pump output potential of circa 270kW per bore hole (ΔT - 3°C)



Ground Source– open loop

- There is some risk associated with the open loop solution.
- There is limited space for abstraction and discharge wells on site.
  - Without significant separation the ability to minimise thermal interaction will be limited
  - If land area cannot be found to significantly separate the wells, it is unlikely abstraction and discharge wells will be viable and so it may be possible to drill a single well where water is abstracted from one aquifer horizon and injected back to another. However, this approach is not tried and tested and detailed hydro geological modelling will be required to further assess viability as will the drilling of a test well.

Air source

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- Available resource with lower installation requirements
- Potential risks of noise to residents and cold plumes can be mitigated with suitable attenuation

Technology assessment summary

Heat source	Comments	Considered further?
Heat network connection	• No suitable networks local to the assessment site	No
Closed Loop GSHP	• Low yield potential from available land • Not viable due to land requirement for ground loops (horizontal and vertical)	No
Open Loop GSHP	• Potential yield to supply full load • High CAPEX associated with drilling boreholes into chalk aquifer • RHI accreditation is time sensitive and installation of bore is time intensive	Yes
ASHP	• Lower initial CAPEX than GSHP options • Potential noise restrictions close to residential developments	Yes

Solar PV assessment

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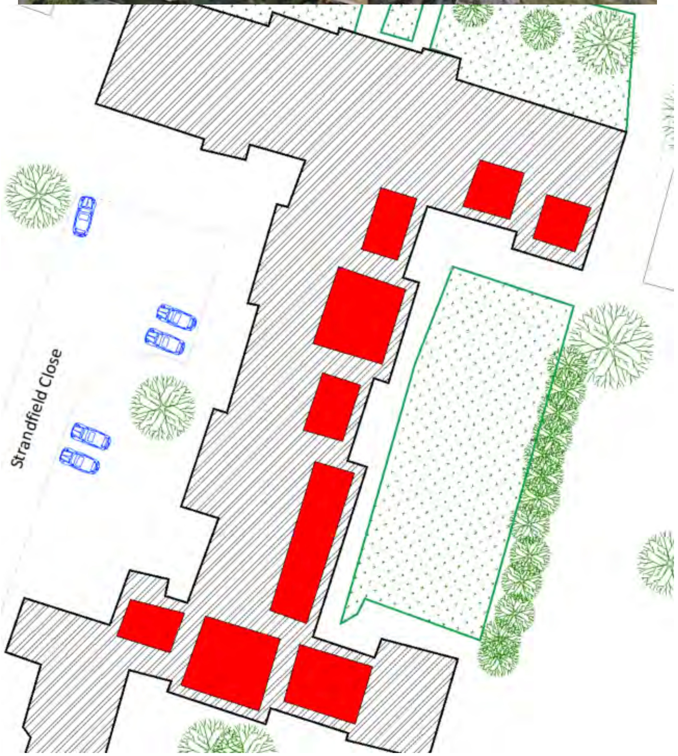
Roof top PV installation

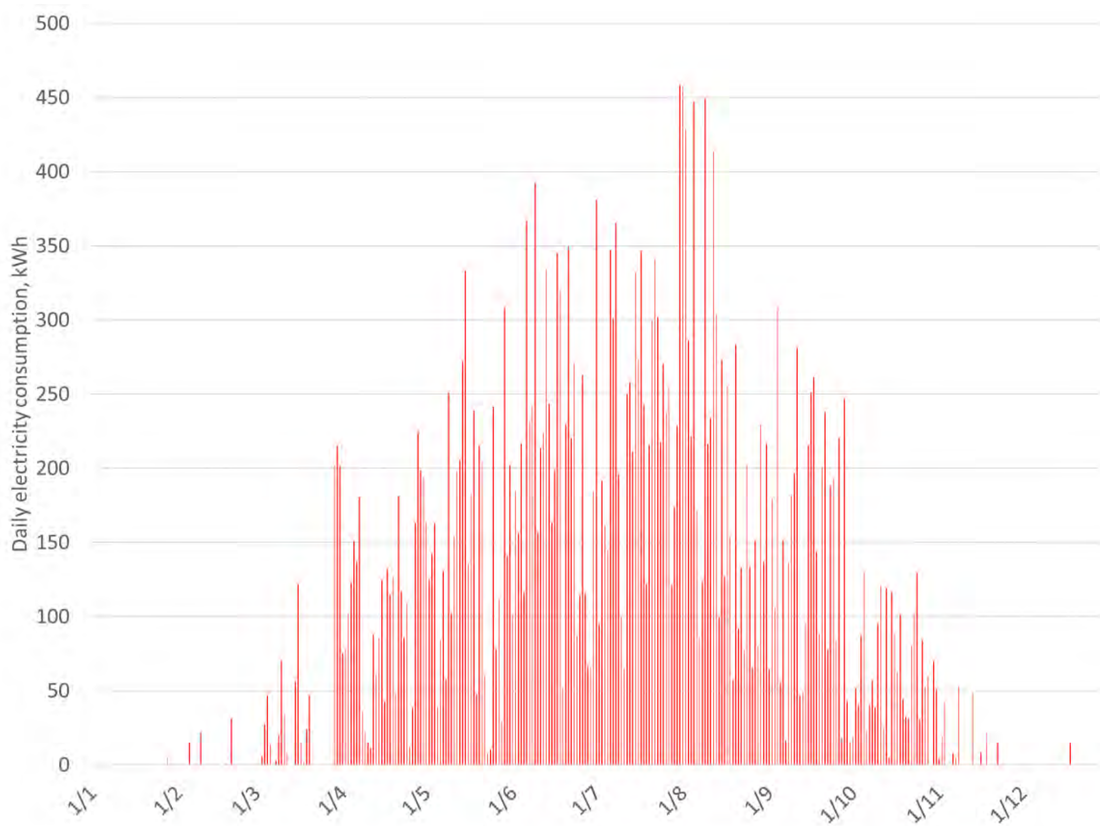
- Circa 340m² of available roof space for installation (red)
  - South facing on pitched roof
  - Mounted flush to pitched roof
  - 30° inclination (assumed pitch of roof)
- Potential peak load circa 70kW

  213xno. 330W panels
- Potential generation 67,752kWh per annum
- Installation cost including cost of PV panels, inverters, roof mounts, cabling and installation - £72,000
- Additional surveys required to determine structural suitability of existing roof for housing the PV array



Roof top PV – Battery Storage

- To recoup/store excess electricity generation on the peak day would require a discharge capacity of 460kWh
- Based on round-trip efficiency of 90% a circa 510kWh battery is required
- The income gain from storing electricity over exporting is £2,712
  - Excess kWh at high tariff minus kWh at export tariff = £4,683 - £1,971= £2,712



- The typical lifespan of a solar battery is between 5-15years; best case scenario the battery would need to be £40,682 to pay back during its lifespan (cost of a suitable battery for this site would be in the £180,000 - £220,000 range)
- Battery storage option not currently viable

Concept design

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Design considerations

- Existing available plant room space = 5.5 x 5.5metres
- Plant room space limits the selection of new heating plant
- The existing plant room is positioned on the ground floor (red)
- Dry air coolers can be placed on the green outside the existing plant room. Additional attenuation required to mitigate any sound issues
  - Potential position for dry air coolers (blue)
- Bore hole can be drilled on the green outside the existing plant. To reduce the risk of interaction between abstraction and discharge and CAPEX for drilling , a bore that allows for abstraction and discharge from the same hole can be used
  - Potential position for bore hole (yellow)

Energy Centre

- New heating plant to be installed in existing plant room
- ASHP solution consists of 2no. 80kW air source heat pumps and 1no. 2,000litre thermal store
- GSHP solution consists of 2no. 95kW water source heat pumps and 1no. 2,000litres
- 2no. 120kW Condensing gas boiler back-up for both solutions

Energy Centre

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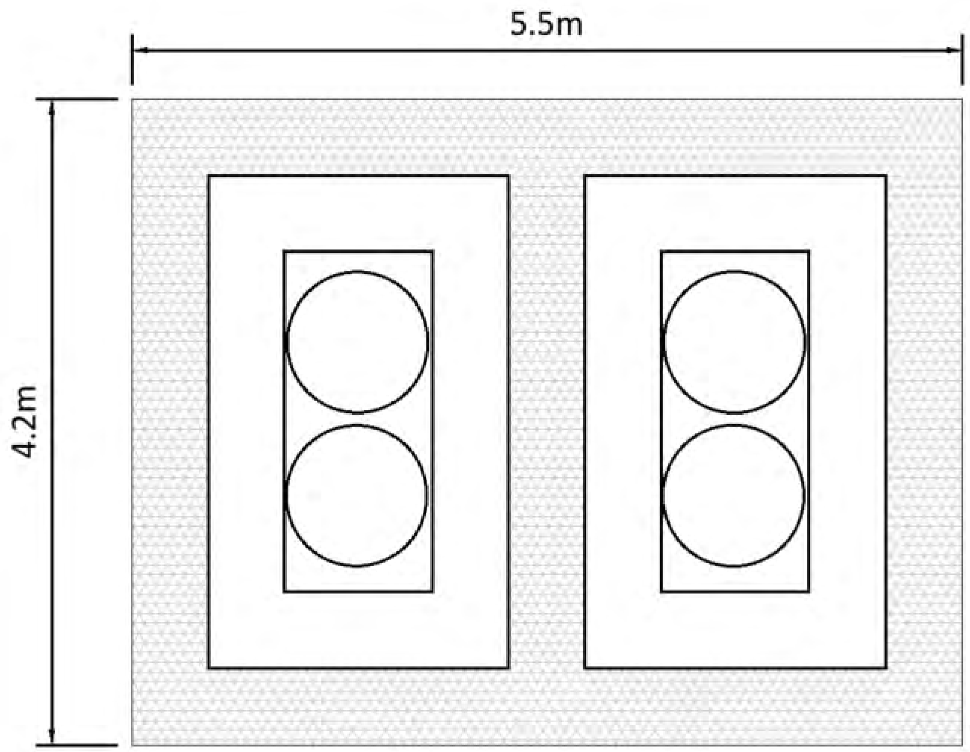
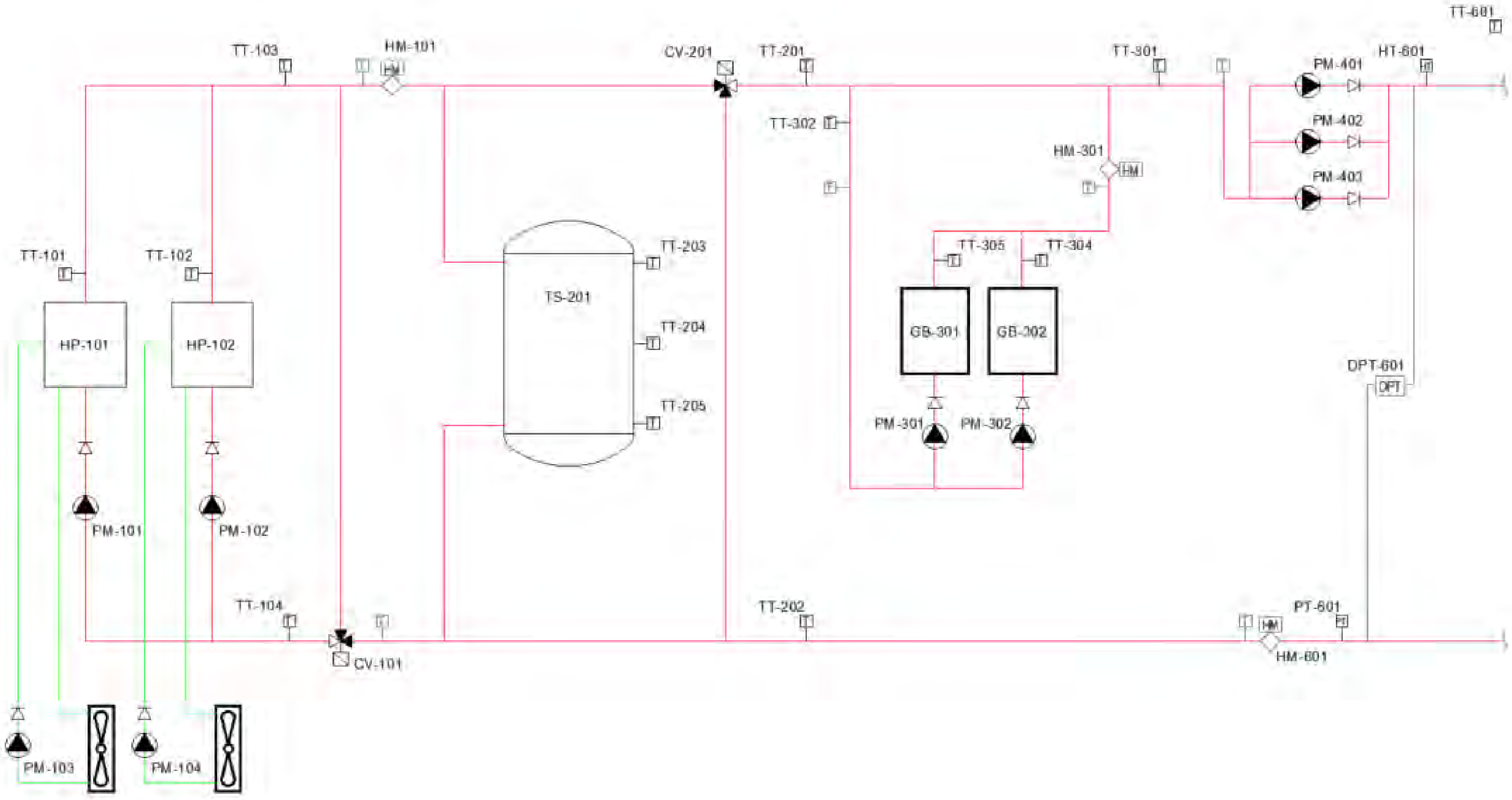
- ASHP solution – Dry air coolers with attenuation

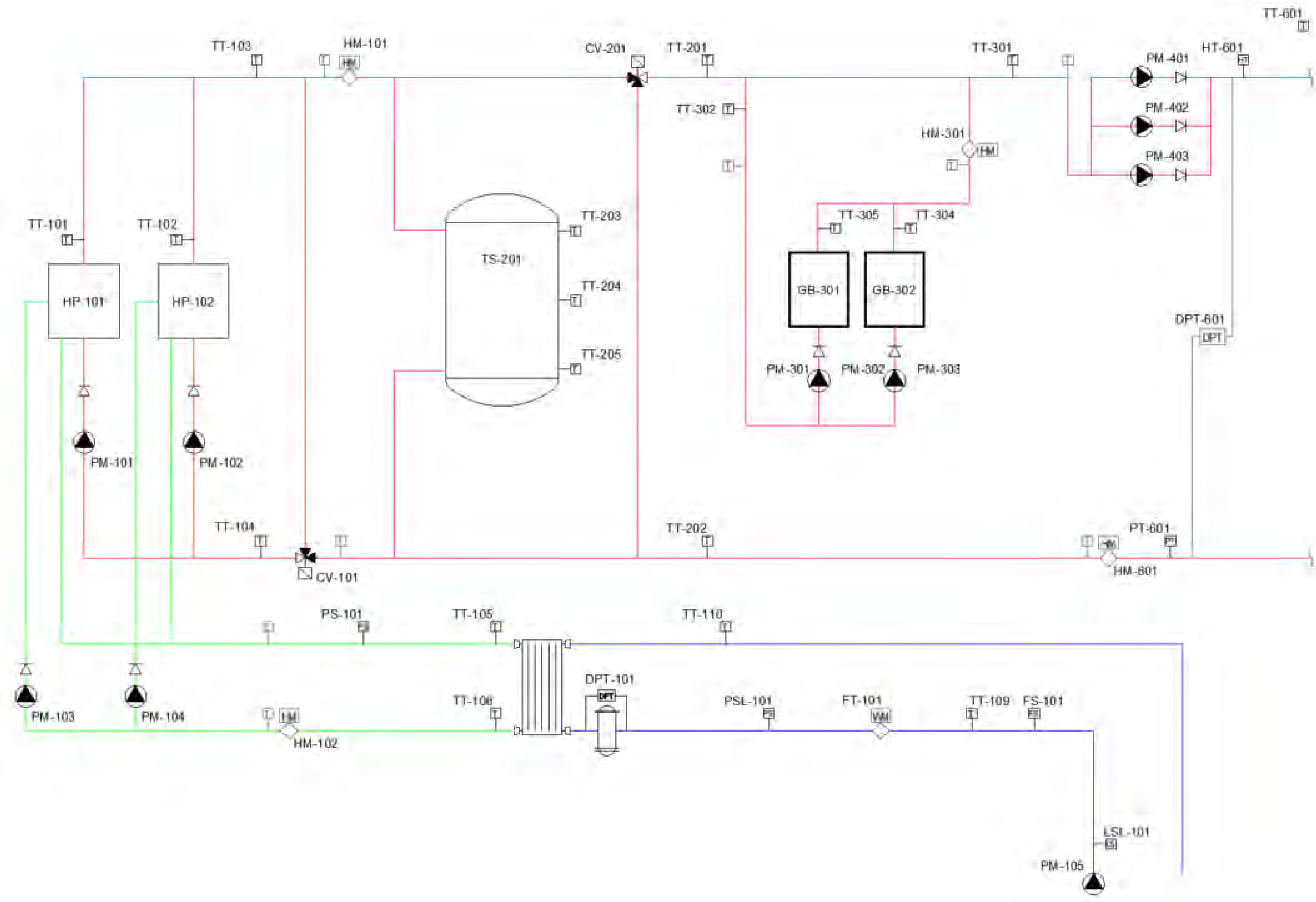


Evaporators / Dry air coolers with additional attenuation

PFD Schematic - ASHP



PFD Schematic - GSHP



Economic Assessment

Sustainable ENERGY

Condensing gas boiler - full scheme CAPEX

	CAPEX	CAPEX inc. contingency
Preliminary		
Contractor prelims including welfare and storage	£45,000	£54,000
Energy Centre works		
Peak and reserve gas boilers	£12,500	£13,125
Peak and reserve gas boiler flues	£5,000	£5,750
Pressurisation	£5,000	£5,250
Water treatment, flushing and testing	£6,500	£7,475
Electrical connection upgrade	£19,000	£23,750
Plantroom controls	£40,000	£48,000
Cabling and electrical housing blocks	£25,000	£30,000
Other energy centre M&E (pipework, pumps, temporary PHE)	£79,449	£95,339
Builders works	£10,000	£11,500
Network - Usual		
Customer HIUs and flat fit out	£240,000	£276,000
Risers and laterals	£225,000	£281,250
Planning, design and management		
Resident liaison officer	£10,000	£11,000
Professional, design and contracting fees	£50,000	£52,500
Clients Engineer - technical support for construction and commissioning	£30,000	£33,000
Total	£802,449	£947,939

Condensing gas boiler - gas boiler only CAPEX

	CAPEX	CAPEX inc. contingency
Energy Centre works		
Peak and reserve gas boilers	£12,500	£13,125
Peak and reserve gas boiler flues	£5,000	£5,750
Electrical connection upgrade	£19,000	£23,750
Plantroom controls	£40,000	£48,000
Cabling and electrical housing blocks	£25,000	£30,000
Other energy centre M&E (pipework, pumps, temporary PHE)	£79,449	£95,339
Planning, design and management		
Professional, design and contracting fees	£50,000	£52,500
Clients Engineer - technical support for construction and commissioning	£30,000	£33,000
Total	£260,949	£301,464

ASHP and Condensing gas boiler scheme – full scheme CAPEX

	Total	Total inc. contingency
Preliminary		
Contractor prelims including welfare and storage	£55,000	£66,000
Energy Centre works – common to ASHP and gas options		
Peak and reserve gas boilers	£12,500	£13,125
Peak and reserve gas boiler flues	£5,000	£5,750
Pressurisation	£5,000	£5,250
Water treatment, flushing and testing	£6,500	£7,475
Electrical connection upgrade	£25,000	£31,250
Plantroom controls	£60,000	£72,000
Cabling and electrical housing blocks	£25,000	£30,000
Other energy centre M&E (pipework, pumps, temporary PHE)	£79,449	£95,339
Builders works	£15,000	£17,250
Network – common to ASHP and gas options		
Customer HIUs and flat fit out	£240,000	£276,000
Risers and laterals	£225,000	£281,250
Energy Centre works – ASHP only		
Heat pump	£90,000	£99,000
ASHP attenuation	£10,000	£11,000
Heat pump M&E works	£30,000	£33,000
Thermal store	£2,200	£2,420
Energy centre civils works	£20,000	£23,000
Planning, design and management – common to ASHP and gas options		
Planning application and fees	£6,000	£7,500
Resident liaison officer	£10,000	£11,000
Professional, design and contracting fees	£65,000	£68,250
Clients Engineer - technical support for construction and commissioning	£40,000	£44,000
RHI Application	£4,500	£4,725
Total	£1,031,149	£1,204,584

ASHP and Condensing gas boiler scheme– ASHP and Condensing gas boiler only CAPEX

Sustainable ENERGY

	Total	Total inc. contingency
Energy Centre works – common to ASHP and gas options		
Peak and reserve gas boilers	£12,500	£13,125
Peak and reserve gas boiler flues	£5,000	£5,750
Electrical connection upgrade	£25,000	£31,250
Plantroom controls	£60,000	£72,000
Cabling and electrical housing blocks	£25,000	£30,000
Other energy centre M&E (pipework, pumps, temporary PHE)	£79,449	£95,339
Energy Centre works – ASHP only		
Heat pump	£90,000	£99,000
ASHP attenuation	£10,000	£11,000
Heat pump M&E works	£30,000	£33,000
Thermal store	£2,200	£2,420
Planning, design and management – common to ASHP and gas options		
Professional, design and contracting fees	£65,000	£68,250
Clients Engineer - technical support for construction and commissioning	£40,000	£44,000
Total	£444,149	£505,134

GSHP and Condensing gas boiler scheme – full scheme CAPEX

Sustainable ENERGY

Preliminary	Total	Total inc. contingency
Contractor prelims including welfare and storage	£65,000	£78,000
Energy Centre works – common to GSHP and gas options		
Peak and reserve gas boilers	£12,500	£13,125
Peak and reserve gas boiler flues	£5,000	£5,750
Pressurisation	£5,000	£5,250
Water treatment, flushing and testing	£6,500	£7,475
Electrical connection upgrade	£25,000	£31,250
Plantroom controls	£60,000	£72,000
Cabling and electrical housing blocks	£25,000	£30,000
Other energy centre M&E (pipework, pumps, temporary PHE)	£79,449	£95,339
Builders works	£15,000	£17,250
Network – common to GSHP and gas options		
Customer HIUs and flat fit out	£240,000	£276,000
Risers and laterals	£225,000	£281,250
Energy Centre works – GSHP only		
Heat pump	£90,000	£99,000
Bore hole	£120,000	£138,000
Heat pump M&E works	£45,000	£49,500
Thermal store	£2,200	£2,420
Energy centre civils works	£20,000	£23,000
Planning, design and management – common to GSHP and gas options		
Planning application and fees	£6,000	£7,500
Resident liaison officer	£10,000	£11,000
Professional, design and contracting fees	£65,000	£68,250
Clients Engineer - technical support for construction and commissioning	£40,000	£44,000
RHI Application	£4,500	£4,725
Total	£1,166,149	£1,360,084

GSHP and Condensing gas boiler scheme– GSHP and Condensing gas boiler only CAPEX

	Total	Total inc. contingency
Energy Centre works – common to GSHP and gas options		
Peak and reserve gas boilers	£12,500	£13,125
Peak and reserve gas boiler flues	£5,000	£5,750
Electrical connection upgrade	£25,000	£31,250
Plantroom controls	£60,000	£72,000
Cabling and electrical housing blocks	£25,000	£30,000
Other energy centre M&E (pipework, pumps, temporary PHE)	£79,449	£95,339
Energy Centre works – GSHP only		
Heat pump	£90,000	£99,000
Bore hole	£120,000	£138,000
Heat pump M&E works	£45,000	£49,500
Thermal store	£2,200	£2,420
Planning, design and management – common to GSHP and gas options		
Clients Engineer - technical support for construction and commissioning	£40,000	£44,000
RHI Application	£4,500	£4,725
Total	£569,149	£648,634

Fuel Tariffs

- Tariff inputs

Gas tariff (excl. CCL)	2.166	p/kWh
Gas standing charge	14.86	£/day
CCL - natural gas (2021)	0.406	p/kWh
CCL - natural gas (2022)	0.568	p/kWh
CCL - natural gas (2023 onwards)	0.672	p/kWh
CCL - electricity	0.775	p/kWh
Energy centre electricity tariff - day	13.07	p/kWh
Energy centre electricity tariff - night	8.8	p/kWh
Electricity standing charge	0.18	£/day

OPEX and REPEX assumptions

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OPEX

- Annual cost for O&M of £2,522 used, which covers the following:
  - Annual servicing for communal heating and hot water (gas only, current maintenance contract only covers gas based systems)
  - HIUs (presumed HIUs for all below estates based on rate receiving for some estates which already have HIUs)
  - Service of BMS with annual servicing of heating and hot water
  - Pressurisation units and expansion vessels
  - Quarterly water treatment
- Annual spares and repair costs £5,884
  - Using estimated of 70% of total costs for maintenance contract from spares and repairs
- Metering and billing cost - £5,400 per annum

REPEX

- Pro-rata cost added per year based on the cost of the asset and its economic life
- Economic lifetime of the technologies used:

Technology	Useful economic lifetime (years)
Heat pump	20
Gas boilers	20
Heat network connections	25

Assessment scenarios - ASHP

- Heat pump solutions sized to provide maximum % of heat demand capable given the limitations on plant room space
- For the assessment cases it is assumed that the availability of the ASHP to supply the heat demand is 96% (2 weeks for maintenance and repairs)
  - The techno economic model has a function to compare 100% (52 weeks), 96% (50 weeks) and 92% (48 weeks) availability
- Table below shows the contribution of the ASHP against the different heat demand scenarios

	Scenario 1	Scenario 2	Scenario 3	Scenario 4
Total heat demand	591,639kWh	556,982kWh	525,994kWh	399,302kWh
Peak heat demand	235kW	223kW	213kW	170kW
Heat pump capacity - ASHP	160kW	160kW	160kW	160kW
Thermal store capacity	2,000litres	2,000litres	2,000litres	2,000litres
% heat demand potentially met by low carbon / renewable technology				
52 weeks availability - ASHP	96%	97%	98%	100%
50 weeks availability - ASHP	95%	96%	97%	98%
48 weeks availability - ASHP	94%	95%	96%	98%

Assessment scenarios - GSHP

- Heat pump solutions sized to provide maximum % of heat demand capable given the limitations on plant room space
- For the assessment cases it is assumed that the availability of the GSHP to supply the heat demand is 96% (2 weeks for maintenance and repairs)
  - The techno economic model has a function to compare 100% (52 weeks), 96% (50 weeks) and 92% (48 weeks) availability
- Table below shows the contribution of the GSHP against the different heat demand scenarios

	Scenario 1	Scenario 2	Scenario 3	Scenario 4
Total heat demand	591,639kWh	556,982kWh	525,994kWh	399,302kWh
Peak heat demand	235kW	223kW	213kW	170kW
Heat pump capacity - GSHP	190kW	190kW	190kW	190kW
Thermal store capacity	2,000litres	2,000litres	2,000litres	2,000litres
% heat demand potentially met by low carbon / renewable technology				
52 weeks availability - GSHP	99.7%	99.9%	99.9%	100%
50 weeks availability – GSHP	98.7%	98.9%	98.9%	98.8%
48 weeks availability - GSHP	98%	98.1%	98.2%	97.8%

Assessment scenarios

- Two CAPEX scenarios are presented:
  - **CASE 1** – installation of condensing gas boiler and energy centre upgrades
  - **CASE 2** – installation of condensing gas boiler, installation of ASHP/GSHP and energy centre upgrades
  - These cases include the CAPEX associated with installation of the heat generation technology systems only
- Two heat demand scenarios are presented:
  - Scenario 1 – existing fabric with upgraded heating system
  - Scenario 4 – upgraded fabric (roof, glazing and EWI) with upgraded heating system
- Additional economic assumptions:
  - ASHP/GSHP cases will include income from RHI
  - Impact of PV array installation will also be presented
    - Electricity generation to offset the energy centre requirements at electricity day rate
    - Excess generation exported at 5.5p/kWh

Economic assessment (heat demand scenario 1)

		Current system	Option 1: Condensing gas	Option 2: ASHP / Condensing gas	Option 3: ASHP / Condensing gas / PV	Option 4: GSHP / Condensing gas	Option 5: GSHP / Condensing gas / PV
Energy and carbon	**Units**						
Heat demand - Peak	kW	243	235	235	235	235	235
Heat annual demand	kWh	725,250	591,639	591,639	591,639	591,639	591,639
Heat annual demand - losses	kWh						
Heat annual demand - Total	kWh	725,250	591,639	591,639	591,639	591,639	591,639
% heat demand low carbon	%	0%	0%	95%	95%	98.7%	98.7%
25 year CO2e savings	tCO2e		341	2,591	2,690	2,757	2,857
First year CO2e savings, tCO2e	tCO2e		12	72	81	81	89
First year CO2e intensity of delivered heat	gCO2e /kWh		210	108	93	94	79
Build and run costs							
Capex of scheme	£		£260,949	£444,149	£516,149	£569,149	£641,149
Capex of scheme + contingency	£		£301,464	£505,134	£584,334	£648,634	£727,834
OPEX – Fuel costs	£		£23,931	£33,096	£28,721	£30,851	£26,476
OPEX – (O&M + fuel/elec costs)	£		£37,736	£49,901	£45,526	£47,656	£43,282
Fixed heat sales	£		£21,900	£21,900	£21,900	£21,900	£21,900
Variable heat sales	£		£41,415	£41,415	£41,415	£41,415	£41,415
Potential annual Income - RHI	£		-	£15,388	£15,388	£33,401	£33,401
Potential annual Income – PV export	£		-	-	£1,970	-	£1,971
Economic indicators – 25 year case							
Fixed heat sales	£/day		1	1	1	1	1
Variable heat sales	p/kWh		7	7	7	7	7
Cost of heat to residence - annual	£		£1,055	£1,055	£1,055	£1,055	£1,055
Payback period	Years		16	24	20	15	15
NPV	£		£15,522	-£150,135	-£119,338	-£1,262	£29,523
IRR	%		4.0%	0.3%	1.4%	3.5%	3.9%
Assumptions	Capital costs excludes heating systems, water treatment and ancillaries Fixed tariff of £1/day Variable tariff of 7p/kWh (in line with Heat Trust costing)						

Economic assessment (heat demand scenario 1)

	Units	Current system	Option 1: Condensing gas	Option 2: ASHP / Condensing gas	Option 3: ASHP / Condensing gas / PV	Option 4: GSHP / Condensing gas	Option 5: GSHP / Condensing gas / PV
Resident costs – Fuel only							
Cost of heat to residence – Fuel (variable)	p/kWh	7.44	4.04	5.59	4.85	5.21	4.48
Cost of heat to residence - annual	£	£734	£399	£552	£479	£514	£441
Resident costs – Fuel + O&M							
Cost of heat to residence – O&M (fixed)	£/day	0.63	0.63	0.77	0.77	0.77	0.77
Cost of heat to residence – Fuel (variable)	p/kWh	7.44	4.04	5.59	4.85	5.21	4.48
Cost of heat to residence - annual	£	£963	£629	£832	£759	£794	£721
Subsidy requirement per apartment							
Cost of heat, savings per apartment (fuel only)	£/year			£182	£255	£220	£293
Cost of heat, savings per apartment (fuel + O&M)	£/year			£131	£204	£169	£242
Remaining RHI income (whole scheme - fuel + O&M)	£/year			£15,388	£15,388	£33,401	£33,401
Assumptions		No accounting has been made for initial capital costs or replacement costs over lifetime. Capital for energy centre and network are part of the building and therefore will be part of the rent rather than in the energy bills.					
Social Economics – 25 year case							
Social IRR			4.7%	4.1%	4.6%	6.1%	6.3%
Social NPV			£41,882	£35,955	£76,469	£198,448	£238,948
Assumptions	Fixed tariff of £1/day Variable tariff of 7p/kWh (in line with Heat Trust costing)						

Economic assessment (heat demand scenario 4)

		Current system	Option 1: Condensing gas	Option 2: ASHP / Condensing gas	Option 3: ASHP / Condensing gas / PV	Option 4: GSHP / Condensing gas	Option 5: GSHP / Condensing gas / PV
Energy and carbon	**Units**						
Heat demand - Peak	kW	243	170	170	170	170	170
Heat annual demand	kWh	725,250	399,302	399,302	399,302	399,302	399,302
Heat annual demand - losses	kWh						
Heat annual demand - Total	kWh	725,250	399,302	399,302	399,302	399,302	399,302
% heat demand low carbon	%	0%	0%	98%	98%	98.8%	98.8%
25 year CO2e savings	tCO2e		230	1,809	1,887	1,862	1,939
First year CO2e savings, tCO2e	tCO2e		8	50	57	54	61
First year CO2e intensity of delivered heat	gCO2e /kWh		210	104	87	94	76
Build and run costs							
Capex of scheme	£		£260,949	£444,149	£516,149	£569,149	£641,149
Capex of scheme + contingency	£		£301,464	£505,134	£584,334	£648,634	£727,834
OPEX – Fuel costs	£		£17,940	£24,552	£21,097	£22,671	£19,260
OPEX – (O&M + fuel/elec costs)	£		£31,745	£41,357	£37,902	£39,476	£36,065
Fixed heat sales	£		£21,900	£21,900	£21,900	£21,900	£21,900
Variable heat sales	£		£27,951	£27,951	£27,951	£27,951	£27,951
Potential annual Income - RHI	£		-	£10,808	£10,808	£27,994	£27,994
Potential annual Income – PV export	£		-	-	£2,339	-	£2,356
Economic indicators – 25 year case							
Fixed heat sales	£/day		1	1	1	1	1
Variable heat sales	p/kWh		7	7	7	7	7
Cost of heat to residence - annual	£		£831	£831	£831	£831	£831
Payback period	Years		22	0	0	20	19
NPV	£		-£74,647	-£281,400	-£260,138	-£153,379	-£132,589
IRR	%		1.0%	-3.4%	-1.6%	0.9%	1.5%
Assumptions	Capital costs excludes heating systems, water treatment and ancillaries Fixed tariff of £1/day Variable tariff of 7p/kWh (in line with Heat Trust costing)						

Economic assessment (heat demand scenario 4)

	Units	Current system	Option 1: Condensing gas	Option 2: ASHP / Condensing gas	Option 3: ASHP / Condensing gas / PV	Option 4: GSHP / Condensing gas	Option 5: GSHP / Condensing gas / PV
Resident costs – Fuel only							
Cost of heat to residence – Fuel (variable)	p/kWh	7.44	4.49	6.15	5.28	5.68	4.82
Cost of heat to residence - annual	£	£734	£299	£409	£352	£378	£321
Resident costs – Fuel + O&M							
Cost of heat to residence – O&M (fixed)	£/day	0.63	0.63	0.77	0.77	0.77	0.77
Cost of heat to residence – Fuel (variable)	p/kWh	7.44	4.49	6.15	5.28	5.68	4.82
Cost of heat to residence - annual	£	£963	£529	£689	£632	£658	£601
Subsidy requirement per apartment							
Cost of heat, savings per apartment (fuel only)	£/year			£325	£382	£356	£413
Cost of heat, savings per apartment (fuel + O&M)	£/year			£274	£331	£305	£362
Remaining RHI income (whole scheme - fuel + O&M)	£/year			£10,808	£10,808	£27,994	£27,994
Assumptions		No accounting has been made for initial capital costs or replacement costs over lifetime. Capital for energy centre and network are part of the building and therefore will be part of the rent rather than in the energy bills.					
Social Economics – 25 year case							
Social IRR			1.7%	0.6%	1.5%	3.2%	3.6%
Social NPV			-£56,857	-£151,571	-£122,633	-£18,538	£9,836
Assumptions	Fixed tariff of £1/day Variable tariff of 7p/kWh (in line with Heat Trust costing)						

GSHP with no RHI

- The heat pump options presented benefit from the RHI subsidy
- There is risk associated with the installation of the GSHP
- The following assessment shows the economic case for the GSHP without the RHI subsidy

Economic assessment (heat demand scenario 1)

		Current system	Option 1: Condensing gas	Option 2: GSHP / Condensing gas	Option 3: GSHP / Condensing gas / PV
Energy and carbon	**Units**				
Heat demand - Peak	kW	243	235	235	235
Heat annual demand	kWh	725,250	591,639	591,639	591,639
Heat annual demand - losses	kWh				
Heat annual demand - Total	kWh	725,250	591,639	591,639	591,639
% heat demand low carbon	%	0%	0%	95%	95%
25 year CO2e savings	tCO2e		341	2,757	2,857
First year CO2e savings, tCO2e	tCO2e		12	81	89
First year CO2e intensity of delivered heat	gCO2e /kWh		210	94	79
Build and run costs					
Capex of scheme	£		£260,949	£569,149	£641,149
Capex of scheme + contingency	£		£301,464	£648,634	£727,834
OPEX – Fuel costs	£		£23,931	£30,851	£26,476
OPEX – (O&M + fuel/elec costs)	£		£37,736	£47,656	£43,282
Fixed heat sales	£		£21,900	£21,900	£21,900
Variable heat sales	£		£41,415	£41,415	£41,415
Potential annual Income - RHI	£		-	-	-
Potential annual Income – PV export	£		-	-	£1,971
Economic indicators – 25 year case					
Fixed heat sales	£/day		1	1	1
Variable heat sales	p/kWh		7	7	7
Cost of heat to residence - annual	£		£1,055	£1,055	£1,055
Payback period	Years		16	0	0
NPV	£		£15,522	-£475,881	-£445,096
IRR	%		4.0%	-5.6%	-3.5%
Assumptions	Capital costs excludes heating systems, water treatment and ancillaries Fixed tariff of £1/day Variable tariff of 7p/kWh (in line with Heat Trust costing)				

Economic assessment (heat demand scenario 1)

	Units	Current system	Option 1: Condensing gas	Option 2: GSHP / Condensing gas	Option 3: GSHP / Condensing gas / PV
Resident costs – Fuel only					
Cost of heat to residence – Fuel (variable)	p/kWh	7.44	4.04	5.21	4.48
Cost of heat to residence - annual	£	£734	£399	£514	£441
Resident costs – Fuel + O&M					
Cost of heat to residence – O&M (fixed)	£/day	0.63	0.63	0.77	0.77
Cost of heat to residence – Fuel (variable)	p/kWh	7.44	4.04	5.21	4.48
Cost of heat to residence - annual	£	£963	£629	£794	£721
Subsidy requirement per apartment					
Cost of heat, savings per apartment (fuel only)	£/year		-	-	-
Cost of heat, savings per apartment (fuel + O&M)	£/year		-	-	-
Remaining RHI income (whole scheme - fuel + O&M)	£/year		-	-	-
Assumptions	No accounting has been made for initial capital costs or replacement costs over lifetime. Capital for energy centre and network are part of the building and therefore will be part of the rent rather than in the energy bills.				
Social Economics – 25 year case					
Social IRR			4.7%	-0.4%	0.6%
Social NPV			£41,882	-£276,171	-£235,671
Assumptions	Fixed tariff of £1/day Variable tariff of 7p/kWh (in line with Heat Trust costing)				

Increased gas tariff

- The gas tariff for Strand Court at the time of this assessment is 2.166p/kWh
- This figure is relatively low and an increase in this tariff has a significant affect on economic case for the condensing gas boiler only solution
- The following table presents the cases with the gas tariff increased the point at which the economics are similar for the gas condensing case and the heat pump plus PV case
  - ASHP gas tariff increase – 2.77p/kWh
  - GSHP gas tariff increase – 2.175p/kWh

Economic assessment (heat demand scenario 1)

		Current system	Option 1: Condensing gas against ASHP	Option 2: ASHP / Condensing gas / PV	Option 3: Condensing gas against GSHP	Option 4: GSHP / Condensing gas / PV
Energy and carbon	**Units**					
Heat demand - Peak	kW	243	235	235	235	235
Heat annual demand	kWh	725,250	591,639	591,639	591,639	591,639
Heat annual demand - losses	kWh					
Heat annual demand - Total	kWh	725,250	591,639	591,639	591,639	591,639
% heat demand low carbon	%	0%	0%	95%	0%	98.7%
25 year CO2e savings	tCO2e		341	2,690	341	2,857
First year CO2e savings, tCO2e	tCO2e		12	81	12	89
First year CO2e intensity of delivered heat	gCO2e /kWh		210	93	210	79
Build and run costs						
Capex of scheme	£		£260,949	£516,149	£260,949	£641,149
Capex of scheme + contingency	£		£301,464	£584,334	£301,464	£727,834
OPEX – Fuel costs	£		£27,902	£28,936	£23,991	£26,477
OPEX – (O&M + fuel/elec costs)	£		£41,707	£45,741	£37,796	£43,282
Fixed heat sales	£		£21,900	£21,900	£21,900	£21,900
Variable heat sales	£		£41,415	£41,415	£41,415	£41,415
Potential annual Income - RHI	£		-	£15,388	-	£33,401
Potential annual Income – PV export	£			£1,970	-	£1,971
Economic indicators – 25 year case						
Fixed heat sales	£/day		1	1	1	1
Variable heat sales	p/kWh		7	7	7	7
Cost of heat to residence - annual	£		£1,055	£1,055	£1,055	£1,055
Payback period	Years		22	20	16	15
NPV	£		-£66,479	-£123,782	£14,300	£29,508
IRR	%		1.3%	1.3%	3.9%	3.9%
Assumptions	Capital costs excludes heating systems, water treatment and ancillaries Fixed tariff of £1/day Variable tariff of 7p/kWh (in line with Heat Trust costing)					

Economic assessment (heat demand scenario 1)

	Units	Current system	Option 1: Condensing gas against ASHP	Option 2: ASHP / Condensing gas / PV	Option 3: Condensing gas against GSHP	Option 4: GSHP / Condensing gas / PV
Resident costs – Fuel only						
Cost of heat to residence – Fuel (variable)	p/kWh	7.44	4.72	4.89	4.05	4.48
Cost of heat to residence - annual	£	£734	£465	£482	£400	£441
Resident costs – Fuel + O&M						
Cost of heat to residence – O&M (fixed)	£/day	0.63	0.63	0.77	0.63	0.77
Cost of heat to residence – Fuel (variable)	p/kWh	7.44	4.72	4.89	4.05	4.48
Cost of heat to residence - annual	£	£963	£695	£762	£630	£721
Subsidy requirement per apartment						
Cost of heat, savings per apartment (fuel only)	£/year		-	£252	-	£293
Cost of heat, savings per apartment (fuel + O&M)	£/year		-	£201	-	£242
Remaining RHI income (whole scheme - fuel + O&M)	£/year		-	£15,388	-	£33,401
Assumptions	No accounting has been made for initial capital costs or replacement costs over lifetime. Capital for energy centre and network are part of the building and therefore will be part of the rent rather than in the energy bills.					
Social Economics – 25 year case						
Social IRR			2.2%	4.6%	4.7%	6.3%
Social NPV			-£40,119	£72,024	£40,660	£238,932
Assumptions	Fixed tariff of £1/day Variable tariff of 7p/kWh (in line with Heat Trust costing)					

Summary and next steps

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Summary

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- The economic case for the ASHP option is less favourable than the gas condensing option at the current gas price but the ASHP offers better CO_2e savings.
  - When gas prices reach 2.77p/kWh then economics reach parity with the social IRR for the ASHP being higher.
- The economic case for the GSHP option is comparable to the gas condensing option at the current gas price
- There is high risk associated with the GSHP option
  - RHI subsidy application required by 31st March 2021. More difficult installation than the ASHP.
  - technical feasibility associated with the abstraction and discharge wells. Detailed hydro geological modelling will be required to further assess viability as will the drilling of a test well.
- Solar PV improves economics and increases CO_2e savings.

Next Steps

- Explore option for RHI tariff guarantee scheme for both heat pump options
  - Critical for GSHP
- Assess surrounding buildings such as Bannockburn primary school and Plumstead Library for larger network from ground source. This benefits from an improvement in local air quality and economies of scale on system installation
- Additional surveys required to determine structural suitability of existing roof for housing the PV array
- Detail dimensions for full energy system and network
- Draft tender specification for energy centre and phased works

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