The engineer in his own way is an artist too - and not just a dead fish with a slide rule.
Jørgen Varming

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BUILDING SERVICES

STEENSEN VARMING

London Guildhall - Cooling Plant Replacement: Option Study

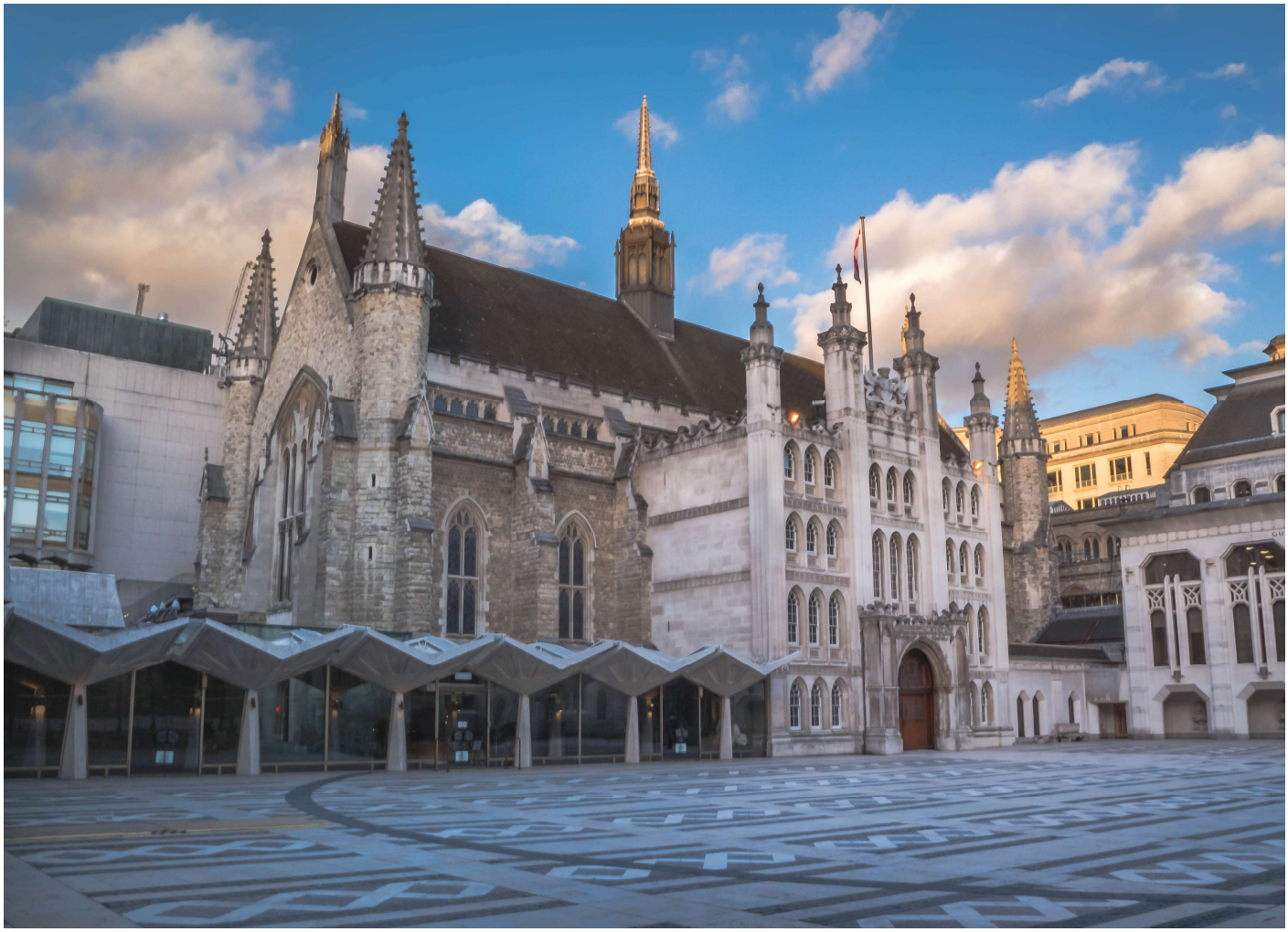

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Table of contents

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1.0 Executive Summary

Steensen Varming have been commissioned to develop a design for the replacement of cooling and steam humidification plant at the Guildhall.

This report presents the findings of a high-level analysis of chiller replacement options that have been considered, alongside a recommended strategy to be progressed at Concept Design stage.

Three options have been considered:

1. A like of like replacement of the East/ West Wing chillers
2. The introduction of a centralised plant strategy in place of the existing East, West and North Wing chillers
3. The implementation of a hybrid approach previously recommended in a report produced by Beveridge Associates.

Each of the above options have been scored against a number of different performance criteria to determine which is the preferred option based on the proposed criteria.

Whilst there are a number of qualifications and caveats involved, the highest scoring option in the centralised chiller solution (Option 2), and as such, based on the analysis presented in this report, and in accordance with the scope and context of works set out in the brief, Steensen Varming's recommendation is that this option should be taken forward.

Whilst the options appraisal presented in this report has been undertaken in accordance with the scope and context set out in the project brief, we are aware that there are other chiller replacement options which could be considered, and there are other factors which are likely to have an impact on the preferred strategy which have not been assessed. As such, we would recommend that if possible, the scope of the project should be reviewed in the context of these other options and site factors to ensure that the final recommendation and agreed strategy will be in the best long-term interests of the Guildhall and the City of London.

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2.0 Introduction

Steensen Varming have been commissioned to develop a design for the replacement of cooling and steam humidification plant at the Guildhall.

This report is focussed on the cooling element of works, and more specifically, on presenting an analysis of potential chiller replacement options and a recommendation as to which strategy should be taken forward, taking into consideration the project brief and the information available at the time of writing.

The assessment is based on the fundamental choice between proceeding with a like for like replacement of the existing chiller systems or implementing a new centralised chiller strategy to serve the site.

In addition to the like for like replacement and centralised plant options, a third option has been included as part of the options appraisal. The 3rd option has previously been put forward in a report produced by Beveridge Associates, which formed part of the original briefing documents for the project.

It should be noted that this report was originally intended to address some additional chiller replacement options and take into consideration a number of factors in the appraisal process that have subsequently been removed following confirmation that the assessment should not go beyond the original scope for the project as confirmed in the original briefing documents.

The following sections of this report provide further information on the scope and context of the works; the basis of the assessment; the existing systems that form part of the review; and the work previously undertaken by Beveridge Associates before then presenting the findings of the options appraisal, the associated recommendations, and possible next steps.

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3.0 Project scope and context

The project scope calls for two options to be investigated:

1. Like for like replacement of the West Wing (and East Wing) chillers and associated cooling towers
2. Potential consolidation of plant into a single, more efficient plant centre.

Based on discussions to date, we understand that in practice, the potential scope of works associated with Option 2 would mean the replacement of both the West Wing and North Wing chillers with new chillers, in a central location.

The justification given for replacing the West Wing chillers is that they are approaching end of life and are increasingly expensive to maintain.

The reasoning for considering the replacement of the North Wing chillers alongside the West Wing chillers is that the North Wing chillers are not considered to be energy efficient by modern standards, and that there may be efficiencies to be realised in switching to a central plant solution.

It has been suggested in previous discussions with the client team that the North Wing chillers may also be considered to be approaching end of life due to increasing maintenance issues, however, since the initial project brief states that the North Wing chillers should only considered for replacement on the grounds of making potential improvements in energy efficiency, the replacement of these chillers is not considered an essential outcome for this project.

It is known that some there are some masterplan proposals currently in development for the site, which could impact upon the proposed chiller replacement strategy. However, the details of these proposals are currently unknown, and Steensen Varming have been asked not to take account of these proposals in developing the chiller replacement strategy, hence no further consideration has been given to these plans or their potential implications for the project.

As part of the options appraisal process, initial contact was made with Citigen regarding the potential to connect the Guildhall to the existing district cooling network which serves a number of buildings in the local area, and has pipework already installed up to the Guildhall boundary, but as this option is not one of the options put forward for investigation in the project brief, we have made no further comment on this option in this report.

In summary, this report has been produced to provide an initial high-level options appraisal of the options that have been put forward for investigation as part of the original brief for this project, within the context that has been set out in the brief for this project. Whilst this approach has been confirmed as the correct approach to follow by the client team, we have some concerns as to whether this approach will provide value because some aspects and potential findings of the review based on the original scope and associated context of the works have already been superseded by other developments, and any recommendations may be at risk of soon becoming outdated based on other proposals for the site that are currently in

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development. In addition to missing out on the opportunity to investigate other options that may be feasible for the site (e.g. connection to the Citigen system), there is a risk that any recommendations made within the context of the information given in the brief for this stand-alone project may not be appropriate when considered in the wider context of other projects that are being progressed across the site (e.g. the site masterplan), and in light of the status of other systems which will have a direct impact on this project (e.g. replacement of building controls systems in the West Wing) but have not been considered.

In light of these concerns, Steensen Varming would recommend that consideration is given to reviewing the current scope of works and the associated design programme before progressing with the Concept Design stage. In particular, it may be worth considering updating the scope to reflect:

1. The potential change in status of the North Wing Chillers to being considered as end of life
2. The end-of-life status of the controls systems serving the West Wing
3. The potential for connection to the Citigen District Cooling System.

In addition, we would recommend that the project be considered in the wider context of proposals across the rest of the site, including the site masterplan, with this project potentially even being paused until more is known with regards to future plans for the site which could impact on the preferred chiller strategy.

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4.0 Basis of assessment

As noted in the previous section, the assessment has been undertaken in accordance with the scope and context set out in the original briefing documents for the client.

To confirm, the original briefing documents included:

- Mechanical and Electrical Engineer's & Principal Designer Services Scope (V7) - Guildhall Cooling Plant Replacement & Steam Humidification Plant Replacement Services
- Appendix 3 – Additional Information (Guildhall Steam Generator Plant Replacement)
- Programme (Oct 20)
- Beveridge Associated Feasibility Study Report

Since being appointed, a significant volume of further information has been made available to inform the study, including:

- Previous Airedale Proposals/ Quotations
- Information on the East Wing, West Wing and North Wing cooling systems, including: schematics; layout drawings; asset register; design criteria; O&M manuals
- Energy and BEMS data and analysis, including: electricity consumption data; logging data for cooling coil valve positions
- 2020 Air Conditioning Inspection Report
- Previous Feasibility Study undertaken by WSP
- Floor plans for the whole site
- Further details on the ventilation systems across the site

Whilst a significant volume of information has already been provided, Steensen Varming have requested further information to enable a full review to be undertaken to consider the performance of the central plant in parallel with the internal environmental conditions (temperature and humidity) that are achieved across the site.

The full set of data will help us to understand where there are any issues with maintaining design conditions, and the extent to which the central plant may be contributing to any issues, be it due to a lack of capacity of ineffective controls. We also hope to be able to use the full set of data to help determine the peak cooling demands across the site.

To confirm, the information requested covers the performance of the NW/WW/EW chillers, the WW condenser water system and the steam generators; details on the operation of AHUs across the site; and temperature/ humidity readings for a number of areas across the site. Ideally, 12 month's data over the same period is required for each of these elements.

As the above information is still in the process of being collected, it has not been possible for the information to feed into analysis that has been undertaken to

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produce this report. Instead, this report considers the potential chiller replacement options against a range of high-level criteria in order to provide an overview of the main advantages and disadvantages of each option with the aim of seeking an agreement on which option should be progressed during the Concept Design Stage.

If available, the above data will feed into the Concept Design when we will be looking to confirm the size/ capacity of the proposed plant. Ideally, this process would be informed by a review of a comprehensive set of data on the existing building systems and their performance, but should the information not be available we will proceed on the basis of the information received to date, supplemented by additional modelling and calculations to determine predicted loads as required.

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5.0 Existing systems

There are five separate chilled water systems serving different areas of the site:

- **West Wing (1640kW)**: Two water-cooled chillers located in basement plant room (connected to cooling towers on the West Wing roof), installed in 1996, supplying chilled water to AHUs and FCUs within various West Wing building areas to provide comfort cooling and dehumidification (also to support close control for manuscripts store).
- **East Wing (1640kW)**: Identical equipment to West Wing located in basement plant room, serving AHUs and FCUs which serve various building areas to provide comfort cooling, and close control for art gallery, amphitheatre and associated stores.
- **North Wing – Main (2250kW)**: Five identical air-cooled chillers mounted on the North Wing roof, installed in 2008. Supply chilled water for North Wing office chilled beams and FCUs and AHUs serving various areas in the North Wing.
- **North Wing – SER (560kW)**: Two smaller air-cooled chillers installed in 2008, located on the North Wing roof, serving comms rooms and kitchen cold stores.
- **Old Justice Rooms**: Three air-cooled chillers installed in 2003, in staff car park plant room, serving datacentre and building rooms.

It is noted in the project brief that the four water-cooled chillers located in the West Wing, which serve the East and West Wings are at the end of their economic life and due for replacement.

The North Wing chillers are considered to be inefficient by modern standards and should be considered for replacement if the project budget will allow.

The North Wing SER chillers and Old Just Rooms CHWS are understood to be in generally good repair with significant operational life remaining.

All chillers use R407C which will be unavailable to purchase (new) from January 2022.

Cooling towers for the East and West Wing chillers are difficult to access and expensive to maintain (£50k/ year, scaffold permanently in place).

CHW systems have not been able to meet demands over the past two summers which have been very warm. In 2019, cooling had to be switched off in some areas to maintain appropriate conditions in critical areas. One of the main issues is the heat rejection systems, including the cooling towers, are considered to be undersized.

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6.0 Beveridge Associates Feasibility Study

It is understood that the Beveridge Associates Feasibility study was commissioned by the Guildhall Energy Team who had identified poor efficiencies and capacity issues across the existing cooling plant. A previous study by WSP had put forward recommendations for consolidating existing plant to provide a centralised solution, and some of these options had subsequently been costed by Airedale. Beveridge Associates were commissioned to develop the centralised option, and in particular to look at:

1. How the different cooling systems could be linked together
2. How the secondary chilled water systems could be optimised (e.g. moving some areas operating on extended hours on to different cooling systems)
3. An overall strategy and phased implementation plan

The main body of the Beveridge Associates Feasibility study sets out an analysis of the chiller system energy data. This analysis is followed by proposals for a chiller rationalisation strategy and associated implementation plan.

The Beveridge Associates feasibility study is broadly split into two parts, with the first presenting a review of the performance and utilisation of the existing, East, West and North Wing Chillers. The second part of the report puts forward recommendations for a chiller rationalisation strategy with a staged implementation programme.

The key findings and observations outlined in the first part of the report include the following:

1. The West Wing chillers and pumps are running year-round, even when there is no demand. As such, basic control improvements (e.g. reducing operation to summer only) could result in significant energy/ cost savings.
2. The East Wing chillers also run for longer periods than they should, but the system has a greater average delta T (between 2-4°C) which suggests the East Wing system operates more efficiently than the West Wing system.
3. Further work is required to establish which items of plant are causing the chillers to operate all year, so that these areas can be removed from the main chiller system, and either moved onto an alternative like the SER chillers, or a new VRF air-water system with dedicated plant operating at longer hours.
4. The scheduling of the North Wing chillers is believed to be more reflective of existing demand, but the average delta T is still low which suggests there may be potential scope for further energy savings in summer.
5. A review of the connected loads on the existing schematics suggests that the North and West Wing chillers are undersized.

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The second part of the Beveridge report outlines a chiller rationalisation strategy which would ultimately result in the following arrangement:

- A new VRF system would be installed to pick up the 'extended hours' loads in the West Wing
- New air-cooled chillers with slightly reduced capacity (compared to existing) would be installed to pick up the remaining West Wing and the East Wing loads
- A permanent link would be installed between the East/ West Wing and North Wing Systems

As the existing water-cooled chillers would be replaced by the new VRF and air-cooled chillers on the roof of the West Wing, the existing cooling towers would be made redundant and would be removed. Space would also be made available in the West and East chiller plant room through the removal of the existing chillers.

The cost of the above works is estimated at £2m, with a programme length of approximately 2.5 years, include a 1-year monitoring period after Stage 1.

Alternative Options

The final section of the Beveridge Associates report puts forward a summary of alternative options that have previously been discussed and costed. A summary of these is provided below for completeness.

Replace WW, EW, and NW in situ like for like and refurbish existing cooling towers	£2,862,801
Replace WW, EW and NW chillers with enhanced like for like, and replace cooling towers	£4,450,120
Replace EW/WW plant and cooling towers and form new larger centralised water-cooled chiller plant serving all areas on NW roof	£6,755,664
Abandon EW/WW plant and cooling towers to form new larger centralised air-cooled chiller plant serving all areas on NW roof	£3,803,858

6.1 Review Comments

As noted above, there are two main parts of the Beveridge Associates Feasibility study: the initial energy data appraisal, and the proposed rationalisation strategy.

Energy Data Appraisal

The report presents a comprehensive analysis of the available information, though as noted in the report, data is unavailable for some systems, and there are some inconsistencies with some of the data that is available.

The analysis presented in the report all appears to be valid, and as such, we would support the associated conclusions with respect to the control issues associated with the operation of the existing plant, and the recommendations with respect to the potential for improvement. We would however note that our assessment is based only on the information presented within the report and that we need to undertake a

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more detailed review of the primary data upon which the report is based to confirm that we are in full agreement with the analysis that has been put forward.

Proposed rationalisation strategy

The proposed strategy meets the basic objective of replacing the East and West Wing chillers (and associated cooling towers) which are approaching the end of their economic life, but the proposed strategy does not allow for the replacement of the North Wing chillers with more modern and efficient alternatives, which is one of the aspirations for the project, at least not in the short term. As such, the proposed strategy would not realise the potential energy, carbon and operational cost savings associated with this approach.

The proposed strategy would provide some rationalisation of existing systems through linking the North and West Wing systems, which in turn may make it possible to reduce the overall installed plant capacity. However, the proposals stop short of moving toward a single centralised system with a single centralised plant area. The proposed link pipework may help to facilitate this solution at a later date under a subsequent phase of works, but the proposed strategy also moves away from a single central plant solution through the installation of a new 'VRF' system to serve significant areas of the West Wing, and the introduction of new air-cooled chillers on the West Wing roof to replace the cooling capacity which is lost through the removal of the existing East and West Wing water-cooled chillers.

To put the changes into some context considering the main cooling plant across the site, the existing capacity of the East and West Wing chillers is 3280kW, and the capacity of the North Wing chillers is 2250kW. The split is roughly 60/40 across the West Wing and North Wing plant.

The proposed approach would see the removal of the East and West Wing chillers, and the addition of a new 400kW VRF system; and two new 1200kW air-cooled chillers on the West Wing roof. The total West Wing plant capacity would effectively be reduced from 3280kW to 2800kW (a 15% reduction). The revised split in capacity across the two mains sets of plant would be approximately 55/45 across the West Wing and North Wing. In summary, the proposal would result in two separate main plant areas, each with a similar combined cooling capacity.

In effect, the proposed strategy appears to represent a compromise between doing the minimum required to meet the basic of aim of replacing the West Wing chiller plant, whilst also taking some steps towards transitioning toward a more rationalised strategy for the site through the installation of the pipework link between the North Wing and West Wing systems.

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7.0 Chiller Replacement Options

As noted above, the brief calls for two options to be considered – like for like replacement of the West Wing chillers, and a change in approach to a new centralised solution.

As the Beveridge Associates Feasibility Study was included with the original briefing documents, the strategy put forward in this document (new VRF and air-cooled chillers on West Wing roof, plus new link pipework to North Wing chillers) has also been considered alongside the two options above.

The three options considered in the assessment below are therefore:

1. Like for like replacement of the West Wing (and East Wing) chillers and associated cooling towers
2. Potential consolidation of West Wing, East Wing and North Wing plant into a single, more efficient plant centre, in a central location (TBC)
3. New VRF/ air-cooled chillers to serve West Wing and introduction of link pipework to existing North Wing chiller system

7.1 Chiller Selection Criteria

For this stage of the analysis, we have carried out a comparative assessment of the following key criteria to determine the preferred solution:

1. Compliance with Brief
2. Satisfy Demands
3. Energy Efficiency
4. Capital Costs
5. Operating Costs
6. Spatial Impact
7. Builders Work
8. Future capacity
9. Regulatory Compliance (F-Gas Regulations)

Each category is scored out of 5, with 5 being the highest achievable score, and 1 the lowest.

Compliance with Brief
This first category considers whether each option complies with the key requirements that have been set out in the brief, namely the replacement of the West Wing chillers to remove the risk of failure due to these chillers having exceeded their optional life expectancy.

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The second, more aspirational requirement, set out in the brief it the replacement of the North Wing chillers in parallel with the replacement of the West Wing chillers to form a centralised chiller plant centre.

Option	Comment	Score
1	Meets the basic requirement but does not achieve aspirational requirement	3.0
2	Meets basic and aspirational requirements	5.0
3	Meets the basic requirement, implements some steps towards aspirational requirement	3.5

Satisfy Demands
This category considers whether the proposed solution will meet the basic requirements for the site in terms of functional performance. This includes both ensuring that sufficient cooling capacity is available to serve all areas of the site and ensuring there is adequate resilience in the system design through incorporation of appropriate redundancy.

Option	Comment	Score
1	Known existing capacity issues, may be a need to replace condense water system	3.0
2	New plant would be sized to ensure demands can be met, preferred/ most efficient solution with respect to redundancy, and also benefitting from diversification of loads	5.0
3	New plant to be sized to ensure demands can be met, works would need to be planned to ensure any periods of reduced capacity would fall outside of cooling season	4.0

Energy Efficiency
In accordance with the brief, the assessment of energy efficiency should consider the energy consumption associated with the areas served by both the West Wing and North Wing chillers.

Option	Comment	Score
1	Option 1 would result in an efficient water-cooled chiller solution in the West Wing whilst retaining the existing inefficient chillers that serve the North Wing.	3.5
2	A new centralised water-cooled chiller solution is likely to be the most energy efficient option, but even a centralised air-cooled chiller solution utilising new energy efficient air-cooled chillers would perform well compared to the other options as a result of replacing the existing inefficient North Wing chillers.	5.0
3	This option would see a combination of new air-cooled chillers and VRF system installed on the West Wing roof, whilst the inefficient air-cooled chillers serving the North Wing would be retained. There are expected to be some operational efficiencies through moving some plant with extended operating hours onto the VRF system which would in turn help to reduce unnecessary operation of the central plant	3.5

Capital Costs

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The scores below reflect relative costs which are based on the broad scope of works associated with each option.

Steensen Varming have not undertaken a detailed cost review, but based on estimates contained within previous reports, it is expected that Option 1 and Option 3 could be delivered within the existing project budget of £3m, whereas the costs of Option 2 are likely to exceed the existing project budget, with estimated costs in the region of £3.9m assuming air-cooled chillers. Costs for a centralised water-cooled chiller solution would exceed the costs for the air-cooled solution.

Option	Comment	Score
1	A straight replacement of the West Wing chillers only would be the least expensive option, but this does not take into consideration the future costs of replacing the North Wing chillers, nor does it take into consideration the additional costs of upgrading the West Controls which would be a requirement, but sits outside the scope of this project.	5.0*
2	The scope of works associated with Option two includes the replacement of both the West Wing and North Wing chillers, making this the most expensive option, if only considering the expenditure associated with this project.	2.0*
3	This would be the second most expensive option due to the installation of the link pipework in addition to the replacement of the West Wing water-cooled chiller with new air-cooled chillers and separate VRF system.	3.5*

**The different options cover different scopes of works with only Option 2 allowing for the replacement of the North Wing chillers, so the costs are not directly comparable in this respect. It should also be noted that the costs only relate to the scope of works that would be delivered under this project. The scores do not take into consideration the costs associated with other projects that may be required to support the implementation of the above options e.g. the replacement of the West Wing controls which are outside the scope of this project. Whilst this approach is understood to be in accordance with the brief and scope of works, it is recommended that a more holistic cost assessment be undertaken to enable a like-for-like comparison to be made, taking into account all relevant costs.*

Operating Costs

Operating costs include energy and maintenance costs. Option 2 has been assigned the highest score in the table below on the basis that this is the only option that would see the (inefficient) existing North Wing chillers replaced, and hence realise a significant reduction in energy consumption associated with the North Wing plant. There are also expected to be significant savings in maintenance costs associated with centralising all plant and removing the need for cooling towers. There are however several factors at play and the preferred solution may vary depending on the time frame of reference.

Option	Comment	Score
1	Water-cooled chillers have a higher efficiency and reduced energy consumption costs, but increased maintenance costs compared to air-cooled chillers; inefficient North Wing air-cooled chillers will be retained in this scenario	3.5

2	Centralised water-cooled chiller solution likely to be most efficient possible solution; centralised air-cooled chiller solution more efficient and reduced maintenance costs compared to distributed air-cooled solution; in the scenario the existing inefficient North Wing air-cooled chillers would be replaced with more efficient alternatives	5.0
3	Air-cooled chillers less efficient than water-cooled chillers but potential efficiency savings associated with moving areas with extended out of hours operation on to dedicated VRF system; in-efficient North Wing air-cooled chillers would be retained in this scenario, and the expectation would be that the utilisation of these chillers would be increased	3.5

Spatial Impact
This category considers spatial planning requirements and potential difficulties/ complications associated with accommodating the plant proposals

Option	Comment	Score
1	Like for like replacement, no issues envisaged	5.0
2	Central plant location to be confirmed, but significant works may be required to accommodate new plant, may be a requirement for planning permission, requirement for new link pipework to be installed	2.0
3	New West Wing roof plant enclosure required, may be a requirement for planning permission, requirement for new link pipework to be installed	3.0

Future Capacity
Whilst it has been confirmed that this assessment should not take into consideration any specific proposals that may be developed as part of the site masterplan, it is good practice to consider the installation of additional capacity, or to ensure provision for future capacity as part of any upgrade works.

Option	Comment	Score
1	Distributed plant with limited flexibility to adapt to meet future demands.	2.5
2	Consolidated central plant solution would provide greatest flexibility for meeting future needs	5.0
3	Infrastructure installed to provide some flexibility for future adaption	3.5

Regulatory Compliance (F-Gas Regulations)
All existing chillers on site use R407c refrigerant. From January 2022, it will only be possible to use recycled R407c refrigerant to service the chillers. Whilst recycled refrigerant can still legally be used for servicing, the change in regulations is likely to result in reduced availability and increased cost. As such, it is suggested that the preferred approach would be to transition away from the use of R407c refrigerant.

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Option	Comment	Score
1	Replacement West Wing chillers would use alternative refrigerant, but existing North Wing chillers would remain in use	2.5
2	New chillers which use alternative refrigerants would be installed to replace existing West Wing and North Wing chillers	5.0
3	Replacement West Wing chillers would use alternative refrigerant, but existing North Wing chillers would remain in use	2.5

7.2 Option Summary Table

The table below summarises the scores from the previous section.

CATEGORY	OPTION 1	OPTION 2	OPTION 3
Compliance with Brief	3.0	5.0	3.5
Satisfy Demands	3.0	5.0	4.0
Energy Efficiency	3.5	5.0	3.5
Capital Costs	5.0	2.0	3.5
Operating Costs	3.5	5.0	3.5
Spatial Impact	5.0	2.0	3.0
Future Capacity	2.5	5.0	3.5
Regulatory Compliance	2.5	5.0	2.5
Total	**28 (70%)**	**34 (85%)**	**27 (67.5%)**

It should be noted that the above scoring assumes all categories are of equal importance, but this is not necessary the case, and we would welcome a discussion to determine whether weightings should be applied to any of the above categories so that the scoring can be updated to reflect the relative importance of each category.

In addition, it should be noted that a number of assumptions and caveats have been made in arriving at the above scores. Whilst it would be possible to make different assumptions or consider a different frame of reference, we have tried to ensure that the assessment has been completed in accordance with the project scope, and that a consistent approach has been applied across all categories. Considering the Capital Cost and Operating Costs for example, the assessment against both categories is based on the scope of works that will be delivered under this project, and as such, the capital costs only consider the costs associated with the plant that will be installed under this project, without any consideration for costs of future plant replacements, and the operating costs only consider the costs associated with the plant that will be in place at the end of this project, irrespective of how long this plant may be in place for.

Based on the equal category weighting approach, and the approach as described above, it is apparent that Option 2 (the new centralised plant solution) is the preferred outcome.

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8.0 Recommendation

Based on the high level/ fundamental Option Study above, the preferred solution for the site would be to introduce a centralised chiller system, i.e. Option 2.

The choice between an air-cooled or water-cooled chiller system should be subject to further analysis if there is agreement to proceed with the development of a central chiller plant solution. It is however noted that the costs associated with water-cooled would require a significant uplift in the project budget (as opposed to a more moderate uplift for a centralised air-cooled chiller solution), and as such, it may be possible to rule out a centralised water-cooled solution at this stage.

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9.0 Proposed next steps

Assuming the project scope remains as existing and there is no change to consider a more holistic approach/ take account of other planned works etc, the recommended next steps are as follows:

1. Guildhall to confirm if happy to proceed along the route of a centralised chiller solution, or to advise what specific further information is required at this stage to enable a decision to be made.
2. Cost Consultant to confirm high-level costs of 3 options that have been considered above. If it is confirmed that Option 2 (in any configuration) will exceed current project budget, it will be necessary to seek confirmation as to whether the project budget can be increased (and reviewed in the context of wider costs associated with other works, e.g. West Wing Controls replacement, eventual replacement of NW chillers) to accommodate this approach as the preferred solution.
3. If the budget can be made available, proceed with the concept design for the central chiller approach, which will include an assessment of air-cooled v water-cooled solutions, considering the different parameters outlined in Appendix A, and a more detailed assessment of performance requirements covering the areas outlined in Appendix B.
4. If it is confirmed that all design proposals should fall within the existing £3m budget, further discussions required with the Guildhall to confirm whether to proceed with Option 1 or a combination of Options 1 and 3.

Whether proceeding in accordance with Item 3 or Item 4 above, the immediate next steps in the design process will be to analyse concurrent performance data (when/ if data received) alongside calculating design loads to cross check against the historic data and to allow for future sensitivity analysis, before then confirming plant capacity and assessing potential plant locations.

If, however, a decision is made to delay the project pending further development of the masterplan, or a decision is made to amend the scope of the project to consider a more holistic assessment of the strategy across the site, then the next steps would need to be reviewed in parallel with the Guildhall.

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10.0 Appendix A – Air-cooled v Water-cooled chillers

The table below an overview of how the two chiller options (air- and water-cooled) perform against some of the relevant selection criteria.

It can be seen that either option has relative strengths and weaknesses, and as such, it's important to understand what the key drivers are for the client before making a final decision.

Selection Criteria	Chiller Type		Comments
	Water-cooled	Air-cooled	
Efficiency	Preferred		- Water-cooled chillers have a higher efficiency than Air-cooled chillers.
Capital cost	-	Preferred	- Air-cooled chillers have a lower up front cost as it doesn't require cooling towers and condenser pumps
Energy cost	Preferred	-	Water-cooled chillers have a better efficiency which results in lower running costs.
Acoustics	Preferred	-	- Water-cooled chillers produce less sounds and more acoustically suited for hospital environments.
Specialist applications	-	Preferred	- Air-cooled chillers are preferable in areas with water shortages, and extremes in humidity.
Maintenance	-	Preferred	- Water-cooled chillers require high levels of maintenance such as tower cleaning, water treatment, makeup water etc. whereas the maintenance for air-cooled chillers is minimal.
Life Span	Preferred	-	- Water-cooled chillers have a longer life span since the chiller is usually located in the plant room, away from the external conditions.
Green Star Rating	Preferred	-	- As water-cooled chillers are more efficient, this results in a lower energy footprint.
Water Consumption	-	Preferred	- There is no requirement for make-up water for the cooling towers
Structural Impact	-	Preferred	- Load bearing capacity should be increased for the roof due to concentrated load of the cooling towers. Standard roof construction for air cooled.
Water Treatment	-	Preferred	- Air cooled chillers do not require treatment of water to prevent legionella disease, rust etc.
Life Cycle Cost	Preferred	-	- Air cooled chillers exceed water cooled chillers in life cycle cost due to the power consumed annually
Total			
Preferred Chiller Type	☆	☆	

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11.0 Appendix B – Base criteria for further analysis

Once the fundamental approach is agreed, Steensen Varming will carry out detailed analysis to refine the sizing and selection of the associated plant requirements. This analysis will be informed by a number of different factors including those listed below.

11.1 Climate Overview

A clear understanding of the local climatic conditions plays a vital role in determining the preferred cooling strategy. Steensen Varming utilise test reference year data in analysing critical infrastructure loads to get an accurate assessment of capacity, part load conditions and the like.

Since the project includes areas that require critical environmental parameters to be met for collection care, we will need to take a close look at the relative humidity levels throughout the year which will allow us to determine the moisture present in the air.

It is recommended to include future climate scenarios to address the likelihood that historic data traditionally used for such studies would need to be adapted.

11.2 Capacity

The actual peak and part load chiller capacities together with needs for future increases, climate and occupancy profiles, redundancy and the like will assist in determining the capacity designed for.

11.3 First Cost (Capital Cost)

With all the ancillaries associated with a water-cooled chiller plant (condenser water pumps, piping, valves and cooling towers), the air-cooled chiller plant cost is expected to be in the order of 30% - 35% lower for the plant design.

This difference may vary based on various sizes, design changes, material but the cost will remain relative.

11.4 Energy, Efficiency and Controls

It can be expected that there will be around 30% increase of power consumption by an air-cooled chiller plant over a water-cooled chiller plant, however this will be verified with use of modelling over the test reference year and future climate scenario.

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Energy efficiency must be a key consideration in the selection of all new equipment and strategies, their configuration and reliability.

The new plant shall be connected to the existing Building Management System (BMS), modifed in accordance with the revised design. To maximise the energy efficiency of the completed works, a central plant optimisation package will be requiredto ensure that all chillers are constantly performing at their peak efficieny potential.

11.5 Water Consumption

The water consumption for the water-cooled system, taking into account the loss due to evaporation from the cooling towers will be assessed.

11.6 Water Treatment Cost

The water used to feed the cooling towers needs to be treated for the following reasons:

- **Rust -** There is a risk that pipework will rust over a period of time due to the salt composition within the potable water which needs to be treated.
- **Legionella Bacteria -** Legionellae are small bacteria which can be found in water adhering to the surface of pipes or other plumbing infrastructure (often in a layer formed with other microorganisms called a 'biofilm'). Legionella pneumophila is known to cause most of the water-related Legionella infections that lead to serious illness. However, in health care facilities, non–Legionella pneumophila species may also cause disease. This can be mitigated by water treatment.
- **Cooling Tower Cycles of Concentration** - As pure water is evaporated, minerals are left behind in the recirculating water. As evaporation continues, the water becomes more concentrated than the original make-up water. This eventually can lead to saturated conditions and requires bleed off.

The costs associated with the above water treatment can be significant and should be factored into the overall cost comparison exercise.

11.7 Maintenance Cost

It can be assumed that the life span of a water-cooled chiller is 20 years whilst the life span of an air-cooled chiller is 15 years. This is due to the locations of the chiller. The air-cooled being outdoor and is prone to various weather conditions whereas the water-cooled is protected and located inside a plantroom.

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11.8 Total Life Cycle Cost

Life Cycle Cost analysis will assist us to collate all the above factors into one single chart which will take into account the capital, running, energy, maintenance cost throughout the life of the system.

11.9 CHW Pumping and Piping Circuit Selection

As well as the best available chiller technologies, a combination of chiller sizes shall be assessed to meet the Guildhall demand profile in the most efficient manner.

The pumping and distribution circuit arrangement will have a significant impact on efficiency and effectiveness, therefore we shall put forward the optimum system arrangement to complement the works that will assess Decoupled Constant Primary-Variable Secondary flow system and Variable Primary flow system arrangements.

11.10 Space Availability

Space availability and cost is a major concern where real estate costs can be very high.

Water-cooled chillers are normally housed in an enclosed space within the building or a separate building nearby. This lost space may be viewed as an opportunity loss for the client who could otherwise occupy or lease the floor area. In contrast, air-cooled chillers are normally located on the roof of the building, not occupying valuable space. However, for this project, as internal plant location opportunities have been offered, space cost has not been included as a factor.

A part of the detailed design process, Steensen Varming shall address the requirements of Safety in Design as one of the primary considerations in system selection and design. Internal QA/QC guidelines and watch points shall be followed to ensure that all system selections adhere to high standards of Safety in Design.

Some of the items that will be addressed during the detailed design shall include:-

- Adequate space provided for servicing of equipment and parts in plantrooms.
- Equipment shall be installed to ensure adequate serviceability without the need for unsafe work practices.

Clear maintenance access around the new chillers and to the CHW primary pumps shall be similar to the existing access or improved upon where possible.

11.11 Building Construction

Building construction cost may be relatively small or go substantially higher if structural assessments require extra load bearing capacity for an air-cooled chiller or acoustic/ vibration design requirement of the site.

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11.12 Sound Emission/Acoustics

The City of London has quite stringent local guidelines/legislation that limit the sound pressure level at the boundary of the buildings. These regulations can have a significant impact on both air-cooled chiller performance and capital cost due if additional acoustic enclosures to reduce transmitted noise are required.

11.13 Staging

As the Guildhall building will require continuous chilled water for the duration of the work, downtime of the chilled water system must be kept to an absolute minimum in order to reduce impact on critical areas and prevent disruption to daily activities as far as practically possible. The work will need to be undertaken during the winter months such that the chilled water demands of the building is at a minimum.

11.14 Risk assessment and mitigation plan

Risk assessment is an important and vital part of any project and a good risk analysis takes place during the project design phase. The following risks have been identified and shall be mitigated during the detailed design phase of the project.

- The handling of refrigerant and the decommissioning of the existing chillers which requires the safe handling of refrigerant.
- Asbestos based materials.
- Spatial limitations.
- Project programme to take into account the current delivery schedule for the proposed chillers and majority of works to be carried out during the winter time when heat rejection is in low demand.
- Deficiencies associated with existing pipework (corrosion and scaling).